CHAPTER 5
WATER TREATMENT EVALUATION
BRIDGE CREEK SUPPLY

Prepared for

City of Bend, Oregon

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WATER TREATMENT EVALUATION BRIDGE CREEK SUPPLY

5.0 Executive Summary

The purpose of this technical evaluation is to provide guidance for the City of Bend (City) in selecting the appropriate treatment process for its existing Bridge Creek surface supply. The evaluation focused on treatment for two water quality scenarios:

- Existing normal range of water quality
- Water quality following a significant fire in the watershed

The alternatives for both water quality scenarios are designed to meet the requirements of the U.S. Environmental Protection Agency's (USEPA) Long Term 2 Enhanced Surface Water Treatment (LT2) Rule and all current and anticipated drinking water regulations. The capacity of the initial plant is anticipated to be 13 million gallons per day (mgd) with two future expansions of 6.5 mgd each for a build-out plant capacity of 26 mgd. This chapter presents an evaluation of four treatment alternatives that will provide the desired inactivation or removal of *Cryptosporidium* to meet the requirements of LT2. The four treatment alternatives evaluated are as follows:

- Alternative 1 – Ultraviolet (UV) Disinfection
- Alternative 2 – UV Disinfection with Pretreatment for Turbidity Reduction
- Alternative 3 - Conventional Treatment (defined as coagulation, flocculation, and sedimentation followed by granular media filtration)
- Alternative 4 - Membrane Filtration (Microfiltration [MF] or Ultrafiltration [UF]) with Pretreatment

The capital, annual operations and maintenance (O&M), and total 20-year present worth costs of the four alternative treatment systems for a 13 mgd water treatment plant (WTP) is presented below. All costs are based on 2009 dollars and are escalated to the anticipated midpoint of construction.

Table 5-1. Alternatives Cost Summary

Treatment alternative	Total capital costs, million dollars	20-year present worth of O&M costs, million dollars	Total 20-year present worth, million dollars
Alternative 1 – UV Disinfection	8.1	2.5	10.6
Alternative 2 – UV Disinfection with Pretreatment	17.3	2.5	19.8
Alternative 3 – Conventional Treatment	23.0	5.0	28.0
Alternative 4 – Membrane Filtration	22.7	6.0	28.7

Each treatment alternative was ranked with respect to the following seven evaluation criteria:

- Capital Cost
- O&M Costs
- Water Quality
- Staffing, Operability, and Automation

- Expandability
- Operational Flexibility
- Site Compatibility

Membrane filtration has the most favorable overall ranking, followed by UV disinfection without pretreatment, conventional filtration, and UV disinfection with pretreatment. Although ranked second with respect to total points, UV disinfection without pretreatment is ranked the lowest in the two most important areas, water quality risks and operational flexibility. Conventional treatment is ranked third but does have the ability to mitigate water quality risks and provides flexibility to treat varying raw water quality conditions. Membrane filtration is ranked first in the most categories including the key criteria of water quality risks and operational flexibility, primarily due to their robustness and ability to produce high quality water regardless or raw water quality conditions. UV disinfection with pretreatment is ranked lowest. Although UV disinfection with pretreatment will provide more operational flexibility than UV disinfection without pretreatment, this alternative will not mitigate against forest fires. In addition, the additional capital costs of the pretreatment process and additional pumping requirements make this alternative significantly more expensive than UV alone.

All of the alternatives assume that a new hydropower facility will be installed on the raw water pipeline at the Outback Facility. If a hydropower facility is not constructed, a UV disinfection facility will be required to meet the LT2 requirements. A UV disinfection facility without hydropower will operate by gravity similar to current conditions. The estimated capital cost of this compliance only option is $7.1 million.

5.1 Introduction

The City has contracted with Brown and Caldwell to provide engineering services for Phase 1 of a long-term water supply improvement project. One of the tasks of the engineering services is to provide a WTP Evaluation to compare UV disinfection, conventional treatment (coagulation, flocculation, and sedimentation followed by granular media filtration), membrane filtration, and UV disinfection with pretreatment for the City's Bridge Creek surface water source. Black & Veatch, as a subcontractor to Brown and Caldwell, is providing the engineering services for this WTP evaluation. The scope of the evaluation is to cover all necessary treatment components for reliable 13-mgd production and to include a 20-year net present worth analysis that includes capital and O&M costs. The report will also discuss components necessary for two future expansions of 6.5 mgd each and include recommendations for the design of the water treatment improvements.

The City's primary water source is a surface supply originating in the Bridge Creek watershed. Due to the raw water quality conditions of the Bridge Creek supply and watershed protection measures implemented by the City, the City currently meets the requirements for systems using a surface water without filtration as defined in the Safe Drinking Water Act's (SDWA) Surface Water Treatment Rules adopted by the Oregon Department of Human Services (ODHS) Drinking Water Program (Oregon Administrative Rules [OAR] 333-061-002). The City avoids filtration of the Bridge Creek supply by meeting the disinfection requirements of OAR.

In January 2006, USEPA issued the LT2 Rule, which formalized disinfection and removal requirements for *Cryptosporidium* oocysts for public water systems (PWSs) treating surface water or groundwater under the direct influence of surface water. OARs that correspond to the LT2 Rule define monitoring requirements that are used to determine the treatment category into which both filtered and unfiltered PWSs will be placed and the required level of *Cryptosporidium* disinfection credits that must be achieved. For unfiltered water systems such as the Bridge Creek water source, the *Cryptosporidium* inactivation requirements are presented in Table 5-2. These additional inactivation requirements must be achieved using chlorine dioxide, ozone or ultraviolet (UV) light.

Table 5-2. *Cryptosporidium* Inactivation Requirements for Unfiltered PWSs [1]

Average *Cryptosporidium* concentration, oocysts per liter	*Cryptosporidium* inactivation requirements
≤ 0.01	2 log [2]
> 0.01	3 log [2]

[1] OAR 333-061-0032(3)(e),(3)(f)

[2] Combined inactivation requirements for Cryptosporidium, Giardia, and virus must be achieved using a minimum of two disinfectants and each of the disinfectants must separately achieve the total inactivation required for Cryptosporidium, Giardia, or viruses [OAR 333-061-0032(3)(g)].

The addition of UV disinfection will meet the LT2 Rule requirements but will not protect against other water quality risks such as a long-term turbidity event resulting from a forest fire. In the event of a long-term turbidity event, the Bridge Creek water source would need to be shut down until the turbidity event passed. A new filtration plant will provide additional insurance against the risks of long-term turbidity events and operational flexibility to address a broader range of water quality issues and future regulations.

This chapter reviews the ability of the following four treatment alternatives to meet the LT2 Rule and to provide additional protection against a long-term turbidity event:

- Alternative 1 – UV Disinfection
- Alternative 2 – UV Disinfection with Pretreatment for Turbidity Reduction
- Alternative 3 – Conventional Treatment (Coagulation, Sedimentation, and Rapid Sand Filtration)
- Alternative 4 – Membrane Filtration (MF or UF) with Pretreatment

This chapter includes evaluation and present worth cost analyses for all major process components with an initial capacity of 13 mgd and assumes that a new bulk sodium hypochlorite system will replace the existing chlorine gas chlorination system currently used for disinfection of the Bridge Creek source. While chlorine gas systems have proven to be both safe and reliable, conversion from chlorine gas to other methods of chlorination is an ongoing trend in the water industry. Safety, security, and regulatory compliance are primary drivers of this trend.

5.2 Existing Facilities

The City's primary water source is a surface supply that originates in the Bridge Creek watershed. Due to the raw water quality conditions of the Bridge Creek supply and watershed protection measures implemented by the City, the City currently meets the requirements for systems using a surface water without filtration as defined in the SDWA's Surface Water Treatment Rules adopted by ODHS. The City avoids filtration of the Bridge Creek supply by meeting the disinfection requirements of the OAR.

Surface water flows in Bridge Creek are supplemented by the diversion of natural springs located in the Tumalo Creek drainage basin. Flows from these natural springs are collected in a pond at the Bridge Creek Diversion and transferred through two parallel pipes to a canal flowing to Bridge Creek. The Bridge Creek Intake Facility, located approximately 4 miles downstream on Bridge Creek, is the point of diversion for raw water that is routed an additional 11.5 miles to the Outback Facility site through two steel transmission pipelines. At the Outback Facility, the raw water is disinfected with chlorine and then flows through a chlorine contact basin to achieve the required disinfection contact time (CT). From the CT basin, water flows through a series of covered storage reservoirs at the Outback Facility and enters the distribution system.

The City also has an existing well supply which consists of nine well fields. The wells are used to meet supply demands during peak summer months and when the Bridge Creek raw water turbidity exceeds the City's internal turbidity limit of 1 nephelometric turbidity unit (NTU).

5.3 Summary of Raw Water Quality

Three years (2006 to 2008) of historical water quality data for both the Bridge Creek Diversion and the Bridge Creek Intake were provided by the City. Turbidity and temperature data are sampled continuously at the Bridge Creek Intake Facility. Additional water quality data are sampled monthly at both the Bridge Creek Diversion and the Bridge Creek Intake. Raw and distributed water total organic carbon (TOC) data are not available as unfiltered water systems are not required to measure or remove TOC. Table 5-3 presents a summary of raw water quality data for the Bridge Creek Diversion and the Bridge Creek Intake.

Table 5-3. Raw Water Quality Data

Water quality parameter	Unit	Minimum		Maximum		Average	
		Diversion	Intake	Diversion	Intake	Diversion	Intake
Turbidity	NTU	--	0.00	--	5.00	--	0.34
Temperature	Degrees Celsius	2.7	3.08	3.98	8.43	3.35	5.96
pH	units	6.04	6.60	7.98	7.91	6.97	7.33
Conductance	µS	19.6	29.5	36.0	38.3	32.0	35.8
Ammonia as N	mg/L [1]	0.02	0.05	0.11	0.05	0.06	0.05
Dissolved oxygen	mg/L	10.20	9.72	14.80	13.10	11.96	11.30
Chloride	mg/L	0.24	0.27	0.55	0.49	0.34	0.36
Phosphorus total	mg/L	0.01	0.02	0.13	0.08	0.05	0.04
Nitrite as N	mg/L	0.03	0.00	0.03	0.00	0.03	--
Nitrate as N	mg/L	0.01	0.01	0.32	0.11	0.10	0.06
Ortho-phosphate as P	mg/L	0.03	0.04	0.16	0.14	0.08	0.06
Sulfate as SO_4	mg/L	0.37	0.24	3.63	0.41	0.56	0.33
Fluoride	mg/L	0.05	0.05	0.28	0.28	0.15	0.14
Total coliform	coliform per 100 milliliters	--	0.0	--	0.0	--	0.0

[1] *mg/L = milligrams per liter*

5.4 Regulatory Review

Current and future regulatory requirements and raw water quality will influence the treatment process selection for the Bridge Creek source. This section provides a summary of recent and future water quality regulatory requirements that will govern treatment of the Bridge Creek source.

5.4.1 Recent Regulatory Framework

Regulations governing the quality of drinking water have evolved since the enactment of the SDWA in 1974. The pace at which new regulations are issued has increased significantly since the enactment of amendments to the SDWA in 1986 and 1996.

The Interim Enhanced Surface Water Treatment Rule (IESWTR) was promulgated in December 16, 1998 and took effect February 16, 1999. The IEWSTR primarily addressed filtered water systems, but also required watershed control of *Cryptosporidium* for unfiltered water supplies. For conventional and direct filtration systems (including those systems utilizing inline filtration), the turbidity level of representative samples of a system's filtered water (measured every 4 hours) at each individual filter must be less than or equal to 0.3 NTU in at least 95 percent of the measurements taken each month. The turbidity level of representative samples of a system's filtered water must not exceed 1 NTU at any time. Beginning December 17, 2001, systems serving at least 10,000 people must meet the turbidity requirements. Systems must maintain the results of individual filter monitoring taken under the regulation for at least 3 years. These records must be readily available for State or Health Department representatives to review during sanitary surveys or other visits.

In January 2006, the USEPA finalized two long-awaited drinking water regulations that impacted U.S. water utilities, and will require some utilities to make significant changes in their treatment systems to achieve compliance. The Stage 2 Disinfectants and Disinfection Byproducts Rule (Stage 2 DBPR), which is intended to reduce exposure to potentially harmful disinfection byproducts (DBPs) in drinking water, focuses on reducing DBPs uniformly throughout the distribution system minimizing DBP exposure for all consumers. The intent of the LT2 Rule is to provide additional protection from waterborne disease-causing microorganisms, *Cryptosporidium* in particular, a chlorine-resistant pathogen implicated in several waterborne disease outbreaks. These two rules were developed concurrently to balance trade-offs in risk between the control of pathogens and the desire to limit exposure to DBPs. For many utilities, the need to achieve higher levels of treatment to control microbial pathogens while simultaneously meeting the more stringent limits on DBPs will be challenging. Most utilities will want to consider an approach that consists of optimization of current treatment practices to maximize particulate removal and/or pathogen inactivation capabilities, coupled with the addition of further enhancements and/or new treatment technologies, if necessary, to achieve compliance. A summary of requirements under these two regulations is presented below.

5.4.1.1 LT2 Rule

The LT2 Rule builds upon earlier rules, and applies to all systems that use surface water sources or groundwater sources subject to direct surface water influence. Systems serving 10,000 or more customers must initially monitor source water for *Cryptosporidium* at least monthly over a 2-year period. For unfiltered water systems such as the Bridge Creek water source, the *Cryptosporidium* inactivation requirements, which must be achieved using chlorine dioxide, ozone or UV light, are presented in Table 5-4.

Table 5-4. *Cryptosporidium* Inactivation Requirements for Unfiltered PWSs [1]

Average *Cryptosporidium* concentration, oocysts per liter	*Cryptosporidium* inactivation requirements
≤ 0.01	2 log [2]
> 0.01	3 log [2]

[1] OAR 333-061-0032(3)(e),(3)(f)

[2]Combined inactivation requirements for Cryptosporidium, Giardia, and virus must be achieved using a minimum of two disinfectants and each of the disinfectants must separately achieve the total inactivation required for Cryptosporidium, Giardia, or viruses [OAR 333-061-0032(3)(g)].

