PROJECT:	Bull Run Filtration Project
PROJECT NUMBER:	W02229
PREPARED BY:	Christopher Bowker
DATE:	August 31, 2018
SUBJECT:	Filtration Plant Key Decisions and Process

1.0 Executive Summary

In August 2017, the Portland City Council voted to construct a water filtration treatment facility to meet the treatment requirements for *Cryptosporidium*. On December 18, 2017 the Oregon Health Authority-Drinking Water Services (OHA) and the Portland Water Bureau (PWB) signed a bilateral compliance agreement that laid out a schedule for construction of a new filtration treatment system on the Bull Run Supply by September 30, 2027. The approved filtration schedule includes three primary phases – Planning, Design, and Construction. It will take approximately 10 years until the treatment facility is operational.

The Bull Run Filtration Project (filtration project) will be one of the largest PWB projects to date. PWB has already begun the planning phase of this project, which included answering four preliminary questions related to filtration of the water supply: project delivery (procurement) method, plant capacity, location, and filtration technology. The results from this process were four preferred alternatives that the project will build upon moving forward.

To reach a decision, each question was evaluated and discussed by the project team (which included stakeholders with broad technical and organizational representation) and the Executive Committee (comprised of PWB Management Team members) at a series of workshop sessions between January and June 2018. Three consultants were hired to assist in gathering and understanding relevant information for these decisions: Barney & Worth (community outreach), HDR (procurement, location, and capacity), and Jacobs (decision framework and filtration technology).

Technical memorandums were used to explain and document this process. Three of the decisions (capacity, location, and filtration technology) used a decision-making process generally referred to as a decision framework, which is discussed in the first document enclosed herein. This decision framework was used to help compare and contrast more complex issues related to these questions. The development and application of the decision framework components were accomplished through the workshops. Decisions were made by the Executive Committee.

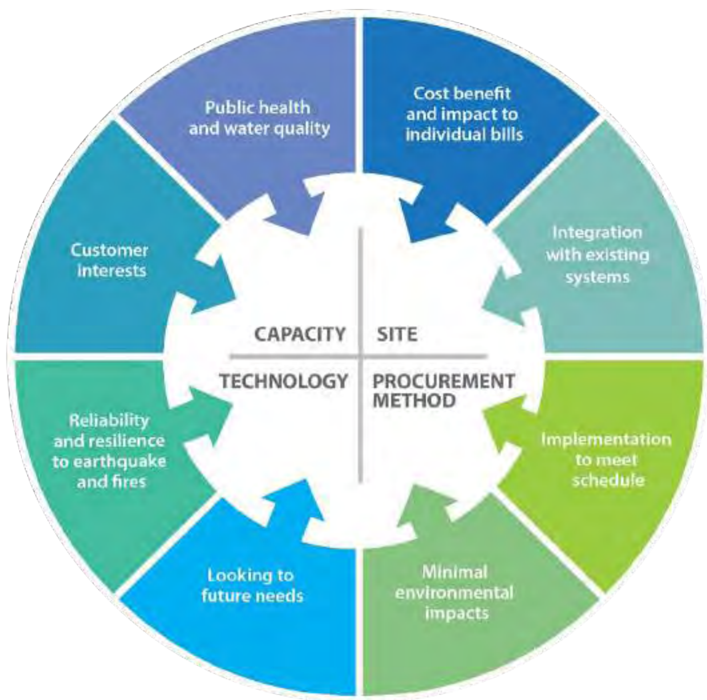
The collection of documents enclosed herein represents the initial work performed during the planning phase of the Bull Run Filtration Project and includes technical memorandums on the decision framework, the four key questions, as well as supporting documents. These documents are summarized below.

Decision Framework

The capacity, location, and filtration technology decisions were complex and had multiple components to consider and weigh. With consultant support, PWB produced a decision framework comprised of building blocks that provided the specific steps to reach the decisions. This framework was paramount to reaching these decisions because it designated who was included in the process, established their roles within the process, provided continuity of decision-making across the three decisions, clarified how conclusions would be reached, structured the inclusion of important values in the process, and characterized how information was presented in workshop settings. This information was captured in the Decision Framework technical memo (Document 1).

Once the framework was established, the next step was to identify and prioritize community and PWB values that were important and relevant to the filtration project, resulting in a values hierarchy. Values were the guiding principles to be considered when making decisions and were used to characterize, understand, and communicate tradeoffs. Criteria were then developed that supported these values. Specific and measurable performance scales were then identified that could be used to evaluate and compare alternatives; these are specific to each fundamental decision. The values, criteria, and performance scales were developed using surveyed community input and project team input. The organization of values, their descriptions, and the criteria that refine the values are incorporated in the Values Hierarchy.

Finally, a decision model was developed. Utilizing weighted scenarios and data-plots, the model incorporated the values, criteria, and performance evaluation into a structure allowing for comparative assessment of the alternatives considered for each of the four key areas.



Developing the decision framework, values hierarchy and decision model standardized a methodical evaluation process, assured incorporation of community and PWB values, and transparently displayed how pre-planning phase filtration decisions were reached.

Filtration Plant Alternative Delivery

The planning, design, construction, and commissioning of a filtration plant is estimated to cost between $350 and $500 million. In order to minimize project delivery risk and cost and schedule impacts, PWB evaluated alternative delivery (AD) procurement methods as allowed under ORS 279.015 and compared them to traditional design-bid-build (DBB or "low bid").

The Filtration Plant AD Methods technical memo (Document 2) described three potential AD methods available to deliver the filtration plant design, construction, and commissioning; discussed the advantages/disadvantages of each compared to traditional Design-Bid-Build (DBB) procurement; and presented a comparison of the alternatives to assist in the determination of the most appropriate delivery method for the filtration project. These three methods are Construction Manager/General Contractor (CM/GC), Fixed-Price Design-Build (FPDB), and Progressive Design-Build (PDB).

To select an AD method, a workshop was held with the consultants, PWB, and City of Portland procurement staff. The purpose of the workshop was to describe the contractual arrangements for DBB, CM/GC, FPDB, and PDB; differentiate the AD methods by their specific characteristics; and compare each AD method and its advantages over DBB with a list of criteria specific to the filtration plant project and PWB concerns.

The starting considerations for the workshop are summarized below:

- All three alternative delivery (AD) methods would reduce project schedule compared with the standard DBB approach. This is due to the elimination of the need to bring the design to 100% completion prior to the advertisement and bidding period required in DBB procurement. In addition, design and early construction activities can occur concurrently. In each case, the selection of the eventual contractor is done early in the design process.
- All three AD methods would require an exemption to competitive bidding under ORS 279.015. However, none would limit competition, and all have the potential to save costs through the shorter delivery schedule and collaborative working relationships they promote.
- All three AD methods have been successfully used by public works agencies in the U.S. However, the default selection would be CM/GC, unless one of the other two options proves superior.

The delivery methods were then evaluated for their ability to satisfy primary PWB considerations under four main categories: project-specific attributes, PWB culture, management and reporting, and past experience. The workshop discussion on these topics revolved around the varied experience of the participants, including current City experience with PDB.

In the workshop, staff deliberated on what AD method best met PWB's project needs. The participants determined that CM/GC procurement was the most advantageous method for delivery of the filtration project. CM/GC would allow greater control of project decision-making, as well as engineering and operations input into the facility design. CM/GC is also anticipated to maximize Disabled/Minority/Women/Emerging Small Business (D/M/W/ESB) participation in both the design and construction contracts. Additionally, PWB has successful prior experience with CM/GC and was more confident in its application for the filtration project.

Filtration Plant Capacity

The capacity decision was a complex decision based on forecasted demands and population growth. The project team and Executive Committee reached a conclusion with the assistance of the decision framework. PWB staff identified the criteria and performance scales used as part of the decision-making process to identify the plant capacity. The performance scales applied to the capacity decision were considered independently of two other key areas: location and filtration technology. The choice of capacity then informed the choice of location and filtration technology.

The capacity decision includes considerations for future demands, level of service goals (both quantity and quality), costs (capital and operations and maintenance) or different filtration plant capacity and supplementary supply alternatives), and other factors. The Filtration Plant Capacity Alternatives technical memo (Document 3) presents the initial plant capacity alternatives, likelihood of need to rely on other PWB management strategies to meet peak demands, applicable decision model criteria related to capacity, and evaluation of each capacity alternative.

Five capacity alternatives for the future filtration plant were initially identified by PWB and HDR (Table 1). The capacity for each alternative was established based on a combination of the physical constraints of the existing Bull Run supply system and PWB demand projections.

Both the 200 mgd capacity and 100 mgd capacity alternatives were found to be unsuitable and eliminated from further consideration. The 200 mgd capacity was rejected from further consideration because it is 40 mgd higher than the projected PDD of 160 mgd in a stress year for 2045 (i.e., the highest demand day between 2027 and 2045). A 100 mgd capacity facility was also rejected because it would not meet system demand up to 50 percent of the time and alternative management strategies would be needed on a regular basis. This is inconsistent with PWB's groundwater policy (Appendix B).

The remaining alternatives were carried forward for evaluation using the decision model and criteria. The range of 115 – 120 mgd was reduced to 115 mgd to simplify the subsequent analysis. Similarly, the range of 135 – 145 mgd became 145 mgd. The potential plant capacities of 115, 145, and 160 mgd took into consideration the projected peak daily demand (PDD), peak 3-day demand (P3D) in a stress year (an unusually warm and dry year) for 2045, and their ability to consistently meet projected PWB water system demands.

Table 1: Initial Capacity Alternatives

Capacity (mgd)	Description
200	Approximately equal to maximum Bull Run conduit capacity
160	Slightly higher than the projected 2045 PDD and P3D demands in a stress year
145	Covers 90% of 2045 PDD and P3D demands in a stress year
115	Slightly higher than the projected 2045 PDD and P3D in a weather normalized year.
100	Slightly higher than the projected 2045 summer average demand in a weather-normalized year

The project team, with agreement from the Executive Team, used the results of the decision model to first remove the 115 mgd alternative from further consideration. This alternative provided the fewest overall benefits to PWB in most of the evaluation scenarios that the team considered and discussed, as well as having the highest cost per unit value of the three modeled scenarios.

The scoring between the 145 mgd and 160 mgd alternatives was very similar. After another analysis of the criteria, with and without scoring, the project team and the Executive Committee merged the two alternatives into a single conclusion.

It was decided that the desired capacity is 160 mgd, with an understanding that the capacity ultimately constructed may be somewhat smaller. This could be due to subsequent decisions about siting and filtration technology as well as later design choices. However, the lowest installed capacity that the PWB would accept is 145 mgd. This decision of a desired capacity and hard lower limit provides adequate direction at this early phase of the project and reflects PWB's current understanding of projected PDD, while providing flexibility during treatment plant design in the coming years.

Filtration Plant Site Alternatives

Based on previous studies, six sites were evaluated for their ability to host a filtration-type treatment facility: Carpenter Lane, Lusted Hill (with expansion), Headworks, Larson's Ranch, Powell Butte, and Roslyn Lake (see Figure 1). These sites were selected on their anticipated ability to meet essential criteria.

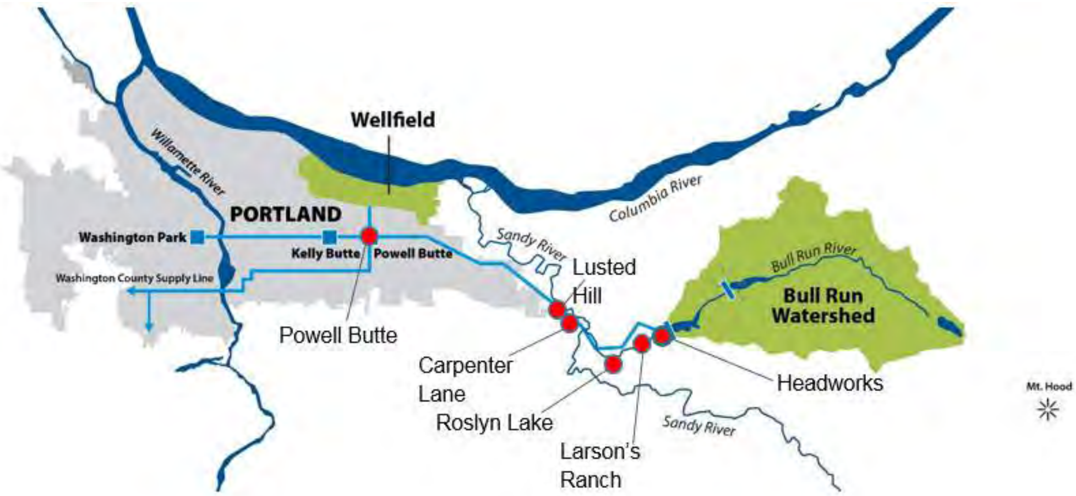


Figure 1: Approximate locations of the six potential filtration sites reviewed.

The location decision was likely the most difficult decision to make. Although the decision framework was used, the final two sites were essentially equal in their value scores. Compounding this was the added difficulty of anticipating how the Bull Run supply transmission system may change in the future. HDR coordinated closely with PWB and their other consultants, Jacobs and Barney & Worth, to develop the criteria and performance scales that drove the location decision. The site was selected after a plant capacity was identified, (see Filtration Plant Capacity Alternatives), but before the filtration technology was determined.

Several major considerations exist that affected site choice such as cost/benefit impacts, meeting future needs, and regulatory compliance. The team developed specific siting criteria that supported these broader values. The criteria used in the evaluation were: maximizing gravity flow, site proximity to existing and future conduit rights-of-ways (ROWs), site size, site slopes and geologic conditions, and impacts to the compliance schedule.

The six potential filtration facility sites were evaluated for their ability to meet these essential criteria. Sites needed to meet all essential criteria or else were considered to have a fatal flaw. Table 2 summarizes each sites' ability to meet the essential criteria (using a pass/fail scoring). Four of the sites failed to meet all essential criteria. Only two sites, Carpenter Lane and Lusted Hill, passed all essential criteria and were therefore evaluated further using the decision framework.

Table 2. Pass/Fail Results of How Well Each Initial Site Met the Essential Criteria.

Site	Hydraulic Grade Line	Proximity to Conduits	Tax Lot Size	Slopes and Geologic Hazards	Schedule
Carpenter Lane	**Pass**	**Pass**	**Pass**	**Pass**	**Pass**
Headworks	Fail	Pass	Fail	Fail	Pass
Larson's Ranch	Fail	Pass	Pass	Pass	Pass
Lusted Hill	**Pass**	**Pass**	**Pass (with site expansion)**	**Pass**	**Pass**
Powell Butte	Pass	Pass	Pass	Pass	Fail
Roslyn Lake	Fail	Pass	Pass	Pass	Pass

The results from the decision model were discussed at length by the project team and the Executive Committee. The scores for both the alternatives were very close in all three weighting scenarios and the filtration team and the Executive Committee were split between the two sites. A major concern with expanding Lusted Hill was related to part of the area being zoned as Exclusive Farm Use (EFU), although the site had other benefits. Receiving a conditional land use approval on EFU zoned land was identified as a significant hurdle. Team members with more extensive knowledge of state land use decisions felt an approval was unlikely to be granted. Others felt that even if an approval could eventually be granted, the approval process would be drawn out to the point where it would likely prevent PWB from meeting the compliance deadline.

The team was very concerned about the risk to the schedule of siting the facility within an EFU zone. To be better informed about this risk, the Executive Committee consulted with the City Attorney. The City Attorney's opinion was that, in this situation, attempting to build on EFU land would be an unacceptable risk to the schedule. Therefore, Carpenter Lane was selected by the Executive Committee as the preferred filtration plant site.

Filtration Plant Filtration Technology

The filtration technology decision was made with the assistance of the decision framework and is captured in the Filtration Plant Technology Assessment (Document 4). Jacobs coordinated closely with PWB and their other consultants, HDR and Barney & Worth, to identify the criteria and performance scales that PWB staff used as part of the decision-making process to identify the filtration plant technology. The performance scales applied to the technology decision were considered after capacity and location were determined because these may have impacted the technology decision.

The Environmental Protection Agency (EPA) recognizes several filtration strategies for compliance with the Surface Water Treatment Rules, including the latest Long-term 2 Enhanced Surface Water Treatment Rule that sets out treatment requirements for *Cryptosporidium* removal and inactivation. These technologies include granular media filtration, membrane filtration, slow sand filtration, cartridge and bag filtration, and diatomaceous filtration. Of these filtration technologies, there are no known large (greater than 50 mgd) cartridge, bag, or diatomaceous earth filtration facilities. Therefore, the team proposed to focus the evaluation on the remaining three technologies.

The consultant team met with PWB and identified a list of filtration benefits that would have measurable impact on evaluating the differences among the remaining three filtration technologies being considered. These filtration benefits are based on the benefits originally described by PWB to City Council in the August 1, 2017 memo identifying the probable benefits of filtration over UV treatment. Potential benefits of filtration are as follows:

- Provide pathogen removal for *Cryptosporidium, Giardia*, bacteria and viruses
- Produce biologically stable water
- Reduce disinfection by-products
- Increase supply reliability
- Reduce distribution system flushing, and lower turbidity levels
- Reduce iron and manganese concentrations
- Improve water quality stability; reduce lead and copper release at customer taps
- Reduce water quality impacts due to warmer weather (such as algae)
- Reduce organic discoloration events
- Improve ability to respond to changes in regulations
- Increase ability to meet several critical service levels
- Treat a sustained elevated turbidity event
- Reduce customer cost of water treatment at the tap

The three technologies were then evaluated for their ability to provide the above desired system benefits. For evaluation purposes, some pre- or post-treatment measures were assumed so that PWB could evaluate the full treatment systems ability to achieve the required desired benefits of filtration. This was done to develop capital and operating costs so that decision-makers could fairly evaluate the alternatives. Actual pre- or post-treatment processes will be determined later. None of the treatment configurations for slow sand filtration provided a good or excellent rating for all filtration benefits. Therefore, it was recommended that only granular media filtration and membrane filtration be evaluated for potential filtration technology to use on the Bull Run supply.

These two technologies were then compared using the decision model. In all three weighing schemes, granular media filtration resulted in higher performance. Granular media filtration provides greater value at less cost while providing the desired filtration benefits. The membrane filtration option costs more and provides less value. The project team and Executive Committee selected granular media filtration as the preferred treatment technology.

Supporting Documents

Included are two documents that provided supporting information not listed in the appendices of the above technical memoranda: the Preliminary Geotechnical Study and the Carpenter Lane Site Evaluation memo. The Preliminary Geotechnical Study and the Carpenter Lane Site Evaluation memo were used to confirm the suitability of Carpenter Lane and will continue to be used in future site-specific evaluations, such as when considering environmental impacts and permitting needs.

Technical Memo

Date:	September 5, 2018
Project:	Bull Run Filtration Project 699275.01.03
To:	Portland Water Bureau Filtration Decision Team
Copy to:	David Peters, PE and Michelle Cheek, PE – Portland Water Bureau
Prepared by:	Dan Speicher
Approved by:	Kelly Irving
Subject:	**Filtration Plant Decision Process**

1.0 Introduction

In August 2017, the Portland City Council voted to build a water filtration treatment facility to meet the treatment requirements associated with Cryptosporidium. On December 18, 2017, the Oregon Health Authority – Drinking Water Services (OHA) and the Portland Water Bureau (PWB) signed a bilateral compliance agreement that laid out a schedule for construction of a new filtration treatment system on the Bull Run Supply by September 30, 2027.

The approved filtration schedule includes three phases – Planning, Design, and Construction. Following the August 2017 City Council approval, the Bull Run Filtration project was initiated in fall 2017. In December 2017, PWB staff and consultants began the pre-planning task as part of the Planning Phase.

Part of this pre-planning task was to make four key decisions related to filtration of the water supply: project delivery method, filtration plant capacity, site suitability, and filtration technology. Three of the decisions (filtration plant capacity, site suitability, and filtration technology) used the decision process described in this document. The project delivery method did not require the use of this process. The decision process was supported by a Filtration Team which included technical representation from throughout the PWB organization. Decisions were made by the Executive Committee comprised of PWB management team members.

Three distinct yet interrelated components were produced to assist the Filtration Team and the Executive Committee in reaching these decisions – a Decision Framework, Values Hierarchy, and Decision Model. The development and application of these components were accomplished through a series of workshop sessions between February and June 2018.

The first component, the Decision Framework, designated who was included in the process, clarified how conclusions would be reached, structured the inclusion of important values in the process, and characterized how information was presented and facilitated.

The second component, Values Hierarchy, is a description and ordering of the values most important to the community and PWB. Values are the guiding principles that must be considered when making decisions and are used to characterize, understand and communicate tradeoffs.

The third component, the Decision Model, incorporated the values, criteria, and performance evaluation of the viable alternatives into a structure allowing for comparative assessment of the alternatives within each decision. The Decision Model brings together the possible alternatives within each decision, displays the performance of the alternatives against the values, and demonstrates the trade-offs of values for the decision makers. Similar results were produced for each of three filtration decisions. The results of the Decision Model evaluation are found in the separate decision technical memoranda.

The combination of the Decision Framework, Values Hierarchy and Decision Model generated and codified the process, assured incorporation of community and PWB values, and transparently displayed the insight that went into reaching the filtration decisions. Although these components supported, informed, and structured the decision process, the team involved made the decisions.

This technical memorandum presents the development of these three parts: Decision Framework, Values Hierarchy, and Decision Model. This memorandum is not intended to repeat material in the separate technical memoranda associated with each individual decision (capacity, site, technology). Rather, this memorandum is designed to capture the development and application of the framework, hierarchy and model that structured and supported reaching the filtration decisions.

This document serves to record the decision-making process and provide a process description for any interested party.

2.0 Background

In 2010, PWB navigated through a decision process associated with another decision effort. At that time, PWB and the consultant team applied a structured decision process to provide direction and reach decisions with the initiation of a 30 percent design.

The factors affecting those decisions, which predicated the use of a structured decision process, were:

- A very short time frame in which to make decisions — roughly a 6-month window
- The likely multiple objectives that would need to be considered in the approach; in particular, a combination of social, environmental, and financial (triple bottom line) criteria
- The large number of stakeholders and other interested parties, mainly internal to PWB
- The significant interest those stakeholders and interested parties had in the decisions
- The large expectation of communication with those stakeholders and interested parties
- The differing perspectives those stakeholders would likely have concerning a direction or decision
- The diverse sets of data that were to be generated as part of the assessment

All of these characterizations contributed to the need to develop a structured, exhaustive, and transparent decision process that involved a large number of stakeholders, interested parties, and yet still produced decisions within the required time frame.

The success of that previous decision process was the basis for applying a similar process when the City concluded that filtration was the preferred technology for Bull Run water treatment. Reaching decisions associated with filtration had many similarities to the previous decision process, including:

- A relatively short time frame in which to make decisions — roughly a 6-month window
- Multiple values from both PWB and the community that needed to be considered in the approach

- A large number of PWB stakeholders, and a significant interest by those stakeholders in the decisions
- A large and diverse set of external stakeholders
- Differing perspectives that those stakeholders would likely have concerning a direction or decision
- The diverse sets of data that were to be evaluated as part of the assessment, and
- Three unique yet interrelated decisions (capacity, site, technology) that had to be considered in a consistent way

These factors, once again, required the development of a structured, comprehensive, and transparent decision process that involved a large number of stakeholders, and still produced decisions within the required time frame.

3.0 Decision Framework

Reaching the three decisions required the assistance of a Decision Framework. This Decision Framework designated who must be included in the process to reach effective conclusions in workshop settings, clarified how conclusions would be reached, structured the inclusion of the Values Hierarchy and Decision Model to apply across all the decisions, and characterized how information would be presented and facilitated in the workshop settings.

With consultant support, PWB produced a Decision Framework comprised of building blocks that provided the specific steps to reach the decisions. This Decision Framework was paramount to reaching these decisions because it established structure among all the participants, provided continuity of decision-making across the three decisions, and clarified the participants and their roles within the process.

Figure 1 presents the resulting Decision Framework.

This page intentionally blank.

JACOBS

Figure 1. Decision Framework

Portland Water Bureau – Filtration Decision Support: Decision Framework

March 9, 2018

This placemat displays and describes the building blocks of the Filtration Decision Framework

Framework Introduction

1 Decision Context

Four decisions will be reached by July 1, 2018; three will use this framework:
- Site selection/suitability
- Capacity
- Filtration Technology

2 Framework Defined

This decision framework provides the structure and associated components to assist PWB in comparing the options and reaching agreement on the preferred option within each decision in the required time-frame.

3 Framework Provisions

The framework provides:
- Consistent and managed decision-making structure
- Clarity of who holds decision authority
- Incorporation of both community and PWB values

4 Framework Intent

Application of the decision framework is intended to:
- Ensure decisions reflect community and PWB values
- Provide transparency to the decision process
- Assure decisions endure

5 Framework Components

A. Values hierarchy
B. Criteria/performance measures
C. Decision-maker designation
D. Workshop schedule
E. Workshop elements

Framework Components Details

A Values Hierarchy

The hierarchy captures and structures the values of both the community and PWB. Decision makers consider the tradeoffs among these values to reach a conclusion. Values will include cost, water quality/ public health, resiliency/reliability, community concerns, and implementation among others.

B Criteria/Performance Measures

Criteria refine the values into measurable components. Performance measures are the specific scales used to gauge the performance of the options against the criteria. Criteria and associated performance measures are developed for each value and customized for the decisions.

C Decision-Maker Designation

Consultants: Explainers. Translators. Trusted advisors. Bring examples and proof. Provide data and analysis. Resources.

PWB Technical Team: Provide guidance, leadership, and support to decision process. Participate. Provide recommendations.

PWB Executive Committee: Provide input, perspective, and questions. Validate with Mike Stuhr. Make decisions.

Mike Stuhr: Provide validation of direction and decisions.

D Decision Workshop Schedule

Feb 28	o Recognition of values o Agreement upon decision making framework
Mar 21	o Validation of information collection, analysis methodology, technical memo production o Comparative position determination
Apr 18	o Capacity conclusion
May 23	o Site conclusion
Jun 20	o Filtration conclusion

E Workshop Elements

Prepared for and shared/ accomplished within meetings:
i. Technical analysis
ii. Comparative position
iii. Define, characterize, and compare
iv. Consensus style
v. Executive Committee decision

Workshop Elements Details

i Technical Analysis

The PWB/consultant technical team will apply the values, criteria, and performance measures to the options associated with each decision. They will prepare a summation of the resulting option performance for review and discussion at the workshops. This is designed to be a starting point for reaching decisions.

ii Comparative Position

Each decision will have a comparative position. This comparative position serves as both the baseline from which other options are considered and value trade-offs are compared. A comparative position may be the minimum requirement within the decision and/or an option maximizing specific values.

iii Define, Characterize, Compare

Each decision will have at least two touches – introduction at the March 21st workshop and detailed review and conclusion at a decision workshop. At the decision workshops, the technical teams will Define the options; Characterize factual advantages and disadvantages; and, Compare the options benefits against cost.

iv Consensus Style

All steps within this decision framework - validation of values; agreement to the comparative position; definition, characterization, and comparison of options; discussion in the meetings - will be conducted in the style of consensus. This includes the decisions reached by the Executive Committee.

v Executive Committee Decision

Recommendations will be concluded by the technical team and the Executive Committee (Chris Wanner, Edward Campbell, Teresa Elliott, Gabriel Solmer) at the dedicated meetings. The Executive Committee will validate the conclusion with Mike Stuhr, and make a decision within 2 days of each workshop.

This page intentionally blank.

Three rows organize the building blocks of the Decision Framework in Figure 1:

- Framework Introduction
- Framework Components Details
- Workshop Elements Details

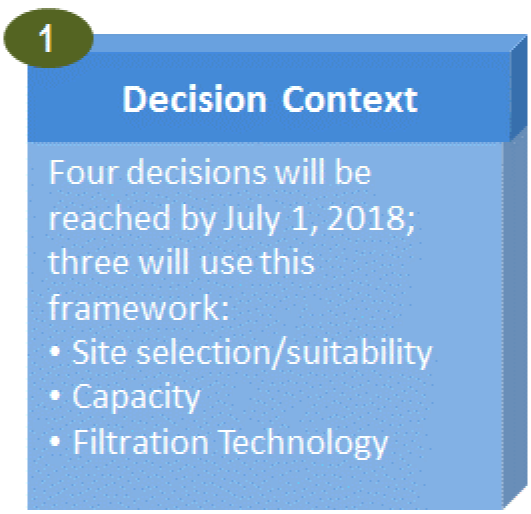
Each building block within each row is described below.

3.1 Framework Introduction

Five building blocks comprise the Framework Introduction. The five blocks include:

- Decision Context
- Framework Defined
- Framework Provisions
- Framework Intent
- Framework Components

These first five building blocks set the stage for what the framework was meant to do. Review and agreement of these items within the PWB team assured that the framework was being designed and implemented in a way to meet the collective needs of the participants.



Decision Context: A total of four decisions were part of the water filtration planning:

- Project delivery model
- Site selection/suitability
- Capacity
- Water Filtration Technology

The project delivery model recommendation was reached on January 30, 2018 and was not part of the application of this Decision Framework. The other three decisions used this Decision Framework to reach agreement and conclusions by July 1, 2018.

2

Framework Defined

This decision framework provides the structure and associated components to assist PWB in comparing the options and reaching agreement on the preferred option within each decision in the required time-frame.

Framework Defined: This Decision Framework was designed to provide the structure for effectively and efficiently reaching agreement and conclusions with the three filtration decisions. Viable alternatives were presented, analyzed and reviewed within each decision. The framework assured these alternatives were appropriate and thoroughly and uniformly considered. The outcome of the effort described in this building block is the framework as a whole shown in Figure 1.

3

Framework Provisions

The framework provides:

- Consistent and managed decision-making structure
- Clarity of who holds decision authority
- Incorporation of both community and PWB values

Framework Provisions: This framework was designed to provide many items in supporting the decision process. In particular, the framework was designed to provide a consistent and managed structure, clarity of how participants were involved in the decision-making, and assurance that the values of both the community and PWB were incorporated into the process.

4

Framework Intent

Application of the decision framework is intended to:

- Ensure decisions reflect community and PWB values
- Provide transparency to the decision process
- Assure decisions endure

Framework Intent: The framework was designed to deliver many results. The intent was a listing of the primary outcomes that were expected through the application of this framework. The development and implementation of this framework was expected to ensure the reflection of community values, offer transparency to the decision process, and lend to the endurance of the decisions.

5

Framework Components

A. Values hierarchy
B. Criteria/performance measures
C. Decision-maker designation
D. Workshop schedule
E. Workshop elements

Framework Components: Five components made up the structure of this Decision Framework. These components were specifically selected to deliver the framework intent and reach the conclusions of the three decisions. Each of these components is further defined below in Framework Component Details.

3.2 Framework Components Details

There are five framework components, as introduced in the last building block of the Framework Introduction above. These five components are further detailed in these building blocks:

- Values Hierarchy
- Criteria/Performance Measures
- Decision Makers Designation
- Workshop Schedule
- Workshop Elements

Values Hierarchy: The Values Hierarchy is a listing of the most important values of PWB and the community. Values serve as the primary means to compare the performance of alternatives within each decision. The decisions must be focused upon what tradeoffs take place among these values. An alternative that maximizes the values may be the most preferred. If one alternative does not maximize performance across all values, the decision makers must consider what tradeoffs among values are appropriate. The Values Hierarchy is a primary component within the decision framework and is described in much greater detail in a subsequent section of this document.

A

Values Hierarchy

The hierarchy captures and structures the values of both the community and PWB. Decision makers consider the tradeoffs among these values to reach a conclusion. Values will include cost, water quality/ public health, resiliency/reliability, community concerns, and implementation among others.

B

Criteria/Performance Measures

Criteria refine the values into measurable components. Performance measures are the specific scales used to gauge the performance of the options against the criteria. Criteria and associated performance measures are developed for each value and customized for the decisions.

Criteria/Performance Measures: Each value had at least one criterion that further refined the value into a measurable component. Each criterion had at least one performance measure that captured a specific scale used to measure or gauge the performance of each alternative. The criteria and the associated performance measures were applied as consistently as possible across all three decisions. However, the nuances of the decisions and the alternatives within them compelled the generation of slightly modified performance measures to capture appropriate comparisons within specific decisions. The nuances of each decision are captured in the technical memoranda summarizing each individual decision.

Decision-Maker Designation: A critical building block of the Decision Framework was clearly defining what roles the participants had in the process, and if those roles provide advice, recommendations, and/or decisions. This building block structured the conversation of specific roles, characterized the recommendation or decision authority of those roles, and determined how and where those decisions were made.

C

Decision-Maker Designation

Consultants: Explainers. Translators. Trusted advisors. Bring examples and proof. Provide data and analysis. Resources.

PWB Technical Team: Provide guidance, leadership, and support to decision process. Participate. Provide recommendations.

PWB Executive Committee: Provide input, perspective, and questions. Validate with Mike Stuhr. Make decisions.

Mike Stuhr: Provide validation of direction and decisions.

D

Decision Workshop Schedule

Feb 28	o Recognition of values o Agreement upon decision making framework
Mar 21	o Validation of information collection, analysis methodology, technical memo production o Comparative position determination
Apr 18	o Capacity conclusion
May 23	o Site conclusion
Jun 20	o Filtration conclusion

Workshop Schedule: Five workshops were planned for this Decision Framework. Each workshop delivered to the listed specific outcomes to maintain the schedule. (See Appendix A for workshop details.)

E

Workshop Elements

Prepared for and shared/ accomplished within meetings:

i. Technical analysis
ii. Comparative position
iii. Define, characterize, and compare
iv. Consensus style
v. Executive Committee decision

Workshop Elements: Five specific elements were prepared for and reviewed in the workshop setting designed to reach the conclusions associated with the three decisions. The workshops on April 18, May 23, and June 20 incorporated all of these elements. These elements were the culmination of the efforts by the technical teams. Each element is further detailed below.

3.3 Workshop Elements Details

There are five workshop elements, as introduced in the last building block of the Framework Components Details. These five elements are further detailed in these building blocks:

- Technical Analysis
- Comparative Position
- Define, Characterize, Compare
- Consensus Style
- Executive Committee Decision

i

Technical Analysis

The PWB/consultant technical teams will apply the values, criteria, and performance measures to the options associated with each decision. They will prepare a summation of the resulting option performance for review and discussion at the workshops. This is designed to be a starting point for reaching decisions.

Technical Analysis: The technical team, comprised of both PWB and consultant staff, evaluated and assessed the performance of the options against the values. The results of the technical analysis were relayed during the decision specific workshops.

Comparative Position: It is sometimes difficult to choose among a set of possible options. The likely differences in performance, plus the tradeoffs associated with values, may produce complexity in comparing results across the multiple options and reaching a conclusion and agreement. A suggested means to make the decision process less complex is to generate a position or option that serves as a point in which all other options are compared. This comparative position allows for the remaining options to be judged in performance as being equal to, worse than or better than that comparative position. This comparative position does not in any way limit the technical detail nor the differentiation of the alternatives. On the contrary, a comparative position could allow for more technical complexity in the process but produces the condition for the human participants in the process to tackle individual comparisons among criteria and values and then sum the results more effectively. The application of this comparative position was specific to each decision and was applied if it lent to reaching a conclusion and agreement more readily.

ii

Comparative Position

Each decision will have a comparative position. This comparative position serves as both the baseline from which other options are considered and value trade-offs are compared. A comparative position may be the minimum requirement within the decision and/or an option maximizing specific values.

Define, Characterize, Compare: Each dedicated decision workshop followed a uniform format of defining the alternatives, characterizing each alternative, and then presenting the performance and comparison of the alternatives. This uniform format both assured all three decisions were equally considered and the flow of the information became familiar to the participants. This familiarity supported the digestion of information and the discussion and deliberation among the team.

iii

Define, Characterize, Compare

Each decision will have at least two touches – introduction at the March 21st workshop and detailed review and conclusion at a decision workshop. At the decision workshops, the technical teams will Define the options; Characterize factual advantages and disadvantages; and, Compare the options benefits against cost.

Consensus Style: How the participants interacted and produced a conclusion and agreement was just as important as the collation and sharing of technical data. The entire Decision Framework and all building blocks took advantage of a consensus style of engagement. Both the culture of PWB and the nature of these decisions were reasons to have this sharing- and agreement-reaching environment. The only exception was the final agreement and decision by the Executive Committee. Although the Executive Committee members themselves looked to the technical team for guidance and advice, the technical team members were not consensus partners in the Executive Committee's ultimate decision.

iv

Consensus Style

All steps within this decision framework - validation of values; agreement to the comparative position; definition, characterization, and comparison of options; discussion in the meetings - will be conducted in the style of consensus. This includes the decisions reached by the Executive Committee.

v

Executive Committee Decision

Recommendations will be concluded by the technical team and the Executive Committee (Chris Wanner, Edward Campbell, Teresa Elliott, Gabriel Solmer) at the dedicated meetings. The Executive Committee will validate the conclusion with Mike Stuhr, and make a decision within 2 days of each workshop.

Executive Committee Decision: All decisions were made by the Executive Committee, which sought internal consensus. All decisions by the Executive Committee took place after the workshop sessions.

4.0 Values Hierarchy

Values represent the most important elements to the community and PWB. They are the guiding principles that must be considered when making decisions and were used to characterize, understand and communicate tradeoffs.

The PWB Filtration Team initiated the conversation about values by learning about the concerns of the public. PWB engaged Barney & Worth, Inc., to conduct a three-step process to identify community values specific to the Bull Run Filtration Project. Details of this community values process are captured in the Community Values Memorandum. Initial engagement of the public produced an impression of the leading community values in Tiers:

Community Values Tier 1:
- Cost
- Public health/water quality

Community Values Tier 2:
- Resilience/reliability
- Consistent quality
- Environmental impacts
- Equity
- Expandability
- Minimal treatment
- Speed
- Preparation for the future

The PWB Filtration Team reviewed these community values, cross-referenced against and supplemented with PWB values. PWB values considered included those captured in PWB's strategic plan:

- Customers: Keep the needs and desires of our customers in the forefront of our thoughts and actions.
- Service: Contribute responsively to the welfare of the community.
- Financial Health: Maintain fiscal integrity, undertake sound financing practices, and ensure auditable results.
- Employees: Recruit, maintain, motivate, and retain a highly qualified, diverse, and committed workforce; and provide a safe work environment.
- Partnership: Partner with our community, our customers, and regional water interests.
- Leadership: Focus on goals, results, and accountability while promoting human health and development.
- Responsiveness: React positively, cooperatively, and efficiently.
- Effectiveness: Make the most appropriate use of resources and infrastructure.
- Communication: Share information and knowledge openly.
- Flexibility: Adapt to new, different, and changing requirements.

- Equity: Ensure fair treatment and service to all.
- Stewardship: Protect the natural environment so its benefits are available to meet today's needs as well as those of future generations.

Through multiple iterations in workshop settings, the Filtration Team agreed upon eight values, shown in Table 1, to reflect the most important elements of PWB and the Community that must guide any decision. These were used to recognize tradeoffs among alternatives within each decision.

Table 1. Values

Values Hierarchy

Value	Public Health and Water Quality	Resiliency/ Reliability	Community Interests	Cost Benefit
Value Description	Provide drinking water that is safe and consistent	Facility maximizes likelihood of continued water provision, even after a fire or disaster	Integrate community interests in the decision-making process	Getting the most benefit for the dollar
Value	Meet Future Needs	Environmental Impacts	Integration	Implementation
Value Description	Maximizes ability to make adjustments in future	Minimize environmental impacts	Optimize operability & integration with PWB's systems & practices	Increases ability to implement and meet compliance schedule

Criteria are the next level within the hierarchy that refine the values into statements that lend themselves to measurable components. Performance scales are the measurable components associated with an individual criterion. The criteria were agreed upon by the Filtration Team and were applied consistently across all three of the decisions. Descriptions of the performance scales used in the decision are captured in the individual decision technical memoranda.

This final list of values and criteria is termed a Values Hierarchy (see Table 2) because the values serve as the top level of the structure and criteria and performance measures fit within that structure.

Table 2. Values Hierarchy

Values Hierarchy – Part A

Value	Public Health and Water Quality					Resiliency/Reliability			Community Interests			Cost Benefit	
Value Description	Provide drinking water that is safe and consistent					Facility maximizes likelihood of continued water provision, even after a fire or disaster			Integrate community interests in the decision-making process			Getting the most benefit for the dollar	
Criteria	Existing Micro-biological Regulations	Emerging Water Quality Regulations	Organics/ Inorganics Regulations	Consistent Water Quality	Chemical Impacts	Earthquake	Catastrophic WQ Event (forest fire, landslide)	Routine WQ Events (elevated turbidity, algae bloom)	Local Impacts	Consistency in Taste and Appearance	Perception of Safety	Cost of Construction	Operating Costs

Values Hierarchy – Part B

Value	Future Needs			Environmental Impacts			Integration					Implementation			
Value Description	Maximizes ability to make adjustments in future			Minimize environmental impacts			Optimize operability & integration with PWB's systems & practices					Increases ability to implement and meet compliance schedule			
Criteria	Capacity	Future Water Quality	Available Gravity Capacity	Electricity Usage	Residuals Produced	Construction and Operations Fuel Consumption	WTP Labor	Safety & Operations	Corrosion Control Integration	Other infrastructure Ramifications	Distribution System WQ	Ease of Construction	Implementation Complexity	Land Use Permits	On- and Off- site Ownership

All values must be part of the decision process, but the influence of those values must reflect the importance PWB places upon those values. Weighting reflects the relative importance the Filtration Team placed on the values and the criteria. In a workshop setting, the Filtration Team produced and agreed to a set of weights for the value hierarchy. The numbers associated with each value or criterion present the relative weight of that element (Table 3).

Table 3. Team-developed Weights

Value	Public Health and Water Quality	Resiliency/ Reliability	Integration	Cost Benefit	Implementation	Meet Future Needs	Community Interests	Environmental Impacts
Value Description	Provide drinking water that is safe and consistent	Facility maximizes likelihood of continued water provision, even after a fire or disaster	Optimize operability & integration with PWB's systems & practices	Getting the most benefit for the dollar	Increases ability to implement and meet compliance schedule	Maximizes ability to make adjustments in future	Integrate community interests in the decision making process	Minimize environmental impacts
Value Weight	25	15	12	12	10	10	9	7
Criteria per Values in rank order	Existing Micro-biological Regulations 6.2	Routine WQ Events (elevated turbidity, algae bloom) 6.3	Safety & Operations 3.6	Operating Costs 6.6	Implementation Complexity 3.1	Capacity 3.4	Consistency in Taste and Appearance 4.2	Residuals Produced 2.7
	Organics/ Inorganics Regulations 5.7	Catastrophic WQ Event (forest fire, landslide) 5.3	Distribution System WQ 2.3	Cost of Construction 5.4	Land Use Permits 2.4	Available Gravity Capacity 3.4	Chemical Concerns 2.9	Electricity Usage 2.3
	Emerging Water Quality Regulations 4.6	Earthquake 3.4	Corrosion Control Integration 2.2		On- and Off- site Ownership 2.2	Future Water Quality 3.2	Local Impacts 1.9	Construction and Operations Fuel Consumption 2.0
	Consistent Water Quality 4.5		Other infrastructure Ramifications 2.1		Ease of Construction 2.2			
	Chemical Impacts 4.1		WTP Labor 1.8					

The Filtration Team also agreed that carrying forward a weighting scheme that provided equal weights to the values would be appropriate. The comparison of results across multiple weighting schemes demonstrates the sensitivity of the results to the weights (Table 4).

Table 4. Equal Weights

Value	Public Health and Water Quality	Resiliency/ Reliability	Integration	Cost Benefit	Implementation	Meet Future Needs	Community Interests	Environmental Impacts
Value Description	Provide drinking water that is safe and consistent	Facility maximizes likelihood of continued water provision, even after a fire or disaster	Optimize operability & integration with PWB's systems & practices	Getting the most benefit for the dollar	Increases ability to implement and meet compliance schedule	Maximizes ability to make adjustments in future	Integrate community interests in the decision making process	Minimize environmental impacts
Value Weight	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Criteria per Values in rank order	Existing Micro-biological Regulations 2.5	Routine WQ Events (elevated turbidity, algae bloom) 4.2	Safety & Operations 2.5	Operating Costs 6.3	Implementation Complexity 3.1	Capacity 4.2	Consistency in Taste and Appearance 4.2	Residuals Produced 4.2
	Organics/ Inorganics Regulations 2.5	Catastrophic WQ Event (forest fire, landslide) 4.2	Distribution System WQ 2.5	Cost of Construction 5.3	Land Use Permits 3.1	Available Gravity Capacity 4.2	Chemical Concerns 4.2	Electricity Usage 4.2
	Emerging Water Quality Regulations 2.5	Earthquake 4.2	Corrosion Control Integration 2.5		On- and Off- site Ownership 3.1	Future Water Quality 4.2	Local Impacts 4.2	Construction and Operations Fuel Consumption 4.2
	Consistent Water Quality 2.5		Other infrastructure Ramifications 2.5		Ease of Construction 3.1			
	Chemical Impacts 2.5		WTP Labor 2.5					

A third weighting scheme was suggested by the Executive Committee. This scheme placed 40 percent of the weight on the "Public Health and Water Quality" and "Resiliency/Reliability" values and the remaining 60 percent equally distributed across the other six values (Table 5).

Table 5. 60/40 Weighting

Value	Public Health and Water Quality	Resiliency/ Reliability	Integration	Cost Benefit	Implementation	Meet Future Needs	Community Interests	Environmental Impacts
Value Description	Provide drinking water that is safe and consistent	Facility maximizes likelihood of continued water provision, even after a fire or disaster	Optimize operability & integration with PWB's systems & practices	Getting the most benefit for the dollar	Increases ability to implement and meet compliance schedule	Maximizes ability to make adjustments in future	Integrate community interests in the decision making process	Minimize environmental impacts
Value Weight	25	15	10	10	10	10	10	10
Criteria per Values in rank order	Existing Micro-biological Regulations 5.0	Routine WQ Events (elevated turbidity, algae bloom) 5.0	Safety & Operations 2.0	Operating Costs 5.0	Implementation Complexity 2.5	Capacity 3.3	Consistency in Taste and Appearance 3.3	Residuals Produced 3.3
	Organics/ Inorganics Regulations 5.0	Catastrophic WQ Event (forest fire, landslide) 5.0	Distribution System WQ 2.0	Cost of Construction 5.0	Land Use Permits 2.5	Available Gravity Capacity 3.3	Chemical Concerns 3.3	Electricity Usage 3.3
	Emerging Water Quality Regulations 5.0	Earthquake 5.0	Corrosion Control Integration 2.0		On- and Off- site Ownership 2.5	Future Water Quality 3.3	Local Impacts 3.3	Construction and Operations Fuel Consumption 3.3
	Consistent Water Quality 5.0		Other infrastructure Ramifications 2.0		Ease of Construction 2.5			
	Chemical Impacts 5.0		WTP Labor 2.0					

All three weighting schemes were carried forward and applied in the Decision Model.

5.0 Decision Model

The Decision Model incorporated the values, criteria, and performance evaluation of the viable alternatives into a structure allowing for comparative assessment of the alternatives. Throughout the evaluation and review, the team reminded itself that the Decision Model does not make the decision, the team does. This context assured that the Decision Model and the evaluation of alternatives was designed to inform the technical team and the Executive Committee, not make the decision for the team.

The Decision Model is a multi-criteria decision analysis methodology. Alternatives were rated in performance with each criterion under the values using a measurable scale. That performance rating was normalized across the spectrum of performance among the alternatives. That normalized performance rating was then multiplied by the weight associated with that criterion. The summation across all criteria produces an overall score, referred to as a value score.

The series of graphics below further describe this evaluation process performed by the Decision Model using a hypothetical example – purchasing a car. More than one weighting scheme may be applied. Six criteria are part of this evaluation. In this example two weighting schemes are developed, one for the parents, one for the kids. Refer to Table 6. Each criterion receives a weight to reflect how the participants view the importance of that criterion. All criteria are considered as part of the evaluation, yet those with higher weight have more of an influence upon the resulting calculations of value. Weights may be displayed as a number or a percentage.

Table 6. Weighting Schemes – Example

	ENV1	SOC1	SOC2	SOC3	SOC 4	SOC 5
	Minimize air pollution and greenhouse gas emissions	Maximize exterior styling	Maximize safety	Maximize "fun" to drive	Maximize comfort in the interior	Maximize cargo capacity
Parents						
Weights	67	83	100	72	86	83
% of Total	13.6%	16.9%	20.4%	14.7%	17.5%	16.9%
Kids						
Weights	100	60	65	30	65	50
% of Total	27.0%	16.2%	17.6%	8.1%	17.6%	13.5%

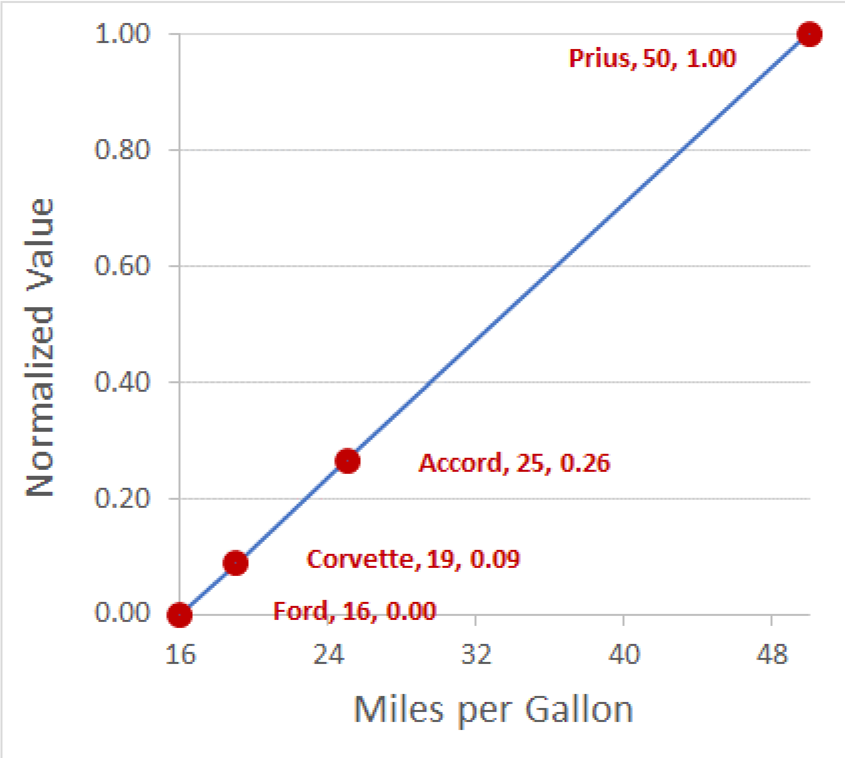
Each alternative is rated in its performance against the criteria. In this case, the alternatives are listed on the far-left column of Table 7. The performance scale is reflective of the characteristics of the criterion. For example, the ENV1 criterion used miles per gallon as its performance scale; whereas the SOC3 criterion uses a subjective scale of 1 to 3. The Decision Model is designed to account for either of these types of performance scales. Refer to Table 7.

Table 7. Performance Ratings – Example

	Environment - minimize the impact to the natural environment	Social - maximize social benefit					Financial
	ENV1	SOC1	SOC2	SOC3	SOC 4	SOC 5	FIN1
	Minimize air pollution and greenhouse gas emissions	Maximize exterior styling	Maximize safety	Maximize "fun" to drive	Maximize comfort in the interior	Maximize cargo capacity	Cost per mile
1. Corvette	19.0	3.0	1.0	3.0	2.0	22.0	$1.10
2. Honda Accord	25.0	1.0	2.0	1.0	3.0	45.0	$0.57
3. Toyota Prius	50.0	1.0	2.0	1.0	2.0	40.0	$0.49
4. Ford F150 Pickup	16.0	2.0	3.0	1.0	2.0	55.0	$0.72

The Decision Model then performs the calculation of multiplying the performance rating by the weight associated with the criterion. In order to produce this calculation, the model normalizes the performance scale, meaning it translates the performance ratings to a 0 to 1 scale. This normalization assigns a “0” to the worst performer in the range of performance and a “1” to the best performer. The remaining scores are then placed within the range of 0 to 1 to reflect the relative performance. As an example, the ENV1 criterion uses miles per gallon as its means of gauging the performance of the alternatives from an environmental perspective. The higher the miles per gallon the better the performance of the alternative. Since the Prius is the best performer at 50 MPG, that alternative receives a “1” in the normalized calculation. At the other end of the range, the Pickup with 16 MPG receives a “0” because it is the worst performer in that criterion. In the middle is the Corvette with a rating of 19 mpg and the Accord with a rating of 25. These two alternatives receive a normalized rating in relationship to where they fit within the range of performance across all the alternatives. Refer to Figure 2 for a graphical representation of the normalization.

Figure 2. Normalization – Example



Note that each point on the line is labeled with the name of the alternative (the car), the actual MPG performance rating of that car (i.e., 25 for the Accord), and the normalized value.

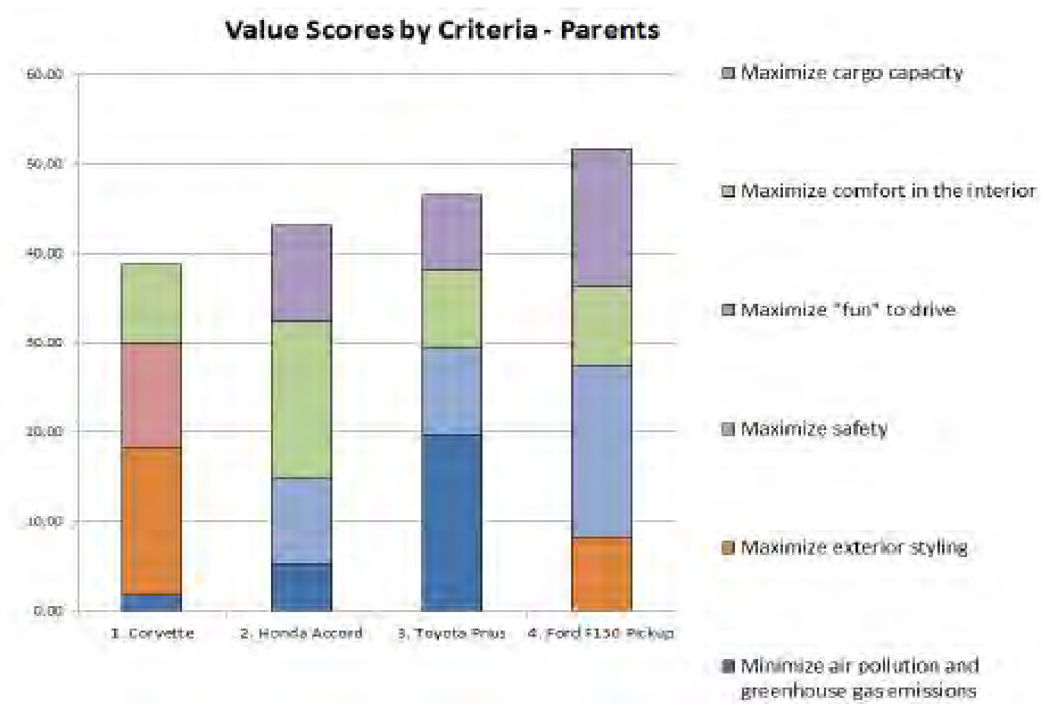
Multiplying the normalized performance of the Pickup at "0" times the weight assigned to that criterion of course produces a contribution of zero (bottom left hand corner of Table 8). Table 8 displays the calculation of the weight (using the parents' weight) times the normalized performance score in this car buying example.

Table 8. Results of Weight times Normalized Performance Rating – Example

Triple Bottom Line Goal	Environment - minimize the impact to the natural environment	Social - maximize social benefit				
	ENV1	SOC1	SOC2	SOC3	SOC 4	SOC 5
Criteria	Minimize air pollution and greenhouse gas emissions	Maximize exterior styling	Maximize safety	Maximize "fun" to drive	Maximize comfort in the interior	Maximize cargo capacity
Low Score	16.000	1.000	1.000	1.000	1.000	22.000
High Score	50.000	3.000	3.000	3.000	3.000	55.000
1. Corvette	1.20	16.90	0.00	14.66	8.76	0.00
2. Honda Accord	3.61	0.00	10.18	0.00	17.52	11.78
3. Toyota Prius	13.65	0.00	10.18	0.00	8.76	9.22
4. Ford F150 Pickup	0.00	8.45	20.37	0.00	8.76	16.90

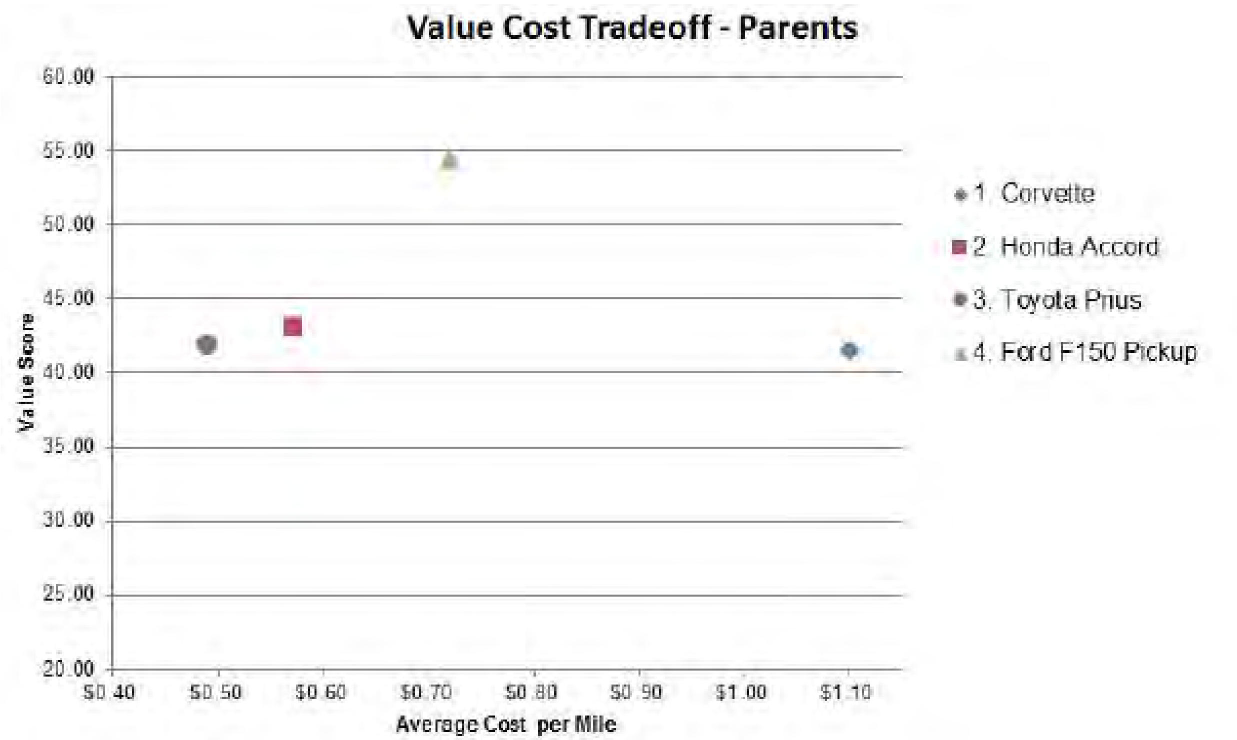
The summation of the criteria produces a value score. The next graphic, Figure 3, displays the results in a histogram. Each color of the bar represents the mathematical contribution of the criteria to the overall value score. The higher the bar the higher the contribution. The highest bar represents the highest overall performance relative to the criteria.

Figure 3. Contributions by Criteria – Example



Another view the Decision Model affords is the comparison of the value score against the cost of the alternative. The scatter plot shown in Figure 4 showcases the value score on the y-axis and the cost on the x-axis. The preferred location on the plot is up and to the left – highest value score with the lowest cost. Although the Pickup has the highest value score, it also has higher cost. The Prius and Accord offer lower value but also lower cost. This tradeoff is considered by the decision makers.

Figure 4. Cost versus Value Scatter Plot – Example



This example displays exactly how the Decision Model was applied to the three filtration decisions – capacity, site, and technology. The individual and separate technical memoranda associated with these three decisions capture the Decision Model results.

6.0 Workshops

Workshops were the primary means of engaging the Filtration Team and the Executive Committee and in reaching the decisions. Table 9 below summarizes the workshops and the objectives of each.

Table 9. Workshop Summary

Date	Meeting	Attendees	Objectives
Tues, January 30	Procurement Method Workshop	PWB Technical Team and Executive Committee	• Recognize the procurement alternatives • Conclude upon preferred procurement method
Wed, February 28	Decision Workshop	PWB Technical Team and Executive Committee	• Recognition of Decision Framework building blocks • Validation of Decision Framework participant's roles and authorities • Conclude value statements are exhaustive of Community and PWB values • Resolve criteria are reflective of values • Establish measures are applicable and provide differentiation of option performance
Wed, March 13	No Meeting; materials due for March Workshop		
Wed, March 21	Filtration Decision Workshop	PWB Technical Team and Executive Committee	• Recognize upcoming workshops content and expected outcomes • Review and accept values/criteria within the Values Hierarchy • Establish common understanding of technical elements of capacity, site and technology decisions • Review of and suggestions for capacity alternatives
Tues, March 27	Progress Meeting	Technical Team	• Produce weights for Values and Criteria • Guidance upon middle Capacity alternative • Provide alternatives evaluation matrix (utilizing agreed upon Values Hierarchy) for Technical Team to begin performance rating of Capacity alternatives • Review Cost curves for Capacity alternatives
Wed, April 11	No Meeting; materials due for April Workshop		
Wed, April 18	Capacity Decision	PWB Technical Team and Executive Committee	• Communication of groundwater policy • Review and reconciliation of Capacity alternatives evaluation (weighting, rating, and results) • Recommendation of preferred Capacity alternative • Review of on-line community survey results

Date	Meeting	Attendees	Objectives
Tues, April 24	Progress Meeting	Technical Team	• Review Site evaluation ratings • Site screening
Wed, May 16	No Meeting; materials due for May Workshop		
Wed, May 23	Siting Decision	PWB Technical Team and Executive Committee	• Review of Siting alternatives and filtering • Review and reconciliation of Siting alternatives evaluation (weighting, rating, and results) • Recommendation of preferred Siting alternative
Tues, May 29	Progress Meeting	Technical Team	• Review Technology evaluation ratings
Wed, June 13	No Meeting; materials due for June Workshop		
Wed, June 20	Technology Decision	PWB Technical Team and Executive Committee	• Review of Technology alternatives and filtering • Review and reconciliation of Technology alternatives performance ratings • Evaluation of value score results • Recommendation of preferred Technology alternative

Appendix A presents the agendas for the workshops, which focused on development and application of the Decision Framework, the Values Hierarchy, and the Decision Model.

Appendices

A. Workshop Agendas

Appendix A. Workshop Agendas

Portland Water Bureau – Filtration Decision Framework

PREPARED BY: Dan Speicher

MEETING DATE: February 28, 2018

LOCATION: Portland Water Bureau Office – 400 SW 6th; 1st floor Conference Room;
8:00 a.m. to 12:00 noon

INVITED ATTENDEES:

Dave Peters, PWB	Edward Campbell, PWB	Pierre Kwan/HDR
Mike Saling, PWB	Tony Re, PWB	Nicki Pozos/Barney & Worth
Michelle Cheek, PWB	Gabriel Solmer, PWB	Libby Barg/Barney & Worth
Rich Seright, PWB	Jodie Inman, PWB	Kelly Irving/Jacobs
Kimberly Gupta, PWB	Christopher Bowker, PWB	Bob Chapman/Jacobs
Yone Akagi, PWB	Janet Senior, PWB	Lee Odell/ Jacobs
Terry Black, PWB	Jonathon Johnson, PWB	Dawn Bierbaum/Jacobs
Chris Wanner, PWB	Jeana Ott, PWB	Dan Speicher/Jacobs
	Scott Bradway, PWB	

Objectives:

- Recognition of Decision Framework building blocks
- Validation of Decision Framework participant's roles and authorities
- Conclude value statements are exhaustive of Community and PWB values
- Resolve criteria are reflective of values
- Establish measures are applicable and provide differentiation of option performance

Agenda:

Timing	Subject	Description/Outcomes/Messages
8:00 – 8:15 **15 Minutes**	Opening	Welcome and Opening Remarks by Dave P Introduce all Safety Moment from Kelly Objectives of this session
8:15 – 8:50 **35 minutes**	Decision Framework Review	Review Decision Framework Building Blocks Note that participants will be asked to present building blocks and provide insights
8:50 – 9:10 **20 minutes**	Decision Framework Roles	Validate roles of participants: PWB technical team, PWB Executive Team, consultants, Mike Stuhr <u>Consultant Staff:</u> Provide technical expertise, support, and resources. <u>PWB Technical Team:</u> Provide guidance to decision process and technical evaluation, actively participate in decision process and workshops, and provide recommendations for conclusions in the workshops. <u>PWB Executive Committee:</u> Reach conclusion in workshop setting, validate conclusion with Mike Stuhr, and make decision within 48 hours of workshop. <u>Mike Stuhr:</u> Provide validation of direction and decisions.
9:10 – 9:20 **10 minutes**	Define Values Hierarchy	Review structure of value hierarchy – what it is, how it will be used, what are the components (values, criteria, performance scales) Questions we are to answer in review: *Are these values all-inclusive of the community and PWB values?* *Which criteria are applicable to which decision?* *Do the performance measures provide differentiation among the options?*

<table>
<tr><th>Timing</th><th>Subject</th><th>Description/Outcomes/Messages</th></tr>
<tr><td>9:20 – 10:10
50 minutes</td><td>Values Review</td><td>Review community values with Nicki/Libby, addition of operability with Lee
Cost: Gabriel, Chris B, Jeana
Public Health and Water Quality: Yone, Terry, Bob
Resiliency/Reliability: Tony, Michelle, Nicki
Consistency: Kim, Rich
Meet Future Needs: Ed, Dave, Kelly
Environmental Impacts: Janet, Jodie, Libby, Scott
Chemical Use: Mike, Pierre
Operability: Chris W, Jonathon, Lee
Question 1: Are there values that are not captured with these eight? If so, what are they?
Question 2: What, if anything, would you add or embellish with your assigned value? Broaden? Clarify? Scribe on a flip chart.</td></tr>
<tr><td>10:10 – 10:20
10 minutes</td><td>Break</td><td></td></tr>
<tr><td>10:20 – 11:10
50 minutes</td><td>Criteria Review</td><td>Criteria development review with Lee and Pierre
Are the criteria capturing the intent of the value (without being overwhelming)? Lee and Pierre panel are available for consultation
<table>
<tr><th>Value</th><th>Criteria</th><th>Owner</th></tr>
<tr><td rowspan="2">Cost</td><td>Capital</td><td>Gabriel</td></tr>
<tr><td>Lifecycle</td><td>Gabriel</td></tr>
<tr><td rowspan="2">Meet Future Needs</td><td>Capacity</td><td>Dave</td></tr>
<tr><td>Water Quality</td><td>Mike</td></tr>
<tr><td rowspan="4">Public Health and Water Quality</td><td>Microbiological</td><td>Kelly</td></tr>
<tr><td>Aesthetics</td><td>Jeana</td></tr>
<tr><td>Cl Residual</td><td>Bob</td></tr>
<tr><td>Chemicals</td><td>Yone</td></tr>
<tr><td>Consistency</td><td>Consistent WQ</td><td>Tony</td></tr>
<tr><td rowspan="5">Resiliency/ Reliability</td><td>Earthquake</td><td>Ed</td></tr>
<tr><td>Forest Fire</td><td>Libby</td></tr>
<tr><td>Turbidity Events</td><td>Michelle</td></tr>
<tr><td>Algal Blooms</td><td>Scott</td></tr>
<tr><td>Res. Turnover</td><td>Nicki</td></tr>
<tr><td rowspan="4">Environmental Impacts</td><td>Habitat</td><td>Jonathon</td></tr>
<tr><td>GHG</td><td>Janet</td></tr>
<tr><td>Residuals Produced</td><td>Jodie</td></tr>
<tr><td>Construction</td><td>Terry</td></tr>
<tr><td>Chemical Use</td><td>Minimal</td><td>Chris B</td></tr>
<tr><td rowspan="3">Operability</td><td>Impact on Ops</td><td>Kim</td></tr>
<tr><td>Impact on Maint</td><td>Chris W</td></tr>
<tr><td>Large WTP in last 20 yrs</td><td>Rich</td></tr>
</table></td></tr>
<tr><td>11:10 – 11:45
35 minutes</td><td>Performance Scales Review</td><td>Performance scales review by Lee and Pierre
Consider if performance measures reflect the criterion, is it understandable and measurable; summarize comments
In group setting, present comments to Lee/Pierre for improving performance scales</td></tr>
</table>

Timing	Subject	Description/Outcomes/Messages
11:45 – 11:55 **10 minutes**	Executive Committee Reactions	Provide reactions to compilation of the Values Hierarchy Executive Committee validation with Mike Stuhr and decision within 48 hours
11:55 – 12:00 **5 minutes**	Closure	Dave provide a summary and close the workshop

Portland Water Bureau – Filtration Decisions

PREPARED BY: Dan Speicher

MEETING DATE: March 21, 2018

LOCATION: Portland Water Bureau Office – 400 SW 6th; 1st floor Conference Room;
8:00 a.m. to 12:00 noon

INVITED ATTENDEES:

Dave Peters, PWB	Tony Re, PWB	Rich Stratton/HDR
Mike Saling, PWB	Gabriel Solmer, PWB	Phillipe Daniel/HDR
Michelle Cheek, PWB	Jodie Inman, PWB	Nicki Pozos/Barney & Worth
Rich Seright, PWB	Christopher Bowker, PWB	Libby Barg/Barney & Worth
Kimberly Gupta, PWB	Janet Senior, PWB	Kelly Irving/Jacobs
Yone Akagi, PWB	Jonathon Johnson, PWB	Bob Chapman/Jacobs
Terry Black, PWB	Jeana Ott, PWB	Lee Odell/ Jacobs
Chris Wanner, PWB	Scott Bradway, PWB	Kim Ervin/Jacobs
Teresa Elliott, PWB	Andy McCaskill/HDR	Dawn Bierbaum/Jacobs
Edward Campbell, PWB	Pierre Kwan/HDR	Dan Speicher/Jacobs

Objectives:

- Recognize upcoming workshops content and expected outcomes
- Review and accept values/criteria within the Values Hierarchy
- Establish common understanding of technical elements of capacity, site and technology decisions
- Review of and suggestions for capacity alternatives

Agenda:

Timing	Subject	Description/Outcomes/Messages
8:00 – 8:10 **10 Minutes**	Opening	Welcome and Opening Remarks by Dave P Safety Moment Objectives of this session
8:10 – 8:25 **15 minutes**	Workshop Schedule Review	Overview of workshops from March through June recognizing the flow of these workshops and the expected outcomes
8:25 – 8:45 **20 minutes**	Values Hierarchy Update	Review updated values and criteria from February workshop agreement upon the values, values definition, and criteria, and recognition of most applicable performance scales
8:45 – 10:00 **75 minutes**	Capacity Education and Alternatives	• Demand projections • Wholesale projections • Wellfield history • 3 Alternatives suggested
10:00 – 10:15 **15 minutes**	Break	
10:15 – 11:00 **45 minutes**	Site Education and possible Alternatives	• Six initial alternatives • Site characteristics • Site hydraulics • Alternative suggestions

Timing	Subject	Description/Outcomes/Messages
11:00 – 11:30 **30 minutes**	Technology Education and Alternatives	• Unit process functions • Alternatives • Large Greenfield Plants Constructed in the past 20-30 years
11:30 – 11:45 **15 minutes**	Executive Committee Reactions	Performance Scales for Capacity decision – suggested improvements
11:45 - 12:00 **15 minutes**	Next Steps and Closure	March 27th progress meeting – weighting and first draft of evaluation matrix Dave provide a summary and close the workshop

Portland Water Bureau – Filtration Decisions: Progress Meeting

PREPARED BY: Dan Speicher

MEETING DATE: March 27, 2018

LOCATION: Portland Water Bureau Office – 400 SW 6th; 1st floor Conference Room; 1:00 to 4:00 p.m.

INVITED ATTENDEES:

Dave Peters, PWB
Mike Saling, PWB
Michelle Cheek, PWB
Rich Seright, PWB
Kimberly Gupta, PWB
Yone Akagi, PWB
Terry Black, PWB
Jodie Inman, PWB
Christopher Bowker, PWB
Janet Senior, PWB
Jonathon Johnson, PWB
Jeana Ott, PWB
Andy McCaskill/HDR
Pierre Kwan/HDR
Phillippe Daniel/HDR
Nicki Pozos/Barney & Worth
Libby Barg/Barney & Worth
Kelly Irving/Jacobs
Bob Chapman/Jacobs
Lee Odell/ Jacobs
Kim Ervin/Jacobs
Dawn Bierbaum/Jacobs
Dan Speicher/Jacobs

Objectives:

- Produce weights for Values and Criteria
- Guidance upon middle Capacity alternative
- Provide alternatives evaluation matrix (utilizing agreed upon Values Hierarchy) for Technical Team to begin performance rating of Capacity alternatives
- Review Cost curves for Capacity alternatives

Agenda:

Timing	Subject	Description/Outcomes/Messages
1:00 – 1:05 **5 Minutes**	Opening	Welcome and Opening Remarks by Dave P Safety Moment Objectives of this session
1:05 – 2:30 **85 minutes**	Weighting	Weighting of the values and criteria Consider Cost/Benefit as part of the Values and as a value equal to all other Values
2:30 – 2:45 **15 minutes**	Percentile of Peak Day	Review of middle alternative options using demand profiles
2:45 – 3:40 **55 minutes**	Performance Review	Present Capacity performance matrix Review performance scales and initial application to Capacity Alternatives Validate level of detail required for performance evaluation of Capacity Alternatives (includes the review of cost curves) Recognize context for Capacity decision (i.e., the most influential criteria upon the decision)
3:40 – 3:55 **15 minutes**	Next Steps and Closure	Socializing of Weighting results April 18th Objectives: • Review On-line survey results/ impacts • Review and reconciliation of Capacity alternatives evaluation and selection of preferred capacity alternatives (if strong preference is obvious, the Capacity conclusion may be reached; if conclusion is not

Timing	Subject	Description/Outcomes/Messages
		evident because of inter-relation with Site decision, Capacity decision will be moved to May workshop); • Communication and sharing of information for site and technology alternatives; Summary of information collection, level of detail required, and packaging of material by April 11th for April 18th Capacity Decision Workshop (Question: more information on technology at April 18th Decision Workshop?)
3:55 – 4:00 **5 minutes**	Closure	Dave provide a summary and close the meeting

Portland Water Bureau – Capacity Decision

PREPARED BY: Dan Speicher

MEETING DATE: April 18, 2018

LOCATION: Portland Water Bureau Office – 400 SW 6th; 1st floor Conference Room; 8:00 a.m. to 12:00 noon

INVITED ATTENDEES:

Dave Peters, PWB
Mike Saling, PWB
Michelle Cheek, PWB
Rich Seright, PWB
Kimberly Gupta, PWB
Yone Akagi, PWB
Terry Black, PWB
Chris Wanner, PWB
Teresa Elliott, PWB
Edward Campbell, PWB
Tony Re, PWB
Gabriel Solmer, PWB
Jodie Inman, PWB
Christopher Bowker, PWB
Janet Senior, PWB
Jonathon Johnson, PWB
Jeana Ott, PWB
Andy McCaskill/HDR
Pierre Kwan/HDR
Phillipe Daniel/HDR
Libby Barg/Barney & Worth
Kelly Irving/Jacobs
Bob Chapman/Jacobs
Lee Odell/ Jacobs
Kim Ervin/Jacobs
Dawn Bierbaum/Jacobs
Dan Speicher/Jacobs

Objectives:

- Communication of groundwater policy
- Review and reconciliation of Capacity alternatives evaluation (weighting, rating, and results)
- Recommendation of preferred Capacity alternative
- Review of on-line community survey results

Agenda:

Timing	Subject	Description/Outcomes/Messages
8:00 – 8:10 10 minutes	Opening	Welcome and Opening Remarks by Dave P Safety Moment Objectives of this session
8:10 – 8:20 10 minutes	Ground Water Policy	Communication of groundwater policy
8:10 – 8:25 15 minutes	Evaluation Methodology	Weighting, performance rating, and calculating value scores process demonstrated with example
8:25 – 8:35 10 minutes	Weighting Scenarios	Three weighting scenarios
8:35 – 9:30 55 minutes	Performance Ratings	Review performance ratings of three alternatives
9:30 – 9:40 10 minutes	Break	
9:40 – 10:40 60 minutes	Evaluations Results	Total value scores, contributions by criteria, cost/value ratios
10:40 – 11:15 35 minutes	Recommendation	Preferred Capacity alternative
11:15 – 11:45 30 minutes	Online Survey	Current results of online community survey
11:45 - 12:00 15 minutes	Next Steps and Closure	Progress meeting – first draft of Site evaluation matrix Dave provide a summary and close the workshop

Portland Water Bureau – Siting Decision

PREPARED BY: Dan Speicher

MEETING DATE: May 23, 2018

LOCATION: Portland Water Bureau Office – 400 SW 6th; 400 Bldg, Rm 415, Floor 4, Chinook; 8:00 a.m. to 12:00 noon

INVITED ATTENDEES:

Dave Peters, PWB
Mike Saling, PWB
Michelle Cheek, PWB
Rich Seright, PWB
Kimberly Gupta, PWB
Yone Akagi, PWB
Terry Black, PWB
Chris Wanner, PWB
Teresa Elliott, PWB
Edward Campbell, PWB
Tony Re, PWB
Gabriel Solmer, PWB
Jodie Inman, PWB
Christopher Bowker, PWB
Janet Senior, PWB
Jonathon Johnson, PWB
Jeana Ott, PWB
Andy McCaskill/HDR
Pierre Kwan/HDR
Nicki Pozos/ Barney & Worth
Libby Barg/Barney & Worth
Kelly Irving/Jacobs
Brad Phelps/Jacobs
Dan Speicher/Jacobs

Objectives:

- Review of Siting alternatives and filtering
- Review and reconciliation of Siting alternatives evaluation (weighting, rating, and results)
- Recommendation of preferred Siting alternative

Agenda:

Timing	Subject	Description/Outcomes/Messages
8:00 – 8:10 **10 minutes**	Opening	Welcome and Opening Remarks by Dave P Caring Moment Objectives of this session
8:10 – 8:20 **10 minutes**	Filtering	Filtering from multiple to two alternatives - brief reminder
8:20 – 8:35 **15 minutes**	Evaluation Methodology	Weighting, performance rating, and calculating value scores process demonstrated with example Focus on the tradeoffs
8:35 – 9:30 **55 minutes**	Performance Ratings	Criteria considerations: Future Needs-Available Gravity Capacity, Implementation-Land Use Permits Review criteria performance ratings of two alternatives Discuss the influence and differentiation of the ratings
9:30 – 9:45 **15 minutes**	Model Improvements	Improve the Decision Model results to reflect the perspectives of the team
9:45 – 10:00 **15 minutes**	Break	Print out resulting value score graphs
10:00 – 11:00 **60 minutes**	Evaluations Results	Review total value scores, contributions by criteria, cost/value ratios
11:00 – 11:30 **30 minutes**	Recommendation from Tech Team	Preferred and/or recommended Siting alternative
11:30 – 11:45 **15 minutes**	Executive Committee Preference	Impressions from Executive Committee members

Timing	Subject	Description/Outcomes/Messages
11:45 - 12:00 **15 minutes**	Next Steps and Closure	Progress meeting – first draft of Technology evaluation matrix Dave P provide a summary and close the workshop

Portland Water Bureau – Technology Decision

PREPARED BY: Dan Speicher

MEETING DATE: June 20, 2018

LOCATION: Portland Water Bureau Office – 400 SW 6th; 400 Bldg, Rm 415, Floor 4, Chinook; 8:00 a.m. to 12:00 noon

INVITED ATTENDEES:

Dave Peters, PWB	Edward Campbell, PWB	Pierre Kwan/HDR
Mike Saling, PWB	Tony Re, PWB	Nicki Pozos/ Barney & Worth
Michelle Cheek, PWB	Gabriel Solmer, PWB	Libby Barg/Barney & Worth
Rich Seright, PWB	Jodie Inman, PWB	Kelly Irving/Jacobs
Kimberly Gupta, PWB	Christopher Bowker, PWB	Lee Odell/Jacobs
Yone Akagi, PWB	Janet Senior, PWB	Kim Ervin/Jacobs
Terry Black, PWB	Jonathon Johnson, PWB	Dan Speicher/Jacobs
Chris Wanner, PWB	Jeana Ott, PWB	Bob Chapman/Jacobs
Teresa Elliott, PWB	Andy McCaskill/HDR	Dawn Bierbaum/Jacobs

Objectives:

- Review of Technology alternatives and filtering
- Review and reconciliation of Technology alternatives performance ratings
- Evaluation of value score results
- Recommendation of preferred Technology alternative

Agenda:

Timing	Subject	Description/Outcomes/Messages
8:00 – 8:10 **10 minutes**	Opening	Welcome and Opening Remarks by Dave P Caring Moment Objectives of this session
8:10 – 8:40 **30 minutes**	Filtering of Alternatives	Filtering from three to two alternatives
8:40 – 9:30 **50 minutes**	Performance Ratings	Review each criterion and performance ratings of two alternatives Discuss the influence and differentiation of the ratings
9:30 – 9:45 **15 minutes**	Model Improvements	Improve the Decision Model to reflect the perspectives of the team
9:45 – 10:00 **15 minutes**	Break	Print out resulting value score graphs
10:00 – 11:00 **60 minutes**	Evaluations Results	Review total value scores, contributions by criteria, cost/value ratios
11:00 – 11:30 **30 minutes**	Recommendation from Tech Team	Preferred and/or recommended Technology alternative
11:30 – 11:45 **15 minutes**	Executive Committee Preference	Impressions from Executive Committee members
11:45 - 12:00 **15 minutes**	Next Steps and Closure	Technical Memo production Dave P provide a summary and close the workshop

Technical Memo

Date:	Tuesday, February 27, 2018
Project:	Bull Run Filtration Plant Project
To:	Portland Water Bureau
From:	HDR
Subject:	**Filtration Plant Project Alternative Delivery Methods - Final**

1.0 Introduction

The Portland Water Bureau (PWB) is moving forward with design, construction, and commissioning of an approximately $500 million Water Filtration Plant. In order to minimize project delivery risk and cost and schedule impacts, PWB is evaluating Alternative Delivery (AD) Methods as allowed under Oregon Revised Statute (ORS) 279C.335.

This Technical Memo describes three potential AD Methods available to deliver the Filtration Plant design, construction, and commissioning; discusses the advantages/disadvantages of each; and presents a comparison of the alternatives to assist in determining the most appropriate delivery method for the Filtration Plant project.

2.0 Starting Considerations

- All three AD methods will reduce project schedule compared with the standard design-bid-build (DBB) approach because they would eliminate the need to bring the design to 100% completion prior to the advertisement and bidding period required in DBB procurement. In addition, design and early construction activities can occur concurrently. In each case, contractor selection is done early in the design process.
- All three AD methods will require an exemption to competitive bidding under ORS 279C.335. However, none will limit competition and all have the potential to save costs through the shorter delivery schedule and collaborative working relationships they promote.
- The necessary commissioning activities can be included in each of the three AD methods.
- The base selection is CM/GC, unless one of the other two options proves superior.
- All three AD methods have been successfully used by public works agencies in Oregon and across the United States.

3.0 Alternative Delivery Approaches

The three AD options being considered are:

1. Construction Manager/General Contractor (CM/GC)
2. Fixed-Price Design-Build (FPDB)
3. Progressive Design-Build (PDB)

Each AD option discussed in the following sections describes the contractual arrangement(s) between Owner, Designer, and Construction Contractor, and specific attributes and applications of each option.

The figures in Attachment A provide a summary comparison of the three AD options, taking the Filtration Plant project characteristics and City's procurement processes into account.

3.1 Construction Manager/General Contractor

CM/GC combines the scope of work of a general contractor with that of a construction manager under a single contract with PWB. The contractual arrangement between PWB, the Designer, and Contractor for CM/GC is similar to that for DBB. Like DBB, PWB retains the Designer under a separate contract. At an early point in the design phase, PWB, using a competitive selection process, would select a CM/GC firm to provide construction management and general contracting services using a qualifications-based selection process, which may include cost considerations, similar in nature to the selection of the Designer. A CM/GC procurement process procedure can be found in ORS 279C.337. The CM/GC contract would include two phases: a pre-construction services phase during the design process followed by the construction services phase. The pre-construction services phase would provide:

1. constructability input into the design
2. construction subcontract packaging recommendations
3. development of a Guaranteed Maximum Price (GMP).

By joining the project team during design, the CM/GC can collaborate with PWB and the Designer on the design development and preparation of construction documents. As the design progresses, the CM/GC would initiate pricing the work and assembling a GMP. Once the design has progressed to a level suitable for construction estimating, the CM/GC submits the project GMP to PWB. After agreement is reached on a GMP, the construction phase can be authorized, and the CM/GC begins construction and eventual commissioning of the facility. Should PWB be unable to come to terms on the GMP, there remains an option to complete the design and publicly advertise the construction contract as a DBB.

During the construction services phase, the CM/GC procures subcontracts with trade contractors using multiple bid packages, typically on a low bid approach, to construct the project, and manages the construction process the same as under a DBB. In addition to management of the construction contract, the CM/GC may be allowed to self-perform portions of the trade work. Because the CM/GC has the flexibility to package subcontracted work during the pre-construction phase with PWB input, local and Disadvantaged/Minority-owned/Women-owned/Emerging Small Business (D/M/W/ESB) participation can be maximized by focusing subcontractor procurement in those areas to the local market.

A major benefit of CM/GC is the collaboration that can result between PWB, the Designer, and the Contractor. The Contractor becomes, in effect, a member of the project delivery team during design, providing constructability and value-engineering input, thereby improving the quality of the design, potentially reducing the cost of construction, and affording the Contractor buy-in to the design documents. This model requires PWB to take an active role in managing the interface between the designer and CM/GC so that CM/GC input and design modification decisions are timely and the resulting schedule/cost impacts are fully analyzed. Because there is no contractual relationship between the Designer and CM/GC, PWB carries the risk associated with warranting the design documents to the Contractor.

3.2 Fixed Price Design-Build

In Fixed Price Design-Build (FPDB), PWB would enter into a contract with a single entity to perform both design and construction functions. This entity may be a single design/construction firm or separate design and construction firms working together under their own contractual arrangement.

The Design-Builder is responsible for providing design and construction of the project under one contract with PWB. This shifts design risks to the Design-Builder and typically reduces change orders, disputes, or claims. FPDB is normally procured using performance-based requirements rather than prescriptive (i.e., specifying the ultimate facility’s performance characteristics rather than facility details). Consequently, this would require less PWB participation and input during design reviews and details than other AD methods.

Because the Designer and Contractor form a single entity, their interest in collaborating to improve constructability, usually enacts value engineering recommendations and an expedited schedule. In addition, subject to PWB authorization, the Design-Builder can initiate equipment pre-purchase and construction activities at the earliest opportunity and in parallel with design completion to shorten the schedule.

For FPDB, the price is submitted with the proposal and evaluated according to the established weighting criteria stated in the Request-for-Proposals (RFP), along with other qualitative-based selection criteria chosen by PWB. The relative weight of the price versus qualitative criteria would also be determined by PWB. The FPDB selection process provides the earliest cost certainty to PWB, as the fixed price is established before much of the design is complete. However, this procurement method requires early definition of project conditions, criteria, and requirements to be completed and included in the RFP, so there is a sufficient basis for an early price. As a result, this model includes the longest and most extensive procurement phase.

Because the Design-Builder is responsible for design work under a fixed-price agreement, a potential area of dispute can occur during design reviews, where PWB design comments or requests result in a change in the Design-Builder’s cost or schedule, thereby potentially resulting in requests for cost/schedule impacts outside the price/schedule submitted with the proposal. Cost savings are realized through this model by promoting innovation from the

Design-Build proposers, provided the RFP requirements are not overly prescriptive and PWB maintains a hands off approach in design review.

Regarding procurement under FPDB, the RFP must include sufficiently developed design documents for the Design-Builder to provide an accurate price proposal and to further the design work as part of the proposal. A two-step process (Request for Qualifications, followed by an RFP issued to shortlisted firms) is typically required for this model because a significant amount of design work would be expected as part of the proposals (the basis of the price proposal). PWB should also consider the payment of a stipend to unsuccessful proposers, to partially offset the cost of proposal preparation. This would also allow PWB to utilize any design work submitted.

3.3 Progressive Design-Build

The contractual structure of PDB is similar to FPDB, in that design and construction responsibilities are procured under one contract. As with FPDB, a PDB contract may be with either a single entity to provide design and construction services or separate design and construction firms working together under their own contractual arrangement. However, the working relationships are more similar to CM/GC. In PDB, selection of the Design-Builder is based primarily on qualitative selection criteria, rather than a fixed price. Cost-based considerations such as design fee, overhead and markup rates, and others can be included during selection, but are not the primary criteria used. In contrast to FPDB, there may be little if any design work done prior to procurement, because price is determined as the design "progresses" after selection.

As in CM/GC, the contract would include two phases:

1. A pre-construction services phase to include basis of design, design development, construction estimating, and negotiation of the final construction price
2. Final design, construction, and commissioning.

In PDB, as the design and permitting are sufficiently defined, PWB would enter into a fixed price construction contract with the Design-Builder. Consequently, because there is no up-front fixed price, PDB affords PWB greater opportunity for involvement in the design process than FPDB; specifically, less upfront project definition prior to procurement. In addition, as in CM/GC, if PWB and the Design-Builder cannot come to terms on the construction price, PWB can retain the option of having the design brought to 100 percent completion, and then publicly bidding the work under a traditional DBB arrangement. Referred to as an "off ramp," the conditions of this option can be included in the original RFP, including the right of PWB to use any design work submitted for a subsequent procurement.

Like FPDB, PDB provides shifting of design risk to the Design-Builder. Under a single design and construction entity, the risk of potential change orders, disputes, or claims is minimized. If the Design-Builder consists of separate design and construction firms, it is likely that PWB's contract would be with the prime contractor and the designer would have a subcontractor arrangement with the prime.

4.0 Alternative Delivery Workshop

On January 30, 2018, an Alternative Delivery Workshop was held with HDR, Jacobs (CH2M), PWB and City of Portland procurement staff. The purpose of the workshop was to describe the contractual arrangements for the three AD methods, differentiate the AD methods by their specific characteristics, and compare each method with a list of criteria specific to the Filtration Plant project and PWB concerns (Figure 3).

The starting considerations for the workshop as discussed in Section 2.0 are summarized below:

- All three AD methods reduce project schedule compared with DBB
- None of the AD methods limit competition
- The necessary commissioning activities can be included in each of the three AD methods
- The base selection is CM/GC, unless one of the other two options proves superior.

4.1 Evaluation

As shown on Characteristics chart (Figure 2) under Best Applications, the bold items are key characteristics that differentiated each of the three methods. These key characteristics were then applied across the Comparison chart in Figure 3, which listed the primary PWB considerations under three main categories: Project-specific Attributes, PWB Culture, and Management and Reporting. The resulting workshop discussion revolved around the varied experience of the participants, including current City experience with PDB. Each of the listed considerations were then scored by a color bar:

Green – most advantageous

Yellow – neutral

Pink – least advantageous

Where differences between delivery methods were slight for a given criterion, the same color was used for both.

4.2 Workshop Summary

4.2.1 Project-Specific Attributes

PWB has extensive experience in CM/GC project delivery. There was higher confidence expressed in the ability to maintain cost and schedule control on the Filtration Plant project utilizing a CM/GC approach. There was some discussion regarding an interest in becoming proficient in PDB as well. However, there was concern expressed with difficulties experienced outside of PWB on other projects utilizing the PDB approach. The determination in the workshop was that there may be a good opportunity to add PDB to PWB’s experience in alternative delivery, but the Filtration Plan project was not considered the right project to gain that experience.

4.2.2 Owner Culture

PWB prefers to maintain control of project decision-making, as well as engineering and operations input into the facility design. Consequently, FPDB was considered the least advantageous method under this category, while CM/GC and PDB provided higher levels of project control. In addition, one of the biggest drivers for PWB is maximizing D/M/W/ESB participation in both the design and construction contracts, which gave CM/GC a slight advantage over PDB. A collaborative working environment was also considered a plus, which is provided under both CM/GC and PDB.

4.2.3 Management & Reporting

Due to a dedicated project staffing level, Contract Administration was not considered an issue under any of the three delivery methods. This was true whether there were one or two contracts to manage, so was not a decision driver under this category. PWB suggested that a new consideration be included, Alternative Delivery experience, which would account for the PWB's familiarity with the type of alternative delivery. This consideration indicated that PWB had successful prior experience with CM/GC and was consequently more confident in its application for the Filtration Plant project than the other two delivery methods.

Figure 4 provides the evaluation results and indicates that CM/GC was the most advantageous method for delivery of the Filtration Plant program, as determined by PWB staff. The results of this workshop were then compared with the community values work currently ongoing, as indicated below.

4.3 Community Values Input

PWB, along with Barney & Worth, is soliciting stakeholder input on community values that will support project decision-making. Attachment B provides a preliminary memo describing the results of interviews completed to date that would relate values to the project delivery method. The relationship of the CM/GC project delivery method to the community values input as described in the memo is described below:

- Based on the top three values of cost, public health/water quality, and resilience, the CM/GC delivery method would support all three. PWB would procure both the designer and the CM/GC through qualifications-based processes and maintain direct contractual relationships with each. By managing both the designer and CM/GC in a collaborative working relationship during the pre-construction phase, PWB would maintain the ability to incorporate the necessary water quality and resiliency characteristics into the design, while bringing construction cost saving ideas from the CM/GC.
- With a high level of stakeholder interest in the decision-making process, the CM/GC delivery approach will allow PWB the maximum level of decision-making control compared with the other delivery options, as indicated under the Owner Culture category in Figure 4. By having the CM/GC participate in the design process, PWB can foster a collaborative working relationship between the designer and contractor while maintaining final authority over project decisions.

- The CM/GC delivery method will not in any way interfere with or alter PWB's open decision-making process. Design decisions, cost estimates, and schedule will be available to stakeholders as the project proceeds. With PWB managing each contract separately in a collaborative working relationship, PWB will have the most current information available for communication to stakeholders as well as the ability to foresee key decision points requiring stakeholder input.
- Economic development opportunities for disadvantaged communities will be enhanced under the CM/GC delivery method. One of the selection criteria included in the procurement documents for both the designer and CM/GC can be the plan for providing opportunities for small businesses, including consulting firms, construction companies, and suppliers. During the pre-construction phase, the CM/GC will have the flexibility to work with PWB and the designer to identify subcontracting work to be advertised specifically to the D/M/W/ESB community. In addition, it is typical during the construction phase of a CM/GC contract to identify additional opportunities for D/M/W/ESB firms that arise during the course of the construction work.

5.0 References

Oregon Legislature

2015 Oregon Revised Statutes, Chapter 279C — Public Contracting - Public Improvements and Related Contracts, 2017 Edition.

Design-Build Institute of America

2015 Design-Build Done Right™ Primer: Choosing a Project Delivery Method, Progressive Design-Build. April 2015

2017 Design-Build Done Right™ Primer: Progressive Design-Build, Design-Build Procured with a Progressive Design & Price. October 2017

Oregon State University

2002 Oregon Public Contracting Coalition Guide to CM/GC Contracting. Construction Engineering Management Program, Department of Civil, Construction, and Environmental Engineering, Oregon State University, Corvallis, Oregon. February 2002.

Appendices

A. Figures

B. Bull Run Filtration Memorandum Community Values Input on Alternative Delivery Approach

Appendix A. Figures

Figure 1. Alternative Delivery Method Processes

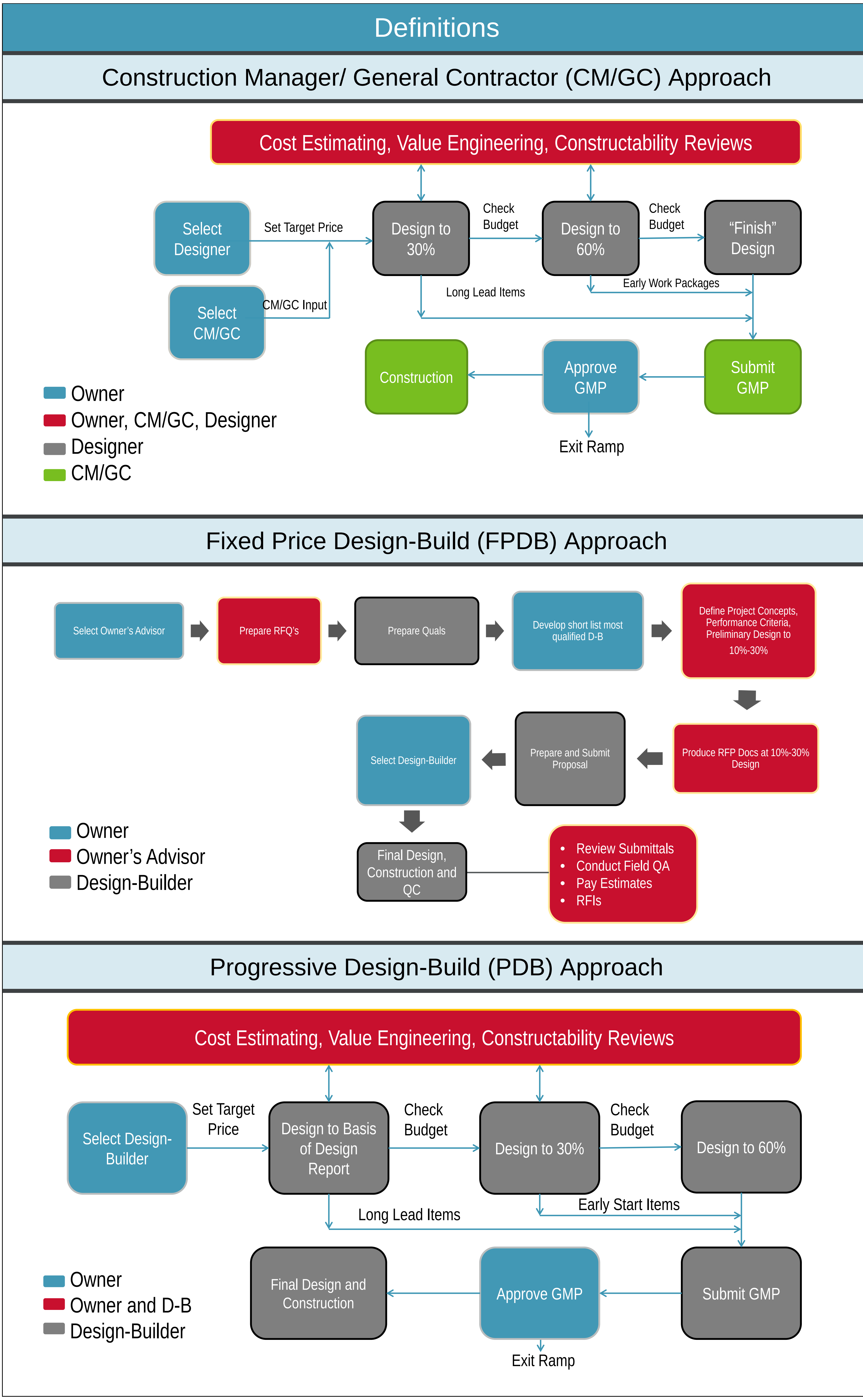


Figure 2. Characteristics of Different Alternative Delivery Approaches

<table>
<tr><th colspan="3">Characteristics</th></tr>
<tr><th>Construction Manager/
General Contractor (CM/GC)</th><th>Fixed Price Design-Build
(FPDB)</th><th>Progressive Design-Build
(PDB)</th></tr>
<tr><th colspan="3">Advantages</th></tr>
<tr><td>➢ Owner remains involved in design development (similar to DBB)
➢ Owner maintains the familiar relationship with the Designer
➢ Constructor input during design phase
➢ GMP Contract Model (accuracy and transparency)
➢ Competitively bid packages drives cost
➢ Can maximize local and D/M/W/ESB subcontractor participation
➢ Early equipment procurement</td><td>➢ Single Point of Accountability (Contractually and Functionally)
➢ Receive Comprehensive (undiluted) Performance Guarantee
➢ Fixed Price Early in Process
➢ Highest potential for schedule savings after procurement if minimal Owner design involvement</td><td>➢ Single Point of Accountability (Contractually)
➢ Qualifications-based selection
➢ Owner has specific preferences and desires high degree of involvement
➢ Promotes innovation during design with input from Design-Builder and Owner
➢ Maximum flexibility and control for the Owner
➢ Benefits of FPDB regarding single Design-Build entity with accuracy and transparency of CM/GC contract</td></tr>
<tr><th colspan="3">Disadvantages</th></tr>
<tr><td>➢ Split Design and Construction responsibilities
➢ Owner warrants Design to CM/GC
➢ Owner must manage two separate contracts and remain aware of schedule/cost impacts of design modifications requested by CM/GC
➢ Self-performing CM/GC may discourage competition for bid packages
➢ Agreement on GMP can be problematic, depending on amount of risk foreseen by CM/GC.
➢ Change management - whether unforeseen costs are “inside” or “outside” the GMP</td><td>➢ Owner involvement is limited once price is established (30% Design)
➢ Only performance is specified, normal design review process doesn’t apply
➢ Increased potential for change orders or claims on Owner-requested changes because price set so early
➢ RFP documents (Basis of Design and Preliminary Drawings) for FPDB procurement take time and cost $ to prepare
➢ Requires separate design contract to produce sufficient design documents ahead of RFP for accurate price proposal.</td><td>➢ Owner access to Designer may be through Contractor for a Contractor-led PDB team
➢ Construction pricing is established after Design-Builder selection
➢ Designer is potentially a sub to Contractor, which has potential of Owner conflicts</td></tr>
<tr><th colspan="3">Best Applications</th></tr>
<tr><td>➢ Owner desires high degree of involvement and control
➢ Owner desires more construction input into design
➢ Owner desires less construction risk (result of CM/GC design input and document buy-in)
➢ Project is complex or scope is uncertain
➢ Maximum local and D/M/W/ESB construction contractor participation</td><td>➢ Existing conditions, project scope and desired outcomes are well understood and defined
➢ Owner does not need direct involvement in detailed design and construction (willing to “let go”)
➢ Operational and aesthetic issues are well-defined
➢ Conventional, well-understood technology
➢ Owner has experience with alternative project delivery</td><td>➢ Owner has specific technology, aesthetic, and equipment preferences
➢ Owner desires high degree of involvement during design and preconstruction activities
➢ Owner desires a single point of responsibility
➢ Project is more complex and scope is uncertain</td></tr>
</table>

Bold items are key characteristics that differentiated each of the three methods

Figure 3. Comparison Chart Template Used in Workshop

Comparison				
Considerations		CM/GC	FPDB	PDB
Project-specific Attributes	➢ Technical complexity, ability to drive innovation			
	➢ Ability to control cost and schedule, impact to annual CIP cash flow			
	➢			
	➢			
Owner Culture	➢ Control of project-level decision-making, input into design, construction, and operation of facility			
	➢ Level of PWB contractual risk transfer			
	➢ Promote D/M/W/ESB participation throughout project term			
	➢ Opportunity for collaborative working environment			
Management and Reporting	➢ Contract administration (availability of PWB staff, design reviews, management of one contract vs. two)			
	➢ Ability to present accurate annual cost/schedule forecast to City Council			

Figure 4. Alternative Delivery Comparison Results from Workshop

Comparison (Results of Workshop)				
Considerations		CM/GC	FPDB	PDB
Project-specific Attributes	➢ Technical complexity, ability to drive innovation			
	➢ Ability to control cost and schedule, impact to annual CIP cash flow			
Owner Culture	➢ Control of project-level decision-making, input into design, construction, and operation of facility			
	➢ Level of PWB contractual risk transfer			
	➢ Promote D/M/W/ESB participation throughout project term			
	➢ Opportunity for collaborative working environment			
Management and Reporting	➢ Contract administration (availability of PWB staff, design reviews, management of one contract vs. two)			
	➢ Ability to present accurate annual cost/schedule forecast to City Council			
	➢ Alternative delivery experience			

Legend: Green – most advantageous
Yellow – neutral
Pink – least advantageous

Appendix B. Bull Run Filtration Memorandum Community Values Input on Alternative Delivery Approach

Portland Water Bureau
Bull Run Filtration
Community Values Input on Alternative Delivery Approach

INTRODUCTION

Barney & Worth is supporting the Portland Water Bureau in developing community values that will inform decision making on the Bull Run Filtration Project. This preliminary information from stakeholder interviews is provided to support the Alternative Delivery Approach decision on January 30, 2018 and ensure consideration of public values can be incorporated. This report reflects the advice, feelings, and attitudes of the initial fourteen stakeholders interviewed. It is not intended to provide a statistically valid profile of the community as a whole.

COMMUNITY VALUES

Key themes that emerged from the stakeholder interviews and are relevant to the Alternative Delivery Approach Decision are as follows:

1. **The top three values are cost, public health/water quality, and resilience.** Cost and public health/water quality were noted repeatedly throughout the stakeholder interviews. Indeed, many framed the treatment decisions as a cost-benefit evaluation – weighing public health/water quality benefits against the costs of those benefits. For those who know Portland's system well, resilience/reliability is their number one value. *"We are doing it for the sake of safety, but also need to consider cost - what is the balance."*

   What does this mean for the Delivery Approach? This value favors delivery approaches with the opportunity to lower project costs, but not if control over water quality or resiliency benefits is compromised.

2. **There is a high level of interest in the process being used to make decisions.** Many stakeholders acknowledged they don't have sufficient expertise to contribute to key decisions. However, they were still very interested in understanding the process being used to make decisions. *"I'd be curious to know the process that is being used to examine and deliberate and arrive at a decision."*

   What does this mean for the Delivery Approach? This value favors delivery approaches where Portland Water Bureau maintains a high level of control.

3. **Almost all stakeholders are asking for increased communication.** Stakeholders noted a past focus on neighborhood associations and coalitions, with greater opportunity to engage with industrial, business, and wholesale customers, as well as communities of color.

   What does this mean for the Delivery Approach? This value favors delivery approaches where there is a high level of decision transparency, allowing the basis of decisions to be clearly communicated with the public.

4. **Maximizing economic development opportunities for disadvantaged communities is a top social equity opportunity.** Filtration is a significant community investment and presents an opportunity for disadvantaged communities. "*People are seeking pathways and entries to living wage jobs and this would be an opportunity to do that. The water bureau has done some really strong work setting high workforce standards then exceeding them and I would expect to see that same sort of commitment to equity on these future projects."*

   What does this mean for the Delivery Approach? This value favors delivery approaches where there is a greater level of control over subconsultant selection.

Technical Memorandum

Date:	September 11, 2018
Project:	Bull Run Filtration Project
To:	David Peters, PE and Michelle Cheek, PE – Portland Water Bureau
From:	Pierre Kwan, PE, Phillippe Daniel, PE, Aparna Garg – HDR; Dan Speicher – Jacobs
Reviewed by:	Rich Stratton, PE, Pete D'Adamo, PhD – HDR
Approved by:	Andy McCaskill, PE – HDR
Subject:	**Filtration Plant Capacity Alternatives**

1.0 Introduction

The Portland Water Bureau (PWB) is in the planning phase for the design and construction of a new filtration plant to treat their existing Bull Run surface water supply. This planning phase includes technical analysis to assist PWB in making four critical decisions: procurement method, filtration plant capacity, site suitability, and filtration technology. This technical memo (TM) documents the assumptions, analysis, and decisions made to determine the preliminary plant capacity.

The decision on plant capacity is framed by the values-based decision-making model, which includes specific criteria and performance scales. HDR has coordinated closely with PWB and their other consultants, Jacobs and Barney & Worth, to identify the criteria and performance scales that PWB staff used as part of the decision-making process in identifying the plant capacity. The performance scales applied to the capacity decision were considered independently of two major unknowns at this time: site location and filtration technology. The intent was to select the preferred plant capacity and then apply that decision to the subsequent site and filtration technology analyses.

The capacity decision includes considerations for future demands, level of service goals (both quantity and quality), costs (capital and operations and maintenance [O&M] for different filtration plant capacity and supplementary supply alternatives), and other factors. This TM presents the initial plant capacity alternatives, likelihood of need to rely on other PWB management strategies to satisfy peak demands, applicable decision model criteria related to capacity, and evaluation of each capacity alternative.

2.0 Demand Projections

A key part of the capacity evaluation is PWB's demand projections. These projections are described in Supply System Master Plan Technical Memo (SSMP TM) 3.1 – Projected Water Demand (dated February 28, 2017; Appendix A). Figures 1 through 3 are key projections from the 2017 TM used for this evaluation. PWB projected that future demands would be less than current demands once the Tualatin Valley Water District (TVWD) leaves the PWB system in 2026. The filtration treatment plant is required to be online by September 30, 2027, a year after the anticipated 2026 drop in demand.

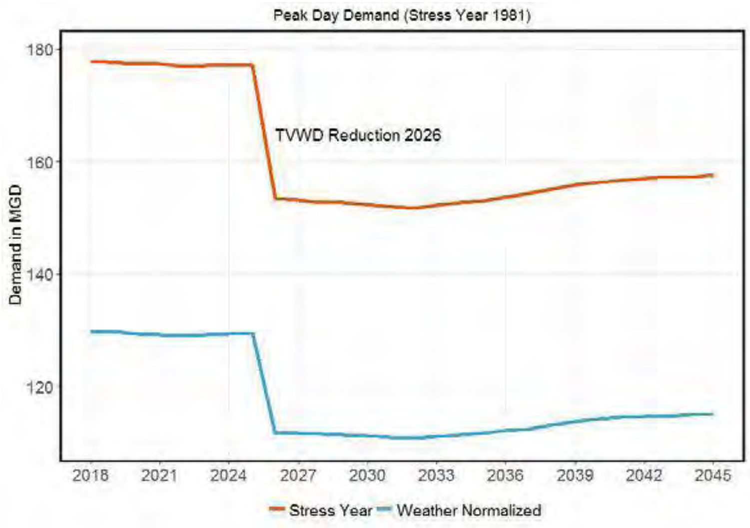


Figure 1. Projected Peak Day Demand
(Reference: SSMP TM 3.1 – Projected Water Demand Figure 5)

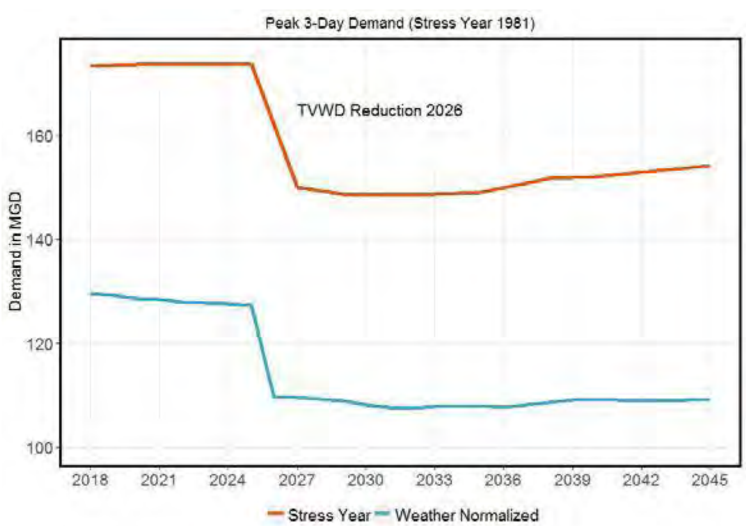


Figure 2. Projected Peak 3-day Demand
(Reference: SSMP TM 3.1 – Projected Water Demand Figure 6)

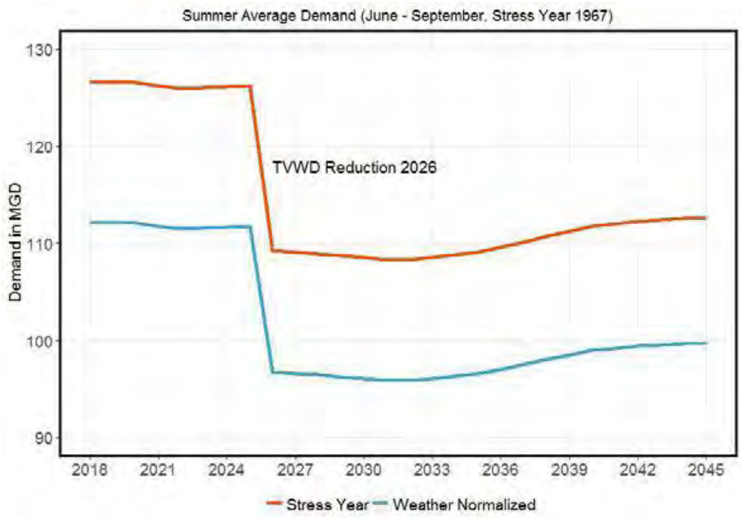


Figure 3. Projected Summer Average Demand
(Reference: SSMP TM 3.1 – Projected Water Demand Figure 3)

The key types of projected demand for this evaluation consist of:

- Peak day demand (PDD) – the highest projected demand in a single day.
- Peak 3-day demand (P3D) – the average of the highest demand over a 3-day period. This is another statistical projection used by PWB to account for the limitations involved in using in-town reservoir storage to understand and manage future peak demands.
- Summer average demand (SAD) – the overall average demand across a summer. By definition, half of the summer days will have demands higher than shown and the other half will have lower demands. This value is used for seasonal supply management.

In addition, the demand projections are described in two different ways:

- Weather normalized – projections based on average historical weather conditions. This method assumes that in the future, each day of the year has the same weather as the average weather of that day over the 1940-2015period.
- Stress year – projections are based on historical weather years that were the most stressful on the supply system. For this evaluation, the stress year corresponded to the conditions encountered in 1981 for the PDD and P3D and in 1967 for the SAD.

This demand information is used to help select and describe the capacity alternatives. A separate analysis was conducted by PWB to assess the likelihood of a demand as high as 160 million gallons per day (MGD) in 2045 given current understanding of the range of variability in weather conditions. The results of the analysis are shown in Figure 4. This figure shows the probability of a PDD of 120 MGD in 2045 as approximately 10th percentile, or for 100 rolls of the weather dice, the corresponding 2045 demand would be at least 120 MGD for 90 of those 100 rolls. Whereas 160 MGD PDD is slightly beyond the 100th percentile, meaning that in 0 of the 100 weather possibilities would 2045 demand exceed 160 MGD. Note that the values shown in this figure are close but do not precisely match the values shown in the prior figures due to the use of different datasets and analytical methodologies.

