2022 EDITION

Recommended Standards for Water Works

Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers

Illinois Indiana Iowa Michigan Minnesota Missouri New York Ohio Ontario Pennsylvania Wisconsin

Recommended Standards For Water Works

2022 EDITION

Policies for the Review and Approval of Plans and Specifications for Public Water Supplies

A Report of the Water Supply Committee of the Great Lakes--Upper Mississippi River Board
of State and Provincial Public Health and Environmental Managers

Illinois Indiana Iowa Michigan Minnesota Missouri
New York Ohio Ontario Pennsylvania Wisconsin

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FOREWORD

The Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers in 1950 created a Water Supply Committee consisting of one associate from each state represented on the Board. A representative from the Province of Ontario was added in 1978. Throughout this document, the term state shall mean a representative state or the Province of Ontario. The Committee was assigned the responsibility for reviewing existing water works practices, policies, and procedures, and reporting its findings to the Board. The report of the Water Supply Committee was first published in 1953, and subsequently has been revised and published in 1962, 1968, 1976, 1982, 1987, 1992, 1997, 2003, 2007, 2012, 2018, and 2022.

This document includes the following:

1. **Policy Statements** - Preceding the standards are policy statements of the Board concerning water works design, practice, or resource protection. Some policy statements recommend an approach to the investigation of innovative treatment processes which have not been included as part of the standards because sufficient confirmation has not yet been documented to allow the establishment of specific limitations or design parameters. Other policy statements recommend approaches, alternatives or considerations in addressing a specific water supply issue and may not develop into standards.

2. **Interim Standards** - Following the policy statements are interim standards. The interim standards give design criteria which are currently being used for new treatment processes, but the use of the criteria is limited and insufficient for recognition as a recommended standard.

3. **Recommended Standards** - The Standards, consisting of proven technology, are intended to serve as a guide in the design and preparation of plans and specifications for public water supply systems. These Standards are intended to suggest limiting values for items upon which an evaluation of such plans and specifications may be made by the reviewing authority, and to establish, as far as practicable, uniformity of practice. Because statutory requirements and legal authority pertaining to public water supplies are not uniform among the states, and since conditions and administrative procedures and policies differ, the use of these standards must be adjusted to these variations.

The terms shall and must are used where practice is sufficiently standardized to permit specific delineation of requirements or where safeguarding of the public health justifies such definite action. Other terms, such as should, recommended, and preferred, indicate desirable procedures or methods, with deviations subject to individual consideration.

Most quantified items in this document are cited in US customary units and are rounded off at two significant figures. Metric equivalent quantities, also rounded off at two significant figures, follow in brackets where compound units are involved. The metric unit symbols follow International System conventions. In the event of a conflict between quantities in US units and the metric equivalent, the quantity in US units shall take precedence.

It is not possible to cover recently developed processes and equipment in a publication of this type. However, the policy is to encourage, rather than obstruct, the development of new processes and equipment. Recent developments may be acceptable to individual states if they meet at least one of the following conditions:

1) Have been thoroughly tested in full scale comparable installations under competent supervision, or
2) Have been thoroughly tested as a pilot plant operated for a sufficient time to indicate satisfactory performance, or
3) A performance bond or other acceptable arrangement has been made so the owners or official custodians are adequately protected financially or otherwise in case of failure of the process or equipment.

The Board recognizes that many states, other than those of the Great Lakes-Upper Mississippi River

Board of State and Provincial Public Health and Environmental Managers, utilize this publication as part of their design requirements for water works facilities. The Board welcomes this practice as long as credit is given to the Board and to this publication as a source for the standards adopted. Suggestions from non-member states are welcome and will be considered.

Adopted April 1997
Revised April 2007
Revised April 2012
Revised April 2018
Revised October 2022

POLICY STATEMENT ON PRE-ENGINEERED WATER TREATMENT PLANTS

Pre-engineered water treatment plants are normally modular process units which are pre-designed for specific process applications and flow rates and purchased as a package. Multiple units may be installed in parallel to accommodate larger flows.

Pre-engineered treatment plants have numerous applications but are especially applicable at small systems where conventional treatment facilities may not be cost effective. As with any design, the proposed treatment must fit the situation and assure a continuous supply of safe drinking water for water consumers. The reviewing authority may accept proposals for pre-engineered water treatment plants on a case-by-case basis where they have been demonstrated to be effective in treating the source water being used. In most cases an applicant will be required to demonstrate, through pilot studies and/or other data, adequacy of the proposed plant for the specific application. A professional engineer is required to prepare plans and specifications for submittal to the reviewing authority for approval. It is recommended that a professional engineer be on site to oversee the installation and initial startup of pre-engineered water treatment plants.

Factors to be considered include:

1) Raw water quality characteristics under normal and worst-case conditions. Seasonal fluctuations must be evaluated and considered in the design.
2) Demonstration of treatment effectiveness under all raw water conditions and system flow demands. This demonstration may be on-site pilot or full-scale testing or testing off-site where the source water is of similar quality. On-site testing is required at sites having questionable water quality or applicability of the treatment process. The proposed demonstration project must be approved by the reviewing authority prior to starting.
3) Each treatment component of the pre-engineered water treatment plant must meet the design criteria of the respective treatment process stipulated in Part 4 – Treatment.
4) Sophistication of equipment. The reliability and experience record of the proposed treatment equipment and controls must be evaluated.
5) Unit process flexibility and monitoring locations that allow for optimization of treatment. Sample taps should be provided before and after each unit process or as required by the reviewing authority.
6) Systems treating surface water, an acute MCL, or ground water under the direct influence of surface water must provide redundancy or other means to consistently provide drinking water.
7) Necessary operational oversight. At surface water sources full-time operators are necessary, except where the reviewing authority has approved an automation plan. See Policy Statement on Automated/Unattended Operation of Surface Water Treatment Plants.
8) Third party certification or approvals such as NSF International, Underwriters Laboratory (UL) or other acceptable ANSI accredited third parties for: a) treatment equipment and b) materials that will be in contact with the water.
9) Suitable pretreatment based on raw water quality and the pilot study or other demonstration of treatment effectiveness. Pretreatment may be included as an integral process in the pre-engineered module.
10) Factory testing of controls and process equipment prior to shipment.
11) Automated troubleshooting capability built into the control system.
12) Start-up and follow-up training and troubleshooting to be provided by the manufacturer or contractor.
13) Operation and maintenance manual that includes a description of the treatment, control and pumping equipment, necessary maintenance and schedule, and a troubleshooting guide for typical problems.

14) In addition to any automation, full manual override capabilities must be provided.
15) Cross-connection control including, but not limited to the avoidance of single wall separations between treated and partially or untreated water.
16) On-site and contractual laboratory capability. The on-site testing must include all required continuous and daily testing as specified by the reviewing authority. Contract testing may be considered for other parameters.
17) Manufacturer's warranty replacement guarantee and confirmation of meeting performance objectives. Appropriate safeguards for the water supplier must be included in contract documents. The reviewing authority may consider interim or conditional project approvals for innovative technology where there is sufficient demonstration of treatment effectiveness and contract provisions to protect the water supplier should the treatment system not perform as guaranteed.
18) Water supplier revenue and budget for continuing operations, maintenance, and equipment replacement in the future.
19) Life expectancy and long-term performance of the units based on the corrosivity of the raw and treated water and the treatment chemicals used.

Adopted April 1997
Revised April 2007
Revised April 2012
Revised April 2018
Revised October 2022

POLICY STATEMENT ON POTABLE WATER REUSE

Demands for reliable and resilient water sources has continued to steadily increase. Water suppliers and users are actively pursuing additional means to diversify their water supplies and allow the water system to adapt and withstand rapid hydrological changes or natural disasters more readily. Potable water reuse is one avenue for public water systems to augment existing water resources. Potable reuse includes use of wastewater that has been treated and cleaned to be safe for the intended use. Potable water reuse generally falls into two categories, direct and indirect reuse, both of which are developing rapidly. Indirect reuse typically includes passage of the treated water through an environmental barrier such as discharge to a groundwater aquifer, lake, or river prior to being withdrawn. Discharges to an environmental barrier must comply with applicable discharge and withdrawal permits and be approved by the reviewing authority. Direct reuse eliminates the environmental barrier, and the treated wastewater receives subsequent drinking water treatment prior to use.

Due to the novel aspect of potable water reuse, regulations and regulatory requirements are still in active development. The US EPA has developed two documents (2012 Guidelines for Water Reuse and 2017 Potable Reuse Compendium) which served as a reference on water reuse practices as well as outlining key science, technical, and policy considerations at the time of release. Additionally, in 2019, US EPA's Assistant Administrator for Water, announced that the Agency would facilitate the development of a National Water Reuse Action Plan (WRAP). The WRAP is intended to integrate federal policies and utilize the expertise of industry and governmental agencies to identify a path forward for potable water reuse.

Prior to the initiation of design plans and specifications, an engineering report including the engineer's design recommendations and a minimum of one year of source water quality sampling shall be submitted to and approved by the reviewing authority.

<u>Public Outreach</u>
Public outreach and public engagement early in the planning and investigation is critical to producing public acceptance and can allow for easier implementation of a final solution. Public outreach should include development of community partnerships and collecting community input through activities such as surveys and focus groups. Focus groups and surveys should be inclusive and accessible to diverse populations and languages spoken within the community.

<u>Pre-design monitoring</u>
Preliminary monitoring and evaluation of the source water shall be completed on a schedule approved by the reviewing authority prior to completing any initial monitoring. The monitoring shall include analysis of all microbiological, physical, chemical, and radiological qualities of the source water on a frequency adequate to capture and characterize seasonal variability in the reuse source. Sampling must demonstrate the proposed potable reuse source is the best available source which is economically reasonable and technically possible as required in Section 3.0. The reviewing authority may require samples to be collected pre- and post-wastewater treatment to verify the efficacy of the wastewater treatment plant operations.

<u>Design requirements</u>
Treatment of a potable water reuse source should include a source water protection and management plan, filtration, and disinfection based upon the resources and monitoring requirements of the following: Surface Water Treatment Rule, Interim Enhanced Surface Water Treatment Rule, Long Term 1 Enhanced Surface Water Treatment Rule, and Long Term 2 Enhanced Surface Water Treatment Rule.

1) Source control programs must be implemented to provide a barrier of protection to the wastewater plant in the interest of ensuring protection of public health. The program should include characterization of wastewater treatment effluent and industrial producers, establishment of programs to limit discharge of contaminants of concern and assurance adequate primary, secondary and tertiary wastewater treatment is provided. Modifications to any wastewater treatment process or addition of new wastewater sources shall be submitted to the reviewing authority. The reviewing authority may require the additional sampling, treatment, or process modifications prior to the addition of the new waste sources to the wastewater treatment plant.

2) Continuous monitoring for ammonia, conductivity, nitrate, pH, temperature, and turbidity shall be provided at the wastewater plant effluent for monitoring of plant control.

3) The wastewater treatment plant operations must be updated to include the establishment of upset conditions, associated monitoring, alert and alarm conditions and the corresponding response conditions.

4) Care must be taken to make sure there is no cross connection between the finished water and raw water or intermediate treatment processes.

5) Systems utilizing indirect potable reuse must ensure the discharge of water to the selected environmental barrier would not result in another water system exceeding a primary drinking water standard. Removal and inactivation credits for the source may be granted by the reviewing authority with demonstrative testing and additional sampling.

6) LRV values for each treatment process must be established from current drinking water guidelines, such as the EPA Membrane Guidance Manual (EPA 2005) or EPA UV Guidance Manual (EPA 2006).

7) The water system virus inactivation and removal design must comply with one of the following or as approved by the reviewing authority:

    a. The potable reuse treatment must be designed to provide a minimum of 8 logs of inactivation or removal for viruses, 6 logs of inactivation or removal for Giardia, and, 5.5 logs of inactivation or removal for Cryptosporidium must be provided from the wastewater treatment plant effluent to the finished water effluent by treatment. Twelve months of giardia, cryptosporidium, and virus samples are required from the treated water discharge. A quantitative microbial risk assessment (QMRA) is required to assure an annual infection risk of less than 1 in 10,000. Additional inactivation or removal may be required to assure these values are met.

    b. The water supplier may elect to forgo additional monitoring and not complete a site-specific QMRA. For water suppliers electing to not complete this monitoring a minimum of 12 logs of inactivation or removal for viruses, 10 logs of inactivation or removal for Giardia, and, 10 logs of inactivation or removal for Cryptosporidium by treatment.

8) Pathogen removal must be achieved by a minimum of three different treatment processes to achieve the required LRVs.

9) Three unique chemical treatment mechanisms must be provided to provide a barrier for multiple chemical contaminants that may be encountered such as advanced oxidation, adsorption, high pressure membrane treatment, photolysis or ion exchange.

10) Conventional or membrane filtration must be provided for all potable reuse installations.

11) All log removal values (LRVs) are provided following the last wastewater treatment process. Additional LRVs from select wastewater treatment processes (e.g. wastewater treatment membrane bioreactors) which may provide LRV beyond typical secondary wastewater treatment may be granted at the discretion of the reviewing authority.

12) A redundant treatment train must be provided to ensure failure of a single treatment step will allow for a continuous water supply which has received the required treatment unless waived by the reviewing authority.

13) Plant supervisory controls must include programming and alarms to ensure water which has not passed through the complete treatment process is not permitted to discharge to the distribution system.

14) Continuous online monitoring of the treatment process is required for critical control parameters such as

turbidity and chlorine residuals.

15) Continuous TOC monitoring must be provided to determine adequate removals from the source water. TOC concentrations in the finished water are not permitted to be greater than 1.5 times the 95th percentile TOC results from the normal water supply

16) The reviewing authority may require chemical samples to be collected more frequently than required by the SDWA during the first year of operations and during subsequent years based on the compliance results.

Additional Considerations

1) Resources

Numerous resources for potable reuse are available, including the following:

a) Guidelines for Direct Potable Reuse in Colorado - NWRI Independent Expert Advisory Panel Final Report
b) EPA 2012 Guidelines for Water Reuse
c) EPA 2017 Potable Reuse Compendium
d) Expert Panel Final Report: Evaluation of Developing Uniform Water Recycling Criteria for Direct Potable Reuse, California State Water Resources Control Board" for IPR and DPR plans.

2) Operator

The addition of potable water reuse may require a higher-level certification or additional operator staffing. Upon installation of treatment, the PWS will be required to employ an appropriately certified operator to operate and maintain the water system according to the regulatory authority requirements.

Adopted October 2022

POLICY STATEMENT ON PER- AND POLYFLUOROALKYL SUBSTANCES

Per- and polyfluoroalkyl substances (PFAS) are a large group of man-made chemicals that include perfluorooctane carboxylate (PFOA) and perfluorooctane sulfonate (PFOS). PFAS have been used globally during the past century in manufacturing, firefighting and thousands of common household and other consumer products such as but not limited to:

- water and stain repellent products,
- non-stick pots and pans
- personal care products (e.g. cosmetics, lotions),
- insect repellants and sunscreens,
- food packaging wrappers

PFAS chemicals are persistent in the environment and can be bioaccumulative - meaning they do not readily break down and they can accumulate in humans, plants, and other animals over time. In recent years, experts have become increasingly concerned by the potential effects of high concentrations of PFAS on human health. The fate and transport of PFAS can be complex since there is a wide variety of PFAS with a range of physical and chemical characteristics that affect their behavior in the environment. Generally, the factors that affect fate/transport the most are chain length, ionic state, type of functional group, and extent of fluorination. The most common PFAS detected in the environment are ones with a carbon-fluorine tail (generally hydrophobic) and a nonfluorinated head with a polar functional group (hydrophilic). PFAS will partition to solid media in the environmental (soil and aquifer matrices) by two general mechanisms: adsorption to organic carbon and electrostatic interactions. Generally, the longer chain PFAS compounds will have a stronger adsorption to the soil and will move slower in the environment than short chain PFAS compounds. In addition, the perfluorosulfonates (PFSA) will adsorb stronger than PFCAs (perfluorocotanates) with the same chain length, so the equal chain length PFSAs will move slower in the environment than PFCAs.

Compared to other compounds, PFAS will adsorb to soil, but can migrate relatively easily through the vadose zone to the groundwater. Once in the groundwater, PFAS can migrate and create large areas of contaminated groundwater that could be used for water supplies or for private drinking water wells. Surface water (lakes, rivers, impoundments, etc.) that is used as a source of drinking water can become contaminated when groundwater contaminated with PFAS discharges to them, surface water runoff that contains PFAS discharges to them, and/or PFAS are spilled or discharged to them.

As of the writing of this policy statement, there are no National Primary Drinking Water Regulations (NPDWR) for PFAS, and some states have enacted state standards. Therefore, when any new source or treatment system is being considered and designed, source water samples should be analyzed for the presence of PFAS. Current Health Advisory Levels (HALs) may be used to guide the project basis of design.

Several treatment methods have proven to remove PFAS from drinking water: Granulated Activated Carbon (GAC), Engineered Resin Adsorption, High-pressure membranes, and Anion Exchange. These technologies can be installed as standalone treatment units within a treatment plant building. There are also a variety of package type treatment skids and mobile treatment units available in the marketplace that are available for use in applications requiring a flow rate of 5 gpm up to 250 gpm. When multiple skids or multiple mobilized treatment units are used together, this can serve applications requiring treatment of several million gallons per day. Capacity for these devices may vary depending on the manufacturer.

The selection of the most effective treatment process as a method to remove PFAS contamination will require a system-specific evaluation of the PFAS contaminant present, water quality, treatment objectives, and other considerations. Pre-treatment may be necessary to remove competing contaminants. If a water system intends to install treatment for PFAS removal, detailed plans including a demonstration study must be submitted and approved, as required by the regulating authority prior to installation. Removal efficiency for the specific PFAS present must be demonstrated.

If using GAC, Engineered Resin Adsorption, or Ion Exchange the design should incorporate at least two treatment vessels configured in series. Vessels should be in a lead/lag configuration to prevent contaminant breakthrough and allow for maintenance activities.

1) Granulated Activated Carbon (GAC) Contactors

GAC contactors are widely used for PFAS removal and the technology is available as standalone treatment units, package treatment skids and mobilized treatment trailers. Raw water quality must be thoroughly evaluated as there is the possibility of competition for adsorption from other contaminants which may reduce the effectiveness of treatment. Pre-treatment may be appropriate to remove competing contaminants. GAC is also generally more effective at removing long-chain PFAS over short-chain PFAS, as long-chain PFAS have a higher affinity for adsorption to carbon. Treatment should be designed for the specific PFAS present.

Initial backwashing and conditioning the GAC before placing it into operation are important parts to the GAC performance. Among other reasons, the initial condition is required because the media may include arsenic in the fines which will need to be adequately flushed. Proper bed expansion is a critical part to the backwashing. Testing the arsenics levels of the effluent from the GAC may be necessary prior to serving water to the public.

Reactivation/Regeneration or disposal of spent GAC must also be considered. Thermal reactivation of spent GAC and incineration is possible for PFAS destruction; however, studies have been ongoing to determine what temperature and for how long it must be sustained to completely destroy PFAS and to determine if there are by-products or incomplete combustion products being emitted. Permanent GAC treatment units have a backwash waste stream which also must be considered.

When granular media filters are in place for treating surface water or ground water under the direct influence of surface water, the use of stand-alone GAC contactors are recommended over modification of the existing granular media filters. If modification of the granular media filters is proposed for PFAS reduction (i.e. replacing anthracite with GAC), demonstration studies must be conducted to ensure turbidity removal performance is not being compromised by modifying the filter design. All the standards for granular media filtration still apply.

The following are general engineering design parameters based on the most recent research:

a. Empty bed contact time (EBCT) – A minimum of 10 minutes is needed to ensure adequate PFAS adsorption.
b. To date GAC sourced from coal has been demonstrated to remove PFAS more efficiently from water than GAC from other source materials.
c. A mesh size of 12 x 40 (~0.5 - 0.7 mm particle size) has been shown to be more efficient at PFAS removal with a minimum Iodine Number of 850 mg/g.

2) Engineered Adsorptive Resins/Media

Resins and other media have been developed to more selectively adsorb PFAS over other contaminants as compared to GAC. Like carbon, the raw water quality should be evaluated to determine if there are compounds that may compete for the adsorption sites. Since these have been engineered, they can typically adsorb a wider range of chain length PFAS and they generally will be able to adsorb a larger mass of PFAS per mass of resin. In addition, some of these media can be regenerated for reuse or be designed for a one-time use. Disposal of spent media and/or wastes will need to be properly managed. Research is being conducted to determine if the concentrated wastes from regeneration of adsorptive resins can be efficiently and effectively destroyed.

The design information for each adsorptive resin will be unique to the resin and water quality, so bench and pilot testing may be required by the regulating authority to ensure that the design can meet treatment objectives. Generally, these resins may have a shorter EBCT than carbon.

3) <u>High-Pressure Membranes</u>

High-pressure membrane filtration can remove multiple contaminants including PFAS. There are two types of high-pressure membrane filtration: reverse osmosis (RO) and nanofiltration; RO has shown to have a higher removal efficiency for PFAS. Research has shown that high-pressure membranes are over 90% effective at removing a wide range of PFAS chain lengths including the short chain compounds. RO has been successfully combined with GAC for higher overall removal rates. Pretreatment may be required due to the high susceptibility of fouling, and post-treatment mineral addition may be necessary for stabilization. Waste considerations are important for RO, as it may be challenging to find an acceptable means of discharging or treating the reject water produced by the process. The high-pressure membrane may be most effective as a point of use application as the volume of water treated and consequently the volume of concentrate would be much lower. Currently, there are several destructive technologies being studied that may provide a solution to the concentrated waste. Additional permits may be required for waste discharge streams and/or disposal of waste.

See Section 4.3.8 for general design considerations for membrane filtration.

4) <u>Anion Exchange</u>

Anion exchange is another treatment process capable of removing some types of PFAS, depending on the material (resin) used. The single use system does not create a waste stream; however, it does require disposal and replacement of the resin, for which additional permits from the regulating authority may be required. Efficiency of treatment is reduced in the presence of organics, total dissolved solids, and minerals which can clog the anion exchange resin. Additionally, competition with common anions can affect treatment efficiency and make anion exchange more effective at removing long-chain PFAS over short-chain PFAS.

The following are general engineering design parameters based on the most recent research:

a. Empty bed contact time (EBCT) – A minimum of 2 minutes is needed to ensure adequate PFAS adsorption.
b. To date the anion exchange resins that have been modified to include both positively charged exchange sites and adsorption sites have been the most efficient at removing PFAS.

5) <u>Powdered Activated Carbon (PAC)</u>

PAC, a smaller diameter form of activated carbon than GAC, can be added as a dry powder or slurry during the coagulation treatment process at larger water treatment plants. Contaminants adsorb to PAC in the same manner they do GAC; however, PAC is not as efficient or effective as GAC, high-pressure membrane, or anion exchange on a long-term basis for PFAS removal. Given the low percent removal of PAC, is not recommended as a primary method of PFAS removal. However, when PAC is already being used to achieve other treatment goals (reduction of taste and odor compounds), it may also provide a reduction in PFAS at higher dosages. Waste considerations are important for PAC, as it may be challenging to find an acceptable means of discharging the residuals produced by the process. Additional permits may be required for waste discharge streams and/or disposal of waste.

6) Additional Considerations

a. Resources

Numerous resources for the evaluation and effectiveness of PFAS treatment are available, including the following:

i. US EPA
   1. Drinking Water Treatability Database
   2. PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024

ii. American Water Works Association
   1. Per-and Polyfluroroalkyl Substances (PFAS) Treatment (August 12, 2019)

iii. Water Research Foundation
   1. Per- and Polyfluoroalkyl Substances (PFAS) Topic Overview

iv. ITRC (Interstate Technology Regulatory Council)
   1. Treatment Technologies and Methods for Per- and Polyfluoroalkyl Substances (PFAS)

b. Operator

The addition of treatment for PFAS may require a higher level or additional operator staffing. Upon installation of treatment, the PWS will be required to employ an appropriately certified operator to operate and maintain the water system according to the regulatory authority requirements.

c. Waste Management

The waste stream produced by any of the options above must be considered to ensure waste is not creating another PFAS contamination source. The cost and options for reject water, residuals, resins or spent media should be researched to ensure contaminants are not released back into the environment. Additional permitting may be required in accordance with the regulating authority requirements.

Adopted October 2022

POLICY STATEMENT ON AUTOMATED/UNATTENDED OPERATION AT SURFACE WATER TREATMENT PLANTS

Developments in computer technology, equipment controls and Supervisory Control and Data Acquisition (SCADA) Systems have made automated and off-site operation of surface water treatment plants feasible. Coincidentally, this comes at a time when renewed concern for microbiological contamination is driving optimization of surface water treatment plant facilities and operations and finished water treatment goals are being lowered to levels of <0.1 NTU turbidity and <20 total particle counts per milliliter.

Review authorities encourage any measures, including automation, which assist operators in improving plant operations and surveillance functions.

Automation of surface water treatment facilities to allow unattended operation and off-site control presents a number of management and technological challenges, which must be overcome before an approval can be considered. Each facet of the plant facilities and operations must be fully evaluated to determine what on-line monitoring is appropriate, what alarm capabilities must be incorporated into the design and what staffing is necessary. Consideration must be given to the consequences and operational response to treatment challenges, equipment failure and loss of communications or power.

An engineering report shall be developed as the first step in the process leading to design of the automation system. The engineering report to be submitted to the reviewing authorities must cover all aspects of the treatment plant and automation system including the following information/criteria:

1) Identify all critical features in the pumping and treatment facilities that will be electronically monitored, have alarms and can be operated automatically or off-site via the control system. Include a description of automatic plant shut-down controls with alarms and conditions that would trigger shut-downs. Dual or secondary alarms may be necessary for certain critical functions.
2) Automated monitoring of all critical functions with major and minor alarm features must be provided. Automated plant shutdown is required on all major alarms. Automated startup of the plant is prohibited after shutdown due to a major alarm. The control system must have response and adjustment capability on all minor alarms. Built-in control system challenge test capability must be provided to verify operational status of major and minor alarms.
3) A standard operating procedure (SOP) to test all major alarms and shutdowns at least once a quarter.
4) The computer system must incorporate cyberspace security and follow EPA cybersecurity best practices.
5) The plant control system must have the capability for manual operation of all treatment plant equipment and process functions.
6) A plant flow diagram that shows the location of all critical features, alarms and automated controls.
7) Description of off-site control station(s) or devices that allow observation of plant operations, receiving alarms and having the ability to adjust and control operation of equipment and the treatment process.
8) An SOP that includes a certified operator on "standby duty" status at all times with remote operational capability and located within a reasonable response time of the treatment plant.
9) An SOP that includes a certified operator perform an on-site check at least once per day to verify plant operation, treatment performance, and plant security.

10) Description of operator staffing and training planned or completed in both process control and the automation system.

11) Operation manuals that give operators step by step procedures for understanding and using the automated control system under all water quality conditions.

12) Emergency operations during power or communications failures or other emergencies must be included.

13) A backup battery shall be provided for the control system.

14) A plan for a 6 month or more demonstration period to prove the reliability of procedures, equipment and surveillance system. A certified operator must be on-duty during the demonstration period. The final plan must identify and address any problems and alarms that occurred during the demonstration period. Challenge testing of each critical component of the overall system must be included as part of the demonstration project.

15) Schedule for maintenance of equipment and critical parts replacement.

16) Sufficient finished water storage shall be provided to meet system demands and contact time (CT) requirements whenever normal treatment production is interrupted as the result of automation system failure or plant shutdown.

17) Sufficient staffing must be provided to carry out daily on-site evaluations, operational functions and needed maintenance and calibration of all critical treatment components and monitoring equipment to ensure reliability of operations.

18) Design consideration should be made for a backup, secondary, redundant, communication system to ensure continuous operation and oversight. A means must be provided for plant staff to perform, at a minimum, weekly checks on the communication and control system to ensure reliability of operations. Challenge testing of such equipment should be part of normal maintenance routines.

19) Provisions must be made to ensure security of the treatment facilities at all times. Incorporation of appropriate intrusion alarms must be provided which are effectively communicated to the operator in charge. (Refer to Section 2.19 – Security)

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Revised April 2012
Revised April 2018
Revised October 2022

POLICY STATEMENT ON HARMFUL ALGAL BLOOMS

Harmful Algal Blooms (HAB) have the potential to produce many different cyanotoxins and may develop quickly with changing source water conditions such as nutrient loading, temperature changes, and stagnation. Studies of cyanotoxin toxicity has resulted in development of stringent Health Action Levels for two of the toxins, Cylindrospermopsin and Microcystins, which are lower for infants and pre-school children. If present in the raw water, the water system must focus on optimization of existing treatment for cyanotoxin removal or oxidation. If other cyanotoxins have been detected in the Public Water System (PWS) source water(s), including optimization strategies to address those cyanotoxins is recommended.

The PWS must consider effective strategies for cyanotoxin treatment such as:

- Avoiding lysing of cyanobacterial cells.
- Optimizing removal of intact cells.
- Optimizing extracellular cyanotoxin removal or destruction.
- Optimizing residuals removal.
- Discontinuing or minimizing backwash recycling.

Source strategies, if available, must also be included, such as:

- Avoidance strategies (e.g., alternate intake, alternate source, suspending pumping).
- Reservoir management/treatment.
- Nutrient management.

Aside from avoidance, an efficient and cost-effective optimization method is the removal of intact cyanobacterial cells prior to oxidation, which ruptures cell walls and may release intracellular toxins. The treatment optimization protocol must describe how the water system will optimize removal of intact cells through coagulation/flocculation/filtration while avoiding additional cell lysis.

Optimizing conventional treatment for turbidity removal (or other relevant indicators, such as natural organic matter (NOM) removal or zeta potential that gauges effective coagulation) can also assist in cell removal. The coagulation, flocculation and sedimentation processes are effective in removing cyanobacteria cells and associated intracellular cyanotoxins but are ineffective at removing extracellular cyanotoxins. A multi-barrier approach, which couples optimization of intact cell removal with steps to remove extracellular cyanotoxins, is needed because cyanobacteria cells can release cyanotoxins during their normal life cycle or when cells die and lyse (cell walls rupture). Extracellular microcystins have been measured at up to 77% of total microcystins in Lake Erie intake samples and 100% of saxitoxins have been in extracellular form in intake samples collected at inland lakes and reservoirs.

Extracellular cyanotoxins are more difficult to remove than intracellular cyanotoxins and require additional physical or chemical processes. Processes that target extracellular cyanotoxins include Powdered Activated Carbon (PAC) or Granular Activated Carbon (GAC) for adsorption, a strong oxidant (e.g., permanganate, chlorine, ozone) for destruction, or rejection through RO membranes.

A common practice to control cyanobacteria is the application of algaecide. When algaecides are applied to a drinking water source under controlled conditions, they can effectively control the growth of cyanobacteria. Application to the early stages of a cyanobacteria bloom is the preferred approach to minimize release of high concentrations of intercellular cyanotoxins that could negatively impact treatment. If multiple raw water reservoirs are available, and one or more that are not in use are impacted by a High Algal Bloom (HAB) event and can be isolated, a PWS can consider algaecide treatment of these reservoirs. By treating impacted reservoirs prior to their need, cyanotoxins that are released may degrade over time and minimize the additional treatment required. The isolated reservoir(s) that have been treated with an algaecide must be sampled prior to being placed back online. Consider physically removing scums or mats (manually or with vacuum trucks, etc.), especially scums located near intake structures.

Other reservoir management strategies that may minimize HABs include:

- Nutrient reduction strategies for inputs into reservoir;
- Source water protection strategies;
- Dilution and flushing of reservoir system with higher quality water;
- Sonication;
- Phosphorus inactivation treatment; or,
- Hypolimnetic aeration (oxygenation) and reservoir mixing/circulation.

Permanganate

Do not apply an oxidant ahead of filtration, if possible. If an oxidant is necessary prior to filtration, permanganate is preferred over chlorine, chloramines or chlorine dioxide. To minimize cell lysis, keep permanganate dosing to 1 mg/L or less, if possible. Any oxidant use for pre-treatment should be followed by PAC to offset release of cyanotoxins from lysed cyanobacteria cells. Permanganate's ability to both lyse cells while also destroying cyanotoxins may depend on the species of cyanobacteria and may be influenced by pH, in addition to the applied dose and contact time and other competing demands. Proceed with caution with its use in this manner.

Pre-oxidation with Chlorine

If possible, do not apply chlorine ahead of filtration, because any dose of chlorine will lyse cyanobacteria cells. Use permanganate instead, at doses less than 1 mg/L, to minimize cell lysis. If either oxidant is used, follow-up with PAC. The only exception would be if testing established: 1) A significant majority of cyanotoxins are extracellular; and 2) A significant majority of the cyanobacteria cells have already been lysed coming into the treatment plant. In this scenario, pre-filter dosing which results in a free chlorine residual could be used to destroy cyanotoxins earlier in the treatment process and maximize contact time. Microcystins destruction via chlorine is more effective at lower pH, however, and raw water pH readings during a HAB are typically elevated. Consider the impact of the presence of natural organic matter (NOM) and the formation of disinfection byproduct (DBP) when establishing a dose. Consider the use of downstream PAC to assist in cyanotoxin and NOM/DBP reduction.

Chlorine dioxide or chloramines

Chlorine dioxide and chloramines can lyse cells, which release cyanotoxins, but are not effective at destroying microcystins. The use of chlorine dioxide should be avoided during a HAB event. If it must be used in pre-treatment, follow up with PAC, if possible, to assist in cyanotoxin reduction. Practicing chloramination as part of a secondary disinfection strategy to maintain a disinfectant residual in the distribution system can continue, however, efforts should be made to optimize contact time with free chlorine post-filtration to destroy cyanotoxins prior to the point of ammonia addition.

Powdered Activated Carbon

The type of Powdered Activated Carbon (PAC) is important because the effectiveness of a particular PAC may vary for different cyanotoxins. Jar testing is recommended to assist with PAC selection and estimate PAC removal capacity for microcystins or other cyanotoxins of concern. When possible, jar testing should be performed with cyanobacteria from the water system source water, to better represent site-specific conditions (including natural organic matter and microcystin variants). The iodine number is not a good indicator of performance for microcystins removal. For microcystins, a wood-based PAC that has a higher mesopore volume, is typically most effective (although not all wood-based PACs are equivalent).

Consider how PAC can be introduced into the treatment process (e.g., fed as a slurry (preferred) or dry. Also, consider how to switch PAC types if a different PAC is used for another treatment objective, such as taste and odor or saxitoxins removal (higher microporous PACs are typically more effective in these cases). Multiple feed point locations should be considered to optimize contact time with the cyanotoxins and overcome competing demands or interferences. Adequate mixing must also be provided. Consider feed points at the:

1) raw water intake
2) rapid mix
3) before settling

Feed points for permanganate, or other oxidants, and PAC should be at least 20 minutes apart to avoid interference. PAC should be applied downstream of any of the pretreatment oxidants listed above.
PAC use can increase solids loading on processes and in residual handling, which needs to be considered.

Flocculation/Sedimentation
Jar testing should be conducted to determine the conditions necessary for optimization of particulate/cell removal. Jar testing results can assist with optimizing coagulant dosing, contact time and filter aids. Be aware that increases in pH due to HABs may impact the effectiveness of coagulants. Coagulant addition should be adjusted with changing raw water conditions based on jar testing. The PWS should develop a reference sheet with chemical addition and dosing requirements for various raw water qualities. The PWS should increase the frequency of residuals removal to dispose of intact accumulated cells before they can lyse. Recirculation of residuals during a HAB event should be discontinued, if possible. Recycling of residuals supernatant should also be discontinued during a HAB event.

Filtration
Shorten filter runs and backwash more frequently to remove intact cells captured in the filter bed to avoid lysing. The frequency of backwash can be refined through monitoring of the filter influent and effluent to determine if cells within the filter are lysing and contributing to extracellular cyanotoxin concentration. Cease filter backwash recycle during a HAB event to avoid reintroducing intact cells and cyanotoxins from lysed cells.

For residuals handling, consider how increased loads from residuals removal and filter backwash waste will be accommodated with current residual handling processes (e.g., on-site lagoons, equalization basins, a permitted discharge to surface water or discharge to a wastewater treatment plant).

Clearwell(s)
Chlorine
A free chlorine residual paired with maximized contact time will optimize the destruction of microcystins.

Consider the following:

1) Maintain a chlorine residual that targets microcystins destruction. Consider increasing the free chlorine residual by 0.5 mg/L to 1.0 mg/L higher than normal operation, up to 3.5 mg/L.
2) Maximize contact time with chlorine in the clearwell.

During an extracellular cyanotoxin event, the free chlorine dose can be increased further to provide more effective destruction of cyanotoxins. An increase in CT can increase DBP formation. However, if PAC is used, it will assist with organics removal and DBP formation may be mitigated. Also, total chlorine residuals entering the distribution system should not exceed the maximum disinfectant residual level (MRDL) of 4.0 mg/L, on a running annual average. Elevated levels of free chlorine should only be used in the short-term to avoid a drinking water advisory.

pH

If pH adjustment is an option, consider adjusting pH slightly to assist with microcystins oxidation. The effectiveness of chlorine on microcystins destruction is greater at a pH less than 8 and above a pH of 6. Corrosion control must be considered when adjusting pH. Any adjustment to pH must not undermine a corrosion control treatment objective or violate any approved corrosion control plan.

Contact Time (CT)

To determine a specific benchmark for CT, see AWWA's CT calculator for destruction of micro cystins by chlorine, as a starting point: AWWA's calculator can be used for estimating oxidant dose (including chlorine and other oxidants) for destruction of cyanotoxins (including microcystins and other cyanotoxins). The AWWA calculator allows for inputs of pH, temperature, chlorine dose and contact time, as well as initial and targeted final microcystins concentrations. The calculator specifies limitations and assumptions of the tool within the first tab of the spreadsheet. Water quality-specific chlorine demands (such as NOM) will also impact chlorine dose. Chlorine dose and contact time estimates generated from a CT calculator may underestimate required CT because of the limitations and assumptions of the model. A safety factor of at least two should be used.

Other Treatment Processes

Membranes [Microfiltration (MF)/Ultrafiltration (UF) and Nanofiltration (NF)/Reverse Osmosis (RO)]

Ensure adequate pretreatment and cleaning cycles to prevent fouling. Evaluate the ability of the membrane to remove cells (MF/UF) and to remove extracellular cyanotoxins (NF/RO). For cyanotoxin removal, consider increasing the percentage processed through the membrane (NF/RO). Consider how other optimization strategies can impact performance of the membrane.

Ozone

Ozone is highly effective for complete microcystin destruction, however residual dose and contact time must be sufficient for cyanotoxin destruction as well as other demands. A potential limiting factor for some source water is the application of ozone can create disinfection byproducts, specifically bromate.

Granular Activated Carbon (GAC)

GAC can remove cyanotoxins through adsorption. Assess the cyanotoxin removal capacity of the GAC by evaluating the presence of competing contaminants, such as Natural Organic Matter (NOM). Reactivated or fresh media should be placed in contactors in advance of the HAB season. Consider conducting rapid small-scale column tests (RSSCT) with specific GAC media in the contactor using the plant's water and microcystins challenge concentration to determine the useful life of the GAC media. Routine treatment train sampling and analysis for TOC or UV254 may help determine changes in GAC adsorption capacity over time.

Ultraviolet Radiation (UV)

Assess functionality and ability to degrade cyanotoxins through sampling and studies UV Radiation with Advanced Oxidation Process UV radiation, if used alone for disinfection, is minimally effective in microcystins destruction and should not be considered as an acceptable optimization option. Dosing of UV ahead of filtration must be avoided to prevent lysing of cells.

An advanced oxidation process used in association with UV, where UV is paired with hydrogen peroxide, has been shown to be effective for microcystins destruction. However, the power requirements for advanced oxidation are many times greater than what is required for UV disinfection.

Cartridge Filters

See filtration section. Consider increasing frequency of element replacement.

Slow Sand Filters

Assess functionality and ability to degrade cyanotoxins. Do not pre-chlorinate or treat with any oxidant.

Monitoring and Testing

Due to the fleeting nature of HABs, monitoring and testing for water quality indicators is particularly challenging. For water systems combating source water HAB issues, developing and implementing a robust and multi-faceted monitoring and testing program is encouraged.

Adopted October 2022

POLICY STATEMENT ON BAG AND CARTRIDGE FILTERS FOR PUBLIC WATER SUPPLIES

Bag and cartridge technology has been used for some time in food, pharmaceutical and industrial applications. This technology is increasingly being used by small public water supplies for treatment of drinking water. A number of states have accepted bag and cartridge technology as an alternate technology for compliance with the filtration requirements of the Surface Water Treatment Rule and the Long Term 1 Enhanced Surface Water Treatment Rule. In addition, bag and cartridge filters are included in the microbial toolbox options for meeting the Cryptosporidium treatment requirements of the Long Term 2 Enhanced Surface Water Treatment Rule.

The particulate loading capacity of these types of filters is low. Once expended the bag or cartridge filter must be discarded. These filters are suitable for small systems with low flow. The operational and maintenance cost of bag and cartridge replacement must be considered when designing a system. These filters can effectively remove particles from water in the size range of Giardia cysts (5-10 microns) and Cryptosporidium (2-5 microns).

At the present time, filtration evaluation is based on Cryptosporidium oocyst removal.

With this type of treatment there is no alteration of water chemistry and after the technology has demonstrated the required removal efficiency, no further pilot demonstration may be necessary. The demonstration of filtration is only applicable to a specific housing and a specific bag or cartridge filter. Any other combinations of different bags, cartridges, or housings will require additional demonstration of filter efficiency.

Treatment of surface water should include source water protection, filtration, and disinfection sufficient to meet the following: Surface Water Treatment Rule, Interim Enhanced Surface Water Treatment Rule, Long Term 1 Enhanced Surface Water Treatment Rule and Long Term 2 Enhanced Surface Water Treatment Rule.

The following items should be considered in evaluating the applicability of bag or cartridge filtration.