The City serves a population of approximately 53,000 and has completed 3 years of *Cryptosporidium* monitoring. The mean *Cryptosporidium* concentration resulting from this monitoring is 0.01 oocysts per liter (refer to letter from USEPA in Appendix 5-A), thus requiring a 2.0 log inactivation of *Cryptosporidium* per the disinfection requirements of the LT2 Rule presented in Table 4. UV light has been proposed by the City as the disinfection technology to be used to attain *Cryptosporidium* inactivation credit.

Following completion of source water monitoring for *Crypotosporidium*, filtered water systems must determine a *Cryptosporidium* bin concentration for each plant for which monitoring was required. The final bin classification will determine the level of additional *Cryptosporidium* treatment over and above the levels currently provided by their conventional processes, as listed in Table 5-5. Systems can choose technologies to comply with these additional treatment requirements from a microbial toolbox of options outlined in the LT2 Rule. Microbial toolbox options include improved watershed control, improved treatment system and/or disinfection performance, and provision of additional treatment barriers.

Table 5-5. Treatment Bin Classification, Additional *Cryptosporidium* Treatment Requirements for Conventional Clarification/Filtration (including softening) [1]		
Average raw water *Cryptosporidium* concentration, oocysts per liter	**Treatment bin classification**	**Additional *Cryptosporidium* inactivation/removal requirements**
< 0.075	1	None
0.075 to < 1.0	2	1-log
1.0 to < 3.0	3	2-log [2]
≥ 3.0	4	2.5-log [2]

[1] *OAR 333-061-0032(4)(f)(F)*

[2] *At least 1-log additional treatment must be provided by bag filters, bank filtration, cartridge filters, chlorine dioxide, membranes, ozone and/or UV.*

As previously noted, the mean *Cryptosporidium* concentration in the raw water is 0.01 oocysts per liter. Should the City implement filtration of the Bridge Creek source, the City will be classified in Bin 1 under the LT2 Rule. A direct filtration or conventional treatment plant will meet the treatment requirements for Bin 1 and additional treatment (i.e., UV, ozone, etc.) for *Cryptosporidium* inactivation will not be required.

The LT2 Rule also includes new requirements for disinfection profiling/benchmarking for those systems that plan to make significant changes in disinfection practices. Following completion of the initial round of source water *Cryptosporidium* monitoring, systems that will need to make significant changes in disinfection practices in order to maintain compliance with the LT2 Rule and/or the Stage 2 DBPR will be required to develop disinfection profiles and calculate disinfection benchmarks for *Giardia lamblia* and viruses. Prior to modifying the disinfection process, systems must notify the state, and must submit the following information:

- A completed disinfection profile and benchmark for *Giardia lamblia* and viruses.
- A description of the proposed change(s) in disinfection practice.
- An analysis of how the proposed changes will affect the current level of disinfection.

Significant changes to disinfection practice are defined in the LT2 Rule as the following:

- Changes to the point of disinfection.
- Changes to the disinfectant(s) used in the treatment plant.
- Changes to the disinfection process.
- Any other modification identified by the state as a significant change to disinfection practice.

In preparing the disinfection profile and benchmark, systems must monitor disinfection conditions at least weekly for a period of 12 consecutive months to assess total log *Giardia* and virus inactivation levels. Systems must determine log *Giardia* inactivation through the entire plant based on published CT values, and log virus inactivation through the entire plant based on a state-approved protocol. Systems that have at least 1 year of existing disinfection monitoring data may utilize that information in preparing the disinfection profiles, and up to 3 years of existing data may be used in preparing the profiles (assuming that no changes in disinfection practices or source water were made during the period that the existing data were collected). The disinfection benchmark is the lowest monthly mean value (for systems with 1 year of profiling data) or the average of the lowest monthly mean values (for systems with more than 1 year of profiling data) of *Giardia* and virus log inactivation in each year of profiling data. Key dates for compliance with the LT2 Rule are summarized in Table 5-6.

Table 5-6. Key Dates for Stage 2 DBPR Compliance (Systems Serving 50,000 to 99,999 Consumers) [1]

Activity	Compliance date
Deadline for initiating source water monitoring program (month beginning)	04/01/2007
Deadline for completion of source water monitoring program	03/31/2009 [2]
Submit source water monitoring report with bin placement recommendation (month beginning) [3]	09/01/2009
Deadline for compliance with additional treatment requirements [4]	10/01/2012
Initiate second round of source water monitoring (month beginning)	10/01/2015

[1]OAR 333-061-0032(1)(F)(iii)

[2]Monitor Cryptosporidium, E.coli, and turbidity; minimum of once per month for 2 years

[3]Refer to letter to USEPA in Appendix 5-A.

[4]2-year compliance extension may be granted (with state approval) if capital improvements are required for compliance. Extension is contingent on City actually working toward compliance. Public notification is also required.

5.4.1.2 Stage 2 DBPR

Under the Stage 2 DBPR, systems will be required to maintain running annual average total trihalomethane (TTHM) concentrations of 0.080 mg/L or lower and haloacetic acid (HAA5) concentrations of 0.060 mg/L or lower at *each* compliance monitoring location within the distribution system, rather than following the current practice of averaging the results for all system monitoring locations. Initial compliance efforts will focus on identifying points within the system where DBP concentrations are typically highest, and for most systems will involve 1 year of expanded monitoring of TTHM and HAA5 concentrations. This monitoring, referred to as the Initial Distribution System Evaluation (IDSE) process, must be conducted in addition to the routine quarterly compliance monitoring required under the Stage 1 DBPR, and results will be used to select new routine compliance monitoring sites. Options under which systems can meet the IDSE provisions of the Stage 2 DBPR include collection of new system DBP data through a Standard Monitoring Program (SMP) or the use of qualifying existing system DBP monitoring data or data from extended-period simulation hydraulic models capable of predicting water age within the system through a System Specific Study. Systems that can certify that all of their recent existing DBP monitoring results are equal to or less than half of the TTHM and HAA5 maximum contaminant levels (MCLs) will be able to obtain exemptions from IDSE monitoring requirements. Schedules for submittal and approval of proposed IDSE monitoring plans, actual system monitoring, and report submittal are phased based on system size.

Under the Stage 2 DBPR, the required number of routine system DBP monitoring sites will be expanded for systems serving more than 50,000 consumers from the current requirement of four sites per treatment plant under the Stage 1 DBPR to as many as 20 sites. The new routine monitoring sites selected following completion of the required IDSE monitoring must include those sites identified as exhibiting the highest DBP concentrations, and at least one quarterly monitoring period must reflect periods of peak historical DBP formation (or highest water temperature).

The Stage 2 DBPR will also introduce an Operational Evaluation requirement that is intended to serve as an early warning of pending DBP compliance problems to allow systems to initiate prior corrective measures. The Operational Evaluation must be conducted quarterly for each routine system monitoring location. An Operational Evaluation level is exceeded at any monitoring location where the sum of the two previous quarters' DBP results (TTHM or HAA5) plus twice the current DBP resulted, divided by 4 to derive an average, exceeds the MCL for that specific DBP. While exceeding an Operational Evaluation level is not considered a regulatory violation, the utility would be required to examine its treatment and distribution operational practices, and to submit a written report to the ODHS not later than 90 days after receiving the DBP analysis that caused the exceedence.

Key dates for compliance with Stage 2 DBPR requirements are summarized in Table 5-7.

Table 5-7. Key Dates for Stage 2 DBPR Compliance (Systems Serving 50,000 to 99,999 Consumers)[1]	
Activity	Compliance date
Deadline for initiating IDSE monitoring (SMP)	04/01/2007
Deadline for completion of IDSE monitoring (SMP)	03/31/2009
Submit report summarizing IDSE results and recommended revised DBP monitoring points	07/01/2009
Initiate Stage 2 DBPR quarterly compliance monitoring at revised monitoring points	010/01/2012

[1]*OAR 333-061-0030(2)(b)(A)*

A review of the City's 2006 and 2007 Consumer Confidence Reports indicates that the City currently meets the requirements of the Stage 2 DBPR.

5.4.1.3 Endocrine Disrupting Compounds (EDCs)/Pharmaceuticals and Personal Care Products (PPCPs)

EDCs interfere with the natural action of hormones in the body, and are thought to interfere with the reproductive systems of both wildlife and humans. EDCs include PPCPs such as antibiotics, prescription drugs, shampoos, cleansers, etc., and may be introduced into water supplies through discharge of treated wastewater flows. Even though the technology to detect these compounds in drinking water is now available, their potentially harmful effects are still largely unknown. To date, the documented levels of these compounds are generally very low (at the low end of the nanograms per liter or parts per trillion range). Most drinking water standards are set in the mg/L (parts per million) or μg/L (parts per billion) range, which are 1,000 to 10,000 times higher than the levels at which EDCs are typically detected in water supplies. Technologies to remove EDCs from water supplies may involve adsorption, rejection (nanofiltration and reverse osmosis), or oxidation. If EDCs are regulated in the future, additional or replacement treatment processes would be necessary at most treatment facilities. However, significant research remains to be conducted in order to develop an adequate understanding of removal capabilities for different treatment processes.

EDCs and PPCPs have an extremely low probability of occurrence in the raw water supply as there are no wastewater discharges upstream of the Bridge Creek Intake Facility. In addition, pets and camping are not allowed in the watershed, but the watershed is open to the public with registration of use required at entry based on an honor system.

5.4.2 Filter Backwash Recycling Rule (FBRR)

The FBRR was promulgated as a separate regulation during June 2001. Provisions of the FBRR addressing in-plant recycling of waste streams apply to all systems using filtration treatment. In addition to filter backwash flows, recycle streams covered under this regulation consist of sludge thickener supernatant, and flows associated with sludge dewatering processes. Recycle streams may contain *Giardia* and *Cryptosporidium* cysts, as well as other contaminants removed during the treatment process. Therefore, treatment plants that practice recycle of these streams within the treatment scheme must return them to a location such that all unit processes of a system's conventional or direct filtration process are employed in the treatment of the recycle flow. (This location will typically be the inlet to the plant prior to the addition of coagulant.) All systems that recycle these flows must submit a plant process schematic to the ODHS for review showing the current recycle return location and the proposed return location that will be used to establish compliance. Data on typical recycle flow rates, maximum recycle flow rates, and the plant design capacity and state-approved maximum operating capacity must also be submitted to the state regulatory agency. Systems must collect and maintain additional information on filter operating data, recycle flow treatment provided, physical dimensions of recycle flow equalization and/or treatment units, and recycle flow rate and frequency data for review and evaluation by the state regulatory agency.

5.4.3 Clean Water Act (CWA)/Resource Conservation and Recovery Act (RCRA)

CWA/RCRA rules affect WTPs that use coagulants and create flocculated residuals. While most treatment processes will produce one or more types of residuals, the amount of residuals produced is a function of raw water quality, facility design and operating flow, and treatment process employed. Flocculated residuals from clarification and filter backwash or membrane back pulse contain aluminum or iron hydroxides from the coagulant, natural organic matter and particulates removed from the raw water, and often, low levels of manganese, or arsenic concentrated from the raw water or the coagulant. Residuals must be managed and disposed of in a legally acceptable manner. The initial step for residuals management is separation of the liquid decant or backwash from the solid coagulated material. Equalization and settling are effective at separating the liquid from the solids. The liquid decant and settled backwash is frequently blended into the raw water at the head of the plant so as to minimize loss of valuable water available for production. Recycle streams must comply with the FBRR. If recycle is not feasible, discharge back to a surface water body or to a wastewater treatment plant may be undertaken with proper permitting. The remaining semi-solids are thickened and disposed of at landfills, composting operations (sometimes commingled with wastewater treatment plant residuals), or land application. Depending on the type and extent of residuals treatment, residuals treatment costs can be a major consideration in the evaluation of overall process life cycle costs.

5.5 Design Basis Of Alternatives

This section discusses the design basis of alternatives.

5.5.1 Plant Capacity

The City has targeted an initial maximum capacity of 13 mgd for this facility which is based on its initial water right. It is anticipated that the WTP will undergo two 6.5 mgd expansions in the future for a build-out plant capacity of 26 mgd. This chapter is focused on the major process trains required for each treatment expansion alternative. The preliminary design will address the full range of plant components, but for the purposes of this treatment evaluation it is assumed that the following components will be required for all treatment alternatives:

- New hydropower after-bay and raw water pump station sized for the initial capacity of 13 mgd and expandable to 26 mgd (capital costs for the after-bay and raw water pump station are included in the hydropower facility costs)
- New bulk hypochlorite system sized for the initial capacity of 13 mgd and expandable to 26 mgd
- Use of existing and/or new Outback Facility reservoirs as CT basins

5.5.2 Disinfection Requirements

The performance of MF/UF membrane systems is superior to conventional filtration in removal of *Giardia* and *Cryptosporidium*. The membrane filtration process provides a physical barrier to these pathogens. Conventional filtration is effective at removing them in a chemical and/or physical process; however *Giardia* and *Cryptosporidium* can pass through the granular media if not properly operated, or if the filters experience an upset (e.g., turbidity breakthrough). Properly functioning conventional filtration plants are generally given credit by the ODHS for the required 2-log removal of *Cryptosporidium* (3-log removal required under the pending LT2 Rule) , and are typically given credit for 2.5-log *Giardia* removal. The additional 0.5-log *Giardia* credit must come from disinfection. To prove effective treatment, the filter effluent turbidity must be maintained within the limits set by ODHS for each type of filtration. Due to the City's bin classification under the LT2 Rule, additional treatment (i.e., UV, ozone, etc.) for *Cryptosporidium* inactivation beyond 3-log will not be required for the conventional treatment alternative and is not included in this evaluation.

Membrane systems are generally credited with higher removal of *Giardia* and *Cryptosporidium* than that of conventional treatment plants. Membrane systems are typically granted 4-log *Giardia* and *Cryptosporidium* removal credit by ODHS. However, membrane based systems must still provide virus inactivation through chlorine disinfection in addition to the removal credits for the membrane systems. The level of virus inactivation required may vary from 2-log to 4-log depending on the membrane manufacturer.

Chlorination will be required for all treatment alternatives for additional disinfection and/or for residual maintenance. This chapter assumes that all treatment alternatives will require an effective clearwell for disinfection residence time. It is assumed that one or more of the existing or new reservoirs at the Outback Facility site will be used as a clearwell.