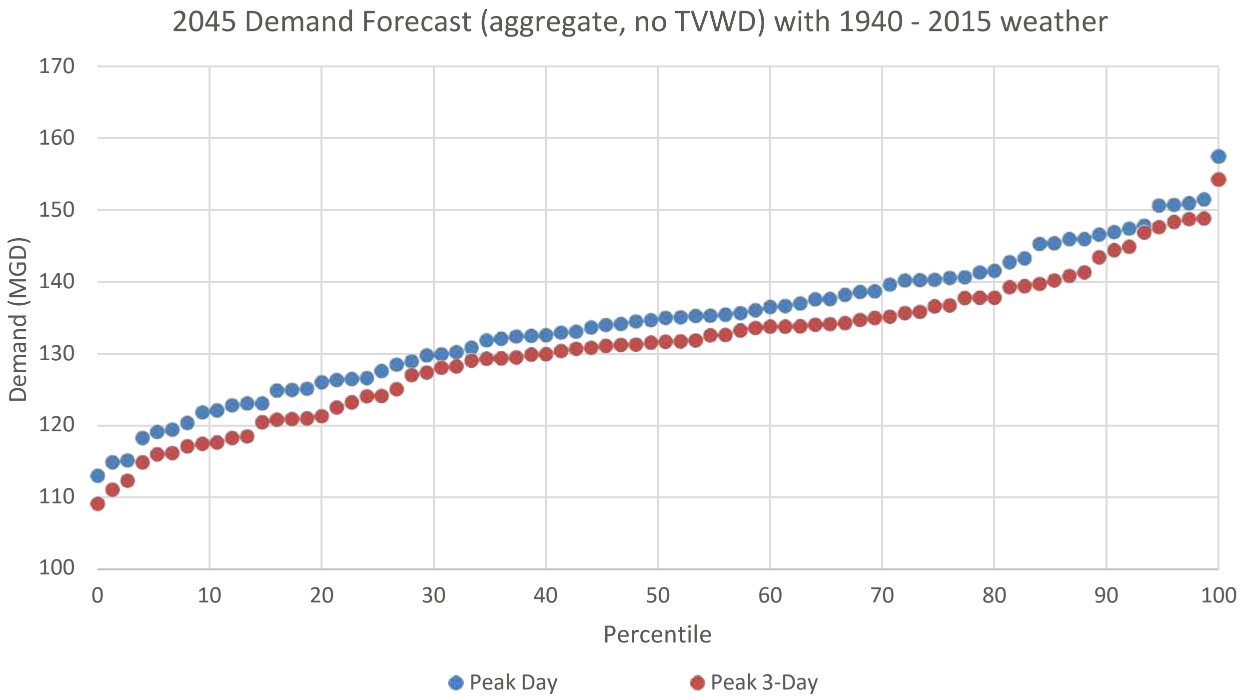


Figure 4. Estimated Probability of 2045 Demand as Influenced by Weather Variability

The future extent of the demand data currently available is limited by the population data available from Portland State University. Population data are not available for the period after 2045. The project team understands that the design life of the treatment plant will extend beyond 2045. The capacity assumption after that date is that additional capacity could be added at the sites being considered, and the layout of the plant can be designed to allow for capacity expansion of individual process components.

3.0 Alternative Management Strategies

Bull Run is the primary and preferred water supply to the PWB system and will remain the primary supply once the future filtration plant is constructed, although alternative management strategies may be used for managing the available water supply to meet water system demand. These strategies are described in this TM only in the context of their potential usage when demands exceed the future filtration capacity. Potential alternative management strategies include:

- Using groundwater pumped from PWB's Columbia South Shore Well Field (CSSWF);
- Drawing down in-town finished water reservoirs lower than current operational practices to meet demands;
- Curtailing water supply to wholesalers and asking them to switch to other water sources;
- Curtailing water supply to major commercial and industrial users and asking them to switch to other water sources, reduce usage, or stop usage altogether;
- Purchasing water from wholesalers that have available water supplies;
- Curtailment measures for residential customers and smaller commercial customers; and
- Stopping non-essential PWB water uses, such as flushing programs

Alternative management strategies, either used individually or in various combinations, could be implemented to allow PWB to meet water demands. PWB has issued the policy document "Characterization of Supplies for Selection of Filtration Capacity" (PWB, 2018; Appendix B) stating that "groundwater will continue to be used as it has been used in the past. Design of the filtration facility, and particularly pretreatment, will determine the degree to which turbidity is removed and is no longer a factor in future groundwater operation. PWB will not size the Bull Run filtration facility in such a manner that would require routine annual use of groundwater to meet average summer season demands." Regular water curtailment is not acceptable to customers and can cause lasting economic damage. There are also no wholesalers nearby that have the excess capacity and transmission capacity to supply a water system as large as PWB. As a result, PWB does not expect to use these management strategies to meet SAD in the future.

For purposes of the evaluations in this memo, the most likely alternative management strategy considered would be some combination of groundwater pumping and increased shorter-term reliance on in-town storage to meet PDD. Other strategies would also be considered in the future if available and if applicable to the situation. There is a cost associated with implementing each of the alternative management strategies. This cost was not calculated but simply noted as an additional cost for capacity alternatives that require the use of alternative management strategies.

4.0 Capacity Alternatives

Five capacity alternatives for the future filtration plant were initially identified by PWB and HDR (Table 1). The capacity for each alternative was established based on a combination of the physical constraints of the existing Bull Run supply system and the PWB demand projections previously summarized.

Table 1. Initial Capacity Alternatives

Capacity (MGD)	Description
200	Approximately equal to maximum Bull Run conduit capacity
160	Slightly higher than the projected 2045 PDD and P3D demands in a stress year
135-145	Covers 90% of 2045 PDD and P3D demands in stress year
115-120	Slightly higher than the projected 2045 PDD and P3D in a weather-normalized year
100	Slightly higher than the projected 2045 summer average demand in a weather-normalized year

The 200 MGD capacity was rejected from further consideration because it is 40 MGD higher than the projected PDD of 160 MGD in a stress year for 2045 (i.e., the highest demand day between 2027 and 2045). A 100 MGD capacity facility was also rejected because it would not meet system demand up to 50 percent of the time and alternative management strategies would be needed on a regular basis. This is inconsistent with PWB's groundwater policy.

The remaining alternatives (115-120 MGD, 135-145 MGD, and 160 MGD) were carried forward for evaluation using the decision model and criteria. The range of 115-120 MGD was reduced to 115 MGD to simplify the subsequent analysis. Similarly, the range of 135-145 MGD became 145 MGD.

5.0 Decision Model and Criteria

The three remaining alternatives were evaluated using the program's adopted decision model. The model consists of eight values, each having several criteria to evaluate each alternative.

Table 2 lists the values and criteria. While all of the values are applied to each alternative, not every criterion is applicable for the capacity decision. For example, the criteria "Existing microbiological regulations" is not applicable because the capacity of the future plant has no direct bearing on how well it would meet the regulations, whereas such regulations have a significant impact on the separate filtration technology decision. The table also lists the criteria specifically excluded from the capacity evaluation and the rationale.

Table 2. Decision Model and Criteria Used for Capacity Evaluation

Value	Criteria	Included/ Excluded	Rationale
Public Health and Water Quality	Existing microbiological regulations	Excluded	Compliance with regulations does not depend on facility capacity.
	Organics/inorganics regulations	Excluded	Compliance with regulations does not depend on facility capacity.
	Emerging water quality regulations	Excluded	Compliance with regulations does not depend on facility capacity.
	Consistent water quality	Included	Water quality can vary with use of alternative management strategies.
	Chemical impacts	Excluded	The water treatment chemicals dosages do not depend on facility capacity.
Resiliency/ Reliability	Earthquake	Included	A higher design capacity results in greater water production after a seismic event.
	Catastrophic water quality event	Included	Similar to the response to earthquakes, a higher design capacity results in greater drinking water production after a catastrophic water quality event.
	Routine water quality event	Excluded	This issue relates to the treatment decision, not capacity.
Community Interests	Local impacts	Included	The facility capacity dictates the size and extent of the construction required. This construction would impact the neighbors.
	Consistency in taste and appearance	Included	Water quality can vary with use of alternative management strategies.
	Chemical concerns	Excluded	Dosage does not depend on capacity but on treatment technology instead.
Cost Benefit	Cost of construction	Included	The extent of construction required is a direct function of the facility size.
	Operating cost	Included	The cost for operating the facility is directly dependent on its size.
	Total cost of delivered water	Included	The capacity of the future facility has impact on the construction costs.

Value	Criteria	Included/ Excluded	Rationale
Future Needs	Capacity	Included	The capacity of the future facility would decide whether alternative management strategies need to be used to meet peak demands.
	Future water quality	Included	The size of additional processes required for the future facility is an inverse function of its capacity.
	Available gravity capacity	Excluded	The gravity capacity available depends on the site and not capacity.
Environmental Impacts	Electricity usage	Included	The capacity of the future facility and the alternative management strategy used would decide the amount of electricity used.
	Residuals produced	Excluded	Initial estimates indicate there is no significant difference between the alternatives.
	Construction and operations fuel consumption	Included	This constitutes the number of truck trips and construction equipment used and is thus a direct function of how large the facility is.
Integration	WTP labor	Excluded	The labor required to operate and maintain the plant, for a given filtration technology, varies very little for the capacities being evaluated.
	Safety and operations	Included	The amount of chemicals that require handling and maintenance is a direct function of capacity.
	Corrosion control integration	Excluded	Corrosion control is related to water quality and not quantity.
	Other infrastructure ramifications	Included	The capacity of the future facility would decide the size of the other infrastructure required, such as pipes, basins, etc.
	Distribution system water quality	Included	Whether the future facility uses alternative management strategies such as groundwater is a direct function of its initial capacity.
Implementation	Implementation complexity	Included	The length of implementation schedule is a function of construction time, land acquisition, design and permitting and start-up time, and is therefore, a function of the facility capacity.
	Ease of construction	Included	Time taken to construct the facility is a direct function of its size.
	Land use permits	Excluded	There is no difference between permitting requirements for a larger plant versus a smaller one with respect to capacity, as opposed to the later site decision.
	On- and off-site ownership	Excluded	Ownership is related to siting instead of capacity.

6.0 Criteria Evaluation

A quantitative score was developed for each criterion used to evaluate the three capacity alternatives. This score was based on either a calculated value developed from various models, or a numerical score assigned to a qualitative description. For this scoring, a higher number means greater benefits and advantages whereas a lower number indicates substantial constraints and negative aspects. Criteria for which actual quantities are available have not been scored and the quantities have been used as such. Criteria that relate to Figure 4 have been scored from 0-100, based on a given alternative's probability of using an alternative management strategy to meet 2045 PDD and P3D. The alternative least likely to use an alternative management strategy was assigned a score of 100. Other criteria were scored on a scale of 1-10, 1 being assigned to the worst alternative and 10 to the best alternative. This section describes each applicable criterion, the scale used to develop the scoring, and the basis for the scoring. Table 3 summarizes the scoring.

Table 3. Evaluation Criteria and Valuation

Value	Public Health and Water Quality					Resiliency/Reliability			Community Interests			Cost Benefit		
Value Description	Provide drinking water that is safe and consistent					Facility maximizes likelihood of continued water provision, even after a fire or disaster			Integrate community interests in the decision-making process			Getting the most benefit for the dollar		
Criteria	Existing Micro- biological Regulations	Organics/ Inorganics Regulations	Emerging Water Quality Regulations	Consistent Water Quality	Chemical Impacts	Earthquake	Catastrophic WQ Event (forest fire, landslide)	Routine WQ Events (elevated turbidity, algae bloom)	Local Impacts	Consistency in Taste and Appearance	Chemical Concerns	Cost of Construction	Operating Costs	Total Cost of Delivered Water
Performance Scale	Ability to meet existing regulations	Ability to meet existing regulations	Ability to meet existing regulations	Use of Alternative Management Strategies	Chemical Selection	Ability to Maintain Supply	Half the Capacity	Treated Water Quality	Neighbors Impacted	Qualitative	Dosage	Capital Cost[1]	Operating Costs[1]	Lifecycle Cost
160 MGD	N/A	N/A	N/A	100 points	N/A	48 MGD	80 MGD	N/A	123,000 truck trips during const.	100 points	N/A	$226,500,000	$11,500,000	5 points
145 MGD	N/A	N/A	N/A	84 points	N/A	44 MGD	73 MGD	N/A	116,000 truck trips during const.	84 points	N/A	$209,000,000 + cost for alternative management strategies	$11,000,000 + cost for alternative management strategies	10 points
115 MGD	N/A	N/A	N/A	3 points	N/A	35 MGD	58 MGD	N/A	97,000 truck trips during const.	3 points	N/A	$177,000,000 + cost for alternative management strategies	$9,000,000 + cost for alternative management strategies	1 point

Value	Future Needs			Environmental Impacts			Integration					Implementation			
Value Description	Maximizes ability to make adjustments in future			Minimize environmental impacts			Optimize operability & integration with PWB's systems and practices					Increases ability to implement and meet compliance schedule			
Criteria	Capacity	Future Water Quality	Available Gravity Capacity	Electricity Usage	Residuals Produced	Construction and Operations Fuel Consumption	WTP Labor	Safety & Operations	Corrosion Control Integration	Other infrastructure Ramifications	Distribution System WQ	Ease of Construction	Implementation Complexity	Land Use Permits	On- and Off-site Ownership
Performance Scale	Time to Next Expansion	Bull Run Water Quality	MGD	MWh/year	Volume produced	# Truck Trips + Operations Fuel Consumption	Required FTEs	Amount of Chemicals	Switching Sources/Use of Management Strategies	Redundancy	Use of Alternative Management Strategies	Risk to Schedule	Risk to Schedule	Risk to Schedule	Ownership
160 MGD	10 points	1 point	N/A	5 points	3,628 cy/year	276,000 Gal (Const. Fuel consumption)	N/A	8,200 dry tons/year	N/A	1 point	100 points	1 point	1 point	N/A	N/A
145 MGD	7 points	4 points	N/A	10 points	3,628 cy/year	261,000 Gal (Const. Fuel consumption)	N/A	7,800 dry tons/yr	N/A	4 points	84 points	4 points	2 points	N/A	N/A
115 MGD	1 points	10 points	N/A	1 point	3,628 cy/year	218,000 Gal (Const. Fuel consumption)	N/A	6,900 dry tons/yr	N/A	10 points	3 points	10 points	10 points	N/A	N/A

1-Capital and operating cost are for a typical granular media filtration water treatment plant and do not specifically represent data or cost of a facility for the Bull Run supply. The cost information is solely for comparative purposes.

This page is blank.

6.1 Consistent Water Quality

Performance Scale: As noted earlier, PWB will need to implement alternative management strategies whenever PWB system demands exceed the Bull Run filtration plant capacity. Some of these alternative management strategies may cause the distribution system water quality to change significantly. For example, groundwater from the CSSWF has different pH, alkalinity, and total dissolved solids than the Bull Run supply. Therefore, the scale for this criterion is based on the likelihood that an alternative management strategy is used to meet 2045 PDD.

Basis for Valuation: The scoring is based on the probability of a capacity alternative to use alternative management strategies to meet 2045 PDD (Figure 4). The scoring is as follows:

- 160 MGD: 100 points, because there is a 1 in 100 chance of using an alternative management strategy to meet the projected 2045 PDD
- 145 MGD: 84 points, because there is a 16 in 100 chance of using an alternative management strategy in 2045
- 115 MGD: 3 points, because there is a 97 in 100 chance of using an alternative management strategy in 2045

6.2 Earthquake

Performance Scale: The ability to quickly restore some measure of drinking water production is crucial after an earthquake. Per the 2013 Oregon Resilience Plan prepared by the Oregon Seismic Safety Policy Advisory Commission, a drinking water utility should restore some level of plant production in the weeks and months following a major earthquake. Specifically, the Plan's Table 8.19 (Water and Wastewater Sector: [Willamette] Valley Zone) indicates that the desired water treatment plant availability (capacity) within 0 to 24 hours after an earthquake is 20-30 percent of the full normal capacity. A larger capacity plant would therefore have the benefit of providing greater immediate supply availability after an earthquake than a smaller capacity one. This does not consider overall system seismic vulnerability, but only focuses on the treatment facility.

Basis for Valuation: The criterion valuation is based on 30 percent of the normal rated plant capacity, which is the desired capacity within 24 hours immediately following an earthquake.

- 160 MGD: 48 MGD
- 145 MGD: 44 MGD
- 115 MGD: 35 MGD

6.3 Catastrophic Water Quality Event

Performance Scale: A catastrophic water quality event, such as large fire or landslide in the watershed, will hinder the ability for a filtration plant, regardless of filtration technology, to produce water that continues to meet all regulatory requirements. In such an event, PWB would implement management strategies and operate the plant at a lower capacity to provide longer coagulation times, greater settling times, lower filter loading rates, higher chlorine disinfection times, and/or other similar adjustments so that the adversely impacted Bull Run supply could still be used to some extent. Such adjustments would occur for a facility with any type of filtration technology and not specific to a single technology.

Basis for Valuation: The criterion valuation assumes the available filtration plant capacity after a catastrophic event is effectively halved to continue Bull Run treatment.

- 160 MGD: 80 MGD
- 145 MGD: 73 MGD
- 115 MGD: 58 MGD

6.4 Local Impacts

Performance Scale: Local impacts are defined as truck trips during construction. The primary impacts to neighbors are anticipated to be related to noise, traffic, and road dust from these truck trips. Truck trips related to ongoing operations were not included as this is not a significant differentiator between different size facilities. A facility requiring more truck trips scored lower than a facility requiring less truck trips.

Basis for Valuation: During construction, a larger capacity filtration plant would have more truck trips than a smaller one as the facility is larger in physical size. The number of construction truck trips is based on the conceptual design modeling for a direct filtration granular media plant. The modeling results are summarized in the document Cost Curves for Granular Media Filtration TM in Appendix C. A different type of treatment process and/or site-specific requirements may cause the values to vary significantly, however the ratios between the alternatives would be similar.

- 160 MGD: 123,000 truck trips during construction
- 145 MGD: 116,000 truck trips during construction
- 115 MGD: 97,000 truck trips during construction

6.5 Consistency in Taste and Appearance

Performance Scale: When an alternative management strategy is used, such as CSSWF groundwater, or purchasing outside water supplies, the taste and appearance of drinking water can change from the Bull Run water. For instance, CSSWF groundwater has higher total dissolved solids and alkalinity than water supplied from Bull Run. Switching between these sources can change taste and appearance characteristics. A facility that is less likely to require the use of an alternative management strategy is less likely to change taste and appearance and scored higher than a facility that is more likely to require the use of groundwater. Therefore, a larger capacity filtration plant is the best alternative as it would be least dependent on a management strategy.

Basis for Valuation: The scoring is based on the probability of a capacity alternative to use an alternative management strategy to meet PDD demand in 2045 (Figure 4). The scoring is as follows:

- 160 MGD: 100 points, because there is a 1 in 100 chance of this alternative using groundwater to meet the 2045 PDD

- 145 MGD: 84 points, because there is a 16 in 100 chance of this alternative using groundwater to meet the 2045 PDD
- 115 MGD: 3 points, because there is a 97 in 100 chance of this alternative using groundwater to meet the 2045 PDD

6.6 Cost of Construction

Performance Scale: The cost of construction takes into consideration the infrastructure that needs to be built and also the alternative management strategies that might need to be used for a given facility size to meet the peak demands.

Basis for Valuation: A larger facility would require more infrastructure to be built but would also be less dependent on alternative management strategies to meet the PDD. A smaller facility, though, would require less infrastructure, would also be more likely to use an alternative management strategy to meet PDD.

- 160 MGD: $226,500,000
- 145 MGD: $209,000,000 + cost of alternative management strategy
- 115 MGD: $177,000,000 + cost of alternative management strategy

6.7 Operation Cost

Performance Scale: The operation cost directly relates to the operational requirements of the facility and also the alternative management strategies that might need to be used for a given facility size to meet the peak demands.

Basis for Valuation: A larger facility would require more infrastructure but would also be less dependent on alternative management strategies to meet the PDD. A smaller facility, though, would require less infrastructure, would also be more likely to use an alternative management strategy to meet PDD.

- 160 MGD: $11,500,000
- 145 MGD: $11,000,000 + cost of alternative management strategy
- 115 MGD: $9,000,000 + cost of alternative management strategy

6.8 Cost of Delivered Water

Performance Scale: The total cost of delivered water includes the cost of drinking water delivered from the Bull Run Filtration Plant and the cost of water delivered through alternative management strategies.

Basis for Valuation: The scoring is based on the total delivered water cost. Ten points are assigned to the alternative which is least expensive and 1 point is assigned to the alternative that is most expensive. The following values are assigned to each capacity alternative based on the aforementioned scale:

- 160 MGD: 5 points, because Bull Run water has the highest estimated cost but incurs management strategy costs very infrequently or not at all.
- 145 MGD: 10 points, because the estimated delivered Bull Run water is 10 percent lower than the 160 MGD alternative while alternative management strategy costs are

incurred less often. This means that the delivered water cost, which includes Bull Run water cost and alternative management strategy cost, is the lowest.

- 115 MGD: 1 point because while the estimated Bull Run water is the lowest cost, this alternative will incur alternative management strategy costs most frequently. This means that the delivered water cost is the highest.

6.9 Capacity

Performance Scale: The capacity scale is based on number of occurrences when the initial filtration plant firm capacity is exceeded through 2045 (the extent of the planning horizon) and alternative management strategies are needed to meet demands.

Basis for Valuation: The scoring is based on the ability of the plant to meet needs of both 2045 weather normalized average PDD and 2045 stress year PDD using Bull Run filtration alone. Ten points are assigned to the alternative that can meet these demands and 1 point to the alternative that cannot meet the demands. Values between 1 and 10 are interpolated linearly based on plant capacity between the 2045 weather normalized PDD and 2045 stress year PDD. The following values are assigned to each capacity alternative based on the aforementioned scale:

- 160 MGD: 10 points, because capacity meets normalized and stress year PDD
- 145 MGD: 7 points, because capacity covers 90% of 2045 PDD and P3D demands in a stress year
- 115 MGD: 1 point, because capacity is just above the 2045 weather normalized PDD and far less than the 2045 stress year PDD

6.10 Future Water Quality

Performance Scale: This criterion is based on the space needed to add additional treatment processes to address future water quality changes; either changes to the untreated Bull Run supply or changes to drinking water requirements for the Bull Run filtration plant.

Basis for Valuation: The scoring is based on the size of additional processes needed for the filtration plant irrespective of a filtration technology. Ten points are assigned to the alternative that would require smaller sized additional processes and 1 point to the alternative that would require larger sized additional processes. The following values are assigned to each capacity alternative based on the aforementioned scale:

- 160 MGD: 1 point for being the largest capacity, which implies that it would need largest sized additional processes among the three alternatives
- 145 MGD: 4 points on linear scaling between 160 MGD and 115 MGD
- 115 MGD: 10 points for being the smallest capacity, which implies that it would need the smallest-sized additional processes among all three alternatives

6.11 Electricity Usage

Performance Scale: Similar to the total cost of the delivered water criterion, PWB water supply electricity usage includes the Bull Run Filtration Plant and the water delivered through alternative management strategies, such as water from wholesalers or pumping CSSWF groundwater. The estimated electricity usage is based on the conceptual design modeling for a direct filtration granular media plant summarized in Appendix C. Site- specific constraints and changes to the filtration technology will cause electricity usage to change, although the ratios between alternatives would be similar. As with the total cost of delivered water, electrical usage for water associated with an alternative management strategy is harder to define as the electricity depends on pumping costs from the CSSWF.

Basis for Valuation: The scoring is based on the estimated combined electricity usage for Bull Run Filtration Plant and the alternative management strategy. Ten points are assigned to the alternative that would consume least amount of electricity and 1 point to the alternative that would consume the most amount of electricity. The following values are assigned to each capacity alternative based on the aforementioned scale:

- 160 MGD: 5 points, because Bull Run Filtration Plant has the highest estimated electricity usage but would require electricity for alternative management strategy usage very infrequently
- 145 MGD: 10 points, because the estimated electricity usage is 10 percent lower than the 160 MGD alternative while alternative management strategy costs are still infrequent
- 115 MGD: 1 point, because while the Bull Run Filtration Plant has the lowest estimated electricity usage, this alternative would incur more frequent electricity usage associated with alternative management strategies

6.12 Construction and Operations Fuel Consumption

Performance Scale: A larger capacity filtration plant would have more truck trips and construction equipment usage than a smaller one as there are more facilities to build and/or facility is larger in physical size. As a result, a larger plant would use more fuel during construction. The estimated construction fuel consumption is based on the conceptual design modeling for a direct filtration granular media plant summarized in Appendix C.

The conceptual design modeling also calculated fuel consumption once the filtration plant becomes operational. This value was not used because the difference between the largest and smallest plant in the number of truck trips during operations is relatively small as compared to the difference in the number of truck trips during construction.

Basis for Valuation: This criterion uses the following values for each alternative:

- 160 MGD: 276,000 gallons of fuel consumed during construction
- 145 MGD: 261,000 gallons of fuel consumed during construction
- 115 MGD: 218,000 gallons of fuel consumed during construction

6.13 Safety & Operations

Performance Scale: Safety and operations are based on the volume of chemicals stored and used in a given treatment facility. The annual volumes of chemicals are based on the conceptual design modeling for a direct filtration granular media plant. The modeling results are summarized in Appendix C. Increased quantities are assumed to result in more handling and maintenance and increase the risk of accidents.

Basis for Valuation: This criterion uses the following values for each alternative:

- 160 MGD: 8,200 dry tons/year
- 145 MGD: 7,800 dry tons/year
- 115 MGD: 6,900 dry tons/year

6.14 Other Infrastructure Ramifications

Performance Scale: A filtration plant has multiple impacts to other infrastructure. A larger capacity filtration plant will require larger capacity (larger diameter) pipelines between the plant site and the existing transmission conduits, larger overflow basins, and other larger hydraulic structures. In addition, a larger capacity plant would mean a larger paved area and result in increased stormwater runoff to manage. Hence, the largest facility would have the lowest score for this criterion.

Basis for Valuation: The scoring is based on the infrastructure requirements for a given alternative. Ten points are assigned to the alternative that would require smaller infrastructure and 1 point to the alternative requiring larger infrastructure. The following values are assigned to each capacity alternative based on the aforementioned scale:

- 160 MGD: 1 point for being the largest capacity, which implies that it would require largest infrastructure among all three alternatives
- 145 MGD: 4 points linearly scaled between 160 MGD and 115 MGD
- 115 MGD: 10 points for being the smallest capacity which implies that it would require smallest infrastructure among all three alternative

6.15 Distribution System Water Quality

Performance Scale: As with the criterion Consistent Water Quality, use of alternative management strategies may cause the distribution system water quality to change. For example, the CSSWF groundwater and water purchased from adjacent wholesalers to meet PWB demands have different pH, alkalinity, and total dissolved solids values than the Bull Run supply.

Basis for Valuation: The scoring is based on the likelihood that an alternative management strategy is used in 2045 PDD per Figure 4. The scoring is as follows:

- 160 MGD: 100 points, because there is a 1 in 100 chance of using an alternative management strategy to meet the PDD
- 145 MGD: 84 points, because there is a 16 in 100 chance of using an alternative management strategy to meet the PDD
- 115 MGD: 3 points, because there is a 97 in 100 chance of using an alternative management strategy to meet the PDD

6.16 Ease of Construction

Performance Scale: Ease of construction takes into consideration the effect of facility size on the length of construction schedules. With all other factors being equal (site, filtration technology, monthly cash flow), a larger capacity filtration plant will take longer to construct than a smaller capacity plant and may make the site more congested.

Basis for Valuation: The scoring is based on the amount of time needed to construct a filtration plant, regardless of the filtration technology. 10 points are assigned to the alternative that requires least amount of time to construct and 1 point is assigned to the alternative requiring most amount of time to construct. The following values are assigned to each capacity alternative based on the aforementioned scale:

- 160 MGD: 1 point for being the largest capacity, i.e., most time needed
- 145 MGD: 4 points linearly scaled between 160 MGD and 115 MGD
- 115 MGD: 10 points for being the smallest capacity, i.e., least time needed

6.17 Implementation Complexity

Performance Scale: Implementation complexity takes into consideration the effect of facility size on the length of construction schedules and start-up time for the facility. Larger sized facility would require more equipment and systems to be tested, started, and placed into service and would likely push the start-up date. For example, Appendix C indicates that a 115 MGD direct filtration media plant would have 16 gravity filters, a 145 MGD plant would have 20 filters, and a 160 MGD plant would have 22 filters. Conversely, a 115 MGD plant would have two rapid mix trains while the 145 and 160 MGD plants would have three trains–a small change. Finally, the backwash pump station has the same capacity regardless of plant capacity. Therefore, implementation complexity increases with capacity but the overall change is not linear.

Basis for Valuation: While the implementation complexity may not be a true discriminator, for the sake of this evaluation, the following 0 to 10 point scoring is assigned for 160 and 115 MGD:

- 160 MGD: 1 point for being the largest capacity and therefore highest relative complexity
- 115 MGD: 10 points for being the smallest capacity and least relative complexity

Given the non-linear differences for complexity, the following scoring is assigned for 145 MGD:

- 145 MGD: 2 points (nearly the same as a 160 MGD plant)

7.0 Evaluation

The PWB Filtration Team, including all representatives of the Executive Team, met on April 18, 2018, to review the performance of the capacity alternatives and reach a conclusion upon the preferred capacity alternative. This decision modeling process was used to support the Filtration Team and the Executive Committee in reaching conclusions. The decision model incorporates the values, criteria, and performance scales of the three viable capacity alternatives. Throughout the evaluation and review, the team reminded itself that the decision model alone does not make the decision. This context assured that the decision model and the evaluation of alternatives was designed to inform the technical team and the Executive Committee, not make the decision for PWB.

Three weighting scenarios were carried through the process to reflect the different perspectives of the PWB team members. The three weighting scenarios were:

1. Team Weighted (TW) – The PWB Filtration Team weights produced on March 27, 2018.
2. Equal Weights (EQ) – Equal weights among the eight values.
3. Split (SP) – A 60/40 split weighting where 40 percent of the weight remained with Public Health Water Quality (25 percent) and Reliability (15 percent) as identified in the team weighted scenario, and the remaining 60 percent was distributed equally among the other six values.

These weighting scenarios were carried through the evaluation process to demonstrate weighting sensitivity. The summary of these weights and their associated impacts on scoring are shown in Table 4.

Table 4: Weighting Scenarios

ID#	Evaluation Criteria	TW	EQ	SP
1	**Public Health and Water Quality**	25	12.5	25
2	**Resiliency/Reliability**	15	12.5	15
2.1	Earthquake: 30% Availability	5.9	6.25	7.5
2.2	Catastrophic WQ event: Maintain half capacity	9.1	6.25	7.5
3	**Community Interests**	9	12.5	10
3.1	Local Impacts: Truck trips	1.9	4.17	3.33
3.2	Consistency in Taste and Appearance: Percentile availability	4.2	4.17	3.33
4	**Cost Benefit**	12	12.5	10
4.1	Cost of Construction: Capital $	5.4	6.25	5
4.2	Operating Cost: Operating $	6.6	6.25	5
5	**Future Needs**	10	12.5	10
5.1	Capacity: Expansion potential 1-10	5.2	6.25	5
5.2	Future Water Quality: Bull Run water quality 1-10	4.8	6.25	5
6	**Environmental Impacts**	7	12.5	10
6.1	Electrical Usage: Megawatts per year	2.3	4.17	3.33
6.2	Residuals Produced: Cubic years/year	2.7	4.17	3.33
6.3	Construction and Operations Fuel Consumption: Construction + opertions fuel consumption	2	4.17	3.33
7	**Integration**	12	12.5	10
7.1	Safety and Operations: Chemical dry tons/year	5.3	4.17	3.33
7.2	Other Infrastructure Ramifications: Redundancy 1-10	3.2	4.17	3.33
7.3	Distribution System WQ: Percentile Availability	3.5	4.17	3.33
8	**Implementation**	10	12.5	10
8.1	Ease of Construction: Risk to schedule 1-10	4.2	6.25	5
8.2	Implementation Complexity: Risk to schedule 1-10	5.8	6.25	5

The performance ratings of the alternatives found in Table 3, and the weighting of the values and criteria found in Table 4 are the inputs for the evaluation of the site alternatives. The normalized performance rating multiplied by the weight and added across values and criteria produces a value score. Table 5 demonstrates this calculation.

Columns N and O in Table 5 list the values and criteria and their associated weights. In the calculation in Table 5, the weights that are showcased are those associated with the Team weighting scheme (TW) in Table 4. Column B of Table 5 displays the weight percentage of each value/criterion. This weight percentage is the number that is carried through the evaluation calculation. Columns E and F and G summarize the performance ratings of each capacity alternative. These are the same numbers that are presented in Table 3 and further characterized in Section 6. Columns C and D reflect the minimum and maximum performance ratings among the alternatives. Columns H, I, and J are the normalized performance ratings of the three alternatives. Normalization (calculating performance in a 0 to 1 scale) is done for all performance scales to allow for common application in the evaluation. Regardless of the scale used to demonstrate performance of the alternatives (i.e., performance scale of site acres for Community Interests/Local Impacts), normalization produces a 0 for the worst performer and a 1 for the best performer within each value/criterion. Columns I and J are the calculated values scores for each value/criterion. This is the multiplication of the weight (Column B) times the Normalized Rating (Column G or H) times 100 (the 100 is just to make the result a more manageable number). The calculations within each cell of Columns I and J reflect the contribution of value the respective alternative receives from the specific value/criteria. The summation of these contributions down Column K or L or M produces the total value score for each capacity alternative. These total values scores demonstrate, relatively, how well the alternatives perform against the values and criteria. The higher the number, the better the relative performance.

Table 5. Value Score Calculations

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
	Weight %	Raw Ratings					Normalized Ratings			Value Scores (weight times normalized rating times 100)				
Value/ Criteria No.	TW	Minimum	Maximum	160 MGD	145 MGD	115 MGD	160 MGD	145 MGD	115 MGD	160 MGD	145 MGD	115 MGD	Value/Criterion	Assigned Weight (TW)
1	25.0%	3	100	100	84	3	1.00	0.84	0.00	25.0	20.9	0.0	**Public Health and Water Quality/**Consistent WQ	25
2.1	5.9%	35	48	48	44	35	1.00	0.69	0.00	5.9	4.1	0.0	**Resiliency/Reliability/**Earthquake	5.9
2.2	9.1%	58	80	80	73	58	1.00	0.68	0.00	9.1	6.2	0.0	**Resiliency/Reliability/**Catastrophic WQ Event	9.1
3.1	2.8%	123000	97000	123000	116000	97000	0.00	0.27	1.00	0.0	0.8	2.8	**Community Interests /**Local Impacts	1.9
3.2	6.2%	3	100	100	84	3	1.00	0.84	0.00	6.2	5.2	0.0	**Community Interests/**Consistency in Taste Appearance	4.2
4.1	5.4%	226.5	177	226.5	209	177	0.00	0.35	1.00	0.0	1.9	5.4	**Cost Benefit/**Cost of Construction	5.4
4.2	6.6%	11.5	9	11.5	11	9	0.00	0.20	1.00	0.0	1.3	6.6	**Cost Benefit/**Operating Costs	6.6
5.1	5.2%	1	10	10	7	1	1.00	0.67	0.00	5.2	3.5	0.0	**Future Needs/**Capacity	5.2
5.2	4.8%	1	10	1	4	10	0.00	0.33	1.00	0.0	1.6	4.8	**Future Needs/**Future WQ	4.8
6.1	2.3%	1	10	5	10	1	0.44	1.00	0.00	1.0	2.3	0.0	**Environmental Impacts/**Electrical Usage	2.3
6.2	2.7%	3628	3628	3628	3628	3628	0.00	0.00	0.00	0.0	0.0	0.0	**Environmental Impacts/**Residuals Produces	2.7
6.3	2.0%	276000	218000	276000	261000	218000	0.00	0.26	1.00	0.0	0.5	2.0	**Environmental Impacts/**Fuel Consumption	2
7.1	5.3%	8200	6900	8200	7800	6900	0.00	0.31	1.00	0.0	1.6	5.3	**Integration/**Safety and Operations	5.3
7.2	3.2%	1	10	1	4	10	0.00	0.33	1.00	0.0	1.1	3.2	**Integration/**Infrastructure Ramifications	3.2
7.3	3.5%	3	100	100	84	3	1.00	0.84	0.00	3.5	2.9	0.0	**Integration/**Distribution System WQ	3.5
8.1	4.2%	1	10	1	4	10	0.00	0.33	1.00	0.0	1.4	4.2	**Implementation/**Ease of Construction	4.2
8.2	5.8%	1	10	1	2	10	0.00	0.11	1.00	0.0	0.6	5.8	**Implementation/**Implementation Complexity	5.8
				lue Scores (sum of all values/criteria value scores):						55.9	55.9	40.1		

Figures 5 through 7 demonstrate the performance of the three capacity alternatives within the three different weighting scenarios. The numbers below each stacked bar present the summation of the value score. Each color of the stacked bar represents the contribution the alternative received from each value. Each value has criteria that are used to gauge the performance of the alternatives. The size of the colored bar is determined by multiplying the performance score the alternative received (Table 3) by the weight of the specific criterion (Table 4). The results of the criteria scores are then added to produce the total contribution per value. The higher the total score, the better the collective performance of the alternative against the values.

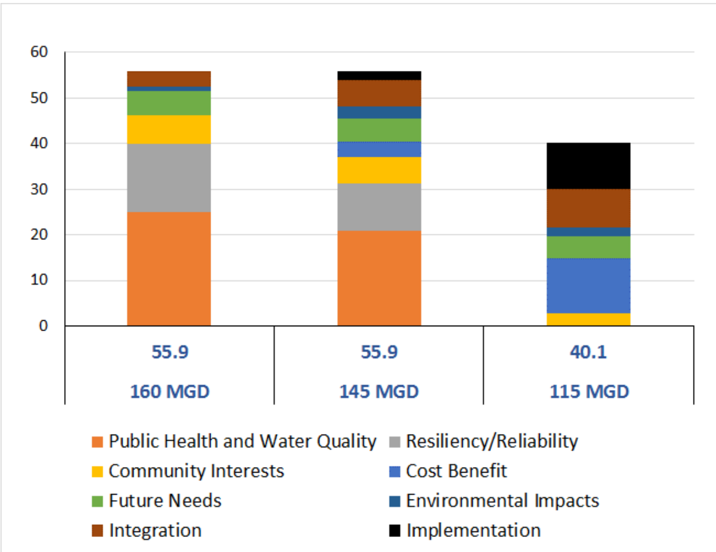


Figure 5. Team Weighting Value Scores

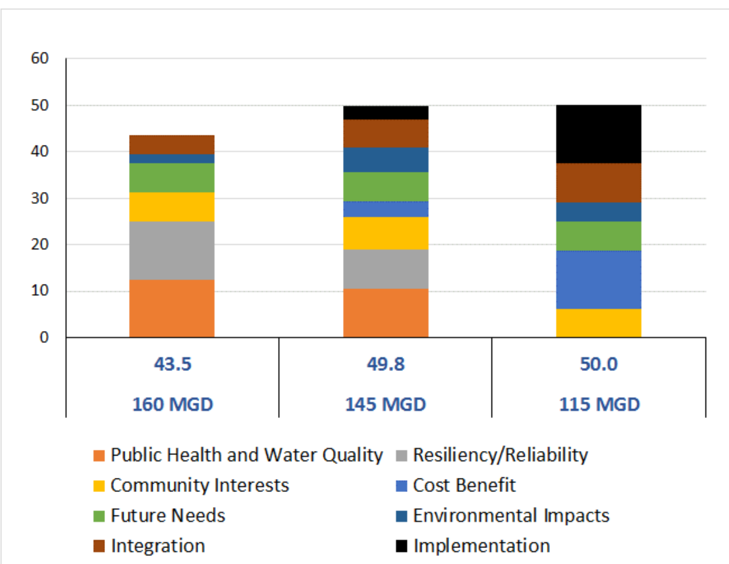


Figure 6. Equal Weighting Value Scores

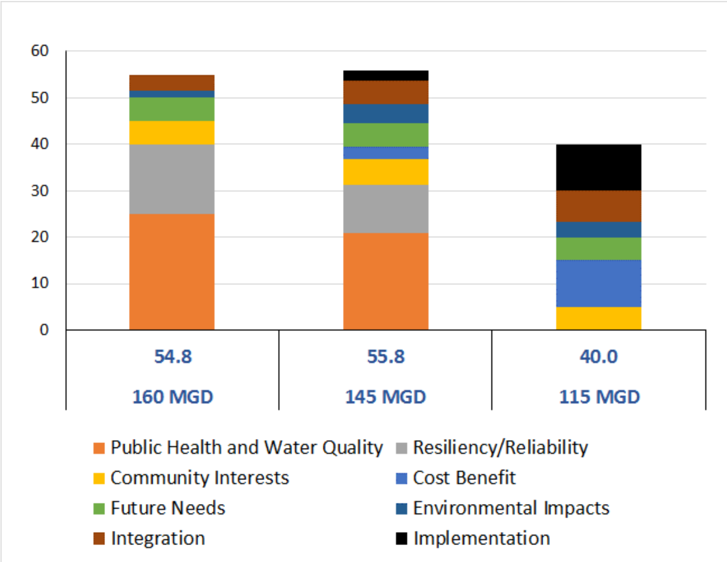
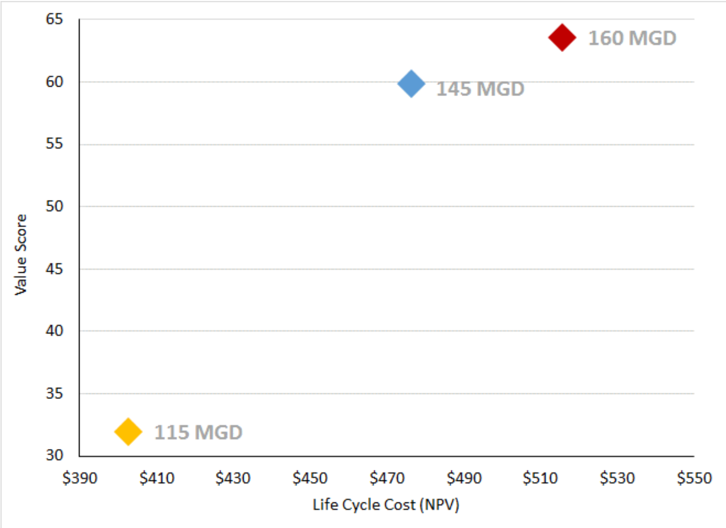


Figure 7. 60/40 Split Weighting Value Scores

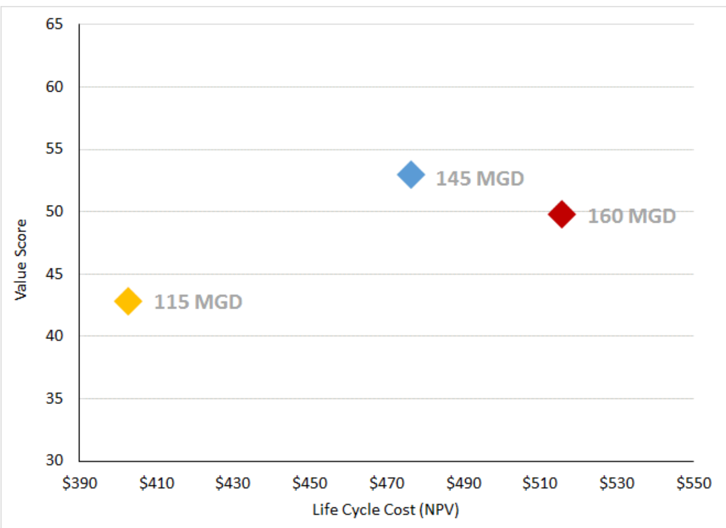
Another means to evaluate the performance of the alternatives is to contrast the total lifecycle cost of the alternatives against their total decision score. To avoid double counting of the cost element, the Cost Benefit value is removed from the calculation of the decision score. The resulting total value score is then graphically plotted against the lifecycle cost (see Figures 8 through 10). The total lifecycle cost is based upon the addition of cost of construction plus the operating costs over a 25-year period.

This comparison also allows for a calculation of the investment required per unit of value. The table associated with the scatter plot presents the total cost ($M) to gain a unit of value. The table also demonstrates the additional lifecycle cost and resulting additional value in the movement to more valued alternatives. The same three weighting scenarios are evaluated.



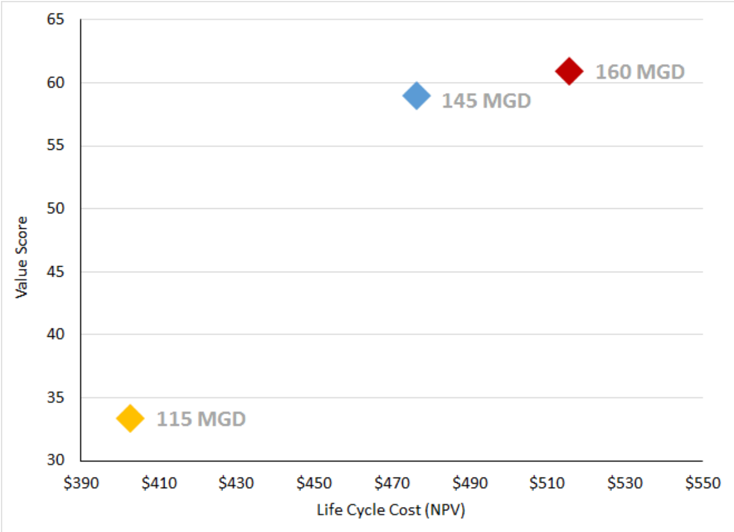
	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
160 MGD	63.5	$ 515.80	$ 8.12	3.7	$ 39.50	10.61
145 MGD	59.8	$ 476.30	$ 7.96	27.9	$ 73.50	2.64
115 MGD	31.9	$ 402.80	$ 12.61	-----	----	----

Figure 8. Team Weighting Scatter Plot



	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
160 MGD	49.7	$ 515.80	$ 10.37	-3.2	$ 39.50	-12.20
145 MGD	53.0	$ 476.30	$ 8.99	10.1	$ 73.50	7.27
115 MGD	42.9	$ 402.80	$ 9.40	-----	----	----

Figure 9. Equal Weighting Scatter Plot



	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
160 MGD	60.9	$ 515.80	$ 8.47	2.0	$ 39.50	20.05
145 MGD	58.9	$ 476.30	$ 8.08	25.6	$ 73.50	2.87
115 MGD	33.3	$ 402.80	$ 12.08	-----	----	----

Figure 10. 60/40 Split Weighting Scatter Plot

Further discussion on April 18, 2018, persuaded the team to reconsider the influence of some of the criteria. The intent was not to manipulate the scores, but to consider the importance and influence of specific criteria. Note, again, that the decision model is not designed or intended to produce the answer. Rather, the decision model is designed to incorporate values, structure meaningful performance comparisons, and demonstrate tradeoffs, and support conversation among the technical team and the Executive Committee. Based upon the technical team's deliberations, a conclusion was reached that four criteria do not lend to differentiation among the alternatives:

a. Ease of construction

b. Implementation complexity

c. Future water quality

The Team agreed to review the evaluation with removal of these three criteria across the three weighting scenarios. The resultant scoring from this revision is shown on the following figures.

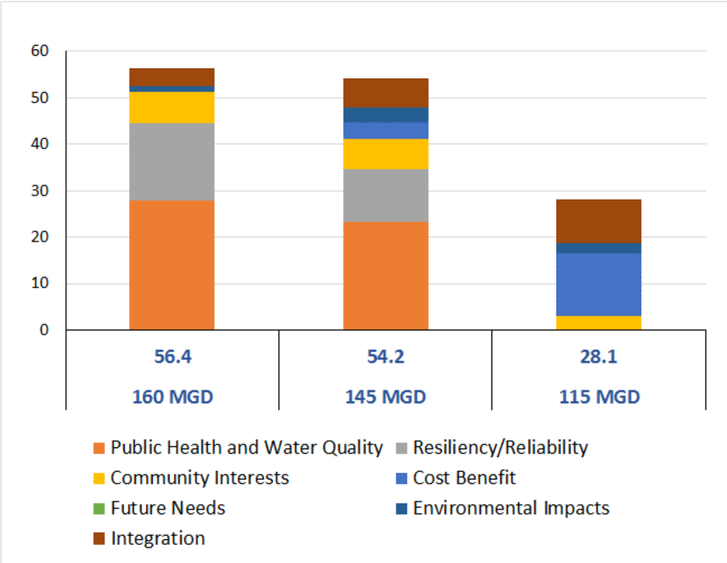


Figure 11. Updated Team Weighting Value Scores

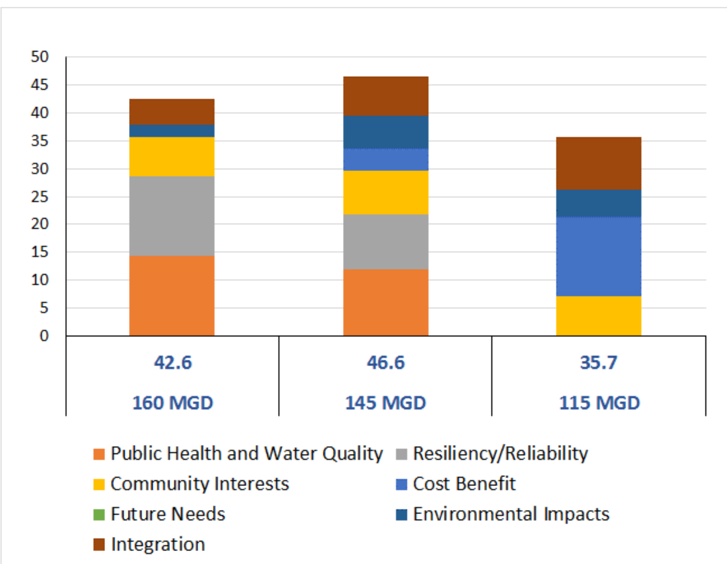


Figure 12. Updated Equal Weighting Value Scores

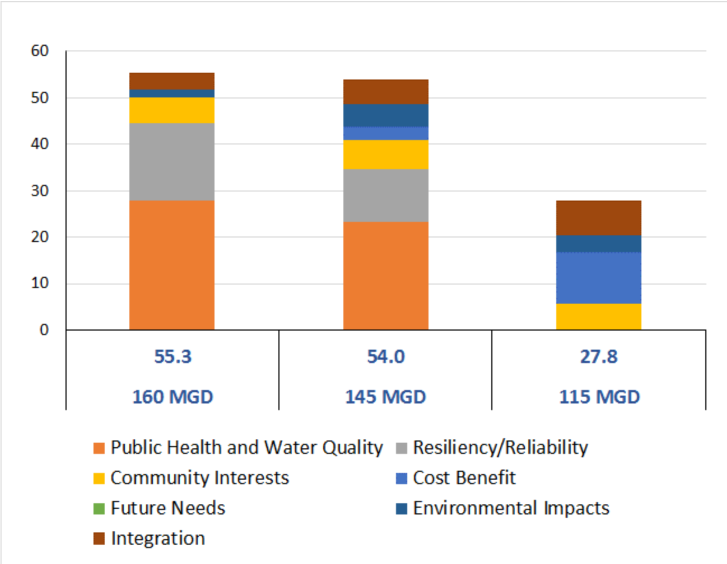
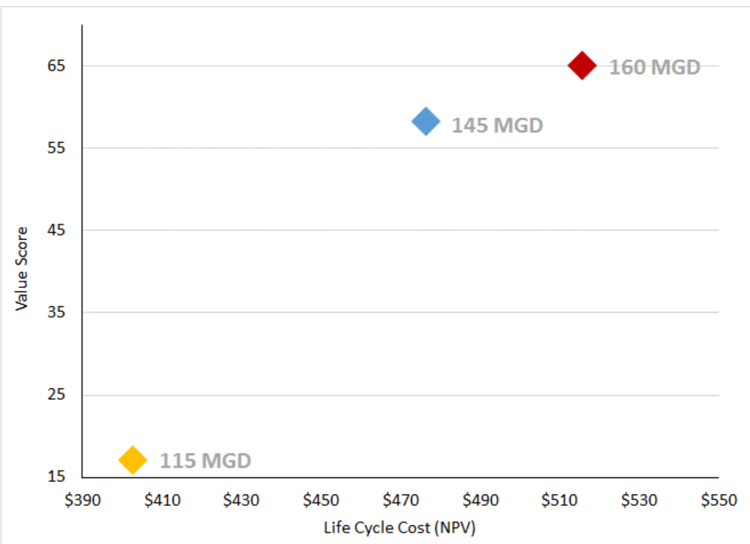
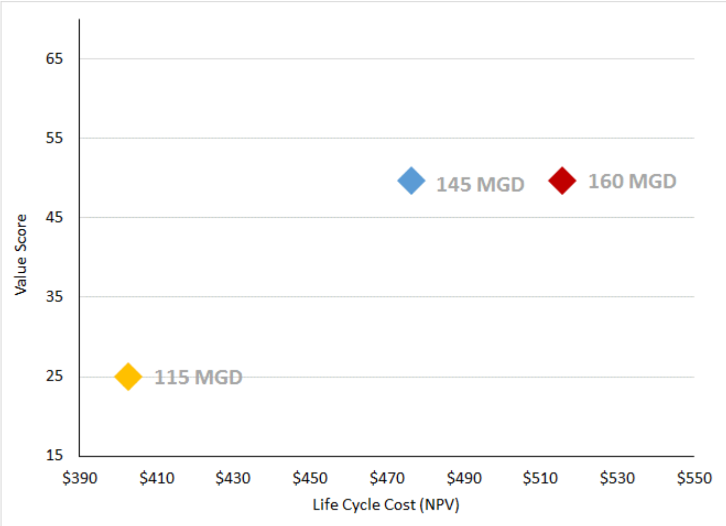


Figure 13. Updated 60/40 Split Weighting Value Scores



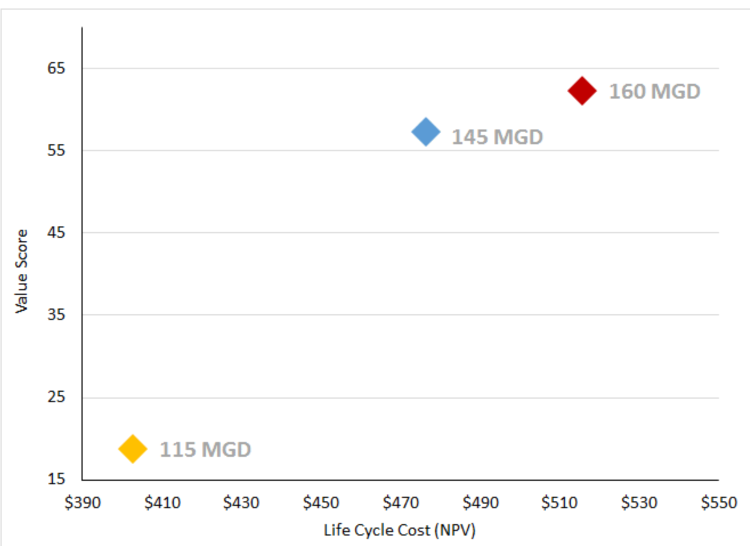
	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
160 MGD	65.0	$ 515.80	$ 7.93	6.6	$ 39.50	5.94
145 MGD	58.4	$ 476.30	$ 8.16	41.3	$ 73.50	1.78
115 MGD	17.1	$ 402.80	$ 23.62	-----	----	----

Figure 14. Updated Team Weighting Scatter Plot



	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
160 MGD	49.7	$ 515.80	$ 10.38	-0.1	$ 39.50	-546.07
145 MGD	49.8	$ 476.30	$ 9.57	24.8	$ 73.50	2.97
115 MGD	25.0	$ 402.80	$ 16.11	-----	----	----

Figure 15. Updated Equal Weighting Scatter Plot



	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
160 MGD	62.3	$ 515.80	$ 8.28	5.0	$ 39.50	7.91
145 MGD	57.3	$ 476.30	$ 8.32	38.5	$ 73.50	1.91
115 MGD	18.8	$ 402.80	$ 21.48	-----	----	----

Figure 16. Updated 60/40 Split Scatter Plot

It was decided by the Filtration Team to use this new cut of the performance data, eliminating ease of construction, implementation complexity, and future water quality from the analysis.

8.0 Recommendation

The potential plant capacities discussed in this memorandum: 115, 145, and 160 MGD were chosen after taking into consideration the projected PDD in a stress year for 2045 and their ability to consistently meet projected PWB water system demands.

The PWB Filtration Team, with concurrence from the Executive Team, used the results of the decision model to first remove the 115 MGD alternative from further consideration. This alternative provided the fewest overall benefits to the PWB in most of the evaluation scenarios that the team considered and discussed, as well as having the highest cost per unit value for all reviewed scenarios.

The same decision models indicated the scoring between the 145 MGD and 160 MGD alternatives were very similar. After another analysis of the criteria, with and without scoring, the Filtration Team and the Executive Committee merged the two alternatives into a single conclusion. The decision is to proceed forward with a desired capacity of 160 MGD, with the understanding that the capacity ultimately constructed may be somewhat smaller as a result of subsequent decisions about siting and filtration technology as well as later design choices. However, the lowest installed capacity that the PWB will accept is 145 MGD. This refined decision of a desired capacity and hard lower limit provides adequate direction at this early phase of the project and reflect PWB’s current understanding of projected peak day demand, while providing flexibility during treatment plant design in the coming years ahead.

Appendices

A. Projected Water Demand

B. Characterization of Supplies for Selection of Filtration Capacity

C. Cost Curves for Granular Media

Appendix A. Projected Water Demand

Technical Memo 3.1
Projected Water Demand

To: Stakeholders

From: Jodie Inman, Janet Senior, Hossein Parandvash

CC: File

Date: February 28, 2017

Re: Projected Water Demand

1.0 PURPOSE

The purpose of this Tech Memo is to document projected aggregate water demand for the PWB service area through the Supply System Master Plan (SSMP) 20-yr planning window. Aggregate demand is the combined demand of both PWB retail and wholesale customers. This information is essential for developing scenarios as part of Task 9.

2.0 BACKGROUND

The 2000 Supply, Transmission, and Storage Analysis (STSA) evaluated and developed demand projections as part of the 2001 Infrastructure Master Plan (IMP) process. The STSA used demand data from the 1996 Regional Water Supply Plan (RWSP). Per the 1996 RWSP, the demand forecast was based on estimated "status quo" forecast of sales per customer class and application of conservation and price increase adjustments. Peak day demands were projected based on historical ratios of peak day to average day. Table 2-1 summarizes the projected demands for the "Existing Customers" (defined as the City of Portland and existing wholesale customers) from Appendix G of the STSA.

Table 2-1 2000 STSA Demand Projections

Metric	Projected Demand, Million Gallons per Day (MGD)			
	2000	2010	2020	2050
SAD – Summer average daily demand	157	167	182	246
PDD – Peak day demand	234	253	284	382

When compared to actual demand data from 1996-2016, PWB demands have seen a significant decrease compared to the 2001 IMP and 2000 STSA projections. Figure 1 demonstrates the trend of reduction in actual demand from 1996-2016. Aggregate demand is comparable to "Existing Customers" from the STSA. Table 2-2 quantifies the percent difference from projected demand in the STSA to actual demand, 1996-2016.

Figure 1 – Actual Aggregate Demand (1996-2016)

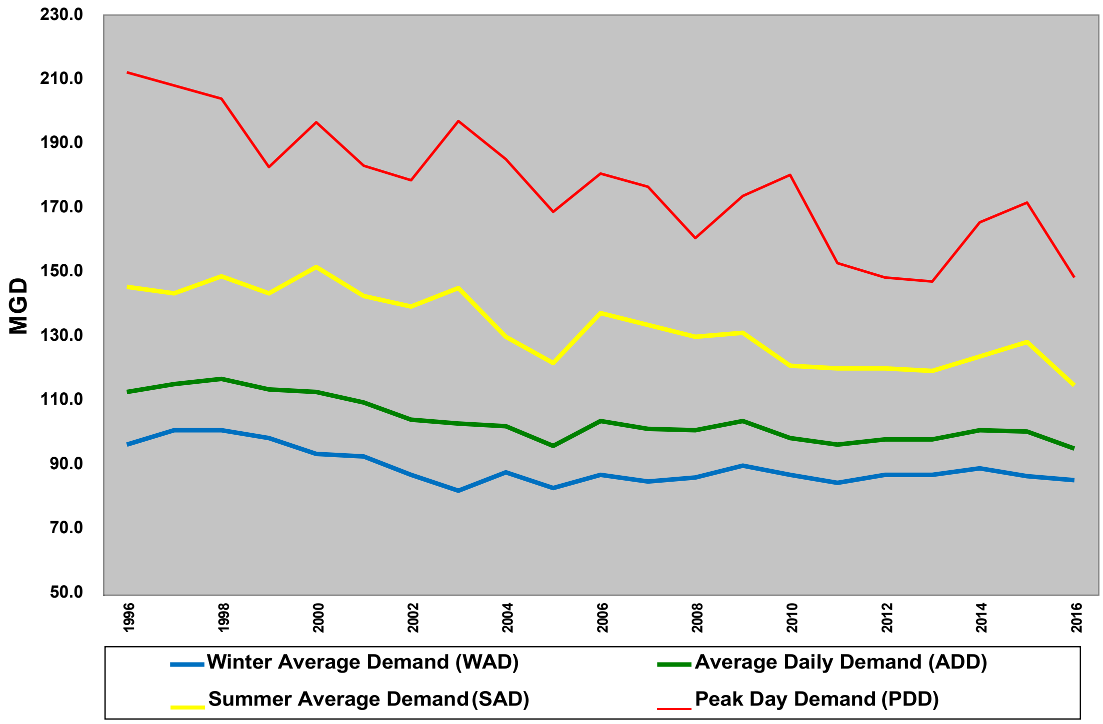


Table 2-2 2000 STSA Projection vs. Actual Demand Comparison

Metric	2000 Projected	2000 Actual	Difference	2010 Projected	2010 Actual	Difference
SAD	157	152	-4%	167	121	-27%
PDD	234	197	-16%	253	181	-28%

* Demands in MGD.

These declines occurred despite a 23% increase in population (770,910 to 951,518) and the addition of the City of Sandy as a wholesale customer (Sandy began drawing water from PWB in 2014). Factors influencing this change in demand include lower per capita use in the retail service area, the 2008-2010 economic recession, conservation, changes in land use patterns, and wholesale customer decisions, among others.

These significant differences between projected and actual demands challenged the relevancy of the planning performed as part of the 2001 IMP. New demand projections are needed for the SSMP to better inform supply decisions such as capacity, timing, and sizing of infrastructure.

3.0 Key Metrics For New Demand Projections

Five key metrics were identified to focus this memo on demand data most relevant to water system operation and infrastructure planning. These metrics are:

1. ADD - Average daily demand
2. SAD – Summer average demand (average daily demand during the peak season, June through September)
3. WAD – Winter average demand (average daily demand during the off-peak season, October through May)
4. PDD - Peak day demand
5. P3D - Peak 3-day demand

Average daily demand (ADD) is a useful measure for the amount of water to be provided in emergency conditions or if various key components of the water system are out of service. Summer average demand (SAD) is important for evaluating the adequacy of existing supply sources to meet summer demands and sizing new sources of supply if needed. Winter average demand (WAD) is useful for estimating the largest amount of water that might be needed from the wellfield, typically during a turbidity event. Peak demands (both peak day and peak 3-day) are important for sizing treatment and transmission systems to provide water during high heat weather, and to avoid short-term curtailment.

These demand metrics were reviewed against historical weather years to determine which demand weather year was the most stressful on the supply system for that metric. These years, known as "stress years", provide indicators for the water supply needed to provide for similar stressful weather years in the future. A "stress year" was not applied to WAD as there would likely not be significant variation from the average. See Appendix Section 4.1 for additional description of weather stress years. The stress years were defined, using the historical weather data from 1960 through 2015, as:

Metric	Historical Stress Weather Year
ADD - Average daily demand	1967
SAD – Summer average demand	1967
PDD - Peak day demand	1981
P3D - Peak 3-day demand	1981

Demands fluctuate from day to day based on the calendar date and whether or not a particular day falls on a weekend or particular holidays (water demand has historically been lower on weekends and some holidays than during the week). Daily demand also changes due to daily weather fluctuations. Since long-term daily weather forecasts are not available, two approaches are considered to reflect the effect of daily weather on future demand. One approach is to project demand under average historical weather conditions. This is similar to assuming that in the future, each day of the year has the same weather as the average weather of that day over the 1960-2015 period. The demand projections under this approach are the "weather normalized" demands. The other approach is to assume that the daily weather conditions of a particular historical "stress year" are repeated in the future. In this approach, the weather conditions of the "stress years" are used to reflect the effect of daily weather on the demand projections. These two approaches provide a comparison of projected demands based on average weather to demands based on a stress year.

4.0 DEMAND MODEL FACTORS

PWB used an econometric model[1], developed internally, to establish and estimate the relationship between water demand and socio-economic, demographic, weather, and other factors that affect aggregate demand by all customer classes served by PWB in the retail and wholesale areas. PWB considered the following factors known to affect water demand for the update to the aggregate demand model approach from previous iterations:

- Weather
- Population
- Land use
- Wholesale customer contracts and behavior
- Water conservation policies, programs and behaviors
- Price of water (revenue per million gallons from sales of retail and wholesale water is used as a proxy for price)
- Climate change

These factors are not fixed or static for the term of the SSMP. The degree to which they will change over the planning horizon can only be estimated based on information currently available. The methodologies, major assumptions, and data sources for these estimates are described in the Appendix. To represent these unknowns in the demand model results, PWB defined each factor, generally described as follows:

Weather: Weather is represented in the analysis both as the stress years described in Section 3.0, and as weather normalized (average) conditions for comparison.

Population and land use: Population in the Portland service area is projected to continue to increase. Population densities will increase as more land area is used for multi-family residential uses versus single family residential uses. These changes are already evident in the retail service area, for example, the Pearl District and close-in Northeast and Southeast Portland. Population for the aggregate service area is estimated at 952,521 for 2018 and rises

[1] An Econometric model uses application of statistical and mathematical theories in economics for establishing relationships between the variable of consideration and other variables that are known to affect it, called "explanatory variables". The model is used for testing hypotheses and forecasting future trends.

to 1,029,403 in 2025. When TVWD reduces demand on the system in 2026, population served declines to 905,123. By 2045, population served recovers to 1,035,326.

Wholesale customers: Aggregate demand incorporated the "most likely" wholesale demand described in Tech Memo 3.2. The most significant change being TVWD reducing wholesale purchases from PWB in 2026 (PWB supply to TVWD Wolf Creek offline - supply to Metzger remaining). Other considerations not part of the "most likely" scenario described in Tech Memo 3.2 may be considered later in the SSMP process, as part of scenario analysis.

Water conservation: Two water conservation scenarios were modeled, one that assumed a continuation of current trends and another that assumed more aggressive programs and technological change. The demands shown in Figures 2-6 incorporate the current trend scenario, which includes plumbing code changes since 1992; technology improvements in appliances, indoor fixtures and irrigation; and customer education and incentive programs. Results from the more aggressive conservation scenario may be considered later in the SSMP process, as part of scenario analysis.

Price: Price can affect customer water use behaviors and decisions to install water saving appliances and fixtures. The demand estimates incorporate a pattern of anticipated price increases over the planning horizon, starting at 7% and plateauing later at 3%. The price increase projections reduce demand in the later years as a result of the compounding effect of rate increases.

Climate change: The Pacific Northwest is expected to experience warmer conditions in the future, which is likely to affect water use especially during the summer season. PWB used five global climate models (GCM) downscaled to the Portland area to estimate the effect on future air temperatures and precipitation, which are key variables in the aggregate demand model. Of the five models evaluated, PWB selected the GCM with the largest effect on demand for the purposes of the demand estimate in this memo (similar to the stress year assumption used for weather). Climate change is projected to increase demands, with more impact on peak metrics such as PDD, P3D and SAD, and less impact on average metrics such as ADD and WAD (see appendix for percentage changes for each metric). Results from the other GCMs can be considered later in the SSMP process, as part of scenario analysis.

5.0 AGGREGATE DEMAND MODEL RESULTS

Model results are presented for the five key metrics, comparing weather normalized conditions with the stress year weather. Changes in wholesale customer usage plays a significant role in reducing demand[2]. Reduction by TVWD in 2026 is clearly evident, with the largest overall effect on anticipated future demand. The change in usage patterns by Rockwood and Gresham

[2] The guaranteed purchase quantity for wholesale customers may differ from actual demand. When making capacity and sizing decisions, need to account for and make sure can meet the guaranteed purchase quantity for all wholesale customers.

to address population growth with alternative (non-PWB) supplies also acts to maintain, vs increase, demand for those customers. In addition, continuing conservation, changes in land use, as well as anticipated price increases, have a negative impact on demands.

Population and climate change increase demand. However, these are not enough to counteract the factors causing reduced demand discussed above. When all factors are combined, the modeled projections of demand gently decline to 2026, with a steep drop in 2026, followed by a relatively flat curve with some increase from 2030-2040, and then a leveling off or gentle decline again after 2040. Overall, future demands are expected to be less than historical demand, and significantly lower than previous projections.

Figure 2 – Average Daily Demand (ADD)

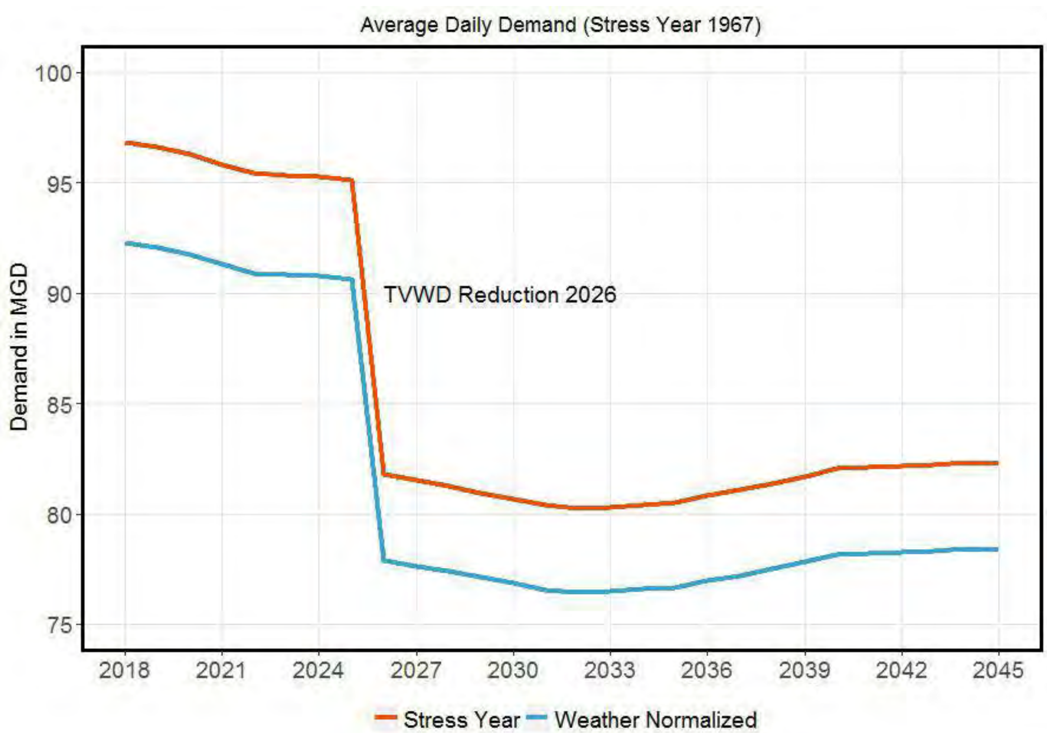


Figure 3 – Summer Average Demand (SAD)

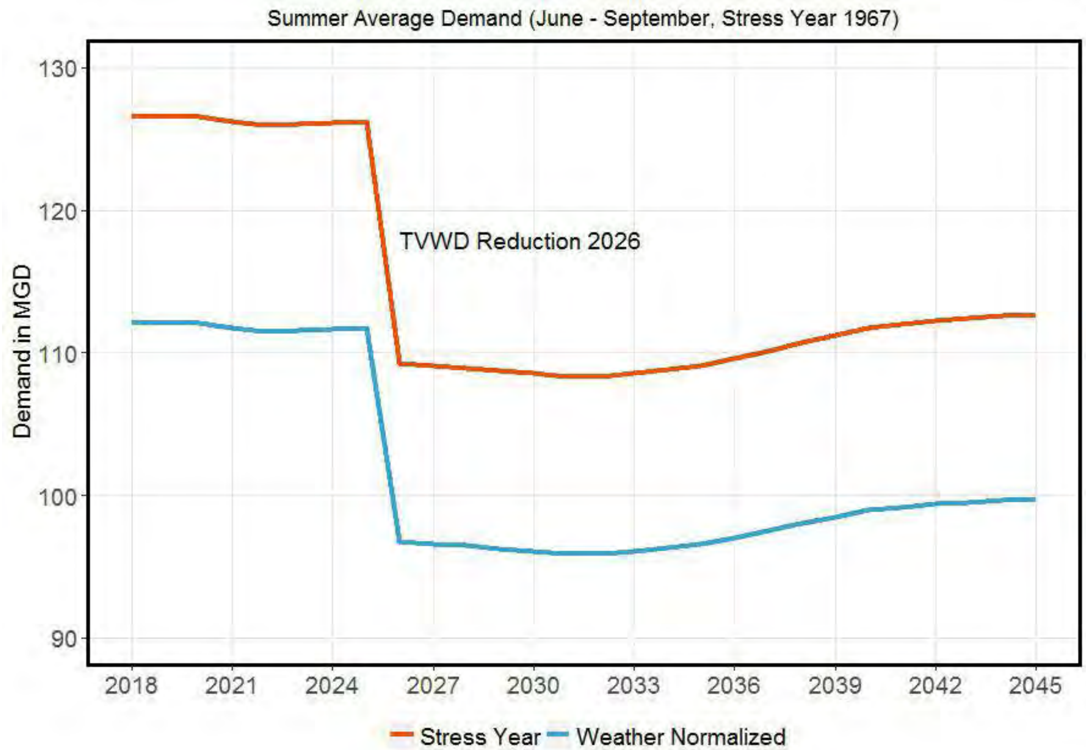


Figure 4 – Winter Average Daily Demand (WAD)

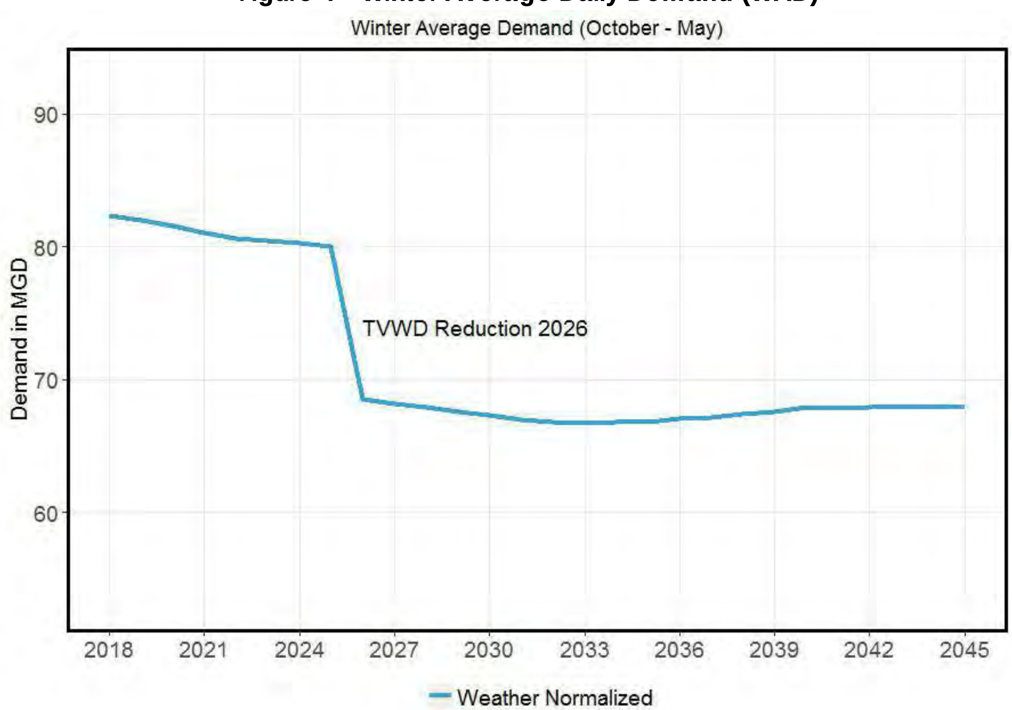


Figure 5 – Peak Day Demand (PDD)

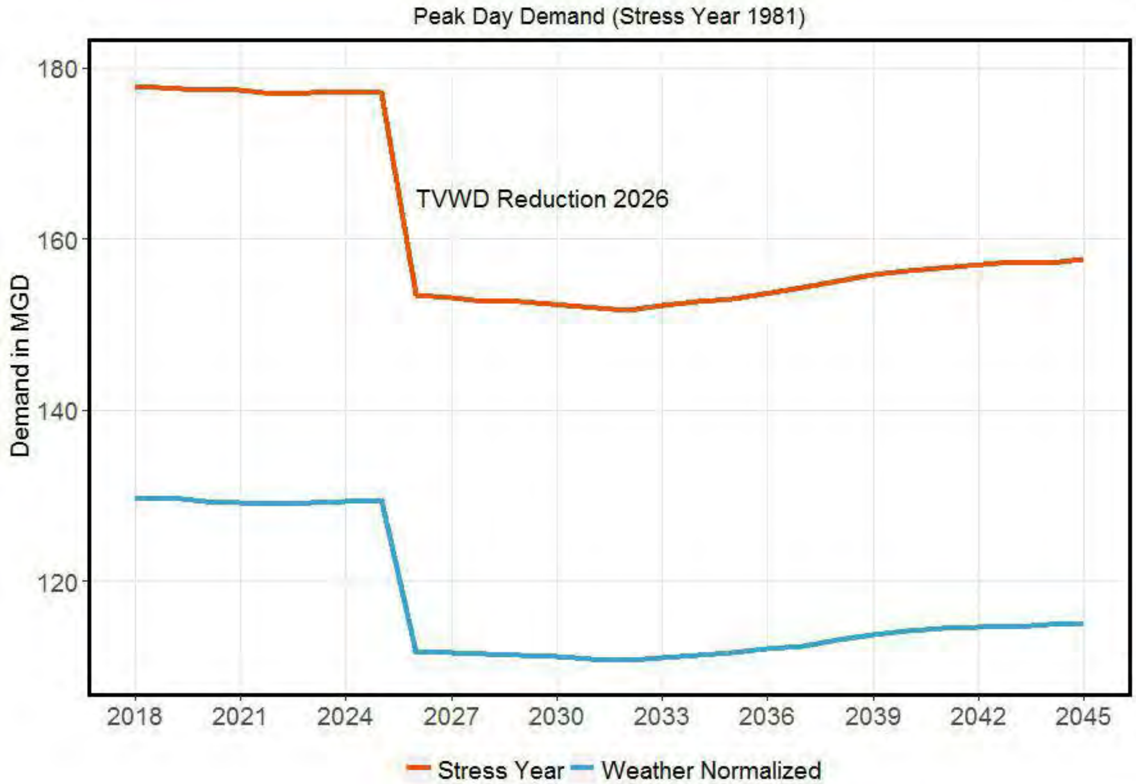
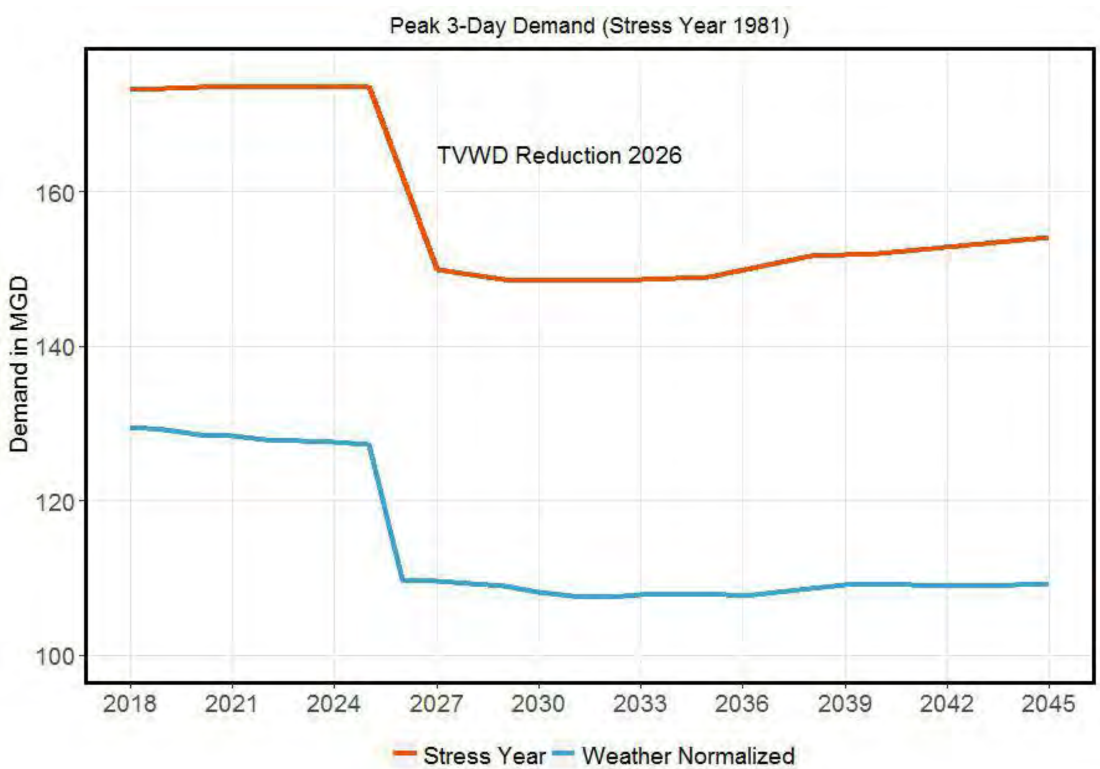


Figure 6 – Peak 3-Day Demand



Conclusion

As indicated in Figure 1, aggregate demand has been declining over the last 20 years. Each of the demand indicators show declines from the 1990s, despite an increase in population from approx. 770,000 to approx. 950,000. When future stress year demand projections are compared with projections from the 2000 STSA, the reduction in the overall demand is even more significant, with reduction of more than 50% in the out years, see Table6-1.

Table 6-1 Comparison of 2000 STSA Demand Projections vs 2017 Demand Projection

Metric	2020 Old	2020 New	Difference	2050 Old	2045 New	Difference
SAD	182	127	-30%	246	113	-54%
PDD	284	177	-38%	382	158	-59%

* Demands in MGD.

Factors that increase demand include population, and to a lesser degree climate change. Factors that decrease demand include wholesale customer decisions, densifying land use, conservation, retail customer behavior, and water prices. Of these dampening factors, wholesale customer decisions have the largest effect – namely the reduction in TVWD demand in 2026 creating steep declines for each demand indicator. After 2026, the net effect of these factors results in relatively flat trend forward from 2027 through 2045.

Overall, demand is projected to be lower in 2045 than today. Summer average demand is expected to decline from approx. 120 mgd in 2010 (actual) to approximately 110 mgd in 2045 (modeled, stress year weather). Average peak day demand is expected to decline from approx. 180 mgd in 2010 (actual) to approximately 155 mgd in 2045 (modeled, stress year weather). These declines in demand occur despite an increase in population served[3] from approx. 945,000 in 2010 (actual) to a modeled estimate of approx. 1,000,000 in 2045.

This new pattern in service area water demand, especially in contrast to projected demand from the STSA modeling work in 2000, will impact the timing, sizing and need for new supply infrastructure.

[3] Population served includes PWB retail service area as well as proportionate population of wholesale customers. For instance, not all of the population of the TVWD service area are included, as some are served by alternative TVWD supplies.

APPENDIX

Demand Model Methodology

Parandvash, Hossein, 2/2017

1.0 Structure and Content of the Demand Model

A regression model was used to estimate the relationship between daily aggregate demand and its major drivers like weather, population, and price. The estimated model along with population forecasts, price projections, and assumptions about future values of other variables were used to forecast daily aggregate demand for water for the 2018-2045period.

Various studies, Hannan (1963), Jorgenson (1964 and 1967), and Harvey and Shephard (1993) show that time series data can be decomposed into trend, seasonal, and irregular components. Chesnutt and McSpadden (1995) show that part of the daily water demand variations can also be decomposed into variables that describe weather effect.

A structural time series model is adopted to represent the demand for water by all customer classes. The general specification of the demand model is represented by **(1)**.

$$D = f(S, W, Pop, Pr, I, LT) \tag{1}$$

where D is daily demand by all customers in the service area, S and W represent seasonal and weather variables respectively, Pop represents the population served, Pr is the proxy for price of water, I represent indicator or dummy variables depicting weekends, holidays, conservation, and some data anomalies, and LT represent long-term trend variables. These variables are explained in more detail in the sections below.

1.1.Seasonal variables

There is a distinct bell-shaped seasonal pattern in daily demand for water in the Portland area. Demand during the winter months is very flat, it starts increasing mid-spring, peaks in June-September period, and declines mid-fall. Granger and Watson (1984) suggest the use of a series of 11 dummy variables to represent 11 months of the year to depict seasonal variations. In this approach the 12th month dummy is dropped to avoid singularity.

Hannan (1963), Jorgenson (1964 and 1967), Harvey and Shepard, (1993), and Dziegielewski and Opitz (2000) also recommend use of Fourier series terms as a continuous function of time to express these seasonal patterns. We consider this approach in this study. For daily demand data these variables can be constructed as

$$SS_{it} = \sin\left(\frac{2\pi it}{DIY}\right) \text{ and } SC_{it} = \cos\left(\frac{2\pi it}{DIY}\right) \tag{1}$$

where i is the number of cycles within each year, t is the day of the year, and DIY is the number of days in the year, i.e., 365 days for regular and 366 for leap years. For instance,

SS_1 and SC_1 (t subscript is dropped to avoid clutter) complete one full Sine and Cosine cycle and SS_2 and SC_2 complete two full cycles within a year.

1.2. Weather variables

Weather is an important driving factor in daily demand. Daily air temperature and precipitation determine the level of water use, especially during the peak season. Weather is obviously governed by a seasonal pattern, which is reflected in demand as well. Using air temperature and precipitation directly as explanatory variables would entangle the seasonal demand pattern with the daily effect of weather on demand.

To resolve such a problem, seasonal variations are removed from both daily air temperature and precipitation by auxiliary regression equations. Natural logarithm of the maximum daily temperature and daily precipitation are used as the dependent variables and the harmonic variables as the explanatory variables in the auxiliary regression models. The predictions of the auxiliary regression models depict the historical daily conditional means of air temperature and precipitation and the residuals show daily deviations from their respective conditional means. Daily precipitation, DP, is scaled to avoid taking the natural log of zero. Equations represented in **(3)** show how the seasonally adjusted contemporaneous daily precipitation values are generated.

$$
\begin{aligned}
&P = \ln(DP+1) \\
&P_t = \hat{\alpha} + \sum_{i=1}^{6} \hat{\beta}_i SS_i + \sum_{j=1}^{6} \hat{\gamma}_j SC_j + e_t \qquad \textbf{(2)} \\
&Pdl(0)_t = P_t - \left(\hat{\alpha} + \sum_{i=1}^{6} \hat{\beta}_i SS_i + \sum_{j=1}^{6} \hat{\gamma}_j SC_j \right)
\end{aligned}
$$

Similarly, the seasonally adjusted contemporaneous maximum daily temperatures are generated according to **(4)**.

$$
\begin{aligned}
&T = \ln(MT) \\
&T_t = \hat{\alpha} + \sum_{i=1}^{6} \hat{\beta}_i SS_i + \sum_{j=1}^{6} \hat{\gamma}_j SC_j + \varepsilon_t \qquad \textbf{(3)} \\
&Tdl(0)_t = T_t - \left(\hat{\alpha} + \sum_{i=1}^{6} \hat{\beta}_i SS_i + \sum_{j=1}^{6} \hat{\gamma}_j SC_j \right)
\end{aligned}
$$

where MT is the maximum daily temperature and $Pdl(0)_t$ and $Tdl(0)_t$ represent contemporaneous deviations from the conditional means, respectively.

Various lags of mean adjusted precipitation and temperature variables are used as explanatory variables in the demand model. These variables are also multiplied by low frequency harmonics and used as interaction variables to allow the model to have flexible coefficients for weather variables throughout the year. This allows the demand model to correctly reflect the effect of changes in precipitation and temperature on demand when they matter, that is, more impact during the peak season and less in winter. In addition, the number of consecutive days without precipitation adjusted for conditional mean is included to reflect the impact of dry spells on demand. This variable is also multiplied by low frequency harmonics, used as interaction variables, to allow for flexible coefficients.

1.3.Indicator variables

There are variations in daily demand, which are not associated with seasonal, weather, economic, or demographic factors. For instance, depending on the customer composition of the service area, demand might drop or rise on weekends and holidays. Usually, one would see a drop in weekend demand when water consumption by nonresidential customer classes comprise a considerable part of the overall demand. This is due to the fact that most public and private work places, schools, and institutions are closed on weekends and holidays and therefore do not use as much water as they do during weekdays.

These variations are represented by indicator or dummy variables in the demand model. Weekend dummy variable takes the value of one (1) for Saturday and Sunday and zero (0) for the rest of the week. Weekend variable is also interacted with the low frequency harmonics to allow seasonal flexibility for the coefficients. Holidays are represented by a series of dummy variables that take the value of one (1) on the days of observance and zero (0) otherwise. Short-term data anomalies as a result of meter malfunction with known periods of occurrences are also handled by a set of daily or monthly dummy variables.

1.4.Demographic, economic, and trend variables

Total demand for water is affected by a variety of demographic and economic factors. Overall, factors that could cause a downward trend in total demand are increases in water and sewer rates, 1992 plumbing fixture code changes for new homes, change in the conservation attitude of customers, impact of conservation programs, changes in land-use, and slowdown in the economy. Positive growth in population, the economy, and income could cause increases in total demand over time. Population and a proxy for the price of water are used to represent demographic and economic factors that could contribute to long-term trend.

Other factors that affect long-term trend are depicted by low frequency harmonics. These variables are generated in a fashion similar to the seasonal variables; however, their phase of oscillation occurs over the period of the data used in the demand model for estimation of the coefficients. The variables are generated as

$$LTS_{it} = \sin\left(\frac{2\pi it}{DD}\right) \text{ and } LTC_{it} = \cos\left(\frac{2\pi it}{DD}\right) \qquad \textbf{(4)}$$

where ***i*** is the number of cycles within the data period, ***t*** is the day number in the data period, and *DD* is the total number of days in the data used in the demand model.

1.5.Functional form

A linear functional form is used to explain the variations in daily demand in terms of the explanatory variables discussed above. Equation **(6)** shows the compact representation of the functional form.

$$\ln(D) = \alpha + \beta S + \gamma W + \delta \ln(Pop) + \varepsilon \ln(Pr) + \theta I + \omega LT + u \qquad \textbf{(6)}$$

where *D* is daily demand in millions of gallons. *S* and *W* are Seasonal and Weather variables as explained in the above. *Pop* and *Pr* are population served and price respectively. *I* are indicator variables representing various factors that affect demand such as weekends, holidays, etc. *LT* are the long-term trend variables that explain effect of factors such as land-use, conservation, and changes in the demand attitude that are not captured by the implicit variables in the model. *a* , *b*, *g*, *d*, *e*, *q*, and *w* are the unknown coefficient vectors to be estimated and *u* is the error term with Gaussian properties.

2.0 THE DATA

Daily production data at Headworks are available from the Supervisory Control and Data Acquisition (SCADA) systems. Production data measure the amount of water supplied to all retail customer classes and wholesale customers plus the unbilled and unaccounted-for water in millions of gallons per day. The daily production data are available since 1960. Data for the 1980-2015 period were used for the estimation of the demand model. The accuracy of the production data is more reliable for this period and the trend in demand is more in line with the changes in demand as a result of conservation and land-use.

The historical population for the retail service area and the service areas of the wholesale customers have been provided by the Population Research Center (PRC) at Portland State University. The population numbers for the wholesale service areas have been adjusted for the water that the wholesale customers obtain from sources other than the PWB.

Since aggregate demand covers all retail and wholesale customers, there are no single rates or rate structures that can be used in the demand model. Instead, annual revenue per million gallons, adjusted for inflation, is used as a proxy for price. The coefficient of the price variable measures the price elasticity of demand, which is the degree of response to price changes by all customers.

Total daily precipitation and maximum daily temperature, measured at the Portland Airport weather station, are available since 1940, by Oregon Climate Service. The weather data are used to generate the explanatory weather variables, which are used in the demand model.

3.0 REGRESSION RESULTS

Results of the regression model estimation are presented in Table 1, where the explanatory variables are defined as:

S(i) and C(i) are seasonal variable of different sine and cosine frequencies, D_WKND is the dummy variable for weekends,

D_NYD, D_MEMD, D_JUL4, D_LBD, D_VETD, D_TG, and D_XMAS are dummy variables for New Year, Memorial, Independence, Labor, Veterans, Thanksgiving, and Christmas days respectively,

NPD is the number of consecutive days without rain,

P_DL(i) are daily precipitation variables with different lags,

T_DL(i) are maximum daily temperature variables with different lags,

Pop is the retail and wholesale population served by PWB sources.

Pr is the annual revenue per million gallons.

D_ECii are annual dummy variables representing changes in demand that could be attributed to the economy, land-use, or other factors that impact demand that are not presented by specific variables.

D_CONS92 is a dummy variable representing the 1992 building code changes of water fixtures.

D_Y92(Jul, Aug, Sep) are dummy variables depicting the reduction in demand as a results 1992 mandatory curtailment.

D_WIN07 is a dummy variable representing the data anomaly in winter of 2007.

C(i)_jj12 and S(i)_jj12 are the long-term cyclical trend sine and cosine wave variables over the 1993-2012 period for PWB retail and 1983-2012 period for Wolf Creek depicting impact of the economy, rates, conservation, land use, etc.,

C is the constant term, and

AR(i) are the error correction terms for autocorrelation.

The model shows a strong relationship between daily demand and the explanatory variables. The adjusted R^2 is 0.89, which is rather high for daily demand data. Initial run of the model demonstrated autocorrelation among the error terms. First order AR was added for error correction. The AR term is significant and the Durbin-Watson statistics shows that the autocorrelation problem is resolved. Moreover, all coefficients have proper signs.

Table 1. Aggregate demand regression model.

Dependent Variable: Daily Aggregate Demand														
Variable	**Coeff.**	**Std. Error**	**t-Statistic**	**Prob.**	**Variable**	**Coeff.**	**Std. Error**	**t-Statistic**	**Prob.**	**Variable**	**Coeff.**	**Std. Error**	**t-Statistic**	**Prob.**
S1	-0.0990	0.0021	-47.7712	0.0000	T_DL3*C1	-0.0587	0.0112	-5.2226	0.0000	P_DL4*S2	-0.0137	0.0078	-1.7524	0.0797
C1	-0.1998	0.0020	-100.1644	0.0000	T_DL4	0.0340	0.0082	4.1515	0.0000	P_DL5	-0.0322	0.0047	-6.8875	0.0000
S2	0.0871	0.0019	46.1455	0.0000	T_DL4*C1	-0.0567	0.0113	-5.0178	0.0000	P_DL5*C1	0.0365	0.0064	5.7326	0.0000
C2	0.0562	0.0019	29.7888	0.0000	T_DL4*C2	-0.0243	0.0112	-2.1613	0.0307	P_DL6	-0.0303	0.0049	-6.1529	0.0000
S3	-0.0264	0.0019	-14.2137	0.0000	T_DL6	0.0284	0.0079	3.6010	0.0003	P_DL6*C1	0.0341	0.0067	5.1053	0.0000
S4	0.0058	0.0019	3.0550	0.0023	T_DL6*C1	-0.0551	0.0103	-5.3258	0.0000	P_DL6*C2	-0.0032	0.0061	-0.5131	0.6079
C5	0.0063	0.0018	3.4354	0.0006	T_DL6*S1	-0.0349	0.0113	-3.0787	0.0021	LOG(POP)	1.0385	0.0637	16.2975	0.0000
C6	-0.0078	0.0019	-4.2340	0.0000	T_DL6*C2	-0.0076	0.0109	-0.6907	0.4898	LOG(Pr)	-0.1812	0.0568	-3.1885	0.0014
D_WKND	-0.0312	0.0016	-19.4976	0.0000	P_DL0	-0.0380	0.0059	-6.4700	0.0000	D_CONS92	-0.0532	0.0104	-5.0908	0.0000
D_WKND*C1	0.0043	0.0023	1.9001	0.0574	P_DL0*C1	0.0425	0.0077	5.5046	0.0000	D_Y92JUL	-0.2611	0.0187	-13.9538	0.0000
D_WKND*S1	0.0019	0.0023	0.8255	0.4091	P_DL0*S1	0.0290	0.0082	3.5449	0.0004	D_Y92AUG	-0.3143	0.0432	-7.2720	0.0000
D_NYD	-0.0150	0.0133	-1.1308	0.2582	P_DL0*C2	-0.0183	0.0071	-2.5685	0.0102	D_Y92SEP	-0.1924	0.0362	-5.3129	0.0000
D_MEMD	0.0009	0.0113	0.0832	0.9337	P_DL0*S2	-0.0209	0.0075	-2.8021	0.0051	D_WIN07	-0.1112	0.0181	-6.1321	0.0000
D_JUL4	-0.0381	0.0112	-3.3969	0.0007	P_DL1	-0.0623	0.0056	-11.1573	0.0000	D_EC01	-0.0604	0.0137	-4.4129	0.0000
D_LBD	0.0182	0.0128	1.4236	0.1546	P_DL1*C1	0.1014	0.0074	13.6217	0.0000	D_EC02	-0.0591	0.0160	-3.6952	0.0002
D_VETD	0.0200	0.0178	1.1192	0.2631	P_DL1*S1	0.0568	0.0081	7.0160	0.0000	D_EC03	-0.0618	0.0197	-3.1419	0.0017
D_TG	-0.0314	0.0097	-3.2538	0.0011	P_DL1*C2	-0.0328	0.0073	-4.4872	0.0000	D_EC04	-0.0605	0.0220	-2.7494	0.0060
D_XMAS	-0.0383	0.0082	-4.6884	0.0000	P_DL1*S2	-0.0433	0.0074	-5.8825	0.0000	D_EC05	-0.0585	0.0236	-2.4795	0.0132
NPD_R	0.0025	0.0004	6.3859	0.0000	P_DL2	-0.0464	0.0064	-7.2999	0.0000	D_EC06	-0.1212	0.0236	-5.1425	0.0000
NPD_R*C1	-0.0005	0.0004	-1.0848	0.2780	P_DL2*C1	0.0842	0.0086	9.7675	0.0000	D_EC07	-0.1264	0.0313	-4.0429	0.0001
NPD_R*S1	0.0011	0.0004	2.5144	0.0119	P_DL2*S1	0.0443	0.0087	5.0665	0.0000	D_EC08	-0.1755	0.0345	-5.0807	0.0000
T_DL0	0.2033	0.0082	24.8048	0.0000	P_DL2*C2	-0.0303	0.0076	-3.9741	0.0001	D_EC09	-0.1660	0.0444	-3.7413	0.0002
T_DL0*C1	-0.2733	0.0108	-25.3476	0.0000	P_DL2*S2	-0.0386	0.0083	-4.6627	0.0000	D_EC10	-0.2127	0.0494	-4.3048	0.0000
T_DL0*S1	-0.0566	0.0120	-4.7258	0.0000	P_DL3	-0.0406	0.0059	-6.8404	0.0000	D_EC11	-0.2480	0.0549	-4.5186	0.0000
T_DL0*C2	0.0616	0.0106	5.8119	0.0000	P_DL3*C1	0.0620	0.0073	8.4601	0.0000	D_EC12	-0.2474	0.0590	-4.1945	0.0000
T_DL0*S2	0.0408	0.0109	3.7325	0.0002	P_DL3*S1	0.0321	0.0089	3.6153	0.0003	D_EC13	-0.2709	0.0586	-4.6239	0.0000
T_DL1	0.1172	0.0082	14.3770	0.0000	P_DL3*C2	-0.0109	0.0072	-1.5072	0.1318	D_EC14	-0.2725	0.0615	-4.4314	0.0000
T_DL1*C1	-0.1636	0.0107	-15.3511	0.0000	P_DL3*S2	-0.0265	0.0084	-3.1549	0.0016	D_EC15	-0.3123	0.0647	-4.8248	0.0000
T_DL1*S1	-0.0710	0.0121	-5.8815	0.0000	P_DL4	-0.0395	0.0060	-6.5692	0.0000	C1_8015	0.0397	0.0114	3.4673	0.0005
T_DL1*S2	0.0261	0.0106	2.4600	0.0139	P_DL4*C1	0.0580	0.0077	7.4892	0.0000	S1_8015	0.0678	0.0076	8.9408	0.0000
T_DL2	0.0590	0.0082	7.1883	0.0000	P_DL4*S1	0.0349	0.0079	4.4072	0.0000	C	-8.0572	0.9152	-8.8035	0.0000
T_DL2*C1	-0.0889	0.0113	-7.8333	0.0000	P_DL4*C2	-0.0190	0.0068	-2.7887	0.0053	AR(1)	0.4611	0.0048	95.5649	0.0000

R-squared	0.8885	Mean dependent var	4.6748	Independent variables = 94
				Seasonal = 7
				Weather = 52
				Weekend and holidays = 10
				Economy and trend = 17
Prob(F-statistic)	0.0000			

The population coefficient is 1.03, which indicates that a 1% increase in population results in a little bit more than 1% increase in daily demand for water. Long-term trend, conservation, and economy variables capture the impact of conservation, land-use, and other factors that result in the downward trend in demand. Coefficient of price has the negative sign and estimates a price elasticity of 0.18 that indicates 1.8% drop in demand as a result of a 10% increase in price. The dummy variable representing weekends, along with its interactions with the harmonics, show percent drop in demand that is higher during the peak season. Holiday dummy variables for New Year, Independence, Thanksgiving, and Christmas Days are all negative and statistically significant. Dummy variables for the Memorial, Labor, and Veterans Days are positive but statistically notsignificant.

Coefficients of the seasonal variables are all significant and depict the seasonal variations in the daily demand. The weather variables, although all significant, have different levels of influence on demand. In general, model results indicate that temperature has a higher effect on daily demand than precipitation. As expected, the weather variables that are interacted with the harmonics make the effect of unseasonable rain and temperature less pronounced.

3.1.Decomposition of the effects

One of the features of the model is that the variations in demand can be decomposed into the effects of different variables. For instance, the linear combination of all seasonal variables, as estimated by the demand equation, shows the seasonal variations in demand. By adding the linear combination of the weather variables to that of seasonal, the peaking behavior can be demonstrated. The antilog of the linear combination of all variables except for the weather variables, gives us the weather-normalized demand with seasonal variation. For simulation purposes also, weather effect from any weather year can be added to the weather normalized demand of any specific year. This would make it possible to simulate demand for a specific year with a historical sample of weather effects and explore demand under the best and worst case weather conditions.

4.0 FORECASTING

In order to use the demand model as a forecasting tool, data on the future values of the explanatory variables are required. The seasonal and weekend variables are predetermined. Some of the indicator variables like conservation can be judgmentally determined as to what value they should take in the future. One can also decide about the effect of the long-term cyclical trend variables. However, the model needs future values of population and price for weather-normalized demand forecasts. Effect of any ongoing or future conservation and land-use need to be determined ex-post and outside of the demand model. For this the Residential End Use demand model, discussed in the “Conservation and land-use impact” section 4.4 below is used, which only applies to the retail service area demand.

The forecast horizon for the Supply System Master Plan (SSMP) is 20 years, but these demand projections cover the period 2018-2045. The population forecasts provided by PRC are used to project future demand. The wholesale populations are adjusted for seasonal offloads and the assumptions regarding the future wholesale contracts (see Tech Memo 3.2). Annual rates of increase in price, provided by Finance group, are used to project price over the forecast horizon. The projected annual rates of increase in price proxy (revenue per millions of gallons sold to retail and wholesale customers adjusted for inflation) are: 7% over 2017-2021, 5% over 2022-2031, and 3% over 2031-2045.

4.1. Demand under historical weather

In order to identify the years that weather driven demand causes stress on the supply system, aggregate demand under historical weather patterns are simulated. The weather variables of the demand model estimate the variation in demand on each day of the historical weather years during the 1940-2015 period. The daily weather effects are applied to the 2017 weather-normalized demand forecasts to simulate demand under 1940-2015 weather conditions. Various demand metrics such as peak day and peak 3-day, peak season average day, annual average day, and average day off-season demands are computed to determine which demand weather years are the most stressful on the supply system. The simulations show that 1981 peak day and peak 3-day demand and 1967 peak season average day and annual average day demand are the most stressful on the system.

4.2. Forecast Evaluation

The usual statistics that result from running the regression equation normally report the fit of the model and how significant the coefficients of the explanatory variables are. However, to evaluate the quality of forecast we need to compute different types of statistics. The one that is used in this study is Mean Absolute Percentage Error (MAPE) of the forecast. The advantage of this statistic is that it is scale-indifferent and easy to explain. It is defined as

$$MAPE = \frac{1}{N}\sum_{t=1}^{N}\left|\frac{\hat{D}_t - D_t}{D_t}\right|$$

where $\hat{D}$ and D are Forecast and Actual demands respectively and $t = 1, \ldots, N$ is the forecast period.

MAPE for daily forecast over the 1980-2015 period is 6.3%. The accuracy is increased when MAPE is computed for monthly and annual average demand. Over the same period, MAPE computed for monthly and annual average are 3.5% and 1.2% respectively. Daily variations in demand are mainly determined by the weather, therefore, any daily demand behavior that is not weather related adds to the inaccuracy of the forecast. For instance, some wholesale customers start filling their reservoirs in advance when they predict hot days ahead. These types of reservoir operations lower the sensitivity of demand and the demand model to daily weather variations.

4.3. Climate impact

PWB used five global climate models (GCMs) downscaled by the University of Idaho (UI) for the Portland area as input data for the demand model. These five models were rated highly by UI for representing weather conditions in the Pacific Northwest. These models were used to recreate 30 years of historical air temperatures and precipitation, and to estimate 30 years of future air temperature and precipitation. The data set from each GCM was used to generate demand projections specific to that GCM.

The demand model coefficients along with climate predictions of 5 GCMs were used to estimate the long-term climate impact on demand over 1950-2005 and 2016-2045 periods. First, the auxiliary regression equations were used to establish the conditional mean for temperature, precipitation, and number of consecutive days without precipitation. The simulated historical climate, as projected by each GCM, was used for the 1950-2005 period. Then, the same set of weather variables was generated based on the simulated historical climate projections and their conditional means. Next, weather coefficients were applied to weather variables to estimate the daily weather effect on demand based on the simulated historical climate projections. In the next step, simulated future climate projections were used to generate the same set of weather variables for the 2016-2045 period. However, these variables are in terms of deviations from the conditional means established for the simulated historical projections. Applying the weather coefficients to these variables estimates the weather effect under the changed climate projections relative to the simulated historical projections for each GCM. Climate projections of each GCM for the two periods are applied to 2017 weather-normalized demand forecasts. Then, averages of the various demand metrics were computed for the two periods. The differences between the two sets of demand metrics over the 1950-2005 and 2016-2045 periods measure the long-term change in demand due to climate change according to each GCM over the two periods. Comparing the demand metrics allows us to choose the GCMs that lead to demand conditions that put the most stress on the supply system.

The percent difference between the historical period and the future period was then used to estimate the effect of climate change on demand for each GCM and each metric. Of the five GCMs, the GCM with the largest effect on the metric was used to define the percent change for that metric for the results presented in this memo. Calculated percent changes were as follows for aggregate demand (retail and wholesale) are shown in Table 2.

Table 2. Calculated GCM percent changes for aggregate demand.

	HadGEM2-ES	GFDL-ESM2M	CanESM2	CSIRO-Mk3-6-0	CNRMCM5	Maximum Effect
ADD	2.80%	2.07%	2.83%	2.17%	1.76%	2.83%
SAD	5.70%	4.66%	6.17%	4.87%	3.68%	6.17%
WAD	0.79%	0.23%	0.51%	0.25%	0.39%	0.79%

	HadGEM2-ES	GFDL-ESM2M	CanESM2	CSIRO-Mk3-6-0	CNRMCM5	Maximum Effect
PDD	3.16%	5.30%	5.13%	3.94%	1.51%	5.30%
P3D	3.67%	5.04%	5.07%	4.08%	1.85%	5.07%

Climate change is anticipated to have an increasing effect on air temperature and precipitation over time. The rate and pattern of change during the SSMP planning horizon is not yet known, and year to year variability is still expected to occur. As a simplifying assumption, PWB applied the percent change as follows: the effect at year one, 2018, was defined as zero and the effect at 2045 was defined as 100 percent of the calculated percent difference. The effect is then gradually increased, in a linear progression, from 0 to 100 percent. So, if the percent change for peak season daily demand (historical compared to future) was 6 percent, then the climate effect on demand in 2018 was zero and in 2045 was 6percent.

It is important to note that this procedure assumes that no aggressive adaptation action to reduce water use in response to climate change (in addition to current water efficiency trends) occurs over time. In that respect, the climate impact projections on demand could represent an over-estimate of demand response under each GCM projection. It is not known, however, if actual changes in air temperature and precipitation will be similar to, less than, or maybe even greater than the GCMs selected for thisanalysis.

4.4.Conservation and land-use impact

Downward trend in demand could be attributed to passive and programmatic conservation, changes in land-use and increases in price of water and sewer. The impact of price of water is estimated in the demand model directly and is reflected in the demand forecasts. The impact of conservation and land-use, however, are not directly estimated in the demand model, and therefore not projected into the future.

A residential end-use model was developed recently by Aquacraft based on the Water Research Foundation study 4309b, Residential End Use of Water, Version 2 (2016). The model can be used to forecast single and multifamily residential demand. It has parameters on water savings of various water fixtures and appliances and customer behaviors that are used in the embedded mathematical equations to adjust demand. The parameters of the model are based on the national survey and the estimated mathematical equations are based on the national data collected for the study. The parameters were developed for both single and multifamily residential customers. The model can be used to forecast residential demand under various conservation scenarios. PWB has purchased the model for the purpose of estimating future water savings that come as a result of passive and programmatic conservation and changes in land-use.

Aquacraft used the available information from PWB and augmented itwith information from Tacoma, which was part of the WRF study, in order to fit the model for PWB's demand forecasting purposes. Tacoma was deemed to be the closest surrogate for the PWB service area among the utilities that participated in the WRF 4309bstudy.

Historical PWB billing data are used to calibrate the parameters of the model. The calibration process is to change the parameters so that the model can generate single and multifamily demand levels that are close to the actual. The calibrated parameters are used to initialize the model for demand forecast. The residential end use demand model allows changes to the parameters over the forecast horizon based on assumptions made about the future changes in technology, land-use, and conservation behavior of the customers. The difference between the baseline forecasts with no changes in the initial parameters and the forecasts with parameters changed based on conservation assumptions, estimates the future savings by the residential classes in the PWB retail service area. Moreover, baseline demand forecasts with no new multifamily development compared with the demand forecasts that incorporate new multifamily development forecasts by the PRC, estimates the impact of changes in land-use on demand.

Two conservation scenarios based on the best guesstimates and conjectures by the Water Efficiency group were considered. Scenario 1 is in line with the recent trends in demand and mainly shows the continued impact of passive conservation and 1992 building code changes. Scenario 2 assumes more aggressive water efficiency programs, more inclination to save water on the part of customers, and smaller and more water efficient landscapes. The estimated savings from changes in land-use, pertaining to retail service area new multifamily development, and conservation Scenarios 1 and 2, are used to adjust the aggregate demand forecasts projected by the econometric demand model.

References

Hannan, E.J., 1963. The estimation of seasonal variation in economic time series. J. Am. Stat. Assoc. 58, 31–44.

Jorgenson, D.W., 1964. Minimum variance, linear, unbiased seasonal adjustment of economic time series. J. Am. Stat. Assoc. 59, 681–724.

Jorgenson, D.W., 1967. Seasonal adjustment of data for econometric analysis. J. Am. Stat. Assoc. 62, 137–140.

A.C. Harvey, N. Shephard, Structural time series models, in: G.S. Maddala, C.R. Rao, H.D. Vinod (Eds.), Handbook of Statistics, vol. 11, 1993, pp. 261–302.

Chesnutt, T.W., McSpadden, C.N., 1995. Determinant of Phoenix Water Demand. A&T Technical Services, Inc., Santa Monica, CA.

Granger, C.W.J., Watson, M.W., 1984. Time series and spectral methods in econometrics. In: Griliches, Zvi, Intriligator, Michael D. (Eds.), Handbook of Econometrics, vol. II. North Holland and Elsevier Science, New York, pp. 980–1022.

B. Dziegielewski, E. Opitz, Water Demand Analysis, in: L.W. Mays (Ed.), Urban Water Supply Handbook, 2002, pp. 5.3–5.55.

DeOreo, W.B., Mayer, P.W., Dziegielewski, B. and Kiefer, J.C., 2016. Residential End Uses of Water, Version 2. Denver, Colo.: Water Research Foundation.

Appendix B. Characterization of Supplies for Selection of Filtration Capacity

To: Executive Committee

From: Christopher Bowker

CC: Yone Akagi, Terry Black, Michelle Cheek, Kimberly Gupta, Jodie Inman, Jonathan Johnson, David Peters, Tony Re, Mike Saling, Janet Senior, Rich Seright

Date: April 9, 2018

Re: Characterization of Supplies for Selection of Filtration Capacity

EXISTING SUPPLY USES

The purpose of this memo is to characterize the anticipated role of groundwater in the future as filtration of the Bull Run is implemented. The Bull Run is the primary source of water for the City of Portland (City). The Watershed Program programmatic service level (PSL) 1 identifies the Bull Run as a primary source and states that the Bull Run watershed is expected to provide 95% or more of the City's annual water supply. When additional supply has been needed, the Columbia South Shore Well Field (CSSWF) has been used as a secondary supply to meet those demands. The groundwater supply is used under the following conditions.

