Guidance Document:

Slow Sand Filtration and Diatomaceous Earth Filtration for Small Water Systems

April 2003

Washington State Department of Health

Environmental Health Programs
Division of Drinking Water

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Chapter 1

Introduction

Purpose

The purpose of this document is to provide useful information regarding the application, design, and operation of slow sand and diatomaceous earth filtration facilities to the owners, operators, and designers of small water systems.

Background

In June 1989, the United States Environmental Protection Agency (EPA) enacted the Surface Water Treatment Rule (SWTR). The purpose of this regulation is to protect the public, as much as possible, from waterborne diseases. Because waterborne diseases are most commonly transmitted by drinking water, the rule requires public water systems with unprotected surface water sources to utilize a combination of filtration and disinfection to remove and inactivate disease-causing microorganisms. The SWTR provides criteria under which filtration is required and procedures for state governments to follow in making these determinations. As a result of the SWTR, many water systems constructed filtration facilities.

The SWTR also required states to test water sources located in the vicinity of surface waters to determine if they were under the direct influence of surface water. As a result of this testing, many more water systems with high quality water sources have been required to implement filtration.

The 1996 Safe Drinking Water Act (SDWA) amendments required EPA to identify technologies that small systems can use to comply with the SWTR. In August 1997, EPA published the *Small System Compliance Technology List for the Surface Water Treatment Rule* to meet that requirement. The following filtration technologies are listed in that document, the first three of which were previously identified in the SWTR as viable filtration alternatives.

- Rapid rate filtration
- Slow sand filtration
- Diatomaceous earth filtration
- Membrane filtration
- Bag or cartridge filtration

The Washington State Department of Health (WSDOH), the state agency responsible for ensuring that water systems are in compliance with the SWTR, recognizes the first three of these technologies as "established" treatment technologies. The last two technologies (membrane and bag and cartridge filters) are considered alternative technologies and are only acceptable when specific criteria found in Washington State Administrative Code (WAC) 246-290-676 are met.

Rapid rate and membrane filtration are generally technologies that are well suited for medium to large water systems (serving >3,300 people). These technologies may be appropriate in certain applications for small systems (serving <3,300 people) with poor raw water quality or highly trained operators, but are generally less appropriate than simpler filtration technologies. Bag or cartridge filtration systems may have certain applications where they are appropriate for small systems, but the lack of approved manufacturers, high cost of bag replacement, and the large amount of waste generated are factors that may cause small systems to consider other alternatives.

This guidance document focuses on two of the surface water treatment technologies that may be considered most appropriate for small systems with high quality water sources: slow sand filtration and diatomaceous earth (DE) filtration. Both technologies are reliable, cost-effective, and require less operator skill and time commitment to operate correctly than typical rapid rate filters. Although these technologies have had limited application in the past in Washington State, they are expected to be more prevalent in the future, as additional higher quality water sources are required to provide filtration.

Scope

This document first describes the process of selecting a filtration technology, pilot testing that technology, and designing a filtration facility. It then provides more specific information on the following topics for both slow sand filtration and DE filtration.

- Process descriptions and variations
- Design considerations
- Operation and maintenance considerations

As part for the process of developing this manual, current literature regarding slow sand filtration and DE filtration was obtained and reviewed. Operators of these types of facilities were also surveyed to obtain information regarding design criteria, operating practices, and common operating problems. A bibliography of available reference materials is included in Appendix A. A compilation of survey information from slow sand filtration facilities is included in Appendix B. A compilation of survey information from DE filtration facilities is included in Appendix C.

This document is not intended to be a comprehensive text for the detailed design of slow sand or DE water filtration facilities. It is intended to provide insight into the application, design, and operation of these types of facilities based upon the experience of the consultants who compiled this manual, the WSDOH, and the operators of facilities surveyed for this project. For more complete design guidance refer to the bibliography in Appendix A. Two of the more helpful design references are the American Water Works Association (AWWA) *Manual of Design of Slow Sand Filtration* and the AWWA *Manual of Water Supply Practices M-30 Precoat Filtration*.

Chapter 2

Filtration Process Selection and Design

This chapter describes the general process for the selection, pilot testing, and design of filtration facilities.

Raw Water Quality

The first step in selecting a filtration process for a particular application is to evaluate raw water quality data. Water quality data should be obtained and examined as far back as possible. A minimum of at least five years of data is preferred. The most important parameter for review is raw water turbidity. If data is available regarding temperature, pH, alkalinity, and organics (such as total organic carbon and color), this should be examined as well. Water quality limitations for various filtration technologies are summarized in Table 2-1. The information shown in Table 2-1 is adapted from the WSDOH *Water System Design Manual* and information from treatment equipment manufacturers. Generally, both slow sand and diatomaceous earth (DE) filtration are best suited for raw water that is low in turbidity and organic matter.

Table 2-1

Raw Water Quality Limitations for Various Filtration Technologies

Parameter	Filtration Technology				
	Rapid Rate	Slow Sand	DE	Membrane	Bag or Cartridge
Average Turbidity[1]	<50 NTU[2]	<1 NTU	<5 NTU	<100 NTU	<5 NTU
Maximum Turbidity[1]	<100 NTU	<10 NTU	<10 NTU	<200 NTU	<10 NTU
Color	<75 SCU[3]	<10 SCU	<10 SCU	<10 SCU	<10 SCU

Notes:
1. Raw water with turbidity higher than that shown in Table 2-1 may be treated; however, pre-treatment may be necessary to ensure that adequate performance is achieved.
2. NTU = Nephelometric Turbidity Units
3. SCU = Standard Color Units

Neither slow sand nor DE filtration is effective at removing color, taste, odor, or dissolved organics from raw water. If any of these are present, additional treatment processes may be necessary to produce the desired finished water quality. Ozone may be used with slow sand filtration to break down larger organic molecules into smaller organic components that are more assimilable by the organisms within the slow sand filter. Granular organic carbon may also be used with slow sand or DE filters to treat a portion of the dissolved organics or color. Polymers may also be used in conjunction with DE filters to aid in filtration of very fine particles.

Special care should be used when water sources contain a significant amount of algae. Both slow sand and DE filters have been used on raw waters with algae, but extremely short filter runs have resulted in some cases.

Filtration Process Alternatives Analysis

Once raw water quality data has been obtained and examined, the various filtration process alternatives should be evaluated. As discussed in Chapter 1, the alternatives include the following:

- Rapid rate filtration
- Slow sand filtration
- Diatomaceous earth filtration
- Membrane filtration
- Bag or cartridge filtration

Each of these alternatives has advantages and disadvantages for a particular application. A brief overview of these is included in Table 2-2.

Table 2-2

Filtration Process Alternatives

Process	Advantages	Disadvantages
Rapid Rate Filtration	• Treats broad range of water quality • Removes color and dissolved organics • Lower capital cost	• Requires high level of operator skill and attention • Requires chemical addition for effective filtration • Sensitive to rapid changes in water quality • Higher operations cost
Slow Sand Filtration	• Lower level of operator skill required • Lower operations and maintenance cost	• Requires larger land area • Feasible only on high quality (low turbidity) water sources.[2]
DE Filtration	• Smaller footprint[1] • Lower capital cost	• Higher degree of material handling • Feasible only on high quality (low turbidity) water sources.[2]
Membrane Filtration	• Smaller footprint • Treats broad range of water quality	• Higher capital cost • High membrane replacement cost • Complex mechanical and electrical equipment
Bag or Cartridge Filtration	• Smaller footprint • Simple operations • Lower capital cost	• Disposal of bags or cartridges and cost of media replacement can be significant depending upon replacement frequency and number of units • Poor *Cryptosporidium* removal • Questionable regulatory future • Uncertain source of future replacement elements

Notes: 1. Footprint refers to the land area necessary to construct a facility.
2. Pre-treatment may expand the range of water sources that can be treated with this process.

Estimated Costs

For each alternative considered, accurate capital and operations and maintenance cost estimates should be prepared. These costs can be developed from various sources including past experience, published cost curves, or budget quotes from suppliers. Quotes from equipment suppliers should not be solely relied upon to develop project cost estimates since they may not include all components or site specific factors. Costs may be verified by consulting with other utilities that have recently installed similar technologies.

Capital Costs

To obtain an initial estimate of capital costs, published cost curve data can be reviewed. Cost curves are developed by plotting actual construction costs versus the capacity of the filtration facility. Figure 2-1 shows a construction cost curve for slow sand filters constructed in the Pacific Northwest. The figure is adapted from research completed by Paul Berg in 1991 for the AWWA Slow Sand Filtration Workshop. Costs have been adjusted to 2002 dollars using a 2002 Construction Cost Index of 6535.

To use the curve, find the capacity of the planned filtration facility along the horizontal axis. Next, go up to the trend line and then horizontally over to the construction cost in $/gpd. Multiply cost in $/gpd times the planned capacity in gallons per day to obtain an estimated slow sand filter construction cost. The equation shown on the graph may also be used to obtain the construction cost in $/gpd. The costs shown in Figure 2-1 only include filter construction costs. Costs for intakes, raw water transmission, clearwells, land acquisition, and engineering have not been included, but should be considered when developing an overall project budget.

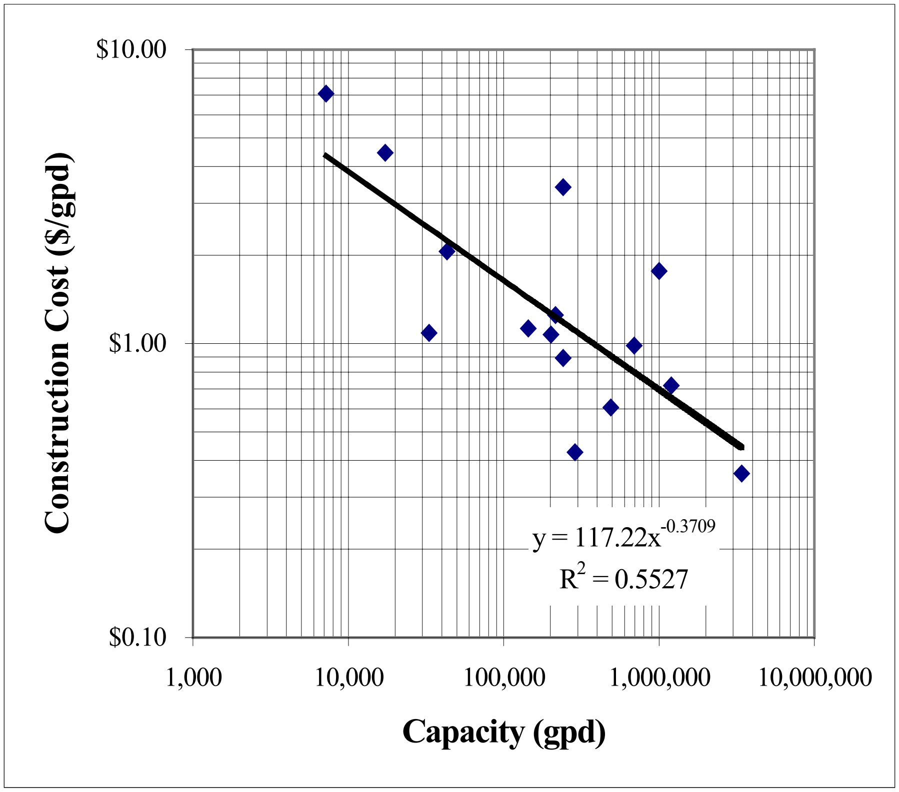


Figure 2-1 Slow Sand Filter Construction Cost Curve

As shown in the cost curve, capital costs can vary significantly from facility to facility, but generally decrease per unit of capacity for larger facilities. Variations in cost may be attributed to a number of factors including location, site constraints, system hydraulics, and specific raw water quality encountered. Capital cost estimates obtained from cost curves should be updated with project specific cost estimates as soon as adequate data is available. Project specific capital cost estimates should also include costs for sitework, buildings, equipment, piping, electrical, land acquisition and engineering costs to provide an accurate estimate of total project capital costs. Table 2-3 details several of the factors that should be included in the estimated capital cost of a facility.

Table 2-3

Capital Cost Considerations

Item	Includes
Mobilization	Contractor's overhead and profit and costs for bringing equipment to site. Typically 5 – 15% of total construction cost.
Filtration Equipment	Vendor quote with delivery, start-up, training, O&M manual, and spare parts.
Pumping Equipment	Cost to modify/add pumping systems to bring raw water to the filtration facility and pump treated water into the distribution system. Vendor quote with delivery, start-up, training, O&M manual, and spare parts.
Installation	Cost for contractor to order, handle, store, install and test equipment. Typically 10 - 50% of the cost of the equipment.
Water Transmission Lines	Cost to construct water lines to bring water to and from the new facility. This cost may be substantial if the site is distant from existing water transmission facilities.
Sitework	Excavation, backfill, compaction, and site grading. Also includes gravel materials required.
Building	Building to house mechanical and electrical equipment. Building should also have space for laboratory and office facilities, chemical feed equipment, and storage.
Piping	Piping and valves required to interconnect filtration equipment with existing piping and pumping equipment. Typically 10 - 20% of total construction cost.
Electrical, Telemetry and Controls	Electrical wiring and controls required to operate the pumps and filtration equipment. May include new power service and emergency generator. Typically 10 - 20% of total construction cost.
HVAC	Fans, heaters, and exhausters required to keep a building from freezing and to minimize condensation.
Finished Water Storage Modifications	Any additional finished water storage required to serve water demands when the treatment facility is not operating. Additional storage may also be required to provide adequate disinfection contact time (CT).
Sales Tax	Washington State Sales Tax on construction cost.
Contingency	Accounts for items and detail not contemplated at the alternatives analysis level. Typically 20 - 30% of the estimated construction cost.
Engineering Design	Costs to develop plans and specifications for the treatment facility. Even projects to be completed by the owner must have plans and specifications approved by the Department of Health. Typically 10 - 15% of construction cost.
Inspection and Construction Management	Costs to administer a construction contract and inspect the work completed by the contractor. May be reduced or omitted if the Owner has qualified personnel available to perform this function. Typically 10 – 15% of construction cost.
Land Acquisition	Costs if land must be purchased or leased for the project.

Operations and Maintenance Costs

Operations and maintenance cost estimates should also be developed carefully for each alternative. Some operations and maintenance cost information is available from equipment vendors including estimated power consumption, chemical usage, and component replacement frequency. These estimates from equipment suppliers can be verified by contacting operators of similar facilities. Labor and power costs can generally be estimated from local conditions. Table 2-4 provides some operations and maintenance factors to consider in evaluation of alternatives.

Table 2-4

Operations and Maintenance Cost Considerations

Item	Includes
Labor	The cost of manpower to operate and maintain a facility. Estimates of operating labor for facilities 0.25 – 2 MGD in size are as follows: Rapid Rate Filtration 4-6 hours/day Slow Sand Filtration 1-2 hour/day plus scraping DE Filtration 1-3 hour/day plus pre-coating Membrane Filtration 1-2 hours/day plus cleaning Bag Filtration 1-2 hour/day plus bag replacement
Power Consumption	Cost to operate pumps and electrical and mechanical equipment in the facility.
Chemicals	Costs for chemicals used for filtration. For rapid rate filtration, this includes coagulant and filter aid. For DE filtration, this includes DE. For membrane filtration, this includes cleaning chemicals. Chemicals are generally not required for slow sand filtration.
Replacement Components	Costs to replace major components during the filter design life. For slow sand filtration, this includes sand replacement. For DE filtration, this includes septum replacement. For membrane filtration, this includes membrane replacement. For bag filtration, this includes bag replacement.

Non-Cost Factors

Each application will have specific characteristics that will impact the feasibility of using a particular filtration technology. Some of these characteristics are difficult to quantify in terms of capital and operating costs. Several of the non-cost factors that should be considered in the initial evaluation of alternatives are discussed below.

Site Constraints

The location, size, and topography of available sites at which to locate a filtration facility will significantly impact the selection process. If space is limited, slow sand filtration may not be feasible. If the site is remote with limited access, a process such as rapid rate filtration that normally requires more operator time and attention for adjusting chemical doses or performing other process control adjustments, may not be as attractive. Remote sites also pose difficulties for processes that require frequent chemical deliveries and disposal, such as rapid rate filtration, DE filtration, or membrane filtration. If commercial power service is not reliable, DE filtration will require special considerations.

System Hydraulics

The hydraulic conditions in the existing water system will also impact the filtration process selection. If a filtration plant is to be located at a site where the raw water supply has a high hydraulic head, pressure DE or membrane filtration may be more attractive to take advantage of available system head. If raw water pumping is required, vacuum DE filtration may not be as advantageous because of the need to re-pump after filtration. If a system does not pump prior to the implementation of filtration, slow sand filtration or rapid rate filtration may allow continued use of gravity flow.

Operational Considerations

In many small communities, highly skilled water treatment plant operators may be difficult to attract and retain or they may have other duties that limit the time available to maintain a water filtration facility. For this reason, simpler technologies such as slow sand or DE filtration may be more attractive. In situations where neighboring communities have a particular filtration technology, it may be advantageous to implement a similar technology to take advantage of shared operator resources and knowledge. Operational considerations can also include the complexity of the process and reliability of the process during abnormal conditions.

Evaluation Matrix

To determine the most appropriate filtration technology for a particular application, both cost and non-cost factors should be considered. One method of evaluating cost and non-cost factors is to develop a decision matrix. In a decision matrix, the alternatives are each ranked or rated for several parameters using a consistent method such as on a scale from 1 (worst) to 10 (best). The rating or ranking for each parameter is then summed for each alternative. The alternative with highest total points is the preferred alternative. In situations where some parameters are more important than others, the rating or ranking can be weighted by multiplying each parameter by an importance factor. Table 2-5 shows an example decision matrix for filtration alternatives. In this example, DE filtration appears to be the best alternative since it has the highest score. This matrix is not intended to represent actual ratings or rankings for a particular technology. In practice, such a matrix could be used as part of the pre-design screening process to determine the most appropriate technology for a specific application.

TABLE 2-5

Example Filtration Technology Decision Matrix

Parameter	Relative Importance	Rapid Rate Filtration		Slow Sand Filtration		Membrane Filtration		DE Filtration	
		Rating	Points	Rating	Points	Rating	Points	Rating	Points
Capital Cost	30	10	300	7	210	6	180	10	300
O & M Cost	30	7	210	10	300	7	210	8	240
Complexity	10	3	30	10	100	6	60	7	70
Reliability	10	4	40	8	80	10	100	6	60
Footprint	20	7	140	3	160	8	160	10	200
Score	**100**		**720**		**750**		**710**		**870**

Note: 1. For ratings in this table, 10 = best, 1= worst.

Pilot Testing

Once the preferred alternative has been identified, it should be pilot tested to verify its suitability and to verify the assumptions used in the alternatives analysis. In some cases, where two technologies are closely rated, it may be beneficial to pilot test more than one technology. Pilot testing consists of setting up and operating a small-scale filtration system to determine its performance using the actual field conditions and raw water that will be treated at full-scale. Pilot testing is required by the WSDOH for most filtration applications. Pilot testing requirements are included in WAC 246-290-676 and are discussed further in the WSDOH *Water System Design Manual*.

In some cases, WSDOH may waive pilot studies based on engineering justification acceptable to the department or may allow a system to pilot full-scale facilities before the system is approved. In the latter situation, it should not be assumed that the purveyor will be allowed to provide water from the full-scale pilot to consumers prior to system approval. Also, there is a risk that piloting full-scale facilities might result in failure of the proposed treatment facilities. Modification to the treatment approach may then be required.

Properly conducted pilot testing can provide valuable data that can help avoid significant mistakes in the application and design of filtration facilities. For a pilot study to be useful, the pilot study should be conducted for a sufficient duration to obtain meaningful data. The length of time will vary depending upon the process selected, but will range from several weeks to a year depending upon raw water quality, the process selected, and the length of filter runs.

Proposed pilot study protocols must be reviewed and approved by the WSDOH. Upon completion of the pilot study fieldwork, a report summarizing the data and results must be submitted to the WSDOH.

Design

Once the pilot study has been completed, the detailed design can be completed. As part of the detailed design, a project report must be completed in accordance with WAC 246-290-110. The project report and design plans and specifications must be prepared by an Engineer licensed in the State of Washington. The project report must include the following information:

- Project description
- Planning information
- Analysis of alternatives
- Water quality data
- Water quantity and water rights
- Design criteria
- Engineering calculations
- Legal considerations
- Operation and maintenance considerations

It is often advantageous to submit the project report as a pre-design report before significant work is put into plans and specifications. The pre-design report provides a vehicle to obtain consensus from the Owner, the Engineer, and the WSDOH on the preferred alternative, facility size, design criteria, and preliminary facility layout. This step allows for changes to be made in the design before spending significant resources on completing plans and specifications.

Once the pre-design report is completed, design plans and specifications should be completed. These plans and specifications must be reviewed and approved by the WSDOH in accordance with WAC 246-290-120 prior to beginning construction. Upon completion of construction, a Certification of Construction Completion form must be filled our by the Engineer and submitted to the WSDOH. For additional information on the requirements for project reports and construction documents, refer to Chapters 2-4 of the WSDOH *Water System Design Manual.*

Chapter 3

Slow Sand Filtration

Process Description

Slow sand filtration is a technology that has been used for potable water filtration for hundreds of years. It is a process well-suited for small, rural communities since it does not require a high degree of operator skill or attention. As its name implies, slow sand filtration is used to filter water at very slow rates. The typical filtration rate of 0.05 to 0.10 gpm/ft^2 is at least fifty times slower than for rapid rate filtration. Due to this slow rate of filtration, a large land area is required for the filtration basins. Small communities that have plenty of available land are often good candidates for slow sand filtration.

Slow sand is a relatively simple filtration process. No chemical addition is required for proper filtration operation. Particle removal is accomplished primarily through biological processes that provide treatment. The biological activity is located primarily in the top surface of the filter known as the "schmutzdecke," although recent research has indicated that biological processes throughout the depth of the filter bed may also influence particle removal. A "ripening" period from several weeks to several months is necessary for the biological organisms to mature in a new slow sand filter.

Slow sand filters are not backwashed like rapid rate filters, but are instead scraped or harrowed periodically when headloss reaches 3 - 4 feet across the filter bed. Typically slow sand filters must be scraped or harrowed every 1 - 12 months depending on water quality. Some facilities with very high water quality can experience even longer filter runs. During scraping, the top 1/8 – 1/2 inch of sand is removed from the filter bed. Eventually, after years of operation, the sand layer must be replaced to restore the depth of the filter bed. In some cases, filters are harrowed to break up the top layer of material and reduce headloss through the filter. Sand is not removed when filters are harrowed, but the top layer of organic material is broken up and floated off the surface of the filter bed using flow up through and across the filter surface. After a filter is scraped or harrowed, the filtered water is typically sent to waste for a period of 1 - 7 days to allow the biological population in the filter to reestablish.

Figure 3-1 shows a slow sand filter built at the City of Roslyn. The facility is rated for 1.0 MGD and consists of two filter beds, each with a surface area of 4,340 square feet. Gravel upflow roughing filters provide pre-treatment of raw water. The filters are provided with floating covers for algae control.

Figure 3-1. 1.0 MGD Slow Sand Filter at the City of Roslyn

Properly designed and operated slow sand filtration facilities are typically given 2.0 log credit for *Giardia lamblia* removal and 2.0 log credit for virus removal by the WSDOH. It is anticipated that slow sand filtration facilities will be given 2.0 log credit for *Cryptosporidium* removal under the Long Term Enhanced Surface Water Treatment Rule.

Pilot Testing for Slow Sand Filtration

As discussed in Chapter 2, pilot testing is required prior to constructing a surface water treatment facility. This section describes pilot plant testing objectives, procedures, and duration for slow sand filtration.

<u>Objectives</u>

Some recommended objectives of slow sand pilot studies are as follows:

1. Determine the suitability of slow sand filtration for treating water from a particular water source.
2. Determine the effectiveness of the slow sand filtration process at removing turbidity from the raw water source.
3. Determine the appropriate filtration rate (gpm/ft^2).
4. Determine the anticipated filter run length.
5. Determine the most effective source of filter sand.
6. Verify design assumptions and related cost estimates.

The pilot study should be conducted such that data will be obtained to satisfy these objectives.