The required disinfection requirements for each treatment alternative are summarized in Table 5-8.

Table 5-8. Disinfection Requirements for Each Treatment Alternative

	Alternative 1 – UV Disinfection	Alternative 2 – UV Disinfection with Pretreatment	Alternative 3 – Conventional Treatment	Alternative 4 – Membrane Filtration
Removal/inactivation requirement				
Cryptosporidium	2-log	2-log	3-log	3-log
Giardia	3-log	3-log	3-log	3-log
Viruses	4-log	4-log	4-log	4-log
Removal/inactivation credit by filtration or UV				
Cryptosporidium	2-log [1]	2-log [1]	3-log	4-log
Giardia	2.5-log	2.5-log	2.5-log	4-log
Viruses	None	None	None	None
Chlorine disinfection requirement				
Cryptosporidium	None	None	None	None
Giardia	0.5-log	0.5-log	0.5-log	None
Viruses	4-log	4-log	2 to 4-log	4-log

[1] Assumes UV system sized for 2.5-log Cryptosporidium inactivation (includes 0.5-log safety factor) which also provides greater than 2.5-log Giardia inactivation.

5.6 Criteria for Evaluating Alternatives

The treatment technology alternatives will be evaluated according to the following criteria:

- *Capital Cost.* Capital costs for this evaluation include the cost of all major treatment plant components including treatment equipment, installation, ancillary equipment, buildings and structures to house the treatment system, miscellaneous site work and site piping as needed to incorporate the new treatment system, and contingency allowances.
- *Operation and Maintenance (O&M) Costs.* These costs include annual costs and recurring filter media and equipment replacement costs. Annual costs include staffing, power, utilities, chemicals, and UV equipment replacement (lamps, sleeves, ballasts, and sensors). Recurring costs include partial replacement and rehabilitation of ancillary equipment (pumps, valves, etc.) at 20 years, and replacement of filter media or membranes at 10-year intervals.

- *Water Quality Risks.* The primary water quality risk to the Bridge Creek source is a forest fire which would likely increase soil erosion and turbidity in Bridge Creek. Some alternatives will not be effective or as effective if there are significant changes in the raw water quality due to a forest fire or other catastrophic water quality event. In addition, some alternatives will not be effective or as effective in treating regular turbidity excursions that occur during spring snow melt.
- *Staffing, Operability, and Automation.* The evaluation of needed plant staffing and operability includes the number of labor hours, or staff full-time-equivalents (FTEs). Automation also affects the needed staffing levels, staff skill sets, and the reliability of operation without operator attendance.
- *Expandability.* The initial plant expansion will have a capacity of 13 mgd; however, it must be expandable by an additional 13 mgd (two 6.5 mgd expansions) without a major disruption of operation.
- *Operational Flexibility.* Some alternatives are more able to respond to sudden changes in raw water quality.
- *Site Compatibility.* Some alternatives may require a larger footprint, making it more difficult to fit the new facilities into the site.

5.7 Treatment Process Alternatives

The following gives a general discussion of UV disinfection and the treatment processes that are available within the conventional and membrane treatment categories. A description of the recommended alternative for each treatment process is also provided.

5.7.1 UV Disinfection

The use of UV light to disinfect drinking water is a reliable and cost-effective technology for meeting the inactivation requirements mandated under the LT2 Rule for public water systems that treat surface water, including unfiltered surface water supplies such as the Bridge Creek source. UV light also does not form any disinfection byproducts. Its application to drinking water treatment is described in the USEPA *UV Disinfection Guidance Manual* (2006), including procedures for the validation, design, and control of UV systems for the inactivation of *Cryptosporidium*, *Giardia*, and viruses. It should be noted that UV is not effective for virus inactivation at the typical design dose for *Cryptosporidium* and *Giardia*.

The mechanism of UV disinfection occurs via absorption of UV light in the germicidal spectrum (200 to 300 nanometers) by the cellular nucleic acids, resulting in photochemical damage to the microorganisms' nucleic acids, consisting of deoxyribonucleic acid (DNA) and/or ribonucleic acid (RNA). The genetic information of a microorganism is mapped in the specific order of the nitrogenous bases of the DNA or RNA genome. The UV inflicted damage to the nitrogenous bases physically inhibits enzymes used for nucleic acid synthesis and thus blocks copying of the damaged strand during replication, rendering the microorganism inactive.

The UV light entering a water volume is influenced by reflection, scattering of light, shadow effects, and absorbance of the light by other compounds or particles in the water matrix in addition to microorganisms. The UV intensity, or the magnitude of UV light entering the water, as well as the UV absorbance of water (measure of the amount of UV light absorbed by the water matrix, which is therefore unavailable for disinfection) are two important factors in monitoring the energy applied to the water. UV dose is a product of the UV intensity that a microorganism population is exposed to (mW/cm^2) and the time of exposure(s), expressed as the energy per unit area ($mW\text{-}s/cm^2$ or mJ/cm^2) applied to water. Therefore the residence time of the water within a UV reactor, or flow rate, is an additional factor impacting the disinfection performance of a UV system.

Together with flow rate, the UV transmittance (UVT) of a water source is a primary criterion in sizing a UV system. Water with lower UVT (or higher absorbance of UV wavelengths) will require higher energy outputs from the UV system. The UVT is calculated from the UV absorbance data using the following equation:

$$UVT = 100*10^{-A}$$

Where A = UV absorbance (based on a 1 centimeter path length)

Other water quality data important in the design of a UV system include temperature, pH, alkalinity, aluminum, iron, magnesium, manganese, hardness, and total organic carbon because they can have an impact on the fouling rate of the UV system. Other than temperature, pH, and alkalinity, many of these water quality parameters have not been collected for the Bridge Creek supply. The City recently purchased a UVT analyzer to collect UVT data for the Bridge Creek Supply.

5.7.1.1 UV Recommendation – Treatment Alternative 1

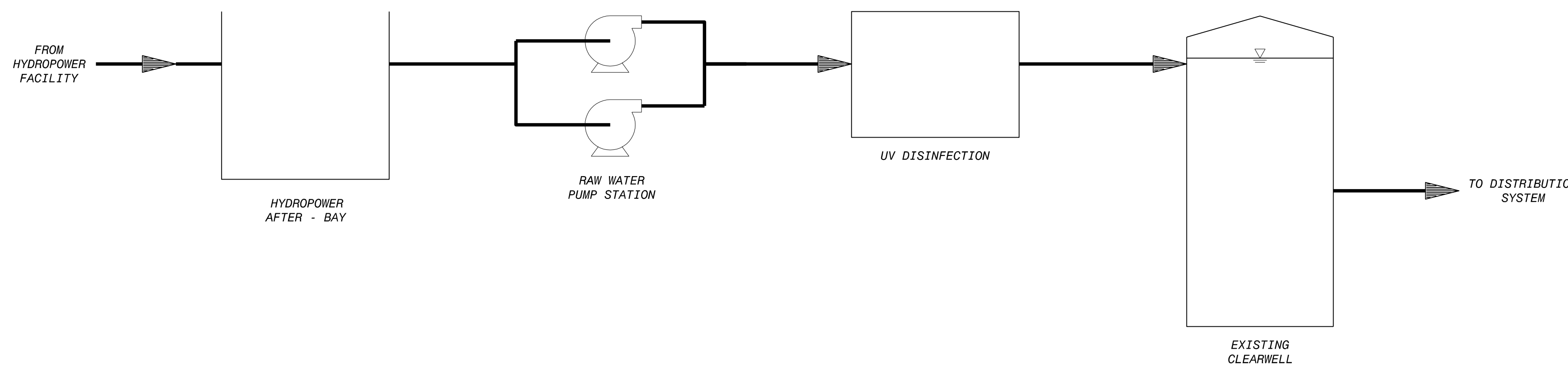
The required number of UV reactors will be determined during preliminary design. UV systems costs for this evaluation are provided as a cost per mgd rather than a specified number of UV reactors. The UV reactors would be installed in a new UV building with space allocated for three to four UV reactors at plant build-out.

A process schematic for UV disinfection is presented in Figure 5-1. A conceptual site layout for UV disinfection is presented in Figure 5-2.

5.7.1.2 UV with Pretreatment Recommendation – Treatment Alternative 2

This UV recommendation is the same as Alternative 1 with the exception of the addition of pretreatment for turbidity reduction upstream of the UV reactors. Pretreatment would likely consist of a high-rate clarification process such as the Actiflo® process described in Section 5.2.7.1. Pretreatment would be used to reduce raw water turbidities from 5 NTU to approximately 1 NTU to meet the City's internal turbidity limits. A process schematic for UV disinfection with pretreatment is presented in Figure 5-3. A conceptual site layout for UV disinfection with pretreatment is presented in Figure 5-4.

It should be noted that this alternative cannot be used when the raw water turbidity exceeds 5 NTU. To meet the filtration avoidance criteria, the raw water source must be shut down until the raw water turbidity returns to 5 NTU or less. OAR 333-061-0030 states that for systems which do not provide filtration, source water turbidity must be less than or equal to 5 NTU immediately prior to the first or only point of disinfection.



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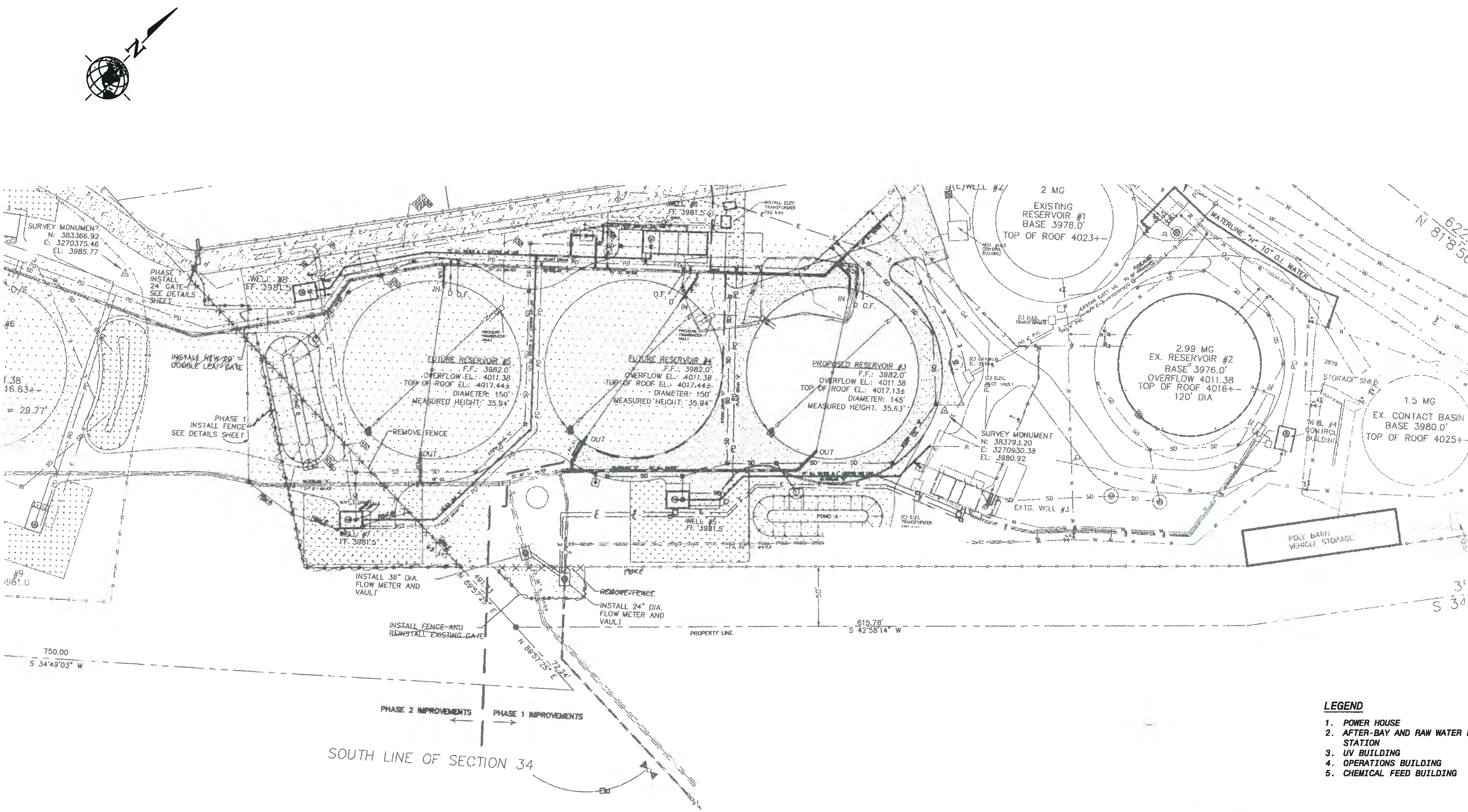
TM4-WATER TREATMENT EVALUATION
Figure 5-1 TREATMENT PROCESS SCHEMATIC
ALTERNATIVE 1 - UV DISINFECTION



LEGEND

1. POWER HOUSE
2. AFTER-BAY AND RAW WATER PUMP STATION
3. UV BUILDING
4. OPERATIONS BUILDING
5. CHEMICAL FEED BUILDING

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Figure 5-2 CONCEPTUAL SITE LAYOUT
ALTERNATIVE 1 - UV DISINFECTION