- Summer supply augmentation – Groundwater is used to augment the Bull Run supply when the Bull Run water supply is insufficient to meet the combined drinking water and regulated fish flow demands of the summer season. Between 1985 and 2016, groundwater has been used fifteen times for supply augmentation, most notably in 1987 (5.3 BG) and 2015 (5.8 BG).

- Turbidity – Groundwater is used to blend with or replace, the Bull Run supply when turbidity levels increase in the Bull Run supply beyond levels allowed by regulations. Between 1985 and 2016, groundwater has been used ten times due to turbidity - eight times as a replacement and two times to blend with the Bull Run supply.

- Augmentation during maintenance or repairs on the Bull Run supply – Groundwater can be used during times when the Bull Run supply system is either down or operating at limited capacity due to maintenance (planned or unplanned). This includes events such as July 2014 when one of the conduits had to be shut down for emergency repairs during a high demand period.

- System readiness – Since 2008, Operations has completed annual maintenance runs of the groundwater system. The purpose of the maintenance runs is to exercise wells, booster pumps, and the treatment system, as well as to maintain operator training. This approach increases system readiness by identifying equipment problems and repairing them prior to an unplanned need or emergency. Routine maintenance runs also enhance staff training and readiness.

- Emergency – Groundwater will also serve as a backup supply during catastrophic events that affect Bull Run such as severe or extended drought, fire in the watershed, flood, landslide, volcanic activity, or earthquake. Groundwater has been used once in this capacity in 1995 when a landslide damaged the conduits and required the Bull Run supply to be shut down. The Eagle Creek fire and elevated *Cryptosporidium* levels are additional examples of events that could require shutdown of the Bull Run supply, either due to danger to staff operating Headworks or due to water quality impacts in the water supply drainage.

FUTURE SUPPLY USES

After meeting with the Executive Committee and after discussing the subject further at the Filtration Education Workshop, it is the team's understanding that groundwater will continue to be used as it has been used in the past. The Bull Run will continue to be the primary source of water for the City. Groundwater will continue to be used as a supplemental source for the situations described above.

With the addition of filtration, the Bull Run supply will be managed and designed to meet at least average summer season demands in the future. Filtration is expected to reduce Bull Run system shutdowns due to turbidity. Design of the filtration facility, and particularly pretreatment, will determine the degree to which turbidity is no longer a factor in future groundwater operation. Otherwise, groundwater will continue to be used as it has been in the past. The Bureau will not size the Bull Run filtration facility in such a manner that would require routine annual use of groundwater to meet average summer season demands.

Specific decisions regarding usage of groundwater to augment summer supply would continue to be made as part of implementing the Summer Supply Plan, which provides a comprehensive strategy for augmenting PWB's baseline water resources, if needed, during the peak demand season.

Appendix C. Cost Curves for Granular Media Filtration

Draft: Cost Curves for Granular Media Filtration

PREPARED FOR:	Dave Peters, Portland Water Bureau Michelle Cheek, Portland Water Bureau
COPY TO:	HDR, Barney & Worth
PREPARED BY:	Lee Odell Enoch Nicholson
DATE:	April 11, 2018
PROJECT NUMBER:	699275.01.03
REVIEWED BY:	Bob Chapman
APPROVED BY:	Kelly Irving

Summary Information

Cost estimates and evaluation criteria metrics are presented in Table 1 for granular media direct filtration for water treatment plant (WTP) capacities of 115, 145, and 160 million gallons per day (mgd).

Values provided are for a typical granular media direct filtration WTP and do not represent data or cost of a facility for the Bull Run Supply. The information in this technical memorandum is solely for comparative purposes. Any resemblance to actual conditions is simply coincidental. They do not include soft costs such as engineering, construction management, permitting etc.

Table 1. Granular Media Direct Filtration Costs and Measures for Water Treatment Plant

	Capacity		
Item	**115 mgd**	**145 mgd**	**160 mgd**
Construction cost	$215,600,000	$253,940,000	$275,720,000
Annual operations and maintenance	$9,827,000	$11,664,000	$12,598,000
25-year life-cycle cost	$402,823,000	$476,259,000	$515,847,000
Cost per CCF delivered*	$0.44	$0.52	$0.56
Electrical usage (megawatt-hours per year)	10,024	12,370	13,677
Residuals (cubic yards per year)	3,628	3,628	3,628
Truck trips during construction	97,133	115,976	122,806
Truck trips per year	682	741	781
Fuel consumption (gallons during construction)	218,276	260,620	275,969
Fuel consumption (gallons per year)	3,831	4,163	4,388
Chemicals (dry tons per year)	6,946	7,808	8,238

*CCF is hundred cubic feet. Includes construction costs and annual operations and maintenance costs.

Introduction

The cost estimating guidance presented in this technical memorandum (TM) was developed by an Excel-based conceptual parametric estimating system (CPES). This guidance supports development of a Class 5 cost estimate, as defined by the Association for the Advancement of Cost Engineering International (see Attachment A for more information). Class 5 cost estimate is provided with very little project definition (0-2%) and is used for concept screening. Refer to the attachment for more information on costs estimate classes.

Granular media filtration was selected for the type of WTP since that is the most common treatment technology used in large WTPs in North America.

Table 2 presents the capital cost elements included in this guide and estimating steps. Guidance is provided thereafter for each cost element presented in Table 2. The overall process flow diagram is shown in Figure 1.

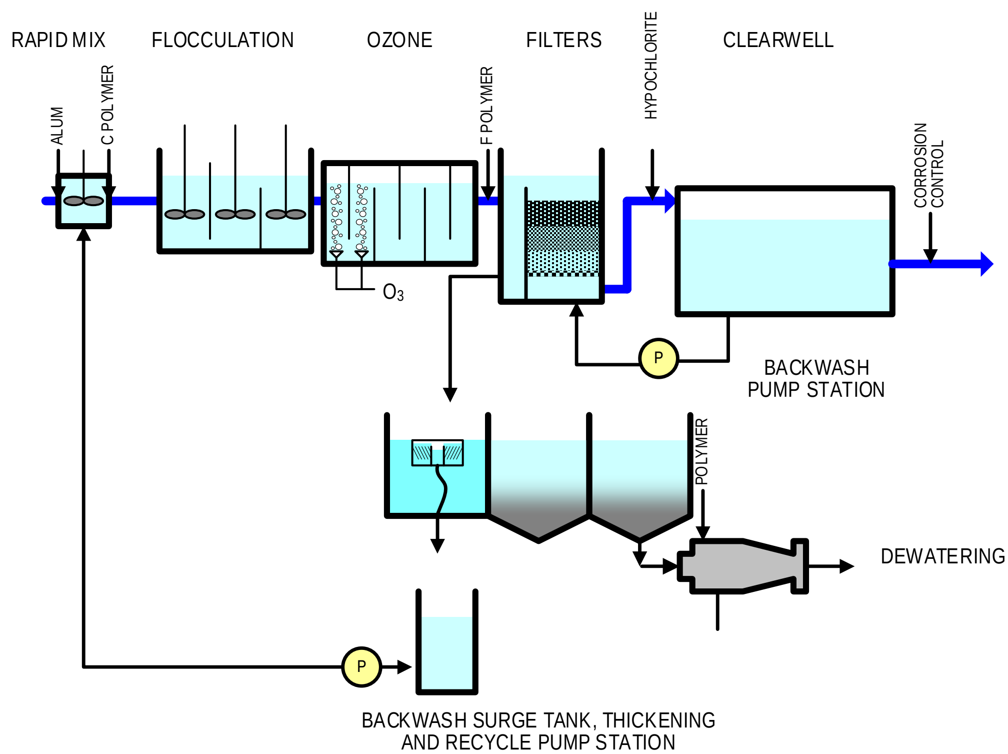


Figure 1. Direct Granular Media Filtration Process Flow Diagram

Figures 2 through 10 (provided at the end of this TM) show granular media filtration construction cost curves, annual O&M cost curves, energy use curves, annual residual production cost curves, number of truck trips during construction, number of truck trips annually, fuel consumption during construction, annual fuel consumption, and annual chemical usage, respectively.

Table 2. Capital Cost Elements for Granular Media Direct Granular Media Filtration Plant Capacity Comparison

	Capacity		
Project Element	**115 mgd**	**145 mgd**	**160 mgd**
Rapid mix, type, No. trains	Turbine, 3	Turbine, 4	Turbine, 4
Flocculation, type, HRT, No. trains	HPW, 30, 6	HPW, 30, 6	HPW, 30, 8
Coagulant, type, average dose (mg/L)	Alum, 5	Alum, 5	Alum, 5
Coagulant aid polymer, type, average dose (mg/L)	Liquid, 0.75	Liquid, 0.75	Liquid, 0.75
Filter aid polymer type, average dose (mg/L)	Liquid, 0.1	Liquid, 0.1	Liquid, 0.1
Ozone generation capacity (lb/day)	2,880	3,630	4,005
Ozone contactors, No.	2	3	4
Media filter type	Sand/Anthracite	Sand/Anthracite	Sand/Anthracite
Media filter size (square feet)/No.	950/16	932/20	926/22
Media filter depth (sand/anthracite in inches)	12/60	12/60	12/60
Disinfection type, average dose (mg/L)	OSHG, 3	OSHG, 3	OSHG, 3
Clear well volume (MG)	11.6	14.5	16.0
Backwash pump station capacity (mgd)	34	34	33
Corrosion control chemicals, average dose (mg/L)	NaOH, 10	NaOH, 10	NaOH, 10
Surge basin volume (MG)	6.4	9.2	11.6
Sludge thickener (MG)	0.65	0.82	0.90
Sludge holding (MG)	0.4	0.5	0.6
Dewatering	Centrifuge	Centrifuge	Centrifuge
Does not include:			
Conveyance to site	Not included	Not included	Not included
Raw water pumping	Not included	Not included	Not included
Finished water pumping	Not included	Not included	Not included
Operations facilities	Not included	Not included	Not included
Overflow basins or containment	Not included	Not included	Not included

Alum = aluminum sulfate; HRT = hydraulic residence time; HPW = horizontal paddle wheel; lb/day = pounds per day; MG = million gallons; mg/L = milligrams per liter; mgd = million gallons per day; NaOH = sodium hydroxide; OSHG = onsite sodium hypochlorite generation.

Table 3 presents the site-wide allowances included within the water infrastructure component construction cost curves developed from CPES for WTPs, as these facilities include additional supporting infrastructure to enable the group of unit processes to perform in a secure environment. These allowances are based on actual constructed projects and experience for the cost of site grading, roadways, site secondary power distribution, site instrumentation and control signal transmission, and yard piping to interconnect the unit processes as a percentage of the total facility unit process component construction cost.

Table 3. Site-wide Allowances for Water Treatment Plant

Project Component	Allowance
Site grading, roadways, stormwater management	5%
Site electrical distribution (less primary & standby power provisions)	4%
Site yard piping	7.5%
Site I&C/SCADA network	5%
Total site-wide allowance	21.5%

I&C = instrumentation and control; SCADA = supervisory control and data acquisition.

Contractor Allowances

Construction contractor allowances include contractor overhead, markup, mobilization, bonds, and insurance. Table 4 presents the percentage of costs related to each of these additional construction costs. These allowances are based on CH2M Constructors, Inc., experience for traditional design-bid-build delivery projects. Certainly, these allowances will vary by project type and market conditions at the time of bidding. For this guide and resulting conceptual cost estimating tool, the total of 15 percent is a reasonable assumption.

Table 4. Construction Contractor Allowances

Allowance & Governing Subtotal	Cost Percentage
Overhead/general conditions allowance applied to project component cost subtotal	14%
Profit	5%
Mobilization/bonds/insurance allowance applied to project component subtotal	3.5%
Total contractor allowance	22.5%

Project Contingency

A 40 percent contingency is applied to the sum of the project component costs and contractor allowances to account for incomplete definition and design.

The following items are not assumed nor explicitly accounted for in the project component costs at this stage of conceptual cost estimating:

- Rock excavation
- Tunneling or boring
- Pile foundations
- Seismic foundations
- Shoring
- Soil contamination
- Dewatering conditions
- Environmental mitigation
- Weather impacts
- Depth of structures
- Local building code restrictions
- Coatings or finishes
- Building or architectural preferences

- Client material preferences
- Client equipment preferences
- Existing utilities interference
- System-wide I&C automation integration
- Primary electrical power source transmission and transformation
- Access and maintenance roadways

Construction Truck Trips and Fuel Consumption

The construction truck volumes were assumed to be 10 cubic yards for construction and residuals hauling. Average distance was estimated at 20 miles per trip. Fuel consumption was estimated at 8.9 miles per gallon.

Annual O&M Cost Estimate Preparation

Annual O&M cost includes the following elements:

- Labor
- Chemicals
- Power
- Residuals disposal

Chemicals, power, and ultimate residuals disposal are based on user input of both average annual day and maximum day design flow capacity, so the chemical usage, residuals production, and total connected horsepower, which are each sized for maximum day, can be proportionally reduced to represent average annual usage. Labor, as well as repair and maintenance materials, are considered fixed costs unrelated to flow rate.

Labor

Table 5 presents the assumed base staffing requirements and hourly rates for WTP based on a wide range of staffing philosophies across water utilities world-wide.

Table 5. Project Component Staffing Requirements and Rates

Project Component Staffing	Staffing Rates
One superintendent 8 hours per day, 5 days per week	$50/hour
Two operators onsite always	$30/hour
Two maintenance workers 8 hours per day, 7 days per week	$30/hour
One clerical worker 8 hours per day, 5 days per week	$20/hour
One lab worker 8 hours per day, 5 days per week	$20/hour

Chemicals

Table 6 presents the chemicals, average annual dose assumptions, and chemical unit costs associated with each WTP type, resulting in a total chemical cost per million gallons by WTP type. Chemical hauling distance is estimated at 50 miles.

Table 6. Project Component Staffing Requirements & Rates

Chemical	Unit Cost ($/dry ton)	Average Surface WTP Dose (mg/L)
Sodium hypochlorite	$1,500	3.0
Sodium hydroxide	$600	10
Aluminum sulfate	$450	5
Polymer	$2,500	0.75/0.1

Power

Power cost is based on a unit power rate of $0.0605 per kilowatt-hour.

Residuals Handling and Disposal

Residuals handling will include 100 percent liquid recycle with solids drying and disposal at a landfill. Hauling distance is estimated at 20 miles; disposal costs are estimated at $50 per cubic yard.

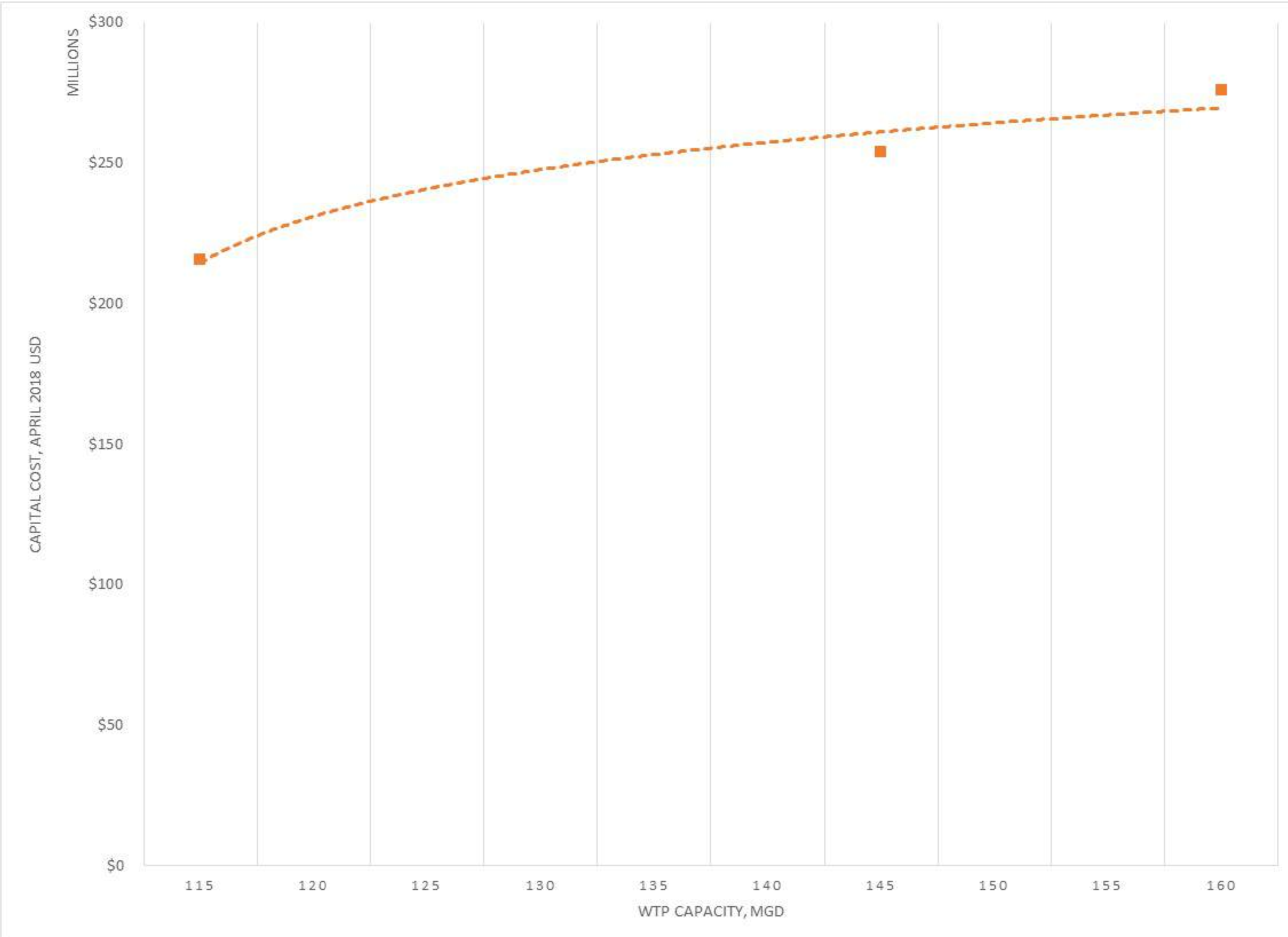


Figure 2. Draft Granular Media Filtration Cost Curve for Construction, Millions USD

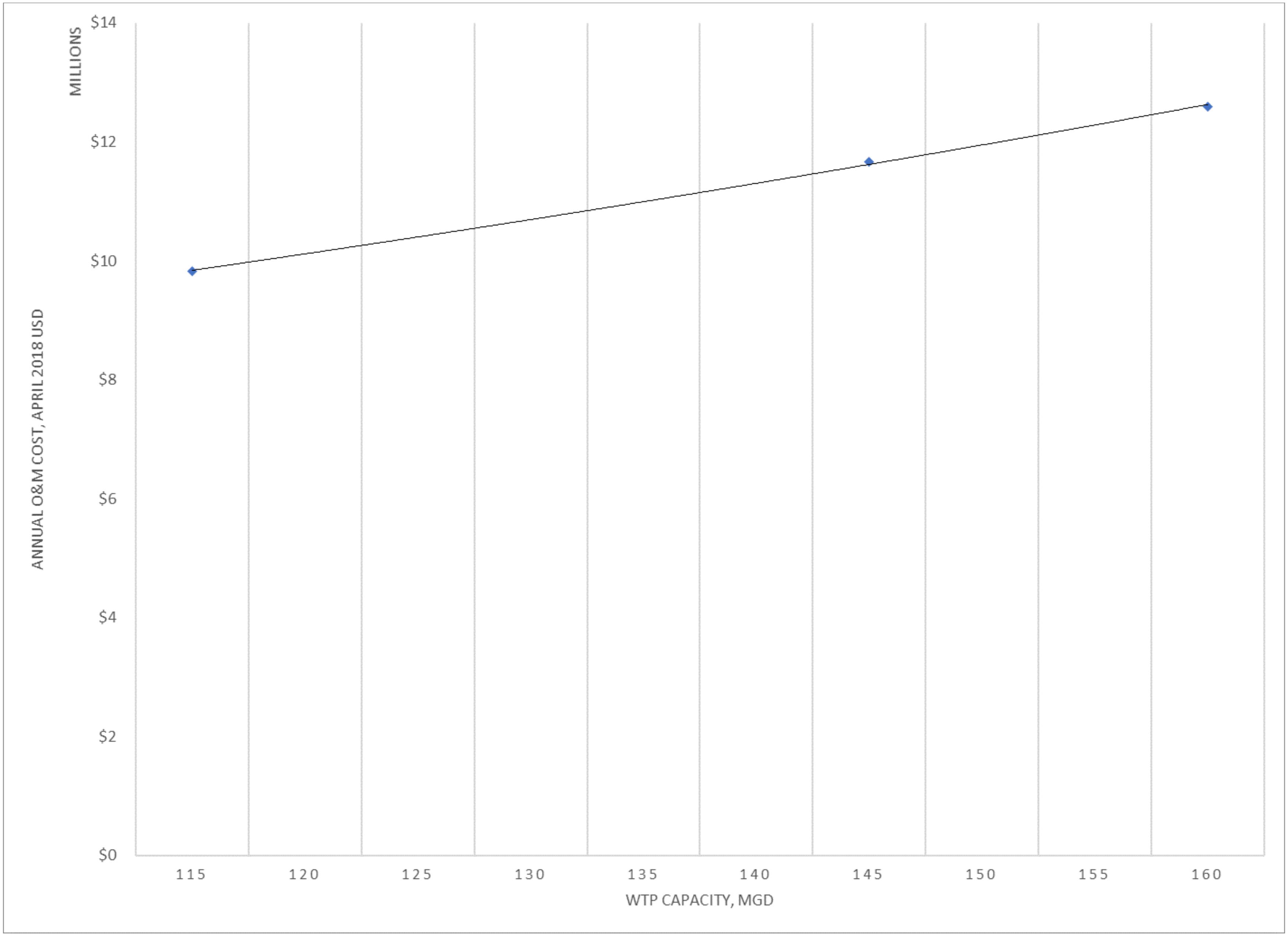


Figure 3. Draft Granular Media Filtration Cost Curve for Annual O&M, Millions USD

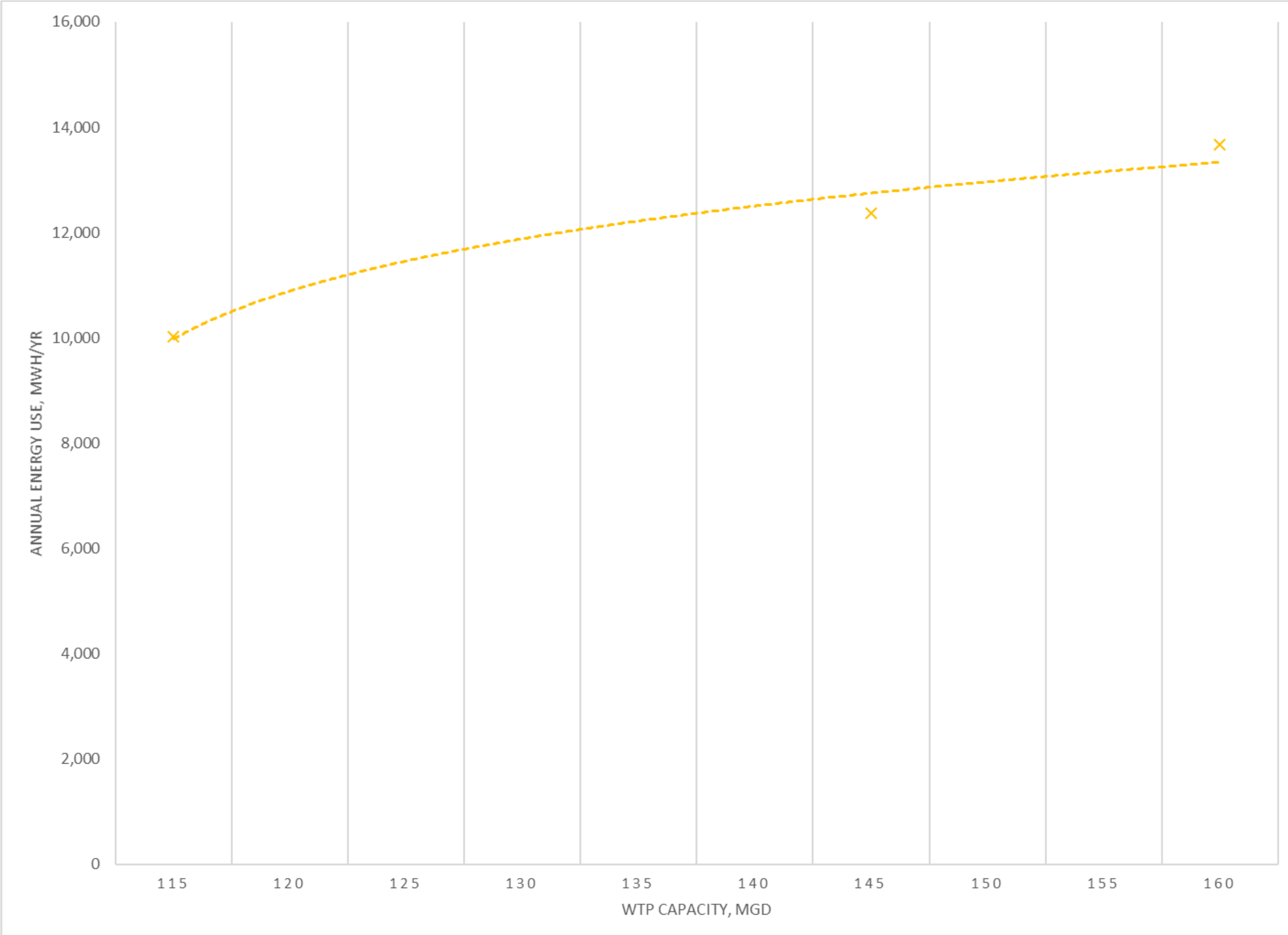


Figure 4. Draft Granular Media Filtration Curve for Annual Energy Use

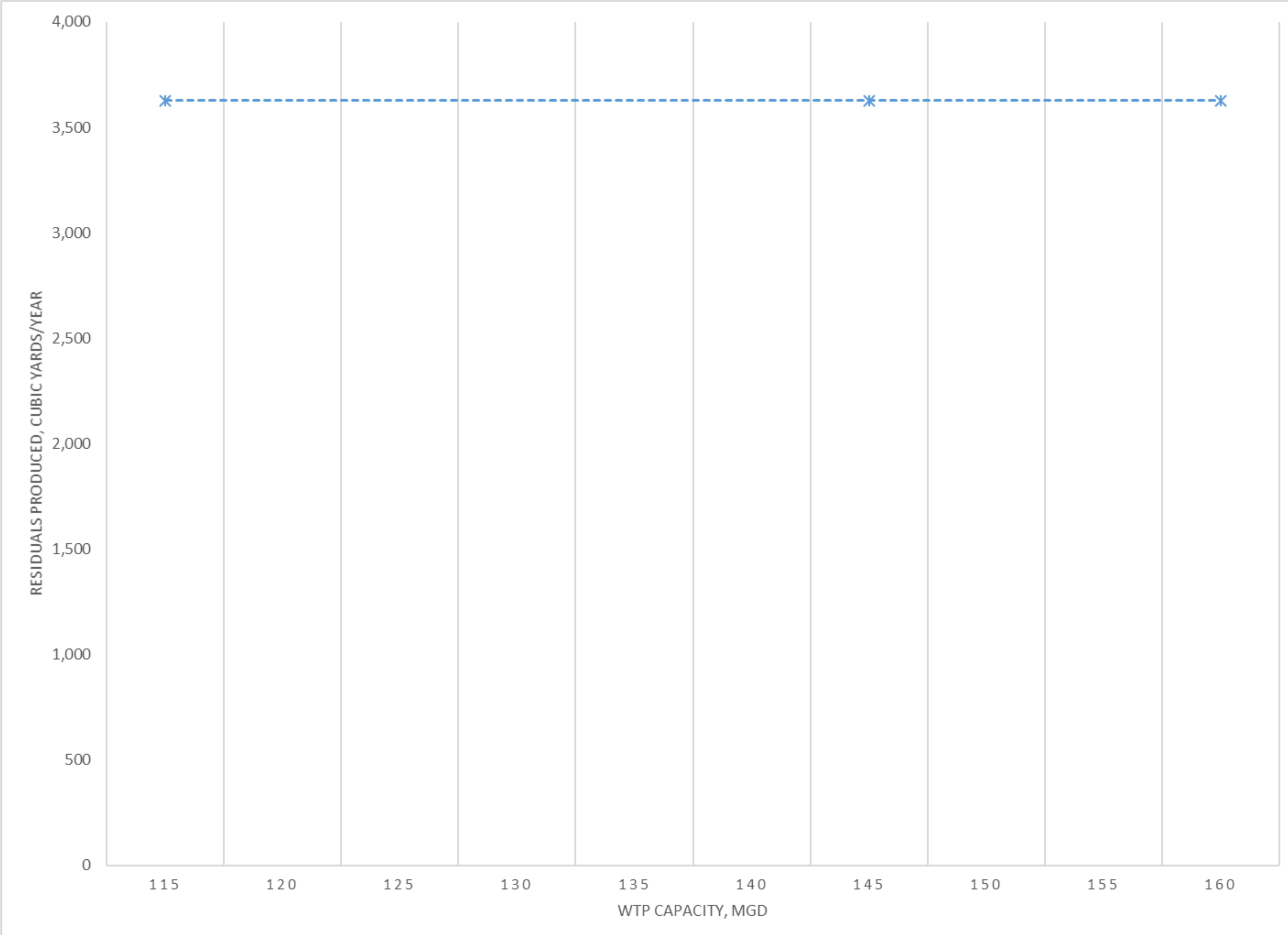


Figure 5. Draft Granular Media Filtration Curve for Annual Residuals Produced

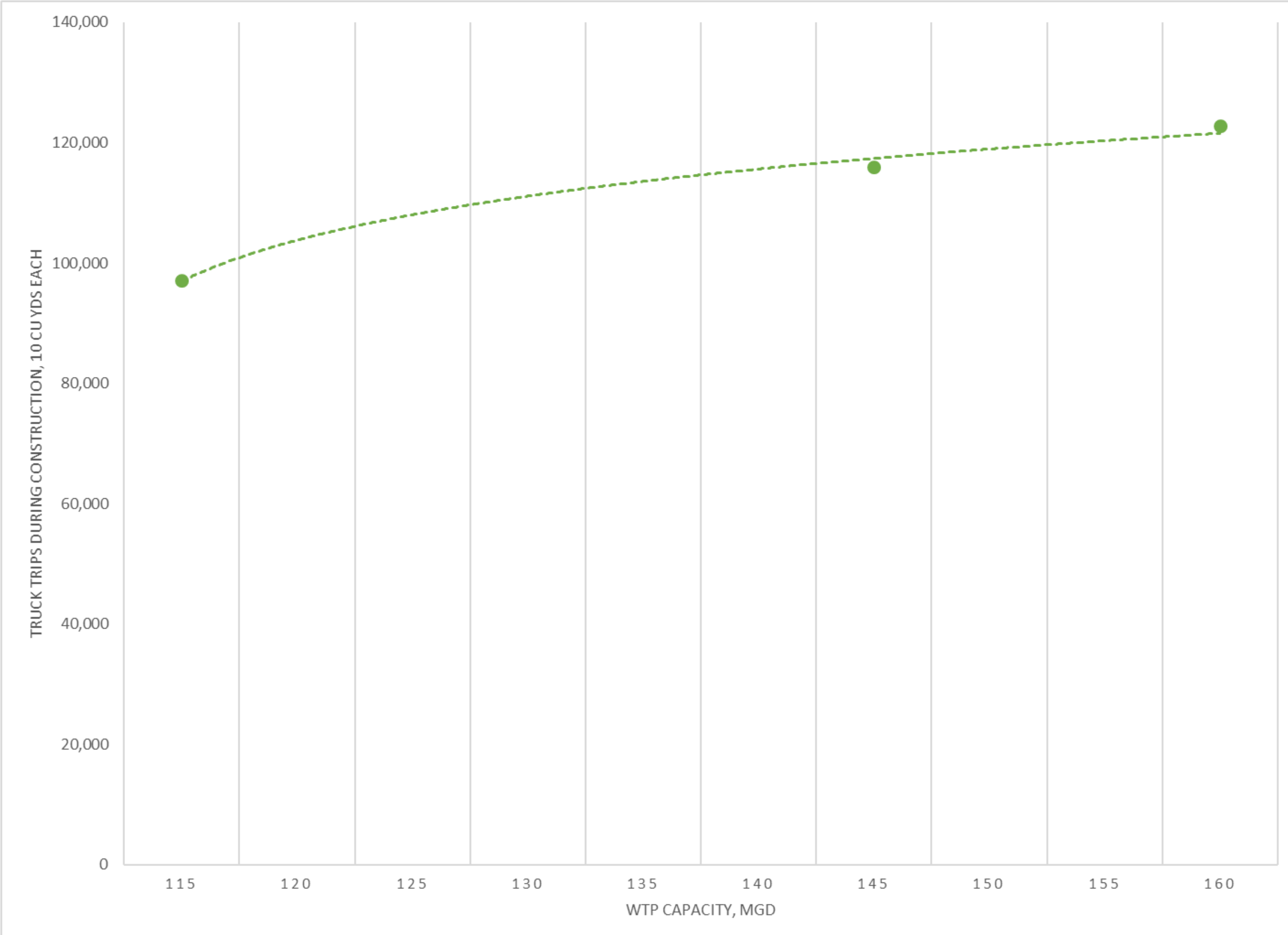


Figure 6. Draft Granular Media Filtration Curve for Truck Trips during Construction

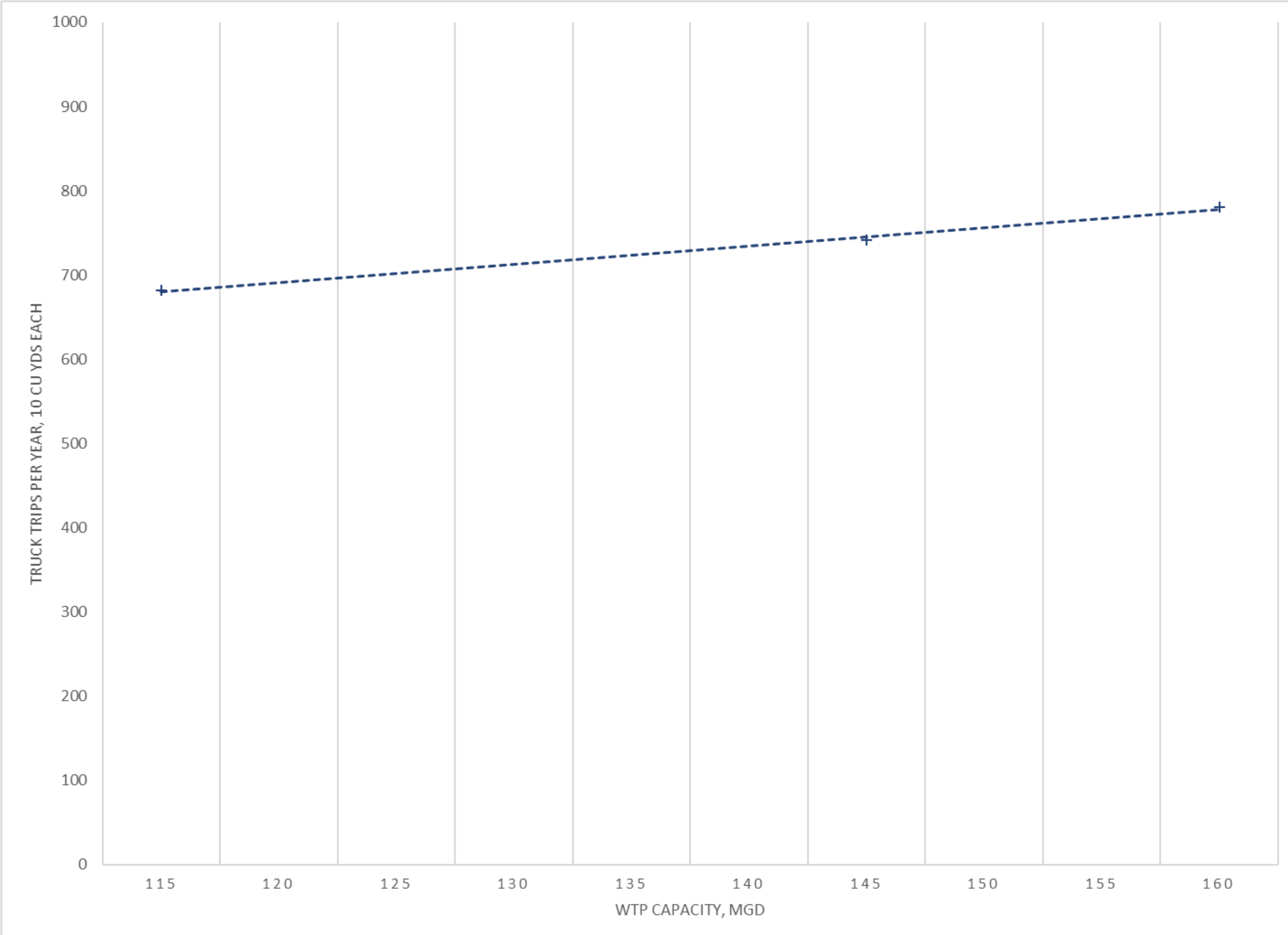


Figure 7. Draft Granular Media Filtration Curve for Truck Trips Annually

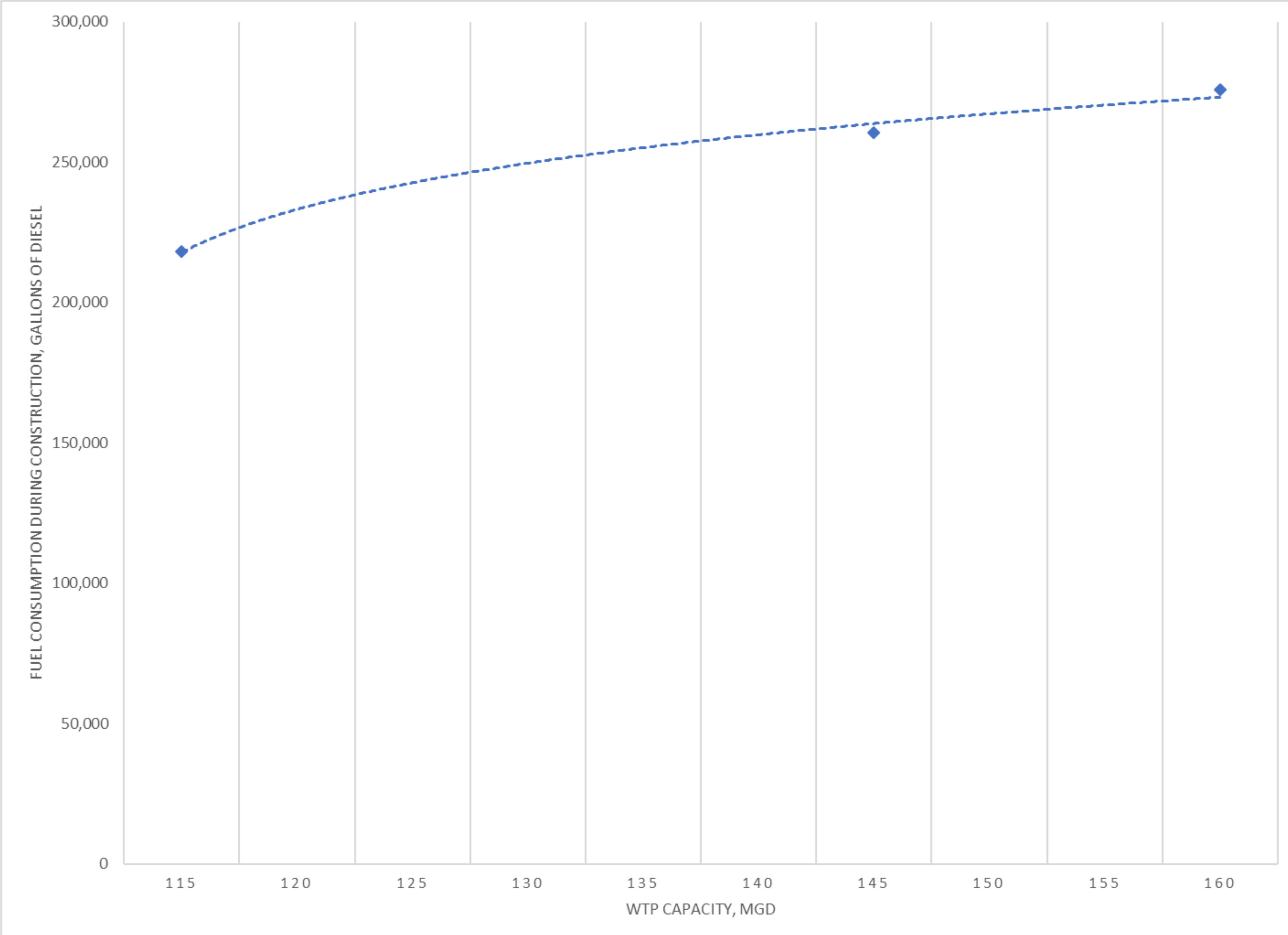


Figure 8. Draft Granular Media Filtration Curve for Fuel Consumption During Construction

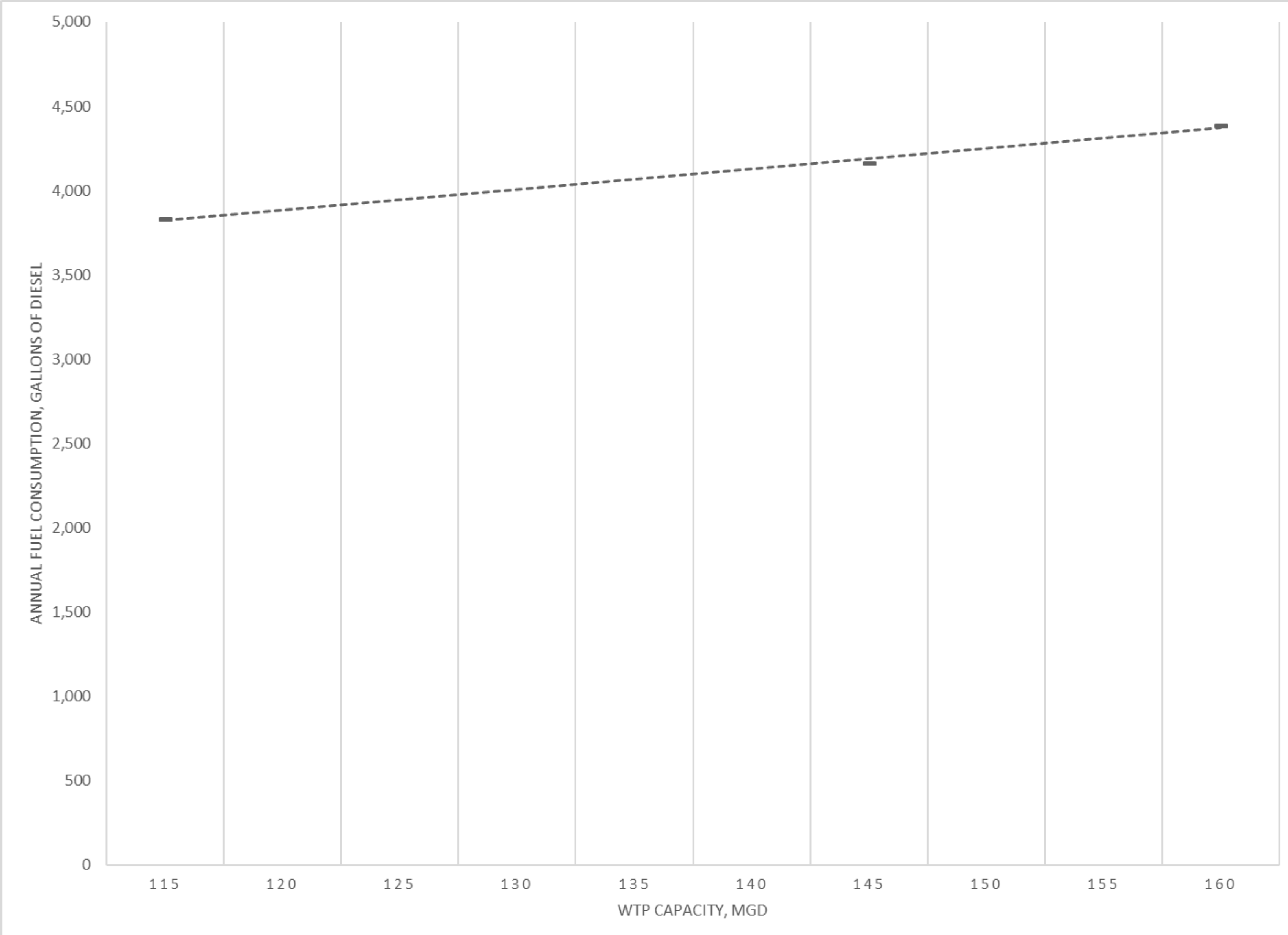


Figure 9. Draft Granular Media Filtration Curve for Fuel Consumption Annually

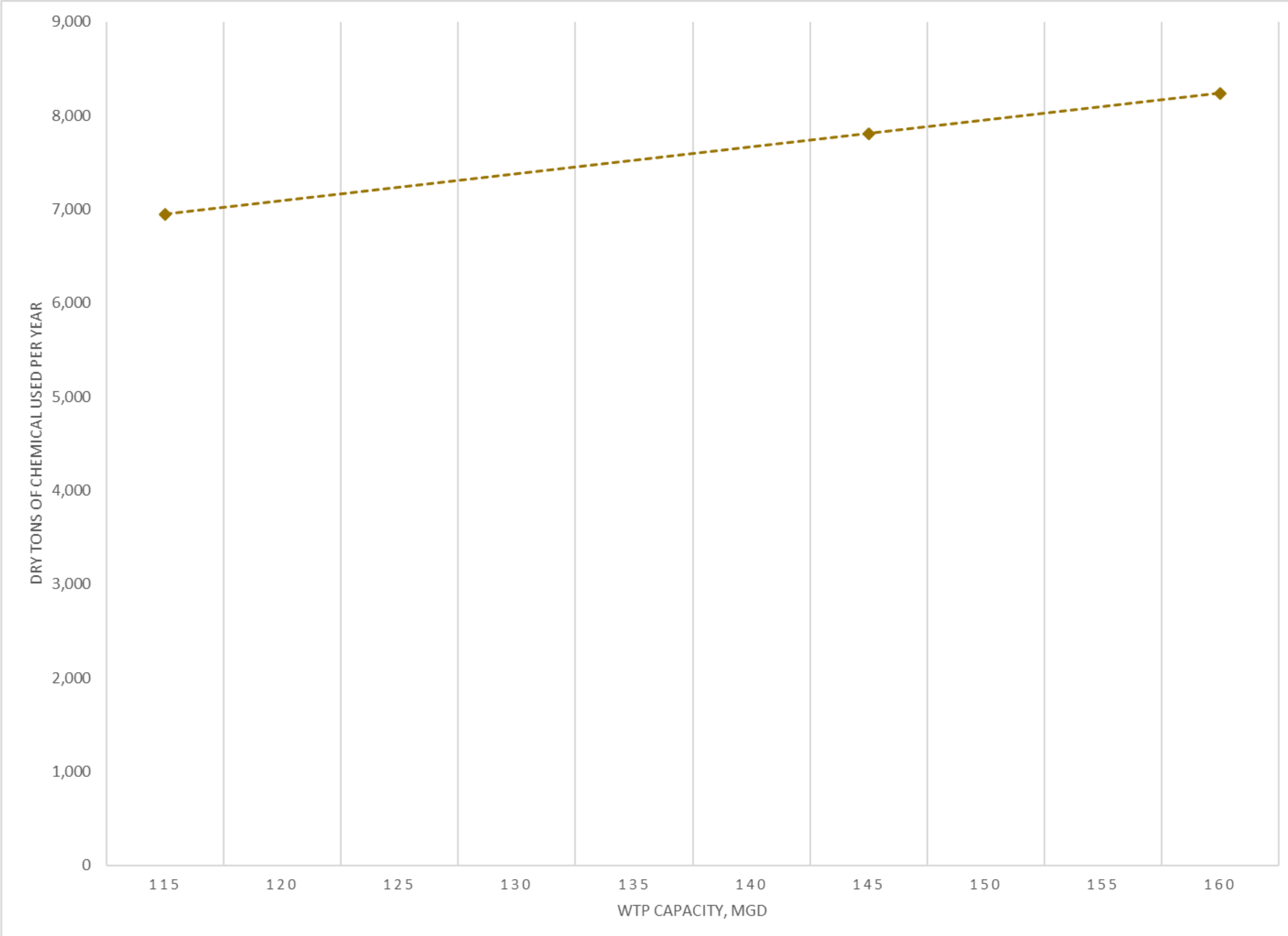
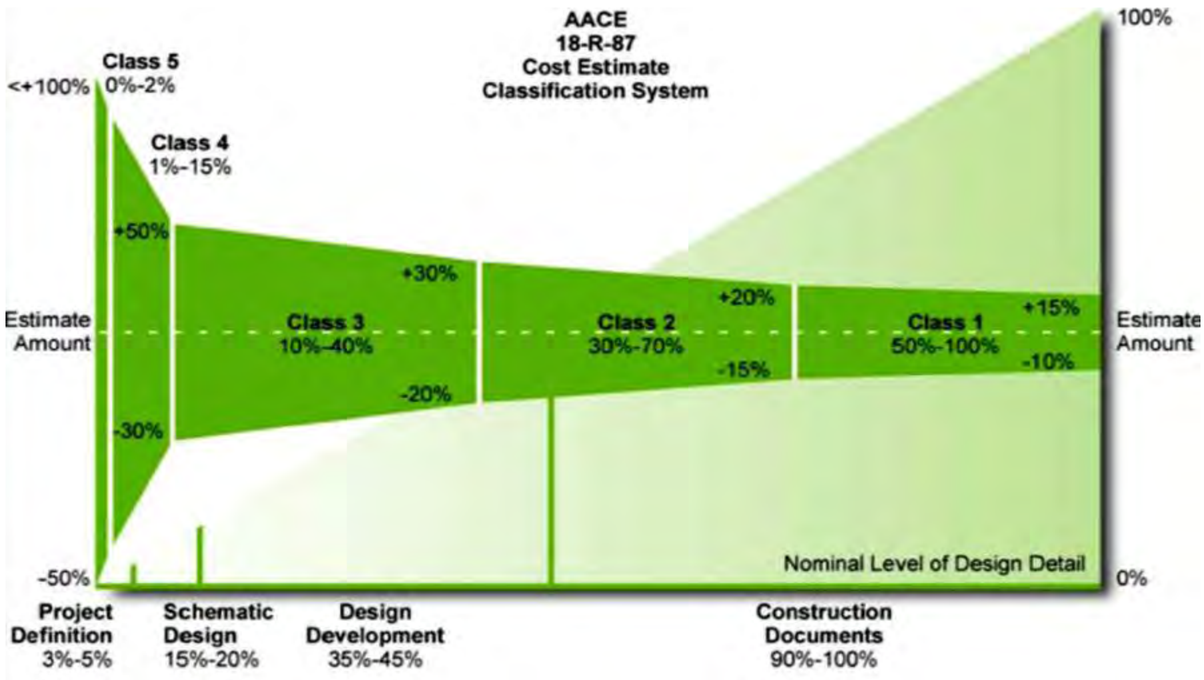


Figure 10. Draft Granular Media Filtration Curve for Chemical Use per Year

Attachment
Cost Estimate Definition

Cost Estimate Definition

The Portland Water Bureau granular media filtration cost estimates were prepared based on 1-to-5-percent-complete preliminary engineering. As such, they are considered Class 5 estimates, as defined by Association for the Advancement of Cost Engineering International. The typical expected accuracy range for a Class 5 estimate is –20 to –50 percent on the low side and +30 to +100 percent on the high side.



Because the water supply schemes defined for this analysis only include major process design criteria inputs sufficient to advance the concept to 0 to 2 percent complete, and rely on information available at the time, the cost estimates produced from the tool developed from the guidance herein, and any resulting conclusions about project financial or economic feasibility or funding requirements, are to be used as preliminary guidance only in project evaluation and implementation.

To proceed with the project, detailed strategic planning, business development, project screening, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval are needed.

The final costs of a project and resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, continuity of personnel and engineering, and other variable factors. Therefore, the final project costs will vary from the estimate developed using the method described in this TM. Because of these factors, project feasibility, benefit/cost ratios, risks, and funding needs must be carefully reviewed, before making specific financial decisions or establishing project budgets, to help ensure proper project evaluation and adequate funding.

Technical Memorandum

Date:	September 11, 2018
Project:	Bull Run Filtration Project
To:	David Peters, PE, and Michelle Cheek, PE – Portland Water Bureau
From:	Christopher Bowker – Portland Water Bureau Pierre Kwan, PE, Aparna Garg – HDR Dan Speicher – Jacobs
Reviewed by:	Phillippe Daniel, PE – HDR
Approved by:	Andy McCaskill, PE – HDR
Subject:	**Filtration Plant Site Alternatives**

1.0 Introduction

The Portland Water Bureau (PWB) is in the planning phase for the design and construction of a new filtration plant to treat their existing Bull Run surface water supply. This planning phase includes technical analysis to assist PWB in making four critical decisions: procurement method, filtration plant capacity, site suitability, and filtration technology. This technical memo (TM) documents the assumptions, analysis, and decisions made to determine the location of the plant.

The decision on plant location is framed by the values-based decision-making framework, which includes specific criteria and performance scales. HDR has coordinated closely with PWB and their other consultants, Jacobs and Barney & Worth, to identify the criteria and performance scales that drove the site decision. The site selection was made after a plant capacity was identified, (see Capacity Alternatives and Decision TM), but before the filtration technology was determined.

This TM presents the initially identified site alternatives, the process to narrow down the initial site alternatives, the applicable decision framework criteria and performance scales related to the site decision, and the evaluation of the remaining site alternatives.

2.0 Background

In 2006, the Environmental Protection Agency (EPA) issued a drinking water rule called the Long Term 2 Surface Water Treatment Rule (LT2). The purpose of the LT2 rule was to reduce disease incidence associated with microorganisms in drinking water and specifically required treatment for *Cryptosporidium*. From 2012 to 2017, the Bureau had a variance from the treatment requirements for *Cryptosporidium*, by demonstrating that treatment for *Cryptosporidium* at the Bull Run watershed intake was not necessary to protect public health because of the nature of the raw water source. However, this variance was revoked in 2017 requiring that the Bureau treat the water from the Bull Run River for the microorganism

Cryptosporidium. The bilateral compliance agreement establishing this requirement was signed on December 18, 2017, and has a compliance deadline of September 2027.

In the years leading up to the issuance of LT2, as well as afterward, PWB investigated how it would meet LT2. This included analyzing the type and size of a potential treatment facility (at this point in time both non-filtration and filtration treatment were possibilities), as well as a potential location. The first significant siting evaluation effort was the 2001 Water Treatment Plant Siting Evaluation Technical Memorandum (Appendix A). This TM provided information to the Bull Run Treatment Panel (Panel). The Panel was established to advise PWB on the Bureau's options for meeting LT2 regulations as well as make recommendations on a treatment facility site. This work was summarized in Recommendations of the Bull Run Treatment Panel TM (Appendix B). Four sites were identified in these documents: Lusted Hill, Larson's Ranch, Headworks, and Powell Butte.

In 2009, PWB re-evaluated potential treatment facility sites in the draft Site Considerations for Portland Water Bureau's Water Treatment Facility TM (Appendix C). Four sites were evaluated for their ability to host a filtration-type treatment facility: Carpenter Lane, Headworks, Lusted Hill, and Roslyn Lake, (Powell Butte and Larson's Ranch were not included in this evaluation). The draft TM discussed factors and relative costs to take into consideration when choosing a site.

Based on previous studies, a total of six potential sites for a filtration facility were identified: Carpenter Lane, Lusted Hill (with expansion), Headworks, Larson's Ranch, Powell Butte, and Roslyn Lake (see Figure 1). These sites were selected on the basis of:

- Taxlot size,
- Accessibility,
- Location,
- Land use, and
- Geologic hazards

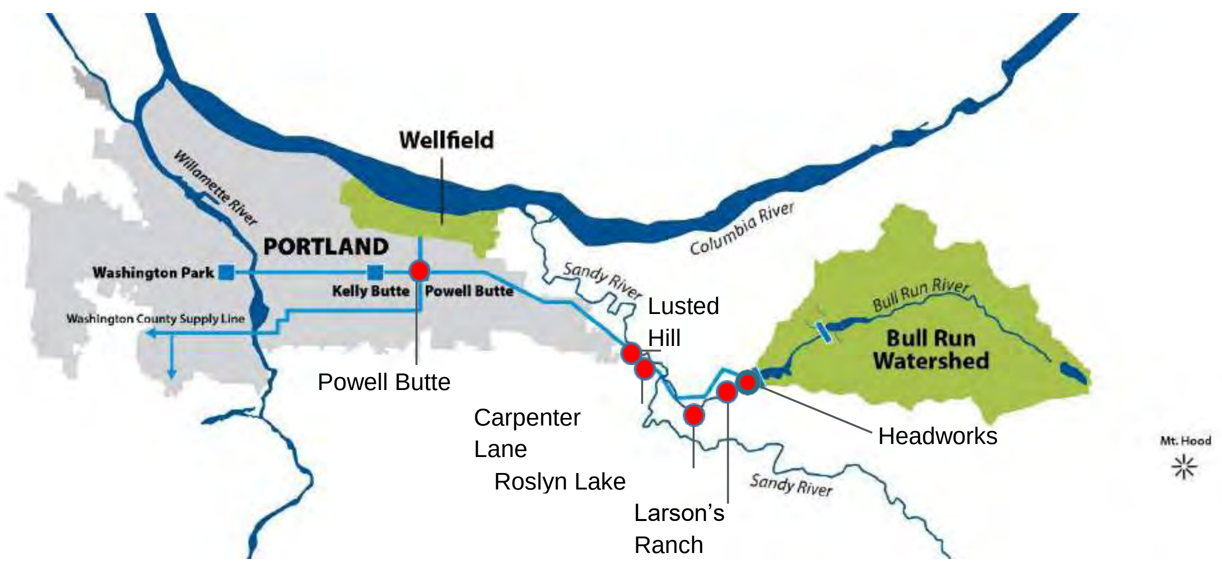


Figure 1. Approximate location of the six sites reviewed in this preliminary evaluation.

3.0 Process

Major considerations and factors affecting site choice were used to create selection criteria and many of the criteria used in this TM are based on previously identified criteria. Criteria categorized as essential are considered necessary for a filtration facility and were graded as pass/fail. In Section 5, each site is introduced, discussed, and evaluated for its ability to meet each essential criterion. Any site unable to meet one or more of these criteria was determined to be unsuitable for a filtration facility and was removed from further consideration. Sites that met all the essential criteria were then further investigated.

4.0 Explanation of Essential Criteria

Several major considerations exist that affect site choice such as cost/benefit impacts, meeting future needs, and regulatory compliance. Siting criteria that support these values are maximizing gravity flow, site proximity to existing and future conduit rights-of-way (ROWs), site size, site slopes and geologic conditions, and impacts to the compliance schedule. This section discusses major considerations, why they are important to site selection, and their application as essential criteria.

4.1 95 MGD Gravity Flow

The existing Bull Run supply is gravity operated, which is simpler and reduces costs associated with pumping water to Portland’s distribution system to meet demands. Potential impacts to gravity flow must be considered as part of the site selection process. Although the goal would be to maximize gravity flow from Bull Run, it is likely that some pumping will be required to meet peak demands, depending on factors such as weather, operations, head loss through the facility, and site elevation.

An essential criterion associated with gravity flow was developed to assist in site selection. To meet this criterion, sites must allow for gravity flow equal to, or greater than, the average daily demand. This is approximately 95 million gallons per day (MGD). A site unable to meet this minimum gravity flow would typically require pumping throughout the year, negatively impacting cost.

Gravity flow was evaluated by comparing approximate site elevations to the hydraulic grade line (HGL). The HGL is the pressure head, or line, that water follows when it flows from a higher to a lower elevation. When water flows naturally from a higher to a lower elevation it is called gravity flow. A site located too far above the HGL may require most or all flows to be pumped from Headworks to the filtration facility, with gravity flow to the distribution system. A site located too far below the HGL would allow gravity flow from Headworks to the filtration facility but would require pumping to town. The existing HGL (from Headworks through the existing Lusted Hill facility to Powell Butte) provides enough gravity flow to move water into the Bureau's distribution system and meet existing demands. The closer a filtration facility is to the existing HGL, the more the PWB would be able to use gravity flow to move water through the filtration facility and downstream to the Bureau's distribution system. This would reduce pumping needs.

Sites that meet the 95 MGD gravity flow criterion will have additional issues to consider in later evaluations, such as how future changes will impact the HGL. Future projects that affect the elevation of the system inlet or outlet could impact the HGL. For example, if flow through the conduits was driven by Reservoir 2 head instead of the Diversion Dam, future gravity flow through the conduits could be increased if a higher elevation facility site is chosen. However, this would likely mean that less gravity flow would be available in the interim. These issues are not addressed herein but will likely differentiate sites that meet all essential criteria.

4.2 Proximity to Conduits Rights-of-Way

It is important that a potential site be close to the existing conduits as well as any future conduit ROW (see Figure 2). For evaluation purposes, an approximate distance of two miles was selected (this is the direct distance between the site and conduit ROW, and not the actual length of new piping needed to connect the site to the conduits). Sites on or near the existing conduits would reduce the need for additional piping to connect to the conduits. Also, sites that avoid the construction of river crossings are anticipated to simplify design and construction needs. For purposes of determining proximity to a future conduit ROW, the location of a future conduit (which was not determined as part of this report) was assumed, based on past land acquisition and planning efforts.

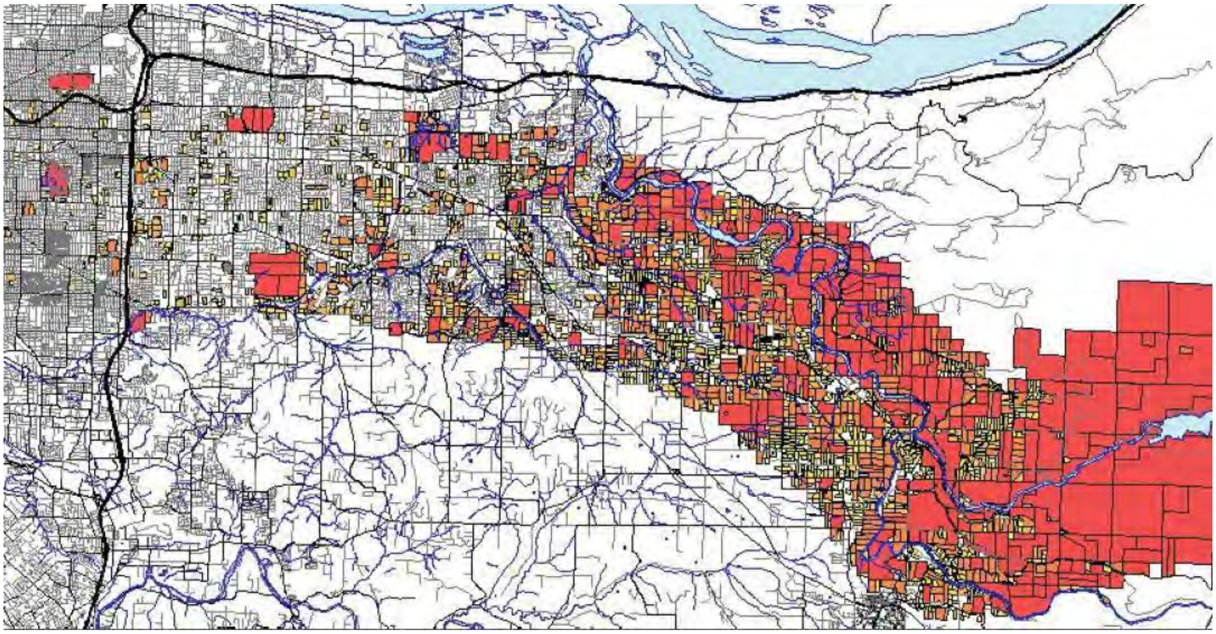


Figure 2. Parcels within two miles of the conduit ROW (parcels smaller than 4 acres were not included).

4.3 Taxlot Size

Another key requirement in selecting a filtration facility site is that it be large enough to accommodate the facility's footprint, including clear wells, solids handling, and any future expansion that may occur. The facility footprint also depends on the filtration treatment technology implemented. For most filtration technologies, the required footprint was estimated at 25 to 50 acres. Slow sand filtration would require considerably more acreage. For this evaluation, it was assumed that slow sand filtration would not be the selected filtration technology. If slow sand is selected in the future, the issue of site size would need to be revisited because the six sites would likely require expansion to accommodate this technology.

4.4 Slopes and Geologic Conditions

Depending on each site's topography and geotechnical conditions, some site earthwork will occur. However, sites with fewer steep slopes and geotechnical issues will reduce the amount of site work needed and/or expensive construction methods used to overcome these risks. All sites were previously determined to have favorable sloping conditions. Geologic conditions were identified using the Bureau's geospatial information system and the Oregon Department of Geology and Mineral Industries (DOGAMI) website. DOGAMI produced a 2016 Statewide Landslide Information Database for Oregon that was used to help determine mapped landslide areas and landslide hazard.

Taxlot size, slopes, and geologic conditions limit how and where the filtration facility can be constructed on a given site. Collectively, the area that is large enough, with favorable sloping, and free of geologic concerns is referred to as the buildable area.

4.5 Impacts to Schedule

PWB has less than ten years to plan, design, and construct a filtration facility. To meet the compliance schedule, all phases of the Bull Run Filtration project will need to be performed expediently. Potential delays impacting PWB's ability to meet this timeline should be avoided as they could lead to significant consequences. Potentially significant schedule delays could include land use reviews and permitting. For example, part of the Lusted Hill permitting process would require that PWB conduct an analysis of the surrounding area and successfully demonstrate to the county that nearby parcels are unsuitable.

4.6 Summary of Criteria

These major considerations were used to help create a list of criteria that are essential to a filtration facility site. Failure to meet these criteria would eliminate a site from further consideration. The essential criteria are:

- The site must allow for at least 95 MGD to flow through the facility and downstream to the Bureau's distribution system using gravity. This criterion assures that PWB will be able to meet average demand without pumping and would reduce operating costs.
- The distance from the existing and future conduit ROW to the site must be less than two miles.
- The buildable area must accommodate the ultimate size of the facility. This includes several key points:
    - In 2017, City Council directed PWB to construct a filtration-type treatment facility. This means that a suitable site would need at least 25 to 50 acres of buildable area.
    - Minimize site slopes to reduce impacts to construction and site earthwork.
    - The site must have space for the facility to be constructed on land free of significant geologic hazards that would require using expensive construction methods to overcome.
- The site selected is not anticipated to pose unnecessary risk to PWB's ability to meet the compliance schedule, such as due to the land use permitting process or other complications.

5.0 Site Evaluation against Essential Criteria

5.1 Carpenter Lane

This site is located less than a mile south of Lusted Hill at the dead end of Carpenter Lane east of SE Cottrell Road. This site is located above the existing HGL. Modeling indicates that 110 to 160 MGD gravity flow is available depending on the location and size of connecting piping and treatment processes. An approximate gravity flow of 130 MGD was assumed. Pumping would be required to meet demands greater than 130 MGD. Carpenter Lane passed the HGL criterion. Figure 3 is an illustration of the Carpenter Lane site relative to the HGL.

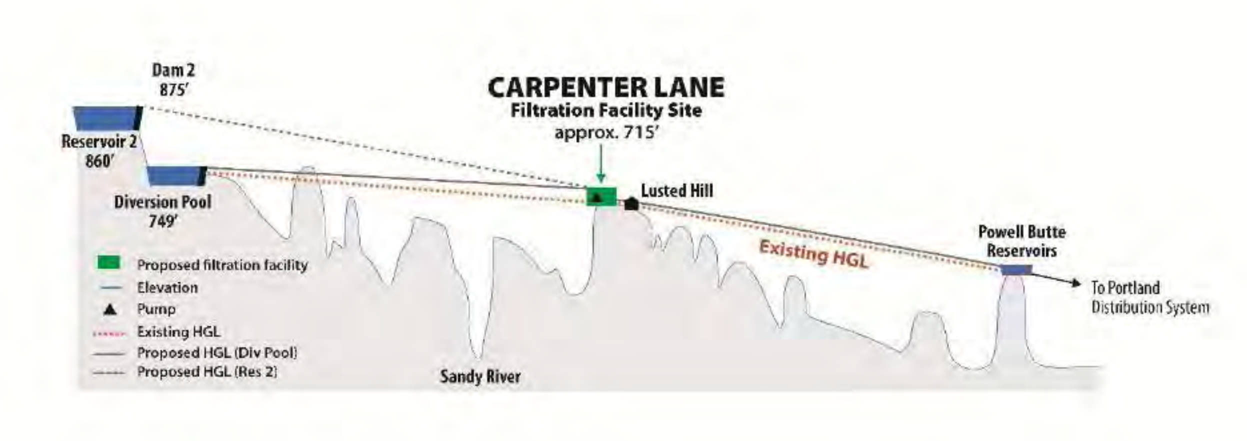


Figure 3. Illustration showing a filtration facility located at Carpenter Lane relative to the HGL. Note the facility is very close to the HGL and would have gravity flow up to approximately 130 MGD.

This site is south of the existing conduits ROWs and would require 13,200 to 21,600 feet of additional piping to connect to Conduits 2, 3, and 4. This site is in line with the anticipated alignment of a future conduit. Carpenter Lane passed the proximity criterion.

Carpenter Lane includes two large taxlots totaling approximately 90 acres. However, some of the site is in or near areas of moderate, high, and very high landslide hazards. Considering this, the buildable area is approximately 65 acres, which is large enough to accommodate a filtration facility. Carpenter Lane passed the taxlot size, slopes, and geologic hazards (buildable area) criteria.

Carpenter Lane is located in Multnomah County, borders Clackamas County, and is zoned by Multnomah County Land Use Planning as Multiple Use Agriculture (MUA-20). A facility located here would be considered a Community Service Use but classified as a Conditional Use in the MUA-20 zone. Both of these land use reviews are Type III Reviews. The filtration facility would be the primary structure with other structures listed as accessory structures. Any tower constructed to hold radio or microwave antennae is considered an accessory structure, but also a separate use. Such towers have a specific land use review. Although there may be several other review types triggered (See Appendix D), all the reviews discussed would be processed together through the Type III Review, which requires a public hearing before a Hearings Officer and approximately 150 days. There are no known significant risks to the project timeline or schedule related to land use reviews or permitting if this site were selected. Carpenter lane passed the schedule criterion.

The Carpenter Lane site is currently accessed via the Carpenter Lane ROW, which is a single-lane, unimproved road. If this site is selected, this road will either need to be widened and improved or a new access route established to the site, perhaps from SE Dodge Park Boulevard or from the south via an easement. Additionally, although the site is owned by PWB, it is rented out for use by a nursery. PWB will need to give advance notice to the renters clarifying expectations and specifying when the site would need to be vacated.

5.2 Headworks

Headworks is in the Bull Run Watershed and is the farthest east of the six sites. Headworks is the point of raw water intake into the conduits and is where chlorination occurs. A filtration facility located at Headworks would sit above the Diversion Pool, which is the driving head for the conduits and establishes the HGL (see Figure 4). A facility above the HGL would have to rely on pumping (to the facility) year-round to send water to town. As a result, Headworks did not pass the gravity flow criterion.

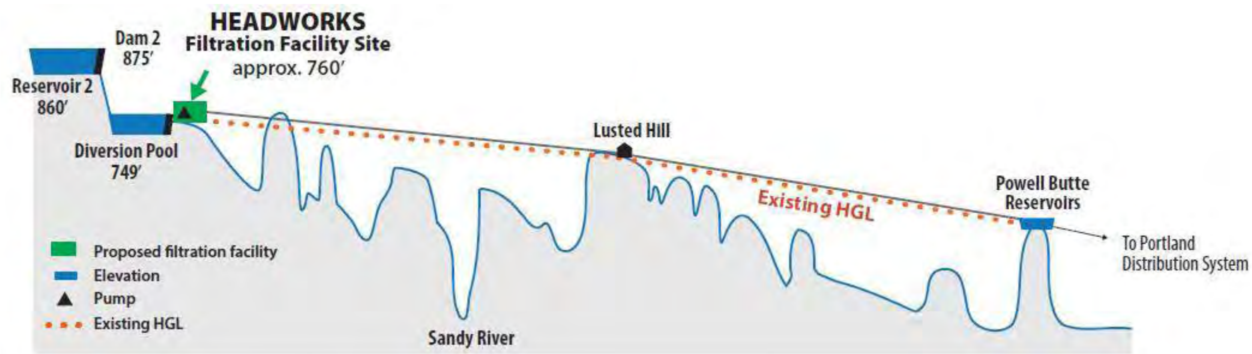


Figure 4. Illustration showing a filtration facility located at Headworks relative to the HGL. Note the facility is above the Diversion Pool and therefore the HGL. Pumping to the facility would be required.

Construction of a facility at this site would not require major extension of large pipe because Headworks is immediately adjacent to Dam 2 and the existing conduits. Since Headworks is within two miles of the existing and future conduit ROW, it passed the proximity criterion.

The existing facilities and site are constrained to a small area, bounded by Dam 2, the Bull Run River, and steep slopes. Less than two acres of land is available to be developed directly on-site while maintaining existing operations using Screenhouse 3, the Primary Intake Structure, and the Chlorine Building. Approximately 15 acres of forested land is located between Headworks, Dam 2, and the spillway but development of this land has significant issues and still wouldn’t be large enough. Headworks did not pass the taxlot size criterion.

Of the six potential filtration facility sites, Headworks has the most geologic concerns. Headworks is sitting on landslide material that is susceptible to moving into the Bull Run River. These soils tend to be less susceptible to liquefaction but much more at risk to further landslide movement. Per DOGAMI, Headworks is in an area of very high landslide hazard, has the highest landslide susceptibility, and highest liquefaction probabilities of all six sites. Headworks did not pass the slopes or geologic hazards criteria.

Headworks is located in Clackamas County and is zoned as Timber District. A facility located here would be considered a Conditional Use Review and is a Type III review. Two sets of conditional use criteria must be addressed at this site: (1) general conditional use criteria that apply to any conditional use in Clackamas County; and (2) forest-related conditional use standards that address potential impacts to primary forest uses. Although there may be several other review types triggered, all the reviews discussed would be processed together through the

Type III Review, which requires a public hearing before a County Hearings Officer and approximately 150 days. Projects in the watershed are often subject to increased public input, although since development already exists at Headworks, this risk may not be significant. Portions of Headworks are within the Federal Energy Regulatory Commission (FERC) boundary. Development on any land this close to Dam 2 would require FERC approval (which may not be feasible) and introduces federal oversight to the project. Constructing a facility at this site would result in significant schedule implications related to demonstrating to FERC the minimal Dam 2 impacts and would significantly increase construction costs to reduce impacts to the dam. Headworks did not pass the schedule criterion.

5.3 Larson's Ranch

Little previous study has occurred at Larson's Ranch. Located in the Bull Run Watershed Management Unit south of Bull Run River and north of the Little Sandy River, this site is the second farthest from Portland, and is currently the most difficult to access. Constructing a filtration facility at this site would require either a new access road constructed to the southwest or would require significant improvement of the existing forest road to the site.

At 765 feet elevation, a filtration facility located at Larson's Ranch would be approximately 35 feet above the existing HGL in this area. Pumping year-round would be required upstream of a facility, although gravity flows downstream into the Bureau's distribution system would be possible. Figure 5 illustrates the fact that Larson's Ranch did not pass the HGL criterion.

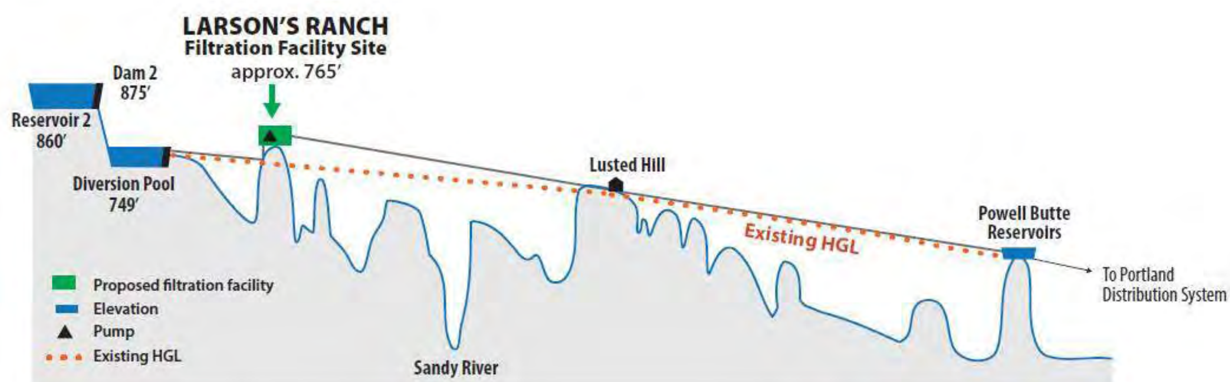


Figure 5. Illustration showing a filtration facility located at Larson's Ranch relative to the HGL. Note the facility is above the HGL. Pumping to the facility would be required.

Larson's Ranch is approximately half a mile from the conduits. Conduits 2 and 4 would each need to cross the Bull Run River twice with new crossings. These crossings would be in areas of high landslide susceptibility. It is estimated that 12,000–13,000 feet of additional piping would be needed to connect to all three conduits. Larson's Ranch passed the proximity criterion.

Although this site is one of the larger taxlots included for evaluation, it is bounded by rivers and significant geologic hazards, reducing the buildable area. Areas of this site have moderate landslide susceptibility and very low liquefaction susceptibility. The buildable area is approximately 60 acres. Larson's Ranch passed the taxlot size, slopes, and geologic hazards criteria.

Larson's Ranch is located in Clackamas County and is zoned as Timber District. A facility located here would be considered a Conditional Use review and is a Type III review. Two sets of conditional use criteria must be addressed at this site: (1) general conditional use criteria that apply to any conditional use in Clackamas County; and (2) forest-related conditional use standards that address potential impacts to primary forest uses. Although there may be several other review types triggered, all the reviews discussed would be processed together through the Type III Review, which requires a public hearing before a Hearings Officer and approximately 150 days. Larson's Ranch would not likely experience significant delays due to the land use review process, but it is unknown if citizen involvement would result in any delays or impact PWB's ability to meet the compliance schedule due to this being in an undeveloped area of the Bull Run Watershed Management Unit. It's assumed that Larson's Ranch would pass the schedule criterion.

5.4 Lusted Hill

Lusted Hill is the name assigned to the pH adjustment and ammoniation facility located on a single taxlot at 6704 SE Cottrell Road. Lusted Hill is close to the existing HGL and is well-suited to maximizing gravity flow. Recent modeling has not occurred at Lusted Hill, but prior modeling performed for ultraviolet (UV) treatment scenarios estimated 200 MGD gravity flow was available at that time (see Figure 6). Headloss would be greater through a filtration facility, thus gravity flow would be less than 200 MGD but greater than 160 MGD. The actual gravity flow would depend on the location and size of connecting piping. Lusted Hill passed the HGL criterion.

Figure 6. Illustration showing a filtration facility located at Lusted Hill relative to the HGL. Note the facility is very close to the HGL and would have gravity flow.

This site is located close to the existing conduits ROWs and would likely require approximately 10,000 feet of additional piping to connect to Conduits 2, 3, and 4. This site is approximately one mile north of the anticipated alignment of a future conduit. Lusted Hill is within two miles of the existing and future conduit ROW and passed the proximity criterion.

The existing Lusted Hill site is approximately 14 acres and is too small to accommodate a filtration facility's footprint. Construction at this site would require the acquisition of additional land adjacent to this site. This would require purchasing or condemning one or more adjacent taxlots to acquire the buildable area needed. There are approximately 40 acres northwest of Lusted Hill that could provide adequate area, are crossed by Conduits 2 and 4, and are close to Conduit 3. This additional area has insignificant geologic hazards (low landslide susceptibility) impacting it. With site expansion, Lusted Hill passed the taxlot size, slopes, and geologic hazards criterion.

Lusted Hill is located in Multnomah County. The existing site is zoned by Multnomah County Land Use Planning as Commercial Forest Use (CFU) and area to the northwest is zoned as Exclusive Farm Use (EFU). A facility located at the existing site would be considered a Community Service Use but classified as a Conditional Use in the CFU zone. Both of these land use reviews are Type III Reviews. A facility located at the likely area of expansion is not specifically listed as an allowed use or conditional use in an EFU zone. A water treatment/filtration facility could be permitted in EFU zones pending an alternative site analysis, whereby a thorough analysis of all reasonable, non-EFU sites are considered along with the reasons for rejection.

To get approval to construct a filtration facility on land zoned as EFU, the following approval criteria ('Necessity Test') must be addressed as part of a land use application with Multnomah County.

> An applicant must show that reasonable alternatives have been considered and that the facility must be sited in an exclusive farm use zone due to one or more of the following factors:
>
> (A) Technical and engineering feasibility;
>
> (B) The proposed facility is locationally dependent. A utility facility is locationally dependent if it must cross land in one or more areas zoned for exclusive farm use in order to achieve a reasonably direct route or to meet unique geographical needs that cannot be satisfied on other lands;
>
> (C) Lack of available urban and non-resource lands;
>
> (D) Availability of existing rights of way;
>
> (E) Public health and safety; and
>
> (F) Other requirements of state and federal agencies.

Although it appears that siting a water treatment plant on this site would only require a Type II land use review, it may be advisable to elevate an application to a Type III if there is a likely possibility for an appeal. Regarding impact to schedule, it is estimated to take 150 days for a Type III review and 6 months with an appeal to the Oregon State Land Use Board of Appeals (LUBA). Land acquisition for the Lusted Hill site expansion could occur if the owner is interested in selling or through the condemnation process. PWB's ROW Services indicated that land acquisition via condemnation is anticipated to require approximately 14 months to complete (and is anticipated to be the longer of the two acquisition processes). Worst case scenario, condemnation and permitting could take approximately two years. This timeline would be accelerated if the owners are willing to sell, if the appeals process is faster or if any of the phases can overlap. Thoughtful planning and project management would be essential to accommodate land acquisition and approval and still allow the project to meet the compliance schedule. Lusted Hill passed the schedule criterion.

5.5 Powell Butte

In 2001, the Panel recommended Powell Butte as a future treatment facility site due to its suitable elevation, location within the urban growth boundary, greater opportunities for public education and community recreation facilities, and the presence of an existing reservoir – thought to offer significant cost savings.

A facility at Powell Butte could be placed close to, or just below, the HGL, maximizing gravity flow to the facility (see Figure 7). However, pumping would be required to send water back up to retail and wholesale customers connected to the conduits between Headworks and Powell Butte, including the existing 16-inch Lusted Road Distribution Main connected to Conduits 2 and 4 at Lusted Hill. This would involve not only a pump station, but new pump mains to deliver water approximately 18–20 miles back east, at a significant cost and effort. Although Powell Butte passed the HGL criterion, it has significant drawbacks related to pumping filtered water back upstream (east) to customers.

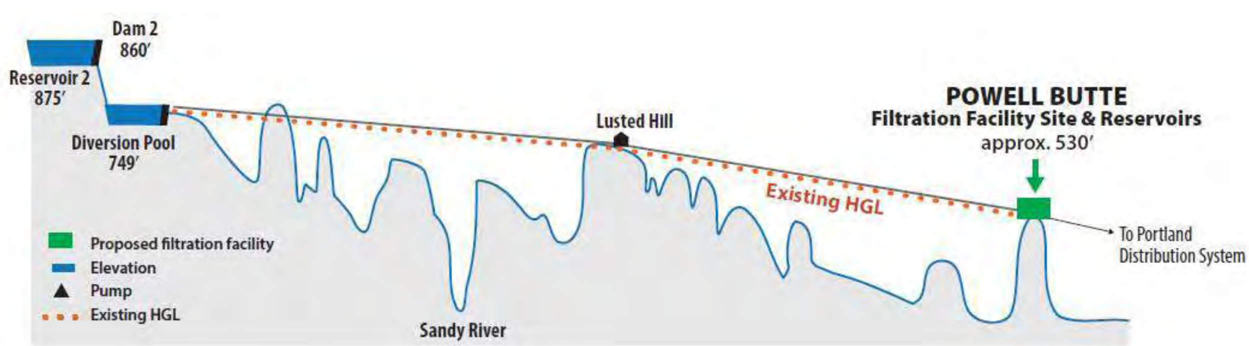


Figure 7. Illustration showing a filtration facility located at Powell Butte relative to the HGL. Note the facility is very close to the HGL and would have gravity flow.

Powell Butte is very close to existing piping infrastructure, with additional piping estimated to be less than most of the other sites, at approximately 2,000 feet. Since Powell Butte is within two miles of the existing and future conduit ROW, it passed the proximity criterion.

Powell Butte includes multiple taxlots, four of which are quite large and total over 530 acres, and therefore is large enough for a filtration facility. Powell Butte is encircled by areas of moderate to high landslide hazard. However, low landslide susceptibility exists near where a potential treatment facility would likely be sited on the butte's interior area. Considering slopes, geologic hazards, and existing facilities, it is estimated that the buildable area is 60 acres. Powell Butte passed the taxlot size, slopes, and geologic hazards criterion.

Powell Butte is located in Multnomah County, within the city of Portland, and is zoned as Open Space, low density residential, and multi-dwelling residential. In 2001, it was recognized that siting a facility at Powell Butte would have significant impacts on the park and surrounding neighborhoods (as the Panel was completing its work, some citizens expressed concerns about the social and environmental impacts of a facility at Powell Butte). Because of uncertainties of siting a treatment facility at Powell Butte, the Panel recommended a second site (Lusted Hill) remain under active consideration should neighborhood, environmental, or other issues render Powell Butte an inappropriate location.

More recently, Powell Butte Reservoir 2 was constructed at Powell Butte. Insight and experience from this project confirmed that neighborhood, environmental, or other difficulties would be significant if PWB were to construct a filtration facility at Powell Butte. It is also anticipated that Powell Butte would be the most difficult to secure land use approvals for development. This is because the land use process would require a Major Amendment to the Bureau's Powell Butte Conditional Use Master Plan (CUMP) and would trigger a subset of other land use reviews including conditional use, environmental, and likely an adjustment review to accommodate the impacts of development in the park and to the surrounding area. The Zoning and Land Use Review Analysis for Bull Run Water Treatment Plant Siting TM concluded that larger Powell Butte land use reviews (such as Reservoir 2 and CUMP) in the past have been appealed to LUBA by the neighborhood association and other public members, creating additional monetary costs, approval delays, and political scrutiny for the project and for PWB. These risks could significantly delay site approval, permitting, and facility construction by years. Therefore, Powell Butte did not pass the schedule criterion.

5.6 Roslyn Lake

In 2008, the large area known as Roslyn Lake was drained, making it available to develop, and therefore it was included in the 2009 TM. This former reservoir was part of the Bull Run Hydroelectric project. This land is not owned by the City or PWB but was for sale as of winter 2017/2018.

Of all six sites, Roslyn Lake deviates the farthest from the HGL (it is below the HGL) and year-round pumping would be required downstream of a facility to lift water back up to the HGL and over Lusted Hill (see Figure 8). Therefore, Roslyn Lake did not pass the HGL criterion.

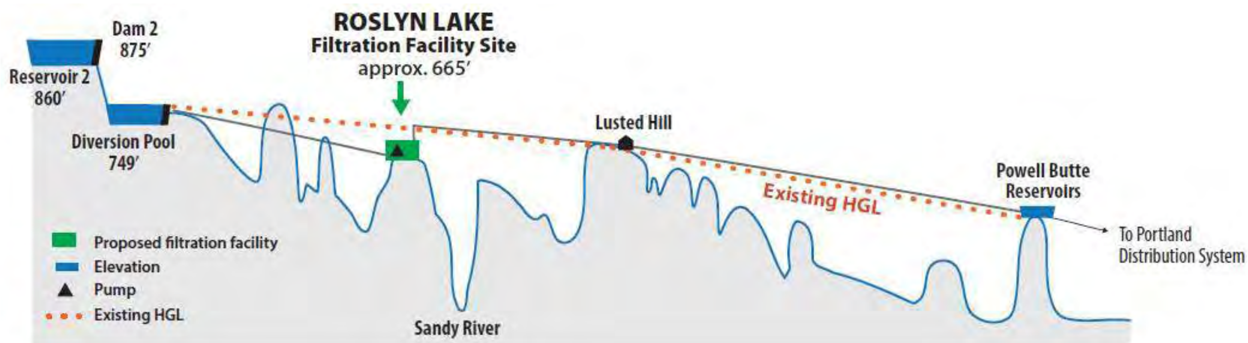


Figure 8: Illustration showing a filtration facility located at Roslyn Lake relative to the HGL. Note the facility is below the HGL. Pumping from the facility would be required.

The site is close to Conduits 2 and 4, although Conduit 3 would cross the Bull Run River twice with a new crossing. This crossing and additional Conduit 2 and 4 piping would pass through areas of high landslide susceptibility. It was previously estimated that 6,000 feet of additional piping would be needed to connect to all three conduits. Roslyn Lake is within two miles of the existing and future conduit ROW and passed the proximity criterion.

Roslyn Lake is large and relatively flat. Per DOGAMI, Roslyn Lake does not appear to be in an area of landslide hazard or have mapped landslides. It is estimated that the entire site (200+ acres) is buildable area and thus passed the taxlot size, slopes, and geologic hazards criteria.

Roslyn Lake is located in Clackamas County and is zoned as Timber and Farm Forest-10 Districts. A facility located here would be considered a Conditional Use review and is a Type III Review. Any tower constructed to hold radio or microwave antennae would be subject to review. Two sets of conditional use criteria must be addressed at this site: (1) general conditional use criteria that apply to any conditional use in Clackamas County; and (2) forest-related conditional use standards that address potential impacts to primary forest uses. Although there may be several other review types triggered, all the reviews discussed would be processed together through the Type III Review, which requires a public hearing before a Hearings Officer and approximately 150 days. There are no known significant risks to the project timeline or schedule related to land use reviews or permitting if this site were selected. Roslyn Lake passed the schedule criterion.

6.0 Summary of Sites Meeting Essential Criteria

Six potential filtration facility sites were evaluated for their ability to meet essential criteria. Table 1 summarizes the pass/fail scoring versus the essential criteria. Four of the sites failed to meet all essential criteria. Only two sites, Carpenter Lane and Lusted Hill, passed all essential criteria and were therefore evaluated further using the developed decision framework.

Table 1. Pass/Fail Results of How Well Each Initial Site Met the Essential Criteria

Site	HGL	Proximity to Conduits	Tax Lot Size	Slopes and Geologic Hazards	Schedule
Carpenter Lane	Pass	Pass	Pass	Pass	Pass
Headworks	Fail	Pass	Fail	Fail	Pass
Larson's Ranch	Fail	Pass	Pass	Pass	Pass
Lusted Hill	Pass	Pass	Pass (with site expansion)	Pass	Pass
Powell Butte	Pass	Pass	Pass	Pass	Fail
Roslyn Lake	Fail	Pass	Pass	Pass	Pass

Note: Shaded cells indicates site that meets all essential criteria.

7.0 Decision Framework and Criteria

The framework consists of eight values each having one or more criterion to help evaluate each alternative. Table 2 lists the values and criteria. Explanation of the decision framework, values, and criteria descriptions are found in the Filtration Decision Process memo. While all of the values are applied to each alternative, not every criterion in the values is applicable for the site decision. For example, the criteria "existing microbiological regulations" was determined as not applicable because the siting of the future plant has no direct bearing on how well it would meet these regulations, whereas such regulations have a significant impact on the separate filtration technology decision. The table also lists the criteria specifically excluded from the evaluation and the rationale.

Table 2. Decision Framework and Criteria Used For Siting Evaluation

Value	Criteria	Include/Exclude for Siting Evaluation	Reason
Public health and water quality	Existing microbiological regulations	Excluded	Compliance with regulations does not depend on siting of the facility.
	Organics/inorganics regulations	Excluded	Compliance with regulations does not depend on siting of the facility.
	Emerging water quality regulations	Excluded	Compliance with regulations does not depend on siting of the facility.
	Consistent water quality	Excluded	Siting does not significantly impact water quality.
	Chemical impacts	Excluded	The water treatment chemical dosage used does not depend on facility siting.
Resiliency/ reliability	Earthquake	Included	The ability to withstand seismic events is dependent on siting of the facility.
	Catastrophic water quality event	Excluded	Siting does not significantly impact the response to a catastrophic water quality event.
	Routine water quality event	Excluded	Siting does not significantly impact the response to a routine water quality event.

Value	Criteria	Include/Exclude for Siting Evaluation	Reason
Community interests	Local impacts	Included	The space between the facility and the neighbors to provide buffering from noise is a function of facility siting.
	Consistency in taste and appearance	Excluded	Water quality is not dependent on siting.
	Chemical concerns	Excluded	The water treatment chemical dosage used does not depend on siting but on treatment technology instead.
Cost benefit	Cost of construction	Included	This is a direct function of the extent of infrastructure that needs to be built at a given site.
	Total cost of delivered water	Included	The siting of the future facility has impact on the construction costs.
Future needs	Capacity	Included	The ability to maximize Dam 2 head is dependent on siting of the facility.
	Future water quality	Excluded	The size of additional processes required for the future facility is a function of its capacity, not siting.
	Available gravity capacity	Included	The gravity capacity available is dependent upon the siting of the facility.
Environmental impacts	Electricity usage	Included	The amount of pumping required is a function of the siting of the facility.
	Residuals produced	Excluded	The volume of residuals produced is independent of the facility site.
	Construction and operations fuel consumption	Excluded	The number of truck trips required depends on facility size and not site.
Integration	WTP labor	Included	The labor required to operate and maintain the pump station, the size of which is a function of hydraulics, is impacted by facility siting.
	Safety and operations	Included	Whether the facility requires a pump station to operate or not, depends on its siting.
	Corrosion control integration	Excluded	Corrosion control is related to water quality and not siting.
	Other infrastructure ramifications	Included	The need to construct connecting conduit piping and pump station depends on siting of the facility.
	Distribution system water quality	Excluded	Whether the future facility uses alternative management strategies such as groundwater is a direct function of its capacity and not siting.

Value	Criteria	Include/Exclude for Siting Evaluation	Reason
Implementation	Ease of construction	Included	Time taken to construct the facility is a function of its site.
	Implementation complexity	Included	The length of implementation schedule is a function of construction time, design, and start-up time, and is therefore related to facility siting.
	Land use permits	Included	The permitting requirements for construction and operation of the facility depends on the sites zoning.
	On- and off-site ownership	Included	Whether land acquisition is required depends on siting of the facility.

8.0 Criteria Evaluation

A quantitative score is developed for each criteria used to evaluate the two site alternatives. The quantitative score is based on either a calculated value developed from various models or a numerical score assigned to a qualitative description. For this scoring, a higher number means greater benefits and advantages whereas a lower number indicates substantial constraints and negative aspects. For this memo, only two alternatives are being considered: Lusted Hill and Carpenter Lane, hence scoring is 1 for the better alternative and 0 for the worse alternative.

This section describes each criterion, the scale used to develop the scoring, and the basis for the scoring. Table 3 summarizes the scoring. Several key assumptions have been made in order to support the criteria evaluation as follows:

1. The plant capacity is approximately 160 MGD per the April 2018 capacity decision.
2. The plant area is based on an assumption of ozone and direct filtration processes with other standard facility requirements. A total of 40 acres provides enough buildable area to construct and operate a 160 MGD plant with these processes and allows future build-out. Therefore, the difference in size between the 65 acre Carpenter Lane site and the 40 acre Lusted Hill site was not identified as a differentiating criterion except as indicated for “Local Impacts.”
3. The Carpenter Lane site is assumed to require the construction of a pump station.
4. The Carpenter Lane site requires a portion of new conduit to be constructed to connect the new facility to the existing infrastructure. The expanded Lusted Hill site is already on top of Conduits 2 and 4 and very close to Conduit 3, thereby needing fewer new connecting pipelines.
5. Property acquisition is not included in “Capital Cost” because the cost is unknown and is likely insignificant when compared with the project’s construction cost.
6. “Operating Costs” are included in “Lifecycle Cost” and are therefore not considered as a separate criterion.
7. Scores are assigned as either 1 or 0.

This page is blank.

Table 3. Evaluation Criteria and Valuation

Value	Public Health and Water Quality					Resiliency/Reliability			Community Interests			Cost Benefit		
Value Description	Provide drinking water that is safe and consistent					Facility maximizes likelihood of continued water provision, even after a fire or disaster			Integrate community interests in the decision making process			Getting the most benefit for the dollar		
Criteria	Existing Micro-biological Regulations	Organics/ Inorganics Regulations	Emerging Water Quality Regulations	Consistent Water Quality	Chemical Impacts	Earthquake	Catastrophic WQ Event (forest fire, landslide)	Routine WQ Events (elevated turbidity, algae bloom)	Local Impacts	Consistency in Taste and Appearance	Chemical Concerns	Cost of Construction	Operating Costs	Total Cost of Delivered Water
Performance Scale	Ability to meet existing regulations	Ability to meet existing regulations	Ability to meet future regulations	Use of Management Strategies	Chemical Selection	Ability to Maintain Supply	Half the Capacity	Treated Water Quality	Neighbors Impacted	Qualitative	Dosage	Capital Cost	Operating Costs	Lifecycle Cost
Carpenter Lane	N/A	N/A	N/A	N/A	N/A	1 point	N/A	N/A	1 point (65 acres to screen and buffer plant from neighbors)	N/A	N/A	0 points	N/A	0 points ($316 M)
Lusted Hill	N/A	N/A	N/A	N/A	N/A	0 points	N/A	N/A	0 points (40 acres to screen and buffer plant from neighbors)	N/A	N/A	1 point	N/A	1 point ($275 M)

Value	Future Needs			Environmental Impacts			Integration					Implementation			
Value Description	Maximizes ability to make adjustments in future			Minimize environmental impacts			Optimize operability & integration with PWB's systems and practices					Increases ability to implement and meet compliance schedule			
Criteria	Capacity	Future Water Quality	Available Gravity Capacity	Electricity Usage	Residuals Produced	Construction and Operations Fuel Consumption	WTP Labor	Safety & Operations	Corrosion Control Integration	Other infrastructure Ramifications	Distribution System WQ	Ease of Construction	Implementation Complexity	Land Use Permits	On- and Off-site Ownership
Performance Scale	Preserving Future Alternatives	Bull Run Water Quality	MGD	MWh/year	Volume produced	# Truck Trips + Operations Fuel Consumption	Required FTEs	Risk Management Program	Switching Sources/ Use of Management Strategies	Additional Infrastructure Needs	Use of Alternative Management Strategies	Risk to Schedule	Risk to Schedule	Risk to Schedule	Ownership
Carpenter Lane	1 point	N/A	0 points (130 +/-)	0 points	N/A	N/A	0 points	0 points	N/A	0 points	N/A	1 point	0 points	1 point	1 point
Lusted Hill	0 points	N/A	1 point (200)	1 point	N/A	N/A	1 point	1 point	N/A	1 point	N/A	0 points	1 point	0 points	0 points

This page is blank.

8.1 Earthquake

Performance Scale: The ability to resist seismic events such as earthquakes and maintain supply after a seismic event is crucial in deciding the facility site.

Note that investments in seismic reliability need to be informed by an overall vulnerability assessment as to the likely points of failure in the system. No assessment has been made as to the relative importance of the treatment plant site in the context of the entire PWB supply, transmission, and distribution systems.

Basis for Valuation: The criterion valuation is based on the alternative's improvement to the system's reliability post a seismic event. Carpenter Lane is a better option because it includes constructing more hardened conduit piping than Lusted Hill.

- Carpenter Lane: 1 point
- Lusted Hill: 0 points

8.2 Local Impacts

Performance Scale: Local impacts are defined as the number of construction trucks entering and leaving a given filtration plant site because the noise, traffic, and road dust from these truck trips are the principal impact to the neighbors. The preferred site would be one that provides more area to separate the plant from the neighbors, so as to buffer and minimize the noise, traffic and dust issues during construction as well as once the plant is operational. Note that both sites have relatively low density of development.

Basis for Valuation: The criterion valuation takes into consideration the area of the facility site. The larger the site area, the more space there is to screen and buffer the treatment plant from neighbors. Carpenter Lane has 65 acres to site the facility and provide dedicated area to screen and buffer the operating plant from adjacent neighbors, whereas the expanded Lusted Hill site only has 40 acres.

- Carpenter Lane: 1 point
- Lusted Hill: 0 points

8.3 Cost of Construction

Performance Scale: The cost of construction directly relates to the infrastructure that needs to be built at a given site. The site that requires less new infrastructure would reduce the cost of construction and would therefore be preferred.

Basis for Valuation: The following scoring is developed for this criterion:

- Carpenter Lane: 0 points, because it requires building of a new pump station and conduit piping in order to achieve 160 MGD hydraulic capacity.
- Lusted Hill: 1 point, because the expanded Lusted Hill site is already on top of Conduits 2 and 4 and very close to Conduit 3, thereby needing fewer new connecting pipelines. The site also does not require a pump station.

8.4 Total Cost of Delivered Water

Performance Scale: The total cost of delivered water is scaled on the basis of lifecycle cost. The lifecycle cost depends on the gravity flow of the Bull Run filtration plant and the need to construct a pump station at a given site. A site that reduces the need for a pump station and/or construction of conduit piping to achieve the desired hydraulic capacity could reduce the cost of delivered water.

Basis for Valuation: Carpenter Lane site requires a pump station in order to achieve 160 MGD hydraulic capacity and construction of conduit piping to connect the plant to the existing transmission system. The Lusted Hill site is capable of up to 200 MGD of gravity flow and does not require a pump station. In addition, the site is located on top of Conduits 2 and 4 and very close to Conduit 3, thereby requiring much less interconnection piping. The total alternative cost for Lusted Hill is the baseline cost of construction of $275 million. For Carpenter Lane, an additional $41.4 million is required for pump station and Conduit 5, bringing its total cost of delivered water to $316 million.

The following scores are assigned to the two sites:

- Carpenter Lane: 0 points
- Lusted Hill: 1 points

8.5 Capacity

Performance Scale: PWB values preserving the future opportunity to utilize the higher head at Dam 2, thereby preserving the opportunity to increase the overall gravity capacity of the system. The site that offers greater ability to utilize Dam 2 head is preferred.

Basis for Valuation: Driving flow with Dam 2 head could increase gravity capacity in the future. Carpenter Lane would achieve greater gravity flow than Lusted Hill due to its higher site elevation. The following qualitative scaling is developed for this criterion:

- Carpenter Lane: 1 point
- Lusted Hill: 0 points

8.6 Available Gravity Capacity

Performance Scale: The available gravity capacity of the treatment facility for a given site is important in order to maximize the ability to make future adjustments. The site that offers more gravity capacity is preferred. The points are assigned based upon the estimated million gallons per day of available gravity capacity.

Basis for Valuation: At the Carpenter Lane site, there is an estimated 130 +/- MGD of available gravity capacity. At the expanded Lusted Hill site, there is an estimated 200 MGD of available gravity capacity. The actual value at either site will vary depending on piping and treatment plant configurations. The following qualitative scaling from is developed for this criterion:

- Carpenter Lane: 0 points

- Lusted Hill: 1 point

8.7 Electricity Usage

Performance Scale: Electricity usage of the Bull Run filtration plant consists of the required treatment processes and pumping of any water into or out of the plant. By assuming that each site has the same treatment processes, the only differentiator is the amount of water pumping required. The alternative that requires a lesser amount of, or no pumping is preferred.

Basis for Valuation: The following scoring is developed for this criterion:

- Carpenter Lane: 0 points, because it does require the water to be pumped whenever demand exceeds the available gravity capacity. The frequency of pumping is not included or evaluated as part of this analysis.
- Lusted Hill: 1 point, because no pumping is required since the available gravity capacity (200 MGD) exceeds the plant capacity (160 MGD).

8.8 WTP Labor

Performance Scale: This criteria is scaled on the basis of full-time equivalent (FTE) required at the facility site. By assuming that each site has the same treatment processes, the only differentiator is the monitoring and maintenance associated with a pump station.

Basis for Valuation: The Carpenter Lane site requires a pump station, which means more labor is required compared to the Lusted Hill site. Thus, Lusted Hill is a better site for this criterion. The scoring for both the alternatives is as follows:

- Carpenter Lane: 0 points
- Lusted Hill: 1 point

8.9 Safety and Operations

Performance Scale: Safety and operations take into consideration the number and complexity of the treatment plant operations. As with the prior criteria, the assumption that each site has the same treatment processes means the only differentiator is the operation of a pump station.

Basis for Valuation: The scoring for the two alternatives is as follows:

- Carpenter Lane: 0 points, because this site requires a pump station.
- Lusted Hill: 1 point, because this site does not require a pump station.

8.10 Other Infrastructure Ramifications

Performance Scale: The performance scale is based on the need to construct new conduit piping and a pump station to connect the new facility to existing infrastructure. A site that reduces the need for conduit piping or a pump station is anticipated to reduce infrastructure ramifications and scores higher than a site that has increased infrastructure ramifications.

Basis for Valuation: More conduit piping and a pump station needs to be constructed for the Carpenter Lane site to connect the site to the other PWB transmission infrastructure. The expanded Lusted Hill site is located next to the existing conduits and would not require extensive modification of other infrastructure.

- Carpenter Lane: 0 points
- Lusted Hill: 1 point

8.11 Ease of Construction

Performance Scale: Ease of construction takes into consideration the effect of facility site on the length of construction schedules. With all other factors being equal (capacity, filtration technology, and monthly cash flow), it might be easier to construct on one site as compared to the other.

Basis for Valuation: The following scoring is assigned for this criterion:

- Carpenter Lane: 1 point for being a greenfield site with almost no interfering infrastructure and no requirements to work around the existing system
- Lusted Hill: 0 points, because it has buried conduits that need to be protected during construction

8.12 Implementation Complexity

Performance Scale: Implementation complexity takes into consideration the effect of facility site on the length of construction schedules, design, and start-up time for the facility.

Basis for Valuation: The following scoring is assigned for this criterion:

- Carpenter Lane: 0 points, because more infrastructure (conduit piping and pump station) needs to be built
- Lusted Hill: 1 point, because less infrastructure needs to be built

8.13 Land Use Permits

Performance Scale: The time to acquire land use permits could impact the project schedule. The site that requires the least amount of permitting time, and schedule risk, is preferred.

Basis for Valuation: Carpenter Lane site is zoned MUA20 and is anticipated to follow a standard Conditional Use review process, making the land use application approval more likely.

The Lusted Hill site is zoned EFU and requires that PWB conduct an analysis of the surrounding area and successfully demonstrate to the county that nearby non-EFU parcels cannot be used. The time and effort for successful demonstration for Lusted Hill will likely be longer than the approval process for Carpenter Lane, and land use application approval at Lusted Hill may still not occur.

- Carpenter Lane: 1 point
- Lusted Hill: 0 points

8.14 On- and Off-site Ownership

Performance Scale: The performance scale is based on whether the site is owned by the City of Portland or not. A site owned by the City would score higher than one not owned by the City.

Basis for Valuation: Carpenter Lane is a City-owned site and therefore does not require land acquisition. The additional land needed to expand Lusted Hill is not owned by the City and requires land acquisition.

- Carpenter Lane: 1 point
- Lusted Hill: 0 points

9.0 Evaluation

The PWB Filtration Team, including all representatives of the Executive Team, met on May 23, 2018, to review the performance of the site alternatives and reach a conclusion on the preferred site alternative. The decision model incorporated the values, criteria, and performance scales of the two viable site alternatives. The resulting scoring was used to highlight site differences, prompt team discussion around potential concerns, and help the team select a preferred alternative. Throughout the evaluation and review, the team reminded itself that the decision model alone does not make the decision. This context assured that the decision model and the evaluation of alternatives were designed to inform the technical team and the Executive Committee, not make the decision for PWB.

Three weighting scenarios were carried through the process to reflect the different perspectives of the PWB team members. The three weighting scenarios were:

1. Team Weighted (TW) – The PWB Filtration Team weights produced on March 27, 2018.
2. Equal Weights (EQ) – Equal weights among the eight values.
3. Split (SP) – A 60/40 split weighting where 40 percent of the weight remained with Public Health Water Quality (25 percent) and Reliability (15 percent) as identified in the team weighted scenario, and the remaining 60 percent was distributed equally among the other six values.

These weighting scenarios were carried through the evaluation process to demonstrate weighting sensitivity. The summary of these weights are shown in Table 4. Note that the Public Health and Water Quality value and its associated criteria are not included in the weighting table. Table 2 above summarizes the reasoning for excluding the Public Health and Water Quality value. The numbers in Table 4 present the relative weight of the values (highlighted in dark blue) and the distribution of the weights across criteria within specific criteria (highlighted in light blue).

Table 4. Weighting Scenarios

ID#	Evaluation Criteria	TW	EQ	SP
2	**Resiliency/Reliability**	15	12.5	15
3	**Community Interests**	9	12.5	10
4	**Cost Benefit**	12	12.5	10
4.1	Capital cost	5.4	6.25	5
4.2	Lifecycle cost	6.6	6.25	5
5	**Future Needs**	10	12.5	10
5.1	Capacity	5.2	6.25	5
5.2	Available gravity capacity	4.8	6.25	5
6	**Environmental Impacts**	7	12.5	10
7	**Integration**	12	12.5	10
7.1	WTP Labor	5.3	4.17	3.33
7.2	Safety & Operations	3.2	4.17	3.33
7.3	Other ramifications	3.5	4.17	3.33
8	**Implementation**	10	12.5	10
8.1	Ease of Construction: Risk to schedule	2.2	3.125	2.5
8.2	Implementation Complexity: Risk to schedule	3.1	3.125	2.5
8.3	Land use permits	2.4	3.125	2.5
8.4	On- and Off-site ownership	2.2	3.125	2.5

The performance ratings of the alternatives found in Table 3 and the weighting of the values and criteria found in Table 4 are the inputs for the evaluation of the site alternatives. The normalized performance rating multiplied by the weight and added across values and criteria produces a value score. Table 5 demonstrates this calculation.

Columns K and L in Table 5 list the values and criteria and their associated weights. In the calculation in Table 5, the weights that are showcased are those associated with the Team weighting scheme (TW) in Table 4. Column B of Table 5 displays the weight percentage of each value/criterion. This weight percentage is the number that is carried through the evaluation calculation. Columns E and F summarize the performance ratings of each site alternative. These are the same numbers that are presented in Table 3 and further characterized in Section 8. Columns C and D reflect the minimum and maximum performance ratings among the alternatives. Columns G and H are the normalized performance ratings of the two alternatives. Normalization (calculating performance in a 0 to 1 scale) is done for all performance scales to allow for common application in the evaluation. Regardless of the scale used to demonstrate performance of the alternatives (i.e., performance scale of site acres for Community Interests/Local Impacts), normalization produces a 0 for the worst performer and a 1 for the best performer within each value/criterion. Columns I and J are the calculated values scores for each value/criterion. This is the multiplication of the weight (Column B) times the Normalized Rating (Column G or H) times 100 (the 100 is just to make the result a more manageable number). The calculations within each cell of Columns I and J reflect the contribution of value the respective alternative receives from the specific value/criteria. The summation of these contributions down Column I or J produces the total value score for each site alternative. The result for Carpenter Lane is 48.1 and for Lusted Hill is 51.9. These total values scores demonstrate, relatively, how well the alternatives perform against the values and criteria. The higher the number, the better the relative performance.

Table 5. Value Score Calculations

A	B	C	D	E	F	G	H	I	J	K	L
	Weight %	Raw Ratings				Normalized Ratings		Value Scores (weight times normalized rating times 100)			
Value/ Criteria No.	TW	Minimum	Maximum	Carpenter Lane	Lusted Hill	Carpenter Lane	Lusted Hill	Carpenter Lane	Lusted Hill	Value/Criteria	Assigned Weight (TW)
2	20.0%	0	1	1	0	1	0	20.0	0.0	**Resiliency/Reliability/**Earthquake	15
3	12.0%	0	1	1	0	1	0	12.0	0.0	**Community Interests/**Local Impacts	9
4.1	7.2%	0	1	0	1	0	1	0.0	7.2	**Cost Benefit/**Cost of Construction	5.4
4.2	8.8%	0	1	0	1	0	1	0.0	8.8	**Cost Benefit/**Cost of Delivered Water	6.6
5.1	6.9%	0	1	1	0	1	0	6.9	0.0	**Future Needs/**Capacity	5.2
5.2	6.4%	0	1	0	1	0	1	0.0	6.4	**Future Needs/**Available Gravity Capacity	4.8
6	9.3%	0	1	0	1	0	1	0.0	9.3	**Environmental Impacts/**Electricity Usage	7
7.1	7.1%	0	1	0	1	0	1	0.0	7.1	**Integration/**WTP Labor	5.3
7.2	4.3%	0	1	0	1	0	1	0.0	4.3	**Integration/**Safety & Operations	3.2
7.3	4.7%	0	1	0	1	0	1	0.0	4.7	**Integration/**Other Ramifications	3.5
8.1	3.0%	0	1	1	0	1	0	3.0	0.0	**Implementation/**Ease of Construction	2.2
8.2	4.2%	0	1	0	1	0	1	0.0	4.2	**Implementation/**Implementation Complexity	3.1
8.3	3.2%	0	1	1	0	1	0	3.2	0.0	**Implementation/**Land Use Permits	2.4
8.4	3.0%	0	1	1	0	1	0	3.0	0.0	**Implementation/**On & Off-site Ownership	2.2
				Total Value Scores (sum of all values/criteria value scores):				48.1	51.9		

Figures 9 through 11 demonstrate the performance of the two site alternatives within the three different weighting scenarios. The numbers below each stacked bar present the summation of the value score. Each color of the stacked bar represents the contribution the alternative received from each value. Each value has criteria that are used to gauge the performance of the alternatives. The size of the colored bar is determined by multiplying the performance score the alternative received (Table 3) by the weight of the specific criterion (Table 4). The results of the criteria scores are then added to produce the total contribution per value. The higher the total score, the higher the collective performance of the alternative against the values.