<u>Procedures</u>

Slow sand filtration pilot units are typically constructed for each particular application. They can consist of columns of PVC pipe with graded gravels and sand layered similarly to how they would be at full-scale. Separate columns should be set up for each gradation of sand or flow rate to be tested. Columns at least 12” in diameter provide adequate access to the filter media while minimizing the effects of short-circuiting along the edges of the unit. If pre-treatment with other unit processes such as ozone or gravel roughing filters is anticipated, pilot-scale pre-treatment units should be set up as well. Figure 3-2 shows a typical slow sand pilot study apparatus.

Figure 3-2. Typical Slow Sand Pilot Apparatus

Raw water used in the pilot study should be the same as that which will be treated at full-scale to ensure the validity of the test data. Raw water for slow sand filtration should not be pre-chlorinated because chlorine may hinder the growth of organisms in the filter bed that aid in the filtration process. Filtered water from the pilot study should be sent to waste and not to the water distribution system. Table 3-1 provides a list of parameters that should be monitored during the pilot study along with the recommended frequency.

TABLE 3-1

Pilot Test Monitoring Parameters

Parameter	Raw Water	Filtered Water
Turbidity	Daily	Daily
Head level	Daily	Daily
Flow Rate	Daily	-
Temperature	Daily	-
Total Coliform	Weekly	Weekly
Fecal Coliform	Weekly	Weekly
Color	Weekly	Weekly
pH	Weekly	Weekly
Total Organic Carbon	Seasonally	-
UV Absorbance	Seasonally	-

In addition to the parameters listed in Table 3-1, algae, chlorophyll-a, particle counts, dissolved oxygen, iron or manganese analyses may provide useful information in certain specific situations.

If chlorine is to be used as a disinfectant in the full-scale facility, the WSDOH Regional Engineer should be consulted to determine if disinfection by-products should be tested for during the pilot study.

<u>Duration</u>

For slow sand filtration, filter runs can last from several weeks to several months. The performance of slow sand filtration can also vary throughout the year based on water quality and temperature. Because of these considerations, slow sand filtration pilot studies should be operated for a minimum of twelve months.

<u>Pilot Test Suggestions</u>

Based on previous experience with pilot studies, the following are suggestions to help ensure that adequate results are obtained:

- Verify that an adequate amount of the filter sand that is being pilot tested is available for full-scale use. Verify that adequate washing facilities are available for this sand.
- Thoroughly wash the filter sand prior to installation in the pilot column.
- Divide the filter columns into two sections just above the sand surface. Connect the two sections with a removable coupling to facilitate installation of filter media and scraping of the filter surface.

- If the pilot equipment is installed outside in cold climates, considering constructing a heated enclosure around the pilot equipment or provide other means of protecting piping from freezing such as heat tracing smaller piping.
- Clear piping components, such as rotameters, that are exposed to sunlight will grow algae. Install a removable cover over clear components.

Slow Sand Filter Design

Due to their size, slow sand filtration systems are typically designed specifically for each site and application. Package slow sand treatment units are available but are not commonly used. This section discusses a number of design criteria and features that are important to consider in the design of the slow sand filter bed.

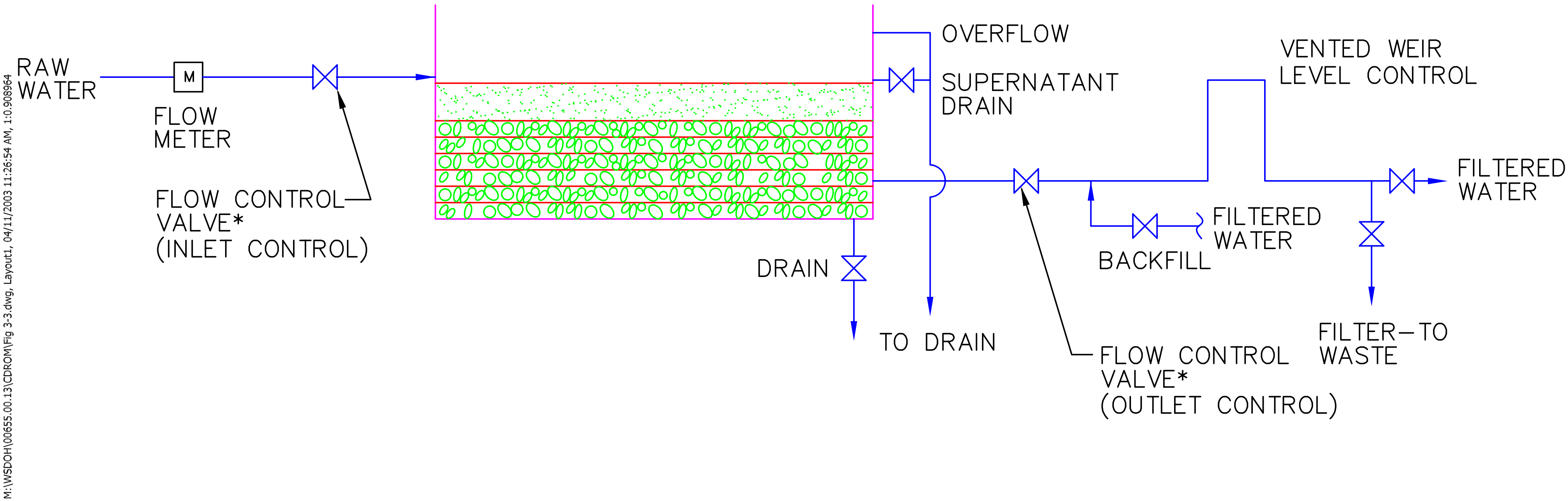
Figure 3-3 shows a typical process flow diagram for slow sand filtration. Figure 3-4 shows a typical design layout for a 0.5 MGD slow sand filter.

<u>Filtration Rate</u>

The primary design parameter for slow sand filtration is the filtration rate. Design filtration rates typically range from 0.05 gpm/ft^2 to 0.1 gpm/ft^2 although rates as high as 0.15 gpm/ft^2 may be tolerated for short periods during filter scraping or ripening. Filtration rates can have a significant impact on filter run lengths. Lower filtration rates may provide longer filter runs. The appropriate filtration rate should be determined by pilot study on the raw water to be treated. Using the design filtration rate, the required filter area can be determined for the design flow rate.

<u>Number of Filter Basins</u>

Since slow sand filtration requires that a filter be off line for up to two weeks for scraping and filter ripening, more than one filter basin is typically necessary. State regulations require multiple filter units that provide redundant capacity when filters are out of service for backwash or maintenance. This requirement may be waived for non-community water systems providing engineering justification acceptable to the WSDOH. Each filter basin that can be operated independently is considered an individual filter unit.



NOTE: * FILTERS CAN USE EITHER INLET CONTROL VALVES OR OUTLET CONTROL VALVES OR BOTH

FIGURE 3–3 SLOW SAND FILTRATION PROCESS FLOW DIAGRAM

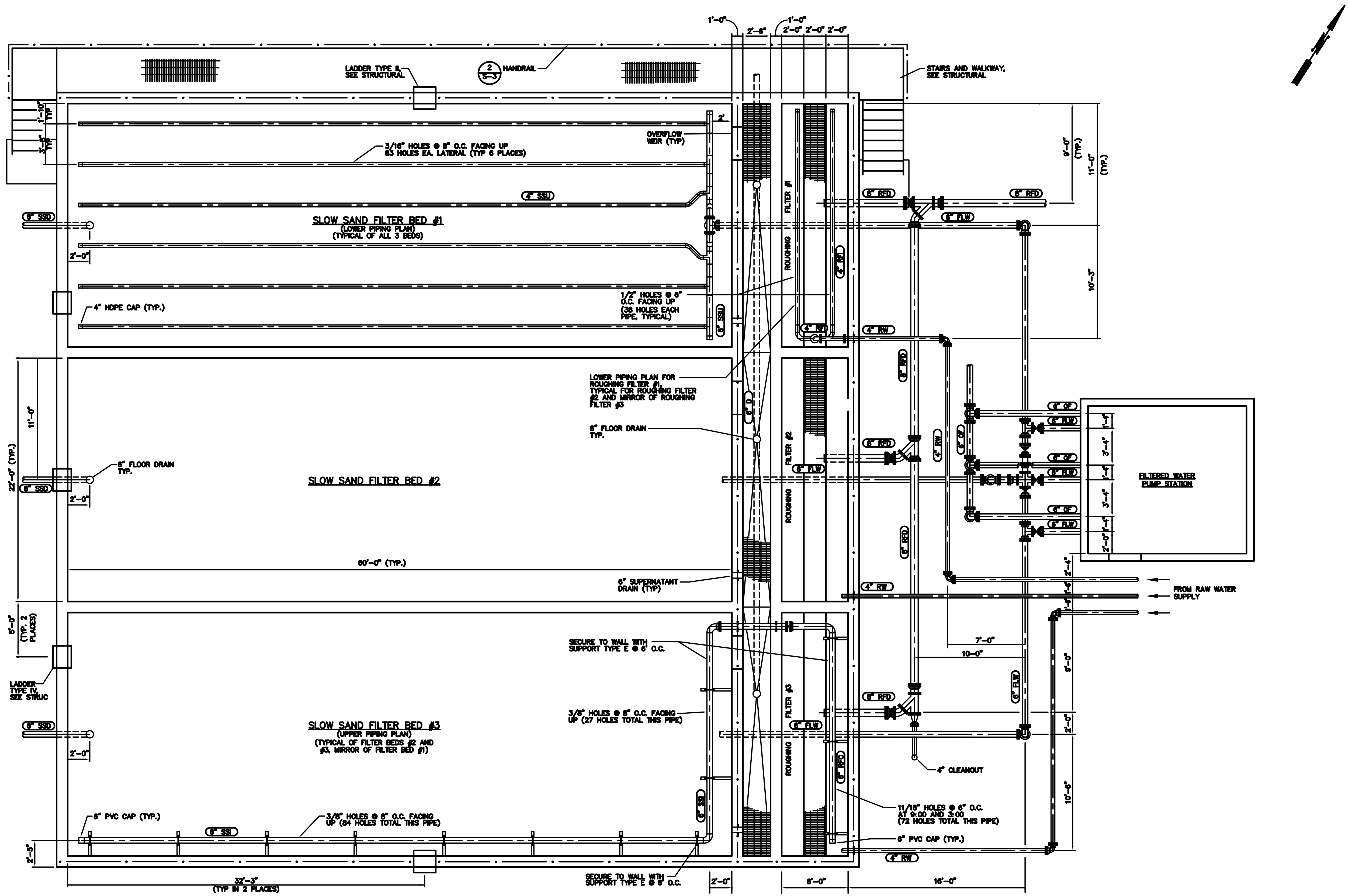


FIGURE 3–4 0.5 MGD SLOW SAND FILTER DESIGN LAYOUT

The number of filter basins provided will depend on the difference between average and peak flows, the anticipated filter run time, and available storage within the water system. The most conservative system design criteria would be to use the maximum day demand as the design filtration rate with one filter basin out of service. Table 3-2 summarizes the recommendations of the World Health Organization for determining the number of filter basins based upon the design flow of the facility.

TABLE 3-2

Recommended Number of Filter Basins

Design Flow	Recommended Number of Basins
<450 gpm	2
450 – 900 gpm	3
900 – 1,400 gpm	4
1,400 gpm – 2,100 gpm	5

Basin Materials of Construction

Filter basins can be constructed using concrete or earthen berm construction. For very small systems (<25 gpm), basins can be constructed from alternative materials such as polyethylene or fiberglass tanks. Except for these very small systems, surface area requirements for slow sand filters are such that these types of tanks are impractical.

Regardless of the construction material, the tank should be made as watertight as practical because filtered water is collected in the bottom of the tank. For concrete tanks, water-stop material should be used at all construction joints. Hydrostatic relief valves should not be used. For earthen berm construction, continuous geomembrane liners should be used. Integrity testing should be performed on all geomembrane liner seams to verify no leak paths are present. Care should be taken when installing underdrains and gravel materials on geomembrane liners so as not to damage the liner material. **It is WSDOH's position that common wall construction not be used between basins containing filtered water and unfiltered water due to the potential for contamination.**

Geomembrane lined earthen berms are typically less expensive to construct than concrete basins but they have a shorter design life. The design life of a geomembrane is typically not greater than 20 years. The design life for a concrete basin is typically 40 - 50 years. Geomembrane liners are also not as durable as concrete basins as they can be damaged by activities such as sand scraping and resanding. Additionally, geomembrane liners must meet the requirements of WAC 246-290-220 pertaining to materials used in public water systems.

Of the six slow sand facilities surveyed in Washington State, five have concrete basins and one has lined earthen berm basins.

Filter Media Selection and Washing

The selection and washing of filter media is another important design consideration. Slow sand filters require a significant amount of filter sand and support gravels. Finding a source of these materials that is located near the treatment plant site can significantly reduce construction and resanding costs.

Slow sand filters typically consist of two to four feet of sand supported by two to three feet of layered graded support gravels. An underdrain system collects filtered water from the lowest level of the support gravel. Figure 3-5 shows a typical filter bed cross-section. Criteria for sand and gravel gradations have been widely published. Sand gradation criteria from the U.S. EPA *Surface Water Treatment Guidance Manual* are shown in Table 3-3. Sand not meeting the criteria listed in Table 3-3 may be used if pilot testing demonstrates that it provides effective filtration.

Table 3-3

Sand Gradation Criteria

Parameter	Recommended Value
Effective Diameter (d_{10})	0.15 – 0.30 mm
Uniformity Coefficient (d_{60}/ d_{10})	< 2.5
% Passing #200 sieve unwashed	< 3%
% Passing #200 sieve washed	< 0.1%

To determine whether a sand source meets the criteria shown in Table 3-3, a sieve analysis should be performed on a representative sample of the material. Figure 3-6 shows a typical sieve analysis for a filter sand. The effective diameter (d_{10}) value is equal to the size of screen through which only ten percent of the material passes. For the sand shown in Figure 3-6, the d_{10} is equal to about 0.20 mm. The uniformity coefficient is equal to the d_{60} value divided by the effective diameter. The d_{60} value is equal to the size of the screen through which sixty percent of the material passes. For the sand shown in Figure 3-6, the d_{60} is equal to 0.40 mm. Therefore the uniformity coefficient would be 2.0.

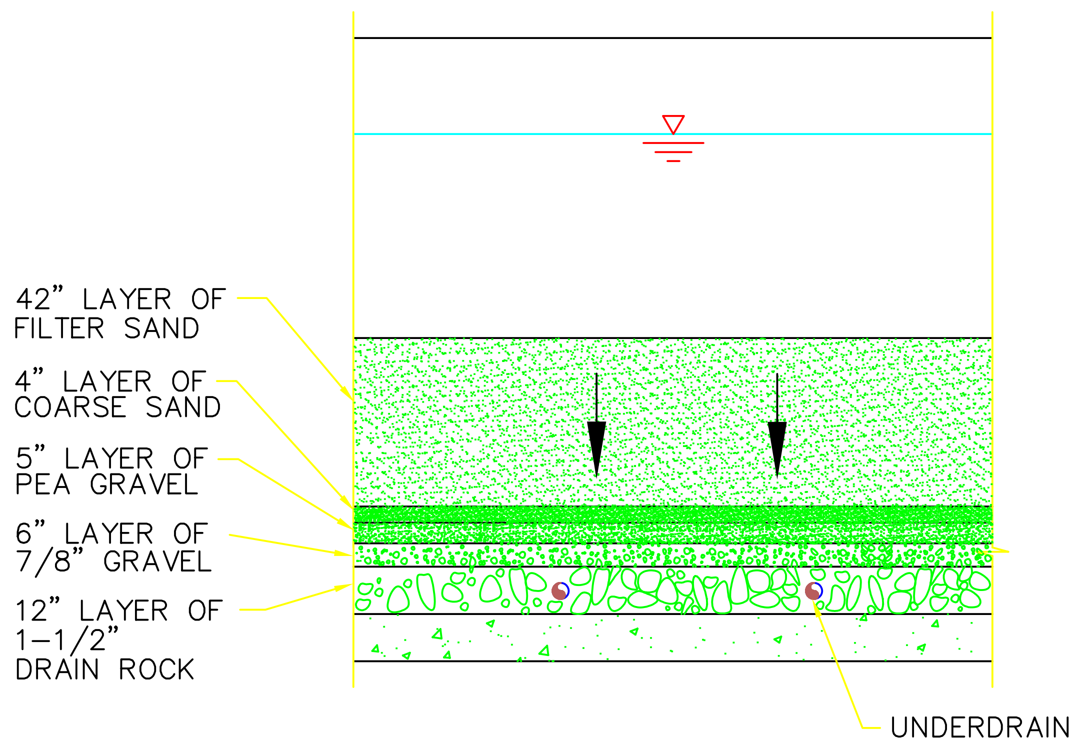


FIGURE 3-5 SLOW SAND FILTER MEDIA TYPICAL SECTION

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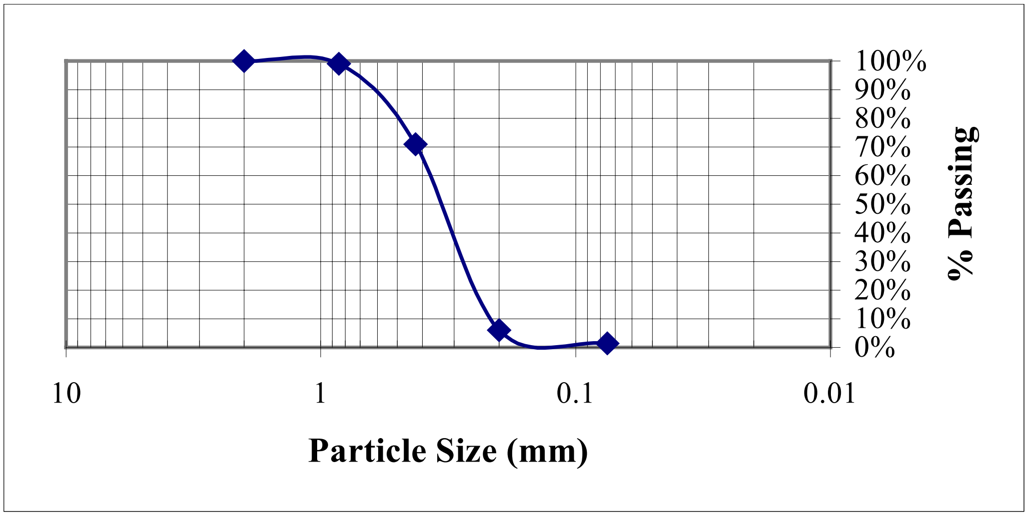


Figure 3-6. Typical Sand Sieve Analysis

Most commercially available gravel and sand materials will contain an unacceptable level of silty material called fines, defined as those particles which pass the #200 sieve. If materials are installed with too many fines, the slow sand filter will actually add turbidity to the raw water for a period of time until the fines are rinsed from the materials. This process can take years. To avoid this problem, sand and gravel materials should be washed prior to being installed. The percentage of fine materials in the filter sand and gravels should be less than 0.1 percent by weight. Washing equipment at most sand and gravel pits should be able to meet these criteria with multiple passes through the washing equipment. Washing sand in the filter bed may also be used to remove fine particles but this method may require additional time and water. Washed sand should be covered to prevent recontamination by dust.

<u>Filter Piping</u>

Several piping features should be specifically incorporated into slow sand filter designs to facilitate operations activities. These piping features include:

- Filter-to-waste
- Overflow
- Supernatant drain
- Drain
- Backfill
- Flow distribution
- Flow collection

Filter-to-Waste

Because slow sand filters are biological processes, they take time to ripen at initial start-up and after filter scraping. During this period of time, water should be passed through the filter but not into the distribution system. For these periods, piping and valving that directs filtered water to waste, instead of to the clearwell, is required. This filter-to-waste piping should be provided with an air gap to avoid a cross connection. Filter-to-waste piping should be configured so that each filter can be sent to waste while the other filters remain on-line.

Overflow

As a filter accumulates headloss, the water level will rise in filters with inlet flow control. If the water level gets too high, water can spill out of the basin. To prevent damage in the case of overflow from the basin, a specific filter overflow should be incorporated in the filter basin design. An overflow also facilitates the removal of scum and floating debris.

Supernatant Drain

Proper piping and valving can greatly expedite the sand scraping and removal process. Each slow sand filter should be provided with a supernatant drain to quickly remove the accumulated water from the top of the filter prior to scraping. The supernatant drain should be located just above the highest sand elevation. In filters that harrow, the supernatant drain should be sized to allow an adequate flow of water to move across the basin to flush material from the filter surface.

Drain

A separate filter drain should be provided at the bottom of each filter to allow the water level to be lowered below the sand surface elevation during filter scraping. This drain can be associated with the underdrain system provided that it is located upstream of any fixed level control device.

Backfill

The outlet pipe for each filter should be manifolded with its adjacent filter to allow backfilling of the drained filter with filtered, unchlorinated water through the underdrain system. Backfilling the filter is necessary after filter scraping to prevent air locking of the filter. Backfilling can not be accomplished with chlorinated water because the chlorine may harm the organisms that assist filtration in the filter bed.

Flow Distribution

Raw water entering the filter bed should not be concentrated in one location, otherwise scouring of the filter media can occur. Raw water should be distributed evenly across at least one side of the filter. This can be accomplished with a header pipe with orifices that evenly distribute flow from the header. In areas where freezing is a concern, the header pipe can be extended around several sides of the basins to prevent an ice block from forming and damaging the basin walls.

Flow Collection

Water should also be collected evenly from beneath the filters. This can be done with a properly designed underdrain system that utilizes manifold principles to ensure uniform headloss through all portions of the underdrain. Detailed manifold design guidance is included in the AWWA *Manual of Design of Slow Sand Filtration.* Figure 3-7 shows a typical filter underdrain system.

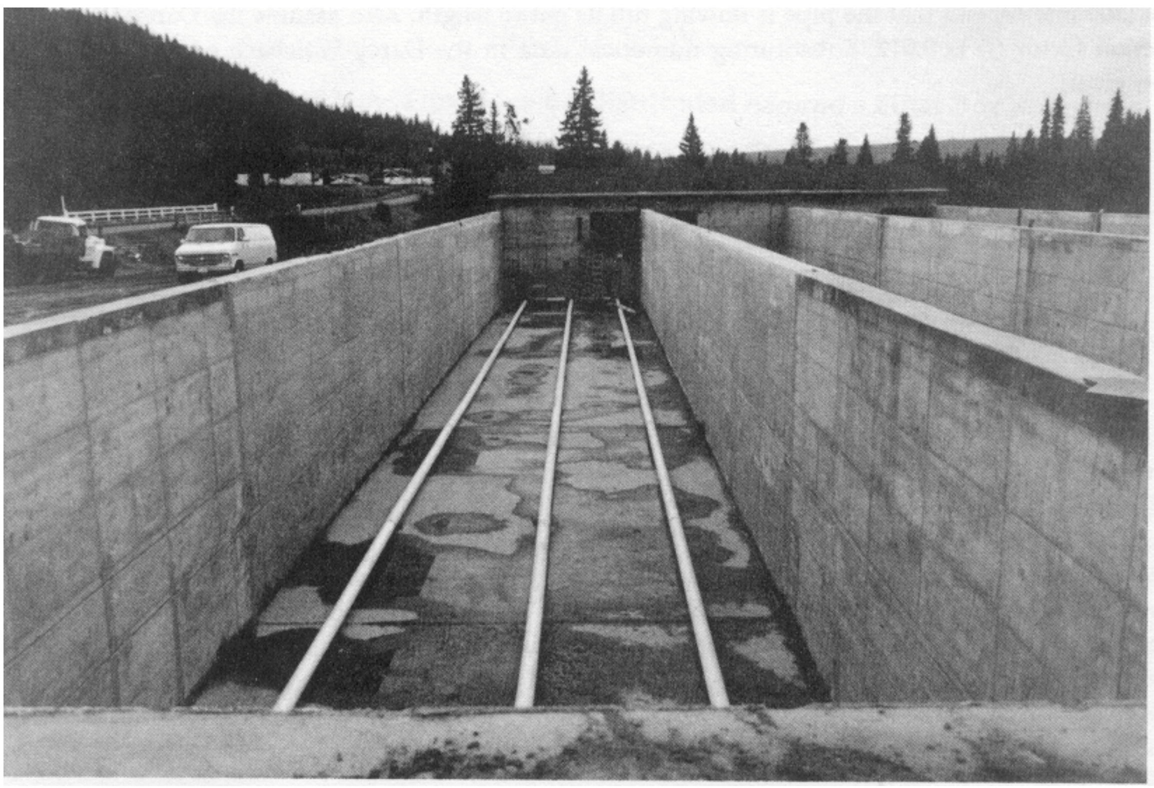


Figure 3-7. Typical Filter Underdrain (AWWA, 1991)

Flow Control

Slow sand filters may be provided with either inlet or outlet flow control. Inlet flow control can provide either constant rate or declining rate filtration. The various types of flow control and their advantages are discussed below.