<u>Predesign/Design</u>

1) The filter housing and bag/cartridge filter must demonstrate a filter efficiency of at least 2-log reduction in particles size 2 micron and above. Demonstration of higher log removals may be required by the reviewing authority depending on raw water quality and other treatment processes employed. The reviewing authority will decide whether a pilot demonstration is necessary for each installation. The filtration efficiency demonstration may be accomplished by completing:
    a. a microscopic particulate analysis, including particle counting, sizing and identification, which determines occurrence and removals of micro-organisms and other particle across a filter or system under ambient raw water source condition, or when artificially challenged;
    b. cryptosporidium particle removal evaluation in accordance with procedures specified in NSF Standard 419 or equivalent. These evaluations must be conducted by NSF or by another third party whose certification would be acceptable to the reviewing authority;
    c. challenge testing procedure for bag and cartridge filters as described in Chapter 8 of the Long Term 2 Enhanced Surface Water Treatment Rule Toolbox Guidance Manual;
    d. "non-consensus" live Cryptosporidium challenge studies that have been designed and carried out by a third-party agent recognized and accepted by the reviewing authority for interim evaluations; or
    e. methods other than these that are approved by the reviewing authority.
2) System components such as housing, bags, cartridges, membranes, gaskets, and O-rings must be certified as NSF Standard 61 compliant.

3) The source water or pre-treated water should have maximum turbidities of less than 3 NTU.

4) The flow rate through the treatment process shall be controlled and monitored with a flow valve and meter. The flow rate through the bag/cartridge filter must not exceed the maximum flow rate established during the filtration efficiency testing.

5) Pretreatment is strongly recommended (if not required by the reviewing authority). Pretreatment will provide a more constant water quality to the bag/cartridge filter and to extend bag and cartridge life. Examples of pretreatment include media filters, larger opening bag/cartridge filters, infiltration galleries, and beach wells. Location of the water intake should be considered in the pretreatment evaluation.

6) Particle count analysis may be useful to determine the amount of submicron particles that will not be removed by bag and cartridge filters.

7) It is recommended that chlorine or another disinfectant be added at the head of the treatment process to reduce/eliminate the growth of algae, bacteria, etc., on the filters. Verification that the disinfectant will not negatively affect the filter should be obtained from the manufacturer. The impact on disinfection-by- product formation should be considered.

8) A filter to waste component is strongly recommended (if not required by the reviewing authority), for any pretreatment pressure sand filters.

9) The ability to discharge or pump to waste after each filter must be provided on cartridge or bag filter vessels for maintenance and disinfection purposes.

10) If pressure media filters are used for pretreatment, they must be designed in accordance with the "Rapid Rate Pressure Filters" section (Section 4.3.2).

11) A sampling tap shall be provided ahead of any pretreatment so a source water sample can be collected.

12) Pressure gauges and sampling taps shall be installed before and after the media filter, and before and after the bag/cartridge filter.

13) Identify the maximum pressure differential or other factors such as filter run time that require a filter change out.

14) An automatic air release valve shall be installed on top of the filter housing.

15) Frequent start and stop operation of the bag or cartridge filter should be avoided. To avoid this frequent start and stop cycle the following options are recommended:

    a. reduce the flow through bag or cartridge filters to as low as possible to lengthen filter run times;

    b. install a recirculating pump that pumps treated water back to a point ahead of the bag or cartridge filter. Care must be taken to make sure there is no cross connection between the finished water and raw water.

16) Slow opening and closing valve should be provided ahead of the filter to reduce flow surges.

17) A minimum of two bag or cartridge filter housings operating in parallel shall be provided for water systems that must provide water continuously.

18) A pressure relief valve should be incorporated into the bag or cartridge filter housing.

19) Complete automation of the treatment system is not required. Automation of the treatment plant should be incorporated into the ability of the water system to monitor the finished water quality. It is important that a qualified water operator is available to run the treatment plant.

20) A plan of action should be in place and implemented when the water quality parameters fail to meet EPA or the local reviewing authorities' standards.

21) For each cartridge filter, the system should be able to monitor the following conditions:

    a) Instantaneous flow rate

b) Operating pressure

c) Pressure differential

d) Turbidity

e) Total flow through all filters

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POLICY STATEMENT ON AEROBIC BIOLOGICAL TREATMENT OF GROUNDWATER SOURCES FOR PUBLIC WATER SUPPLIES

Aerobic biotreatment of groundwater requires oxygen concentrations to encourage biological degradation/oxidation of water contaminants. The most commonly targeted contaminants are iron, manganese, and ammonia. Ammonia can reduce free chlorine levels in finished water, and lead to nitrification and corrosion problems in the water distribution system unless it is addressed. Therefore, treatment to remove ammonia is recommended. Systems that have high nitrates in the raw water may not be good candidates for biological ammonia removal since the ammonia is converted to nitrate on a one-to-one ratio. Additional second stage treatment for nitrate removal may be needed if high levels of ammonia removal (6-8 ppm) are needed.

Treatment Goals and Objectives: Prior to designing a proposed biotreatment system, treatment objectives and water quality goals should be clearly defined. Water quality goals for constituents such as iron (less than 0.3 ppm), manganese (less than 0.05 ppm), and free ammonia (less than 0.05 ppm) should be established for the proposed treatment technology.

Pilot Testing: Since there are limited full-scale aerobic biotreatment drinking water installations, pilot testing is recommended and may be required by the reviewing authority. If required, the pilot study design and objectives must be pre-approved. Pilot testing must be of sufficient duration to ensure establishment of steady state biological activity and should address (1) the range of temperatures and water quality conditions anticipated for the full-scale system, and (2) the range of operating conditions anticipated for the full-scale system (e.g., continuous or intermittent operation, extended shut-down periods, etc.) Key design parameters that should be identified or confirmed during pilot testing include empty bed contact time, chemical doses and dosing strategy, biomass control strategy, backwash wastewater solids settling/removal strategy (if this is planned for the full-scale application), post-treatment (filtration), and disinfection strategy. In addition to monitoring the target constituent(s), potential by-products should also be monitored (e.g., nitrite, hydrogen sulfide, disinfection by-products).

Prior to the initiation of design plans and specifications, a pilot study report including the engineer's design recommendations shall be submitted to and approved by the reviewing authority.

1.1 Design Criteria

The design criteria should include the following considerations:

a. type of filtration/contactor (gravity or pressure)
b. depth of filter/contactor media
c. type, size, and gradation of filter/contactor media
d. filtration and backwash rates, backwash system design
e. filter-to-waste
f. type of backwash water (raw, treated, unchlorinated, chlorinated, etc.)
g. empty bed contact time
h. dissolved oxygen concentration and method of / need for oxygen addition
i. number and types of filters piloted
j. need for chemical addition and dose
k. maximum allowable filter/contactor head loss before backwash
l. Approximate hydraulic trends (run time, "clean-bed" headloss, total headloss).

1.2 Media Selection

Sand, gravel, anthracite, and granular activated carbon are common choices for filter/reactor media. There are other specialized media that can also be used, however they must be ANSI/NSF Standard 61 certified. The size and gradation of the media can be critical to biofilter/contactor operation.

1.3 Dissolved Oxygen Levels

The dissolved oxygen in the water is critical to the operation of the aerobic biotreatment filters and contactors, particularly for nitrifying systems. The method of addition of oxygen to the water stream may vary from forced draft aerators, in-line aerators, to oxygen generation and injection. The air source for oxygen addition must be a clean, sanitary source.

1.4 Empty Bed Contact Time

The filtration rate and empty bed contact time for each filter/contactor shall be stated in the project specifications. For systems that are being retrofitted, the existing flow rate and maximum daily demand of the treatment plant must be taken into consideration.

1.5 Start-up and Shut-down Procedures

Consideration shall be made for the typical filter operation and filter down time for the treatment plant. The maximum expected shutdown time for the biological filter/contactor must be established while still being able to maintain water quality goals upon start-up. Plant operational hours and flow rates shall be established for optimum operation.

Protocol for start-up after a period of shutdown and after backwashing events should be established. Backwashing the filter/contactor after a period of shut down may be necessary. A minimum volume of water may be required to be filtered to waste upon filter startup.

1.6 Backwashing Considerations

The appropriate water and air backwash rates and duration for the proper removal of loose clusters of bacteria that may break through the filter must be determined. The use of air and water backwash is essential. If it is anticipated that biofouling in the filter media may occur, consideration should be given to backwashing with chemical addition.

The provisions for backwashing the filter/contactor shall be described in detail. Filter to waste piping should be provided.

1.7 Post Treatment

The proposed post treatment disinfectant (monochloramine or free chlorine) should be specified. If monochloramine disinfectant type is used, it is recommended that free ammonia in the finished water be less than or equal to 0.05 mg/L. Continuous disinfection should be provided and may be required by the reviewing authority.

The disinfectant dosage should be high enough to reach a goal of 0.0 cfu/ml heterotrophic plate count (HPC) in the finished water. The tests shall be conducted at intervals specified by the reviewing authority. The potential shift from chloramination to the use of a free chlorine residual may impact disinfection by-product formation.

The use of a polishing filter should also be considered after the biofilter/contactor.

1.8 Filter Backwash Reclaim

It should be determined if filter backwash reclaim in the final water treatment plant design will be used. If filter backwash reclaim is provided, the reclaim rate shall not exceed 10 percent of the total influent flow. Filter backwash reclaim tanks must be designed in accordance with Section 7.1.4.

1.9 Clearwell

The clearwell shall be designed in accordance with Section 7.1.2.

1.10 System Monitoring

Regular monitoring of the raw water, biotreatment influent, biotreatment system, biotreatment effluent and finished water is recommended. Smooth-nosed sample taps shall be provided on the raw water influent, on the effluent line from each biological filter, and on the finished water effluent downstream of the final chemical feed point.

It is recommended that the following items be monitored and recorded at intervals to be determined by the reviewing authority:

Parameters	Raw Water	Filter Influent	Filter Effluent	Finished Water
Iron, Manganese, Total Ammonia, or other contaminants of concern	X			X
By Product Contaminant (e.g., nitrates and nitrites)	X			X
* Dissolved Oxygen	X	X	X	X
Total Phosphorus	X			X
Alkalinity	X			X
pH	X			X
Temperature	X			X
Total Organic Carbon (TOC)	X			X
Total Coliform				X

* Dissolved Oxygen should be monitored continuously at the filter influent.

The treatment system should be monitored for:

a. filter headloss,

b. water flow rates,

c. filter run times.

1.11 System Control

Split stream treatment (blending) of treated and untreated water is not recommended for biological ammonia treatment.

1.12 Operator Training

Additional or specialized training may be required by the reviewing authority for operation of a biological treatment system.

1.13 Other Design Considerations

All chemicals that are used in the treatment of the water for potable use must be in accordance with Part 5. Consideration should be given to the building size and layout to allow for additional chemical feed equipment for the biofiltration process if future chemical addition is needed to enhance performance.

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POLICY STATEMENT ON ANOXIC BIOLOGICAL TREATMENT FOR PUBLIC WATER SUPPLIES

Anoxic biological treatment (biotreatment) involves the addition of an electron donor/carbon source (substrate), which bacteria use under low-oxygen conditions in a bioreactor to degrade dissolved constituents (e.g., nitrate, perchlorate, selenate, chromate, volatile organic compounds). Anoxic processes are distinct from aerobic biofiltration in that these processes are designed around biological degradation of dissolved constituents not particle removal. Anoxic bioreactors can either be heterotrophic, in which organic carbon (e.g., acetic acid or ethanol) is dosed as an electron donor and carbon source, or autotrophic, in which an inorganic compound is dosed as an electron donor (e.g., hydrogen or sulfur), and inorganic carbon is used for cell synthesis (e.g., carbon dioxide). Depending on the target constituent, anoxic biotreatment could be used in lieu of separation-based technologies such as ion exchange, reverse osmosis, or granular activated carbon adsorption. Any chemicals used in the treatment process must be ANSI/NSF Standard 60 listed.

The following items should be addressed when considering anoxic biotreatment for drinking water applications.

1.1 Reactor configuration:

There are three main types of anoxic bioreactor configurations

1) Fixed bed
2) Fluidized bed
3) Membrane

There are other anoxic configurations as well, including Continuous Stirred Tank Reactor (CSTR)-based systems, and systems that use specialized biological media.

1.2 Fixed Bed Bioreactors:

Fixed-bed bioreactors use a stationary bed of media on which biofilms develop (similar to conventional aerobic biofiltration). The granular media can be contained in open basins or pressure vessels. Raw water is amended with an organic or inorganic substrate and then flows by gravity or is pumped across the media bed. As constituents are degraded, biofilms will grow and accumulate causing a pressure drop across the media bed. Fixed-bed bioreactors are then routinely taken off line and backwashed to remove excess biomass from the system.

1.3 Fluidized Bed Bioreactors

In fluidized-bed anoxic bioreactor configurations, water is pumped up-flow through the reactor to fluidize the biofilm-coated granular media (approximately 25-30% expansion relative to the resting bed height). A portion of the bioreactor effluent flow is recycled and blended with raw water to provide the necessary fluidization velocity. An organic or inorganic substrate is dosed to the combined feed flow. Excess biomass is removed from the media bed through fluid shearing forces and/or by in-line mechanical biomass/media separation devices. Thus, though fluidized-bed bioreactors require higher feed-flow capacity, they do not require an off-line backwashing step.

1.4 Membranes

Membranes can also be used to support biofilm growth. In this case, hydrogen (electron donor) is delivered across a gas-transfer membrane and diffuses directly into the biofilm attached to the other side of the membrane. Carbon dioxide can also be delivered through the membrane as a carbon source, but this may not be required. The membranes are submerged in a reactor vessel through which raw water passes, and constituents diffuse from the bulk water into the biofilms where they are degraded. Occasionally, the membranes are backwashed and/or chemically cleaned in place to remove excess biomass.

Conventional systems and packaged systems are available for most of the different types of these configurations.

1.5 Media Selection

For anoxic biotreatment applications, various media types are used to support the growth of biofilms, including granular activated carbon, sand, plastic, expanded clay, membranes, or specialized media. The selection of a specific reactor configuration may also dictate media selection, but not always. For fixed bed designs, filter media depths may be greater than 36 inches with approval from the reviewing authority. Filter media must be ANSI/NSF standard 61 listed.

1.6 Substrate Selection and Dose

Anoxic biotreatment processes require the addition of an electron donor and sometimes a separate carbon source. For heterotrophic processes (i.e., process that use an organic carbon source), the electron donor and carbon source are the same chemical, and acetic acid is a common selection. For autotrophic processes (i.e., processes that use an inorganic carbon source), carbon dioxide may be dosed as the carbon source, and hydrogen is often dosed as the electron donor, though other electron donors such as sulfur and iron can be considered. For many anoxic applications, phosphorus is a limiting factor and also must be dosed to the bioreactor. The electron donor dose is typically calculated based on the concentration of dissolved oxygen and target contaminant in the raw water. Where possible, feed-forward and/or feedback chemical dosing control (i.e., tying chemical dosing to real-time raw water or treated water quality monitoring, respectively) should be considered to minimize incidences of over- or under-dosing an electron donor.

1.7 Empty Bed Contact Time (EBCT)

For most biotreatment processes, constituent removal is strongly impacted by the length of time that the water is in contact with the microbial community in a bioreactor. A longer contact time may be required when the water is cold (e.g., <15ºC/59ºF). The design reactor volume/contact time must consider any seasonal changes in constituent loading, temperature, and water demand, and it may also be impacted by which bioreactor configuration is used. When membrane bioreactors and fluidized bed reactors are being evaluated, hydraulic residence time (HRT) is used interchangeably with EBCT.

1.8 Biomass Control

One of the most important elements of any anoxic biotreatment process is the method and tools used to control biomass within the bioreactors. Autotrophic and heterotrophic processes generate significant amounts of biomass and require special biomass control considerations. The specified biomass control strategy can include mechanical tools (e.g., air scour, fluidization, mechanical media cleaning) and chemical tools (e.g., hydrogen peroxide, chlorine), but should be designed to maintain uniform hydraulic conditions without impacting the overall biological activity/constituent degradation capacity of the process. Systems should be designed to limit biomass carry-over into the finished water (e.g. second stage filtration). If the filter effluent discharges to a clearwell, it is recommended that a multi-compartment clearwell be provided to allow flexibility to periodically remove any biomass accumulation from the clearwell. Well-designed and operated systems should not experience significant biomass accumulation in the clearwell.

1.9 Biomass Waste Handling

Biomass control strategies generate a waste stream that contains microbial cells and other biofilm components. The waste stream will not likely contain any chemical constituents of concern. However, applications involving hexavalent chromium or selenate removal may need to characterize and quantify the inorganic solids, and obtain a permit from the reviewing authority.

Without implementing a solids/biomass recovery step with the waste stream (e.g., biomass settling or floatation, both of which may involve the addition of a polymer or coagulant), wastage rates can be 4 to 10 percent of the treated water flow. With a biomass recovery step, wastage rates can be less than 1 percent of the treated water flow. Biomass that has been concentrated through settling or floatation can be further concentrated using a mechanical dewatering process if additional water recovery is critical.

Waste biomass storage time is a critical issue, as storage for more than a few hours can generate offensive odors. Along with shortening the waste biomass storage time, aeration can also help minimize odors before the wastewater is disposed or treated. Treated or untreated wastewater disposal options may include discharge to the local sewer or to an on-site lagoon or percolation basin. A portion of treated wastewater may also be recirculated back into the treatment process.

1.10 Post Treatment

Treatment downstream of an anoxic bioreactor is important in the overall design. In general, downstream treatment is designed to re-oxygenate the water, remove any residual electron donor (particularly applicable to heterotrophic processes), remove turbidity (i.e., biomass that sloughs from the anoxic bioreactor process, and disinfect the water. A second stage filtration step for biomass control may be required by the reviewing authority.

1.11 Monitoring

Multiple parameters can be monitored in-line to provide real-time feedback on anoxic bioreactor health and performance. For example, nitrate/nitrite and perchlorate analyzers can be used to directly quantify constituent removal and to determine the appropriate substrate dose. Raw water dissolved oxygen (DO) can be monitored as part of the substrate dose calculation, and treated water DO is monitored to track re- oxygenation efficacy. Turbidity is typically measured in the system effluent to ensure that biomass stays within the treatment process, thereby, limiting any demand on the final disinfection step. Hydraulic parameters (e.g., headloss across a fixed-bed bioreactor) should also be monitored to track whether the biomass control strategy is working or needs to be modified. Microbiological parameters (e.g., ATP) can also be monitored as a direct measure of biological activity, but these analyses tend to cost more and a concerted effort is required to correlate these data to observed treatment performance. Alarms shall be provided to indicate when parameters are out of range.

Parameters that indicate biological activity should be considered to establish a baseline of performance and understand when process upsets may be occurring:

1) Dissolved oxygen concentration at the influent and effluent of the filter
2) Oxidation-reduction potential
3) Assimilable organic carbon [AOC] and biodegradable organic carbon [BDOC]
4) Carboxylic acids and aldehydes
5) Biological activity indicators (Adenosine triphosphate [ATP])
6) Biological indicator organisms (total coliform, heterotrophic plate count, etc.)
7) Temperature
8) pH

If chemical addition is employed, monitoring of those chemicals shall be considered.

1.12 Control

Anoxic bioreactor processes rely on the addition of an external substrate (and sometimes nutrients such as phosphorus) to meet constituent removal goals. Therefore, a robust chemical feed system must be integrated that not only ensures consistent substrate delivery, but also monitors raw or treated water quality and adjusts the substrate dose as necessary.

1.13 Pilot Testing

Since there is a limited track record of full-scale anoxic biotreatment performance in the United States, pilot testing is recommended, and may be required by the reviewing authority. Pilot testing should address:

1) the range of temperatures and water quality conditions anticipated for the full-scale system, and
2) the range of operating conditions anticipated for the full-scale system (e.g., continuous or intermittent operation, extended shut-down periods, filter acclimation, etc.). Key design parameters that should be identified or confirmed during pilot testing include empty bed contact time, chemical doses and dosing strategy, biomass control strategy, backwash wastewater solids settling/residuals disposal strategy (if this is planned for the full-scale application), post-treatment (re-oxygenation and filtration), and disinfection strategy. In addition to monitoring the target constituent(s), potential by-products should also be monitored (e.g., nitrite, hydrogen sulfide, disinfection by-products).

1.14 Operator Training

Anoxic biological treatment processes can be fully automated to minimize on-site operator demands. However, specialized training is recommended to familiarize operators with any hydraulic and water quality performance trends of concern, so that operational adjustments can be made on a timely basis to maintain system performance and reliability. Specific trends will vary based on the anoxic biotreatment process/system in operation (e.g., clean-bed headloss for a fixed-bed based process

POLICY STATEMENT ON DESIGN CONSIDERATIONS FOR THE OPTIMIZATION OF RAPID RATE FILTRATION AT SURFACE WATER TREATMENT PLANTS

Concern for microbiological contamination is driving optimization of surface water treatment plant facilities and operations, and finished water treatment goals have been lowered to levels of <0.10 NTU turbidity.

Treatment plant design should allow for the voluntary pursuit of optimized performance goals to provide improved public health protection and to assure continuous regulatory compliance. The capability for surveillance and data collection should be provided for each unit process in order to achieve better process control and operation, to enhance problem diagnostics, and to document overall improvement.

The following optimization goals should be considered during design:

1.1 Minimum Data Monitoring Requirements

- Daily raw water turbidity (every 4 hours)
- Individual basin settled water turbidity (frequency of data acquisition from continuous meters should be not less than every 15 minutes)
- Filtered water turbidity (frequency of data acquisition from continuous meters should be not less than every one minute)
- Filter backwash (each backwash)

Sedimentation

- Settled water turbidity ≤ 2 NTU, 95th percentile of maximum daily values when annual average source turbidity > 10 NTU
- Settled water turbidity ≤ 1 NTU, 95th percentile of maximum daily values when annual average source turbidity ≤ 10 NTU

Clarification is the process used to remove suspended solids following coagulation and flocculation and reduce solids loading on subsequent filtration processes. In conventional surface water treatment plants, clarification is one of the multiple barriers provided to reduce the potential of turbidity and microorganisms to pass through the treatment process and into the distribution system.

Sedimentation basin capacity is primarily based on surface overflow rate (SOR), with consideration given for depth and residuals removal characteristics. Greater depths generally result in more quiescent conditions and allow higher SORs to be used. Residuals removal mechanisms should also be considered when establishing an SOR for sedimentation capability.

In cases where flocculated color (i.e. a lightweight floc) and/or low water temperatures are encountered, the capacity should be based on the lower SORs. Higher SORs can be used for treatment capacity in cases where plant data demonstrate that a sedimentation basin achieves the desired settled water turbidity performance goals at the higher loading rates.

1.2 Flow Arrangements

Short-circuiting occurs when water bypasses the normal flow path through the basin and reaches the outlet in less than the design detention time. Inlets and outlets should be designed to ensure that water is distributed evenly across the clarifier/settling tank at uniform velocities to minimize short-circuiting. To achieve even flow distribution in horizontal-flow basins, baffles may be installed at the inlet and outlet to improve flow conditions. Consideration should be given to:

1) The number of ports across the baffle wall provided;

2) The distribution of the ports (e.g. uniform distribution of flow across the baffle wall)

3) Head loss through the ports; and

4) The potential for floc breakage across the baffle wall.

Density currents caused by changes in water temperature, wind effects, and solids concentrations should also be minimized to prevent short-circuiting. The provision of a cover or structure over the sedimentation basin can reduce the impact of the sun and wind on settling efficiency. Installation of baffles or diffuser walls can promote mixing of the density current with the ambient water, improving the flow distribution in the tank and the efficiency of hydraulic performance.

1.3 Controlling Plant Flow Rate

In many small plants that are operated less than 24 hours each day, plant flow rate is the primary means for process control. At these plants, an excessive hydraulic loading rate on the sedimentation process can be avoided by operating at a lower flow rate for a longer period of time. Continuous flow through the sedimentation units is generally a preferable operating mode.

Controlling plant flow rates provides an option to meet more rigorous performance requirements with existing units without major capital improvements. The capability to reduce plant flow rate to improve performance is offset by the need to staff the plant for longer periods of time, which adds to operating costs. Therefore, both options should be considered.

1.4 Residuals Removal

Residuals needs to be removed from conventional sedimentation basins frequently enough to prevent solids carryover to the filters. To optimize residuals removal, the amount of residuals accumulated in a basin should be kept to a minimum.

For basins with mechanical and/or automatic residuals removal systems, residuals pumping can be controlled by residuals density meters.

The reactor section of the basin must be monitored daily and the appropriate amount of residuals removed from the basin to maintain the optimum reactor concentration and residuals blanket depth. Inadequate monitoring of the basin can lead to a loss of the residuals blanket over the weirs, which significantly impacts basin and, ultimately, filter performance.

1.5 Filtration

1) Filtered water turbidity ≤ 0.10 NTU, 95th percentile of maximum daily values recorded

2) Maximum filtered water turbidity ≤ 0.30 NTU

The filter should be designed based on the capability to achieve effluent turbidity of less than 0.1 NTU continuously to ensure the integrity of filtration as a viable barrier in the treatment scheme. Operation of filters to produce filtered water quality of less than 0.1 NTU is attainable by proper design of filters, and provides greater confidence that pathogens, such as *Cryptosporidium* oocysts and *Giardia* cysts, are being removed prior to disinfection, the final treatment barrier. If particle counters are used, the maximum filtered water measurement should be less than 10 particles (in the 3 to 18 µm range) per ml.

Filtration capacity is designed and based primarily on hydraulic loading rates, with consideration given to media type. For example, a mono-medium sand filter would be assessed at a maximum rate of 7 $m^3/m^2 \cdot h$ (or m/h) because of the susceptibility of this filter to surface blinding by removing particles at the top of the filter media; whereas a dual or mixed media filter would be assessed at a higher rate because of the ability to utilize the solids storage capacity within the anthracite layer.

Limitations caused by air binding can also impact the selected loading rate for the filter's performance potential and could bias the selected loading rate toward more conservative values within each range. Inadequate backwash or surface wash facilities, rate control systems, media depth and underdrain integrity are areas that can contribute to the poor performance of filters.

The rate of filtration should be determined through consideration of such factors as raw water quality, degree of pre-treatment provided, filter media type(s) and depth, and the competency of operating personnel. For traditional conventional dual media filter designs with a maximum filtration rate of 12 m/h, this rate may not be achievable with floc formed from highly colored water. Higher filtration rates, up to 20 m/h or higher, may be considered by sufficient operating data.

Continuous effluent turbidity measuring and recording devices should be provided for each filter. Particle counters should be used if it is necessary to analyze the number and size of particles in the filter effluent at levels below the detectable range of a turbidimeter.

Proper filter design that may contribute to filter performance include:

1) Sufficient freeboard above the filter (particularly in cold water conditions); and
2) Proper media selection, including media type, depth, effective size, uniformity co-efficient, or a combination of these factors.

1.6 Filter Control

The most important aspect of flow rate control related to filter performance is minimizing the magnitude of a change in flow rate and the speed at which the change occurs. Rapid, high magnitude flow rate increases cause a large number of particles being pushed through the filter as evidenced by significant increases in turbidity. This breakdown in filter performance allows previously contained/removed particles to pass through the filters into the distribution system. This disrupts the continuous and proper filter performance that is required in water treatment. Since filtration is the most effective barrier within the treatment system to cysts such as *Cryptosporidium*, even short-term performance problems can potentially expose consumers to significant concentrations of cysts. These performance failures can occur even when the finished water turbidity objectives are being met.

Filtration rate changes most often occur when:

1) A filter is removed from service for backwashing;
2) High volume constant speed raw water pumps are cycled on and off;
3) A filter is started when it is dirty; or
4) A filter rate controller is malfunctioning.

Removing a filter from service for washing and directing the entire plant flow to the remaining filter(s) causes an instantaneous flow increase on the remaining filters, causing attached particles to be swept out of the filter. This can be prevented by lowering the plant flow rate prior to removing the filter from service, thereby controlling the hydraulic loading on the filters remaining in service.

Starting dirty filters results in a rapid increase in flow rate and subsequent poor filtered water quality. Backwashing of filters prior to returning them to service is essential to maintaining the integrity of the filtration process.

Rapid changes in plant influent flow by starting and stopping constant speed raw water pumps also hydraulically push particles through filters. This may be prevented by using a control valve (automatic or manual) to slowly adjust plant influent flow rate or by installing/modifying pumps with variable frequency drives.

1.7 Filter Configuration

The type and size of media affects filter throughput, performance and head loss. Characteristics such as media size, shape, composition, density, hardness and depth need to be considered carefully for the design of filters to achieve optimal filtration.

The most common types of media in granular filters are anthracite and sand. Problems may arise with the filter due to improper media selection. If the media grain size is too small, head loss during the filter run will increase. If the media grain size is too large, smaller particulate matter in the filter influent may not be removed effectively.

Post Backwash Turbidity

1) Plants with filter-to-waste capability
    - Minimize spike during filter-to-waste
    - Return to service ≤ 0.10 NTU
2) Plants without filter-to-waste capability
    - Maximum turbidity ≤ 0.30 NTU
    - Return to service ≤ 0.10 NTU within 15 minutes of startup

Adequate filter washing, both in terms of rate and duration, can prevent residual accumulation of particles in the filter ensuring clean filtered water quality when filtering is resumed.

The filter backwash duration and intensity should be great enough to clean the filter, but not too great to damage the support gravels/underdrain system or to blow media out of the filter. The length of wash should be long enough to produce clean spent backwash water to maintain filter performance. However, over washing can be detrimental to the filter as well. Termination of the backwash is dependent on media type, expansion of media, the manufacturer’s recommendation and other design parameters.

Required CT values for disinfection should be achieved at all times. A tracer study to determine the baffling factor is strongly recommended. Sample taps should be provided at all locations throughout the treatment process where disinfection credit and filter optimization is desired to be achieved.

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POLICY STATEMENT ON AQUIFER STORAGE AND RECOVERY FOR PUBLIC WATER SUPPLIES

Aquifer storage and recovery (ASR) has been used in the water supply industry primarily to match the supply of treated drinking water with demand. During periods of low demand water is injected into an aquifer displacing the water present in the aquifer and creating a zone of water within the aquifer that can be recovered during periods of increased demand to supplement water supplied from the main treatment plants. This recovered water is generally pumped directly into the distribution system with little or no additional treatment.

1.1 Location selection Aquifer Considerations

Not all aquifer systems are suitable for ASR. Aquifer systems with steep hydraulic gradients allow the displacement zone to migrate during the storage time reducing recovery efficiencies. Aquifer systems where fracture flow is the predominant recharge mechanism also reduce recovery rates. Aquifer systems that are unconfined or highly vulnerable to contamination from surface sources should not be considered. Lastly the permeability of the aquifer can significantly impact the injection flow rates. Assumptions made during site selection should be confirmed during pilot study investigations.

1.2 Control of the Displacement Zone

Beyond protection from contamination consideration should be given to controlling water withdrawals from the displacement zone and areas immediately adjacent to the displacement zone. The potential for competing withdrawals from other aquifer users within the displacement zone should be considered during design. Large volume withdrawals from wells immediately adjacent to displacement zones can impact recovery rates.

1.3 Demonstration Studies, Engineering Report, and Development Testing

Given the variability of aquifer systems and potential sources of contamination a demonstration study shall be conducted for each ASR well. Demonstration studies shall be approved by the reviewing authority prior to conducting a demonstration study to ensure all state specific concerns are addressed. Upon completing the demonstration study and prior to conducting any development testing an engineering report shall be prepared and submitted to the reviewing authority.

1.4 Demonstration Study Proposal

The demonstration study proposal should include:

1) Well locations and construction information for any ASR well, ASR monitoring well, or any other well within at least 1200 feet (or other distance specified by the reviewing authority) of the outer perimeter of the anticipated displacement zone.
2) The results of any modeling or investigations used to identify the proposed location of any ASR well.
3) The anticipated location and dimensions of the displacement zone.
4) A description of geologic strata through and into which injection is taking place.
5) Proximity to contaminated areas and existing water quality concerns.
6) The current groundwater flow direction and any anticipated changes in flow patterns based on injection or withdrawal.
7) Proposed maximum volume of water to be injected, flow rate and injection pressure for injection water, expected water storage period, proposed water retrieval rates, anticipated percentage of injected water to be recovered, and use or disposal method for recovered water.
8) Proposed injected water quality monitoring. Water injected into the aquifer must be water that has been treated to meet all SDWA drinking water and Underground Injection Control (UIC) standards.

9) Proposed water level and groundwater quality monitoring. Including frequency, collection locations, and parameters to be tested to ensure compliance with SDWA drinking water and UIC standards.

10) The engineering report shall include the results of the water level and water quality monitoring conducted during the demonstration study and a comparison of assumptions made prior to the demonstration study and any adjustments made to:

    a. The location and dimensions of the displacement zone.

    b. The current groundwater flow direction and any anticipated changes in flow patterns based on injection or withdrawal.

    c. Maximum volume of water to be injected, flow rate and injection pressure for injection water, water storage period, water retrieval rates, percentage of injected water recovered, and use or disposal method for recovered water.

1.5 Development Testing

Prior to recovering water to be used for potable purposes a final development test shall be conducted. The test shall evaluate the final proposed operational practices and monitoring criteria established by the reviewing authority.

1.6 Design Considerations

Well construction - Injection and recovery well construction shall follow the recommended standards contained in Part 3.2.

1.7 Materials Selection

Additional consideration should be given to selection of materials for well screens, well casings, and pumping equipment. Water quality differences, including increased chlorine levels, can increase the frequency of well maintenance and rehabilitation practices. Use of materials with improved resistance to chlorine, acids, and other rehabilitation chemicals should be considered.

1.8 Injection Control

A means of controlling injection flow rate shall be provided, e.g., throttling or control valves. Injection rates and volumes shall be metered. Injection rates should be controlled to minimize scouring within distribution systems. Biofilm or sediments scoured from distribution systems accelerate borehole and screen plugging, reduce injection efficiencies, and lead to increased frequency of maintenance.

1.9 Maintenance

Wells used for injection may require more frequent maintenance and/ or rehabilitation. Special attention should be paid to design of structures and well discharge heads. Isolation and pump to waste piping should be provided to facilitate taking the wells offline for maintenance practices. Increased sizing of sanitary sewer lines or other methods of handling large volumes of wastewater generated during well development and maintenance should be provided.

1.10 Water Quality Concerns

Cascading water into well boreholes and introducing high levels of chlorine or other oxidants should be avoided. Differing oxidation potential between injected water and water present in the aquifer can result in release of metals such as arsenic, iron, and manganese. Similarly, changing water levels and rewetting of portions of the aquifer can result in release of metals. Release rates may decline during conditioning phases of ASR well development. However, in some cases, additional treatment of the water upon withdrawal will be necessary. Chlorine levels of injection water can also be a concern for disinfection by-product formation due to the long residence time for injected water.

1.11 Monitoring

1) Monitoring wells. Monitoring wells shall be provided to allow monitoring to confirm assumptions of aquifer characteristics, flow direction, and water quality changes.
2) Underground injection control. Design and installation of a monitoring well network may be necessary for documenting compliance with state specific underground injection control requirements.
3) Water levels. Consideration should be given to installing continuous recording water level recorders on injection wells and monitoring wells. Installation of these devices will aid in monitoring "mounding" of the injected water and in evaluating the performance of the injection wells.
4) Injection analysis. Monitoring of the quality of water injected into the aquifer shall be provided to ensure the integrity of existing water quality is maintained.

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PART 1 – REGULATORY SUBMISSION GUIDANCE

1.0 APPLICATION

All reports, final plans specifications, and design criteria should be submitted at least 60 days prior to the date on which action by the reviewing authority is desired. Requirements for submitting, identifying, and disclosing security features of the design, and the confidentiality of the submission and regulatory review should be discussed with the reviewing authority prior to submittal.

Where the Design/Build construction concept is to be utilized, special consideration must be given to designation of a project coordinator; close coordination of design concepts and submission of plans and necessary supporting information to the reviewing authority; allowance for project changes that may be required by the reviewing authority; and reasonable time for project review by the reviewing authority.

Environmental Assessments, and permits for construction, to take water, for waste discharges, for stream crossings, etc., may be required from other federal, state, or local agencies. Preliminary plans and the engineer's report should be submitted for review prior to the preparation of final plans. No approval for construction can be issued until final, complete, detailed plans and specifications have been submitted to the reviewing authority and found to be satisfactory. Documents submitted for formal approval shall include but not be limited to:

a) Engineer's report, where pertinent.

b) Summary of the design criteria and/or basis of design memo.

c) Operation requirements, where applicable.

d) General layout.

e) Detailed plans.

f) Specifications.

g) Cost estimates.

h) Water purchase contracts between water supplies, and/or inter-municipal agreements, where applicable.

i) Evaluation of technical, managerial, and financial capacity. Public water systems are required by the USEPA and the States to demonstrate adequate capacity. The evaluation should include, as required by the reviewing authority.

    1) A discussion of the system's current technical capacity along with any project related changes with respect to operator certification requirements and the operator's ability to implement any system changes that may be required upon project completion.

    2) A discussion of the system's current overall management and how the system's management will be impacted by the project including but not limited to whether the system has an asset management plan and, if so, how the project components will be incorporated into that plan.

j) Other information as required by reviewing authority.

1.1 ENGINEER'S REPORT

The engineer's report for water works improvements shall, where pertinent, include the following information:

1.1.1 General information

a) Description of the existing water works and sewerage facilities.

b) Identification of the municipality or area served.

c) Name and mailing address of the owner or official custodian.

d) Imprint of professional engineer's seal or conformance with engineering registration requirements of the individual state or province.

1.1.2 Extent of water works system

a) Description of the nature and extent of the area to be served including topography.

b) Provisions for extending the water works system to include additional areas.

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

1.1.3 Justification of project

Where two or more solutions exist for providing public water supply facilities, each of which is feasible and practicable, discuss the alternatives. Consideration shall be given to consolidation or regionalization of public water supplies. Give reasons for selecting the one recommended, including financial considerations, operational requirements, operator qualifications, reliability, simultaneous compliance, and water quality considerations.

1.1.4 Soil, groundwater, and foundation conditions

a) Character of the soil through which water mains are to be installed.

b) The approximate elevation of ground water in relation to subsurface structures.

c) Foundation conditions at sites of proposed structures.

1.1.5 Water use data:

a) 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 five-year intervals or over the useful life of critical structures/equipment.

b) Present water consumption and the projected average and maximum daily demands, including fire flow demand (see Section 1.1.6).

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

d) Unusual occurrences.

e) Current percent of unaccounted water for the system and the estimated reduction of unaccounted for water after project completion if applicable, i.e., project is to replace aged water mains, leaking storage, or other improvements that will result in reduced water loss.

f) For systems with a high percentage of unaccounted for water (generally > 20% of water production), a water audit may be required by the reviewing authority.

1.1.6 Flow requirements:

a) Hydraulic analyses based on flow demands and pressure requirements (See "System Design" - Section 8.2).

b) Fire protection requirements should be established by the public water system with guidance from local fire protection authorities, subject to review and approval by the reviewing authority. When fire protection is to be provided, fire flows should be established with guidance available from the Insurance Services Office (ISO) or National Fire Protection Association (NFPA).

1.1.7 Sources of water supply

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

1.1.8 Surface water sources,

a) Hydrological data, stream flow and weather records.

b) Safe yield, including all factors that may affect it.

c) Maximum flood flow, together with approval for safety features of the spillway and dam from the appropriate reviewing authority.

d) Description of the watershed, noting any existing or potential sources of contamination (such as highways, railroads, chemical facilities, land/water use activities, etc.) which may affect water quality.

e) Summarized quality of the raw water with special reference to fluctuations in quality, changing meteorological conditions, etc.

f) Source water protection issues or measures, including erosion and siltation control structures, that need to be considered or implemented.

1.1.9 Groundwater sources

a) Sites considered.

b) Advantages of the site selected.

c) Elevations with respect to surroundings.

d) Probable character of formations through which the source is to be developed.

e) Geologic conditions affecting the site, such as anticipated interference between proposed and existing wells.

f) Summary of source exploration, test well depth, and method of construction; placement of liners or screen; test pumping rates and their duration; water levels and specific yield; water quality.

g) Sources of possible contamination such as sewers and sewage treatment/disposal facilities, highways, railroads, landfills, outcroppings of consolidated water-bearing formations, chemical facilities, waste disposal wells, agricultural uses, flooding, etc.

h) Wellhead protection measures being considered.

1.1.10 Proposed treatment processes

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

1.1.11 Sewerage system available

Describe the existing sewerage system and sewage treatment works, with special reference to their relationship to existing or proposed water works structures which may affect the operation of the water supply system, or which may affect the quality of the supply.

1.1.12 Waste disposal

Discuss the various wastes from the water treatment plant, their volume, proposed treatment and points of discharge. If discharging to a sanitary sewerage system, verify that the system, including any lift stations, can handle the flow to the sewage treatment works and that the treatment works is capable and will accept the additional loading.

1.1.13 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.

1.1.14 Project sites

a) Discussion of the various sites considered and advantages of the recommended ones.

b) The proximity of residences, industries, and other establishments.

c) Any potential sources of pollution that may influence the quality of the supply or interfere with effective operation of the water works system, such as sewage absorption systems, septic tanks, privies, cesspools, sink holes, sanitary landfills, refuse and garbage dumps, etc.

1.1.15 Cost and financing

a) Estimated cost of integral parts of the system, broken down by dollar amount or percentages for source development, storage, distribution mains, pumping, transmission mains, treatment, and planning (including all soft costs).

b) Detailed estimated annual cost of operation.

c) Proposed methods to finance both capital charges and operating expenses.

1.1.16 Future growth, capacity and water demand analysis

a) Summarize planning for future needs and services.

1.1.17 Pumping facilities

a) Description of the area to be served and the basis for design.

b) Maximum and minimum discharge heads and flows.

c) Pump operational controls.

d) Provisions for emergency operation.