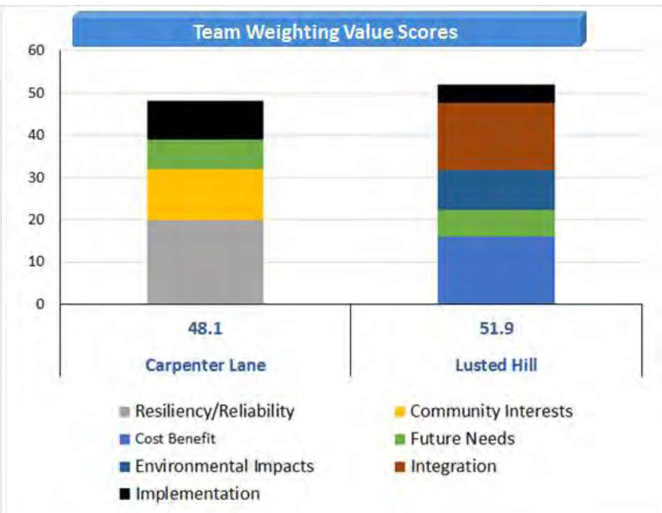


Figure 9. Team Weighting Value Scores

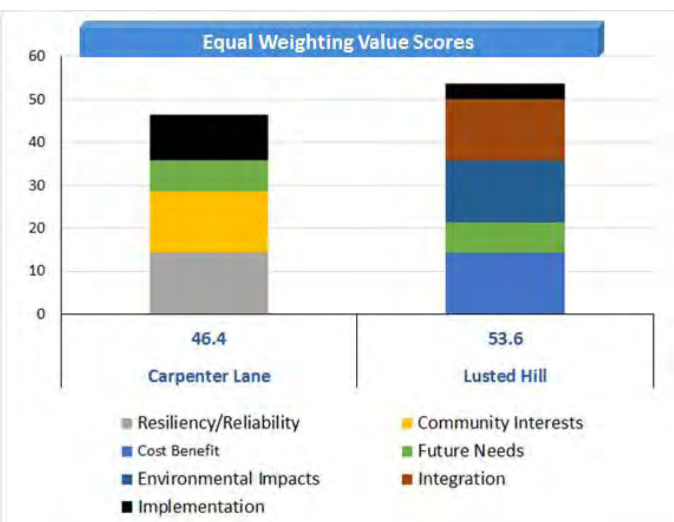


Figure 10. Equal Weighting Value Scores

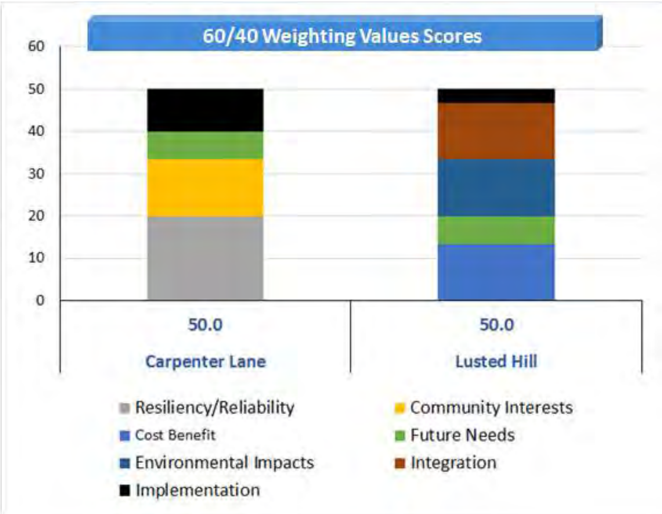


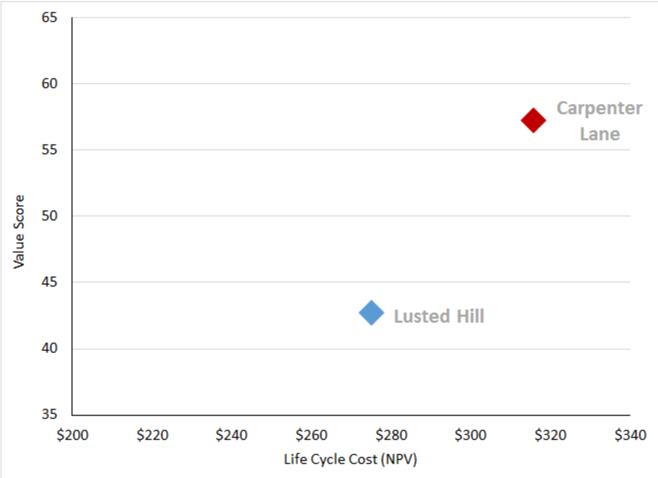
Figure 11. 60/40 Split Weighting Value Scores

In two of the three weighing schemes, Lusted Hill has a slight numerical advantage over Carpenter Lane. The split weighting scheme (the third weighting scheme) shows the two alternatives performing evenly.

Another means to evaluate the performance of the alternatives is to contrast the total cost of the alternatives (the actual cost of construction plus the cost of total delivered water) against their total value score. This comparison provides another view of the value received versus the total cost of the alternative. The value score for this calculation includes Resiliency/Reliability, Community Interests, Future Needs, Environmental Impacts, Integration, and Implementation values. To avoid double counting of the cost element, the Cost Benefit value is removed from the calculation of the value score. The resulting total value score is then graphically plotted against the total alternative cost (see Figures 12 through 14). The results demonstrate the superior position of Carpenter Lane in terms of cost and cost per unit of value.

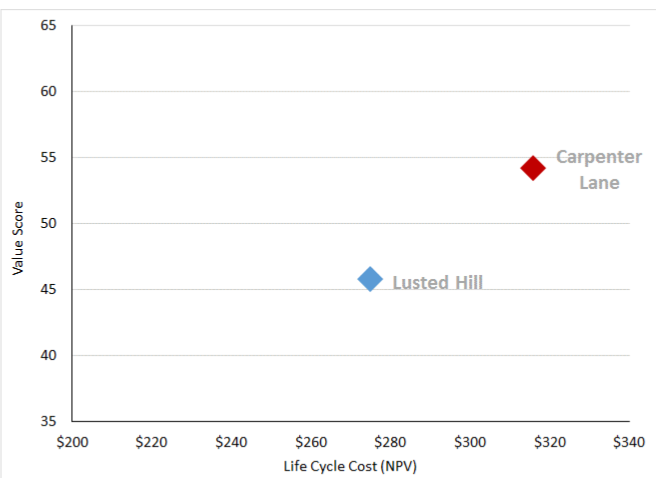
The total alternative cost is based upon the addition of a baseline cost of construction of $275 million for a 160 MGD facility. The total cost of delivered water is added to this baseline cost to produce the total alternative cost associated with each site. Lusted Hill has no additional cost of delivered water. Carpenter Lane has an additional cost of delivered water of: $41.4 million – a $13.1 million pump station and $28.3 million for 2.8 miles of Conduit 5.

This comparison also allows for a calculation of the investment required per unit of value. The table associated with the scatter plot presents the total cost ($M) to gain a unit of value. The table also demonstrates the additional alternative cost and resulting additional value in the movement to more valued alternatives. The same three weighting scenarios are evaluated.



	Value Score	Alternative Cost $M	$M per unit of value (lower better)	Additional value	Additional Alternative Cost $M	Additional $M per unit of value
Carpenter Lane	57.3	$ 316.00	$ 5.52	14.5	$ 41.00	2.83
Lusted Hill	42.7	$ 275.00	$ 6.43	---	---	---

Figure 12. Team Weighting Scatter Plot[1]



	Value Score	Alternative Cost $M	$M per unit of value (lower better)	Additional value	Additional Alternative Cost $M	Additional $M per unit of value
Carpenter Lane	54.2	$ 316.00	$ 5.83	8.3	$ 41.00	4.92
Lusted Hill	45.8	$ 275.00	$ 6.00	---	---	---

Figure 13. Equal Weighting Scatter Plot[2]

	Value Score	Alternative Cost $M	$M per unit of value (lower better)	Additional value	Additional Alternative Cost $M	Additional $M per unit of value
Carpenter Lane	57.7	$ 316.00	$ 5.48	15.4	$ 41.00	2.67
Lusted Hill	42.3	$ 275.00	$ 6.50	---	---	---

Figure 14. 60/40 Split Weighting Scatter Plot[3]

All of the scatter plot views demonstrate the performance benefit of Carpenter Lane, but with additional investment required.

The PWB Filtration Team produced one additional view of the performance data. Further discussion on May 23, 2018, moved the team to reconsider the influence of some of the criteria; in particular, the weighting of the values and criteria. This was done to help the technical team and the Executive Committee better understand the importance and influence of specific criteria, demonstrate tradeoffs, and support conversation among the team members. Based upon the technical team's deliberations, a refreshed weighting scheme was produced. Table 6 below displays the results of this modified weighting scheme. The modified weighting scheme is the first set of numbers, the last column presents the original weighting scheme for comparison. Note that the Public Health and Water Quality value and its associated criteria are not included in the weighting table because that value was deemed to not be applicable to the evaluating the site alternatives.

[1] The total alternative cost is based upon the addition of a baseline cost of construction of $275 million for a 160 MGD facility. The total cost of delivered water is added to this baseline cost to produce the total alternative associated with each site. Lusted Hill has no additional cost of delivered water. Carpenter Lane has an additional cost of delivered water of: $41.4 million – a $13.1 million pump station and $28.3 million for 2.8 miles of Conduit 5.
[2] ibid
[3] Ibid

Table 6. Modified Weighting Scheme

ID#	Evaluation Criteria	Modified Weighting SP	Original Weighting SP
2	**Resiliency/Reliability**	10	15
3	**Community Interests**	5	10
4	**Cost Benefit**	10	10
4.1	Capital cost	5	5
4.2	Lifecycle cost	5	5
5	**Future Needs**	20	10
5.1	Capacity	6	5
5.2	Available gravity capacity	14	5
6	**Environmental Impacts**	10	10
7	**Integration**	10	10
7.1	WTP Labor	3.33	3.33
7.2	Safety & Operations	3.33	3.33
7.3	Other ramifications	3.33	3.33
8	**Implementation**	30	10
8.1	Ease of Construction: Risk to schedule	7.5	2.5
8.2	Implementation Complexity: Risk to schedule	7.5	2.5
8.3	Land use permits	7.5	2.5
8.4	On- and Off-site ownership	7.5	2.5

The modifications to this new weighting scheme included a decrease in Resiliency/Reliability and Community Interests values (which some team members thought seemed over-valued), and an increase in Future Needs and Implementation values (which some team members thought seemed under-valued), and an increase in Future Needs and Implementation values (which some team members thought seemed under-valued due to the possible complexities of land use). This was done primarily to reflect the strong influence of land-use upon the schedule. The resultant scoring from this revision is shown on the following figures 15 and 16.

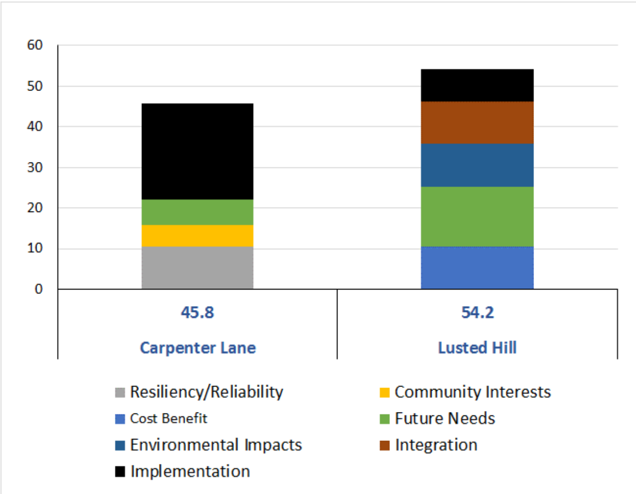
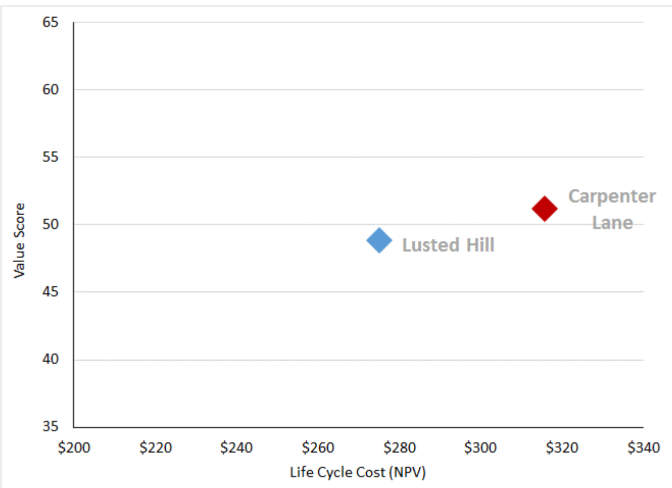


Figure 15. Modified Team Weighting Value Scores



	Value Score	Alternative Cost $M	$M per unit of value (lower better)	Additional value	Additional Alternative Cost $M	Additional $M per unit of value
Carpenter Lane	51.2	$ 316.00	$ 6.17	2.4	$ 41.00	17.41
Lusted Hill	48.8	$ 275.00	$ 5.63	---	---	---

Figure 16. Modified Weighting Value Scatter Plot

Again, this modified weighting scheme demonstrated that Lusted Hill value score when incorporating all values (Figure 15), but Carpenter Lane was a better alternative in the value versus alternative cost view (Figure 16).

All four weighting scenarios were used to help the Filtration Team discuss the pros and cons of each site, which included the uncertainty associated with land use application approval at Lusted Hill and the additional costs associated with Carpenter Lane. At two times in the deliberations, voting was cast for a preferred alternative. No clear consensus was reached by the project team but the pros and cons of both options were relayed to the Executive Committee for their consideration.

Upon seeking legal advice on setting up a facility on a land designated as EFU, the following feedback was received:

Under ORS 215.275, a utility facility for public service may be sited on EFU land in a nonmarginal lands county if reasonable alternatives have been considered and the facility <u>must</u> be sited on EFU land due to one or more of the following six factors:

- Technical and engineering feasibility;
- The proposed facility is locationally dependent. A utility facility is locationally dependent if it must cross land in one or more areas zoned for EFU in order to achieve a reasonably direct route or to meet unique geographical needs that cannot be satisfied on other lands;
- Lack of available urban and non-resource lands;
- Availability of existing rights of way;
- Public health and safety; and
- Other requirements of state or federal agencies.

Per these factors, the availability of existing ROWs (Conduits 2 and 4) is the most reasonably applicable factor. This single factor is likely insufficient to support rejecting Carpenter Lane as a reasonable alternative. The fact that Carpenter Lane is an available non-resource land, condemned for the purpose of a future filtration plant is also a factor that will likely weigh heavily against any argument that the filtration plant must be sited on EFU land.

The other point of discussion during the Executive Committee meeting was handling capacity at the Carpenter Lane site. Since the Carpenter Lane site is located higher than the existing HGL, the gravity flow capacity would be less than 160 MGD (approximately 130 MGD), the chosen capacity of the future facility. Although the site can be connected to Dam 2 to take advantage of higher head in the future, construction of Conduit 5 and connecting to Dam 2 are not part of the treatment plant development. To provide capacity of 160 MGD, a combination of treatment facility elevation, pumping, and piping choices will need to be developed. Further, after Tualatin Valley Water District reduces their demand, the stress year summer average demand is anticipated to be around 110 MGD. In that case, 130 MGD might be sufficient to meet the near-term average day demands.

10.0 Recommendation

The results from the decision model were discussed at length by the PWB Filtration Team and the Executive Committee. Since the scores for both the alternatives were so close in all three initial weighting schemes and the modified weighting scheme, the filtration team and the Executive Committee were split between the two sites. A major concern was with Lusted Hill being an EFU zoned site. Receiving a conditional land use approval on EFU zoned land was identified as a significant hurdle. Team members with more extensive knowledge of state land use felt an approval was unlikely to be granted. Others felt that even if an approval would eventually be granted, the approval process would be drawn out to the point where it would likely prevent PWB from meeting the compliance deadline.

The team was concerned about the risk to the schedule of siting the facility within an EFU zone. To be better informed about this risk, the Executive Committee consulted with the City Attorney. The City Attorney's opinion was that in this situation attempting to build on EFU land would be an unacceptable risk to the schedule. Therefore, Carpenter Lane was selected by the Executive Committee.

Appendices

A. Bull Run Treatment Decision

B. Bun Run Treatment Panel

C. Draft Site Considerations for PWB Water Treatment Facility

D. Zoning and land Use Review Analysis for Bull Run Treatment

Appendix A: Bull Run Treatment Decision

BULL RUN TREATMENT DECISION PROJECT

TECHNICAL MEMORANDUM: WATER TREATMENT PLANT SITING EVALUATION

This Technical Memorandum summarizes the results of siting investigations for a potential future water treatment facility for the City of Portland.

BACKGROUND

Treatment for the inactivation of the parasite *Cryptosporidium* will be mandated by federal regulation, scheduled for promulgation in 2003. It is anticipated that the schedule for compliance with this regulation will require the installation of additional disinfection or filtration treatment for the Bull Run supply by 2011.

In April 2001, the Portland Bureau of Water Works (Bureau) convened the Bull Run Treatment Panel (BRTP) to evaluate options for the future treatment of the Bull Run supply. The BRTP included representatives from a broad range of interests and backgrounds, including public health, environmental protection, wholesale water customers of the City, the business community and the public at large. The BRTP was asked to make recommendations to the Bureau and to Portland City Commissioner Eric Sten on three specific questions:

- What type of treatment should Portland use to meet its water quality goals?
- Where should the treatment facility be sited?
- How should the facility be financed and implemented?

Siting evaluations were conducted in order to provide information to the BRTP. The BRTP was asked to conduct its deliberations within a framework that included considerations of long-term water supply, demand and related issues in the region.

SITING EVALUATION TECHNICAL SUMMARY

This Technical Memorandum summarizes the technical information and analysis that was presented to the BRTP. This information provided the basis for the siting recommendation given above.

Site selection criteria

A set of site selection criteria was developed by the Bureau in order to screen the universe of potential treatment sites. These criteria were categorized by the Bureau as either “essential” or “desirable”. The essential criteria are “pass/fail”, in that any site unable to meet one or more of these criteria would not be considered. This criteria list served as the primary screening tool. The list of desirable criteria is much longer, and was used by the BRTP to select among potentially feasible sites. These criteria consider relative costs and benefits, and can be measured either qualitatively or quantitatively.

Tier 1 - Essential Criteria. These criteria are essential to the proper functioning of the water treatment facility. Failure to meet the criteria eliminates a site from consideration. The BRTP reviewed and approved these criteria. The essential siting criteria are:

- The distance from the existing Bull Run transmission conduits to the treatment plant site must be less than 2 miles. This criterion functions as a surrogate for cost, and sets a limit on the acceptable cost of transmission into and out of the treatment plant. For an initial plant capacity of 250 mgd, an approximate cost for connection to the existing conduits is $30 million. This assumes that two 84-inch diameter lines would be constructed and intertied to the existing conduits. Transmission costs have been taken from the technical report *Supply, Transmission and Storage Analysis* (CH2M Hill & Montgomery Watson, August 2000) and updated based on the current Seattle-area Construction Cost Index of 7556 (May 2002). Costs include construction, engineering and administration, environmental studies and permitting. Potential environmental mitigation costs are not included in this cost estimate.
- The size of the parcel must accommodate the ultimate size of the facility. The facility is assumed to be ultimately expandable to 500 million gallons per day (mgd) of capacity. For non-filtration technologies (UV and ozone), the required size of the parcel is 5 to 10 acres. For filtration treatment (direct filtration or membranes), the required size of the parcel is 25 to 50 acres. Based on the BRTP’s recommendation for membrane treatment, the required minimum parcel size is 25 acres.
- The parcel must be located outside a geologic hazard zone. Site geology must be suitable for construction.
- Site slopes must be less than 20 percent over at least 90 percent of the area of the parcel.
- The facility must be able to achieve a minimum flow by gravity of 95 mgd. This flow is equal to the current average winter demand. This criterion assures that the Bureau will be able to deliver a base level of supply by gravity and prevents a situation where the Bureau is completely dependent on pumping facilities to meet demand. The Bull Run system currently operates entirely by gravity to deliver water to major storage reservoirs at Powell Butte, Mount Tabor and Washington Park. Some pumped service is required to provide supply to the west hills and portions of south Washington County. The gravity flow criterion constrains the elevation of suitable sites. If a potential treatment site is too high, water will not be able to flow into the plant by gravity. Similarly, if the site is too low, water cannot flow out of the plant for

delivery. It is assumed that pumping would be required to achieve the full plant flow of 250 mgd.

Tier 2 – Desirable Criteria. These site criteria were developed by the Bureau. They are not essential to the functioning of the facility, but will affect cost, reliability, and ease of operation. These criteria are:

- In Water Bureau ownership or vacant with ability to purchase. The criterion assumes that the City would not condemn existing residential or commercial developments in order to acquire property
- Distance to conduits equal/less than 1 mile
- Maximizes gravity flow
- Secure site
- Ease of locating SCADA/communications
- Ability to secure environmental permits
- Known site conditions
- Power availability
- Power reliability
- minimize upstream customers
- maximize available head
- good work location for staff
- minimize emergency response time
- ability to use/treat multiple sources
- ease of access
- no pretreatment required for conduits
- minimize construction costs
- compatibility with existing operations
- compatibility with existing facilities
- compatibility with potential future regional connections
- ease of FERC permitting
- ease of waste stream discharge
- compatibility with land use
- minimize neighborhood opposition
- outside of wild and scenic corridors
- favorable hydraulic conditions at high flows
- educational/public value

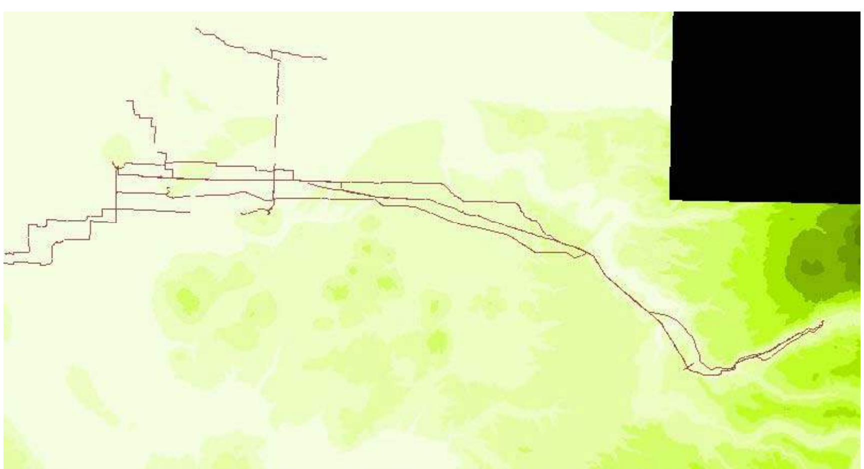
GIS Screening for Essential Criteria

GIS is a computer system that is capable of assembling, storing, manipulating and displaying geographically-referenced information. GIS has many applications, and is commonly used for development planning and siting. A GIS system can integrate many different sets of information and overlay them to evaluate a site with respect to multiple criteria. This approach was used in the siting evaluation. The criteria listed above were translated into physical features that could be mapped, and information was graphically layered to eliminate unsuitable sites in an iterative process. The sections below provide a step-by-step discussion of the site screening process.

Step 1. Data from Metro's Regional Land Information System (RLIS) was used as a starting point for development of the site screening GIS database. The RLIS files are the most accurate and current files available. These files contain multiple data sets including: streets, tax lots, service boundaries, land use and zoning designations, environmental conditions including water features (i.e. streams, rivers and wetlands) and major structures. The RLIS data files were supplemented with a Digital Elevation Model (DEM) created from the US Geological Survey (USGS). The DEM file provided a virtual model of the geographic landform of the region, and was used to screen potential sites for elevation and slope.

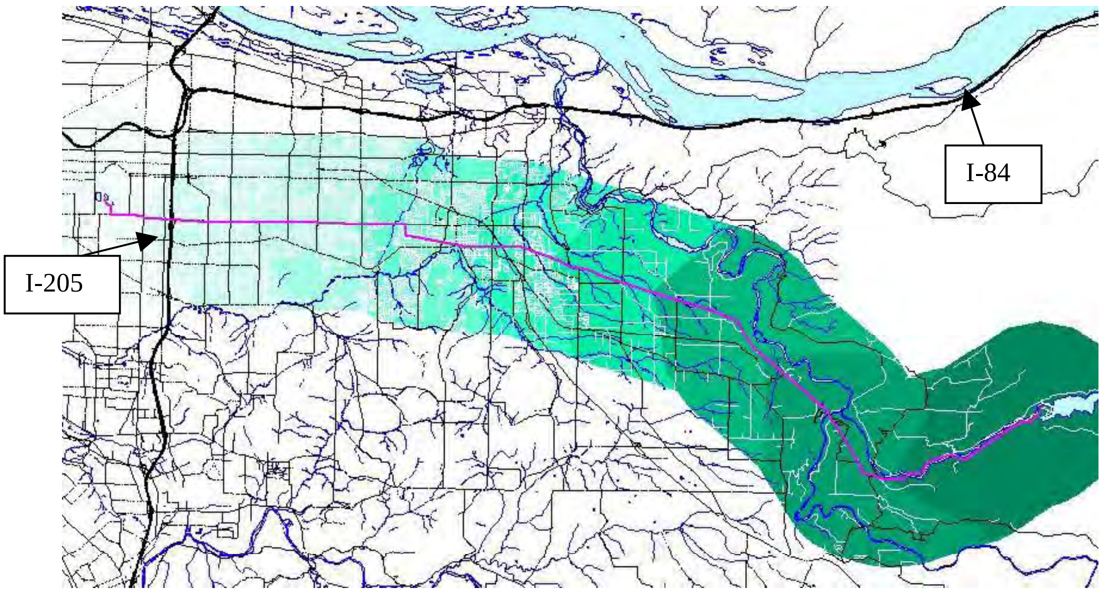
Step 2. The alignment of the existing Bull Run supply conduits was incorporated into the GIS database, as shown in Figure 1. In order to simplify the analysis, a generalized conduit alignment was developed to approximate the centerline of the three existing conduits.

Figure 1
Existing Conduit Alignments



Step 3. A two-mile buffer was established along each side of the generalized conduit alignment. This created a visual representation of the first essential site selection criteria. The buffer was approximate and did not account for road access, terrain or major barriers such as freeways and rivers. Figure 2 illustrates the 2-mile buffer.

Figure 2
Two-Mile Buffer Along the Generalized Conduit

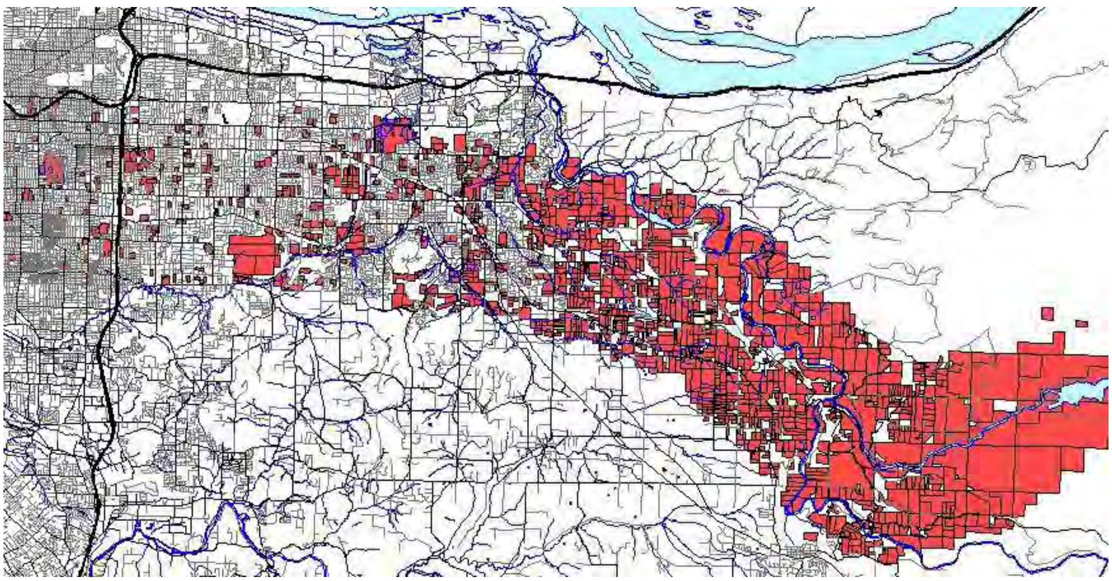


Step 4. The minimum parcel size as described above is 5 acres for a disinfection only treatment process. Filtration processes are more space intensive, and could require as much as 50 acres of land to achieve an ultimate capacity of 500 mgd. The GIS database was sorted by parcel size. As a simplifying assumption, no allowance was made for assembling smaller parcels to create a parcel of adequate size. Subsequent analysis considered areas within parcels that might limit development. Figure 3 shows a breakdown of parcels within the two-mile corridor by size classifications: >5 acres but < 15 acres, >15 acres but < 25 acres and >25 acres. Parcel size classifications are shown in Figure 3.

Step 5. Site slopes have the potential to limit construction on the site. Maximum acceptable slopes for construction of the treatment facility were defined as 20 percent. The analysis sorted parcels into slope ranges of 0-10 percent, 10-20 percent and above 20 percent. This information is shown in Figure 4. If a parcel had a portion that met the minimum size requirement with acceptable slopes, that parcel was considered adequate, even if parts of the parcel had slopes outside the acceptable range.

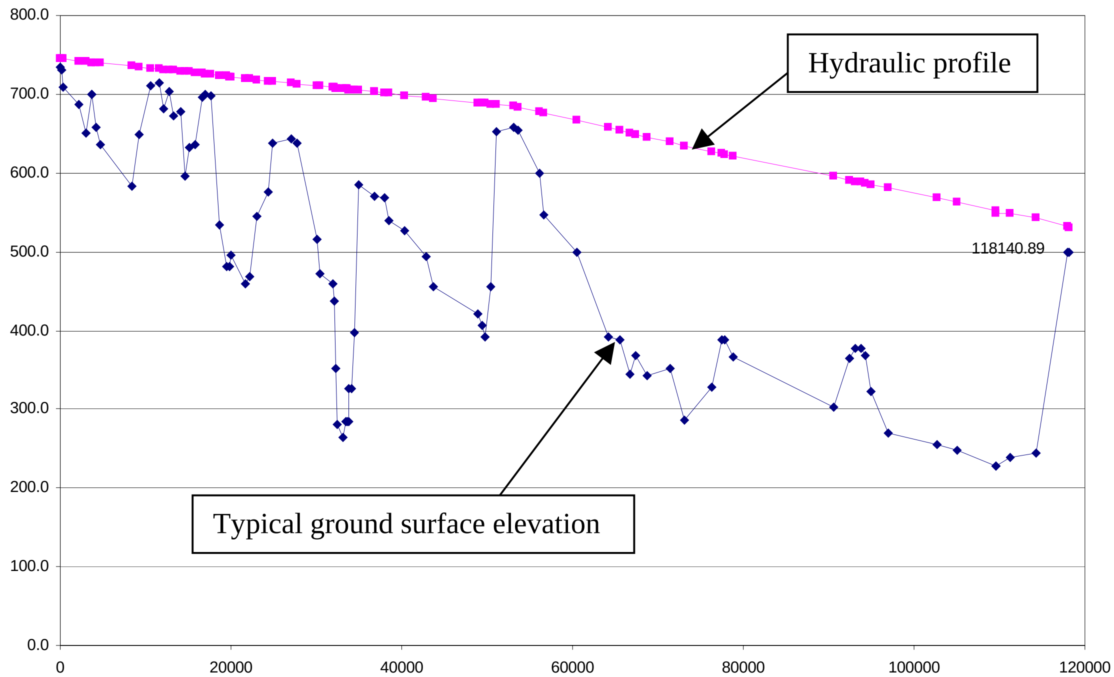
Step 6. The information generated for site slope, parcel size and distance from conduits was combined to provide a preliminary view of the universe of sites meeting most of the essential criteria. This view is given in Figure 5.

Figure 5
Parcels Meeting Size, Distance and Slope Criteria



Step 7. Site elevation was the final essential criteria to be evaluated. Specifically, the site must be capable of achieving a flow by gravity of 95 mgd. In a gravity system, water possesses energy (also known as "head"), and that energy is dissipated as water flows downhill from the Bull Run watershed to the City. Energy is primarily lost through friction in the piping, valves and fittings of the conduit system. The profile of energy loss through the system determines the acceptable elevation of the treatment facility. The facility must be at an elevation below the potential head at any location, yet high enough to retain energy for subsequent distribution. Thus, the acceptable elevation will vary along the conduit route, and must also account for head loss between the facility and the conduits. Figure 6 illustrates the energy profile for existing Conduit 4 at its origin in the Bull Run outlet works to its connection at the Powell Butte Reservoir.

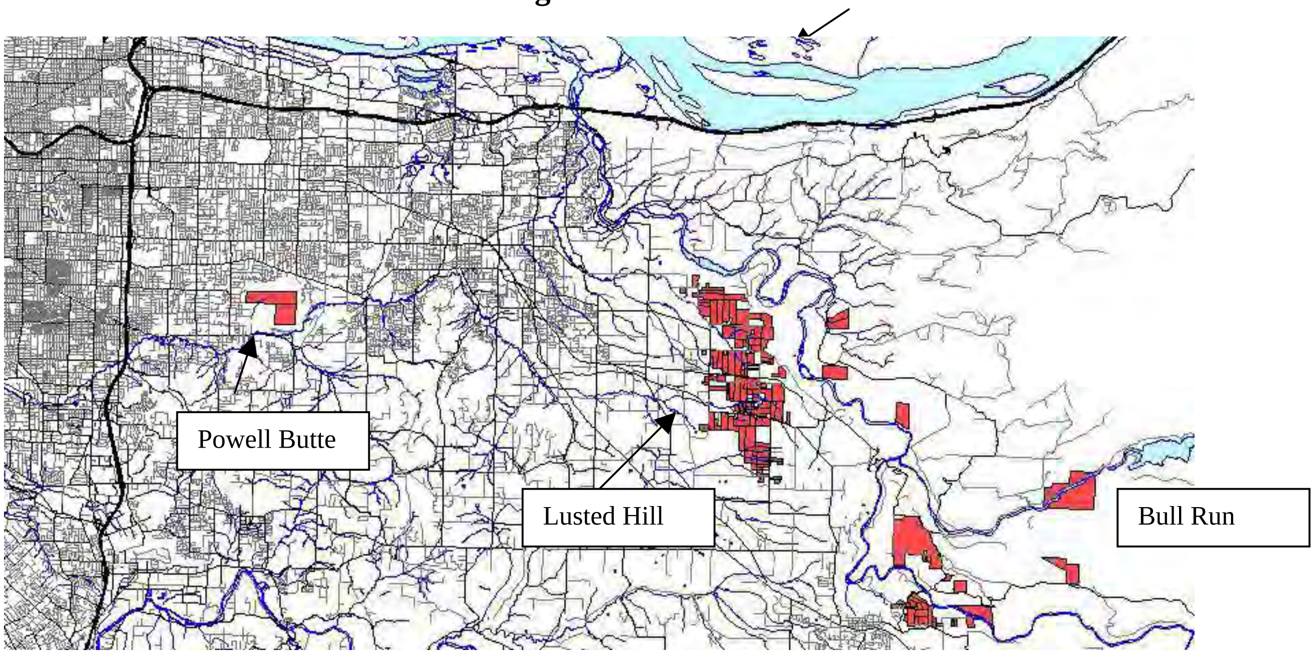
Figure 6
Hydraulic Profile of Conduit 4



For the siting evaluation, a gradient of headloss along the generalized conduit alignment was created. Headloss along the lateral lines connecting the treatment plant to the conduits was also accounted for, within the two-mile buffer. A three-dimensional surface representing acceptable elevation was created along the conduit alignment. The range of acceptable ground elevation was assumed to extend from 0 to 15 feet below the hydraulic profile, because some flexibility is provided by the ability to lower the water surface on a particular site by burying the water-holding structures. Site elevation data and the headloss surface profile were layered in order to identify hydraulically acceptable sites. This view is shown in Figure 7. A second iteration was performed to identify additional sites lying from 15 to 30 feet below the hydraulic grade line. No additional sites were found in this elevation range that met the other essential site criteria.

Step 8. In the final iteration, all essential criteria were layered to observe those sites capable of meeting criteria. This view is shown in Figure 8. Suitable parcels are shaded red.

Figure 8
Parcels Meeting All Essential Criteria



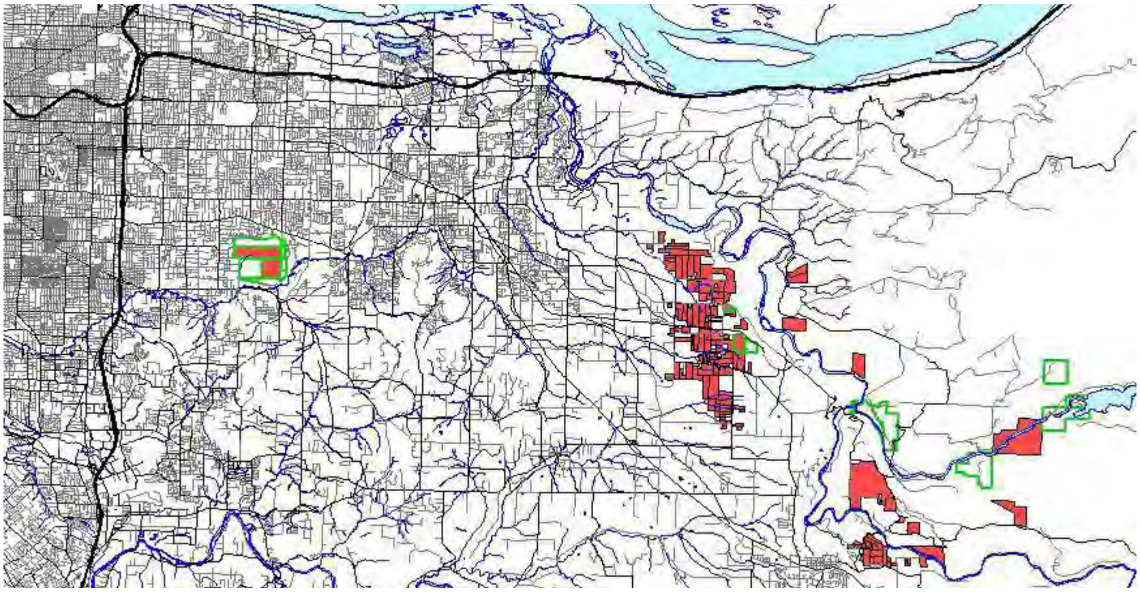
To the west, the Powell Butte property is seen to meet all essential criteria. Further east, multiple parcels in the Lusted Hill area meet the criteria. Even farther east, parcels in and around the Bull Run watershed also meet these criteria.

GIS screening of desirable criteria

Some additional evaluation was undertaken to provide information on the suitability of acceptable sites with respect to non-essential criteria. Specifically, land ownership and zoning were evaluated using the GIS tool. The results of an iterative evaluation of these criteria are given below.

Land ownership. This criterion assumes that sites already in City ownership are preferable, and that the Bureau would not condemn existing residential or commercial developments in order to acquire property. Figure 9 overlays City ownership on those sites meeting all essential criteria. City ownership is shown by the green boundary, and acceptable sites are shaded red. Powell Butte and Lusted Hill parcels meet all of these criteria. With the exception of a small area (less than 10 acres) at the Bull Run Headworks, most of the City's property in the Bull Run area is not at suitable elevation for a treatment facility.

Figure 9
Sites Meeting Essential Criteria Overlain with City Ownership



Land Use and Zoning. The relationship of sites meeting the essential criteria to the Urban Growth Boundary (UGB) is shown in Figure 10. Only the Powell Butte site is within the UGB. Sites outside the UGB are subject to state regulations for resource protection. Specifically, lands designated by the state as Exclusive Farm Use (EFU) or equivalent timber zone are subject to stringent regulations limiting development. A GIS view was created to evaluate the compatibility of sites meeting essential criteria having resource lands designations. Presumably, parcels having such designations would be much more difficult for siting. Figure 11 shows a view of acceptable sites that are also free of restrictive resource lands designations.

Figure 10
Relationship of Sites to UGB

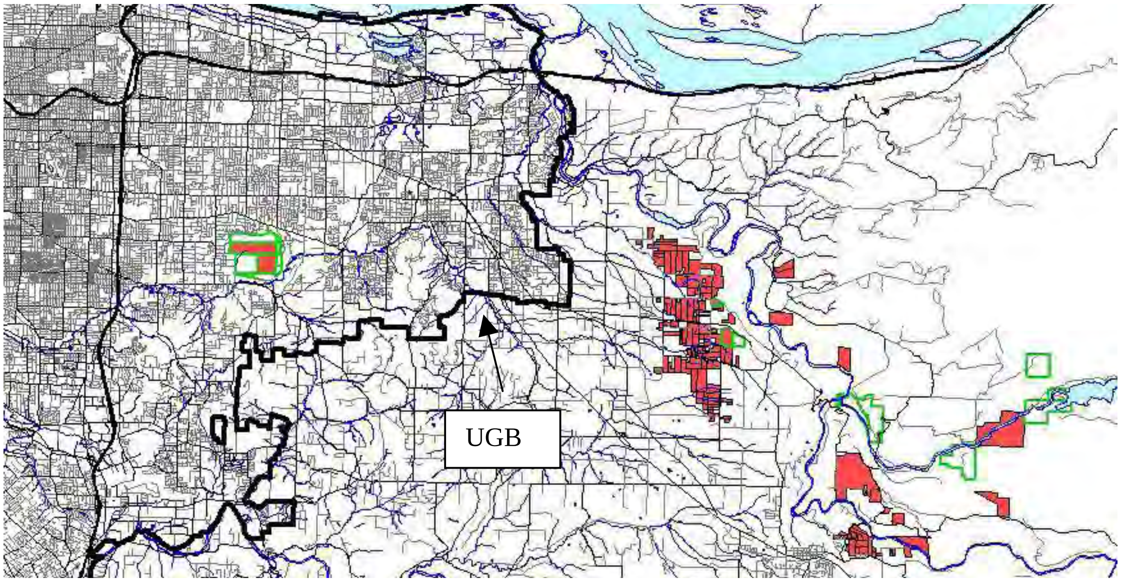
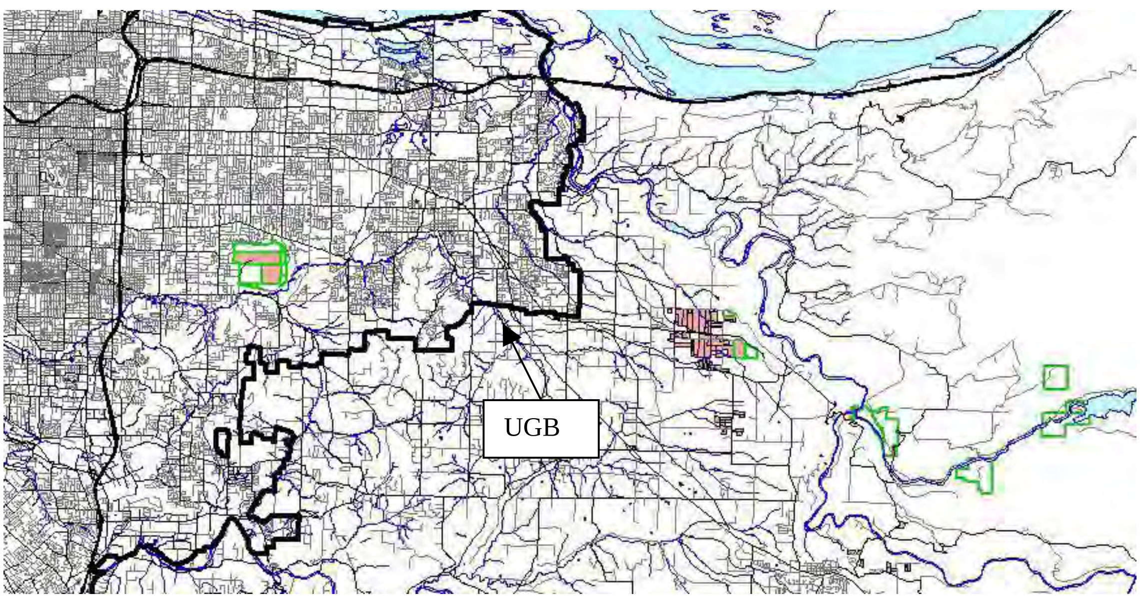


Figure 11
Relationship of Sites to Non-Resource Lands Designation



The Powell Butte site and the Lusted Hill area are still acceptable according to these criteria. The BRTP requested additional information on whether the treatment plant could trigger a conflict with the Statewide Planning Goals related to development outside the UGB for the Lusted Hill site. Additional research was conducted on the compatibility of the treatment facility at Lusted Hill, and a memorandum summarizing these findings is contained in the Appendix. In summary, neither the Statewide Planning Goals nor the Oregon Administrative Rules will prevent the siting of a facility at Lusted Hill. Multnomah County would need to approve a conditional use permit. County approval will be based on the nature of the impacts, and these would need to be carefully addressed by the Bureau.

Summary of candidate sites

The GIS tool was applied in order to identify a field of sites that met all essential criteria. Limited evaluation of sites with respect to land use and ownership was also conducted using GIS. The evaluation resulted in the identification of three primary sites for a future treatment facility. The characteristics of these sites are described below.

Bull Run Headworks. The parcel size in City ownership is about 10 acres. It is the current location for disinfection treatment with chlorine. The site is closed to public access and is within the Mount Hood National Forest Management Unit. The existing conduits number 2, 3 and 4 originate at the Headworks. The primary advantage of this site is its compatibility with existing operations, including proximity to the conduits, the presence of utility connections and microwave communication and good geotechnical knowledge of the site. The major disadvantages are the severe space constraints, difficult access for construction and operation in this remote location and vulnerability of the facilities to landslides. Space is adequate in the Bull Run for UV and ozone disinfection facilities up to an ultimate capacity of 500 mgd, and for membrane filtration at 250 mgd. Space constraints would preclude the ability to expand a membrane facility to the ultimate capacity of 500 mgd. Space in the watershed is inadequate for direct filtration at the initial capacity of 250 mgd.

Lusted Hill. The land in Bureau ownership totals almost 100 acres, and is comprised of several parcels. One parcel at Lusted Hill is the site of a downstream Bureau treatment facility, where ammonia is added to the chlorinated supply. The balance of the Bureau's property is currently in use for farming and nursery operations. The available properties are located from 1 to 1.2 miles from the existing conduits. Access for construction and operation would be much easier here, compared to the Bull Run site. Plenty of space is available. Potential obstacles to siting at Lusted Hill are land use impacts in this rural residential area, the presence of homes immediately adjacent to the property, construction in a scenic river corridor and treatment plant discharge to the federally- protected Sandy River. Although this site meets the essential criterion of distance to conduits of less than

2 miles, significant costs would be incurred by the need to construct major inlet and outlet transmission connections to the conduits.

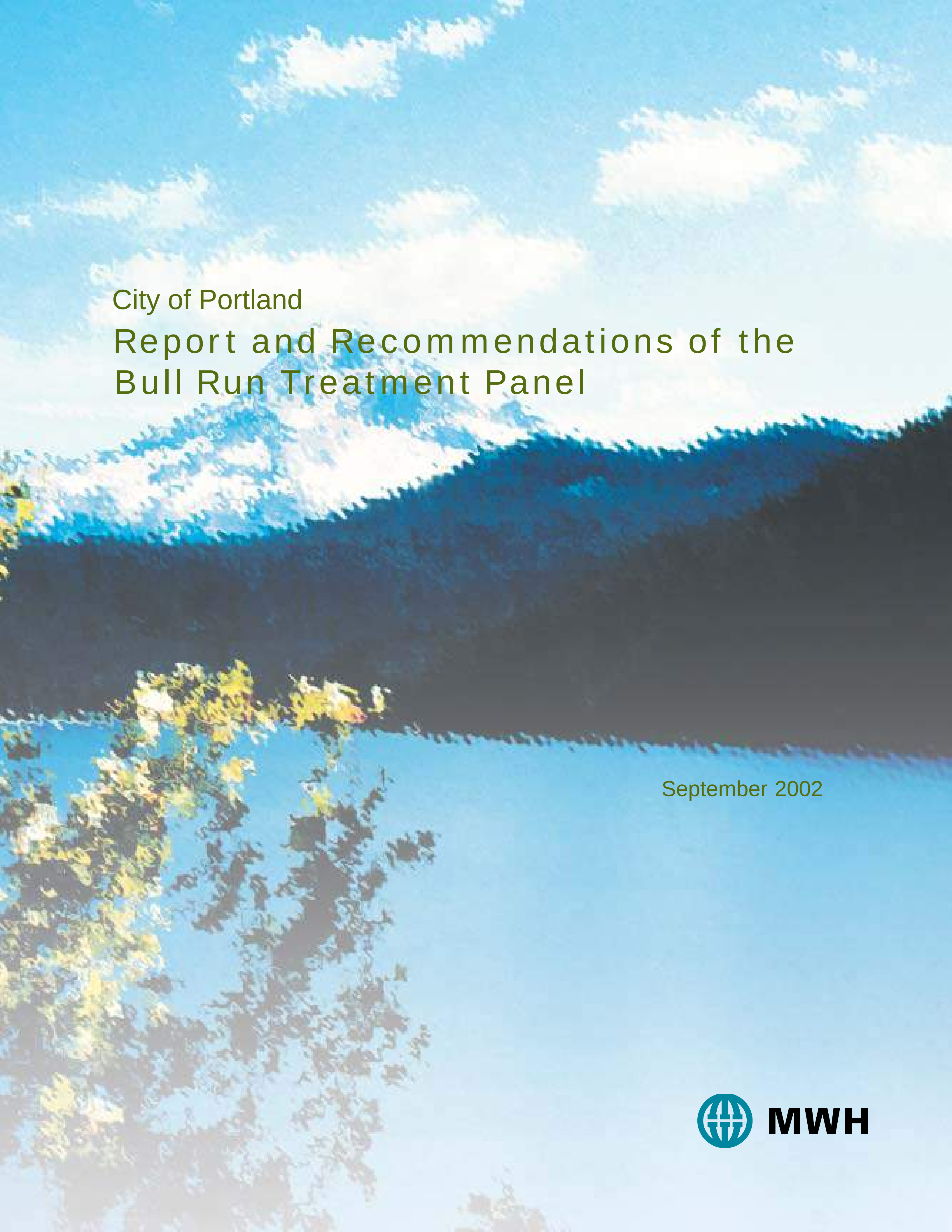
Powell Butte. The parcel size in Bureau ownership is 578 acres. This site was purchased by the Bureau in 1925 specifically for the siting of water facilities. Powell Butte functions as the hub of the existing water system. Water from the Bull Run flows to an existing 50 million gallon buried reservoir at Powell Butte, and is then distributed by gravity to the region. The Powell Butte reservoir also receives the City’s groundwater supply when the Columbia South Shore Wellfield is in operation. Powell Butte’s location and elevation are the reasons that this site is the central point for storage and distribution of the region's two primary water supplies. Distance to the conduits is measured in hundred of feet. The major advantages of this site is its function as the hub of the existing water system, and its location within the UGB. This site also provides the best opportunities for public education and awareness of water quality, treatment and supply. It provides good access for construction and operation. The major disadvantage of the site relates to its current function as a nature park hosting multiple recreational uses. The property is overlain with an Open Space designation that is intended to preserve open space and natural areas. Environmental and neighborhood issues must be carefully evaluated by the Bureau. Plant overflow and site drainage will present engineering challenges.

Conclusions

Essential and desirable criteria were developed to screen potential treatment plant sites in the area extending east of Interstate 205 and south of the Columbia River, to the Bull Run Headworks. Essential criteria were developed by the Bureau and reviewed by the BRTP. These criteria were deemed to be critical to the proper functioning of a treatment plant. Individual tax lots were evaluated with respect to these essential criteria using GIS. Results of this screening exercise identified Powell Butte, the Lusted Hill area and a small area in the Bull Run watershed as suitable for siting of a facility.

A limited evaluation of sites with respect to desirable criteria was conducted using the GIS tool. A review of land ownership and zoning indicate that all three sites are feasible, with the Bull Run site being restricted to facilities less than 10 acres in size. This would eliminate the possibility of constructing direct filtration treatment in the Bull Run watershed.

Appendix B. Bull Run Treatment Panel



City of Portland

Report and Recommendations of the Bull Run Treatment Panel

September 2002

MWH

September 12, 2002

Mr. Erik Sten
Commissioner of Public Works
Portland City Council
1220 SW 4th Avenue
Portland, Oregon 97204

Mr. Dan Saltzman
Commissioner of Public Affairs
Portland City Council
1220 SW 4th Avenue
Portland Oregon 97204

Dear Commissioners Sten and Saltzman:

The Bull Run Treatment Citizens Panel is pleased to transmit its final report and recommendations for your consideration. We thank you for the opportunity to work with City of Portland staff and the community in considering the important questions you asked us to address:

What treatment methodology should Portland use to meet its water quality goals?
Where should the treatment facility be located?
How should the facility be financed and delivered?

In considering these questions, the Panel reviewed a number of technical reports and received presentations from public agency and national experts on water treatment technologies and public health issues. The Panel sought feedback from the public through focus groups, community meetings, public hearings, and public comment at its regular meetings. As directed by its charge, the Panel considered the treatment question within the context of broader water supply and demand issues in the region.

A clear majority of the Panel supports filtration as the preferred technology to treat Bull Run water. Filtration technology will enable Portland's system to meet the pending federal regulation regarding *Cryptosporidium*, improve the reliability of the system, make additional water available from current storage at Bull Run, and facilitate future expansion of Bull Run should the region elect to pursue that supply option. Membrane filtration is preferred over direct filtration, for reasons detailed in the report.

The Panel's selection of Powell Butte as the preferred site for a filtration facility is based solely on consideration of water system issues such as site ownership, location and elevation. Citizens and interest group users of Powell Butte Nature Park have voiced concerns over this recommendation. If the Council decides to pursue filtration, the Panel recommends that a community-based siting process be conducted to provide the opportunity to more fully consider the siting issue.

It should be noted that full consensus regarding the preferred treatment option was not achieved by the Panel. Of fourteen panelists, twelve support filtration, one prefers ultraviolet light treatment and one abstained from the recommendations.

We look forward to actively participating in the Council's discussion of this topic when it comes before you later this year. Please feel free to contact us should you have questions or want to discuss our recommendations further.

Sincerely

Serena Cruz
Chair
Citizens' Panel on Bull Run Treatment

Lloyd Anderson

Bill Blosser

Greg DiLoreto

Jay Formick

Gary Larsen

Dave Rouse

Charles Shi

Dr. David Shute

Chris Thomas

Dr. Catherine Thomasson

Jay Waldron

Cathryn Young

Citizen's Panel on Bull Run Treatment

Commissioner Serena Cruz, Panel Chair

Lloyd Anderson
Bill Blosser
Bud Clark
Greg DiLoreto
Jay Formick
Gary Larsen
Dave Leland
Regna Merritt
Dr. Gary Oxman
Dave Rouse
Charles Shi
Dr. David Shute
Chris Thomas
Dr. Catherine Thomasson
Jay Waldron
Harold Williams
Cathryn Young

Table of Contents

5.0 Panel Recommendations

Technical Appendices

Appendix A - Regulatory Requirements

Appendix B - Water Supply and Demand

Appendix C - Treatment Technology

Appendix D - Public Involvement

Appendix E - Treatment Plant Siting

E1. Technical Memorandum - Water Treatment Plant Siting

E2. Technical Memorandum - Lusted Hill Land Use Issues

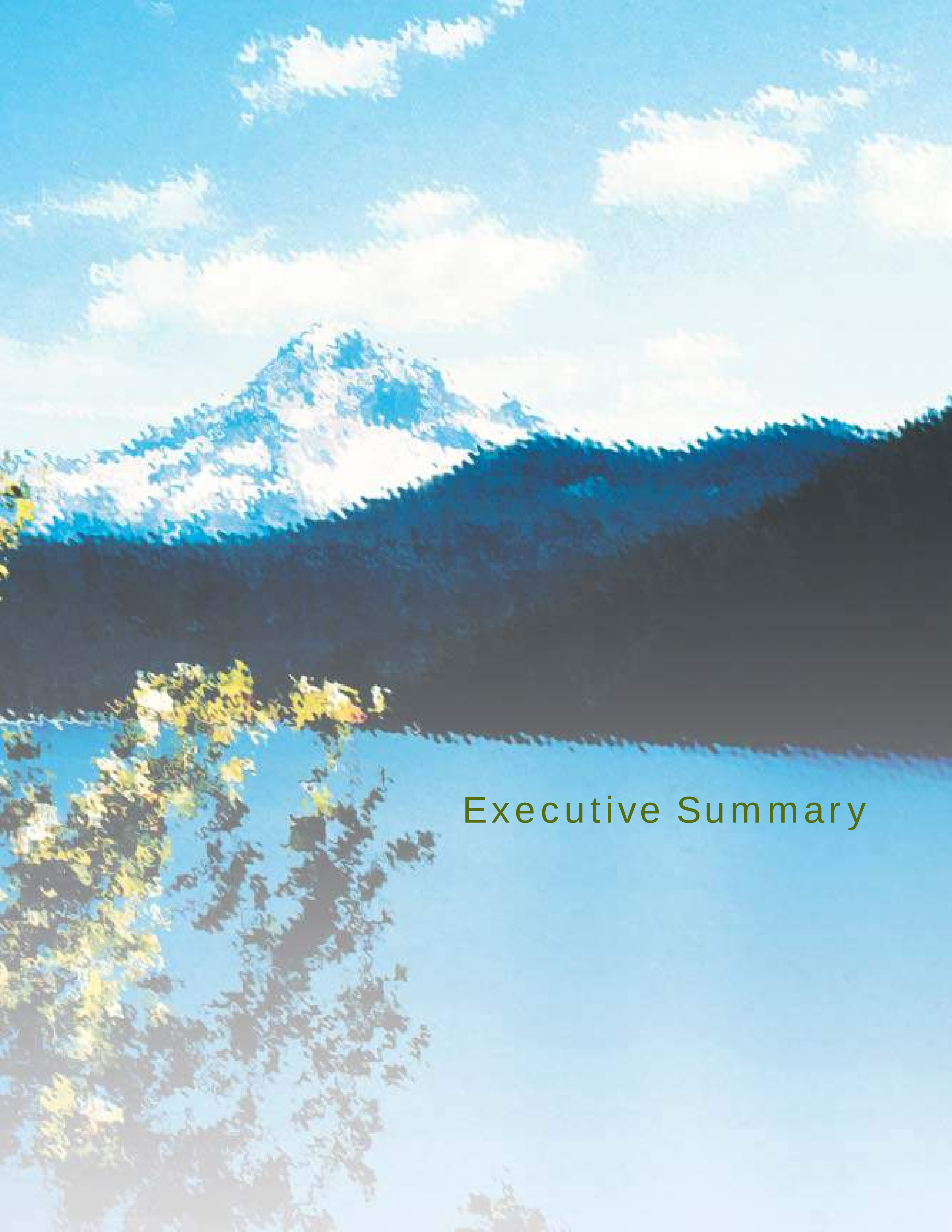
Appendix F - Project Implementation and Financing

F1. Technical Memorandum - Alternative Project Delivery Assessment

F2. Panel Survey on Alternative Delivery

Appendix G - Additional Information

G1. Minneapolis Water Works Treatment Decision



Executive Summary

Part I. Executive Summary

Next year, the federal Environmental Protection Agency (EPA) is scheduled to promulgate new regulations requiring that treatment of Bull Run water be modified to assure protection of public health from naturally occurring microbial contaminants, including the waterborne microorganism *Cryptosporidium*. The implications of the regulations are significant for Portland, because current treatment of Bull Run water with chlorine is not sufficient to inactivate *Cryptosporidium*.

The Bull Run Treatment Panel (Panel) was established to advise the Portland Water Bureau and its Commissioner on Portland's options for meeting these regulations. The Panel was asked to consider the treatment question within the context of long-term water supply, demand and related issues in the region.

The Panel was asked for recommendations on three specific questions:

- *What treatment methodology should Portland use to meet its water quality goals?*

There are four basic methodologies for treating Bull Run water to meet the anticipated federal regulations – ozone disinfection, ultraviolet light disinfection, direct filtration and membrane filtration. Each of these methodologies has different costs and benefits, some of which go beyond regulatory compliance to address other water quality and supply goals.

The Panel was not asked to consider a "no treatment" option because EPA is not expected to include such an option for unfiltered systems in the new regulations.

- *Where should the treatment facility be located?*

Four potential sites were initially identified for a treatment facility – the Headworks facility at Bull Run, Powell Butte, Lusted Hill and Larson's Ranch. In addition, an analysis was conducted to identify other potential sites on the basis of size, accessibility, location, land use, geologic hazards, and other considerations.

- *How should the facility be financed and delivered?*

There are several options for implementation of the treatment decision, including design-bid-build (the traditional approach to building public projects) and alternative approaches such as design-build, design-build-maintain and design-build-operate.

Summary of Panel Recommendations

The Panel makes the following recommendations in response to its charge:

• *What treatment methodology should Portland use to meet its water quality goals?*

A clear majority of the Panel recommends membrane filtration technology. Membrane technology will meet federal regulatory requirements for removal of *Cryptosporidium* and provide additional public benefits for Portland and other users of the Bull Run system. Although membrane filtration is the most expensive of the four treatment technologies, a majority of the Panel concludes that the higher cost of membrane filtration is justified by the additional benefits it provides.

The Panel recognizes that because the technology is evolving, there are certain uncertainties associated with membrane filtration. The Panel makes specific suggestions regarding strategies to reduce the uncertainties associated with membranes in Section 5.6 of the report.

• *Where should the treatment facility be located?*

The Panel recommends that the treatment facility be located at Powell Butte. The Panel's siting recommendation is based solely on consideration of water system issues such as site ownership, location and elevation. The Panel recognizes neighborhood concerns and recommends that as part of the siting process the Water Bureau fully engage the community in discussion of the issues surrounding location of the treatment facility.

• *How should the facility be financed and delivered?*

A majority of the Panel recommends that a design/build approach be pursued to deliver the treatment facility. The Panel did not conduct a thorough review of alternatives to traditional public financing of the project, and therefore does not make a recommendation regarding financing.

Panel Background

The Panel's membership included representatives from a broad range of interests and backgrounds, including public health, environmental conservation, wholesale customers of the Bull Run system, the business community, and the public at large. Ex officio Panel members representing state and local public health agencies and the Water Bureau provided additional technical expertise.

The Panel held its first meeting in April 2001 and met monthly (excepting August 2001) through June 2002. All meetings of the Panel were held in centrally located, accessible meeting facilities. Meetings were open to the public and opportunity for public comment was provided at each meeting. Additional public involvement opportunities were provided through focus groups, a community workshop and several public hearings.

This executive summary presents the Panel's key findings and recommendations. The Panel's full report, including more detailed explanations of treatment options and a full description of the Panel's findings and recommendations, follows. Additional detail can be found in the appendices and other referenced material at the back of the report.

Panel Values

The Panel adopted values and assumptions to guide the treatment decision. The values and assumptions cover a wide range of issues, from water quality and conservation to affordability and worker safety. To summarize, the following values were most relevant to the Panel's decision-making.

- *Safety* – Bull Run water must be safe to drink – meeting or exceeding all regulatory standards.

- *Reliability* – The drinking water supply must be reliable, with adequate safeguards from weather-driven and seasonal shortages and catastrophic events (e.g. seismic events, land-slides, forest fires).

- *Quality and Aesthetics* – In addition to being safe and reliable, it is also important that the water supply is consistent in quality, well suited for everyday use and that it contains a minimum of added chemicals. Drinking water should be clear (i.e., no sediment, cloudiness or color), free of chemical odors and pleasant to drink.

- *Cost and Affordability* – The cost of treatment must be affordable and represent a good value for ratepayer dollars spent. It must be allocated fairly among Portland and other users of Bull Run water according to a cost-of-service model.

- *Protection of the Environment* – The treatment decision should be consistent with protection of the environment and with the City's sustainability goals, especially with respect to water and energy conservation. It should also be consistent with protection of the Bull Run watershed, not only because it is a primary source of the region's drinking water, but also because it supports valuable ecosystem processes, fish and wildlife habitat, old-growth forest and wildlands values.

Key Panel Findings

- The Bull Run is a protected watershed. As a result, Bull Run water normally needs minimal treatment to meet or exceed all current state and federal drinking water standards. Certain weather events can raise the turbidity of Bull Run water above federal standards for unfiltered systems, in which case the system must be shut down.

- Based on the protected nature of the Bull Run watershed, monitoring results that reveal *Cryptosporidium* only at low levels, and the absence of epidemiologic evidence of illness caused by *Cryptosporidium*, the Panel's perspective is that the risk of disease from *Cryptosporidium* is relatively small for Bull Run users.

- All four of the principal treatment technologies will inactivate or remove *Cryptosporidium* to the levels necessary to achieve regulatory compliance for Bull Run. Three of the four – ozone disinfection, direct filtration and membrane filtration – will provide additional public benefits. The additional benefits afforded by these technologies include improved reliability (filtration options), additional source capacity (filtration options), and better water aesthetics (ozone and filtration options).

- Projections made in connection with recent regional water studies indicate that over 4.8 billion gallons of new capacity will be required to meet peak season demand for water throughout the region by the year 2050. Major potential sources of additional supply to meet future needs include the Tualatin/Trask watershed, the Willamette River, the Clackamas River and expanded capacity at Bull Run.

- Filtration technologies would enable the use of up to 2.0 billion gallons of additional water from Bull Run reservoirs. In addition, filtration technologies would facilitate expansion of Bull Run supply by protecting water quality during construction related to modifying Dams 1 and 2 to increase storage capacity or developing a third dam.

- The cost of a treatment facility ranges from approximately $55 million for UV disinfection at Headworks to approximately $200 million for a membrane filtration plant at Powell Butte. The table on the next pages summarizes the cost of alternative treatment technologies for a 250 mgd capacity plant at various locations.

- Information received by the Panel showed that the incremental increase in monthly residential water bills as a result of treatment (costs associated with plant only) would range from a little over $1.00 per month for ultraviolet light treatment to about $3.50 per month for membrane

Cost Estimates of Treatment Options

Treatment Process	Location	Capital Cost Plant Only (millions)[1]	Annual O&M Costs (millions)
UV Disinfection	Headworks	$55	$5.2
Ozone Disinfection	Headworks	$66	$6.2
Direct Filtration	Lusted Hill Powell Butte	$203 $179	$6.5*
	Lusted Hill Powell Butte	$204 $202	$8.0*

* Annual O&M costs are the same for both the Lusted Hill and Powell Butte sites.

filtration[2] in the peak month of the 20-year debt repayment period. Input from two focus groups and one public meeting indicated that residential ratepayers would be willing to absorb the increase projected for filtration to obtain the additional increment of safety and other values afforded by these treatment options.

- The Panel was asked to review four initial sites for a treatment facility (Headworks, Larson's Ranch, Lusted Hill and Powell Butte) and to explore the possibility of other sites. Analysis revealed no additional sites. Analysis of different combinations of treatment technologies and sites showed there are no clear advantages to siting an ozone or UV plant at sites other than Headworks. These two options, along with the possibility of siting a membrane plant at Headworks or a direct or membrane filtration facility at Lusted Hill or Powell Butte, were further analyzed for cost and other considerations.

Recommendations

The following recommendations are based on the Panel's consideration of a large quantity of data, numerous technical presentations and other information regarding the costs, benefits and risks associated with various treatment technologies, facility sites and project delivery mechanisms. Ultimately, however, the treatment decision could not be reduced to a simple cost/benefit calculation. Instead, the Panel's recommendations evolved from a more subjective weighing and balancing of costs and benefits against the values adopted by the Panel to guide the treatment decision.

1. What treatment methodology should Portland use to meet its water quality goals?

As noted, all four of the treatment technologies reviewed by the Panel will meet the requirements of the anticipated EPA rules. The filtration options also

[1] Cost of a 250 mgd capacity plant exclusive of additional reservoir storage, transmission expansions or distribution system storage. Costs shown in 2001 dollars.
[2] The full cost of membrane filtration - including the treatment plant and associated supply and transmission costs for a 250 mgd plant - was estimated at about $5.00 per month for the typical residential customer

address supply and reliability, thereby supporting two of the key values embraced by the Panel. On the other hand, the Panel's values also reflect a concern for cost and affordability – and the filtration options are much more expensive than the two disinfection options.

In developing their response to the treatment question, Panel members spent considerable time weighing whether the added benefits provided by filtration justified the additional cost. Results of their collective consideration of this question are reflected in the following recommendations.

- A clear majority of the Panel believes that the benefits of treatment by filtration (direct or membranes) justify the additional costs of these technologies. The Panel therefore, recommends a filtration strategy. The Panel's rationale can be summarized as follows:

    - Filtration provides a more robust barrier to pathogens and is more adaptable to meeting potential future regulatory requirements.

    - Filtration will increase the reliability of the system by enabling Bull Run water to be delivered during times of high turbidity. Wholesale customers, in particular, place a high value on increasing system reliability through filtration.

    - By enabling drawdown of the reservoirs during the onset of fall rains, filtration will increase the total water available from the Bull Run by an estimated 2 billion gallons (approximately 10%). Currently, the Water Bureau limits the amount of water it takes from available storage in the fall to minimize the risk from significant turbidity events.

    - This increased supply will, in turn, provide one or more of the following benefits: (a) provide the City with additional capacity to meet endangered species requirements (if any), (b) decrease the need to use the Columbia South Shore Wellfields as a summer augmentation source and (c) delay the need to develop other supply sources to meet increasing customer demand.

    - Filtration can improve water quality by removing organic materials that color the water in the fall. This is an aesthetic issue of particular importance to Portland's wholesale customers.[3]

    - Assuming reduced reliance on the wellfield, filtration will decrease in-plant treatment costs for industrial customers. These customers now must be able to treat varying water qualities from the Bull Run and the wellfield, which impacts their operations and increases their costs. Industrial customers will also benefit from improved reliability of supply to meet production requirements.

    - Filtration will make Portland's supply more reliable and consistent and thus comparable to other filtered sources in the region (all other surface water supply in the region is filtered). Portland's increased ability to retain its wholesale customers will spread system operations costs, thereby lowering rate increases for Portland customers.

    - Filtration provides Portland and the region with more flexibility to meet future water needs. The potential exists to expand Bull Run supply by raising the height of Dams 1 and 2 or building a third dam. Filtration would likely be needed during development of any of these projects to protect water quality from the effects of construction and meet federal regulatory standards.

- The Panel considered detailed information on the advantages and disadvantages of direct filtration and membrane filtration. After weighing the information, a clear majority of the Panel recommends membrane filtration over

[3] Ozone disinfection also removes color. Membrane filtration will require an additional treatment step to remove color.

direct filtration, because membrane filtration technology:

- Offers the greatest flexibility to adapt to changing circumstances because of the potential to upgrade membranes without altering the basic structure or functioning of the facility.

- Is simpler to operate, with less chance for operator error in chemical dosing and other operator-driven adjustments.

- Has the ability to remove smaller-sized contaminants without the use of coagulating agents.

- Generates less solid waste.

- Requires a lesser amount and fewer types of chemicals.

- Has a smaller "footprint", resulting in less impact on the environment and providing greater flexibility to increase capacity or add treatment to deal with future regulations.

• The Panel recognizes that because the technology is evolving, there are uncertainties associated with membranes. The Panel recommends that prior to implementation of membrane treatment, the Water Bureau address these uncertainties as follows:

  - To provide adequate cost competition, assure there are at least two acceptable suppliers of installable membranes.

  - Require that membrane suppliers have facilities in operation that utilize the same component size and configuration that will be utilized as building blocks in the Portland treatment plant.

  - To minimize scale-up concerns, require demonstration of successful operation of at least one membrane plant with a minimum capacity of approximately 100 mgd.

  - To assure membrane performance, require membrane suppliers to guarantee performance for at least 10 years.

  - To assure long-term availability of membranes, require contractual arrangements with membrane suppliers that allow Portland to manufacture replacement membranes itself if replacements are not available from the original supplier.

  - To alleviate concerns about potentially harmful chemicals leaching from membranes, review the National Sanitation Foundation (NSF) certification process for membrane materials that membranes are currently required to meet, and require supplemental certification testing if appropriate.

• The Panel recommends that direct filtration remain under consideration as a back-up treatment technology. Direct filtration has a long track record of effective treatment of municipal water supplies, with many installations of the size needed in Portland. Should the Water Bureau not be able to implement the risk management strategies for membrane treatment described above, the Panel recommends that the City Council work with the Bureau to review the reasons for not meeting the strategies and the options then available, including the use of direct filtration. Because of the many benefits of membrane filtration, some Panel members would prefer that the City wait for further development of membrane technology instead of moving immediately to direct filtration.

• The Panel notes that the least expensive way to achieve compliance with the anticipated regulations is by installing ozone or UV treatment. UV carries the lowest cost of the four treatment options. The Panel observes, therefore, that if the City wished only to achieve regulatory compliance at the lowest cost, it would select UV treatment. A minority of the Panel recommends UV as the preferred treatment strategy.

- One Panel member recommends that UV treatment be installed to meet federal requirements to address *Cryptosporidium* in the short-term, and that membrane filtration be held as a long-term capital goal for the Bull Run.

2. Where should the treatment facility be located?

- From a water system perspective, the Panel recommends that the filtration facility be sited at Powell Butte. The City of Portland purchased this 578-acre property in 1925 to serve as a site for future water facilities. Powell Butte's location and elevation make it a central point for storage and distribution of Portland's water supplies. It is located within Portland's urban growth boundary, a key consideration for permitting. Powell Butte's urban location has the additional benefit of providing greater opportunities to use the treatment facility to contribute to public awareness of water resource management issues and to develop public education and community recreation facilities.

- The Panel recognizes that siting the treatment facility at Powell Butte will have impacts on the park and surrounding neighborhoods. The Panel believes the advantages of a Powell Butte site warrant a serious effort to resolve these potential impacts. As the Panel neared completion of its work, some citizens expressed concerns about the social and environmental impacts of siting a filtration treatment facility at Powell Butte. The Panel recommends that the Water Bureau fully engage the community in future deliberations and decision-making regarding the siting of the facility.

- The Panel recommends that the Lusted Hill site remain under active consideration as an alternate to Powell Butte should neighborhood, environmental or other issues render the Powell Butte site an inappropriate location for the treatment facility.

3. How should the treatment facility be delivered?

- A majority of the Panel recommends that the City pursue a design-build approach to project delivery. Design-build provides advantages to the City in time and money savings, and reduces the risks and uncertainties of membrane filtration at a large scale. If a design-build approach is pursued, the City and the Water Bureau must carefully and thoughtfully develop the design and operating criteria that will define the project.

- The Panel recommends that the Water Bureau and the City further evaluate other aspects of alternative delivery, including those that include treatment plant operation.

Additional Recommendations

- To meet the anticipated 2011 deadline for addressing the *Cryptosporidium* regulations, and to achieve the other water quality benefits of treatment, the Panel recommends that the Water Bureau begin the next phase of work related to the treatment project in 2003. The next phase of work is expected to include such tasks as community-based planning for the treatment facility, applying for necessary permits, pilot testing and additional review of alternative project delivery approaches.

- The Panel's support for filtration is premised on the assumption that the cost of treatment will be allocated fairly among Portland and other users of the Bull Run system on a cost-of-service model. To protect the current and future interests of all parties, the Panel recommends that the financial, ownership, cost sharing and/or contractual arrangements regarding treatment are in place before major financial commitments (i.e. construction) are made.

- To address affordability issues, the Panel recommends that the Water Bureau – and other utilities whose ratepayers will share in the cost of treatment – evaluate current programs for low-income ratepayers, adopt changes to improve the accessibility and coverage of these programs, and work aggressively to ensure that the programs are fully utilized by eligible customers.

- The Panel recommends that to the greatest extent possible, implementation of the treatment decision be timed to avoid overlapping with other large maintenance and capital improvement projects such as capping and repairing the reservoirs, replacement of the water distribution system or expansion of Bull Run.

- EPA's regulations regarding treatment for *Cryptosporidium* are scheduled for adoption in mid-2003. Since final rule language was not available, the Panel had to rely on language in an "agreement in principle" adopted by a stakeholder group as part of the rule-making process and an EPA "pre-proposal draft" based on that agreement. Should the final rule represent a substantially different regulatory approach or requirements, or provide different options for addressing *Cryptosporidium*, the City and Water Bureau should revisit the Panel's recommendations.

Summary

The Panel recognizes and appreciates the significance of the treatment question to Portland and the region. Few public services are more essential than the provision of safe drinking water, and few places are blessed with better, safer water than that provided by Bull Run. Bull Run's status as one of the few large, unfiltered public drinking water systems remaining in the United States is a source of pride to some – and concern to others. The potential for Bull Run to help meet the growing need for water in the region is both welcomed and questioned. All these views were represented on – and debated by – the Panel. The Panel hopes its report and recommendations reflect this diversity of thought and opinion. The Panel also hopes its report and recommendations reflect a goal shared by all its members – to protect the precious heritage of Bull Run while preparing the system to meet the demands and challenges of an uncertain future.

Report and Recommendations

Part II. Report and Recommendations

1.0 Introduction

1.1 History

President Benjamin Harrison designated the Bull Run Forest Reserve and closed the forest to entry and development in 1892. Three years later, via a system built largely by hand, the first Bull Run water flowed into the City of Portland.

The Bull Run system was expanded throughout the 20th century to meet the region's growing need for water. Conduits were added, dams were constructed to impound the source water, and supply lines were built to allow transmission of Bull Run water to Portland and surrounding areas.

View of Bull Run Watershed and Dam 2.

Protection of the Bull Run watershed has been addressed through a series of legislative actions over the past hundred years. Through the 1904 Trespass Act, Congress prohibited all human entry into the Bull Run Reserve. Exceptions were limited to the Water Board, federal and state officers, forest rangers and others actively protecting the forest and water.

While logging became legal with the 1977 passage of Public Law 95-200 (see Appendix 1.0), other types of human activity were generally restricted, limiting the introduction of pollutants into the Bull Run Management Unit. Federal legislation in 1996 and 2001 amended PL 95-200, increasing protection for the watershed and the entire Bull Run Management Unit including general prohibitions against logging.

The excellent quality and protection of its source water have allowed Bull Run to operate as one of only a few large, unfiltered water systems in the United States. Bull Run water was essentially untreated until 1929, when chlorine was first used as a disinfectant. In 1957, the Portland Water Bureau began adding ammonia to the water at the system's headworks, a process meant to ensure maintenance of a persistent chlorine residual that continues to disinfect water as it travels through the distribution system.

Chlorine residual levels were increased throughout the system in 1989 to comply with a federal drinking water regulation known as the Total Coliform Rule. Portland modified its treatment of Bull Run water twice in the 1990's – first in 1991, by modifying disinfection practices to meet the requirements of the Surface Water Treatment Rule, and again in 1997 by adding corrosion treatment to meet the requirements of the Lead and Copper Rule.

New federal regulations affecting Portland's management of the Bull Run system are due to be adopted in 2003. Language describing the regulations is contained in a "pre-proposal draft" of the Long-term 2 Enhanced Surface Water Treatment Rule (available at http://www.epa.gov/safewater/lt2/st2eswtr.html). The purposes of the rule are to improve control of microbial pathogens, specifically the protozoan *Cryptosporidium*, in drinking water, and to address risk trade-offs associated with disinfection by-products. The implications of the rule are significant for Portland, because current treatment of Bull Run water with chlorine is not sufficient to inactivate *Cryptosporidium*.

Disinfection and Corrosion Treatment Facility.

In anticipation of the federal government's promulgation of this rule, the Portland Water Bureau and its Commissioner-in-Charge convened a citizen panel to review the proposed drinking water regulations and related issues and make recommendations regarding Portland's treatment options. This report describes the Panel's decision-making process, including the Panel's findings and recommendations. Additional detail is provided in a series of technical memos and other material appended to the report.

1.2 Charge to the Panel

The Bull Run Treatment Panel (Panel) was charged to advise the Portland Water Bureau and its Commissioner on treatment options for Portland's primary water source within a decision-making framework that included consideration of long-term water supply, demand and related issues in the region. The Panel was asked for recommendations on three specific questions:

- *What treatment methodology should Portland use to meet its water quality goals?*

The Panel was asked to look at four basic methodologies for treating Bull Run water – ozone disinfection, ultraviolet light disinfection, direct filtration and membrane filtration.The Panel was not asked to consider a "no treatment" option because Enviormental Protective Agency is not expected to include such an option for unfiltered systems.

The four treatment methodologies are briefly described in Section 4.0. Additional detail can be found in the Appendix 2.0.

- *Where should the treatment facility be located?*

Four potential sites were initially identified for a treatment facility – the Headworks facility at Bull Run, Powell Butte, Lusted Hill and Larson's Ranch. In addition, an analysis was conducted to identify other potential sites on the basis of size, accessibility, location, land use, geologic hazards, and other considerations.

- *How should the facility be financed and delivered?*

The Panel was asked to review "traditional" financing as well as alternative financing and implementation approaches such as design-build and design-build-operate.

1.3 Summary of Panel Recommendations

The Panel makes the following recommendations in response to its charge:

- *Treatment methodology* – A clear majority of the Panel recommends membrane filtration technology. Membrane technology will meet federal regulatory requirements for removal of *Cryptosporidium* and provide multiple other public benefits for Portland and other users of the Bull Run system. Although membrane filtration is the most expensive of the four treatment technologies, a majority of the Panel concludes that the higher cost of membrane filtration is justified by the additional benefits it provides.

  The Panel recognizes that because the technology is evolving, there are certain uncertainties associated with membrane filtration. The Panel makes specific suggestions regarding strategies to reduce the uncertainties associated with membranes in Section 5.6.

- *Facility siting* – The Panel recommends that the treatment facility be located at Powell Butte. The Panel's siting recommendation is based solely on consideration of water system issues such as site ownership, location and elevation. The Panel recognizes neighborhood concerns and recommends that the Water Bureau engage the community in a thorough discussion of the issues surrounding location of the treatment facility.

- *Facility financing and delivery* – A majority of the Panel recommends that the City pursue a design/build approach to project implementation. The Panel did not conduct a through review of alternatives to traditional public financing of the project, and therefore does not make a recommendation regarding financing.

1.4 Process and Timetable

The Panel held its first meeting in April 2001 and met monthly (excepting August 2001) through June 2002. All meetings of the Panel were held in centrally located, accessible meeting facilities. Meetings were open to the public and opportunity for public comment was provided at each meeting. A project team of consulting engineers, Water Bureau employees and others provided technical briefings and data to the Panel as needed to provide for informed decision-making. Ex officio Panel members representing state and local public health agencies and the Water Bureau provided additional technical expertise.

The Panel's work was conducted in three phases:

- Orientation (background information; goals, values, criteria) April - October 2001;
- Analysis/Evaluation (applying goals, values, criteria to options) November 2001-February 2002; and
- Recommendation (draft recommendations and report) March - June 2002.

1.5 Public Involvement

The Panel conducted its decision-making through an open public process. Through this process, citizens and ratepayers from across the region were informed about and involved in the treatment issue.

The focal point for public outreach was the Panel itself, which served as a conduit to many interested organizations. Panel members were selected to be broadly representative of key constituent groups sharing an interest in the Bull Run system. Among the organizations and interests represented on the Panel were residential, industrial and wholesale customers; Bull Run advocacy groups; environmental / clean water advocates; low-income ratepayers; medical community and public health officials; Portland Utilities Review Board (PURB) and citizens.

During the first phase of its work, the Panel oversaw the development of a public involvement plan. Public outreach methods were targeted as appropriate to reach different audiences based upon their level of interest: highly interested, interested, or less interested general public. This approach is illustrated in the *public involvement pyramid* shown on the next page. Based on the plan, the Panel organized and participated in a series of public outreach activities designed to inform and involve citizens in the treatment decision. These activities are summarized below.

- *Stakeholder Interviews* - At the outset of the project, interviews were conducted with more than 30 key stakeholders, who were asked to share their advice on issues surrounding Bull Run treatment. The results contributed to the *values* and *assumptions* adopted by the Panel to guide its decision-making.

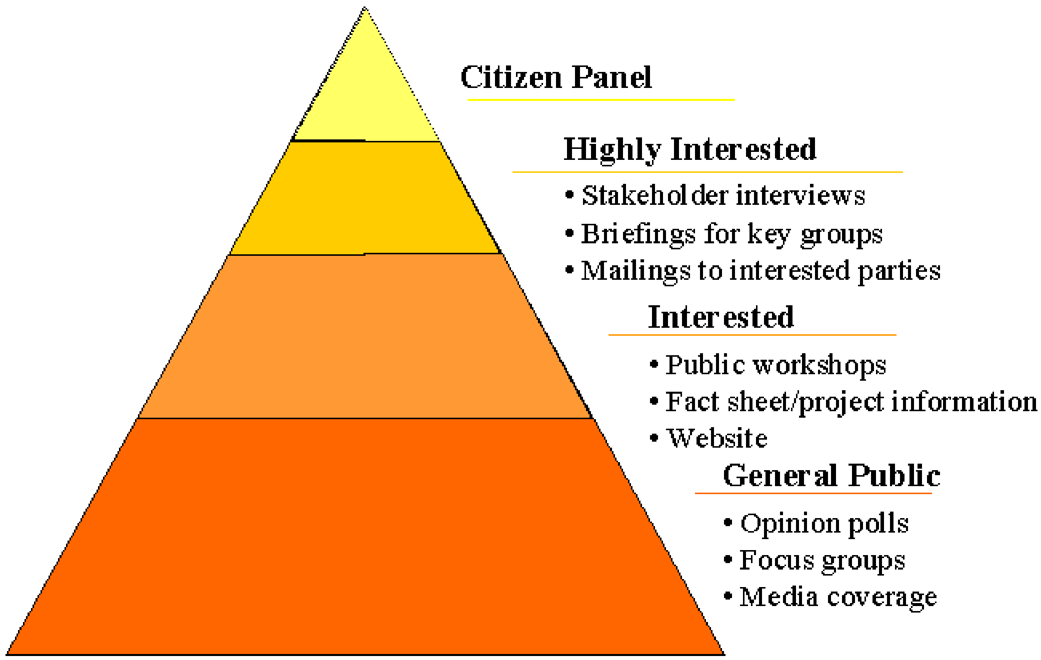
- *Polling* - The Panel reviewed results of previously conducted public opinion polls related to drinking water quality and cost.

- *Focus Groups* - To gauge broad-based public opinion, two focus groups were held in October and November 2001. The 42 participants – water customers selected at random from throughout the Bull Run service area – were asked to serve as "citizen advisors", giving their views on the issues and choices being considered by the Panel.

- *Public Hearings* - Four public hearings were held at various locations across the Bull Run service area: in Beaverton, Gresham, and Portland. More than 40 citizens participated in the hearings.

- *Public Information* - Information materials, including a project fact sheet, were developed and distributed to interested parties.

Public Hearing on Draft Report



Public Involvement Pyramid

- *Speakers Bureau* - During the decision process, the project team gave presentations and updates to regional water suppliers, the Portland Utilities Review Board, Water Bureau employees, and other interested groups.

- *Website* - A website (www.bullrun.ci.portland.or.us) was established to offer information on the treatment decision and key planning documents, including Panel meeting and presentation summaries, to interested citizens and groups.

- *Media Coverage* - The Portland Water Bureau contacted media representatives to update them as the treatment decision process progressed. Project team members also appeared on community cable television broadcasts. News items, editorials and letters about the Bull Run treatment decision process were published in a variety of publications, including: *The Oregonian, Portland Tribune, Gresham Outlook, and Daily Journal of Commerce*. These items appeared approximately monthly over the 18-month course of Citizen Panel's work.

- *Report to the Community* - The Panel's findings and recommendations were summarized in a report designed for the lay public and policymakers.

The results of public input and advice regarding Bull Run treatment are discussed in Section 4.9. Additional information regarding public involvement can be found in Appendix 3.0.

2.0 Context for Panel Recommendations

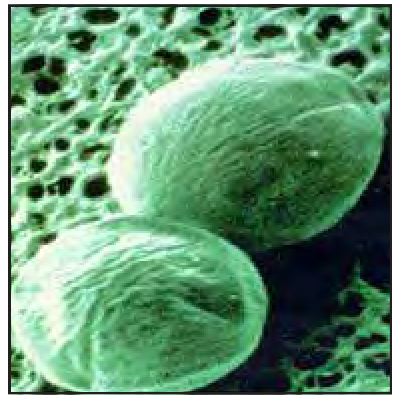
The context for the Bull Run treatment decision process has both national and regional dimensions. At the national level, a series of rulemaking activities by the Environmental Protection Agency (EPA) set the stage for and triggered the need to review treatment options for Bull Run. Understanding the evolution of these regulations over the past decade helped the Panel better understand the implications for Portland. Discussions with wholesale customers regarding the future ownership and management of the Bull Run provided perspective on the role of Bull Run in meeting the region's growing need for water and the significance of treatment in that equation.

2.1 Regulatory Context

Both the state and federal governments have roles in overseeing drinking water treatment in the United States. At the federal level, the Environmental Protection Agency has been responsible for establishing and enforcing rules related to drinking water since 1974, when Congress adopted the Safe Drinking Water Act.

Through amendments to the Act in 1986, Congress directed that all surface supplies of drinking water be filtered to ensure that consumers are protected from exposure to microbial pathogens found in rivers, lakes, and streams. EPA responded to Congress' direction in 1989 by promulgating the Surface Water Treatment Rule (SWTR). Under the SWTR, public water systems were required to filter surface sources of drinking water unless they met certain defined water quality and disinfection requirements and maintained a watershed control program. The Bull Run is one of a relatively small number of systems not required to filter because it has continuously met the specific criteria for safe water in the rule. (Compliance with the SWTR did require that the disinfection process used at Bull Run be modified to address *Giardia*, one of the microbial pathogens covered by the rule.)

Federal regulation of drinking water continued to evolve during the 1990's. In 1998, following several



Photograph of *Cryptosporidium*,
the target of new EPA regulations.

years of negotiated rulemaking, EPA promulgated the Stage 1 Disinfectant/Disinfection Byproducts Rule and the Interim Enhanced Surface Water Treatment Rule (IESWTR). The first rule lowered the standard for exposure to certain by-products of the water treatment process. The second rule focused on improving the performance of water filtration plants to reduce the risk of epidemic occurrences of waterborne illness from microbial contaminants, especially the water-borne microorganism *Cryptosporidium*.[4]

Beyond being required to include *Cryptosporidium* in their watershed control programs, unfiltered systems were not addressed in the IESWTR. However, in 1999, EPA began conducting a second negotiated rule-making process focused in part on the risks posed by low-level ("endemic") transmission of waterborne pathogens. Endemic transmission is thought to be associated with low-level, intermittent exposure of a population to disease-causing organisms. Such transmission is not typically

4. Although *Cryptosporidium* is found in most surface waters in the United States, only a few epidemic outbreaks of illness traced to *Cryptosporidium* in drinking water have been documented. The first such outbreak, which occurred in 1987 in Carrollton, Georgia, affected 13,000 people. The most significant U.S. outbreak occurred in 1993 in Milwaukee, Wisconsin, where an estimated 400,000 people became ill. In both cases, the municipal water systems in question were operating within state and federal drinking water standards in effect at the time. Problems with plant design and/or operation/maintenance were cited as reasons for the problems in both cases.

detected by traditional disease surveillance mechanisms, and represents the kind of risk that might be associated with unfiltered systems. This effort produced draft rule language expected to be promulgated as the Stage 2 Disinfection/ Disinfectant Byproducts Rule and the Long Term 2 Enhanced Surface Water Treatment Rule.

Of particular interest to the Panel is the latter rule, which as drafted would require water systems to conduct site specific risk analyses for *Cryptosporidium* and take action to improve treatment to address the endemic risks of waterborne pathogens. Under the current pre-proposal draft of the rules, unfiltered systems, including Portland, would be required to provide a minimum of 99% inactivation or removal of C*ryptosporidium*. This requirement would bring unfiltered systems in line with the minimum level of treatment being provided by filtered systems meeting performance criteria established in the IESWTR. The required level of removal or inactivation is not achieved by current disinfection of Bull Run water.

The Long Term 2 Enhanced Surface Water Treatment Rule is expected to be promulgated by EPA in mid-2003. The negotiated agreement provides eight years for water systems to comply following promulgation of the rule.

2.2 Regional Context

Bull Run – A Regional Resource

The Bull Run system provides drinking water to approximately 800,000 people – more than 450,000 of those in the city of Portland (primarily in Multnomah County) and 317,000 outside the city. Portland wholesales water to fourteen water districts and cities. Major wholesale customers include the City of Gresham, the City of Tigard and the Tualatin Valley Water District. Currently, wholesale customers account for 44% of annual water demand.

A shared stake in the region's water has engendered significant regional cooperation in planning for, conserving and developing water supplies, as reflected by several recent long-range plans and studies. The most comprehensive of these studies is the Phase 2 Regional Water Supply Plan (RWSP), completed in 1996. Other important studies are the Infrastructure Master Plan for the Portland water system (October 2000) and the Regional Transmission and Storage Strategy developed for the Regional Water Providers Consortium (July 2000). The Panel relied on regional supply and demand projections developed for these plans in its deliberations regarding the treatment question.

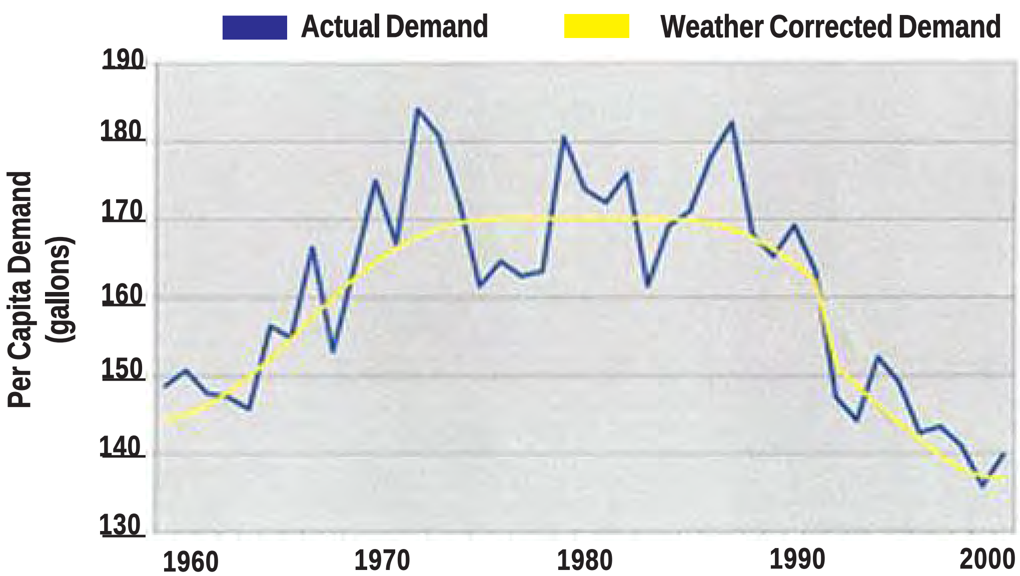
Regional Water Supply and Demand

Regional supply and demand is relevant to the treatment issue for two reasons. First, two of the treatment technologies under consideration (the filtration technologies) would enable additional water to be made available from Bull Run. The significance of this benefit depends on the extent of the regional need for new supply and the degree to which filtration could help address that need. Second, the filtration options improve the reliability of the supply. This is a major issue for wholesale customers, who represent a substantial portion of the overall demand for Bull Run water.

In reviewing the supply and demand question, the Panel was presented with year 2050 projections for "peak season" supply needs[5], using estimates from the Regional Water Supply Plan and Regional Transmission and Storage Strategy[6]. Current peak

5. The forecasting approach used in the RWSP was based on individual forecasts for each of 47 water providers. Growth in demand was based on population and employment rates developed by Metro. Some of the considerations incorporated into the RWSP model were naturally occurring conservation (the reduction in water demand due to changes in water service technologies, building codes, appliance standards and the competitive marketplace), reductions in demand due to increases in water prices, and peak day demand. Forecasts included baseline (mid-level), low and high growth scenarios.

6. The "peak season" is the season of heaviest demand on the system – the hottest, driest months of the year. In Portland, peak season occurs during the extended summer drawdown period when demands are higher than stream inflows.



Per capita water demand has dropped as conservation programs have been implemented.

season capacity and year 2050 peak season demand are summarized in the tables on page 9.[7]

The numbers shown in the table indicate that:

- Approximately 4.8 billion gallons of additional peak season capacity will be needed to meet regional demand by the year 2050;
- The most significant "shortages" will occur in Washington and Clackamas counties.

7. The Panel notes the limitations of the long-term demand estimates. First, the projections used by the Panel estimate the demand for water in the year 2050, nearly five decades from now. While modeling tools have improved in recent years, it is still difficult to make accurate projections that far into the future.

Second, the future demand projections presented to the Panel are based on certain assumptions about population and economic growth, demographic and land use changes, conservation trends and other factors. Endangered Species Act listings and global warming may also impact the regional demand picture. Estimates for different demand "nodes" represent aggregations of local projections based on a variety of source data and forecasting methodologies. This variability in sources and methodologies can affect the comparability of the numbers being used.

New regional demand forecasts to 2050 are currently being developed as part of the Regional Water Supply Plan update. This update will provide a comprehensive water demand forecast, using a common set of assumptions and methods. Revised demand figures will be available in mid-2003. The significance of filtration as a means to increase regional water supply should be evaluated with respect to these revised regional demand forecasts.

- Without expanded capacity at Bull Run, Portland will need to rely more on the Columbia South Shore Wellfields than it currently does[8], or make use of other approved sources.

According to the forecasts, much of the increased demand for water in the region will occur by 2020. Additional information on supply, demand and Endangered Species Act considerations is provided in Appendix 4.0.

Demand Nodes, Major Sources, Current Capacity and Year 2050 Peak Season Demand

Demand Node	Major Sources	Peak Season Capacity (Bgal)	Year 2050 Peak Season Demand (Bgal)
EAST	Bull Run River CSS Wellfield	20.0 8.6 28.6	21.6
SOUTH	SFWB Lake Oswego CRW NCCWC	3.0 2.4 4.5 1.5 11.4	14.0
WEST	Trask/Tualatin Willamette	9.0 2.3 11.3	20.5
TOTAL		**51.3**	**56.1**

The demand forecasts used in the RWSP incorporate naturally occurring water conservation, i.e., conservation resulting from plumbing code changes and changing technologies such as clothes washers that use less water and energy. The plan projected that demand could be reduced by as much as 76 million gallons per day by the year 2050 through conservation, out of an anticipated peak day demand of 350 mgd in this time period. These estimates are a projected maximum, based on implementation of a wide range of conservation measures, including residential and commercial education, audits, incentive programs, aggressive conservation rate design and ordinances restricting outdoor water use for new development.[9]

8. Current use of the wellfields is limited by city policy to seasonal augmentation and emergency back-up of Bull Run.
9. A review of potential conservation savings conducted by the Regional Water Providers Consortium in 1999 reduced the estimate of probable savings that could be achieved by 2020 by about 20 percent. This reduction in the estimate of conservation potential was primarily due to the recommended elimination of the outdoor landscaping ordinances, due to trade group and public opposition. A second major reason for the reduction in savings estimates was a lower projection in the number of residential and commercial accounts from Metro. The RWSP Update project will review projected conservation savings.

Even accounting for demand reduction through conservation, however, the RWSP projected that additional supply would be needed by 2050. Through the RWSP and the Regional Storage and Transmission Strategy, the region has embraced an overall supply framework to address these future needs. The supply framework includes conservation, aquifer storage and recovery, the use of the CSSW to meet peak season and emergency demands, better interties between supply and demand nodes in the region, and the development of additional source water in the future. A third reservoir in Bull Run was among the sources preliminarily evaluated, but the plan made no recommendation about which source option should be pursued.

Regional Water Authority Initiative

The RWSP culminated several years of cooperative work by the region's water utilities to develop common water demand forecasts and water supply and conservation strategies. This plan, and the Regional Transmission and Storage Strategy that followed, have provided the framework for much stronger regional cooperation on water supply and distribution issues.

With these efforts as a backdrop, in 2000 the City of Portland began negotiating new long-term contracts with its wholesale customers. During this process, it became clear that some wholesale customers hoped to institutionalize regional cooperation by acquiring an ownership interest in their water supply. In response to this interest, in April 2001 – the same month the Panel began meeting – Portland City Commissioner Eric Sten, then Commissioner-in-Charge of the Water Bureau, initiated discussions with regional water utilities and the public regarding the possibility of developing a regional drinking water agency. Commissioner Sten, Water Bureau staff, and the suburban water utilities represented on the Panel have kept the Panel apprised of the status of those discussions.

The Panel faced a unique challenge in deliberating the treatment issue during the same timeframe that the regional water authority question was being actively discussed. Questions related to the size and location of a treatment facility, and the allocation of the cost of treatment among users of the system, were made more complicated by the uncertainty surrounding the ultimate configuration of ownership and management. As the Panel was developing its recommendations, it was informed that the scope of the regional water authority discussions had narrowed to focus on regional ownership and management of the Bull Run system, rather than "full regionalization" of all major supply and distribution systems in the region.

3.0 Assumptions and Values

The recommendations contained in this report are based in part on technical considerations – factors like the efficacy of various treatment methodologies, regional supply and demand projections and the geologic stability of prospective treatment facility sites. At the same time, the Panel recognized that the treatment decision couldn't be based solely on technical matters. The decision also needs to reflect the goals, concerns and desires – that is to say, the *values* – of the region and its citizens.

Accordingly, during the first stages of its deliberations the Panel worked to identify and agree on a set of values to guide the treatment decision. The panel also agreed on certain assumptions about the process and the decision. The purpose of the assumptions was to clarify a number of premises or "givens" about the treatment decision and to provide assurances to panel members and the public regarding the relationship between the treatment decision and other issues of concern regarding Bull Run.

The Panel's values were tested against – and found to be consistent with – public and stakeholder values through a series of focus groups, public meetings and interviews. In addition the various treatment options were subjected to a qualitative evaluation against the panel's values. (See Appendix 5.0 for this evaluation.) This exercise helped illuminate the differences among the options and focused discussion on those options most consistent with the panel's values.

Following are the consensus assumptions and values adopted by the BRTP.

3.1 Assumptions

- New federal regulations will be adopted requiring unfiltered water systems – including Portland's Bull Run system – to provide additional treatment. Portland will comply with the new regulations.
- Separate discussions regarding possible regionalization of the Bull Run system and development of new water sources will be ongoing during the treatment decision process. The Treatment Panel must consider various future scenarios, and its recommendations may inform these other discussions.
- The treatment decision process will consider several options for Bull Run's future customer base: serving Portland customers only; serving the current customer base – including Gresham and Tualatin Valley Water District as wholesale customers; or serving a larger regional area.
- Consistent with City policy, Portland will continue to rely on Bull Run as its primary source of drinking water supply. The Portland wellfields' chief role will be for seasonal augmentation and emergency supply. (If additional supply is developed or customer demand on the Bull Run supply is reduced significantly, the role of the wellfield as a summer augmentation supply could change.)
- The Bull Run watershed will continue to be protected, in compliance with PL 95-200 as amended and other applicable federal law, regardless of future treatment.
- Four alternative water treatment technologies have been proven to be effective in deactivating *Cryptosporidium*: UV disinfection, ozone, direct filtration and membrane filtration.
- Bull Run is a regional water source, and the region will participate in the treatment decision process.
- Evaluation of facility size and capacity will be based on a range of demand assumptions that include maximum use of current sources (including non-potable sources where feasible and appropriate) and water conservation.
- Portland will exercise leadership and foresight in caring for its water supply and in planning for and ensuring the safety, quality and reliability of the Bull Run system.

3.2 Values

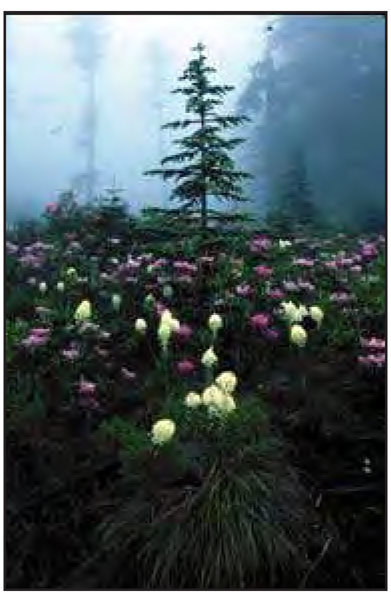
- Bull Run water must be safe to drink - meeting or exceeding all regulatory standards.
- The treatment decision must be based on the best available scientific information, taking into account that scientific understanding of public health issues is evolving, and regulatory standards may change over time.
- The cost of treatment must be affordable and represent a good value for ratepayer dollars spent.
- The cost of treatment will be allocated fairly among Portland and other users of Bull Run water according to a cost-of-service model.
- The drinking water supply must be reliable, with adequate safeguards from weather-driven and seasonal shortages and shortages due to catastrophic events (seismic, fires, other).
- We value high quality water - water that is consistent in quality, well suited for everyday use and that contains minimum added chemicals.
- The treatment process should be flexible and "tunable" to meet changing requirements and the variability in natural conditions.
- The treatment decision should be consistent with protection of the environment.
- We value water that is clear (i.e., no sediment, cloudiness or color), free of chemical odors and pleasant to drink.
- The treatment process should be consistent with the City's sustainability goals, especially with respect to water and energy conservation.
- We value the unique nature of Bull Run as a water source - protected and requiring

minimal treatment.

- The decision process should include consideration of worker safety, operational impacts, impacts to the transmission system and other system-wide impacts and benefits.
- We value the Bull Run watershed not only because it is the source of our drinking water, but also because it supports valuable ecosystem processes, fish and wildlife habitat, old-growth forest and wildlands values.

4.0 Panel Findings

During the course of its deliberations the Panel was briefed on a wide range of issues, including evolving public health concerns about drinking water, the technology behind current water treatment methods, the sites available for locating a new treatment facility, and alternative methods of financing and delivering a treatment plant. In addition, because it was charged to make its recommendations within the context of regional water needs, the Panel received information on long-term supply and demand projections and related issues in the region. The following findings represent a synthesis of the information, facts, trends and issues most relevant to the treatment decision.



The protected nature of the Bull Run is key to high quality water.

4.1 The Bull Run Source

The Bull Run is a protected watershed. The storage reservoirs at Bull Run are surrounded by publicly owned federal forest land, the management of which is carefully regulated to ensure the safety and quality of Portland's primary water source. The Bull Run Management Unit is closed to public use. Federal law generally prohibits logging in the Bull Run Management Unit. As a result of these protections, Bull Run water normally needs minimal treatment to meet or exceed all current state and federal drinking water standards.

Portland water customers are justifiably proud of the superior "aesthetics" of their drinking water, and of the pristine character of the Bull Run watershed. Except during the fall and in periods of extreme low water or major storm events, the water that flows from Bull Run is clear. Certain weather events can raise the turbidity of Bull Run water above federal standards for unfiltered systems, in which case the system must be shut down.

4.2 Public Health Benefits and Regulatory Requirements

- *Cryptosporidium*, the pathogen to be regulated by pending federal regulations, is a water-borne microorganism. In healthy people with normal immune systems, *Cryptosporidium* causes a mild-to-moderately severe diarrheal illness typically lasting one to two weeks. In healthy people, the illness is sometimes complicated by dehydration needing medical treatment; this may be more of a problem for young children, pregnant women and the elderly. In individuals with significant immune system problems (e.g., HIV/AIDS, and cancer or transplant chemotherapy), infection with *Cryptosporidium* often causes chronic diarrhea, which can be debilitating and life-threatening.

- Transmission of relatively high numbers of *Cryptosporidium* organisms through water tends to result in sudden outbreaks of illness ("epidemics") that are relatively easy to detect. *Cryptosporidium* transmission can also occur on an ongoing or episodic basis at low levels (i.e., "endemic" transmission). This pattern of transmission typically produces illness at levels that are not readily detected by routine public health monitoring. The EPA and the Centers for Disease Prevention and Control (CDC) have been concerned about the risks and associated public health and economic impacts of both patterns of *Cryptosporidium* transmission. Both patterns have been drivers for EPA's rulemaking under the Safe Water Drinking Act, and for CDC's pursuing epidemiologic studies of drinking water-borne illness.

- Results of water testing indicate that *Cryptosporidium* organisms occur in Bull Run water at low levels. It is not clear how often *Cryptosporidium* is present in Bull Run water because testing is technically unreliable. Since the watershed is closed to human entry and use by domestic animals, wildlife is the probable source of *Cryptosporidium* in Bull Run water. *Cryptosporidium* is highly resistant to chlorine;

Monitoring Results for *Cryptosporidium* in Bull Run.

Year	Samples	Mean (#/100L)	Peak (#/100L)
1995	16	< 1	< 2
1996	13	0.6	4
1997	15	0.8	5
1998	24	0.1	1
1999	85	1	30
2000	48	0.2	4
2001	4	0.2	1

- Routine epidemiologic monitoring ("surveillance") by state and local public health agencies has not revealed any evidence of past or current transmission of *Cryptosporidium* through Bull Run water. This strongly suggests that Bull Run has not been a source of any significant outbreaks (epidemics) of illness caused by Cryptosporidium. Despite this, it is possible that low levels of illness due to *Cryptosporidium* do occur in the community, but are not detected. Failure to detect such endemic illness might happen for two reasons. First, routine disease surveillance systems are not designed to reliably detect small changes in the occurrence of illnesses that have common, nonspecific symptoms (like those caused by *Cryptosporidium*). Special studies are needed to assess the occurrence of such illnesses and identify their causes.

  Second, current methods of sampling and detection for *Cryptosporidium* are widely acknowledged to be unreliable.[10] This compromises both the ability to detect the occurrence of *Cryptosporidium* in the water supply, and the ability to analyze any association between its occurrence and illness in the community.

- The Panel's perspective is that the risk of disease from *Cryptosporidium* is relatively small for Bull Run users. While it recognizes its responsibility to be cautious in interpreting the evidence, the Panel believes that treatment will add only a small degree of safety to the Bull Run water supply – one that probably will not be measurable. The Panel bases this belief on three findings: 1) the protected nature of the Bull Run watershed, which has eliminated human and bovine sources of *Cryptosporidium*, 2) monitoring results that reveal *Cryptosporidium* only at low levels, and 3) the absence of epidemiologic evidence of epidemic or endemic transmission of *Cryptosporidium* via Bull Run water.

10. The standard method for detecting protozoa in water samples is the indirect fluorescent antibody (IFA) procedure. This method has been heavily scrutinized. Generally this method is regarded as having low capture and recovery efficiencies. The results are widely variable both within and among laboratories; it is difficult to perform and requires a skilled microscopist; and it can determine neither viability nor speciation of oocysts and cysts. The cost of analysis is also significant. The Water Bureau reports that a typical cost is $750 per sample to obtain a detection limit of 1 cyst per 100 liters. New analytical methods are under development.

- The Panel received information showing that scientific understanding of drinking water contaminants and their potential risk to public health is continuously evolving. For example, research is ongoing regarding the risks of exposure to disinfection by-products and other organic chemicals. The Panel believes that drinking water regulations are likely to become more stringent and cover an ever-wider range of contaminants over time. Filtration methodologies are more likely to satisfy future regulatory requirements, whereas disinfection methodologies may not.

4.3 Types of Treatment

There are four treatment technologies that will either inactivate or remove *Cryptosporidium* as required under the pending regulations: ultraviolet (UV) light disinfection, ozone disinfection, direct filtration, and membrane filtration. A brief summary of each, along with its advantages and disadvantages, is provided below. The treatment options are described in more detail in a technical memorandum found in the Appendix 2.0

- *Ultraviolet Light* - Under this technology, water flows past ultraviolet lamps. UV light damages replicating DNA in *Cryptosporidium* oocysts[11], preventing their reproduction. UV has been shown to be highly effective against *Cryptosporidium*. It is inexpensive, and requires the use of no additional chemicals.

UV lamps used to disinfect water

Applications of UV technology to drinking water are relatively new and small compared to the application needed for Bull Run. Issues involved with the patenting of UV technology may increase operating costs over time.

- *Ozone* - Ozone is a powerful oxidant that destroys the walls and cell contents of *Cryptosporidium* oocysts. In addition to effectively addressing *Cryptosporidium*, ozone controls colors, tastes and odors in source water and reduces disinfection by-product formation. Many large-scale applications exist.

  Ozone may increase the potential for bacterial re-growth in the distribution system. It is an energy-intensive technology.

- *Direct Filtration* – With direct filtration technology, water passes through sand and carbon filters to physically separate organisms from drinking water. Coagulants are added to the water prior to filtration.

  Direct filtration is a time-tested technology used by many water utilities and installed at sizes comparable to that needed for Bull Run. Direct filtration plants require larger sites for installation, creating additional challenges for siting. Issues related to the health impacts, handling and disposal of coagulant materials are a concern. Large *Cryptosporidium* outbreaks have occurred in water systems that use direct filtration.

- *Membrane Filtration* - Membrane filtration uses micro-porous fiber membranes to provide an absolute physical barrier to organisms and other contaminants. With this treatment method, chemicals are not required to achieve effectiveness against *Cryptosporidium*.

11. The *Cryptosporidium* life cycle includes the formation of hardy, microscopic oocysts that are infectious and have been found to be resistant to common chemical disinfectants. The *Cryptosporidiosis* disease is transmitted by the ingestion of oocysts excreted by infected humans and animals.

Water is drawn through membrane fibers.

At the present time, there are no installations of membrane filtration treatment plants close to Portland's required size. Membrane filtration is the most expensive of the four alternatives.

4.4 Other Benefits of Treatment

The Panel's review of the four principal treatment technologies showed that all options except ultraviolet light provide public benefits above and beyond mere regulatory compliance. Among the many other benefits afforded by treatment are improved reliability (filtration options only), additional source capacity (filtration options only) and better water "aesthetics" (color and taste – ozone and filtration).

Improved System Reliability

- Over the last six years the Bull Run supply has been shut down three times due to high turbidities after winter storms (13 days in February of 1996, 8 days in December of 1998, and 18 days in November of 1999). These events have been triggered by peak flows during rain and snow events, the effects of which can be exacerbated by the extensive system of roads in the watershed.