Inlet Control – Constant Rate

Inlet flow control to provide constant rate filtration consists of a throttling valve and flow meter on the raw water line prior to each filter. The operator uses the flow control valve to set the desired filtration rate. As headloss accumulates across the filter bed, the water level in the filter rises. The primary advantages to this type of flow control are that the operator can easily control the flow rate and can physically observe the accumulation of headloss across the filter by simply observing the filter water surface.

Inlet Control – Declining Rate

Inlet flow control with declining rate filtration consists of a hydraulic control valve on the raw water line prior to each filter that regulates flow while maintaining a constant water surface elevation above the filter. As a filter run progresses, the water level in the filter remains constant while the flow through the filter decreases. This type of flow control is simple and provides relatively smooth changes in flow, but it does not allow much flexibility to the operator in controlling flow. Piezometers are also necessary to determine headloss across the filter, since the water level is not indicative of headloss across the filter.

Outlet Control

Outlet flow control consists of a control valve and flow meter on the outlet pipe from each filter. With outlet flow control, the level of water on top of the filter can be controlled by using float switches to turn on and off raw water pumps or by using an inlet control valve to throttle flow to maintain a constant water surface elevation. In some cases excess raw water can simply be diverted out an overflow and directed back to the water source. Outlet flow control is a simple control method that allows the operator to easily control flow through the filter. This type of flow control can simplify the control of raw water pumping schemes while providing raw water storage above the filter that can be used in case of power loss or intake shutdown. The larger volume of water above the filter also reduces the potential for freezing. The main drawback to outlet flow control is that piezometers are necessary to determine headloss across the filter bed.

Filter Tailwater Control

The tailwater on the outlet of each filter should be controlled to keep it above the sand level water at all times. Maintaining the tailwater above the filter surface prevents air binding in the filter, reduces scouring of the filter bed by water entering the filter, and maintains biological activity necessary for filtration. Three methods are commonly used to maintain the tailwater level above the filter beds:

- Outlet weir
- Outlet piping configuration
- Outlet control valve

Outlet Weir

This option consists of installing a weir or weir gate in a concrete weir box on the outlet piping of each filter. The weir provides a positive method of maintaining the tailwater elevation above the sand level, with the weir elevation typically set at 6" – 12" above the sand level. An adjustable weir can allow the operator to recover the 6" – 12" of driving head pressure initially lost from forcing the water level to be above the sand level. Once the headloss across the filter reaches a minimum of one foot, the operator can recover this driving head by lowering the weir to the sand level. However, there is an increased risk of air binding if the weir is lowered to far.

Piping Configuration

This option consists of configuring the outlet piping to maintain a constant water level above the filter. The outlet piping is routed so that the outlet pipe invert is approximately 6" - 12" above the sand level in the filter bed. An air relief or vent should be supplied for this option to avoid trapping air in the pipeline. The outlet piping option is generally not adjustable; therefore, the distance from the pipe invert to the sand level is lost as driving head. However, during a filter run headloss typically develops exponentially. As a result, the last foot of headspace is not as important as the first 2 - 3 feet. The outlet piping option is a usually a less expensive method of level control than the outlet weir option.

Outlet Control Valve

This option consists of using a valve on the outlet piping from each filter to back the filter tailwater up to one foot above the filter surface. This is an inexpensive option but it is not recommended since it does not provide a positive method of preventing dewatering of the filter bed at all flow rates.

Level Monitoring

Headloss across a slow sand filter can be measured in a variety of ways. The most common method is to use piezometers. Piezometers provide a simple physical indication of the static water level prior to and after the filter media. Piezometers typically consist of small diameter (1/4") PVC pipe connected to a section of clear polyethylene tubing and mounted on a wall next to a staff gauge. Bright colored indicator floats can be placed in the tubing to highlight the water levels. Figure 3-8 shows a typical piezometer. For facilities using inlet control, headloss can be monitored using a staff gauge mounted on the inside of the filter basin. A staff gauge can consist of a survey rod or a wood panel with painted graduations.

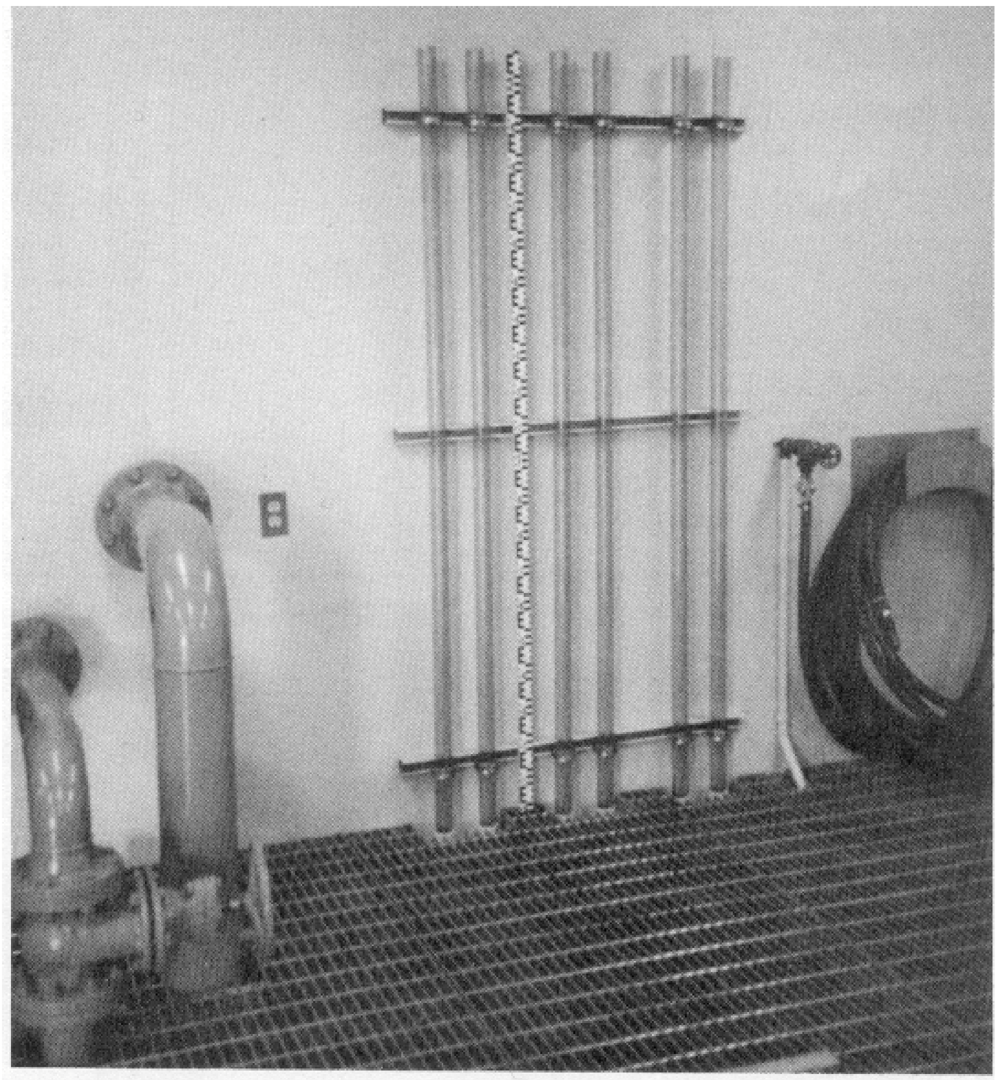


Figure 3-8. Typical Piezometer (AWWA, 1991)

Sand Removal / Harrowing

Approximately every 1 - 12 months, when terminal headloss is reached across the filter, a thin layer of sand and biological growth (typically 1/8″ to 1/2″) will need to be removed from the slow sand filter beds to reduce the headloss across the filter beds. Terminal headloss will usually be around 4 feet. At the extremes, terminal headloss can be defined as that point where the applied water in an influent controlled filter reaches the overflow, or where there is insufficient water production in an effluent controlled filter.

In most small communities, sand removal is accomplished using manual labor. Rakes, shovels, and wheelbarrows are used to remove the top layer of clogged sand material. Figure 3-9 shows an operator scraping a filter bed.

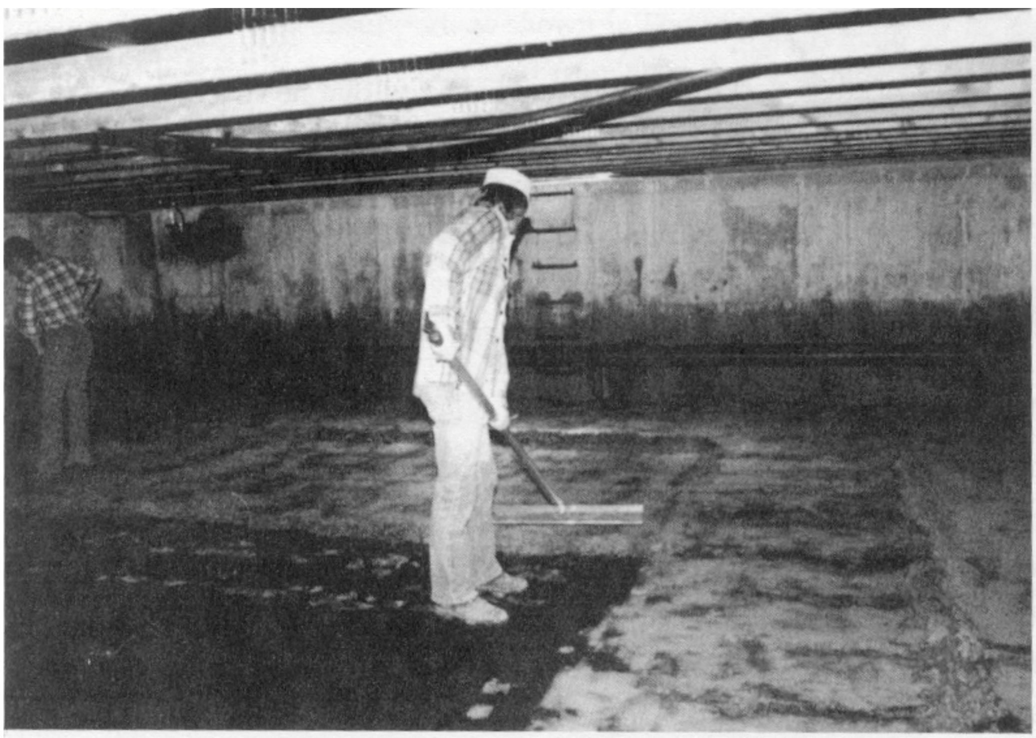


Figure 3-9. Filter Scraping (AWWA, 1991)

Slow sand filter beds should be designed to facilitate scraping. If a roof is provided over the filter beds, the roof should be at least seven feet above the highest sand level to allow adequate headroom for workers. Access should be provided to each filter bed to allow operators to move wheelbarrows, waste sand, and small tools in and out of the filter. Keep in mind that a cubic foot of wet sand will weigh in excess of 100 lbs., so lifting equipment may be required. If a roof is provided over the filters, water tight access doors located at the top of sand level should be considered to provide access to the filter. Otherwise, large hatches and hoist equipment may be necessary to move sand and equipment into and out of the filter beds. If the filter basins are uncovered, hoists or lift mechanisms can provide adequate access to the filters. Ladders should also be provided into each open basin to facilitate access. Operators, designers, and managers should always be aware of confined space issues associated with these maintenance activities.

In some slow sand facilities, harrowing can be used instead of sand scraping and removal to return filter headloss to its original level. Harrowing consists of raking the filter surface to break up the schmutzdecke and floating the biological material off the top of the filter. During harrowing operations, approximately six inches of water is left above the sand surface. Water is allowed to flow up through the filter bed as raw water passes across the surface of the bed. The water with the accumulated solids can be drained from the filter surface using the supernatant drain. This water should be disposed of properly, usually using a lagoon or pond to separate the solids from the liquid. The primary advantages of harrowing include less labor required during filter scraping and no resanding required.

Harrowing is a relatively new technique and currently only one of the six slow sand filters surveyed in Washington State uses harrowing.

Freezing and Algae Control

Uncovered filter basins can cause several operational problems for slow sand filters. In colder regions, the water above uncovered filter basins has the potential to freeze. If the water freezes across the entire bed, an ice block can form, causing damage to the filter piping and walls. If a filter reaches terminal headloss with ice on top of it, the filter can be very difficult to scrape. In warmer climates, algae can grow on the surface of uncovered filter beds. Algae can prematurely clog the filter media and can also impart undesirable taste and odors to the water. In areas with potential freezing or algae problems, filter basins should be constructed with covers. The two types of covers typically used are:

- Fixed covers
- Floating covers

All covers constructed must meet requirements of WAC 246-290-220 pertaining to materials used in public water systems.

Fixed Covers

Fixed covers (or roofs) for the filter basins can be constructed from a variety of materials including concrete, wood, and steel. Filters with fixed covers should be provided with adequate lighting and ventilation. As discussed previously, fixed covers should be constructed to provide at least seven feet of headroom above the highest sand elevation. Fixed covers are typically more expensive to construct than floating covers.

Floating Covers

Floating covers can also be constructed of a variety of materials including high-density polyethylene, polypropylene, or Hypalon. Floating covers are typically provided with foam floats to keep the cover above the sand surface. Floating covers need not be watertight since the water above the filter is raw water. Floating covers can be less expensive than fixed covers but require more labor for removal during filter scraping and sand addition operations. Floating covers also can accumulate debris that should be periodically removed from the filter basin.

Of the six slow sand filters surveyed in Washington State, three have fixed filter covers, one has floating filter covers, and two have no filter covers.

Slow Sand Filter Facility Design

In addition to design of the filters, the rest of the treatment facility and its components must be designed to optimize filter operation. Factors to consider include:

- Pre-treatment
- Pumping and storage
- Power considerations
- Instrumentation and controls

Pre-Treatment

In some cases the performance of slow sand filters can be significantly improved with pre-treatment of the raw water prior to slow sand filtration. Gravel upflow roughing filters can significantly reduce the solids loading to slow sand filters, improving turbidity removal and extending filter run times. The use of roughing filters can allow slow sand filters to operate on water sources with higher raw water turbidities (< 10 NTU) and can provide longer filter run times at higher filtration rates. Roughing filters should be considered in the design of new slow sand filtration facilities. A typical gravel upflow roughing filter cross-section is shown in Figure 3-10.

Of the six slow sand facilities surveyed in Washington State, two use gravel roughing filters.

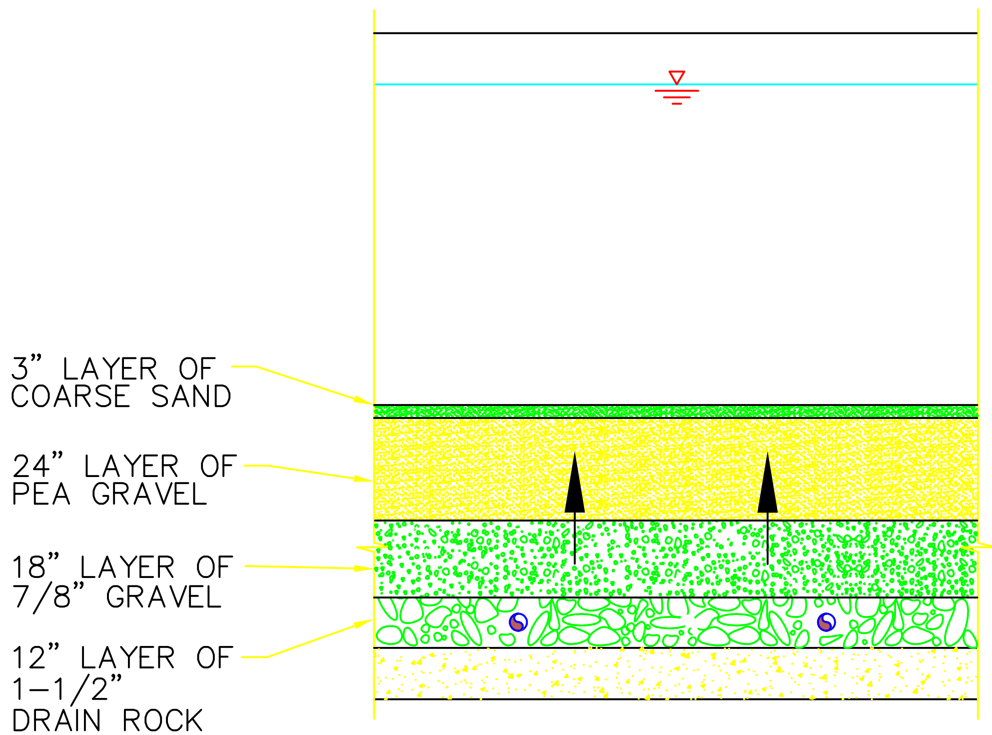


FIGURE 3-10 VERTICAL UPFLOW ROUGHING FILTER MEDIA TYPICAL SECTION

Other types of pre-treatment that may be considered in certain applications include presedimentation for high turbidity applications and ozonation for applications with organic matter, color, taste, or odor issues.

Pumping and Storage

Since slow sand filtration relies on biological processes for filtration, slow sand filters should be provided with consistent operating conditions to operate properly. Slow sand filters are most effective when changes in flow rate are gradual and when they are not started and stopped frequently. System components that are affected by these considerations include:

- Raw water pumping
- Finished water pumping and storage

Raw Water Pumping

Since flow through a slow sand filter should be relatively continuous without starts and stops, raw water pumping schemes should be designed to operate properly over a wide range of flows. Raw water pumping schemes can include the following:

- Constant speed pumping with flow control valves
- Constant speed pumping with raw water storage and floats
- Variable speed pumping

Regardless of the system configuration, consideration should be given to keeping pumping systems compatible with the skill level required for operation of the treatment facility.

Constant Speed Pumping with Flow Control Valves

Constant speed pumping with flow control valves provides for simple control of raw water pumping equipment. With this type of system, one or more pumps always run with their output throttled by flow control valves. If this type of pumping is used, pumps should be selected with operating curves that show the pump can operate efficiently over a wide range of flows. Control valves with good throttling characteristics such as globe or butterfly valves should be used for flow control. This type of raw water pumping is well suited for inlet flow control.

Constant Speed Pumping with Raw Water Storage and Floats

Constant speed pumping with raw water storage and floats is a simple control scheme that is more efficient than flow control valves. In order to provide water to the filters over a range of flow rates, raw water storage is used. For inlet controlled filters, this storage must be upstream of the filter. For outlet controlled filters, the headspace above the filter can be used as raw water storage. For this scheme, floats in the raw water storage start and stop the raw water pump(s). The raw water storage should be sufficient to allow continuous operation of the filter at its highest and lowest flow rates without short cycling the pumps.

Variable Speed Pumping

If the raw water pumps are large (>20 hp), variable frequency drives may be considered to pump a range of flow rates more efficiently. Variable speed drive control schemes are more complicated and the drive equipment requires more sophisticated maintenance than constant speed drives. However, in certain circumstances, the pumping cost savings will be enough to offset the additional complexity of the equipment.

Finished Water Pumping and Storage

Finished water pumping and storage for slow sand filtration can be an important design consideration. Like raw water pumping, finished water pumping systems must be designed to operate without frequently starting and stopping flow through the filter beds. If filtered water cannot be sent to waste periodically, adequate finished water storage should be provided to meet daily fluctuations in water system demands without constantly adjusting the flow rate through the filter plant. An analysis of daily water demand data at different times of the year using a range of continuous flow rates as inputs from the slow sand filters should guide the sizing of finished water storage. Additional storage will likely be necessary for disinfection contact time if disinfection is provided at the filter plant.

Power Considerations

Available Power

The power available at a treatment site is an important design consideration. The cost of bringing power service to a remote site can be expensive. If pumps greater than 10 horsepower are to be used, three phase power will likely be required. Methods of generating three-phase power from single-phase power are available, but they are expensive and less efficient than using three-phase power.

Power Interruptions

For most slow sand water filtration plants, a back-up power source should be provided to power mechanical equipment in the event of the loss of primary power. Water systems with alternate water sources or significant amounts of excess water storage may not need back-up power. Back-up power can be provided through a separate power feed or with a standby generator. In most cases, separate power feeds will not be economical for small systems.

Standby generators are more economical and can be powered by gasoline, diesel or propane. They should be sized to power all process, pumping, and control equipment. Building lights and HVAC equipment may also be powered by the generator. Manual or automatic transfer switches can be provided depending on the preference of the water system. A manual transfer switch requires that an operator respond to the facility in the event of a power failure to transfer power feeds.

Instrumentation and Controls

Instrumentation

Several on-line process instruments are used to properly operate slow sand filtration facilities. The following on-line process instruments are required by WSDOH for a slow sand filter:

- Filtered water flowmeter (Indicator and totalizer)

Other recommended on-line process instruments include:

- Raw water flowmeter (Indicator and totalizer)
- Raw water turbidimeter
- Individual filter turbidimeter
- Combined filter turbidimeter

On-line filter turbidimeters are not required by WAC 246-290-664(3)(b) for slow sand filtration, but they can aid in evaluating and reporting filter performance.

Automation

A wide range of automation options is available for filtration facilities. At a minimum, the water treatment facility should shut down automatically before the filtered water turbidity exceeds the allowable level of 1.0 NTU. When designing slow sand filtration facilities, the level of automation should be designed to match the operator skill required to operate the plant. Automated valves and control systems (outside of automatic shutdown) should be used only when other alternatives are not feasible. Where possible, manual control and simpler control solutions should be considered.

One simple type of automatic control has been used where high raw water turbidity spikes can occasionally create short filter runs. The control consists of an inlet roughing filter that plugs quickly upon high turbidity. The plugged roughing filter stops the flow of highly turbid raw water to the slow sand filters. The operator can then clean the roughing filter and restart water to the slow sand filters once the high turbidity event has passed.

Alarms

The control system for a water filtration facility should generate an alarm whenever specific conditions occur. Recommended alarm conditions for slow sand filtration are included in Table 3-4.

Table 3-4

Recommended Alarms

Instrument	Setpoint
High Raw Water Turbidity[1]	5.0 NTU
High Filter Individual Turbidity	1.0 NTU
High Combined Filter Turbidity	1.0 NTU
Filter High Level Alarm	-
Loss of Commercial Power	-
Low Chlorine Residual Alarm	Below normal entry point concentration but not less than 0.2 mg/L

Notes: 1. The high raw water turbidity alarm may not be necessary on raw water sources with very consistent turbidity.

Telemetry

For water treatment facilities that will be operated for portions of the day without an operator present, some level of telemetry is required. Telemetry can consist of radio or telephone equipment that sends signals indicating plant status. Generally radio telemetry equipment has a higher capital cost than telephone telemetry when telephone service is available at or near the site. However, telephone telemetry can be more expensive to operate than radio telemetry due to the monthly telephone charges. Underground telephone lines can be more reliable than overhead lines or radio telemetry.

The type of signals transmitted by telemetry can vary significantly depending on the level of automation desired. At a minimum, a common water treatment plant alarm should be sent out when any of the alarms indicated in Table 3-4 occur. If desired by the operator, individual telemetry signals can be sent out for specific alarms.

Slow Sand Filter Operations and Maintenance

This section provides a general overview of operations and maintenance requirements for slow sand filtration facilities. More specific operations and maintenance requirements should be generated as part of the design process for a facility. A detailed operations and maintenance manual should be produced as part of the project once specific equipment information is obtained from each equipment vendor. The final operations and maintenance manual should include the information required in Washington Administrative Code (WAC) 246-290-654 (4)(b)(ii) and (5).

Operator Certification

All drinking water treatment facilities require an operator certified in accordance with WSDOH requirements. Operator certification requirements are specified in WAC 246-292-060. The WSDOH determines the required level of certification for each treatment facility. The level of certification required is based on a point system that accounts for the size of the facility and the complexity of the treatment processes employed.

Most slow sand filter facilities will require a lead operator with a Basic Treatment Operator (BTO) or Water Treatment Plant Operator Level 1 (WTPO1) certification. Assistant or back-up operators who operate a filtration plant when the lead operator is not present must hold a minimum certification of one level below that required for the lead operator.