1.1.18 Storage

a) A description of the high to low static pressure range which the proposed facility will provide for existing and future service areas and the volume of domestic and fire storage required within the design period.

b) Explain how the proposed and existing facilities will meet these requirements.

c) Relate the compatibility of the proposed facilities with existing facilities and any changes that will have to be made to the existing facilities.

1.1.19 Security, contingency planning, and emergency preparedness
(Review authority may consider this portion of the submittal as confidential.)

a) An evaluation of single points of failure and description of redundancy, recovery, and response measures.

b) An evaluation of access to water system facilities and control systems by individuals, vehicles, and electronics and a description of prevention, deterrence, and surveillance measures.

c) An evaluation of the chemicals to be used, stored, or generated at water supply facilities and a description of the means and methods used to protect the chemicals from contamination or misuse.

d) An evaluation of the need for "real time" water quality monitoring and a description of the means for collecting the data and issuing alarms or alerts.

1.2 **PLANS**

Plans for waterworks improvements shall, where pertinent, include the following:

1.2.1 General layout

a) Suitable title, deed, and plat information.

b) Name of municipality, or other entity or person responsible for the water supply.

c) Area or institution to be served.

d) Scale.

e) North point.

f) Datum used.

g) Boundaries of the municipality or area to be served.

h) Date, name, and address of the designing engineer.

i) Imprint of professional engineer's seal or conformance with engineering registration requirements of the individual state.

j) Legible prints suitable for reproduction.

k) Location and size of existing water mains.

l) Location and nature of existing water works structures and appurtenances affecting the proposed improvements, noted on one sheet.

1.2.2 Detailed plans

a) Stream crossings, providing profiles with elevations of the stream bed and the normal and extreme high and low water levels.

b) Profiles having a horizontal scale of not more than 100 feet to the inch and a vertical scale of not more than 10 feet to the inch, with both scales clearly indicated.

c) Location and size of the property, plat information to be used for the groundwater development with respect to known references such as roads, streams, section lines, or streets.

d) Topography and arrangement of present or planned wells or structures, with contour intervals not greater than two feet.

e) Elevations of the highest known flood level, floor of the structure, upper terminal of protective casings and outside surrounding grade, using United States Coast and Geodetic Survey, United States Geological Survey, or equivalent elevations where applicable as reference.

f) Plat and profile drawings of well construction, showing diameter and depth of drill holes, casing and liner diameters and depths, grouting depths, elevations and designation of geological formations, water levels and other details to describe the proposed well completely.

g) Location of all existing and potential sources of pollution which may affect the water source or, underground treated water storage facilities.

h) Size, length, and materials of proposed water mains.

i) Location of existing or proposed streets; water sources, ponds, lakes, and drains; storm, sanitary, combined and house sewers; septic tanks, disposal fields and cesspools.

j) Schematic flow diagrams and hydraulic profiles showing the flow through various plant units.

k) Piping in sufficient detail to show flow through the plant, including waste lines.

l) Locations of all chemical storage areas, feeding equipment and points of chemical application (see Part 5).

m) All appurtenances, specific structures, equipment, water treatment plant waste disposal units and points of discharge having any relationship to the plans for water mains and/or water works structures.

n) Locations of sanitary or other facilities, such as lavatories, showers, toilets, and lockers, when applicable or required by the reviewing authority.

o) Locations, dimensions, and elevations of all proposed plant facilities.

p) Locations of all sampling taps.

q) Adequate description of any features not otherwise covered by the specifications.

r) Security measures (See “Resiliency/Emergency Preparedness/Contingency” - Section 2.21).

1.3 SPECIFICATIONS

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

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

b) Laboratory facilities and equipment.

c) The number and design of chemical feeding equipment (see Section 5.1).

d) Procedures for flushing, disinfection, and testing, as needed, prior to placing the project in service.

e) Materials or proprietary equipment for sanitary or other facilities including any necessary backflow or back-siphonage protection.

1.4 DESIGN CRITERIA

A summary of complete design criteria shall be submitted for the proposed project, containing but not limited to the following:

a) Long-term dependable yield of the source of supply.

b) Reservoir surface area, volume, and a volume-versus-depth curve, if applicable.

c) Area of watershed, if applicable.

d) Estimated average and maximum day water demands for the design period.

e) Number of proposed services.

f) Fire flow requirements.

g) Proposed unit processes.

h) Unit/process capacities.

i) Retention times.

j) Unit process loading rates.

k) Filter area and the proposed filtration rate.

l) Backwash rate.

m) Chemical feed capacities and ranges.

n) Minimum and maximum chemical application rates.

1.5 REVISIONS TO APPROVED PLANS

Any substantial deviations from approved plans or specifications must be approved by the reviewing authority before such changes are made. These include, but are not limited to deviations in: capacity, hydraulic conditions, operating units, the functioning of water treatment processes, or the quality of water to be delivered. Revised plans or specifications should be submitted in time to permit the review and approval of such plans or specifications before any construction work, which will be affected by such changes, is begun.

1.6 ADDITIONAL INFORMATION REQUIRED

The reviewing authority may require additional information which is not part of the construction drawings, such as head loss calculations, proprietary technical data, copies of deeds, copies of contracts, etc.

PART 2 - GENERAL DESIGN CONSIDERATIONS

2.0 GENERAL

The design of a water supply system or treatment process encompasses a broad area. Application of this part is dependent upon the type of system or process involved.

2.1 DESIGN BASIS

The system including the water source and treatment facilities shall be designed for maximum day demand at the design year.

2.2 PLANT LAYOUT

Design shall consider:

a) Functional aspects of the plant layout.

b) Provisions for future plant expansion.

c) Provisions for expansion of the plant waste treatment and disposal facilities.

d) Access roads.

e) Site grading.

f) Site drainage.

g) Walks.

h) Driveways.

i) Chemical delivery.

2.3 BUILDING LAYOUT

Design shall provide for:

a) Adequate ventilation.

b) Adequate lighting.

c) Adequate heating.

d) Adequate drainage.

e) Dehumidification equipment, if necessary.

f) Accessibility of equipment for operation, servicing, and removal.

g) Flexibility of operation.

h) Operator safety.

i) Convenience of operation.

j) Chemical storage and feed equipment in a separate room to reduce hazards and dust problems.

2.4 LOCATION OF STRUCTURES

The appropriate regulating authority must be consulted regarding any structure which is so located that normal or flood stream flows may be impeded.

2.5 ELECTRICAL CONTROLS

Main switch gear electrical controls shall be located above grade, in areas not subject to flooding. All electrical work shall conform to the requirements of the National Electrical Code or to relevant state and/or local codes.

2.6 STANDBY POWER

Dedicated standby power shall be provided so that water may be treated and/or pumped to the distribution system during power outages to meet the average day demand. Alternatives to dedicated standby power may be considered by the reviewing authority with proper justification.

Carbon monoxide detectors are recommended when fuel-fired generators are housed.

2.7 SHOP SPACE AND STORAGE

Adequate facilities should be included for shop space and storage consistent with the designed facilities.

2.8 LABORATORY FACILITIES

Each public water supply shall have its own equipment and facilities for routine laboratory testing necessary to ensure proper operation. Laboratory equipment selection shall be based on the characteristics of the raw water source and the complexity of the treatment process involved.

Sufficient bench space, adequate ventilation, adequate lighting, storage room, laboratory sink, and auxiliary facilities shall be provided. Air conditioning may be necessary.

Laboratory test kits which simplify procedures for making one or more tests may be acceptable. An operator or chemist qualified to perform the necessary laboratory tests is essential. Analyses conducted to determine compliance with drinking water regulations must be performed in an appropriately certified laboratory in accordance with Standard Methods for the Examination of Water and Wastewater or approved alternative methods. Persons designing and equipping laboratory facilities shall confer with the reviewing authority before beginning the preparation of plans or the purchase of equipment. Methods for verifying adequate quality assurances and for routine calibration of equipment should be provided.

2.9 LABORATORY TESTING EQUIPMENT

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

a) Surface water supplies shall provide the necessary facilities for microbiological testing of water from both the treatment plant and the distribution system. The reviewing authority may allow deviations from this requirement.

b) Surface water supplies shall have a nephelometric turbidimeter meeting the requirements of Standard Methods for the Examination of Water and Wastewater.

c) 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.

d) 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.

e) Each iron and/or manganese removal plant shall have test equipment capable of accurately measuring iron to a minimum of 0.1 milligrams per liter, and/or test equipment capable of accurately measuring manganese to a minimum of 0.05 milligrams per liter.

f) Public water supplies which chlorinate shall have test equipment for determining both free and total chlorine residual by methods in Standard Methods for the Examination of Water and Wastewater.

g) Equipment shall be provided for measuring the quantity of fluoride in the water. Such equipment shall be subject to the approval of the reviewing authority.

h) Public water supplies which feed poly and/or orthophosphates shall have test equipment capable of accurately measuring phosphates from 0.1 to 20 milligrams per liter.

2.10 **MONITORING EQUIPMENT**

Water treatment plants should be provided with equipment (including recorders, where applicable) to monitor the water as follows:

a) Plants treating surface water and ground water under the direct influence of surface water should have the capability to monitor and record turbidity, free chlorine residual, water temperature and pH at locations necessary to evaluate adequate CT disinfection, and other important process control variables as determined by the reviewing authority. Continuous monitoring and recording may be required.

b) Plants treating ground water using iron removal and/or ion exchange softening should have the capability to monitor and record free chlorine residual.

c) Ion exchange plants for nitrate removal should continuously monitor and record the treated water nitrate level.

2.11 **SAMPLE TAPS**

Sample taps shall be provided so that water samples can be obtained from each water source and from appropriate locations in each unit operation of treatment, 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.

2.12 **FACILITY WATER SUPPLY**

The facility water supply service line and the plant finished water sample tap shall be supplied from a source of finished water at a point where all chemicals have been thoroughly mixed, and the required disinfectant contact time has been achieved (See “Contact Time, CT, and Point(s) of Application” - Section 4.4.1). There shall be no cross-connections between the facility water supply service line and any piping, troughs, tanks, or other treatment units containing wastewater, treatment chemicals, raw or partially treated water.

2.13 **WALL PENETRATIONS**

Consideration shall be given to providing extra wall penetrations to facilitate installation of future chemical feed and sample lines.

2.14 **SPARE FEED LINES**

Consideration shall be given to providing spare chemical feed lines where additional chemicals may need to be added or where chemical feed lines are likely to clog.

2.15 **METERS**

All water supplies shall have an acceptable means of measuring the flow from each source, the wash water, the recycled water, any blended water of different quality, and the finished water.

2.16 **PIPING COLOR CODE**

To facilitate identification of piping in plants and pumping stations, it is recommended that the color scheme in Table 2.1 be utilized.

Table 2.1 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
Residuals	Dark Brown
Sewer (Sanitary or Other)	Dark Gray
Other	
Compressed Gas	Dark Green
Gas	Red
Other Lines	Light Gray

For liquids or gases not listed above, a unique color scheme and labeling should be used. In situations where two colors do not have sufficient contrast to easily differentiate between them, a six-inch band of contrasting color should be on one of the pipes at approximately 30-inch intervals. The name of the liquid or gas should also be on the pipe. In some cases, it may be advantageous to provide arrows indicating the direction of flow.

2.17 DISINFECTION

All wells, pipes, tanks, and equipment which can convey, or store potable water shall be disinfected in accordance with current AWWA procedures. Plans or specifications shall outline the procedure and include the disinfectant dosage, contact time, and method of testing the results of the procedure.

2.18 **OPERATION AND MAINTENANCE MANUAL**

An operation and maintenance manual including a parts list and parts order form, operator safety procedures and an operational trouble-shooting section shall be supplied with all treatment systems and/or unit processes installed in the facility.

2.19 **OPERATOR INSTRUCTION**

Provisions shall be made for operator instruction at the start-up of a plant or pumping station.

2.20 **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 that may include the Uniform Building Code, Uniform Fire Code, National Fire Protection Association Standards, and state and federal OSHA standards. Items to be considered include noise arresters, 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.

2.21 **RESILIENCY/EMERGENCY PREPAREDNESS/CONTINGENCY**

Security shall be an integral part of drinking water system design. Security measures are required to help ensure that public water suppliers attain an effective level of security. Design considerations shall address physical infrastructure security and facilitate security related operational practices and institutional controls. Because drinking water systems cannot be made immune to all possible attacks, the design shall address issues of critical asset redundancy, monitoring, response and recovery. All public water supplies shall identify and address security needs in design and construction for new projects and for retrofits of existing drinking water systems.

Security shall be an integral part of drinking water system design.

a) Facility layout shall consider critical system assets and the physical needs of security for these assets. Requirements for submitting, identifying, and disclosing security features of the design, and the confidentiality of the submission and regulatory review should be discussed with the reviewing authority.

b) The design shall identify and evaluate single points of failure that could render a system unable to meet its design basis. Redundancy and enhanced security features should be considered to eliminate single points of failure when possible, or to protect them when they cannot reasonably be eliminated.

c) Consideration shall be made to ensure effective response and timely replacement of critical components that are damaged or destroyed. Critical components that comprise single points of failure (e.g., high volume pumps) that cannot be eliminated shall be identified during design and given special consideration. Design considerations should include component standardization, availability of replacements and key parts, re-procurement lead times, and identification of suppliers and secure retention of component specifications and fabrication drawings. Readily replaceable components should be used whenever possible, and provisions should be made for maintaining an inventory of critical parts. Identify potential failure which cannot be mitigated, what responses are possible, and critical components that comprise single points of failure.

d) Human access shall be through controlled locations only. Intrusion deterrence measures (e.g., physical barriers such as fences, window grates and security doors; traffic flow and check-in points; effective lighting; lines of sight; etc.) should be incorporated into the facility design to protect critical assets and security sensitive areas. Appropriate and effectively operated detection should be included in the system design to protect critical assets and security sensitive areas. All cameras and alarms installed for security purposes should be connected to SCADA where available and include monitors at manned locations. Alternative methods should be considered for primary use where there is no SCADA or as a SCADA support system.

e) Vehicle access shall be through controlled locations only. Physical barriers such as moveable barriers or ramps should be included in designs to keep vehicles away from critical assets and security sensitive areas. It should be impossible for any vehicle to be driven either intentionally or accidentally into or adjacent to finished water storage or critical components without facility involvement. Designated vehicle areas such as parking lots and drives should be separated from critical assets with adequate standoff distances to eliminate impacts to these assets from possible explosions of material in vehicles.

f) Sturdy, weatherproof, locking hardware shall be included in the design for the access to tanks, vaults, wells, well houses, pump houses, buildings, power stations, transformers, chemical storage, delivery areas, chemical fill pipes, and similar facilities. Hardened protective covers should be considered for padlocks or similar devices. Vent and overflow openings should be placed in secure areas. When not placed in secure areas, they shall be provided with deterrence or intrusion detection equipment.

g) Computer based control technologies such as SCADA shall be secured from unauthorized physical access and potential cyber-attacks. Wireless and network-based communications should be encrypted as deterrence to hijacking by unauthorized personnel. Vigorous computer access and virus protection protocols should be built into computer control systems. Effective data recovery hardware and operating protocols should be employed and exercised on a regular basis. All automated control systems shall be equipped with manual overrides to provide the option to operate manually. The procedures for manual operation including a regular schedule for exercising and ensuring the operator's competence with the manual override systems shall be included in facility operation plans.

h) Real time water quality monitoring with continuous recording and alarms should be considered at key locations to provide early warning of possible contamination events.

i) Facilities and procedures for delivery, handling and storage of chemicals shall be designed to ensure that chemicals delivered to and used at the facility cannot be released, introduced or otherwise used to debilitate a water system, its personnel, or the public. Particular attention should be given to potentially harmful chemicals used in treatment processes (e.g., strong acids and bases, toxic gases and incompatible chemicals) and on maintenance chemicals that may be stored on-site (e.g., fuels, herbicides, paints, solvents).

2.22 **FLOOD PROTECTION**

Other than surface water intakes, all water supply facilities and water treatment plant access roads shall be protected to at least the 100-year flood elevation or maximum flood of record, as required by the reviewing authority. A freeboard factor may also be required by the reviewing authority.

2.23 **CHEMICALS AND WATER CONTACT MATERIALS**

Chemicals and water contact materials shall be approved by the reviewing authority or be certified for compliance with ANSI/NSF Standards 60 or 61. Product certification shall be conducted by an ANSI approved entity. All materials used in the construction of a public water supply system must comply with the 2011 Reduction of Lead in Drinking Water Act, as amended.

2.24 **OTHER CONSIDERATIONS**

All facilities and structures shall conform to all applicable building and fire codes.

Consideration must be given to the design requirements of other federal, state, and local regulatory agencies for items such as cybersecurity, energy efficiency, water conservation, environmental impact, safety, disability access, construction in the flood plain, and freeze protection, etc.

PART 3 - SOURCE DEVELOPMENT

3.0 GENERAL

In selecting the source of water to be developed, the designing engineer must demonstrate to the satisfaction of the reviewing authority that an adequate quantity of water will be available, and that the water which is to be delivered to the consumers will meet the current requirements of the reviewing authority with respect to microbiological, physical, chemical, and radiological qualities. Each water supply should take its raw water from the best available source which is economically reasonable and technically possible. Security features listed in Section 2.19 should be considered.

3.1 **SURFACE WATER**

A surface water source includes all tributary streams and drainage basins, natural lakes and artificial reservoirs or impoundments above the point of water supply intake. A source water protection plan enacted for continued protection of the watershed from potential sources of contamination shall be provided as determined by the reviewing authority.

3.1.1 Water Quantity

The quantity of water at the source shall:

a) Be adequate to meet the maximum projected water demand of the service area as shown by calculations based on a one in fifty-year drought or the extreme drought of record and should include consideration of multiple year droughts. Provisions for flows downstream of the intake shall comply with requirements of the appropriate reviewing authority; see emergency section for drought response.

b) Provide a reasonable surplus for anticipated growth.

c) Be adequate to compensate for all losses such as silting, evaporation, seepage, etc.

d) Be adequate to provide ample water for other legal users of the source.

3.1.2 Water Quality

A study shall be made of the factors, both natural and man-made, which may affect water quality in the water supply stream, river, lake or reservoir. Such a study shall include, but not be limited to:

a) Determining possible future uses of impoundments or reservoirs.

b) Determining degree of control of watershed by owner.

c) Assessing degree of hazard to the supply posed by agricultural, domestic, industrial, or recreational activities in the watershed, which may generate toxic or harmful substances detrimental to treatment processes.

d) Assessing all waste discharges (point source and non-point sources) and activities that could impact the water supply. The location of each waste discharge shall be shown on a scale map.

e) Obtaining samples over a sufficient period of time to assess the microbiological, physical, chemical, and radiological characteristics of the water.

f) Assessing the capability of the proposed treatment process to reduce contaminants to applicable standards.

g) Consideration of currents, wind and ice conditions, and the effect of confluencing streams.

h) Source water protection plan for continued protection of the watershed from potential sources of contamination.

3.1.3 Minimum treatment

a) The design of the water treatment plant must consider the wide range of challenging conditions that may exist during the life of the facility.

b) The minimum treatment required shall be determined by the reviewing authority.

c) Filtration preceded by appropriate pretreatment shall be provided for all surface waters. Exemptions may be approved by the reviewing authority on a case-by-case basis.

d) Alternative filtration may be approved by the reviewing authority on a case-by-case basis after the completion of the pilot study.

3.1.4 Intake facilities

Design of intake structures shall provide for:

a) Withdrawal of water from more than one level if quality varies with depth.

b) Separate facilities for release of less desirable water held in storage.

c) Intake structure influent velocities of 0.5 feet per second or less where frazil ice may form.

d) Access manholes every 1,000 feet on intakes large enough to permit internal inspections.

e) Periodic backflushing and/or pigging of the intake line.

f) Adequate protection against rupture by dragging anchors, ice, etc.

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

h) Where shore wells are not provided, a diversion device capable of keeping large quantities of fish or debris from entering an intake structure.

i) Sufficient intake screen open area to minimize inlet headloss when buried surface water collectors are used.

j) The installation of the appropriate backfill material for the collector screen slot size and gradation of the native material over the collector system when buried surface water collectors are used.

k) The control of biological growth such as algae and biological species, such as zebra mussels.

3.1.5 Intake chemical treatment

If it is determined that chemical treatment is warranted to address taste and odor control or the control of zebra and other mussels and other nuisance organisms at the intake:

a) Chemical treatment shall be in accordance with Part 5 of the Recommended Standards for Water Works and shall be acceptable to the reviewing authority.

b) Plant safety items, including but not limited to ventilation, operator protective equipment, eyewashes/showers, cross connection control, etc., shall be provided.

c) Solution piping and diffusers shall be installed within the intake pipe or in a suitable carrier pipe. Provisions shall be made to prevent dispersal of chemical into the water environment outside the intake. Diffusers shall be located and designed to protect all intake structure components.

d) A spare solution line should be installed to provide redundancy and to facilitate the use of alternate chemicals.

e) The chemical feeder shall be interlocked with plant system controls to shut down automatically when the raw water flow stops.

f) When alternative control methods are proposed, appropriate piloting or demonstration studies, satisfactory to the reviewing authority, may be required.

3.1.6 Raw water pumping stations

Raw water pumping stations shall:

a) Have no less than two pumps and a minimum pumping capacity not less than the design maximum day demand.

b) Have motors and electrical controls located above grade, and protected from flooding as required by the reviewing authority.

c) Be accessible during a hundred-year flood or highest flood of record, whichever is higher.

d) Be designed to protect against flotation.

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

f) Provide for application of chlorine or other chemicals in the raw water transmission main if necessary, for quality control.

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

h) Have provisions for withstanding surges where necessary.

i) Be constructed in a manner to prevent intrusion of contaminants.

3.1.7 Off-stream raw water storage reservoir

An off-stream raw water storage reservoir is a structure into which water is pumped during periods of good quality and high stream flow for future release to treatment facilities. These off-stream raw water storage reservoirs shall be constructed to assure that:

a) Water quality is protected by controlling runoff into the reservoir.

b) Dikes are structurally sound and protected against wave action and erosion.

c) Intake structures and devices meet requirements of Section 3.1.4.1.

d) Point of influent flow is separated from the point of withdrawal.

e) Separate pipes are provided for influent to and effluent from the reservoir.

f) A bypass line is provided around the reservoir to allow direct pumping to the treatment facilities.

3.1.8 Impoundments and reservoirs

Dams shall be designed and constructed in accordance with the requirements of the appropriate regulatory agency. Construction may require:

a) Approval from the appropriate regulatory agencies of the safety features for structural stability and spillway design.

b) A permit from an appropriate regulatory agency for controlling stream flow or installing a structure on the bed of a stream or interstate waterway.

Site preparation for impoundments and reservoirs shall include where applicable:

a) Removal of brush and trees to high water elevation.

b) Protection from floods during construction.

c) Abandonment of all wells which will be inundated, in accordance with requirements of the reviewing authority.

3.2 **GROUNDWATER**

A groundwater source includes all water obtained from dug, drilled, bored or driven wells, and infiltration galleries.

3.2.1 Water quantity

3.2.1.1 Source capacity

The total developed groundwater source capacity, unless otherwise specified by the reviewing authority, shall equal or exceed the design maximum day demand with the largest producing well or pump out of service.

3.2.1.2 Number of sources

A minimum of two sources of groundwater shall be provided, unless otherwise specified by the reviewing authority. Consideration should be given to locating redundant sources in different aquifers or different locations of an aquifer.

3.2.1.3 Standby power

a) To ensure continuous service when the primary power has been interrupted, a standby power supply shall be provided through a dedicated portable or in-place auxiliary power supply of adequate capacity and connectivity.

b) When automatic pre-lubrication of pump bearings is necessary, and an auxiliary power supply is provided, design shall assure that the pre-lubrication is provided when auxiliary power is in use.

3.2.2 Water Quality

An assessment should be made of the factors, both natural and man-made, which may affect water quality in the well and aquifer.

Such an assessment may include, obtaining samples over a sufficient period of time to assess the microbiological and physical characteristics of the water including dissolved gases, chemical, and radiological characteristics. A ground water under the direct influence of surface water determination acceptable to the reviewing authority shall be provided for all new wells.

3.2.2.1 Microbiological quality

After disinfection of each new, modified or reconditioned groundwater source, one or more water samples shall be submitted to a laboratory satisfactory to the reviewing authority for microbiological analysis with satisfactory results reported to such agency prior to placing the well into service.

3.2.2.2 Physical, chemical, and radiological characteristics

a) Every new, modified, or reconditioned groundwater source shall be examined for applicable physical, chemical and radiological characteristics as required by the reviewing authority by tests of a representative sample in a certified laboratory, with results reported to such authority.

b) Samples shall be collected and analyzed at the conclusion of the test pumping procedure.

c) Field determinations of physical and chemical constituents or special sampling procedures may be required by the reviewing authority.

3.2.3 Siting requirements

3.2.3.1 Well location

The reviewing authority shall be consulted prior to design and construction regarding a proposed well location as it relates to required separation between existing and potential sources of contamination and groundwater development. The well location should be selected to minimize the impact on other wells and other water resources.

3.2.3.2 Continued sanitary protection

Continued sanitary protection of the well site from potential sources of contamination shall be provided either through ownership, zoning, easements, leasing, or other means acceptable to the reviewing authority.

3.2.3.3 Wellhead protection

A wellhead protection plan for continued protection of the wellhead from potential sources of contamination shall be provided as determined by the reviewing authority.

3.2.4 General well construction

3.2.4.1 Drilling fluids and additives shall:

a) Not impart any toxic substances to the water or promote bacterial contamination.

b) Be acceptable to the reviewing authority.

3.2.4.2 Minimum protected depths

Minimum protected depths of drilled wells shall provide watertight construction to such depth as may be required by the reviewing authority to:

a) Exclude contamination.

b) Seal off formations that are, or may be, contaminated or contain undesirable water.

3.2.4.3 Temporary steel casing

Temporary steel casing used for construction shall be capable of withstanding the structural load imposed during its installation and removal. Temporary casing shall be removed during or prior to well grouting. If the temporary casing cannot be withdrawn, approval of a method to finish the well must be obtained from the reviewing authority.

3.2.4.4 Permanent steel casing pipe

Permanent steel casing pipe shall:

a) be new single steel casing pipe meeting AWWA Standard A-100, ASTM or API specifications for water well construction

b) have minimum weights and thickness indicated in Table 3.1

c) have additional thickness and weight if the minimum thickness is not considered sufficient to assure reasonable life expectancy of a well

d) be capable of withstanding forces to which it is subjected

e) be equipped with a drive shoe when driven; and

f) have full circumferential welds or threaded coupling joints.

3.2.4.5 Polyvinyl chloride (PVC) plastic well casing

The reviewing authority may approve the use of PVC casing for all or for limited applications. Where approved, PVC casing, at a minimum shall:

a) be new pipe meeting ASTM F480 and ANSI/NSF Standard 61 and be marked accordingly.

b) have a minimum wall thickness equivalent to SDR (Standard Dimension Ratio) 21; however, diameters of 8 inches or greater or deep wells may require greater thickness to meet collapse strength requirements.

c) not be used at sites where permeation by hydrocarbons or degradation may occur.

d) consider heat of hydration when concrete or cement grout is used.

e) be properly stored in a clean area free from exposure to direct sunlight.

f) be assembled using couplings or solvent welded joints; all couplings and solvents shall meet ANSI/NSF Standard 14, ASTM F480, or equivalent requirements; and

g) not be driven.

3.2.4.6 Other nonferrous casing materials

a) Approval of the use of any nonferrous material as well casing shall be subject to special determination by the reviewing authority prior to submission of plans and specifications.

b) Nonferrous material proposed as a well casing must be resistant to the corrosiveness of the water and to the stresses to which it will be subjected during installation, grouting, and operation.

3.2.4.7 Packers

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

3.2.4.8 Screens

Screens shall:

a) be constructed of materials resistant to damage by chemical action of groundwater or cleaning and disinfection operations

b) have size of openings based on sieve analysis of formation and/or gravel pack materials

c) have sufficient length and diameter to provide adequate specific capacity and low aperture entrance velocity

d) be installed so that the pumping water level remains above the screen under all operating conditions

e) be applicable, be designed and installed to permit removal or replacement without adversely affecting water-tight construction of the well.

f) Be fabricated with a bottom plate or fitted with washdown bottom fitting of the same material as the screen; and

g) be installed concentrically in the well.

3.2.4.9 Grouting requirements

All permanent well casing shall be surrounded by a minimum of 1 ½ inches of grout to the depth required by the review authority. Other forms of grouting may be approved for driven casing. All temporary construction casings shall be removed. Where removal is not possible or practical, the casing shall be withdrawn at least five feet to ensure grout contact with the native formation.

a) Neat cement grout

    1) Cement conforming to AWWA A100, and water, with not more than six gallons of water per 94 pounds of cement, must be used for 1½ inch openings.

    2) Additives may be used to increase fluidity when approved by the reviewing authority.

b) Concrete grout

    1) Equal parts of cement conforming to AWWA A100, and sand, with not more than six gallons of water per 94 pounds of cement may be used for openings larger than 1½

inches.

2) Where an annular opening larger than four inches is available, gravel not larger than one-half inch in size may be added.

c) Bentonite grout

When allowed by the reviewing authority, a mixture of water and commercial sodium-bentonite clay manufactured for the purpose of water well grouting may be used. Bentonite mixture shall contain no less than 20 percent bentonite solids. Organic polymers used in the grout mixtures must be certified as ANSI/NSF Standard 60 compliant.

d) Clay seal

Where an annular opening greater than six inches is available, a clay seal of clean local clay mixed with at least 10 percent swelling bentonite may be used when approved by the reviewing authority.

e) Application

1) Sufficient annular opening shall be provided to permit a minimum of 1½ inches of grout around permanent casings, including couplings.

2) Prior to grouting through creviced or fractured formations, bentonite or similar materials may be added to the annular opening, in the manner indicated herein for grouting.

3) When the annular opening is less than four inches, grout shall be installed under pressure by means of a grout pump from the bottom of the annular opening upward in one continuous operation until the annular opening is filled.

4) When the annular opening is four or more inches and less than 100 feet in depth, and concrete grout is used, it may be placed by gravity through a grout pipe installed to the bottom of the annular opening in one continuous operation until the annular opening is filled.

5) When the annular opening exceeds six inches, is less than 100 feet in depth, and a clay seal is used, it may be placed by gravity.

6) After grouting, work on the well shall be discontinued until the cement or concrete grout has properly set.

7) Grout placement must be sufficient to achieve proper density or percent solids throughout the annular space.

f) Guides

The casing shall be fitted with sufficient guides welded to the casing to center the casing in the drill hole, prevent displacement of the casing and still permit unobstructed flow and uniform thickness of grout.

3.2.4.10 Wellhead construction

a) Permanent casing for all groundwater sources shall project at least 12 inches above the pumphouse floor, well platform floor, or concrete apron surface and at least 18 inches above final ground surface.

b) Where a well house is constructed, the floor surface shall be at least six inches above the final ground elevation.

c) Sites subject to flooding shall be provided with an earth mound to raise the pumphouse floor to an elevation at least two feet above the 100-year flood or highest known flood elevation, or other suitable protection as determined by the reviewing authority.

d) The top of the well casing at sites subject to flooding shall terminate at least three feet above the 100-year flood level or the highest known flood elevation, whichever is higher, or as the reviewing authority directs.

e) Protection from physical damage shall be provided when required by the reviewing authority.

f) The wellhead shall be constructed to prevent contamination from entering the well.

g) Where well appurtenances protrude through the wellhead, the connections to the wellhead shall be mechanical or welded connections that are watertight.

3.2.4.11 Development

a) Every well shall be developed to remove the native silts and clays, sand, drilling mud or finer fraction of the gravel pack.

b) Development should continue until the desired specific capacity is obtained from the completed well.

c) Where chemical conditioning is required, the specifications shall include provisions for the method, equipment, chemicals, testing for residual chemicals, and disposal of waste and inhibitors.

d) Where blasting procedures may be used, the specifications shall include the provisions for blasting and cleaning. Special attention shall be given to assure that the grouting and casing are not damaged by the blasting.

3.2.4.12 Disinfection of every new, modified, or reconditioned groundwater source

a) Shall be provided after completion of work, if a substantial period elapses prior to test pumping or placement of permanent pumping equipment.

b) Shall be provided after placement of permanent pumping equipment.

c) Shall be done in accordance with AWWA C654 or method approved by the reviewing authority.

3.2.4.13 Capping requirements

a) All wells temporarily or permanently taken out of service shall be sealed to prevent the entrance of water and contaminants.

b) A welded metal plate or a threaded cap shall be used to cap the out-of-service well unless another method of sealing is approved by the reviewing authority.

c) Until and while a well is capped, the well site shall be secured to prevent unauthorized access to the well, well tampering, or vandalism.

3.2.4.14 Well abandonment

d) Test wells and groundwater sources which are not in use shall be sealed by such methods as necessary to restore the controlling geological conditions which existed prior to construction or as directed by the appropriate regulatory agency.

e) Wells to be abandoned shall:

1) Be sealed to prevent the transfer of water from one aquifer to another and/or the intrusion of surface water.

2) Preferably be sealed by filling with neat cement grout.

3) If filled with materials other than cement grout or concrete, be filled with materials that are approved by the reviewing authority for sealing a well that is free of debris and foreign materials.

4) When filled with cement grout or concrete, these materials shall be conveyed into the well through a pipe, tremie, or bailer.

3.2.5 Testing and records

3.2.5.1 Well geological data shall:

a) Be determined from samples collected at 5-foot intervals and at each pronounced change in formation.

b) Be recorded and samples submitted to the appropriate authority.

c) Be supplemented with a driller's log, accurate geographical location such as latitude and longitude or GIS coordinates, and other information on accurate records of drill hole diameters and depths, assembled order of size and length of casing, screens and liners, grouting depths, formations penetrated, water levels, and location of any blast charges.

3.2.5.2 Yield and drawdown tests

a) A yield and drawdown test shall be conducted in accordance with a protocol pre-approved by the reviewing authority.

b) The test shall be performed on every production well after construction or subsequent treatment and prior to placement of the permanent pump.

c) The test methods shall be clearly indicated in the project specifications.

d) The test pump should have a capacity at least 1.5 times the well screen design flow.

e) As a minimum, the yield test shall provide for continuous pumping as follows: until stabilized drawdown has continued for at least 6 hours when pumped at the design pumping rate for at least 24 hours AND until stabilized drawdown has continued for at least 6 hours, or as otherwise required by the reviewing authority.

f) The following data shall be submitted to the reviewing authority:

1) Test pump capacity-head characteristics.

2) Static water level.

3) Depth of test pump setting.

4) Time of starting and ending each test cycle.

5) The zone of influence for the well or wells.

g) A report shall be submitted which provides recordings and graphic evaluation of the following at one-hour intervals or less as may be required by the reviewing authority:

1) Pumping rate.

2) Pumping water level.

3) Drawdown.

4) Water recovery rate and levels.

h) At the discretion of the reviewing authority, more comprehensive testing may be required.

3.2.5.3 Plumbness and alignment requirements

a) Every well shall be tested for plumbness and alignment in accordance with AWWA Standards.

b) The test method and allowable tolerance shall be clearly stated in the specifications.

c) If the well fails to meet the plumbness and alignment requirements, it may be accepted by the engineer if the conditions do not interfere with uniform placement of grout or the installation or operation of the pump.

3.2.5.4 Retention of records

The owner of each well shall retain all records pertaining to each well, until the well has been properly abandoned.

3.2.6 Aquifer types and construction methods -- Special conditions

3.2.6.1 Sand or gravel wells

a) If clay or hard pan is encountered above the water bearing formation, the permanent casing and grout shall extend through such materials or at least 25 feet below the original ground elevation, whichever is lower.

b) If a sand or gravel aquifer is overlaid only by permeable soils the permanent casing and grout shall extend to at least 25 feet below original or final ground elevation, whichever is lower. Excavation of topsoil around the well casing should be avoided.

c) If a temporary casing is used, it shall be completely withdrawn.

3.2.6.2 Gravel pack material

a) Gravel pack materials shall:

   1) Be sized based on sieve analysis of the formation.

   2) Be well-rounded particles, 95 percent siliceous material, that are smooth and uniform, free of foreign material, properly sized, washed and then disinfected immediately prior to or during placement.

b) Gravel pack construction

   1) Gravel pack shall be placed in one continuous operation.

   2) Gravel pack shall be placed in a manner that prevents segregation and gradation during placement.

   3) The annular space between the well screen and the hole shall allow proper placement of gravel pack.

   4) Gravel refill pipes, when used, shall be Schedule 40 steel pipe incorporated within the pump foundation and terminated with screwed or welded caps at least 12 inches above the pump house floor.

   5) Gravel refill pipes located in the grouted annular opening shall be surrounded by a minimum of 1 ½ inches of grout.

   6) Gravel pack shall extend above the highest well screen with an allowance for settling.

   7) Protection from leakage of grout into the gravel pack or screen shall be provided.

3.2.6.3 Radial water collector

a) Locations of all caisson construction joints, and porthole assemblies shall be indicated on the design drawings.

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

c) Radial collectors shall be in areas and at depths approved by the reviewing authority.

d) Radial collectors shall be horizontal.

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

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

g) The pump discharge piping shall not be placed through the caisson walls. In unique situations where this is not feasible, a watertight seal must be provided at the wall.

3.2.6.4 Infiltration lines

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

b) The area around infiltration lines shall be under the control of the water purveyor for a distance acceptable to or required by the reviewing authority.

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

d) Water from infiltration lines shall be considered as groundwater under the direct influence of surface water unless demonstrated otherwise.

3.2.6.5 Limestone or sandstone wells

a) Where the depth of unconsolidated formations is more than 50 feet, the permanent casing shall be firmly seated and grouted into solid, unbroken rock. Grouting requirements shall be determined by the reviewing authority.

b) Where the depth of unconsolidated formations is less than 50 feet, the depth of casing and grout shall be at least 50 feet or as determined by the reviewing authority.

3.2.6.6 Naturally flowing wells

a) Where there is no impervious confining layer naturally flowing wells shall require special consideration by the reviewing authority.

b) Flow shall be controlled. Overflows shall discharge at least 18 inches above grade and flood level and be visible. Discharge shall be to an effective drainage structure.

c) Permanent casing and grout shall be provided.

d) If erosion of the confining bed appears likely, special protective construction may be required by the reviewing authority.

3.2.7 Well pumps, discharge piping and appurtenances

3.2.7.1 Line shaft pumps

Wells equipped with line shaft pumps shall:

a) Have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least one-half inch into the pump base.

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

c) Be water lubricated. If oil lubricated pumps are allowed, food grade lubricant shall be used.

3.2.7.2 Submersible pumps

Where a submersible pump is used:

a) The pump shall be water lubricated.

b) Mercury seals shall not be permitted.

c) The top of the pump housing shall be effectively sealed against the entrance of water with a seal suitable for use given the expected vibration and/or movement of conductor cables.

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

3.2.7.3 Discharge piping

a) The discharge piping shall:

1) Be designed to minimize friction loss.

2) Have control valves and appurtenances located above the pumphouse floor when an above-ground discharge is provided.

3) Be protected against the entrance of contamination.

4) Be equipped with a check valve in or at the well, a shutoff valve, a pressure gauge, and a means of measuring flow.

5) Be equipped with a smooth nosed sampling tap located at a point where positive pressure is maintained, but before any treatment chemicals are applied. The sample tap shall be at least 18-inches above the floor to facilitate sample collection.

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

7) Be valved to allow isolation of the well for test pumping, pumping to waste, and control of each well.

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

9) Be properly anchored to prevent movement and be properly supported to prevent excessive bending forces.

10) Be protected against surge or water hammer.

11) Conform to the latest standards issued by the ASTM, AWWA and ANSI/NSF, where such standards exist, or in the absence of such standards, conform to applicable product standards and be acceptable to the reviewing authority.

12) Be constructed so that it can be disconnected from the well or well pump to allow the well pump to be pulled.

b) The discharge piping shall be provided with a means of pumping to waste, and shall not be directly connected to a sewer.

c) For submersible, jet and line shaft pumps, the discharge, drop or column piping inside the well shall:

1) Conform to the latest standards issued by the ASTM, AWWA and ANSI/NSF, where such standards exist, or in the absence of such standards, conform to applicable product standards and be acceptable to the reviewing authority. Any, fittings, brackets, tape or other appurtenances shall meet ANSI/NSF Standard 61, where applicable.

2) Be capable of supporting the weight of the pump, piping, water and

appurtenances and of withstanding the thrust, torque and other reaction loads created during pumping. The actions of fatigue from repeated starting and stopping of the pump shall be considered when choosing a pipe and fittings.

3) Be fitted with guides or spacers to center piping and well pump in the casing.

3.2.7.4 Pitless well units

a) Approval to use a pitless unit must be obtained from the reviewing authority.

b) Pitless 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 connected with a compression fitting approved by the reviewing authority.

3) Be of watertight construction throughout.

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

5) Have a 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 three feet above the 100-year flood level or the highest known flood elevation, whichever is higher, or as the reviewing authority directs.

c) The design of the pitless unit shall make provision for:

1) Access to disinfect the well.

2) A properly constructed casing vent.

3) Facilities to measure water levels in the well.

4) A cover at the upper terminal of the well that will prevent the entrance of contamination.

5) A contamination-proof entrance connection for electrical cable.

6) 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, and.

7) At least one check valve within the well casing or in the discharge piping adjacent to the pitless adaptor if allowed by the reviewing authority.

d) 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 needed to connect a pitless unit to the casing.

3.2.7.5 Casing vent

Provisions shall be made for venting the well casing to atmosphere. The vent shall terminate in a downturned position, at or above the top of the casing or pitless unit, no less than 12 inches above grade or floor, in a minimum 1½ 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 the reviewing authority.

3.2.7.6 Water level measurement

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

b) Where pneumatic water level measuring equipment is used it 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.