- These shutdowns – and the possibility that the system could be shut down for even longer periods due to catastrophic events like landslides or forest fires in the watershed – undermine the real and perceived reliability of the Bull Run supply. A consistent, dependable water supply is a key system performance measure for all users of Bull Run, including wholesale and large industrial customers. For example, when the system is shut down, wholesale customers must off-load demand to alternative sources. Industrial customers may be required to modify their in-house treatment of water to meet specific manufacturing needs. Millions of gallons of treated water left in the conduits must be disposed of by the Water Bureau.

- Providing filtration would virtually eliminate the need for these shutdowns, improving the reliability of the Bull Run source. Turbidity spikes measured during storm events in Bull Run source water since 1996 have ranged between 8 and 26 NTU – well within the treatment capability of membrane filtration.[12] Disinfection treatment would not provide the benefits of increased supply reliability.

Additional Source Capacity

- As noted in Section 2.0, projections made in connection with recent regional water studies indicate that over 4.8 billion gallons of new capacity will be required to meet

12. Currently, there are about 120 operating drinking water treatment facilities in the U.S. that use the type of membrane filtration process contemplated for the Bull Run. These systems operate at source water turbidities that are on average, higher than Bull Run throughout the year, and reach as high as 4,000 NTU during storm events. The majority of these plants treat surface water from reservoirs, lakes and rivers that are subject to storm-driven turbidity spikes similar to those observed in the Bull Run watershed.

The Environmental Protection Agency conducted a recent survey of 24 U.S. utilities using membrane filtration (EPA, April 2001). The most commonly reported treatment challenge among these utilities was an increase in raw water turbidity following rain or winter storm events. Most utilities surveyed stated that a primary benefit of membrane filtration is its ability handle influent water quality fluctuations.

Turbidity plume moving through reservoir after a storm.

peak season demand throughout the region by the year 2050.[13] Future demand in Portland's current direct service area can be met by minor expansions of existing supplies (based on ongoing use of the Columbia South Shore Wellfields), but new sources of supply will be needed to meet the growth in demand in Washington and Clackamas counties. Major potential sources of additional supply for these areas include the Tualatin/Trask watershed, the Willamette River, the Clackamas River and expanded capacity at Bull Run.

(Note: The Panel did not study expansion capacity for other sources, the constraints on expanding capacity for other sources or the implications of such expansion. The Panel also did not make any judgement about expansion of Bull Run.)

- A growing population will not be the only source of pressure on the region's water system in the future. The City of Portland and others in the region have obligations to meet the Clean Water Act and the Endangered Species Act. The latter, in particular, has implications for meeting regional water needs, as listed fish may require increased instream flows during periods of high customer demand on the system. The potential for climate change – which could increase the number and intensity of storm events, or result in longer, warmer summers in the Pacific Northwest – also exists.

- Portland's ability to expand the amount of water currently available from the Bull Run source is constrained by two factors. First, the onset of fall rains – at a time when the reservoirs are at their lowest, and surrounded by exposed, unvegetated shore and bank – elevates the risk of significant turbidity events. To minimize this risk, the Water Bureau limits the amount of water it takes from available storage. Currently, the Water Bureau is able to make use of approximately 10 billion gallons of the 17 billion gallons stored at Bull Run. Filtration would address this risk factor, enabling the Water Bureau to use up to 2.0 billion gallons more of the water stored in existing reservoirs.

Risk of turbidity from exposed shore and bank limits current reservoir rawdown.

- The second factor affecting source water availability is the current capacity of the reservoirs. The potential exists to increase Bull Run supply by modifying existing dams to allow raising reservoir levels. Increased storage at Reservoirs 1 and 2 has been projected to

13. 4.8 BG figure based on estimated year 2050 peak season demand minus current peak season capacity. (Sources: See Appendix 4.)

provide an additional 2.5 billion gallons of storage capacity. The potential also exists to add a new reservoir to the system. A third dam would provide additional storage capacity of 19 billion gallons. The construction-related impacts of these projects include erosion (which could raise turbidity levels) and the water quality impacts of inundating areas previously above water. These impacts could affect the City of Portland's ability to continuously meet filtration avoidance criteria in state and federal regulations. Failure to meet these standards could result in a requirement to provide for filtration.

Better Water Aesthetics

The "aesthetics" of water – its clarity, taste and odor – are of concern not only to consumers, but also to the water utilities that strive to produce high quality drinking water and must respond to consumer complaints. The aesthetics of Bull Run water are generally very good. Sometimes during the late summer and fall, decomposing leaves release tannins and lignins into the Bull Run reservoirs, giving the source water the color of weak tea. While this occurrence does not present a threat to public health, it often triggers a flood of complaints from customers.

Ozone disinfection will remove color from raw source water. Direct and membrane filtration will remove color with the addition of coagulants.

Typical ozone generating equipment.

4.5 Siting

- As part of its charge, the Panel was asked to recommend a site for a treatment facility. A variety of factors must be weighed in considering the siting issue. Among these are the size and physical characteristics of the site; the implications of the site for the functioning of the water system; and land use, environmental and community issues.

- The Panel was asked to review four initial sites (Headworks, Larson's Ranch, Lusted Hill and Powell Butte) and to explore the possibility of other sites. Selection of the four initial sites was based on ownership and construction and operational requirements and costs. A majority of the Panel visited these four sites during the orientation phase of the treatment decision process (summer 2001).

- The hydraulic profile of the Bull Run system, and the compatibility of a site with the gravity-driven flow of water through the system, is a key to siting. A treatment plant must be located at the right elevation – if the elevation is too high, water will not be able to reach the plant without pumping; if it is too low, water will need to be pumped after treatment. The use of gravity as an essential screening criterion supports the Panel's values of cost-effectiveness, reliability and sustainability (in terms of energy conservation).

- To determine whether additional sites were available, the Water Bureau defined a set of criteria determined to be essential to the proper functioning of a treatment plant. These criteria include a maximum distance from the site to the existing conduits, a minimum lot size to accommodate an eventual plant capacity of 500 mgd, suitable slopes and geologic conditions, and the ability to serve a base amount of flow by gravity. The essential criteria were used to evaluate an area east of Interstate 205 and south of the

Columbia River for potential treatment plant sites. Results of this screening revealed no additional sites, and eliminated Larson's Ranch from further consideration.

- The analysis also confirmed Powell Butte, the Lusted Hill area in east Multnomah County and limited portions of the Bull Run watershed as meeting the essential criteria for treatment plant siting. (Only about 10 acres of buildable land in the Bull Run watershed meet the essential criteria, restricting this site to the smaller, non-filtration options.)

- The Panel considered land use issues at the sites meeting the essential criteria, giving special attention to the Lusted Hill site since it is outside Portland's Urban Growth Boundary. A preliminary analysis suggested that siting a facility at the Lusted Hill location would not conflict with statewide planning goals. Existing zoning is compatible with treatment plant siting at the Powell Butte and Bull Run watershed locations. The City should carefully consider and address land use impacts at all sites.

- Combinations of potential treatment methodologies and sites were reviewed in terms of their space requirements, community/environmental impacts, and operating requirements. Further analysis of these combinations showed there were no clear advantages to siting an ozone or UV plant at sites other than Headworks. These two options, along with the possibility of siting a membrane plant at Headworks or a direct or membrane filtration facility at Lusted Hill or Powell Butte, were further analyzed for cost and other considerations.

A technical memorandum regarding siting is included as Appendix 6.0.

4.6 Cost and Affordability

- The cost of a treatment facility ranges from approximately $55 million for UV disinfection at Headworks to approximately $200 million for a membrane filtration plant at Powell Butte. The table below summarizes the cost of alternative treatment technologies for a 250 mgd capacity plant at various locations.

Capital and Operating Costs of Alternatives

Treatment Process	Location	Capital Cost Plant Only (millions)[14]	Annual O&M Costs (millions)
UV Disinfection	Headworks	$55	$5.2
Ozone Disinfection	Headworks	$66	$6.2
Direct Filtration	Lusted Hill Powell Butte	$203 $179	$6.5
Membrane Filtration	Lusted Hill Powell Butte	$204 $202	$8.0

14. Cost of a 250 mgd capacity plant exclusive of additional reservoir storage, transmission expansions or distribution system storage. Costs shown in 2001 dollars.

- The total cost of a treatment project would include items beyond the plant itself, including additional reservoir storage, transmission expansions and required operations and maintenance facilities. For a 250 mgd membrane treatment at Powell Butte, these associated costs would add an estimated $43 million to the cost of treatment, bringing the total for that treatment option at that site to $245 million.

- The Panel's adopted values include a statement that the cost of treatment should be "affordable" and "represent a good value for ratepayer dollars spent". The Panel recognizes that "affordability" is a subjective concept; items that one family finds affordable may be considered luxuries by another family.

- The Panel's analysis of this issue included information from a national expert on utility affordability. Data presented showed that the median cost of water as a percent of median household income in Oregon is 0.6% - the sixth lowest in the nation. The median cost as a percentage of median income in Portland, at 0.4%, is even lower.[15]

- Another measure of affordability comes from the 1993 EPA report, "Affordability of the 1986 Amendments to Community Water Systems". This report used an affordability threshold (the upper limit for the costs of water bills as a percentage of median household income) of 2.0% to assess the financial impacts of new regulations on small drinking water systems.

- Information received by the Panel showed that the incremental increase in monthly residential water bills as a result of treatment (costs associated with plant only) would range from a little over $1.00 per month for ultraviolet light treatment to about $3.50 per month for membrane filtration. Input from two focus groups and one public meeting indicated that ratepayers would be willing to absorb the increase projected for filtration to obtain the additional increment of safety and other values afforded by these treatment options.[16]

- The Panel also received information regarding the impact of a membrane treatment facility on both small (11 ccf[17] per month) and large (20,000 ccf per month) businesses. The information showed that the average monthly bill would increase from the current $19.38 to $21.73 for a small business (using 11 ccf of water per month) and from the current $32,640 per month to $36,917 for very large, water-intensive businesses (using 20,000 ccf per month).

- The Panel felt it was important to understand the cost and rate impacts of treatment in relation to other long-term capital improvements planned by the Portland Water Bureau. Analysis of projected rate impacts showed that the average monthly residential water bill would increase from $14.60 currently to between $20.50 and $23.50 over the next 20 years to pay for membrane filtration, small supply increases, reduction of vulnerabilities in the water system, and on-going maintenance.

4.7 Alternative Delivery Mechanisms

- The Panel was asked to make recommendations regarding the financing and delivery of a treatment facility. The Panel reviewed the following alternative delivery options:

---

15. Estimates are based on 1990 census data. Data from the 2000 census were not available during the Panel process. Use of more recent data would yield different results, reflecting increased public expenditures to address sewer and stormwater issues.
16. The monthly impact for membrane filtration including the treatment plant and associated supply and transmission costs was estimated at about $5.00.
17. A "ccf" is one hundred cubic feet, which is considered one "unit" of water. A unit of water is also equal to 748 gallons.

- *Design-Bid-Build (DBB)* – DBB is the traditional approach to delivering projects. In DBB, the City first selects the engineer to define and develop the project bid documents. A contractor is selected to build the project based on the lowest bid.
- *General Contractor/Construction Manager (GC/CM)* – In GC/CM the City enters into two contracts, one for design services and the second for GC/CM services. The GC/CM team is responsible for working with the design team to refine design, as well as for managing the construction of the project. All construction work is competitively bid through subcontracts with public bid openings.
- *Design-Build (DB)* – In DB, the City hires a design-build team through a qualifications and price-based selection process. Typically, the City defines the existing conditions and desired outcomes, then requests a 30% design and bid price.
- *Design-Build-Maintain (DBM)* – DBM utilizes one contractor for design, construction and long-term maintenance of major equipment. Contractor selection can be similar to either DB or DBO.
- *Design-Build-Operate (DBO)* – DBO involves a single umbrella contractor for overall design, construction, and long-term operation. In DBO the City typically hires a single design-build-operate team through a two-step process: (1) short-list based on qualifications and (2) selection based on requested criteria.

• The traditional Design-Bid-Build approach is well understood and allows the City to retain a high degree of control and involvement in all aspects of project implementation. However, alternative delivery approaches offer advantages to the City:

- Alternative delivery can be used to shift risk from the City to the private contractors performing the design, construction, and even maintenance and operation of the facility. Experience with design-build suggests it will reduce costs in the design and construction phases, and therefore reduce overall project costs.
- DB/DBO/DBM could shorten the implementa tion schedule for the treatment project.
- Alternative project delivery offers the ability to meet the City's goals with respect to minority and disadvantaged business involvement, regulatory compliance, reliability, quality, cost and other aspects of project development.

Seattle's new Tolt WTP was built using a DBO approach.

• The primary disadvantage of the DB approach is that the City relinquishes some control over the project in exchange for the benefits. The City and the Water Bureau would need to carefully consider desired criteria and outcomes to ensure a successful project.

• The Panel was asked to consider which criteria are important in the selection of a specific delivery method. Almost all of the Panel members that responded felt that the ability to meet cost and schedule goals were important criteria to consider. In addition, all respondents felt that the designer and contractor must be well-qualified to perform the work. The quality of the project, its reliability, and the ease of operation and maintenance were also rated as high priorities for decision-making.

- The Panel did not give detailed consideration to alternative financing methods. However, in general the financing information presented to the Panel did not provide persuasive arguments that the benefits of private financing outweigh its higher cost relative to public financing.

Additional information on project delivery alternatives is found in Appendix 7.0.

4.8 Timetable for Regulatory Compliance

The Water Bureau estimates that it is likely to take from five to eight years to plan, design and construct a treatment facility of the size needed to meet the long-term needs of Portland and other municipalities that rely on the Bull Run. The anticipated deadline for meeting the new *Cryptosporidium* regulations is 2011.

4.9 Public Input Regarding Treatment

Over the course of its work, the Panel solicited input from the general public as well as groups and individuals with a particular interest in drinking water and the question of treatment. This input was gathered through stakeholder interviews, two randomly-selected focus groups, and several public workshops in which participants were asked about issues related to the treatment question, including their values about Bull Run, their opinions about the four treatment methodologies and their concerns about cost and affordability. In each setting, the Panel received a consistent message from this diverse range of citizens, interest groups and elected officials. This message can be summarized as follows:

- The Panel's values regarding treatment are representative of the values of the community as a whole.

- There is support for taking a long-term view when addressing problems related to such basic services as drinking water.

- People felt generally inclined to support filtration treatment options over disinfection options because of the multiple public benefits of filtration.

- In general, people are willing to pay for filtration treatment because they feel the additional benefits or value received from filtration are worth the additional cost.

- There is recognition that increased costs will fall more heavily on some than others, and support for finding ways to mitigate that impact.

5.0 Panel Recommendations

Within the described framework of assumptions, values and findings, and consistent with public input received during the process, the Bull Run Treatment Panel makes the following recommendations:

5.1 Bull Run Watershed Protection

The Panel supports continued legislative protection of the Bull Run watershed as expressed in PL 95-200 and Portland City Council Resolution 35981 (See Appendix 1.0). Treatment of Bull Run water, whether by disinfection or filtration, should not be viewed as an alternative to strong watershed protection policies. The most effective way to ensure long-term water quality and safety is through a multiple barrier strategy that begins with source water protection.

5.2 Conservation

The Panel strongly supports water conservation. The Panel believes that effective water conservation programs can help reduce the cost of, and perhaps postpone, development of new water supplies in the region. The Panel recommends that the City of Portland and other regional providers continue their efforts to review and refine existing and potential conservation programs as part of the update of the Regional Water Supply Plan. A primary goal of refining these programs should be to make more efficient use of the currently available supply of Bull Run drinking water.

5.3 Preferred Technology

The following recommendations are based on the Panel's consideration of a great deal of data, numerous technical presentations and other information regarding the costs, benefits and risks associated with various treatment technologies. Ultimately, however, the treatment decision could not be reduced to a simple cost/benefit calculation. Instead, the Panel's recommendations evolved from a more subjective balancing of costs and benefits against the values adopted by the Panel to guide the treatment decision.

As noted, all four of the treatment technologies reviewed by the Panel will meet the requirements of the anticipated EPA rules. The filtration options also address supply and reliability, thereby supporting two of the key values embraced by the Panel. On the other hand, the Panel's values also reflect a concern for cost and affordability – and the filtration options are much more expensive than the two disinfection options.

In developing their response to the treatment question, Panel members spent considerable time weighing whether the added benefits provided by filtration justified the additional cost. Results of their collective consideration of this question are reflected in the following recommendations.

- A clear majority of the Panel believes that the benefits of treatment by filtration (direct or membranes) justify the additional costs of these technologies. The Panel therefore, recommends a filtration strategy. The Panel's rationale can be summarized as follows:

  - Filtration provides a more robust barrier to pathogens and is more adaptable to meeting potential future regulatory requirements.
  - Filtration will increase the reliability of the system by enabling Bull Run water to be delivered during times of high turbidity. Wholesale customers, in particular, place a high value on increasing system reliability through filtration.
  - By enabling drawdown of the reservoirs during the onset of fall rains, filtration will increase the total water available from the Bull Run by an estimated 2 billion gallons (approximately 10%). Currently, the Water Bureau limits the amount of water it takes from available storage in the fall to minimize the risk from significant turbidity events.
  - This increased supply will, in turn, provide one or more of the following benefits: (a) provide the City with additional capacity to meet endangered species requirements (if any), (b) decrease the need to use the wellfields as a summer augmentation source and (c) delay the need to develop other supply sources to meet increasing customer demand.
  - Filtration can improve water quality by removing organic materials that color the water in the fall. This is an aesthetic issue of particular importance to Portland's wholesale customers.[18]
  - Assuming reduced reliance on the wellfield, filtration will decrease in-plant treatment costs for industrial customers. These customers now must be able to treat varying water qualities from the Bull Run and the wellfield, which impacts operations and increases costs. Industrial customers will also benefit from improved reliability of supply to meet production requirements.
  - Filtration will make Portland's supply more reliable and consistent and thus comparable to other filtered sources in the

18. Ozone disinfection also removes color. Membrane filtration will require an additional treatment step to remove color.

region (all other surface water supply in the region is filtered). Portland's increased ability to retain its wholesale customers will spread system operations costs, thereby lowering rate increases Portland customers.

- Filtration provides Portland and the region with more flexibility to meet future water needs. The potential exists to expand Bull Run supply by raising the height of Dams 1 and 2 or building a third dam. Filtration would likely be needed during development of any of these projects to protect water quality from the effects of construction and meet federal regulatory standards.

Membrane cartridges are placed into a basin.

- The Panel considered detailed information on the advantages and disadvantages of direct filtration and membrane filtration. After weighing the information, a clear majority of the Panel recommends membrane filtration over direct filtration, because membrane filtration technology:

  - Offers the greatest flexibility to adapt to changing circumstances because of the potential to upgrade membranes without altering the basic structure or functioning of the facility.

  - Is simpler to operate, with less chance for operator error in chemical dosing and other operator-driven adjustments.

  - Has the ability to remove smaller-sized contaminants without the use of coagulating agents.

  - Generates less solid waste.

  - Requires a lesser amount and fewer types of chemicals.

  - Has a smaller "footprint", resulting in less impact on the environment and providing greater flexibility to increase capacity or add treatment to deal with future regulations.

View of a typical direct filtration plant.

- The Panel recommends that direct filtration remain under consideration as a back-up treatment technology. Direct filtration has a long track record of effective treatment of municipal water supplies, with many installations of the size needed in Portland. (One panel member preferred direct to membrane filtration.) Should theWater Bureau not be able to implement the risk management strategies discussed in Section 5.6, the Panel recommends that the City Council work with the Bureau to review the reasons for not meeting the strategies and the options then available, including the use of direct filtration. Because of the many benefits of membrane filtration, some Panel members would prefer that the City wait for further development of membrane technology instead of moving immediately to direct filtration.

- One member of the Panel recommends that the UV treatment method be installed to meet federal requirements in the short term, and that membrane filtration be held as a long-term capital goal for the Bull Run. This member embraces all the advantages of membrane filtration, and agrees with the majority that benefits beyond meeting federal requirements are worth paying a premium. However, this Panel member gives greater weight to the following: rate impacts on all customer classes; the combined rate impacts of membrane filtration and the Combined Sewer Overflow projects ramping up simultaneously; deferral of other pressing capital needs for Portland's water distribution system as a consequence of tying up bond revenue; uncertainties of Bull Run ownership; the exposure of Portland to incurring stranded costs if wholesale customers find less expensive supply options and do not participate in paying the cost of membrane filtration; and the prospect that membrane technology will further evolve and drop in cost as more water systems deploy it.

- The Panel notes that the least expensive way to achieve compliance with the anticipated regulation is by installing ozone or UV treatment. UV carries the lowest cost of the four treatment options. The Panel observes that if the City wished only to achieve regulatory compliance at the lowest cost, it would select UV treatment. (It should be noted that several Panel members believe UV treatment should not be considered under any circumstances because UV technology provides few benefits beyond *Cryptosporidium* removal and because of other uncertainties associated with this technology.)

5.4 Preferred Site

- From a water system perspective, the Panel recommends that the treatment facility be sited at Powell Butte. The Panel's rationale for recommending Powell Butte can be summarized as follows:

  - The City of Portland purchased this 578-acre property in 1925 to serve as a site for future water facilities. Powell Butte's location and elevation make it a key element in the regional water supply system. [19]

  - Powell Butte is located within Portland's urban growth boundary, a key consideration for permitting. Powell Butte's urban location has the additional benefit of providing greater opportunities to use the treatment facility to contribute to public awareness of water resource management issues and to develop public education and community recreation facilities.

  - This site offers significant cost savings compared to Lusted Hill due to the presence of the existing reservoir.

Aerial view of Powell Butte site (1995).

- The Panel recognizes that siting the treatment facility at Powell Butte will have significant impacts on the park and surrounding neighborhoods. However, the Panel believes that the advantages of this site warrant a serious effort to resolve these potential impacts.

- As the Panel neared completion of its work, some citizens expressed concerns about the

19. Water from the Bull Run Watershed flows by gravity directly to a 50-million gallon buried reservoir at the Butte, and is then distributed by gravity to Portland and the region. The Powell Butte reservoir receives the City's groundwater supply when the wellfield is in operation. Also, the major transmission pipeline to the westside wholesale customers, the 66-inch Washington County Supply Line, originates at the existing Powell Butte reservoir. The Bureau's captial plans call for the construction of additional storage reservoirs at Powell Butte.

social and environmental impacts of siting a filtration treatment facility at Powell Butte. The Panel recommends that the Water Bureau fully engage the community in future deliberations and decision-making regarding the siting of the facility.

- The Panel's support for the Powell Butte site should not be construed as support for the concept of an intertied regional supply and distribution system. There are many issues associated with such a system; addressing or making recommendations regarding these issues was not part of the charge to the Panel.

5.5 Project Delivery

- A majority of the Panel recommends that the City pursue a design/build approach to project delivery. Design/build provides advantages to the City in time and money savings and reduces the risks and uncertainties of membrane filtration at a large scale. If a design-build approach is pursued, the City and the Water Bureau must carefully and thoughtfully develop the design and operating criteria that will define the project. The City must clearly define how risk is to be allocated and the level of control that the City and Bureau will have over all aspects of the project.

- The Panel recommends that the Water Bureau and the City further evaluate other aspects of alternative delivery, including treatment plant operations.

5.6 Uncertainty and Risk Management

The Panel's recommendations are based on the best available information about drinking water quality and treatment, water supply and demand in the region, and the siting and delivery of treatment facilities. At the same time, it is important to note that the Panel's deliberations were influenced not only by what is known about alternative treatment technologies and sites, but also by what is *not* known.

The Panel's review and analysis of treatment and site options revealed four key areas of uncertainty – uncertainties about treatment technologies, uncertainties about ownership and management of the Bull Run system, siting uncertainties and questions about the cost and affordability of treatment. Each of these areas is described below, along with related strategies for minimizing or mitigating its associated risks.

Technology

The recommended treatment technology of a majority of Panel members is membrane filtration. Membrane technology has been around for a number of years, and the effectiveness of membranes in removing *Cryptosporidium* and other contaminants is well-proven. As more potential users recognize the benefits of membrane technology, and as the cost of membrane filtration drops, its application in the field of drinking water treatment will continue to expand. This is a positive development in terms of improving the safety of public drinking water supplies in the years ahead.

However, the Panel recognizes that there are certain uncertainties associated with membrane technology. Membrane filtration has not yet been applied at the scale required to meet Portland's needs. In addition, "early adopters" of membrane technology need to recognize that the membrane vendor market may be unsettled in the near term. Strategies are needed to minimize vulnerability to vendor turnover (e.g. the possibility that early users of membranes could get "stuck" with technology or filters that cannot be replaced).

The Panel recommends that the Water Bureau address the uncertainties associated with membranes as follows:

- To provide adequate cost competition, assure there are at least two acceptable suppliers of membranes that could be installed.
- Require that membrane suppliers have operating facilities that utilize the same size and configuration of component membrane modules and trains that will be utilized as building blocks in the Portland treatment plant.
- To minimize concerns regarding whether membrane filtration is effective and reliable at the scale needed by Portland, require that membrane plants with a minimum capacity of approximately 100 mgd are operating in the U.S. or internationally.
- To assure membrane performance, require membrane suppliers to guarantee performance for at least 10 years.
- To assure long-term availability of membranes, require contractual arrangements with membrane suppliers that allow Portland to manufacture replacement membranes itself if replacements are not available from the original supplier.
- With respect to uncertainty regarding evolving regulatory requirements, the Panel believes that membranes offer the greatest flexibility to adapt to changing circumstances because of the potential to upgrade membranes without altering the basic structure or functioning of the facility.
- To alleviate concerns about potential leachates from membranes, review the National Sanitation Foundation (NSF) certification process for membrane materials that membranes are currently required to meet, and require supplemental certification testing if appropriate.

Finally, the Panel notes that the risk management strategy described above could be compatible with a design-build approach to project delivery, because it will take some time to carefully evaluate the suitability of membrane technology for Portland. A design-build approach could give Portland the time to evaluate the technology and still be able to meet the anticipated implementation deadline of 2011.

Membrane modules of appropriate size and configuration should be operational before using this technology.

System Ownership and Management

Two basic concerns underlie the uncertainty some Panel members have expressed about system ownership and management. First is the concern that current discussions might lead to a fully regionalized system – that is, a system with multiple intertied sources owned and managed by a single regional entity. It is the Panel's understanding that full regionalization is not part of the current proposal and that these discussions are now focused on regional ownership and management of the Bull Run system only.

The second and larger concern is how the costs of treatment will be allocated among users of the system, and how to assure that all users will pay their "fair share" of those costs. Wholesale customers represented on the Panel have provided repeated assurances that that they – and their ratepayers – will share in the cost of treatment whether as owners or buyers of Bull Run water.

Another important principle for some Panel members is "growth pays for growth" – that is, those areas generating the growing demand should pay for the infrastructure and expanded supply needed to meet that demand. The ability to allow for expanded supply was a key factor in the Panel's preference for filtration. Population and demand forecasts show that the need for that expanded supply will originate largely outside the City of Portland.

Determining how "growth pays for growth" is a complex undertaking. Calculating the growth-related increments of storage and distribution is relatively straightforward. However, in the case of filtration, there are multiple benefits and beneficiaries involved and a host of complicating factors. Apart from the demands generated by population growth, the system faces demands under the Endangered Species Act to release more water to enhance stream flows for fish. Climate change may result in a "double squeeze" of heightened demand and lower rainfall. These costs and constraints will need to be faced and shared by the region.

Given these multiple variables, further analysis is needed to determine whether the supply benefits of filtration are "ancillary" and cost neutral, or whether they would impose an additional increment of capacity at an additional cost not appropriately borne by Portland ratepayers. This question is particularly applicable to the analysis of costs and benefits of the largest treatment plant under consideration (400 mgd).

The City should approach this question carefully given the unresolved nature of regionalization discussions. A range of interests must be included in defining and negotiating a cost allocation formula that clearly acknowledges Portland's stake in the Bull Run while reflecting regional needs and realities.

To address the uncertainties surrounding system ownership and management, the Panel recommends the following:

- The Panel reiterates that its support for filtration is based on the assumption that the cost of treatment will be allocated fairly among Portland and other users of the Bull Run system on a cost-of-service model.

- In addition, to protect the current and future interests of all parties, the Panel recommends that the financial, ownership, cost sharing and/or contractual arrangements regarding treatment are in place before major financial commitments (i.e. construction) are made.

Aerial view of Lusted Hill Area.

Siting

The Panel recognizes that siting of public facilities is an inherently difficult process. While confident that the two sites under consideration are not "fatally flawed" from an environmental, permitting, or land-use perspective, detailed, site-specific planning and public involvement will be needed before proceeding with construction on any site selected.

- Because of these uncertainties, the Panel recommends that a Lusted Hill site remain under active consideration as an alternate to Powell Butte should neighborhood, environmental or other issues render the Powell Butte site an inappropriate location for the treatment facility.

Cost and Affordability

While in general the cost of treatment appears affordable for most ratepayers, the Panel recognizes that for some segments of the population, rising utility costs impose a burden regardless of their size. Moreover, treatment is not the only water-related capital project on the horizon for Portland. The rate impacts of treatment should be considered in the context of other planned maintenance and capital improvements, such as capping and repairing reservoirs, replacement of the water distribution system or expansion of the Bull Run system.

The Panel believes approaches (e.g. rate structures) can and should be developed and adopted that account for ratepayer needs and addresses affordability issues, and therefore recommends the following:

- The Water Bureau – and other utilities whose ratepayers will share in the cost of treatment – should evaluate current programs for low-income ratepayers, adopt changes to improve the accessibility and coverage of these programs, and work aggressively to ensure that the programs are fully utilized by eligible customers. The Panel recommends that this review occur during the implementation planning phase of this project.

- In addition, the Panel recommends that to the greatest extent possible, implementation of the treatment decision be timed to avoid overlapping with other large maintenance and capital improvement projects such as capping and repairing the reservoirs, replacement of the water distribution system or expansion of Bull Run.

5.7 Timing

- EPA's regulations regarding treatment for *Cryptosporidium* are scheduled for adoption in mid-2003. Since final rule language was not available, the Panel had to rely on language in an "agreement in principle" adopted by a stakeholder group as part of the rule-making process and an EPA "pre-proposal draft" based on that agreement. Should the final rule represent a substantially different regulatory approach or requirements, or provide different options for addressing *Cryptosporidium*, the City and Water Bureau should revisit the Panel's recommendations.

- Assuming adoption of the regulations as expected in mid-2003, the deadline for compliance with the *Cryptosporidium* regulations will be 2011. It will take five to eight years to plan, design and construct a new treatment facility. To meet the anticipated 2011 deadline for addressing the *Cryptosporidium* regulations, and to achieve the other water quality benefits of treatment, the Panel recommends that the Water Bureau begin the next phase of work related to the treatment project in 2003. The next phase of work is expected to include such tasks as community-based planning for the treatment facility, applying for necessary permits, pilot testing and additional review of alternative project delivery approaches.

A Note about the Numbers Used in this Report

The Bull Run Treatment Panel was presented with and reviewed a great deal of information during its deliberations. Some of this information was critical to the Panel's work and affected its recommendations. Key information reviewed by the Panel included regional water supply and demand projections, projected costs of treatment facilities and estimates of the impacts of various treatment technologies on both residential and business water and sewer bills.

The numbers contained in these projections and estimates came from a variety of secondary sources and are based on a wide range of underlying data and assumptions. The Panel used these numbers to compare alternative technologies and show general trends. Development of new numbers based on more current data was outside the scope of the Panel process.

The Panel notes that some of the numbers used in this report are being revised as part of an update to the Regional Water Supply Plan.

Appendix C. Draft Site Considerations for PWB Water Treatment Facility

To: Mike Stuhr, Eddie Campbell, Chris Wanner

From: David Peters, P.E., Principal Engineer

Re: Site Considerations for Portland Water Bureau's Water Treatment Facility

Date: April 2, 2009

This memorandum discusses factors and relative costs to take into consideration when choosing a site for a filtration facility for the Bull Run water supply. A summary of the factors and costs for each site is provided on page 9 followed by a recommendation for the site that will provide the greatest benefit at the lowest cost.

Background

In 2006, the Environmental Protection Agency (EPA) issued a new drinking water rule called the Long Term 2 Surface Water Treatment Rule (LT2). The purpose of the LT2 rule is to reduce disease incidence associated with microorganisms in drinking water. One requirement of the rule is that the City of Portland must treat the water from the Bull Run River for the microorganism *Cryptosporidium*. The EPA deadline for compliance with the treatment requirement is April 1, 2012.[1]

Portland Water Bureau engineers are evaluating two methods of water filtration—direct filtration and membrane filtration (which includes either submerged or pressurized membranes)—at four possible sites: a site located on the hydraulic grade line (HGL) such as **Lusted Hill**, a site below the HGL such as the former site of **Roslyn Lake**, and two sites above the HGL such as the bureau-owned **Carpenter Lane** property or **Headworks**. A direct filtration plant would require approximately 30-40 acres. A membrane filtration facility requires less land than a direct filtration facility. For the purposes of this memorandum, filtration is assumed to be either direct filtration or submerged membrane filtration, unless pressurized membranes are specifically discussed. The decision regarding the type of filtration system to be installed is not the topic of this memo; this decision will be made at a later date.

The major factor that affects site choice is the location of the site relative to the hydraulic grade line (HGL). The HGL is the line that water follows when it flows from a higher to a lower elevation. When water flows naturally from a higher to a lower elevation it is called gravity flow. The greater the elevation difference between the starting elevation and the final elevation, the greater the gravity flow and the steeper the HGL. The existing HGL (from Headworks through the existing Lusted Hill chloramination facility to Powell Butte reservoir), provides enough gravity flow to move the water into the Portland distribution system. The closer a filtration facility site is to the existing HGL, the more the Water Bureau would be able to use gravity flow to move water through the facility and to the Portland distribution system.

The alternative to using gravity flow is to pump the water. Pumping water requires electricity. Every 10 feet of elevation that the bureau must lift the water would cost $150,000 per year in

[1] Although the EPA deadline for compliance is 2012, the Portland Water Bureau would apply to extend the deadline for two years to April 1, 2014.

additional electricity costs. Therefore, the greater the potential at a site to maximize the gravity flow, the lower the annual operations and maintenance (O&M) costs will be for the life of the facility (assumed to be 50 years).

Other factors that can affect initial capital and O&M costs and the project schedule include proximity to the existing conduit rights-of-way; the capacity of the site to accommodate process waste, including filter backwash water; current land ownership and use; the potential to accommodate future demand; the possibility of generating hydroelectric power at the plant; necessary site improvements; and the impact of the site choice on the community.

Major Factor Affecting Costs

Hydraulic Considerations

A site with a surface elevation that is on or close to the HGL is better-suited to maximizing gravity to move water than a site that is not on the HGL. Although a facility could be built at a range of elevations at any of the sites,[2] some choices would require cutting or filling to establish the facility on or near the HGL.

- At a site such as **Lusted Hill** where a filtration facility could be placed close to the HGL, little or no pumping would be required to move water through a the facility and into the Portland distribution system (see Figure 1). At this site, it is estimated that 200 million gallons a day (mgd) could be treated by gravity flow; therefore pumping would be needed only for the highest summer peak flows. Estimated costs for pumping are \$2,000 to \$20,000 per year for the life of the facility.

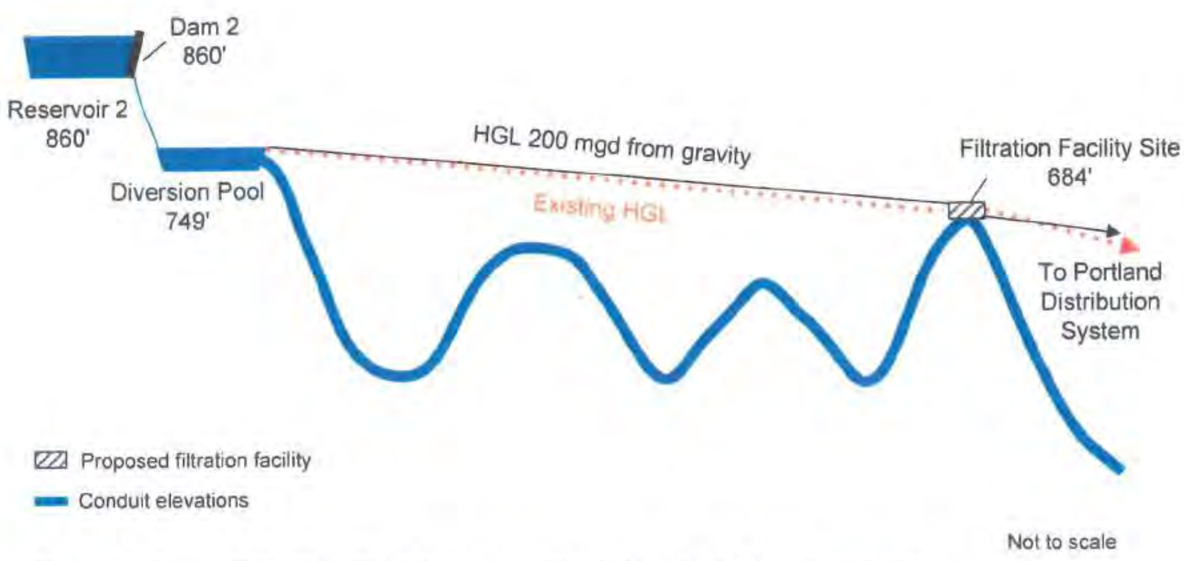


Figure 1. Direct Filtration Facility on Existing HGL—Such As Lusted Hill

---

[2] See the scenario description in the Filtration Hydraulics spreadsheet (Attachment 1) for examples of gravity capacity and estimated pumping at different elevations at each site.

- The existing ground elevation at a filtration site such as **Roslyn Lake** is below the HGL. If a facility were built at that elevation, pumping would always be required downstream of the facility to lift the water back up to the HGL and over Lusted Hill (see Figure 2).[3] Estimated costs for pumping are $650,000 to $1,200,000 per year for the life of the facility.

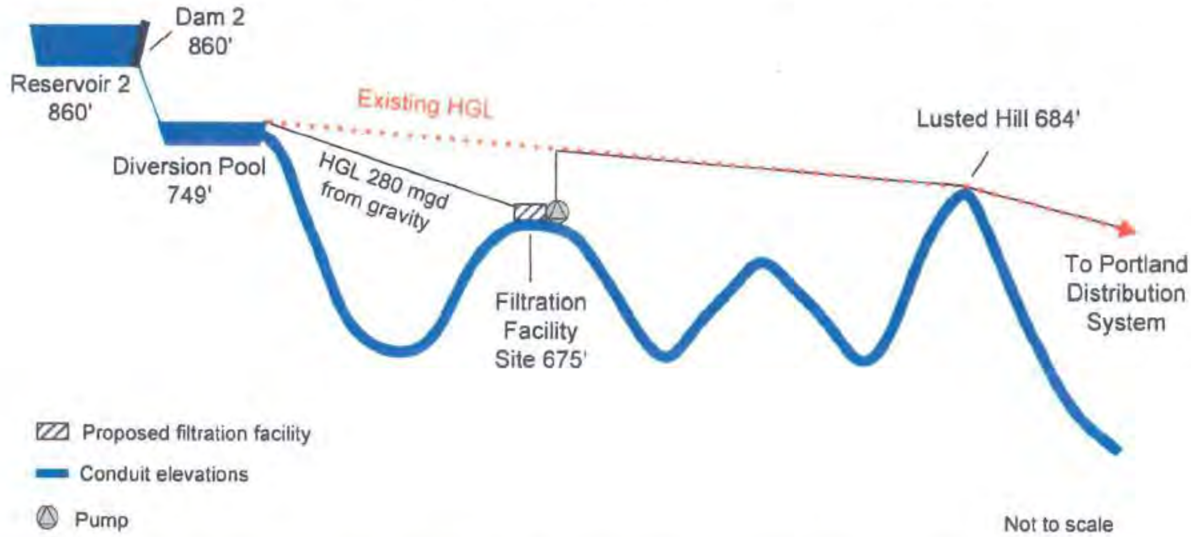


Figure 2. Direct Filtration Facility Below Existing HGL—Such As Roslyn Lake Site

- A site such as **Carpenter Lane** is above the existing HGL. Some gravity flow can be achieved at Carpenter Lane; the amount is dependent on the drop in elevation from the Diversion Pool. Figure 3 shows that a 160 mgd flow could be achieved from gravity flow. Pumping upstream of the facility would be required during the summer peak season to lift the water to Lusted Hill and connect to the conduits. Estimated costs for pumping are $30,000 to $200,000 per year for the life of the facility.

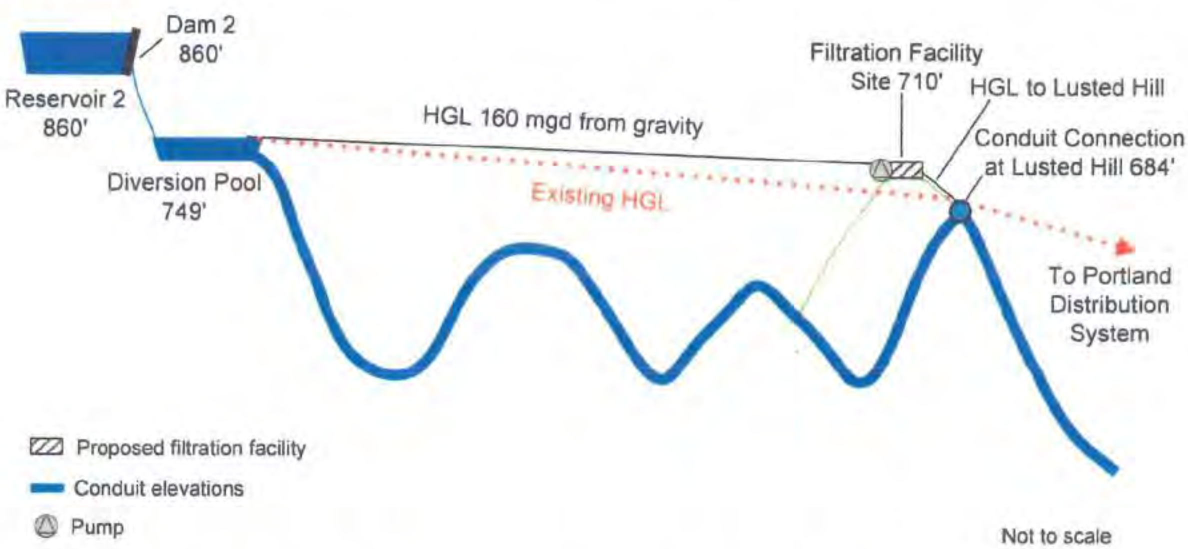


Figure 3. Direct Filtration Facility Above Existing HGL—Such As Carpenter Lane

[3] Another option would be to raise the site up to the existing HGL instead of pumping water to the existing HGL.

- A pressurized membrane facility at **Headworks** would be at the highest possible point on the existing HGL to take advantage of the gravity flow from Reservoir 2. No pumping would be required to move water to Lusted Hill and on to Portland. This option would rely on the additional water pressure available from the Reservoir 2 elevation (see Figure 4). Currently, Reservoir 2 water pressure is used to generate power through the Portland Hydroelectric Project (PHP). If this site were chosen, power generation through PHP would be reduced because the drinking water would no longer flow through the PHP powerhouse.

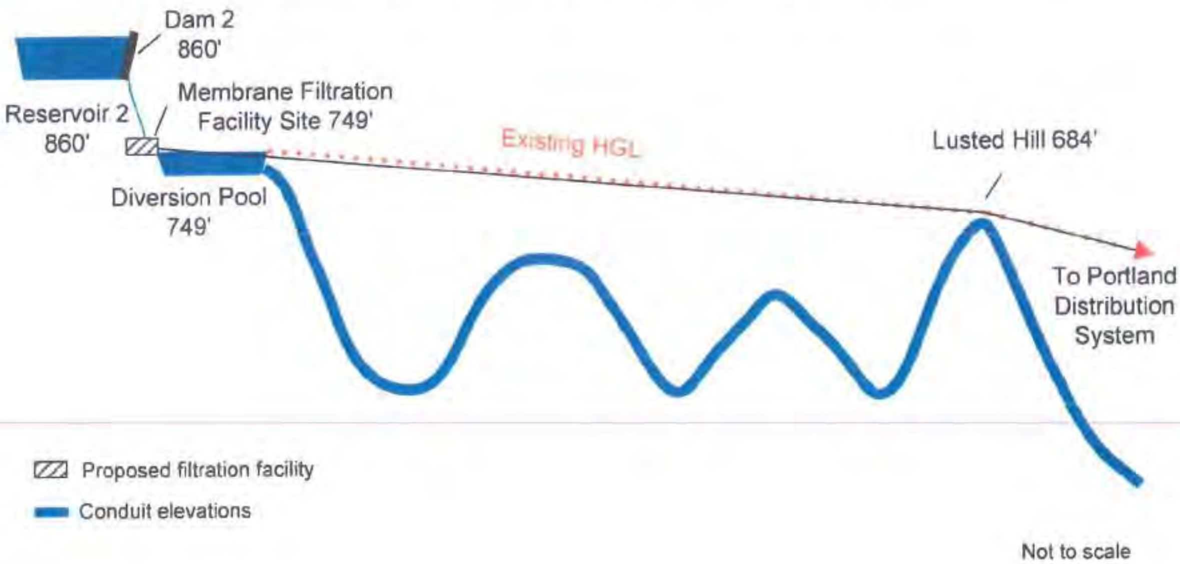


Figure 4. Membrane Filtration Facility on Existing HGL—Such As at Headworks

Other Factors Affecting Costs and Schedule

Proximity to the Conduit Rights-of-Way

Sites on or near the existing conduit rights-of-way would reduce the need for additional piping to connect to the conduits. New conduit pipeline is estimated to cost approximately $1,000 per foot.

- In some scenarios, the **Lusted Hill** site would require about 10,000 feet of additional piping to connect to the existing three conduits, Conduits 2, 3, and 4.
- A site such as **Roslyn Lake** is fairly close to two of the existing conduits; about 6,000 feet of additional piping would be needed to connect to all three conduits. This would include bringing Conduit 3 under the Sandy River twice.
- A site such as **Carpenter Lane** would require the greatest length of additional piping (13,200 feet to 21,600 feet) to connect to the existing conduits. Also, the existing conduits might need reinforcement upstream of the existing Lusted facility because the elevation of the Carpenter Lane site would add pressure to the pipes upstream of the Lusted Hill conduit connection (shown in Figure 3 as "HGL to Lusted Hill"). The increase in pressure could be as much as 60 feet (or 25 psi).

- The **Headworks** site is at the diversion point for the conduits. This option for a pressurized membrane facility would not require major extensions of large pipe.

Capacity to Accommodate Process Waste

Both membrane and direct filtration methods generate some process waste: a small amount of solids (15-55 pounds per million gallons) and filter backwash water (3-10 percent of the total volume of water).[4] The small amount of solid waste can be removed from the facility site. At peak volumes, the filter backwash water could be as much as 20 mgd. Three basic methods have been used at other facilities for discharging filter backwash water: settling, mechanical removal (with presses or centrifuges) and recycling for landscape irrigation, or discharging to a surface water source such as a stream or water body. Settling ponds or basins require space; mechanical removal requires energy; and discharge requires proximity to an acceptable surface water source.

- If additional land could be acquired at the **Lusted Hill** site (see Current Land Ownership section), the facility could handle filter backwash water through settling or mechanical removal and recycling. Discharging to a surface water source would require easements and piping to the Sandy River. The reach of the Sandy River that backwash water would be discharged to is designated as a federal Wild and Scenic River and a state Scenic Waterway; acquiring permits for an outfall may be a somewhat lengthy process, requiring coordination with several agencies.
- A site as large as **Roslyn Lake** could easily accommodate a settling pond or basin and would have sufficient power for mechanical removal of filter backwash water. In addition, piping is already in place from the abandoned Portland General Electric (PGE) powerhouse to a surface water source.
- The **Carpenter Lane** site is also large enough to accommodate a settling pond or basin and could have sufficient power for mechanical removal of filter backwash water. Discharging to a surface water source would likely require easements and piping to the Sandy River as well as a permitting process similar to that for the Lusted Hill site.
- The **Headworks** site (under consideration for a pressurized membrane facility only) is too small for a settling pond or basin or for extensive mechanical removal. Filter backwash water would be discharged to the lower Bull Run River.

Current Land Ownership and Use

Sites already owned by the City of Portland reduce the risk of failing to complete design and construction by the compliance deadline. The time frame for land-use review, permitting, and land acquisition for sites not owned by the City of Portland may be longer than the five-year time frame available to meet the final April 1, 2014 compliance deadline.

- Although the property at **Lusted Hill** is already owned by the City of Portland, the filtration plant footprint would require the acquisition of approximately 15-40 additional acres. Analyses

[4] Filter backwash water is water used to remove particles from either membrane filters or a direct filtration medium. The particles that are removed are the same particles that were present in the raw water source.

of lots to the north, west, and south indicate primarily residential improved land with some acreage zoned nonexclusive farm use. Future investigation should cover the likelihood of, and potential time frame for, acquiring property.

- The **Roslyn Lake** site is owned by PGE. The Roslyn Lake site would be large enough for a direct treatment facility. The bureau anticipates that permitting agencies already have a body of knowledge about the site that might facilitate acquiring permits. Future investigation should cover PGE's willingness to sell and confirm the status of land-use and permitting issues.
- The **Carpenter Lane** site is owned by the City of Portland. No further major land acquisition would be needed and preliminary planning for the site has been completed.
- The **Headworks** site is owned by the City of Portland. No further major land acquisition would be needed and preliminary planning for the site has been completed. Attachment 2 shows the potential permitting issues associated with constructing a pressurized membrane filtration facility at Headworks.[5]

Potential to Accommodate Future Demand

The Bull Run system's potential to accommodate future demand by gravity flow through a single treatment plant is predicated on two assumptions: the construction of Conduit 5 (along existing rights-of-way) and the future ability to divert water from Reservoir 2 rather than the Diversion Pool. The Water Bureau currently owns the right-of-way for Conduit 5; therefore, the location of a site close to the planned path for Conduit 5 would require little additional land acquisition and permitting. At an elevation of 860-832 feet above mean sea level (MSL), Reservoir 2 would provide greater water pressure to Conduit 5 than the existing Diversion Pool (at 749 above MSL). [6]

- Although the **Lusted Hill** site is relatively close to the Conduit 5 right-of-way, the site would be slightly below the Reservoir 2 modeled HGL, which means it could accommodate future demand with minimal pumping.
- The **Roslyn Lake** site is relatively far from the Conduit 5 right-of-way, and would be as much as 100 feet lower than the Reservoir 2 modeled HGL. Once the Reservoir 2 water pressure was lost at the Roslyn Lake elevation, future demand would have to be accommodated through pumping.
- The **Carpenter Lane** site is on the Conduit 5 right-of-way. The elevation of the Carpenter Lane site is on the Reservoir 2 modeled HGL, which means the site could accommodate future demand with little or no pumping.
- The use of the Reservoir 2 elevation to operate a pressurized membrane facility at **Headworks** would preclude using Conduit 5 because the elevation at the downstream end of the filtration facility would be similar to the elevation today—therefore there would be no net gain in water pressure. To accommodate future demand, water would have be to pumped or a second treatment facility would have to be constructed.

---

[5] The Headworks site is too small to accommodate a direct filtration facility.

[6] Depending on the site chosen, however, the Water Bureau may opt to build a second treatment facility at a different location to treat water from Conduit 5 or the path of Conduit 5 could be changed.

Potential to Generate Power

A site below the HGL, such as **Roslyn Lake**, would have the greatest potential for power generation, because it has the greatest difference between the starting elevation and the end-point elevation, therefore the greatest water pressure.[7] Any water pressure used to generate power also reduces the gravity flow capacity.

The option of placing a pressurized membrane facility at **Headworks** and connecting it to Reservoir 2 is another possibility for power generation. The water pressure over and above what is necessary to push the water through the filtration facility could be used to generate power. It should be noted that the water pressure from Reservoir 2 used to pressurize the filter would not be available to generate power through the Portland Hydroelectric Project turbines.

In addition to hydroelectric power generation, solar generation at the **Carpenter Lane** site could be considered as an auxiliary for all options.

Necessary Site Improvements

If a filtration facility is constructed, it is assumed that all treatment facilities would be consolidated into one location. Estimated site improvements may include buildings, storage tanks, clearwells, dewatering systems, trenching or boring for conduit connections, or filling to achieve elevations necessary to minimize pumping. Future investigation should be made regarding the quality of, and capacity for, electrical power at each site.

- Depending on the land available for acquisition, additional pipeline from the **Lusted Hill** facility to the existing conduits may be lengthy and may need to be placed in a trench.
- The **Roslyn Lake** site is relatively flat, but may require significant site work.
- Although the **Carpenter Road** site is fairly flat, some deep (at least 20-foot) trenching or boring may be required to connect to the existing conduits. Further investigations should include a geotechnical analysis to confirm the feasibility of trenching or boring at the site.
- The **Headworks** site would need significant alterations to be able to fit a facility on to this site. The clearwell and dewatering systems would likely need to be constructed in Kaiser Park and other downstream areas. The Diversion Pool would need to be filled to create more buildable land. It is likely that a pressurized membrane facility at Headworks could utilize existing conduit piping.

Impact of Site Choice on the Community

The development and construction of a filtration facility of the proposed 215 mgd capacity has the potential to affect neighbors in the surrounding community. In addition to generating additional traffic during construction, the Water Bureau may need to mitigate the site to reduce the visual and noise impact of a new water treatment facility.

---

[7] Raising a site that is below the existing HGL closer to the existing HGL will reduce the amount of water pressure that is available for generating hydroelectricity.

- Although a treatment facility at **Lusted Hill** is already in operation, expansion and the related land-acquisition process would be affected by land-use regulations and may affect land values in an area that is predominantly residential.
- The **Roslyn Lake** site is the largest and has the greatest potential for including features valued by the surrounding community, such as open space. The Roslyn Lake site also reduces the amount of backfeed pipeline necessary to serve upstream customers, and would provide the greatest flexibility in serving the City of Sandy.
- The **Carpenter Lane** site and easements are already owned by the City of Portland. The facility site is somewhat separate from the road, which might be considered an amenity by the community.
- The **Headworks** site would have little impact on the community except for the additional traffic into the watershed during construction.

Table 1 on the next page provides a summary of the major considerations for site selection as well as the range of estimated costs to construct and operate and maintain a facility at each of the sites under consideration.

Table 1. Considerations for Filtration Facility Site[a]

	On HGL	Below HGL	Above HGL	On HGL
Proposed Sites	Lusted Hill	Such as Roslyn Lake	Such as Carpenter Lane	Headworks
Hydraulic Considerations				
Pumping required	Minimal	All year at the current elevation	Summer	No
Estimated pipe length needed for conduit connection	10,000'	6,000'	13,200' to 21,600'	Minimal
Process Waste Accommodation	Settling or mechanical removal; discharge would require piping and permits.	Discharge would require permits.	Settling or mechanical removal; discharge would require piping and permits.	Discharge would require permits.
Current Land Ownership and Use				
Land ownership	Water Bureau owns some land but would need to acquire approximately 15-40 acres.	Portland General Electric owns entire site (~300 acres).	Water Bureau owns sufficient acreage.	Water Bureau owns all land.
Land use	Adjacent land use is mostly residential improved land with some nonexclusive farm land.	Timber District	Multiple Use Agriculture	Timber District
Potential to Accommodate Future Demand by Gravity[b]	Limiting factors	Limiting factors	Limiting factors	Could utilize maximum water pressure currently available
Potential to Generate Power	No	Yes—hydroelectric	Yes—solar[c]	Yes—hydroelectric
Necessary Site Improvements	All treatment facilities would be consolidated at the site. Clearwell and backwash facilities.	Site may require cut and fill. All treatment facilities would be consolidated at the site. Clearwell and backwash facilities.	All treatment facilities would be consolidated at the site. Clearwell and backwash facilities.	All treatment facilities would be consolidated at the site. Clearwell and backwash facilities.
Impact on Community	Facility would require a conditional use approval. Neighborhood would experience more industrial traffic.	Site size has potential to accommodate water feature or park; reduces length of backfeed pipe necessary.	Facility would require a conditional use approval. Neighborhood would experience more industrial traffic.	Facility would require a conditional use approval. Neighborhood outside watershed would experience more industrial traffic.
Scheduling Risks for Compliance Deadline	Land acquisition and permitting effort may constrain schedule.	Land acquisition and permitting effort may constrain schedule.	No land acquisition is required. Permitting effort may constrain schedule.	No land acquisition is required. Permitting effort may constrain schedule.
Total Estimated Cost to Construct (in millions of dollars)	\$385—\$405	\$395—\$415	\$400—\$420	<\$405
Total Estimated Lifecycle Cost	\$680—\$730	\$720—\$770	\$700—\$750	<\$730+

[a]Modeling for all site analyses was conducted under the calendar year 2008 peak-day conditions

[b]Limiting factors include proximity to proposed Conduit 5 right-of-way and site elevation relative to modeled hydraulic grade line from Reservoir 2

[c]Provided the bureau retains ownership of Carpenter Lane site, solar power generated there could provide offsets for pumping power costs at other sites.

Recommendation

The potential filtration sites discussed in this memorandum, Lusted Hill, Roslyn Lake, Carpenter Lane, and Headworks, were chosen for their position relative to the existing HGL and, to a lesser degree, their proximity to the existing conduit rights-of-way. Building a new treatment facility on the Lusted Hill site would generate the lowest lifecycle costs, require a moderate amount of new piping to connect to the conduits, and would have the least impact on the existing system. Lusted Hill is the recommended option.

As Table 1 shows, the Water Bureau would face challenges building and operating a filtration facility at any of the sites under consideration. The challenges associated with the Lusted Hill option include handling filtration backwash water, obtaining permits, and acquiring land.

Currently, the Lusted treatment facility generates a small amount of waste water that is discharged to a septic system. To accommodate as much as 20 mgd of filter backwash water during peak season, the Water Bureau would need to obtain permits to discharge the water to the Sandy River or develop an alternate form of disposal.

The Lusted Hill site as it currently exists is too small to accommodate the footprint of a direct filtration facility. Approximately 15-40 additional acres would need to be acquired in order to begin construction. Acquiring land around the existing Lusted Hill site will require permitting work and acquiring easements—tasks that can take time and entail a robust public outreach effort. The Carpenter Lane property may be an asset that can be negotiated or traded for a lot closer to the Lusted Hill facility.

It is recommended that the Water Bureau make contact with property owners in the Lusted Hill area to see whether any are interested in selling or trading properties. If there are willing sellers, then the bureau can begin to take actions on an appropriate property for the filtration facility.

Regardless of whether the bureau uses the Carpenter Lane site for a filtration facility, it is suggested that the bureau use this site for the installation of a solar-power-generation facility. If this recommendation is accepted, then the bureau should provide notice to the current land user that they would need to vacate the property in two years.

Attachment 1

Filtration Hydraulics
2/20/2009

Scenario Description	Units	Scenarios										
		Base Case	**Lusted 675** 215 mgd to Plant	**Lusted 680**	**Lusted 684** Max Gravity	**Carpenter 710 inline**	**Carpenter 730 inline**	**Roslyn 675**	**Roslyn 700**	**Roslyn 715** Max Gravity	**Roslyn 700** no C3	**Roslyn 715** no C3
					See Figure 1.	*See Figure 2.*		*See Figure 2*				
Diversion Pool HGL	feet	749	749	740	749	749	749	749	749	749	740	749
Plant Inlet Pool Elevation	feet	--	675	680	[illegible]	710	730	675	700	715	700	715
Clearwell Pool Elevation	feet	--	650	655	[illegible]	685	705	660	675	690	675	690
Powell Butte HGL	feet	525	525	525	525	525	525	[illegible]	525	525	525	525
Demand Settings		CY 2008 PDD	CY 2008 PDD	CY 2008 PDD	CY 2008 PDD	CY 2008 PDD	CY 2008 PDD	CY 2008 PDD	CY 2008 PDD	CY 2008 PDD	CY 2008 PDD	CY 2008 PDD
Plant Location			Lusted	Lusted	Lusted	Carpenter	Carpenter	Roslyn	Roslyn	Roslyn	Roslyn	Roslyn
Approximate ground elevation	feet		650 - 680	680 - 680	660 - 680	700 - 740	700 - 740	640 - 660	640 - 660	640 - 660	640 - 660	640 - 660
Diameter of new pipe between Conduits and plant	in		66, 58, 52	66, 58, 52	66, 58, 52	96	96	66, 58, 52	66, 58, 52	66, 58, 52	66, 52	66, 52
New Pipe Length - Conduits to Plant	feet		350, 1350, 350	350, 1350, 350	350, 1350, 350	6600	6600	200, 2600, 200	200, 2600, 200	200, 2600, 200	200, 200	200, 200
Diameter of new pipe between Conduits and plant	in		56, 50, 44, 24	56, 50, 44, 24	66, 50, 44, 24	96	96	66, 58, 52	66, 58, 52	66, 58, 52	66, 52	66, 52
New Pipe Length - Plant to Conduits	feet		1900, 1300, 1900, 2300	1650, 1300, 1650, 2300	1400, 1300, 1400, 2300	6600	6600	200, 2600, 200	200, 2600, 200	200, 2600, 200	200, 200	200, 200
New Pipe Length - Alternate Outlet to C3	*feet*		–	–	–	~~*5500 (96")*~~	*5500 (96")*	–	–	–	–	–
New Pipe Length - Alternate Outlet C3 to C4 & C2	*feet*		–	–	–	*2500 (72")*	*2500 (72")*	–	–	–	–	–
Conduit Intertie	#		–	–	–	2	2	–	–	–	–	–
River Crossing	#		–	–	–	–	–	2	2	2	–	–
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	mgd	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Using alternate outlet	*mgd*	–	–	–	–	*211*	*224*	–	–	–	–	–
Upstream Pump Head required to achieve 215 mgd	feet	5	0	5	9	30	50	0	0	10	–	–
Downstream Pump Head required to achieve 215 mgd	feet	–	30	25	21	18	0	69	44	29	–	–
Using alternate outlet	*feet*	–	–	–	–	*5*	*0*	–	–	–	–	–
Potential upstream excess head recovery at 95 mgd	feet	178	58	53	48	24	4	84	33	24	34	18
Potential downstream excess head recovery at 95 mgd	feet	–	93	98	107	173	143	85	110	126	105	121
Using alternate outlet	*feet*	–	–	–	–	*126*	*146*	–	–	–	–	–
Potential upstream excess head recovery at 215 mgd	feet	0	0	0	0	0	0	30	5	0	–	–
Potential downstream excess head recovery at 215 mgd	feet	0	0	0	0	0	2	0	0	0	–	–
Using alternate outlet	*feet*	–	–	–	–	*5*	*14*	–	–	–	–	–

0.1 Environmental Permitting

Several activities associated with the construction and operation of a pressurized membrane facility at Headworks in the Bull Run watershed have been identified as potentially requiring environmental permits. Each of these actions that would trigger a permit is listed in Table 4.1, with the associated permit, permitting agency, and any secondary permitting activities that would be involved. The listed "Approval Time Frame" refers to the time it takes to obtain the permit after materials have been submitted to the permitting agency. Permitting agencies usually will not start the permitting process until the design of a facility is far enough along for impacts (to wildlife, air quality, etc.) to be fairly well known. However, early communication with permitting agencies will help agency staff become familiar with the details and potential impacts of such a large, complex facility. The City's Streamlining process provides staff the opportunity to discuss upcoming projects with agency personnel. This should be done early in the design phase.

The most significant permit that might be required for the project, in terms of the level of agency coordination, is a Clean Water Act Section 404 permit (Sec. 404 permit), obtained from the U.S. Army Corps of Engineers (USACE). A joint permit application for the 404 and Division of State Lands (DSL) permits would be required if wetlands were disturbed or if fill were placed below the ordinary high water line in order to modify an existing outfall or construct a new outfall. The approval timeframe for the Sec. 404 permit would be governed by whether the activity falls within a Nationwide Permit category or requires issuance of an "individual permit." The project is unlikely to require an environmental assessment or formal Sec. 7 ESA consultation with the National Marine Fisheries Service (NMFS) or U.S. Fish and Wildlife Service (USFWS). Table 4 .1 reflects the longest anticipated time frames with regard to NEPA and ESA documentation and review.

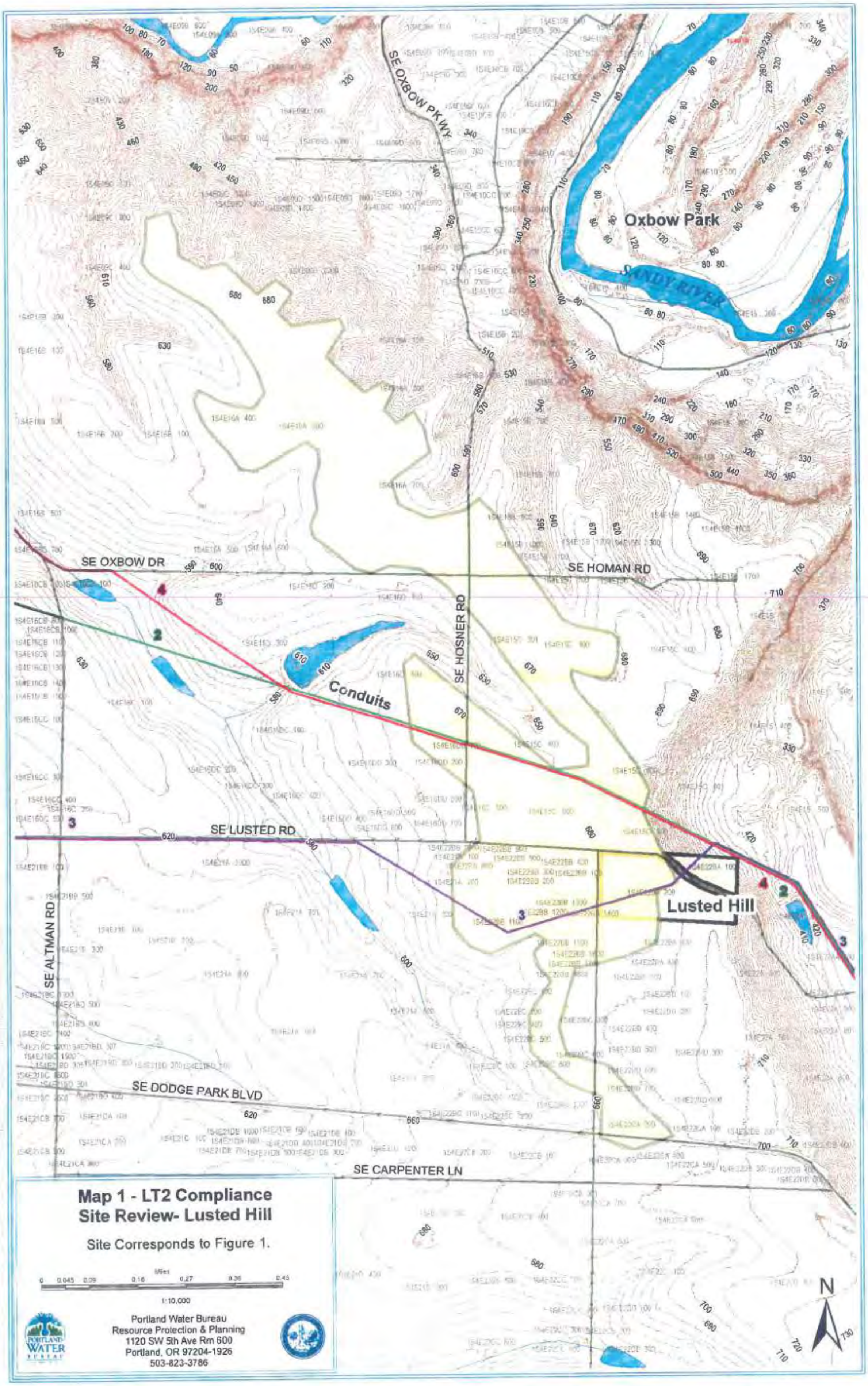
The approval timeframe for Sec. 404 Nationwide Permits is assumed to be three months, versus 9-12 months for individual permits. Nationwide Permits do not require a public notification and comment period and many of the categories, including No. 7 (Outfall Structures and Associated Intake Structures), have received pre-approval by the Oregon Department of Environmental Quality for certification with Sec. 401 of the Clean Water Act. If no disturbance to wetlands or placement of fill below the ordinary high water mark would be associated with the project, no Sec. 404 permit or secondary permits would be required.

The Bureau completed a Habitat Conservation Plan (HCP) for the Bull Run water supply system in 2008 to support its application for an Incidental Take Permit from NMFS for compliance with Sec. 10 of the ESA. The HCP did not seek coverage for terrestrial ESA-listed species from the USFWS, but includes an Implementation Plan for Spotted Owl and Bald Eagle Management which outlines a habitat evaluation and survey protocol for work being done in areas with potentially suitable habitat for these species. Although this is not a permit, it is listed as it will be considered in any permitting activities with federal agencies. An aerial photograph review of the Headworks area concluded that no suitable habitat was present that would be affected by the noise of construction or operation of the facilities. However, the recommended alternative includes activities in a location where spotted owl habitat may potentially be present – the timber stands adjacent to the fiber optic cable alignment (Road 10). Evaluations of the fiber optic cable alignment will be undertaken to determine whether further survey work is necessary

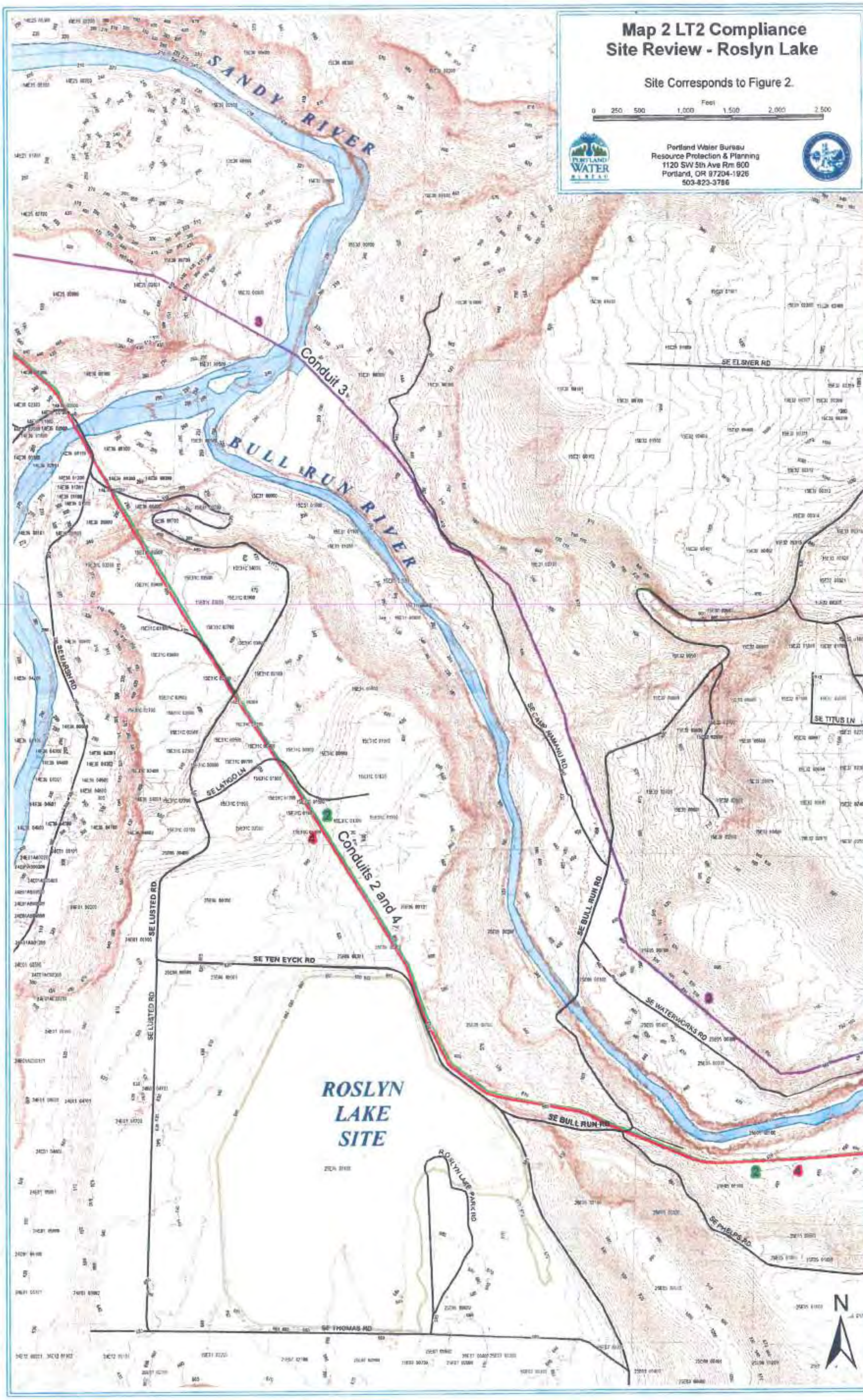
Table 4.1. Potential Permitting Requirements for a Pressurized Membrane Filtration Facility Sited in Bull Run Watershed*

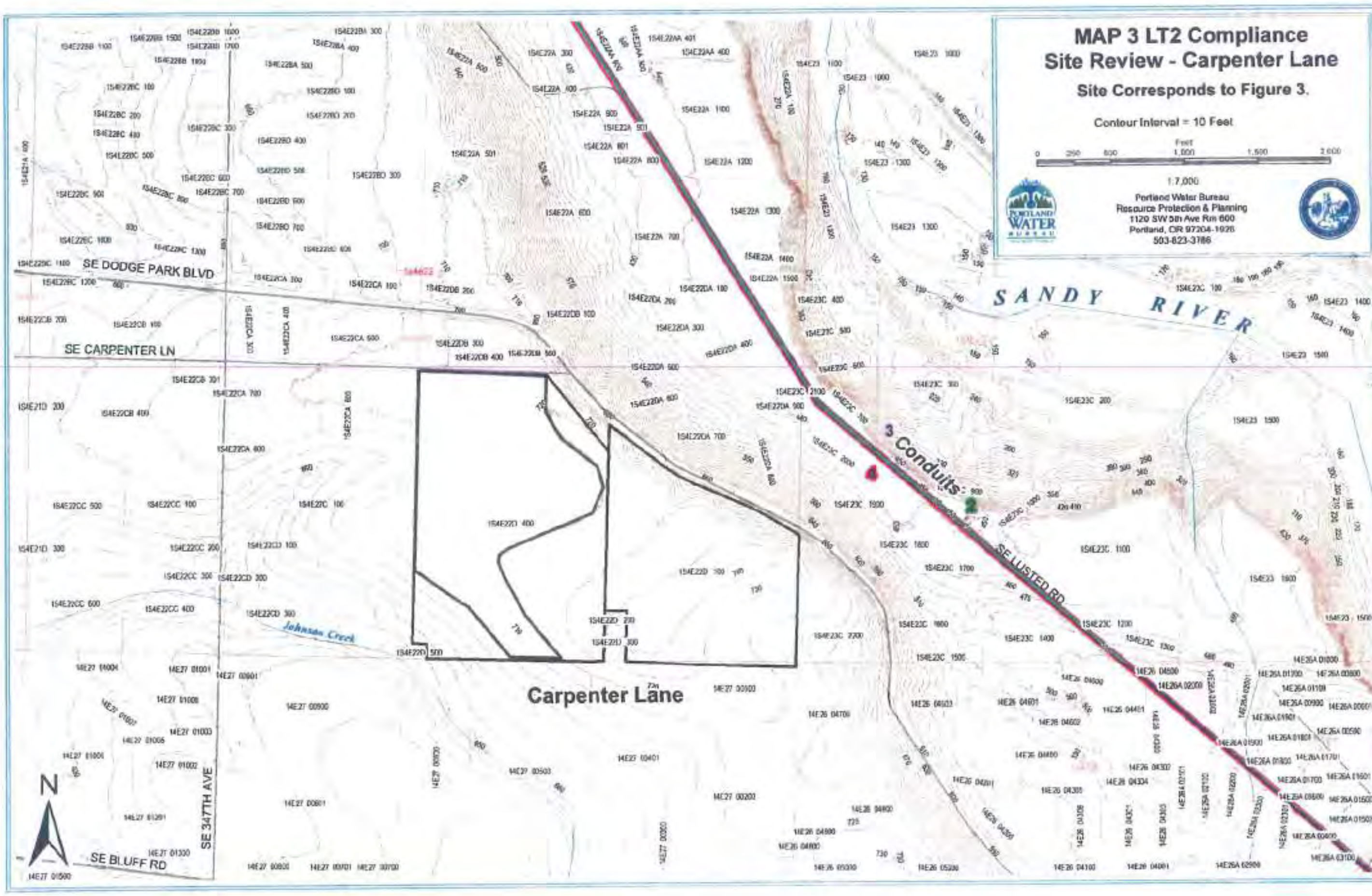
	Primary		Secondary			
Action That May Trigger Permit	**Permit**	**Permitting Agency**	**Permit**	**Permitting or Review Agency**	**Approval Time Frame**	**Notes**
New outfall structure on City of Portland land that involves placement of material below ordinary high water	Modification to systemwide NPDES permit	DEQ			3 months	
	USACE 404/DSL permit	USACE, Division of State Lands	ESA Sec. 7 consultation NHPA Sec. 106 review CWA 401 certification	USFWS, NMFS SHPO DEQ	9-12 months for individual permit 3 months for Nationwide permit	USACE will most likely consider the impacts of the entire treatment plant if any 404 permit is needed (i.e. if there is a federal nexus). Some Nationwide 404 permit categories have been pre-certified by DEQ with respect to CWA 401 certification.
Construction of filtration facility and fuel storage/generator facilities for back-up power supply	Conditional Use Permit, compliance with River & Stream Conservation Area overlay zoning	Clackamas County			3-6 months	Potential to pursue rezoning of land to be compatible with PWB projects rather than obtaining a conditional use permit for individual projects
	Building permit and trade permits	Clackamas County			6-9 months	
Air quality emissions associated with backup generator	Possibly permits related to Clean Air Act	DEQ			3 months	
Land disturbance associated with filtration facility construction	1200c Construction Stormwater permit	DEQ			2-3 months	
Tree removal in riparian zone associated with construction of new outfall or modification of existing outfall at Headworks	River & Stream Conservation Area zoning permit	Clackamas County			3 months	
Noise harassment to spotted owls from construction along *City of Portland* land portion of roadway (buried fiber optic line)	Compliance with HCP measure W-2	USFWS			15 months to conduct habitat evaluation and nesting survey (seasonally dependent)	This is not a permit. The bureau's Habitat Conservation Plan contains an agreement to survey for owls on city land if suitable habitat exists and there is a potential to disturb owls during nesting season. No surveys or permitting required of construction activity occurs July 1- February 28.
Noise harassment to spotted owls from construction along *Forest Service* land portion of roadway (buried fiber optic line)	Compliance Willamette Province Spotted Owl Noise Disturbance Biological Assessment, Forest Service Special Use Permit	Forest Service	ESA Sec. 7 consultation	USFWS	15 months to conduct habitat evaluation and nesting survey (seasonally dependent)	Willamette Province Spotted Owl Noise Disturbance Biological Assessment is a programmatic ESA Sec. 7 document that contains guidance on disruption distances and seasonal operations that apply to noise disturbance on federal land. Forest Service would *not* require habitat surveys or nesting surveys for their land if no historical nest sites are located within ¼ mile of the project area or if construction activity occurs between July 15 and February 28. The bureau has already applied for a Special Use Permit from the Forest Service for maintenance of roads on Forest Service land, including segments of Road 10 on Forest Service land between Bull Run Watershed Management Unit western boundary and Headworks. If historical nest sites are located within ¼ mile of the roadway, the Forest Service would amend the road Special Use Permit to include seasonal restrictions for buried cable construction for those locations.

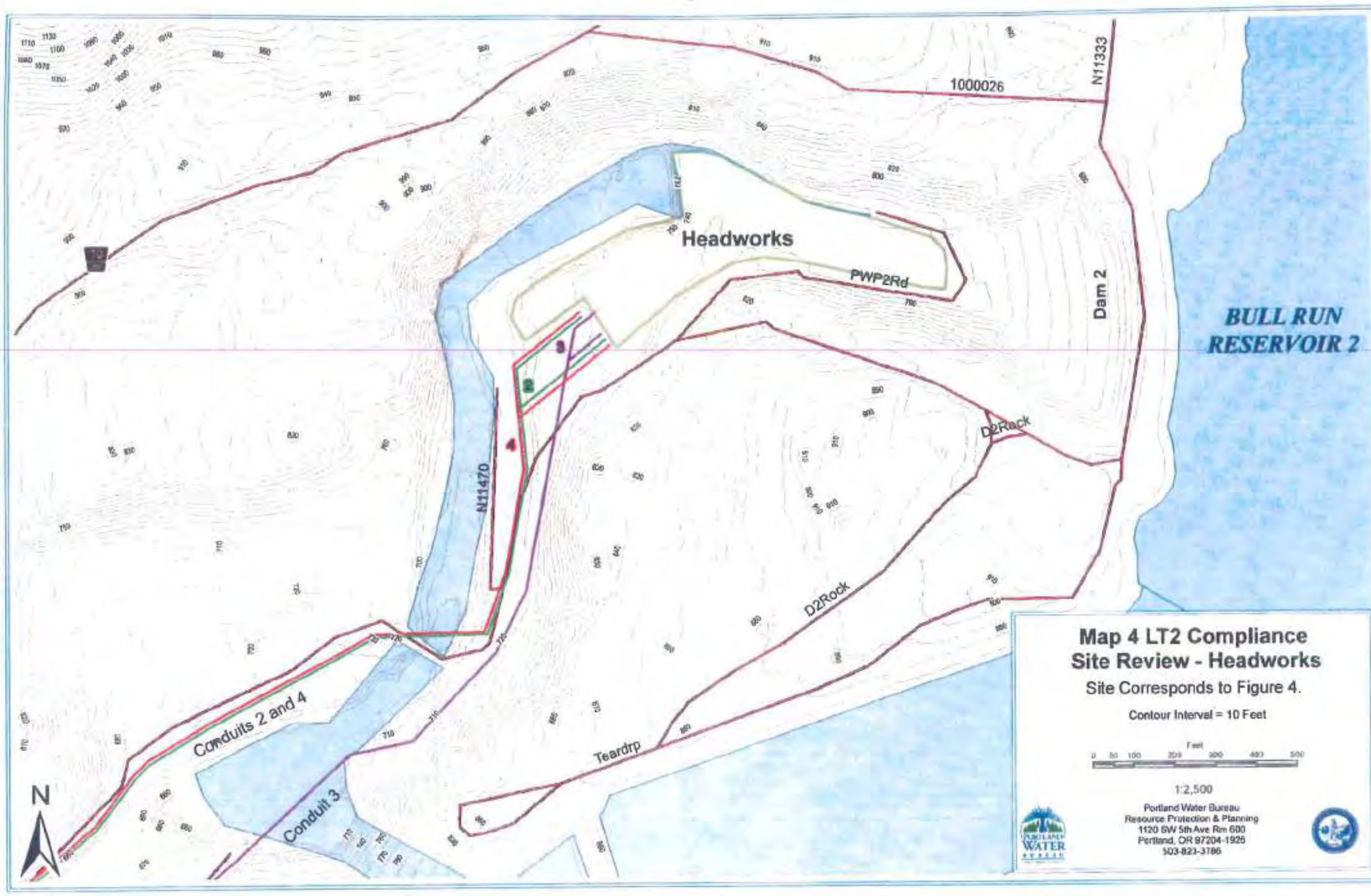
*Abbreviations:
USACE—U. S. Army Corps of Engineers
DEQ—Oregon Department of Environmental Quality
DSL—Oregon Division of State Lands
ESA—Endangered Species Act
FERC—Federal Energy Regulatory Commission
NEPA—National Environmental Policy Act
NHPA, section 106—National Historic Preservation Act, section 106 review (protection of historic properties)NMFS—National Marine Fisheries Service
NPDES—Federal Water Pollution Control Act, section 401 permits (National Pollutant Discharge Elimination System permits)
PWB – Portland Water Bureau
SHPO—State Historic Preservation Office
USFWS—U. S. Fish & Wildlife Service
404—Federal Water Pollution Control Act (Clean Water Act), section 404 permits (Permits for dredged or fill material)



SE OXBOW PKWY
Oxbow Park
SANDY RIVER
SE OXBOW DR
SE HOMAN RD
SE HOSNER RD
Conduits
SE LUSTED RD
Lusted Hill
SE ALTMAN RD
SE DODGE PARK BLVD
SE CARPENTER LN
Map 1 - LT2 Compliance
Site Review- Lusted Hill
Site Corresponds to Figure 1.
1:10,000
Portland Water Bureau
Resource Protection & Planning
1120 SW 5th Ave Rm 600
Portland, OR 97204-1926
503-823-3786
N


Map 2 LT2 Compliance
Site Review - Roslyn Lake
Site Corresponds to Figure 2.
Feet
0 250 500 1,000 1,500 2,000 2,500
Portland Water Bureau
Resource Protection & Planning
1120 SW 5th Ave Rm 600
Portland, OR 97204-1926
503-823-3786
SANDY RIVER
BULL RUN RIVER
Conduit 3
Conduits 2 and 4
SE ELSNER RD
SE MARSH RD
SE LATIGO LN
SE LUSTED RD
SE TEN EYCK RD
SE CAMP NAMANU RD
SE BULL RUN RD
SE WATERWORKS RD
SE TITUS LN
SE PHELPS RD
ROSLYN LAKE PARK RD
SE THOMAS RD
ROSLYN
LAKE
SITE
N


MAP 3 LT2 Compliance
Site Review - Carpenter Lane
Site Corresponds to Figure 3.
Contour Interval = 10 Feet
1:7,000
Portland Water Bureau
Resource Protection & Planning
1120 SW 5th Ave Rm 600
Portland, OR 97204-1926
503-823-3786
SE DODGE PARK BLVD
SE CARPENTER LN
SANDY RIVER
Conduits
SE LUSTED RD
Carpenter Lane
Johnson Creek
SE 347TH AVE
SE BLUFF RD
N


Headworks
PWP2Rd
1000026
N11333
Dam 2
BULL RUN
RESERVOIR 2
D2Rock
D2Rock
N11470
Conduits 2 and 4
Conduit 3
Teardrp
N
Map 4 LT2 Compliance
Site Review - Headworks
Site Corresponds to Figure 4.
Contour Interval = 10 Feet
1:2,500
Portland Water Bureau
Resource Protection & Planning
1120 SW 5th Ave Rm 600
Portland, OR 97204-1926
503-823-3786

Appendix D. Zoning and Land Use Review Analysis for Bull Run Treatment

Zoning and Land Use Review Analysis for Bull Run Water Treatment Plant Siting

I. Overview

This report provides a *high level* review of the zoning and land use permitting requirements for six sites under consideration for a future water treatment facility for the City of Portland. The selected sites listed below are located in unincorporated Multnomah and Clackamas Counties and the City of Portland. Zoning information was collected from each jurisdiction's GIS mapping system (including Metro RLIS) and land use procedural information was derived from each jurisdiction's development code. The sites considered below are categorized by jurisdiction, not by overall developability or rank based on zoning regulations and/or land use process.

II. Sites Considered

CARPENTER LANE

Owner(s):	City of Portland – Water Bureau
Location:	Multnomah County – West of the Sandy River and between SE Dodge Park Blvd and Clackamas County border
Site Address:	SE Carpenter Lane (not addressed)
Property ID:	R342619 (1S4E22D 00400). 56.87 Acres. R342603 (1S4E22D 00100). 36.62 Acres.
Site Area:	93.49 acres
Zoning:	MUA-20 (Multiple Use Agriculture – 20) West of Sandy River Rural Plan Area Hydric Soils: Inside Urban and Rural Reserves: Rural Fire District: Multnomah County Fire Protection District #10 Watershed Name: Johnson Creek (Willamette WS) SEC-H: Inside SEC-WR: Inside Slope Hazard: Inside

Environmental Resources:

- Significant Environmental Concern – Stream (or Water Resources). Applies to approximately 1.2 acres in the southwest corner of R342619 (the western taxlot).
- Significant Environmental Concern – Wildlife. Applies to approximately 4.5 acres of hillslope on the northeast margin of R342603 (the eastern taxlot).

Other Mapped Information:

- Slopes in the southwest two or three acres range from 10 to 25%.

- Slopes along the northeast margin of the site range from 25% to over 40%.
- Hydric soil is mapped over approximately ½ acre on the western boundary of the west lot and on less than 0.1 acre in the southwest corner of the west lot. There are no mapped wetlands on the site.
- Both taxlots have mapped frontage on SE Dodge Park Blvd, although it is separated from them by a steep slope.
- The west lot has frontage on SE Carpenter Lane. Carpenter Lane apparently serves seven residences between the Water Bureau properties and SE Cottrell Road.
- The south boundary of the two lots is also the Clackamas County line.

Mixed Use Agriculture (MUA 20) Zone:
The MUA 20 zone is a relatively flexible zone intended to conserve agriculture lands not suited to full-time commercial farming and encourage non-agriculture lands for other purposes, including Conditional Uses.

A water treatment/filtration facility is considered a "Community Service Use," which is a Conditional Use in the MUA-20 zone. The filtration building (if standalone) will be the primary structure. Other structures, if separate from the filtration structure, may be "accessory" structures, depending on the uses they serve.

Any tower constructed to hold radio or microwave antennae is considered an accessory structure, but also a separate use. Such towers have a specific review.

The site layout and the preliminary designs of the visible structures will be subject to a Design Review (Note: this is normally much simpler than a "Design Review" in Portland).

Review Types
Community Service Review (Section 36.6000) and **Conditional Use Review** (Section 36.6300). Community Service Uses are classified as Conditional Uses in the MUA-20 zone, and thus the CS review is a conditional use review for this proposal. In general, CS and CU reviews consider potential off-site impacts a proposal may create and can impose conditions of approval to avoid, minimize, or mitigate them. Both CS and CU reviews are Type III procedures.

In addition to the CS review triggered by this proposal, Community Service Use development standards will be reviewed at the same time.

Two specific elements of PWB's proposal are conditional uses and are subject to CS/CU reviews.

- Filtration Facility as a Community Service
- Radio and Television Transmission Tower as a Community Service (Section 36.6100).

Design Review (Section 36.7000). The County's Design Review ensures that development is "functional, safe, innovative, attractive, and compatible with the natural and man-made environment." It requires detailed site plans plus building elevations. A new filtration facility and communication tower will both require design review.

Significant Environmental Concern Review (Section 36.4500). This review has approval criteria for specific environmental factors, two of which are present on the property. This is a Type II procedure.

Because the SEC overlays cover only small portions of the property near the property boundaries, we will likely be able to keep our development out of the overlay areas and thereby meet the clear and objective standards. If not, additional steps will be required.

If pipelines must cross the SEC-habitat area to reach the facility, this will probably trigger additional requirements. The extra requirements could include a wildlife conservation plan, but this appears unlikely.

Hillside Development Review (Section 36.5500). This review is triggered when development (including ground disturbance) takes place in a hazard area as identified on the County's "Slope Hazard Map," or on lands with average slopes of 25 percent or more. This permit is reviewed under a Type II procedure.

Both properties at Carpenter Lane have hazard areas mapped along their northeast lot lines where the slope drops down to SE Dodge Park Boulevard. Work on the slope—such as installing a conduit connection to the facility—will trigger the requirement for this permit.

This permit focuses on slope stability, erosion control, and stream protection in the slope hazard area. It should be in conformance with the DEQ 1200-C stormwater and erosion control permit.

Review Procedures

Multnomah County numbers its permit review processes I through IV. Process types I and II are both administrative and do not require a hearing (unless appealed). The Type III process is initially decided by a Hearings Officer. The Type IV process is initially heard by the County's Planning Commission. Applications are heard using the highest-level procedure that applies to any of the individual reviews (such as Design Review, Community Service Review).

Because the CS and CU reviews are Type III, all the reviews discussed will be processed together through the Type III procedure, which requires a public hearing before a Hearings Officer.

LUSTED HILL

Owner(s):	City of Portland – Water Bureau
Location:	Multnomah County – West of the Sandy River and Immediately East of Lusted Hill Road
Site Address:	6704 SE Cottrell Rd
Property ID:	R342553 (1S4E22BA 00200)
Site Area:	14.55 acres
Zoning:	CFU - Commercial Forest Use (min. 80 ac.) West of Sandy River Rural Plan Area Fire District: Multnomah County Fire Protection District #10

Watershed Name: Lower Sandy WS
Hydric Soils: Inside
SEC-H: Inside
Slope Hazard: Inside

Environmental Resources:

- Significant Environmental Concern – Wildlife. Applies to the majority of the site with the exception of a small area located at the northwest corner of the property.

Other Mapped Information:

- Slopes on the majority of the property range from 0 to 10%.
- Slopes along the northeastern 4-5 acres of the site range from 25% to over 40%.
- Access to the property is from SE Cottrell Rd. SE Cottrell Road serves a number of agricultural uses in the area.
- The surrounding area is zoned MUA to the south/southwest, EFU to the north/northwest, and CFU to the east/northeast.

<u>Commercial Forest Use (CFU) Zone</u>
The CFU zone conserves and protects designated lands for continued commercial growing and harvesting of timber while providing for recreational opportunities and other uses which are compatible with forest use.

A water treatment filtration facility is considered a "Community Service Use," which is a Conditional Use in the CFU zone (36.2030). The site layout and the preliminary designs of the visible structures will be subject to a Design Review.

<u>Review Types</u>
Community Service Review (Section 36.6000) and **Conditional Use Review** (Section 36.6300). Community Service Uses are classified as Conditional Uses in the CFU zone, and thus the CS review is a conditional use review for this proposal. In general, CS and CU reviews consider potential off-site impacts a proposal may create and can impose conditions of approval to avoid, minimize, or mitigate them. Both CS and CU reviews are Type III procedures.

In addition to the CS review triggered by this proposal, Community Service Use development standards will be reviewed at the same time.

Design Review (Section 36.7000). The County's Design Review ensures that development is "functional, safe, innovative, attractive, and compatible with the natural and man-made environment." It requires detailed site plans plus building elevations. **A new filtration facility and communication tower will both require design review.**

Significant Environmental Concern Review (Section 36.4500). This review has approval criteria for specific environmental factors. This is processed as a Type II procedure.

Because the SEC-h overlay covers most of the property, any new development onsite would require a Type II SEC review.

Hillside Development Review (Section 36.5500). This review is triggered when development (including ground disturbance) takes place in a hazard area as identified on the County's "Slope Hazard Map," or on lands with average slopes of 25 percent or more. This permit is reviewed under a Type II procedure. The property has hazard areas mapped with 25% or greater slopes along the northeast lot line where the slope rises toward SE Lusted Rd. Work on the slope—such as installing a conduit connection to the facility—will trigger the requirements for this permit.

This permit focuses on slope stability, erosion control, and stream protection in the slope hazard area. It should be in conformance with the DEQ 1200-C stormwater and erosion control permit.

Review Procedures

Because the CS and CU reviews are Type III, all the reviews noted above will be processed together through the Type III procedure.

ROSYLYN LAKE

Owner(s): Unknown

Location: Clackamas County – Bounded by SE Lusted Rd to the west, SE Thomas Rd to the south and SE Ten Eyck Rd to the east and north

Site Address: 41401 SE Thomas Rd
Sandy, OR 97055

Property ID: 00687064 (240 ac) & 05024114 (95.82 ac)

Site Area: +/- 335 acres

Zoning: TBR/FF10 (Timber and Farm Forest) Districts

Environmental Resources:

- Clackamas County zoning maps and its online mapping system do not identify any environmental overlays on the site; **presence of any significant habitat, riparian, or other significant environmental areas should be identified prior to site selection.**

Other Mapped Information:

- Slopes on the majority of the site appear to range from 0 to 10%.
- Both parcels are not mapped in the 100-year floodplain.
- Clackamas County and Metro mapping do not provide data on upland or riparian habitat on the site.

Timber (TBR) and Farm Forest 10-Acre (FF-10) Districts

The TBR District (ZDO 406) is intended primarily for commercial forest operations. The FF-10 District (ZDO 316) is designed to provide for the full range of agricultural and forest uses for such lands. Clackamas County's Zoning and Development Ordinance Table 406-1 lists '*water intake facilities, related treatment facilities, pumping stations, and distribution lines*' as a conditional use in the TBR zone. Uses in this category are subject to 406.05(A)(1) & (6). Table 316-1 lists '*Public Utility Facilities*' as a conditional use in the (Farm Forest 10) FF-10 zone. Additionally, if radio communication facilities such as a tower to hold radio or microwave antennae is proposed, both the TBR and FF-10 Districts require conditional use review.

Review Types

Conditional Use Review (ZDO 1203). Conditional Use reviews are processed as a Type III review and consider potential off-site impacts a proposal may create and can impose conditions of approval to avoid, minimize, or mitigate them.

Two specific elements of PWB's proposal are conditional uses and are subject to review:

- Filtration Facility (water intake facilities, related treatment facilities)
- Radio and Television Transmission Tower

Two sets of conditional use criteria must be addressed: (1) general conditional use criteria that apply to any conditional use in Clackamas County; and (2) forest-related conditional use standards that address potential impacts to primary forest uses.

Design Review (ZDO 1102). Design Review applies to development in commercial, industrial and multifamily zoning districts. However, ZDO 1102.01 also states that the Planning Director may "require" Design Review for other uses. In past land use cases, Clackamas County planning staff advised PWB that Design Review is applicable to proposed water facilities in the Timber District. ZDO 1102.02 Criteria and Procedure describes procedures and criteria for Design Review approval. ZDO 1102.02 A. states that:

> ***A design review application may be approved pursuant to Subsection 1305.02 if the applicant provides evidence substantiating that the proposed development complies with Section 1000, the standards of the zoning district in which the subject property is located, and all other applicable provisions of this ordinance.***

PRCA/SCA Review (ZDO 704). The RSCA overlay requires a 100-foot setback from the "median high water line" of "large streams." Development and tree-cutting activities regulated by Section 704 in a Principal River Conservation Area (PRCA) are reviewed to ensure consistency with Section 704. Proposed developments on lands within and beyond 150 feet of the mean high water line shall be reviewed through a Type II application pursuant to Section 1307. For lands beyond 150 feet of the mean high water line notice is required to be sent to the US Forest Service and Bureau of Land Management.

Development and grading permits in a Stream Conservation Area (SCA) are also reviewed through a Type II application pursuant to Section 1307. (**Note – The site appears to contain a tributary of the Sandy River. It is unknow how this resource is classified and if the PRCA/SCA standards apply. Prior to site selection, all resources onsite should be identified.**

HEADWORKS

Owner(s):	City of Portland – Water Bureau
Location:	East Clackamas County – East Clackamas County within the Bull Run Watershed. The site is surrounded by the Mount Hood National Forest.

Site Address: 50105 SE Rock Cut Road, Corbett, OR 97019

Property ID: 00162530
Site Area: +/- 229 acres

Zoning: Timber (TBR) District
Rivers and Streams Conservation Area (RSCA) Overlay District

Environmental Resources:

- The Rivers and Streams Conservation Area (RSCA) overlay district applies to portions of the subject property. The RSCA overlay requires a 100-foot setback from the "median high water line" of "large streams" (i.e., the Bull Run Reservoir, its spillway, and the Bull Run River below the spillway), but not to the Bull Run River or the Diversion Pool above the spillway.
- Development that is located within the buffer of an unregulated stream is not subject to the River & Stream Conservation Area (RSCA) development standards of Section 704 of the County Zoning & Development Ordinance (ZDO).

Other Mapped Information:

- Slopes on the site appear to range from 0 to greater than 40% (slope data is not available through County or Metro mapping). A geotechnical study will be required for development on slopes 20% or greater.
- Both parcels are likely not mapped in the 100-year floodplain.

<u>Timber (TBR) District</u>
The TBR District (ZDO 406) is intended primarily for commercial forest operations. Clackamas County's Zoning and Development Ordinance Table 406-1 lists '*water intake facilities, related treatment facilities, pumping stations, and distribution lines*' as a conditional use in the TBR zone. Uses in this category are subject to 406.05(A)(1) & (6).

<u>Review Types</u>
Conditional Use Review (ZDO 1203). Conditional Use review are processed as a Type III review and consider potential off-site impacts a proposal may create and can impose conditions of approval to avoid, minimize, or mitigate them.

Two specific elements of PWB's proposal are conditional uses and are subject to review:

- Filtration Facility (water intake facilities, related treatment facilities)
- Radio and Television Transmission Tower

Two sets of conditional use criteria must be addressed: (1) general conditional use criteria that apply to any conditional use in Clackamas County; and (2) forest-related conditional use standards that address potential impacts to primary forest uses.

Design Review (ZDO 1102). Design Review applies to development in commercial, industrial and multifamily zoning districts. However, ZDO 1102.01 also states that the Planning Director may "require" Design Review for other uses. In past land use cases, Clackamas County planning staff advised PWB that

Design Review is applicable to proposed water facilities in the Timber District. ZDO 1102.02 Criteria and Procedure describes procedures and criteria for Design Review approval. ZDO 1102.02 A. states that:

> ***A design review application may be approved pursuant to Subsection 1305.02 if the applicant provides evidence substantiating that the proposed development complies with Section 1000, the standards of the zoning district in which the subject property is located, and all other applicable provisions of this ordinance.***

PRCA/SCA Review (ZDO 704). The RSCA overlay requires a 100-foot setback from the "median high water line" of "large streams" (i.e., the Bull Run Reservoir, its spillway, and the Bull Run River below the spillway), but not to the Bull Run River or the Diversion Pool above the spillway. Development and tree-cutting activities regulated by Section 704 in a Principal River Conservation Area (PRCA) are reviewed to ensure consistency with Section 704. Proposed developments on lands within and beyond 150 feet of the mean high water line shall be reviewed through a Type II application pursuant to Section 1307. For lands beyond 150 feet of the mean high water line notice is required to be sent to the US Forest Service and Bureau of Land Management.

Development and grading permits in a Stream Conservation Area (SCA) are also reviewed through a Type II application pursuant to Section 1307.

Protection of Natural Features (ZDO 1002). All development proposed on slopes of 20 percent or greater requires an engineering geologic study approved by the County ***to establish*** that the site is stable for the proposed development. Development on slopes up to 35% are reviewed through a Type I process; development on slopes greater than 35% are reviewed through a Type II process.

LARSON'S RANCH

Owner(s):	Unknown
Location:	East Clackamas County – Inside the Bull Run Watershed. East of SE Water Works Rd, south of SE Camp Howard Road
Site Address:	Not Addressed
Property ID:	00686760
Site Area:	+/- 226 acres
Zoning:	Timber (TBR) District

Environmental Resources:

- Clackamas County zoning maps and its online mapping system do not identify any environmental overlays on the site; **presence of any significant habitat, riparian, or other significant environmental areas should be identified prior to site selection.**

Other Mapped Information:

- The site rests on a bluff. Slopes at the north, south/southeast areas of site appear to be greater than 20-25%.

- A segment of the Bull Run River traverses the northern portion of the property.
- Access to the site is unclear and may be challenging.
- Clackamas County and Metro mapping do not provide data on upland or riparian habitat on the site.

Timber (TBR) District

The TBR District (ZDO 406) is intended primarily for commercial forest operations. Clackamas County's Zoning and Development Ordinance Table 406-1 lists '*water intake facilities, related treatment facilities, pumping stations, and distribution lines*' as a conditional use in the TBR zone. Uses in this category are subject to 406.05(A)(1) & (6).

Review Types

Conditional Use Review (ZDO 1203). Conditional Use review are processed as a Type III review and consider potential off-site impacts a proposal may create and can impose conditions of approval to avoid, minimize, or mitigate them.

Two specific elements of PWB's proposal are conditional uses and are subject to review:

- Filtration Facility (water intake facilities, related treatment facilities)
- Radio and Television Transmission Tower

Two sets of conditional use criteria must be addressed: (1) general conditional use criteria that apply to any conditional use in Clackamas County; and (2) forest-related conditional use standards that address potential impacts to primary forest uses.

Design Review (ZDO 1102). Design Review applies to development in commercial, industrial and multifamily zoning districts. However, ZDO 1102.01 also states that the Planning Director may "require" Design Review for other uses. In past land use cases, Clackamas County planning staff advised PWB that Design Review is applicable to proposed water facilities in the Timber District. ZDO 1102.02 Criteria and Procedure describes procedures and criteria for Design Review approval. ZDO 1102.02 A. states that:

> ***A design review application may be approved pursuant to Subsection 1305.02 if the applicant provides evidence substantiating that the proposed development complies with Section 1000, the standards of the zoning district in which the subject property is located, and all other applicable provisions of this ordinance.***

PRCA/SCA Review (ZDO 704). The RSCA overlay requires a 100-foot setback from the "median high water line" of "large streams." Development and tree-cutting activities regulated by Section 704 in a Principal River Conservation Area (PRCA) are reviewed to ensure consistency with Section 704. Proposed developments on lands within and beyond 150 feet of the mean high water line shall be reviewed through a Type II application pursuant to Section 1307. For lands beyond 150 feet of the mean high water line notice is required to be sent to the US Forest Service and Bureau of Land Management.

Development and grading permits in a Stream Conservation Area (SCA) are also reviewed through a Type II application pursuant to Section 1307. **(Note – The site appears to contain a tributary of the Sandy River. It is unknow how this resource is classified and if the PRCA/SCA standards apply. Prior to site selection, all resources onsite should be identified).**

Protection of Natural Features (ZDO 1002). All development proposed on slopes of 20 percent or greater requires an engineering geologic study approved by the County to establishe that the site is stable for the proposed development. Development on slopes up to 35% are reviewed through a Type I process; development on slopes greater than 35% are reviewed through a Type II process.

POWELL BUTTE

Owner(s): City of Portland – Water Bureau

Location: Southeast Portland between SE Powell Blvd and SE Foster Rd and between roughly SE 143rd and 163rd

Site Address: 16160 SE Powell Blvd

Property ID: R025703610 (multiple others)

Site Area: +/- 640 acres

Zoning: OSpc—Open Space base zone, with Environmental Conservation and Environmental Protection overlay zones. Additional zones include R10 (low density residential), and R2 (multi-dwelling residential)

Johnson Creek Basin Plan District – South Subdistrict

Powell Butte 2003 Master Plan as amended (LU 07-112412 CUMS, LU 10-169463 CUMS); Metro Title 13 High Value Habitat Areas; Scenic Resources Protection Plan

Environmental Resources:

- Environmental Conservation and Environmental Protection overlay zones

Other Mapped Information:

- The outer rim of Powell Butte consists of slopes 25% or greater and is susceptible to landslides.
- Access to the Butte is provided by means of a paved 20-foot wide driveway that extends south from SE Powell Blvd at SE 162nd Avenue.
- The Butte is surrounded largely by residential development.

Overview of Zoning

The site is zoned OS (open space), R10 (low density residential), and R2 (multi dwelling residential) base zones with c (environmental conservation), p (environmental protection) and a (alternative design density) overlay zones.

The Open Space base zone is intended to preserve public and private open and natural areas to provide opportunities for outdoor recreation and a contrast to the built environment, preserve scenic qualities and the capacity and water quality of the stormwater drainage system, and to protect sensitive or fragile environmental areas.

The R10 designation is one of the City's single-dwelling zones which is intended to preserve land for housing and to promote housing opportunities for individual households. The zone implements the comprehensive plan policies and designations for single-dwelling housing.

The R2 designation is one of the City's multi-dwelling zones which is intended to create and maintain higher density residential neighborhoods. The zone implements the comprehensive plan policies and designations for multi-dwelling housing.

Environmental overlay zones protect environmental resources and functional values that have been identified by the City as providing benefits to the public. The environmental regulations encourage flexibility and innovation in site planning and provide for development that is carefully designed to be sensitive to the site's protected resources. They protect the most important environmental features and resources while allowing environmentally sensitive urban development where resources are less sensitive.

The City's Scenic Resources Protection Plan maps 6 specific Scenic Viewpoints on the site, identified as Viewpoint 34-08. The Powell Butte Master Plan limits development on the site in order to protect views from these points.

The application of the environmental overlay zones is based on detailed studies that have been carried out in separate areas throughout the City. Environmental resources and functional values present in environmental zones are described in environmental inventory reports for these study areas.

The project site is mapped within the *Johnson Creek Basin Protection Plan* as Site # 29. Resources and functional values of concern on the project site, as identified by the Plan, include water, storm drainage, aesthetics, scenic, pollution and nutrient retention and removal, sediment trapping, recreation, education, and heritage. The site description includes management recommendations for protecting the forested perimeter and taking advantage of the natural attributes at Powell Butte.

The "a" overlay is intended to allow increased density that meets design compatibility requirements. It focuses development on vacant sites, preserves existing housing stock, and encourages new development that is compatible with the surrounding residential neighborhood. This proposal is not using any of the provisions of the "a" overlay.

<u>Review Types</u>

Major Amendment to a Conditional Use Master Plan (CUMP)

Powell Butte operates under a Conditional Use Master Plan. The Powell Butte CUMP implements the planned water system and park amenities and provides an overall framework for the future of Powell Butte. The Master Plan also sets forth land use and approval criteria for a variety of development, uses, or actions allowed by the master plan. The master plan notes that "any uses not allowed" by the master plan such as new filtration facility and any associated development would require a major amendment to the approved master plan (Type III process). Expansions of the master plan boundary would also be processed through a Type III process.

Conditional Use Review (Section 33.815). Basic Utilities are classified as Conditional Uses OS zone, and thus a conditional use review for this proposal would be required. CU reviews are processed as a Type III review. Additionally, Rail Lines and Utility Corridors are conditional uses in the OS zone.

The required conditional use reviews triggered by this proposal would be processed as part of the Major Amendment to the Conditional Use Master Plan.

Environmental Review (Section 33.430). Environmental review would be required for any development within environmental zones on the site including the new filtration facility, accessory structures and buildings, or new conduits or utility lines. The proposed projects must comply with the approval criteria established by the 2003 Master Plan and any subsequent relevant master plan amendments.

Adjustment Review (Section 33.805). The master plan establishes a number of development standards that apply to permitted uses within the master plan. When the proposed development does not comply with the clear and objective standards in the plan, an Adjustment must be approved. For example, potential adjustments may arise if minimum building setbacks cannot be met, prescribed utility corridors exceed the maximum disturbance area allowed by the CUMP, or tree preservation/removal exceeds limitations under the CUMP.

Review Procedures

The Type III process is initially decided by a Hearings Officer. Applications are heard using the highest-level procedure that applies to any of the individual reviews. An appeal of a Hearings Officer decision would be considered by Portland City Council and is then appealable to LUBA.

III. Discussion and Conclusion

This assessment provides a general zoning and land use review analysis of six sites currently under consideration for a water filtration facility. A more comprehensive analysis should be considered as part of the decision process if a specific site is determined to be more desirable based on developed site selection criteria.

Of the six selected sites, Powell Butte would likely be the most difficult to secure land use approvals for development. This is because the land use process would require a Major Amendment to the Powell Butte Conditional Use Master Plan and would trigger a subset of other land use reviews including conditional use, environmental, and likely adjustment review to accommodate the impacts of development in the park and to the surrounding area. Additionally, larger Powell Butte land use reviews (Reservoirs and 2003 CUMP) in the past have been appealed to the State Land Use Board of Appeals (LUBA) by the neighborhood association and other public members, creating additional monetary costs, approval delays, and political scrutiny for the project and for PWB.

The other five potential sites are located outside of the Urban Growth Boundary (UGB) and are rural in nature. The timing and difficulty of the land use review process would likely be driven by PWB's success in demonstrating minimal impact to forest and farm uses/operations in each immediate area as well as to any existing residential uses. Because all five sites in the rural area will require Conditional Use Review and likely environmental review, additional factors that will need to be considered include (but not limited to) provision of utility service (sewer, water etc.), access to the site, impact on the transportation system because of additional generated trips to the site, potential transportation system improvements (e.g., right-of-way dedication, road or site distance improvements, etc.), and any onsite environmental disturbance that would occur as a result of development.

Addendum

Owner(s): Bottomley Evergreens of Oregon - % Martha Bottomley

Location: Multnomah County – West of the Sandy River and Immediately north of Lusted Road

Site Address: 34519 SE Lusted Rd

Property ID: R341823 (14.32 ac), R341822 (4.32 ac), R341821 (19.86 ac)

Site Area: **+/- 38.50 ac**

Zoning: **EFU – Exclusive Farm Use**
West of Sandy River Rural Plan Area (MCC Chapter 36)
Fire District: Multnomah County Fire Protection District #10
Watershed: Lower Sandy WS
SEC – Water Resources (R341821 only)
Hydric Soils are mapped on portions of R341821 & R341823 (a segment of Beaver Creek bisects R341821 and terminates on R341823) .

Other Mapped Information:

- Slopes on the majority of the property range from 0 to 10%.
- Soils consist of 10c (Cornelius Silt Loam), 27b (Mershon Silt Loam), and 57 (Wollent Silt Loam) – all high value farm land soil types.
- Access to the property would be from SE Lusted Rd or SE Hosner Rd.
- The surrounding area is zoned MUA to the south/southwest, EFU to the north/northwest, and CFU to the east/northeast.

Exclusive Farm Use (EFU) Zone

The Exclusive Farm Use District preserves and maintains agricultural lands for farm use consistent with existing and future needs for agricultural products, forests and open spaces.

A water treatment/filtration facility is not specifically listed as an allowed use, a 'Review Use' (use requiring at least Type II review), or Conditional Use in the EFU zone. Rather, MCC 36.2625 (A) provides that **"Utility facilities necessary for public service….."** are "Review Uses." This means that the proposed water treatment facility can be administratively reviewed (decision by Planning Director) and would not require a hearing unless appealed.

MCC 36.2675 (A) supports **ORS 215.275 (Uses Permitted in Exclusive Farm Use Zones in Nonmarginal Lands Counties)** by requiring an alternative site analysis, whereby a thorough analysis of all reasonable, non-EFU sites are considered along with the reasons for rejection. ORS 215.275 is implemented by OAR 660-033-0130(16) and it provides the following approval criteria (**'Necessity Test'**) that must be addressed as part of a land use application:

OAR 660-033-0130

(16)(a) A utility facility is necessary for public service if the facility must be sited in an exclusive farm use zone in order to provide the service. ***To demonstrate that a utility facility is necessary, an applicant must show that reasonable alternatives have been considered and that the facility must be sited in an exclusive farm use zone*** *due to one or more of the following factors:*
(A) Technical and engineering feasibility;
(B) The proposed facility is locationally dependent. A utility facility is locationally dependent if it must cross land in one or more areas zoned for exclusive farm use in order to achieve a reasonably direct route or to meet unique geographical needs that cannot be satisfied on other lands;
(C) Lack of available urban and nonresource lands;
(D) Availability of existing rights of way;
(E) Public health and safety; and
(F) Other requirements of state and federal agencies.