Staffing Requirements

Staffing requirements will depend upon the size of a facility, the treatment processes that it employs, and its level of automation. Table 3-5 summarizes the level of staffing provided at the slow sand filtration facilities surveyed for this manual.

Table 3-5

Slow Sand Water Treatment Plant Staffing

Facility	Rated Capacity	Daily Staffing	Labor to Scrape Filters
1	80 gpm	2 hr / day	3 – 4 man hours
2	140 gpm	15 min / day	18 man hours
3	480 gpm	3 hr / day	24 man hours
4	520 gpm	1 hr / day	80 man hours
5	700 gpm	2 hr / day	48 man hours
6	2,400 gpm	8 hr / day	50 – 200 man hours

Daily Operations

The operation of slow sand filtration plants is divided into three major modes: filter ripening, filtration, and filter scraping. Filter ripening and filtration require little operator time, while filter scraping is labor intensive.

Filter Ripening

Prior to beginning each filter run, a new filter should be ripened to build the biological growth that accomplishes a significant portion of the filtration. Typical activities to ripen a filter include the following:

1. Open the backfill valve to bring filtered water into the slow sand filter through the underdrain system.
2. Close the backfill valve when the filter water level is one foot above the sand surface.
3. Open the filter-to-waste valve and close the filtered water valve to direct water to waste.
4. Start raw water flow to the newly backfilled filter.
5. Water should be sent to waste until certain prescribed turbidity criteria are met. Although there are no criteria specified by the WSDOH, the turbidity level should return to near the filter's normal operating level before bringing the filter back on-line. Initially, data from the pilot study can be useful in determining when the filter is ripe. Other methods used to determine filter ripening include reductions in coliform counts to negligible levels, or reductions in ammonia concentrations in uncovered filters. In these filters, there should be no ammonia in the filtrate of a mature filter during the day.
6. Close the filter-to-waste valve and open the filtered water valve to resume normal filter operation.

According to a survey of six slow sand facilities in Washington, ripening can take anywhere from 1 day to 2 weeks. Most facilities use turbidity as a criteria for placing the filter back in service. One facility uses coliform counts.

Filtration Mode

When the filters are in filtration mode, the operator should match filtered water production to daily water demands. Depending on the level of automation provided in the facility, this may entail checking tank levels, reviewing the previous day's water usage, and adjusting control valve positions. The following tasks are typically performed by the operator daily during the course of a filter run:

1. Check plant flow rate in comparison to daily water demands. Adjust flow rate as necessary.
2. Check filter headloss.
3. Check raw and finished water turbidity.

4. Visually inspect filter basins and piping.
5. Check operation of any pumping equipment.
6. Complete daily report forms.

Filter Scraping

When a filter reaches terminal headloss, the filter should be scraped. Depending on water quality and temperature, the frequency of filter scraping may range from 1 to 12 months. Headloss usually accumulates slowly, over a period of weeks, so scraping activities can typically be planned well in advance. During initial operation of a new filter, operators may not know how long it will take to reach terminal headloss, so scheduling scraping activities may be difficult. Pilot study results can provide an estimate of filter run time; however, while headloss increases slowly over a period of time, the rate of headloss accumulation increases appreciably near the end of the filter run. Experience with their own filter system will enable operators to better anticipate and schedule scraping activities.

Filters should be scraped individually in sequence to allow one filter to ripen while the other filters continue producing water. Typical steps to scrape a filter include the following:

1. Close the filtered water valve and raw water valve to isolate the filter.
2. Open the supernatant drain valve to lower the water to the top of sand.
3. Open the filter drain valve to lower the water level several inches below the sand level.
4. Using shovels, rakes and wheelbarrows scrape 1/8″ to 1/2″ off the top of the filter. Remove the material from the filter bed.
5. Fill and ripen the filter as described above.

Where harrowing is used to scrape slow sand filters, the water level should be left above the sand level to allow biological material to float from the sand surface. The supernatant drain and raw water control valve should be opened to flush water across the surface of the filter bed towards the supernatant drain.

At the six slow sand facilities surveyed in the State of Washington, filter runs last from 5 months to several years, with the typical run length being about 6 months.

Daily SWTR Compliance Monitoring and Reporting

Surface Water Treatment Rule (SWTR) compliance must be determined daily by the water treatment plant operator. Each day, the operator must review the turbidity records from the previous day (or from the time of last visit) to determine if turbidity exceeded 1.0 NTU or 5.0 NTU. Turbidity must be below 1.0 NTU in 95% of the measurements taken for a month and below 5.0 NTU in all measurements taken. The filtration performance must be recorded daily on WSDOH filtration report forms. A typical WSDOH report from is provided in Appendix D.

In addition to verifying daily filtration compliance, the operator must verify disinfection compliance. This is done by comparing the concentration and time (CT) that a disinfectant was in contact with filtered water to the CT required for a particular disinfectant concentration, temperature, and pH. The CT provided, CT required, and compliance factor must also be recorded daily on WSDOH disinfection forms. Refer to WAC 246-290-662 or contact the WSDOH Regional Engineer for more specific guidance regarding disinfection.

Regular Maintenance

Table 3-6 shows the typical regular maintenance activities and their frequency for slow sand filtration.

TABLE 3-6

Slow Sand Filtration Regular Maintenance Activities

Item	Activity	Frequency
Filter	Scrape	Every 1 – 12 months
Instrumentation	Calibrate	Monthly
Pumping Equipment	Lubricate Bearings Replace Packing Change Mechanical Seals	Yearly Yearly Every 5 Years
Emergency Generator	Exercise	Weekly

Periodic Maintenance

The primary periodic maintenance activity for slow sand filtration is resanding. Each time a slow sand filter is scraped, some of the filter sand is removed (except in harrowing). Over time, the depth of sand will decrease within the filter bed. 18-inches of sand remaining should be considered the minimum practical bed depth, although turbidity removal may be reduced at this level. The filter bed should be resanded with sand from the same source as the original sand unless additional pilot testing is completed on a new sand source. At some slow sand facilities, sand scraped from the filter is washed, stored, and reused in the filter. The AWWA *Manual of Design of Slow Sand Filtration* recommends that sand washing and storage facilities be included in the design of slow sand filtration facilities.

Of the five slow sand filtration plants surveyed for this project that remove sand from the filters, one stockpiled the sand for potential reuse, while the *other four disposed of the sand. Most facilities feel that resanding is such an infrequent event that sand washing and reuse is not warranted.*

When a filter bed is resanded, the biological activity in the bed should be considered. The AWWA *Manual of Slow Sand Design* recommends a procedure for resanding that includes moving the remaining sand to one side of the filter basin while new sand is added above the support gravels. The old sand is then moved on top of the new sand and the procedure repeated on the other side of the filter basin. In this way, the old sand that includes the microorganisms that aid in filtration is left on the top filtration surface. This procedure can reduce ripening times for resanded filters. Figure 3-11 shows the recommended resanding procedure.

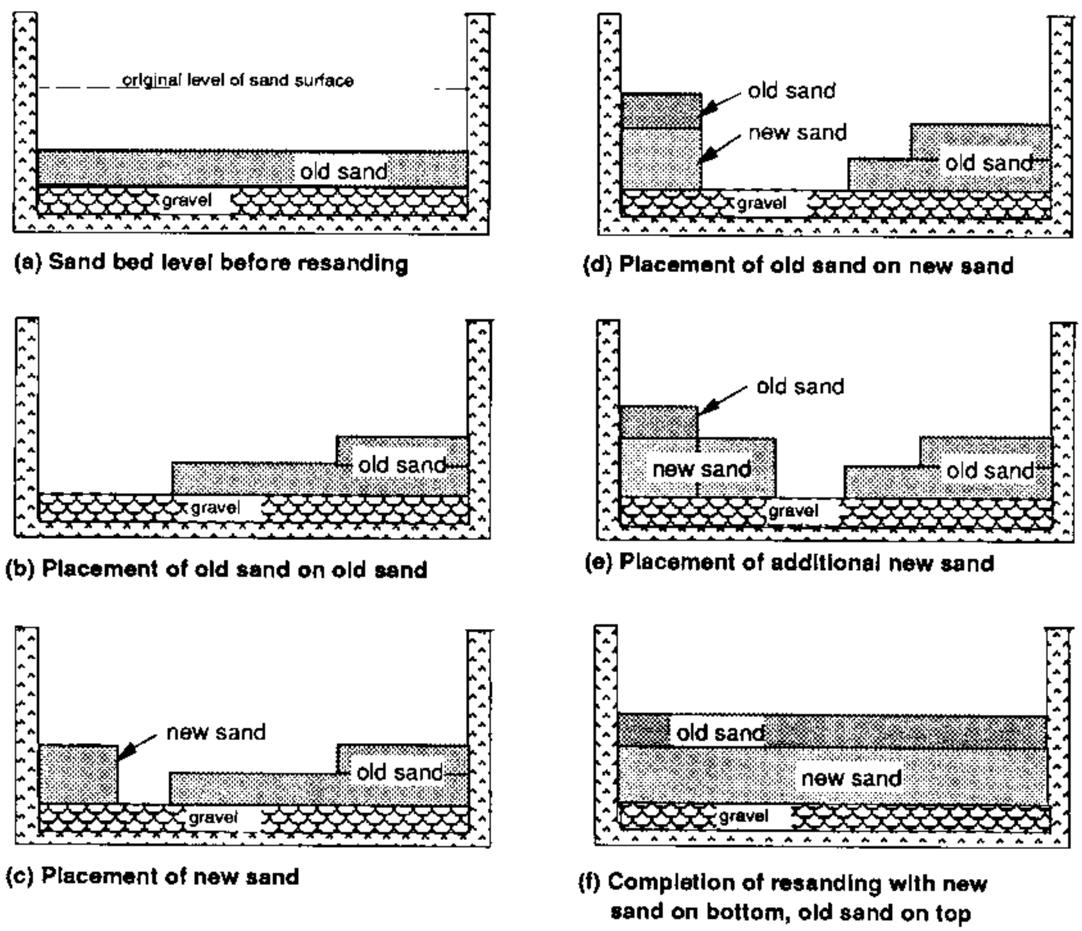


Figure 3-11. Recommended Resanding Procedure (AWWA, 1991)

Safety Precautions

Slow sand filtration is a relatively safe filtration technology because it does not require handling any hazardous chemicals. The primary hazards with slow sand filtration are hazards associated with the strains of physical labor during filter scraping or resanding activities.

Common Operating Problems

Many common operating problems can be avoided with proper design and by following recommended preventive maintenance procedures. Some of the common problems that slow filtration plant operators experience and ways to prevent them are shown in Table 3-7.

TABLE 3-7

Common Slow Sand Filter Operating Problems

Problem	Potential Solutions
Raw water turbidity spikes significantly reduce filtered water quality and the length of filter runs.	Shut down the facility during turbidity spikes if adequate storage is available. Pretreatment with gravel upflow roughing filters can significantly reduce solids loading to the slow sand filters, extending the length of filter runs.
Algae growth in the filter basins shortens filter runs and imparts taste and odor to the water.	Cover the filter basins.
Water freezing in the filter basins causes damage to the basins and prevents scraping in the winter.	Cover the filter basins. Extend water inlet piping around the perimeter of the basin.
Corrosion of metal piping in the filter basin.	Use PVC or HDPE pipe in the filter basin. Proper painting can extend the life of metal pipe in submerged service. Stainless steel or aluminum pipe supports and ladders will not corrode.
Accessing the filter is difficult.	Ladders, stairs, and platforms should be provided so that operators can effectively get around and into filters.
Instrumentation, control, and telemetry issues require operator time and attention.	Automation and electronic equipment also require maintenance to keep the equipment in good working order. Simple filtration processes should be provided with a degree of automation appropriate to the skills of the operator.

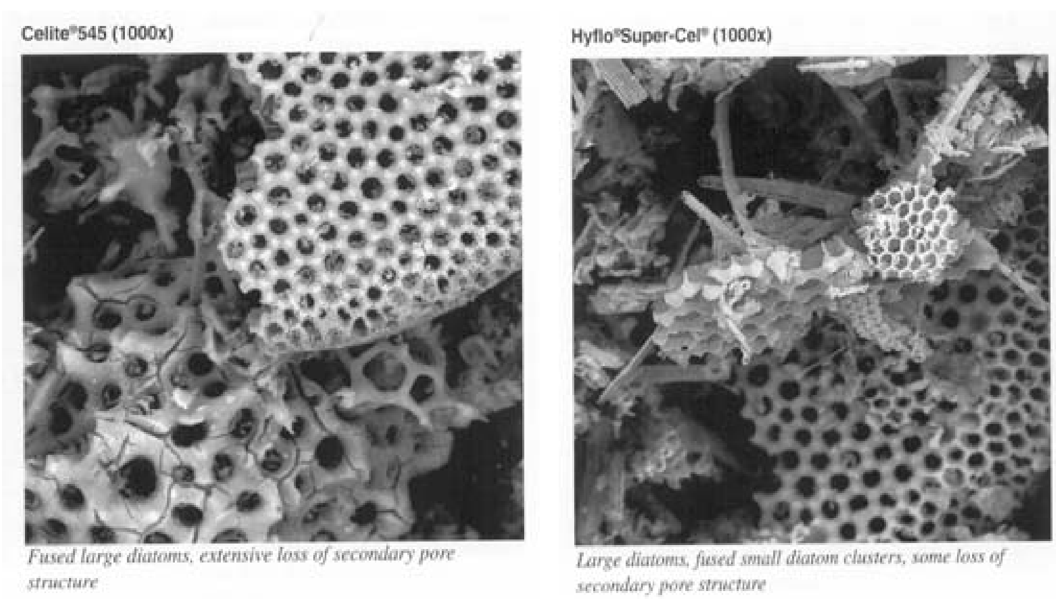
Chapter 4

Diatomaceous Earth Filtration

Process Description

Diatomaceous earth filtration is a pre-coat filtration method in which the filter media, diatomaceous earth, is applied to a mesh screen (called a septum) prior to each filter run. The diatomaceous earth filter media is flushed and wasted at the end of each filter run. Diatomaceous earth (DE) filtration has been used since the 1940s to successfully treat potable water. Diatomaceous earth is a chalky sedimentary material comprised of the skeletal remains of microscopic organisms called diatoms. The diatoms range in size from under 5 to over 100 microns and are characterized by a porous structure with openings as small as 0.1 microns in diameter. The combination of small pore sizes and high porosity allow DE to remove small particles from water at high water filtration rates. When properly processed, DE becomes a virtually inert filter media that is predominantly pure silica. DE filtration is effective for treating raw water with low turbidity and low organic loading. Figure 4-1 shows two grades of DE magnified 1,000 times.

Figure 4-1. Diatomaceous Earth (courtesy Celite Co.)



To begin a filter run, a 1/8-inch thick layer of DE is applied to the filter septum in a process called pre-coating. During pre-coating, a DE slurry is added to a filter basin and recirculated through the filter. Initially a portion of the DE passes through the openings in the filter septa. As the slurry of DE is recirculated through the filter basin, it bridges the openings on the filter septa. After a period of time ranging from 5 minutes to 45 minutes, the DE accumulates on one side of the filter septa creating the pre-coat layer. Figure 4-2 shows a representation of a pre-coated filter.

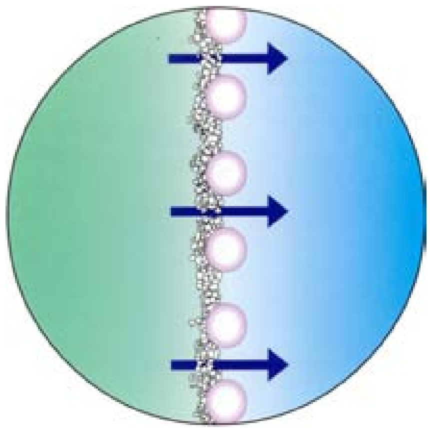


Figure 4-2. Pre-coated Filter (courtesy Celite Co.)

After the completion of the filter pre-coat process, water can be effectively filtered. During a filter run, the pre-coat layer is supplemented by a continuous "body feed" of DE, which maintains the porosity of the filter. Since the predominant method of particle removal for a DE filter is through surface straining, filter runs without body feed will have particles accumulate rapidly on the filter surface, plugging the filtration layer, and causing rapid head loss. If the body feed is continued at an optimum rate, the filtered particles are distributed throughout the depth of the DE filter cake, maximizing filter run time. Figure 4-3 shows a representation of a filter in operation with body feed.

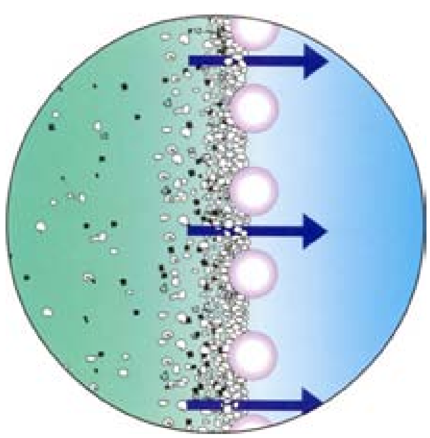


Figure 4-3. Operating Filter w/ Body Feed (courtesy Celite Co.)

Filter runs for DE filtration can range from several hours to several weeks depending on the raw water quality, body feed rate, and design of the system. Depending on the length of filter run anticipated, a wide range of automation can be designed into the filtration equipment.

Until recently, DE filtration has seen limited application for municipal drinking water treatment. A combination of lower quality source waters being filtered and process difficulties with maintaining a stable pre-coat limited the application of DE filtration. With more high quality source waters requiring filtration and advances in the design of filters and septa, DE filtration has become an attractive alternative for small drinking water applications. DE filtration is particularly appropriate where raw water turbidity, color, and organic loading are low.

Properly designed and operated DE filtration facilities are typically given 2.0 log credit for *Giardia lamblia* removal and 1.0 log credit for virus removal by the WSDOH. It is anticipated that DE filtration facilities will be given at least a 2.0 log credit for *Cryptosporidium* removal under the Long Term Enhanced Surface Water Treatment Rule. Recent research has indicated that 4-6 log removal of *Cryptosporidium* can be obtained using DE filtration (Ongerth, 1997).

DE filtration equipment is available in many different configurations from several manufacturers. The three main categories of DE filtration equipment are vacuum filtration, pressure filtration, and horizontal plate filtration. All categories of equipment operate on the same basic principle of pre-coating a filter prior to each filter run. The differences in equipment are due to the location of the filter pump and the disposal methods of spent diatomaceous earth. Figure 4-4 shows photographs of the three types of filtration equipment.

<u>Vacuum DE Filtration</u>

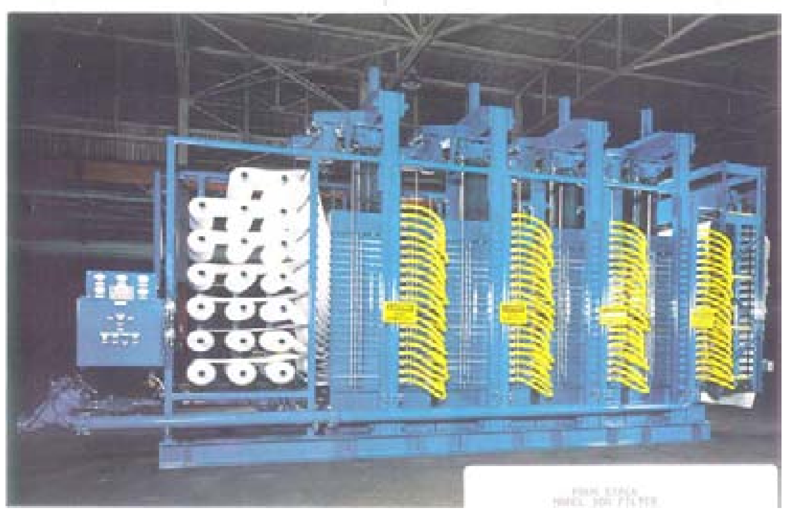
In vacuum DE filtration, the filter vessel consists of an open tank with multiple flat filter elements submerged in the tank. The filter elements are arranged vertically on approximately 6" centers. A septum is wrapped around each filter element. Water passes through the septum on both sides of the filter element into the filter element core. Water is removed from the tank by a filter pump that pulls water from filter elements through a manifold system. The force of the water passing through the filter septa holds the DE on the filter elements.

Vacuum DE filters are typically used for larger installations treating higher flow rates since they can hold a large amount of surface area in a small unit. Vacuum filters are typically less automated and more operator effort is required to flush and pre-coat a filter. Because they require more operator labor to flush and pre-coat, filter run length is an important consideration in the design of a vacuum filter.

Figure 4-5 shows a typical process flow diagram for vacuum DE filtration.

Pressure DE Filtration Equipment (Courtesy of Blace Filtronics)

Vacuum DE Filtration Equipment (Courtesy of Separmatic)



Horizontal Plate DE Equipment (Courtesy of JR Schneider)

Figure 4-4. Diatomaceous Earth Filtration Equipment

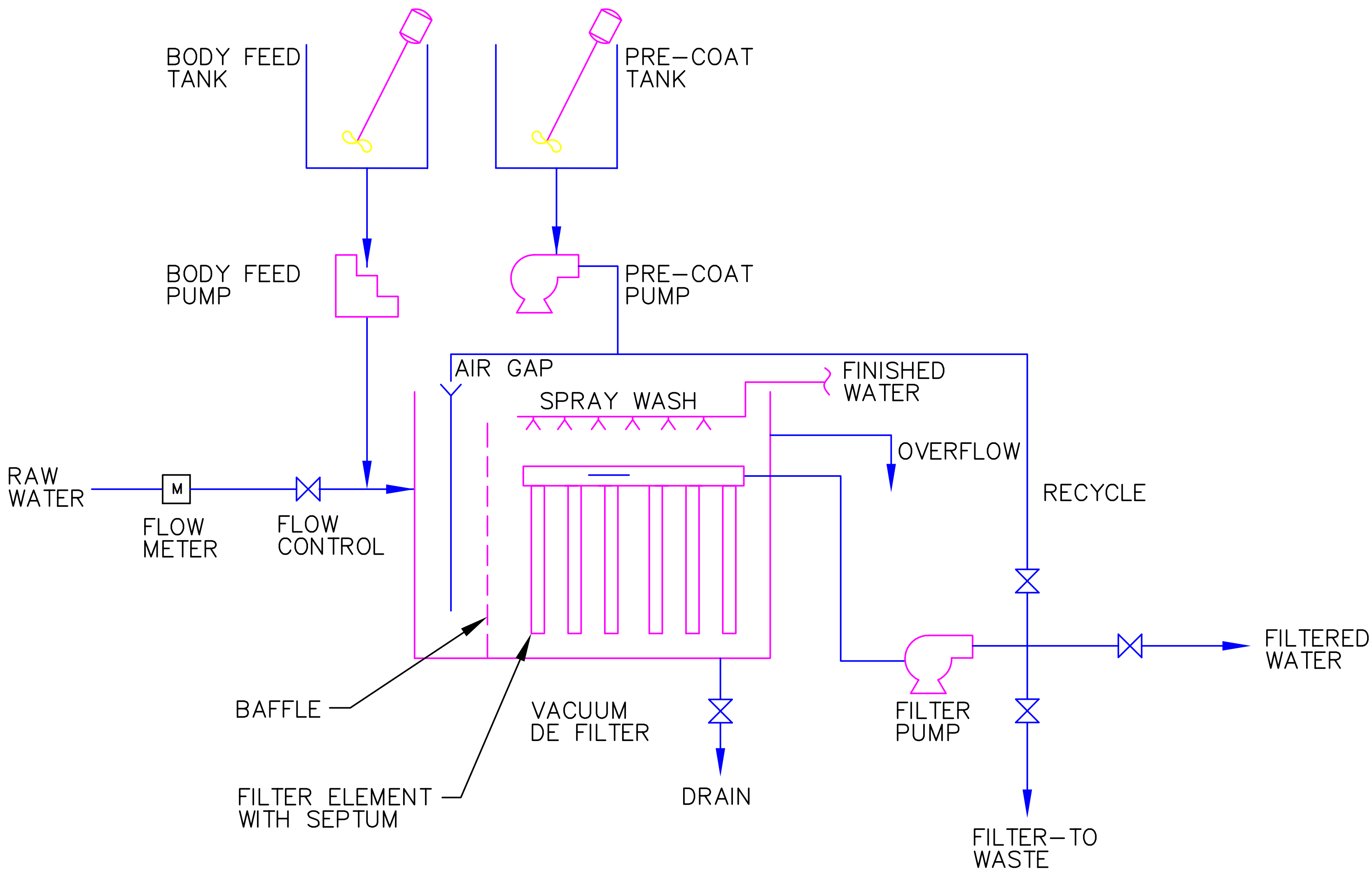


FIGURE 4–5 VACUUM DIATOMACEOUS EARTH FILTRATION PROCESS FLOW DIAGRAM

Pressure DE Filtration

In pressure DE filtration, the filter vessel consists of an enclosed pressure vessel with flat plates or cylinders connected to a manifold. A pump supplies raw water to the pressure vessel. As with the vacuum filter, the DE is held onto the filter septa by the pressure of the water passing through the filter element. Pressure filter systems are typically used for smaller installations since the maximum practical size of pressure vessels is limited. Pressure filters are typically more automated to reduce labor associated with flushing and pre-coating. Because of their automation, filter run length is typically not as critical a design parameter and DE usage can be optimized.