3.2.7.7 Observation wells

Observation wells shall be:

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

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

3.2.7.8 Liners

Approval to use a liner must be obtained from the reviewing authority. Liners shall be:

a) Fabricated out of steel or PVC well casing pipe.

b) Installed with a well packer just above the well screen that will prevent the entrance of soil, sand, and gravel into the well screen.

c) Sealed immediately above the packer with grout or a bentonite seal that will prevent the entrance of water that may be leaking into the well casing into the well screen.

d) Perforated with enough holes to keep the entrance velocities into the casing at or below 0.1 feet per second if the liner extends to the bottom of the well.

Table 3.1					
STEEL PIPE					
				Weight Per Foot (lbs.)	
Pipe Size	External Diameter (inches)	Internal Diameter (inches)	Thickness (inches)	Plain Ends (inches)	With Threads and Couplings
6 id.	6.625	6.065	0.280	18.97	19.18
8	8.625	7.981	0.322	28.55	29.35
10	10.750	10.020	0.365	40.48	41.85
12	12.750	12.000	0.375	49.56	51.15
14 od.	14.000	13.250	0.375	54.57	57.00
16	16.000	15.250	0.375	62.58	
18	18.000	17.250	0.375	70.59	
20	20.000	19.250	0.375	78.60	
22	22.000	21.000	0.500	114.81	
24	24.000	23.000	0.500	125.49	
26	26.000	25.000	0.500	136.17	
28	28.000	27.000	0.500	146.85	
30	30.000	29.000	0.500	157.53	
32	32.000	31.000	0.500	168.21	
34	34.000	33.000	0.500	178.89	
36	36.000	35.000	0.500	189.57	

PART 4 - TREATMENT

4.0 GENERAL

The design of treatment processes and devices shall depend on the specific quality of the water to be treated, seasonal variations, the desired quality of the finished water and the mode of treatment plant operation planned. The design of water treatment processes shall be suitable for treating the worst quality water under the peak demand conditions that are expected during the design life of the facility.

4.1 MICROSCREENING

Microscreening is a mechanical treatment process used to remove suspended organic matter from surface water sources. Microscreening can protect subsequent treatment processes by reducing particulate loads and minimize fouling. Microscreening shall not be used in place of coagulation and filtration.

4.1.1 General Design

4.1.1.1 Number

At least two units shall be provided. Where only two units are provided, each shall be capable when operating at the approved design rate of treating the plant design capacity, normally the projected maximum daily demand. Where more than two units are provided, the units shall be capable when operating at the approved rate of treating the plant design capacity with the largest unit removed from service.

4.1.1.2 Microscreen designs

Microscreen designs shall include:

a) Durable, corrosion resistant screens.

b) Protection against back-siphonage when potable water is used for backwashing.

c) Proper disposal of backwash waters.

4.1.1.3 Design considerations

Design consideration shall be given to the:

a) Nature of the suspended matter to be removed.

b) Source water quality.

c) Effect of chemicals used for pre-treatment.

d) Provision of automated backwashing.

4.2 **CLARIFICATION**

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

4.2.1 General Design

4.2.1.1 Number

At least two units shall be provided. Where only two units are provided, each shall be capable when operating at the approved design rate of treating the plant design capacity, normally the projected maximum daily demand. Where more than two units are provided, the units shall be capable when operating at the approved rate of treating the plant design capacity with the largest unit removed from service.

4.2.1.2 Design of clarification treatment facilities shall:

a) Permit operation of the clarifiers in parallel, or in series if secondary clarification is needed.

b) Provide drains or pumps of sufficient capacity to allow dewatering in a reasonable period of time to minimize treatment plant disruption.

c) Provide a means of measuring and modifying the flow to each clarifier unless otherwise approved by the reviewing authority.

d) Provide multiple stage clarification when required by the reviewing authority.

e) Minimize hydraulic head losses between treatment process components to allow future changes in processes without the need for re-pumping.

4.2.2 Presedimentation

Waters containing high turbidity may require pretreatment, usually sedimentation, with or without the addition of coagulation chemicals.

Presedimentation basins shall:

a) Be designed and configured so they can be maintained and cleaned without interruption of the treatment plant operation.

b) Have hopper style bottoms or be equipped with continuous mechanical residuals removal apparatus.

c) Be plumbed and valved so they can be dewatered.

d) Have piping or channels configured to disperse the incoming water across the full width of the basins.

e) Be configured and/or baffled to prevent short-circuiting.

f) Include provisions for bypassing.

g) Be sized to provide a minimum of three hours of detention.

4.2.3 Coagulation

Coagulation refers to a process of adding and mixing coagulant chemicals to stabilize charges on colloidal and suspended materials. Once the charge is stabilized, the suspended particles are capable of mixing and agglomerating into settleable or filterable flocs, or both. The engineer shall submit the design basis for the velocity gradient (G value) selected, considering the chemicals to be added and water temperature, pH, 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.

a) The mixing period should be instantaneous, but not longer than thirty seconds.

b) Basins should be equipped with mixing devices capable of imparting a minimum velocity gradient (G) of at least 750 feet per second/foot and providing adequate mixing for all treatment flow rates. The design engineer should determine the appropriate G value and detention time through jar testing.

c) Static mixing should only be considered where the flow is relatively constant and will be high enough to maintain the necessary turbulence for complete chemical reactions.

d) Coagulation and flocculation basin shall be as close together as possible.

4.2.4 Flocculation

Flocculation, through gentle mixing, increases the particle size from suspended submicroscopic particles to visible suspended floc or flake materials, either spontaneously or due to the addition of coagulating agents. This allows for enhanced agglomeration or collection of smaller floc particles into larger, more easily settleable or filterable particles. Gentle mixing is used and achieved by hydraulic or mechanical means.

a) 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 shall be designed so that individual basins may be isolated without disrupting treatment plant operation. A drain and/or pumps shall be provided to handle dewatering and residuals removal.

b) 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 to prevent floc from settling, tearing apart or shearing.

c) Equipment - Agitators shall be driven by variable speed drives with the peripheral speed of paddles ranging from 0.5 to 3.0 feet per second. External, non-submerged motors are preferred.

d) Other designs - Baffling may be used to provide for flocculation in small plants only after consultation with the reviewing authority. The design should be such that the velocities and flows noted above will be maintained.

e) Superstructure - A superstructure over the flocculation basins may be required.

f) Observation - To assist in observing floc formation, effective size, and density, consideration should be given to providing access and adequate lighting.

g) 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 be no less than 0.5 nor greater than 1.5 feet per second to prevent floc from settling, tearing apart or shearing. Allowances must be made to minimize turbulence at bends and changes in direction.

h) Consideration should be given to the need for modification or addition of a chemical feed in the future to optimize flow formation.

4.2.5 Sedimentation

Sedimentation is a process that allows particles in suspension to settle out by gravity and typically precedes filtration. Sedimentation is accomplished by decreasing the velocity of water to a point at which the particles will no longer remain in suspension. When the velocity no longer supports the particle suspension they will settle to the bottom of the basin. The detention time for effective sedimentation is dependent upon a number of factors related to basin design and the raw water quality. The following criteria apply to conventional gravity sedimentation processes:

a) Basin design shall be such that a minimum of four hours of settling time is provided. This may be reduced to two hours for lime-soda softening facilities treating only groundwater. Reduced detention time may also be approved by the reviewing authority 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.).

b) 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. 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.

c) Velocity - The velocity through a sedimentation basin should not exceed 0.5 feet per minute to prevent resuspension of particles. The basins must be designed to minimize short-circuiting. Fixed or adjustable baffles must be provided as necessary to facilitate sedimentation.

d) Outlet devices - Outlet weir, launders or submerged orifice collectors shall be provided to maintain velocities suitable for settling in the basin and minimize short-circuiting. The use of submerged orifice collectors is recommended to provide a volume above the orifices for storage when there are fluctuations in flow. Outlet weirs, launders and submerged orifice collectors shall be designed as follows:

    1) The rate of flow over the outlet weir launders or through the submerged orifice collectors shall not exceed 20,000 gallons per day per foot (250 m^3/day/m) of the outlet launder or orifice collector.

    2) Submerged orifice collectors should not be located lower than three (3) feet below the flow line.

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

e) 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 an air gap at a location where the discharge can be observed.

f) Superstructure - A superstructure over the sedimentation basins may be required. 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.

g) Drainage - Sedimentation basins must be provided with a means for dewatering. Basin bottoms should slope toward the drains at not less than one foot in twelve feet when mechanical residuals collection equipment is not provided.

h) Flushing lines - Flushing lines or hydrants shall be provided and must be equipped with backflow prevention devices acceptable to the reviewing authority.

i) Safety - Permanent ladders or handholds should be provided on the inside walls of basins above the water level. Guard rails should be included. Compliance with other applicable safety requirements, such as those issued by OSHA, is required.

j) Residuals collection systems shall be designed for the collection of residuals from throughout the basin and shall:

    1) Have residuals collection pipes not less than three inches in diameter that are arranged to facilitate cleaning.

    2) Have openings in the residuals collection piping that are not prone to clogging.

    3) Have valves located outside the tank for accessibility.

    4) Be configured so the operator can observe and sample residuals being withdrawn from the unit.

k) Residuals disposal facilities are required by the reviewing authority (see “Waste Residuals” - Part 9).

4.2.6 Solids contact unit

Solids contact units are generally acceptable for combined softening and clarification where water characteristics, especially temperature, do not fluctuate rapidly, flow rates are uniform, and operation is continuous. Before solids contact units are considered for use as clarifiers without softening, specific approval of the reviewing authority shall be obtained.

4.2.6.1 Number

At least two units shall be provided. Where only two units are provided, each shall be capable when operating at the approved design rate of treating the plant design capacity, normally the projected maximum daily demand. Where more than two units are provided, the units shall be capable when operating at the approved rate of treating the plant design capacity with the largest unit removed from service. Plants designed for the removal of a non-acute primary drinking water contaminant or for aesthetic purposes shall have a minimum of two solid contact units with a total capacity at least equal to the design maximum day demand.

4.2.6.2 Installation

Supervision by a representative of the solids contact unit manufacturer shall be provided during the installation and initial startup of all solid contact units.

4.2.6.3 Operation

Adequate piping with suitable sampling taps located to permit the collection of samples from various depths of the units shall be provided. Sampling taps should be located at the residuals withdrawal level and preferably spaced at two-foot intervals from the basin bottom to two feet below the effluent level.

4.2.6.4 Chemical feed

Chemicals shall be applied at such points and by such means as to insure satisfactory mixing of the chemicals with the water. Interference between treatment chemicals and optimum locations and sequences for feeding different chemicals shall be considered.

4.2.6.5 Mixing

A rapid mix device or chamber ahead of solids contact units may be required by the reviewing authority to assure proper mixing of the chemicals applied.

Mixing devices within each unit shall be provided to:

a) Mix the raw water with the treatment chemicals.

b) Prevent deposition of solids in the mixing zone.

4.2.6.6 Flocculation

Flocculation equipment:

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

b) Shall provide for coagulation in a separate chamber or baffled zone within the unit.

c) Should provide at least 30 minutes of flocculation and mixing time.

4.2.6.7 Residuals concentrators

a) The equipment should provide either internal or external concentrators to minimize the amount of wastewater in the residuals.

b) Large basins should have at least two sumps for collecting residuals located in the central flocculation zone.

4.2.6.8 Residuals removal

Residuals removal systems shall:

a) Have residuals pipes that are not less than three inches in diameter and arranged to facilitate cleaning.

b) Be designed and configured to prevent clogging at the entrance to residuals withdrawal piping system.

c) Have valves located outside the tank for accessibility that are buried or housed to prevent them from freezing.

d) Include permanent fittings to allow for the flushing or unplugging of the blow-off lines.

e) Be configured to allow the operator to observe and sample residuals being withdrawn from the unit.

4.2.6.9 Cross-connections

a) Blow-off outlets and drains shall terminate in a location with an acceptable air gap for backflow protection.

b) A backflow prevention device shall be included on the potable water supply lines used to back flush residuals lines.

4.2.6.10 Detention period

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 flow rates, the detention time should be:

a) Two to four hours for suspended solids contact clarifiers and softeners treating surface water or groundwater under the direct influence of surface water.

b) One to two hours for suspended solids contact softeners treating only groundwater.

The reviewing authority may alter detention time requirements.

4.2.6.11 Suspended slurry concentrate

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

4.2.6.12 Water losses

a) Units shall have controls to allow for adjusting the rate or frequency of residuals withdrawal.

b) Total water losses should not exceed:

   1) Five percent for clarifiers.

   2) Three percent for softening units.

c) Solids concentration of residuals bled to waste should be one of the following:

   1) Three percent by weight for clarifiers.

   2) Five percent by weight for softeners.

4.2.6.13 Weirs or orifices

a) The units should be equipped with either overflow trough with weirs or with submerged launder with orifices constructed so that water does not travel over 10 feet horizontally to the collection trough or launder.

b) Where troughs with weirs are provided, weirs shall be adjustable and be at least equivalent in length to the perimeter of the unit.

c) Weir loading shall not exceed:

1) 10 gpm per foot of weir length (120 L/min/m) for clarifiers.

2) 20 gpm per foot of weir length (240 L/min/m) for softeners.

d) Where submerged launders with orifices are provided, the loading rates per foot of launder should be equivalent to the weir loadings rates and the launders must be configured to produce uniform rising rates over the entire area of the unit.

4.2.6.14 Upflow rates

Unless supporting data is submitted to the reviewing authority to justify higher rates, the upflow rates shall not exceed:

a) 1.0 gpm per square foot of area (2.4 m/hr.) at the residuals separation line for units used as clarifiers.

b) 1.75 gpm per square foot of area (4.2 m/hr.) at the slurry separation line, for units used as softeners.

4.2.7 Modular tube or plate settling units

Modular settling units consisting of variously shaped tubes or plates, which are installed in multiple layers and at an angle to the flow in the sedimentation basin, may be used to enhance solids settling. Proposals for the installation of modular settling units must demonstrate satisfactory performance under on-site pilot plant conditions, or documentation of full-scale plant operation with similar raw water quality conditions as allowed by the reviewing authority, prior to the preparation of final plans and specifications for approval.

4.2.7.1 Modular tube or plate settling units shall:

a) Have support systems capable of carrying the weight of the modules when the basin is drained plus any additional weight to support maintenance personnel and equipment.

b) Be protected from freezing - Although most units will be located within a plant, outdoor installations must provide sufficient freeboard above the top of settlers to prevent freezing in the units. A cover or enclosure is strongly recommended.

c) Have tube settler application rates that do not exceed 2 gpm per square foot of cross-sectional area (4.8 m/hr.) for tube settlers unless higher rates are successfully shown through pilot plant or in-plant demonstration studies.

d) Have plate settler application rates that do not exceed 0.5 gpm per square foot (1.2

m/hr.), based on 80 percent of the projected horizontal plate area.

e) Have potable water lines and hose connections to facilitate maintenance, that are properly protected against backflow or back siphonage, and that are strategically located.

f) Have drainage systems sized to facilitate a quick drainage of the settling units and to prevent flooding other portions of the plant.

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4.2.7.2 Modular tube or plate settling units should:

a) Be placed in either:

1) Zones of stable hydraulic condition.

2) Areas nearest effluent launders for basins not completely covered by the modules.

b) Have provisions to allow the water level to be dropped, and a water or air jet system to be activated to clean the modules.

4.2.8 High-rate clarification processes

High-rate clarification processes may be approved upon demonstrating satisfactory performance under on-site pilot plant conditions or documentation of full-scale plant operation with similar raw water quality conditions as allowed by the reviewing authority. Reductions in detention times and/or increases in weir loading rates shall be justified. Examples of such processes may include, but are not limited to, dissolved air flotation, ballasted flocculation, contact flocculation/clarification, helical upflow, solids contact units, and pulsating clarifiers.

4.3 **FILTRATION**

Filtration is a process for removing particulate matter from the water by passing through porous media. Pretreatment shall be required prior to filtration unless otherwise approved by the reviewing authority. Acceptable filters shall include, upon the discretion of the reviewing authority, the following types:

a) Rapid Rate Gravity Filters (4.3.1)

b) Rapid Rate Pressure Filters (4.3.2)

c) Diatomaceous Earth Filtration (4.3.3)

d) Slow Sand Filtration (4.3.4)

e) Direct Filtration (4.3.5)

f) Deep Bed Rapid Rate Gravity Filters (4.3.6)

g) Biologically Active Filters (see Policy Statement on Aerobic Biological Treatment, Policy Statement on Anoxic Biological Treatment, and Aerobic Bio-Filtration of Surface Water, part 4.3.7)

h) Membrane Filtration (4.3.8), and;

i) Bag and Cartridge Filters (see Policy Statement on Bag and Cartridge Filters for Public Water Systems).

The application of any type of filtration system must be supported by water quality data representing a reasonable period of time to characterize the variations in water quality. Pilot treatment 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

The use of rapid rate gravity filters shall require pretreatment.

4.3.1.2 Rate of filtration

The rate of filtration shall be determined through consideration of such factors as raw water quality, degree of pretreatment provided, filter media, water quality control parameters, competency of operating personnel, and other factors as required by the reviewing authority. Typical filtration rates are from 2 to 4 gpm/ft^2. In any case, the filter rate must be proposed and justified by the design engineer to the satisfaction of the reviewing authority prior to the preparation of final plans and specifications.

4.3.1.3 Number

At least two units shall be provided. Where only two units are provided, each shall be capable when operating at the approved design rate of treating the plant design capacity, normally the projected maximum daily demand. Where more than two units are provided, the units shall be capable when operating at the approved rate of treating the plant design capacity with the largest unit removed from service. Where declining rate filtration is provided, the variable aspect of filtration rates, and the number of filters must be considered when determining the design capacity for the filters.

4.3.1.4 Structural details and hydraulics

The filter structure shall be designed to provide for:

a) Vertical walls within the filter.

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

c) Cover by superstructure.

d) Head room to permit normal inspection and operation.

e) Minimum depth of filter box of 8.5 feet.

f) Minimum water depth over the surface of the filter media of three feet.

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

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

i) Prevention of flooding by providing overflow.

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

k) Cleanouts and straight alignment for influent pipes or conduits where solids loading is heavy or when the filters follow lime-soda-softening systems.

l) Wash water drain capacity to carry maximum flow.

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

n) Safety handrails or walls around all filter walkways.

o) Construction to prevent cross connections and common walls between potable and non-potable or filtered and unfiltered water.

4.3.1.5 Wash water troughs

Wash water troughs should be constructed to have:

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

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

c) The top edge of all trough level and at the same elevation.

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

e) Maximum horizontal travel of suspended particles to reach the trough not to exceed three feet.

4.3.1.6 Filter material

All filter materials shall meet the current applicable AWWA standards for filtering materials. The media shall be clean silica sand or other natural or synthetic media free from detrimental chemical or bacterial contaminants, approved by the reviewing authority, and having the following characteristics:

a) A total depth of not less than 24 inches and generally not more than 30 inches.

b) A uniformity coefficient of the smallest material not greater than 1.65.

c) A minimum of 12 inches of media with an effective size range no greater than 0.45 mm to 0.55 mm.

4.3.1.7 Types of filter media

a) Anthracite - Filter anthracite shall consist of hard, durable anthracite coal particles of various sizes. Blending of non-anthracite material is not acceptable. Anthracite shall have an:

    1) Effective size of 0.45 mm - 0.55 mm with uniformity coefficient not greater than when used alone.

    2) Effective size of 0.8 mm - 1.2 mm with a uniformity coefficient not greater than 1.7 when used as a cap.

3) Effective size for anthracite used as a single media on potable groundwater for iron and manganese removal only shall be a maximum of 0.8 mm (effective sizes greater than 0.8 mm may be approved based upon onsite pilot plant studies or other demonstration acceptable to the reviewing authority).

   a. Specific gravity greater than 1.4.

   b. Acid solubility less than 5 percent.

   c. A mho's scale of hardness greater than 2.7.

b) Sand filter- sand shall have:

1) An effective size of 0.45 mm to 0.55 mm.

2) A uniformity coefficient of not greater than 1.65.

3) A specific gravity greater than 2.5.

4) An acid solubility less than 5 percent.

c) 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:

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

2) Have an effective size of 0.2 to 0.3 mm.

3) Have a uniformity coefficient of not greater than 1.65.

4) Have an acid solubility less than 5 percent.

d) Granular activated carbon (GAC) - Granular activated carbon as a single media may be considered for filtration only after pilot or full-scale testing and with prior approval of the reviewing authority. The design shall include the following:

1) The media must meet the basic specifications for filter media as given in the Filter Material Section herein. Alternate media sizes may be allowed where pilot or full-scale tests have demonstrated that treatment goals can be met under all conditions.

2) There must be provisions for a free chlorine residual and adequate contact time in the water following the filters and prior to distribution as described herein.

3) There must be means for periodic treatment of filter material for control of bacterial and other growth.

4) Provisions must be made for frequent replacement or regeneration.

e) Other media types or characteristics may be considered based on experimental data and operating experience.

4.3.1.8 Support media

a) Torpedo sand - A three-inch layer of torpedo sand shall be used as a supporting media for filter sand where supporting gravel is used, and shall have both:

   1) An effective size of 0.8 mm to 2.0 mm.

   2) A uniformity coefficient not greater than 1.7.

b) Gravel - Gravel, when used as the supporting media shall consist of cleaned and washed, hard, durable, rounded silica 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 a lateral 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:

Table 4.1
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 ½	3 to 5
1.5 to ¾	3 to 5
2.5 to 1.5	5 to 8

Reduction of gravel depths, number of layers, and other size gradations may be considered upon justification to the reviewing authority for slow sand filtration or when proprietary filter bottoms are specified.

4.3.1.9 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 waters softened by lime. The design of manifold-type collection systems shall:

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

b) Ensure an even distribution of wash water and an even rate of filtration over the entire area of the filter.

c) Provide the ratio of the area of the final openings of the strainer systems to the area of the filter at about 0.003.

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

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

f) Lateral perforations without strainers shall be directed downward.

4.3.1.10 Surface wash or subsurface wash

Surface or subsurface wash facilities are required except for filters used exclusively for iron, radionuclides, arsenic or manganese removal, and may be accomplished by a system of fixed nozzles or a revolving-type apparatus. All devices shall be designed with:

a) Provisions for water pressures of at least 45 psi (310 kpa).

b) A properly installed vacuum breaker or other approved device to prevent back siphonage if connected to the filtered or finished water system.

c) Rate of flow of 2.0 gallons per minute per square foot of filter area (4.9 m/hr.) with fixed nozzles or 0.5 gallons per minute per square foot (1.2 m/hr.) with revolving arms.

d) Air wash can be considered based on experimental data and operating experiences.

4.3.1.11 Air scouring

Air scouring can be considered in place of surface wash.

a) Air flow for air scouring the filter must be 3-5 standard cubic feet per minute per -square foot of filter area (0.9 - 1.5 m3/min/m2) 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.

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

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

d) Air must be free from contamination.

e) Air scour distribution systems 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.

f) Piping for the air distribution system shall not be flexible hose which may 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.

g) 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.

h) Consideration should be given to maintenance and replacement of air delivery piping.

i) The backwash water delivery system must be capable of 15 gallons per minute per square foot of filter surface area (37 m/hr.); however, when air scour is provided the backwash water rate must be variable and should not exceed 8 gallons per minute per square foot (20 m/hr.) unless operating experience shows that a higher rate is necessary to remove scoured particles from filter media surfaces.

j) The filter underdrains shall be designed to accommodate air scour piping when the piping is installed in the underdrain.

k) Air scouring controls must allow the operator to control the air flow rates and duration. Rate of flow indicators for air and water shall be provided.

4.3.1.12 Appurtenances

a) The following shall be provided for every filter:

   1) Influent and effluent sampling taps.

   2) An indicating loss of head gauge or transmitter.

   3) A meter indicating the instantaneous rate of flow.

b) Where used for surface water, provisions for filtering to waste with appropriate measures for cross connection control.

c) For surface water or systems using ground water under the direct influence of surface water with three or more filters, on-line turbidimeters shall be installed on the effluent line from each filter. All turbidimeters shall consistently determine and indicate the turbidity of the water in NTUs. 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. Graphical display capability should be provided for turbidity data. Turbidimeters on individual filters should be designed to accurately measure low-range turbidities and have an alarm that will sound when the effluent level approaches 0.3 ntu. It is recommended that turbidimeters be placed in a location that also allows measurement of turbidity during filter to waste.

d) A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

e) It is recommended the following also be provided for every filter:

   1) Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing.

   2) A 1 to 1.5-inch pressure hose equipped with shutoff nozzle or valve and storage rack at the operating floor for washing filter walls.

   3) Particle monitoring equipment as a means to enhance overall treatment operations when treating surface water.

   4) Automatic shutoff valves on each filter effluent to prevent the filters from draining down after the plant is shut off.

4.3.1.13 Backwash

Provisions shall be made for washing filters as follows:

a) A minimum backwashing rate of 15 gallons per minute per square foot (37 m/hr.), consistent with water temperatures and specific gravity of the filter media. A rate of 20 gallons per minute per square foot (50 m/hr.) or a rate necessary to provide for a 50 percent expansion of the filter bed is recommended. A reduced rate of 10 gallons per minute per square foot (24 m/hr.) may be acceptable for full depth anthracite or granular activated carbon filters.

b) Filtered water provided at the required rate by wash water tanks, a wash water pump, from the high service main, or a combination of these.

c) Wash water pumps in duplicate unless an alternate means of obtaining wash water is available.

d) Not less than 15 minutes wash of one filter at the design rate of wash.

e) A wash water regulator or valve on the main wash water line to obtain the desired rate of filter wash with the wash water valves on the individual filters open wide.

f) A flow meter, preferably with a totalizer, on the main wash water line or backwash waste line, located so that it can be easily read by the operator during the washing process.

g) Design to prevent rapid changes in backwash water flow.

h) Backwash shall be operator initiated. Automated systems shall be operator adjustable.

i) Appropriate measures for cross-connection control.

4.3.2 Rapid rate pressure filters

The normal use of these filters is for iron and manganese removal. Pressure filters shall not be used in the filtration of surface, or other polluted waters or following lime-soda-softening.

4.3.2.1 Number

At least two units shall be provided. Where only two units are provided, each shall be capable when operating at the approved design rate of treating the plant design capacity, normally the projected maximum daily demand. Where more than two units are provided, the units shall be capable when operating at the approved rate of treating the plant design capacity with the largest unit removed from service.

4.3.2.2 Rate of filtration

The rate shall not exceed four gallons per minute per square foot of filter area except where pilot or full-scale testing as approved by the reviewing authority has demonstrated satisfactory results at higher rates.

4.3.2.3 Details of design

The filters shall be designed to provide for:

a) Loss of head gauges on the inlet and outlet pipes of each filter.

b) An easily readable meter or flow indicator on each battery of filters. A flow indicator is recommended for each filtering unit.
c) Filtration and backwashing of each filter individually with an arrangement of piping as simple as possible to accomplish these purposes.

d) Minimum side wall shell height of five feet. A corresponding reduction inside wall height is acceptable where proprietary bottoms permit reduction of the gravel depth.

e) The top of the wash water collectors to be at least 18 inches above the surface of the media.

f) The underdrain system to efficiently collect the filtered water and to uniformly distribute the backwash water at a rate not less than 15 gallons per minute per square foot of filter area (37 m/hr.).

g) Backwash flow indicators and controls that are easily readable while operating the control valves.

h) An air release valve on the highest point of each filter.

i) An accessible manhole of adequate size to facilitate inspection and repairs for filters 36 inches or more in diameter. Sufficient handholds shall be provided for filters less than 36 inches in diameter. Manholes should be at least 24 inches in diameter where feasible.

j) Means to observe the wastewater during backwashing.

k) Construction to prevent cross connection.

4.3.3 Diatomaceous earth filtration

The use of these filters may be considered for application to surface waters with low turbidity and low bacterial contamination.

4.3.3.1 Conditions of use

Diatomaceous earth filters are expressly excluded from consideration for the following conditions:

a) Bacteria removal.

b) Color removal.

c) Turbidity removal where either the gross quantity of turbidity is high, or the turbidity exhibits poor filterability characteristics.

d) Filtration of waters with high algae counts.

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.

a) Conditions of the study such as duration, filter rates, head loss accumulation, slurry feed rates, turbidity removal, bacteria removal, etc., must be approved by the reviewing authority prior to the study.

b) Satisfactory pilot plant results must be obtained prior to preparation of final construction plans and specifications.

c) 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 filter area.

4.3.3.4 Treated water storage

Treated water storage capacity in excess of normal requirements shall be provided to:

a) Allow operation of the filters at a uniform rate during all conditions of system demand at or below the approved filtration rate.

b) Guarantee continuity of service during adverse raw water conditions without by-passing the system

4.3.3.5 Pre-coat

a) 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.

b) Quantity - Diatomaceous earth in the amount of 0.2 pounds per square foot of filter area (0.98 kg/m2) or an amount sufficient to apply a 1/8-inch coating should be used with recirculation.

4.3.3.6 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.

a) Quantity - Rate of body feed is dependent on raw water quality and characteristics and must be determined in the pilot plant study.

b) Operation and maintenance can be simplified by providing accessibility to the feed system and slurry lines.

c) Continuous mixing of the body feed slurry is required.

4.3.3.7 Filtration

a) Rate of filtration - The recommended nominal rate is 1.0 gallon per minute per square foot of filter area (2.4 m/hr.) with a recommended maximum of 1.5 gallons per minute per square foot (3.7 m/hr.). The filtration rate shall be controlled by a positive means.
b) Head loss - The head loss shall not exceed 30 psi (210 kPa) for pressure diatomaceous earth filters, or a vacuum of 15 inches of mercury (-51 kPa) for a vacuum system.

   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 gallon per minute per square foot of filter area (0.24 m/hr.) shall be provided.

c) 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 one inch is provided between elements or between any element and a wall.

d) Inlet design - The filter influent shall be designed to prevent scour of the diatomaceous earth from the filter element.

4.3.3.8 Backwash

A satisfactory method to thoroughly remove and dispose of spent filter cake shall be provided.

4.3.3.9 Appurtenances

a) The following shall be provided for every filter:

    1) Sampling taps for raw and filtered water.

    2) Loss of head or differential pressure gauge.

    3) Rate-of-flow indicator, preferably with totalizer.

    4) A throttling valve used to reduce rates below normal during adverse raw water conditions.

    Provisions for filtering to waste with appropriate measures for backflow prevention

b) It is recommended the following also be provided:

    1) A 1 to 1.5-inch pressure hose and storage rack at the operating floor for washing the filter.

    2) Access to particle counting equipment as a means to enhance overall treatment operations.

    3) A throttling valve used to reduce rates below normal during adverse raw water conditions.

    4) Evaluation of the need for body feed, recirculation, and any other pumps, in accordance with section 6.3.

    5) A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

    6) A continuous monitoring turbidimeter with recorder on each filter effluent for plants treating surface water.

4.3.4 Slow sand filters

The use of these filters shall require prior engineering studies to demonstrate the adequacy and suitability of this method of filtration for the specific raw water supply.

4.3.4.1 Quality of raw water

Slow rate gravity filtration shall be limited to waters having maximum turbidities of 10 units and maximum color of 15 units; such turbidity 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

At least two units shall be provided. Where only two units are provided, each shall be capable when operating at the approved design rate of treating the plant design capacity, normally the projected maximum daily demand. Where more than two units are provided, the units shall be capable when operating at the approved rate of treating the plant design capacity with the largest unit removed from service.

4.3.4.3 Structural details and hydraulics

Slow rate gravity filters shall:

a) Be covered.

b) Have enough headroom to permit normal movement by operating personnel for scraping and sand removal operations.

c) Have adequate access hatches and access ports for handling of sand and for ventilation.

d) Have an overflow at the maximum filter water level.

e) Be protected 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 on the basis of experimental data derived from the water to be treated. The nominal rate may be 45 to 150 gallons per day per square foot of sand area (1.8 - 6.1 m/day), with somewhat higher rates acceptable when demonstrated to the satisfaction of the approving authority.

4.3.4.5 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 underdrain will not exceed 0.75 feet per second. The maximum spacing of laterals shall not exceed 3 feet if pipe laterals are used.

4.3.4.6 Filter material

a) Filter sand shall be placed on graded gravel layers for a minimum depth of 30 inches.

b) The effective size shall be between 0.15 mm and 0.30 mm. Larger sand sizes may be considered by the reviewing authority; a pilot study may be required.

c) The uniformity coefficient shall not exceed 2.5.

d) The sand shall be cleaned and washed free from foreign matter.

e) The sand shall be re-bedded when scraping has reduced the bed depth to no less than 19 inches. Where sand is to be reused to provide biological seeding and shortening of the ripening process, re-bedding 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.

4.3.4.7 Filter gravel

The supporting gravel should be similar to the size and depth distribution provided for rapid rate gravity filters described herein.

4.3.4.8 Depth of water on filter beds

Design shall provide a depth of at least three to six feet of water over the sand. Influent water shall not scour the sand surface.

4.3.4.9 Control appurtenances

Each filter shall be equipped with:

a) Influent and effluent sampling taps.

b) An indicating loss of head gauge or other means to measure head loss.

c) An indicating rate-of-flow meter. A modified rate controller that 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 onto 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 the reviewing authority.

d) Provisions for filtering to waste with appropriate measures for cross connection control.

e) An orifice, venturi meter, or other suitable means of discharge measurement installed on each filter to control the rate of filtration.

f) An effluent pipe designed to maintain the water level above the top of the filter sand.

4.3.4.10 Ripening

Slow sand filters shall be operated in a filter-to-waste mode after scraping or re-bedding for a ripening period until the filter effluent turbidity falls to consistently below the regulated drinking water standard established for the system.

4.3.5 Direct filtration

Direct filtration, as used herein, refers to the filtration of a surface water following chemical coagulation and possibly flocculation but without settling. The nature of the treatment process will depend upon the raw water quality. A full-scale direct filtration plant shall not be constructed without prior pilot studies which are acceptable to the reviewing authority. In-plant demonstration studies may be appropriate where conventional treatment plants are converted to direct filtration.

Where direct filtration is proposed, an engineering report shall be submitted prior to conducting pilot plant or in-plant demonstration studies.

4.3.5.1 Engineering report

In addition to the items described in Section 1.1, "Engineering Report", the report shall include a historical summary of meteorological conditions and of raw water quality with special reference to fluctuations in quality, and possible sources of contamination. The following raw water parameters shall be evaluated in the report:

a) Color.

b) Turbidity.

c) Bacterial concentration.

d) Microscopic biological organisms.

e) Temperature.

f) Total solids.

g) General inorganic chemical characteristics.

h) Additional parameters as required by the reviewing authority.

The report shall also include a description of methods and work to be done during a pilot plant study or, where appropriate, an in-plant demonstration study.

4.3.5.2 Pilot plant studies

After approval of the engineering report and pilot plant protocol, a pilot study or in-plant demonstration study shall be conducted. The study must be conducted over a sufficient time to treat all expected raw water conditions throughout the year. The study shall emphasize but not be limited to, the following items:

a) Chemical mixing conditions including shear gradients and detention periods.

b) Chemical feed rates.

c) Use of various coagulants and coagulant aids.

d) Use of various coagulants and coagulant aids.

e) Flocculation conditions.

f) Filtration rates.

g) Filter gradation, types of media and depth of media

h) Filter breakthrough conditions.

i) Adverse impact of recycling backwash water due to solids, algae, trihalomethane formation and similar problems.

j) Length of filter runs.

k) Length of backwash cycles.

l) Quantities and make-up of the wastewater.

Prior to the initiation of design plans and specifications, a final report including the engineer's design recommendations shall be submitted to the reviewing authority.

The pilot plant filter must be of a similar type and operated in the same manner as proposed for full scale operation.

The pilot study must determine the contact time necessary for optimum filtration for each coagulant proposed.

4.3.5.3 Pretreatment - coagulation and flocculation

The final coagulation and flocculation basin design should be based on the pilot plant or in-plant demonstration studies augmented with applicable portions of the “Coagulation” and “Flocculation” sections herein.

4.3.5.4 Filtration

Filters shall be rapid rate gravity filters with dual or mixed media. The final filter design shall be based on the pilot plant or in-plant demonstration studies and all portions of the "Rapid Rate Gravity Filters" section herein. Pressure filters or single media sand filters shall not be used.

4.3.5.5 Appurtenances

a) The following shall be provided for every filter:

1) Influent and effluent sampling taps.

2) An indicating loss of head gauge.

3) A meter indicating instantaneous rate of flow.

4) Where used for surface water, provisions for filtering to waste with appropriate measures for cross connection control.

5) For systems with three or more filters, on-line turbidimeters shall be installed on the effluent line from each filter. All turbidimeters shall accurately determine and indicate the turbidity of the water in NTUs. Each turbidimeter shall report to a recorder that is designed and operated to allow the operator to monitor the turbidity at least once every 15 minutes. Turbidimeters on individual filters should be designed to accurately measure low-range turbidities and have an alarm that will sound when the effluent level exceeds 0.3 NTU. It is recommended that turbidimeters be placed in a location that also allows measurement of turbidity during filter to waste.

6) A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

b) It is recommended the following be provided for every filter:

1) Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing.

2) 1 to 1.5-inch pressure hose and storage rack at the operating floor for washing filter walls.

3) Particle monitoring equipment as a means to enhance overall treatment operations where used for surface water.

4.3.5.6 Siting requirements

The plant shall be located on a site that is large enough to allow for the expansion of the plant and the addition of additional pretreatment facilities.

4.3.6 Deep bed rapid rate gravity filters

Deep bed rapid rate gravity filters, as used herein, generally refers to rapid rate gravity filters with filter material depths equal to or greater than 48 inches. Filter media sizes are typically larger than those listed in the "Rapid Rate Gravity Filters Material" section herein.

Deep bed rapid rate filters may be considered based on pilot studies pre-approved by the reviewing authority.

The final filter design shall be based on the pilot plant studies and shall comply with all applicable portions of the "Rapid Rate Gravity Filters" section herein. Careful attention shall be paid to the design of the backwash system which usually includes simultaneous air scour and water backwash at sub-fluidization velocities.

4.3.7 Aerobic bio-filtration of surface water

Biological drinking water treatment can be divided into two process lines that impact their design: aerobic and anoxic bio-filtration. This section addresses aerobic biological filtration of surface water. The design of aerobic biological filtration of ground waters and anoxic biological treatment of groundwater are addressed in separate policy statements located at the beginning of this document. Biological treatment within a filter (i.e., a biofilter) at a drinking water treatment facility is an operational practice of managing, maintaining, and promoting biological activity on granular media in the filter to enhance the removal of organic and inorganic constituents before treated water is introduced into the distribution system. Typical objectives of biofiltration include:

a) Control of disinfection byproduct (DBP) precursors.
b) Increased disinfectant stability.
c) Taste and odor (T&O) control.
d) Reduction in organics and inorganics.
e) Reduction of substrates for microbial regrowth in the distribution system.

A naturally occurring biomass is allowed to accumulate by limiting or eliminating the pre-disinfectant residual, most commonly chlorine, in the filter influent. Removal of contaminants is based on redox chemistry: there needs to be an electron acceptor and an electron donor. For biological degradation of organics and inorganics to take place, there needs to be sufficient oxygen in the filter influent to serve as the electron acceptor.

If ozone is placed upstream of a granular media filter, organics will be degraded to more readily biodegradable compounds. Additionally, the dissolved oxygen concentration in the filter influent will be elevated. Typically, any filter downstream of ozonation will be an aerobic biological filter.

Design considerations for the following are described in the subsequent sections:

1. Pilot Studies.
2. Filter Design.
3. Empty Bed Contact Time.
4. Media Selection.
5. Filter Bottoms and Strainer Systems.
6. Backwash.
7. Pretreatment.
8. Disinfection.
9. Monitoring and Control.
10. Design Considerations.
11. Engineering Report, Plans, and Specifications.

4.3.7.1 Pilot studies

Pilot studies may be required by the reviewing authority. If required, the pilot study design and objectives must be pre-approved. As a minimum, the pilot study must be of sufficient duration to ensure establishment of steady state biological activity and encompass all anticipated conditions of operation.

Prior to the initiation of design plans and specifications, a pilot study report including the engineer's design recommendations shall be submitted to and approved by the reviewing authority.

4.3.7.2 Filter design

Biofilters are typically rapid rate gravity filters in surface water treatment plants where the primary objective is particle control. In such filters, biological treatment is always the secondary objective. Design criteria presented in the “Rapid Rate Gravity Filters” and the “Deep Bed Rapid Rate Gravity Filters” sections shall apply.

4.3.7.3 Number

At least two units shall be provided. Where only two units are provided, each shall be capable when operating at the approved design rate of treating the plant design capacity, normally the projected maximum daily demand. Where more than two units are provided, the units shall be capable when operating at the approved rate of treating the plant design capacity with the largest unit removed from service.

4.3.7.4 Empty bed contact time

Constituent removal is strongly impacted by the length of time that the water is in contact with the microbial community in the filter. Empty bed contact time shall be determined by a pilot study based on treatment objectives. Filter media depths greater than 30 inches may be allowed if supported by the results of a pilot study. A longer empty bed contact time may be required when the water is cold (e.g., less than 15ºC or 59ºF). Empty bed contact times typically range between 5 and 20 minutes.

4.3.7.5 Media selection

Sand, anthracite, and granular activated carbon (GAC) can be used as filter media for aerobic biofiltration. Granular activated carbon media is commonly used due its large surface area to volume ratio. Use of media with an effective size of less than 0.45 mm should be avoided.

4.3.7.6 Filter bottoms and strainer systems

Filter bottoms with small openings may be prone to clogging. Porous plate bottoms shall not be allowed. Evidence that the proposed filter bottom has successfully been used in the past with biofilters or pilot testing of the proposed underdrain may be required by the reviewing authority.

4.3.7.7 Backwash

Backwashing design shall include the following:

a) The ability to add chlorine or other approved chemicals to the backwash.

b) Backwash air scour system.

c) Filter-to-waste piping.

d) Backwash design criteria presented in the “Rapid Rate Gravity Filters Air Scouring” and “Backwashing” sections shall apply.