(b) Costs associated with any of the factors listed in subsection (16)(a) of this rule may be considered, but cost alone may not be the only consideration in determining that a utility facility is necessary for public service. Land costs shall not be included when considering alternative locations for substantially similar utility facilities and the siting of utility facilities that are not substantially similar.

(c) The owner of a utility facility approved under this section shall be responsible for restoring, as nearly as possible, to its former condition any agricultural land and associated improvements that are damaged or otherwise disturbed by the siting, maintenance, repair or reconstruction of the facility. Nothing in this subsection shall prevent the owner of the utility facility from requiring a bond or other security from a contractor or otherwise imposing on a contractor the responsibility for restoration.

(d) The governing body of the county or its designee shall impose clear and objective conditions on an application for utility facility siting to mitigate and minimize the impacts of the proposed facility, if any, on surrounding lands devoted to farm use in order to prevent a significant change in accepted farm practices or a significant increase in the cost of farm practices on surrounding farmlands.

Review Types

Administrative Decision by Planning Director (Type II Review unless appealed to Hearings Officer) for review of the proposed water treatment facility and compliance with the zoning code.

Design Review (Section 36.7000). **A new filtration facility will require design review.** The County's Design Review ensures that development is "functional, safe, innovative, attractive, and compatible with the natural and man-made environment." Design Review is processed as a Type II review.

Significant Environmental Concern Review (Section 36.4500). Because the SEC-Water Resources overlay covers a small swath of the northern taxlot, any new development within the SEC overlay would require a Type II SEC review.

Conclusion

Although it appears that siting a water treatment plant on this site would only require a Type II land use review, it may be advisable to elevate the application to a Type III if there is a likely possibility for an appeal. In consideration of this site, PWB will need to make a strong finding in its land use application that the water treatment facility must be sited in an EFU zone pursuant to ORS 215.275. In a previous case, LUBA (the Land Use Board of Appeals) explained that *"at the core of the necessity test is the requirement that the local government determine that the utility facility cannot feasibly be located on non-EFU land, which in turn requires that the local government consider reasonable alternatives to siting the facility on EFU-zoned land."* ***Central Klamath County Community Action Team v. Klamath County, LUBA No. 2001-043 (2001)***. PWB will need to provide a robust alternatives analysis that adequately demonstrates why this facility must be located on this site in lieu of other non-EFU sites currently under consideration.

Robert Fraley|Senior City Planner
Portland Water Bureau|City of Portland
400 SW 6th Avenue, Suite 400
Portland, OR 97204
(d) 503.823.3573
robert.fraley@portlandoregon.gov
http://www.portlandoregon.gov/water

PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Technical Memo

Date:	September 18, 2018
Project:	Bull Run Filtration Project 699275.01.03
To:	Portland Water Bureau Filtration Decision Team
Copy to:	HDR, Barney &Worth
Prepared by:	Lee Odell, Dan Speicher
Approved by:	Kelly Irving
Subject:	**Filtration Plant Technology Alternatives**

1 Introduction

The purpose of this technical memorandum is to provide an alternatives analysis of filtration technologies that were considered for the treatment technology decision.

Information was provided to the project decision team over a series of several workshops. The information provided to the team included:

- A review of raw water quality data collected by PWB over the past 10 years. This information included important information used to select treatment for surface waters like turbidity, algae counts, color, manganese as well as microbiological testing results, and other parameters. This information is included in Appendix A.
- A summary of previous filtration pilot testing efforts conducted by PWB. These efforts included a significant amount of granular media filtration testing and two shorter efforts with low pressure membrane filtration technologies. This information is included in Appendix B.
- A listing of 167 large (> 50 million gallons per day) surface water treatment plants in North America and the type of filtration technology they each use. This information is included in Appendix C.

Additional information provided to the project team on the capabilities of treatment technologies, and on the capital and operations and maintenance costs and related impacts and benefits of facilities, are described in this technical memorandum.

2 Description of Filtration Technologies

The USEPA recognizes several filtration strategies for compliance with the Surface Water Treatment Rules, including the latest Long-term 2 (LT2) Enhanced Surface Water Treatment Rule that sets out treatment requirements for *Cryptosporidium* removal and inactivation. These technologies include:

- Granular media filtration (includes conventional and direct filtration)
- Membrane filtration
- Slow sand filtration
- Cartridge and bag filtration, and
- Diatomaceous filtration

Of these filtration technologies, there are no known large (greater than 50 million gallons per day [mgd]) cartridge, bag, or diatomaceous earth filtration facilities. Therefore, the team proposed to focus the evaluation on the remaining three technologies. Each of the three technologies is described below.

2.1 Granular Media Filtration

Granular media filtration is the most commonly used technology for large surface water plants in the U.S. There are two basic types of granular media filters in use for potable water treatment: Rapid granular media filters and biologically active filters.

2.1.1 Rapid Granular Media Filtration

Most conventional surface water treatment plants use rapid granular media filters after coagulation and often clarification processes to produce filtered water. This is referred to as Conventional Filtration throughout this memorandum. Most granular media designs use sand, anthracite, granular activated carbon (GAC), or combinations of media types. Typical design filter loading rates for modern filters are 6 to 8 gallons per minute per square foot (gpm/sq. ft.) but can range from 3 to 12 gpm/sq. ft. of filter area.

Dual media filters are the most common filters found at water treatment plants today. Most designs are anthracite/sand or GAC/sand. The dual media design is typically a shallow bed with 18 to 24 inches of anthracite or GAC followed by 12 inches of sand. Media sizes can vary, but the most common media size for the sand part of the filter is 0.5 mm (effective size), while the anthracite and GAC can range from 0.8 to 1.2 mm (effective size). Dual media filters provide excellent finished water quality. The smaller sand media provides a barrier to particle breakthrough, and more efficient filter runs.

2.1.2 Biologically Active Filtration (BAF)

BAF filters are used to provide additional removal of organics resulting in better disinfection byproduct (DBP) control and a biologically stable filter effluent. The filter design is generally the same as a rapid media filter with large media and deep beds to promote biofilm growth. Biological growth can be supported on GAC and anthracite. GAC is most amenable to biological growth because of the rougher surface characteristics than the other granular media types. The filters are usually preceded by ozonation to convert many of the large organic molecules into smaller organic molecules that are readily assimilable by microbiological activity in the filter. Ozone also introduces large amounts of oxygen to the water, creating excellent aerobic conditions for microbial growth on the filter media. A biological filter system may also include additions of nutrients to encourage more biological growth and hydrogen peroxide to manage the growth. To sustain the biofilms, biological filters are typically backwashed with unchlorinated water.

Advantages to BAF include:

- Production of a biologically stable filter effluent that reduces regrowth in the distribution system
- Removal of organic precursors to DBPs
- Reduction in the disinfectant demand of the filter effluent, thereby reducing the amount of disinfectant required in the finished water and possibly reducing DBPs
- Removal of ozonated DBPs (bromates)

2.2 Membrane Filtration

With increasingly stringent requirements for better drinking water quality and reduction in use of disinfectants because of health concerns, the drinking water industry has investigated alternative processes to conventional treatment. Membrane filtration is gaining popularity in the U.S. The long-term experience with membranes in large surface water treatment applications is limited, but there are a few plants with capacities of 50 to 120 mgd in North America.

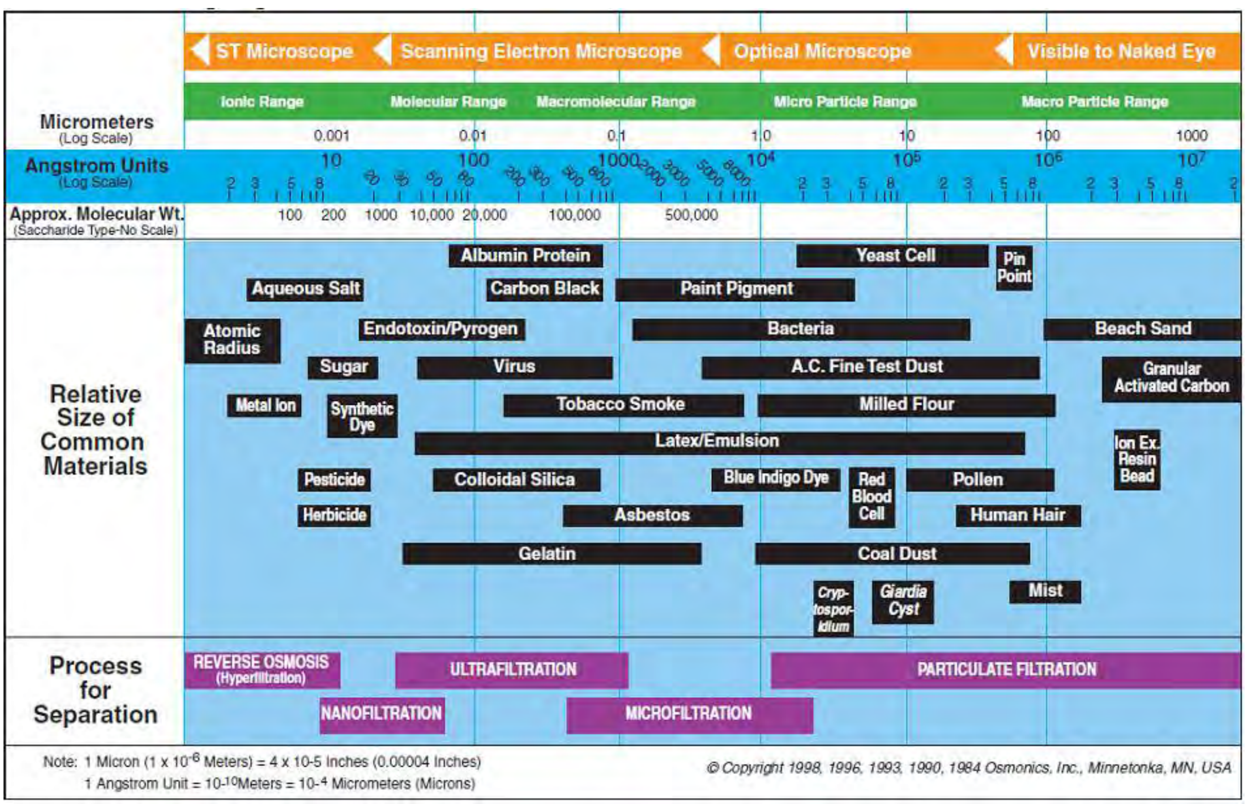
Membrane filtration can be separated into four basic categories—reverse osmosis, nanofiltration, ultrafiltration, and microfiltration.

Reverse osmosis (RO) and nanofiltration (NF) are used to remove dissolved inorganic compounds such as sodium, calcium, and magnesium ions, or dissolved organic compounds such as humic and fulvic acids that make up the primary source of DBP precursors. They operate at transmembrane pressures of about 80 to 1,200 psi, depending upon the source water quality and degree of separation required. Some uses for RO and NF include desalination of seawater and membrane softening, respectively. Ultrafiltration (UF) and microfiltration (MF), on the other hand, cannot remove dissolved materials, and are limited to removal of particles. UF membranes have a nominal pore size of between 0.003 and 0.03 micrometer (µm), whereas MF membranes have a nominal pore size of between 0.05 and 0.5 µm.

MF membranes, because of the pore size, are most effective at removal of turbidity, bacteria and oocysts such as *Giardia* and *Cryptosporidium*, while UF membranes have the added feature of removing not only turbidity, bacteria, and *Giardia* and *Cryptosporidium,* but also viruses. NF membranes remove particles but also can remove most DBP precursors and some dissolved salts. RO membranes remove everything the other membranes do, plus almost all dissolved salts. Figure 1 shows the particle size removal capacity of each type of membrane.

The cost of installing and operating RO or NF systems make this process cost-prohibitive for a surface water like the Bull Run. MF is the typical membrane filtration technology for this type of surface water.

Figure 1. Membrane Pore Sizes



The earliest commercially available UF and MF membrane systems designed to filter/sterilize liquids are known as pressure-driven, hollow-fiber membranes. The liquid is passed either from the outside to the inside of the fibers (called the lumen) of the hollow fiber (outside-in) or from the lumen to the outside of the fiber (inside-out). The hollow fibers are installed in vessels, which provide support for the pressure necessary to drive the liquid through the membrane pores. This type of filter is commercially available from many suppliers. These units use water, air, or air/water backwash systems.

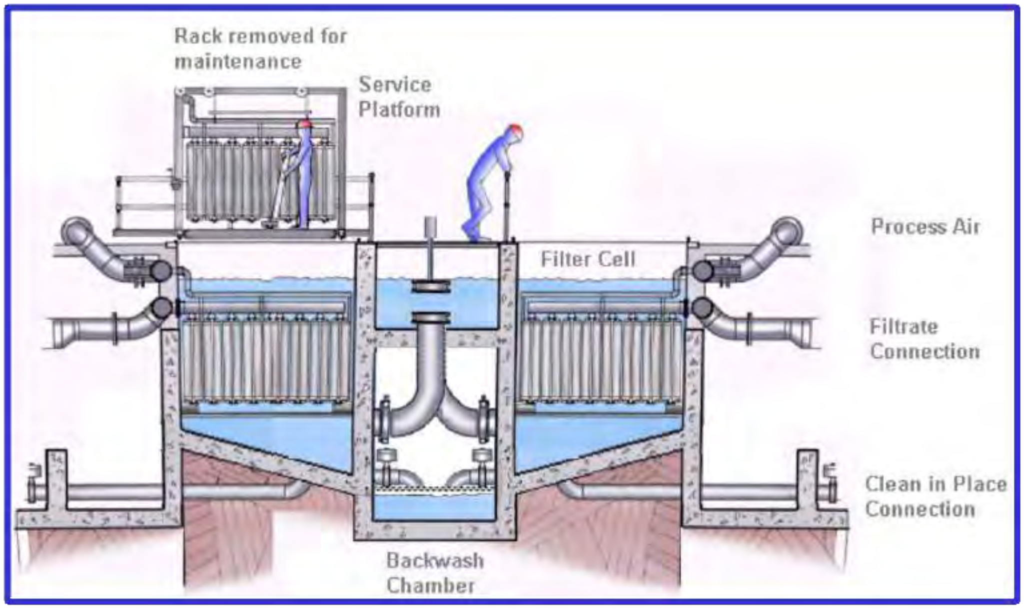
Immersed membranes have been used in the largest membrane surface water treatment plant applications. In this process, hollow fiber membranes are installed (immersed) in a raw water vessel and a small vacuum is applied to their downstream side. This process is more energy efficient and can result in a smaller footprint than pressure-driven configurations. Immersed membranes are available from Zenon (UF) and Memcor (MF). With the Zenon ZeeWeed® Process, air is introduced at the bottom of the membrane feed vessel, which creates turbulence in the tank effectively scrubbing the solids from the membrane surface. Memcor uses air only in the backwash of its immersed membranes.

The advantage of a solids separation barrier with a known diameter makes MF or UF a feasible technology for control of microbes and provides effective filtration while achieving reasonable recovery of the product water. Product water recovery for MF and UF membranes ranges from 85 to 95% and can be even higher in some cases.

An example pressurized microfiltration system is shown in Figure 2. An immersed membrane configuration is shown in Figure 3.

Figure 2. Pressurized Microfiltration System *(Courtesy of Pall Corporation)*

Figure 3. Immersed Microfiltration System *(Courtesy of Evoqua)*



Advantages of membranes compared to granular media filtration include increased particle removal, reliably consitent treated water quality and often improved pathogen removal. The disidvantages include the necessity of adding pretreatment for removal of materials smaller than the pore size. For example, coagulation is needed to remove dissolved organic matter prior to microfiltration or ultrafiltration. Membrane cleaning and replacement are also significant operational activities. Disposal or treatment and recycling for membrane concentrate can be more significant than for granular media filter backwash wastes, and capital and operating costs for membranes are often higher than for granular media filters.

2.3 Slow Sand Filtration

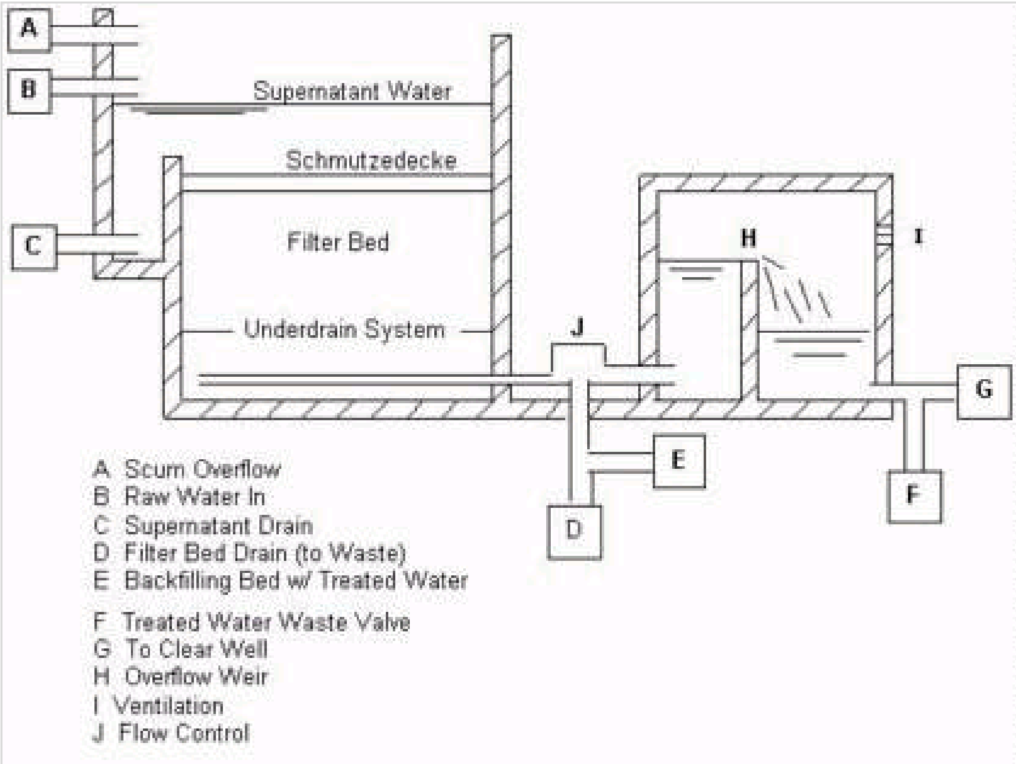
As the name suggests, slow sand filtration utilizes a sand filter operated at a low filtration loading rate, typically 50 to 100 gallons per day (gpd) per square foot of filter area. The one large slow sand plant in North America, Salem, Oregon's Geren Island Water Treatment Plant (WTP), has a design loading rate of 72 gpd per square foot.

Slow sand filters are typically characterized by certain design components: the supernatant (water above the filter sand), filter sand varying in depth, the underdrain medium (typically consisting of graded gravel), and a set of control devices.

In a mature sand bed, a thin upper sand layer called a schmutzdecke forms. The schmutzdecke consists of biologically active microorganisms that break down organic matter while suspended inorganic matter is removed by straining. The primary purpose of the schmutzdecke is turbidity removal, and while it is a microbiologically active layer, it has a limited ability to remove DBP precursors, taste and odor (T&O) causing compounds, and algal toxins.

A schematic of a slow sand filter is presented in Figure 4. This example used concrete basins.

Figure 4. Slow Sand Filter Schematic



Because of their low filtration rate, slow sand filters require a relatively large surface area. Slow sand filters may be configured as earthen or concrete basins (Figure 5), with concrete basins tending to be significantly more expensive. However, the only slow sand filter facility designed to withstand a Cascadia Subduction Zone seismic event is in the City of Camas, WA. Constructed in 2016, the Camas' slow sand facility was built using concrete basins specifically because geologic conductions and structural design requirements to meet the expected seismic impacts could not be met by using earthen berms at that site (CH2M, 2016).

Figure 5. Slow Sand Filter Beds, Geren Island, Salem, OR *(Photo Credit USGS)*

Slow sand filters can be differentiated from standard granular media filters by the following characteristics:

- Use of biological mechanisms as well as physical/chemical mechanisms for removal of particulates and pathogens (although granular media filtration can be modified to include biological filtration, too).
- Use of smaller sand particles.
- Required replacement of the surface media layer rather than backwashing for removal of solids trapped by the filter.
- Much longer run times between cleanings.
- Required ripening period, e.g. re-establishment of biological mechanisms (schmutzdecke), at the beginning of each run.

Maintenance of a slow sand filter involves two periodic tasks:

- Removal of the top 0.25 to 0.5 inches of the sand bed when headloss becomes excessive.
- Replacement of the sand when repeated scrapings have reduced the bed depth to approximately one-half of the initial depth.

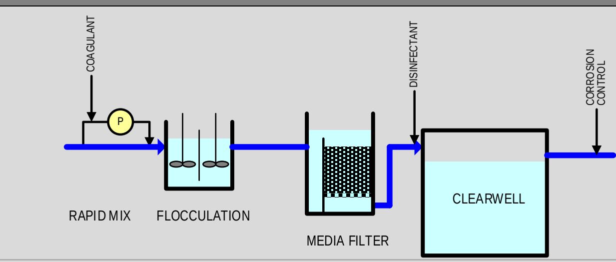
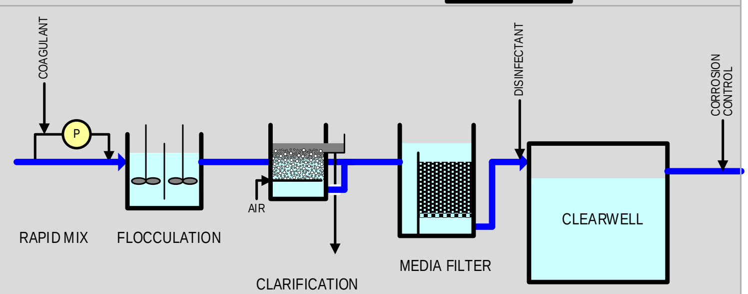
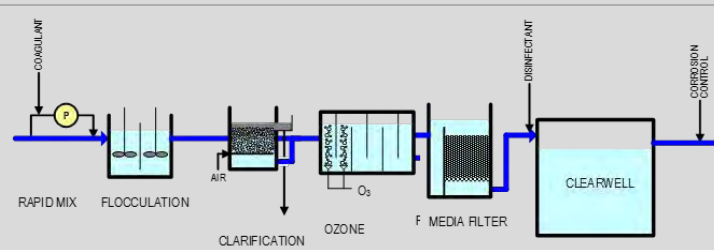
Following removal of filter bed material, re-establishment of the schmutzdecke may take several days or even weeks. Proper application of slow sand filtration requires pilot testing to confirm the design and operating parameters required to reliably meet water quality objectives for a given site. Typically, pretreatment is not extensively used with slow sand filters. There is a concern that extended use of clarification prior to slow sand filtration would remove the bacterial food sources and nutrients required for effective treatment.

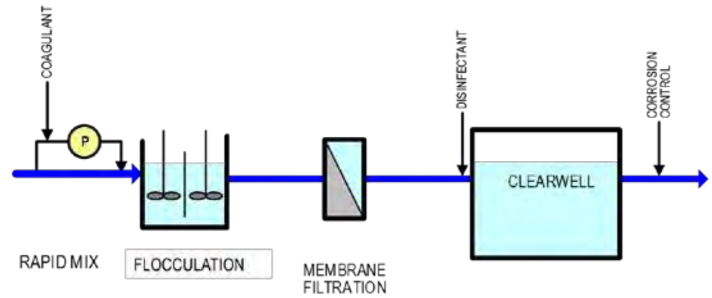
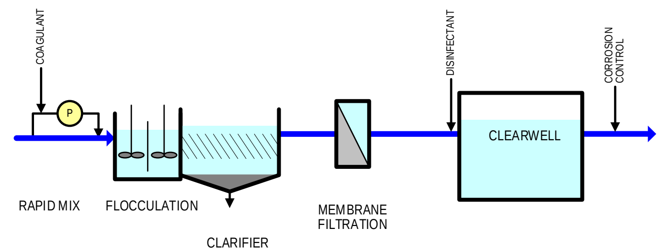
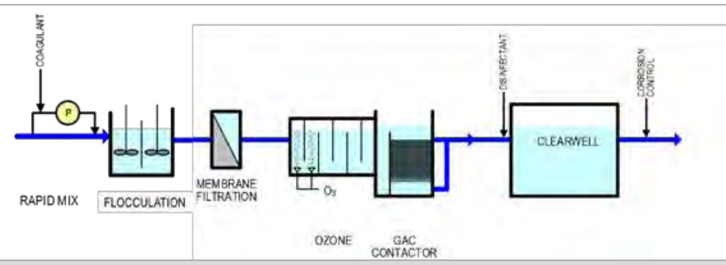
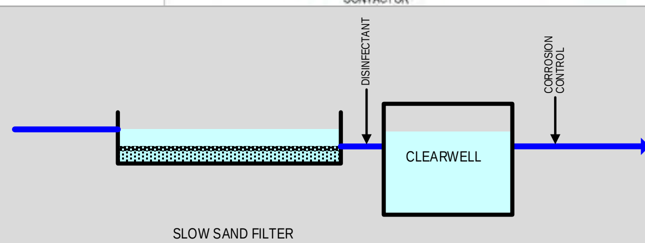
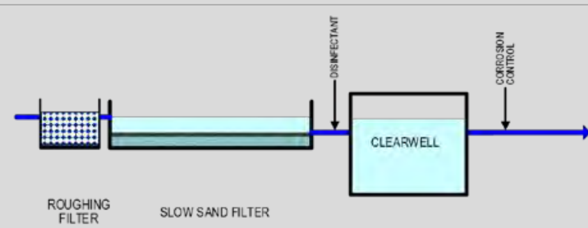
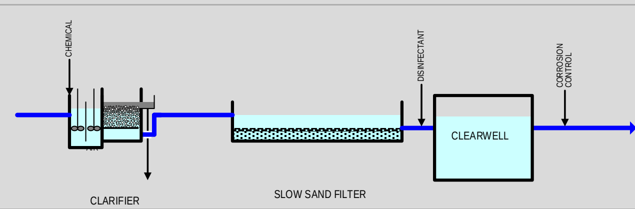
3 Filtration Technology Screening

At this stage in the decision-making process, prior to selecting the WTP designer, this screening evaluation provides basic information about filtration technology performance to determine which filtration technology should be carried forward in the decision process. Screening is not intended to describe the final configuration of the technologies selected, but rather to provide a basis for evaluating the expected performance of each type of filtration.

For each of the three filtration technologies being evaluated, there are many ways to configure the treatment plant. For example, a low-pressure membrane plant will not remove dissolved organic chemicals, so it may result in higher levels of disinfection by-products compared to a media filter. A media filter requires coagulant chemicals and rapid mixing to meet the regulatory requirements. Coagulants could also be added to the membrane plant, if desired, to lower disinfection by-products or just to reduce membrane fouling. To aid in the discussion, three general configurations are provided for each filtration technology, as shown in Table 1.

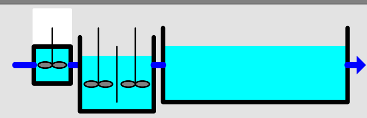
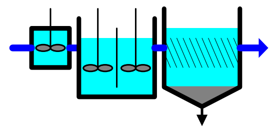
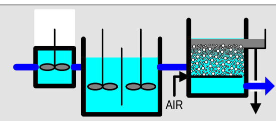
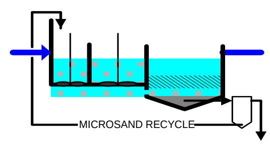
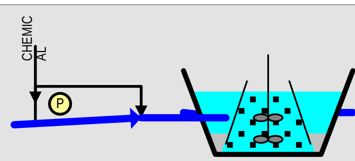
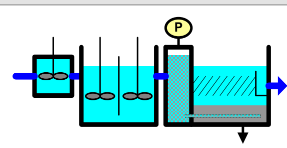
Table 1. General Configurations of Filtration Technologies

#	Filtration Technology	Treatment Goal of Configuration	Example Process Flow Diagram
1	**Granular media filtration (Direct Filtration)**	Basic configuration: rapid mix, coagulation/floccula-tion, filter, backwash, disinfection, corrosion control	
1A	Add clarification (Conventional Filtration)	Removal of elevated turbidity, algae, and TOC	
1B	Biological granular media filtration	Improved removal of dissolved organic chemicals, improved aesthetics	

#	Filtration Technology	Treatment Goal of Configuration	Example Process Flow Diagram
2	**Membrane filtration**	Basic configuration: rapid mix, coagulation/flocculation, membrane, backwash, clean in place, disinfection, corrosion control	
2A	Add clarification	Removal of elevated turbidity, diatoms, algae, and TOC	
2B	Add post filter ozone and biological contactor	Removal of dissolved organic chemicals, improved aesthetics	
3	**Slow sand filtration**	Basic configuration: slow sand filter, disinfection, corrosion control	
3A	Add Roughing Filter	Removal of elevated turbidity, algae, and TOC	
3B	Add Clarification	Removal of elevated turbidity, algae, and TOC	

There are many types of pretreatment technologies that could be used. Examples are shown in Table 2.

Table 2. Clarification Alternatives

Pretreatment Alternative	Process Schematic	How it Works
Conventional sedimentation	 CONVENTIONAL SEDIMENTATION	Settleable particles are formed and allowed to settle to the bottom of the basin
Plate or tube settling	 PLATE SETTLERS	Tubes or plates are used to reduce settling distance and footprint
Dissolved air flotation (DAF)	 DISSOLVED AIR FLOTATION	Super-saturated oxygen is used to float particles to surface
Sand-ballasted clarification	 ACTIFLO	Micro-sand intercepts particles and carries them to the bottom; sand is recycled after separating
Upflow clarifier		Particles flow from the center through the bottom of the basin and out the top, passing through a blanket of sludge.
Pulsed sludge blanket clarification, SuperPulsator™	 SUPERPULSATOR	Vacuum pumps pulse water through a solids contactor

Post treatment could include methods to improve pathogen removal, like ultra-violet (UV) light or advanced oxidation, or it could include post filter ozonation and biological contactors. These technologies have been widely used in the drinking water industry.

It is not the intent of this evaluation to identify the pre- and post-treatment technology that would be used with each filtration technology. The intent is to identify if pre- or post-treatment measures may be used to achieve the required desired benefits of filtration and to develop capital and operating costs so that decision-makers can fairly evaluate the alternatives.

3.1 Filtration Benefits

Potential benefits of filtration are as follows:

- Provide pathogen removal for *Cryptosporidium, Giardia*, bacteria and viruses
- Produce biologically stable water
- Reduce disinfection by-products
- Increase supply reliability
- Reduce (not eliminate) distribution system flushing, and lower turbidity levels
- Reduce iron and manganese concentrations
- Improve water quality stability, and lower lead and copper levels (optimized corrosion control would still be required)
- Effectively treat an algae event
- Reduce water quality impacts due to warmer weather
- Reduce organic discoloration events
- Improve ability to respond to changes in regulations
- Increase ability to meet several critical service levels
- Treat a sustained elevated turbidity event
- Reduce customer cost of home water filtering or treatment

The consultant team met with Bureau staff and identified the list of filtration benefits as those that would have measurable impact on evaluating the differences among the filtration technologies being considered. These filtration benefits are based on the filtration benefits described by the Bureau to the City Council in the August 1, 2017, memo to Council identifying the probable benefits of filtration over UV treatment.

3.2 Granular Media Filtration Screening

These benefits were used to conduct an initial alternatives analysis of the treatment technologies. The screening evaluation of granular media filtration against the filtration benefits is shown in Table 3 and further explained in the following text. The results of the screening show that with the addition of clarification, granular media filtration can achieve a good or excellent rating in each of the benefit categories. Without clarification, granular media filtration cannot withstand an extended elevated turbidity event of greater than 10 NTU.

Table 3. Granular Media Filtration Screening

Treatment Process	Granular Media Filtration			
Benefits	**Granular Media Filter (Direct Filtration)**	**Add Clarification (Conventional Filtration)**	**Biological Granular Media Filtration**	**Notes/references**
Provide pathogen removal for *Cryptosporidium, Giardia*, bacteria and viruses (3.2.1)	Excellent	Excellent	Excellent	USEPA, 2010 (LT2 Toolbox)
Produce a biologically stable water (3.2.2)	Good	Good	Excellent	AOC reduction, CH2M TM 4.1

Treatment Process	Granular Media Filtration			
Benefits	**Granular Media Filter (Direct Filtration)**	**Add Clarification (Conventional Filtration)**	**Biological Granular Media Filtration**	**Notes/references**
Reduce DBPs (3.2.3)	Good	Good	Excellent	THM and HAA reduction
Increase supply reliability (3.2.4)	Good	Excellent	Excellent	Turbidity events, AWWA ASCE, 2012
Reduce distribution system flushing, lower turbidity levels (3.2.5)	Excellent	Excellent	Excellent	USEPA, 2010 (LT2 Toolbox)
Reduce iron and manganese (3.2.6)	Good	Good	Excellent	AWWA ASCE, 2012
Improve WQ stability, lower lead and copper levels (3.2.7)	Excellent	Excellent	Excellent	Assumes optimal corrosion control for all options
Effectively treat an algae event (3.2.8)	Good	Excellent	Excellent	Production, T&O, cyanotoxins
Reduce water quality impacts due to warmer weather (3.2.9)	Good	Good	Excellent	Increases algal blooms, T&O, cyanotoxins
Reduce organic discoloration events (3.2.10)	Good	Good to Excellent	Excellent	Tannins and lignins, AWWA ASCE, 2012
Improve ability to respond to changes in regulations (3.2.11)	Good	Excellent	Excellent	Removal of contaminants of emerging concern
Increase ability to meet several critical service levels (3.2.12)	Good	Excellent	Excellent	Color, manganese, sediment
Treat a sustained elevated turbidity event (3.2.13)	Poor	Excellent	Excellent	AWWA ASCE, 2012
Reduce customer cost of water treatment (3.2.14)	Good	Excellent	Excellent	Consistent water quality with low color, T&O

3.2.1. Provide pathogen removal for cryptosporidium, giardia, bacteria and viruses

Direct Filtration: Granular media filtration can achieve > 2 log removal credits (2 log removal credit is equal to 99% removal) for *Cryptosporidium*, at least 2 log removal credits for *Giardia* and at least 1 log (90%) removal credit for viruses.

With Clarification: If clarification is added prior to the filters, an additional 0.5 log removal credit for *Giardia* and additional 1 log removal credit for viruses can be achieved.

With Ozone/Biological Filtration: Ozone is an effective disinfectant for pathogens; however, Oregon does not allow disinfection credit for ozone applied prior to filtration, although a variance may be possible.

3.2.2. Produce a biologically stable water

Direct Filtration: Granular media filtration with coagulation can typically achieve at least 20% reduction of total organic carbon (TOC), a portion of which can contribute to biological regrowth in the distribution system. Coagulation involves adding polymers to the water to clump small particles together into larger aggregates that are more easily removed.

With Clarification: No additional improvement expected.

With Ozone/Biological Filtration: If ozone is added prior to the filters, it will produce elevated levels of assimilable organic carbon (AOC). If the ozone is followed by a biologically active filter, the reduction of AOC and TOC is usually significantly increased over granular media filtration alone. In Portland's pilot testing, UV 254, which is a surrogate measure of dissolved inorganic carbon, was reduced 57% to 84% with ozone and biological filtration, compared to approximately 24% reduction with coagulation and filtration alone.

3.2.3. Reduce disinfection by-products

Direct Filtration: With direct filtration, reductions in trihalomethanes (THMS) and haloacetic acids (HAAs) would be expected to reflect reductions in TOC of approximately 20%.

With Clarification: Results would be similar to direct filtration.

With Ozone/Biological Filtration: Portland's pilot testing of Bull Run water found that ozone reduced total THM formation by 40 to 50% and haloacetic acids (HAAs) by 50 to 70% over un-ozonated Bull Run water. Subsequent pilot testing using granular media filtration was all done using pre-ozonated water. Additional reductions were achieved with both GAC and anthracite filter medias.

3.2.4. Increase supply reliability

Direct Filtration: Increased supply reliability would be achieved if the Bull Run water supply could remain online through normal turbidity events, e.g., less than 10 NTU for 1-3 days of duration. All the granular media filtration options provide an improved supply reliability over the unfiltered status. With direct filtration, the system should be able to operate routinely with turbidity up to 10 NTU and for short periods with turbidity up to 20 NTU.

With Clarification: With clarification, elevated turbidities up to 500 NTU can be treated. Reduced plant output may be experienced at higher turbidity levels.

With Ozone/Biological Filtration: No additional improvement over clarification.

3.2.5. Reduce distribution system flushing, and lower turbidity levels

Direct Filtration: Reduction in distribution system flushing would be a result of lower sediment load being sent to the distribution system. During pilot testing, turbidity was routinely maintained below 0.1 NTU in granular media filtered water. A full-scale granular media filtration plant would be expected to have a filtered water turbidity well below 0.1 NTU.

With Clarification: Results would be similar to direct filtration.

With Ozone/Biological Filtration: Results would be similar to direct filtration.

3.2.6. Reduce iron and manganese concentrations

Direct Filtration: In granular media filtration facilities that maintain a chlorine residual across their filters, it is very common for oxides to form on the surface of the filter media. These oxides can form in as little as a few weeks and, once established, help remove iron and manganese from the influent water supply. Granular media filtration plants are very capable of producing water with iron and manganese levels below 0.05 mg/L and 0.02 mg/L, respectively. During Bull Run pilot testing, iron and manganese in the raw water were low – ranging from 0.03 to 0.04 mg/L for iron and 0.003 to 0.009 mg/L for manganese. Results are less predictable in filters that do not maintain a chlorine residual across the media bed.

With Clarification: Results would be similar to direct filtration.

With Ozone/Biological Filtration: With ozone followed by biological filtration, ozone can effectively oxidize iron and manganese prior to the filters, so results would be similar to direct filtration where a chlorine residual is maintained across the filters. However, too much ozone can oxidize manganese to permanganate, which could pass through the filters.

3.2.7. Improve water quality stability, and lower lead and copper levels

Direct Filtration: Filtration will provide a reduction in both DOC and particulate metals loading to the system and is therefore anticipated to provide a reduction in lead release observed at customer taps (Black & Veatch, 2014). Optimized corrosion control would still be required.

With Clarification: Results would be similar to direct filtration.

With Ozone/Biological Filtration: This option would also reduce nitrification. Nitrification can contribute to lead leaching.

3.2.8. Effectively treat an algae event

Direct Filtration: A few studies have examined the effect of granular media filtration on algae and algal toxins. In one, rapid sand filtration achieved 14-30% removal of Microcystis aeruginosa cells (Drikas et al.,1997). Another study showed 14% removal of cyanobacterial cells in rapid sand filtration (Lepisto et al., 1996). A third study demonstrated 42% removal of cyanobacteria cells in rapid sand filtration using GAC media (Lambert et al., 1996). However, researchers have expressed concerns over cell lysis and toxin release during filtration (Mouchet and Bonnélye, 1998).

With Clarification: Large blooms can be treated with coagulants or powdered activated carbon to prevent filter clogging and remove geosmin, 2-Methylisoborneol (MIB) and algal toxins. Typically, if significant algal blooms occur, they require clarification to prevent filter clogging.

With Ozone/Biological Filtration: In addition to clarification removal, ozone is very effective at oxidizing geosmin, MIB and algal toxins. When an algae bloom breaks down, the cells can release cyanotoxins and taste and odor (T&O) causing compounds such as geosmin and MIB.

Clarification with ozonation are needed to effectively remove these dissolved organic compounds.

3.2.9. Reduce water quality impacts due to warmer weather

Direct Filtration: The discussion provided concerning algal events also applies to warmer weather impacts on water treatment technology. In addition, warmer water produces disinfection by products in the presence of free chlorine at a faster rate compared to cooler water. Filtration reduces the amount free chlorine contact time required for primary disinfection which will result in lower disinfection by products during warm weather periods.

With Clarification: Large algal blooms can be treated with coagulants or powdered activated carbon to prevent filter clogging and remove geosmin, MIB and algal toxins.

With Ozone/Biological Filtration: In addition to clarification removal, ozone is very effective at removing taste and odor causing compounds and algal toxins.

3.2.10. Reduce organic discoloration events

Direct Filtration: The Bull Run has highly colored raw water, averaging 11 color units, and levels as high as 75 color units have been noted. Granular media filtration with effective coagulation should be successful in achieving an average color of below 5 color units. At peak color levels without clarification, the filters may be overloaded with particles due to high coagulant doses.

With Clarification: Clarification would allow color removal even during peak raw water color periods.

With Ozone/Biological Filtration: In addition to clarification removal, ozone is also very effective at oxidizing color causing compounds such as tannin and lignins and could reduce the amount of coagulant needed during a color event.

3.2.11. Improve ability to respond to changes in regulations

Direct Filtration: A granular media filter provides flexibility in being able to meet potential future regulatory issues. There are a number of potential regulations that could impact PWB in the future, including those that would require: changes to pathogen monitoring and testing methods; changes to distribution water quality that address DBPs, heterotrophic plate counts, lead, copper, nitrite and nitrate, and manganese to prevent scaling; and regulations addressing algal toxins, nitrosamines and other contaminants of emerging concern. While a direct filtration plant can address many of these issues, some may require more robust multiple barrier approaches including clarification, ozone or advanced oxidation, and biological filtration.

With Clarification: Clarification would provide more flexibility for addressing future regulations than direct filtration.

With Ozone/Biological Filtration: Ozone and biological filtration would provide the most flexibility for addressing future regulations.

3.2.12. Increase ability to meet several critical service levels

Direct Filtration: Critical service level issues include several water quality issues such as distribution system disinfectant residuals, coliform, taste and odor, and manganese, among others. Granular media filtration would provide benefits.

With Clarification: Clarification would provide improved performance over direct filtration.

With Ozone/Biological Filtration: Ozone and biological filtration would provide the best performance.

3.2.13. Treat a sustained elevated turbidity event

Direct Filtration: While direct filtration can treat short-term turbidity spikes of 10 or 20 NTU, these events will require frequent backwashing and could reduce the overall capacity or overwhelm the residuals handling systems. A sustained elevated turbidity event (over 10 NTU) would require the addition of clarification for granular media filtration.

With Clarification: Clarification would provide improved performance over direct filtration and could treat turbidities up to 500 NTU.

With Ozone/Biological Filtration: No additional improvement over clarification.

3.2.14. Reduce customer cost of water treatment

Direct Filtration: Customers could reduce their need for in-home or business water treatment facilities with granular media filtration. Granular media filtration would provide a consistently lower sediment load and more aesthetically pleasing water.

With Clarification: Clarification would provide improved performance over direct filtration in that it could stay online during extended turbidity events.

With Ozone/Biological Filtration: Ozone and biological filtration would provide the best performance in terms of customer cost.

3.3 Membrane Filtration Screening

The membrane filtration screening results are summarized in Table 4 and described in detail in the following text. The basic configuration of prescreening, flocculation and microfiltration membrane followed by disinfection and corrosion control was able to achieve a good or excellent rating in all the filtration benefit categories. The ratings assume that coagulation chemicals would be required in all cases to achieve the benefits desired.

Table 4. Membrane Filtration Screening

Treatment Process	Microfiltration Membrane Filtration			
Benefits	Membrane Filtration	Add clarification	Add post filter ozone and biological contactors	Notes/references
Provide pathogen removal for *Cryptosporidium, Giardia*, bacteria and viruses (3.3.1)	Excellent	Excellent	Excellent	USEPA, 2005
Produce a biologically stable water (3.3.2)	Good	Good	Excellent	AOC reduction, CH2M TM 4.1
Reduce DBPs (3.3.3)	Good	Good	Excellent	THM and HAA reduction
Increase supply reliability (3.3.4)	Excellent	Excellent	Excellent	Turbidity events, AWWA ASCE, 2012
Reduce distribution system flushing, lower turbidity levels (3.3.5)	Excellent	Excellent	Excellent	USEPA, 2010 (LT2 Toolbox)

Treatment Process	Microfiltration Membrane Filtration			
Benefits	Membrane Filtration	Add clarification	Add post filter ozone and biological contactors	Notes/references
Reduce iron and manganese (3.3.6)	Good	Good	Good	AWWA ASCE, 2012
Improve WQ stability, lower lead and copper levels (3.3.7)	Excellent	Excellent	Excellent	Assumes optimal corrosion control for all options
Effectively treat an algae event (3.3.8)	Good	Good	Excellent	Production, T&O, cyanotoxins
Reduce water quality impacts due to warmer weather (3.3.9)	Good	Good	Excellent	Increases algal blooms, T&O, cyanotoxins
Reduce organic discoloration events (3.3.10)	Good	Good to Excellent	Excellent	Tannins and lignins, AWWA ASCE, 2012
Improve ability to respond to changes in regulations (3.3.11)	Good	Excellent	Excellent	Removal of contaminants of emerging concern
Increase ability to meet several critical service levels (3.3.12)	Good	Good	Good	Color, manganese, sediment
Treat a sustained elevated turbidity event (3.3.13)	Excellent	Excellent	Excellent	AWWA ASCE, 2012
Reduce customer cost of water treatment (3.3.14)	Good	Excellent	Excellent	Consistent water quality with low color, T&O

3.3.1 Provide pathogen removal for *Cryptosporidium*, *Giardia*, bacteria and viruses

Membrane Filtration: Microfiltration membrane plants can achieve >2-log removal credits for *Cryptosporidium* and > 3 log removal credits for *Giardia,* but no removal credit for viruses. Systems are required to provide an additional 1-log of disinfection for *Giardia* and 4-log disinfection for viruses. 4-log of virus credit can be achieved with a free chlorine contact time of approximately 9 to 12 mg/L*min, which is easily attainable in a pipe or clear well after filtration without adding any additional infrastructure or equipment.

With Clarification: No additional credit.

With Ozone/Biological Contactors: No additional credit.

3.3.2 Produce a biologically stable water

Membrane Filtration: Microfiltration membrane pores are too large to remove dissolved organic compounds. With coagulation chemicals like those used for granular media filtration, TOC reduction should be expected to be similar.

With Clarification: Some organic removal would be achieved prior to the membranes, typically 20%.

With Ozone/Biological Contactors: Results would be very similar to granular media filtration with ozone and biological filtration. One big difference between microfiltration and granular media filtration is that ozone and a biological contactor are provided after the membrane to achieve biological reduction of the AOC produced during ozonation.

3.3.3 Reduce disinfection by-products

Membrane Filtration: Reduction of DBPs in PWB's membrane pilot testing showed 13 to 34% reduction of THMs and 1 to 49% reduction of HAAs using an ultrafiltration membrane with a coagulant. Microfiltration membrane plants in the pacific northwest have shown 20% to 40% TOC reduction and are expected to have similar reduction in DBPs.

With Clarification: Some organic DBP precursor removal would be achieved prior to the membranes, typically 20%.

With Ozone/Biological Contactors: The addition of ozone/biological contactors would improve DBP reduction to 40 to 70%.

3.3.4 Increase supply reliability

Membrane Filtration: Increased supply reliability would be achieved if the Bull Run water supply could remain online through normal turbidity events. All membrane options could stay online during turbidity events. Without clarification, increased turbidity above 10 NTU could reduce the plant output.

With Clarification: The plant could stay online during extended elevated turbidity periods. Clarification performance would be the same as with a granular media filtration plant.

With Ozone/Biological Contactors: Ozone/GAC contactors would increase reliability during turbidity events.

3.3.5 Reduce distribution system flushing and lower turbidity levels

Membrane Filtration: Reduction in distribution system flushing would result from lower sediment load being sent to the distribution system. A full-scale membrane filtration plant would be expected to have a filtered water turbidity below 0.05 NTU.

With Clarification: Similar to membrane filtration alone.

With Ozone/Biological Contactors: Similar to membrane filtration alone, although this option would reduce distribution system biological activity.

3.3.6 Reduce iron and manganese concentrations

Membrane Filtration: Iron is easy to oxidize with exposure to dissolved oxygen or other oxidants and can be normally removed with microfiltration membranes. Manganese is more difficult and tends to foul the membranes.

With Clarification: Enhanced cleaning or other pre-treatment measures to address manganese fouling would be needed seasonally.

With Ozone/Biological Contactors: No additional removal.

3.3.7 Improve water quality stability, and lower lead and copper levels

Membrane Filtration: Filtration will provide a reduction in both DOC and particulate metals loading to the system and is therefore anticipated to provide a reduction in lead release observed at customer taps. Optimized corrosion control would still be required.

With Clarification: Results similar to membrane filtration alone.

With Ozone/Biological Contactors: Optimal treatment. This option would also reduce nitrification. Nitrification can contribute to lead leaching.

3.3.8 Effectively treat an algae event

Membrane Filtration: Flat-sheet studies of UF and MF membranes have shown high efficiency of removal (> 98%) of whole cells of toxic M. aeruginosa with minimal cell damage (Chow et al., 1997b). However, MF membranes will not remove dissolved organic compounds, including cyanotoxins, MIB and geosmin that can be released in a dying algal bloom.

With Clarification: Clarification would allow the plant to maintain peak capacity during algal blooms, but would not address taste, odor or toxins.

With Ozone/Biological Contactors: Would provide effective removal of taste- and odor-causing compounds and algal toxins and allow the plant to maintain peak capacity during algal blooms.

3.3.9 Reduce water quality impacts due to warmer weather.

Membrane Filtration: The discussion provided concerning algal events also applies to warmer weather impacts on water treatment technology. In addition, warmer water produces disinfection by products in the presence of free chlorine at a faster rate compared to cooler water. Filtration reduces the amount free chlorine contact time required for primary disinfection which will result in lower disinfection by products during warm weather periods.

With Clarification: Clarification would allow the plant to maintain peak capacity during algal blooms.

With Ozone/Biological Contactors: Would provide effective removal of taste and odor causing compounds and algal toxins.

3.3.10 Reduce organic discoloration events

Membrane Filtration: Color removal with microfiltration membranes is expected to be similar to granular media filtration.

With Clarification: Clarification would improve color removal during high raw water color events.

With Ozone/Biological Contactors: Would provide effective removal of color year-round.

3.3.11 Improve ability to respond to changes in regulations

Membrane Filtration: A microfiltration membrane provides flexibility in being able to meet potential future regulatory issues. There are many potential regulations that could impact PWB in the future, including requirements to: change pathogen monitoring and testing methods; change distribution water quality contents of DBPs, lead, copper, nitrite and nitrate, and manganese, and heterotrophic plate counts; and regulations addressing algal toxins, nitrosamines and other contaminants of emerging concern.

With Clarification: While a membrane filtration plant can address many of these issues, some may require more robust multiple-barrier approaches, including clarification.

With Ozone/Biological Contactors: These additional barriers would provide the most flexibility for addressing future regulations.

3.3.12 Increase ability to meet several critical service levels

Membrane Filtration: Critical service level issues include several water quality issues such as distribution system disinfectant residuals, coliform, taste and odor, and manganese, among others. Membrane filtration would provide benefits.

With Clarification: Improved performance over just coagulation.

With Ozone/Biological Contactors: Improved performance would be provided with ozone/biological contactors.

3.3.13 Treat a sustained elevated turbidity event

Membrane Filtration: A sustained elevated turbidity event (over 10 NTU) would not require the addition of clarification for membrane filtration, but the plant would operate at a higher pressure or reduced production level.

With Clarification: Clarification would increase plant efficiency and capacity during these events and would not experience reduced production until turbidity exceeded 10 NTU.

With Ozone/Biological Contactors: No additional improvement over clarification.

3.3.14 Reduce customer cost of water treatment

Membrane Filtration: Customers could reduce their need for in-home or business water treatment facilities with membrane filtration. Membrane filtration would provide more consistent water quality.

With Clarification: Clarification would increase plant efficiency and capacity during water quality events.

With Ozone/Biological Contactors: Would address color, taste and odor issues.

3.4 Slow Sand Filtration Screening

The results of the slow sand filtration screening are shown in Table 5 and discussed in detail in the following text. None of the treatment configurations for slow sand filtration provide a good or excellent rating for all the filtration benefits.

Table 5. Slow Sand Filtration Screening

Treatment Process	Slow Sand Filtration			
Benefits	**Slow sand filtration**	**Add roughing filter**	**Add clarification**	**Notes/References**
Provide pathogen removal for *Cryptosporidium, Giardia*, bacteria and viruses (3.4.1)	Good	Good	Good	USEPA, 2005
Produce a biologically stable water (3.4.2)	Good	Good	Good	AOC reduction, CH2M TM 4.1
Reduce DBPs (3.4.3)	Good	Good	Good	THM and HAA reduction
Increase supply reliability (3.4.4)	Good	Good	Excellent	Turbidity events, AWWA ASCE, 2012

Treatment Process	Slow Sand Filtration			
Benefits	**Slow sand filtration**	**Add roughing filter**	**Add clarification**	**Notes/References**
Reduce distribution system flushing, lower turbidity levels (3.4.5)	Poor to Good	Poor to Good	Poor to Good	USEPA, 2010 (LT2 Toolbox)
Reduce iron and manganese (3.4.6)	Poor	Poor	Poor	AWWA ASCE, 2012
Improve WQ stability, lower lead and copper levels (3.4.7)	Excellent	Excellent	Excellent	Assumes optimal corrosion control for all options
Effectively treat an algae event (3.4.8)	Poor	Poor	Poor to Good	Production, T&O, cyanotoxins
Reduce water quality impacts due to warmer weather (3.4.9)	Poor	Poor	Poor to Good	Increases algal blooms, T&O, cyanotoxins
Reduce organic discoloration events (3.4.10)	Good	Good	Good to Excellent	Tannins and lignin's, AWWA ASCE, 2012
Improve ability to respond to changes in regulations (3.4.11)	Poor to Good	Poor to Good	Good	Removal of contaminants of emerging concern
Increase ability to meet several critical service levels (3.4.12)	Poor to Good	Good	Good	Color, manganese, sediment
Treat a sustained elevated turbidity event (3.4.13)	Poor to Good	Good	Unknown	AWWA ASCE, 2012
Reduce customer cost of water treatment (3.4.14)	Good	Good	Good	Consistent water quality with low color, T&O

3.4.1 Provide pathogen removal for cryptosporidium, giardia, bacteria and viruses

Slow Sand Filter: Slow sand filtration plants can achieve > 2 log removal credits for *Cryptosporidium*, 2 log removal credits for *Giardia,* and 2 log removal credits for viruses. Systems are required to provide at least 1 log of disinfection for *Giardia* and 2 logs of disinfection for viruses. However, the performance of slow sand filters can be highly variable. Fogel, et. al., 1993, found 93% removal of *Giardia* cysts in a two-year study of a full-scale operating slow sand plant, but only an average of 48% removal of *Cryptosporidium* cysts, with detections in 46% of the filtered water samples.

With Roughing Filter: A roughing filter is a pretreatment process specifically designed for slow sand plants, consisting of several layers of gravel. Its purpose is to reduce influent turbidity spikes for short term turbidity events. A roughing filter would not provide any additional pathogen removal credit.

With Clarification: Because slow sand filters require a fair amount of organic material in the raw water to maintain biological activity within the schmutzdecke, clarification would be used only for limited durations of a few days during turbidity or algae events and would not provide any additional pathogen removal credit. The formation of the schmutzdecke in slow sand filters is the primary pathogen removal mechanisms, while in granular media biological filters, pathogen removal is obtained through the filter bed depth.

3.4.2 Produce a biologically stable water

Slow Sand Filter: The slow sand process is a largely microbiological process, and it will consume some of the readily available portion of the dissolved organic carbon referred to as assimilable organic carbon or AOC. Typically, about 10% of the raw water TOC is in the form of AOC. Removal of AOC in a biological filter prevents this material from entering the distribution system and becoming food for biofilm in the distribution system piping system.

Dissolved organic carbon (DOC) removal in slow sand filters is variable and may range from 10 to 25% (Collins., 1989; Fox et. al., 1987). About 90% of the remaining TOC in the effluent samples is dissolved (USEPA, Microbial and Disinfection Byproduct Rules Simultaneous Compliance Guidance Manual, 1999).

With Roughing Filter: No additional benefit.

With Clarification: Clarification would be used only for limited durations of a few days during turbidity or algae events, since it would remove much of the food source for the schmutzdecke and would provide limited benefit.

3.4.3 Reduce disinfection by-products

Slow Sand Filter: Reduction of DBPs in slow sand plants is typically 20-30% (Collins, 1998).

With Roughing Filter: A roughing filter would provide no additional benefit, since it is used primarily for the removal of suspended solids

With Clarification: Clarification would be used only for limited durations of a few days during turbidity or algae events, thus it would not provide an ongoing reduction of disinfection by product precursors.

3.4.4 Increase supply reliability

Slow Sand Filter: Increased supply reliability would be achieved if the Bull Run water supply could remain online through normal turbidity events. Slow sand plants are recommended only for waters with raw water turbidity less than 10 NTU, which includes most but not all regular normal turbidity events.

With Roughing Filter: Roughing filters can treat some short-term turbidity spikes and may remove 50% to 90% of influent turbidity (Wegelin, et.al., 1998).

With Clarification: Since clarification removes the organics needed for a healthy schmutzdecke clarification would be used only for limited durations of a few days during turbidity events but would be effective during these periods of use.

3.4.5 Reduce distribution system flushing, and lower turbidity levels

Slow Sand Filter: Reduction in turbidity with slow sand plants can be highly variable. For CT (concentration X time) credit, effluent turbidity must be less than 1 NTU in 95% of monthly samples with no samples over 5 NTU. Typically, slow sand plants will achieve at least 50% removal (Leland, 1991). Some plants may experience higher effluent turbidity than influent turbidity during periods of low raw water turbidity (CH2M, 2014).

With Roughing Filter: A roughing filter would provide no additional benefit.

With Clarification: Clarification would provide no additional benefit.

3.4.6 Reduce iron and manganese concentrations

Slow Sand Filter: Slow sand filtration can provide removal of manganese and iron. Both are dependent on maintaining an oxidizing condition within the filter, but removal of up to 67% of manganese is possible (Collins, 1998). However, since it is a biological process, manganese release can occur during periods of low dissolved oxygen or other changing water quality conditions.

With Roughing Filter: A roughing filter would provide no additional benefit.

With Clarification: Since clarification would be used only for a few days at a time, it would not be effective for iron and manganese control.

3.4.7 Improve water quality stability, and lower lead and copper levels

Slow Sand Filter: Filtration will provide a reduction in both DOC and particulate metals loading to the system and is therefore anticipated to provide a reduction in lead release observed at customer taps.

With Roughing Filter: A roughing filter would not add benefits for lead and copper removal.

With Clarification: Since clarification would only be used infrequently, it would not provide additional benefits beyond filtration alone.

3.4.8 Effectively treat an algae event

Slow Sand Filter: Algal blooms can clog slow sand filters. Because they take several days or longer to clean and ripen prior to putting the filters back on line, clogging events can have a significant impact on the ability of a plant to meet demand. Slow sand filters are also susceptible to taste and odor events and cyanobacteria detections in filtered water during or at the end of an algal bloom. In addition, slow sand filters are not well suited to addressing cyanobacteria toxins.

With Roughing Filter: A roughing filter may provide some benefit for algae removal, similar to turbidity reduction, of 30 to 50%.

With Clarification: Since clarification removes the necessary food supply for the slow sand filters it would be used only for limited durations of a few days during turbidity or algae events but would provide effective treatment during these periods.

3.4.9 Reduce water quality impacts due to warmer weather

Slow Sand Filter: The discussion provided concerning algal events also applies to warmer weather impacts on water treatment technology. In addition, warmer water produces disinfection by products in the presence of free chlorine at a faster rate compared to cooler water. Filtration reduces the amount free chlorine contact time required for primary disinfection which will result in lower disinfection by products during warm weather periods.

With Roughing Filter: A roughing filter may provide some benefit for algae removal, similar to turbidity reduction, of 30 to 50%.

With Clarification: Since clarification would be used only for limited durations of a few days during turbidity or algae events, its benefit would only occur during these periods. If the algal bloom died off and released algal toxins and taste-and odor-causing compounds, clarification would require the addition of powdered activated carbon to effectively remove these compounds.

3.4.10 Reduce organic discoloration events

Slow Sand Filter: Some color removal is generally seen with slow sand filtration; however, the Oregon Health Authority recommends slow sand filters be used with raw water color of less than 5 color units. Elevated color could occur with a slow sand plant on Bull Run.

With Roughing Filter: A roughing filter would provide no additional benefit.

With Clarification: As discussed previously, clarification would be used only for limited durations of a few days during turbidity or algae events and would not typically be used for color events.

3.4.11 Improve ability to respond to changes in regulations

Slow Sand Filter: A slow sand filtration plant provides some flexibility in being able to meet potential future regulatory issues. There are many potential regulations that could impact PWB in the future, including requirements to: change pathogen monitoring and testing methods; change distribution water quality content of DBPs, lead, copper, nitrite and nitrate, and manganese, and change to heterotrophic plate counts; and regulations addressing algal toxins, nitrosamines and other contaminants of emerging concern. A slow sand plant can provide some benefit for many of these issues but may require a more robust multiple treatment barrier approach.

With Roughing Filter: A roughing filter would provide no additional benefit.

With Clarification: Clarification would be used only for limited durations of a few days during turbidity or algae events and would provide little additional benefit.

3.4.12 Increase ability to meet several critical service levels

Slow Sand Filter: Critical service level issues include several water quality issues such as distribution system disinfectant residuals, coliform, taste and odor, and manganese, among others. Slow sand filtration will provide benefits for many of these issues.

With Roughing Filter: A roughing filter would provide little additional benefit.

With Clarification: Clarification would be used only for limited durations of a few days during turbidity or algae events and would provide benefits only during times of use.

3.4.13 Treat a sustained elevated turbidity event

Slow Sand Filter: A sustained elevated turbidity event (over 10 NTU) would require the addition of clarification for slow sand filtration; however, clarification prior to slow sand filtration is rarely used and often only as a short-term measure to address a turbidity or algal event.

With Roughing Filter: A roughing filter would reduce turbidity somewhat (see 3.4.5) but would only allow treatment of long-term events with turbidities of 10 to 20 NTU.

With Clarification: Clarification would be used only for limited durations of a few days during turbidity or algae events but would provide effective treatment during these periods.

3.4.14 Reduce customer cost of water treatment

Slow Sand Filter: Customers could reduce their need for in-home or business water treatment facilities with a slow sand filter. The slow sand filter would allow more consistent use of Bull Run water; however, aesthetic issues may still exist.

With Roughing Filter: A roughing filter would provide no additional benefit.

With Clarification: Clarification would be used only for limited durations of a few days during turbidity or algae events and would provide limited additional benefit.

3.5 Summary of Filtration Screening

Table 6 presents a side-by-side comparison of the filtration technologies considered in this alternatives analysis. The granular media filtration alternative with clarification and the basic membrane filtration alternative are the simple forms of the two technologies that provide good or excellent benefits in each of the categories.

Slow sand does not provide a good or excellent rating in all the benefits, no matter which level of treatment is used. In addition, it has limited ability to remove some dissolved organic materials including algal toxins and cannot treat a sustained turbidity event without clarification. There are no known slow sand filters using clarification on a sustained long-term basis and there is a concern that it may degrade the performance of the filter by limiting food and nutrients. In addition, the only slow sand filter that has been designed to withstand a Cascadia Subduction Zone seismic event required the use of concrete basins, which will significantly increase the cost of slow sand filtration.

Slow sand filters are also poor at removing color. It is recommended that influent color for slow sand be less than 5 color units (Oregon Health Authority, 2018). Also, it is noted that slow sand plants are subject to both algal clogging events as well as taste, odor and algal toxin events. The extended “do not drink” event related to algal toxins in Salem in June 2018 should be a strong reminder that slow sand plants are not well suited to addressing cyanotoxins and have treatment limitations in waters potentially subject to algal blooms.

Therefore, it is recommended that the following two alternatives be evaluated for potential filtration technology to use on the Bull Run supply:

- Granular media filtration with clarification, and
- Membrane filtration (microfiltration).

The granular media filtration process flow diagram is shown in Figure 6. The proposed membrane filtration process flow diagram is shown in Figure 7.

Table 6. Comparison of Filtration Technologies

Treatment Process	Granular Media Filtration			Membrane filtration			Slow Sand Filtration		
Benefits	Granular Media Filtration (Direct Filtration	Add clarifi-cation (Conventional filtration)	Biological granular media filtration	Membrane filtration	Add clarifi-cation	Add post filter ozone and biological contactors	Slow sand filtration	Add roughing filter	Add clarifi-cation
Provide pathogen removal for cryptosporidium, giardia, bacteria and viruses	++	++	++	++	++	++	+	+	+
Produce a biologically stable water	+	+	++	+	+	++	+	+	+
Reduce DBPs	+	+	++	+	+	++	+	+	+
Increase supply reliability	+	++	++	++	++	++	+	+	++
Reduce distribution system flushing, lower turbidity levels	++	++	++	++	++	++	- to +	- to +	- to +
Reduce iron and manganese	+	+	++	+	+	+	-	-	-
Improve WQ stability, lower lead and copper levels	++	++	++	++	++	++	++	++	++
Effectively treat an algae event	+	++	++	+	+	++	-	-	- to +
Reduce water quality impacts due to warmer weather	+	+	++	+	+	++	-	-	- to +
Reduce organic discoloration events	+	+ to ++	++	+	+ to ++	++	+	+	+ to ++
Improve ability to respond to changes in regulations	+	++	++	+	++	++	- to +	- to +	+
Increase ability to meet critical service levels	+	++	++	+	+	+	- to +	+	+
Treat a sustained elevated turbidity event	-	++	++	++	++	++	- to +	+	?
Reduce customer cost of water treatment	+	++	++	+	++	++	+	+	+

Ratings Key - ++ = excellent, += good, - = poor

Figure 6. Granular Media Filtration Process Flow Diagram

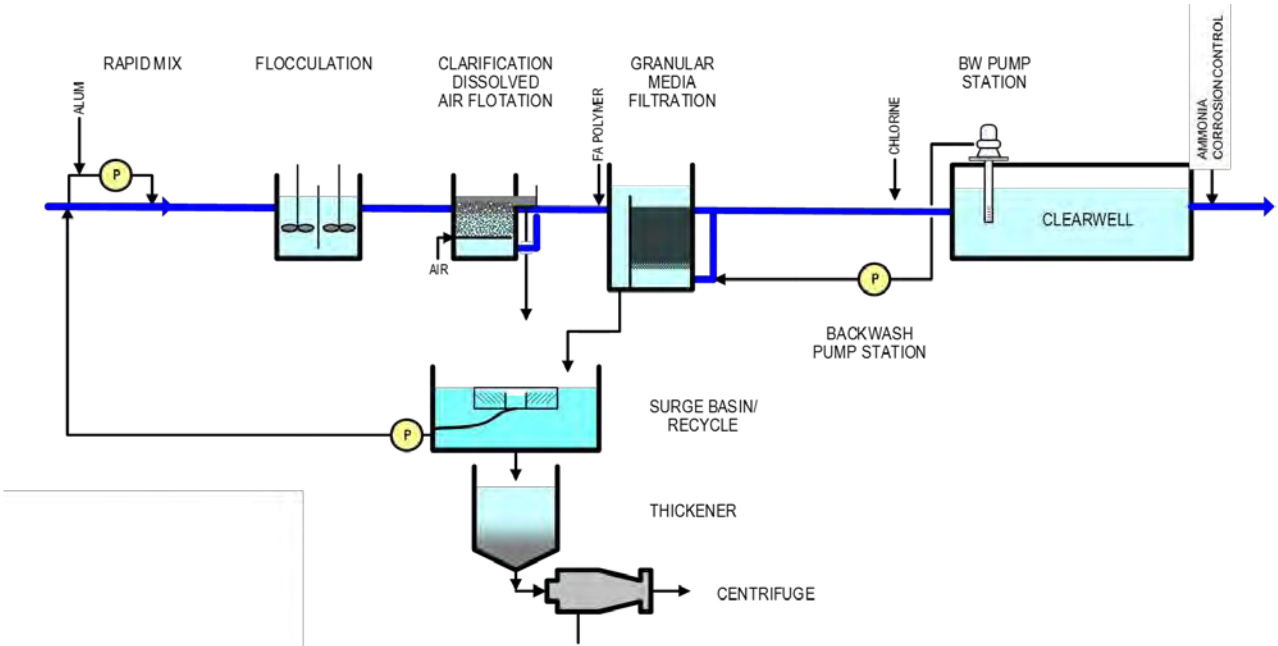
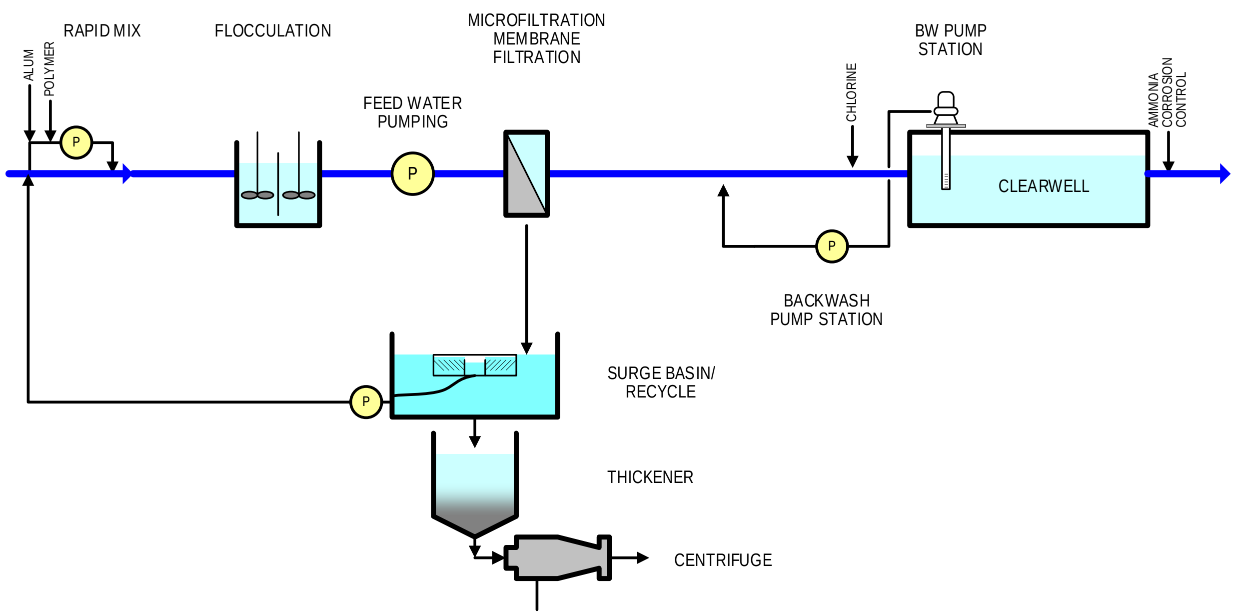


Figure 7. Microfiltration Membrane Process Flow Diagram



4 Decision Framework and Criteria

The two remaining alternatives were evaluated using the program's adopted Decision Framework. The framework consists of eight values, each having several criteria to evaluate each alternative. Table 7 lists the values and criteria.

While all the values are applied to each alternative, not every criterion is applicable for the capacity decision. For example, the criteria "On- and off-site ownership" is not applicable because the treatment technology selection is not dependent upon the ownership of the parcel. Table 7 also lists the criteria specifically included and excluded from the technology evaluation and the rationale associated with that inclusion or exclusion.

Table 7. Decision Framework and Criteria Used for Technology Evaluation

Value	Criteria	Inclusion Rationale	Exclusion Rational
Public Health and Water Quality (4.2)	Existing microbiological regulations	Included; treatment technology is directly measured by microbiological removal	
	Organics/inorganics regulations	Included; treatment technology can be measured by its efficacy of iron and manganese removal	
	Emerging water quality regulations	Included; ability to treat contaminants of emerging concern (CECs) is related to treatment technology	
	Consistent water quality	Included; treatment technologies perform differently in consistency of water quality	
	Chemical impacts	Included; disinfection byproducts differ per treatment technologies	
Resiliency/ Reliability (4.3)	Earthquake	Included; technologies may differ in their response to a seismic event	
	Catastrophic water quality event	Included; days of recovery following a catastrophic event may differ	
	Routine water quality event	Included; online percentage may differ	
Community interest (4.4)	Local impacts	Included; transport of materials and chemicals will differ	
	Consistency in taste and appearance	Included; performance can differ	
	Chemical concerns	Included; performance of pathogen removal may differ	

Value	Criteria	Inclusion Rationale	Exclusion Rational
Cost Benefit (4.5)	Cost of construction	Included; cost profiles are different	
	Operating costs	Included; operating costs differ among technologies	
Future Needs (4.6)	Capacity	Included; expansion potential differs	
	Future water quality	Included; CEC treatment can be differentiated	
	Available gravity capacity	Included; use of gravity flow will influence performance and costs	
Environmental Impacts (4.7)	Electricity usage	Included as it is a direct function of treatment technology	
	Residuals produced	Included; production of residuals differs depending on treatment technology	
	Construction and operations fuel consumption	Included; fuel consumption is a direct function of treatment technology	
Integration (4.8)	WTP labor	Included; amount of required labor may differ	
	Safety and operations	Included; chemical use differs with treatment technology	
	Corrosion control integration	Included; selection of treatment technology may influence the application and integration of corrosion control	
	Other infrastructure ramifications		Excluded; treatment technology does not influence other system components
	Distribution system water quality	Included; elimination of suspended solids may differ; may reduce flushing	
Implementation (4.9)	Ease of construction	Included; differing treatment facilities may influence schedule differently	
	Implementation complexity	Included; differing treatment facilities may influence schedule differently	
	Land use permits		Excluded; type of treatment is not influenced by land use permitting
	On- and off-site ownership		Excluded as ownership is related to siting only and not treatment technology

4.1. Evaluation of Screened Alternatives

The two alternatives carried forward from the screening of alternatives:

- Granular Media Filtration with Clarification (Conventional Filtration), and
- Membrane Filtration (microfiltration)

Table 8 provides the initial ratings for each of the criteria identified in the March 2018 workshop using the technology scales also developed during that workshop. The initial ratings are explained below.

Two types of performance scales are used to present the performance of the two alternatives across the 25 included criteria. The first is a quantitative scale based upon the natural performance of the specific criterion. Examples include cost of construction (millions of dollars) and electricity usage (kilowatt hours per year). These natural scales are simply used to demonstrate the performance of the different alternatives. For natural scales, the values are relative to each other in the table, but are concerted to either a 1 (best) or 0 (worst) within the decision scoring model. In the Public Health and Water Quality Value, related to the Emerging Water Quality Regulations, a natural scale was used based on the technologies' ability to partially remove a broad base of emerging contaminants, even though many of these contaminates are not expected to be found in the Bull Run source water.

The criteria that do not have a natural scale require the use of a constructed scale. A constructed scale considers a combination of materials and involves some professional judgement. For the criteria requiring a constructed scale, a 0 to 10 numbering system is used. The best performance is represented by a 10, the worst performance represented by a 0. Examples of criteria utilizing this constructed scale include 'consistency in taste and appearance' and 'perception of safety.'

Table 8. Summary of Ratings for Screened Water Treatment Technologies

Value	Value Statement	Criteria	Technology Scales	Granular Media Filtration with Clarification	Membrane Filtration
Public Health and Water Quality (4.2)	Provide drinking water that is safe and consistent	Existing Microbiological Regulations	Log removal	7	10
		Emerging Water Quality Regulations	Ability to treat CECs	30%*	30%*
		Organics and Inorganics Removal	SMCLs	7	3
		Consistent Water Quality	Consistency of water treatment	7	5
		Chemical Impacts	Disinfection byproducts formation	8	5

Value	Value Statement	Criteria	Technology Scales	Granular Media Filtration with Clarification	Membrane Filtration
Resiliency/ Reliability (4.3)	Facility maximizes likelihood of continued water provision, even after a fire or disaster	Earthquake	Ability to recovery	10	10
		Catastrophic WQ Event (forest fire, landslide)	Days of recovery	7	5
		Routine WQ Events (elevated turbidity, algae bloom)	Online capacity during event	10	7
Community Interests (4.4)	Integrate community interests in the decision-making process	Local Impacts	Neighbors impacted, expressed as truck trips	143,000	82,500
		Consistency in Taste and Appearance	Scaling	10	7
		Perception of Safety	Chemicals in customers' taps	7	5
Cost Benefit (4.5)	Getting the most benefit for the dollar	Cost of Construction	Capital cost $	$318 million	$413 million
		Operating Costs	Operating $	$13 million	$20 million
Meet Future Needs (4.6)	Maximizes ability to make adjustments in future	Capacity	Expansion potential	10	5
		Future Water Quality	CEC treatment percentage	30%	30%
		Available Gravity Capacity	mgd	130	0
Environmental Impacts (4.7)	Minimize environmental impacts	Electricity Usage	kWh/year	13 million	47 million
		Residuals Produced	Volume produced	3,630	1,900
		Construction and Operations Fuel Consumption	# truck trips + operations fuel consumption	322,000	237,000
Integration (4.8)	Optimize operability & integration with PWB's	WTP Labor	Required FTEs	12	12
		Chemical Use	Tons/year	5,770	3,290
		Corrosion Control Integration	Ability to install optimal treatment	10	10

Value	Value Statement	Criteria	Technology Scales	Granular Media Filtration with Clarification	Membrane Filtration
	systems & practices	Other infrastructure Ramifications	Impacts on other infrastructure	N/A	N/A
		Distribution System WQ	Elimination of suspended solids	10	10
Implementation (4.9)	Increases ability to implement and meet compliance schedule	Ease of Construction	Risk to schedule	8	10
		Implementation Complexity	Risk to schedule	10	5
		Land Use Permits	Risk to schedule	N/A	N/A
		On and off-site Ownership	N/A	N/A	N/A

* Based on the technology's ability to remove a broad base of emerging contaminants, regardless of whether they are likely to be found in Bull Run.

All the criteria that are included in the treatment alternatives are characterized below. Each has a description of the scale used to present alternative performance, characterizes the basis for the valuation and repeats the performance results summarized in Table 8.

4.2 Public Health and Water Quality

4.2.1 Existing Micro-Biological Regulations

Performance Scale: The constructed scale of 0-10 was used to rate the performance of this criterion. This constructed scale is used to incorporate a number of elements of microbiological regulations into one index of performance.

Basis for Valuation: Microbiological performance is rated on pathogen removal. Conventional filtration can receive 2.5 logs of credit for G*iardia*, greater than 2 logs of credit for C*ryptosporidium*, and 2 logs of credit for virus removal.

Membrane filtration can receive greater than 3 logs of credit for *Giardia* removal, greater than 2 logs of removal credit for *Cryptosporidium* removal, but no credit for viruses.

Membranes were rated higher because even though membranes receive no credit for virus removal, viruses can be addressed with the addition of chlorine. Virus disinfection requires a very low CT value for chlorine -- 9 to 12 mg/L - minutes, compared to the large values required for *Cryptosporidium* and *Giardia* disinfection.

Performance Results:

- Granular media filtration with clarification: 7 out of a possible 10
- Membrane filtration: 10 out of a possible 10

4.2.2 Emerging Water Quality Regulations

Performance Scale: This criterion was evaluated based on the alternatives' ability to remove contaminants of emerging concern (CECs) such as algal toxins, nitrosamine precursors or even pharmaceutical chemicals. A quantitative scale of the ability to remove contaminants of emerging concern is applied.

Basis for Valuation: There are no known CECs in the Bull Run Water Supply, as most of these compounds are man-made and would not likely be present in the protected watershed. The ability to remove a broad spectrum of CECs was used as a surrogate for potential future regulations, since these could include future disinfection byproducts, other algal toxins or unknown compounds.

Coagulation and clarification as part of the conventional filtration plant are expected to remove approximately 30% of a broad base of CECs, based on evaluations conducted by Snyder, and Westerhoff, (2008). Microfiltration membranes do not remove these small dissolved organic compounds; however, with coagulants added, they would likely perform similar to clarification.

Performance Results:

- Granular media filtration with Clarification: 30% Reduction
- Membrane Filtration: 30% Reduction

4.2.3 Organics and Inorganics Removal

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion. This constructed scale is used to incorporate a number of elements including the removal of iron and manganese and AOC reduction into one index of performance.

Basis for Valuation: Granular media filtration provides excellent removal of iron and manganese, and clarification will remove color even at its peak levels. Membrane filtration may not be effective for manganese removal without extended preoxidation and pH adjustment and the membranes may be subject to fouling from manganese.

Granular media filtration outperforms membrane for AOC reduction. In addition, AOC removal can be optimized with granular media filtration by pre-ozonating, while MF membranes will not remove dissolved organic material and cannot be used with ozone unless post filter biological contactors are added to remove AOC.

Performance Results:

- Granular media filtration with Clarification: 7 out of a possible 10
- Membrane Filtration: 3 out of a possible 10

4.2.4 Consistency of Water Quality

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion. This constructed scale was used to incorporate a number of elements and professional judgement.

Basis for Valuation: Granular media filtration was ranked slightly higher than membranes in consistency of water quality. Membranes may have higher potential for distribution biological activity which can affect scales. Membranes can also have higher manganese levels which can form scale and attract other metals.

Performance Results:

- Granular media filtration with Clarification: 7 out of a possible 10
- Membrane Filtration: 5 out of a possible 10

4.2.5 Chemical Impacts

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion.

Basis for Valuation: Disinfection byproduct formation potential was used to evaluate the technologies in this criterion. Based on the results of PWB's previous pilot testing, granular media filtration had lower DBP levels than the microfiltration and ultrafiltration membranes tested.

Performance Results:

- Granular media filtration with Clarification: 8 out of a possible 10
- Membrane Filtration: 5 out of a possible 10

4.3 Resiliency/Reliability

4.3.1 Earthquake

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion.

Basis for Valuation: Both water treatment technologies can be designed to withstand a Cascadia Subduction seismic event and should be available immediately after an event.

Performance Results:

- Granular media filtration with Clarification: 10 out of a possible 10
- Membrane Filtration: 10 out of a possible 10

4.3.2 Catastrophic WQ Event (forest fire, landslide)

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion, based on the number of days of recovery it would take to return to service.

Basis for Valuation: The principal water quality impacts of a forest fire or catastrophic landslide would be highly elevated turbidity and dissolved organic material. Both technologies would be able to treat the water, but the membranes would likely have a significantly reduced capacity without clarification, therefore it would take longer to return to full capacity after the event.

Performance Results:

- Granular media filtration with Clarification: 7 out of a possible 10
- Membrane Filtration: 5 out of a possible 10

4.3.3 Routine WQ Events (elevated turbidity, algae bloom)

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion, based on the technologies on-line capacity during the event.

Basis for Valuation: Both technologies can treat elevated turbidity and algal bloom events. If algal blooms result in taste and odor events or algal toxin release, powdered activated carbon could be added to both. Membranes are rated slightly lower, because the capacity is expected to decrease during an event. In the granular media filtration plant, clarification would allow the filters to operate at full capacity, prior to the filters.

Performance Results:

- Granular media filtration with Clarification: 10 out of a possible 10
- Membrane Filtration: 7 out of a possible 10

4.4 Community Interests

4.4.1 Local Impacts

Performance Scale: Local impacts are evaluated based on the number of truck trips to occur over a 25-year period to transport materials and chemicals. A natural scale of the number of truck trips is applied.

Basis for Valuation: Neighbors impacted were evaluated based on lifecycle truck trips for each technology. The granular media filtration plant would require 123,000 truck trips during construction and approximately 800 truck trips per year, while the membrane plant would require 60,000 truck trips during construction and approximately 900 truck trips per year.

Performance Results:

- Granular media filtration with Clarification: 143,000 truck trips over 25-year live cycle of the water treatment plant.
- Membrane Filtration: 82,500 truck trips over 25-year live cycle of the water treatment plant.

4.4.2 Consistency in Taste and Appearance

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion, based on the potential for disruption of distribution pipeline scales.

Basis for Valuation: Granular media filtration was ranked slightly higher than membranes in consistency in taste and appearance. Membranes may have higher potential for distribution biological activity which can affect scales. Membranes can also have higher manganese levels which can form scale and attract other metals.

Performance Results:

- Granular media filtration with Clarification: 10 out of a possible 10
- Membrane Filtration: 7 out of a possible 10

4.4.3 Perception of Safety

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion, based on the concentrations of chemicals in customers tap water.

Basis for Valuation: Ratings were provided based on the quantity of chemicals used in treatment and the effluent water quality produced by the treatment systems. Granular media filtration was rated a 7, and membranes were rated a 5, based on their ability to remove dissolved organic matter and provide lower disinfection by-products.

Performance Results:

- Granular media filtration with Clarification: 7 out of a possible 10
- Membrane Filtration: 5 out of a possible 10

4.5 Cost Benefit

4.5.1 Cost of Construction

Performance Scale: A quantitative scale of construction costs is applied.

Basis for Valuation: The capital cost of granular media filtration with clarification is estimated at $318 million. The capital cost of membrane filtration is estimated at $413 million. CH2M Technical Memorandum 4.5 provides details on costs, design and operation of each water treatment technology.

Performance Results:

- Granular media filtration with Clarification: $318 Million
- Membrane Filtration: $413 Million

4.5.2 Operating Costs

Performance Scale: A natural scale of operating costs is applied.

Basis for Valuation: The annual O&M cost of granular media filtration is estimated at $13 million. The annual O&M cost of membrane filtration is estimated at $20 million.

Performance Results:

- Granular media filtration with Clarification: $13 Million
- Membrane Filtration: $20 Million

4.6 Meet Future Needs

4.6.1 Capacity

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion.

Basis for Valuation: This rating was based on the ability to expand the plants in the future. Granular media filtration was rated higher, because the filter loading rate could likely be increased after design to obtain additional capacity, whereas, membranes would require additional equipment.

Performance Results:

- Granular media filtration with Clarification: 10 out of a possible 10
- Membrane Filtration: 5 out of a possible 10

4.6.2 Future Water Quality

Performance Scale: A quantitative scale of contaminants of emerging concern treatment percentage is applied.

Basis for Valuation: This rating was based on the ability of the technology to remove CECs. Granular media filtration is expected to remove several types of CECs through coagulation and clarification. Membranes with coagulation are expected to have similar levels of removal.

Performance Results:

- Granular media filtration with Clarification: 30% Reduction
- Membrane Filtration: 30% Reduction

4.6.3 Available Gravity Capacity

Performance Scale: A quantitative scale of mgd available by gravity is applied.

Basis for Valuation: The granular media filtration plant is estimated to be able to provide 130 mgd of gravity flow at the Carpenter Lane site (depending on piping size, configuration, and elevation), whereas membranes would require pumping for the entire plant capacity.

Performance Results:

- Granular media filtration with Clarification: 130 mgd for the Carpenter Lane site
- Membrane Filtration: 0 mgd

4.7 Environmental Impacts

4.7.1 Electricity Usage

Performance Scale: A quantitative scale of kilowatt hours (kWh) used per year is applied.

Basis for Valuation: Appendix E provides details on costs, design and operation of each water treatment technology. The annual power required of granular media filtration is estimated at 13 million KW-hours per year. The power requirement of membrane filtration is estimated at 47 million kilowatt-hours per year.

Performance Results:

- Granular media filtration with Clarification: 13 million kWh per year
- Membrane Filtration: 47 million kWh per year

4.7.2 Residuals Produced

Performance Scale: A quantitative scale of the volume in dry tons of residuals produced per year is applied.

Basis for Valuation: Section 7 provides details on costs, design and operation of each water treatment technology. The annual residuals produced with granular media filtration is estimated at 3,360 try tons. The annual residuals with membrane filtration is estimated at 1,900 dry tons.

Performance Results:

- Granular media filtration with Clarification: 3,630 dry tons per year
- Membrane Filtration: 1,900 dry tons per year

4.7.3 Construction and Operations Fuel Consumption

Performance Scale: A quantitative scale of the volume in gallons of consumed over 25 years is applied.

Basis for Valuation: Section 7 provides details on costs, design and operation of each water treatment technology. The life-cycle fuel consumption for granular media filtration is estimated at 322, 000 gallons of diesel. The life-cycle fuel consumption with membrane filtration is estimated at 237,000 gallons.

Performance Results:

- Granular media filtration with Clarification: 322,000 gallons
- Membrane Filtration: 237,000 gallons

4.8 Integration

4.8.1 Water Treatment Plant Labor

Performance Scale: A quantitative scale of the required FTEs is applied.

Basis for Valuation: Section 7 provides details on costs, design and operation of each water treatment technology. Both plants are expected to have the same staffing requirements.

Performance Results:

- Granular media filtration with Clarification: 12 FTEs
- Membrane Filtration: 12 FTEs

4.8.2 Chemical Use

Performance Scale: A quantitative scale of tons of chemicals consumed per year is applied.

Basis for Valuation: Section 7 provides details on costs, design and operation of each water treatment technology. The annual chemical use for granular media filtration is estimated at 5,770 tons. The annual chemical use with membrane filtration is estimated at 3,290 tons.

Performance Results:

- Granular media filtration with Clarification: 5,770 tons
- Membrane Filtration: 3,290 tons

4.8.3 Corrosion Control Integration

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion.

Basis for Valuation: Filtration will remove dissolved organic matter and suspended solids that will contribute to lower lead levels. Both technologies are expected to include optimal corrosion control treatment in a similar fashion.

Performance Results:

- Granular media filtration with Clarification: 10 out of a possible 10
- Membrane Filtration: 10 out of a possible 10

4.8.4 Distribution System WQ

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion.

Basis for Valuation: Both technologies are expected to reduce suspended solids entering the distribution system to similar levels.

Performance Results:

- Granular media filtration with Clarification: 10 out of a possible 10
- Membrane Filtration: 10 out of a possible 10

4.9 Implementation

4.9.1 Ease of Construction

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion.

Basis for Valuation: The membrane filtration technology is expected to be somewhat easier to construct, since clarification facilities are not required.

Performance Results:

- Granular media filtration with Clarification: 8 out of a possible 10
- Membrane Filtration: 10 out of a possible 10

4.9.2 Implementation Complexity

Performance Scale: The constructed scale of 0-10 was used to present the performance of this criterion.

Basis for Valuation: Membranes are expected to be more difficult to implement because of the high degree of mechanical equipment and instrumentation included in the technology.

Performance Results:

- Granular media filtration with Clarification: 10 out of a possible 10
- Membrane Filtration: 5 out of a possible 10

5 Cost Estimating

Cost estimates and evaluation criteria metrics are presented in Table 9 for the two filtration technologies for a 160 mgd plant. This section provides a summary of the cost details presented in Appendix E to this technical memorandum.

Values provided are for a typical granular media and membrane filtration WTP and do not specifically represent data or cost of a facility for the Bull Run Supply. The information is solely for comparative purposes. Decisions about the actual makeup of the filtration plant will be made by PWB after selection of a designer and program manager.

Table 9. Filtration Technology Estimated Costs and Measures for Water Treatment Plant

Item	Filtration Technologies at 160 mgd Capacity	
	Granular Media with Clarification	Membrane Filtration
Construction cost	$318,200,000	$413,450,000
Annual operations and maintenance	$12,520,000	$19,980,000
25-year life-cycle cost	$556,770,000	$794,410,000
Cost per CCF delivered*	$0.61	$0.87
Electrical usage (megawatt-hours per year)	12,600	46,950
Residuals (cubic yards per year)	3,630	1,900
Truck trips during construction	115,390	54,670
Truck trips per year	450	810
Fuel consumption during construction (gallons)	259,300	122,850
Fuel consumption (gallons per year)	2,520	4,570
Chemicals (dry tons per year)	5,770	3,290

*CCF is hundred cubic feet. Includes construction costs and annual operations and maintenance costs.

5.1 Capital Cost Estimates

The cost estimating guidance presented in Appendix E was developed by an Excel-based conceptual parametric estimating system (CPES). This guidance supports development of a Class 5 cost estimate, as defined by the Association for the Advancement of Cost Engineering International (see Attachment A for more information). A Class 5 cost estimate is provided with very little project definition (0-2%) and is used for concept screening.

The costs described in this technical memorandum are developed for granular media filtration with clarification, and membrane filtration without clarification. Neither of the alternatives include costs for conveyance of water to the site. Granular media filtration does not include raw water pumping facilities, which is a requirement for the membrane alternative. The cost estimates also do not include operations or an administration building. The purpose of the cost estimate is to compare the filtration technologies, not to provide a cost estimate of the full treatment project.

5.1.1 Granular Media Filtration

The granular media filtration process flow diagram is shown in Figure 8. Table 10 presents the capital cost elements included in the granular media filtration alternative. Dissolved air flotation was chosen as the clarification process for this cost model, but several other clarification types exist. The final decision on the treatment train will be developed after PWB selects the program manager and design teams for the project.

Figure 8. Direct Granular Media Filtration Process Flow Diagram

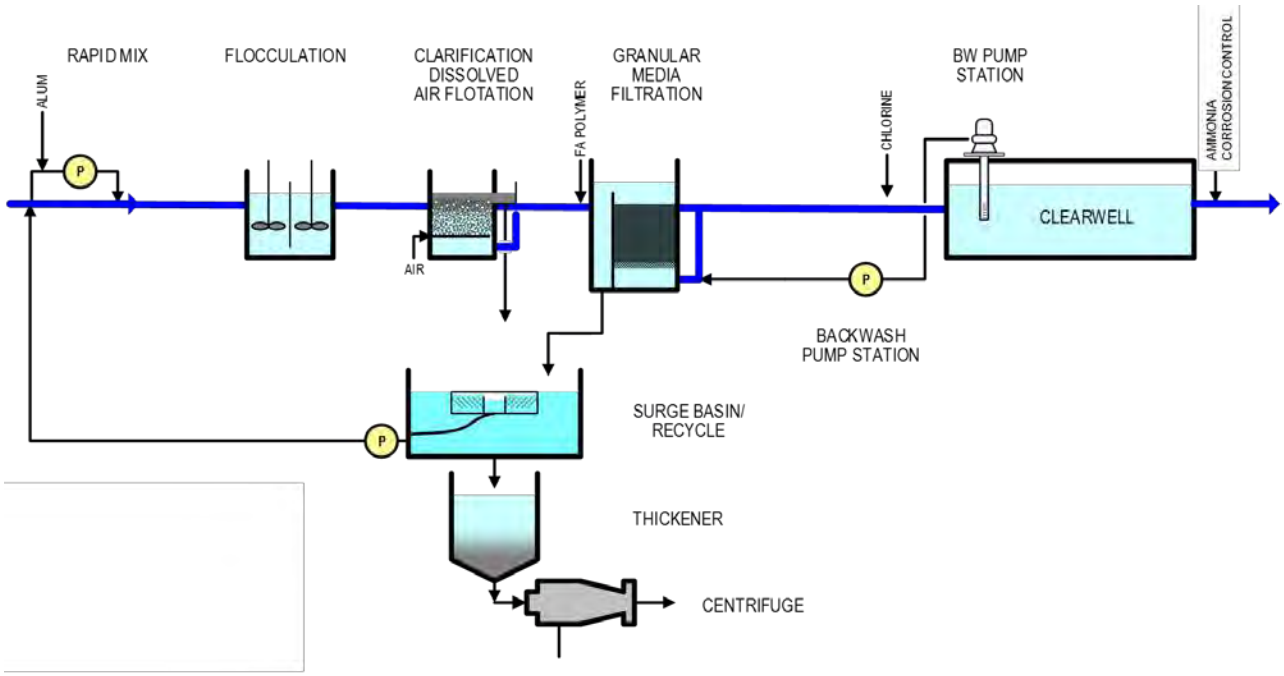


Table 10. Capital Cost Elements for Granular Media Filtration Plant

Project Element	Value
Capacity	160 mgd
Rapid mix, type, No. trains	Turbine, 4
Flocculation, type, HRT min, No. trains	HPW, 30, 8
Clarification Type, No. of trains	Dissolved Air Flotation, 4
Coagulant, type, average dose (mg/L)	Alum, 5
Coagulant aid polymer, type, average dose (mg/L)	Liquid, 0.75
Filter aid polymer type, average dose (mg/L)	Liquid, 0.1
Media filter type	Sand/Anthracite
Media filter size (square feet)/No.	926/22
Media filter depth (sand/anthracite in inches)	12/60
Disinfection type, average dose (mg/L)	OSHG, 3
Clear well volume (MG)	16.0
Backwash pump station capacity (mgd)	33
Corrosion control chemicals, average	NA_2CO_3 ,25

Table 10. Capital Cost Elements for Granular Media Filtration Plant

Project Element	Value
dose (mg/L)	CO_2, 5
Surge basin volume (MG)	11.6
Sludge thickener (MG)	0.90
Sludge holding (MG)	0.6
Dewatering	Centrifuge

Alum = aluminum sulfate; HRT = hydraulic residence time; HPW = horizontal paddle wheel; lb/day = pounds per day; MG = million gallons; mg/L = milligrams per liter; mgd = million gallons per day; NA_2CO_3 = soda ash; CO_2 = carbon dioxide, OSHG = onsite sodium hypochlorite generation.

5.1.2 Membrane Filtration

Figure 9 shows the process schematic for membrane filtration used in the cost estimate. Feed water pumping is provided for each membrane train. Table 11 shows the design criteria for the membrane filtration plant.

Figure 9. Microfiltration Membrane Process Flow Diagram

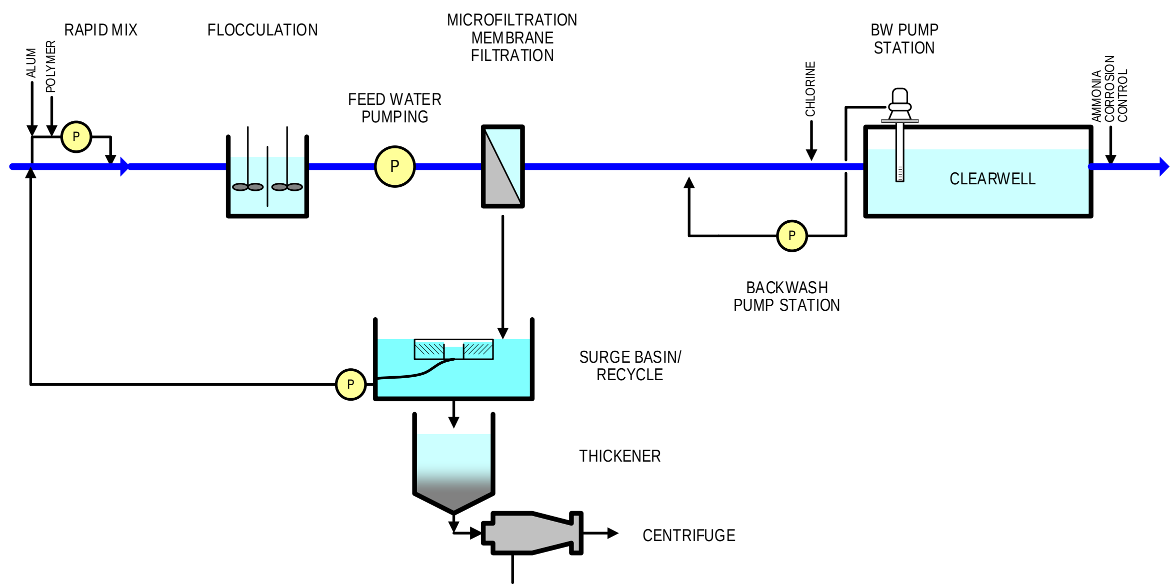


Table 11. Capital Cost Elements for Membrane Filtration Plant

Project Element	Value
Capacity	160 mgd
Rapid mix, type, No. trains	Turbine, 4
Flocculation, type, HRT min, No. trains	HPW, 30, 8
Coagulant, type, average dose (mg/L)	Alum, 5
Coagulant aid polymer, type, average dose (mg/L)	Liquid, 0.75
Membrane type	Pressure Modules, Microfiltration

Table 11. Capital Cost Elements for Membrane Filtration Plant

Project Element	Value
Membrane Subsystems, No.	6
Membrane trains per subsystem	9 on line, 1 standby
Maximum Instantaneous Flux Rate, gfd	58
Permeate recovery, %	97%
Disinfection type, average dose (mg/L)	OSHG, 3
Clear well volume (MG)	16.0
Feedwater pumping design TDH, ft	102
Corrosion control chemicals, average dose (mg/L)	NA_2CO_3 ,25 CO_2, 5
Surge basin volume (MG)	11.6
Sludge thickener (MG)	0.90
Sludge holding (MG)	0.6
Dewatering	Centrifuge

Alum = aluminum sulfate; HRT = hydraulic residence time; HPW = horizontal paddle wheel; lb/day = pounds per day; MG = million gallons; mg/L = milligrams per liter; mgd = million gallons per day; NA_2CO_3 = soda ash; CO_2 = carbon dioxide; OSHG = onsite sodium hypochlorite generation.

5.2 Cost Estimating Allowances

Table 12 presents the site-wide allowances included within the water infrastructure component construction cost curves developed from CPES for WTPs, as these facilities include additional supporting infrastructure to enable the group of unit processes to perform in a secure environment. These allowances are based on actual constructed projects and experience for the cost of site grading, roadways, site secondary power distribution, site instrumentation and control signal transmission, and yard piping to interconnect the unit processes as a percentage of the total facility unit process component construction cost.

Table 12. Site-wide Allowances for Water Treatment Plant

Project Component	Allowance
Site grading, roadways, stormwater management	5%
Site electrical distribution (less primary & standby power provisions)	4%
Site yard piping	7.5%
Site I&C/SCADA network	5%
Total site-wide allowance	**21.5%**

I&C = instrumentation and control; SCADA = supervisory control and data acquisition.

5.2.1 Contractor Allowances

Construction contractor allowances include contractor overhead, markup, mobilization, bonds, and insurance. Table 13 presents the percentage of costs related to each of these additional construction costs. These allowances are based on CH2M Constructors, Inc., experience for traditional design-bid-build delivery projects. These allowances will vary by project type and market conditions at the time of bidding. For this guide and resulting conceptual cost estimating tool, the total of 22.5% is a reasonable assumption.

Table 13. Construction Contractor Allowances

Allowance & Governing Subtotal	Cost Percentage
Overhead/general conditions allowance applied to project component cost subtotal	14%
Profit	5%
Mobilization/bonds/insurance allowance applied to project component subtotal	3.5%
Total contractor allowance	**22.5%**

5.2.2 Project Contingency

A 40% contingency is applied to the sum of the project component costs and contractor allowances to account for incomplete definition and design.

The following items are not assumed nor explicitly accounted for in the project component costs at this stage of conceptual cost estimating:

- Rock excavation
- Tunneling or boring
- Pile foundations
- Seismic foundations
- Shoring
- Soil contamination
- Dewatering conditions
- Environmental mitigation
- Weather impacts
- Depth of structures
- Local building code restrictions
- Coatings or finishes
- Building or architectural preferences
- Client material preferences
- Client equipment preferences
- Existing utilities interference
- System-wide I&C automation integration
- Primary electrical power source transmission and transformation
- Access and maintenance roadways

5.2.3 Construction Truck Trips and Fuel Consumption

The construction truck volumes were assumed to be 10 cubic yards for construction and residuals hauling. Average distance was estimated at 20 miles per trip. Fuel consumption was estimated at 8.9 miles per gallon.

5.3 Annual O&M Cost Estimate Preparation

Annual O&M cost includes the following elements:

- Labor
- Chemicals
- Power
- Residuals disposal

Chemicals, power, and ultimate residuals disposal are based on user input of both average annual day and maximum day design flow capacity, so the chemical usage, residuals production, and total connected horsepower, which are each sized for maximum day, can be proportionally reduced to represent average annual usage. Labor, as well as repair and maintenance materials, are considered fixed costs unrelated to flow rate.

5.3.1 Labor

Table 14 presents the assumed base staffing requirements and hourly rates for a WTP based on a wide range of staffing philosophies across water utilities world-wide. This results in a total WTP labor force equal to 13 full time equivalent (FTE) positions.

Table 14. Project Component Staffing Requirements and Rates

Project Component Staffing	Staffing Rates
One superintendent 8 hours per day, 5 days per week	$50/hour
Two operators onsite always	$30/hour
Two maintenance workers 8 hours per day, 7 days per week	$30/hour
One clerical worker 8 hours per day, 5 days per week	$20/hour
One lab worker 8 hours per day, 5 days per week	$20/hour

5.3.2 Chemicals

Table 15 presents the chemicals, average annual dose assumptions, and chemical unit costs associated with each WTP type, resulting in a total chemical cost per million gallons by WTP type. Chemical hauling distance is estimated at 50 miles.

Table 15. Project Component Staffing Requirements & Rates

Chemical	Unit Cost ($/dry ton)	Average Surface WTP Dose (mg/L)
Sodium hypochlorite	$1,500	3.0
Sodium hydroxide	$600	10
Aluminum sulfate	$450	5
Polymer	$2,500	0.75/0.1

5.3.3 Power

Power cost is based on a unit power rate of $0.0605 per kilowatt-hour.

5.3.4 Residuals Handling and Disposal

Residuals handling will include 100% liquid recycle with solids drying and disposal at a landfill. Hauling distance is estimated at 20 miles; disposal costs are estimated at $50 per cubic yard.

6 Evaluation

The PWB Filtration Team, including representatives of the Executive Team, met on June 20, 2018, to review the performance of the technology alternatives and reach a conclusion upon the preferred technology alternative. The decision model incorporated the values, criteria, and performance evaluation of the two technology alternatives. Throughout the evaluation and review, the team reminded itself that the decision model does not make the decision, the team does. This context assured that the decision model and the evaluation of alternatives were designed to inform the technical team and the Executive Committee, not make the decision for the team.

Three weighting scenarios were carried through the process to reflect the different perspectives of the PWB team members. The three weighting scenarios were:

1. Team Weighted (TW) – The PWB Filtration Team weights produced on March 27, 2018.
2. Equal Weights (EQ) – Equal weights among the eight values.
3. Split (SP) – A 60/40 split weighting where 40% of the weight remained with Public Health Water Quality (25%) and Reliability (15%) as identified in the team weighted scenario, and the remaining 60% was distributed equally among the other six values.

These weighting scenarios were carried through the evaluation process to demonstrate weighting sensitivity. The summary of these weights and their associated impacts on scoring are shown in Table 16.

Table 16: Weighting Scenarios Evaluation

ID#	Evaluation Criteria	TW	EQ	SP
1	**Public Health and Water Quality**	25	12.5	25
1.1	Log Removal	6.22	2.5	5
1.2	Ability to treat CECs	4.56	2.5	5
1.3	Aesthetics Goals: SMCLs	5.66	2.5	5
1.4	Scale-stability: Consistency	4.5	2.5	5
1.5	Chemical Impacts: Disinfection byproducts	4.06	2.5	5
2	**Resiliency/Reliability**	15	12.5	15
2.1	Earthquake: Days of Recovery	3.4	4.167	5
2.2	Catastrophic WQ Event: Days of Recovery	5.3	4.167	5
2.3	Routing WQ Events: Online %age	6.3	4.167	5
3	**Community Interests**	9	12.5	10
3.1	Local Impacts: Neighbors impacted	1.9	4.167	3.333
3.2	Consistency in Taste/Apearance: Scaling	4.2	4.167	3.333
3.3	Perception of Safety	2.9	4.167	3.333
4	**Cost Benefit**	12	12.5	10
4.1	Cost of Construction	5.4	6.25	5
4.2	Operating Costs	6.6	6.25	5
5	**Future Needs**	10	12.5	10
5.1	Capacity: Expansion potential	3.4	4.167	3.333
5.2	Future WQ: CEC treatment %age	3.2	4.167	3.333
5.3	Available Gravity Capacity: MGD	3.4	4.167	3.333
6	**Environmental Impacts**	7	12.5	10
6.1	Electricity Usage: Kilowatts per year	2.3	4.167	3.333
6.2	Residuals Produced: Volume	2.7	4.167	3.333
6.3	Fuel Consumption: Truck Trips	2	4.167	3.333
7	**Integration**	12	12.5	10
7.1	WTP Labor: FTEs	2.225	3.125	2.5
7.2	Chemical Use: Tons/Year	4.315	3.125	2.5
7.3	Corrosion Control Integration	2.629	3.125	2.5
7.4	System WQ: Suspended Solids	2.831	3.125	2.5
8	**Implementation**	10	12.5	10
8.1	Ease of Construction: Risk to schedule	4.2	6.25	5
8.2	Implementation Complexity: Risk to schedule	5.8	6.25	5

The performance ratings of the alternatives found in Table 8, and the weighting of the values and criteria found in Table 16 above, are the inputs for the evaluation of the site alternatives. The normalized performance rating multiplied by the weight and added across values and criteria produces a value score. Table 17 demonstrates these calculations.

Table 17. Value Score Calculations

A	B	C	D	E	F	G	H	I	J	K	L
	Weight %	Raw Ratings				Normalized Ratings		Value Scores (weight times normalized rating times 100)			
Value/ Criteria No.	TW	Minimum	Maximum	Conventional Filtration	Membrane Filtration	Conventional Filtration	Membrane Filtration	Conventional Filtration	Membrane Filtration	Value/Criterion	Assigned Weight (TW)
1.1	6.2%	7	10	7	10	0	1	0.0	6.2	**Public Health and Water Quality/**Log Removal	6.2
1.2	4.6%	30	30	30	30	0	0	0.0	0.0	**Public Health and Water Quality/**Ability to treat CEC's	4.6
1.3	5.7%	3	7	7	3	1	0	5.7	0.0	**Public Health and Water Quality/**Aesthetics Goals	5.7
1.4	4.5%	5	7	7	5	1	0	4.5	0.0	**Public Health and Water Quality/**Scale-stability	4.5
1.5	4.1%	5	8	8	5	1	0	4.1	0.0	**Public Health and Water Quality/**Chemical Impacts	4.1
2.1	3.4%	10	10	10	10	0	0	0.0	0.0	**Resiliency/Reliability/**Earthquake	3.4
2.2	5.3%	5	7	7	5	1	0	5.3	0.0	**Resiliency/Reliability/**Catastrophic WQ Event	5.3
2.3	6.3%	7	10	10	7	1	0	6.3	0.0	**Resiliency/Reliability/**Routing WQ Events	6.3
3.1	1.9%	143	82.5	143	82.5	0	1	0.0	1.9	**Community Interests/**Local Impacts	1.9
3.2	4.2%	7	10	10	7	1	0	4.2	0.0	**Community Interests/**Consistency in Taste Appearance	4.2
3.3	2.9%	5	7	7	5	1	0	2.9	0.0	**Community Interests/**Perception of Safety	2.9
4.1	5.4%	413	318	318	413	1	0	5.4	0.0	**Cost Benefit/**Cost of Construction	5.4
4.2	6.6%	20	13	13	20	1	0	6.6	0.0	**Cost Benefit/**Operating Costs	6.6
5.1	3.4%	5	10	10	5	1	0	3.4	0.0	**Future Needs/**Capacity	3.4
5.2	3.2%	30	30	30	30	0	0	0.0	0.0	**Future Needs/**Future WQ	3.2
5.3	3.4%	0	130	130	0	1	0	3.4	0.0	**Future Needs/**Available Gravity Capacity	3.4
6.1	2.3%	47	13	13	47	1	0	2.3	0.0	**Environmental Impacts/**Electricity Usage	2.3
6.2	2.7%	3630	1900	3630	1900	0	1	0.0	2.7	**Environmental Impacts/**Residuals Produced	2.7
6.3	2.0%	322	237	322	237	0	1	0.0	2.0	**Environmental Impacts/**Fuel Consumption	2
7.1	2.2%	12	12	12	12	0	0	0.0	0.0	**Integration/**WTP Labor	2.2
7.2	4.3%	5770	3290	5770	3290	0	1	0.0	4.3	**Integration/**Chemical Use	4.3
7.3	2.6%	10	10	10	10	0	0	0.0	0.0	**Integration/**Corrosion Control	2.6
7.4	2.8%	10	10	10	10	0	0	0.0	0.0	**Integration/**System WQ	2.8
8.1	4.2%	8	10	8	10	0	1	0.0	4.2	**Implementation/**Ease of Construction	4.2
8.2	5.8%	5	10	10	5	1	0	5.8	0.0	**Implementation/**Implementation Complexity	5.8
				Total Value Scores (sum of all values/criteria value scores):				59.8	21.3		

Columns K and L in Table 17 list the values and criteria and their associated weights. In the calculation in Table 17, the weights that are showcased are those associated with the Team weighting scheme (TW) in Table 16. Column B of Table 17 displays the weight percentage of each value/criterion. This weight percentage is the number that is carried through the evaluation calculation.

Columns E and F summarize the performance ratings of each capacity alternative. These are the same numbers that are presented in Table 8 and further characterized in Sections 4.2 through 4.9. Columns C and D reflect the minimum and maximum performance ratings among the alternatives. Columns G and H are the normalized performance ratings of the three alternatives. Normalization (calculating performance in a 0 to 1 scale) is done for all performance scales to allow for common application in the evaluation. Regardless of the scale used to demonstrate performance of the alternatives (e.g., performance scale of site acres for Community Interests/Local Impacts), normalization produces a 0 for the worst performer and a 1 for the best performer within each value/criterion.

Columns I and J in Table 17 are the calculated values scores for each value/criterion. This is the multiplication of the weight (Column B) times the Normalized Rating (Column G or H) times 100 (the 100 is just to make the result a more manageable number). As an example, the 6.2% of Column B in row 1.1, reflecting the weight of Public Health and Water Quality/Log Removal is multiplied by the 1 in Column H, reflecting the normalized performance rating of membrane filtration, then multiplied by 100 to produce the 6.2 result in Column J. The calculations within each cell of Columns I and J reflect the contribution of value the respective alternative receives from the specific value/criteria. The summation of these contributions down Column I or J produces the total value score for each capacity alternative. Value scores for each value/criterion for each alternative are added to produce a total value score. These total values scores demonstrate, relatively, how well the alternatives perform against the values and criteria. The higher the number, the better the relative performance.

Figures 10, 11, and 12 demonstrate the performance of the two technology alternatives within the three difference weighting scenarios. The numbers below each stacked bar present the summation of the value score. Each color of the stacked bar represents the contribution the alternative received from each value. Each value has criteria that are used to gauge the performance of the alternatives. The size of the colored bar is determined by multiplying the performance score of the alternative by the weight of the specific criterion (as shown in Table 17). The results of the criteria scores are then added to produce the total contribution per value, and then summed across all values and criteria to produce the total value score for each alternative. The higher the total score, the higher the collective performance of the alternative against the values.