Figure 4-6 shows a typical process flow diagram for pressure DE filtration.

Horizontal Plate DE Filtration

Horizontal plate DE filtration is a type of pressure DE filtration that combines filtration and spent filter cake dewatering in one unit of equipment. As the name suggests, this type of equipment orients its filter elements in horizontal plates. Raw water is pumped through only one side of the filter plate. When terminal headloss is reached through the filter, the raw water supply is turned off and compressed air is blown through the filter plates to force the remaining water from the system. The dewatered filter cake is then removed from the filter plates. To ensure proper dewatering and cake removal, each horizontal plate is provided with a disposable paper filter septum for each filter run. Horizontal plate filters are typically used in smaller applications where disposal of wash water is difficult.

Figure 4-7 shows a typical process flow diagram for horizontal plate DE filtration.

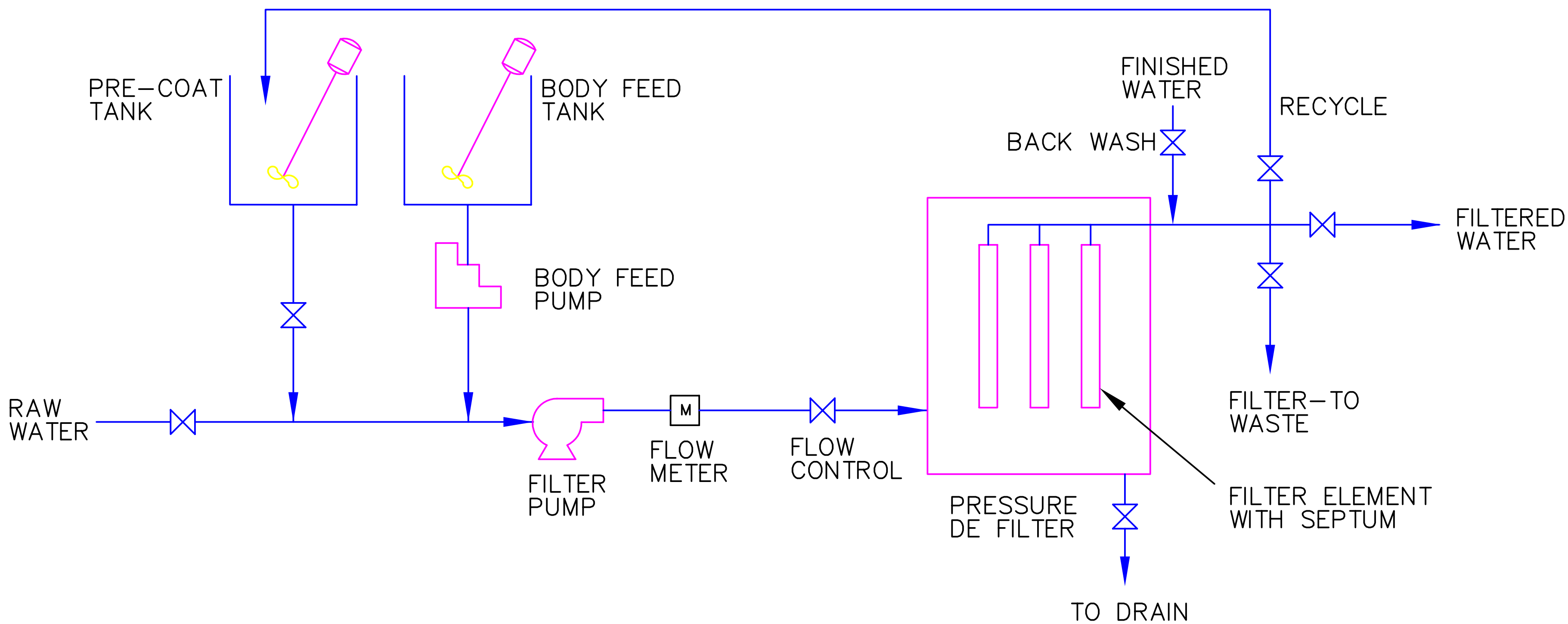


FIGURE 4–6 PRESSURE DIATOMACEOUS EARTH FILTRATION PROCESS FLOW DIAGRAM

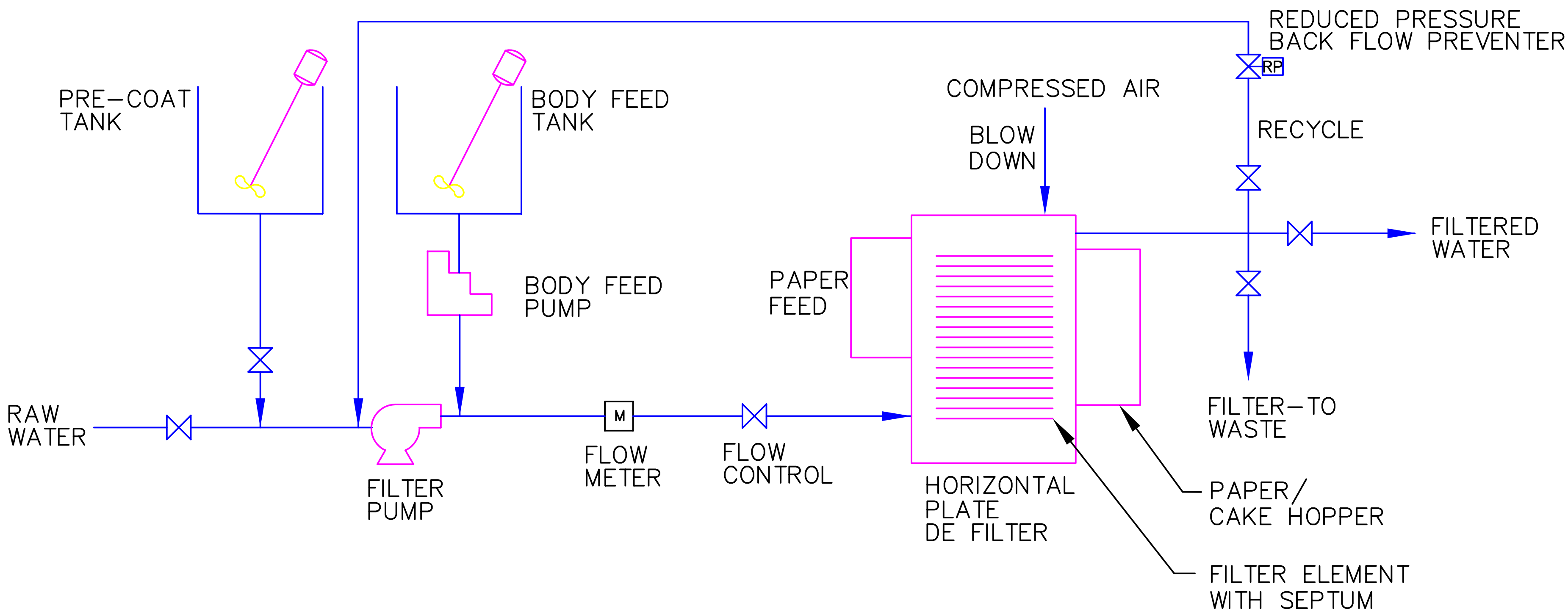


FIGURE 4-7 HORIZONTAL PLATE DIATOMACEOUS EARTH FILTRATION PROCESS FLOW DIAGRAM

DE Filtration Equipment Comparison

Table 4-1 provides a comparison of the characteristics of the various types of DE filtration equipment.

Table 4-1

Diatomaceous Earth Filtration Equipment Comparison

Parameter	Vacuum	Pressure	Horizontal Plate
Footprint[1]	Small	Medium	Medium
Available Automation	Low	Low - High	Medium
Pump Location	Filtered Water	Raw Water	Raw Water
Washdown	Manual	Semi-Automatic	Automatic
Pre-Coat	Manual	Automatic	Semi-Automatic
Terminal Headloss	10-12 in. of Hg	15 – 30 psi	30 –50 psi
Access to Filter Elements	Open tank allows access for inspection and maintenance	View port allows limited inspection. Vessel must be unbolted and opened for inspection and maintenance	Cannot inspect while operating. Must open vessels for inspection and maintenance.
Manufacturers	Separmatic, Westfall	Blace, RP Adams, Separmatic	JR Schneider

Note: 1. Footprint refers to the physical land area taken up by filtration equipment.

Pilot Testing for Diatomaceous Earth Filtration

As discussed in Chapter 2, pilot testing is required prior to constructing a surface water treatment facility. This section describes pilot plant testing objectives, procedures, and duration for diatomaceous earth filtration.

Objectives

Properly conducted pilot testing can provide valuable data that can help avoid significant mistakes in the application and design of filtration facilities. Some recommended objectives of DE filtration pilot studies are as follows:

1. Determine the suitability of the proposed filtration equipment for treating water from a particular water source.

2. Determine the effectiveness of the filtration equipment at removing turbidity from the raw water source.
3. Determine the appropriate filtration rate (gpm/ft^2).
4. Determine the anticipated filter run length.
5. Determine the most effective grade of filter media.
6. Verify design assumptions and related cost estimates.

The pilot study should be conducted such that data will be obtained to satisfy these objectives.

Procedures

DE filtration pilot units are typically rented from the various equipment manufacturers for a period of time. Rental rates can range from $500 – $2,000 per month. The type of DE filtration equipment to be evaluated should be selected prior to the pilot study. This can be done using an alternative evaluation similar to that described in Chapter 2. If multiple types of DE filtration equipment (vacuum, pressure, and horizontal plate) are considered viable, each type of DE filtration equipment being contemplated should be pilot tested. The DE pilot units typically are provided with all of the required pumps, tanks, and monitoring equipment. If pre-treatment is contemplated prior to filtration, pilot scale pre-treatment equipment should be installed upstream of the filtration equipment. Figure 4-8 shows a typical vacuum DE pilot unit.

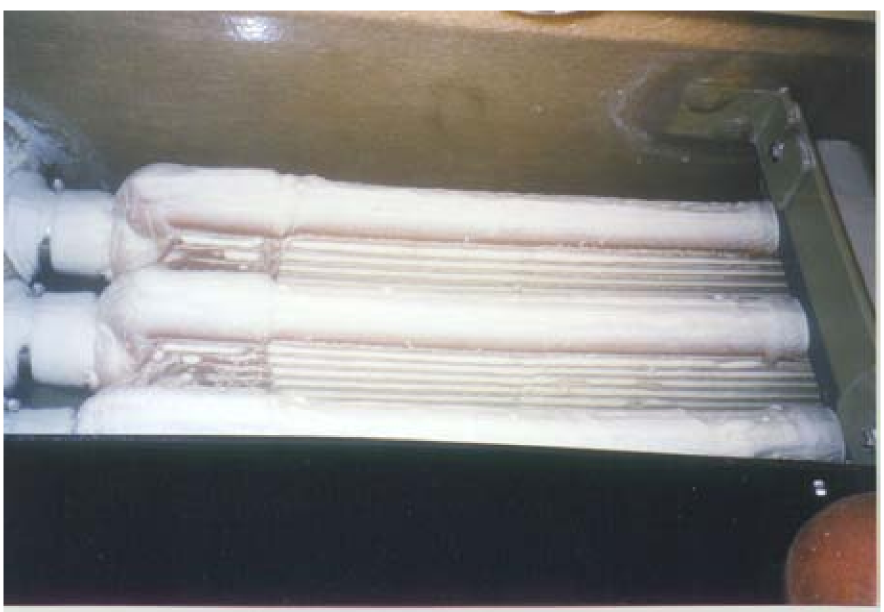


Figure 4-8. Vacuum DE Pilot Unit

Raw water used in the pilot study should be the same as that which will be treated at full-scale to ensure the validity of the test data. Filtered water from the pilot study should be sent to waste and not to the water distribution system. Table 4-2 provides a list of parameters that should be monitored during the pilot study along with the recommended frequency.

TABLE 4-2

Pilot Test Monitoring Parameters

Parameter	Raw Water	Filtered Water
Turbidity	Continuous	Continuous
Head Level	Daily	Daily
Flow Rate	Daily	-
Temperature	Daily	-
Color	Daily	Daily
pH	Daily	Daily
Total Coliform	Weekly	Weekly
Fecal Coliform	Weekly	Weekly
Total Organic Carbon	Every 2 Weeks	Every 2 Weeks

The pre-coat rate, filter media grade, and body feed rate should also be recorded as they are adjusted. In addition to the parameters listed in Table 4-2, algae and chlorophyll-a, particle counts, dissolved oxygen, iron or manganese analyses may provide useful information in specific situations.

If chlorine is to be used as a disinfectant in the full-scale facility, the WSDOH Regional Engineer should be consulted to determine if disinfection by-products should be tested for during the pilot study.

<u>Duration</u>

In DE filtration, filter runs can last from 1 - 30 days depending on water quality. To obtain adequate information on filter performance, DE pilot studies should be conducted for at least one month when filter runs are less than five days and for at least two months where they are greater than five days. Where water quality changes significantly during the course of the year, DE pilot studies should be conducted in more than one season.

<u>Pilot Test Suggestions</u>

Based on previous experience with pilot studies, the following are suggestions to help ensure that adequate results are obtained:

- Test several grades of DE to determine which is the most appropriate grade.
- Test the grades starting from finest to coarsest, since the finer grades will provide shorter run times.

- For the grade of DE that provides the best performance, test DE from at least two manufacturers to obtain price competition at full-scale.
- Plugging of body feed piping and pumps can be very disruptive to pilot testing. Use a durable body feed pump, such as a tubular diaphragm or plunger pump, and a properly sized body feed mixer to keep DE in suspension. Keep body feed lines short and straight. If possible, install a fresh water flush system on the body feed lines.

Diatomaceous Earth Filter Design

The design of the filtration equipment is critical to the success of a water filtration plant. This section discusses a number of design criteria and features that are important to consider in the design process.

Figure 4-9 shows a typical design layout for vacuum diatomaceous earth filter system.

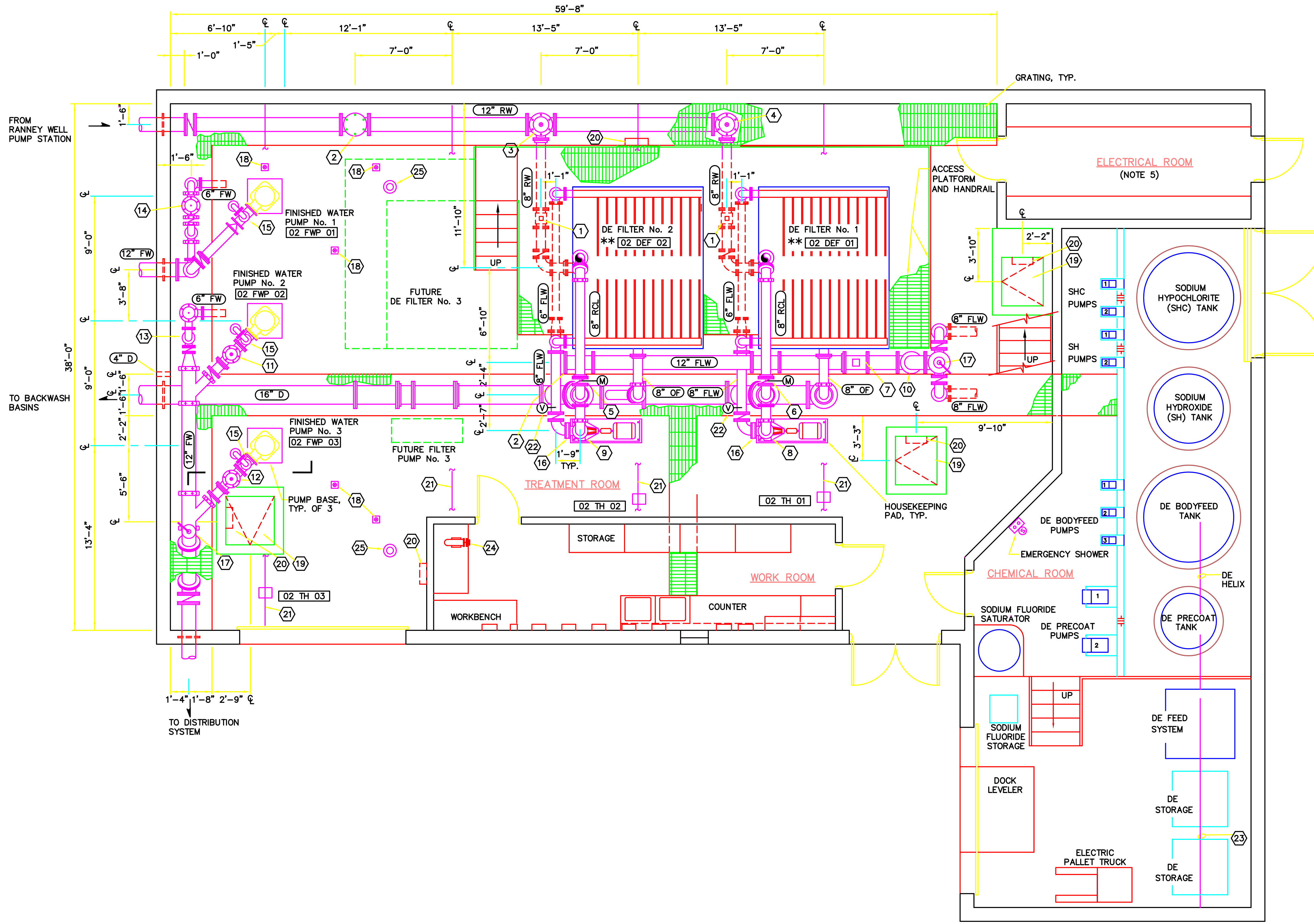
Diatomaceous Earth Filtration

Most DE filtration equipment is supplied as a package by an equipment manufacturer. These packages can consist of the filter equipment, pumps, tanks, mixers and controls, or any combination thereof. As a result, the design of DE filters typically consists of collecting information, making decisions about available options, and making minor modifications to standard equipment so that it will meet WSDOH requirements and best suit the owner's needs. The following sections describe the design of various DE filtration components.

Filtration Equipment

As discussed previously, there are three main types of DE filtration equipment available:

- Vacuum
- Pressure
- Horizontal plate



LEGEND:

1. RAW WATER FLOW METER
2. 12"x8" D.I. TEE W/ BLIND FLANGE
3. 8" RAW WATER CONTROL VALVE
4. 8" RAW WATER CONTROL VALVE
5. 8" RECYCLE CONTROL VALVE
6. 8" RECYCLE CONTROL VALVE
7. FILTERED WATER FLOW METER
8. FILTER PUMP NO. 1
9. FILTER PUMP NO. 2
10. STATIC MIXER
11. 8" PUMP CONTROL VALVE
12. 8" PUMP CONTROL VALVE
13. 6" SURGE ANTICIPATOR VALVE
14. 6" PRESSURE RELIEF VALVE
15. 4" SLOW CLOSING AIR/VACUUM VALVE
16. 8" FLANGE FILLER
17. 1" AIR RELEASE
18. 2" OPERATING NUT AND FLOOR BOX, COORDINATE FLOOR PENETRATION WITH GATE OR VALVE LOCATION IN CLEARWELL
19. 3'-0"x3'-0" ALUMINUM ACCESS HATCH
20. LADDER
21. HOIST-BEAM (SEE STRUCTURAL SHEETS)
22. VACUUM GUAGE AND TRANSMITTER
23. MONORAIL, HOIST AND TROLLEY
24. HEAVY DUTY BENCH VISE
25. CLEARWELL ACCESS PORT

FIGURE 4-9 2.6 MGD VACUUM DE FILTER LAYOUT

M:\WSDOH\0655.00.13\CDROM\Fig 4-9.dwg, Layout1, 04/11/2003 11:34:57 AM, 1:1

The type of DE filtration equipment should be determined through an alternatives analysis and pilot testing. Once the type has been determined, a specification should be developed for the equipment. Where several vendors make similar types of equipment, preliminary budget proposals should be obtained from each vendor. The scope of supply, equipment configuration, and component materials should be compared and the desired features listed in the specifications. The following are items that should be included in the equipment specifications:

1. Performance requirements (Turbidity removal, clean filter headloss, minimum filter run time, terminal headloss)
2. NSF Approval for all materials in substantial contact w/ potable water (See WAC 246-290-220 for details)
3. Filter surface area and maximum filtration rate
4. Materials of construction for the filter unit and filter elements
   - Material of the tank, element, and septum
   - Pressure rating of pressure tanks (ASME code)
5. Ancillary equipment to be supplied:
   - Pumps
   - Tanks
   - Mixers
   - Washdown piping and equipment
   - Monitoring equipment
   - Controls
6. Warranty (including guaranteed septum life)
7. Operations and maintenance manual
8. Start-up assistance

Filtration Rate

In development of the specifications, consideration should be given to the filtration rate. The current maximum filtration rate is 1.0 gpm/ft^2 according to the WSDOH. This is an appropriate filtration rate in most instances since it strikes a balance between size of the filtration equipment and length of filter runs. In some cases a higher filtration rate may be attractive. Recent research has indicated that DE filtration is actually more effective at higher filtration rates (Ongerth, 1997). WAC 246-290-654 allows for higher filtration rates if the purveyor demonstrates to the WSDOH's satisfaction that filtration at the higher rate consistently achieves at least 2 log removal of *Giardia lamblia* cysts and meets the turbidity requirements of WAC 246-290-660. If higher filtration rates are desired, they should be evaluated only after consultation with the WSDOH and following a pilot study. Please be advised that the Long Term 1 Enhanced Surface Water Treatment Rule also requires at least 2 log removal of *Cryptosporidium* oocysts. *Cryptosporidium* removal should also be addressed in any alternative filtration rate proposals.

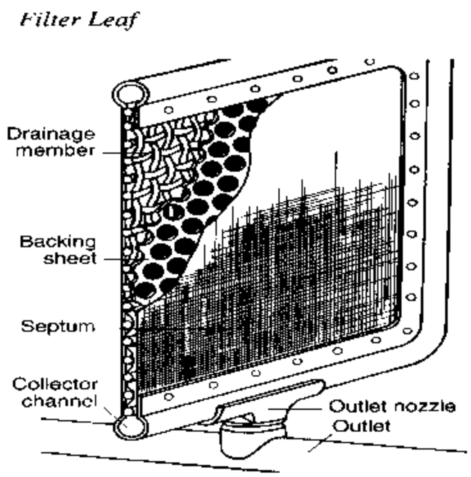
Number of Filter Units

The number of filter units provided will depend on the type of equipment, water demands, available storage, and availability of other water sources. State regulations require multiple filter units that provide redundant capacity when filters are out of service for backwash or maintenance. This requirement may be waived for non-community water systems providing engineering justification acceptable to the WSDOH. Each DE filter that can be operated independently is considered an individual filter unit.

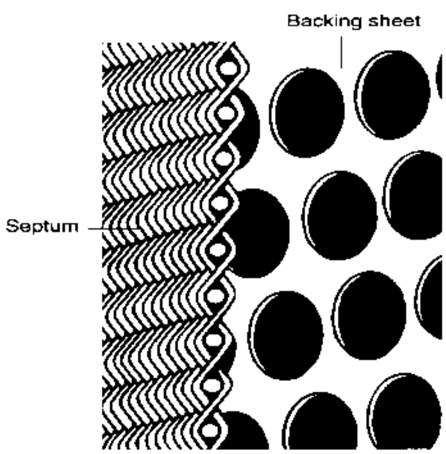
Septum Construction

When specifying filtration equipment, special attention should be given to the filter septa. Filter septa provide the porous support on which DE bridges to form the filter layer. The filter septa material should be NSF-61 approved and should be the same as used in the pilot study. Since filter septa should be replaced periodically, the manufacturer's guaranteed septum life and replacement cost should be considered.