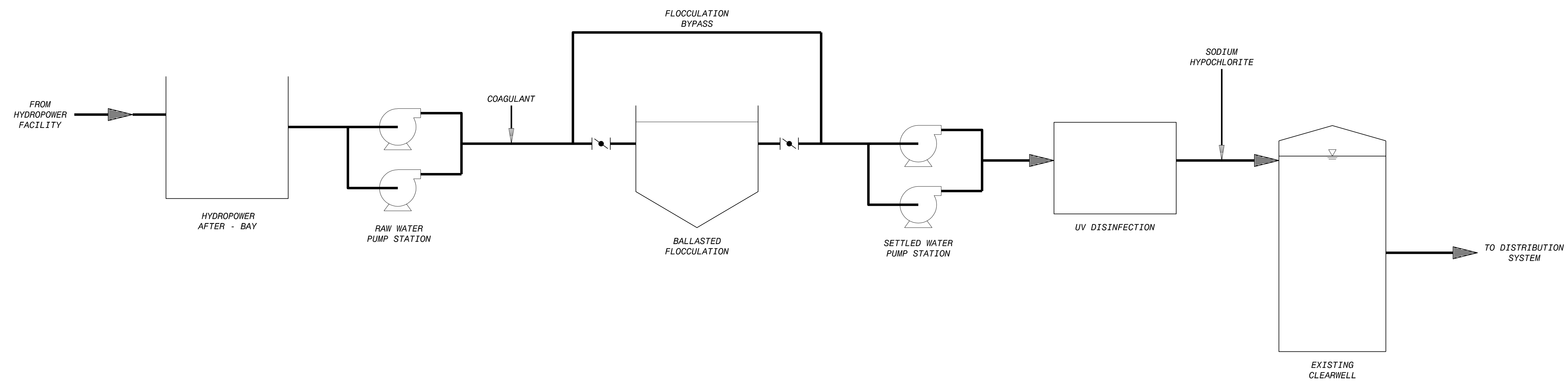

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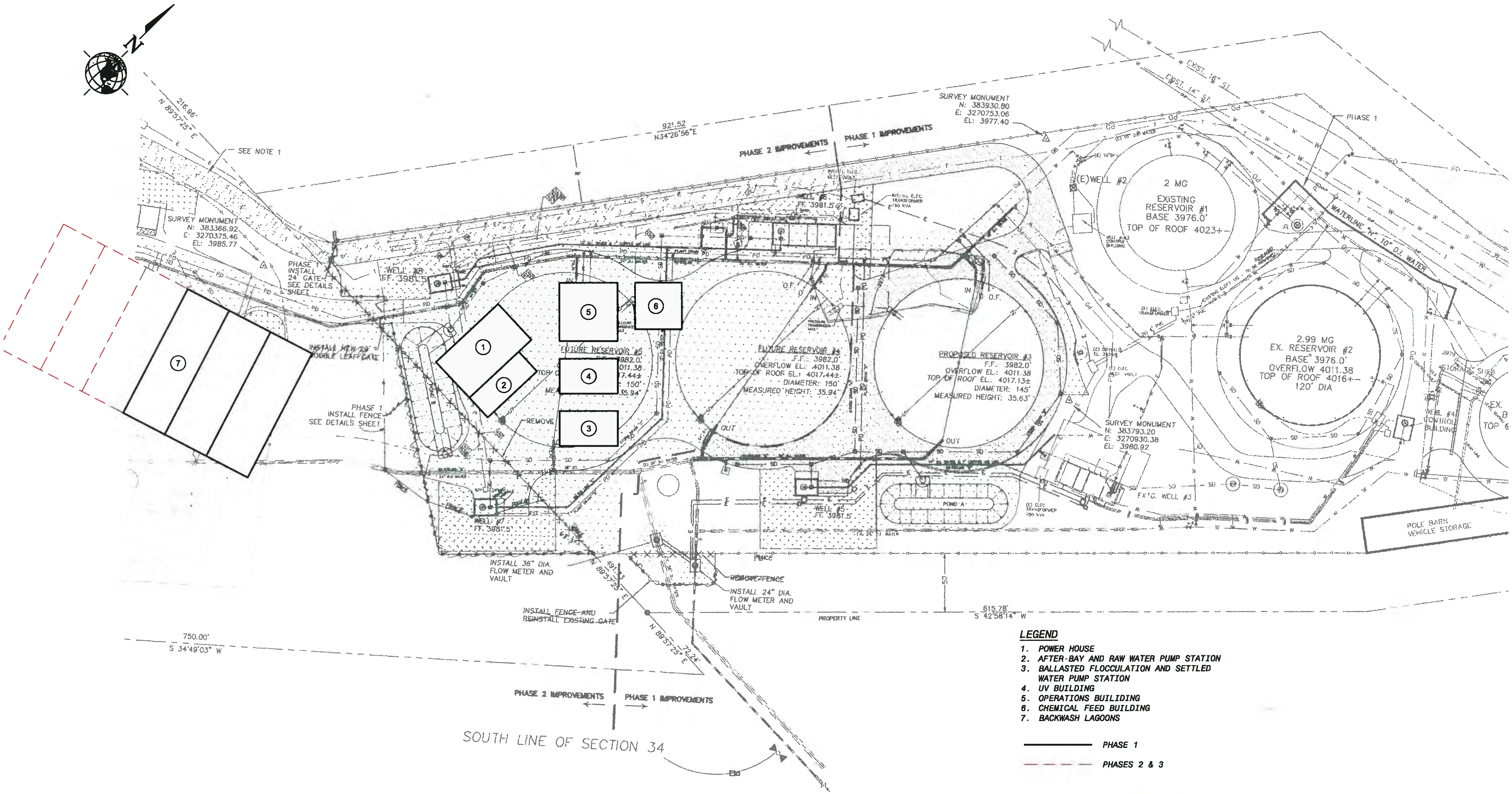
Figure 5-3 TREATMENT PROCESS SCHEMATIC
ALTERNATIVE 2 - UV DISINFECTION WITH PRETREATMENT



LEGEND

1. POWER HOUSE
2. AFTER-BAY AND RAW WATER PUMP STATION
3. BALLASTED FLOCCULATION AND SETTLED WATER PUMP STATION
4. UV BUILDING
5. OPERATIONS BUILIDING
6. CHEMICAL FEED BUILDING
7. BACKWASH LAGOONS

PHASE 1

PHASES 2 & 3

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TM4-WATER TREATMENT EVALUATION
Figure 5-4 CONCEPTUAL SITE LAYOUT
ALTERNATIVE 2 - UV DISINFECTION WITH PRETREATMENT

5.7.2 Conventional Treatment

Conventional treatment is defined as coagulation, flocculation, and sedimentation followed by granular media filtration. Conventional treatment has been shown to be capable of effectively removing turbidity, manganese oxide particles, color, disinfection by-product precursors, viruses, bacteria, *Giardia* cysts, and *Cryptosporidium* oocysts. Following is a description of the conventional treatment process.

5.7.2.1 Coagulation, Flocculation, and Sedimentation Options

In conventional coagulation, flocculation, and sedimentation pretreatment, a coagulant chemical, such as aluminum sulfate, polyaluminum chloride, aluminum chlorohydrate, or iron-based sulfates or chlorides, is added to the raw water and dispersed thoroughly in a rapid mix process. Next, flocculation of the chemical with particulates and dissolved organic matter occurs in a tank or series of tanks in order to allow the particles to agglomerate into larger, more settleable floc. During sedimentation, these large floc particles are removed from the water by gravity. Table 5-9 presents typical design parameters for these processes.

Table 5-9. Typical Design Parameters for Conventional Pretreatment Processes

Process	Residence time	Function	Mixing intensity, G
Rapid mix	1 to 30 seconds	Disperse coagulant chemicals	3,000 to 7,000
Flocculation	20 to 45 minutes	Form large aggregates (floc)	70 to 20
Sedimentation – conventional	2 to 4 hours	Remove the bulk of the floc to reduce loading on the filters	0
Sedimentation – plate settlers	0.5 hour	Remove the bulk of the floc to reduce loading on the filters	0

There are variations on the conventional coagulation filtration process that have been developed to replace sedimentation with other clarification processes. For raw water with significant natural organic concentrations or high levels of algae, dissolved air flotation (DAF) may be appropriate. Where space for expansion or retrofit is extremely limited, ballasted flocculation has been used. Descriptions of both of these alternative clarification processes follow.

DAF is a high-rate clarification process that is available from several manufacturers. In the DAF process, raw water particles are flocculated with coagulants and seeded with micro-bubbles and then separated out of the water by floating to the surface, as opposed to settling to the bottom of a basin. For this reason, DAF is better suited for light particles that tend to float or have near neutral buoyancy.

A DAF system consists of air compressors, recirculation pumps, and saturators (or dissolving tanks) and the DAF basin in which solids flotation and separation takes place. The process introduces micro-sized air bubbles through diffusers at the bottom of the DAF basin to float the floc. The air bubbles are produced by recycling a portion of the effluent through the saturator, or dissolving tank, where air is introduced under pressure, resulting in water that is saturated with air at the increased pressure, but substantially supersaturated with air when exposed to atmospheric pressure. The pressurized stream is then reduced to ambient pressure, releasing the micro-bubbles. This effect is similar to opening a can of soda. As the micro-bubbles are released, they attach to solid particles, and float to the surface. The floated sludge is removed from the top of the basin by mechanical or hydraulic means, while the clarified water is removed through an under baffle beneath the water surface. Typical design criteria for the DAF process are presented in Table 5-10.

Table 5-10. Typical Design Parameters for the DAF Process		
Process	**Residence time**	**Comments**
Rapid mix	1 to 2 seconds	Coagulant added and dispersed
Flocculation	5 to 15 minutes	High intensity flocculation, forms tight floc
Flotation	40 minutes	Inject micro-sized air bubbles (form around floc)
Flotation – e.g., AQUADAF, ClariDAF	15 minutes	High-rate DAF

Figure 5-5 illustrates the DAF process.

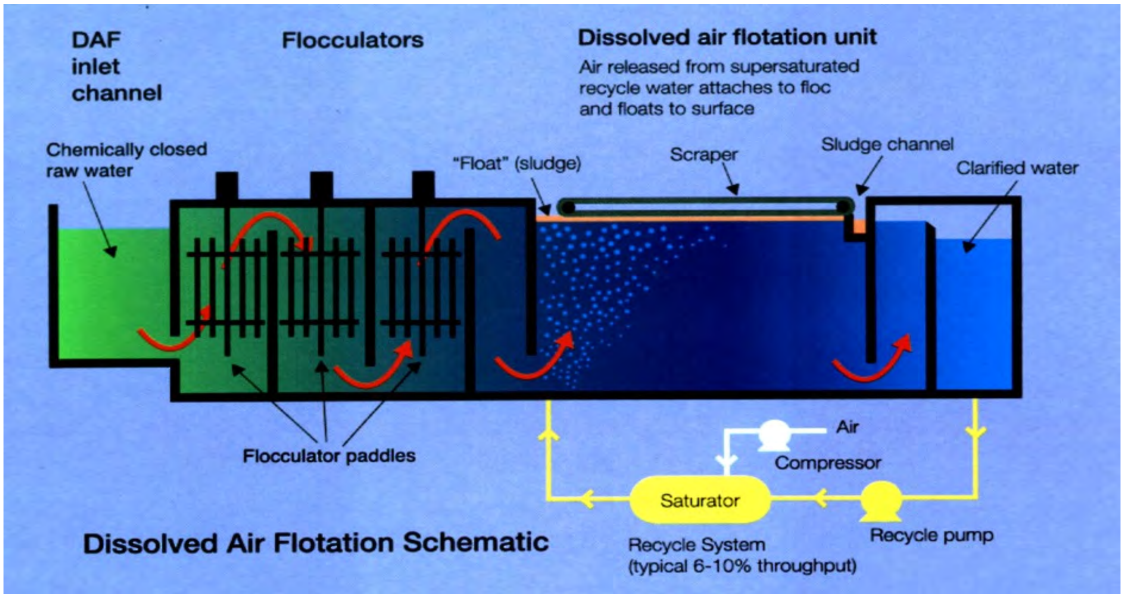

Figure 5-5. DAF Process

Actiflo Ballasted Flocculation (Actiflo) systems accelerate the clarification process by applying microsand to which the floc is attached through the addition of a polymer. The microsand is recovered during settling and separated from the floc in a hydrocyclone while the clarified water continues to the filters. A key to the success of ballasted flocculation lies in the ability to identify the appropriate polymer to use in conjunction with the primary coagulant. Once this is accomplished, the ballasted flocculation process can provide a high degree of treatment at extremely high loading rates for varying water qualities. Very compact facility layouts result and significant construction cost savings can be achieved compared with a conventional sedimentation basin. The tradeoff is a continuing operational cost for the microsand and microsand handling facilities, and polymer as well as coagulant. Process control can also be critical—changes in raw water quality or intermittent operation of the plant can lead to process upsets or clarified water that may not meet water quality targets. Typical design parameters for the Actiflo process are presented in Table 5-11.

Table 5-11. Typical Design Parameters for the Actiflo Process		
Process	**Residence time, minutes**	**Comments**
Coagulation	2	Coagulant added before coagulation chamber; begin to form floc
Injection	2	Micro-sand and polymer are added
Maturation	4	Complete process of attaching floc to micro-sand
Sedimentation	8	Includes tube settlers or plate settlers

Figure 5-6 presents a schematic of the Actiflo process.