Figure 10: Team Weighting Value Scores

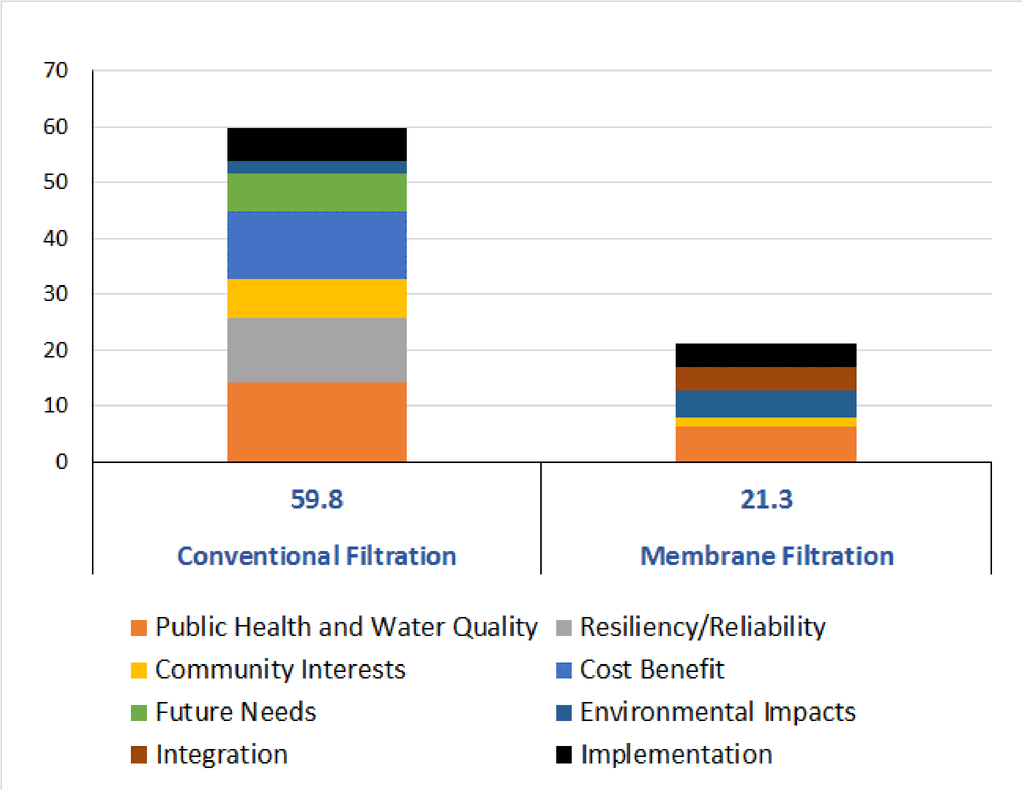


Figure 11: Equal Weighting Value Scores

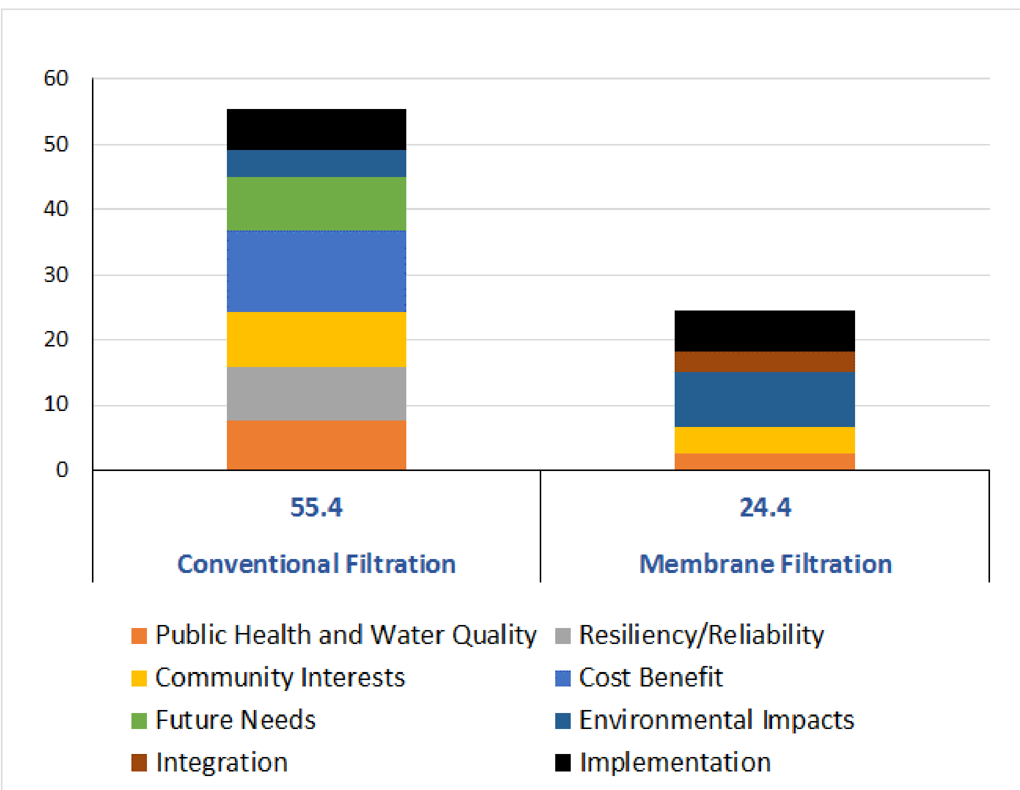
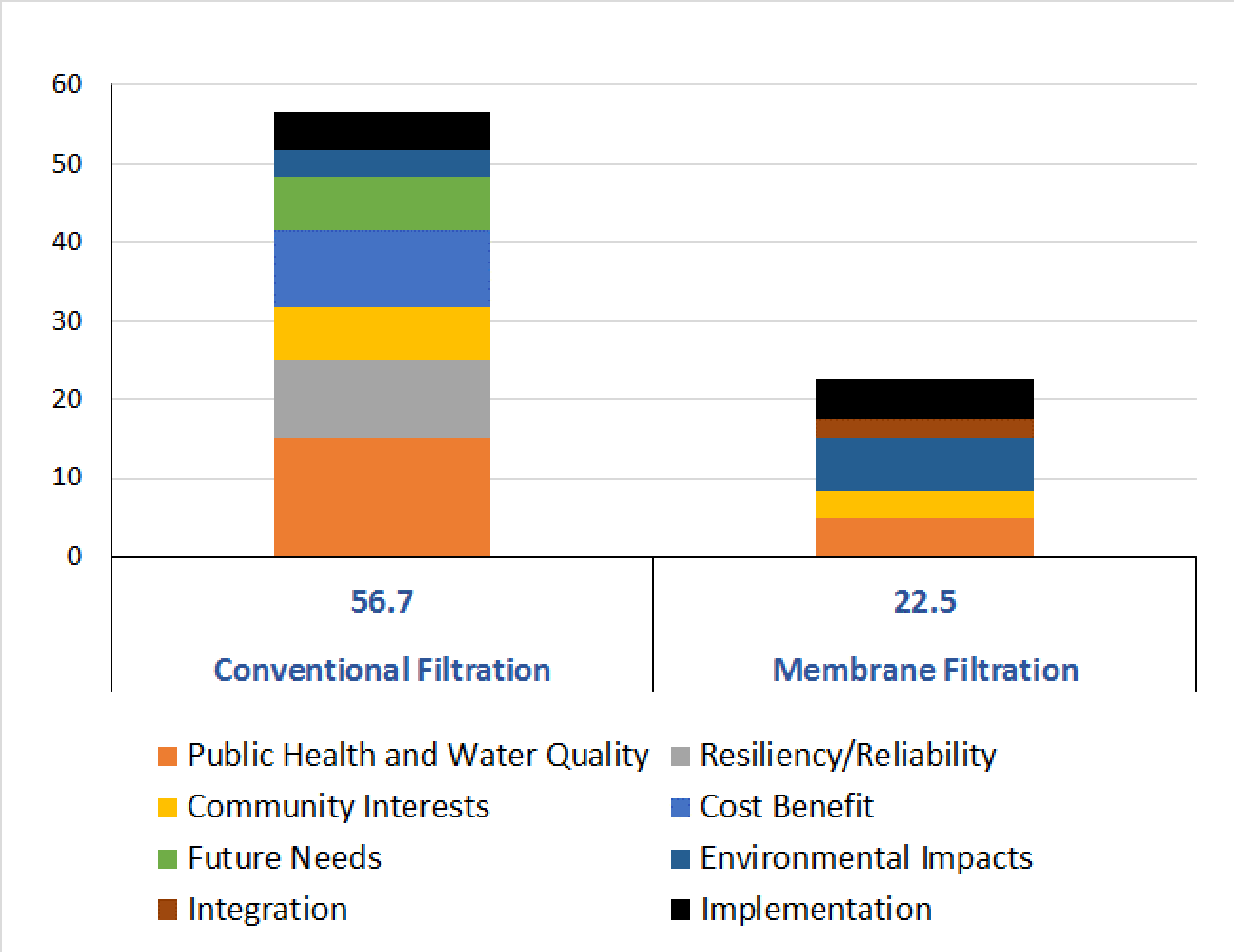


Figure 12: 60/40 Split Weighting Value Scores



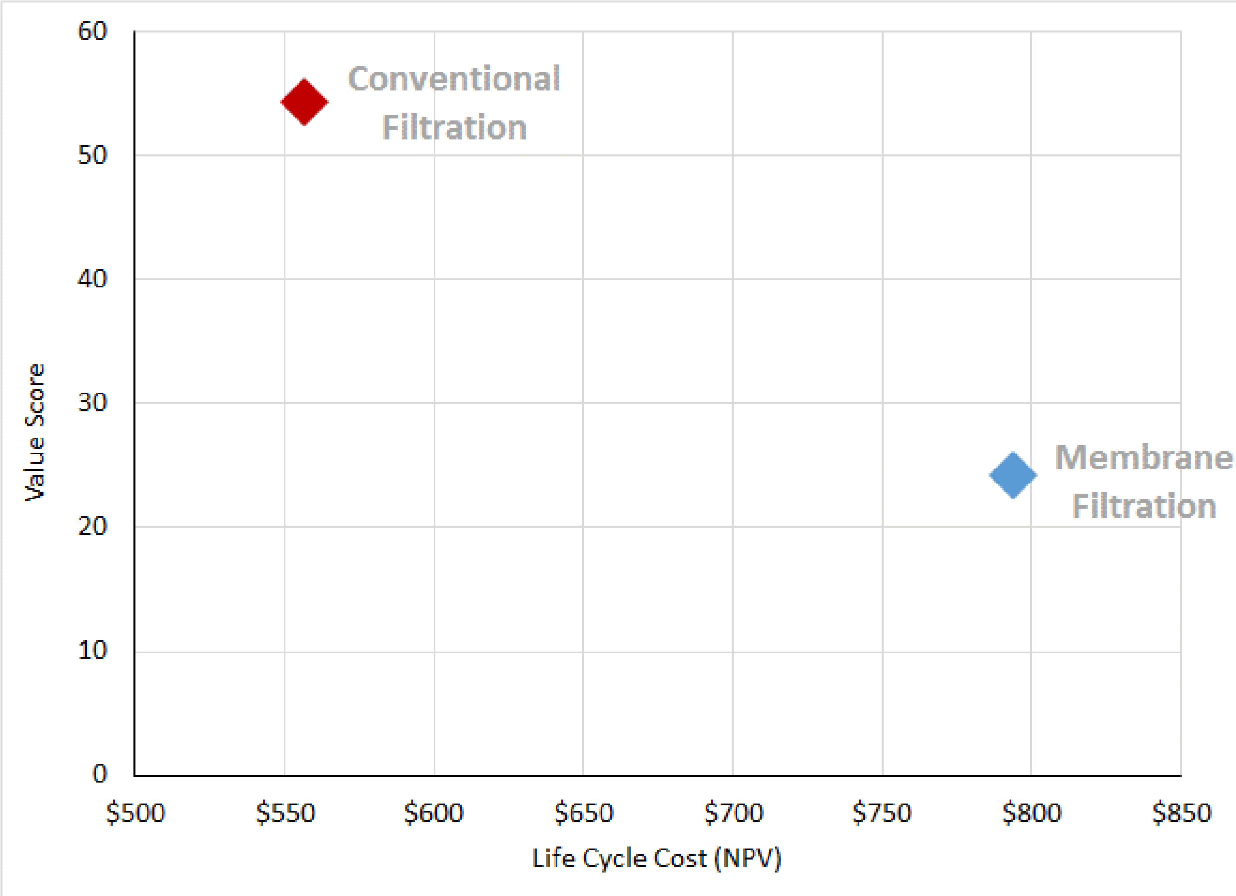
In all three weighing schemes, the Conventional Filtration alternative results in higher performance.

Another means to evaluate the performance of the alternatives is to contrast the total lifecycle cost of the alternatives against their total decision score. To avoid double counting of the cost element, the Cost Benefit value is removed from the calculation of the decision score. The lifecycle cost is the addition of the construction cost and 25 years of operating costs. The resulting total value score is then graphically plotted against the lifecycle cost (see Figures 13, 14, and 15).

This comparison also allows for a calculation of the investment required per unit of value. The table associated with the scatter plot presents the total cost ($M) to gain a unit of value. The same three weighting scenarios are evaluated.

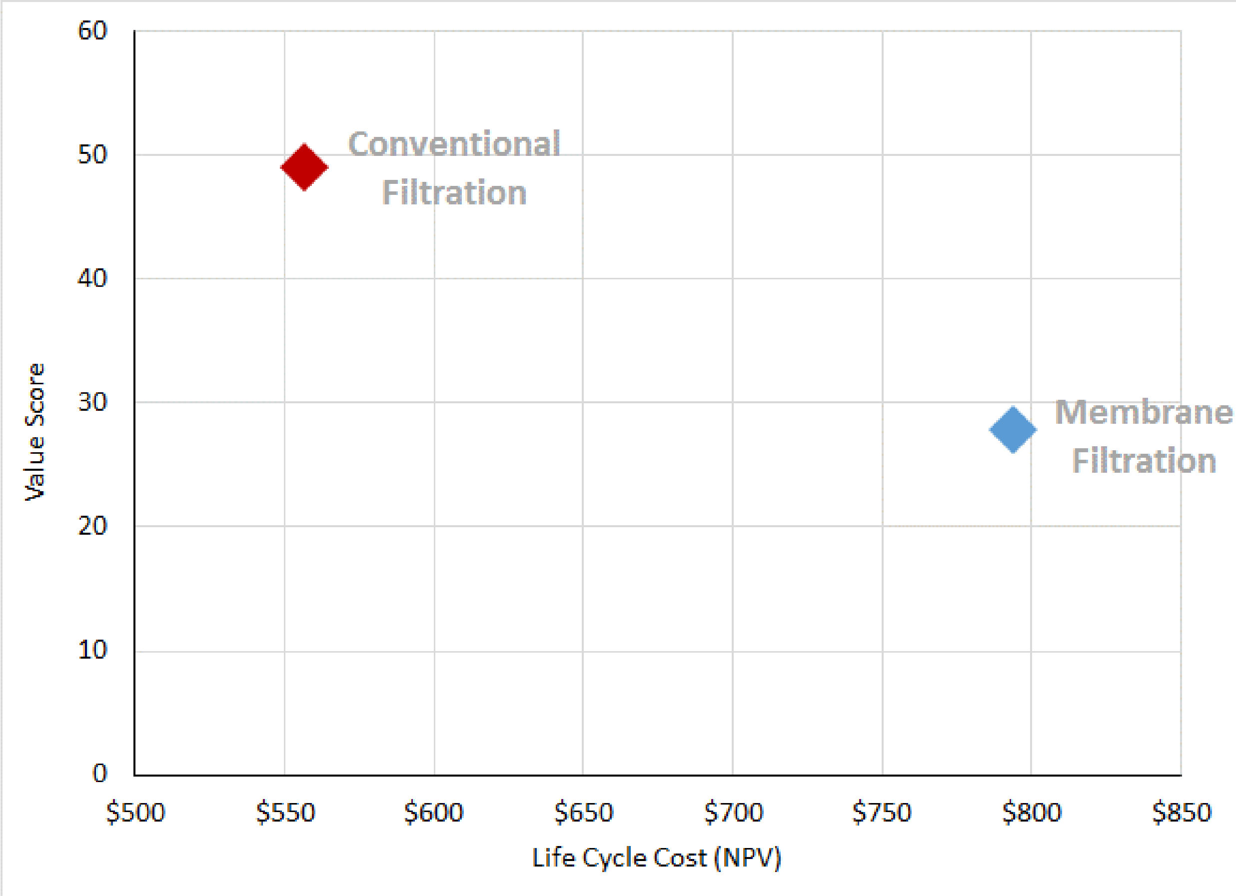
The results indicate that the Conventional Filtration alternative provides greater value at less cost. The Membrane Filtration option costs more and provides less value; therefore, the additional value per million dollars invested is a negative number when moving from the Conventional to the Membrane Filtration. Conventional Filtration is the superior alternative in both value and cost in all three weighting scenarios.

Figure 13: Team Weighting Scatter Plot and Table



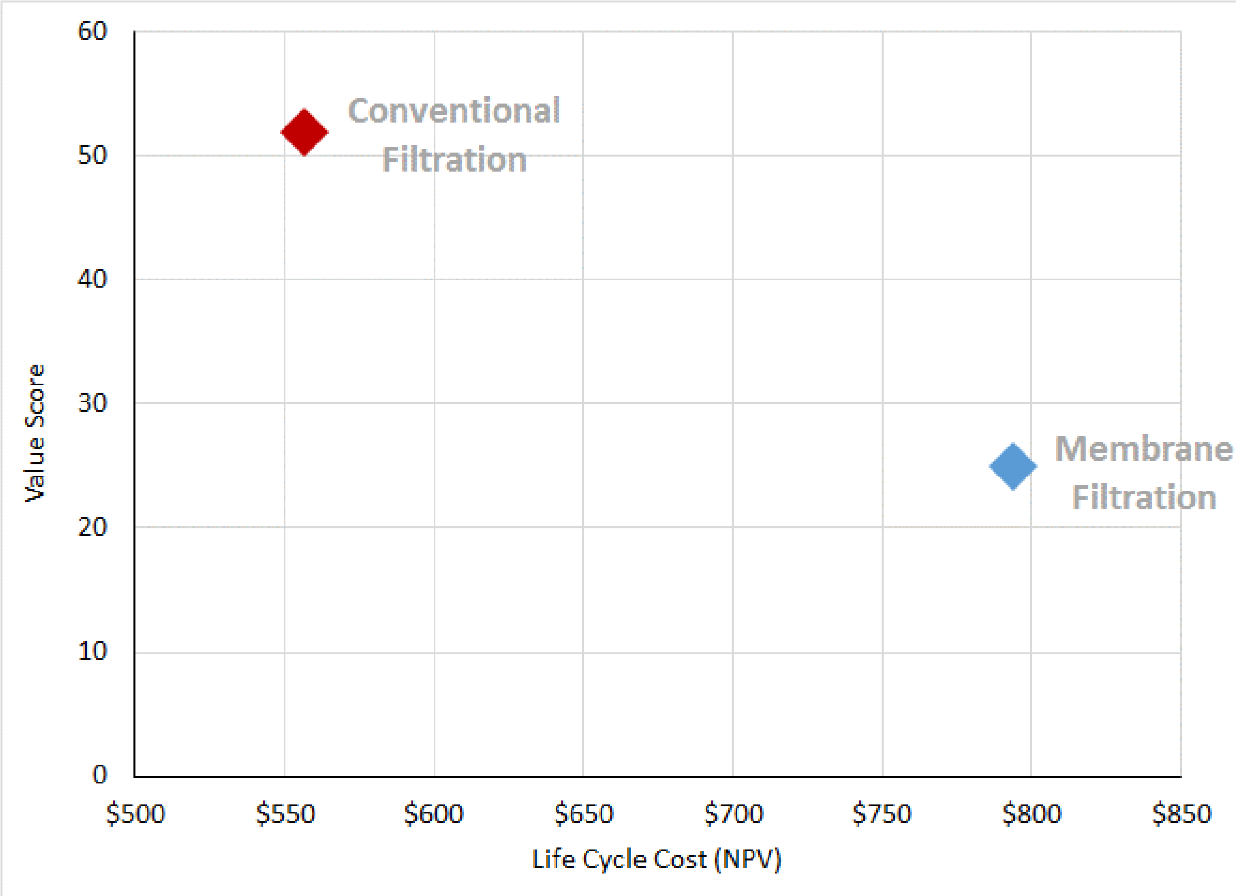
	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
Conventional	54.3	$ 557.00	$ 10.25	---	---	---
Membrane	24.2	$ 794.00	$ 32.75	-30.1	$ 237.00	-7.87

Figure 14: Equal Weighting Scatter Plot and Table



	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
Conventional	49.0	$ 557.00	$ 11.36	---	---	---
Membrane	27.9	$ 794.00	$ 28.50	-21.2	$ 237.00	-11.18

Figure 15: 60/40 Split Weighting Scatter Plot and Table



	Value Score	Lifecycle Cost $M	$M per unit of value (lower better)	Additional value	Additional Lifecycle Cost $M	Additional $M per unit of value
Conventional	51.9	$ 557.00	$ 10.74	---	---	---
Membrane	25.0	$ 794.00	$ 31.76	-26.9	$ 237.00	-8.83

This scatter plot view and associated table demonstrate the superior performance benefit of Conventional Filtration.

The Filtration Team used this performance evaluation to inform their discussion.

7 Summary and Recommendation

PWB has generated a significant amount of source water quality data and pilot testing results that are directly applicable to decisions made on filtration technology for Bull Run. The water has turbidity levels that average 0.4 NTU, with some episodes of elevated color. Algal blooms are not apparent in the source water monitoring, but future changes in how the water is withdrawn from the reservoir could exacerbate that.

Information was presented on the treatment technologies used by large water treatment plants in North America. The clear majority (146) of the facilities use granular media filtration. Thirty-eight (38) use granular media as part of their biological filtration system and very few (4) use membrane filtration. Only one large plant, Salem, Oregon, is using slow sand filtration technology.

For each of the three technologies used by large treatment systems, an evaluation of the technology's ability to provide the benefits important to the community and PWB staff was conducted. The evaluation was performed in two phases: a screening phase to identify how the treatment systems could be configured to meet the required treatment benefits, and a cost-development phase. A rigorous multivariate decision process was used to select the preferred technology.

Both the technical team and the Executive Committee concluded granular media filtration, which includes conventional and direct filtration, as the preferred technology alternative for treatment of Bull Run water.

Appendices

Appendix A

Technical Memo

Date:	September 18, 2018
Project:	Bull Run Filtration Project 699275.01.03
To:	Portland Water Bureau Filtration Decision Team
Copy to:	HDR, Barney &Worth
Prepared by:	Lee Odell
Approved by:	Kelly Irving
Subject:	**Bull Run Intake Water Quality**

Introduction

The purpose of this technical memorandum is to provide a summary of the intake water quality for the Bull Run Intake. Data for the past 10 years, from January 2007 through December 2017, were reviewed.

Bull Run Water Quality Summary

Raw water quality was reviewed and summarized as a first step in evaluating filtration technologies. Examining the raw water quality can help identify the appropriate filtration technology. For example, if high levels of algae were present in a drinking water source, that may indicate the need for clarification prior to filtration. Table 1 shows a summary of intake water quality parameters that were available for the Bull Run Supply over the past 10 years, except microbiological measures, for the intake. Microbiological water quality parameters are presented later in this TM. A summary of water quality analytes is provided as Attachment A at the end of this Technical Memorandum.

Table 1. Water Quality Parameter Data Summary from the Bull Run Intake, 2007-2017

	Algae #/ml	Color C.U.	TOC, mg/L	DOC, mg/L	UV_{254}, mg/L	Fe, ug/L	Mn, ug/L	Temp C	pH, s.u.	TSS, mg/L	Turb, NTU	ALK, mg/L as $CACO_3$
Maximum	3340	75	4.1	6.58	0.110	223	55.7	18.7	7.6	16	17	18
Average	291	11	1.09	2.08	0.047	46	9.9	9.5	7.1	1.0	0.4	7.8
Minimum	4.1	6	0.67	0.35	0.024	0	1.1	2.5	6.3	0.5	0.1	4.1
# of samples	1067	3826	329	28	286	209	212	3022	4439	210	6819	573

Note: Abbreviated terms defined in following text.

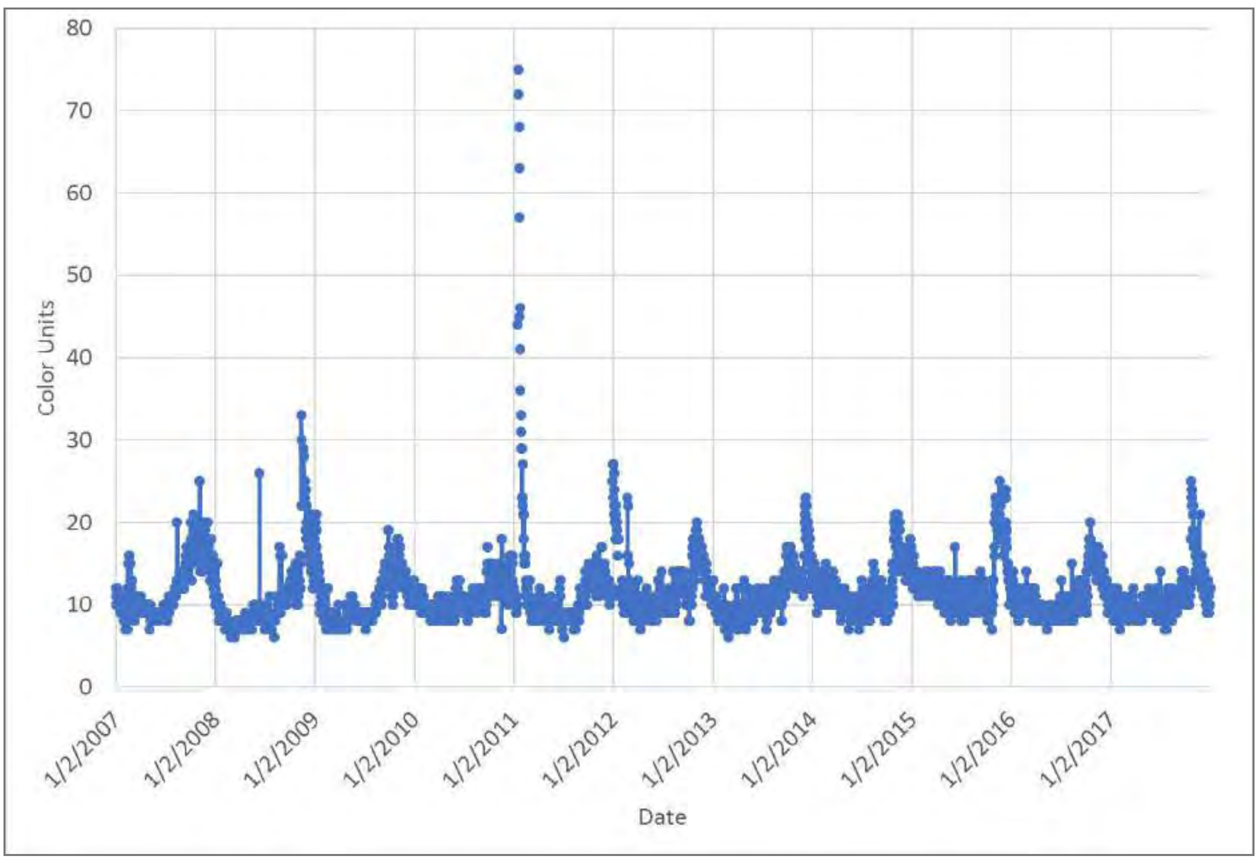
Algal analysis is done using the Whipple grid method by counting algal presence in 30 fields of view at 1,000X magnification, and reported as natural counting units (e.g., cells, colonies, filaments) per milliliter. Comparing these numbers to other methods, which use cell/mL or biovolume, would be misleading.

Algae data include 1,067 data points collected in seven different data sets. Most of the algae data were collected and analyzed by Portland Water Bureau (PWB) staff while about 3% of the samples were tested by an outside contractor.

Discussion of algae levels and their effect on selection of a water treatment process is not straightforward. Some northwest surface supplies such as Bellingham and Salem OR have recorded algal counts in excess of 1,000,000 colonies/mL during filter clogging events. Yet, other sources such as AWWA's operator training program define an algae bloom as 2,000 colonies/mL and still others have noted that as few as 3 colonies of specific cyanobacteria such as Uroglena (Schafran, 2016) can cause taste and odor events. In addition, the Water Bureau's intake supply can come from the various levels of the Bull Run Reservoir, to manage the release of colder water during critical periods to improve fish habitat. This variation can result in a range of algal counts from 4.1 to 3,340 colonies per ml (Table 1). A time series graph was not provided because the typical algae levels recorded at the intake are well below any definition of a large bloom and may not represent future conditions.

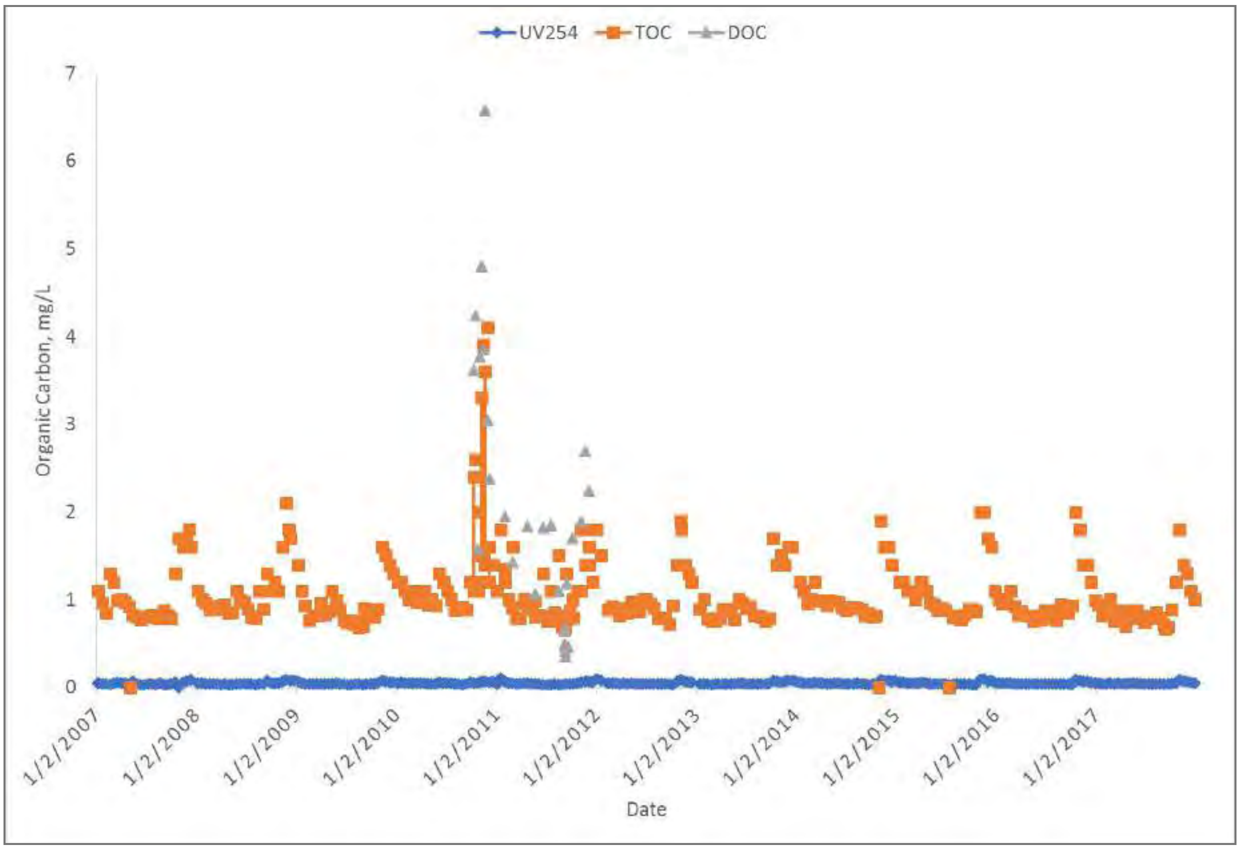
Color is routinely collected by treatment operators, which represents nearly 85% of the data. Some additional samples were analyzed by Bureau staff and a contract lab. Average color in the water is 11 color units (c.u.), which is less than the EPA's secondary maximum contaminant level (MCL) standard of 15. Color does exceed 15 c.u. each fall or winter. Figure 1 shows a time series chart of color over the 10-year period.

Figure 1. Bull Run Intake Water Color, 2007-2017



For total organic carbon (**TOC**), dissolved organic carbon (**DOC**) and **UV_{254}**, there is a limited data set. The average TOC in 329 samples collected over the 10-year period shows an average concentration of 1.1 mg/L and a maximum concentration of 4.1 mg/L. DOC was tested during a Water Research Foundation project in 2010 and 2011, and the data set is limited to 28 samples collected at the intake. There were 286 samples tested for UV_{254}. This data shows low levels of organic compounds that react to that specific wavelength of UV light. Figure 2 shows a time series plot of TOC, DOC and UV_{254}. Some DOC levels appear higher than TOC levels. The DOC samples were conducted by a consultant as part of a Water Research Foundation project and did not necessarily use the same analytical method as PWB normally uses.

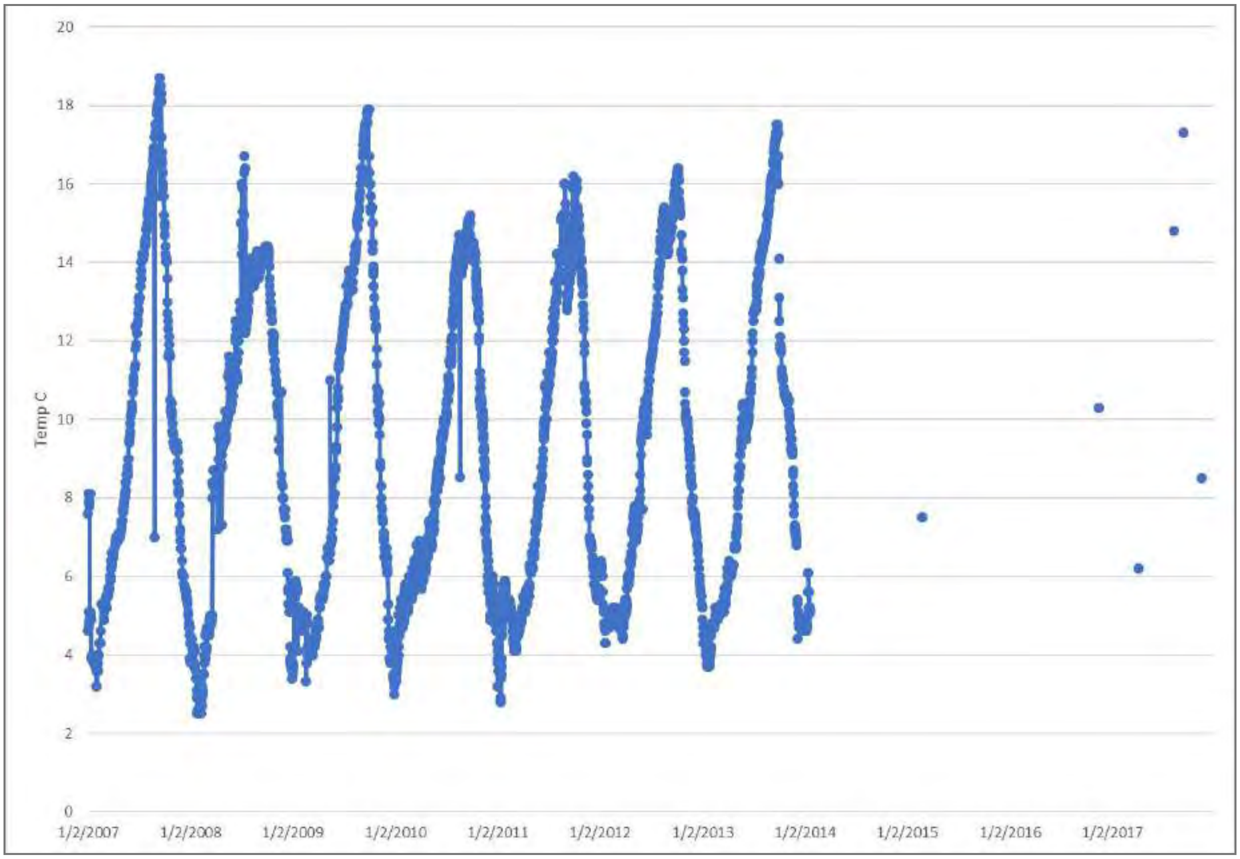
Figure 2. Bull Run Intake TOC, DOC and UV254, Time Series 2007-2017



Iron (**Fe**) concentrations in the raw water average 46 micrograms per liter (ug/L), far below the secondary MCL of 300 ug/L. Even the maximum value recorded is less than the MCL, therefore no graph was provided. Manganese (**Mn**) concentrations average only 9.9 ug/L, well below the secondary MCL of 50. Some systems have established a treatment goal of 20 ug/L for manganese to prevent scale buildup in the distribution system. For manganese, 33 samples of the 212 samples (16%) were 20 ug/L or greater.

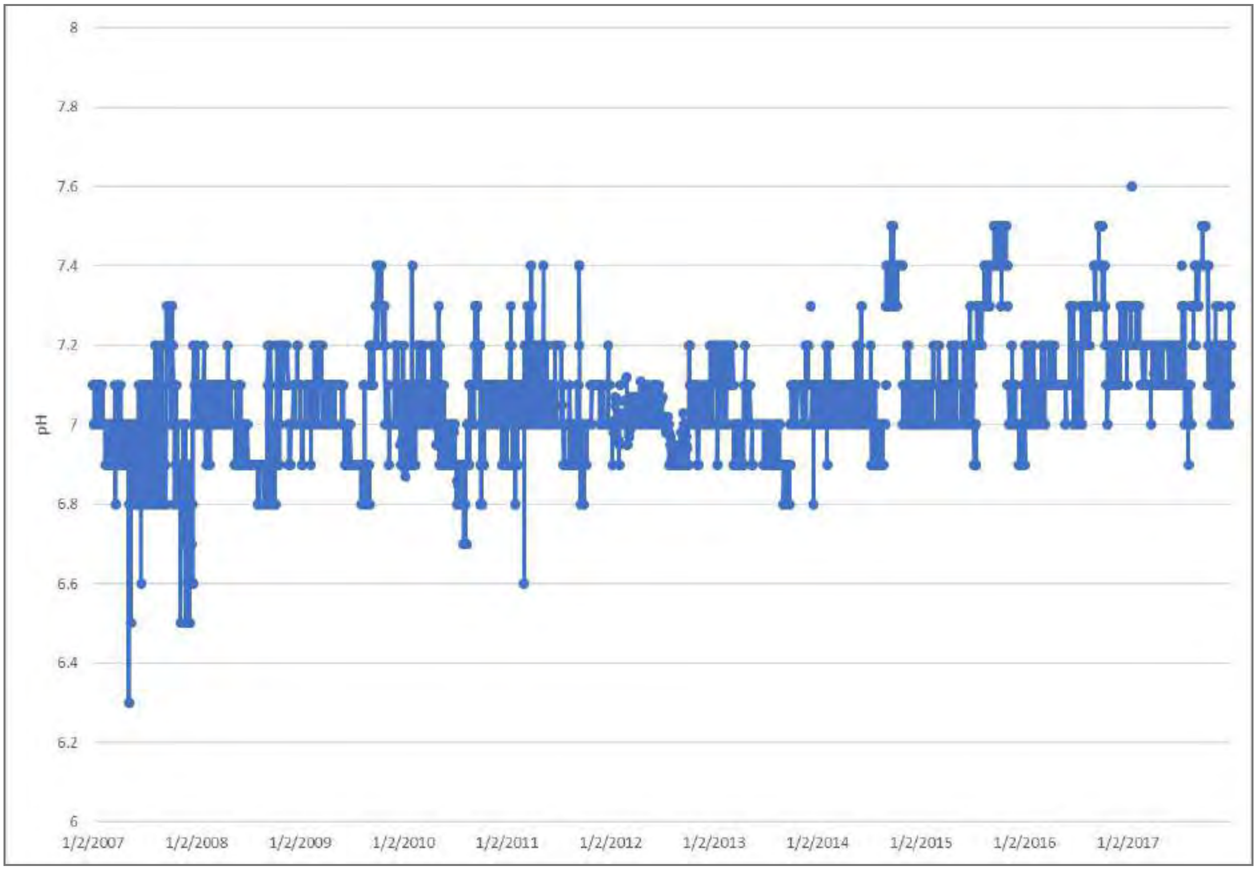
Water **temperature** is routinely collected by the treatment operators. Temperatures ranged from 2.5 to 18.7 degrees C. Figure 3 shows a time series plot of temperature.

Figure 3. Water Temperature at Bull Run Intake, Time Series 2007-2017



The intake **pH** varies from 6.3 to 7.6 standard units (s.u.). Samples are routinely collected by the treatment operators, as well as additional samples by Bureau staff. Figure 4 shows the pH over the 10-year period.

Figure 4. Bull Run Intake pH, Time Series 2007-2017



Total suspended solids (**TSS**) samples were collected 210 times over the 10-year period. The range was 0.5 to 16 mg/L and averaged 1 mg/L. Because TSS has the same trend as turbidity and turbidity is more widely used in filtration evaluations, TSS data is not shown graphically

Turbidity was collected frequently over the period by treatment operators and recorded continuously by the SCADA system. The SCADA system continues to record the influent turbidity when the system is off-line during turbidity events. The turbidimeter is located within the intake chamber and since no water is flowing through the intake chamber when the system is off-line, it does not capture the turbidity peaks during these events. The turbidity measurement was recorded once or twice per day in the data set from the SCADA system. The data set includes 6,819 readings. The average turbidity is 0.4 nephelometric turbidity units (NTU) and the maximum value was 17 NTU. Figure 5 shows a time series plot of turbidity over the period and Figure 6 shows a probability distribution for turbidity. The distribution shows that 99.9% of samples are less than 11 NTU, 99.5% of samples are less than 4 NTU, and 99% of samples are less than 3 NTU.

Figure 5. Bull Run Intake Turbidity, Time Series 2007-2017

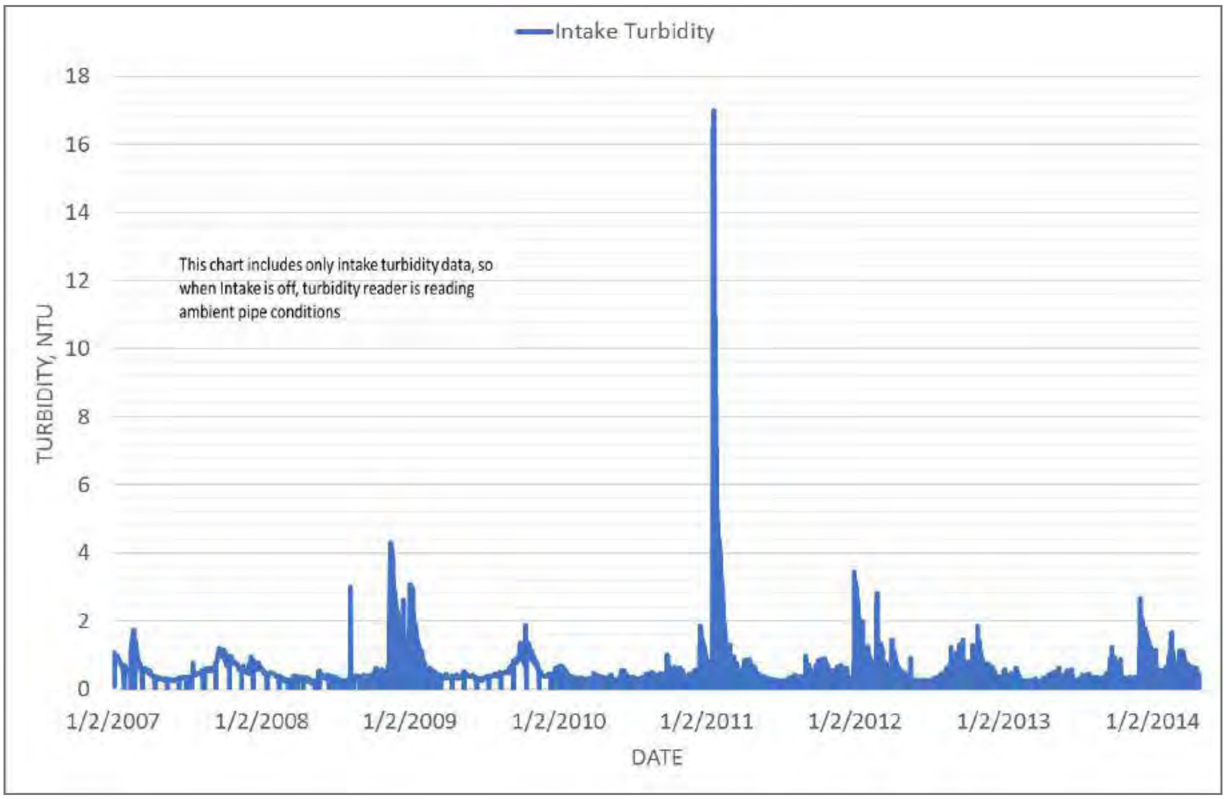
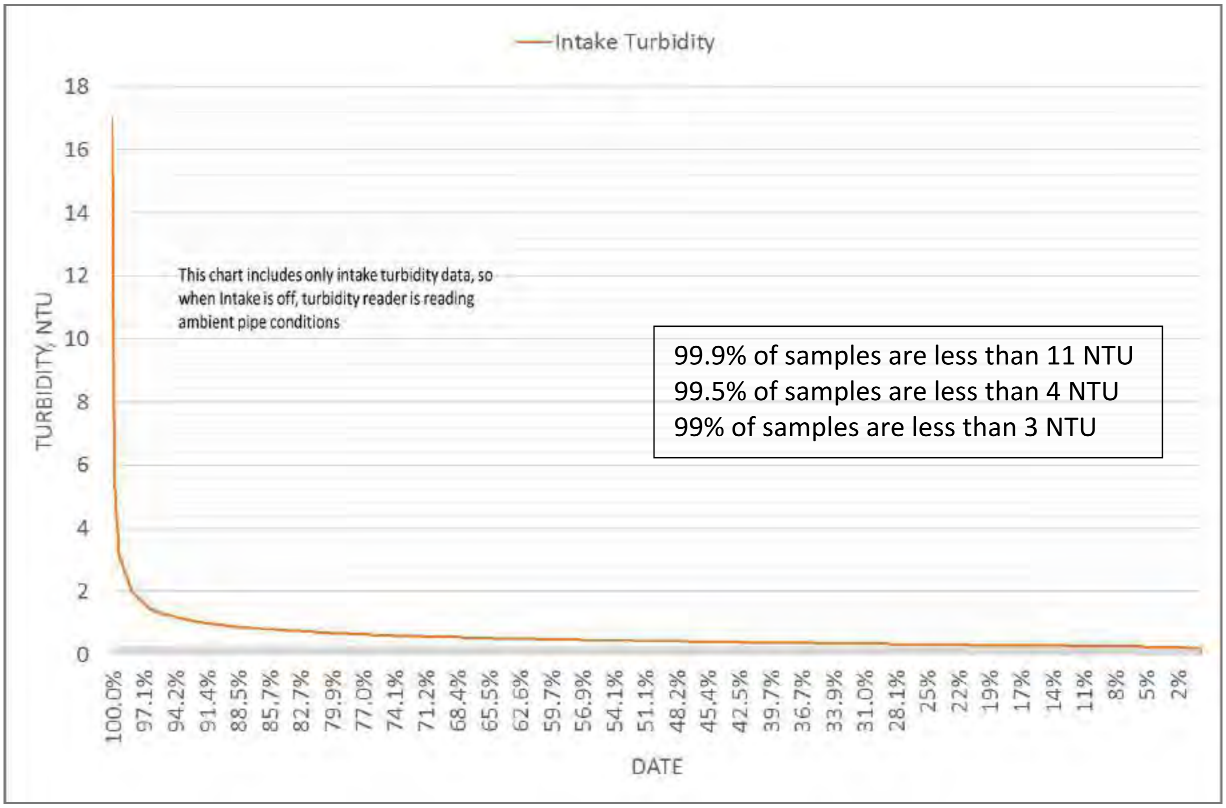
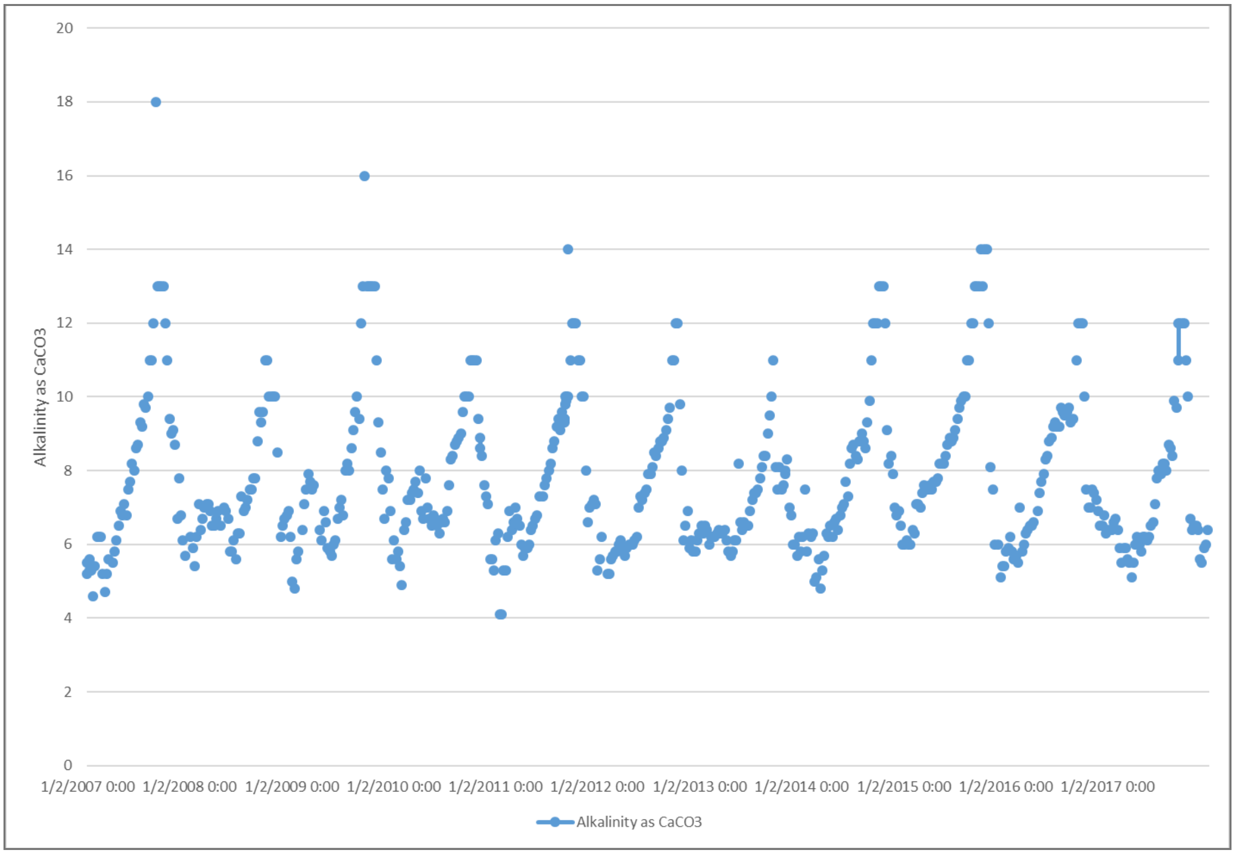


Figure 6. Bull Run Intake Turbidity Distribution, Time Series 2007-2017



Raw water **alkalinity** levels range between 4 and 18 mg/L as $CaCO_3$, with an average of 7.8 mg/L as $CaCO_3$, as shown in Figure 7.

Figure 7. Bull Run Intake Alkalinity, Time Series 2007-2017



Summary of Microbiology Data

Microbiological water quality can impact the selection of filtration technology, especially if microbiologically concentrations indicate the source water is degraded. Table 2 shows concentrations of *Cryptosporidium* oocysts, E. Coli, fecal coliforms, *Giardia* oocysts, and total coliform at the intake. These indicators demonstrate that the watershed is well protected, and that microbiological quality of the source is very good. To remain unfiltered, Portland had to conduct rigorous monitoring and demonstrate low levels of microbiological contaminants since the 1989 passing of the surface water treatment rule filtration avoidance criteria.

Table 2: Bull Run Intake Microbiological Water Quality

	CRYPTOSPORIDIUM, OOCYSTS/L	GIARDIA, OOCYST/L	E. COLI, CFU/ML	FECAL COL., CFU/ML	TOTAL COL., CFU/ML
Maximum	0.18182	0.270	55.6	47	1203
Average	0.00074368	0.0036	2.7	2.1	1160
Minimum	Not Detected	Not Detected	Not Detected	Not Detected	1
Number of Samples	2243	3314	1310	1096	4278

References

Schafran, Gary C., 2016, Controlling Alae Related Tastes and Odors, VA AWWA Water Quality and Research Committee Seminar

Attachment A

Intake Water Quality Analytes

Analysis Code	Analyte	Unit	Method Reporting Limit	Analysis Method
ALG-T	Algae, total	cells/ml	1	SM10200A-F
ALG-T	Algae, total	units/mL	0	SM10200A-F
ALG-TX	Algae, total by contract lab	#/ml	1	ML/SM 10200F
ALG-V	Algae, viable	cells/ml	1	SM10200A-F
ALG-V	Algae, viable	units/mL	0	SM10200A-F
ALG-V	Algae, viable	units/mL	1	SM10200A-F
ALG-VX	Algae, viable by contract lab	cells/ml	0	SM10200A-F
ALK-T	Alkalinity, total by lab	mg/L as CaCO3	1	SM2320B
ALK-T	Alkalinity, total by lab	mg/L as CaCO3	2	SM2320B
ALK-T	Alkalinity, total by lab	mL	1	SM2320B
ALK-TX	Alkalinity, total, by contract lab	mg/L as CaCO3	2	SM2320B
ALK-TX	Alkalinity, total, by contract lab	mg/L as CaCO3	9	SM2320B
COLOR-A	Color, Apparent, by lab	units	5	SM2120F
COLOR-ATO	Apparent Color, by Treatment Operator (TO)	units	5	HM 10048
COLORX	Color, by contract lab	units	5	SM2120B
CRYPT-C	Crypto count			
CRYPT-CNC	Crypto count, Non-Compliance			
CRYPT-CX	Crypto count, by contract lab			
CRYPT-CX	Crypto count, by contract lab			
CRYPT-DL	Crypto detection limit			
CRYPTO	Crypto per L	oocysts/L		
CRYPTOX	Crypto per 100 L, by contract lab			
DOC	Dissolved organic carbon	mg/L	0.1	SM5310C
DOCX	Dissolved organic carbon, by outside lab	mg/L	0.5	SM5310C
EC-NAM	E. Coli by NA/MUG		1	SM9221 F
EC-QTY	E. Coli Quanti-Tray, by lab	MPN/100mL		SM9223 B QTY
EC-QTY	E. Coli Quanti-Tray, by lab	MPN/100mL		SM9223 B QTY
EC-QTY18	E. Coli Quanti-Tray - 18 Hr	MPN/100mL		SM9223 B QTY
EC-QTY18	E. Coli Quanti-Tray - 18 Hr	MPN/100mL		SM9223 B QTY
EC-QTY-TO	E. Coli Quanti-Tray, by TO	MPN/100 mL		SM9223 B QTY
EC-QTYX	E. Coli by Quantitray, by contract lab			SM9223 B QTY
FC-MF	Fecal coliform, membrane filter (MF)	cfu/100 ml		SM9222 D
FC-MF	Fecal coliform, membrane filter	cfu/100 ml		SM9222 D
FC-MFX	Fecal coliform, MF, by contract lab	cfu/100 ml		SM9222 D
FE	Iron	mg/L	0.2	SM3111B
FE-DX	Iron, dissolved, by contract lab	mg/L	0.01	EPA 200.7
FE-DX	Iron, dissolved, by contract lab	mg/L	0.02	EPA 200.7
FE-ICPMS	Iron, by ICPMS	ug/L	5	EPA 200.8
FEX	Iron, by contract lab	mg/L	0.01	EPA 200.7
FEX	Iron, by contract lab	mg/L	0.02	EPA 200.7
FEX	Iron, by contract lab	mg/L	0.03	EPA 200.7
GIARD-C	Giardia count			
GIARD-CNC	Giardia count, non-compliance			
GIARD-CX	Giardia count, by contract lab			
GIARD-CX	Giardia count, by contract lab			
GIARD-DL	Giardia detection limit			
GIARDIA	Giardia per L	cysts/L		
GIARDIAX	Giardia per 100 L, by contract lab			
MN	Manganese	mg/L	0.005	SM3111B
MN	Manganese	mg/L	0.03	SM3111B
MN-DX	Manganese, dissolved, by contract lab	mg/L	0.0006	EPA 200.7
MN-ICPMS	Manganese, by ICPMS	ug/L	0.5	EPA 200.8
MN-ICPMS	Manganese, by ICPMS	ug/L	0.5	EPA 200.8
MNX	Manganese, by contract lab	mg/L	0.00005	EPA 200.7

Analysis Code	Analyte	Unit	Method Reporting Limit	Analysis Method
MNX	Manganese, by contract lab	mg/L	0.00006	EPA 200.7
MNX	Manganese, by contract lab	mg/L	0.0001	EPA 200.7
MNX	Manganese, by contract lab	mg/L	0.0003	EPA 200.7
MNX	Manganese, by contract lab	mg/L	0.0006	EPA 200.7
MNX	Manganese, by contract lab	mg/L	0.005	EPA 200.7
PH	pH by lab	units	0.1	SM4500-H B
PH-ALK	pH by lab, for alkalinity	units	0.1	SM4500B
PH-TO	pH by TO	units	0.1	SM4500B
PH-WQ	pH by WQ Insp	units		SM4500B
SOLID-SS	Solids, total suspended	mg/L	0.5	SM2540D
SOLID-SS	Solids, total suspended	mg/L	1	SM2540D
SOLID-SS	Solids, total suspended	mg/L	1	SM2540D
SOLID-SSX	Solids, total suspended, by contract lab	mg/L	5	SM2540 D
TC-ATYP	Total coliform, atypical count (MF test)	cfu/100 ml	1	SM9222B
TC-MF	Total coliform, membrane filter	cfu/100 ml	1	SM9222 B
TC-MF	Total coliform, typical count (MF Test)	cfu/100 ml	1	SM9222 B
TC-NC	Total coliform, non-coliform (MF Test)	cfu/100 ml	1	SM9222B
TC-QTY	Total coliform by Quanti-Tray, by lab	MPN/100 mL	1	SM9223 B QTY
TC-QTY18	Total coliform by Quanti-Tray - 18 Hr	MPN/100 mL	1	SM9223 B QTY
TC-QTY-TO	Total coliform by Quanti-Tray, by TOs	MPN/100 mL	1	SM9223 B QTY
TC-QTYX	Total coliform by Quantitray, by cont. lab		1	SM9223 B QTY
TEMPW	Temperature, Water, by lab	degrees C	0.1	SM2550B
TEMPW-TO	Temperature, Water, by TO	degrees C	0.1	SM2550B
TEMPW-WB	Temperature, Water, by WB Personnel	degrees C		SM2550B
TEMPW-WQ	Temperature, Water, by WQ Insp	degrees C	0.1	SM2550B
TOC	Total organic carbon	mg/L	0.1	SM5310C
TOC	Total organic carbon	mg/L	0.3	SM5310C
TOC	Total organic carbon	mg/L	0.3	SM5310C
TOCX	Total organic carbon, by contract lab	mg/L	0.5	SM5310C
TURB	Turbidity, by lab	NTU	0.05	SM2130B
TURB	Turbidity, by lab	NTU	0.1	SM2130B
TURB	Turbidity, by lab	NTU	0.3	SM2130B
TURB-TO	Turbidity, by TO	NTU	0.05	SM2130B
TURB-TO-END	End turbidity, crypto/giardia by TO	NTU	0.05	SM2130B
TURB-TO-OLTIME	Online turbidity reading time, by TO			
TURB-TO-OLTIME	Online turbidity reading time, by TO			
TURB-TO-START	Start turbidity, crypto/giardia by TO	NTU	0.05	SM2130B
TURB-WQ	Turbidity by WQ Insp	NTU	0.05	SM2130B
TURBX	Turbidity, by contract lab	NTU	0.2	EPA 180.1
UV_{254}	UV_{254}	absorbance/cm	0.001	SM5910B
UV_{254}	UV_{254}	absorbance/cm	0.005	SM5910B
UV_{254}	UV_{254}	absorbance/cm	0.005	SM5910B
UV_{254X}	UV_{254}, by contract lab	absorbance/cm	0.001	SM5910B

Appendix B

Technical Memo

Date:	August 30, 2018
Project:	Bull Run Filtration Project 699275.01.03
To:	Portland Water Bureau Filtration Decision Team
Copy to:	HDR, Barney &Worth
Prepared by:	Lee Odell
Approved by:	Kelly Irving
Subject:	**Bull Run Filtration Pilot Testing Summary**

Introduction

Between February 1990 and April 1993, the Portland Water Bureau (PWB) produced seven reports pertaining to pilot testing conducted by James M. Montgomery, Inc., in the Bull Run Watershed, as follows:

- Alternatives Analysis (JMM, 1990a),
- Pre-Design Report (JMM, 1990b),
- Equipment Specifications (JMM 1991a),
- Disinfection Report (JMM 1991b),
- Chloramination Chemistry Study (JMM 1991c),
- Pilot Plant Study (JMM 1992a),
- Preliminary Facility Plan (JMM 1992b),
- Summary Report (JMM 1993).

In addition, the Water Bureau participated in a Water Research Foundation pilot study to evaluate the microbial removal capabilities of low pressure membranes (MWH Americas, 1997) and an EPA Environmental Verification Pilot Study using the Zenon ZeeWeed® ZW-500 submerged membrane in June 2001.

This section of the TM summarizes the key findings from each of these pilot efforts.

Bull Run Media Filtration Pilot Testing Summary

The 1990-1993 pilot testing identified above successfully demonstrated media filtration with ozone at high loading rates with a wide range of media configurations.

Granular media filtration pilot testing was completed in several phases. First, water chemistry was evaluated, followed by studies examining pre-oxidation, flocculation, filter media and loading rates, heterotrophic plate count control, disinfection by product formation, elevated turbidity performance, and finally *giardia* challenge testing. A set of pilot testing goals was developed for the testing, as shown in Table 1.

Table 1. Portland Media Pilot Filtration Pilot Testing Goals

Parameter	Pilot Testing Goal
Filtered Water Turbidity	0.1 NTU
Particle Removal 4-7 microns 5-15 microns	 99% 99%
Giardia cyst Removal	99%
Virus Removal	90%
Disinfection Byproducts Total trihalomethanes (THMs) Total haloacetic acids(HAAs) Cyanogen chloride	 15 µg/L 10 µg/L 5 µg/L
Filtered Water heterotrophic plate count (HPC)	10 cfu/mL
Minimum Unit Filter Run Volume (UFRV)	5,000 gal/sq ft
Filter Maturation Turbidity	0.2 NTU
Turbidity Breakthrough Level	Not defined*
Terminal Headloss	10 feet, including clean bed headloss
Maximum Filter Maturation	3% of UFRV

*Generally, turbidity breakthrough occurs as the void spaces within the filter media become filled and the solids holding capacity becomes exhausted, resulting in a rapid increase in filtered water turbidity. During this study, turbidity breakthrough was characterized by a gradual increase from a stable, low-operating turbidity. Because the increase was not rapid, it was difficult to determine a "turbidity breakthrough level" that was acceptable as a goal. Filter runs were generally terminated due to headloss or when the filtered water turbidity began to increase from a stable operating level.
Abbreviations: NTU is nephelometric turbidity units, ug/L is micrograms per liter, cfu/ml is colony forming units per milliliter, UFRV is unit filter run volume, gal is gallon, sq ft is square foot.

Chemical Evaluation

The chemical evaluation considered alternative coagulant, coagulant aid polymers, filter aid polymers and pH of coagulation to determine the optimal chemical addition scheme for subsequent pilot testing. Longer filter runs were observed with polymer alone, compared to a combination of coagulant salt (ferric chloride) and polymer; however, organics removal was significantly less effective with polymer alone. A filter aid significantly improved filter run length and filter efficiency, while pH adjustment with the combination of ferric chloride and polymer had little impact on filter performance.

Preoxidation Evaluation

The pre-oxidation study examined the oxidant demand and decay characteristics for ozone, chlorine and chloramine, and compared their performance as a pretreatment for filtration. Figure 1 shows that longer filter runs were achieved with each of the pre-oxidants. Figure 2 shows that pre-oxidation with ozone improved particle removal efficiency compared to chlorine and chloramines. The optimal ozone dose was approximately 1.4 mg/L.

Figure 1. Effect of Pre-oxidant Dose on Unit Filter Run Volume (UFRV) *(JMM, 1993a)*

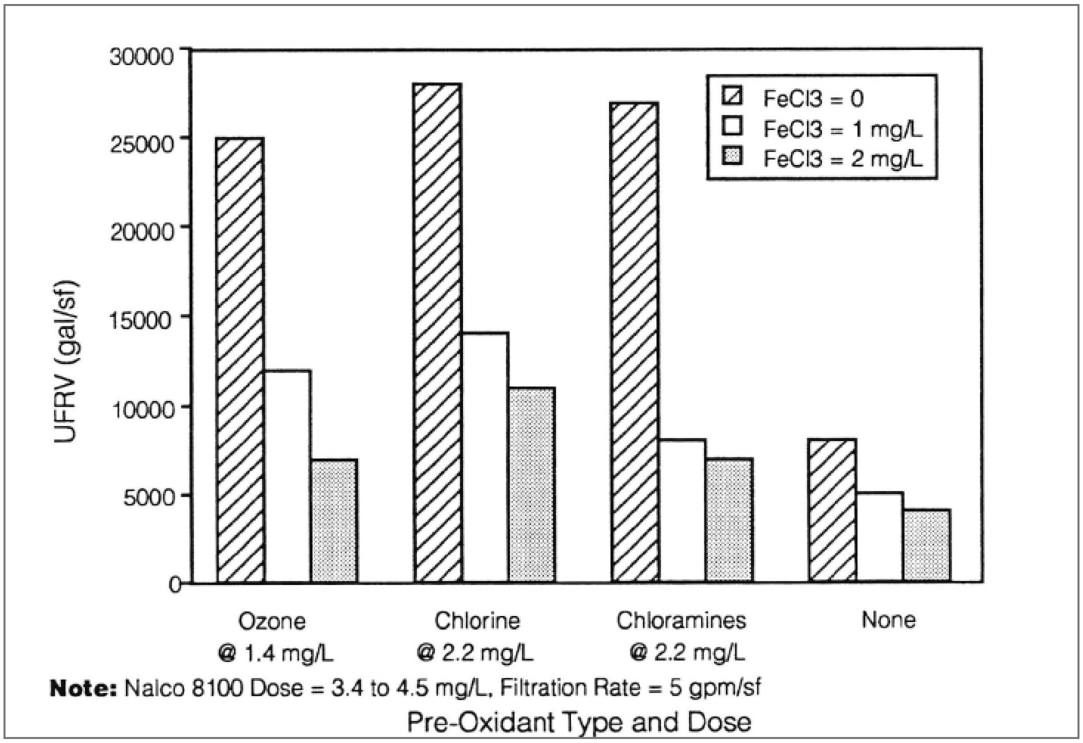
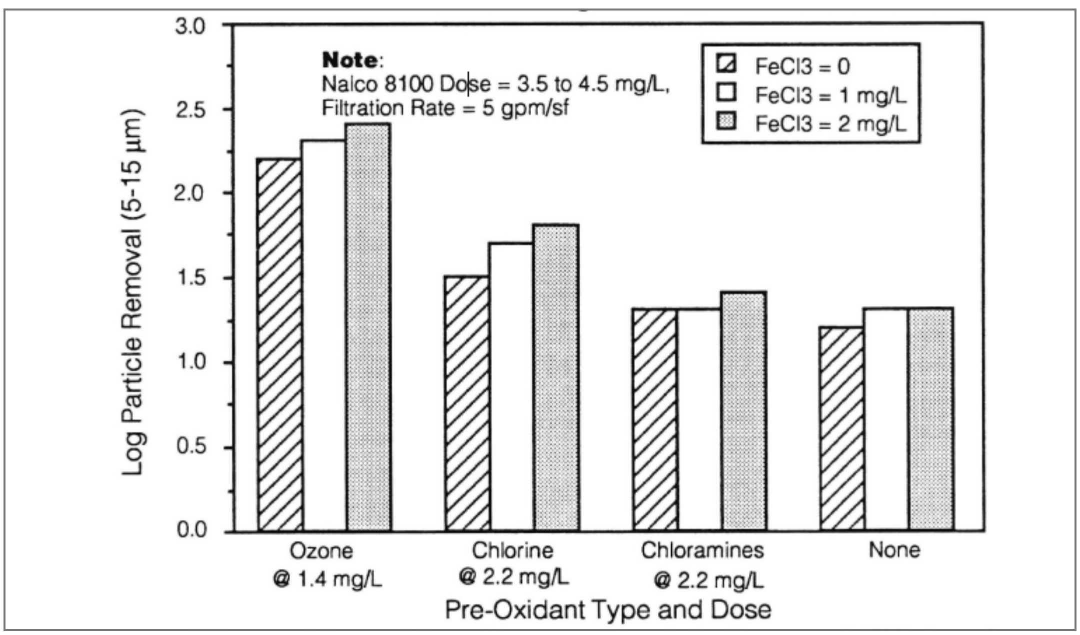


Figure 2. Effect of Pre-oxidant Dose on Particle Removal Efficiency *(JMM, 1993a)*



Flocculation Evaluation

The flocculation evaluation showed mixed results. With a combination of ferric chloride and polymer, flocculation up to 30 minutes shortened filter run lengths and produced higher filtered water turbidity compared to polymer alone. With a polymer alone, flocculation improved filter run length and reduced the amount of time it took the filter to mature after backwashing.

Evaluation of Filter Media and Filtration Rates

Multiple granular media types, sizes, bed depths and loading rates were tested during this phase of the pilot testing. The three filter media and filtration rates evaluated were mono media anthracite, mono media granular activated carbon (GAC), and dual media sand with anthracite. The tests were conducted with a preoxidation ozone dose of 1.5 mg/L and polymer only as a coagulant. A filter aid polymer was also used. Filter media sizes for the anthracite ranged from 1 to 2 mm and bed depths of 20", 40" and 120" were tested. GAC media size was 1.4 mm and a bed depth of 94" was used. The dual media filter used a 0.5 mm sand with a 9" depth under 80" of 1.5 mm anthracite.

Initial tests were done using 20-inch, 40-inch, and 60-inch of anthracite media, with a 1 mm effective size. Loading rates of 5, 7.5 and 10 gallons per minute per square foot (gpm/sq. ft.) were tested, with results showing adequate filter run UFRVs, but the filtered water turbidity and log particle removal were decreased as the filter loading rate increased. Unit filter run volume is the number of gallons run through a square foot of filter during a filter run.

Deeper media beds and different sizes of anthracite were investigated. The filter's performance improved with greater L:d ratios (length of filter media depth in mm to diameter of media in mm) of the media bed design. The L:d ratio is the length or depth of the filter in mm, divided by the diameter of the media in mm. An L:d ratio of 1,300 for 1.0 mm anthracite is 51" deep, for 1.5 mm anthracite the bed depth would be 77" and for 2.0 mm anthracite the bed depth would be 102". Table 2 summarizes the results of this deeper media bed testing, which was conducted March 19 through May 17, 1991. During this period, the ozone dose and coagulant/filter aid feed doses were kept relatively constant.

Table 2. Summary of Filter Media and Filter Rate Testing (JMM,1993a)

Date	Media	Size, mm	Depth, in	L:d ratio	Loading Rate, GPM/sq ft	UFRV, gal/sq ft	Filtered Water Turbidity, NTU	Log Particle Removal	Filter Run Termination
3/19/1991	Anthracite	1.5	68	1,151	15	45,000	0.06	1.71	Headloss
3/19/1991	Anthracite	1.5	77	1,304	15	25,200	0.07	1.40	Turbidity
3/19/1991	Anthracite	1.0	100	2,540	15	29,700	0.06	1.62	Turbidity
3/22/1991	Anthracite	1.5	68	1,151	15	34,200	0.05	1.82	Headloss
3/22/1991	Anthracite	1.5	77	1,304	15	20,700	0.06	1.49	Headloss
3/22/1991	Anthracite	1.0	100	2,540	15	21,600	0.04	1.62	Headloss
3/25/1991	Anthracite	1.5	68	1,151	15	30,600	0.05	1.85	Headloss
3/25/1991	Anthracite	1.5	77	1,304	15	32,400	0.06	1.54	Headloss
3/25/1991	Anthracite	1.0	100	2,540	15	27,000	0.04	1.68	Headloss
3/28/1991	Anthracite	1.5	100	1,693	10	61,200	0.05	1.78	Turbidity
3/28/1991	Anthracite	1.5	120	2,032	10	78,000	0.05	1.84	Turbidity
3/28/1991	GAC	1.4	94	1,705	10	46,800	0.04	1.93	Turbidity
4/2/1991	Anthracite	1.5	100	1,693	15	57,600	0.05	1.59	Time
4/2/1991	Anthracite	1.5	120	2,032	15	63,000	0.04	1.73	Time
4/2/1991	GAC	1.4	94	1,705	15	40,500	0.04	1.58	Turbidity
4/5/1991	Anthracite	1.5	100	1,693	10	8,400	0.04	2.23	Turbidity
4/5/1991	Anthracite	1.5	120	2,032	10	7,200	0.04	2.05	Turbidity
4/5/1991	GAC	1.4	94	1,705	10	5,280	0.04	1.85	Turbidity
4/7/1991	Anthracite	1.5	100	1,693	17.5	27,300	0.07	1.58	Headloss
4/7/1991	Anthracite	1.5	120	2,032	17.5	29,400	0.06	1.73	Headloss
4/7/1991	GAC	1.4	94	1,705	17.5	19,320	0.05	1.82	Headloss
5/14/1991	Anthracite	1.5	100	1,693	15	72,900	0.04	1.90	Headloss
5/14/1991	Anthracite and Sand	1.5/0.5	80/10	1,863	15	66,600	0.04	1.89	Headloss
5/17/1991	Anthracite	1.5	100	1,693	15	55,800	0.04	1.94	Time
5/17/1991	Anthracite and Sand	1.5/0.5	80/10	1,863	15	54,900	0.04	1.95	Time

Note: all tests with 1.5 mg/L ozone dose, NALCO 8100 polymer coagulant and filter aid polymer.

An L:d ratio of 1500 or greater appears to have some slight benefit in lower filtered water turbidity, increased particle removal and increased UFRV as shown in Figures 3, 4 and 5, respectively.

Figure 3. PWB 1991 Pilot Testing Results for Filter Various Bed Configurations L:d vs FW Turbidity (March 19 through May 17, 1991)

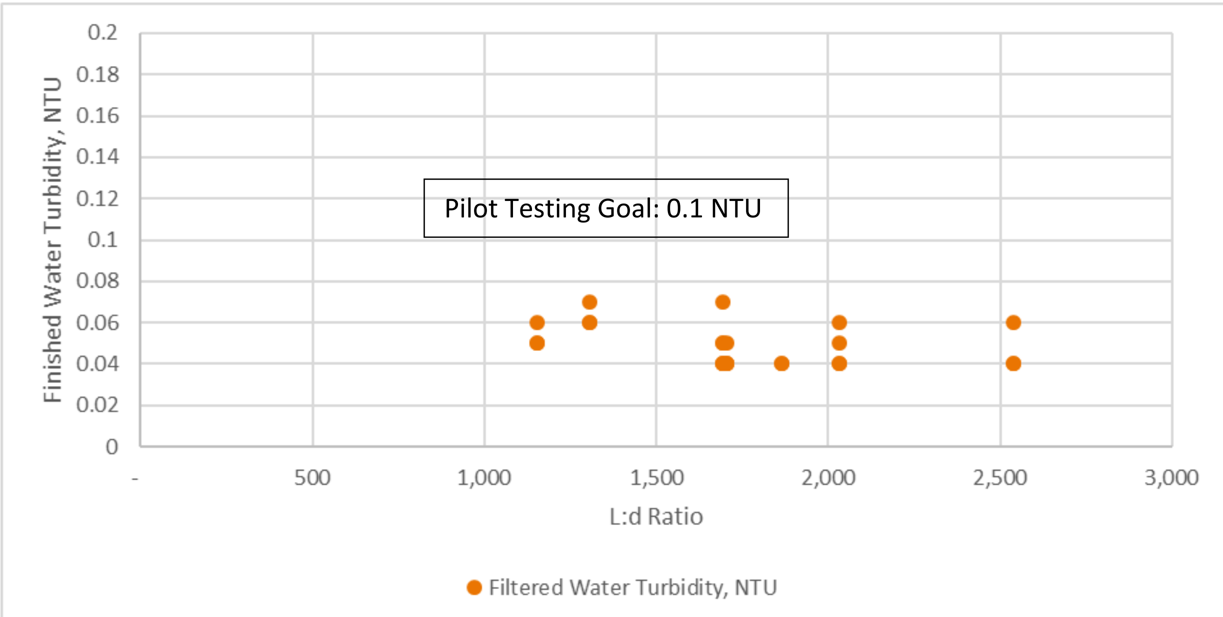


Figure 4. PWB 1991 Pilot Testing Results for Filter Various Bed Configurations L:d vs Log Particle Removal (March 19 through May 17, 1991)

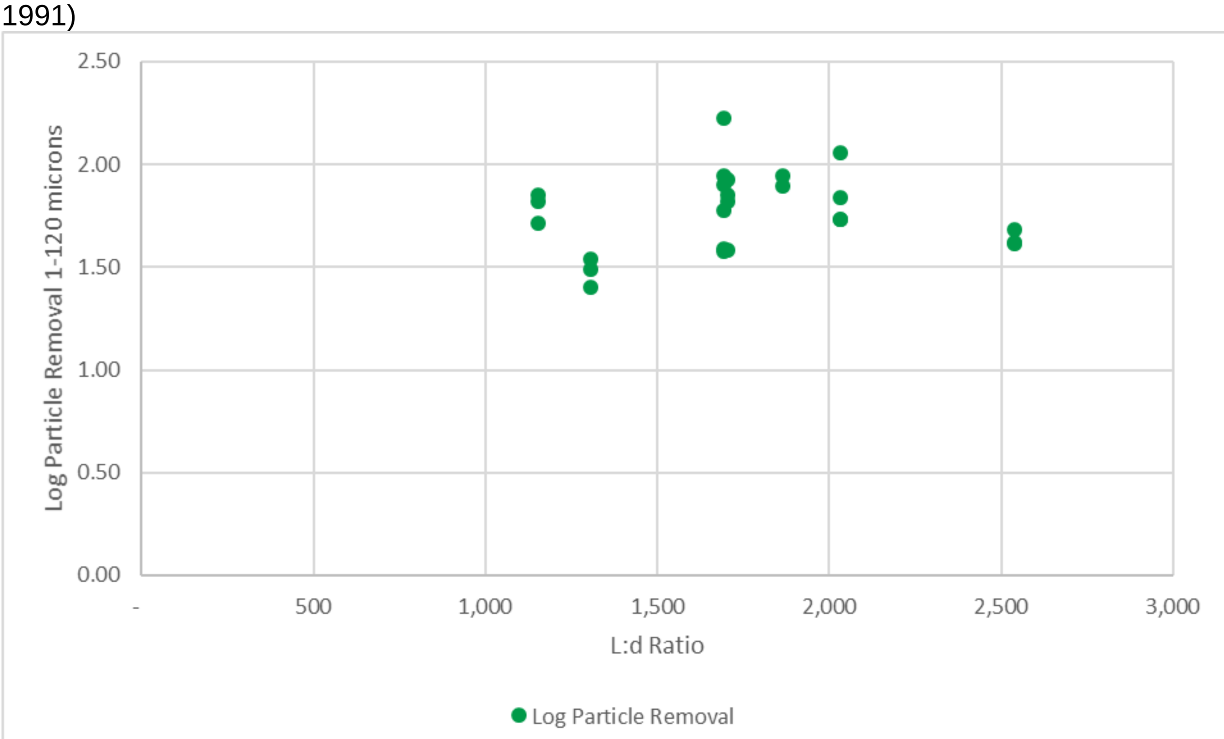
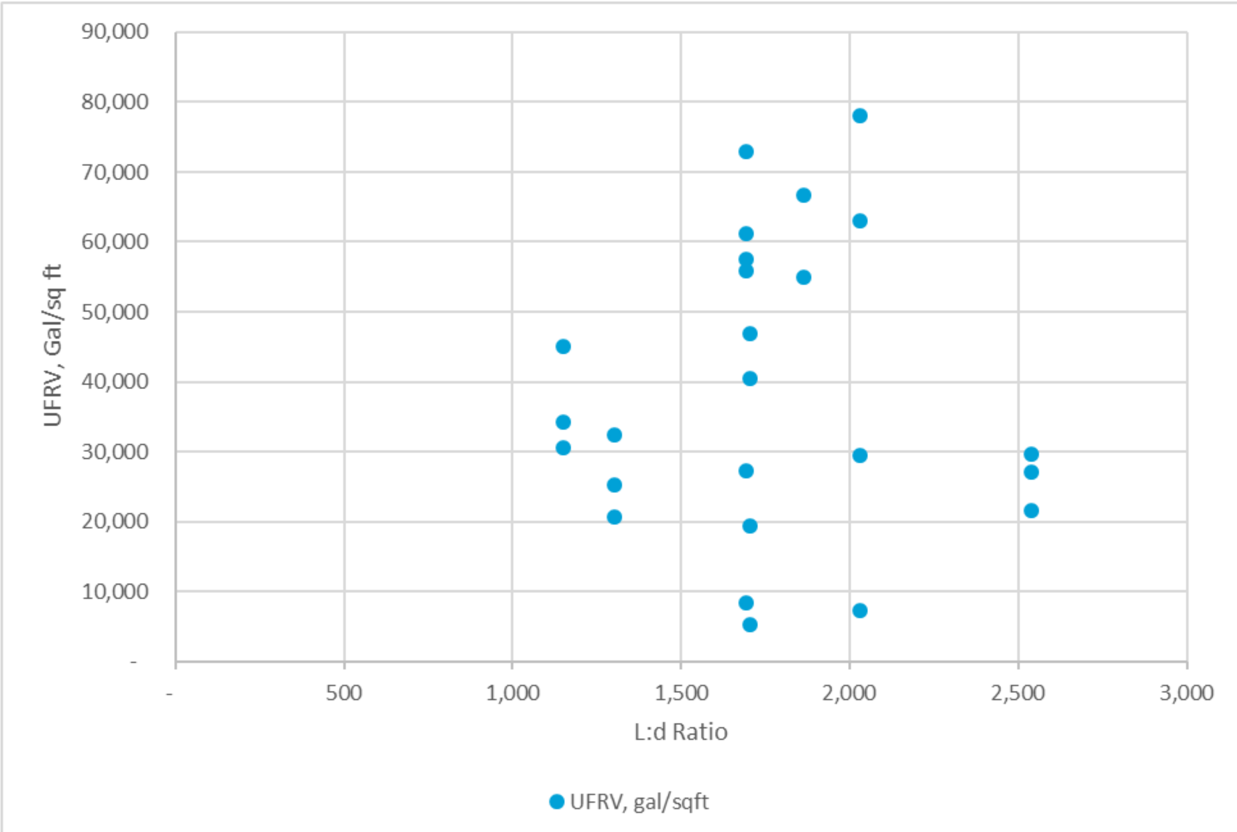


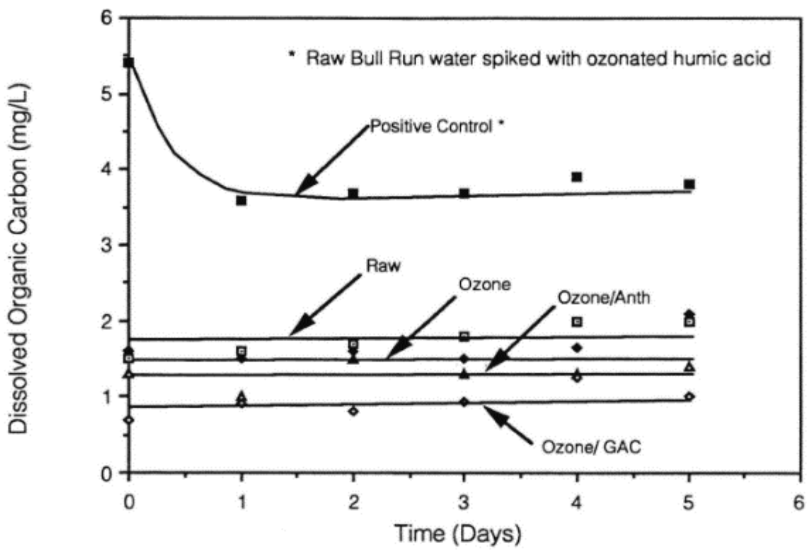
Figure 5. PWB 1991 Pilot Testing Results for Filter Various Bed Configurations L:d vs UFRV (March 19 through May 17, 1991)



Heterotrophic Plate Count Evaluation

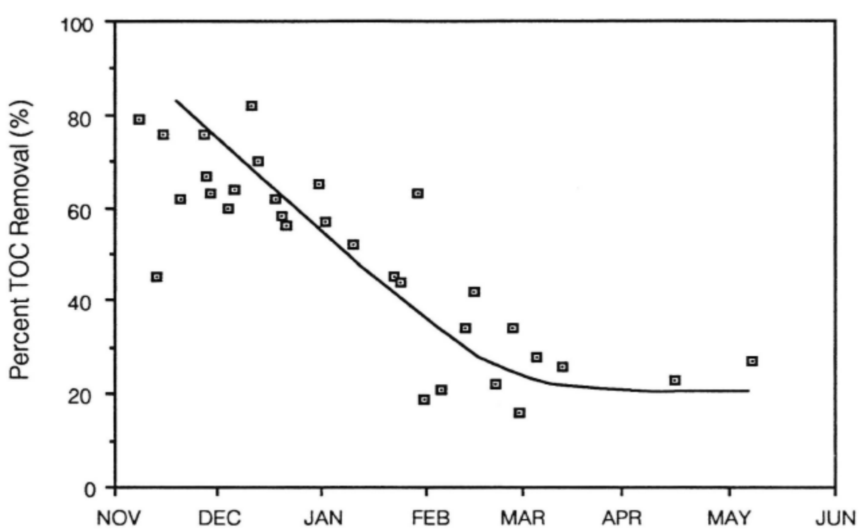
The evaluation conducted during this phase of the testing examined whether pre-oxidation with ozone was likely to exacerbate potential regrowth of bacteria in the distribution system. The evaluation included the impact of ozone and media filtration with anthracite and GAC on the levels of heterotrophic plate counts (HPC), total organic carbon (TOC), dissolved organic carbon (DOC) and biodegradable organic carbon (BDOC). The test results showed that the raw water, and the ozonated or ozonated/filtered water were very stable, as shown in Figure 6. Over a period of five days, the BDOC level in the water stayed the same in the raw and treated waters. By comparison, raw Bull Run water that was spiked with ozonated humic acid had decreased BDOC levels of 33% over the same period. The same waters spiked with HPC showed essentially no difference in biological growth potential between raw Bull Run water, ozonated water and ozonated water filtered with anthracite or GAC.

Figure 6. Biodegradable Dissolved Organic Carbon in Raw and Treated Bull Run Water (JMM, 1993a)



The ozonated GAC media filter was operated for more than 175 days of continuous operation. During this period, TOC removal decreased from initial levels of approximately 80% removal to a sustained value of approximately 20% removal as the GAC became exhausted, as shown in Figure 7.

Figure 7. TOC Removal across a Continuously Operated Ozone-GAC Filter



Disinfection By-Product Formation

Tests were conducted for disinfection by-product formation using a simulated distribution system reaction both at the University of North Carolina and in the pilot trailer at Bull Run headworks. The results demonstrated that ozone significantly reduced the amount of total Trihalomethanes (THM) and Halo Acetic Acids (HAA) formed after chlorine or chlorine and chloramine formation. Cyanogen chlorine was minimized in chloraminated waters by increasing the chlorine to ammonia ratio and minimizing the free chlorine contact time, prior to ammonia addition. The primary DBPs produced by ozonation were aldehydes. The results from this study indicated that ozonation of raw Bull Run water resulted in formaldehyde concentrations of approximately 15 µg/L.

Pilot treatment processes were evaluated for their ability to control oxidation by-products (OBP) formation. Disinfection by-product (DBP) production appeared to be directly related to the process' ability to remove organic precursor material as measured by total oil and grease (TOG) and ultraviolet light (UV_{254}) absorbance. UV_{254} appeared to be a better surrogate for THM and HAA formation potential than total organic carbon (TOC). Granular activated carbon (GAC) filtration removed more precursor material than did anthracite filtration and resulting DBP levels were lower for GAC-filtered water compared to anthracite. Water which had been coagulated/filtered with ferric chloride and cationic polymer also produced lower DBPs than did water coagulated/filtered with cationic polymer alone.

Taste and Odor Control Evaluation

The two most common taste and odor causing compounds in surface water are algal by-products: geosmin and 2-methylisoborneol (MIB), which can exhibit a swampy, musty flavor and odor to the water. GAC media that had been in service for two months was able to remove 20 nanograms per liter (ng/l) of MIB and geosmin to undetectable levels with empty-bed contact times of 2.5 and 5 minutes. Ozone was also effective at oxidizing these compounds at doses as low as 0.5 mg/L. The ozone dose used in the pilot filters of 1.5 mg/l was enough to reduce geosmin and MIB to levels below the detection limit. Coagulation filtration with anthracite removed approximately 25% of spiked MIB.

Elevated Turbidity Evaluation

Bull Run water was spiked with clay and sediments collected from the watershed and filtered with 100" of 1.5 mm anthracite and with a dual media filter of 80" of 1.5 mm anthracite over 10" of sand. The water was pre-ozonated and treated with a coagulant polymer and filter aid polymers. The raw water turbidity was elevated in the range of 2 to 5 nephelometric turbidity units (NTU). The sediments collected within the watershed were more readily removed than the clay added to the water. The dual anthracite and sand media performed similarly to the mono media filter of anthracite.

Giardia Challenge Evaluation

Raw water was spiked with *giardia* cysts in the mono media and dual media filters. The filters tested were pretreated with ozone at 1.5 mg/l and the coagulant polymer and filter aids were used. Filter loading rates of 10 and 15 gpm/sq. ft. were tested. The evaluation did not achieve 2 log removal (99%); however, the cyst removal did generally correspond to log particles removal discussed previously and those that were measured during this evaluation.

Lessons Learned from the Filtration Pilot Study

The pilot study results clearly demonstrated that ozone is useful as a pre-oxidant to improve filter performance and reduce taste, odor, and disinfection by-product levels.

The coagulant selection of polymer-only is unusual, and additional evaluation is merited if a coagulation process is part of the future filtration facility.

The deep media filter beds also increased filter efficiency, but additional study is merited to explore the trade-offs of head loss, increased log particle removal and long filter runs. It is likely that a shorter media bed depth operated at a lower filter loading rate could achieve similar or better log removal performance at a lower overall plant head loss than a deep bed at a higher loading rate.

Operating the filters in a biological filter mode, with either anthracite or GAC media, does not appear to pose a higher risk for distribution system regrowth than unfiltered chlorinated and chloraminated Bull Run water.

Water Research Foundation Membrane Bench and Pilot Scale Testing

The PWB participated in a Water Research Foundation project conducted by MWH Americas. The report, titled Membrane Filtration for Microbial Removal, was published in 1997. The specific objectives of the study were to:

- Evaluate the efficiencies of a variety of membranes for removing several different microorganisms and characterize them in terms of microbial removal, molecular weight cutoff and/or pore size,
- Provide greater insight into the mechanisms of microbial removal by low-pressure membranes,
- Identify and investigate existing and potential methods to assess membrane integrity and treatment reliability; and
- Conduct a survey of low-pressure membrane plants to determine full-scale treatment efficiency and process costs.

The project was conducted at two levels: bench and pilot scale. The bench scale studies, which were conducted with laboratory scale membrane modules, were designed to evaluate microbial removal efficiencies under controlled conditions, as well as to provide greater insight into the mechanisms of microbial removal by membranes.

Microbial challenge studies were conducted on both synthetic and natural waters. Pilot scale studies were employed to confirm results obtained at bench scale as well as to provide information on removal and operation under continual membrane operation over extended time periods. Portland tested three membrane configurations:

1. A 0.2-micron hollow fiber (out-in flow) microfiltration (MF) membrane
2. A 500,000 dalton hollow fiber (in-out flow) ultrafiltration (UF) membrane
3. A 100,000 dalton hollow fiber (in-out flow) UF membrane

The MF and UF membranes were operated at a pressure of 30 psi.

Microbial challenge studies were conducted using microorganisms targeted or being targeted by current and anticipated water quality regulations as well as those found in natural waters. *Cryptosporidium parvum, Giardia muris*, *MS2* virus, *Pseudomonas aeruginosa*, total coliform, and heterotrophic plate count (HPC) bacteria were all employed to evaluate the microbial removal efficiencies of the various membranes.

In challenge testing with spiked *giardia* and *cryptosporidium* cysts, each of the membranes showed greater than 6 log (99.9999%) removal. Coliform bacteria were removed from raw water levels of 53 to 160 cfu/mL to less than 1 cfu/mL in the permeate. HPC removals were 2.1 to 2.5 logs. MS2 bacteriophage removal was 2 logs (99%) for the MF membrane and greater than 5 logs (99.999%) for the UF membranes. Log rejection of MS2 decreased significantly as the flux rate was increased. At a flux rate of 12 gallons per square foot per day per psi of operating pressure (gfd/psi), the log removal was reduced to 1 log (90%). During the pilot study, transmembrane pressures in the UF membranes increased to over 20 psi within the first 10 days of operation. The MF membrane transmembrane pressure increased to 15 psi in six days of operation.

TOC removal in the membranes ranged from 5 to 12%. UV_{254} removal ranged from 7 to 17%.

U.S. EPA Verification Testing

Zenon tested a pilot unit of their ZeeWeed® ZW-500 ultrafiltration membrane at Bull Run headworks in 2001. The ZW-500 UF is not commonly used in drinking water applications. It has a pore size of 157,000 dalton and is a hollow fiber immersed membrane with an outside-in flow path. A vacuum is applied to the downstream side of the membrane to pull water through the unit. The tests occurred in three separate one-month periods over the course of a year. Flux rates ranged from 46 to 50 gfd, and water temperatures ranged from 6 to 15 degrees C. Filtered water turbidity was 0.04 to 0.05 NTU. Influent turbidity was spiked up to 200 NTU. *Giardia*, *cryptosporidium* and MS-2 Phage were also spiked. *Giardia* removal was greater than 3.3 logs in all three periods. *Cryptosporidium* removal was greater than 4.3 logs, and MS 2 Phase removal was 3.3 logs or greater in each period. Transmembrane pressure was less than 11 psi in each of the three tests.

TOC removal ranged from 19 to 22%. UV_{254} removal ranged from 13 to 34%. THM reduction ranged from 13% to 34%, and HAA reduction ranged from 1% to 49%, as shown in Table 3.

Table 3. Removal of TOD, UV_{254}, and Reduction of THMs and HAAs in Simulated Distribution System (SDS) Testing with the ZW-500 UF Membrane

Testing Period	TOC	UV_{254}	TTHMs, SDS	HAA, SDS
Period 1	19%	24%	13%	1%
Period 2	22%	22%	14%	5%
Period 3	13%	45%	34%	49%

References

JMM, 1990a. City of Portland Bureau of Water Works, Alternative Analysis Report for the Water Treatment Plant Pilot Study, February, 1990.

JMM, 1990b. City of Portland Bureau of Water Works, Pre-Design Report for the Water Treatment Plant Pilot Study, April, 1990.

JMM, 1991a. City of Portland Bureau of Water Works, Equipment Specifications Manual for the Water Treatment Plant Pilot Study, April, 1991.

JMM, 1991b. City of Portland Bureau of Water Works, Disinfection Report for the Water Treatment Plant Pilot Study, September, 1991.

JMM, 1991c. City of Portland Bureau of Water Works, Chloramination Chemistry Report for the Water Treatment Plant Pilot Study, December, 1991.

JMM, 1992a. City of Portland Bureau of Water Works, Pilot Plant Study Report for the Water Treatment Plant Pilot Study, April 1991.

JMM, 1992b. City of Portland Bureau of Water Works, Preliminary Facility Plan Report for the Water Treatment Plant Pilot Study, October, 1992.

JMM, 1993. City of Portland Bureau of Water Works, Summary Report for the Water Treatment Plant Pilot Study, January 1993.

Water Research Foundation, 1997. Membrane Filtration for Microbial Removal.

USEPA, 2001. Environmental Technology Verification Report. Physical Removal of Microbiological and Particulate Contaminants in Drinking Water, Zenon ZeeWeed ® ZW-500 Ultrafiltration Membrane System, Sandy, OR.

Appendix C

Technical Memo

Date:	September 18, 2018
Project:	Bull Run Filtration Project 699275.01.03
To:	Portland Water Bureau Filtration Decision Team
Copy to:	HDR, Barney &Worth
Prepared by:	Lee Odell
Approved by:	Kelly Irving
Subject:	**Summary of Existing Large Water Treatment Plant Technologies**

Introduction

The purpose of this technical memorandum is to summarize the technologies in use at large water treatment plants (WTPs) in North America. The list is not complete but summarizes the type of filtration in use at 167 of the largest surface water treatment plants in North America. It is expected that additional water treatment plants will be added to the list by the time the filtration technology decision is made.

Large Water Treatment Plant Treatment Technologies

Table 1 provides a list of large (at least 50 million of gallons per day [MGD]) surface water treatment plants serving most of the largest cities and metropolitan areas in North America. There are some notable exceptions Like Miami and Orlando, FL, which are both served by 100% groundwater. The list is arranged from largest capacity to the lowest. Of the 167 plants currently on the list:

- 1 (Salem, OR) uses slow sand filtration,
- 4 use membrane filtration,
- 146 use media filtration,
- 38 include biological filtration,
- 6 (including Portland) are unfiltered

The table shows that most large water treatment plants use media filtration. The large plants that use membranes include:

- The Region of Peel's Lakeview Water Treatment Plant (located in Ontario), which is a 240 MGD WTP. Of that total, 120 MGD is treated with a submerged ultrafiltration (UF) membrane and 120 MGD is treated with biological media filtration.
- The Region of Peel also owns the Lorne Park Water Treatment Plant which splits its 132 MGD capacity between submerged UF membranes and biological media filtration.
- San Diego County Water Authority's Twin Oaks Water Treatment Operator (WTO), is a 120 MGD submerged UF membrane WTP that is followed by ozone and biological GAC filters.
- The Columbia Heights WTP in Minneapolis, MN, is the largest pressure UF membrane plant at 70 MGD.

Table 1. Filtration Type of North American Water Treatment Plants Over 50 MGD

Utility	Plant	Design Capacity, (MGD)	Slow Sand	Membrane	Media Filter	Media w/ Biological Filter	Unfiltered
New York Dept. of Env. Protection, NY	Cat-Del WTP	2,020	▪	▪	▪	▪	■
City of Chicago, Dept. of Water, IL	Jardine WPP	960	▪	▪	■	▪	▪
North Texas Municipal Water Dist., TX	Wylie WTPs I, II, III & IV	700	▪	▪	■	■	▪
Los Angeles Water & Power, CA	Los Angeles Aqueduct WTP	600	▪	▪	■	■	▪
Southern Nevada Water Authority, NV	Alfred Merritt Smith WTP	600	▪	▪	■	■	▪
Metro Water District of Southern CA	Robert A. Skinner WTP #1	570	▪	▪	■	■	▪
Metro Water District of Southern CA	F. E. Weymouth WTP	520	▪	▪	■	■	▪
Metro Water District of Southern CA	Robert B. Diemer WTP	520	▪	▪	■	■	▪
City of Chicago, Dept. of Water, IL	South WPP	480	▪	▪	■	▪	▪
Metro Vancouver, BC	Seymour-Capilano WTP	475	▪	▪	■	▪	▪
Massachusetts Water Resources Authority, MA	Carroll WTP	450	▪	▪	▪	▪	■
City of Houston, TX	Northeast WTP	400	▪	▪	■	▪	▪
Dallas Water Util., TX	Eastside WTP	400	▪	▪	■	■	▪
Great Lakes Water Authority, MI (Detroit)	Lake Huron WTP	400	▪	▪	■	▪	▪
Metro Water District of Southern CA	Joseph Jensen WTP	400	▪	▪	■	■	▪
Mexico City, MX	Los Berros WTP	396	▪	▪	■	▪	▪
Great Lakes Water Authority, MI (Detroit)	Springwells WTP	370	▪	▪	■	▪	▪
City of Montreal, QC	Atwater WTP	359	▪	▪	■	▪	▪
San Francisco Public Utilities Comm., CA	Tesla WTP	350	▪	▪	▪	▪	■
Dallas Water Util., TX	Elm Fork WTP	330	▪	▪	■	■	▪
Guadalajara, MX	Lake Chalap WTP	328	▪	▪	■	▪	▪
Philadelphia Water Dept., PA	Baxter WTP	320	▪	▪	■	▪	▪
Metro Vancouver, BC	Coquitlam	317	▪	▪	▪	▪	■
City of Montreal, QC	Charles Baillets WTP	300	▪	▪	▪	▪	▪
Southern Nevada Water Authority, NV	River Mountains WTP	300	▪	▪	■	■	▪
New York DEP, NY	Croton WTP	290	▪	▪	■	■	▪
Washington Suburban Sanit. Comm., DC	Potomac Filtration Plant	285	▪	▪	■	▪	▪

Utility	Plant	Design Capacity, (MGD)	Slow Sand	Membrane	Media Filter	Media w/ Biological Filter	Unfiltered
Milwaukee Water Works, WI	Linnwood WTP	275	▪	▪	■	▪	▪
City of Toronto, ON	RC Harris WPP	265	▪	▪	■	▪	▪
Denver Water Dept, CO	Foothills WTP	250	▪	▪	■	▪	▪
Washington Aqueduct, DC	Dalecarlia WTP	246	▪	▪	■	▪	▪
Region of Peel, ON	Lakeview WTP	244	▪	■	■	■	▪
Great Lakes Water Authority, MI (Detroit)	Water Works Park WTP	240	▪	▪	■	■	▪
Kansas City Water Svcs Dept., MO	WaterWorks 1 NW Briarcliff Rd	240	▪	▪	■	▪	▪
Louisville Water Company, TN	Crescent Hill WTP	240	▪	▪	■	▪	▪
City of Hamilton, ON	Woodward Ave. Plant	238	▪	▪	■	▪	▪
Cincinnati Water Works, OH	Richard Miller Treatment Plant	235	▪	▪	■	▪	▪
New Orleans Water/Sewer Board, LA	Carrollton WTP	232	▪	▪	■	▪	▪
St. Louis County Water Co, MO	Central Plant 3	217	▪	▪	■	▪	▪
City of Toronto, ON	F J Horgan WPP	212	▪	▪	■	■	▪
Portland Water Bureau, OR	Bull Run	211	▪	▪	▪	▪	■
Denver Water Dept., CO	Marston WTP	200	▪	▪	■	▪	▪
United Water New Jersey (Suez)	Haworth WTP	200	▪	▪	■	▪	▪
Denver Water Dept., CO	Moffat WTP	195	▪	▪	■	▪	▪
DuPage Water Comm., IL	DuPage WTP	185	▪	▪	■	▪	▪
City of Charlotte, NC	Franklin WTP	181	▪	▪	■	▪	▪
Great Lakes Water Authority, MI (Detroit)	Northeast WTP	180	▪	▪	■	▪	▪
Great Lakes Water Authority, MI (Detroit)	Southwest WTP	180	▪	▪	■	▪	▪
Salt Lake Cnty Water Cons. Dist., UT	Jordan Valley WTP	180	▪	▪	■	▪	▪
San Francisco Public Utilities Comm., CA	Harry W. Tracy WTP	180	▪	▪	■	▪	▪
Seattle Public Utilities, WA	Cedar WTP	180	▪	▪	▪	▪	■
East Bay Municipal Utility Dist., CA	Orinda WTP	175	▪	▪	■	▪	▪
City of Austin, TX Water/WW	Ullrich WTP	167	▪	▪	■	▪	▪
City of Tacoma, WA	Green River WTP	165	▪	▪	■	■	▪
Cleveland Div. of Water, OH	Baldwin WTP	165	▪	▪	■	▪	▪
City of Toronto, ON	R.L. Clark WTP	162	▪	▪	■	▪	▪
City of Phoenix, AZ	Union Hills WTP	160	▪	▪	■	▪	▪
City of Witchita, KS	Main WTP	160	▪	▪	■	▪	▪

Utility	Plant	Design Capacity, (MGD)	Slow Sand	Membrane	Media Filter	Media w/ Biological Filter	Unfiltered
Omaha Metro Util. Dist., NE	Florence WTP	158	▪	▪	■	▪	▪
City of Calgary, AB	Bearspaw WTP	155	▪	▪	■	▪	▪
Cleveland Div of Water, OH	Garrett A. Morgan	150	▪	▪	■	▪	▪
Fairfax County Water Auth, VA	Corbalis WTP	150	▪	▪	■	▪	▪
Gwinnett County Department of Water Resources	Lanier Filtration Plant	150	▪	▪	■	▪	▪
Metro Water District of Southern CA	Henry J. Mills WTP	150	▪	▪	■	▪	▪
Toledo, (City of) Water Div., OH	Toledo WTP	150	▪	▪	■	▪	▪
City of Calgary, AB	Glenmore WTP	145	▪	▪	■	▪	▪
Metropolitan Water Dist., SLC, UT	Little Cottonwood WTP	143	▪	▪	■	■	▪
City of Phoenix, AZ	24th Street WTP	140	▪	▪	■	▪	▪
City of San Diego), CA	Miramar WTP	140	▪	▪	■	▪	▪
Monroe County Water Authority, NY (Rochester)	Shoremont WTP	140	▪	▪	■	▪	▪
City of Atlanta, GA	Hemphill WTP	136	▪	▪	■	▪	▪
City of Grand Rapids, MI	Lake Michigan Filtration Plant	135	▪	▪	■	▪	▪
Region of Peel, ON	Lorne Park WTP	132	▪	■	■	▪	▪
Richmond Dept. of Public Util., VA	Richmond WTP	132	▪	▪	■	▪	▪
Saint Paul Regional Water Services, MN	McCarrons WTP	130	▪	▪	■	■	▪
DeKalb County Public Works, GA	Scott Chandler WFP	128	▪	▪	■	▪	▪
Columbus Water Div., OH	Hap. Cremean WTP	125	▪	▪	■	■	▪
Dallas Water Util., TX	Bachman WTP	125	▪	▪	■	■	▪
Tulsa Public Works Dept., OK	A. B. Jewell WTP	125	▪	▪	■	▪	▪
City of Austin, TX Water/WW	Albert R. Davis WTP	120	▪	▪	■	▪	▪
City of San Diego), CA	Alvarado WTP	120	▪	▪	■	▪	▪
City of Tampa, FL	David L. Tippin WTP	120	▪	▪	■	▪	▪
Everett Water Util, WA	Everett WTP	120	▪	▪	■	▪	▪
Philadelphia Water Dept., PA	Queen Lane WTP	120	▪	▪	■	▪	▪
San Juan Suburban Water Dist., PR	Sidney N. Peterson WTP	120	▪	▪	■	▪	▪

Utility	Plant	Design Capacity, (MGD)	Slow Sand	Membrane	Media Filter	Media w/ Biological Filter	Unfiltered
Washington Aqueduct, DC	McMillan WTP	120	▪	▪	■	▪	▪
Charleston Comm Public Works, SC	Hanahan WTP	118	▪	▪	■	▪	▪
Pittsburgh Water and Sewer Auth., PA	Aspinwall WTP	117	▪	▪	■	▪	▪
City of Toronto, ON	Island WTP	116	▪	▪	■	▪	▪
Fairfax County Water Auth., VA	Occoqual WTP	111	▪	▪	■	▪	▪
City of Edmonton, AB	Rossdale WTP	110	▪	▪	■	▪	▪
City of Norfolk, VA	Moores Bridge WTP	108	▪	▪	■	▪	▪
Evanston Water Dept., IL	Evanston	108	▪	▪	■	▪	▪
City of Ottawa, ON	Lemieux Island WTP	106	▪	▪	■	▪	▪
City of Winnipeg, MB	Winnipeg WTP	106	▪	▪	■	■	▪
City of Edmonton, AB	E.L. Smith Plant	106	▪	▪	■	▪	▪
Milwaukee Water Works, MN	Howard Avenue WTP	105	▪	▪	■	▪	▪
Passaic Valley Water Comm., NJ	Little Falls Treatment Facility	104	▪	▪	■	▪	▪
City of Phoenix, AZ	Deer Valley WTP	100	▪	▪	■	▪	▪
City of Sacramento, Util Dept., CA	E. A. Fairbairn WTP	100	▪	▪	■	▪	▪
Cleveland Div of Water, OH	Nottingham WTP	100	▪	▪	■	▪	▪
Houston, (City of), TX	East Purification Plant III	100	▪	▪	■	▪	▪
San Diego County, CA	Twin Oaks WTP	100	▪	■	▪	■	▪
Santa Clara Valley Water Dist., CA	Santa Teresa WTP	100	▪	▪	■	■	▪
Springfield Water Dept., IL	West Parish Filters	100	▪	▪	■	▪	▪
Tulsa Public Works Dept., OK	Mohawk WTP	100	▪	▪	■	▪	▪
PRASA - North Coast Super Aqueduct Project, PR	Dr. Antonio Santiago Vazquez WTP	100	▪	▪	■	▪	▪
Tampa Water Dept., FL	Hillsborough River WTP	99	▪	▪	■	■	▪
City of Dayton, OH	Miami River WTP	96	▪	▪	■	▪	▪
Indianapolis Water Co, IN	White River WTP	96	▪	▪	■	▪	▪
St. Louis County Water Co, MO	North Plant (E & W Basins)	96	▪	▪	■	▪	▪
City of Ottawa, ON	Britannia WTP	95	▪	▪	■	▪	▪
Cobb County Marrietta, GA	Quarles	94	▪	▪	■	▪	▪

Utility	Plant	Design Capacity, (MGD)	Slow Sand	Membrane	Media Filter	Media w/ Biological Filter	Unfiltered
Albuquerque-Bernalillo County Water Authority, NM	San Juan Chama WTP	93	▪	▪	■	■	▪
City of Windsor, ON	AH Weeks WTP	92	▪	▪	■	■	▪
City of London, Regional Water Supply, ON	Lake Huron WTP	90	▪	▪	■	▪	▪
City of Minneapolis, MN	Fridley WTP	90	▪	▪	■	■	▪
City of Oklahoma City, OK	Draper WTP	90	▪	▪	■	▪	▪
East Bay Municipal Utility Dist., CA	Upper San Leandro WTP	90	▪	▪	■	■	▪
Erie County Water Authority, NY (Greater Buffalo)	Sturgeon Point WTP	90	▪	▪	■	▪	▪
Metro Water Services, TN	K. R. Harrington WTP	90	▪	▪	■	▪	▪
Metro Water Services, TN	Omohundro WTP	90	▪	▪	■	▪	▪
Seattle Public Utilities, WA	Tolt WTP	90	▪	▪	■	■	▪
Vista Irrigation Dist., CA	Vista-Escondido Joint WTP	90	▪	▪	■	▪	▪
Wyoming Util Dept., MI	Donald K. Shine WTP	90	▪	▪	■	▪	▪
Fort Collins, CO	Fort Collins WTP	87	▪	▪	■	▪	▪
Joint Water Commission, OR	JWC WTP	85	▪	▪	■	▪	▪
Aurora Water, CO	Peter Binney WFP	83	▪	▪	■	■	▪
Aurora Water, CO	Griswold WFP	80	▪	▪	■	▪	▪
Aurora Water, CO	Wemlinger WFP	80	▪	▪	■	▪	▪
City of Phoenix, AZ	Lake Pleasant WTP	80	▪	▪	■	▪	▪
Columbus Water Div., OH	Dublin Road WTP	80	▪	▪	■	■	▪
Santa Clara Valley Water Dist., CA	Rinconada WTP	80	▪	▪	■	▪	▪
Washington Suburban San. Comm., MD	Patuxent WTP	80	▪	▪	■	▪	▪
City of Burlington, ON	Burlington WTP	79	▪	▪	■	▪	▪
Des Moines Water Works, IA	Fleur Drive WTP	75	▪	▪	■	▪	▪
Gwinnett County Department of Water Resources	Shoal Creek Filtration Plant	75	▪	▪	■	▪	▪
Philadelphia Water Dept, PA	Belmont WTP	75	▪	▪	■	▪	▪
Cobb County Marrietta, GA	Wyckoff WTP	72	▪	▪	■	■	▪
Halton Region, ON	Burlington WTP	72	▪	▪	■	■	▪
City of Minneapolis, MN	Columbia Heights WTP	70	▪	■	▪	▪	▪

Utility	Plant	Design Capacity, (MGD)	Slow Sand	Membrane	Media Filter	Media w/ Biological Filter	Unfiltered
Eugene Water & Electric Board, OR	Hayden Bridge WTP	70	▪	▪	■	▪	▪
North Texas MWD, TX	Leonard WTP	70	▪	▪	■	■	▪
City of El Paso, TX	Jonathan Rogers WTP	60	▪	▪	■	■	▪
City of Syracuse, NY	Woodland Reservoir WTP	60	▪	▪	▪	▪	■
East Bay Municipal Utility Dist., CA	Sobrante WTP	60	▪	▪	■	■	▪
Mobile Area Water and Sewer Service, Mobile, AL	Stickney WTP	60	▪	▪	■	▪	▪
Montgomery Water Works and Sanitary Sewer Board, Montgomery, AL	C. T. Perry WTP	60	▪	▪	■	▪	▪
Truckee Meadows Water Authority, NV	Chalk Bluff WTP	60	▪	▪	■	▪	▪
City of Huntsville Utilities, AL	South Parkway WTP	56	▪	▪	■	■	▪
Cities of Regina & Moose Jaw, SK	Buffalo Pound WTP	55	▪	▪	■	▪	▪
Saskatoon, SK	Avenue H WTP	53	▪	▪	■	▪	▪
City of Ann Arbor, MI	Ann Arbor WTP	50	▪	▪	■	■	▪
City of Austin, TX Water/WW	Water Treatment Plant 4	50	▪	▪	■	▪	▪
City of Salem, OR	Geren Island WTP	50	■	▪	▪		▪
Erie County Water Authority, NY (Greater Buffalo)	WandeWater WTP	50	▪	▪	■	▪	▪
Monroe County Water Authority, NY (Rochester)	Webster WTP	50	▪	▪	■	▪	▪
Suez Delaware	Stanton WTP	50	▪	▪	■	▪	▪

Key:
WTP is Water Treatment Plant
WPP is Water Purification Plant
WFP is Water Filtration Plant

Appendix D

References

AWWA ASCE, 2012, Water Treatment Plant Design, 4th Ed. McGraw Hill.