The construction of the backing for the filter septum should generally be rigid, preventing the septum material from bowing or bending over the course of the filter run. The septum should be easily removed from the backing so that it can be replaced. Once in place, the septum should be securely mounted to the backing and the collection header so that solids cannot pass through any gaps. The septa should also be easily accessible so that they can be periodically inspected and replaced. Elements should have at least three inches of clearance between them to allow adequate space for inspection. Hoisting equipment located above the filtration equipment can significantly aid the inspection and replacement of filter septa. Figure 4-10 shows a typical filter element and septum.



a) Filter Element



b) Filter Septum

Figure 4-10. Typical DE Filter Leaf and Septum (courtesy Celite Co.)

Filter Media Selection

A wide variety of filter media are available for use in DE filters. A relatively small range of these products is typically used in potable water filtration. Generally, the optimal filter media used during pilot testing should be used in full-scale operation. In most cases, several suppliers will have similar gradations of DE. Table 4-3 lists the grades of DE for two of the main suppliers of DE products. The products are listed in order from finest to coarsest. The finest products will produce the best water quality with the shortest filter runs. The coarsest products will produce lower water quality with longer filter runs.

Table 4-3

Diatomaceous Earth Grades in Potable Water Filtration

	Permeability (D'arcys)	Celite	Eagle Picher
Fine	1.3 - 1.5	501	FW 18
|	1.9 - 2.1	503	FW 20
↓	3.0 - 3.2	535	FW 40
Coarse	3.5 - 4.0	545	FW 50

<u>Filter Cake Removal</u>

Each filter unit should be provided with a suitable method to remove accumulated DE from the filter septa at the end of a filter run. The following paragraphs discuss filter cake removal for each category of DE filtration.

Vacuum filter systems should be provided with a spray wash system directly above the filter elements. Spray wash water should be finished water. Adequate water supply should be brought to the filters to provide at least 70 psi of pressure when the spray system is operating. A flush system should be provided in the bottom of the tank to direct DE to the filter drain. Hose bibs at least one inch in diameter should also be provided at the filter tank to provide suitable flow and pressure for washdown by plant operators.

Pressure filter systems should be provided with a connection to filtered water to flush water back through the filter septa. Provisions can also be made to surge the filter to "bump" or dislodge the filter cake from the filter elements. Pressure filter systems must also be connected to a drain to facilitate removal of waste solids. Regardless of the type of wash system employed, the pressure filter should allow for inspection of and access to the filter elements by opening the pressure vessel.

Horizontal plate filter systems provide solids dewatering as part of the filtration equipment. Solids dewatering is accomplished at the end of each filter run by blowing compressed air through the filter elements. A compressed air source is required for this type of system. Dewatered solids are discharged to a hopper for disposal.

Wastewater Handling

Wastewater that includes DE must be treated prior to discharge to surface water. Typical treatment can include settling or dewatering. Settling can be accomplished in a settling tank or clarifier. Dewatering can be accomplished by various types of filter presses. Settled or dewatered solids can be land applied, used as soil amendment, or land filled. Local regulations should be reviewed to determine the best disposal method.

Filter Piping Configuration

DE filter equipment should be provided with certain piping arrangements to allow it to operate properly. The following piping features should be considered:

- Recycle
- Filter-to-waste
- Overflow
- Washdown
- Drains

Recycle

For DE filter equipment, a recycle line is necessary to return filtered water to the raw water line or directly to the filter tank. This recycle line is used to pre-coat the filter and hold the filter cake on the filter during periods of low water demand. The recycle line should be provided with some type of backflow prevention. In vacuum filters, the recycle line should be submerged when it reenters the filter tank to ensure proper distribution of flow. In pressure filters, recycle water is often routed through the pre-coat tank to provide an air gap. A reduced pressure backflow preventer can also be used where adequate pressure is available.

Filter-to-Waste

Filter-to-waste piping must also be provided for DE filtration per WAC 246-290-678(4)(b)(iii). When a filter is initially placed into service after pre-coat, a short turbidity spike can be observed with some filters. This spike may be due to DE accumulating in the sample line or an initial surge of DE passing through the filter. Filter-to-waste also allows the operator to diagnose a problem while running raw water through the filter.

Five of the seven DE filter installations surveyed had the ability to send water to waste rather than to the distribution system. The other two installations indicated that they would like to have filter-to-waste capability.

Overflow

Vacuum filtration equipment should be provided with an overflow to prevent overtopping of the filter basins in case of failure of the vacuum pump or inlet control valve.

Washdown

Vacuum and pressure DE filtration equipment should be provided with a source of filtered water to facilitate washdown or spraywash of the filter equipment. A cross connection control device should be provided on any spraywash or washdown line potentially in contact with raw water.

Drains

Vacuum and pressure DE filtration equipment must be provided with drains to convey wastewater containing the DE slurry from the filters. Drains carrying spent DE should be sized and sloped to maintain DE in suspension without depositing in the pipes. Cleanouts should be provided at regular intervals in drain lines.

<u>DE Pre-Coat Equipment</u>

All DE filters should be provided with pre-coat equipment. On the smallest vacuum filter installations (<50 gpm), DE pre-coat can be added directly to the baffled inlet of the filter basin. For larger vacuum systems and all pressure systems, DE pre-coat equipment should consist of a pump, tank, and mixer.

A minimum of two pre-coat pumps should be provided so that one can act as a standby pump in case the first pump malfunctions. When raw water pumps are located at the treatment plant, a separate pre-coat pump may not be required. Pre-coat pumps used only for slurry transfer should be sized to transfer the required amount of DE slurry to the filter tank in a period of 5 – 10 minutes. Pre-coat pumps also used as raw water pumps should be sized to pump the required amount of raw water through the filters. All pumps used to pump DE pre-coat slurry should be constructed of hardened steel or plastic materials that are abrasion resistant.

The pre-coat tank should be sized to hold the volume of DE slurry required to pre-coat at least one filter. Pre-coat rates typically range from 0.15 - 0.2 lb/ft^2 of filter surface area. The maximum recommended slurry concentration is ten percent solids. In some package units, slurry for pre-coating more than one filter is kept in the pre-coat tank. The pre-coat tank should be supplied with a sloped bottom and drain for removal of accumulated solids. Where possible, the pre-coat tank should be covered to minimize the dispersal of air borne DE when DE is being added to the tank.

The pre-coat tank should be provided with a slow speed mixer with hardened steel blades to keep the DE in suspension. A speed range of 40 - 60 rpm is recommended by AWWA *Manual M30* so that the DE is not damaged during mixing. The mixer should operate continuously when there is DE in the tank.

DE pre-coat piping should be sized to keep DE slurry moving at 3 - 5 feet per second to avoid deposition in pipelines. Piping should be constructed of smooth abrasion resistant materials such as PVC or CPVC. Where possible, 45 degree bends or sweep 90 degree bends should be used. Cleanouts and flushing connections should be provided periodically to allow cleaning of the slurry lines.

<u>DE Body Feed Equipment</u>

All DE filters should be provided with body feed equipment. DE body feed is dosed continuously to DE filters to extend the length of filter runs. Body feed rates can range from 1 – 20 mg/L depending upon the application and raw water quality. DE body feed equipment should consist of a metering pump, tank, and mixer. In some cases the pre-coat tank can be used for body feed provided that sufficient volume is available in the tank.

The body feed pumps should be metering pumps that consistently dose a specific amount of body feed. The pump feed rates should be adjustable to allow a range of DE body feed concentrations. In cases where the flow rate through the filter changes over time, the body feed pumps should be flow paced based on a signal from a flowmeter. Body feed pumps should be constructed from durable abrasion resistant materials. Tubular diaphragm pumps, piston pumps, and rotary lobe pumps have been used successfully in body feed applications. Standard diaphragm metering pumps tend to wear out diaphragms very quickly. Each body feed pump should be provided with a pressure relief valve and calibration column. A spare body feed pump should be provided as a back up.

Body feed tanks and mixers should be similar to those provided for DE pre-coat systems.

DE body feed piping should also be sized to keep DE slurry moving at 3 - 5 feet per second. However, this is not often practical due to the amount of water required. To prevent clogging of the body feed lines, a clean water flushing system can be connected to the body feed piping. The flush line should provide at least 50 psi through the body feed lines. A timer and solenoid valve should be used to flush the piping frequently. Body feed piping should be constructed of smooth abrasion resistant materials such as polyethylene tubing, PVC, or CPVC. Where possible 45 degree bends or sweep 90 degree bends should be used. Cleanouts and flushing connections should be provided periodically to allow cleaning of the slurry lines.

DE Storage and Handling Equipment

DE is available in 50 lb. bags, 1,000 lb. bulk sacks, and larger bulk deliveries. In most cases, small systems will use 50 lb. bags of DE. DE is an inert material that is not harmful if ingested, but can be harmful if inhaled. DE can also be an eye irritant. DE is a very light material and tends to disperse throughout a facility unless adequate provisions are made for dust control during design. DE should be stored and handled in a dry location, preferably a separate room from where other treatment activities occur.

Adding 50 lb. bags of DE to open tanks can be onerous and hazardous from an operations and maintenance standpoint. When 50 lb. bags are opened, a certain amount of dust escapes no matter how carefully it is done. Dust masks or respirators should be provided and used by all personnel handling DE. Small dry feed systems that contain the 50 lb. bag and meter the material into tanks are available. These systems are strongly recommended to reduce fugitive dust emissions. Proper lifting and hoisting equipment should also be provided to allow unloading of pallets and bags.

Diatomaceous Earth Filter Facility Design

DE filtration has several special operational requirements that impact the overall treatment facility design. Components to consider include:

- Pre-Treatment
- Pumping and Storage
- Power Considerations
- Instrumentation and Controls

Pre-Treatment

In some cases the performance of DE filters can be significantly improved with pre-treatment of the raw water prior to filtration. Clarifiers or roughing filters and self-cleaning screens can be used upstream of DE filters to reduce turbidity loadings and extend filter runs. In cases where the raw water has very fine turbidity, coagulants or polymers can be used to improve particle removal. If pre-treatment equipment is used, additional hydraulic head should be provided to maintain flow through the facility. Consideration should be given to using multiple pre-treatment units or adding a bypass around pre-treatment units to ensure uninterrupted flow to the filtration equipment when the pre-treatment equipment fouls or must be maintained.

At one pressure DE installation surveyed, poor pre-treatment design caused operational difficulties during high turbidity events. The facility uses a gravity raw water feed to provide pressure to the filter. A self-cleaning screen was installed upstream of the filter to improve filter run times. The screen was *installed without a redundant unit or bypass. When the screen plugged, the filter would lose its pressure source and the filter cake would drop.*

Pumping and Storage

In DE filters, water should be continually passed through the filter to maintain the DE on the filter septum. If water production is stopped during a filter run, water should be recycled through the filter or the filter must be re-coated. System components that are affected by these considerations include:

- Raw pumping
- Finished water pumping and storage

Raw Water Pumping

For DE filtration, pumping considerations will depend on the type of filtration equipment used. If raw water pumping is used for pressure filtration, consideration should be given to sizing the raw water pumps so that they have adequate discharge head to pump through the filter at terminal headloss. If raw water pumping is located remotely from the treatment site, a separate recirculation pump will be required to pre-coat the filter and maintain the filter cake in recycle mode. If raw water pumping equipment is located at the treatment site, it can also be used as a recirculation pump. In most cases, constant speed pumps with control valves will be suitable. In some cases, where raw water pumps are large, variable frequency drives may be more economical over the life of the facility. For vacuum filter systems, raw water pumping can typically be accomplished with constant speed pumps and control valves.

Finished Water Pumping and Storage

Finished water pumping for DE filtration is less dependent on the operation of the filtration process. For vacuum DE filtration, consideration should be given to using the filter pump to pump into finished water storage. If finished water storage is significantly higher in elevation or is a significant distance from the treatment facility, separate finished water pumps should be used. For all types of DE filtration, adequate finished water equalization storage should be provided to prevent excessive cycling of the DE filtration equipment.

Power Considerations

Available Power

The power available at a treatment site is an important design consideration. The cost of bringing power service to a remote site can be expensive. If pumps greater than 10 horsepower are to be used, three phase power will likely be required. Methods of generating three phase power from single phase power are available, but they are expensive and less efficient than using three phase power.

Power Interruptions

For most water filtration plants, a back-up power source should be provided to power mechanical equipment in the event of the loss of primary power. Water systems with alternate water sources or significant amounts of excess water storage may not need back-up power. Back-up power can be provided through a separate power feed or with a standby generator. In most cases, separate power feeds will not be economical for small systems. Standby generators can be powered by gasoline, diesel or propane. They should be sized to power all process, pumping, and control equipment. Building lights and HVAC equipment may also be powered by the generator. Manual or automatic transfer switches can be provided depending on the preference of the water system. A manual transfer switch requires that an operator respond to the facility in the event of a power failure to transfer power feeds.

DE filtration equipment requires special attention for power interruptions. The DE filter cake is held against the filter septum by the hydraulic force of water passing through the septum. When water stops flowing through the septum, as it would if a filter pump stopped during a power interruption, the filter cake can begin to slough away from the septum. If the filter cake sloughs, the integrity of the filter cake cannot be guaranteed and the filter should be washed and pre-coated. Facilities with back-up power and automatic transfer switches can reduce the impact of power interruptions.

Upon power interruption, it typically takes from 30 seconds to 5 minutes for a back-up generator to start and take on load. This period may be short enough to avoid significant sloughing of the filter cake. If a power interruption occurs, the filters should be sent to recycle mode and not allowed to filter water until inspected. If a filter shows signs of cracking or sloughing, it should be washed and re-coated. Pressure systems that cannot be adequately inspected should be washed and re-coated. To avoid having to re-coat a filter due to power interruptions, an uninterruptable power supply (UPS) can be provided to supply power to the filter pump during power interruptions. UPS equipment typically consists of battery or flywheel powered systems. These systems can be quite expensive, so an evaluation of their cost versus the cost of re-coating filters in the event of power interruption should be made during the design process.

In a survey of seven DE filtration plants, only one has UPS equipment. The remainder have some sort of back-up power source. In the event of a power interruption, most systems send the filter into recycle mode until it can be inspected or re-coated.

Instrumentation and Controls

Instrumentation

Several on-line process instruments are used to properly operate DE filtration facilities. The following on-line process instruments are required by the WSDOH for a DE filter:

- Individual filter turbidimeter
- Combined filter turbidimeter
- Filtered water flowmeter (Indicator and totalizer)

Other recommended on-line process instruments include:

- Raw water flowmeter (Indicator and totalizer)
- Raw water turbidimeter
- Pressure/vacuum transmitter

Grab samples to measure raw water turbidity may be used in place of on-line turbidimeters for water sources with very consistent raw water turbidity.

Automation

A wide range of automation options is available for filtration facilities. At a minimum, the water treatment facility should shut down automatically before the filtered water turbidity exceeds the allowable level of 1.0 NTU.

DE filtration facilities contain more mechanical equipment than slow sand filters so a greater range of automation is suitable for these facilities. Automation can range from simply switching the filter from filter mode to recycle mode to complete automation of filter flushing and filter pre-coating. Automation should be designed to match the available operator skill and capability. When selecting automation, the designer and owner should consider that increased automation increases the maintenance required to keep the automation functional.

Alarms

The control system for a water filtration facility should generate an alarm whenever specific conditions occur. Recommended alarm conditions for DE filtration are included in Table 4-4.

Table 4-4

Recommended Alarms

Instrument	Setpoint
High Raw Water Turbidity[1]	10.0 NTU
High Individual Filter Turbidity	1.0 NTU

High Combined Filter Turbidity	1.0 NTU
High Differential Pressure / Vacuum[2]	Varies
Filter Low Level Alarm[3]	-
Filter Pump Fail	-
Body Feed Tank Low Level	-
Loss of Commercial Power	-
Low Chlorine Residual Alarm	Below normal entry point concentration but not less than 0.2 mg/L

Notes: 1. The high raw water turbidity alarm may not be necessary on raw water sources with very consistent turbidity.
2. The high differential pressure and filter high level alarm may not be necessary on DE pressure filters that automatically flush and re-coat.
3. The filter low level alarm is only necessary on vacuum DE filters.

Telemetry

For water treatment facilities that will be operated for portions of the day without an operator present, some level of telemetry is required. Telemetry can consist of radio or telephone equipment that sends signals indicating plant status. Generally, radio telemetry equipment has a higher capital cost than telephone telemetry when telephone service is available at or near the site. Telephone telemetry can be more expensive to operate that radio telemetry due to the monthly telephone charges. Underground telephone lines can be more reliable than overhead lines or radio telemetry.

The type of signals transmitted by telemetry can vary significantly depending on the level of automation desired. At a minimum, a common water treatment plant alarm should be sent out when any of the alarms indicated in Table 4-4 occur. If desired by the operator, individual telemetry signals can be sent out for specific alarms.

Diatomaceous Earth Filter Operations and Maintenance

This section provides a general overview of operations and maintenance requirements for DE water filtration facilities. More specific operations and maintenance requirements should be generated as part of the design process for a facility. A detailed operations and maintenance manual should be produced as part of the project once specific equipment information is obtained from each equipment vendor. The final operations and maintenance manual should include the information required in Washington Administrative Code (WAC) 246-290-654 (4)(b)(ii) and (5).

Operator Certification

All drinking water treatment facilities require an operator certified in accordance with Washington State Department of Health (WSDOH) requirements. Operator certification requirements are specified in WAC 246-

292-060. The WSDOH determines the required level of certification for each treatment facility. The level of certification required is based on a point system that accounts for the size of the facility and the complexity of the treatment processes employed.

Most DE filtration facilities will require a lead operator with a WTPO1 or WTPO2 certification due to the chemical addition and mechanical equipment used in these facilities.

Assistant or back-up operators who operate a filtration plant when the lead operator is not present must hold a minimum certification of one level below that required for the lead operator.

Staffing Requirements

Staffing requirements will be dependent upon the size of a facility, the treatment processes that it employs, and its level of automation. Table 4-5 summarizes the level of staffing provided at the DE filtration facilities surveyed for this manual.

Table 4-5

Diatomaceous Earth Water Treatment Plant Staffing

Facility	Rated Capacity	Daily Staffing	Labor to Flush and Pre-Coat
1	50 gpm	15 min / day	30 minutes
2	50 gpm	30 min / day	1 – 3 hours
3	90 gpm	30 min / day	3 hours
4	100 gpm	1 hr / day	3 – 4 hours
5	160 gpm	2 hr / day	30 minutes
6	1,800 gpm	2 hr / day	2 hours
7	14,000 gpm	9 hr / day	3 – 4 hours

DE filtration is a relatively simple filtration technology; however, it does include equipment and processes that require operator attention to properly operate and maintain. The following paragraphs describe the operation and maintenance tasks associated with DE filtration.

Daily Operations Tasks

The operation of DE filtration plants is divided into three major modes: pre-coat, filtration, and flush. The pre-coat and flush modes can range from completely manual to completely automatic. Filtration mode operation is predominantly automatic with little operator intervention.

Pre-coat

Pre-coating a filter is required to begin each filter run. Depending on the level of automation designed into the equipment, the process can involve little or significant operator attention. Typical activities to pre-coat a filter include the following:

1. Fill the pre-coat tank with water.
2. Start the pre-coat mixer.
3. Add the desired amount of pre-coat material. This is generally 0.15 - 0.20 lb/ft^2 of filter surface area.
4. Fill the filter to be pre-coated with finished water.
5. Start the filter pump recycling water through the filter.
6. Transfer the contents of the pre-coat tank to filter being pre-coated. This can be done using a pre-coat transfer pump or opening a valve to allow slurry into the suction side of the filter pump.
7. Continue recycling until a certain filtered water turbidity criteria is met. This criteria is typically 0.1-0.5 NTU depending on normal filter operating conditions.

8. Prior to entering filtration mode, a short period (1-5 minutes) of filter-to-waste is recommended in order to pass any short turbidity spikes caused by excess DE in the filter piping or sample lines.

Filtration mode

When a filter is in filtration mode, the operator's activities primarily consist of monitoring and optimizing its operation. The following tasks are typically performed by the operator daily during the course of a filter run:

1. Check plant production in comparison to daily water demands. Adjust flow rate as necessary.
2. Check filter headloss.
3. Check raw and finished water turbidity.
4. Visually inspect the filter cake for cracks, pinholes, or other defects. (This does not apply to horizontal plate filters)
5. Check operation of the filter pump.
6. Check operation of body feed equipment including metering pump and mixer.
7. Adjust the body feed rate with the metering pump as necessary. Typical body feed rates range from 1 – 20 mg/L.
8. If the body feed tank level is low, create new body feed slurry by adding the required amount of DE and filling the tank with water.

Flush

When a filter reaches terminal headloss, the filter should be flushed. Terminal headloss for pressure filters ranges from 15 psi to 50 psi. Terminal headloss for vacuum filters ranges from 10 in. Hg to 15 in. Hg. Filter runs can range from several hours to several weeks depending on water quality, body feed rate, and design of the system. Typical steps to flush a filter include the following:

1. Take the filter out of service by putting it in recycle mode.
2. For vacuum filters, stop the filter pump and allow the vacuum to release from the filter elements (5 – 15) minutes. For pressure filters, open the flush water valve.
3. Open the filter drain valve to allow water and solids to leave the system.
4. Wash down the filter elements to remove spent filter cake. This will require manual labor for vacuum filters and will be automatic for most pressure filters.
5. When clean, visually inspect the filter septa and connectors for damage or defects. For pressure filters, this may be done less frequently due to labor required to open the pressure vessel for inspection.
6. The filter is now ready for pre-coat.

For horizontal plate filters, the flush process is replaced by a dewatering process in which compressed air is blown through the filter cake once the filter is isolated. The dewatered filter cake is then removed from the filter plates and new filter septa are placed on the plates.

Daily SWTR Compliance Monitoring and Reporting

Surface Water Treatment Rule (SWTR) compliance must be determined daily by the water treatment plant operator. Each day, the operator must review the turbidity records from the previous day to determine if turbidity exceeded 1.0 NTU or 5.0 NTU. Turbidity must be below 1.0 NTU in 95% of the measurements taken for a month and below 5.0 NTU in all measurements taken. The filtration performance must be recorded daily on WSDOH filtration report forms.

In addition to verifying daily filtration compliance, the operator must verify disinfection compliance. This is done by comparing the concentration and time (CT) that a disinfectant was in contact with filtered water to the CT required for a particular temperature and pH. The CT provided, CT required, and compliance factor must also be recorded daily on WSDOH disinfection forms. Refer to WAC 246-290-662 or contact the WSDOH Regional Engineer for more specific guidance regarding disinfection.

Regular Maintenance

Table 4-6 shows the typical regular maintenance activities and their frequency for DE filtration.

TABLE 4-6

DE Filtration Regular Maintenance Activities

Item	Activity	Frequency
Filter	Flush and Recoat Replace Filter Septa	1 day – several weeks 6 months to 5 years
DE Pre-Coat	Flush Pre-Coat Lines	Monthly
DE Body Feed	Add DE to Body Feed Tank Flush Body Feed Lines	Daily Monthly
Instrumentation	Calibrate	Monthly
Pumping Equipment	Lubricate Bearings Replace Packing Change Mechanical Seals	Yearly Yearly Every 5 Years
Emergency Generator	Exercise	Weekly

Periodic Maintenance

Periodic maintenance activities are those which may occur at any time rather than being performed on a regular schedule. Owners should be aware that these activities will be necessary and have adequate resources to perform them. Typical periodic maintenance activities for DE filtration include the following:

1. Metering pump replacement
2. Filter pump repair or replacement
3. Filter element repair or replacement
4. Slurry tank mixer repair or replacement
5. Automatic control valve repair or replacement

Safety Precautions

The primary safety precaution associated with DE filtration concerns material handling. DE can be harmful if inhaled. Appropriate measures should be taken in design and during operation to minimize operator exposure to inhaled DE. Design measures can include the use of enclosed dry feeders, placing covers on DE pre-coat and body feed tanks, and providing exhaust hoods and fans in the vicinity of DE bag unloading areas. Operational safety precautions include wearing protective goggles and appropriate dust mask or respirator during unloading activities.