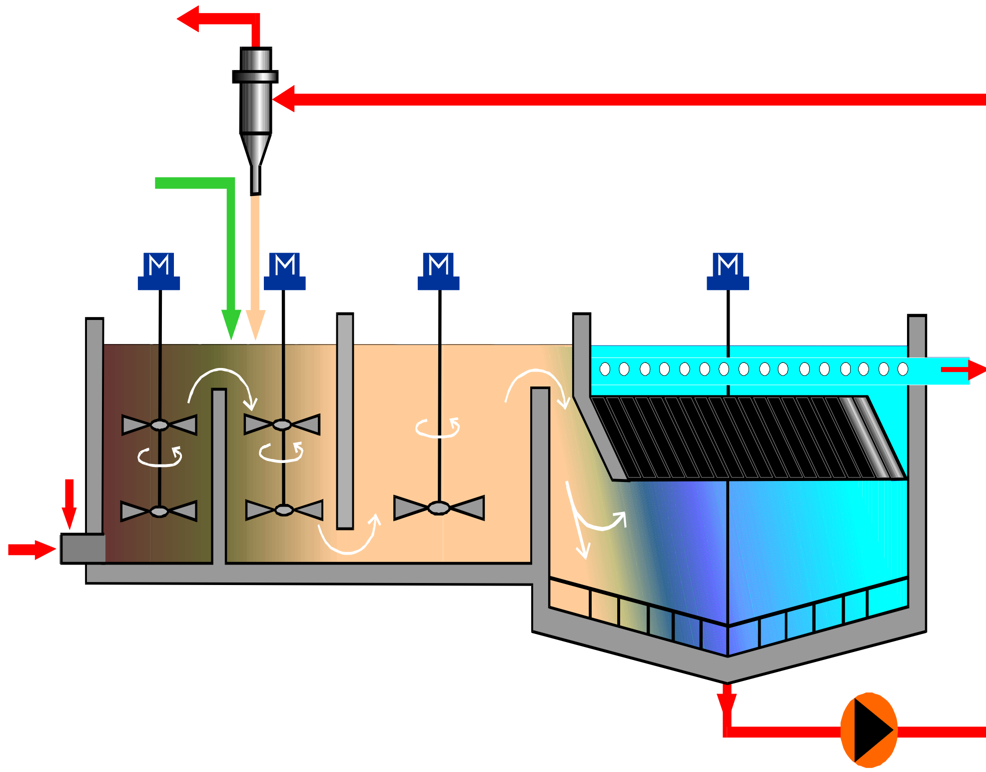

Figure 5-6. Actiflo Schematic

5.7.2.2 Granular Media Filters

Granular media filters are used as a final barrier after the coagulation, flocculation, and sedimentation/ clarification processes. Granular media filters are categorized as gravity or pressure filters. Most installations larger in size than 1 mgd use gravity to eliminate the added expense of constructing pressure vessels. The maximum headloss for most gravity granular media filters is between 8 and 10 feet and is dependent upon the maximum water depth above the filter. Filter productivity is defined as the amount of water that can be filtered starting with a clean filter before it reaches maximum headloss or turbidity breakthrough. Typically, filters with adequate pretreatment can operate between 24 and 96 hours at filtration rates of 6 gallons per minute/square foot (gpm/sf) before either reaching the headloss limit or experiencing poor filtered water quality. This would equate to a productivity of 9,000 to 36,000 gallons per square foot.

The effective size of the media has a significant impact on the rate of headloss in the filter. Coarse media, in general, allow for greater penetration of particles within the filter bed compared with fine media. This translates to a lower rate of headloss accumulation, longer filter runs, and potentially greater water production. Conversely, because fine particles tend to penetrate further within coarse media, greater depths of coarse media than fine media are necessary to achieve the same particle capture. Many filters are constructed of layers of different media with different size and density characteristics to provide optimal filtration capacity. Dual media filtration generally consists of a layer of anthracite coal or granular activated carbon (GAC), over a layer of sand. The upper layer (anthracite or GAC) is relatively coarse, which allows for a greater penetration of particles in the filter bed, thus minimizing headloss. The lower sand layer has a finer gradation than the upper layer and functions as a second barrier to remove fine particles.

5.7.2.3 Direct Filtration

Direct coagulation and flocculation, also called direct filtration, is similar to conventional treatment. The major difference is that in a direct filtration process, the floc is removed by the filters and not through a sedimentation or advanced clarification process. Direct filtration is more suitable for better quality surface waters, with low turbidity values (typically less than 10 NTU). The direct process results in a smaller footprint than the conventional treatment process. However, removal credit based on the direct treatment process is 2.0-log for *Giardia*, 1.0-log for viruses, and 2.0-log for *Cryptosporidium*. The remaining microbial inactivation must be obtained through disinfection. An example of a direct filtration plant is the Eugene Water & Electric Board's Hayden Bridge Water Filtration Plant, which is operated as a direct filtration plant in the summer and as a conventional filtration plant in the winter.

5.7.2.4 Conventional Treatment Recommendation – Treatment Alternative 3

For this project, a combination of direct filtration and conventional filtration treatment is assumed. Raw water turbidity is typically less than 0.5 NTU which falls within the limits of direct filtration. In the event of a forest fire, turbidity could increase significantly and other water quality parameters could change dramatically. Direct filtration would continue to be suitable for turbidities up to 10 NTU (typical peak turbidity events for Bend are approximately 5 NTU). If turbidity exceeds 10 NTU, additional pretreatment will be required. For turbidity events of 10 NTU (characteristic of a forest fire) or higher, a ballasted flocculation system sized for half of the plant capacity, or 6.5 mgd, has been assumed. A ballasted flocculation system sized for 6.5 mgd would provide operational flexibility to treat a wide range of water quality issues but at reduced flows. A second 6.5 mgd ballasted flocculation system could be added if the duration of poor raw water quality conditions and demands dictate. Under normal operating conditions, the ballasted flocculation system would be bypassed.

Four 3.25-mgd granular media filters would follow pretreatment. It is assumed that new filters can operate successfully at up to 6 gpm/sf. A total filter area of 2,000 square feet would provide 13 mgd firm filtration capacity (firm capacity assumes one filter is out of service for backwashing).

For a plant of this size, filter boxes are typically constructed of site-built concrete; however, filter boxes could also be fabricated aluminum or factory-built. For the purposes of this evaluation, it is assumed that the filter boxes will be constructed of concrete. A filtered water wet well is assumed for collection of filtered water. A filtered water pump station will be required to pump filtered water from the wet well to the clearwell(s) and will also house the backwash pumps.

Backwash waste lagoons will be required to store and settle the filter backwash waste. For this evaluation, it is assumed that decant from the lagoons will be recycled back to the head of the plant. Recycling of filter backwash flows will reduce the raw water supply requirements by approximately 5 percent (or 0.65 mgd cubic feet per second at 13 mgd plant flow) but will also recycle contaminants removed during the filtration process back into the treatment process. Recycling of filter backwash flows will require the addition of a small pump station.

Discharge of decant to Tumalo Creek may be allowed and will require the City to obtain a National Pollutant Discharge Elimination System permit. Handling of filter backwash flows should be evaluated further during detailed design.

It should be noted that the existing raw water quality will be difficult to treat conventionally due to the very low turbidity of the raw water. Bench scale testing is recommended prior to the selection of conventional treatment of the Bridge Creek source.

A process schematic for conventional treatment is presented in Figure 5-7. A conceptual site layout for conventional treatment is presented in Figure 5-8.

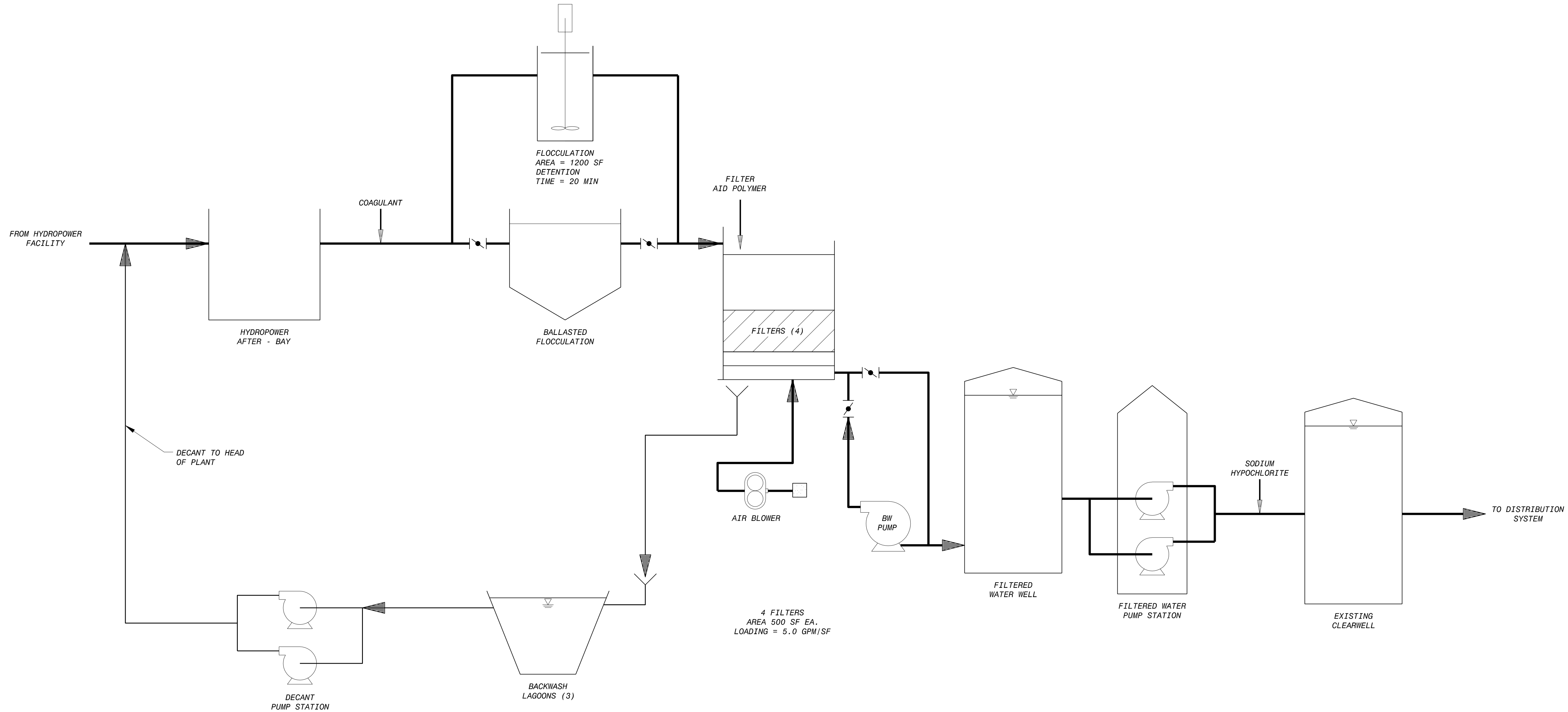

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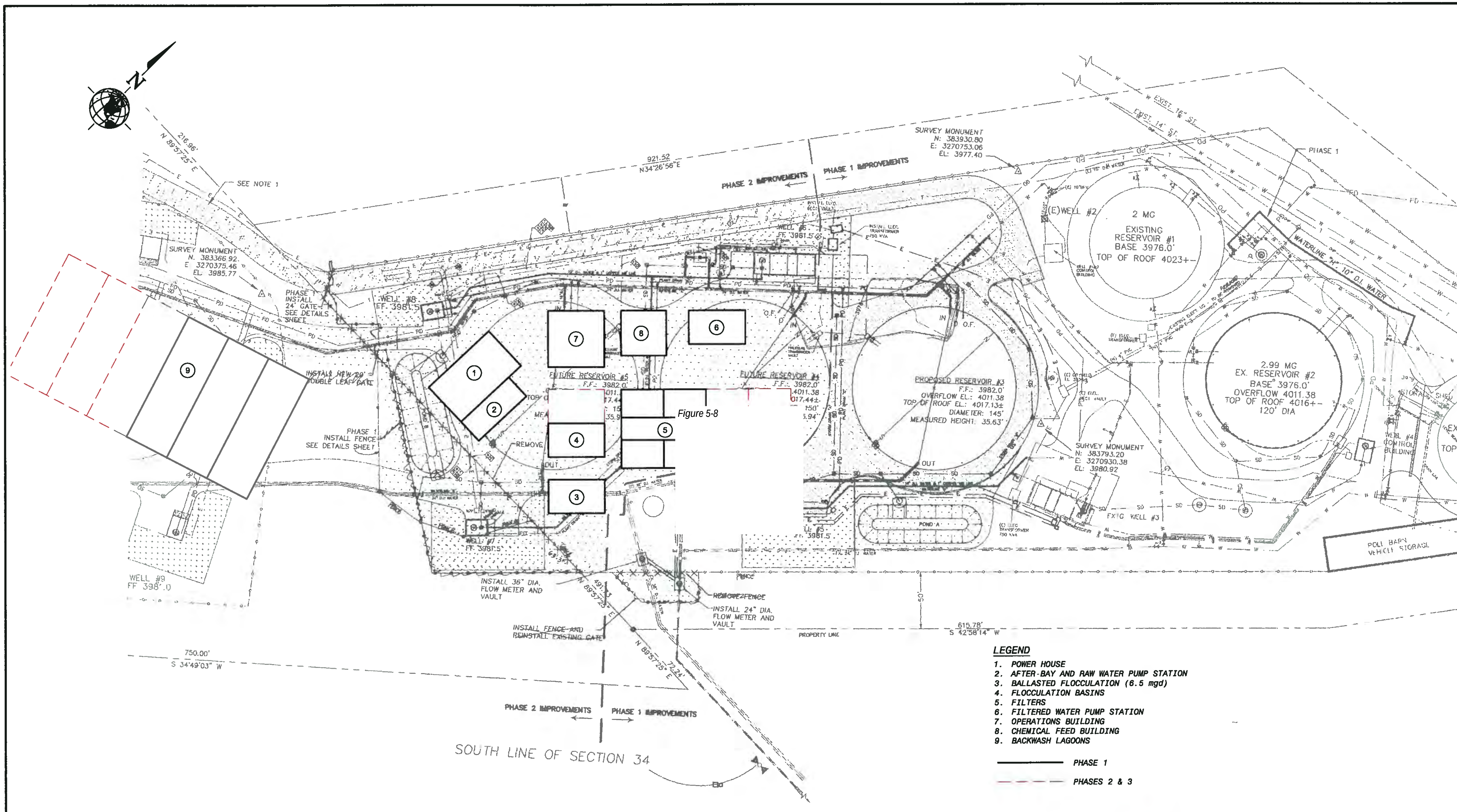
Figure 5-7 TREATMENT PROCESS SCHEMATIC
ALTERNATIVE 3 - CONVENTIONAL TREATMENT PLANT



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TM4-WATER TREATMENT EVALUATION
Figure 5-8 CONCEPTUAL SITE LAYOUT
ALTERNATIVE 3 - CONVENTIONAL TREATMENT PLANT

5.7.3 Membrane Filtration

Based on our review of the City's water quality data, membrane filtration is a viable alternative. The benefits of membranes include the following:

- It provides a high quality, low turbidity filtered water.
- Physical barrier provides low turbidity filtered water and high log removal values for cysts (*Giardia* and *Cryptosporidium*).
- Unlike conventional treatment, finished water quality is independent of upstream raw water and pretreatment conditions. Therefore, changes in raw water quality or an upset of the pretreatment process (e.g., loss of coagulant feed) will not affect the microbial log removal or turbidity of the filtered water. Although changes in raw water quality do not impact the quality of the filtered water, the membranes may operate at reduced capacity during degraded raw water quality conditions.
- Automated process allows some costs savings due to minimizing labor requirements.
- Membrane systems are modular and can be added when the demand is actually needed. Membrane systems are typically designed for future expansion and will allow the City to defer capital expenditures for additional membrane capacity to the future when capacity is necessary.