4.3.7.8 Pretreatment

Chemical addition, such as ozone upstream of a rapid rate filter will promote biological activity on the granular filter media and increase the dissolved oxygen concentration. Refer to Section 4.4.6 for design considerations. Additional chemicals may be added to promote biological oxidation, biological activity, or reduce headloss. If performance of the biofilter is not meeting desired goals, testing for a micronutrient limitation should be conducted and a low dose of micronutrients may be added (i.e. orthophosphate, etc.). If headloss is significant, a low dose of a pre-oxidant should be considered.

Provisions to add approved chemicals to the filter influent for biomass and headloss control may be required.

4.3.7.9 Disinfection

Following biological filtration, a disinfectant shall be applied with the appropriate contact time in the Disinfection Section herein.

4.3.7.10 Monitoring and control

In addition to laboratory equipment listed in Section 2.8.1, test equipment for the following parameters shall be provided:

a) Dissolved oxygen concentration at the influent and effluent of the filter.

b) Oxidation-reduction potential.

c) Biological indicator organisms (total coliform, heterotrophic plate count, etc.).

d) Temperature.

e) The contaminant targeted for biological treatment.

f) Additional items as required by the reviewing authority.

4.3.8 Membrane Filtration

Membrane technologies have a wide range of applications from the use of reverse osmosis for desalination, inorganic compound removal, and radionuclide removal to the use of lower pressure membranes for removal of surface water contaminants such as giardia and cryptosporidium. Membrane technologies are typically separated into four categories based on membrane pore size: reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF).

RO and NF membrane systems are designed for the removal of dissolved contaminants such as; total dissolved solids (TDS), hardness, nitrates, and disinfection byproduct precursors. Their design are typically **not** meant to be used for surface water filtration.

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 UF or MF system is composed of a number of identical filter units or skids that, in combination, generate the total production filtrate. Their design are typically meant to be used for surface water filtration requirements.

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).

In this section the term “filter unit” refers to a group of membranes that share common valving and which can be isolated as a group for testing, cleaning, or repair. For these purposes, the term filter unit or membrane unit is considered synonymous with other commonly used terms like *rack, train,* and *skid*.

4.3.8.1 Membrane filtration: ultrafiltration (UF) and microfiltration (MF) systems

4.3.8.1.1 Support Documentation

1. For proposed membrane installations, project-specific information that shall be submitted includes, at a minimum:

    a) Treatment objectives.

    b) An analysis of any pretreatment needs.

    c) Maximum feed rate to each filter unit (Qf).

    d) Maximum production rate from each filter unit (Qp).

e) Percent recovery (R).

f) Design flux rate (J).

g) Pertinent ANSI/NSF 61 certifications.

h) ANSI/NSF Standard 419 challenge test results.

2. 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.

3. 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:

   1) Minimum direct integrity test starting pressure (P_{test}).

   2) Pressure decay test result (ΔP_{test}).

   3) Minimum applicable log removal value (LRV).

   4) Air-to-liquid conversion ratio (ALCR).

   5) Volume of pressurized air in the membrane system during a pressure decay test (V_{sys}).

   6) Volumetric concentration factor (VCF).

   7) Maximum backpressure during pressure decay test (BP).

   8) Liquid-membrane contact angle (θ).

   9) Pore shape factor (K).

   10) Surface tension (σ).

   11) Transmembrane pressure (TMP).

   12) Water temperature (T).

   13) Time/Length of direct integrity test.

4. Indirect integrity testing information including laser turbidimeter make and model, data logging frequency, and alarm set points.

5. Additional system information, to include:

   1) Process type (pressure/vacuum-driven).

   2) Materials of construction.

   3) Membrane surface area per filter unit (A_{sys}).

4) Effective Pore Size.

5) Minimum/Maximum Operating Pressures.

6) Manufacturer-recommended limitations to prevent equipment damage.

6. Specifications for all system equipment components, to include: pretreatment, the membrane filter unit, membrane modules, compressed air equipment, Clean-in-Place (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.

7. 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:

      1) Frequency for each backwash mode.

      2) Duration of steps.

      3) Impact to solids accumulation (expressed as VCF).

      4) Justification of the selected backwash process.

8. 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:

   a) Who is to provide the training?

   b) Schedule of training.

   c) Training forms.

   d) Operators who will be trained.

   e) Collecting, recording, and interpreting data.

   f) Startup and shutdown procedures.

   g) All fiber testing and repair procedures.

4.3.8.1.2 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.

4.3.8.1.3 Raw Water Quality

1) Weekly source water quality monitoring should be conducted to include different seasons, to capture seasonal variations, 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.

2) 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).

4.3.8.1.4 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.

4.3.8.1.5 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 the reviewing authority allows a pilot study that can demonstrate coagulation, flocculation, and sedimentation are not necessary.

4.3.8.1.6 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.

a) Neither polymers nor phosphates shall be used in advance of the membranes due to the potential for irreversible fouling.

b) Ability to pre-treat to waste should be included.

4.3.8.1.7 Redundancy

a) 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.

b) 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.

4.3.8.1.8 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.

a) Backwash water supply shall be filtered water.

b) 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.

4.3.8.1.9 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.

a) All cleaning chemicals shall be certified for conformance with ANSI/NSF Standard 60 or meet the food grade standards of the United States Pharmacopeia.

b) Provisions for safe chemical storage, handling, and waste disposal shall be addressed.

c) 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.

d) A functional description of CIP procedures shall be provided, addressing the following:

    1) A SOP for respective operator CIP activities, including frequency, triggers, automated/manual cleaning aspects, and post-CIP approach for the return to production mode.

    2) Identification of the different chemicals to be utilized.

    3) Methods to neutralize and dispose of the CIP chemical waste stream.

4.3.8.1.10 Direct Integrity Testing

Each filter unit shall be equipped with a direct integrity testing system that is consistent with Chapter 4, Direct Integrity Testing in the EPA's Membrane Filtration Guidance Manual (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 Log Reduction Value (LRV).

The 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.

a) 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.

b) 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.

c) 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.

d) 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.

e) The time for direct integrity test to determine the decay rate shall be at least five (5) minutes during any direct integrity test.

f) 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:

   1) Minimum initial direct integrity test starting pressure, after a stabilization period, is less than the required value (P_{test}).

   2) The pressure decay rate (PSI per minute) exceeds the upper control limit value.

   3) PLC-generated LRV is less than the required value.

4.3.8.1.11 Indirect Integrity Testing

a) An online laser turbidimeter shall be provided for each filter unit for continuous monitoring and recording of the membrane permeate also known as individual filter effluent (IFE). This shall include measurement and recording of permeate turbidity at least once every 15 minutes that the system is operated.

b) 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.

4.3.8.1.12 Flux

Permit applications shall include the rationale and a justification for the proposed maximum flux rate (gallons per square foot of membrane 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.

4.3.8.1.13 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.

a) Pretreatment may be required to provide a low, practical range for operational TMP.

b) Permit applications shall identify acceptable operational TMP ranges, alarm, and shutdown conditions.

c) The PLC shall trigger an alarm at a prescribed TMP to notify the operator of rising pressure differential and unusual conditions.

d) The PLC shall trigger an automatic shutdown at a prescribed maximum TMP to protect the membrane from damage or failure.

4.3.8.1.14 Instrumentation/Appurtenances

At a minimum, the following equipment and instrumentation shall be provided:

a) Taps for sampling feed water, permeate, and concentrate.

b) Appropriate pressure gauges for TMP and for direct integrity testing. Include these devices on feed, permeate, and concentrate lines.

c) Flow meter for feed, permeate, and waste flow rate.

d) Flow rate controller to control the flux rate.

e) All required means of removing membrane modules and cartridges for replacement or repair, including cranes, lifts, adequate ceiling heights, and specialty tools, as applicable.

f) All fiber leak detection instrumentation and fiber repairing/pinning equipment, including test beds and pressurization systems, as applicable.

g) A dedicated workspace within the plant large enough to perform all fiber repair/pinning and maintenance.

h) The feed water line shall include continuous monitors and recorders for turbidity, pH, conductivity, and temperature.

i) 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.

j) The combined permeate line or Combined Filter Effluent (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.

4.3.8.1.15 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:

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 (Qp).

2) Percent recovery (R).

3) Flux rate (J).

4) Permeate turbidity (NTU).

5) Pressure decay test result (ΔPtest).

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).

i) Control systems shall provide alarms, off site notices, and automatic shutdown processes. Notification alarms and shutdown alarms are to be utilized where appropriate. At a minimum, these alarms/shutdown parameters are to be provided:

1) High turbidity (raw, membrane feed, individual filter unit, and combined permeate).

2) Membrane failure (low pressure differentials).

3) Pump failures.

4) High pressure decay test result (ΔPtest).

5) High transmembrane pressure (TMP).

6) Low log removal value (LRV).

7) PLC failure.

8) Membrane equipment failure.

9) Clearwell level (high and low).

10) Entry point chlorin residual (high and low).

11) Low chemical levels.

12) Power failure.

13) Building intrusion.

4.3.8.1.16 PLC Programming

The membrane system's PLC shall be programmed to operate, and be able to demonstrate that it is programmed, in accordance with the review authority's approved site-specific operational control limits and process parameters.

Applicable process parameters include the following:

a) Maximum production from each filter unit (Qp).

b) Percent recovery (R).

c) Design flux rate (J).

d) Raw, membrane feed, and membrane permeate turbidity (NTU) setpoints.

e) Minimum direct integrity test starting pressure (Ptest).

f) Minimum direct integrity end pressure (Pf).

g) Pressure decay test result (ΔPtest).

h) Minimum applicable log removal value (LRV).

i) Air liquid conversion ratio (ALCR).

j) Volume of pressurized air in a membrane system during a pressure decay test (Vsys).

k) Membrane surface area per filter unit (Asys).

l) Volumetric concentration factor (VCF).

m) Maximum backpressure during pressure decay test (BP).

n) Liquid-membrane contact angle (θ).

o) Pore shape factor (K).

p) Surface tension (σ).

q) Transmembrane pressure (TMP).

r) Water temperature (T).

4.3.8.2 Nanofiltration (NF) and reverse osmosis (RO) systems membrane separation treatment processes

4.3.8.2.1 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.

4.3.8.2.2 Pilot Studies

The reviewing authority 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), operating parameters (e.g., flux) and fouling characteristics 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) Clean-in-Place (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 clean-in-place (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.

a) The pilot study shall determine specifics such as:

1) Most suitable membrane.

2) Ability to meet all treatment objectives.

3) Pretreatment needs.

4) Post-treatment needs.

5) Quantity of reject water.

6) Operation and maintenance needs.

7) Optimum system recovery and flux rate.

8) Process efficiency.

9) Cold and warm water flux rates.

10) Fouling potential.

11) Optimum membrane pressures.

12) Optimum cleaning procedures and frequency.

b) The pilot study monitoring shall include:

1) Continuous low rate, run time, flux rate, filtrate pressures, TMP, and raw (including blended, if applicable), feed, and membrane effluent turbidities.

2) Daily nitrates (if applicable), pH, hardness, and temperature.

3) Weekly raw, membrane influent water and membrane effluent alkalinity, total hardness, calcium hardness, ammonia, silica, iron, sulfate, color, manganese, total suspended solids, total organic carbon (for DBP pre-cursor treatment objectives), and total dissolved solids.

4) All backwash volumes, rats, and CIP chemical usage.

c) The pilot study shall include at least three (3) CIP cycles.

d) The pilot study should monitor for water quality parameters related to corrosion for corrosion control treatment evaluations.

e) A pilot study protocol shall be submitted to the appropriate regulating authority for approval prior to initiating the pilot study.

f) The Certified Operators for the proposed system should be heavily involved in the pilot study to 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.

g) The minimum performance goals of the membrane during the pilot study shall be:

1) Permeate samples are 50% or less of MCL for each contaminant of concern.

2) The target flux and recovery rates are maintained.

h) Upon study completion, a report shall be submitted to the regulating authority summarizing the procedures and all test results. The report shall contain sufficient detail to establish design parameters for the full-scale plant.

i) 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.

4.3.8.2.3 Permitting Support Documentation

For proposed membrane installations, project-specific information and calculations to be submitted to regulatory authority as part of the detail plan submission shall include:

a) Treatment objectives.

b) Raw water quality information, including all new source sampling results.

c) An analysis of any pretreatment needs.

d) Predicted finished water qualities for the key operating parameters.

e) Maximum feed rate to each filter unit (Qf).

f) Maximum production from each filter unit (Qp).

g) Predicted net driving pressure (NDP).

h) Percent recovery (R).

i) Design flux rate (J).

j) Concentration Factor.

k) Pertinent ANSI/NSF Standard 61 certifications.

l) Summary describing any computer modeling or bench scale study (of the blended water) used to determine that the system will produce finished water meeting the regulatory requirements and the treatment objectives.

m) 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.

n) 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.

o) Corresponding information on the specific system being proposed for use shall also include:

    1) Dimensioned filter unit layout drawings.

    2) Process and instrumentation diagrams.

    3) Descriptions of the respective production, backwash, and CIP modes.

    4) For cross-connection control, a block and bleed assembly or an equivalent assembly which is equally or more protective, be installed on the permeate line to prevent cleaning chemical discharge to the clearwell.

    5) Calculations adequately describing the establishment of critical operational control limits.

    6) Information on how redundancy requirements are being met.

    7) A description of the backwash process should include frequency for each model-equipped backwash mode, duration of steps/events, and basis of approach for this process.

p) 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.

4.3.8.2.4 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.

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)

4.3.8.2.5 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.

a) All pretreatment processes shall be compatible with the membrane system.

b) Pretreatment shall be provided for all raw water quality parameters that are outside of the manufacturer's 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:

1) Turbidity: 0.5 NTU

2) TOC: 2 mg/L

3) Iron: 0.1 mg/L

4) Manganese: 0.05 mg/L

5) Oil & Grease: 0.1 mg/L

6) Silt Density Index (SDI): 3.0

7) VOCs: in µg/L range

c) 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.

d) Pretreatment for groundwater should include acid and antiscalants to inhibit the formation of scale precipitates.

e) Pretreatment for surface waters should include coagulation, flocculation, sedimentation, and filtration.

f) If a pre-oxidant is provided, a means to neutralization or remove the oxidant prior the RO/NF filter unit needs to be provided.

4.3.8.2.6 Design Considerations

a) 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.

b) 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.

   1) 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.

   2) For secondary contaminants, the target blended water concentration shall be 80 percent of the corresponding MCL.

c) 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.

d) The ability to filter-to-waste should be provided.

e) 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.

f) Backwash water supply water, if provided, shall be filtered water with adequate cross-connection control provisions.

g) Consideration should be given to the disposal of the reject water. Evaluation should include quantity, water quality and disposal options. Discharge permits may be required by the regulating authority.

4.3.8.2.7 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.

a) All cleaning chemicals shall be ANSI/NSF Standard 60-certified.

b) Provisions for safe cleaning chemical storage, chemical handling, and resulting waste disposal shall be addressed.

c) 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.

d) CIP procedures shall be provided, addressing the following:

    1) 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.

    2) Identification of the different chemicals to be utilized.

    3) Methods to neutralize and dispose of the CIP chemical waste stream.

    4) Cross-connection control provisions for chemical feeds and waste piping.

4.3.8.2.8 Instrumentation/Appurtenances

The following monitoring instrumentation and appurtenances, at a minimum, shall be provided:

a) Appropriate pressure gauges for TMP. Include these devices on feed, permeate, and concentrate lines.

b) Flow meter for feed, permeate, and waste flow rate.

c) Flow rate controller (i.e. VFD for pump) to control the flux rate.

d) All required means of removing membrane modules including cranes, lifts, required ceiling heights, and specialty tools, as applicable.

e) Sample taps for the following: feed, permeate from each stage (as applicable), combined permeate, combined concentrate, and blended (as applicable).

f) The feed water line and the permeate line from each filter unit shall include continuous monitors and recorders for, pH, conductivity, and temperature.

g) The combined permeate line shall be equipped with a continuous monitor and recorder for totalizing flow rate.

4.3.8.2.9 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:

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 voltage and power spikes.

c) Have the capability to resume full functionality utilizing all applicable site-specific control limits and parameters after power restoration.

d) Be capable of meeting all the continuous recording requirements.

e) Be capable of generating applicable reports for plant operators, such as parameter trending and alarm histories.

f) Be capable of trending at minimum the following parameters:

    1) Production flow rate from each filter unit

    2) Percent recovery (R).

    3) Flux rate (J).

    4) Transmembrane pressure.

    5) Conductivity.

g) Systems shall provide alarms, communication systems, and automatic shutdown processes. Notification alarms and shutdown alarms are to be utilized where appropriate. The regulating authority 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) Programable Logic Control failure.

    7) Membrane equipment failure.

    8) Entry point chlorine residual (high or low).

    9) Low chemical levels.

    10) Power failure.

    11) Building intrusion.

4.3.8.2.10 Operation and Maintenance

An O&M Manual shall be provided. The O&M manual shall include at a minimum:

a) SOPs for startup, shutdown, CIPs, alarm conditions responses, monthly reporting, and data trending.

b) The recommended or required maintenance requirements for each piece of equipment, including maintenance schedule for turbidimeters, pressure sensors, and flow sensors.

c) The proper operation parameters of the membrane units and associated appurtenances including software user instructions.

d) Trouble shooting guide for all equipment and procedures.

e) Assessment of potential equipment failure/damage and accompanying warranty documents.

f) Guidance to determine when the membrane modules are approaching the end of useful life (i.e., percent recovery, permeability, life span, total production, etc.).

4.3.8.2.11 Post-Treatment

a) Due to the very corrosive characteristics of the permeate, post alkalinity, and pH adjustment shall be provided. A minimum of 20 mg/L as CaCO3 of alkalinity and a pH of at least 7.0 shall be provided in the finished water.

b) Water treated using RO or NF typically includes aeration for degasification of carbon dioxide (if excessive) and hydrogen sulfide removal (if present).

4.4 DISINFECTION

Chlorine is historically the preferred disinfecting agent. Disinfection may be accomplished with chlorine, chloramines, chlorine dioxide, ozone, or ultraviolet light. Other disinfecting agents will be considered, providing reliable application equipment is available and testing procedures for a residual are recognized in "Standard Methods for the Examination of Water and Wastewater," latest edition or an equivalent means of measuring effectiveness exists. Disinfection is required for all surface water supplies, groundwater under the direct influence of surface water, and for any groundwater supply of questionable sanitary quality or where other treatment is provided.

Primary disinfection kills or inactivates bacteria, viruses, and other potentially harmful organisms in drinking water. Secondary disinfection provides longer lasting water treatment as the water moves through pipes to consumers. Disinfection with chloramines is recommended only for secondary disinfection. Continuous disinfection to maintain a detectable residual throughout the distribution system is recommended for all water supplies. Consideration must be given to the formation of disinfection byproducts (DBP) when selecting the disinfectant.

4.4.1 Contact time, CT, and point(s) of application

a) At plants treating surface water or groundwater under the direct influence of surface water, provisions shall be made for applying the disinfectant to the raw water, settled water, filtered water, and water entering the distribution system.

b) As a minimum, at plants treating groundwater, provisions shall be made for applying the disinfectant to the detention basin inlet and water entering the distribution system,

c) The amount of contact time provided will depend on the type of disinfectant, disinfectant residual, pH, temperature, peak flow rate, minimum basin volume, and baffling factor. As a minimum, for surface water, groundwater under the direct influence of surface water and if required under the Groundwater Rule the system must be designed to meet the CT requirements set by the reviewing authority. CT is defined as the disinfectant residual concentration multiplied by contact time.

4.4.2 Residual chlorine

If primary disinfection is accomplished using ozone, ultraviolet light (UV), or some other chemical that does not provide a residual disinfectant, then chlorine must be added to provide a residual disinfectant. Minimum free chlorine residual in a water distribution system should be 0.2 mg/L. Minimum chloramine residuals, where chloramination is practiced, should be 1.0 mg/L at distant points in the distribution system.

4.4.3 Testing equipment

a) Chlorine residual test equipment recognized in the latest edition of Standard Methods for the Examination of Water and Wastewater shall be provided and should be capable of measuring residuals to the nearest 0.01 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. It is recommended that all systems, as a minimum, use an instrument with a digital readout.

b) Automatic chlorine residual recorders should be provided where the chlorine demand varies appreciably over a short period of time.

c) All treatment plants having a capacity of 0.5 million gallons per day or greater should be equipped with recording chlorine analyzers monitoring water entering the distribution system.

d) All surface water treatment plants that serve a population greater than 3300 must have equipment to measure chlorine residuals continuously entering the distributionsystem.

e) Systems that rely on chlorination for inactivation of bacteria or other microorganisms present in the source water shall have continuous chlorine residual analyzers and other equipment that automatically shut down the facility when chlorine residuals are not met unless otherwise approved by the reviewing authority.

f) All continuously recording chlorine residual analyzers must be compatible with the requirements of EPA Method 334.0 or ChloroSense (Palintest).

g) Public water supplies with a chloramine residual shall have test equipment for ammonia, nitrite, nitrate, total chlorine, and free chlorine, with consideration given for the possible interference of chloramines.

4.4.4 Chlorine

4.4.4.1 Feed System Design

Chlorine chemical feed systems must meet the requirements in the “Chemical Application” section herein. Specific chemical requirements for chlorine gas and sodium hypochlorite are in Section 5.4.

4.4.4.2 Capacity

The chlorinator or metering pump capacity shall be such that a chlorine residual of at least 2 mg/L can be maintained in the water once all demands are met after an effective contact time when maximum flow rate coincides with anticipated maximum chlorine demand. The equipment shall be of such design that it will operate accurately over the desired feeding range.

4.4.4.3 Automatic switch-over

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

4.4.4.4 Automatic proportioning

Automatic proportioning chlorinators will be required where the rate of flow or chlorine demand is not reasonably constant.

4.4.4.5 Eductor

Each eductor must be selected for the point of application with particular attention given to the quantity of chlorine to be added, the maximum injector water flow, 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 eductor should be provided.

4.4.4.6 Injector/diffuser

The chlorine solution injector/diffuser must 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.

4.4.4.7 Cross-connection protection

The chlorinator water supply piping shall be designed to prevent contamination of the treated water supply by sources of questionable quality. At all facilities treating surface water, pre- and post-chlorination systems must be independent to prevent possible siphoning of partially treated water into the clear well. The water supply to each eductor shall have a separate shut-off valve. No master shut-off valve will be allowed.

4.4.4.8 Pipe material

The pipes carrying elemental liquid or dry gaseous chlorine under pressure must be Schedule 80 seamless steel tubing or other materials recommended by the Chlorine Institute (never use

PVC). Rubber, PVC, polyethylene, or other materials recommended by the Chlorine Institute must be used for chlorine solution piping and fittings. Nylon products are not acceptable for any part of the chlorine solution piping system.

4.4.4.9 Housing

Adequate housing must be provided for the chlorination equipment and for storing the chlorine. (See Part 5).

4.4.5 Chloramines

Chlorine combines with ammonia to form chloramine compounds. The ammonia may be naturally occurring or may be added to the water usually after the chlorine injection point. Chloramines are a weaker disinfectant and typically are used for secondary disinfection. Chloramine, which is less powerful than free chlorine, may be suitable for disinfection of some ground water supplies but it is inadequate in strength for primary disinfection of surface waters. In the distribution system, chloramines are more persistent and better at controlling biofilms than free chlorine. Monochloramines have less fewer taste and odor issues than free chlorine.

4.4.5.1 Chloramine formation

Chloramine formation is dependent on temperature, pH, mixing, organics, and chlorine to ammonia-nitrogen weight ratio. The chlorine to ammonia-nitrogen weight ratio is based upon chlorine residual not chlorine dose. The desired chloramine compound is monochloramine. The chlorine to ammonia-nitrogen weight ratio for monochloramine formation is between 3:1 to 5:1. Typically, the desired ratio is 4.5:1. A higher ratio can lead to formation of dichloramine and trichloramine and the production of undesirable taste and odors. Too low of a ratio will result in excess free ammonia and possible nitrification in the distribution system.

4.4.5.2 Feed system design

a) Chemical feed systems shall meet the requirements in the “Chemical Application” section. Specific chemical requirements for chlorine gas, sodium hypochlorite, ammonium sulfate, aqua ammonia, and anhydrous ammonia are in the “Specific Chemical” section.

b) Ammonia and ammonia compounds shall be stored in a separate room from chlorine because of potential explosive or violent reactions that could occur if they are mixed.

c) Both chlorine and ammonia must be mixed thoroughly and rapidly in the main plant stream to prevent formation of dichloramine and trichloramine.

d) A method to maintain the desired chlorine to ammonia-nitrogen weight ratio shall be provided. An automated, continuous instrument control method is recommended.

4.4.5.3 Chloramine concentration

The required chloramine concentration at each entry point depends on the size of the distribution system and the decay rate. Typically, the initial chloramine concentration is 2 mg/L or higher. A chloramine residual of at least 1 mg/L should be maintained throughout the distribution system.

4.4.5.4 Chloramine booster system

Booster chlorination of chloraminated water in the distribution system can be used to reform monochloramine from the ammonia released during the decay process. Booster chloramination (adding chlorine and ammonia) may be necessary in certain situations.

4.4.5.5 Monitoring

a) See the chloramine specific testing equipment requirements in “Testing Equipment” – Section 4.4.3.

b) A monitoring program shall be established for each entry point, booster chlorination station and throughout the distribution system to verify proper chloramine formation and to monitor for nitrification occurrences.

4.4.5.6 Nitrification

a) Free ammonia concentration should be kept below 0.1 mg/L.

b) A nitrification control plan that includes flushing and the temporary use of a free chlorine residual should be prepared along with the triggering criteria for implementation.

4.4.5.7 Corrosion control

a) Switching from free chlorine to chloramines may increase lead solubility in water. An evaluation of the corrosion control strategy is required prior to making this switch.

b) The type of chlorine and ammonia chemicals used can affect the finished water pH. An evaluation of the corrosion control strategy is required prior to changing chemicals.

4.4.5.8 Public Water Supply interconnections

Blending water supplies that contain both free chlorine and chloramines should be avoided except in an emergency.

4.4.5.9 Public notice

Chloramines in water present risks to kidney dialysis patients and fish aquariums. Provide public notice prior to changing the type of chlorine residual.

4.4.6 Ozone

4.4.6.1 Design considerations

Ozonation systems are generally used for the purpose of disinfection, oxidation and microflocculation. When applied, all of these reactions may occur but typically only one is the primary purpose for its use. The other reactions may be secondary benefits of the ozonation installation.

Effective disinfection occurs as demonstrated by the fact that the "CT" values for ozone, for inactivation of viruses and Giardia cysts, are considerably lower than the "CT" values for other disinfectants. In addition, recent research indicates that ozone can be an effective disinfectant for the inactivation of cryptosporidium. Microflocculation and enhanced filterability benefits have been realized by many, but not all, water supplies using ozonation. Oxidation with ozonation of organic compounds such as color, taste and odor, and detergents and inorganic compounds such as iron, manganese, heavy metals and hydrogen sulfide is possible. The effectiveness of oxidation of the compound varies depending on pH and alkalinity of the water.

The pH and alkalinity of the water also 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 necessary to maximize ozone residual or maximize hydroxyl radical formation. For disinfection, residual ozone is necessary for development of "CT".

As a minimum, bench scale studies shall be conducted to determine minimum and maximum ozone dosages for disinfection "CT" compliance and oxidation reactions. More involved pilot studies shall be conducted when necessary to document benefits and DBP precursor removal effectiveness. Consideration shall be given to multiple points of ozone addition. Pilot studies shall be conducted for all surface waters. Extreme 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 disinfectant which maintains a measurable residual will be required in order to ensure bacteriologically safe water is carried throughout the distribution system.

Furthermore, because of the more sophisticated nature of the ozone process a higher degree of operator maintenance skills and training is required. The ability to obtain qualified operators must be evaluated in selection of the treatment process. The necessary operator training shall be provided prior to plant startup.

The production of ozone is an energy intensive process. Substantial reductions in electrical usage, ozone generation equipment sizes, and waste heat removal systems can be realized by using oxygen enriched air or 100% oxygen in the ozone generators, and by powering the ozone generators with higher frequency electricity.

Use of ozone may result in increases in biologically available organics content of the treated water. Consideration of biologically active filtration may be required to stabilize some treated waters. Ozone use may also lead to increased chlorinated byproduct levels if the water is not stabilized, and free chlorine is used for distribution protection.

Other Applications – ozone can be used for algal control, advanced oxidation, and other treatment processes. Contact the reviewing authority for other requirements.

4.4.6.2 Feed Gas Preparation

a) General

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

2) 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 "heat-less" desiccant dryer. In all cases the design engineer must ensure that the maximum dew point of -76oF (-60oC) will not be exceeded at any time.

b) 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 shall 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 shall 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 after-cooler and/or entrainment separator with automatic drain shall be provided prior to the dryers to reduce the water vapor.

5) A back-up air compressor must be provided so that ozone generation is not interrupted in the event of a break-down.

c) Air Drying

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 -76ºF (-60ºC) 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 shall be used.

3) A refrigeration dryer capable of reducing inlet air temperature to 40ºF (4ºC) 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 shall be provided so that the ozone generation is not interrupted in the event of dryer breakdown.

6) Each dryer shall be capable of venting "dry" gas to the atmosphere prior to the ozone generator, so each dryer can be operated and tested when other dryers are "on-line".

d) 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 be capable of removing aerosol and particulates larger than 0.3 microns in diameter. The filter after the desiccant dryer shall be of the particulate type and be capable of removing all particulates greater than 0.1 microns in diameter, or smaller if required by the generator manufacturer.

e) 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.

4.4.6.3 Ozone Generator

a) Capacity

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

2) The design shall ensure that the minimum 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 pertinent data 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) A backup ozone generator must be provided.

b) 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.

c) 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 5ºF (2.8ºC). 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 are maintained. Where cooling water is treated, cross connection control shall be provided to prevent contamination of the potable water supply. Steam condensation, engine jacket cooling water, nor water used by heat exchange dryers may be returned to the potable water supply.

d) Materials

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

4.4.6.4 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.

a) 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 contact time shall be 10 minutes. A shorter contact time may be approved by the reviewing authority if justified by appropriate design and "CT" considerations.

3) For ozone applications in which precipitates are formed, such as with iron and 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 should be separate closed vessels that have no common walls with adjacent rooms. The contactor must be kept under negative pressure and sufficient ozone 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) Where necessary a system shall be provided between the contactor and the off-gas destruct unit to remove froth from the air and return_the air to the contactor or other location acceptable to the reviewing authority. If excessive foaming is expected, 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/vacuum 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 should 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 should be a minimum of 18 feet. The contactor should also have a minimum of 3 feet of freeboard to allow for foaming.

13) All contactors shall have provisions for cleaning, maintenance, and drainage.

14) Each contactor compartment shall also be equipped with an access hatchway.

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

b) Other contactors

Other contactors, such as the venturi or aspirating turbine mixer contactor, may be approved by the reviewing authority provided adequate ozone transfer is achieved and the required contact times and residuals can be met and verified.

4.4.6.5 Ozone destruction unit

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

b) In order 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.

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

d) At least two units shall be provided which are each capable of handling the entire gas flow.

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

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

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

4.4.6.6 Piping materials

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

4.4.6.7 Joints and connections

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

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

c) 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 reaching the generator.

4.4.6.8 Instrumentation

a) 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.

b) Electric power meters should 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 certain preset level.

c) 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 for proper adjustment of the dryer cycle. 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 shall be used.

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

e) Temperature gauges shall be provided for the inlet and outlet of the ozone cooling water and the inlet and outlet of the ozone generator feed gas, and, if necessary, for the inlet and outlet of the ozone power supply cooling water.

f) 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.

g) 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 shall also 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.

h) A minimum of one ambient ozone monitor shall be installed in the vicinity of the contactor and a minimum of one shall be installed in the vicinity of the generator. Ozone monitors shall also be installed in any areas where ozone gas may accumulate.

4.4.6.9 Alarms

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

a) Dew point shutdown/alarm - This system should shut down the generator in the event the system dew point exceeds -76ºF (-60ºC).

b) Ozone generator cooling water flow shutdown/alarm - This system should shut down the generator in the event that cooling water flows decrease to the point that generator damage could occur.

c) Ozone power supply cooling water flow shutdown/alarm - This system should shut down the power supply in the event that cooling water flow decreases to the point that damage could occur to the power supply.

d) Ozone generator cooling water temperature shutdown/alarm - This system should shut down the generator if either the inlet or outlet cooling water exceeds a certain preset temperature.

e) Ozone power supply cooling water temperature shutdown/alarm - This system should shut down the power supply if either the inlet or outlet cooling water exceeds a certain preset temperature.

f) Ozone generator inlet feed-gas temperature shutdown/alarm - This system should shut down the generator if the feed-gas temperature is above a preset value.

g) Ambient ozone concentration shutdown/alarm - The alarm should 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 should occur when ambient ozone levels exceed 0.3 ppm (or a lower value) in either the vicinity of the ozone generator or the contactor.

h) Ozone destruct temperature alarm - The alarm should sound when temperature exceeds a preset value.

4.4.6.10 Safety

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

b) Noise levels resulting from the operating equipment of the ozonation system shall be controlled to within acceptable limits by special room construction and equipment isolation.

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

d) Emergency exhaust fans must be provided in the rooms containing the ozone generators to remove ozone gas if leakage occurs.

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

f) 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.

4.4.6.11 Construction Considerations

a) 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.

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

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

4.4.7 Chlorine dioxide

Chlorine dioxide may be considered as a primary and residual disinfectant, a pre-oxidant to control tastes and odors, to oxidize iron and manganese, and to control hydrogen sulfide and phenolic compounds. Chlorine dioxide is to be a strong disinfectant which does not form THMs or HAAs.

When choosing chlorine dioxide, consideration must be given to formation of the regulated byproducts, chlorite and chlorate.

4.4.7.1 Chlorine dioxide generators

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 three percent of the theoretical stoichiometric concentration required.

4.4.7.2 Feed and storage facilities

Chlorine gas, sodium hypochlorite, and sodium chlorite feed and storage facilities shall comply with the requirements in the “Specific Chemical” section.

4.4.7.3 Other design requirements

a) The design of chlorine dioxide systems shall comply with all applicable portions of the “Disinfection” section.

b) The minimum residual disinfectant level shall be established by the reviewing authority.

4.4.7.4 Public notification

Notification of a change in disinfection practices and the schedule for the changes shall be made known to the public; particularly to hospitals, kidney dialysis facilities, and fish breeders, as chlorine dioxide and its byproducts may have similar effects as chloramines.

4.4.8 Ultraviolet Disinfection

Disinfection of drinking water utilizing ultraviolet light (UV) is an established technology that is rapidly developing based on ongoing research into low and medium pressure UV reactors as well as additional validation protocols for low and high wavelength UV light generated by medium pressure reactors. The US EPA recommendations on UV disinfection (e.g. USEPA ULTRAVIOLET DISINFECTION GUIDANCE MANUAL FOR THE FINAL LONG TERM 2 ENHANCED SURFACE WATER TREAMENT RULE (UVDGM)) and any subsequent research information) provides the most current regulatory guidance for the design, validation and operation of UV disinfection systems used by public water systems and is the basis for the development of the recommended standards for those systems. Other validation protocols may be acceptable upon review and approval of the reviewing authority. Challenge microorganisms such as MS2 may be utilized in UV reactor validation protocols and may be sufficient when used with algorithms to predict virus, giardia, and cryptosporidium inactivation. Selection and use of challenge microorganisms shall be a conservative representation of the target pathogen and shall be approved by the reviewing authority. Also, the UVDGM uses two approaches for UV dose monitoring, the UV intensity set point and the calculated dose. Validation of the UV intensity set-point approach has been more defined and recent UV disinfection research has provided more information concerning pathogen inactivation credit and validation methods for the calculated dose approach.

UV disinfection may also be considered as primary disinfection for public water systems with microbiologically unsafe groundwater and must meet the disinfection requirements of the Ground Water Rule (GWR).

Supplemental disinfection for additional virus inactivation or to provide a residual in the water distribution system may be required by the reviewing authority. When UV light treatment disinfection systems are used for non-health related purpose, the UV unit may provide doses less than indicated in the following criteria.

a) Criteria for UV Water Treatment Devices

1. The UV unit must be validated following an accepted protocol (e.g., USEPA UV Disinfection Guidance Manual (UVDGM), German DVGW, or Austrian ONORM). A third-party certification of validation must be submitted (in English) or other standards as approved by the reviewing authority.
2. Unit must be validated to provide the required level of inactivation of the target pathogen(s) under the design flow and water quality conditions. Maximum and minimum flows should be considered. UV transmissivity (UVT) measurements of the water to be treated, covering the range of UVTs expected for that water, should be submitted to support selection of the design UVT. The sampling shall be of a frequency and duration satisfactory to the reviewing authority and surface water may require more frequent sampling and longer sample periods. Consideration should be given to the levels of other water quality parameters that can affect UV system performance. Levels higher than those listed below may be acceptable to the reviewing authority if experience with similar water quality and UV reactors shows that adequate treatment is provided and there are no treatment problems or excessive maintenance is required. The water entering the UV unit shall meet the following parameters:

Table 4.4.8
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 or manufacturers recommendation may be considered by the reviewing authority 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 parameters higher than these maximums.

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.

a) A fouling/aging factor should be applied to ensure that the UV unit will still supply the required dose with some level of lamp aging and lamp sleeve fouling.

b) The UV housing should be stainless steel 304 or 316L

c) The lamp sleeve shall be made of Type 214 clear fused quartz or other sleeve material as approved by the reviewing authority.

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

e) The units shall meet ANSI/NSF Standard 55 Class A.

4.4.8.1 Pretreatment

The reviewing authority will evaluate the need for pre and post treatment on a specific case basis depending on raw water quality. A 5-um sediment filter or equivalent is recommended for all UV installations used on unfiltered systems.

4.4.8.2 Installation of UV System

a) Other treatment processes may affect the efficacy of UV disinfection. In evaluating the order of treatment processes, the following should be considered:

    1. Filtration, if provided, should be performed prior to UV treatment

    2. Chlorination prior to UV treatment may increase fouling on UV lamp sleeves, decreasing UVT

    3. UV treatment of chlorinated water may reduce chlorine residuals

    4. ozone, permanganate, ferric iron and thiosulfate absorb UV light; however, addition of UV absorbing chemicals prior to UV treatment may be desired, as they can act to increase the UVT of water (e.g. by oxidizing organics or precipitating metals) or to suppress algae growth in the treatment plant. If chlorine or ozone residuals are to be quenched prior to UV treatment, sodium bisulfite is a better choice than thiosulfate.

b) UV units must be installed in the same configuration or a more conservative configuration than that used during validation testing. The following are acceptable:

The length of straight pipe installed upstream of each UV reactor must be the length of upstream straight pipe used during validation plus a minimum of 5 times the diameter of the pipe

<u>OR</u>

the installation configuration is identical to the configuration use during validation testing for at least 10 pipe diameters upstream and 5 pipe diameters downstream of the UV reactor

<u>OR</u>

velocity profiles of the water upstream and downstream of the UV reactor may be measured during validation testing and after the unit has been installed in the treatment plant. Velocities must be within 20% of the theoretical velocity for both the validation testing and installed conditions. Theoretical velocity is defined as the flow rate divided by the interior cross-sectional area of the pipe.

In addition, the inlet piping should have no expansions within 10 pipe diameters of the UV unit, and valves located within the straight pipe section upstream of the unit should be fully open under normal operations.

A sufficient number (required number plus one) of parallel UV treatment units shall be provided to ensure a continuous water supply when one unit is out of service, unless other satisfactory disinfection can be provided when the unit is out of service. Other forms of redundancy including spare lamps, ballasts etc., or other treatment may be allowed by the reviewing authority.

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

b) No bypasses shall be installed unless allowed by the reviewing authority.

c) For systems using an unfiltered surface water supply, screens or other features should be installed upstream of the UV units to prevent objects from entering the reactor that might damage reactor components.

d) Consideration should be given to providing a sump downstream of the UV reactor to capture mercury and debris from broken lamps.

e) At a minimum, the following appurtenances, which are necessary to the operation and control of the UV reactors, must be provided:

   1. Flow control valves
   2. Isolation valves
   3. Sample taps upstream and downstream of the reactor
   4. Flow meters
   5. Air relief/vacuum relief valves
   6. Alarms
   7. Instrumentation and calibration for monitoring and controlling the system
   8. UV intensity sensors (duty and reference)
   9. UVT monitors (if necessary)
   10. On-line UVT analyzers (required for systems for which UVT is integral to dose monitoring or as otherwise required by the review authority).

f) Headloss through the UV reactor and associated valves and 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 treatment devices.

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

h) 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 UV unit shut down between operating cycles to prevent heat build-up in the water due to the UV lamp. If cooling water is provided during the warm-up period, the design must allow for wasting this water (since it will be inadequately treated), or monitoring this flow to account for the volume of "off-specification" water sent to distribution.

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

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

k) A wiper assembly or chemical-in-place system may be installed to allow in-situ cleaning of lamp sleeves. Adequate controls shall be in place to prevent contamination of the potable water with cleaning chemicals. For cleaning methods that require a UV unit to be off-line while being cleaned, treatment and/or storage capacity must be sufficient to ensure adequate water supply at all times. Chemical cleaning methods may require chemical storage and delivery facilities and provisions for dealing with chemical waste. Cleaning chemicals shall be certified for compliance with ANSI/NSF Standard 60.

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

m) pH adjusted injection location(s) should be after the UV units to prevent unnecessary hardness deposition requiring frequent cleaning of the units and calcium carbonate buildups that can cause lamp breakages.