The other safety concern associated with DE filtration concerns the handling of DE bags. Most small systems use 50 lb bags of DE. These bags can be awkward to lift and safely empty into tanks. DE storage and slurry tank facilities should be designed to reduce the strain caused by operators bending over to lift 50 lb bags. Lifting equipment and platforms should be designed to aid operators in emptying these bags into slurry tanks.

Common Operating Problems

Many common operating problems can be avoided with proper design and by following preventive maintenance procedures. Some of the common problems that DE plant operators experience and ways to prevent them are shown in Table 4-7.

TABLE 4-7

Common DE Filter Operating Problems

Problem	Potential Solutions
Short spikes in filtered water turbidity immediately after pre-coat.	Add filter-to-waste piping to send initial turbidity spike to waste. Extend the time of filter-to-waste operation.
Plugging of DE slurry lines.	Keep water velocities in slurry lines above 3 - 5 fps. Add periodic clean water flush to body feed lines where these velocities cannot be obtained.
Excessive wear in filter and body feed pumping components.	Use durable materials that are resistant to abrasion. Buna N is an abrasion resistant rubber material. Use heavy duty positive displacement body feed pumps.
Short filter runs.	Increase body feed rate. Add pre-treatment such as screening or pre-chlorination.
Difficult to access septa for inspection or replacement.	Add hoisting equipment above all filtration equipment to aid in operator maintenance activities.
Instrumentation, control, and telemetry issues require operator time and attention.	Automation and control equipment also requires maintenance. Consideration should be given to the capabilities of operator staff to maintain complex control equipment.

Appendix A

Literature Review

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Appendix B

Slow Sand Surveys

Washington State Department of Health
Surface Water Treament
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Slow Sand Filtration Questionairre

Date: 10/2/2002 Survey By: SLB

1. Background Information		**2. Facility Data**	
a. Facility Name	Roslyn WTP	a. Rated Capacity	1 MGD
b. Location	Roslyn, WA	b. Year Constructed	1998
c. Address		c. Why Chosen	Neighboring facilities - Cashmere High quality water source
d. Phone Number	(509) 649-3446		
e. Lead Operator	Joe Peck		
f. Years at Facility	5 years		

3. Water Quality	
a. Source	Domerie Creek
b. Watershed Characteristics	Forested, No Roads, Pristine, USFS/Plum Creek
c. Average Raw Water Turbidity (NTU)	0.1-0.5
d. Maximum Raw Water Turbidity (NTU)	5
e. Typical Finished Water Turbidity (NTU)	0.25
f. Organics (Algae, TOC)	Algae grew on filters without cover
g. Color	Little color

4. Design Information	
a. Number of Filter Units	2
b. Surface Area per Filter (sf)	4,340 SF
c. Average Filtration Rate (gpm/sf)	0.02 - 0.08
d. Maximum Filtration Rate (gpm/sf)	0.08 gpm/sf
e. Pre-Treatment	Gravel roughing filter
f. Basin Construction	Concrete
g. Sand Source	WSDOT Trinidad pit
h. Sand Effective Size (d10)	0.3 mm
I. Sand Uniformity Coefficient	2.5
j. Maximum Sand Depth (ft)	3'-4"
k. Minimum Sand Depth (ft)	1'-0"
l. Headspace (ft)	4'-10"
m. Freeboard (ft)	1'-0"
n. Filter Cover	Yes, floating HDPE coated foam (Lemna)
o. Filter Access	Ladders, jib crane, sand conveyor
p. Underdrain Type	Perforated HDPE laterals
q. Filter Level Control	Adjustable weir
r. Flow Control	Inlet-automatic butterfly valve (adjust flow)

Washington State Department of Health
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Slow Sand Filtration Questionairre

4. Design Information (cont.)	
s. Filter-to-Waste	Yes
t. Sand Removal / Cleaning Method	Scape, wheel barrow to conveyor
u. Reuse or Dispose of Sand	Dispose
v. Filter to Waste or Wash Water Disposal	Detention pond, drain to ditch
5. Operating Information	
a. Operating Staff	2
b. Hours Plant Staffed	1.5 hours/day 7 days/wk
c. Operator Certification Level	BTO/WDM1
d. Terminal Headloss	4 feet
e. Typical Filter Run Length	3+ years, Flush roughing filter twice per year
f. Time to Clean	8 hr/filter
g. Labor to Clean	3 man crew
h. Initial Ripening Time	Several months
I. Ripening Time after Cleaning	1 day
h. Criteria for Placing Filter Back in Service	Probably turbidity
I. Sand Disposal	On site
j. Common Operating Problems	1. PLC controls, 2. Matching flow to demand, 3. Radio communication problems, 4. Motor butterfly valve
6. Maintenance Information	
a. Sand Replenishment Frequency	Long time
b. Procedure for Resanding	Don't know yet
c. Special Maintenance Required	Patch cracks in filter basin
7. Cost Information	
a. Construction Cost of Treatment Facility	$1,800,000
b. Annual Operating Budget	

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Guidance Manual
Slow Sand Filtration Questionairre

Date: 10/18/2002 Survey By: SLB

1. Background Information		**2. Facility Data**	
a. Facility Name	Naselle Water Company	a. Rated Capacity	480 gpm
b. Location	Naselle, WA	b. Year Constructed	1996
c. Address	318 Knappton Rd	c. Why Chosen	
d. Phone Number	(360) 484-3515		
e. Lead Operator	Regan Wirkkala		
f. Years at Facility	5 years		

3. Water Quality	
a. Source	Lane Creek and O'Connor Creek
b. Watershed Characteristics	Tree farm, forest
c. Average Raw Water Turbidity (NTU)	0.5
d. Maximum Raw Water Turbidity (NTU)	25
e. Typical Finished Water Turbidity (NTU)	0.07
f. Organics (Algae, TOC)	Some algae (late summer only)
g. Color	None
4. Design Information	
a. Number of Filter Units	3 filters
b. Surface Area per Filter (sf)	1,600 SF
c. Average Filtration Rate (gpm/sf)	0.0375
d. Maximum Filtration Rate (gpm/sf)	0.1
e. Pre-Treatment	None
f. Basin Construction	Concrete
g. Sand Source	Lone Star Northwest
h. Sand Effective Size (d10)	0.28 mm
I. Sand Uniformity Coefficient	<2.5
j. Maximum Sand Depth (ft)	4 feet
k. Minimum Sand Depth (ft)	2 feet
l. Headspace (ft)	6 feet
m. Freeboard (ft)	5 feet
n. Filter Cover	Concrete roof
o. Filter Access	1 bay door on front and 2 roof hatches/filter
p. Underdrain Type	Slotted 6" PVC
q. Filter Level Control	Piping and valve
r. Flow Control	Meter and valve combination

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4. Design Information (cont.)	
s. Filter-to-Waste	Yes
t. Sand Removal / Cleaning Method	Scraping
u. Reuse or Dispose of Sand	Dispose
v. Filter to Waste or Wash Water Disposal	Fiter to waste
5. Operating Information	
a. Operating Staff	1 full time and 2 part time
b. Hours Plant Staffed	3 hours per day
c. Operator Certification Level	BTO
d. Terminal Headloss	4 feet
e. Typical Filter Run Length	5 to 6 months
f. Time to Clean	4 hours
g. Labor to Clean	12 hours (3 man crew)
h. Initial Ripening Time	30 days
I. Ripening Time after Cleaning	1 to 2 days
h. Criteria for Placing Filter Back in Service	When filter achieves turbidity level before cleaning
I. Sand Disposal	Stock piled outside
j. Common Operating Problems	
6. Maintenance Information	
a. Sand Replenishment Frequency	5 years down 16"
b. Procedure for Resanding	Conveyor belts and man power
c. Special Maintenance Required	
7. Cost Information	
a. Construction Cost of Treatment Facility	$585,000
b. Annual Operating Budget	$30,000

Washington State Department of Health
Surface Water Treament
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Slow Sand Filtration Questionairre

Date: 10/10/02 Survey By: SLB

1. Background Information		**2. Facility Data**	
a. Facility Name	Lake Margaret	a. Rated Capacity	80 gpm
b. Location	Duvall, WA	b. Year Constructed	1996
c. Address		c. Why Chosen	Reliability, ample water supply, ease of operation
d. Phone Number	(360) 788-4923		
e. Lead Operator	Dexter Burlingame		
f. Years at Facility	6 years		

3. Water Quality	
a. Source	44 acre lake - Lake Margaret
b. Watershed Characteristics	2 stream feed lake bed springs
c. Average Raw Water Turbidity (NTU)	1.3
d. Maximum Raw Water Turbidity (NTU)	2.5
e. Typical Finished Water Turbidity (NTU)	0.10-0.20
f. Organics (Algae, TOC)	TOC 5mg/L Chlorophyll 1-40 mg/L
g. Color	15-20

4. Design Information	
a. Number of Filter Units	3
b. Surface Area per Filter (sf)	450
c. Average Filtration Rate (gpm/sf)	0.015
d. Maximum Filtration Rate (gpm/sf)	0.02
e. Pre-Treatment	3 stage gravel roughing filter, ozone
f. Basin Construction	Concrete
g. Sand Source	Local - Cadman
h. Sand Effective Size (d10)	0.15mm to 0.30 mm
I. Sand Uniformity Coefficient	<3.0
j. Maximum Sand Depth (ft)	3
k. Minimum Sand Depth (ft)	2
l. Headspace (ft)	6 to 15
m. Freeboard (ft)	2.5
n. Filter Cover	Yes
o. Filter Access	Above water hatchway
p. Underdrain Type	Slotted PVC pipe
q. Filter Level Control	Manual
r. Flow Control	Set by operator

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4. Design Information (cont.)	
s. Filter-to-Waste	Yes
t. Sand Removal / Cleaning Method	Scrape manually, shovel out
u. Reuse or Dispose of Sand	Dispose
v. Filter to Waste or Wash Water Disposal	Sedimentation pond
5. Operating Information	
a. Operating Staff	2
b. Hours Plant Staffed	1.5-2 hr daily, on-call
c. Operator Certification Level	BTO
d. Terminal Headloss	Approx. 30-inches
e. Typical Filter Run Length	7-9 months
f. Time to Clean	3-4 hrs
g. Labor to Clean	3-4 hrs
h. Initial Ripinging Time	15 days
I. Ripening Time after Cleaning	48 hours allowed
h. Criteria for Placing Filter Back in Service	Turbidity < 0.5 NTU
I. Sand Disposal	
j. Common Operating Problems	Minimal - Pump maintenance
6. Maintenance Information	
a. Sand Replenishment Frequency	Estimated 10-12 years
b. Procedure for Resanding	Standard protocol - Trench and reverse
c. Special Maintenance Required	Instrument calibration Roughing filter flushing
7. Cost Information	
a. Construction Cost of Treatment Facility	$750,000 incl. 18 month of pilot testing
b. Annual Operating Budget	$45,000

Washington State Department of Health
Surface Water Treatment
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Slow Sand Filtration Questionnaire

Date: 10/24/2002 Survey By: SLB

1. Background Information		**2. Facility Data**	
a. Facility Name	Town of Eatonville	a. Rated Capacity	520 gpm
b. Location	Eatonville	b. Year Constructed	1982
c. Address	PO Box 309	c. Why Chosen	Not sure. It has not been very effective
d. Phone Number	(360) 839-6110		
e. Lead Operator	Mike Tiller		
f. Years at Facility	4 years		

3. Water Quality	
a. Source	Mashell River
b. Watershed Characteristics	High turbidity stream
c. Average Raw Water Turbidity (NTU)	<3.0
d. Maximum Raw Water Turbidity (NTU)	>50 NTU (not operated above 3 NTU)
e. Typical Finished Water Turbidity (NTU)	0.4
f. Organics (Algae, TOC)	
g. Color	Yes, does not remove

4. Design Information	
a. Number of Filter Units	4 Filters
b. Surface Area per Filter (sf)	1,300 sf
c. Average Filtration Rate (gpm/sf)	0.024
d. Maximum Filtration Rate (gpm/sf)	0.034
e. Pre-Treatment	None
f. Basin Construction	Concrete
g. Sand Source	Randles Quarry
h. Sand Effective Size (d10)	
I. Sand Uniformity Coefficient	
j. Maximum Sand Depth (ft)	4 feet
k. Minimum Sand Depth (ft)	3 feet
l. Headspace (ft)	
m. Freeboard (ft)	3 feet
n. Filter Cover	Yes, wood frame with composition shingles
o. Filter Access	Roof doors (3)
p. Underdrain Type	PVC pipe
q. Filter Level Control	End overflow
r. Flow Control	Inlet, with raw water gate valve

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4. Design Information (cont.)	
s. Filter-to-Waste	Yes
t. Sand Removal / Cleaning Method	By hand
u. Reuse or Dispose of Sand	Dispose
v. Filter to Waste or Wash Water Disposal	
5. Operating Information	
a. Operating Staff	1
b. Hours Plant Staffed	2 hrs /day
c. Operator Certification Level	BTO or WTPO1
d. Terminal Headloss	3 feet
e. Typical Filter Run Length	varies, 1 MG to several MG
f. Time to Clean	5 hours per filter
g. Labor to Clean	4 men
h. Initial Ripening Time	
I. Ripening Time after Cleaning	1-2 weeks
h. Criteria for Placing Filter Back in Service	Lack of water
I. Sand Disposal	Bedding for pipe projects
j. Common Operating Problems	High raw water turbidity. More work than the amount of water you get
6. Maintenance Information	
a. Sand Replenishment Frequency	Every 4 years
b. Procedure for Resanding	Hand labor
c. Special Maintenance Required	
7. Cost Information	
a. Construction Cost of Treatment Facility	
b. Annual Operating Budget	

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Slow Sand Filtration Questionairre

Date:	10/9/2002	Survey By:	SLB
1. Background Information		**2. Facility Data**	
a. Facility Name	Doe Bay Water Users	a. Rated Capacity	2 Filters each @ 70 gpm
b. Location	Orcas Island	b. Year Constructed	1988
c. Address	PO Box 28	c. Why Chosen	Reliable and met their water quality needs
d. Phone Number	(360) 376-4990		
e. Lead Operator	Ted Wixom		
f. Years at Facility	6 years		

3. Water Quality	
a. Source	Mountain lake
b. Watershed Characteristics	State park, all natural
c. Average Raw Water Turbidity (NTU)	0.36
d. Maximum Raw Water Turbidity (NTU)	1.68
e. Typical Finished Water Turbidity (NTU)	0.5
f. Organics (Algae, TOC)	no
g. Color	no
4. Design Information	
a. Number of Filter Units	2 Filters
b. Surface Area per Filter (sf)	700 SF
c. Average Filtration Rate (gpm/sf)	0.027
d. Maximum Filtration Rate (gpm/sf)	0.07 Filter #1 / 0.06 Filter #2
e. Pre-Treatment	No
f. Basin Construction	Concrete circle
g. Sand Source	Lonestar
h. Sand Effective Size (d10)	>.028 and < 0.8 mm
I. Sand Uniformity Coefficient	2.4
j. Maximum Sand Depth (ft)	4 feet
k. Minimum Sand Depth (ft)	2 feet
l. Headspace (ft)	5.2 feet
m. Freeboard (ft)	0.3 feet
n. Filter Cover	No
o. Filter Access	Ladder
p. Underdrain Type	Schedule 40 PVC with 1/2" holes
q. Filter Level Control	Cla-val altitude valve
r. Flow Control	Outlet, manual butterfly valve

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4. Design Information (cont.)	
s. Filter-to-Waste	Yes
t. Sand Removal / Cleaning Method	Remove with 5 gal bucket
u. Reuse or Dispose of Sand	Reuse after washing in cone
v. Filter to Waste or Wash Water Disposal	Sedimentation basin
5. Operating Information	
a. Operating Staff	Three operators = 1 1/4 FTE
b. Hours Plant Staffed	15 min/day 7 day/week
c. Operator Certification Level	WTPO2 and WTPO1
d. Terminal Headloss	12" on Filter #1 and 4.1" on Filter #2
e. Typical Filter Run Length	6 months
f. Time to Clean	1 day
g. Labor to Clean	18 man hours
h. Initial Ripinging Time	
I. Ripening Time after Cleaning	3 to 4 days
h. Criteria for Placing Filter Back in Service	Turbidity < 1.0 NTU
I. Sand Disposal	Reuse sand
j. Common Operating Problems	Corrosion of metal piping in filter. The filters sit above ground, so accessiblity is not easy. There is no big center drain when you want to harrow.
6. Maintenance Information	
a. Sand Replenishment Frequency	N/A
b. Procedure for Resanding	N/A
c. Special Maintenance Required	None
7. Cost Information	
a. Construction Cost of Treatment Facility	$207,000
b. Annual Operating Budget	$105,000 year on entire system

Washington State Department of Health
Surface Water Treatment
Guidance Manual
Slow Sand Filtration Questionnaire

Date: 10/10/2002 Survey By: SLB

1. Background Information		**2. Facility Data**	
a. Facility Name	Cashmere WTP	a. Rated Capacity	3.4 MGD
b. Location	Cashmere, WA	b. Year Constructed	1990
c. Address	Museum Rd	c. Why Chosen	
d. Phone Number	(509) 782-3513		
e. Lead Operator	Charles Cruickshank		
f. Years at Facility	13 years		

3. Water Quality	
a. Source	Wenatchee River
b. Watershed Characteristics	
c. Average Raw Water Turbidity (NTU)	<1.0
d. Maximum Raw Water Turbidity (NTU)	>30
e. Typical Finished Water Turbidity (NTU)	0.25
f. Organics (Algae, TOC)	
g. Color	

4. Design Information	
a. Number of Filter Units	2
b. Surface Area per Filter (sf)	1/2 acre
c. Average Filtration Rate (gpm/sf)	0.1425
d. Maximum Filtration Rate (gpm/sf)	0.06
e. Pre-Treatment	Pre-chlorination
f. Basin Construction	Hypalon lined earthen cells
g. Sand Source	WSDOT Trinidad Pit
h. Sand Effective Size (d10)	0.2 mm
I. Sand Uniformity Coefficient	2.25
j. Maximum Sand Depth (ft)	3.5 ft
k. Minimum Sand Depth (ft)	2.0 ft
l. Headspace (ft)	5.5 ft
m. Freeboard (ft)	2.0 ft
n. Filter Cover	None
o. Filter Access	360 degrees - sloped edges
p. Underdrain Type	PVC
q. Filter Level Control	Annual inspections
r. Flow Control	Limitorque motor actuated valve

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4. Design Information (cont.)	
s. Filter-to-Waste	Yes
t. Sand Removal / Cleaning Method	Manual scraping/shoveling/brooming
u. Reuse or Dispose of Sand	Dispose
v. Filter to Waste or Wash Water Disposal	To river
5. Operating Information	
a. Operating Staff	5 personnel (part time)
b. Hours Plant Staffed	M-F 7-4 and Sat/Sun 1 hour each
c. Operator Certification Level	WTPO 1
d. Terminal Headloss	>2 ft
e. Typical Filter Run Length	1 year
f. Time to Clean	Usually spring
g. Labor to Clean	25-100 man hours per cell
h. Initial Ripening Time	1-2 months
I. Ripening Time after Cleaning	1-2 weeks
h. Criteria for Placing Filter Back in Service	Coliform count <2/100ml
I. Sand Disposal	Used for other purposes such as pipe bedding
j. Common Operating Problems	Frozen - ice plugging intake screen; various river conditions, which shorten filter life.
6. Maintenance Information	
a. Sand Replenishment Frequency	Have not resanded yet, projected 2010
b. Procedure for Resanding	Replenish one cell at a time. Winrow remaining sand and them cover over new sand to aid in ripening
c. Special Maintenance Required	Critical to monitor intake water quality in order to achieve 1 year filter runs.
7. Cost Information	
a. Construction Cost of Treatment Facility	$1,300,000
b. Annual Operating Budget	$143,000

Appendix C

Diatomaceous Earth Surveys

Washington State Department of Health
Surface Water Treament
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Diatomaceous Earth Filtration Questionairre

Date: 10/2/2002 Survey By: MBJ

1. Background Information		**2. Facility Data**	
a. Facility Name	Rock Creek Water	a. Rated Capacity	100 gpm
b. Location	Grande Ronde, OR	b. Year Constructed	March 2002
c. Address	PO Box 123	c. Why Chosen	Engineer Recommended. Lack of discharge options.
d. Phone Number	503-879-5497		
e. Lead Operator	Leonard Fischer		
f. Years at Facility	1.5		

3. Water Quality	
a. Source	Open spring in ravine
b. Watershed Characteristics	Rocky, forested. Logging doesn't impact water quality significantly. A raw water settling pond is located upstream.
c. Average Raw Water Turbidity (NTU)	1
d. Maximum Raw Water Turbidity (NTU)	10 NTU (Shutdown at 4 NTU)
e. Typical Finished Water Turbidity (NTU)	0.06 - 0.1
f. Organics (Algae, TOC)	Algae in settling pond in summer.
g. Color	None

4. Design Information	
a. Manufacturer	Schneider / Horizontal Plate
b. Number of Filter Units	2
c. Surface Area per Filter (sf)	60
d. Average Filtration Rate (gpm/sf)	0.2
e. Maximum Filtration Rate (gpm/sf)	0.5
f. Pre-Treatment	Settling Pond (Nylon screen on intake)
g. Filter Pump - Constant or Variable Speed	Variable speed
h. Continuous Filtration or Intermittent w/ Recycl	Continuous (No recycle when stopped)
I. Power Failure Operation	Pump stops. Pump recirculates water when power returns.
j. Cross Connection Control on Recycle	None
k. Filter-to-Waste Piping	Yes. It was added as an afterthought due to foul odor if filter set for more than 1 day.
l. Type of Pre-Coat Pump	Endsuction centrifugal pump (raw water pump)
m. Pre-Coat Pipe Type, Size and Flowrate	
n. Type of Body Feed Pump	Air actuated piston pump
o. Body Feed Pipe Type, Size and Flowrate	1/2" SS 0.5 - 1 gph
p. DE Slurry Valve Type	Diaphragm valves

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4. Design Information (cont.)	
q. DE Feed Equipment	None. Add 50 lb bags
r. Cake Removal Method	Filter dewaters DE cake. Tip it into a dumpster.
s. Waste Cake Disposal	Land applies on site (smells)
t. Wash Water Disposal	Back to creek
5. Operating Information	
a. Operating Staff	2
b. Hours Plant Staffed	1 hr/day
c. Operator Certification Level	Level 2
d. Typical Filter Run Length	10 days (200,000 gallons)
e. Terminal Headloss	50 psi
f. Diatomaceous Earth Grade Used	Celite 512
g. Other Grades Used	No
h. Other Pre-Coat Media Used	No
I. Time to Flush Filter	2 people, 2 hours
j. Time to Pre-Coat	1 - 2 hours
k. Criteria for Putting Filter in Service	< 0.5 NTU
l. Pre-Coat Rate (lb/sf) and (gpm)	0.15 lb/sf 1 gpm/sf
m. Body Feed Rate (mg/L)	4
n. Diatomaceous Earth Disposal	Land applies on site (smells)
o. Common Operating Problems	Mixer used to turn off allowing DE to settle in slurry tank. DE slurry check valves plugged. Added filter to waste to deal with odor problem. On re-start, filter must be recycled to stabilize filter
6. Maintenance Information	
a. Septum Replacement Frequency	Each run
b. Body Feed Pump Replacement Frequency	Replace check valves and o-rings
c. Special Maintenance Required	Rotate pumps
7. Cost Information	
a. Construction Cost of Treatment Facility	$240,000
b. Annual Operating Budget	?