5.7.3.1 Membrane Systems

The operating mechanism of membranes is completely different than that of granular filter media. The pores in the membrane fiber wall are much smaller than the protozoan cysts, so the microbes are removed easily by simple size exclusion, independently of pretreatment coagulation conditions. The result is a very high level of removal of small particles, resulting in finished water turbidities of less than 0.08 NTU, and frequently much less. Membrane systems are typically granted 4-log *Giardia* and *Cryptosporidium* removal credit by ODHS. However, membrane-based systems must still provide virus inactivation through chlorine disinfection in addition to the removal credits for the membrane systems. The level of virus inactivation required may vary from 2-log to 4-log depending on the membrane manufacturer.

Generally, membrane filtration systems are distinguished by two characteristics: the pressure required for treating the water, and the effective pore size. MF and UF systems are commonly referred to as low-pressure membrane filtration systems. Microfiltration systems have larger pore sizes (about 0.2 µm) than ultrafiltration systems (about 0.02 µm). *Cryptosporidium* oocysts range in size from 2 to 5 µm. In membrane filtration systems, water flows through the membrane and particles larger than the pores are trapped by the membrane. Because of this exclusion mechanism of operation, the breakthrough of particles is nearly non-existent in membrane filtration, so long as membrane integrity is maintained. Figure 5-9 illustrates the size of a *Cryptosporidium* oocyst and other common contaminants as compared to a microfiltration pore.

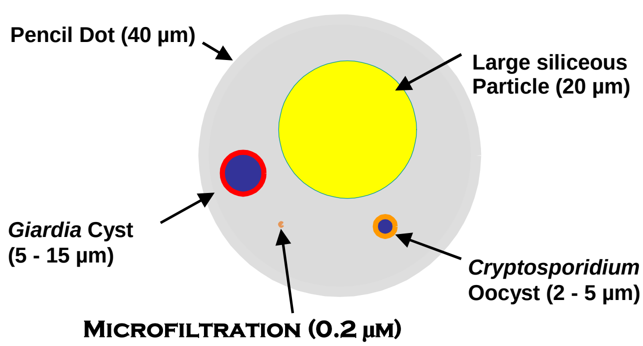

Figure 5-9. Relative Size of Small Particles

Nearly all membrane filtration systems used in the treatment of municipal drinking water are hollow fibers in which the water is either driven from the inside of the fiber through the membrane to the outside (inside-out) or from the outside of the fiber through the membrane to the inside (outside-in). There are two basic membrane configurations—pressure vessel membrane systems and submerged membranes. Pressure vessel systems use a pumped influent flow to essentially *push* water through the membrane, thus requiring a pressurized vessel enclosing the membrane fibers. Submerged membrane systems essentially *pull* water by vacuum through the membrane. The process tanks for submerged membranes, thus, can be open to the atmosphere. The Umpqua Basin Water Association has a 6-mgd submerged membrane system. The City of Cottage Grove has a 4-mgd pressure membrane system. Examples of pressure and submerged membrane systems are presented in Figures 5-10 and 5-11.

Figure 5-10. Pressure Membrane System

Figure 5-11. Submerged Membrane System

Choosing a suitable membrane for a water system is critical because the membrane material will determine its performance and durability for any given water. The majority of membranes used for drinking water treatment are polymeric membranes, made from materials such as cellulose acetate, polysulfone, poly-ether-sulfone, or polyvinylidene difluoride (PVDF).

Ceramic membranes are also used for drinking water treatment, but to a lesser extent than polymeric membranes. Ceramic membranes are similar to PVDF membranes from the perspective of what they remove from the water. However, a key difference is that the ceramic membranes are more tolerant to high solids loading because ceramic is a stronger material than polymer. Additionally, ceramic membranes can tolerate more aggressive cleaning solutions than polymeric membranes. Ceramic membranes typically have a higher capital costs that polymeric membranes.

Each of these materials offers advantages and disadvantages for a specific water source, depending upon the particles and dissolved matter in the water source. Thus, a specific type of membrane is usually recommended depending upon water quality. Table 5-12 presents capabilities of MF and UF membranes.

Table 5-12. Capabilities of MF and UF Membranes

Parameter to be Removed	MF	UF
Cysts	99.9 percent, >3-log	99.9 percent, >3-log
Bacteria	99 percent, >2-log	99 percent, >2-log
Virus	0 to 99 percent, 0- to >2-log	0 to 99.9 percent, 0- to >3-log
TOC	0 to 20 percent	0 to 20 percent
Color	[1]	[1]
DBP-precursors	[1]	[1]

[1] Without chemical pretreatment, MF does not remove dissolved material and removal by UF is limited. Removal of dissolved organic material can be achieved by operating MF in a direct filtration mode and/or with poly-aluminum chloride addition. Ongoing research is being conducted to determine the limits.

Mainly due to physical size, certain particles in the feed water are rejected by the membrane, as water is forced through it. These particles collect on the membrane surface, causing the required pressure for water production to increase. Backwashing is required to release this material from the surface of the membrane. Backwashing cycles are dependent on the applied water quality, membrane type, and the flow pattern in the membrane system. In general, as the water quality degrades, the frequency and duration of backwashing increases. Although backwashing regimes are very effective for restoring the permeability of the membrane, they do not restore 100 percent of the permeability with each backwash cycle. Over time, the permeability of the membrane after backwashing is compromised by particles and dissolved constituents becoming embedded into or adsorbed onto the membrane surface. This loss of permeability over time is called fouling. A chemical cleaning cycle is needed to dissolve the contaminants and restore the membrane's permeability. The spent cleaning solution is typically neutralized onsite and discharged to a sanitary sewer, or hauled offsite for disposal.

Membrane filtration systems generate two residual streams—backwash flow and spent cleaning solution flow. For many potable water applications, the membrane filtration backwash streams are disposed of without treatment to a receiving body of water or sewer system. Since the backwash reject can be up to 10 percent of plant flow, many utilities are using backwash flow recovery processes. Alternative viable treatment options to recover water from the backwash include a secondary membrane filtration system to further concentrate the waste stream, or coagulation and clarification treatment process such as high rate plate settler systems.

5.7.3.2 Pretreatment Requirements

Pretreatment may be required upstream of membranes to aid in removal of dissolved constituents (i.e., iron or manganese) and TOC which can increase membrane fouling. Depending on raw water quality, pretreatment may consist of one or a combination of coagulant addition, flocculation, sedimentation, and oxidation.

5.7.3.3 Membrane System Recommendation – Treatment Alternative 4

Treatment Alternative 4 is discussed in this section.

5.7.3.3.1 Pretreatment Requirements

The low levels of both turbidity and TOC (low TOC values are assumed based on DBP data) in the Bridge Creek source make it a good candidate for membrane filtration without coagulation pretreatment. In the event of a forest fire, raw water turbidity could increase significantly and the water quality could change dramatically for an extended period of time. It is assumed that pretreatment would be required in the event of a forest fire. Although membranes do not require pretreatment for turbidity removal, they operate more efficiently when there are fewer suspended solids in the water being filtered. Fewer suspended solids correspond to less membrane fouling, lower pressure loss, and longer filter run times. For this evaluation, it is assumed that pretreatment including coagulation and flocculation will be provided for the initial 13 mgd plant. Pretreatment will provide operational flexibility to meet a wide range of water quality issues. During low turbidity periods the pretreatment process will be bypassed.

5.7.3.3.2 Membrane System Selection

For this project, either a submerged-membrane system or a pressure membrane system would function equivalently. For most projects, there is no clear advantage of submerged membranes over pressure membranes or vice-versa. Typically membrane procurement bids allow selected submerged and pressure membrane manufacturers to compete economically. Care should be taken to ensure that any damaging debris is removed upstream of the membranes by automatic fine screens.

Membrane filtration for the initial 13 mgd plant would most likely consist of four to five trains of approximately 2.6 mgd to 3.25 mgd each. All the membrane equipment, pumping equipment, ancillary equipment, chemical systems for cleaning and backwashing, and controls would fit into a new treatment building of approximately 6,500 square feet. The new treatment building will be sized for the build-out capacity of 26 mgd to allow easy installation of additional treatment capacity in the future. Rather than build a separate storage tank for backwash supply, it is assumed that the existing finished water reservoir(s) will be used for backwash supply storage.

Backwash waste lagoons will be required to store and settle the membrane backwash waste. Similar to the conventional treatment options, it is assumed that backwash flows will be recycled back to the head of the plant. However, recycling of filter backwash flows should be evaluated further during detailed design. It is assumed that spent cleaning solution will be neutralized on site and hauled off-site for disposal.

Process schematics for submerged and pressure membranes are presented in Figures 5-12 and 5-13, respectively. A conceptual site layout for the membrane alternative is presented in Figure 5-14.

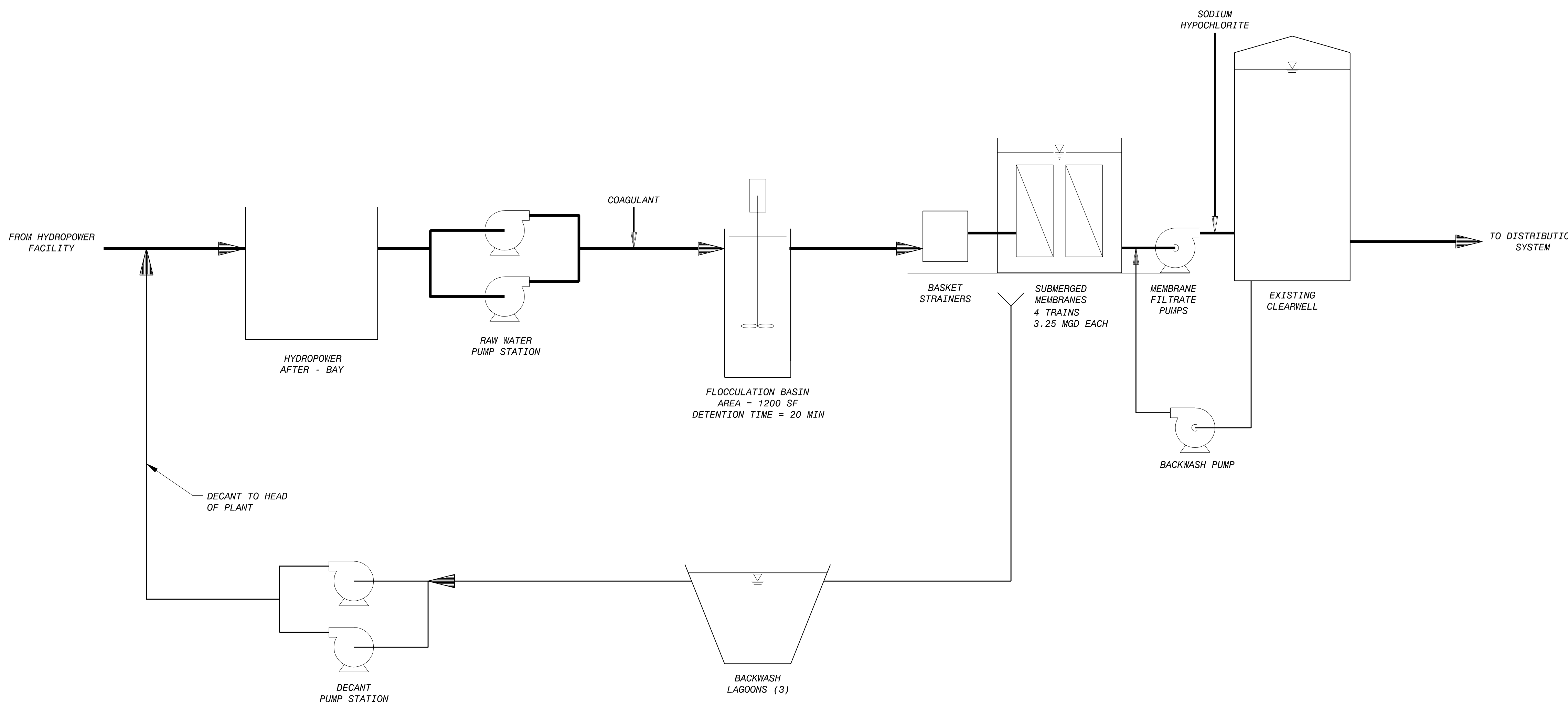

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Figure 5-12 TREATMENT PROCESS SCHEMATIC
ALTERNATIVE 4A - SUBMERGED MEMBRANE TREATMENT