4.4.8.3 Associated Instrumentation and Parts

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

b) If an on-line UVT analyzer is required for operation of the UV system (i.e. if it is required for dose monitoring), this on-line instrument must be properly calibrated. A benchtop UVT analyzer must be available to check the calibration of the on-line meter. Calibration of the on-line meter should be checked at least weekly.

c) A reference sensor must be available to check calibration of the UV duty sensor(s), which must be checked at least monthly. Reference sensors shall be calibrated annually by the manufacturer.

d) The need to maintain spare parts for the UV system should be addressed. At a minimum, the following parts should be maintained at the treatment plant:

1. UV lamps - 10% with a minimum of 2 lamps
2. lamp sleeves - 5% with a minimum of 1 sleeve
3. O-ring seals - 5% with a minimum of 2 seals
4. ballasts - 5% with minimum of 1 unit

5. ballast cooling fan - 1 unit
6. duty UV sensor - minimum of 2 units
7. reference UV sensor - minimum of 2 units
8. on-line UVT analyzer - 1 unit if required for dose-monitoring

4.4.8.4 Seasonal Operations

UV water treatment devices that are operated on a seasonal basis shall be inspected and cleaned prior to use at the start of each operating season. The UV water treatment system including the filters shall be disinfected prior to placing the water treatment system back into operation. A procedure for shutting down and starting up the UV treatment system shall be developed for or by each owner based upon manufacturer recommendations and submitted in writing to the review authority.

4.4.8.5 Record Keeping and Access

A record shall be kept of the water quality test data, dates of lamp replacement and cleaning, a record of when the device was shut down and the reason for shutdown, and the dates of pre-filter replacement.

The reviewing authority shall have access to the UV water treatment system and records. Water system owners will be required to submit operating reports and required sample results on a monthly or quarterly basis as required by the reviewing authority.

4.4.8.6 Other disinfecting agents

Proposals for use of disinfecting agents other than those listed shall be approved by the reviewing authority prior to preparation of plans and specifications

4.5 **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 residuals or brine waste, cost of plant, cost of chemicals and plant location. Applicability of the process chosen shall be demonstrated.

4.5.1 Lime or lime-soda process

Design standards for rapid mix, flocculation and sedimentation processes are in the “Clarification” section. Additional consideration must be given to the following process elements.

4.5.1.1 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.

4.5.1.2 Aeration

The raw water carbon dioxide content should be determined. 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 dissolved oxygen in the finished water will not cause corrosion problems in the distribution system.

4.5.1.3 Chemical feed point

Lime should be fed directly into the rapid mix basin.

4.5.1.4 Rapid mix

Rapid mix detention times should be instantaneous, but not longer than 30 seconds with adequate velocity gradients to keep the lime particles dispersed.

4.5.1.5 Stabilization

Stabilization of water softened by the lime or lime-soda process is required. (See "Stabilization and Corrosion Control" – Section 4.10)

4.5.1.6 Residuals collection

a) Mechanical residuals removal equipment shall be provided in the sedimentation basin.

b) Residuals should be recycled to the point of rapid mix. If it is to be recycled to a different location, the reviewing authority must approve the point of recycle.

4.5.1.7 Residuals disposal

Provisions must be included for proper disposal of softening residuals. See "Waste Residuals".

4.5.1.8 Disinfection

The use of excess lime shall not be considered an acceptable substitute for disinfection.

4.5.1.9 Plant start-up

The plant processes must be manually started following shut-down.

4.5.2 Cation exchange process

Alternative methods of hardness reduction should be investigated when the sodium content and dissolved solids concentration is of concern for waste disposal. 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.

4.5.2.1 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. Pre-treatment is required when the content of iron, manganese, or a combination of the two, is one milligram per liter or more (See "Iron and Manganese Control" - Section 4.8). Waters having 5 units or more turbidity should not be applied directly to the cation exchange softener.

4.5.2.2 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 the reviewing authority. A manual override shall be provided on all automatic controls.

4.5.2.3 Exchange capacity

The design capacity for hardness removal should not exceed 20,000 grains per cubic foot (46 kg/m^3) when resin is regenerated with 0.3 pounds (0.14 kg) of salt per 1000 grains of hardness removed.

4.5.2.4 Depth of resin

The depth of the exchange resin should not be less than three feet.

4.5.2.5 Flow rates

The rate of softening should not exceed seven gallons per minute per square foot of bed area (17 m/hr.) and the backwash rate should be six to eight gallons per minute per square foot (14 to 20 m/hr.) of bed area. Rate-of-flow controllers or the equivalent must be installed on the feed, backwash, regeneration, and rinse water lines.

4.5.2.6 Freeboard

The freeboard will depend upon the size and specific gravity of the resin and the direction of water flow. Generally, the wash water collector should be 24 inches above the top of the resin on downflow units.

4.5.2.7 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 the applicable portions in the “Rapid Rate Gravity Filters” section.)

4.5.2.8 Brine distribution

Facilities should be included for even distribution of the brine over the entire surface of both upflow and downflow units.

4.5.2.9 Cross-connection control

Regeneration, rinse, and air relief discharge pipes shall be installed with an air gap between the discharge and the disposal point to prevent back-siphonage.

4.5.2.10 Bypass piping and equipment

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. The bypass line must have a shutoff valve and should have an automatic proportioning or regulating device. 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.

4.5.2.11 Additional limitations

Silica gel resins should not be used for waters having a pH above 8.4 or containing less than six milligrams per liter 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 resin should not be used.

4.5.2.12 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.

4.5.2.13 Brine and salt storage tanks

a) Salt dissolving or brine tanks and wet salt storage tanks must be covered and must be corrosion resistant.

b) The make-up water inlet must be protected from back-siphonage by an approved backflow prevention device or an air gap. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank.

c) Tanks must be equipped with manholes or hatchways for access and filling. 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.

d) Overflows, where provided, must be protected with corrosion resistant screens and must terminate with either a turned downed bend having a proper free fall discharge or a self-closing flap valve.

e) Two wet salt storage tanks or compartments designed to operate independently should be provided.

f) The wet salt storage tanks should have graduated layers of gravel placed over a brine collection system.

g) Alternative designs that allow frequent cleaning of the wet salt storage tank may be considered.

4.5.2.14 Salt and brine storage capacity

Total salt storage should have sufficient capacity to store in excess of 150 percent of delivery volume 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.

4.5.2.15 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.

4.5.2.16 Stabilization

Stabilization of water softened by a cation exchange process may be required. (See "Stabilization and Corrosion Control" - Section 4.10)

4.5.2.17 Waste disposal

Suitable disposal of the brine waste must be provided. (See "Waste Residuals" – Part 5) Where the volume of spent brine must be reduced, consideration may be given to using a part of the spent brine for a subsequent regeneration.

4.5.2.18 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 suitable for use when exposed to salt or brine.

4.5.2.19 Housing

Bagged salt and dry bulk salt storage shall be enclosed and separated from other operating areas to prevent damage to equipment.

4.5.2.20 Water quality test equipment

Test equipment for alkalinity, total hardness, carbon dioxide content, and pH should be provided to determine treatment effectiveness.

4.6 **ANION EXCHANGE TREATMENT**

Anion exchange treatment can be used to treat for a variety of contaminants, including arsenic, nitrates, organics, sulfides, uranium, and taste and odor compounds and others.

4.6.1 Pre-treatment requirements

Pre-treatment may be required for contaminant specific resins. 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. Pre-treatment is required when a combination of iron and manganese exceeds 0.5 mg/L.

4.6.2 Design

a) 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.

b) If a portion of the water is bypassed around the units and blended with treated water, the maximum blend ratio allowable must be determined based on the highest anticipated raw water level of the contaminant of concern. If bypassing is provided, a totalizing meter and a proportioning or regulating device or flow regulating valves must be provided on the bypass line.

4.6.3 Exchange capacity

The design capacity of the regeneration process should be in accordance with the specifications of the resin manufacturer. For nitrate removal, the design capacity should not exceed 10,000 grains per cubic foot (23 g/L) when the resin is regenerated at 15 pounds of salt per cubic foot (240 g/L) of resin.

4.6.4 Number of units

For community water systems treating acute contaminants, at least two units shall be provided. The treatment capacity must be capable of producing the maximum day water demand at a level below the MCL for the contaminant of concern with one exchange unit out of service.

4.6.5 Type of resin

Unless otherwise approved by the reviewing authority, the anion exchange resin must have high selectivity for the contaminant of concern.

4.6.6 Flow Rates

For the contaminant of concern, the treatment flow rate should not exceed the manufacturer's recommendation for the selected resin.

4.6.7 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. Generally, the wash water collector should be 24 inches above the top of the resin on downflow units.

4.6.8 Miscellaneous appurtenances

a) The treatment equipment shall be designed to include an adequate underdrain and support system and brine distribution system.

b) Sample taps, brine and salt storage, salt and brine storage capacity and brine pump or eductor shall comply with the requirements for the so-named appurtenances in the "Cation Exchange Process" section.

4.6.9 Cross connection control

Regeneration, rinse, and air relief discharge pipes shall be installed with an air gap between the discharge and the disposal point to prevent back-siphonage.

4.6.10 Construction materials

Pipes and contact materials must be resistant to the aggressiveness of the regenerant. Steel and concrete must be coated with a non-leaching protective coating which is suitable for use when exposed to salt, brine, or other regenerants.

4.6.11 Housing

Bagged salt and dry bulk salt storage shall be enclosed and separated from other operating areas in order to prevent damage to equipment.

4.6.12 Pre-conditioning of the resin

Prior to start-up of the equipment, the resin must be regenerated with no less than two bed volumes of water containing sodium chloride, or other appropriate regenerant followed by an adequate rinse.

4.6.13 Waste disposal

Suitable disposal of the brine waste must be provided. (See the “Waste Residuals” – Part 9)

4.6.14 Water quality test equipment

Appropriate test equipment must be provided to determine treatment effectiveness.

4.7 **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. or 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 61 or be approved by the reviewing authority.

4.7.1 Natural draft aeration

The design of natural draft aerators shall:

a) Have a distribution pan with 3/16 to 1/2 inches in diameter perforations spaced 1 to 3 inches on centers as needed to maintain a six-inch water depth, or some other effective system for the distribution of water uniformly over the top tray.

b) Have a series of three or more discharge trays with separation of trays not less than 12 inches.

c) Have loading rates of 1 to 5 gallons per minute for each square foot of total tray area (2.5 - 12.5 m/hr.).

d) Have trays with slotted, heavy wire (1/2-inch openings) mesh or perforated bottoms.

e) Be constructed of durable materials that are resistant to the aggressiveness of the water and dissolved gases.

f) Have enclosures with louvers sloped to the inside at an angle of approximately 45 degrees to prevent the loss of spray water by wind carriage.

g) Have air intakes with 24-mesh screen and louver or shroud covers that are removable for maintenance and inspection.

h) Include provisions for continuous disinfection feed shall be provided after aeration.

4.7.2 Forced or induced draft aeration

The design of forced or induced draft aerators shall:

a) Have blowers with weatherproof motors in tight housings and screened enclosures.

b) Provide adequate counter current of air through the enclosed aerator column.

c) Exhaust air directly to the outside atmosphere.

d) Have air intakes and outlet with 24-mesh screen and louver or shroud covers that are accessible for maintenance and inspections.

e) Introduce air free from obnoxious fumes, dust, and dirt.

f) Allow easy access to the aerator for maintenance and inspection of the interior.

g) Have loading rates of 1 to 5 gallons per minute for each square foot of total tray area (2.5 - 12.5 m/hr.).

h) Have water outlets that are adequately sealed to prevent unwarranted loss of air.

i) Have a series of five or more trays with separation of trays not less than six inches or as approved by the reviewing authority.

j) Have an effective system for the distribution of water uniformly over the top tray.

k) Be constructed of durable materials that are resistant to the aggressiveness of the water and dissolved gases.

l) Include provisions for continuous disinfection feed after aeration.

4.7.3 Spray aeration

The design of spray aerators shall:

a) Have hydraulic heads of between 5 - 25 feet;

b) Have nozzles of the size, number, and spacing required for the flowrate, space, and the amount of head available.

c) Have nozzle diameters in the range of 1 to 1.5 inches to minimize clogging.

d) Have enclosed basins to contain the spray.

e) Have ventilation openings with 24-mesh screens and louver or shroud covers that are removable for maintenance and inspections.

f) Include provisions for continuous disinfection feed after aeration.

4.7.4 Pressure aeration

Pressure aerators may only be used for oxidation purposes. They may not be used for removal of dissolved gases. Filters following pressure aeration must have adequate air release devices.

The design of pressure aerators shall:

a) Provide thorough mixing of compressed air with the water being treated.

b) Be supplied with screened and filtered air, free of obnoxious fumes, dust, dirt, and other contaminants.

4.7.5 Packed tower aeration

Packed tower aeration (PTA) which is also known as air stripping involves passing water down through a column of packing material while pumping air counter-currently up through the packing. PTA is used for the removal of volatile organic chemicals, trihalomethanes, carbon dioxide, and radon. Generally, PTA is feasible for compounds with a Henry's Constant greater than 100 atm mol/mol at 12^0C, but not normally feasible for removing compounds with a Henry's Constant less than 10. For values between 10 and 100, PTA may be feasible but should be evaluated using pilot studies. Values for Henry's Constant should be discussed with the reviewing agency prior to final design.

4.7.5.1 Process design

a) Process design methods for PTA involve the determination of Henry's Constant for the contaminant, the mass transfer coefficient, air pressure drop and stripping factor. The applicant shall provide justification for the design parameters selected (i.e. height and diameter of unit, air to water ratio, packing depth, surface loading rate, etc.). Pilot plant testing may be required.

   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. Special consideration should be given to removal efficiencies when multiple contaminations occur. Where there is considerable past performance data on the contaminant to be treated and there is a concentration level similar to previous projects, the reviewing authority may approve the process design based on use of appropriate calculations without pilot testing. Proposals of this type must be discussed with the reviewing authority prior to submission of any permit applications.

b) The tower shall be designed to reduce contaminants to below the maximum contaminant level (MCL) and to the lowest practical level.

c) The ratio of the packing height to column 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.

d) The minimum volumetric air to water ratio at peak water flow should be 25:1 and the maximum should be 80:1. Air to water ratios outside these ranges should not be used without prior approval from the reviewing authority.

e) The design should consider potential fouling problems from calcium carbonate and iron precipitation and from bacterial growth. It may be necessary to provide pretreatment. Disinfection capability shall be provided prior to and after PTA.

f) The effects of temperature should be considered since a drop in water temperature can result in a drop in contaminant removal efficiency.

4.7.5.2 Materials of construction

a) The tower may be constructed of stainless steel, concrete, aluminum, fiberglass or plastic. Uncoated carbon steel is not recommended because of corrosion. Towers constructed of light-weight materials should be provided with adequate support to prevent damage from wind.

b) Packing materials shall be resistant to the aggressiveness of the water, dissolved gases and cleaning materials and shall be suitable for contact with potable water.

4.7.5.3 Water flow system

a) Water should be distributed uniformly at the top of the tower using spray nozzles or orifice-type distributor trays that prevent short circuiting. For multi-point injection, one injection point for every 30 in^2 (190 cm^2) of tower cross-sectional area is recommended.

b) A mist eliminator shall be provided above the water distributor system.

c) A side wiper redistribution ring shall be provided at least every 10 feet in order to prevent water channeling along the tower wall and short circuiting.

d) Sample taps shall be provided in the influent and effluent piping.

e) The effluent sump, if provided, shall have easy access for cleaning purposes and be equipped with a drain valve. The drain shall not be connected directly to any storm or sanitary sewer.

f) A blow-off line should be provided in the effluent piping to allow for discharge of water/chemicals used to clean the tower.

g) The design shall prevent freezing of the influent riser and effluent piping when the unit is not operating. If piping is buried, it shall be maintained under positive pressure.

h) The water flow to each tower shall be metered.

i) An overflow line shall be provided that discharges 12 to 14 inches above a splash pad or drainage inlet. Proper drainage shall be provided to prevent area flooding.

j) Butterfly valves may be used in the water effluent line for better flow control, as well as to minimize air entrainment.

k) Provisions shall be included to prevent flooding of the air blower.

l) The water influent pipe should not be supported off the tower.

4.7.5.4 Air flow system

a) The air intake and outlet vent shall be protected with 24-mesh screens and louvers or shroud covers that are removable for maintenance and inspections.

b) The air inlet shall be in a location protected from airborne contaminants.

c) An air flow meter shall be provided on the influent air line or an alternative method to determine the air flow shall be provided.

d) A positive air flow sensing device and a pressure gauge must be installed on the air influent line. The positive air flow sensing device must be a part of an automatic control system which will turn off the influent water if positive air flow is not detected. The pressure gauge will serve as an indicator of fouling buildup.

e) A backup motor for the air blower must be readily available.

4.7.5.5 Other features that shall be provided include:

a) Enough access ports with a minimum diameter of 24 inches to facilitate inspection, media replacement, media cleaning and maintenance of the interior.

b) A method of cleaning the packing material when fouling occurs.

c) Tower effluent collection and pumping wells constructed to clearwell standards.

d) Provisions for extending the tower height without major reconstruction.

e) An acceptable alternative supply must be available during periods of maintenance and operational interruptions. No bypass shall be provided unless specifically approved by the reviewing agency.

f) Disinfection application points both ahead of and after the tower to control biological growth.

g) Disinfection and adequate contact time after the water has passed through the tower and prior to the distribution system.

h) Adequate packing support to allow free flow of water and to prevent deformation of the packing when packing heights are excessive.

i) Provisions for the operation of the blower and disinfectant feeder equipment during power failures.

j) Adequate foundation to support the tower and lateral support to prevent overturning due to wind loading.

k) Fencing and locking gate to prevent vandalism.

l) An access ladder with safety cage for inspection of the aerator including the exhaust port and de-mister.

m) Electrical interconnection between blower, disinfectant feeder and well pump.

4.7.5.6 Environmental factors

a) The applicant must contact the appropriate air quality office to determine if permits are required under the Clean Air Act.

b) Noise control facilities should be provided on packed tower aeration systems located in residential areas.

4.7.6 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 processes must be designed to meet the particular needs of the water to be treated and are subject to the approval of the reviewing authority.

4.7.7 Protection of aerators

All aerators except those discharging to surface water treatment plants shall be protected from contamination by birds, insects, wind borne debris, rainfall and water draining off the exterior of the aerator.

4.7.8 Disinfection

Groundwater supplies exposed to the atmosphere by aeration must be disinfected.

4.7.9 Bypass

A bypass should be provided for all aeration units except those installed to comply with maximum contaminant levels.

4.7.10 Corrosion control

The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary. (See “Stabilization and Corrosion Control” – Section 4.10)

4.7.11 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.

4.7.12 Redundancy

Redundant equipment shall be provided for units installed to comply with Safe Drinking Water Act primary contaminants, unless otherwise approved by the reviewing authority.

4.8 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 analyses of representative samples of water to be treated, and receive the approval of the reviewing authority. It may be necessary to operate a pilot plant in order to gather all information pertinent to the design. Consideration should be given to adjusting pH of the raw water to optimize the chemical reaction.

4.8.1 Removal by oxidation, detention and filtration

4.8.1.1 Oxidation

Oxidation may be by aeration and/or by chemical oxidation with chlorine, potassium permanganate, sodium permanganate, ozone or chlorine dioxide. Chemical feed points shall be provided prior to filtration.

4.8.1.2 Detention

a) 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 omitted only where a pilot plant study indicates a reduced need for detention. The reaction tank/detention basin should be designed to prevent short circuiting. The reaction tank/detention basin shall be provided with an overflow, vent, and access hatch.

b) Sedimentation - Sedimentation basins may be required 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 residuals removal shall be included.

4.8.1.3 Filtration

Filters shall be provided and shall conform to the “Filtration” section.

4.8.2 Removal by the lime-soda softening process

(See the “Lime or Lime-Soda Process” section.)

4.8.3 Removal by manganese greensand or oxide-coated media filtration

This process consists of a continuous or batch feed of oxidant to the influent of a manganese greensand or oxide-coated media filter.

a) Provisions should be made to apply the oxidant as far ahead of the filter as practical and to a point immediately before the filter.

b) Aeration may be used prior to the oxidant feed to reduce the amount of the chemical needed.

c) An anthracite media cap of at least six inches or more as required by the reviewing authority should be provided over manganese coated media.

d) Typical filtration rate is four gallons per minute per square foot (9.5 m/hr.).

e) Typical wash rate is 8 to 10 gallons per minute per square foot (20 - 24 m/hr.) with manganese coated or synthetic greensand and 15 to 20 gallons per minute per square foot (37 - 49 m/hr.) with oxide-coated media.

f) Air washing should be provided.

4.8.4 Removal by ion exchange

This process of iron and manganese removal should not be used for water containing more than 0.3 milligrams per liter of iron, manganese or combination thereof. This process is not acceptable where either the raw water or wash water contains dissolved oxygen or other oxidants.

4.8.5 Biological removal

See Policy Statement for Aerobic Biological Treatment of Groundwater Sources located at the beginning of this document.

4.8.6 Sequestration by polyphosphates

This process is not recommended when iron, manganese or combination thereof exceeds 0.5 mg/L and shall not be used when it exceeds 1.0 mg/L. The total phosphate applied shall not exceed 10 mg/L as PO_4. Where phosphate treatment is used, satisfactory chlorine residuals shall be maintained in the distribution system. Possible adverse effects on corrosion must be addressed when phosphate addition is proposed for iron sequestering. Polyphosphate treatment may be less effective for sequestering manganese than for iron.

a) Feed equipment shall conform to the requirements of the “Feed Equipment” section.

b) Unless the phosphate is unable to support bacterial growth and the phosphate is being fed from the covered shipping container, stock phosphate solution must be kept covered and disinfected by carrying approximately 10 mg/L free chlorine residual. Phosphate solutions having a pH of 2.0 or less may also be exempted from this requirement by the reviewing authority.

c) Polyphosphates shall not be applied ahead of iron and manganese removal treatment processes. The point of application shall be prior to any aeration, oxidation and/or disinfection processes if no iron or manganese removal treatment processes are provided.

d) The phosphate feed point shall be located as far ahead of the oxidant feed point as possible.

4.8.7 Sequestration by sodium silicates

Sodium silicate sequestration of iron and manganese is appropriate only for 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 such as 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 five per cent silica as SiO_2 should also be avoided for the same reason. Sodium silicate treatment may be less effective for sequestering manganese than for iron.

a) Sodium silicate addition is applicable to waters containing up to 2 mg/L of iron, manganese or combination thereof.

b) Chlorine residuals shall be maintained throughout the distribution system to prevent biological breakdown of the sequestered iron.

c) The amount of silicate added shall be limited to 20 mg/L as SiO_2, but the combined amount of added and naturally occurring silicate shall not exceed 60 mg/L as SiO_2.

d) Feed equipment shall conform to the requirements of the “Chemical Application” section.

e) Sodium silicate shall not be applied ahead of iron or manganese removal treatment.

4.8.8 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, and should be provided at points between the anthracite media and the manganese coated media.

4.9 **ARSENIC CONTROL**

Several types of treatment technologies are available to remove arsenic from drinking water, from simple to more complex. In much of the upper Midwest, arsenic typically exists as As (III) (arsenite) in groundwater, and as As (V) (arsenate) in surface waters. However, some groundwaters can contain arsenic only as As(V), or a combination of As(III) and As(V). It is recommended that speciation be done in the field to determine which forms of arsenic are in the raw water source. Most arsenic removal technologies are more effective at removing As(V) due to its insolubility and negative charge. Arsenic (III) can be converted to As (V) by adding an oxidizing agent such as chlorine, permanganate, ozone or other solid phase oxidants prior to the removal process. Aeration alone usually is not able to convert As (III) to As (V). For all of the removal technologies listed, As (III) (arsenite) should be converted to As (V) (arsenate) to promote removal and the use of an oxidizing agent at the head of the process is a critical step in achieving optimum removal. Oxidation of iron and arsenic should occur simultaneously for optimal arsenic removal. And prior to selection of a removal technology, raw water analysis should include, but not limited to the following parameters: Arsenic speciation, Alkalinity, pH, ORP, Chloride, Fluoride, Iron, Manganese, Nitrate, Nitrite, Orthophosphate, Sulfate, TDS, TOC, Aluminum, Silica, Hardness, Temperature.

The selection of an arsenic treatment technology such as sorption oxidation/filtration, and membrane processes, usually involve a pilot project or study and a wide range of monetary investment. In addition, the issue of discharging treatment waste streams such as concentrated wastewater and/or the disposal of solid or hazardous wastes must be resolved. The safe and proper disposal of all related treatment wastes must comply with all local, state, federal and provincial requirements. When planning facilities for arsenic reduction, it is recommended that the treatment be capable of reducing arsenic levels in the water to one-half the MCL (currently 5 ppb) or less. The reviewing agency should be contacted, prior to initiating design of the arsenic removal facility, to determine if a pilot plant study is required. The following list provides information on different types of typical arsenic treatment technologies and options for optimization. Filtration rates and Empty Bed Contact Times (EBCT) stated are only for informational purposes and will be determined by the regulatory agency on a case-by-case basis.

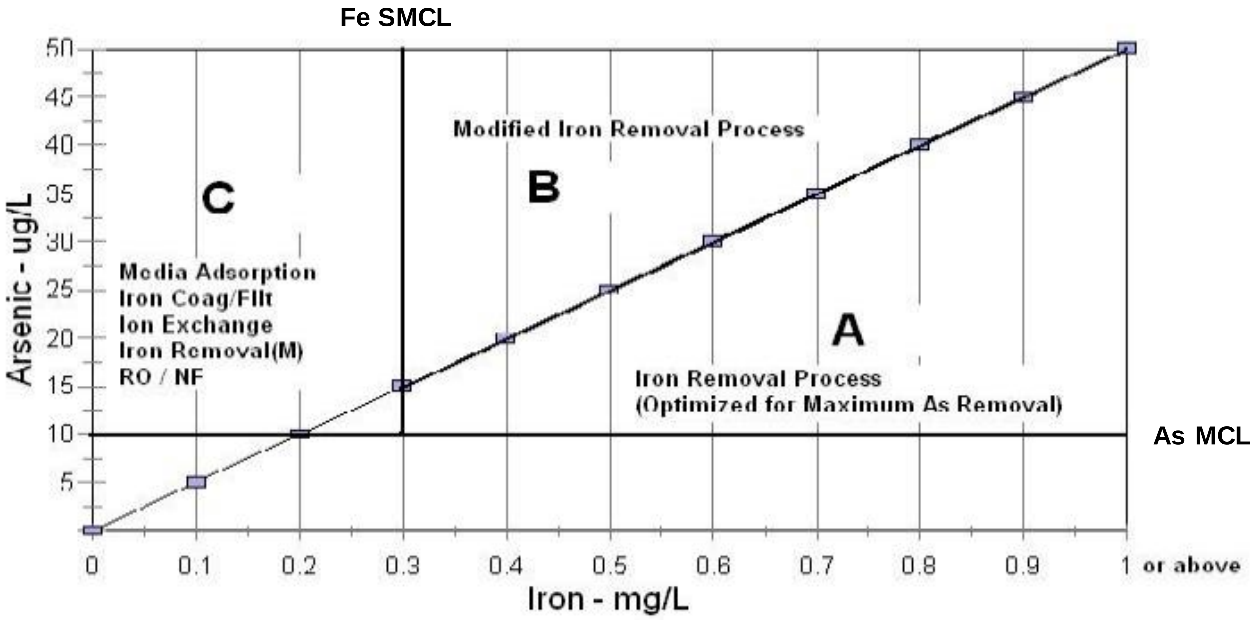
4.9.1 Adsorptive Media

These types of media remove arsenic from water by attachment of arsenic onto the surface of a porous solid. They use metal oxide coatings, usually iron, titanium or aluminum, on the filter media to remove arsenic. Pre- and post-adjustment of pH may enhance removal rates and reduce corrosivity. Chemical pre-oxidation is usually required to ensure all arsenic is in the As (V) form. If iron and manganese are present in the raw water, they should be removed with a filter or other method prior to arsenic removal to prevent media fouling High levels of sulfate or dissolved solids may also cause interference or reduce the treatment efficiency. Filtration rates can range from 2 - 8 gpm/ft2 and EBCT from 3 – 10 minutes

4.9.2 Oxidation/Filtration (Iron & Manganese removal)

Treatment methods that have historically been used for iron and manganese removal can also be effective in removing arsenic. By oxidizing the iron, manganese, and arsenic in the raw water, the As (V) is adsorbed onto iron hydroxide precipitates that can be removed by filtration. When the iron to arsenic ratio in the raw water is 20:1 (or greater), these types of arsenic removal systems work well and the following table illustrates a relationship between iron and arsenic concentrations and effective removal methods.

Figure 4.9 Arsenic Treatment Strategy Selection Guide as a Function of Initial Arsenic and Iron Content of Water. Based on optimized arsenic removal as As V. [1]



1. Sorg EPA (2002), Ohio EPA (2010)

Water with low iron (less than a 20 to 1 ratio of iron to arsenic) may need additional iron in the form of ferric chloride or ferric sulfate to increase arsenic removal efficiencies. Filtration rates are usually in the 2 - 4 gpm/ft2 range. Higher filtration rates for manganese greensand, manganese dioxide or other proprietary media may be allowed if approved by the reviewing authority.

4.9.3 Coagulation/Filtration

This method typically consists of chemical oxidation and the addition of a coagulant or polymer to remove arsenic by sedimentation and filtration. Other contaminants may be removed in this process and pre- and post-adjustment of pH may be needed. Sulfate may cause interference or reduce treatment efficiency.

Other Types of Treatment Technologies:

4.9.4 Anion Exchange

An anion exchange resin removes 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 arsenate (V) form and the pH is in the 6.5 to 9.0 range. In general, ion exchange for arsenic removal is only applicable for low TDS, low sulfate waters. Sulfate, nitrates and other anions will compete for sites on the resin so it is important to know the feed water characteristics and the selectivity sequence before considering an anion exchange treatment system.

Treatment vessels may be placed in parallel or series as required by the reviewing authority to avoid contaminant breakthrough. Treatment may include cation exchange followed by anion exchange to remove both hardness and arsenic. However, mixed beds are not recommended since anion resins are lighter and the column may become service intensive. Typical loading rates are 8 -12 gpm/ft2 with EBCT from 2 – 5 minutes.

4.9.5 Electrodialysis/Electrodialysis Reversal

Uses an electrical charge of a reverse osmosis (R.O.) membrane to remove arsenic. Chemical oxidation of arsenic, iron and manganese with filtration is used to remove oxidized iron and manganese to prevent fouling of the R.O. membrane. Pre- and post-adjustment of pH may be needed to prevent scaling, to enhance filtration, and to reduce corrosivity. Other contaminants that may be removed using this technology include hardness, dissolved solids, nitrates, and sulfates. If iron and manganese are too high, this may cause interference with the arsenic removal process.

4.9.6 Membrane Processes

Reverse osmosis or nanofiltration membranes can be used as stand-alone arsenic treatment under most water quality conditions. If micro or ultra-membranes are used, they usually require a coagulation step to create arsenic bound floc to remove the arsenic. Membrane processes are usually not sensitive to pH, but pre-filtration may be needed if the feed water contains NOM, iron and inorganic ions such as chlorides, silica, calcium and magnesium. To increase the arsenic removal efficiency and reduce the volume of reject water, multiple units should be installed in series. See Part 4.3.8 for membrane filtration process design considerations.

4.9.7 Lime Softening

This technology is based on the optimization of Mg(OH)2 precipitation. High iron concentrations are desired for optimal arsenic removal. Waters with low dissolved iron may require the addition of ferric chloride or ferric sulfate. Hardness may also be removed in this process. Other issues include the disposal of lime residuals, and the high labor intensity of handling lime.

4.10 **STABILIZATION AND CORROSION CONTROL**

Water that is unstable due either to natural causes or to treatment effects 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, high levels of total dissolved solids, etc. Subsequent corrosion may also be caused by galvanic or biochemical action.

Addition of certain chemicals or coagulants change the water characteristics (e.g., adjusting pH, alkalinity, dissolved inorganic carbon (DIC), 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 water utility's distribution system.

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 processes are 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 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.

4.10.1 Corrosion control study

A corrosion control study may be required by the regulatory agency for source and treatment changes that could alter the water quality. The study should include:

a) A sample site location plan for water quality parameter monitoring. Entry point and distribution system samples shall be collected for water quality data and other system information pertinent to achieving optimum corrosion control. The frequency of sampling and number of sites shall be determined by the regulatory authority.

b) Testing for the following water quality parameters:

1) pH
2) Temperature
3) Alkalinity
4) Calcium
5) Sulfate
6) Ammonia
7) Total Phosphorus
8) Chloride
9) Corrosion Control Inhibitors (Orthophosphate, Silica)
10) Conductivity
11) Hardness
12) Iron
13) Manganese
14) Aluminum
15) Dissolved Oxygen
16) Natural Organic Matter
17) Total and Free Chlorine

c) 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. The results should also include monitoring before and after the source and/or treatment change occurs

d) A desktop evaluation utilizing corrosion control computer modeling or regulatory guidance. The evaluation shall recommend optimal corrosion control treatment and water quality parameter performance requirements for the selected treatment. The recommendation could be treatment is not needed, with the appropriate justification.

e) Identification of possible limitations and/or secondary impacts of treatment options (e.g. coagulant change, pH adjustment, disinfection changes).

f) If required by the regulatory agency, a demonstrative study of corrosion control treatment with physical testing such as pipe loops, solubility tests, and/or pipe scale analysis must be completed. The final outcome of the demonstrative study is to provide an informed recommendation of optimal corrosion control treatment, including all treatment targets (i.e. selected chemical(s), applicable dose(s), water quality such as pH, and system residuals/levels).

4.10.2 Instrumentation

Monitoring/testing 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 three standards for calibration.

4.10.3 Carbon dioxide addition

Carbon dioxide is typically added for pH adjustment during or after a lime-soda ash softening process to recarbonate or adjust the ionic condition of the water so that it will not be corrosive and will not precipitate calcium carbonate (CaCO3).

The design of recarbonation basins required for the addition of carbon dioxide should follow these guidelines:

a) Include two compartments: a mixing compartment with a depth that will provide a diffuser submergence of not less than 7.5 feet nor greater than recommended by the manufacturer and a reaction compartment.

b) Provide a mixing detention time of at least three minutes and a total detention time of twenty minutes.

c) The regulatory authority may allow shorter detention times than those above for alternative feed systems when proven effective in a pilot study.

d) Where liquid carbon dioxide is used, include provisions 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 low areas.

e) Locate recarbonation tanks outside or seal and vent the tanks to the outside with adequate seals and adequate purge flow of air to ensure workers safety.

f) Include provisions for draining the recarbonation basin and for the removal of residuals

Facilities for on-site generation of carbon dioxide should only be included where the use of bulk liquid carbon dioxide is not feasible and only after approval is obtained from the regulatory authority.

4.10.4 Acid addition

a) Feed equipment shall conform to the "Chemical Application" section.

b) Adequate precautions shall be taken for operator safety. See the "Operator Safety" and the "Acids and Caustic" subsection in the "Specific Chemicals" section.

4.10.5 Phosphates

The feeding of phosphates may be applicable for sequestering iron and manganese, for corrosion control, and in conjunction with alkali feed. Polyphosphate addition is typically not considered effective for managing corrosion control in the distribution system.

a) 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 and copper leaching into the water. Phosphates containing zinc will help protect cement and cement mortar-lined pipes at low alkalinity/hardness/pH conditions.

b) 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 and should limit polyphosphate dosage to meet only the needs for sequestration.

c) Phosphate systems:

1. Shall have chemical feed equipment that conforms to the “Chemical Application” section.

2. Shall have a chemical feed system designed to maintain an orthophosphate residual of at least 1.0 mg/L as P (3.0 mg/L as PO4) throughout the distribution system, although the required dose, which should be established by conducting a corrosion control study, may be lower or higher, depending on the characteristics of the water being treated.

3. Shall be designed to operate within the optimum pH range and alkalinity concentration for the selected treatment strategy.

4. Should follow manufacturer’s recommendations for handling, storage, and use.

5. Shall 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 reviewing authority.

6. Shall operate with 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.

7. Shall have testing equipment that utilizes an EPA accepted method and is equipped with a digital display for monitoring the phosphate residual.

8. Should consider a 6-month higher dose period to establish the desired residual, with any changes to the initial treatment to be approved by the regulatory agency.

9. Should not operate until the distribution system has been cleaned by flushing or with hydraulic pigs.

Phosphates can have secondary impacts that may limit their applicability. Factors that shall be evaluated prior to the installation of these corrosion control systems are (1) presence of nutrients in the system contributing to biological growth, (2) reactions with aluminum, and (3) impacts on wastewater treatment plants. Additional treatment capabilities may be necessary to meet phosphate discharge limits at the wastewater treatment plant.

4.10.6 pH/alkalinity adjustment

pH/Alkalinity adjustments are typically made by adding a base or similar chemical to the water to increase pH to a level where the lead or copper and other metal compounds that can precipitate and build up in the distribution systems are less soluble, and acids are neutralized. Optimum pH range and alkalinity concentrations shall be determined for effective treatment (I.e., coagulation, disinfection) while ensuring compliance with all National Primary Drinking Water Standards.

a) pH/alkaline chemicals include:

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 obtain and sustain when using caustic soda on water with low alkalinity. Caustic soda can cause severe burns and eye damage.

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.

3) Lime

Lime (calcium hydroxide) will increase the pH, alkalinity, DIC, and hardness. A stable pH is very difficult to obtain and sustain when using lime on water with low alkalinity. Some types of lime can cause an increase in turbidity.

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.

b) Secondary impacts

Alkalinity, pH, and DIC can have secondary impacts that limit the use of caustic soda, soda ash, lime and sodium bicarbonate. 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) Disinfection byproducts (DBP) formation (trihalomethanes)

5) Increased rate of corrosion of copper at high DIC levels

c) Alkalinity/pH adjustment systems:

1) Shall be capable of providing a range of pH levels determined to be optimal to meet treatment objectives.

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 the requirements in the "Chemical Application" section.

4) Shall produce treated water with an alkalinity of at least 20 mg/L as CaCO3 unless a higher target is required by the regulatory agency.

5) Shall be provided for all systems utilizing anion-exchange treatment except when exempted by the reviewing authority.

4.10.7 Split treatment

Under some conditions, a lime-softening water treatment plant can be designed using "split treatment" in which raw water is blended with lime-softened water to partially stabilize the water prior to secondary clarification and filtration. Treatment plants designed to utilize "split treatment" should also contain facilities for further stabilization by other methods.

4.10.8 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. The carbon dioxide content of aggressive water may be reduced by aeration. Aeration devices shall conform to the "Aeration" section.

4.10.9 Other treatment

Other treatment for controlling corrosive waters by the use of sodium silicate may be used where necessary. Any proprietary compound must receive the specific approval of the reviewing authority before use. Chemical storage and feed equipment shall conform with the requirements in the "Chemical Application section.

4.10.10 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 reactions within tubercles, nitrifying bacteria, and the reduction of sulfates to sulfides should be prevented by the maintenance of a free and/or combined chlorine residual throughout the distribution system.

4.10.11 Chloride to Sulfate Mass Ratio (CSMR)

Using or changing to chloride-base coagulant, utilizing anion exchange treatment, and higher chloride concentrations in source waters caused by runoff containing road salt can increase lead release due to galvanic corrosion. The CSMR is calculated by dividing the effluent chloride concentration by the effluent sulfate concentration. The CSMR value of the water can be an indicator of potential lead releases and can be a useful tool when evaluating source waters and treatment needs.

4.11 **TASTE AND ODOR CONTROL**

Provisions shall be made for taste and odor control at all surface water treatment plants when and where needed. Chemicals shall be added to assure adequate contact time for effective and economical use of the chemicals. Where severe taste and odor problems are encountered, in-plant and/or pilot plant studies should be considered.

4.11.1 Monitoring

Methyl-Isoborneol (MIB) and geosmin are naturally occurring compounds produced by some kinds of algae and bacteria most often during the late summer and early fall. When present in drinking water, the compounds can cause the water to have an earthy, musty taste and odor. MIB and geosmin do not, however, pose a public health risk. Some people can taste and smell the compounds at levels above 0.005 nanograms/liter (ng/l), but the compounds become a taste and odor issue for most water customers when the levels increase to about 0.01 ng/l.

Design consideration for surface water sources that are susceptible to the formation of the MIB and geosmin compounds should include monitoring in the summer and treatment processes that will reduce the concentration of the compounds in finished water.

4.11.2 Operational flexibility

Plants treating water known to have taste and odor problems should be equipped to implement several of the control processes so that the most appropriate and effective control process can be quickly placed in operation.

4.11.3 Controls

4.11.3.1 Chlorination

Chlorination can be used for the removal of some objectionable odors. The potential disinfection byproduct formation shall be investigated by bench-scale testing prior to design.

4.11.3.2 Chlorine dioxide

Chlorine dioxide has been generally recognized as a treatment for tastes caused by industrial wastes, such as phenols. Chlorine dioxide, however, can be used in the treatment of any taste and odor that is treatable by an oxidizing compound. Provisions shall be made for proper storing and handling of the sodium chlorite to eliminate any potential for explosion.

4.11.3.3 Powdered activated carbon

a) Powdered activated carbon 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 the point of chlorine or other oxidant application.

b) The carbon can be added as a pre-mixed slurry or by means of a dry-feed machine as long as the carbon is properly wetted.

c) Continuous agitation or resuspension equipment shall be provided to keep the carbon from depositing in the slurry storage tank.

d) Provision shall be made for adequate dust control.

e) The required carbon feed rate in a water treatment plant depends upon the tastes and/or odors involved, but provision should be made for adding from 0.1 milligrams per liter to at least 40 milligrams per liter of carbon.

f) Selection of the optimal PAC and feed rate to meet treatment objectives should be based on jar testing or other studies. Studies should also account for competing raw water constituents such as microcystin, PFAS, etc.

g) Powdered activated carbon, a potentially combustible material, shall be stored and handled in accordance with AWWA Standard B600.

h) Settling and removal facilities should be provided, unless the reviewing authority approves the removal of the powder activated carbon using the filters.