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Surface Water Treament
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Diatomaceous Earth Filtration Questionairre

Date: 10/8/2002 Survey By: MBJ

1. Background Information		**2. Facility Data**	
a. Facility Name	Hearst Castle	a. Rated Capacity	30 gpm / 50 gpm
b. Location	San Simeon, CA	b. Year Constructed	1996
c. Address	750 Hearst Castle Road	c. Why Chosen	
d. Phone Number	805-927-2122		
e. Lead Operator	Earl Moon		
f. Years at Facility	6		

3. Water Quality	
a. Source	Artesian springs that feed 1.5 MG covered concrete raw water reservoir
b. Watershed Characteristics	Forested? Not sure where springs are from
c. Average Raw Water Turbidity (NTU)	0.2
d. Maximum Raw Water Turbidity (NTU)	2
e. Typical Finished Water Turbidity (NTU)	0.05 - 0.1
f. Organics (Algae, TOC)	Not much
g. Color	Very little
4. Design Information	
a. Manufacturer / Type	Schneider / Horizontal Plate
b. Number of Filter Units	2 (1-30 gpm and 1-50 gpm)
c. Surface Area per Filter (sf)	40 sf and 60 sf
d. Average Filtration Rate (gpm/sf)	0.75 and 1
e. Maximum Filtration Rate (gpm/sf)	0.75 and 1
f. Pre-Treatment	Settling and polymer addition (0.2 mg/L of CatflocTC)
g. Filter Pump - Constant or Variable Speed	Constant Speed
h. Continuous Filtration or Intermittent w/ Recycle	Intermittent. Pump turns off when not in use. Filter recycles each time it turns back on.
I. Power Failure Operation	Pump turns off. Filter recycles when it restarts.
j. Cross Connection Control on Recycle	None
k. Filter-to-Waste Piping	No
l. Type of Pre-Coat Pump	End suction centrifugal pump. Uses raw water pump.
m. Pre-Coat Pipe Type, Size and Flowrate	?
n. Type of Body Feed Pump	Plastomatic piston with Buna O-rings
o. Body Feed Pipe Type, Size and Flowrate	3/8" PE and 1/4" SS tubing 0.6 gph

4. Design Information (cont.)	
p. DE Slurry Valve Type	Brass ball valves
q. DE Feed Equipment	None. Add 50 lb bags by hand
r. Cake Removal Method	Cake is dewatered on filter unit. Plates are dumped into hopper.
s. Waste Cake Disposal	Landfill and gardner use on rose beds
t. Wash Water Disposal	Sewer
5. Operating Information	
a. Operating Staff	4
b. Hours Plant Staffed	1/2 hr per day, 1-3 hours on flush days
c. Operator Certification Level	Level 2
d. Typical Filter Run Length	8 hours - 7 days
e. Terminal Headloss	42 - 46 psi
f. Diatomaceous Earth Grade Used	Calcite FP-2
g. Other Grades Used	Tried others
h. Other Pre-Coat Media Used	No
I. Time to Flush Filter	1 hour
j. Time to Pre-Coat	1 hour +
k. Criteria for Putting Filter in Service	Turbidity <0.2 NTU
l. Pre-Coat Rate (lb/sf) and (gpm.sf)	0.1 lb/sf 1 gpm/sf
m. Body Feed Rate (mg/L)	5 mg/L
n. Diatomaceous Earth Disposal	Landfill and gardens
o. Common Operating Problems	LMI diaphragm metering pump wore out quickly. Body feed lines have plugged. Air valves have malfunctioned.
6. Maintenance Information	
a. Septum Replacement Frequency	Each filter run
b. Body Feed Pump Replacement Frequency	Not since replaced LMI
c. Special Maintenance Required	Raw water pump wear rings and impellers must be replaced due to wear from DE.
7. Cost Information	
a. Construction Cost of Treatment Facility	
b. Annual Operating Budget	

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Diatomaceous Earth Filtration Questionairre

Date: 10/1/2002 Survey By: MBJ

1. Background Information		**2. Facility Data**	
a. Facility Name	Kalama DWTF	a. Rated Capacity	2.6 MGD
b. Location	Kalama, WA	b. Year Constructed	2002
c. Address	PO Box 1007	c. Why Chosen	Lifecycle cost analysis. High quality water source. Ease of operation.
d. Phone Number	360-673-3706		
e. Lead Operator	Carl McCrary		
f. Years at Facility	0.25		

3. Water Quality	
a. Source	Ranney Well Collector below the Kalama River
b. Watershed Characteristics	Forested hills.
c. Average Raw Water Turbidity (NTU)	0.2 - 0.6 NTU
d. Maximum Raw Water Turbidity (NTU)	20 NTU
e. Typical Finished Water Turbidity (NTU)	0.1 NTU
f. Organics (Algae, TOC)	1 - 2 mg/L TOC, no algae
g. Color	Little

4. Design Information	
a. Manufacturer / Type	Separmatic / Vacuum
b. Number of Filter Units	2
b. Surface Area per Filter (sf)	900 sf
c. Average Filtration Rate (gpm/sf)	0.8 gpm/sf
d. Maximum Filtration Rate (gpm/sf)	1.0 gpm/sf
d. Pre-Treatment	None
e. Filter Pump - Constant or Variable Speed	Variable Speed
f. Continuous Filtration or Intermittent w/ Recycl	Intermittent w/ Recycle
g. Power Failure Operation	Standby generator and UPS on one filter.
h. Cross Connection Control on Recycle	Yes, siphon break on submerged recycle line
I. Filter-to-Waste Piping	Yes
j. Type of Pre-Coat Pump	Fiberglass end suction centrifugal
k. Pre-Coat Pipe Type, Size and Flowrate	1 1/2" Sched. 80 PVC 40-50 gpm
l. Type of Body Feed Pump	Tubular Diaphragm
m. Body Feed Pipe Type, Size and Flowrate	1/2" Sched. 80 PVC 10 gph
n. DE Slurry Valve Type	PVC ball valve
o. DE Feed Equipment	1000 lb bulk bag volumetric feeder
p. Cake Removal Method	Spray wash bars and manual hose down

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Diatomaceous Earth Filtration Questionairre

4. Design Information (cont.)	
q. Waste Cake Disposal	Settling basin then disposed on site
r. Wash Water Disposal	Settling basin then returned to the Kalama River
5. Operating Information	
a. Operating Staff	6
b. Hours Plant Staffed	1-2 hr per day, 3-4 hours on pre-coat day
c. Operator Certification Level	2
d. Typical Filter Run Length	3-6 days
e. Terminal Headloss	10.5 in. Hg
f. Diatomaceous Earth Grade Used	Celite 535
g. Other Grades Used	Kenite 1000, Eagle Picher FW 50
h. Other Pre-Coat Media Used	Cellulose fiber used in the pilot study
I. Time to Flush Filter	30 min - 1 hr
j. Time to Pre-Coat	1 - 1.5 hr
k. Criteria for Putting Filter in Service	Turbidity less than 0.5 NTU
l. Pre-Coat Rate (lb/sf) and (gpm/sf)	0.17 lb/sf, 1.0 gpm/sf
m. Body Feed Rate (mg/L)	10 mg/L
n. Diatomaceous Earth Disposal	On-site
o. Common Operating Problems	Erratic body feed due to wear on body feed pump backpressure valves. Body feed line plugged once. Some short filter runs.
6. Maintenance Information	
a. Septum Replacement Frequency	?
b. Body Feed Pump Replacement Frequency	?
c. Special Maintenance Required	Body feed backpressure valve seats must be replaced every 3 months.
7. Cost Information	
a. Construction Cost of Treatment Facility	$3.8 Million
b. Annual Operating Budget	$60,000 / yr

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Date:	10/11/2002	Survey By:	MBJ
1. Background Information		**2. Facility Data**	
a. Facility Name	Westlake	a. Rated Capacity	20 MGD
b. Location	Calabasas, CA	b. Year Constructed	1989
c. Address	4232 Las Virgenes Rd	c. Why Chosen	High quality raw water. Easiest to maintain seasonally
d. Phone Number	818-251-2370		
e. Lead Operator	Steve Jackson		
f. Years at Facility	1994		

3. Water Quality	
a. Source	Open reservoir storing municipal water (Seasonal)
b. Watershed Characteristics	Protected open reservoir. Steep dry hills w/ shrubs.
c. Average Raw Water Turbidity (NTU)	0.5 - 1.0
d. Maximum Raw Water Turbidity (NTU)	5.0 - 7.0
e. Typical Finished Water Turbidity (NTU)	0.05 - 0.3
f. Organics (Algae, TOC)	Significant algae
g. Color	Not much <5 SCU
4. Design Information	
a. Manufacturer / Type	Westfall / Vacuum
b. Number of Filter Units	10
c. Surface Area per Filter (sf)	1,290
d. Average Filtration Rate (gpm/sf)	0.6
e. Maximum Filtration Rate (gpm/sf)	1
f. Pre-Treatment	Pre-chlorination for Mn precipitation
g. Filter Pump - Constant or Variable Speed	Constant Speed w/ Control Valve
h. Continuous Filtration or Intermittent w/ Recycl	Intermittent w/ Recycle
I. Power Failure Operation	Filters enter recycle. Standby generator turns on within 30 seconds. Filters remain in recycle until
j. Cross Connection Control on Recycle	No
k. Filter-to-Waste Piping	No. They wish they did to pass short DE spike at start-up.
l. Type of Pre-Coat Pump	Goulds slurry pump
m. Pre-Coat Pipe Type, Size and Flowrate	3" Sched. 80 PVC, 125 gpm
n. Type of Body Feed Pump	Dry Feed Eductor System
o. Body Feed Pipe Type, Size and Flowrate	3/4" Sched. 80 PVC, 5-10 gpm
p. DE Slurry Valve Type	PVC Ball Valves
q. DE Feed Equipment	1,000 lb Bulk Bag Dry Feeder

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4. Design Information (cont.)	
r. Cake Removal Method	Oscillating spray bars and manual hose down
s. Waste Cake Disposal	Washwater goes to an agitated sump. Slurry is pumped to a belt filter press for dewatering. Dewatered solids are trucked to a landfill where they are used landfill cover.
t. Wash Water Disposal	Sewer
5. Operating Information	
a. Operating Staff	2
b. Hours Plant Staffed	9 hr / day
c. Operator Certification Level	T4
d. Typical Filter Run Length	7-8 days
e. Terminal Headloss	15" Hg
f. Diatomaceous Earth Grade Used	Diacolite 735
g. Other Grades Used	They have tried many other grades
h. Other Pre-Coat Media Used	No
I. Time to Flush Filter	20 - 25 min to wash, 1 hr to inspect
j. Time to Pre-Coat	1 - 1.5 hours
k. Criteria for Putting Filter in Service	Turbidity less than 0.4 NTU
l. Pre-Coat Rate (lb/sf) and (gpm/sf)	0.15 - 0.2 lb/sf 1.3 gpm/sf
m. Body Feed Rate (mg/L)	8 - 11 mg/L
n. Diatomaceous Earth Disposal	Landfill
o. Common Operating Problems	Originally they had body feed plugging. Now they don't turn off the water through the body feed lines.
6. Maintenance Information	
a. Septum Replacement Frequency	Completely replaced in 1997. Replacing 10% yr. Replacing couplings each year.
b. Body Feed Pump Replacement Frequency	N/A
c. Special Maintenance Required	Filter pumps impellers must be replaced periodically. 1/10 years due to cavitation induced damage.
7. Cost Information	
a. Construction Cost of Treatment Facility	$8 - 26 Million
b. Annual Operating Budget	$400,000

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Date: 10/10/2002 Survey By: MBJ

1. Background Information		**2. Facility Data**	
a. Facility Name	Sunnybank Water System	a. Rated Capacity	53 gpm
b. Location	Chelan, WA	b. Year Constructed	1998
c. Address	PO Box 2326	c. Why Chosen	High quality water source. High cost of bag filters. Cryptosporidium
d. Phone Number	509-682-5212		
e. Lead Operator	John McLaughlin		
f. Years at Facility	4		

3. Water Quality	
a. Source	Lake Chelan Submersible Pump
b. Watershed Characteristics	Forested - High Recreational Use
c. Average Raw Water Turbidity (NTU)	0.7 - 1.0
d. Maximum Raw Water Turbidity (NTU)	1.5 (Summer)
e. Typical Finished Water Turbidity (NTU)	0.2 - 0.3
f. Organics (Algae, TOC)	Some particulate - not sure if organic
g. Color	None

4. Design Information	
a. Manufacturer	Blace / Pressure
b. Number of Filter Units	1
c. Surface Area per Filter (sf)	53
d. Average Filtration Rate (gpm/sf)	1
e. Maximum Filtration Rate (gpm/sf)	1
f. Pre-Treatment	Pre-chlorinate
g. Filter Pump - Constant or Variable Speed	Constant speed
h. Continuous Filtration or Intermittent w/ Recycl	Intermittent w/ Recycle
I. Power Failure Operation	Manual Backwash and Recoat
j. Cross Connection Control on Recycle	Pre-coat tank provides air gap
k. Filter-to-Waste Piping	Yes. It is used at the beginning of each run.
l. Type of Pre-Coat Pump	End suction centrifugal - cast iron
m. Pre-Coat Pipe Type, Size and Flowrate	2 1/2" CPVC 50 gpm
n. Type of Body Feed Pump	Diaphragm metering pump
o. Body Feed Pipe Type, Size and Flowrate	1/2" PE tubing
p. DE Slurry Valve Type	?
q. DE Feed Equipment	None - Use 50 lb bags w respirator and hat
r. Cake Removal Method	Automatic backwash and spraydown

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4. Design Information (cont.)	
s. Waste Cake Disposal	Settling Tank Pumped by Septic Hauler
t. Wash Water Disposal	Drain Field
5. Operating Information	
a. Operating Staff	1
b. Hours Plant Staffed	15 min/day
c. Operator Certification Level	BTO / WTPO1 / WDM1
d. Typical Filter Run Length	48 - 72 hours
e. Terminal Headloss	15 - 20 psi
f. Diatomaceous Earth Grade Used	Eagle Picher FW50
g. Other Grades Used	None
h. Other Pre-Coat Media Used	Polymer used occasionally for fines removal
I. Time to Flush Filter	2 - 5 minutes
j. Time to Pre-Coat	15 minutes
k. Criteria for Putting Filter in Service	Time
l. Pre-Coat Rate (lb/sf) and (gpm/sf)	0.15 - 0.2 lb/sf 1 gpm/sf
m. Body Feed Rate (mg/L)	None currently
n. Diatomaceous Earth Disposal	Septic Hauler
o. Common Operating Problems	Body feed pump and pipe plugging. Body feed pump is being replaced. DE feed is messy. Would like exhaust fan and hood above slurry tank. Automation problems are difficult to troubleshoot. Level sensors are too sensitive. Solenoid coils have burned out. Air compressor has
6. Maintenance Information	
a. Septum Replacement Frequency	Twice per year
b. Body Feed Pump Replacement Frequency	Replacing currently
c. Special Maintenance Required	When replacing septa, would like hoist to aid in removal of filter housings.
7. Cost Information	
a. Construction Cost of Treatment Facility	~ $50,000 for equipment
b. Annual Operating Budget	?

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Date: 10/9/2002 Survey By: MBJ

1. Background Information		**2. Facility Data**	
a. Facility Name	Crystal Mountain Resort	a. Rated Capacity	90 gpm
b. Location	Crystal Mountain, WA	b. Year Constructed	1983
c. Address	33914 Crystal Mtn. Blvd.	c. Why Chosen	Good performance over wide flow range. Didn't break head. Engineer recommended
d. Phone Number	360-663-3083		
e. Lead Operator	Andrew Basket		
f. Years at Facility	1.5 years		

3. Water Quality	
a. Source	Two creeks
b. Watershed Characteristics	Forested, rocky, alpine meadows
c. Average Raw Water Turbidity (NTU)	0.6
d. Maximum Raw Water Turbidity (NTU)	2.5
e. Typical Finished Water Turbidity (NTU)	0.03 - 1.0
f. Organics (Algae, TOC)	Not much
g. Color	Not much

4. Design Information	
a. Manufacturer / Type	Duriron (out of business) / Pressure
b. Number of Filter Units	1
c. Surface Area per Filter (sf)	90 sf?
d. Average Filtration Rate (gpm/sf)	0.33 - 1
e. Maximum Filtration Rate (gpm/sf)	1
f. Pre-Treatment	Self-cleaning screen (Teclean)
g. Filter Pump - Constant or Variable Speed	None - Gravity
h. Continuous Filtration or Intermittent w/ Recycl	Continuous (Filter-to-Waste when not needed)
I. Power Failure Operation	Doesn't affect due to gravity
j. Cross Connection Control on Recycle	Air gap on pre-coat tank
k. Filter-to-Waste Piping	Yes. Opens on high turbidity
l. Type of Pre-Coat Pump	Durco - end suction centrifugal
m. Pre-Coat Pipe Type, Size and Flowrate	2" Sched. 80 PVC 90 gpm?
n. Type of Body Feed Pump	LMI Diaphragm Metering Pump
o. Body Feed Pipe Type, Size and Flowrate	2" Sched. 80 PVC 48 gpd
p. DE Slurry Valve Type	Diaphragm valves - work well
q. DE Feed Equipment	None - Use 50 lb bags
r. Cake Removal Method	Air compressor, backwash, and hose cake off.

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4. Design Information (cont.)	
s. Waste Cake Disposal	Pick off plant floor and put in garbage
t. Wash Water Disposal	Back into creek
5. Operating Information	
a. Operating Staff	3 (manager, operator, helper)
b. Hours Plant Staffed	30 min/day and 3 hours on pre-coat day
c. Operator Certification Level	WTPO1
d. Typical Filter Run Length	14 - 25 days
e. Terminal Headloss	10 psi at 30 gpm and 50 psi at 90 gpm
f. Diatomaceous Earth Grade Used	Eagle Picher FW14
g. Other Grades Used	Yes, but others didn't work as well
h. Other Pre-Coat Media Used	None
I. Time to Flush Filter	20 minutes
j. Time to Pre-Coat	30 minutes
k. Criteria for Putting Filter in Service	Time
l. Pre-Coat Rate (lb/sf) and (gpm)	0.3 lb/sf and 1 gpm/sf
m. Body Feed Rate (mg/L)	4
n. Diatomaceous Earth Disposal	Garbage
o. Common Operating Problems	If the pre-filter plugs, the filter cake drops. Redundancy and bypass should be added. Filter access hatch sticks.
6. Maintenance Information	
a. Septum Replacement Frequency	Rotate leaves and pressure wash every 6 months.
b. Body Feed Pump Replacement Frequency	Replace diaphragm 1/yr
c. Special Maintenance Required	Inspect body feed pump diaphragm 1/3 months
7. Cost Information	
a. Construction Cost of Treatment Facility	$70,000 for equipment (installed by owner)
b. Annual Operating Budget	$30,000/yr (water system)

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Date: 10/8/2002 Survey By: MBJ

1. Background Information		**2. Facility Data**	
a. Facility Name	Buell Red Praire	a. Rated Capacity	160 gpm
b. Location	Sheridan, OR	b. Year Constructed	1994
c. Address	6430 Red Prairie Rd	c. Why Chosen	Capture microfines that passed through conventional
d. Phone Number	503-843-2885		
e. Lead Operator	Mark Lyon		
f. Years at Facility	7		

3. Water Quality	
a. Source	Small lake (5 acres)
b. Watershed Characteristics	Forested, protected
c. Average Raw Water Turbidity (NTU)	Winter 1-2 NTU, Summer 3-12 NTU
d. Maximum Raw Water Turbidity (NTU)	12 NTU
e. Typical Finished Water Turbidity (NTU)	0.1 - 0.7 NTU
f. Organics (Algae, TOC)	A lot of algae and organics
g. Color	Yes, PAC has reduced

4. Design Information	
a. Manufacturer	Blace / Pressure
b. Number of Filter Units	4
b. Surface Area per Filter (sf)	40
c. Average Filtration Rate (gpm/sf)	0.5 gpm/sf
d. Maximum Filtration Rate (gpm/sf)	1.0 gpm/sf
d. Pre-Treatment	Sand filter and DAF have been added
e. Filter Pump - Constant or Variable Speed	Constant with control valve
f. Continuous Filtration or Intermittent w/ Recycle	Intermittent w/ Recycle
g. Power Failure Operation	Backwash and recoat
h. Cross Connection Control on Recycle	Yes, air gap at pre-coat tank
I. Filter-to-Waste Piping	Yes
j. Type of Pre-Coat Pump	End suction centrifugal
k. Pre-Coat Pipe Type, Size and Flowrate	2" PVC and Galv.
l. Type of Body Feed Pump	Triplex plunger
m. Body Feed Pipe Type, Size and Flowrate	1/2" tubing
n. DE Slurry Valve Type	?
o. DE Feed Equipment	None. 50 lb bags
p. Cake Removal Method	Automatic backwash

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4. Design Information (cont.)	
q. Waste Cake Disposal	Settling pond used as a drying pit
r. Wash Water Disposal	Settling pond then discharge to creek
5. Operating Information	
a. Operating Staff	1
b. Hours Plant Staffed	2 - 2.5 hr/day
c. Operator Certification Level	1
d. Typical Filter Run Length	Summer 1-8 hr, winter 12 hr
e. Terminal Headloss	15 psi
f. Diatomaceous Earth Grade Used	Eagle Picher FW 50
g. Other Grades Used	FW 20 clogged, FW 80 didn't filter enough
h. Other Pre-Coat Media Used	No, add polymer to remove fines
I. Time to Flush Filter	3-5 minutes
j. Time to Pre-Coat	10 minutes
k. Criteria for Putting Filter in Service	Time
l. Pre-Coat Rate (lb/sf) and (gpm/sf)	0.12 lb/sf, 1.0 gpm/sf
m. Body Feed Rate (mg/L)	varies, 5 - 15 mg/L
n. Diatomaceous Earth Disposal	Land apply
o. Common Operating Problems	Algae significantly shortens filter runs. Microfines pass through without polymer causing high turbidity. Polymer fouls septa. LMI body feed pump wore out quickly. DE accumulates in check valve seat of new pump.
6. Maintenance Information	
a. Septum Replacement Frequency	Every 9 months
b. Body Feed Pump Replacement Frequency	Not since replace LMI
c. Special Maintenance Required	Automatic valves must be serviced periodically.
7. Cost Information	
a. Construction Cost of Treatment Facility	Insurance replacment cost = $240,000
b. Annual Operating Budget	$120,000 / yr

Appendix D

WSDOH Report Forms

Washington State Department of Health
Slow Sand Filtration Plant Monthly Report

Water System Name:	Month/Year:
County:	Report Submitted By:
Water System I.D. #:	WTPO Certification #:
Source Name: Lake Roosevelt Source #:	Signature:
Filter Surface Area:	Telephone #:

Date	Water Treated (1000 gals.)	Chlorine Used (pounds)	Filtration Rate (gpm/sf)				Head Loss (inches)				Turbidity (NTU)		Remarks (Note the following events): 1. Date when filter is off-line for scraping. 2. Date and turbidity of ripened filter being returned to service.
			Filt. 1	Filt. 2	Filt. 3	Filt. 4	Filt. 1	Filt. 2	Filt. 3	Filt. 4	Raw	Fin	
1													
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31													
Total													
Avg.													
Min.													
Max.													

Water Treatment Plant Monthly Report

Washington State Department of Health

Division of Drinking Water

Mail report to: District Engineer

Southwest Operations LD-11 PO Box 47823
Olympia Wa 98504-7823

County ____________________

System Name _______________

Source Name _______________

ID No.__________________

SO No. __________________

Reporting Month/Year ______________

Date	Water treated in 1000 gals	Total Hours of Operation	Filter washwater Total, in 1000 gals	Chemicals used							Turbidity, NTU	Finished Turbidity 4 Hour sample, NTU							No. of Samps. >0.5	Max. Fin. Turb. NTU	% NTU Reduction See Note 7	Temp. C	pH		Iron mg/L		Fluoride Residual mg/L	Remarks
				Pounds					Gallons																			
				DE Pre-coat	DE Body feed	Cellulose Fiber	Polymer	Sodium Fluoride	4.1% NaOCL	25% NaOH	Raw	1st	2nd	3rd	4th	5th	6th	Avg.				Raw	Raw	Fin	Raw	Fin	Fin	
1																												
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30																												
31																												
Total																												
Avg.																												

Total number of finished water turbidity samples analyzed for month: N =

Total number of finished water turbidity samples exceeding 0.5 NTU: E =

Satisfactory turbidity performance is 95% or greater. Performance determination: [1-(E+N)] 8 100% =

Did finished water turbidity exceed 5.0 NTU at any time during the month? No Yes If Yes, record on reverse side of this form the date and maximum turbidity for each day filtered water turbidity exceeded 5.0 NTU

Did the finished water continuous monitoring turbidimeter fail to operate more than Five (5) consecutive days during the month? No Yes

Note 1 Calculate percent turbidity reduction for each day of operation: P.T.R. = (Avg Raw NTU) - (Avg Fin NTU) * 100%
(Avg Raw NTU)

Report Submitted by:

WTPO Certificate No.:________________________

Telephone Number: ___