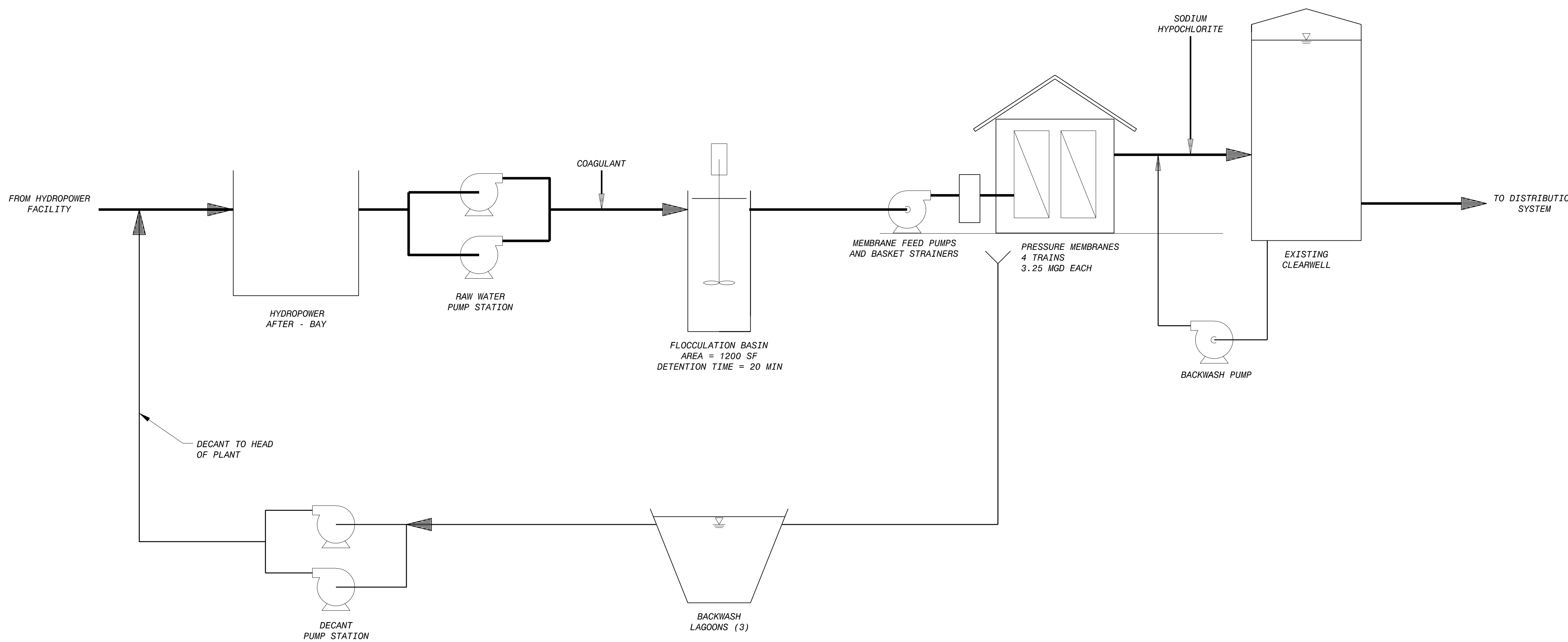

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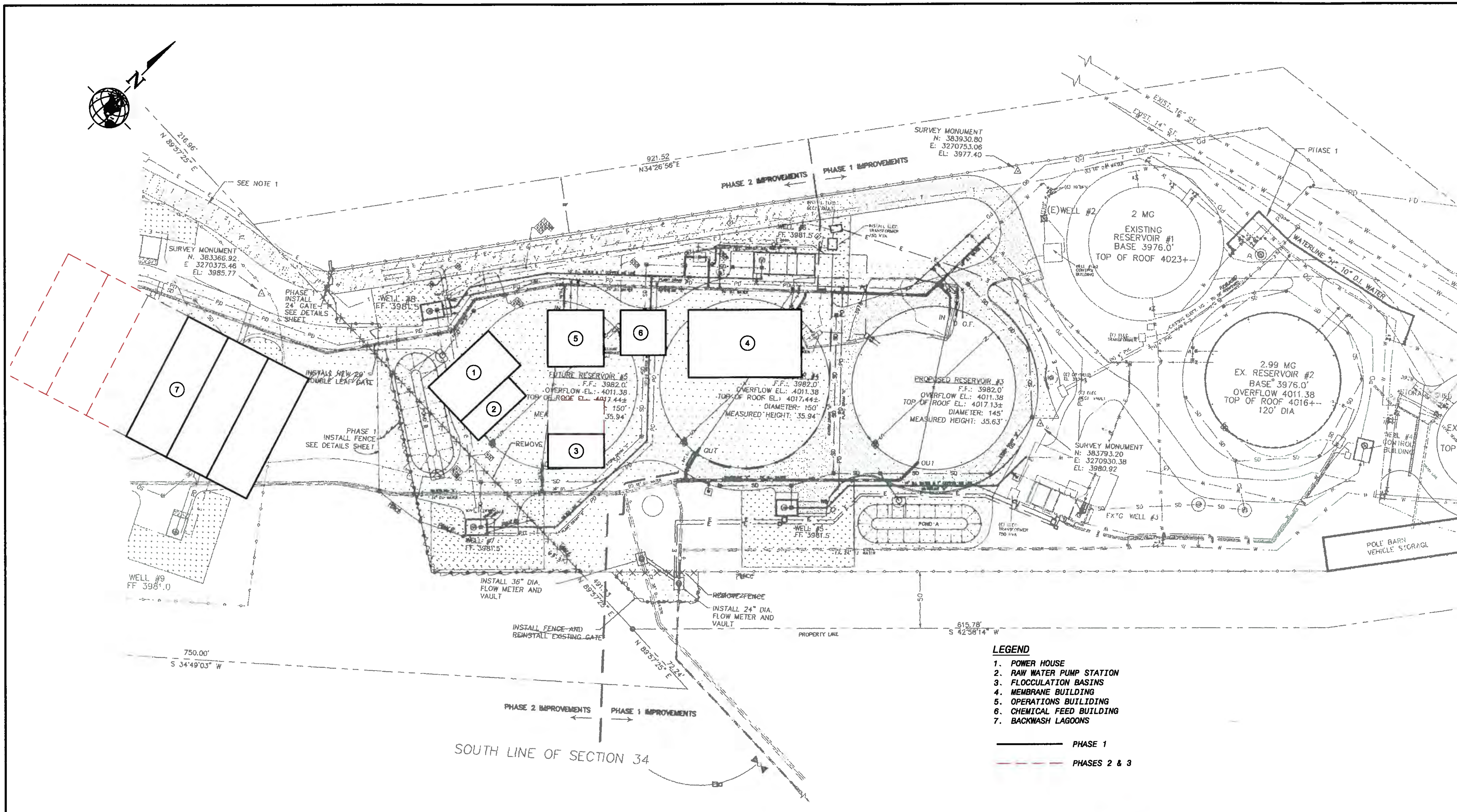
Figure 5-13 TREATMENT PROCESS SCHEMATIC
ALTERNATIVE 4B - PRESSURE MEMBRANE TREATMENT



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TM4-WATER TREATMENT EVALUATION
Figure 5-14 CONCEPTUAL SITE LAYOUT
ALTERNATI EMBRANE TREATMENT PLANT

5.8 Evaluation Of Alternatives

The evaluation of the alternatives includes comparison of treating the Bridge Creek source using the following:

- Alternative 1 – UV Disinfection
- Alternative 2 – UV Disinfection with Pretreatment for Turbidity Reduction
- Alternative 3 - Conventional Treatment (Defined as coagulation, flocculation, and sedimentation followed by granular media filtration)
- Alternative 4 - Membrane Filtration (MF or UF) with Pretreatment

5.8.1 Capital Cost

Estimated capital costs for this evaluation are based on 2009 dollars and include the cost of all major treatment plant components required for the initial 13 mgd plant capacity including treatment equipment, installation, ancillary equipment, buildings and structures to house the treatment system, miscellaneous site work and site piping as needed to incorporate the new treatment system, and the following contingency allowances

- General Conditions 10 percent
- Contractor Markups (Labor, Materials, and Equipment) 8 to 10 percent
- Bonds and Insurance 3.5 percent
- Escalation to Mid-point of Construction (October 2011) 4 percent
- Construction Contingency 30 percent
- Engineering, Legal, and Administration 18 percent

Table 5-13 summarizes the major plant components included in each treatment alternative. Some plant components are common to more than one alternative.

Table 5-13. Summary of Major Treatment Plant Components

Plant Component	Alternative 1– UV Disinfection	Alternative 2– UV Disinfection with Pretreatment	Alternative 3– Conventional Treatment	Alternative 4– Membrane Filtration
Hydropower after-bay and raw water pump station[1]	X	X	X	X
UV system[2]	X	X		
Ballasted floc		X	X	
Flocculation basins			X	X
Rapid media filtration			X	
Membrane filtration[3]				X
Treated/filtered water wet well[1]		X	X	
Treated/filtered water pump station[4]		X	X	
Coagulant feed system		X	X	X
Sodium hypochlorite feed system	X	X	X	X
Backwash waste lagoons and decant pump station			X	X
Operations building	X	X	X	X

Table 5-13. Summary of Major Treatment Plant Components				
Plant Component	Alternative 1– UV Disinfection	Alternative 2– UV Disinfection with Pretreatment	Alternative 3– Conventional Treatment	Alternative 4– Membrane Filtration
Emergency power	X	X	X	X
Site civil and yard piping	X	X	X	X

[1] Hydropower after-bay and treated/filtered water tanks are sized for 5 percent of 26 mgd, or 1.3 MG. Costs for the hydropower after-bay and raw water pump station are included in the capital costs for the hydropower facility.

[2] UV System costs assume medium-pressure and low-pressure/high-output UV systems are comparable in capital costs.

[3] Membrane equipment costs assume pressure and submerged membrane systems are comparable in capital costs. Costs also include a new membrane building, membrane feed or suction pumps, chemical cleaning systems, and backwash systems.

[4] Includes backwash pumping for Alternative 2 – Conventional Treatment. Backwash pumping for Alternative 3 – Membrane Filtration is included in the cost of the membrane equipment.

The estimated capital costs for each treatment alternative are presented in Table 5-14. These are considered to be Association of the Advancement of Cost Engineering International (AACE) Class 4 cost estimates for the treatment alternatives. AACE Class 4 opinions of probable cost are considered order-of-magnitude costs and have an accuracy range of -30 percent to +50 percent. These planning level estimates provide a basis for evaluating the different treatment alternatives.

Table 5-14. Alternatives Opinion of Capital Costs	
Treatment alternative	Capital cost, million dollars
Alternative 1 – UV Disinfection	8.1
Alternative 2 – UV Disinfection with Pretreatment	17.3
Alternative 3 – Conventional Treatment	23.0
Alternative 4 – Membrane Filtration	22.7

The UV alternatives are the least expensive, with Alternative 2 being higher due to the addition of the pretreatment component and additional pumping required following pretreatment. Conventional treatment and membrane filtration are approximately the same cost.

5.8.2 O&M Costs

O&M costs for each treatment alternative are presented in Table 5-15. These are based on treating the current water quality and do not include operational costs associated with treating degraded water quality following a forest fire or other water quality event. They include annual costs and recurring filter media and equipment replacement costs. Annual costs include staffing, power, utilities, chemicals, and UV equipment replacement (lamps, sleeves, ballasts, and sensors). Annual coagulant costs were considered only in the conventional treatment alternative, as this is the only alternative that requires coagulant for treatment of the current raw water quality.

Recurring costs include partial replacement and rehabilitation of ancillary equipment (pumps, valves, etc.) at 20 years, and replacement of filter media or membranes at 10 year intervals.

Table 5-15. 20-year Present Worth of O&M Costs[1]			
Treatment alternative	Present worth of annual costs, dollars[2]	Present worth of recurring replacement costs, dollars	Total present worth of O&M costs, dollars
Alternative 1 – UV Disinfection	2,400,000	60,000	2,500,000
Alternative 2 – UV Disinfection with Pretreatment	2,400,000	60,000	2,500,000
Alternative 3 – Conventional Treatment	4,700,000	300,000	5,000,000
Alternative 4 – Membrane Filtration	5,000,000	1,000,000	6,000,000

[1] Annual O&M costs are based on 13-mgd plant flow. Assumes average electric power costs of $0.072 per kilowatt hour (to be confirmed based on the City's current electrical rates).

[2] Present worth factors are calculated at a net 5 percent interest rate for the 20-year period evaluated.

The two UV alternatives have the lowest 20-year O&M costs of the four treatment alternatives. The two UV alternatives also have the same 20-year O&M costs, as pretreatment would not be required under current raw water quality conditions. Membrane filtration has the highest 20-year O&M costs due primarily to membrane replacement costs.

5.8.3 Water Quality Risks

As previously noted, the primary water quality risk to the Bridge Creek source is a forest fire which would likely increase soil erosion and turbidity in Bridge Creek. The UV disinfection alternatives do not mitigate this risk. If a forest fire results in raw water turbidities in excess of 5 NTU, the UV disinfection alternatives will require shut-down until the turbidity returned to allowable levels for an unfiltered supply. Under normal operating conditions, UV disinfection with pretreatment will allow the City to reduce raw water turbidities from 5 NTU to approximately 1 NTU to meet its internal turbidity limits. Therefore, Alternative 4 is ranked higher than Alternative 1.

Conventional treatment and membrane filtration with pretreatment will mitigate the forest fire risk and can successfully treat varying water quality conditions resulting from a forest fire. However, the membrane system will still be superior in resistance to upset during high turbidity events and therefore has a slight advantage in this regard. Membranes will also produce the lowest finished water turbidities of the alternatives considered. Depending on the raw water quality and the effectiveness of the pretreatment process, the membrane system may be required to operate at reduced capacity. The City's well supply can be used to meet demands during periods of reduced membrane capacity.

5.8.4 Staffing, Operability, and Automation

The assumption of the analysis has been that the operations staff hours spent at a conventional treatment plant will be essentially the same number at a membrane plant. A UV plant would require less full-time operator(s) than would be required for a conventional or membrane plant. However, the membrane system, by virtue of its positive barrier, would be more reliable if conditions change rapidly, and less dependent on constant staff attention during periods of poor water quality. Therefore, the membrane system has an advantage in this category. A membrane plant requires a greater emphasis on mechanical and control systems, while a conventional plant focuses more on the chemical treatment process. Membrane plants also require staff time to plug any broken fibers. A UV plant requires annual UV lamp replacements and ballast replacement. The membrane and UV alternatives were therefore ranked higher than the conventional treatment alternative.

Automation also affects the needed staffing levels, and the reliability of operation without operator attendance. UV and membrane systems are designed with a high level of internal automation and easily can be incorporated into a new or existing plant supervisory control and data acquisition (SCADA) system. Because the filtered water quality from membranes is not affected by changes in raw water quality or upsets in pretreatment, the system lends itself well to minimally-staffed operations. However, many membrane plants still choose to staff fully. For example, the City of Albany's 12-mgd Albany-Millersburg Membrane Filtration Plant staffs three full-time operators during the week and one operator on the weekends.

Regardless of the level of automation, we believe that either a conventional treatment plant or a membrane filtration plant will require more staff time than a UV plant. This is due primarily to greater complexity of the systems proposed. The experience of other utilities does not show a strong advantage for either MF/UF membrane filtration or conventional treatment in terms of total staff time. However, a membrane system would have higher reliability when left unattended during high-turbidity excursions.

Four FTEs have been assumed for the conventional treatment and membrane filtration alternatives. Two FTEs have been assumed for the UV alternatives.