4.11.3.4 Granular activated carbon

Replacement of anthracite with GAC may be considered as a control measure for geosmin and 2- methylisoborneol (MIB) taste and odors caused by algae blooms. Demonstration studies of the effectiveness of the control measure may be required by the reviewing authority.

See Section 4.3.1.6 for application within filters.

4.11.3.5 Copper sulfate and other copper compounds

Continuous or periodic treatment of water with copper compounds to kill algae or other growths shall be carefully planned and implemented to prevent copper in excess of 1.0 milligrams per liter as copper in the plant's finished water. Care shall be taken to assure an even distribution of the chemical within the treatment area. Necessary approval and/or permits shall be obtained prior to application, if required. Consult the responsible regulatory agencies (e.g., Fish and Wildlife or Water agencies or the Department of Natural Resources) before making applications to public waters.

4.11.3.6 Aeration

Aeration may be effective in controlling some tastes and odors. Aeration facilities shall conform with the requirements in the "Aeration" section.

4.11.3.7 Potassium permanganate

Application of potassium permanganate may be considered, providing the treatment shall be designed so that the products of the reaction are not visible in the finished water. See "Potassium Permanganate" in the "Chemical Application" section.

4.11.3.8 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. See the "Ozone" section.

4.11.3.9 Advanced oxidation processes

The UV/H2O2 (ultra-violet/hydrogen peroxide) system is an advanced oxidation process (AOP) in which hydrogen peroxide is added in the presence of ultraviolet light to generate hydroxyl radicals (OH). This process has been shown to be effective in the treatment of taste and odor compounds such as 2-methylisoborneol (MIB) and geosmin.

4.11.4 Other control methods

The decision to use any other control methods for taste and odor control should be made only after careful laboratory and/or pilot plant tests and on consultation with the reviewing authority.

PART 5 - CHEMICAL APPLICATION

5.0 GENERAL

No chemicals shall be added to treat drinking waters unless specifically permitted by the reviewing authority.

5.1 **Plans and specifications**

Plans and specifications, as outlined in Part 2, shall be submitted for review and approval, and shall include:

a) Descriptions of feed equipment, including maximum and minimum feed ranges.

b) Location of feeders, piping layout and points of application.

c) Descriptions and locations of storage and handling facilities.

d) Written operating and control procedures including proposed application rates.

e) Descriptions of testing equipment.

f) System diagrams showing all tanks with capacities, (with drains, overflows, and vents), feeders, transfer pumps, connecting piping, valves, points of application, backflow prevention devices, and air gaps.

g) Descriptions and locations of secondary containment systems, and safety eye washes and showers.

5.2 **Chemical application**

Chemicals shall be applied to the water at such points and by such means as to:

a) Assure maximum efficiency of treatment.

b) Assure maximum safety to consumer.

c) Provide maximum safety to operators.

d) Assure satisfactory mixing of the chemicals with the water.

e) Provide maximum flexibility of operation through various points of application, when appropriate.

f) Prevent backflow or back-siphonage between multiple points of feed through common manifolds.

5.3 **General equipment design**

General equipment design shall be such that:

a) Feeders will be able to supply, at all times, the necessary amounts of chemicals at an accurate rate, throughout the range of feed.

b) Chemical-contact materials and surfaces are resistant to the aggressiveness of the chemical solution.

c) Corrosive chemicals are introduced in such a manner as to minimize potential for corrosion.

d) Chemicals that are incompatible are not stored or handled together.

e) All chemicals are conveyed from the feeder to the point of application in separate conduits.

f) Chemical feeders are as near as practical to the feed point.

g) Chemical feeders and pumps shall operate at no lower than 20 percent of the maximum feed rate, 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 rated maximum unless approved by the reviewing authority.

h) Gravity feed may be used where practical and approved by the reviewing authority.

5.4 **Chemical Information**

For each chemical the information submitted shall include:

a) Documentation that the chemical is NSF/ANSI Standard 60 approved.

b) Specifications for the chemical to be used.

c) Purpose of the chemical.

d) Proposed minimum non-zero, average and maximum dosages, solution strength or purity (as applicable), and specific gravity or bulk density,

e) Method for independent calculation of amount fed daily.

f) Chemical hazards class, if any, and regulatory workplace health/safety and chemical exposure standards listed in Safety Data Sheets (SDS).

5.5 **FEED EQUIPMENT**

5.5.1 Feeder redundancy

a) Where a chemical feed pump and/or a booster pump are necessary for the effectiveness of a water treatment process, such as chlorination, coagulation or other essential processes, a standby pump or a combination of pumps of sufficient capacity shall be provided to replace the largest unit when out of service, and the reviewing authority may require that more than one be installed.

b) A separate chemical feed pump(s) shall be used for each chemical applied.

5.5.2 Control

a) Feeders may be manually or automatically controlled. Automatic controls shall be designed and installed to allow override by manual controls.

b) Chemical feed rates shall be proportional to the flow stream being dosed.

c) A means to measure the flow stream being dosed shall be provided to determine chemical feed rates.

d) Provisions shall be made for measuring the quantities of chemicals used.

e) Weighing scales:

1. Shall be provided for weighing cylinders at all plants utilizing chlorine gas.

2. Shall be required for fluoride solution fed from supply drums or carboys.

3. Should be provided for volumetric dry chemical feeders.

4. Shall be capable for monitoring the quantity of the chemical being fed through the full range of the required feed rate.

f) Where conditions warrant, for example with rapidly fluctuating intake turbidity, coagulant and coagulant aid addition may be made according to turbidity, streaming current or other sensed parameter.

5.5.3 Dry chemical feeders

Dry chemical feeders shall:

a) Measure chemicals volumetrically (see 5.1.2.e.3) or gravimetrically.

b) Provide adequate solution/slurry water and agitation of the chemical where the chemical solution/slurry are being generated.

c) Completely enclosed chemicals to prevent emission of chemical dust to the operating areas.

5.5.4 Positive displacement solution feed pumps

Positive displacement solution feed pumps:

a) Should be used to feed liquid chemicals but shall not be used to feed chemical slurries.

b) Must be capable of operating at the required maximum rate against the maximum head conditions found at the point of injection.

c) Should be installed with calibration tubes or mass flow monitors which can be used to physically measure the actual feed rates.

d) Should be installed with a pressure relief valve on the pump discharge line.

5.5.5 Liquid chemical feeders

Liquid chemical feeders shall be installed and plumbed so that chemical solutions cannot be siphoned or overfed into the water being treated by having:

a) A vacuum relief valve;

b) A suitable air gap, or anti-siphon device; or
c) Other effective means or combinations of means to prevent siphoning or overfeeding the chemical acceptable to the reviewing authority.

5.5.6 Cross-connection control

Cross-connection control shall be provided to assure that:

a) The service water lines discharging to liquid storage tanks shall be properly protected from backflow as required by the reviewing authority.

b) Chemical solutions or slurries cannot be siphoned through liquid chemical feeders into the water supply.

c) No direct connection exists between any sewer and a drain or overflow from the liquid chemical feeder, liquid storage chamber or tank by providing that all drains terminate at least six inches or two pipe diameters, whichever is greater, above the overflow rim of a receiving sewer sump, conduit or waste receptacle.

d) 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.

5.5.7 Chemical storage and feed equipment systems

Chemical storage and feed equipment systems:

a) Shall be located in spaces and readily accessible for servicing, repair, and observation.

b) Should be located in a separate room when hazards and dust problems may exist.

c) Should be located near points of application to minimize length of feed lines.

5.5.8 In-plant water supply

In-plant water supply shall be:

a) Ample in quantity and adequate in pressure.

b) Provided with a means for measurement when preparing specific solution concentrations by dilution.

c) Properly treated for hardness, when necessary.

d) Properly protected against backflow.

e) Obtained from the finished water supply, or from a location sufficiently downstream of any chemical feed point to assure adequate mixing.

f) Have a means to measure the volume of water used.

5.5.9 Storage of chemicals

a) Adequate space shall be provided for:

   1) At least 30 days of chemical supply.

2) Convenient and efficient handling of chemicals.

3) Dry chemical storage and chemical handling operations.

4) A minimum storage volume of 1.5 times the tanker delivery truck volume.

b) Chemical-specific storage tanks and pipelines for liquid chemicals shall be provided for the individual chemicals and not used for different chemicals. Fill connections for all bulk chemical deliveries shall be clearly labeled to prevent accidental cross-contamination.

c) Chemicals shall be stored in covered or unopened shipping containers unless the chemical is transferred into an approved storage unit.

d) Liquid chemical storage tanks shall:

1) Have a liquid level indicator.

2) Have an overflow and a receiving basin capable of receiving accidental spills or overflows without uncontrolled discharge. A common receiving basin may be provided for each group of compatible chemicals, which provides sufficient containment volume to prevent accidental discharge in the event of failure of the largest tank.

5.5.10 Bulk liquid chemical storage tanks

Bulk liquid chemical storage tanks:

a) When required by the nature of the chemical stored shall have a means to maintain a uniform chemical strength. Continuous agitation shall be provided to maintain slurries in suspension.

b) Shall have a means to assure continuity of chemical supply when a liquid storage tank must be taken out of service for inspection, maintenance, or replacement.

c) Shall have a means to measure the liquid level in the liquid storage tank.

d) Shall be enclosed or be covered. Large liquid storage tanks with access openings shall have curbed openings fitted with overhanging covers.

e) Access openings on storage tanks containing an acidic or hazardous chemical shall be gasketed.

f) Liquid storage tanks that are partially or wholly installed below grade shall:

1) Be free from sources of possible contamination.

2) Have surface grading to assure positive drainage away from the area for ground waters, accumulated water, chemical spills, and overflows.

g) Overflow pipes shall:

1) Be turned downward, with the end screened.

2) Terminate 18 to 24 inches above grade to prevent splashing.

3) Have a free discharge with air gap.

4) Be located where an overflow will be noticeable.

h) Liquid storage tanks shall be vented. Common vents for bulk and/or day tanks storing different chemicals are prohibited. Acid and other hazardous chemical storage tanks shall be vented to the outside atmosphere.

i) All liquid storage tanks shall have a valved drain.

j) All liquid storage tanks shall be protected against cross-connections.

k) All bulk liquid storage tanks shall be clearly labeled with the chemical name.

l) Liquid storage tanks shall be located, and secondary containment provided so that chemicals from equipment failure, spillage or accidental releases shall not be able to drain into the water being conveyed, treated, and stored in conduits, treatment or storage basins, or to drain into any storm or sanitary sewer system. Secondary containment volumes shall be able to hold the volume of the largest storage tank and shall have surface coatings that are resistant to chemical corrosion. Piping shall be designed to minimize or contain chemical spills in the event of pipe ruptures.

5.5.11 Day tanks

Day tanks shall be provided when liquid chemical bulk storage tanks are installed. The reviewing authority may allow chemicals to be fed directly from shipping containers no larger than 55 gallons.

a) Day tanks shall:

1) When required by the nature of the chemical being fed, have a means to maintain a uniform chemical strength.

2) Have a means to assure continuity of chemical feed process when a day tank must be taken out of service for maintenance or replacement.

3) Be enclosed or be covered.

4) Be protected against cross connections.

5) Be located in secondary containment areas or over the bulk storage tank secondary containment pallet.

b) Day tank vents may be connected with vents for bulk tanks storing the same chemical. Such vents may also serve as an overflow back to the bulk tank. Piping must be designed to prevent siphoning of bulk chemical to the day tank.

c) Day tanks should hold no more than a 30-hour supply based on the average day demand.

d) 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 may be used.

e) Except for fluosilicic acid, hand pumps may be provided and used for transferring chemicals from a shipping container. A tip rack may be used to permit withdrawal into a bucket from a spigot. Where motor-driven transfer pumps are provided, a liquid level limit switch shall be provided.

f) Day tanks shall be clearly labeled with the chemical name.

g) Filling of day tanks shall not be automated, unless otherwise authorized by the reviewing authority.

5.5.12 Feed lines

a) Feed lines should be:

1) As short as possible.

2) Color coded and labeled.

3) Of durable, corrosion-resistant material.

4) Easily accessible throughout the entire length.

5) Cleanable by flushing or pigging.

6) Should slope upward from the chemical source to the feeder when conveying gases.

7) Feed lines conveying chemicals or chemical solutions that are scale-forming or contain solids that may deposit in the lines shall be designed and installed to account for and address the depositions.

5.5.13 Chemical handling

a) Carts, elevators and other appropriate means shall be provided for lifting chemical containers to minimize excessive lifting by operators.

b) Provisions shall be made for disposing of empty bags, drums, carboys, or barrels by an approved procedure which will minimize exposure to the chemicals and/or chemical dusts.

c) Provisions shall be made for the proper transfer of dry chemicals from shipping containers to storage bins or hoppers in such a way as to minimize the generation of dust. Dust control should be provided by use of:

1) Vacuum pneumatic equipment or closed conveyor systems;

2) Facilities for emptying shipping containers in special enclosures; and/or

3) Exhaust fans and dust filters that put the storage hoppers or bins under negative pressure.

d) Provision shall be made for measuring quantities of chemicals used to prepare feed solutions.

5.5.14 Chemical housing

a) Floor surfaces shall be smooth and impervious, slip-proof and well drained.

b) Vents from feeders, storage facilities and equipment exhaust shall discharge to the outside atmosphere above grade and be remote from air intakes.

5.6 **CHEMICALS**

5.6.1 Shipping containers

Chemical shipping containers shall be fully labeled. Labels shall include:

a) The chemical name

b) The purity and concentration.

c) The supplier's name and address.

5.6.2 Chemical specifications

Chemicals shall comply with the appropriate ANSI/AWWA standards and/or ANSI/NSF Standard 60.

5.6.3 Chemical assay

Provisions may be required for assay of chemicals delivered.

5.7 **OPERATOR SAFETY**

5.7.1 Ventilation

Special provisions shall be made for ventilation of chlorine storage and feed rooms.

5.7.2 Respiratory protection equipment

Respiratory protection equipment, meeting the requirements of the National Institute for Occupational Safety and Health (NIOSH) shall be available where chlorine gas is handled, and shall be stored at a convenient heated 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 units used by the fire department responsible for the plant.

5.7.3 Chlorine gas leak detection

A bottle of concentrated ammonium hydroxide (56 per cent ammonia solution) shall be available for chlorine leak detection. Where ton containers are used, a leak repair kit approved by the Chlorine Institute shall be provided. Where pressurized chlorine gas is present, continuous chlorine leak detection equipment is required and shall be equipped with both an audible alarm and a warning light.

5.7.4 Other protective equipment

a) At least one pair of rubber gloves, a dust respirator of a type certified by NIOSH for toxic dusts, an apron or other protective clothing and goggles or face mask shall be provided for each operator as required by the reviewing authority.

b) An appropriate deluge shower and eye washing device shall be installed where strong acids and alkalis are used or stored.

c) Other protective equipment should be provided as necessary.

5.7.5 Bulk chemical delivery

To prevent inadvertent mixing of bulk chemicals, facilities for receiving bulk chemicals shall provide the following, unless exempted by the reviewing authority agency:

a) Clear color coding and labeling of chemical receiving connections.

b) Chemical-specific and lockable connections.

c) Isolation valves interior to the building that also clearly label the chemical being received.

d) Accessible driveway to minimize transfer pipe length.

e) Containment below the pipe connections for spilled chemicals.

f) Written operating procedures when receiving all chemical deliveries, including for example:

   1) requiring chemical suppliers to notify in advance of all hazardous chemical deliveries.

   2) assigning single employee to order, track, and receive chemical deliveries.

   3) visually verifying the content of all deliveries by checking the manifests and material data safety sheets.

   4) checking chemical delivery personnel identifications.

   5) never accepting unscheduled chemical deliveries or deliveries from uncredentialed delivery personnel.

   6) testing the chemical product prior to accepting delivery.

g) Separate unloading stations and unloading spill containment systems for hazardous and incompatible chemicals.

h) Separate storage rooms for all hazardous and incompatible chemicals.

i) Separate chemical feed lines for all hazardous and incompatible chemicals.

j) Chemical storage facilities that are housed in structures that are designed and constructed in compliance with applicable building and fire codes for the storage of the specific chemical being stored.

k) Chemical unloading, storage, and feed areas that are always secure.

l) Restricting access to all unloading, storage, and feed areas by unauthorized personnel.

m) Closed-circuit television (CCTV) systems to monitor unloading and hazardous chemical areas.

5.8 **SPECIFIC CHEMICALS**

5.8.1 Chlorine gas

a) Chlorinators should be housed in a room separate from but adjacent to the chlorine storage room.

b) 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.

c) Chlorine feed rooms should be heated to 60°F and be ventilated and/or cooled as needed to protect the feed equipment from excessive heat. Cylinders and gas lines should be protected from excessive temperatures.

d) Chlorine gas feed and storage rooms shall be enclosed and separated from other operating areas. Both the feed and storage rooms shall be designed and constructed to comply with the following requirements:

1. A shatter resistant inspection window shall be installed in an interior wall.

2. All openings between the rooms and the remainder of the building shall be sealed.

3. Doors shall open outward only to the building exterior and be equipped with panic hardware.

4. A ventilation system with a capacity large enough to provide one air change per minute when the room is occupied shall be provided. Where this is not appropriate due to the size of the room, a lesser ventilation rate may be considered.

5. The ventilation system suction shall be near the floor and as far as possible from the door and air inlet. The ventilation system's discharge shall be screened and above grade outside of the building away from air inlets to any rooms or structures and designated walkway areas.

6. Air inlets with corrosion resistant louvers shall be airtight and installed near the ceiling.

7. Separate switches for the ventilation system and for the lights shall be located outside and at the inspection window. Outside switches must be protected from vandalism. A signal light indicating ventilation system operation shall be provided at each entrance when the system can be controlled from more than one point.

8. Floor drains are discouraged. Where provided, the floor drains must discharge to the outside of the building and not be directly connected to other internal or external drainage systems.

9. Provisions must be made to chemically neutralize or contain chlorine gas in the event of any measured chlorine release (or other acceptable measures as approved by the reviewing authority) where feed and/or storage is located near residential or developed areas. The chemical neutralizing equipment must be sized to treat the entire contents of the largest storage container in service.

10. Automatic shut-off devices on in-service chlorine cylinders should be installed when impacts of a chlorine leak to the surrounding area are possible. These devices quickly and effectively stop the flow of gas through the feed line by closing the container valve. These devices may be operated remotely, by the use of pressure-sensing switches, and/or chlorine gas detection systems. Installation of an automatic shut-off device should not significantly impede or inhibit manual closing of the container valve or require the use of any tools other than the standard gas cylinder wrench.

e) Chlorine gas feed systems shall be of the vacuum type and include the following:

1. Vacuum regulators on all individual cylinders in service.
2. 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.

f) Pressurized chlorine feed lines shall not convey chlorine gas outside the chlorine feed room.

g) All chlorine gas feed lines located outside the chlorinator or storage rooms shall be installed in airtight conduit pipe.

h) Full and empty chlorine gas cylinders shall be:

1. Housed only in the chlorine storage room.
2. Restrained in position.
3. Protected from direct sunlight and/or excessive heat.

i) Full and empty chlorine gas cylinders shall not be stored with any ammonia storage containers.

j) Premanufactured chlorine cabinets may be used for retrofit situations only. These cabinets shall have an observation window, air intake, and ventilation system as required for chlorine gas rooms. These cabinets should not be placed on the sunny side of the building.

5.8.2 Acids and caustics

a) Acidic and caustic chemicals shall be kept in closed corrosion-resistant shipping containers or be stored in bulk liquid storage tanks.

b) Acidic and caustic chemicals shall not be handled in open vessels but should be pumped undiluted to and from bulk liquid storage tanks and covered day tanks, or from shipping containers to the point of treatment.

5.8.3 Sodium chlorite

Proposals for the storage and use of sodium chlorite must be approved by the reviewing authority prior to the preparation of plans and specifications. Provisions shall be made for proper storage and handling of sodium chlorite to eliminate any danger of fire or explosion caused by its powerful oxidizing nature.

a) Storage

1) Sodium chlorite shall be stored in a separate room or preferably in a separate building away from organic materials which will ignite and burn violently when in exposed to sodium chlorite.
2) The sodium chlorite storage structures shall be constructed of noncombustible materials.
3) If a sodium chlorite structure is in an area where fire may occur, water must be available to keep the sodium chlorite area cool enough to prevent heat induced explosive decomposition of the sodium chlorite.

b) Handling

1) Care should be taken to prevent spillage.

2) An emergency plan of operation must be available for the cleanup of any spillage.

3) Storage drums must be thoroughly rinsed and flushed to an acceptable drain prior to recycling or disposal.

c) 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 between the different chemical feeders, or in a separate room designed and constructed to comply with the requirements feed for chlorine gas feed 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.

5.8.4 Sodium hypochlorite

Sodium hypochlorite may react with oxidizing agents and will react with acidic compounds. Sodium hypochlorite should never be stored with an acid or an oxidizing agent. Mixing liquid sodium hypochlorite with an acid will cause a violent chemical reaction and the release of chlorine gas.

5.8.4.1 Delivery

Every precaution should be taken when transporting, receiving, handling, storing, and feeding liquid sodium hypochlorite to prevent the inadvertent or intentional mixing of the chemical with an acid, including, but not limited to:

a) Written operating procedures when receiving all chemical deliveries, including for example:

1) Requiring chemical suppliers to notify in advance of all hazardous chemical deliveries.

2) Assigning employee(s) to order, track, and receive chemical deliveries.

3) Verify the content of all deliveries by checking the manifests and material data safety sheets.

4) Verify chemical delivery personnel identifications.

5) Not allow unscheduled chemical deliveries or deliveries from uncredentialed delivery personnel.

6) Testing the chemical product prior to accepting delivery.

5.8.4.2 Sodium hypochlorite storage and handling

Storage and handling procedures should be arranged to minimize the slow natural decomposition process of sodium hypochlorite either by contamination or by exposure to excessive heat and/or sunlight.

a) Storage

1) Sodium hypochlorite shall be stored in the original shipping containers or in sodium hypochlorite compatible bulk liquid storage tanks.

2) Storage containers or tanks shall be located out of the sunlight in a cool area and shall be vented to the outside of the building.

3) Sodium hypochlorite should be pumped undiluted to the point of addition. If dilution is unavoidable, deionized or softened dilution water should be used.

4) Storage areas, tanks, and pipe work shall be designed to prevent uncontrolled discharges, and a sufficient amount of appropriately selected spill absorbent shall be stored on-site.

5) Reusable sodium hypochlorite storage containers shall be reserved for use with sodium hypochlorite only and shall not be rinsed out or otherwise contaminated.

b) Feeders

1) Positive displacement pumps with sodium 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, and the piping shall be designed and constructed to facilitate the purging of trapped gases.

4) Calibration tubes or mass flow monitors which allow for direct physical checking of actual feed rates shall be provided.

5) Injectors shall be removable for regular cleaning when hard water is being treated.

6) Feed rates should be regularly adjusted to compensate for this progressive loss in chlorine content.

5.8.5 Ammonia

Ammonia for chloramine formation may be added to water either as a water solution of ammonium sulfate, or as aqua ammonia, or as anhydrous ammonia (purified 100% ammonia in liquid or gaseo us form). Special provisions required for each form of ammonia is listed below.

a) Ammonium sulfate

An ammonia water solution is made by dissolving solid ammonium sulfate in water with agitation. The mixing tank and dosing equipment contact surfaces should be made of corrosion resistant non- metallic materials. Provision should be made for removal of the agitator after dissolving the solid. The tank should be fitted with an air-tight lid and vented outdoors. The application point should be at the center of treated water flow at a location where there is adequate turbulence to blend the ammonia solution with the treated water.

b) Aqua ammonia (ammonium hydroxide)

Aqua ammonia feed pumps and storage shall be enclosed and separated from other operating areas. The aqua ammonia room shall be designed and constructed to comply with the requirement for the "Chlorine Gas Room" section.

a) Corrosion resistant, closed, unpressurized tanks shall be used for bulk liquid storage and day tanks, and the tanks shall be vented through inert liquid traps to a high point outside

b) An incompatible connector or lockout provisions shall be provided to prevent accidental addition of other chemicals to the bulk liquid storage tank(s).

c) 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:

   1) Refrigeration or other means of external cooling, and/or;

   2) Dilution and mixing of the contents with softened water without opening the bulk liquid storage tank.

d) An exhaust fan shall be installed to draw air from high points in the room and makeup air shall be allowed to enter at a low point.

e) 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.

f) The aqua ammonia should be conveyed from a day tank to the treated water application injector undiluted. If diluted, softened dilution water must be used.

g) The application point should be placed in a region of rapid, preferably turbulent, water flow.

h) Provisions should be made for easy access to the injector to allow for removal of calcium carbonate deposits.

i) Provision of an appropriately sized scrubber capable of handling occasional minor emissions should be considered.

c) Aqua ammonia (ammonium hydroxide)

Anhydrous ammonia is available as a pure liquefied gas under moderate pressure in cylinders or as a cryogenic liquid with a boiling point of -15 Celsius when at atmospheric pressure. The liquid causes severe burns on skin contact.

a) Anhydrous ammonia and storage feed systems (including heaters where required) shall be enclosed and separated from other areas and constructed of corrosion resistant materials.

b) Pressurized ammonia feed lines should be restricted to the ammonia room and any feed lines located outside the room should be installed in airtight conduit.

c) A ventilation system with a capacity large enough to provide one air change per minute when the room is occupied shall be provided.

d) The ventilation system suction shall be near the ceiling and as far away as possible from the door and air intake. The ventilation system's discharge shall be screened and be above grade outside of the building away from air inlets to any rooms or structures and designated walkway areas.

e) Leak detection systems shall be provided in all areas through which ammonia is conveyed.

f) Special vacuum breaker/regulator provisions must be included to avoid the potentially violent results that will occur if water backflows into cylinders or storage tanks.

g) Carrier water systems of soft water may be used to transport ammonia to the application point and to assist in mixing.

h) 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 or other scale deposits.

i) Provision should be made for the periodic removal of lime or other scale deposits from injectors and carrier piping.

j) Consideration shall be given to the provision of an emergency gas scrubber capable of absorbing the entire contents of the largest anhydrous ammonia storage unit whenever there is a risk to the public as a result of potential ammonia leaks.

5.8.6 Potassium permanganate

a) A source of heated water should be available for dissolving potassium permanganate.

b) Mechanical mixers shall be provided.

5.8.7 Fluoride

All fluoride compounds shall conform to the applicable AWWA Standards and be ANSI/NSF Standard 60 certified.

a) Storage

1) Fluoride chemicals should 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) Storage and day tanks for fluosilicic acid shall be sealed and vented to the atmosphere outside the building. Vents to atmosphere shall be turned down and protected with a corrosion

resistant 24 mesh screen.

4) Bags, fiber drums and steel drums should be stored on pallets.

b) Chemical feed equipment and methods

1) At least two diaphragm operated anti-siphon devices shall be provided on all fluoride saturator or fluosilicic acid feed systems.

   a. One diaphragm operated anti-siphon device shall be located on the discharge side of the feed pump, and;

   b. 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 through the required feed range.

5) Fluoride compound shall not be added before lime-soda softening or ion exchange softening processes.

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 treated water flow rate shall be provided.

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 as allowed by the reviewing authority,

11) Saturators should be of the upflow type and be provided with a meter and backflow protection on the makeup water line.

12) A separate room for fluosilicic acid storage and feed shall be provided unless allowed by the reviewing authority.

c) 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. In general, the preferred method for secondary controls is a physical wiring in series of the two signals to the chemical pump outlet, energizing only when the well or low service pump and secondary control signals allow. In situations where low service pumping is remote, reliance on the programmable logic computer (PLC) may be allowed by the reviewing authority.

d) Protective equipment

Personal protective equipment as outlined in the "Operator Safety" section shall be provided for operators handling fluoride compounds. Deluge showers and eye wash devices shall be provided at all fluosilicic acid installations.

e) 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 cleaning.

f) Testing and monitoring equipment

1) Testing equipment shall be available for measuring the concentration of fluoride in the water.

2) Equipment shall be provided for monitoring the concentration of fluoride in the water. Such equipment shall be subject to the approval of the reviewing authority.

5.8.8 Activated carbon

Activated carbon is a potentially combustible material requiring isolated storage. Storage facilities should be fireproof 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.

PART 6 - PUMPING FACILITIES

6.0 GENERAL

Pumping facilities shall be designed and constructed to protect and preserve the quality of pumped water. Pumping facilities should be designed to avoid the creation of confined spaces. No pumping station shall be subject to flooding. Pumping equipment is a major part of a public water supplies investment in equipment and machinery and must be properly operated and maintained to provide efficient and reliable long-term service. Where pumping is necessary it generally accounts for most of the energy consumed in water supply operations.

6.1 **LOCATION**

The pumping facilities shall be located and positioned to protect and preserve pumped water quality, hydraulics of the system, and protection against interruption of service by fire, flood or any other hazard.

6.1.1 Site protection

Pumping facilities shall be:

a) In fenced enclosure and/or in buildings that are secured.

b) Designed and constructed to maintain the sanitary quality of the pumped water.

c) Elevated so that the operating floor levels are not less than three feet above the 100-year flood elevation, or three feet above the highest recorded flood elevation, whichever is higher, or the stations are protected from flooding to such elevations.

d) Readily accessible at all times including by maintenance vehicles during all weather conditions.

e) Graded around the station to convey surface drainage away from the station.

f) Secured to prevent vandalism and entrance by animals or unauthorized persons.

6.2 **PUMPING STATIONS**

6.2.1 Pumping station design

All pumping stations shall have at least two pumps. Raw water pumping station shall have the capacity, with the largest pump out of service, to convey the design flow rate of the treatment facility. Finished water pumping stations should have the capacity, with the largest pump out of service, to convey the flow required to supply the design maximum day demand in the distribution system.

When fire protection is provided, finished water pumping stations, including booster pumping stations, should have the capacity, with the largest pump out of service, to convey the flow required to supply the design maximum day demand and the volume of the largest needed fire flow in the distribution system.

All finished water and booster pumping station should have the capacity, with the largest pump out of service, to supply the flows required to maintain the normal system design pressure described in the “Distribution System Design Pressure” section. All finished water and booster pumping station must have the capacity, with the largest pump out of service, working in conjunction with the available system water storage facilities, to supply the flows required to maintain the minimum pressure described in the “Distribution System Design Pressure” section.

All pumping stations shall have a flow meter with a flow rate indicator and flow totalizer.

All pumping stations should have smooth-nosed sample tap on the discharge line.

Booster pumping station should have the valves and piping to bypass the station when hydraulic conditions warrant and allow for a bypass operation.

Labeled such that the pumps and valves in the station are tagged to correspond to the inspection interval and maintenance record and for proper identification.

Both raw and finished water pumping stations shall:

a) Have adequate space and clearance for the installation of additional units if needed, and for the safe servicing of all equipment.

b) Be constructed out of durable fire and weather resistant materials.

c) Have outward-opening doors and operating floor elevations of at least six inches above the outside finished grade

d) Have all floors sloped to drains designed and installed in accordance with applicable codes and regulations.

e) Include drains and drain inlets where required for collecting drainage without allowing discharge across the floor from equipment, including pumps, backflow prevention devices, vacuum air release valves and the like to prevent drainage across floors.

6.2.2 Suction wells

Suction wells shall:

a) Be watertight.

b) Have floors sloped to permit removal of water and settled solids.

c) Be covered or otherwise protected against contamination.

d) Have two pumping compartments or other means to allow the suction well to be taken out of service for inspection maintenance or repair.

e) Have two pumping compartments or other means to allow the suction well to be taken out of service for inspection maintenance or repair.

f) Be designed to avoid turbulence near the pump intake and prevent vortex formation.

g) Be sized when necessary, with consideration to fill time and pump cycle times. The pump manufacturers duty cycle recommendations shall be used in selecting the minimum cycle time.

h) Be sized when necessary, with consideration to fill time and pump cycle times. The pump manufacturers duty cycle recommendations shall be used in selecting the minimum cycle time.

i) Be designed and have pump intake configured in accordance with guidance in ANSI/HI 9.8-2018 or current standard.

6.2.3 Servicing equipment

Pump stations shall be provided with:

a) Areas where an operator will walk or perform maintenance clear of overhead obstructions to a height of at least 7 feet and a minimum of 36 inches of clearance between piping, pumps, and other mechanical equipment.

b) Crane-ways, hoist beams, eyebolts, or other adequate facilities for servicing or removal of pumps, motors or other heavy equipment.

c) Openings in floors, roofs or wherever else needed for removal of heavy or bulky equipment.

d) Spare parts and all special tools and materials or other equipment required for the proper maintenance of all equipment systems.

e) A tool board for the storage of all special tools and a cabinet for the storage of materials and maintenance equipment.

f) A detailed O & M manual, including: a complete set of operating instructions, emergency procedures, a maintenance schedule, and the manufacturer's recommendations for service and maintenance of the pumps, motors, and other equipment systems.

g) Spare parts and all special tools and materials or other equipment required for proper maintenance of all equipment systems.

h) Hearing protection and other measures to protect the hearing of people in the station when noise levels exceed 85dBA.

6.2.4 Stairways and ladders

Stairways or ladders shall:

a) Be provided between all floors, and in pits or compartments which must be entered.

b) Conform to the requirements of the uniform building code, or relevant state and/or local codes and shall meet OSHA rules for landings, ladder cages, non-skid treads and toe plates.

c) Be provided with adequate safety equipment.

6.2.5 Heating

Adequate hearing shall be provided for:

a) The comfort of the operator.

b) The safe and efficient operation of the equipment.

In pump houses/stations not occupied by personnel, only enough heat need be provided to prevent freezing of equipment, and to allow proper operation of equipment and treatment processes.

6.2.6 Ventilation

Ventilation shall conform to relevant state and/or local codes. Adequate ventilation shall be provided for all pumping stations for operator comfort and dissipation of excess heat from the equipment. Forced ventilation systems shall be designed to provide:

a) At least six changes of air per hour for all confined rooms, compartments, pits and other below grade enclosures.

b) At least twenty changes of air per hour for any area where an unsafe atmosphere may develop, where chemicals may be stored, or where excessive heat may build up.

6.2.7 Dehumidification

Dehumidification shall be provided in areas where excess moisture could cause hazardous conditions for operator safety issues, or damage to equipment.

6.2.8 Lighting

Pump stations shall be adequately lit inside and outside to deter vandalism and facilitate maintenance. All electrical work shall conform to the requirements of the National Electrical Code or to relevant state and/or local codes.

6.2.9 Sanitary and other conveniences

All pumping stations that are manned for extended periods should be provided with potable water, lavatory and toilet facilities as allowed by state and /or local codes. Plumbing must be so installed as to prevent contamination of a public water supply. Wastes shall be discharged in accordance with Part 9.

6.2.10 Isolation valves and bypass

Adequate space outside or room inside shall be provided for installation of isolation valves. Bypass piping should be provided in case of pumping equipment failure when hydraulic conditions allow.

6.3 **PUMPS**

At least two pumping units shall be provided. With any pump out of service, the remaining pump or pumps shall be capable of providing the maximum pumping system demand while maintaining the minimum system pressure as described in the “System Design Pressure” - Section 8.2.1.

Pumps shall:

a) Have ample capacity to supply the peak demand against the required distribution system pressure without overloading.

b) Be driven by prime movers able to meet the maximum horsepower condition of the pumps.

c) Be supplied with all spare parts, materials, and tools required for operation and maintenance of the pumps and motors.

d) Be installed with electrical equipment and controls that are designed to operate through the full range or temperature they are expected to be exposed to, and have overload protection systems.

e) Be installed with variable frequency drives when required to minimize hydraulic surges.

f) Have suction and discharge isolation valves.

g) Have discharge check valves.

h) Have suction and discharge pressure gauges.

6.3.1 Suction lift

Suction lift conditions shall be avoided if possible but, if necessary, will be within practical limits, preferably less than 15 feet. When suction lift conditions are necessary, provision shall be made for priming the pumps.

6.3.2 Pump priming

When pumps are primed with water the prime water must not be of lesser sanitary quality than that of the water being pumped. Means shall be provided to prevent either backpressure or back siphonage backflow. When an air-operated ejector is used for priming, 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 the reviewing authority. Vacuum priming may be used.

6.3.3 Variable frequency drives

If the system design requires continually varying pump discharge rates, variable frequency-speed drives should be provided. A means must be provided to monitor the pump speed, and under speed and over speed alarms must be provided.

Variable frequency drives should be in spaces that are conditioned with equipment large enough to keep the temperatures in the spaces within acceptable limits.

6.3.4 Standby power

To ensure continuous service when the primary power has been interrupted, a power supply shall be provided from a standby or auxiliary source. If standby power is provided by onsite generators or engines, the fuel storage and fuel line must be designed to protect the water supply from contamination (see Section 2.6).

a) Generating unit size shall be adequate to provide power for pump motor starting current and for lighting, ventilation, and other auxiliary equipment necessary for safety and proper operation of the station.

b) The engine must be protected from operating conditions that would result in damage to equipment. Unless continuous manual supervision is planned, protective equipment shall be capable of shutting down the engine and activating an alarm on site. Protective equipment shall monitor for conditions of low oil pressure and overheating, except that oil pressure monitoring will not be required for engines with splash lubrication.

c) Be protected from damage during the restoration of regular electrical power.

d) Provided with instructions indicating the need for regular starting and running such units at full load.

e) Provisions shall be made for automatic and manual start-up and load transfer unless only manual start-up and operation is justified. The generator must be protected from operating conditions that would result in damage to equipment. Provisions should be considered to allow the engine to start and stabilize at operating speed before assuming the load.

f) Provide for secondary containment for fuel storage and fuel lines.

g) Be supplied with an O&M manual which includes guidance and instructions for the regular exercising of the unit under load.

6.3.5 Independent utility substations

Where independent substations are used for emergency power, each separate substation and its associate transmission lines must be capable of starting and operating the pump station at its rated capacity.

6.3.6 Internal-combustion engines

Where internal-combustion engines are used to drive pumps proper engine starting and operating procedures shall be posted near each internal-combustion engine.

6.4 BOOSTER PUMPS

6.4.1 Booster pumps

Booster pumps shall be designed, located and/or controlled so:

a) Pumps installed in the distribution system do not lower water pressures in the distribution system they are pumping from below the minimum system design pressure described in the "System Design Pressure" - Section 8.2.1.

b) Pumps pumping from storage tanks shall have adequate net positive suction head through the full range of operating water levels in the storage tank.

c) All pumps can maintain the system design pressures described in the "System Design Pressure" - Section 8.2.1, throughout the distribution system they are pumping into under all operating conditions.

d) An automatic shutoff or low-pressure controller maintains at least 20 psi (140 kPa) in the suction line under all operating conditions, unless otherwise acceptable to the reviewing authority. Pumps taking suction from ground storage tanks shall be equipped with automatic shutoffs or low-pressure controllers as recommended by the pump manufacturer.

e) All automatic or remote-control devices have a range between the start and cutoff pressure which will prevent excessive cycling.

f) They may be bypassed when hydraulic conditions permit.

6.4.2 Inline booster pumps

Inline booster pumps shall be installed in spaces where there is sufficient room for servicing and repairing the pumps and appurtenances.

6.4.3 Individual residential booster pump

Private booster pumps shall not be allowed for any individual residential service from the public water supply main

6.4.4 Real time monitoring

Consideration should be given to installing facilities that enable real-time monitoring of pumping station suction and discharge pressures

6.5 **AUTOMATIC AND REMOTE-CONTROLLED STATIONS**

All automatic stations should be provided with 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.

6.6 **APPURTENANCES**

6.6.1 Valves

Each pump must have an isolation valve on the intake and discharge side of the pump 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 ½ 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 shut-off valve. The check valve shall be mounted horizontally and have an outside lever indicating whether it is opened or closed. Surge relief valves or slow acting check valves shall be designed to minimize hydraulic transients. Continuous bleed valves or air-release valves should be installed on pumps at unattended pump stations.

All valves shall be located so they are easily accessible for all routine maintenance and must clearly indicate the normal direction of opening and closing.

6.6.2 Piping

In general, piping shall:

a) Be designed to minimize friction losses.

b) Not be exposed or in contact with sources of contamination.
c) Have watertight joints.

d) Be designed such that each pump has an individual suction line or that the lines shall be so manifolded that they will insure similar hydraulic and operating conditions.

e) Be designed for the expected working and transient pressures.

f) Have suitable restraints designed for the expected working and transient pressures where necessary.

6.6.3 Gauges and meters

Each pump shall have a standard pressure gauge on its discharge line and a compound gauge on its suction line. Larger stations shall have recording gauges or the pressure transmitter, telemetry, and controls to record the pressures. Each pump should have a means for measuring the discharge.

6.6.4 Water seals

When water seals are in service, water seals shall not be supplied with water of 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 water piping system shall include an approved reduced pressure principal backflow preventer (RPZ) or a break tank open to atmospheric pressure. When a RPZ backflow preventer is installed, it must drain into an appropriate-sized drain and be provided with a proper air gap. When a break tank is installed, it must have an air gap of at least six inches or two pipe diameters, whichever is greater, between the feeder line and the flood rim 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 alternations. Provision shall be made to prevent energizing the motor in the event of a backspin cycle. Electrical controls shall be located above grade. Equipment shall be provided, or other arrangements made to prevent surge pressures from activating controls which switch on pumps or activate other equipment outside the normal design cycle of operation

6.6.6 Water pre-lubrication

When automatic pre-lubrication of pump bearings is necessary and an auxiliary power supply is provided, design shall assure that pre-lubrication is provided when auxiliary power is in use, or that bearings can be lubricated manually before the pump is started

6.6.7 Oil or grease lubrication

All lubricants used in potable water pumping systems shall meet NSF International Standard H1, 3H, or H3.

PART 7 - WATER STORAGE

7.0 GENERAL

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 follow the current AWWA standards concerning storage tanks, standpipes, ground storage reservoirs, clearwells, and elevated tanks wherever they are applicable. Materials of construction shall meet the requirements of Part 7.

7.1 **General Storage**

7.1.1 Sizing

Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands, and where fire protection is provided, fire flow demands.

a) The minimum storage capacity (or equivalent capacity) for systems not providing fire protection shall be equal to the average daily 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.

b) Fire protection requirements should be established by the public water system with guidance from local fire protection authorities, subject to review and approval by the reviewing authority. When fire protection is to be provided, fire flows should be established with guidance available from the Insurance Services Office (ISO) or National Fire Protection Association (NFPA).

c) 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.

7.1.2 Location of finished water storage structures

a) The lowest elevation of the floor and sump floor of 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 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 no closer than 20 feet.

b) The bottom of 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.

7.1.3 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.

7.1.4 Security

Fencing, locks on access manholes, and other necessary precautions shall be provided to prevent trespassing, vandalism, and sabotage. Consideration should be given to the installation of high strength, cut resistant locks or lock covers to prevent direct cutting of a lock. Refer to Section 2.19 for additional security considerations.

7.1.5 Drains

If a gravity drain is provided, an air gap must be maintained at the outlet. No drain on a water storage structure may 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.

7.1.6 Stored water age and turnover

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.

a) Separate inlet and outlet pipe should be provided.
b) Consideration should be given to mixing systems to avoid stagnation and freezing.
c) All products in contact with potable water shall be certified for compliance with ANSI/NSF Standard 61.
d) 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.
e) Storage structures should 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.

7.1.7 Overflow

All water storage structures shall be provided with an overflow that extends down to an elevation between 12 and 24 inches above the ground surface, and discharges over a drainage inlet structure or a splash plate. No overflow may be connected directly to any drain, sanitary sewer or storm sewer. All overflow pipes shall be located so that any discharge is visible.

a) When an internal overflow pipe is used on elevated tanks, it shall be in the access tube or inside an enclosed support structure. For vertical drops on other types of storage facilities, the overflow pipe shall be located on the outside of the structure.

b) Overflow pipe shall not be in the wetted interior of the storage structure.

c) The overflow shall open downward and be screened with twenty-four mesh non-corrodible screen. 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.

d) Use of a solid flapper or duckbill valve should be considered to minimize air movement and ice formation in the tank. When a solid flapper is used, a screen shall be provided inside the overflow. If a duckbill valve is used, a screen is not required. Provisions must be included to prevent the flapper or duckbill from freezing shut.

e) The overflow pipe shall be of sufficient diameter to permit the discharge of water in excess of the maximum filling rate.

7.1.8 Access

Finished water storage structures shall be designed with reasonably convenient access to the interior for cleaning and maintenance. At least two (2) access manholes shall be provided above the waterline at each water compartment where space permits.

7.1.8.1 Elevated Storage or Dome Roof Structures

a) At least one of the access manholes shall be framed at least four 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 two inches, shall be hinged on one side, and shall have a locking device.

b) All other manholes or access ways shall be bolted and gasketed according to the requirements of the reviewing authority or shall meet the requirements of (a).

7.1.8.2 Ground Level or Flat Roof Structures

a) Each manhole shall be elevated at least 24 inches above the top of the tank or covering sod, whichever is higher.

b) Each access manhole shall be fitted with a solid watertight cover which overlaps a framed opening and extends down around the frame at least two inches. The frame shall be at least four inches high. Each cover shall be hinged on one side and shall have a locking device.

7.1.9 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:

a) Shall prevent the entrance of surface water and rainwater.

b) Shall exclude birds and other animals.

c) Should exclude insects and dust, as much as this function can be made compatible with effective venting.

d) Shall, on ground-level structures, open downward with the opening at least 24 inches above the roof or sod and be covered with twenty-four mesh non-corrodible screen. The screen shall be installed within the pipe vent where less susceptible to vandalism.

e) Shall, on elevated tanks and standpipes, open downward, and be fitted with twenty-four mesh non-corrodible screen in combination with an automatically resetting pressure-vacuum relief mechanism.

7.1.10 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. Particular attention shall be given to the sealing of roof structures which are not integral to the tank body, including access tubes.

a) Any pipes running through the roof or sidewall of a metal storage structure 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.

b) 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.

c) 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.

d) The roof of the storage structure shall be sloped to facilitate drainage. Downspout pipes 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.

e) 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.

f) When earthen cover is used on concrete reservoirs, it shall be graded and sloped to facilitate drainage.

7.1.11 Construction materials

The material used in construction of reservoirs shall be acceptable to the reviewing authority. Porous materials, including wood and concrete block, are not suitable for potable water contact applications.

7.1.12 Safety

Safety must be considered in the design of the storage structure. The design shall conform to pertinent laws and regulations of the area where the water storage structure is constructed.

a) 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 to prevent the entrance of unauthorized personnel.

b) Elevated tanks with riser pipes over eight inches in diameter shall have protective bars over the riser openings inside the tank.

c) 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.

d) Confined space entry requirements shall be considered for all water tanks.

7.1.13 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 functioning. Equipment used for freeze protection that will come into contact with the potable water shall meet ANSI/NSF Standard 61 or be approved by the reviewing authority. If a water circulation system is used, it is recommended that the circulation pipe be located separately from the riser pipe.

7.1.14 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.

7.1.15 Silt stop

The discharge pipes from water 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.

7.1.16 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 the structure.

7.1.17 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.

Paint systems shall meet ANSI/NSF standard 61 and be acceptable to the reviewing authority. 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 volatile organic compounds is advisable to establish that the coating is properly cured. Consideration should be given to 100 percent solids coatings.

Wax coatings for the tank interior shall not be used on new tanks. Recoating with a wax system is strongly discouraged. Old wax coating must be completely removed before using another tank coating. Cathodic protection should be designed by competent technical professionals and installed by personnel that are trained and certified cathodic protection equipment manufacturer to install the equipment. A maintenance contract with the installer should be obtained.

7.1.18 Disinfection

Finished water storage structures shall be disinfected in accordance with AWWA Standard C652. Following disinfection and prior to placing the tank in service, water shall be tested for total coliform bacteria and chlorine residual. If the test for total coliforms is negative, and the chlorine residual meets the requirements of the reviewing authority, the tank may be placed into service. If the test shows the presence of coliform bacteria, two or more successive sets of samples, taken at 24-hour intervals, shall indicate microbiologically satisfactory water before the facility is placed into operation.

The disinfection procedure specified in AWWA Standard C652 chlorination method 3, section 4.3 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 diluted before being disposed of.

Disposal of chlorinated water from the tank disinfection process shall be disposed of in a sanitary sewer with the approval of the local sewer authority or shall be disposed of to a location other than a sanitary sewer after the water has been dechlorinated in accordance with AWWA Standard C655.

7.1.19 Provisions for sampling

Smooth-nosed sampling tap(s) shall be provided to facilitate collection of water samples for both bacteriological and chemical analyses. The sample tap(s) shall be easily accessible and protected from freezing.

7.2 **TREATMENT PLANT STORAGE**

The applicable design standards of Section 7.0 shall be followed for plant storage.

7.2.1 Filter washwater tanks

Filter washwater tanks shall be sized, in conjunction with available pump units and finished water storage, to provide the required backwash water as described in the "Backwash" subsection in the "Filtration" – Section 4.3. Consideration must be given to the backwashing of several filters in rapid succession.

7.2.2 Clearwell

Clearwell water storage should be sized to provide disinfection contact time and in conjunction with distribution system water storage to allow the filters to operate at a constant rate. Distribution water storage should not be used to provide disinfectant contact time.

Clearwells shall:

a) Be designed to achieve as close to as possible to 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.

b) Be sized to ensure adequate disinfectant contact time, and include extra volume to accommodate depletion of storage during the nighttime for intermittently operated filtration plants with automatic high service pumping from the clearwell during nontreatment hours.

c) Have a minimum of two clearwell compartments. Clearwells also should be designed so that

50 percent of the clearwell can be isolated for routine cleaning, inspection and maintenance.

d) Have an overflow and be vented.

Mixers shall not be installed in clearwells without the reviewing authority's approval.

7.2.3 Adjacent storage

Finished or treated water must not be stored or conveyed in a compartment adjacent to untreated or partially treated water when the two compartments are separated by a single wall, unless approved by the reviewing authority.

7.2.4 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.

7.3 HYDROPNEUMATIC TANK SYSTEMS

Hydropneumatic (pressure) tanks, when provided as the only water storage are acceptable only in very small water systems. Systems serving more than 150 living units should have ground or elevated storage designed in accordance with Section 7.1 or 7.3. Hydropneumatic tank storage is not to be permitted for fire protection purposes. Pressure tanks shall meet 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 the reviewing authority.

7.3.1 Location

Hydropneumatic tanks shall be located above normal ground surface and be completely housed.

7.3.2 System sizing

a) The capacity of the wells and pumps in a hydropneumatic system should be at least ten times the average daily consumption rate.

b) The gross volume of the hydropneumatic tank, in gallons, should be at least ten times the capacity of the largest pump, rated in gallons per minute. For example, a 250 gpm pump should have a minimum 2,500-gallon pressure tank, unless other measures (e.g., variable speed drives in conjunction with the pump motors) are provided to meet the maximum demand.

7.3.3 Piping

The hydropneumatic tank(s) shall have bypass piping and valves to permit operation of the system while the tank is being repaired or painted.

7.3.4 Appurtenances

Each tank shall have an access manhole, 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 the access manhole should be at least 24 inches in diameter.

7.3.5 Disinfection contact time

Hydropneumatic tanks shall not be is used to provide disinfection contact time.

7.4 **DISTRIBUTION SYSTEM STORAGE**

The applicable design standards in the "General" section - Section 7.0 shall be followed for distribution system storage.

7.4.1 Pressures

The maximum variation between high and low levels in water storage structures providing pressure to a distribution system should not exceed 30 feet. The normal working pressure should be approximately 60 to 80 psi (410 - 550 kPa) and shall not be less than 35 psi (240 kPa) unless otherwise approved by the reviewing authority. When static pressures exceed 100 psi (690 kPa), pressure reducing devices shall be provided on mains or as part of the meter setting on individual service lines in the distribution system.

7.4.2 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. The storage structure drain shall discharge to the ground surface with no direct connection to a sewer or storm drain.

7.4.3 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.

a) 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.

b) Altitude valves or equivalent controls may be required for a second and subsequent structures on the system.

c) Overflow and low-level warnings or alarms should be located where they will be under responsible surveillance 24 hours a day.

7.4.4 Passive mixing

Finished water storage facilities shall be designed to provide mixing. Mixing of finished water in storage can reduce 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. Passive mixing design considerations include:

a) The inlet flow should be placed where it will have the longest flow path. 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.

b) The inlet diameter should be minimized to maximize inlet velocity. Multiple smaller inlets should not be considered.

c) Deflectors on inlets, tangential inlets, inlets into sumps, or wall side and inlets discharging above the water surface should not be provided.

d) Baffling should not be provided.

e) 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.

7.4.5 Mechanical mixing

In-tank mixers and in-tank aeration units that are being installed to maintain or improve finished water quality shall conform with the following requirements.

a) All equipment materials being placed inside the tank and headspace, including a power cable, shall have ANI/NSF Standard 61 certification.

b) All penetrations shall be properly sealed and watertight. All power or air lines shall penetrate the facility above the maximum water height in the storage facility.

c) 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

d) 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.

e) If removing disinfection by-products, ventilation of head space shall be provided.

PART 8 - DISTRIBUTION SYSTEM PIPING AND APPURTENANCES

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 design of multidirectional flow, adequate valving for distribution system control, and provisions for adequate flushing. Systems should be designed to maximize turnover and to minimize water residence times while delivering acceptable pressures and flows.

8.1 **MATERIALS**

8.1.1 Standards and materials selection

All materials including pipe, fittings, valves and fire hydrants, and those used for the rehabilitation of water mains shall conform to the latest standards issued by the ASTM, AWWA and ANSI/NSF, where such standards exist, and be acceptable to the reviewing authority. In the absence of such standards, materials meeting applicable product standards and acceptable to the reviewing authority may be selected. 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 standards in this section and have been restored practically to their original condition.

8.1.4 Joints

Packing and jointing materials used in the pipe joints shall meet the standards of AWWA and the reviewing authority. Pipe with mechanical joints or slip-on joints with rubber gaskets are preferred. Gaskets containing lead shall not be used. Repairs to lead joint pipe shall be made using alternative methods. Transition couplings used between dissimilar piping materials shall have pressure ratings greater than or equal to the pipe pressure rating and be acceptable to the reviewing authority.

8.2 **SYSTEM DESIGN**

8.2.1 System design 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 system shall be designed to maintain a minimum pressure of 20 psi (140 kPa) at ground level at all points in the distribution system under all conditions of flow**.** The normal working pressure in the distribution system should be approximately 60 to 80 psi (410 - 550 kPa) and shall not be less than 35 psi (240 kPa) unless otherwise approved by the reviewing authority.

8.2.2 Pipe diameter

The minimum size of water main which provides for fire protection and serving fire hydrants shall be six (6) inch diameter. Larger size mains will be required if necessary, to deliver the required fire flow while maintaining the minimum residual pressure specified in Section 8.2.1.

The minimum size of water main in the distribution system where fire protection is not to be provided shall be a three (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

Fire protection requirements should be established by the public water system with guidance from local fire protection authorities, subject to review and approval by the reviewing authority. When fire protection is to be provided, fire flows should be established with guidance available from the Insurance Services Office (ISO) or National Fire Protection Association (NFPA).

8.2.4 Dead ends

a) Dead end water mains shall be minimized to provide increased reliability of service and reduce head loss by making appropriate tie-ins whenever practical.

b) Dead end mains shall be equipped with a means to provide adequate flushing. Flushing devices should be sized to provide flows which will give a velocity of at least 3.0 feet per second in the water main being flushed. Flushing may be performed using fire hydrants if flows and pressures are sufficient. No flushing device shall be directly connected to any sewer.

8.3 **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 districts. Where systems serve widely scattered customers and where future development is not expected, the valve spacing should not exceed one mile.

8.4 **HYDRANTS**

8.4.1 Location and spacing

a) Fire hydrants should be provided at each street intersection and at intermediate points between intersections. Generally, fire hydrant spacing ranges from 350 to 600 feet depending on the area being served.

b) Water mains not designed to carry fire-flows shall not have fire hydrants connected to them. It is recommended that flushing hydrants be provided on these systems. 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. No flushing device shall be directly connected to any sewer.

8.4.2 Valves and nozzles

Fire hydrants should have at least five-inch diameter bottom valves, one 4 ½ -inch pumper nozzle and two 2 1/2 -inch nozzles.

8.4.3 Hydrant leads

The hydrant lead shall be a minimum of six inches in diameter. Auxiliary valves shall be installed on all hydrant leads. Long hydrant leads should be avoided.

8.4.4 Hydrant drainage

a) Hydrant drains should be plugged. When the drains are plugged the barrels must be pumped dry before and during cold weather periods when temperatures are likely to be cold enough to freeze the water in the hydrant barrel.

b) Hydrant drains, where allowed, shall not be located within 10 feet of sanitary sewers, storm sewers, or storm inlets.

c) Hydrant drains, where allowed, must be above the seasonal groundwater table.

d) Where hydrant drains are not plugged, a gravel pocket or dry well shall be provided unless the natural soils will provide adequate drainage.

8.5 **AIR RELIEF VALVES**

8.5.1 Air relief valves

Provisions shall be made to remove the air by means of air relief valves at high points in water mains where air can accumulate. Use of manual air relief valves is preferred wherever possible. Manual and automatic air relief valves should be installed in manholes or chambers that are located and positioned so that flooding of the manhole or chamber will not occur. Automatic air relief valves shall not be used in situations where flooding of the manhole or chamber may occur unless equipped with an inflow preventer that is acceptable to the reviewing authority and conforms to AWWA C514.

8.5.2 Air relief valve piping

a) The open end of an air relief pipe from a manually operated valve in a manhole or chamber should extend to the top of the interior of the manhole or chamber and be screened and have downward-facing elbow if drainage is provided for the manhole.

b) The open end of an air relief pipe from automatic valves shall:

    1) Extended to at least one foot above grade and provided with a screened, downward facing elbow, or

    2) Be equipped with an inflow preventer that is acceptable to the reviewing authority and conforms to AWWA C514.

c) Discharge piping from air relief valves shall not connect directly to any storm inlet, storm sewer, or sanitary sewer.

8.6 **VALVE, METER AND BLOW-OFF CHAMBERS**

Wherever possible, chambers, pits or manholes containing valves, blowoffs, 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 connect directly to any storm inlet, storm sewer, or sanitary sewer. Blowoffs shall not connect directly to any storm inlet, storm sewer or sanitary sewer.

8.7 INSTALLATION OF WATER MAINS

8.7.1 Standards

Specifications shall incorporate the provisions of the applicable AWWA standards and/or manufacturers recommended installation procedures.

8.7.2 Bedding

A 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 six inches below the bottom of the pipe. Stones in the bedding shall also be removed.

8.7.3 Cover

Water mains shall be covered with sufficient earth or other insulation to prevent freezing.

8.7.4 Blocking

All tees, bends, plugs and hydrants shall be provided with reaction blocking, tie rods or restrained joints designed to prevent movement.

8.7.5 Anchoring of fusible pipe

Additional restraint may be necessary on fusible pipe at the connection to appurtenances or transitions to different pipe materials to prevent joint separation. The restraint may be provided in the form of an anchor ring encased in concrete or other methods as approved by the reviewing authority.

8.7.6 Pressure and leakage testing

Installed pipe shall be pressure tested and leakage tested in accordance with the applicable AWWA Standard.

8.7.7 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.

8.7.8 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 the water main.

8.8 SEPARATION DISTANCES FROM CONTAMINATION SOURCES

8.8.1 General

The following factors should be considered in providing adequate separation:

a) Materials and type of joints for water and sewer pipes.

b) Soil conditions.

c) Service and branch connections into the water main and sewer line.

d) Compensating variations in the horizontal and vertical separations.

e) Space for repair and alterations of water and sewer pipes.

f) Offsetting of pipes around manholes.

g) Sanitary sewer shall be defined as a gravity pipe carrying untreated wastewater. Storm sewer shall be defined as a gravity pipe carrying surface water runoff to a point of discharge.

8.8.2 Parallel installation

Water mains shall be laid at least 10 feet horizontally from any existing or proposed gravity sanitary or storm sewer, septic tank, or surface treatment system. The distance shall be measured edge to edge.

In cases where it is not practical to maintain a 10-foot separation, the reviewing authority may allow deviation on a case-by-case basis, if supported by data from the design engineer.

8.8.3 Crossings

Water mains crossing sanitary or storm sewers shall be laid to provide a minimum vertical distance of 18 inches between the outside of the water main and the outside of the sewer. This shall be the case where the water main is either above or below the sewer with preference to the water main located above the sewer.

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.

8.8.4 Exceptions

When it is impossible to obtain the minimum specified separation distances, the reviewing authority must specifically approve any deviation from the requirements of Sections 8.8.2 and 8.8.3. Where water mains and/or sanitary or storm sewers are being installed and the parallel installation and crossing requirements cannot be met, the following methods of installation may be considered:

a) The water main is laid in a 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 gravity sewer; or

b) The sanitary sewer pipe materials shall be pressure rated and the manholes watertight or otherwise sealed as approved by the reviewing authority and shall be pressure and/or leak tested to demonstrate watertightness; or

c) The storm sewer pipe materials shall be pressure rated and the manholes and inlets watertight or otherwise sealed as approved by the reviewing authority and shall be pressure and/or tested to demonstrate watertightness.

8.8.5 Force mains

There shall be at least a 10-foot horizontal separation between water mains and sanitary or storm sewer force mains. There shall be an 18-inch vertical separation at crossings as required in the “Crossings” – Section 8.8.3. The reviewing authority must approve any deviations prior to construction.

8.8.6 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 main shall be located at least 10 feet from sewer manholes, inlets, and structures; any deviation from this requirement must be approved by the reviewing authority prior to construction. Factors for consideration of deviations should include the following:

a) Materials and type of joints for sewer structures.

b) Material of sewer pipe.

c) Presence of impermeable liners in or coatings of sewer structures.

d) Presence of multiple pipe inlets/outlets into sewer structures.

e) Soil conditions.

f) Compensating variations in the horizontal and vertical separations.

g) Allowing adequate space for repair and alterations of the water and sewer systems.

8.8.7 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, industrial complexes, petroleum storage or any other potential sources of contamination. On site waste disposal facilities including absorption fields must be located and avoided. The engineer must contact the reviewing authority to establish specific design requirements for locating water mains near any source of contamination.

8.9 **SURFACE WATER CROSSINGS**

Surface water crossings, whether over or under water, present special problems. The reviewing authority should be consulted before final plans are prepared.

8.9.1 Above water crossings

Water mains installed over water bodies shall be adequately supported and anchored, protected from vandalism, damage and freezing, and accessible for repair or replacement.

8.9.2 Underwater crossings

Water mains installed under water bodies shall have a minimum cover of five feet over the pipe unless otherwise approved by the reviewing authority. When crossing water courses which are greater than 15 feet in width, the following shall be provided:

a) The pipe shall be of special construction, having flexible, restrained or welded watertight joints.

b) 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.

c) Permanent taps or other provisions to allow insertion of a small meter to determine leakage and obtain water samples on each side of the valve closest to the water supply source.

8.10 **CROSS-CONNECTIONS**

8.10.1 Cross-connections

There shall be no connection between the distribution system and any pipes, pumps, hydrants, or tanks through which unsafe water or other contaminating materials may be present and could be drawn into the water distribution system. Each water utility shall have a program conforming to state requirements to detect and eliminate cross connections.
Water utilities shall not have multiple connections to privately-owned water systems that are not designed and constructed to prevent water flowing through the privately-owned water system and back into the water utility's distribution system.

8.10.2 Cooling water

Neither steam condensate, cooling water from engine jackets, nor water used in conjunction with heat exchange devices shall be returned to the potable water system.

8.11 **INTERCONNECTIONS**

The approval of the reviewing authority shall be obtained for interconnections between potable water supplies.

8.11.1 Interconnection materials requirements:

Interconnections shall:

a) Be constructed using materials, including pipes, fittings, and valves that conform with ANSI/NSF Standard 61.

b) Have at least two valves to separate the two systems.

c) Have sample taps on both sides of the interconnection.

d) When emergency interconnections are required, a riser with a small, protected outlet should be installed that, when flowing, will visibly indicate operation of the emergency interconnection and/or failure of, or improper position of, one of the isolation valves.

e) Be designed to provide the maximum flow rates, volumes, and pressures.

f) Have flushing hydrants.

8.11.2 Water quantity analysis:

The water quantity analysis shall be performed and shall include:

a) A demonstration of the source capacity and hydraulic capacity of the supplying and receiving systems at the designed flow rate through the interconnection.

b) Calculations of each system's capacity, in regard to well rating, storage, pressure, service pumps and emergency power, to prove the seller has enough production, treatment, and pumping capacity to meet or exceed the combined maximum daily commitments specified in its various contractual obligations.

c) A hydraulic analysis conducted to identify the potential impacts the interconnection will have upon each water system's quantity and pressures

8.11.3 Water quality analysis:

The water quality analysis shall be performed and shall include:

a) An analysis report of the chemical differences between the purchaser's and seller's and the potential impact the interconnection may have on the interconnected system's water quality. The reviewing authority may require analyses of additional chemical parameters. At a minimum, test parameters from both the purchaser's interconnection point, and the seller's interconnection point are to include:

1) pH
2) Alkalinity (mg/L as $CaCO_3$)
3) Orthophosphate (mg/L as P) (if used by either PWS)
4) Hardness (mg/L as $CaCO_3$)
5) Temperature (˚C)
6) Calcium (mg/L as Ca)
7) Total Dissolved Solids (mg/L)
8) Conductivity (as µmho/cm @ 25 ˚C)
9) Total Chlorine (mg/L as Cl_2)
10) Free Chlorine (mg/L as Cl_2)
11) Chloride (mg/L)
12) Sulfate (mg/L)
13) Iron (mg/L)
14) Manganese (mg/L)
15) Silica (mg/L as SiO_2) (if used by either PWS)
16) Total Trihalomethanes (mg/L)
17) Haloacetic Acids (mg/L)

b) A detailed evaluation of the potential effects interconnection may have in the distribution system due to differences in water chemistry between the two PWS.

c) A description of each system's corrosion control treatment.

d) A description of the disinfection and disinfection systems used in both systems.

e) A map showing predicted mixing zones (if different disinfectants are used).

f) A nitrification control plan that conforms to the requirements in American Water Works Association Manual M56 (if either system uses chloramines).

8.11.4 Inter-water system coordination plan:

An inter-water system coordination plan should include:

a) A list of all interconnections with other water sellers and purchasers, purchasing agreements, and whether the interconnection is permanent or emergency.

b) All pertinent information, to include, at a minimum, the size, available capacity, disinfectants, and materials used for the interconnection.

c) 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.

d) 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.

8.12 **WATER SERVICES AND PLUMBING**

8.12.1 Plumbing

Water services and plumbing shall conform to the applicable local and/or state plumbing codes.

8.12.2 Booster pumps

Individual booster pumps shall not be allowed for any individual residential service from the public water supply mains. Where permitted for other types of services, booster pumps shall be designed in accordance with the "Booster Pumps" section.

8.13 **SERVICE METERS**

Each water service connection should be individually metered.

Water meters shall conform to the applicable AWWA standard. Water meters shall be selected, installed, tested, maintained, and repaired in accordance with the recommendations and guidance in the AWWA's M6 Manual.

8.14 **WATER LOADING STATIONS**

Water loading stations present special problems since the fill line may be 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 water loading stations:

a) The loading station shall be located in an area that ensures the station will not change the flow direction or adversely affect the distribution supply or pressure. Locating the loading station near a storage facility is recommended.

b) All materials including pipes, fittings, valves, and transfer tubing shall be certified for conformance with ANSI/NSF Standard 61.

c) Any transfer pump shall be enclosed in a cabinet to protect against contamination.

d) 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 tested and maintained.

e) The piping arrangement shall prevent contaminants from being transferred between users of the station.

f) The loading station shall be designed to ensure the hoses will not be contaminated from contact with the ground.

g) All cleaning or disinfecting chemicals used in the loading station shall be certified for conformance with ANSI/NSF Standard 60.

h) Mobile loading stations shall meet all the same regulatory and design standards as fixed loading stations. Mobile loading station equipment may only be used at approved taking points to ensure the station will not change to flow direction or adversely affect the distribution supply or pressure.

Acceptable Water Loading Station
See Section 8.14

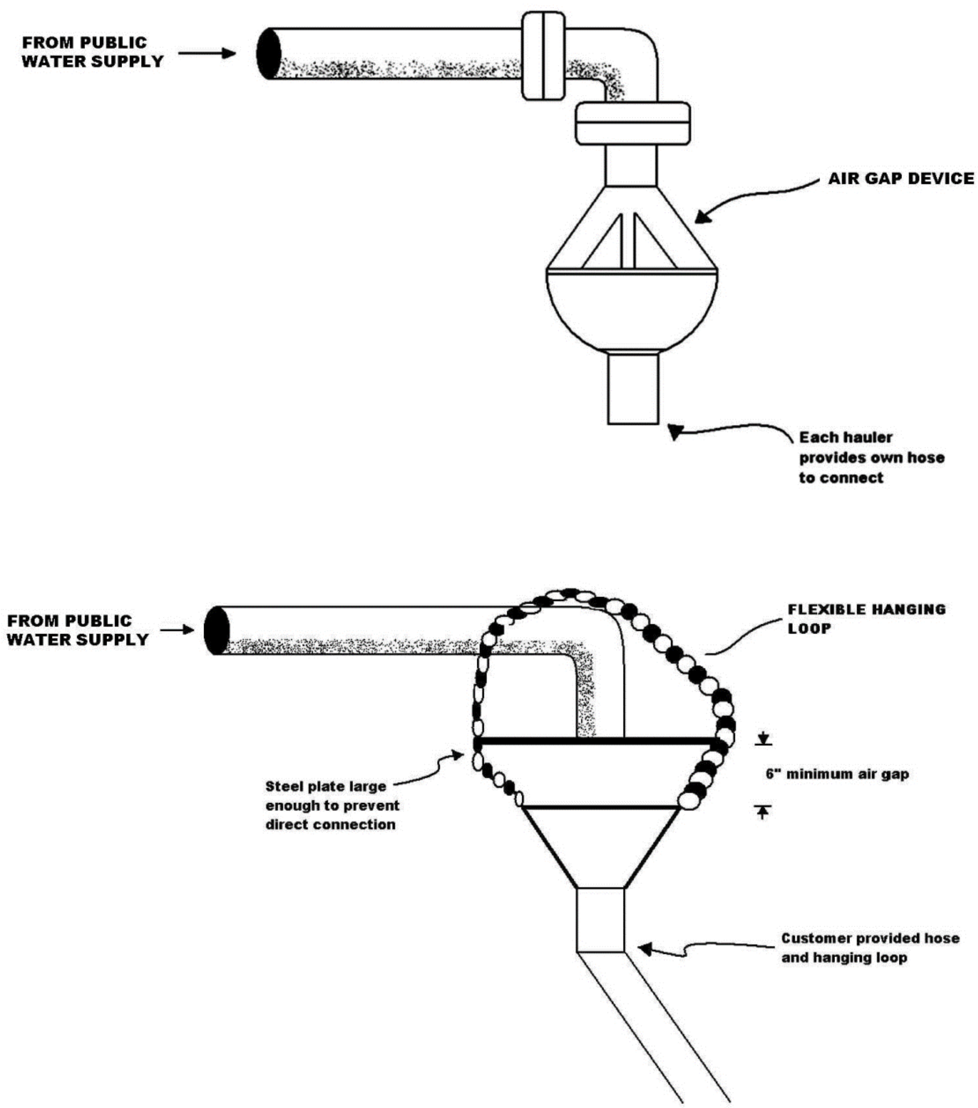


FIGURE 1 – SUGGESTED FILLING DEVICE FOR WATER LOADING STATIONS

PART 9 - WASTE RESIDUALS

9.0 GENERAL

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. All waste discharges shall be in accordance with all federal, state and/or local laws and ordinances. The requirements outlined herein must, therefore, be considered minimum requirements and federal, state, and/or local water pollution control authorities may have more stringent requirements.

Provisions must be made for proper disposal of water treatment plant wastes such as sanitary and laboratory wastes, clarification residuals, softening residuals, iron residuals, filter backwash water, backwash residuals, and brines (including softener and ion exchange regeneration wastes and membrane and reverse osmosis wastes). Some regulatory agencies require monitoring of discharges from overflow pipes/outlets. In locating sewer lines and waste disposal facilities, consideration shall be given to preventing potential contamination of the water supply.

The appropriate federal, state, and local officials should be notified when designing treatment facilities to ensure that the local sanitary sewer system and wastewater treatment facility can accept the anticipated wastes.

Backflow prevention measures as approved by the reviewing authority must be provided where required to protect the public water supply.

9.1 SANITARY WASTE

The sanitary waste from water treatment plants, pumping stations, and other waterworks installations must be treated or disposed of as required by the reviewing authority. Waste from these facilities shall discharge directly to a sanitary sewer system, when available and feasible, or to an on-site sewage treatment system that is approved by the reviewing authority.

9.2 BRINE WASTES

Waste from ion exchange, demineralization, and membrane plants, or other plants which produce a brine, must be treated or discharged in accordance with all federal, state, and local rules. When discharging to a sanitary sewer, an equalization basin or tank may be required to prevent the overloading of the sewer and/or interference with the waste treatment processes. The effect of brine discharge to sewage lagoons may depend on the rate of evaporation from the lagoons.

9.3 PRECIPITATIVE SOFTENING RESIDUALS

Residuals from plants using precipitative softening varies in quantity and in chemical characteristics depending on the softening process and the chemical characteristics of the water being softened. The quantity of residual produced may be much larger than indicated by stoichiometric calculations, so additional capacity for residuals should be considered. Methods of treatment and disposal are as follows:

9.3.1 Lagoons

a) Short term storage lagoons should be designed on the basis of 0.7 acres per million gallons per day per 100 mg/L of hardness removed based on a usable lagoon depth of five feet. This should provide about 2 ½ years storage. At least two, but preferably more, lagoons must be provided in order to give flexibility in operation. An acceptable means of final residual disposal must be provided. Provisions must be made for convenient cleaning of the lagoons.

b) Long term lagoons should have a volume of at least four times that for short-term storage lagoons.

c) The design of both short-term and long-term lagoons should:

   1) Be located outside flood plains or in a location free from flooding.

   2) When necessary, include dikes, deflecting gutters or other means of diverting surface water runoff so that it does not flow into the lagoons.

   3) Have a minimum usable depth of five feet.

   4) Have freeboards of at least two feet.

   5) Have adjustable decanting device.

   6) Have a designated effluent sampling point.

   7) Have adequate safety provisions.

   8) Be configured for parallel operation.

   9) Should only have subsurface infiltration if approved by the reviewing authority.

d) The application of liquid lime or dewatered residuals to farmland should be considered as a method of disposal. Prior to land application, a chemical analysis of the residuals including calcium and heavy metals shall be conducted. Approval from the reviewing authority shall be obtained. When this method is selected, the following provisions should be considered:

   1) Transport of residuals by vehicle or pipeline should incorporate a plan or design which prevents spillage or leakage during transport.

   2) Interim storage areas at the application site should be kept to a minimum and facilities should be provided to prevent runoff of residuals or flooding of the facilities.

   3) Residuals should not be applied at times when runoff from the land could be expected.

   4) Residuals should not be applied to sloping land where runoff could be expected unless provisions are made, for suitable land, to immediately incorporate the residuals into the soil.

   5) Trace metals loading should be limited to prevent significant increases in trace metals in the food chain, phytotoxicity or water pollution.

   6) Each area of land to receive lime residuals should be considered individually and a determination made as to the amount of residuals needed to raise soil pH to the level required for the crop to be grown.

e) Discharge of lime residuals to sanitary sewers should be avoided since it may cause both liquid and solids volume problems at the sewage treatment plant. This method should be used only when the sewage system has the capability to adequately handle the lime residuals.

f) Mixing of lime residuals with activated sludge waste may be considered as a means of co-disposal.

g) Disposal at a landfill can be done as either a solid or liquid if the landfill can accept such waste, depending on individual state requirements.

h) Mechanical dewatering of residuals may be considered. It is recommended that a pilot study on the particular plant waste be conducted. Mechanical dewatering shall be preceded by residuals concentration and chemical pre-treatment.

i) Calcination of residuals may be considered. Pilot studies on a particular plant waste are required.

j) Lime residuals drying beds may be considered if space and geographic concerns are addressed.

9.4 ALUM RESIDUALS

Lagoons may be used as a method of handling alum residuals. Lagoon size can be calculated using total chemicals used plus a factor for turbidity. Mechanical concentration should be considered. It is recommended that a pilot plant study be conducted prior to the design of a mechanical dewatering installation.

Alum residuals can be discharged to a sanitary sewer if the owner of the sewage system and the reviewing authority give approval before final designs are made.

9.4.1 Lagoons

Lagoons should be designed to produce an effluent satisfactory to the regulatory agency and should:

a) Be located outside of flood plains.

b) When necessary, include dikes, deflecting gutters or other means of diverting surface water runoff so that it does not flow into the lagoon.

c) Have a minimum usable depth of five feet.

d) Have freeboards of at least two feet.

e) Have adjustable decanting device.

f) Have a designated effluent sampling point.

g) Have adequate safety provisions.

h) Have a minimum of two cells, each with appropriate inlet/outlet structures to facilitate independent filling/dewatering operations.

9.4.2 Mechanical dewatering

a) A mechanical dewatering pilot study on the particular plant waste should be conducted.

b) Mechanical dewatering shall be preceded by residuals concentration and chemical pre- treatment.

9.4.3 Land application

Alum residuals may be disposed of by land application either alone, or in combination with other wastes, and disposal has been approved by the reviewing authority.

9.5 "RED WATER" WASTE

Waste filter wash water from iron and manganese removal plants can be disposed of as follows:

9.5.1 Sand filters

Sand filters should have the following features:

a) Total filter area shall be sufficient to adequately dewater applied solids. Unless the filter is small enough to be cleaned and returned to service in one day, two or more cells are required.

b) The "red water" filter shall have sufficient capacity to contain, above the level of the sand, the entire volume of wash water produced by washing all of the production filters in the plant, unless the production filters are washed on a rotating schedule and the flow through the production filters is regulated by true rate of flow controllers. Then sufficient volume shall be provided to properly dispose of the wash water involved.

c) Sufficient filter surface area should be provided so that, during any one filtration cycle, no more than two feet of backwash water will accumulate over the sand surface.

d) The filter shall not be subject to flooding by surface runoff or flood waters. Finished grade elevation shall be established to facilitate maintenance, cleaning and removal of surface sand as required. Flash boards or other non-watertight devices shall not be used in the construction of filter side walls.

e) The filter media should consist of a minimum of twelve inches of sand, three to four inches of supporting small gravel or torpedo sand, and nine inches of gravel in graded layers. All sand and gravel should be washed to remove fines.

f) Filter sand should have an effective size of 0.3 to 0.5 mm and a uniformity coefficient not to exceed 3.5. The use of larger sized sands shall be justified by the designing engineer to the satisfaction of the reviewing authority.

g) The filter should be provided with an adequate under-drainage collection system to permit satisfactory discharge of filtrate.

h) Provision shall be made for the sampling of the filter effluent.

i) Overflow devices from "red water" filters shall not be permitted.

j) Where freezing is a problem, provisions should be made for freeze protection for the filters during the winter months.

k) "Red water" filters shall comply with the common wall provisions contained in Sections 7.1.3 and 8.10.1, which pertain to the possibility of contaminating treated water with unsafe water.

The reviewing authority must be informed of and approve any arrangement where a separate structure is not provided.

9.5.2 Lagoons

Lagoons shall have the following features:

a) Be designed with a volume 10 times the total quantity of wash water discharged during any 24-hour period.

b) Have a minimum usable depth of three feet.

c) Have lengths four times width, and the widths at least three times the depths, as measured at the operating water level.

d) Have outlets at the end opposite from the inlets.

e) Have a weir overflow device at the outlet end with weir length equal to or greater than depth.

f) Have inlets designed to lower influent flow velocities and dissipate influent flows.

Subsurface infiltration lagoons may be acceptable if approved by the reviewing authority.

9.5.3 Discharge to community sanitary sewer

Red water can be discharged to a community sewer if the sewage system authority and the reviewing authority give approval before designs are initiated. An equalization basin or tank is recommended to prevent overloading the sewers. Design shall prevent cross connections and there shall be no common walls between potable and non-potable water compartments.

9.5.4 Discharge to surface water

To discharge backwash water to a surface water the water utility must have all required discharge permits, including an NPDES (National Pollutant Discharge Elimination System) permit.

9.5.5 Recycling "red water" wastes

Recycling of supernatant or filtrate from "red water" waste treatment facilities to the head of an iron removal plant may be allowed by the reviewing authority. Backwash reclaim tanks for plants treating groundwater shall be constructed to finished water storage tank standards and sized to contain the total backwash waste volume from two consecutive backwash cycles at a minimum.

Backwash reclaim tanks may not be directly connected to a sewer or a storm drain. It is recommended that the recycled water be returned at a rate of less than 10 percent of the instantaneous raw water flow entering the plant.

9.6 FILTER BACKWASH WASTEWATER

Suspended solids in the waste backwash water from surface water treatment and lime softening plants should be reduced prior to recycling the clarified water to the head of the plant.

The backwash reclaim tank must contain:

a) The anticipated volume of wastewater produced by the plant when operating at design capacity.

b) The total volume of waste wash water from both filters using 15 minutes of backwashing at a rate of 20 gallons per minute per square foot for a plant that has two filters.

c) A volume that takes into account the number of the filters and the anticipated backwash frequency and volume using 15 minutes of backwashing at a rate of 20 gallons per minute per square foot for a plant with more than two filters.

The reviewing authority may approve the recycling of the waste filter backwash water, thickener supernatant, and other liquids to the head of the plant under the following conditions:

a) Reclaimed water shall be returned at a rate of less than 10 percent of the instantaneous raw water flow rate entering the plant.

b) Reclaiming filter backwash water should be avoided if there is increased risk to treated water quality. Reclaimed water should not be recycled when the raw and/or reclaimed water contains excessive algae, algal toxins, excessive turbidity, or when finished water taste and odor are problematic. Consideration should be given to the presence of protozoans such as Giardia and Cryptosporidium concentrating in the wastewater stream.

c) Pre-treatment of filter backwash wastewater prior to recycling may be required to reduce pathogen populations and to improve coagulation.

9.7 RADIOACTIVE MATERIALS

Radioactive materials may be found in the following waste streams, including, but not limited to:

a) Granulated activated carbon (GAC) used for radon removal.

b) Radium adsorptive filter media.

c) Ion-exchange regeneration wastewater.

d) Manganese greensand backwash solids from manganese removal systems.

e) Precipitative softening residuals.

f) Reverse osmosis concentrates.

The buildup of radioactive decay products shall be considered, and adequate shielding, ventilation, and other safeguards shall be provided in the plant design to protect water operators and visitors. Some materials may require disposal as radioactive waste in accordance with Nuclear Regulatory Commission regulations. Approval shall be obtained from the regulatory authority prior to disposal of all wastes.

9.8 ARSENIC WASTE RESIDUALS

Arsenic-bearing wastes may be found in the following waste streams and may be considered hazardous, including but not limited to:

a) Filter backwash wastewater and residuals.

b) Lime softening residuals.

c) Reverse osmosis reject water.

d) Adsorptive filter media.

Under the Resource Conservation and Recovery Act (RCRA) residual wastes from an arsenic water treatment facility may be defined as being hazardous waste if it exhibits a Toxicity Characteristic Leaching Procedure (TCLP) result higher than the thresholds set in rule. The administrative authority must be contacted and must grant approval prior to disposal of arsenic residual wastes.