5.8.5 Expandability

The initial plant expansion will have a capacity of 13 mgd; however, it must be expandable to 26 mgd without a major disruption of operation. Initially, all major components except pretreatment basins and filter trains will be sized for the build-out capacity of 26 mgd. The conventional treatment alternative would require construction of four additional filters to reach the build-out capacity. The membrane system would require the addition of membrane skids or membrane filtration basins in the proposed filter building. The UV system would require the addition of lamps to the existing reactors or additional reactors. UV and membranes have an advantage in the expandability area due to their smaller footprint and modular construction.

5.8.6 Operational Flexibility

All of the alternatives can treat the normal water quality of the Bridge Creek source successfully. The conventional and membrane filtration alternatives will provide flexibility to treat a wide range of raw water quality conditions, whereas the UV disinfection alternatives will require shut-down during a turbidity excursion above 5 NTU. As previously noted, UV disinfection with pretreatment will allow the City to reduce raw water turbidities from 5 NTU to approximately 1 NTU to meet its internal turbidity limits. Therefore, Alternative 4 is ranked higher than Alternative 1.

Conventional treatment will respond quickly to increase in raw water turbidity, but will require staff input to change coagulant dose, filter rates, and filter performance during significant changes in raw water turbidity. In addition, the existing raw water quality may be difficult to treat with conventional treatment due to the low raw water turbidity and TOC values.

Membranes are also capable of responding more quickly to increases in raw water turbidity. As previously noted, membranes will be superior in resistance to upset during rapidly changing raw water turbidity and will be less dependent on constant staff attention during periods of poor water quality. The membrane system has an advantage in this category. However, membrane capacity may be reduced during periods of poor water quality and may require use of the City's well supply.

5.8.7 Site Compatibility

Preliminary review of the Outback Facility site indicates that any of the alternatives can be constructed on the existing site in the location of the future storage reservoirs. All of the treatment alternatives are considered to be equal with respect to site compatibility. The UV alternatives will have the smallest footprint while the conventional alternative will have the largest footprint.

5.9 Results And Recommendations

This section discusses results and recommendations.

5.9.1 Summary of Evaluation

According to our analysis, the total 20-year present worth of the four alternative treatment systems for 13 mgd capacity is listed in Table 5-16.

Table 5-16. 20-year Present Worth Cost

Treatment alternative	Cost, million dollars
Alternative 1 – UV Disinfection	10.6
Alternative 2 – UV Disinfection with Pretreatment	19.8
Alternative 3 – Conventional Treatment	28.0
Alternative 4 – Membrane Filtration	28.7

A ranking of the treatment alternatives for the Bridge Creek source according to the evaluation criteria is given in Table 5-17. The initial rankings were assigned by Black & Veatch and will be revised as needed upon review with City staff.

Table 5-17. Treatment Alternatives Evaluation Criteria

Criteria (rank)	Alternative 1– UV Disinfection	Alternative 2– UV with Pretreatment	Alternative 3– Conventional Treatment	Alternative 4– Membrane Filtration
Capital cost	1	2	3	3
O&M costs	1	1	2	3
Water quality risks	4	3	2	1
Staffing, operability, and automation	1	4	2	1
Expandability	1	1	2	1
Operational flexibility	3	2	1	1
Site compatibility	1	1	1	1
Total points (lower is best)	12	14	13	11

Membrane filtration has the most favorable overall ranking followed by UV disinfection without pretreatment, conventional filtration, and UV disinfection with pretreatment. Although ranked second with respect to total points, UV disinfection without pretreatment is ranked the lowest in the two most important areas—water quality risks and operational flexibility. Conventional treatment is ranked third but does have the ability to mitigate water quality risks and provides flexibility to treat varying raw water quality conditions. Membrane filtration is ranked first in the most categories including the key criteria of water quality risks and operational flexibility, primarily due to their robustness and ability to produce high quality water regardless or raw water quality conditions. UV disinfection with pretreatment is ranked lowest. Although UV disinfection with pretreatment will provide more operational flexibility than UV without pretreatment, this alternative will not mitigate against forest fires. In addition, the additional capital costs of the pretreatment process and additional pumping requirements make this alternative significantly more expensive than UV alone.

USEPA Letter Regarding LT2 *Cryptosporidium* Level

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

OFFICE OF
WATER AND WATERSHEDS

August 3, 2009

Steve J. Prazak – Laboratory Manager
City of Bend Water Quality Laboratory
575 NE 15th Street
Bend, Oregon 97701

RE: Long Term 2 Enhanced Surface Water Treatment Rule Mean *Cryptosporidium* Level
Bend Water Department – 4100100

Dear Mr. Prazak:

Thank you for your July 14, 2009, letter in which you reported a mean *Cryptosporidium* level of 0.01 oocysts/L based on *Cryptosporidium* monitoring conducted between December 12, 2005 and January 15, 2008. With this letter and the summary of the source water monitoring data that you submitted previously, the Bend Water Department has satisfied the initial *Cryptosporidium* monitoring and reporting requirements of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

As you are probably aware, unfiltered water systems with a mean *Cryptosporidium* level of 0.01 oocysts/L are required to provide at least 2-log *Cryptosporidium* inactivation. (The LT2ESWTR identifies "maximum treatment" for an unfiltered system as 3-log *Cryptosporidium* treatment.) The Bend Water Department must comply with this treatment requirement no later than October 1, 2012, although the State may allow up to an additional two years for complying with the treatment requirement if you will be making capital improvements.

Water systems serving between 50,000 and 99,999 people must conduct a second round of source water monitoring starting October 2015. If, however, the Bend Water Department installs "maximum treatment" as described above, this monitoring will not be required.

Within the next few months the Environmental Protection Agency will be transferring implementation of the LT2ESWTR (and the Stage 2 Disinfection Byproducts Rule) to the Oregon Drinking Water Program, so if you have any questions pertaining to your treatment requirements or to your second round of monitoring, please contact the state. If, however, you have any questions pertaining to this letter, please feel free to contact me at (206) 553-1890 or marshall.wendy@epa.gov.

Sincerely,

Wendy Marshall

Wendy Marshall
Environmental Scientist

APPENDIX 5-B

Estimate of Probable Construction Cost and 20-year Present Worth Cost

City of Bend
Water Supply Alternatives Project
TM4 - Water Treatment Evaluation
Opinion of Probable Construction Cost
Alternative 1 - UV Disinfection

Item	Phase 1 13 MGD
General Conditions, Bonds, and Insurance (11.5%)	$500,000
Contractor Markups (10%)	$400,000
UV System	$1,800,000
Chemical Feed Facilities	$400,000
Operations Building	$600,000
Emergency Generator	$500,000
Site Civil & Yard Piping	$700,000
Alternative 1 Probable Construction Cost	**$4,900,000**
Contingency (30% of Probable Construction Cost)	$1,500,000
Engineering, Legal, & Administration (18% of Subtotal Probable Construction Cost)	$900,000
Subtotal Alternative 3 Probable Project Cost	$7,300,000
Mid-Point of Construction (October 2011)	$800,000
Rate= 4%	
Time= 2.5 years	
TOTAL ALTERNATIVE 1 PROBABLE PROJECT COST	**$8,100,000**

City of Bend
Water Supply Alternatives Project
TM4 - Water Treatment Evaluation
Opinion of Probable Construction Cost
Alternative 2 - UV Disinfection with Pre-treatment

Item	Phase 1 13 MGD
General Conditions, Bonds, and Insurance (11.5%)	$1,000,000
Contractor Markups (10%)	$900,000
Ballasted Flocculation (13 MGD)	$900,000
UV System	$1,800,000
Settled Water Wetwell	$800,000
Settled Water Pump Station	$1,400,000
Chemical Feed Facilities	$800,000
Operations Building	$600,000
Emergency Generator	$500,000.0
Site Civil & Yard Piping	$1,800,000
Alternative 2 Probable Construction Cost	**$10,500,000**
Contingency (30% of Probable Construction Cost)	$3,200,000
Engineering, Legal, & Administration (18% of Subtotal Probable Construction Cost)	$1,900,000
Subtotal Alternative 2 Probable Project Cost	**$15,600,000**
Mid-Point of Construction (October 2011)	**$1,700,000**
Rate= 4%	
Time= 2.5 years	
TOTAL ALTERNATIVE 2 PROBABLE PROJECT COST	**$17,300,000**

City of Bend
Water Supply Alternatives Project
TM4 - Water Treatment Evaluation
Opinion of Probable Construction Cost
Alternative 3 - Conventional Treatment

Item	Phase 1 13 MGD
General Conditions, Bonds, and Insurance (11.5%)	$1,400,000
Contractor Markups (10%)	$1,200,000
Ballasted Floc (6.5 MGD)	$450,000
Flocculation Basins	$400,000
Granular Media Filters	$2,000,000
Treated/Filtered Water Wetwell	$1,600,000
Filtered Water Pump Station w/ Backwash	$1,900,000
Chemical Feed Facilities	$800,000
Backwash Waste Lagoons and Decant Pump Station	$750,000
Operations Building	$600,000
Emergency Generator	$500,000
Site Civil & Yard Piping	$2,400,000
Alternative 3 Probable Construction Cost	**$14,000,000**
Contingency (30% of Probable Construction Cost)	**$4,200,000**
Engineering, Legal, & Administration (18% of Subtotal Probable Construction Cost)	$2,600,000
Subtotal Alternative 3 Probable Project Cost	**$20,800,000**
Mid-Point of Construction (October 2011)	$2,200,000
Rate= 4%	
Time= 2.5 years	
TOTAL ALTERNATIVE 3 PROBABLE PROJECT COST	**$23,000,000**

City of Bend
Water Supply Alternatives Project
TM4 - Water Treatment Evaluation
Opinion of Probable Construction Cost
Alternative 4 - Membrane Filtration

Item	Phase 1 13 MGD
General Conditions, Bonds, and Insurance (11.5%)	$1,300,000
Contractor Markups (10%)	$1,200,000
Flocculation Basins	$400,000
Membrane Facility (includes Membranes and Ancillary Equipment)	$5,800,000
Chemical Feed Facilities	$800,000
Backwash Waste Lagoons and Decant Pump Station	$800,000
Operations Building	$600,000
Emergency Generator	$500,000
Site Civil & Yard Piping	$2,400,000
Alternative 4 Probable Construction Cost	**$13,800,000**
Contingency (30% of Probable Construction Cost)	$4,200,000
Engineering, Legal, & Administration (18% of Subtotal Probable Construction Cost)	$2,500,000
Subtotal Alternative 4 Probable Project Cost	$20,500,000
Mid-Point of Construction (October 2011)	$2,200,000
Rate= 4%	
Time= 2.5 years	
TOTAL ALTERNATIVE 4 PROBABLE PROJECT COST	**$22,700,000**

	Alternative 1 UV Disinfection	Alternative 2 UV Disinfection with Pretreatment	Alternative 3 Conventional Treatment	Alternative 4 Membrane Filtration
TOTAL PROBABLE PROJECT COST	**$8,100,000**	**$17,300,000**	**$23,000,000**	**$22,700,000**

OPERATION AND MAINTENANCE COSTS (O&M)
RECURRING AND ANNUAL COSTS

Item Description	Unit	Qty	Unit Cost	Item Cost	Subtotal	Alternative 1 UV Disinfection	Alternative 2 UV Disinfection with Pretreatment	Alternative 3 Conventional Treatment Subtotal	Alternative 4 Membrane Filtration Subtotal
Staffing									
Staff time O&M - annual 2 FTE	Hours	4,160	$31	$129,000		**$129,000**	**$129,000**		
Staff time O&M - annual 4 FTE	Hours	8,320	$31	$257,900				**$257,900**	**$257,900**
Power									
Conventional	kWh	680,000	$0.07500	$51,000		**--**	**--**	**$51,000**	**--**
Membranes	kWh	850,000	$0.07500	$63,800		**--**	**--**	**--**	**$63,800**
UV	kWh	690,000	$0.07500	$51,800		**$51,800**	**$51,800**	**--**	**--**
Chemical Usage									
Filter Aid Polymer	LS	1	$5,000	$5,000		**--**	**--**	**$5,000**	**--**
CIP Chemicals	LS	1	$44,000	$44,000		**--**	**--**	**--**	**$44,000**
CIP Chemicals Disposal	LS	1	$35,000	$35,000		**--**	**--**	**--**	**$35,000**
Pre-treatment Coagulant & Polymer	LS	1	$60,000	$60,000		**--**	**--**	**$60,000**	**--**
UV Annual O&M Costs	LS	1	$10,000	$10,000		**$10,000**	**$10,000**	**--**	**--**
Total Annual Costs						**$190,800**	**$190,800**	**$373,900**	**$400,700**
20-YEAR PRESENT WORTH OF ANNUAL COSTS AT 5% INTEREST						**$2,380,000**	**$2,380,000**	**$4,660,000**	**$4,990,000**

Replacement Costs	Unit	Qty	Unit Cost	Item Cost	Replacement Interval-Years	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Filter Media Replacement - Conventional Filters	LS	1	$174,000	$174,000	10	--	--	$174,000	--
Membrane Replacement	LS	1	$913,000	$913,000	10	--	--	--	$913,000
Mechanical/Ancillary Equipment	LS	1	$300,000	$300,000	20	$150,000	$150,000	$300,000	$300,000
Total 5-yr Replacement Costs						**$0**	**$0**	**$0**	**$0**
Total 10-yr Replacement Costs						**$0**	**$0**	**$174,000**	**$913,000**
Total 15-yr Replacement Costs						**$0**	**$0**	**$0**	**$0**
Total 20-yr Replacement Costs						**$150,000**	**$150,000**	**$474,000**	**$1,213,000**
20-YEAR PRESENT WORTH OF REPLACEMENT COSTS AT 5% INTEREST						**$60,000**	**$60,000**	**$290,000**	**$1,020,000**
TOTAL OF RECURRING AND ANNUAL O&M COSTS						**$2,440,000**	**$2,440,000**	**$4,950,000**	**$6,010,000**
TOTAL PRESENT WORTH OF CAPITAL AND O&M COSTS (AT 5 % INTEREST)						**$10,540,000**	**$19,740,000**	**$27,950,000**	**$28,710,000**