Black & Veatch, 2014 Water Quality Corrosion Control Study, Portland Water Bureau

CH2M, 2014. Camas WA, Basis of Design Report for Slow Sand Filtration Water Treatment Plant

CH2M, 2016. Camas, WA Slow Sand Filtration Plant, Final Design and Specifications

Collins, M. R., T. T. Eighmy, J. M. Fenstermachar, and S. K. Spanos. 1989. Modifications to the Slow Sand Filtration Process for the Improved Removals of Trihalomethane Precursors. Final Report. Denver: AWWA Research Foundation

Drikas, M., Chow, C.W.K., House, J. and Burch, M.D. 1997 A pilot study of the removal of intact cyanobacterial cells. J. AWWA (In Preparation).

Fogel, Doug, Judith Isaac-Renton, Ronald Guasparini, William Moorehead, and Jerry Ongerth. "Removing Giardia and Cryptosporidium by Slow Sand Filtration." *Journal of the American Water Works Association* 85.11 (1993): 77-84.

Fox, K. Drinking Water Treatment Using Slow Sand Filtration. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/D-87/088 (NTIS PB87174819), 1987.

Lambert, T.W., Holmes, C.F. and Hrudey, S.E. 1996 Adsorption of microcystin-LR by activated carbon in full scale water treatment. Wat. Res. 30,1411-1422.

Leland, D. E., and G. S. Logsdon. 1991. Pilot Plants for Slow Sand Filters. In Slow Sand Filtration Manual of Practice, edited by G. S. Logsdon. New York: American Society of Civil Engineers

Lepistö, L., Lahti, K., Niemi, J. and Färdig. M. 1994 Removal of cyanobacteria and other phytoplankton in four Finnish waterworks. Arch. Hydrobiol. Algological Studies, 75, 167- 181.

Mouchet P. and Bonnélye V. 1998 Solving algae problems: French expertise and worldwide applications. J. Water SRT, Aqua., 47, 125-141.

Oregon Health Authority, 2018. Slow Sand Class On Line Materials, Accessed April 24, 2018 https://www.oregon.gov/oha/PH/HealthyEnvironments/DrinkingWater/Operations/Treatment/Pages/sw-slowsand.aspx

Snyder, S. and Westerhoff, P., 2008; Removal of Endocrine Disruption Compounds (EDCs) and Pharmaceuticals by Conventional and Advanced Water Treatment.

USEPA 2010, Long term 2 enhanced surface water treatment rule: toolbox guidance manual.

USEPA, 1999, Microbial and Disinfection Byproduct Rules Simultaneous Compliance Guidance Manual

Appendix E

CPES Model Cost Estimates

Granular Media Filtration Cost Estimate

CH2M Parametric Engineering System (CPES)

FACILITIES DESIGN & CONSTRUCTION COST MODULE

File Version: 1/26/2018

Project Capacity: >>>	160.00	Project Unit: >>>	MGD	(For example: MGD, HP, GPM…)

Project Name:	PWB Filtration Decision
Project Number:	699275
Project Manager:	Kelly Irving
Estimator:	Enoch Nicholson/Lee Odell
Project Description:	PWB Granular Media Filtration
Project Location (City):	Portland OR
Project Location (State):	OREGON
Project Location (Country):	USA
Cost Basis (Month/Year):	April/2018

Roundup to the nearest: $10,000

Item	Include? (Yes or No)	SCOPE OF PROJECT	Cost
	Yes	Flocculation: RapMix	$1,570,000
	Yes	Flocculation: Floc	$7,560,000
	Yes	DAF: DAF	$53,510,000
	No	Ozone Serpentine: Ozone	$0
	Yes	Filters: Filt	$35,130,000
	Yes	Concrete Clearwell: Clearwell	$22,620,000
	Yes	Liquid Chemical: Alum	$1,370,000
	Yes	Liquid Chemical: FAP	$320,000
	Yes	Liquid Chemical: CAP	$730,000
	No	Liquid Chemical: Hypo	$0
	Yes	On-Site Sodium Hypo: OSHG	$5,480,000
	Yes	Liquid Chemical: Caustic	$1,090,000
	Yes	Surge Basin-Decanter: BWSurge	$4,170,000
	Yes	Gravity Thickener: BWClar	$8,630,000
	Yes	Gravity Thickener: GravThick	$1,430,000
	Yes	WTP Centrifuge: Centrifuge	$6,340,000
	No	WPSPS: RecPS	$0
	Yes	Filter BW PS: BWPS	$2,720,000

SUBTOTAL - PROJECT COST			$152,670,000
ADDITIONAL PROJECT COSTS:			
Demolition:	0.00%		$0
Overall Sitework:	5.00%		$7,640,000
Plant Computer System:	5.00%		$7,640,000
Yard Electrical:	4.00%		$6,110,000
Yard Piping:	7.50%		$11,460,000
UD #1 Default Description	0.00%	$0	$0

	A	B	C	D	E
47	UD #2 Default Description		0.00%		$0
48	UD #3 Default Description		0.00%		$0
49	SUBTOTAL with Additional Project Costs				$185,520,000
50					
51	RED FLAGS:				
52	1	Rock Excavation			
53	2	Pile Foundations			
54	3	Seismic Foundations			
55	4	Dewatering Conditions			
56	5	Wetlands Mitigation			
57	6	Weather Impacts			
58	7	Depth of Structures			
59	8	Local Building Code Restrictions			
60	9	Coatings or Finishes			
61	10	Building or Architectural Considerations			
62	11	Client Material Preferences			
63	12	Client Equipment Preferences			
64	13	Piping Galleries, Piping Trenches, Piping Racks			
65	14	Yard Piping Complexity			
66	15	Existing Site Utilities (New, Retrofit, and Complexity)			
67	16	I & C Automation (New or Retrofit)			
68	17	Electrical Feed (New or Retrofit)			
69	18	Electrical Distribution			
70	19	Shoring			
71	20	Contamination			
72	21	User Defined Red Flag 1			
73	22	User Defined Red Flag 2			
74	23	User Defined Red Flag 3			
75	24	User Defined Red Flag 4			
76	25	User Defined Red Flag 5			
77	26	User Defined Red Flag 6			
78	27	User Defined Red Flag 7			
79	TOTAL - RED FLAGS				$0
80					
81	SUBTOTAL - PROJECT COST with Additional Project Costs and Red Flag Costs				$185,520,000
82					
83	TAX:		0.00%	$0	$0
84	SUBTOTAL with Tax				$185,520,000
85					
86	CONTRACTOR MARKUPS:				
87	Overhead (includes General Conditions and General Administrative Costs)		14.00%	$185,520,000	$25,980,000
88	Subtotal				$185,520,000
89	Profit		5.00%	$185,520,000	$9,280,000
90	Subtotal				$185,520,000
91	Mob/Bonds/Insurance		3.50%	$185,520,000	$6,500,000
92	Subtotal				$227,280,000
93	Contingency		40.00%	$227,280,000	$90,920,000
94	SUBTOTAL with Markups				$318,200,000

	A	B	C	D	E
95					
96	***LOCATION ADJUSTMENT FACTOR***		**100**	**$318,200,000**	**$318,200,000**
97	***SUBTOTAL - with Local Adjustment Factor***				**$318,200,000**
98					
99	***MARKET ADJUSTMENT FACTOR***			**$318,200,000**	**$0**
100	***SUBTOTAL - CONSTRUCTION COST with Market Adjustment Factor***				**$318,200,000**
101	***Your CPES Estimate MUST be reviewed by a Process person AND an Estimator:***				
102	***Name of Process Reviewer***			**Odell, Lee**	
103	***Name of Estimator Reviewer***				
104	***MAXIMUM CONSTRUCTION COST***				**$318,200,000**
105					
106	***NON-CONSTRUCTION COSTS:***				
107	***Permitting:***		**0.00%**	**$318,200,000**	**$0**
108	***Engineering:***		**0.00%**	**$318,200,000**	**$0**
109	***Services During Construction:***		**0.00%**	**$318,200,000**	**$0**
110	***Commissioning & Startup:***		**0.00%**	**$318,200,000**	**$0**
111	***Land / ROW:***		**$0.00**		**$0**
112	***Legal / Admin:***		**$0.00**		**$0**
113	***program management***		**$0.00**		**$0**
114	***SUBTOTAL - Non-Construction Costs***				**$0**
115					
116	***TOTAL - CAPITAL COST***				**$318,200,000**
117					
118	***Currency Conversion of TOTAL CAPITAL COST:***				
119		***Currency***	***Unit of Measure***	***Conversion Rate***	***Converted Amount***
120		**None**	**U.S. Dollar**	**1**	**318,200,000**

	B	C	D	E	F	G	H	I
1	***Flocculation (Horizontal Paddle Wheel Flocculation for Downstream Sedimentation)***							
2								
3	**Is This Facility Included in My Project? Yes**							
4	Assumptions:							
5								
6	Based on Denver Water Reuse Project							
7	2 Basins @ 15 MGD each							
8	***If this is a Seawater Desalination Application, the materials in contact with seawater need to be corrosion resistant.***							
9	***NOTE TO USER: The Lamella Plate Clarifier should be sized before working on the Flocculation model.***							
10								
11	**Process User Inputs**	**Value (English)**	**Unit (English)**	**Value (Metric)**	**Unit (Metric)**	**Name**	**Red Flags**	**Comment**
12	Is this a Seawater Desalination Application?	**No**	Y/N					
13	Has the USER Contacted Equipment Suppliers to Obtain Equipment Quotes?	**No**	Y/N					
14	Input Total Flocculation Flow Rate	**160.00**	mgd	**605.67**	ML/d			
15	Conversion of Total Flocculation Flow Rate	111,111.11	gpm	7,010.02	L/s			
16	Conversion of Total Flocculation Flow Rate	247.56	cfs	7.01	m3/s			
17	Input Number of Active Flocculation Trains	**4**	#					
18	Input Number of Standby Flocculation Trains	**0**	#					Typically 0.
19	Calculate Total Number of Flocculation Trains	4	#			NT		
20	Input Flocculation Detention Time	**0.50**	min					
21	Input Number of Flocculation Basin Stages per Train	**1**	#			NFS		Valid Range: 1 - 6.
22	Calculate Flocculation Basin Water Volume per Train	1,856.67	cf	52.58	m3			
23	Calculate Flocculation Stage Water Volume	1,856.67	cf	52.58	m3			
24	Select Flocculation Baffle Type	**O/U**	Type					
25	Input Flocculation Basin Influent Weir Head, If Serpentine Baffling Selected	**1.00**	ft	**304.80**	mm			
26	Calculate Flocculation Basin Influent Weir Length	0.00	ft	0.00	mm	WL		
27	Input Internal Flocculation Basin / Stage Width per Train = Lamella Plate Clarifier Train Width (W)	**15.00**	ft	**4,572.00**	mm	IBW		The Flocculation Basin / Stage Width should equal the Clarifier Stage Width. For information, the DAF Clarifier Stage Width can be found in the DAF model cell C25. Lamella Clarifier Width can be found in cell C46 of the Lamella Clarifier model.
28	Calculate Stage Length	11.13	ft	3,391.07	mm	SL		
29	Calculate Side Water Depth	11.13	ft	3,391.07	mm	SWD		Equal to Stage Length.
30	Input Flocculator Equipment Type	**VT**	Type					For VP and VT, the flocculation stage length must be less than 20-feet.
31	Calculate Horizontal Paddle Wheel Flocc Pedestal Height	0.00	ft	0.00	mm	FPH		
32	Number of Baffle Walls per Train	0	#					
33	Include Influent Channel?	**Yes**	Y/N					
34	Input Influent Channel Width	**5.00**	ft	**1,524.00**	mm	ICW		Valid Range: ≥ 3 ft.
35	Calculate Internal Flocculation Basin Length per Train	11.13	ft	3,391.07	mm	IBL		
36	Input Basin Freeboard	**3.00**	ft	**609.60**	mm	FB		Valid Range: 1-3 ft.
37	Calculate Basin Depth	14.13	ft	4,305.47	mm			Flocculation Basin BD should be less than or equal to lamella clarifier BD. If not, add more trains and / or more stages
38	Input Perimeter Operator Deck Walkway Width	**6.00**	ft	**1,524.00**	mm	WWW		Typically 4 to 8 ft.
39	Input Central Operator Deck Walkway Width	**10.00**	ft	**1,828.80**	mm	WWWC		Typically 8 to 12 ft.
40	Include Building over Basin?	**No**	Y/N					
41	Input Structure Depth of Burial	**6.00**	ft	**0.00**	mm			
42	Input Cutback Slope	**1.50**	:1					Cutback slope should be 1:1 for depth of burial ≤ 5 ft, and at least 1.5:1 for depth of burial > 5 ft.
43	Input Over Excavation Depth	**1.00**	ft	**0.00**	mm			
44	For Horizontal Paddle Wheel, Input Number of Reels per Stage	**6**	#			NRS		
45	Calculate Number of Flocculation Basin Pedestal Supports	0						
46	Distance between Reel and Pedestal	0.00	in	0.00	mm			
47	Conversion from Inches to Feet	0.00	ft	0.00	mm	RPW		
48	Width of Pedestal	0.00	in	0.00	mm			
49	Conversion from Inches to Feet	0.00	ft	0.00	mm	PW		
50	Calculate Reel Length	0.00	ft	0.00	mm	RL		Valid Range: 6 to 20 ft.
51	Calculate Reel Diameter	0.00	ft	0.00	mm	RD		
52	For Vertical Paddle Wheel or Vertical Turbine, Calculate Number of Mixers per Stage	1	#					
53	For Vertical Paddle Wheel or Vertical Turbine, Calculate Number of Mixers per Train	1	#					
54	For Vertical Paddle Wheel or Vertical Turbine, Calculate Total Number of Mixers per All Trains	4	#					
55	For Vertical Paddle Wheel or Vertical Turbine, Calculate Mixer Diameter, Each	9.00	ft	2,743.20	mm	MD		
56	For Vertical Paddle Wheel or Vertical Turbine, Calculate Distance Between Mixers	3.00	ft	914.40	mm	DBM		
57	Input Stage 1 Velocity Gradient	**700.00**	sec-1					
58	Input Stage 2 Velocity Gradient	**40.00**	sec-1					
59	Input Stage 3 Velocity Gradient	**20.00**	sec-1					
60	Input Stage 4 Velocity Gradient	**0.00**	sec-1					
61	Input Stage 5 Velocity Gradient	**0.00**	sec-1					
62	Input Stage 6 Velocity Gradient	**0.00**	sec-1					
63	Input Wire to Water Flocculation Energy Input Efficiency	**75.00%**						
64	Input min water temperature	33.80	degrees F	**1.00**	degrees C			Valid Range: 0 - 40 deg C.

	B	C	D	E	F	G	H	I
65	Dynamic (Absolute) Viscosity of Water	0.000037	lb•s/sf	0.001792	Pa•s			Reference: *Viscosity of Liquid Water in the Range -8°C to 150°C*, J. Phys. Chem. Ref. Data, Vol. 7, No. 3, 1978 (Eqn. 15).
66	Calculate Stage 1 Power per Mixer	83.00	hp	61.89	kW			
67	Calculate Stage 2 Power per Mixer	0.00	hp	0.00	kW			
68	Calculate Stage 3 Power per Mixer	0.00	hp	0.00	kW			
69	Calculate Stage 4 Power per Mixer	0.00	hp	0.00	kW			
70	Calculate Stage 5 Power per Mixer	0.00	hp	0.00	kW			
71	Calculate Stage 6 Power per Mixer	0.00	hp	0.00	kW			
72								
73	Electrical User Inputs and Sizing Requirements:							
74	Is this a "Critical" Facility (requiring standby power)?	Yes	Y/N					
75	Is there SWGR?	No						
76								MCC
77	**Item**	**Quantity**	**HP per Each**	**AFD's Required?**	**MCC Spaces for Motor Starters**	**MCC Spaces for AFD's less than 50hp)**	**MCC Spaces for Breakers**	**Total MCC Spaces**
78	Flocculation Mixers Stage 1 (total facility)	4.00	83.00	Yes	0.00	0.00	12.00	
79	Flocculation Mixers Stage 2 (total facility)	0.00	0.00	Yes	0.00	0.00	0.00	
80	Flocculation Mixers Stage 3 (total facility)	0.00	0.00	Yes	0.00	0.00	0.00	
81	Flocculation Mixers Stage 4 (total facility)	0.00	0.00	No	0.00	0.00	0.00	
82	Flocculation Mixers Stage 5 (total facility)	0.00	0.00	No	0.00	0.00	0.00	
83	Flocculation Mixers Stage 6 (total facility)	0.00	0.00	No	0.00	0.00	0.00	
84	User Defined Item #1	0.00	0.00	No	0.00	0.00	0.00	
85	User Defined Item #2	0.00	0.00	No	0.00	0.00	0.00	
86	User Defined Item #3	0.00	0.00	No	0.00	0.00	0.00	
87	**TOTAL**		**332.00**		**0.00**	**0.00**	**12.00**	**12.00**
88								
89	Electrical Equipment Widths:							
90	**Equipment**	**Depth (ft)**						
91	MCC	1.67						
92	Small AFD's	2.08						
93	Large AFD's	0.00						
94	Switchgear	0.00						
95	**Maximum Depth**	**2.08**						
96								
97	Clear Distances:							
98	**Clear Distance**	**Width**	**Length**	**Comment**				
99	CD1		3.00	Clear Distance between wall and MCC	Typically 3 feet			
100	CD2		1.00	Clear Distance between MCC and Small AFD	Typically 1 foot			
101	CD3		0.00	Clear Distance between Small AFD and Large AFD	Typically Zero			
102	CD4		0.00	Clear Distance between Large AFD and Switchgear	Typically Zero			
103	CD5		0.00	Clear Distance between Switchgear and Contingency Space	Typically Zero			
104	CD6	4.00		Clear Distance behind Switchgear (If				
105	CD7	3.00		Clear Distance in front of Equipment	Typically 3 feet			
106	Contingency Length		0.00	Contingency length	Typically Zero			
107								
108	Electric Room Length (ft):							
109	CD1	3.00						
110	MCC	11.67						
111	CD2	1.00						
112	Small AFD's	13.32						
113	CD3	0.00						
114	Large AFD's	0.00						
115	CD4	0.00						
116	Swithgear	0.00						
117	CD5	0.00						
118	Contingency	0.00						
119	**Total Length**	**28.99**						
120								
121	Electric Room Width (ft):							
122	CD6	0.00	If there is no switchgear, this distance will be Zero.					
123	Maximum Equipment Depth	2.08						
124	CD7	3.00						
125	**Total Width**	**5.08**						
126								
127	**Estimating Dimensions (per trian):**	**Value English**	**Unit (English)**	**Value (Metric)**	**Unit (Metric)**	**Name**	**Red Flags**	**Comment**
128								
129	Influent Channel:							
130	Slab on Grade:							Use Wall Thickness Spreadsheet to Adjust Based on Overall Wall Height and Depth of Burial
131	Concrete Thickness	24.00	in	609.60	mm			Model based on 24"
132	Concrete Thickness	2.00	ft	609.60	mm	TICS0G		
133	SOG Length	8.50	ft	2,590.80	mm			
134	SOG Width	71.50	ft	21,793.20	mm			
135	Channel Walls:							Use Wall Thickness Spreadsheet to Adjust Based on Overall Wall Height and Depth of Burial
136	Concrete Thickness	18.00	in	457.20	mm			Model based on 18"
137	Concrete Thickness	1.50	ft	457.20	mm	TWIC		
138	Wall Length	135.00	ft	41,148.00	mm			
139	Wall Height	14.13	ft	4,305.47	mm			
140	Elevated Slab:							
141	Concrete Thickness	12.00	in	304.80	mm			Model based on 12"
142	Concrete Thickness	1.00	ft	304.80	mm			

	B	C	D	E	F	G	H	I
143	Elevated Slab Length	8.00	ft	2,438.40	mm			
144	Elevated Slab Width	67.50	ft	20,574.00	mm			
145								
146	Flocculation Basin:							
147	Slab on Grade:							Use Wall Thickness Spreadsheet to Adjust Based on Overall Wall Height and Depth of Burial
148	Concrete Thickness	**24.00**	in	**609.60**	mm			Model based on 24"
149	Concrete Thickness	2.00	ft	609.60	mm	TFBSOG		
150	SOG Length	12.63	ft	3,848.27	mm			
151	SOG Width	71.50	ft	21,793.20	mm			
152	Basin Walls:							Use Wall Thickness Spreadsheet to Adjust Based on Overall Wall Height and Depth of Burial
153	Concrete Thickness	**18.00**	in	**457.20**	mm			Model based on 18"
154	Concrete Thickness	1.50	ft	457.20	mm	TWFB		
155	Wall Length	80.63	ft	24,575.37	mm			If flocc basin shares a common wall with downstream facility, then common wall is counted with downstream facility.
156	Wall Height	14.13	ft	4,305.47	mm			
157	Baffle Walls:							
158	Concrete Thickness	**12.00**	in	**304.80**	mm			Model based on 12"
159	Concrete Thickness	1.00	ft	304.80	mm	BWTF		
160	Wall Width per Train	15.00	ft	4,572.00	mm	BWL		
161	Quantity of Over Baffle Walls per Train	0	#					
162	Quantity of Under Baffle Walls per Train	0	#					
163	Quantity of Under Baffle Walls per Train	0	#					
164	Over Baffle Wall Length per Facility	0.00	ft	0.00	mm			
165	Under Baffle Wall Length per Facility	0.00	ft	0.00	mm			
166	Serpentine Baffle Wall Length per Facility	0.00	ft	0.00	mm			
167	Over Baffle Wall Height	9.13	ft	2,781.47	mm			Assumes top of wall 2 ft below WSE.
168	Under Baffle Wall Height	13.13	ft	4,000.67	mm			Assumes bottom of wall 1 ft above basin floor.
169	Serpentine Baffle Wall Height	0.00	ft	0.00	mm			
170	Elevated Slab:							
171	Concrete Thickness	**12.00**	in	**304.80**	mm			Model based on 12"
172	Concrete Thickness	1.00	ft	304.80	mm	TESLC		
173	Center Walkway:							
174	Elevated Slab Width	10.00	ft	3,048.00	mm			
175	Elevated Slab Length per 2 Trains	5.13	ft	1,562.27	mm			
176	Elevated Slab Length per Facility	15.38	ft	4,686.82	mm			
177	Perimeter and Baffle Wall Walkway:							
178	Elevated Slab Width at Perimeter	7.50	ft	2,286.00	mm			Includes basin wall thickness.
179	Elevated Slab Length at Perimeter per Facility	77.75	ft	23,698.55	mm			
180	Elevated Slab Width at Baffle Wall	6.00	ft	1,828.80	mm			For VP and VT flocc basin mixing only.
181	Elevated Slab Length at Baffle Wall per Facility	0.00	ft	0.00	mm			For VP and VT flocc basin mixing only.
182								
183	Electrical Room Slab on Grade:							
184	Concrete Thickness	**12.00**	in	**304.80**	mm			Model based on 12"
185	Concrete Thickness	1.00	ft	304.80	mm			
186								
187	Overall Dimensions:							
188	Total Basin/Building Length	19.13	ft	5,829.47	mm	TBL		
189	Total Basin/Building Width	67.50	ft	20,574.00	mm	TBW		
190	SOG Length	21.13	ft	6,439.07	mm			
191	SOG Width	71.50	ft	21,793.20	mm			
192	Electrical Room Length	28.99	ft	8,835.14	mm			
193	Electrical Room Width	5.08	ft	1,549.40	mm			
194	Excavation Length	25.13	ft	7,658.27	mm			
195	Excavation Width	75.50	ft	23,012.40	mm			
196	Excavation Depth	9.00	ft	2,743.20	mm			
197								
198								
199	**Description**	**Quantity (English)**	**Unit (English)**	**Quantity (Metric)**	**Unit (Metric)**	**$/Unit**	**Total Cost**	**User Over-Write**
200								
201	SITEWORK:							
202	Excavation	1,215	CY	929.21	m3	***$6.72***	$8,171	
203	Imported Structural Backfill	141	CY	107.43	m3	***$50.94***	$7,158	
204	Native Backfill	453	CY	346.20	m3	***$8.27***	$3,743	
205	Haul Excess	763	CY	583.01	m3	***$8.27***	$6,303	
206	Allowance for Misc Items	5%				$25,374.40	$1,269	
207	Subtotal						$26,643	
208								
209	CONCRETE:							
210	Influent Channel:							
211	Foundation	45	CY	34.42	m3	***$541.11***	$24,360	
212	Walls	106	CY	81.00	m3	***$880.79***	$93,313	
213	Elevated Slab	20	CY	15.29	m3	***$1,333.77***	$26,675	
214	Flocc Basin							
215	Foundation	67	CY	51.12	m3	***$541.11***	$36,183	
216	Basin Walls	63	CY	48.38	m3	***$880.79***	$55,730	
217	Over Baffle Wall	0	CY	0.00	m3	***$880.79***	$0	
218	Under Baffle Wall	0	CY	0.00	m3	***$880.79***	$0	
219	Serpentine Baffle Wall	0	CY	0.00	m3	***$880.79***	$0	
220	Elevated Slab	23	CY	17.96	m3	***$1,333.77***	$31,338	
221	Flocc Bearing Supports	0	EA			$0.00	$0	
222	Electrical Room							

	B	C	D	E	F	G	H	I
223	Slab on Grade	5	CY	4.17	m3	*$490.62*	$2,677	
224	Allowance for Misc Items	5%				$270,276.92	$13,514	
225	Subtotal						$283,791	
226								
227	MASONRY:	**High**						
228	CMU Building	0	SF	0.00	m2	*$198.37*	$0	
229	Electrical Room	147	SF	13.69	m2	*$198.37*	$29,229	
230	Subtotal	147					$29,229	
231								
232	METALS:							
233	Aluminum Handrail	259	LF	79.02	m	*$90.92*	$23,571	
234	Stairs (1 set per basin)	55	RISERS			*$495.92*	$27,153	
235	Allowance for Misc Items	10%				$50,724.21	$5,072	
236	Subtotal						$55,797	
237								
238	WOODS & PLASTICS:							
239	FRP Weir	60	LF	18.29	m	$41.64	$2,498	
240	FRP Ladder	8	EA			$1,529.16	$12,233	
241	Allowance for Misc Items	5%				$14,731.45	$737	
242	Subtotal						$15,468	
243								
244	THERMAL & MOISTURE PROTECTION:							
245	Concrete Liner	0	SF	0.00	m2	**$16.00**	$0	
246	Allowance for Misc Items	10%				$0.00	$0	
247	Subtotal						$0	
248								
249	DOORS & WINDOWS:							
250	Stainless Steel Door (2' x 2') for O/U Baffling	0	EA			$1,332.36	$0	
251	Stainless Steel Door (7' x 2.5') for O/U Baffling	0	EA			$5,829.09	$0	
252	Stainless Steel Door (2' x 2') for Serpentine Baffling	0	EA			$1,332.36	$0	
253	Allowance for Misc Items	5%				$0.00	$0	
254	Subtotal						$0	
255								
256	EQUIPMENT:							**Budgetary Quote: (CPES will automatically add Installation Factor)**
257	Horizontal Paddle Wheel Flocculation Mechanism (Paddles & Drives)	0	LF	0.00	m	***$0.00***	$0	
258	Vertical Paddle Wheel Flocculation Mechanism (Paddles & Drives)	4	EA			***$0.00***	$0	
259	Vertical Turbine Flocculation Mechanism (Turbines & Drives)	332	hp	247.57	kW	***$1,546.21***	$513,342	
260	Vertical Turbine Flocculator VFD's	332	hp	247.57	kW	***$563.81***	$187,186	
261	Fabricated Slide Gate	4	EA			***$9,614.74***	$38,459	
262	Allowance for Misc Items	10%				$738,987.57	$73,899	
263	Subtotal						$812,886	
264								
265	ELECTRICAL:							
266	*MCC's*							
267	Sections	7	EA			***$10,730.27***	$75,112	
268	*AFD's*							
269	Flocculation Mixers Stage 1 (total facility) (83 hp each)	4	EA			***$19,749.53***	$78,998	
270	Flocculation Mixers Stage 2 (total facility) (0 hp each)	0	EA			***$8,865.56***	$0	
271	Flocculation Mixers Stage 3 (total facility) (0 hp each)	0	EA			***$8,865.56***	$0	
272	Flocculation Mixers Stage 4 (total facility) (0 hp each)	0	EA			***$8,865.56***	$0	
273	Flocculation Mixers Stage 5 (total facility) (0 hp each)	0	EA			***$8,865.56***	$0	
274	Flocculation Mixers Stage 6 (total facility) (0 hp each)	0	EA			***$8,865.56***	$0	
275	*Switchgear*							
276	Units	0	EA			***$49,359.23***	$0	
277	Electrical Conduit & Wire	572	LF	174.35	m	***$12.06***	$6,898	
278	Allowance for Misc Items	10%				$161,007.72	$16,101	
279	Subtotal						$177,108	
280								
281	INSTRUMENTS & CONTROLS:							
282	Instruments							
283	Level Switch	4	EA			***$695.44***	$2,782	
284	Number of Analog I/O Counts	10	EA			***$264.27***	$2,537	
285	Number of Digital I/O Counts	24	EA			***$62.59***	$1,502	
286	Number of PLC's	1	EA			***$13,074.33***	$13,074	
287	I&C Conduit & Wire	1,080	LF	329.18	m	***$12.06***	$13,024	
288	Allowance for Misc Items	10%				$32,918.93	$3,292	
289	Subtotal						$36,211	
290								
291	**USER DEFINED ESTIMATE ITEMS:**	**QUANT (ENGLISH)**	**UNIT (ENGLISH)**	**QUANT (METRIC)**	**UNIT (METRIC)**	**$/UNIT**	**TOTAL COST**	
292	Item 1 Description	0.00		0.00		0.00	$0	
293	Item 2 Description	0.00		0.00		0.00	$0	
294	Item 3 Description	0.00		0.00		0.00	$0	
295	Item 4 Description	0.00		0.00		0.00	$0	
296	Item 5 Description	0.00		0.00		0.00	$0	
297	Item 6 Description	0.00		0.00		0.00	$0	
298	Item 7 Description	0.00		0.00		0.00	$0	
299	Item 8 Description	0.00		0.00		0.00	$0	
300	Item 9 Description	0.00		0.00		0.00	$0	
301	Item 10 Description	0.00		0.00		0.00	$0	
302	Item 11 Description	0.00		0.00		0.00	$0	
303	Item 12 Description	0.00		0.00		0.00	$0	
304	Item 13 Description	0.00		0.00		0.00	$0	
305	Item 14 Description	0.00		0.00		0.00	$0	
306	Item 15 Description	0.00		0.00		0.00	$0	
307	Subtotal						$0	
308								
309	Subtotal						$1,437,133	
310								
311	ALLOWANCES:		**User Override**					
312	Finishes Allowance	2.00%		$1,562,101	$31,242			
313	I&C Allowance	2.00%		$1,562,101	$31,242			
314	Mechanical Allowance	2.00%		$1,562,101	$31,242			
315	Electrical Allowance	2.00%		$1,562,101	$31,242			
316						Facility Cost Name		
317	Facility Cost	**160,000,000**	**GPD**	**$0.01**	**$1,562,101**	FCPFC01		
318	Facility Cost with Standard Additional Project Costs Added	**160,000,000**	**GPD**	**$0.01**	**$1,898,219**	FCPFC02		

	B	C	D	E	F	G	H	I
319	Facility Cost with Standard Additional Project Costs and Contractor Markups Added	**160,000,000**	**GPD**	**$0.02**	**$3,255,785**	FCPFC03		
320	Facility Cost, Contractor Markups, and Location Adjustment Factor Added (excluding ALL Additional Project Costs)	**160,000,000**	**GPD**	**$0.02**	**$2,679,284**	FCPFC05		
321	Facility Cost with Standard Additional Project Costs, Contractor Markups, and Location Adjustment Factor Added	**160,000,000**	**GPD**	**$0.02**	**$3,255,785**	FCPFC06		

	B	C	D	E	F	G	H	I
1	***Flocculation (Horizontal Paddle Wheel Flocculation for Downstream Sedimentation)***							
2								
3	**Is This Facility Included in My Project? Yes**							
4	Assumptions:							
5								
6	Based on Denver Water Reuse Project							
7	2 Basins @ 15 MGD each							
8	***If this is a Seawater Desalination Application, the materials in contact with seawater need to be corrosion resistant.***							
9	***NOTE TO USER: The Lamella Plate Clarifier should be sized before working on the Flocculation model.***							
10								
11	**Process User Inputs**	**Value (English)**	**Unit (English)**	**Value (Metric)**	**Unit (Metric)**	**Name**	**Red Flags**	**Comment**
12	Is this a Seawater Desalination Application?	**No**	Y/N					
13	Has the USER Contacted Equipment Suppliers to Obtain Equipment Quotes?	**No**	Y/N					
14	Input Total Flocculation Flow Rate	**160.00**	mgd	**605.67**	ML/d			
15	Conversion of Total Flocculation Flow Rate	111,111.11	gpm	7,010.02	L/s			
16	Conversion of Total Flocculation Flow Rate	247.56	cfs	7.01	m3/s			
17	Input Number of Active Flocculation Trains	**8**	#					
18	Input Number of Standby Flocculation Trains	**0**	#					Typically 0.
19	Calculate Total Number of Flocculation Trains	8	#			NT		
20	Input Flocculation Detention Time	**10.00**	min					
21	Input Number of Flocculation Basin Stages per Train	**3**	#			NFS		Valid Range: 1 - 6.
22	Calculate Flocculation Basin Water Volume per Train	18,566.75	cf	525.75	m3			
23	Calculate Flocculation Stage Water Volume	6,188.92	cf	175.25	m3			
24	Select Flocculation Baffle Type	**O/U**	Type					
25	Input Flocculation Basin Influent Weir Head, If Serpentine Baffling Selected	**1.00**	ft	**304.80**	mm			
26	Calculate Flocculation Basin Influent Weir Length	0.00	ft	0.00	mm	WL		
27	Input Internal Flocculation Basin / Stage Width per Train = Lamella Plate Clarifier Train Width (W)	**25.00**	ft	**7,620.00**	mm	IBW		The Flocculation Basin / Stage Width should equal the Clarifier Stage Width. For information, the DAF Clarifier Stage Width can be found in the DAF model cell C25. Lamella Clarifier Width can be found in cell C46 of the Lamella Clarifier model.
28	Calculate Stage Length	15.73	ft	4,795.70	mm	SL		
29	Calculate Side Water Depth	15.73	ft	4,795.70	mm	SWD		Equal to Stage Length.
30	Input Flocculator Equipment Type	**HP**	Type					For VP and VT, the flocculation stage length must be less than 20-feet.
31	Calculate Horizontal Paddle Wheel Flocc Pedestal Height	7.87	ft	2,397.85	mm	FPH		
32	Number of Baffle Walls per Train	2	#					
33	Include Influent Channel?	**Yes**	Y/N					
34	Input Influent Channel Width	**5.00**	ft	**1,524.00**	mm	ICW		Valid Range: ≥ 3 ft.
35	Calculate Internal Flocculation Basin Length per Train	49.20	ft	14,996.71	mm	IBL		
36	Input Basin Freeboard	**3.00**	ft	**609.60**	mm	FB		Valid Range: 1-3 ft.
37	Calculate Basin Depth	18.73	ft	5,710.10	mm			Flocculation Basin BD should be less than or equal to lamella clarifier BD. If not, add more trains and / or more stages
38	Input Perimeter Operator Deck Walkway Width	**6.00**	ft	**1,524.00**	mm	WWW		Typically 4 to 8 ft.
39	Input Central Operator Deck Walkway Width	**10.00**	ft	**1,828.80**	mm	WWWC		Typically 8 to 12 ft.
40	Include Building over Basin?	**Yes**	Y/N					
41	Input Structure Depth of Burial	**6.00**	ft	**0.00**	mm			
42	Input Cutback Slope	**1.50**	:1					Cutback slope should be 1:1 for depth of burial ≤ 5 ft, and at least 1.5:1 for depth of burial > 5 ft.
43	Input Over Excavation Depth	**1.00**	ft	**0.00**	mm			
44	For Horizontal Paddle Wheel, Input Number of Reels per Stage	**6**	#			NRS		
45	Calculate Number of Flocculation Basin Pedestal Supports	7						
46	Distance between Reel and Pedestal	3.00	in	76.20	mm			
47	Conversion from Inches to Feet	0.25	ft	76.20	mm	RPW		
48	Width of Pedestal	12.00	in	304.80	mm			
49	Conversion from Inches to Feet	1.00	ft	304.80	mm	PW		
50	Calculate Reel Length	2.50	ft	762.00	mm	RL	**Warning! Reel length outside valid range.**	Valid Range: 6 to 20 ft.
51	Calculate Reel Diameter	13.73	ft	4,186.10	mm	RD		
52	For Vertical Paddle Wheel or Vertical Turbine, Calculate Number of Mixers per Stage	0	#					
53	For Vertical Paddle Wheel or Vertical Turbine, Calculate Number of Mixers per Train	0	#					
54	For Vertical Paddle Wheel or Vertical Turbine, Calculate Total Number of Mixers per All Trains	0	#					
55	For Vertical Paddle Wheel or Vertical Turbine, Calculate Mixer Diameter, Each	0.00	ft	0.00	mm	MD		
56	For Vertical Paddle Wheel or Vertical Turbine, Calculate Distance Between Mixers	0.00	ft	0.00	mm	DBM		
57	Input Stage 1 Velocity Gradient	**60.00**	sec-1					
58	Input Stage 2 Velocity Gradient	**40.00**	sec-1					
59	Input Stage 3 Velocity Gradient	**20.00**	sec-1					
60	Input Stage 4 Velocity Gradient	**0.00**	sec-1					
61	Input Stage 5 Velocity Gradient	**0.00**	sec-1					
62	Input Stage 6 Velocity Gradient	**0.00**	sec-1					
63	Input Wire to Water Flocculation Energy Input Efficiency	**75.00%**						

	B	C	D	E	F	G	H	I
64	Input min water temperature	32.00	degrees F	0.00	degrees C			Valid Range: 0 - 40 deg C.
65	Dynamic (Absolute) Viscosity of Water	0.000037	lb•s/sf	0.001792	Pa•s			Reference: *Viscosity of Liquid Water in the Range -8°C to 150°C*, J. Phys. Chem. Ref. Data, Vol. 7, No. 3, 1978 (Eqn. 15).
66	Calculate Stage 1 Power per Mixer	3.00	hp	2.24	kW			
67	Calculate Stage 2 Power per Mixer	1.00	hp	0.75	kW			
68	Calculate Stage 3 Power per Mixer	1.00	hp	0.75	kW			
69	Calculate Stage 4 Power per Mixer	0.00	hp	0.00	kW			
70	Calculate Stage 5 Power per Mixer	0.00	hp	0.00	kW			
71	Calculate Stage 6 Power per Mixer	0.00	hp	0.00	kW			
72								
73	Electrical User Inputs and Sizing Requirements:							
74	Is this a "Critical" Facility (requiring standby power)?	Yes	Y/N					
75	Is there SWGR?	No						
76								MCC
77	**Item**	**Quantity**	**HP per Each**	**AFD's Required?**	**MCC Spaces for Motor Starters**	**MCC Spaces for AFD's less than 50hp)**	**MCC Spaces for Breakers**	**Total MCC Spaces**
78	Flocculation Mixers Stage 1 (total facility)	8.00	3.00	Yes	0.00	24.00	16.00	
79	Flocculation Mixers Stage 2 (total facility)	8.00	1.00	Yes	0.00	24.00	16.00	
80	Flocculation Mixers Stage 3 (total facility)	8.00	1.00	Yes	0.00	24.00	16.00	
81	Flocculation Mixers Stage 4 (total facility)	0.00	0.00	No	0.00	0.00	0.00	
82	Flocculation Mixers Stage 5 (total facility)	0.00	0.00	No	0.00	0.00	0.00	
83	Flocculation Mixers Stage 6 (total facility)	0.00	0.00	No	0.00	0.00	0.00	
84	User Defined Item #1	0.00	0.00	No	0.00	0.00	0.00	
85	User Defined Item #2	0.00	0.00	No	0.00	0.00	0.00	
86	User Defined Item #3	0.00	0.00	No	0.00	0.00	0.00	
87	**TOTAL**		**40.00**		**0.00**	**72.00**	**48.00**	**120.00**
88								
89	Electrical Equipment Widths:							
90	**Equipment**	**Depth (ft)**						
91	MCC	1.67						
92	Small AFD's	0.00						
93	Large AFD's	0.00						
94	Switchgear	0.00						
95	**Maximum Depth**	**1.67**						
96								
97	Clear Distances:							
98	**Clear Distance**	**Width**	**Length**	**Comment**				
99	CD1		3.00	Clear Distance between wall and MCC	Typically 3 feet			
100	CD2		1.00	Clear Distance between MCC and Small AFD	Typically 1 foot			
101	CD3		0.00	Clear Distance between Small AFD and Large AFD	Typically Zero			
102	CD4		0.00	Clear Distance between Large AFD and Switchgear	Typically Zero			
103	CD5		0.00	Clear Distance between Switchgear and Contingency Space	Typically Zero			
104	CD6	4.00		Clear Distance behind Switchgear (If				
105	CD7	3.00		Clear Distance in front of Equipment	Tyipcally 3 feet			
106	Contingency Length		0.00	Contingency length	Typically Zero			
107								
108	Electric Room Length (ft):							
109	CD1	3.00						
110	MCC	26.67						
111	CD2	1.00						
112	Small AFD's	0.00						
113	CD3	0.00						
114	Large AFD's	0.00						
115	CD4	0.00						
116	Swithgear	0.00						
117	CD5	0.00						
118	Contingency	0.00						
119	**Total Length**	**30.67**						
120								
121	Electric Room Width (ft):							
122	CD6	0.00	If there is no switchgear, this distance will be Zero.					
123	Maximum Equipment Depth	1.67						
124	CD7	3.00						
125	**Total Width**	**4.67**						
126								
127	**Estimating Dimensions (per trian):**	**Value English**	**Unit (English)**	**Value (Metric)**	**Unit (Metric)**	**Name**	**Red Flags**	**Comment**
128								
129	Influent Channel:							
130	Slab on Grade:							Use Wall Thickness Spreadsheet to Adjust Based on Overall Wall Height and Depth of Burial
131	Concrete Thickness	24.00	in	609.60	mm			Model based on 24"
132	Concrete Thickness	2.00	ft	609.60	mm	TICS0G		
133	SOG Length	8.50	ft	2,590.80	mm			
134	SOG Width	217.50	ft	66,294.00	mm			
135	Channel Walls:							Use Wall Thickness Spreadsheet to Adjust Based on Overall Wall Height and Depth of Burial
136	Concrete Thickness	18.00	in	457.20	mm			Model based on 18"
137	Concrete Thickness	1.50	ft	457.20	mm	TWIC		
138	Wall Length	427.00	ft	130,149.60	mm			
139	Wall Height	18.73	ft	5,710.10	mm			
140	Elevated Slab:							
141	Concrete Thickness	12.00	in	304.80	mm			Model based on 12"

	B	C	D	E	F	G	H	I
142	Concrete Thickness	1.00	ft	304.80	mm			
143	Elevated Slab Length	8.00	ft	2,438.40	mm			
144	Elevated Slab Width	213.50	ft	65,074.80	mm			
145								
146	Flocculation Basin:							
147	Slab on Grade:							Use Wall Thickness Spreadsheet to Adjust Based on Overall Wall Height and Depth of Burial
148	Concrete Thickness	24.00	in	609.60	mm			Model based on 24"
149	Concrete Thickness	2.00	ft	609.60	mm	TFBSOG		
150	SOG Length	50.70	ft	15,453.91	mm			
151	SOG Width	217.50	ft	66,294.00	mm			
152	Basin Walls:							Use Wall Thickness Spreadsheet to Adjust Based on Overall Wall Height and Depth of Burial
153	Concrete Thickness	18.00	in	457.20	mm			Model based on 18"
154	Concrete Thickness	1.50	ft	457.20	mm	TWFB		
155	Wall Length	487.82	ft	148,686.36	mm			If flocc basin shares a common wall with downstream facility, then common wall is counted with downstream facility.
156	Wall Height	18.73	ft	5,710.10	mm			
157	Baffle Walls:							
158	Concrete Thickness	12.00	in	304.80	mm			Model based on 12"
159	Concrete Thickness	1.00	ft	304.80	mm	BWTF		
160	Wall Width per Train	25.00	ft	7,620.00	mm	BWL		
161	Quantity of Over Baffle Walls per Train	1	#					
162	Quantity of Under Baffle Walls per Train	1	#					
163	Quantity of Under Baffle Walls per Train	0	#					
164	Over Baffle Wall Length per Facility	200.00	ft	60,960.00	mm			
165	Under Baffle Wall Length per Facility	200.00	ft	60,960.00	mm			
166	Serpentine Baffle Wall Length per Facility	0.00	ft	0.00	mm			
167	Over Baffle Wall Height	13.73	ft	4,186.10	mm			Assumes top of wall 2 ft below WSE.
168	Under Baffle Wall Height	17.73	ft	5,405.30	mm			Assumes bottom of wall 1 ft above basin floor.
169	Serpentine Baffle Wall Height	0.00	ft	0.00	mm			
170	Elevated Slab:							
171	Concrete Thickness	12.00	in	304.80	mm			Model based on 12"
172	Concrete Thickness	1.00	ft	304.80	mm	TESLC		
173	Center Walkway:							
174	Elevated Slab Width	10.00	ft	3,048.00	mm			
175	Elevated Slab Length per 2 Trains	43.20	ft	13,167.91	mm			
176	Elevated Slab Length per Facility	302.41	ft	92,175.35	mm			
177	Perimeter and Baffle Wall Walkway:							
178	Elevated Slab Width at Perimeter	7.50	ft	2,286.00	mm			Includes basin wall thickness.
179	Elevated Slab Length at Perimeter per Facility	299.90	ft	91,410.61	mm			
180	Elevated Slab Width at Baffle Wall	0.00	ft	0.00	mm			For VP and VT flocc basin mixing only.
181	Elevated Slab Length at Baffle Wall per Facility	0.00	ft	0.00	mm			For VP and VT flocc basin mixing only.
182								
183	Electrical Room Slab on Grade:							
184	Concrete Thickness	12.00	in	304.80	mm			Model based on 12"
185	Concrete Thickness	1.00	ft	304.80	mm			
186								
187	Overall Dimensions:							
188	Total Basin/Building Length	57.20	ft	17,435.11	mm	TBL		
189	Total Basin/Building Width	213.50	ft	65,074.80	mm	TBW		
190	SOG Length	59.20	ft	18,044.71	mm			
191	SOG Width	217.50	ft	66,294.00	mm			
192	Electrical Room Length	30.67	ft	9,347.20	mm			
193	Electrical Room Width	4.67	ft	1,422.40	mm			
194	Excavation Length	63.20	ft	19,263.91	mm			
195	Excavation Width	221.50	ft	67,513.20	mm			
196	Excavation Depth	9.00	ft	2,743.20	mm			
197								
198								
199	**Description**	**Quantity (English)**	**Unit (English)**	**Quantity (Metric)**	**Unit (Metric)**	**$/Unit**	**Total Cost**	**User Over-Write**
200								
201	SITEWORK:							
202	Excavation	6,661	CY	5,092.90	m3	*$6.72*	$44,784	
203	Imported Structural Backfill	1,037	CY	792.83	m3	*$50.94*	$52,825	
204	Native Backfill	1,281	CY	979.52	m3	*$8.27*	$10,589	
205	Haul Excess	5,380	CY	4,113.39	m3	*$8.27*	$44,468	
206	Allowance for Misc Items	5%				$152,666.73	$7,633	
207	Subtotal						$160,300	
208								
209	CONCRETE:							
210	Influent Channel:							
211	Foundation	137	CY	104.70	m3	*$541.11*	$74,101	
212	Walls	444	CY	339.78	m3	*$880.79*	$391,434	
213	Elevated Slab	63	CY	48.37	m3	*$1,333.77*	$84,373	
214	Flocc Basin							
215	Foundation	817	CY	624.54	m3	*$541.11*	$442,009	
216	Basin Walls	508	CY	388.17	m3	*$880.79*	$447,184	
217	Over Baffle Wall	102	CY	77.78	m3	*$880.79*	$89,606	
218	Under Baffle Wall	131	CY	100.43	m3	*$880.79*	$115,703	
219	Serpentine Baffle Wall	0	CY	0.00	m3	*$880.79*	$0	
220	Elevated Slab	99	CY	75.93	m3	*$1,333.77*	$132,453	
221	Flocc Bearing Supports	168	EA			$970.52	$163,048	

	B	C	D	E	F	G	H	I
222	Electrical Room							
223	Slab on Grade	5	CY	4.05	m3	*$490.62*	$2,600	
224	Allowance for Misc Items	5%				$1,942,511.32	$97,126	
225	Subtotal						$2,039,637	
226								
227	MASONRY:	**High**						
228	CMU Building	12,213	SF	1,134.59	m2	*$198.37*	$2,422,572	
229	Electrical Room	143	SF	13.30	m2	*$198.37*	$28,389	
230	Subtotal	12,356					$2,450,961	
231								
232	METALS:							
233	Aluminum Handrail	948	LF	289.02	m	*$90.92*	$86,211	
234	Stairs (1 set per basin)	165	RISERS			*$495.92*	$81,731	
235	Allowance for Misc Items	10%				$167,941.92	$16,794	
236	Subtotal						$184,736	
237								
238	WOODS & PLASTICS:							
239	FRP Weir	200	LF	60.96	m	$41.64	$8,327	
240	FRP Ladder	16	EA			$2,028.03	$32,449	
241	Allowance for Misc Items	5%				$40,775.82	$2,039	
242	Subtotal						$42,815	
243								
244	THERMAL & MOISTURE PROTECTION:							
245	Concrete Liner	0	SF	0.00	m2	**$16.00**	$0	
246	Allowance for Misc Items	10%				$0.00	$0	
247	Subtotal						$0	
248								
249	DOORS & WINDOWS:							
250	Stainless Steel Door (2' x 2') for O/U Baffling	16	EA			$1,332.36	$21,318	
251	Stainless Steel Door (7' x 2.5') for O/U Baffling	16	EA			$5,829.09	$93,265	
252	Stainless Steel Door (2' x 2') for Serpentine Baffling	0	EA			$1,332.36	$0	
253	Allowance for Misc Items	5%				$114,583.32	$5,729	
254	Subtotal						$120,312	
255								
256	EQUIPMENT:							**Budgetary Quote: (CPES will automatically add Installation Factor)**
257	Horizontal Paddle Wheel Flocculation Mechanism (Paddles & Drives)	600	LF	182.88	m	***$1,627.75***	$976,648	
258	Vertical Paddle Wheel Flocculation Mechanism (Paddles & Drives)	0	EA			***$0.00***	$0	
259	Vertical Turbine Flocculation Mechanism (Turbines & Drives)	0	hp	0.00	kW	***$0.00***	$0	
260	Vertical Turbine Flocculator VFD's	0	hp	0.00	kW	***$0.00***	$0	
261	Fabricated Slide Gate	8	EA			***$9,614.74***	$76,918	
262	Allowance for Misc Items	10%				$1,053,565.57	$105,357	
263	Subtotal						$1,158,922	
264								
265	ELECTRICAL:							
266	*MCC's*							
267	Sections	16	EA			***$10,730.27***	$171,684	
268	*AFD's*							
269	Flocculation Mixers Stage 1 (total facility) (3 hp each)	8	EA			***$9,258.95***	$74,072	
270	Flocculation Mixers Stage 2 (total facility) (1 hp each)	8	EA			***$8,996.69***	$71,974	
271	Flocculation Mixers Stage 3 (total facility) (1 hp each)	8	EA			***$8,996.69***	$71,974	
272	Flocculation Mixers Stage 4 (total facility) (0 hp each)	0	EA			***$8,865.56***	$0	
273	Flocculation Mixers Stage 5 (total facility) (0 hp each)	0	EA			***$8,865.56***	$0	
274	Flocculation Mixers Stage 6 (total facility) (0 hp each)	0	EA			***$8,865.56***	$0	
275	*Switchgear*							
276	Units	0	EA			***$49,359.23***	$0	
277	Electrical Conduit & Wire	10,440	LF	3,182.11	m	*$12.06*	$125,896	
278	Allowance for Misc Items	10%				$515,598.67	$51,560	
279	Subtotal						$567,159	
280								
281	INSTRUMENTS & CONTROLS:							
282	Instruments							
283	Level Switch	8	EA			*$695.44*	$5,564	
284	Number of Analog I/O Counts	58	EA			*$264.27*	$15,222	
285	Number of Digital I/O Counts	144	EA			*$62.59*	$9,013	
286	Number of PLC's	1	EA			*$13,074.33*	$13,074	
287	I&C Conduit & Wire	13,664	LF	4,164.79	m	*$12.06*	$164,774	
288	Allowance for Misc Items	10%				$207,646.55	$20,765	
289	Subtotal						$228,411	
290								
291	**USER DEFINED ESTIMATE ITEMS:**	**QUANT (ENGLISH)**	**UNIT (ENGLISH)**	**QUANT (METRIC)**	**UNIT (METRIC)**	**$/UNIT**	**TOTAL COST**	
292	Item 1 Description	0.00		0.00		0.00	$0	
293	Item 2 Description	0.00		0.00		0.00	$0	
294	Item 3 Description	0.00		0.00		0.00	$0	
295	Item 4 Description	0.00		0.00		0.00	$0	
296	Item 5 Description	0.00		0.00		0.00	$0	
297	Item 6 Description	0.00		0.00		0.00	$0	
298	Item 7 Description	0.00		0.00		0.00	$0	
299	Item 8 Description	0.00		0.00		0.00	$0	
300	Item 9 Description	0.00		0.00		0.00	$0	
301	Item 10 Description	0.00		0.00		0.00	$0	
302	Item 11 Description	0.00		0.00		0.00	$0	
303	Item 12 Description	0.00		0.00		0.00	$0	
304	Item 13 Description	0.00		0.00		0.00	$0	
305	Item 14 Description	0.00		0.00		0.00	$0	
306	Item 15 Description	0.00		0.00		0.00	$0	
307	Subtotal						$0	
308								
309	Subtotal						$6,953,253	
310								
311	ALLOWANCES:		**User Override**					
312	Finishes Allowance	2.00%		$7,557,883	$151,158			
313	I&C Allowance	2.00%		$7,557,883	$151,158			
314	Mechanical Allowance	2.00%		$7,557,883	$151,158			
315	Electrical Allowance	2.00%		$7,557,883	$151,158			
316						Facility Cost Name		
317	Facility Cost	**160,000,000**	**GPD**	**$0.05**	**$7,557,883**	FCPFC01		
318	Facility Cost with Standard Additional Project Costs Added	**160,000,000**	**GPD**	**$0.06**	**$9,184,113**	FCPFC02		

	B	C	D	E	F	G	H	I
319	Facility Cost with Standard Additional Project Costs and Contractor Markups Added	**160,000,000**	**GPD**	**$0.10**	**$15,752,397**	FCPFC03		
320	Facility Cost, Contractor Markups, and Location Adjustment Factor Added (excluding ALL Additional Project Costs)	**160,000,000**	**GPD**	**$0.08**	**$12,963,122**	FCPFC05		
321	Facility Cost with Standard Additional Project Costs, Contractor Markups, and Location Adjustment Factor Added	**160,000,000**	**GPD**	**$0.10**	**$15,752,397**	FCPFC06		

	B	C	D	E	F	G	H	I
1	***Dissolved Air Flotation***							
2								
3	**Is This Facility Included in My Project? Yes**							
4	***Assumptions:***							
5								
6	***1.) High-rate DAF based on Infilco Degremont AquaDAF.***							
7	***2.) Conventional DAF based on Parkson DAF.***							
8	***3.) Precede DAF with Flocculation with equal basin width to DAF.***							
9	***4.) Default System includes Mechanical Float Skimming.***							
10	***If this is a Seawater Desalination Application, the materials in contact with seawater need to be corrosion resistant.***							
11	**Process User Inputs**	**Value (English)**	**Unit (English)**	**Value (Metric)**	**Unit (Metric)**	**Name**	**Red Flags**	**Comment**
12	DAF SYSTEM SIZING							
13	1.) Is this a Seawater Desalination Application?	**No**	Y/N					
14	2.) Has the USER Contacted Equipment Suppliers to Obtain Equipment Quotes?	**No**	Y/N					Fixed
15	3.) Input Total Plant Flow	**160.00**	mgd	**605.67**	ML/d	Q		
16	Conversion of Total Plant Flow from MGD to GPM	111,111.11	gpm	25,236.08	m3/hr	QM		
17	4.) Input DAF Type	**High Rate**	Type			DTYP		Conventional OR High Rate
18	5.) Input Flotation Zone Surface Loading Rate	**10.00**	gpm/sf	**24.45**	m/h	FSLR		Typically, 4 to 6 gpm/sf for Conventional & 10 to 12 gpm/sf for High Rate
19	6.) Input Flotation Zone Side Water Depth	**15.00**	ft	**4,572.00**	mm	SWD		Typically 10 to 15 feet
20	Calculate Total Surface Area of Flotation Zone per Train = QM/FSLR	11,111.11	sf	1,032.26	m2	FZA		
21	7.) For Conventional DAF, Select Single Train Flotation Area from Standard Sizes	**1,395.00**	sf	129.60	m2	SCTS		
22	8.) For High Rate DAF, Select Single Train Flotation Area from Standard Sizes	**717.00**	sf	66.61	m2	SHTS		
23	Calculate Number of Trains	16	#			NT		
24	Calculate Length of Flotation Zone	17.90	ft	5,455.92	mm	FZL		
25	Calculate Width of Flotation Zone	40.00	ft	12,192.00	mm	FZW		
26	Calculate Capacity of Each Train	6,944.44	gpm	1,577.25	m3/hr	QTM		
27	9.) Input Influent Channel, Contact Zone, and Effluent Channel Velocity	**0.50**	fps	**0.15**	m/s	VEL		Typically < 0.5 fps
28	Calculate Influent Channel, Contact Zone, and Effluent Channel Length = QTM/7.48/60/VEL/FZW OR 3	3.00	ft	914.40	mm	ICL, CZLB, SBL, ECL		
29	Calculate Contact Zone Under Baffle Entry Opening Height = QTM/7.48/60/VEL/FZW OR 3	3.00	ft	914.40	mm	CZEH		
30	Calculate Contact Zone Top Length = sin(15)/cos(15)*(CZBH - CZEH) + CZLB	6.35	ft	1,935.29	mm	CZLT		
31	Effluent Collection System Plenum Height for High Rate DAF	3.00	ft	914.40	mm	PH		
32	10.) Input Effluent Collection Lateral Velocity for Conventional DAF	**2.50**	fps	**0.76**	m/s	ECVEL		Typically 2.5 fps or less
33	Number of Effluent Collection Laterals for Conventional DAF	0.00	#			NCL		
34	Calculate Effluent Collection Lateral Pipe Diameter for Conventional DAF Train	0.00	in	0.00	mm	CLD		2.5 feet lower than effluent weir
35	Calculate Effluent Collection Lateral Spacing for Conventional DAF Train	0.00	ft	0.00	mm	CLSP		2.5 feet lower than effluent weir
36	Calculate Contact Zone 75-Degree Exit Baffle Height =	15.50	ft	4,724.40	mm	CZBH		2.5 feet lower than effluent weir
37	Calculate Float Weir Height = SWD+PH+0.5	18.50	ft	5,638.80	mm	FWH		0.5 feet higher than effluent weir
38	Sludge Float Trough Width	1.50	ft	457.20	mm	FTW		
39	Calculate Sludge Float Trough Depth	4.00	ft	1,219.20	mm	FTD		Based on hydraulic float removal at 3 fps
40	Calculate Recycle Pumping & Compressor Gallery Length	17.58	ft	5,359.40	mm	GL		
41	11.) Input Freeboard	**3.00**	ft	**1,219.20**	mm	FB		Typically 2 to 4 feet
42	Calculate Basin Depth BD = SWD+PH+FB	21.00	ft	6,400.80	mm	BD		
43	12.) Input Structure Depth of Burial	**0.00**	ft	**1,828.80**	mm	DB		
44	13.) Is the Basin Covered?	**No**	Y/N					
45	SATURATED AIR RECYCLE SYSTEM SIZING							
46	14.) Input Grams of Air per Cubic Meter Water Treated	**10.00**	g/m3			ALR		Typically 8 to 10 g/m3
47	15.) Input Air Saturation Recycle Stream Pressure	**85.00**	psig	**586.05**	kPa	RSP		Typically 60 to 90 psig
48	Conversion of Air Saturation Recycle Stream Pressure from PSIG to kPA	586.06	kPa			RSPM		
49	16.) Input Maximum Water Temperature	68.00	degrees F	**20.00**	degrees C	WT		Valid Range: 0 - 40 deg C. Warmer water requires greater recycle ratio for a given air loading rate and recycle stream pressure.
50	Dynamic (Absolute) Viscosity of Water	0.000021	lb•s/sf	0.001002	Pa•s			Reference: *Viscosity of Liquid Water in the Range -8°C to 150°C*, J. Phys. Chem. Ref. Data, Vol. 7, No. 3, 1978 (Eqn. 15).
51	Calculate Air Dissolution at Recycle Stream Pressure & Water Temperature	117.21	mg/L			AD		See Data from air dissolution graphs worksheet
52	Calculate Air Saturation Recycle Stream Ratio = ALR/AD	0.09				ARR		
53	Calculate Number of Packed Saturators	16.00	#			#S		Equals Number of Trains
54	17.) Input Saturator Surface Loading Rate	**34.00**	gpm/sf	**83.12**	m/h			Typically 34 gpm/sf
55	18.) Input Saturator Packing Depth	**4.00**	ft	**1,219.20**	mm			Typically 4 feet or 0 feet, if No Packing
56	19.) Input Saturator Bottom Pool Depth	**3.00**	ft	**914.40**	mm			Typically 3 feet
57	20.) Input Saturator Freeboard Above Packing	**3.00**	ft	**914.40**	mm			Typically 3 feet
58	21.) Input Saturator Clear Height Above Deck	**3.00**	ft	**914.40**	mm			Typically 3 feet
59	22.) Input Saturator Inlet Velocity	**5.00**	fps	**1.52**	m/s			Typically 5 fps
60	23.) Input Saturator Outlet Velocity	**2.50**	fps	**0.76**	m/s			Typically 2.5 fps
61	Calculate Saturator Diameter	4.71	ft	1,435.70	mm	SD		
62	Calculate Saturator Height	13.00	ft	3,962.40	mm	SH		
63	Calculate Saturator Inlet Header Diameter	6.96	in	176.72	mm	SIHD		
64	Calculate Saturator Inlet Lateral Diameter	4.92	in	124.96	mm	SILD		
65	Calculate Saturator Outlet Header Diameter	9.84	in	249.91	mm	SOHD		
66	Calculate Saturator Outlet Half-Lateral Diameter	6.96	in	176.72	mm	SOHLD		
67	Calculate Number of Saturator Sub-Laterals	5.00	#			NSL		
68	Calculate Saturator Sub Lateral Diameter	4.40	in	111.77	mm	SOSLD		
69	Calculate Saturator Outlet Nozzle Header Diameter	3.48	in	88.36	mm	SODH		
70	Calculate Number of Recycle Pumps	16.00	#			#RP		Equals Number of Trains

	B	C	D	E	F	G	H	I
71	Calculate Recycle Pump Capacity, each = QTM*ARR	592.47	gpm	134.56	m3/hr	RPC		
72	Calculate Recycle Pump Power, each = RPC*RSP/1714/0.75	40.00	hp	29.83	kW	RPP		
73	24.) Select Standard Recycle Pump Horsepower	55.00	hp	41.01	kW			Based on ITT Goulds Model 3196 Horizontal End Suction Centifugal Pump
74	Calculate Recycle Pump Suction Diameter	8.00	in	203.20	mm	RPS		
75	Calculate Recycle Pump Discharge Diameter	6.00	in	152.40	mm	RPD		
76	Calculate Recycle Pump Length	5.58	ft	1,701.80	mm	RPL		
77	Calculate Recycle Pump Width	2.00	ft	609.60	mm	RPW		
78	Calculate Recycle Pump Height	3.25	ft	990.60	mm	RPH		
79	Calculate Number of Compressors	2.00	#			#C		1 Duty and 1 Standby
80	25.) Input Compressor Inlet Air Density	0.08	lb/cf	1.28	kg/m3	IAD		0.075 for Dry Air @ Sea Level and 70 deg F
81	Calculate Compressor Capacity, each = AD*Q*ARR*8.3454/1440/IAD	115.91	icfm	3.28	m3/min	CC		
82	26.) Select Standard Rotary Screw Compressor Capacity	116.00	scfm	3.28	m3/min			Based on Gardner Denver Rotary Screw Compressor
83	Calculate Compressor Power	30.00	hp	22.37	kW	CHP		
84	Calculate Compressor Length	3.96	ft	1,206.50	mm	CL		
85	Calculate Compressor Width	2.46	ft	749.30	mm	CW		
86	Calculate Compressor Height	5.42	ft	1,651.00	mm	CH		
87	27.) Input Minimum Number of DAF Trains On-Line to Size Compressor Receiver Storage Volume	1.00	#			MDT		
88	28.) Input Maximum Number of Compressor Motor Starts per Hour	3.00	#			MMS		Typically 3 to 4
89	Calculate Minimum Compressed Air Use	7.24	icfm	0.21	m3/min	MCA		
90	29.) Input Compressed Air Density	0.63	lb/cf	10.09	kg/m3	CAD		0.626 for Dry Air @ 120 psig and 120 deg F
91	Calculate Minimum Receiver Storage Volume for 125 psig/120 deg F Air	2,064.42	gal	7.81	m3	TRSV		Calculated
92	Calculate Number of Receivers	2.00	#			#R		1 Duty and 1 Standby
93	30.) Select Standard Receiver Volume	2,180.00	gal	8.25	m3	SRSV		
94	Calculate Receiver Storage Diameter, each	5.00	ft	1,524.00	mm	RSD		
95	Calculate Receiver Storage Height w/1-Foot Stand, each	6.00	ft	1,828.80	mm	RSH		
96	Calculate Receiver Storage Length, each	16.00	ft	4,876.80	mm	RSL		
97	**(1) PARKSON CONVENTIONAL DAF SINGLE TRAIN STANDARD FLOTATION AREA (SF)**	**(2) Flotation Basin Width (ft)**	**(3) Flotation Basin Length (ft)**	**(4) Budget Quote**	**(5) Number of Saturator Outlet Quarter Laterals**	**(6) Number of 14-inch Perforated Effluent Collection Laterals on 4-foot Centers**	**(1) IDI High Rate AQUADAF Single Train Standard Flotation Area (SF)**	**(2) Flotation Basin Width (ft)**
98	720	24	30	$ 376,505.00	3.0	8.0	65	8.0
99	920	27	34	$ 455,513.00	4.0	8.0	110	12.0
100	1040	29	36	$ 502,918.00	4.0	8.0	162	16.0
101	1150	30	38.5	$ 546,372.00	4.0	8.0	222	20.0
102	1395	30	46.5	$ 643,157.00	4.0	8.0	292	24.0
103							369	28.0
104							463	32.0
105							581	36.0
106							717	40.0
107	**Process User Inputs**	**Value (English)**	**Unit (English)**	**Value (Metric)**	**Unit (Metric)**	**Name**	**Red Flags**	**Comment**
108	Estimating Dimensions (per Train):							
109	DAF Basin							
110	Slab on Grade:							
111	Concrete Thickness	24.00	in	609.60	mm			Model based on18"
112	Concrete Thickness	2.00	ft	609.60	mm	TLCS0G		
113	SOG Width (2 + PWLC + FZW + PWLC + 2)	48.00	ft	14,630.40	mm	WLCSOG		Assumes no common wall
114	SOG Length (IWLC + CL + IWLC + CL + CZBH/2*SIN15 + FZL + IWLC + STW + IWLC + CL + IWLC + CL + PWLC + 2)	46.69	ft	14,231.03	mm	LLCSOG		
115	Perimeter Walls:							
116	Concrete Thickness	24.00	in	609.60	mm			Model based on 16"
117	Concrete Thickness	2.00	ft	609.60	mm	PWLC		
118	Wall Length = (L + L + W)	133.38	ft	40,654.06	mm			
119	Wall Height = BD	21.00	ft	6,400.80	mm			
120	Internal Walls:							
121	Concrete Thickness	15.00	in	381.00	mm			Model based on 12"
122	Concrete Thickness	1.25	ft	381.00	mm	IWLC		
123	Wall Length = (5 * FZW)	200.00	ft	60,960.00	mm			
124	Wall Height = BD - FB	18.00	ft	5,486.40	mm			
125	Elevated Slab:							
126	Concrete Thickness	18.00	in	457.20	mm			Model based on 12"
127	Concrete Thickness	1.50	ft	457.20	mm	TESLC		
128	Elevated Slab Length = (L + L + W + W)	177.38	ft	54,065.26	mm			Assumes Perimeter Walkway on all 4 sides
129	Elevated Slab Width	6.00	ft	1,828.80	mm	TESIC		Fixed
130								
131	Gallery							
132	Slab on Grade:							
133	Concrete Thickness	24.00	in	609.60	mm			Model based on 18"
134	Concrete Thickness	2.00	ft	609.60	mm	TECS0G		
135	SOG Width (Match DAF Basin)	48.00	ft	14,630.40	mm	WECSOG		
136	SOG Length (2 + TWEC + GL + TWEC + 2)	25.58	ft	7,797.80	mm	LECSOG		
137	Walls:							
138	Concrete Thickness	24.00	in	609.60	mm			Model based on 16"
139	Concrete Thickness	2.00	ft	609.60	mm	TWEC		
140	Wall Length = (GL + W + GL)	75.17	ft	22,910.80	mm			
141	Wall Height = BD	21.00	ft	6,400.80	mm			
142	Elevated Slab:							
143	Concrete Thickness	15.00	in	381.00	mm			Model based on 12"
144	Concrete Thickness	1.25	ft	381.00	mm	TESEC		
145	Elevated Slab Width (Match DAF Basin)	44.00	ft	13,411.20	mm			

	B	C	D	E	F	G	H	I
146	Elevated Slab Length (TWEC + GL + TWEC)	21.58	ft	6,578.60	mm	TESIC		
147								
148	Overall Dimensions:							
149	SOG Width	48.00	ft	14,630.40	mm	SOGW		
150	SOG Length	72.27	ft	22,028.83	mm	SOGL		
151	Building Width (SOGW - 4)	44.00	ft	13,411.20	mm			
152	Building Length (SOGL - 4)	68.27	ft	20,809.63	mm			
153	Excavation Width	52.00	ft	15,849.60	mm			
154	Excavation Length	76.27	ft	23,248.03	mm			
155	Excavation Depth (DB + TLCSOG + 1)	3.00	ft	914.40	mm			
156								
157								
158	**Description**	**Quantity (English)**	**Unit (English)**	**Quantity (Metric)**	**Unit (Metric)**	**$/Unit**	**Total Cost**	**User Over-Write**
159	SITEWORK:							
160	Excavation	8,663.36	CY	6,623.62	m3	***$6.72***	$58,244	
161	Imported Structural Backfill	2,350.34	CY	1,796.96	m3	***$50.94***	$119,730	
162	Native Backfill	684.12	CY	523.05	m3	***$8.27***	$5,654	
163	Haul Excess	7,979.24	CY	6,100.57	m3	***$8.27***	$65,951	
164	Allowance for Misc Items	5%				$249,579.71	$12,479	
165	Subtotal						$262,059	
166								
167	CONCRETE:							
168	*DAF Basin:*							
169	Foundation	2,656.13	CY	2,030.75	m3	***$541.11***	$1,437,246	
170	Perimeter Walls	3,319.67	CY	2,538.07	m3	***$880.79***	$2,923,940	
171	Internal Walls	2,666.67	CY	2,038.81	m3	***$1,333.77***	$3,556,710	
172	Elevated Slab	946.02	CY	723.29	m3	***$490.62***	$464,135	
173	*Gallery:*							
174	Foundation	1,455.41	CY	1,112.74	m3	***$541.11***	$787,529	
175	Walls	1,870.81	CY	1,430.34	m3	***$880.79***	$1,647,801	
176	Elevated Slab	703.46	CY	537.83	m3	***$1,333.77***	$938,247	
177	Allowance for Misc Items	5%				$11,755,607.51	$587,780	
178	Subtotal						$12,343,388	
179								
180	MASONRY:	**High**						
181	CMU Building	0.00	SF	0.00	m2	***$198.37***	$0	
182	Subtotal						$0	
183								
184	METALS:							
185	Aluminum Handrail	1,924.37	LF	586.55	m	***$90.92***	$174,960	
186	Additional Handrail with NO Building	1,544.55	LF	470.78	m	***$90.92***	$140,427	
187	Aluminum Grating	960.00	SF	89.19	m2	***$90.92***	$87,281	
188	Stairs (1 per basin)	504.00	RISERS			***$495.92***	$249,942	
189	Allowance for Misc Items	10%				$652,611.06	$65,261	
190	Subtotal						$717,872	
191								
192	WOODS & PLASTICS:							
193	FRP Ladder	32.00	EA			***$2,050.07***	$65,602	
194	Allowance for Misc Items	5%				$65,602.22	$3,280	
195	Subtotal						$68,882	
196								
197	THERMAL & MOISTURE PROTECTION:							
198	Concrete Liner	0.00	SF	0.00	m2	**$16.00**	$0	
199	Allowance for Misc Items	10%				$0.00	$0	
200	Subtotal						$0	
201								
202	EQUIPMENT:							
203								**Budgetary Quote: (CPES will automatically add Installation Factor)**
204	Conventional DAF Equipment Scope of Supply per DAF Unit	16.00	EA			***$0.00***	$0	
205	Single Train Flotation Area (sf):	1,395.00						
206	Surface Skimmer, 304 SS reciprocating type mechanisms and							
207	Sludge Beach, 304SS with mounting hardware.							
208	Air Dispersion System, SCH 10 304SS vertical riser with isolation valves and lateral header with nozzles, for 10% recycle @ design flow.							
209	Recycle Pumps, base mounted Goulds Model 3196, suction and discharge wafer style isolation valves, check valves and magnetic flow meter with transmitter, One installed spare.							
210	Underflow Collection Pipes, SCH 80 PVC with 304 SS support brackets.							
211	Effluent Level Control Weir, FRP or SS with mounting hardware							
212	Sludge hopper spray system with spray nozzles and auto valve.							
213	Packed Tower Saturator with level control valve, outlet with isolation valve, air pressure controls and air filters with isolation valving.							
214	Duplex Screw Compressor and air receiver, each @ 100% of air required.							
215	Control Panel with PLC for process control and HOA operations.							
216	Lot of Isolation Valves, Anchors and Fasteners for supplied equipment.							
217	Submittals, Startup Services and IOM Manual							
218								
219	High Rate DAF Equipment Scope of Supply per DAF Unit	16.00	EA			***$1,774,928.51***	$28,398,856	
220	Single Train Flotation Area (sf):	717.00						
221	Mechanical sludge scraper system.							
222	Sludge Beach, 304SS with mounting hardware.							
223	Air Dispersion System, SCH 10 304SS vertical riser with isolation valves and lateral header with nozzles, for 10% recycle @ design flow.							
224	Recycle Pump, vertical turbine pumps per unit with VFD, butterfly isolation and check valves.							
225	Aluminum false flooring and support columns.							

	B	C	D	E	F	G	H	I
226	Effluent Level Control Weir, FRP or SS with mounting hardware							
227	Sludge hopper spray system with spray nozzles and auto valve.							
228	Unpacked Saturator with level control valve, outlet with isolation valve, air pressure controls and air filters with isolation valving.							
229	Rotary Screw Compressor and air receiver system.							
230	Control Panel with PLC for process control and HOA operations.							
231	Lot of Isolation Valves, Anchors and Fasteners for supplied equipment.							
232	Submittals, Startup Services and IOM Manual							
233	Allowance for Misc Items	10%				$28,398,856.23	$2,839,886	
234	Subtotal						$31,238,742	
235								
236	INSTRUMENTS & CONTROLS:							
237	Turbidimeters	16.00	EA			*$11,714.68*	$187,435	
238	Allowance for Misc Items	5%				$187,434.90	$9,372	
239	Subtotal						$196,807	
240								
241	MECHANICAL:							
242	Mud Valves	48.00	EA			*$2,252.82*	$108,136	
243	Allowance for Misc Items	10%				$108,135.52	$10,814	
244	Subtotal						$118,949	
245								
246	**USER DEFINED ESTIMATE ITEMS:**	**QUANT (ENGLISH)**	**UNIT (ENGLISH)**	**QUANT (METRIC)**	**UNIT (METRIC)**	**$/UNIT**	**TOTAL COST**	
247	Item 1 Description	0.00		0.00		0.00	$0	
248	Item 2 Description	0.00		0.00		0.00	$0	
249	Item 3 Description	0.00		0.00		0.00	$0	
250	Item 4 Description	0.00		0.00		0.00	$0	
251	Item 5 Description	0.00		0.00		0.00	$0	
252	Item 6 Description	0.00		0.00		0.00	$0	
253	Item 7 Description	0.00		0.00		0.00	$0	
254	Item 8 Description	0.00		0.00		0.00	$0	
255	Item 9 Description	0.00		0.00		0.00	$0	
256	Item 10 Description	0.00		0.00		0.00	$0	
257	Item 11 Description	0.00		0.00		0.00	$0	
258	Item 12 Description	0.00		0.00		0.00	$0	
259	Item 13 Description	0.00		0.00		0.00	$0	
260	Item 14 Description	0.00		0.00		0.00	$0	
261	Item 15 Description	0.00		0.00		0.00	$0	
262	Subtotal						$0	
263								
264	Subtotal						$44,946,699	
265								
266	ALLOWANCES:		**User Override**					
267	Finishes Allowance	2.00%		$53,507,975	$1,070,159			
268	I&C Allowance	4.00%		$53,507,975	$2,140,319			
269	Mechanical Allowance	6.00%		$53,507,975	$3,210,478	Includes Drain, USL, SA (Sample) piping		
270	Electrical Allowance	4.00%		$53,507,975	$2,140,319			
271						Facility Cost Name		
272	**Facility Cost**	**160,000,000**	**GPD**	**$0.33**	**$53,507,975**	CDFFC01		
273	**Facility Cost with Standard Additional Project Costs Added**	**160,000,000**	**GPD**	**$0.41**	**$65,021,284**	CDFFC02		
274	**Facility Cost with Standard Additional Project Costs and Contractor Markups Added**	**160,000,000**	**GPD**	**$0.70**	**$111,523,138**	CDFFC03		
275	**Facility Cost, Contractor Markups, and Location Adjustment Factor Added (excluding ALL Additional Project Costs)**	**160,000,000**	**GPD**	**$0.57**	**$91,775,752**	CDFFC05		
276	**Facility Cost with Standard Additional Project Costs, Contractor Markups, and Location Adjustment Factor Added**	**160,000,000**	**GPD**	**$0.70**	**$111,523,138**	CDFFC06		

	B	C	D	E	F	G	H	I
1	***Ozone - Serpentine***							
2	**PROCESS DESIGN CRITERIA**							
3	**Is This Facility Included in My Project? No**							
4	**Type of Feed Gas: Delivered LOX**							
5	**Type of Dissolution: Diffused Bubble**							
6	**Type of Contactor: Serpentine**							
7	**Number of parallel trains or contactors: Minimum of 2**							
8								
9	**Process User Inputs:**	**Value (English)**	**Value (English)**	**Value (Metric)**	**Value (Metric)**	**Name**	**Red Flags**	**Comment**
10	1.) Input Summer Maximum Plant Flow Rate	**160.00**	mgd	**605.67**	ML/d			
11	2.) Input Winter Maximum Plant Flow Rate	**70.00**	mgd	**264.98**	ML/d			
12	3.) Input Maximum Oxidation Flow Rate	**160.00**	mgd	**605.67**	ML/d			
13	4.) Input Number of Contactors	**4**	each	4.00	each			Typically 2 minimum.
14								
15	**Process User Inputs:**	**Value (English)**	**Value (English)**	**Value (English)**	**Unit (English)**	**Value (Metric)**	**Value (Metric)**	**Value (Metric)**
16	Ozone Chemistry and Contactor Sizing:	**Summer**	**Winter**	**Oxidation**		**Summer**	**Winter**	**Oxidation**
17	4.) Input Water Temperature	77.00	42.80	42.80	degrees F	**25.00**	**6.00**	**6.00**
18	Calculate Maximum Plant Flow Rate	160.00	70.00	160.00	mgd	605.67	264.98	605.67
19	5.) Input Ozone Immediate Demand	**0.40**	**0.40**	**1.00**	mg/L	0.40	0.40	1.00
20	6.) Input Ozone Residual Development to Ozone Transferred Ratio	**0.40**	**0.40**	**0.40**	Slope development line	0.40	0.40	0.40
21	Calculate Ozone Residual Intercept	-0.16	-0.16	-0.40	mg/L	-0.16	-0.16	-0.40
22	7.) Input Ozone Residual Decay Rate	**0.30**	**0.15**	**0.15**	1/min	0.30	0.15	0.15
23	8.) Input Ozone Transfer Efficiency	**95.00%**	**95.00%**	**95.00%**		95.00%	95.00%	95.00%
24	9.) Input Hydraulic Retention Time for Disinfection Cell at Max Flow	**5.00**	11.43	5.00	minutes	5.00	11.43	5.00
25	10.) Input Short Circuiting Factor for Disinfection Cell	**0.60**				0.60	0.00	0.00
26	Calculate T10 Time for Disinfection Cell	3.00	6.86	3.00	minutes	3.00	6.86	3.00
27	Calculate Disinfection Cell Water Volume, Each Train	18,566.75	18,566.75	18,566.75	cf	525.75	525.75	525.75
28	Calculate Required Disinfection Contactor Water Volume, Each Train	18,566.75			cf	525.75		
29	11.) Input Hydraulic Retention Time for AOP Contactor at Max Flow	**5.00**	11.43	5.00	minutes	5.00	11.43	5.00
30	12.) Input Short Circuiting Factor for AOP Contactor	**0.60**	0.60	0.60		0.60	0.60	0.60
31	Calculate T10 Time for AOP Contactor	3.00	6.86	3.00	minutes	3.00	6.86	3.00
32	Calculate AOP Contactor Water Volume, Each Train	18,566.75	18,566.75	18,566.75	cf	525.75	525.75	525.75
33	Calculate Required AOP Contactor Water Volume, Each Train	18,566.75			cf	525.75		
34	13.) Input Desired Cryptosporidium Log Inactivation	**0.0**	**0.0**	**0.0**	-log	0.00	0.00	0.00
35	Calculate Required Cryptosporidium Inactivation CT	0.00	0.00	0.00	mg-min/L	0.00	0.00	0.00
36	14.) Input Desired Giardia Log Inactivation	**0.0**	**0.0**	**0.0**	-log	0.00	0.00	0.00
37	Calculate Required Giardia Inactivation CT	0.00	0.00	0.00	mg-min/L	0.00	0.00	0.00
38	15.) Input Desired Virus Log Inactivation	**0.0**	**0.0**	**0.0**	-log	0.00	0.00	0.00
39	Calculate Required Virus Inactivation CT	0.00	0.00	0.00	mg-min/L	0.00	0.00	0.00
40	Calculate Controlling Required Pathogen Inactivation CT	0.00	0.00	0.00	mg-min/L	0.00	0.00	0.00
41	16.) Input Design Applied Ozone Dose	**1.50**	**1.50**	**3.00**	mg/L	1.50	1.50	3.00
42	Calculate Transferred Ozone Dose	1.43	1.43	2.85	mg/L	1.43	1.43	2.85
43	Calculate Ozone Generation Capacity	2,002.90	876.27	4,005.79	lb/d	908.50	397.47	1,817.00
44	17.) Input if Hydrogen Peroxide required	**No**	**No**	**No**	Y/N	No	No	No
45	Calculate Initial Residual in Disinfection Contactor	0.41	0.41	0.74	mg-min/L	0.41	0.41	0.74
46	Calculate End Residual in Disinfection Contactor	0.09	0.07	0.35	mg-min/L	0.09	0.07	0.35
47	Calculate CT Achieved in Disinfection Contactor	0.27	0.51	1.05	mg-min/L	0.27	0.51	1.05
48	Calculate Initial Residual in AOP Contactor	0.09	0.07	0.35	mg-min/L	0.09	0.07	0.35
49	Calculate End Residual in AOP Contactor	0.02	0.01	0.17	mg-min/L	0.02	0.01	0.17
50	Calculate CT Achieved in AOP Contactor	0.06	0.09	0.50	mg-min/L	0.06	0.09	0.50
51	Calculate Total CT Achieved in Full Contactor	0.34	0.60	1.54	mg-min/L	0.34	0.60	1.54
52	**Process User Inputs:**	**Value (English)**	**Value (English)**	**Value (Metric)**	**Value (Metric)**	**Name**	**Red Flags**	**Comment**
53	18.) Input Contactor Side Water Depth	**20.00**	ft	**6,096.00**	mm	SWD		Typically 20 ft for Good Transfer Efficiency
54	Distance from Top of SWD to Roof of Building	3.00	ft		mm	FB		Fixed
55	19.) Input Desired AOP Contactor Length to Width Ratio	**20.00**						Typically 20 to 40:1 to Promote Plug Flow
56	20.) Input Odd Number of Passes, Minimum 3 Passes	**3**	#			NP		
57	Calculate Pass Water Width	6.81	ft	2,076.60	mm	SPW		
58	Calculate Pass Water Length	45.42	ft	13,844.00	mm	SPL		
59	Calculate Contactor Water Width	22.78	ft	6,943.03	mm	CW		

	B	C	D	E	F	G	H	I
60	Calculate Injection Cell Length	8.46	ft	2,577.43	mm	ICL		
61	Calculate Disinfection Cell Water Length	40.75	ft	12,421.86	mm	DCL		
62	Calculate Upflow Cell Water Length Required	6.79	ft	2,070.31	mm	UCL		
63	Calculate Overflow Channel Length	10.00	ft	3,048.00	mm	OFL		
64	Calculate Effluent Weir Distance from Contactor Outlet	6.81	ft	2,076.60	mm	EWCL		
65	Calculate Effluent Weir Head	1.95	ft	595.07	mm	WH		
66	Ozone Generation and Off-Gas Destruction Sizing:							
67	Calculate Ozone Design Dose	3.00	mg/L	3.00	mg/L			Maximum of Design Applied Ozone Dose
68	Calculate Design Daily Ozone Generation Capacity	4,005.79	lb/d	1,817.00	kg/d			Maximum of Ozone Generation Capacity
69	21.) Input Design Ozone Weight Percent	10%						Either 10% or 12%
70	Calculate Design Daily Oxygen Usage	40,057.92	lb/d	18,169.97	kg/d			
71	Calculate Ozone Generation Capacity at 10% Weight	4,005.79	lb/d	1,817.00	kg/d			
72	Standby Ozone Generation Capacity Provided at 10% Weight	0%						Fixed
73	Calculate Ozone Generation Capacity at 8% Weight	6,409.27	lb/d	2,907.19	kg/d			
74	Standby Ozone Capacity Provided at 8% Weight	60%						Fixed
75	Convert Design Daily Oxygen Usage from lb/d to scfm	335.00	scfm	9.49	m3/min			Assumes gaseous oxygen density of 0.08304 lb/ft3 at standard conditions of 1 atm and 20 deg C.
76	Calculate Number of Porous Plate Dome Diffusers for Dissolution	335.00	#					Based on 1 scfm per 7-inch diameter Sanitaire Ozone dome diffuser at 20-inch water headloss.
77	Calculate Minimum Area Required to Accommodate Diffusers	770.49	sf	71.58	m2			Based on 1 diffuser per 2.3 square foot (i.e., spacing at 18 inches)
78	22.) Input Number of Active Ozone Generators	2	#					
79	23.) Input Number of Standby Ozone Generators	1	#					Typically 1 or Rely on Higher Production Capacity at Lower Ozone Concentration
80	Calculate Design Ozone Generator Capacity, Each	2,002.90	lb/d	908.50	kg/d			
81	Calculate Total Number of Generators	3	#					
82	24.) Select Ozone Cooling Water System	Closed Loop					**Open loop is not acceptable**	
83	25.) Input Ozone Generator and Power Supply Unit Energy Consumption	4.70	kWh/lb	10.36	kWh/kg			Typically 4.5 to 7 kWh/lb
84	26.) Input Ozone Generator and Power Supply Unit Energy Consumption Conversion to Waste Heat	85%						Typically 85% to 95%
85	Calculate Maximum Waste Heat Generation Rate	60,705.24	BTU/min	25,618.97	kWh/d			
86	27.) Input Design Temperature Rise for Heat Rejection Water	7.50	degrees F	-13.61	degrees C			Typically 5 to 10 deg F
87	28.) Input Heat Exchanger Efficiency	90%						Typically 70% to 90%
88	Calculate Preliminary Heat Rejection Water Flow Rate	1,077.64	gpm	67.99	L/s			Confirm cooling water requirement with ozone generator supplier or specify refrigerant chiller system.
89	Calculate Preliminary Cooling Pump Horsepower, Each	9.72	hp	7.25	kW			Assume 25 ft TDH and 70% pump efficiency
90	29.) Input Design Days of Liquid Oxygen Storage at Design Ozone Weight Percent	30.00	days					
91	Calculate Total Liquid Oxygen Storage	1,201,737.60	lb	545,099.01	kg			
92	Convert Total Liquid Oxygen Storage from lb to gallons	126,232.94	gal	477,843.67	L			
93	Calculate Minimum Days of Liquid Oxygen Storage at 10% Ozone	30.00	days					
94	Calculate Minimum Days of Liquid Oxygen Storage at 8% Ozone	15.00	days					
95	30.) Input Number of Liquid Oxygen Storage Tanks	3	#					Typically 2 or More
96	Calculate Volume of Liquid Oxygen Storage Tank, Each	42,077.65	gal	159,281.22	L			
97	31.) Input Liquid Oxygen Storage Tank, Diameter	12.00	ft	3,657.60	mm	DLOX		Typically 14' or Less
98	32.) Indicate Orientation of LOX Tank	Horizontal						Use Horizontal Only if There is an Aesthetic Concern
99	Calculate Liquid Oxygen Storage Tank Length/Height	49.74	ft	15,159.41	mm	LLOX		
100	Calculate Number of Liquid Oxygen Vaporizers	3	#			#VP		Fixed to Equal Number of Tanks, Minimum of 2
101	Liquid Oxygen Vaporizer Footprint, each	24.00	sf	2.23	m2	VPFP		Fixed
102	Number of Active Thermal Catalytic Ozone Destructors	4	#					Fixed to Equal Number of Contactors
103	33.) Input Number of Standby Thermal Catalytic Ozone Destructors	1	#					
104	34.) Input Design Ozone Weight % in Ozone Off-Gas to Thermal Catalytic Ozone Destructors	2.40%						Typically assume worst case ozone transfer efficiency to contactor and highest ozone production concentration in the feed gas. If 80% transfer worst case at 12% ozone concentration, then (1-0.8)*0.12*100 = 2.4%.
105	35.) Do Destruct Units Need Enclosure for Noise Concerns?	Yes						Locate Indoors if Noise is a Concern

	B	C	D	E	F	G	H	I
106	Calculate Capacity of Thermal Catalytic Ozone Destructor, Each	115.15	scfm	3.26	m3/min			Assumes 110% of the gas flow at 8% ozone by weight. Assumes gaseous oxygen density of 0.08304 lb/ft3 at standard conditions of 1 atm and 20 deg C.
107	36.) Input Cooling Water Flow per Generator - value to come from Vendor	700.00	gpm	44.16	L/s			
108	37.) Input Cooling Water Flow per PSU - value to come from Vendor	20.00	gpm	1.26	L/s			
109	Calculate Cooling Pump Horsepower, Each	6.49	hp	4.84	kW			Assume 25 ft TDH and 70% pump efficiency
110	38.) Input Distance from LOX Pad to Generation Room	20.00	ft	6,096.00	mm			
111	39.) Input Distance from Generation Room to Upstream End of Contactor	150.00	ft	45,720.00	mm			
112	40.) Input Distance from Middle of Contactor to Destruct Room	50.00	ft	15,240.00	mm			
113	41.) Input Ozone Generation Bldg Depth of Burial	0.00	ft	914.40	mm			
114	42.) Input Ozone Generation Bldg Cutback Slope	1.00	:1					Cutback slope should be 1:1 for depth of burial ≤ 5 ft, and at least 1.5:1 for depth of burial > 5 ft.
115	43.) Input Ozone Generation Bldg Over Excavation Depth	1.00	ft	609.60	mm			
116	44.) Input LOX Pad Depth of Burial	0.00	ft	609.60	mm			
117	45.) Input LOX Pad Cutback Slope	1.00	:1					Cutback slope should be 1:1 for depth of burial ≤ 5 ft, and at least 1.5:1 for depth of burial > 5 ft.
118	46.) Input LOX Pad Over Excavation Depth	1.00	ft	609.60	mm			
119	47.) Input Ozone Contactor Depth of Burial	10.00	ft	3,048.00	mm			
120	48.) Input Ozone Contactor Cutback Slope	1.50	:1					Cutback slope should be 1:1 for depth of burial ≤ 5 ft, and at least 1.5:1 for depth of burial > 5 ft.
121	49.) Input Ozone Contactor Over Excavation Depth	1.00	ft	609.60	mm			
122								
123	**Mechanical Sizing Requirements:**							
124	**Pipe Name**	**Input Velocity (fps, fpm)**				**Standard Pipe Size (inches)**	**Nominal Pipe Size (mm)**	**Name**
125	Influent Pipe	5.00	fps	1.52	m/s	48.00	1200.00	53.26152154
126	Effluent Pipe	5.00	fps	1.52	m/s	48.00	1200.00	
127	Overflow Pipe	5.00	fps	1.52	m/s	96.00	2050.00	
128	Total LOX Pipe	2.00	fps	0.61	m/s	1.50	40.00	
129	Total GOX Pipe Upstream of PRV	1,800.00	fpm	9.14	m/s	3.00	80.00	
130	Total GOX Pipe Downstream of PRV	1,800.00	fpm	9.14	m/s	6.00	150.00	
131	Individual GOX Pipe Downstream of PRV	1,800.00	fpm	9.14	m/s	4.00	100.00	
132	Nitrogen	1,800.00	fpm	9.14	m/s	1.00	25.00	
133	Header Ozone Gas PIpe	1,800.00	fpm	9.14	m/s	6.00	150.00	
134	Individual Ozone Generator Gas Pipe	1,900.00	fpm	9.65	m/s	4.00	100.00	
135	Individual Ozone Contactor Gas Pipe	1,800.00	fpm	9.14	m/s	3.00	80.00	
136	Ozone Off-Gas Pipe per Train	1,800.00	fpm	9.14	m/s	4.00	100.00	
137	Ozone Off-Gas Pipe Combined	1,800.00	fpm	9.14	m/s	8.00	200.00	
138	Ozone Off-Gas Pipe per Destruct Unit	1,800.00	fpm	9.14	m/s	4.00	100.00	
139	Total Cooling Water Pipe (open loop)	7.00	fps	2.13	m/s	8.00	200.00	
140	Individual Skid Cooling Water Pipe (open loop)	7.00	fps	2.13	m/s	6.00	150.00	
141	Total Cooling Water Pipe (closed loop)	7.00	fps	2.13	m/s	12.00	300.00	
142	Individual Generator Cooling Water Pipe (closed loop)	7.00	fps	2.13	m/s	8.00	200.00	
143	Individual PSU Cooling Water Pipe (closed loop)	7.00	fps	2.13	m/s	1.50	40.00	
144								
145	**Mechanical Material Requirements:** **Note to User: Only piping, valves, and fittings outside of Ozone Supplier Skids are summarized below.**							

	B	C	D	E	F	G	H	I
146	Pipe Name	Pipe ID	Installation Type	Pipe Material	Pipe Lining Material	Pipe Coating Material	Comments	Red Flags
147	Influent Pipe	OZI	Buried	Steel	Cement Mortar	Cement Mortar		
148	Effluent Pipe	OZW	Buried	Steel	Cement Mortar	Cement Mortar		
149	Overflow Pipe	OF	Buried	Steel	Cement Mortar	Cement Mortar		
150	LOX Pipe	LOX	Exposed	Copper	NA	NA		
151	Total GOX Pipe Upstream of PRV	GOX	Exposed	304 SST	NA	NA		
152	Total GOX Pipe Downstream of PRV	GOX	Exposed	316 SST	NA	NA		
153	Individual GOX Pipe Downstream of PRV	GOX	Exposed	316 SST	NA	NA		
154	Header Ozone Gas PIpe	O3	Exposed	316 SST	NA	NA		
155	Individual Ozone Generator Gas Pipe	O3	Exposed	316 SST	NA	NA		
156	Individual Ozone Contactor Gas Pipe	O3	Exposed	316 SST	NA	NA		
157	Nitrogen	N2	Exposed	Copper	NA	NA		
158	Ozone Off-Gas Pipe per Train	OZG	Exposed	316 SST	NA	NA		
159	Ozone Off-Gas Pipe Combined	OZG	Exposed	316 SST	NA	NA		
160	Ozone Off-Gas Pipe per Destruct Unit	OZG	Exposed	316 SST	NA	NA		
161	Total Cooling Water Pipe (open loop)	CWS/CWR	Buried	Steel	Cement Mortar	Cement Mortar		
162	Individual Skid Cooling Water Pipe (open loop)	CWS/CWR	Exposed	Steel	Cement Mortar	Cement Mortar		
163	Total Cooling Water Pipe (closed loop)	GCWS/GCWR	Exposed	304 SST	NA	NA		
164	Individual Generator Cooling Water Pipe (closed loop)	GCWS/GCWR	Exposed	304 SST	NA	NA		
165	Individual PSU Cooling Water Pipe (closed loop)	GCWS/GCWR	Exposed	304 SST	NA	NA		
166								
167	Electrical User Inputs and Sizing Requirements:							
168	50.) Is this a "Critical" Facility (requiring standby power)?	Yes	Y/N					
169	51.) Is there SWGR?	No						
170								
171	Electrical Equipment Lengths:							MCC
172	Item	Quantity	HP per Each	AFD's Required?	MCC Spaces for Motor Starters	MCC Spaces for AFD's less than 50hp)	MCC Spaces for Breakers	Total MCC Spaces
173	Ozone Generators/Destruct (Active)	2.00	525.99	No	24.00	0.00	0.00	
174	Ozone Generators/Destruct (Standby)	1.00	525.99	No	12.00	0.00	0.00	
175	Cooling Water Pumps (Active)	2.00	6.49	No	4.00	0.00	0.00	
176	Cooling Water Pumps (Standby)	1.00	6.49	No	2.00	0.00	0.00	
177	TOTAL		1597.46		42.00	0.00	0.00	42.00
178								
179	Electrical Equipment Widths:							
180	Equipment	Depth (ft)						
181	MCC	1.67						
182	Small AFD's	0.00						
183	Large AFD's	0.00						
184	Switchgear	0.00						
185	Maximum Depth	1.67						
186								
187	Clear Distances:							
188	Clear Distance	Width	Length	Comment				
189	CD1		3.00	Clear Distance between wall and MCC	Typically 3 feet			
190	CD2		1.00	Clear Distance between MCC and Small AFD	Typically 1 foot			
191	CD3		0.00	Clear Distance between Small AFD and Large AFD	Typically Zero			
192	CD4		0.00	Clear Distance between Large AFD and Switchgear	Typically Zero			
193	CD5		0.00	Clear Distance between Switchgear and Contingency Space	Typically Zero			
194	CD6	4.00		Clear Distance behind Switchgear (If there is no Switchgear, this distance will be Zero)				
195	CD7	3.00		Clear Distance in front of Equipment	Tyipcally 3 feet			
196	Contingency Length		0.00	Contingency length	Typically Zero			
197								
198	Electric Room Length (ft):							
199	CD1	3.00						
200	MCC	16.67						
201	CD2	1.00						
202	Small AFD's	0.00						
203	CD3	0.00						
204	Large AFD's	0.00						
205	CD4	0.00						
206	Swithgear	0.00						
207	CD5	0.00						
208	Contingency	0.00						
209	Total Length	20.67						
210								
211	Electric Room Width (ft):							
212	CD6	0.00	If there is no switchgear, this distance will be Zero.					
213	Maximum Equipment Depth	1.67						
214	CD7	3.00						
215	Total Width	4.67						
216								
217	Estimating Dimensions:	Value English	Unit (English)	Value (Metric)	Unit (Metric)	Name	Comment	Red Flags
218	Ozone Contactor Facility:							
219	Basin Width	98.11	ft	29902.68	mm	Total BW		
220	Basin Length	119.09	ft	36299.41	mm	BL		

	B	C	D	E	F	G	H	I
221	Basin Divider Wall Length	106.09	ft	32337.01	mm			
222	Walls							
223	Perimeter and Divider Wall Height (Walls 11, 12, 13, 14) (SWD + FB)	23.00	ft	7010.40	mm	PDWH		
224	Wall 1 Height (SWD)	20.00	ft	6096.00	mm	CIWH-1		
225	Wall 2 Height (SWD - 3)	17.00	ft	5181.60	mm	CIWH-2		
226	Wall 3 Height (SWD + FB - 4)	19.00	ft	5791.20	mm	CIWH-3		
227	Wall 4 Height (SWD - 3)	17.00	ft	5181.60	mm	CIWH-4		
228	Wall 5 Height (SWD + FB)	23.00	ft	7010.40	mm	CIWH-5		
229	Wall 6 Height (SWD + FB)	23.00	ft	7010.40	mm	CIWH-6		
230	Wall 7 Height (SWD + FB)	23.00	ft	7010.40	mm	CIWH-7		
231	Wall 8 Height (SWD + FB)	23.00	ft	7010.40	mm	CIWH-8		
232	Wall 9 Height (SWD + FB)	23.00	ft	7010.40	mm	CIWH-9		
233	Wall 10 Height (SWD + FB)	23.00	ft	7010.40	mm	CIWH-10		
234	Wall 15 Height (SWD - WH)	18.05	ft	5500.93	mm	CIWH-15		
235	Perimeter Wall Thickness (Walls 11, 12, 13)	**1.50**	ft	**457.20**	mm	WPT	Model based on 1.5'	
236	Wall 1 Thickness	**1.00**	ft	**304.80**	mm	W1T		
237	Wall 2 Thickness	**1.33**	ft	**405.38**	mm	W2T	Model based on 1.33'	
238	Wall 3 Thickness	**1.17**	ft	**356.62**	mm	W3T	Model based on 1.17'	
239	Wall 4 Thickness	**1.33**	ft	**405.38**	mm	W4T	Model based on 1.33'	
240	Wall 5 Thickness	**1.17**	ft	**356.62**	mm	W5T	Model based on 1.17'	
241	Wall 6 Thickness	**1.33**	ft	**405.38**	mm	W6T	Model based on 1.33'	
242	Wall 7 Thickness	**1.17**	ft	**356.62**	mm	W7T	Model based on 1.17'	
243	Wall 8 Thickness	**1.33**	ft	**405.38**	mm	W8T	Model based on 1.33'	
244	Wall 9 Thickness	**1.00**	ft	**304.80**	mm	W9T		
245	Wall 10 Thickness	**1.00**	ft	**304.80**	mm	W10T		
246	Wall 15 Thickness	**1.17**	ft	**356.62**	mm	W15T	Model based on 1.17'	
247	Contactor Divider Walls 14 Thickness	**1.33**	ft	**405.38**	mm	W14T	Model based on 1.33'	
248	Wall 1 Length	22.78	ft	6943.03	mm	W1L		
249	Wall 2 Length	22.78	ft	6943.03	mm	W2L		
250	Wall 3 Length	22.78	ft	6943.03	mm	W3L		
251	Wall 4 Length	22.78	ft	6943.03	mm	W4L		
252	Wall 5 Length (ft)	54.57	ft	16633.83	mm	W5L		
253	Wall 6 Length (ft)	38.61	ft	11767.40	mm	W6L		
254	Wall 7 Length	38.61	ft	11767.40	mm	W7L		
255	Wall 8 Length	38.61	ft	11767.40	mm	W8L		
256	Wall 9 Length	38.61	ft	11767.40	mm	W9L		
257	Wall 10 Length	38.61	ft	11767.40	mm	W10L		
258	Wall 15 Length	6.81	ft	2076.60	mm	W15L		
259	Slab on Grade							
260	Slab on Grade Width	102.11	ft	31121.88	mm			
261	Slab on Grade Length	123.09	ft	37518.61	mm			
262	Slab on Grade Thickness	**18.00**	in	**457.20**	mm		Model based on 18"	
263	Slab on Grade Thickness	1.50	ft	457.20	mm	SOGT		
264	Elevated Slab							
265	Elevated Slab Thickness	**12.00**	in	**304.80**	mm		Model based on 12"	
266	Elevated Slab Thickness	1.00	ft	304.80	mm	ESLBT		
267	Excavation							
268	Excavation Width	106.11	ft	32341.08	mm			
269	Excavation Length	127.09	ft	38737.81	mm			
270	Excavation Depth	12.50	ft	3810.00	mm			
271								
272	Ozone Generator Building:							
273	Ozone Generator Width	**8.00**	ft	**2,438.40**	mm	WOG	Model is based on 8'	
274	Ozone Generator Length	**16.00**	ft	**4,876.80**	mm	LOG	Model is based on 16'	
275	Clear Distance Around Ozone Generators	**10.00**	ft	**3,048.00**	mm	CDG	Model is based on 10'	
276	Number of Ozone Generators	3.00		3.00			Input	
277	Closed Loop Cooling Skid Length	**10.00**	ft	**3,048.00**	mm	LOC	Model is based on 10'	
278	Closed Loop Cooling Skid Width	**8.00**	ft	**2,438.40**	mm	WOC	Model is based on 8'	
279	Wall Height	12.50	ft	3810.00	mm			
280	Building Width	64.00	ft	19507.20	mm	GBW		
281	Building Length	56.00	ft	17068.80	mm	GBL		
282	Building Area	3584.00	sf	332.96	m2			
283	Slab on Grade Thickness	**12.00**	in	**304.80**	mm		Model based on 12"	
284	Slab on Grade Thickness	1.00	ft	304.80	mm	TGB		
285	Excavation							
286	Excavation Width	68.00	ft	20726.40	mm			
287	Excavation Length	60.00	ft	18288.00	mm			
288	Excavation Depth	2.00	ft	609.60	mm			
289								
290	**Ozone Destruct Room (attached to Ozone Generation Building):**							
291	Width	20.00	ft	6096.00	mm	DBW	Fixed	
292	Length	60.00	ft	18288.00	mm	DBL		
293	Height	12.50	ft	3810.00	mm		Fixed	
294	Slab on Grade Thickness	12.00	in	304.80	mm		Model based on 12"	
295	Slab on Grade Thickness	1.00	ft	304.80	mm			
296	Indoor Ozone Destruct Building Area	1200.00	sf	111.48	m2			
297	Excavation							
298	Excavation Width	24.00	ft	7315.20	mm			
299	Excavation Length	64.00	ft	19507.20	mm			
300	Excavation Depth	2.00	ft	609.60	mm			
301								
302	**Electrical Room (in Ozone Generation Building:**							
303	Width	4.67	ft	1422.40	mm	ERW	Fixed	
304	Length	20.67	ft	6299.20	mm	ERL		

	B	C	D	E	F	G	H	I
305	Height	12.50	ft	3810.00	mm		Fixed	
306	Slab on Grade Thickness	12.00	in	304.80	mm		Model based on 12"	
307	Slab on Grade Thickness	1.00	ft	304.80	mm			
308	Indoor Electrical Room Area	96.44	sf	8.96	m2			
309	Excavation							
310	Excavation Width	8.67	ft	2641.60	mm			
311	Excavation Length	24.67	ft	7518.40	mm			
312	Excavation Depth	2.00	ft	609.60	mm			
313								
314	**Outdoor Ozone Destruct Pad:**							
315	Width	0.00	ft	0.00	mm	DBW	Fixed	
316	Length	0.00	ft	0.00	mm	DBL		
317	Slab on Grade Thickness	**12.00**	in	**304.80**	mm		Model based on 12"	
318	Slab on Grade Thickness	0.00	ft	0.00	mm	SOG2		
319								
320	LOX Tank Pad: Horizontal Tanks							
321	Clear Distance Around Tanks	**6.00**	ft	**1,828.80**	mm	CDT	Model is based on 6'	
322	LOX Vaporizer Length & Clear Distance	**14.00**	ft	**4,267.20**	mm		Model is based on 14'	
323	Width	60.00	ft	18288.00	mm	LPW		
324	Length	75.74	ft	23084.21	mm	LPL		
325	Area of Tank Pad	4544.14	sf	422.16	m2			
326	Allowance for Other Equipment (additional 10% area)	454.41	sf	42.22	m2			
327	Total Pad Area	4998.55	sf	464.38	m2			
328	Slab on Grade Thickness	**12.00**	in	**304.80**	mm		Model based on 12"	
329	Slab on Grade Thickness	1.00	ft	304.80	mm	TLOX		
330	Excavation							
331	Excavation Width	64.00	ft	19507.20	mm			
332	Excavation Length	79.74	ft	24303.41	mm			
333	Excavation Depth	2.00	ft	609.60	mm			
334								
335	**COST ESTIMATE**							
336	**Description**	**Quantity (English)**	**Unit (English)**	**Quantity (Metric)**	**Unit (Metric)**	**$/Unit**	**Total Cost**	**User Over-Write**
337								
338	SITEWORK:							
339	Ozone Generator Building							
340	Excavation	359.73	CY	275.03	m3	*$6.72*	$2,418	
341	Imported Structural Backfill	302.22	CY	231.07	m3	*$50.94*	$15,396	
342	Native Backfill	18.96	CY	14.50	m3	*$8.27*	$157	
343	Haul Excess	340.76	CY	260.53	m3	*$8.27*	$2,817	
344	Ozone Destruct Room							
345	Excavation	142.03	CY	108.59	m3	*$6.72*	$955	
346	Imported Structural Backfill	113.78	CY	86.99	m3	*$50.94*	$5,796	
347	Native Backfill	13.04	CY	9.97	m3	*$8.27*	$108	
348	Haul Excess	129.00	CY	98.62	m3	*$8.27*	$1,066	
349	LOX Tank Pad							
350	Excavation	447.22	CY	341.92	m3	*$6.72*	$3,007	
351	Imported Structural Backfill	378.01	CY	289.01	m3	*$50.94*	$19,256	
352	Native Backfill	21.29	CY	16.28	m3	*$8.27*	$176	
353	Haul Excess	425.92	CY	325.64	m3	*$8.27*	$3,520	
354	Ozone Contactor							
355	Excavation	9259.57	CY	7079.45	m3	*$6.72*	$62,253	
356	Imported Structural Backfill	998.91	CY	763.72	m3	*$50.94*	$50,886	
357	Native Backfill	2024.29	CY	1547.68	m3	*$8.27*	$16,731	
358	Haul Excess	7235.28	CY	5531.77	m3	*$8.27*	$59,802	
359	Electrical Room							
360	Excavation	23.27	CY	17.79	m3	*$6.72*	$156	
361	Imported Structural Backfill	15.84	CY	12.11	m3	*$50.94*	$807	
362	Native Backfill	4.94	CY	3.78	m3	*$8.27*	$41	
363	Haul Excess	18.33	CY	14.01	m3	*$8.27*	$151	
364	Allowance for Misc Items	5%				$245,498.74	$12,275	
365	Subtotal						$257,774	
366								
367	CONCRETE:							
368	Contactor Basin:							
369	Foundation	698.25	CY	533.85	m3	*$541.11*	$377,826	
370	Perimeter Walls	555.06	CY	424.38	m3	*$880.79*	$488,895	
371	Divider Wall	360.60	CY	275.70	m3	*$880.79*	$317,611	
372	Wall 1	67.49	CY	51.60	m3	*$880.79*	$59,448	
373	Wall 2	76.30	CY	58.34	m3	*$880.79*	$67,206	
374	Wall 3	75.02	CY	57.36	m3	*$880.79*	$66,076	
375	Wall 4	76.30	CY	58.34	m3	*$880.79*	$67,206	
376	Wall 5	217.56	CY	166.34	m3	*$880.79*	$191,629	
377	Wall 6	174.96	CY	133.77	m3	*$880.79*	$154,104	
378	Wall 7	0.00	CY	0.00	m3	*$880.79*	$0	
379	Wall 8	0.00	CY	0.00	m3	*$880.79*	$0	
380	Wall 9	0.00	CY	0.00	m3	*$880.79*	$0	
381	Wall 10	0.00	CY	0.00	m3	*$880.79*	$0	
382	Wall 15	21.31	CY	16.29	m3	*$880.79*	$18,772	
383	Elevated Roof Slab	432.73	CY	330.85	m3	*$1,333.77*	$577,159	
384								
385	Ozone Destruct Pad:							
386	Slab on Grade	44.44	CY	33.98	m3	*$490.62*	$21,805	
387	Ozone Generator Building:							
388	Slab on Grade	132.74	CY	101.49	m3	*$490.62*	$65,125	
389	Electrical Room:							
390	Slab on Grade	3.57	CY	2.73	m3	*$490.62*	$1,752	
391	LOX Tank and Vaporizer Pad:							
392	Slab on Grade	185.13	CY	141.54	m3	*$490.62*	$90,828	
393								
394	Allowance for Misc Items	5%				$2,565,443.84	$128,272	
395	Subtotal						$2,693,716	
396								

	B	C	D	E	F	G	H	I
397	MASONRY:	High						
398	Ozone Generator/ Building (incl Elec Room)	3680.44	SF	341.92	m2	*$198.37*	$730,078	
399	Ozone Destruct Building	1200.00	SF	111.48	m2	*$198.37*	$238,040	
400	Subtotal	4880.44					$968,119	
401								
402	METALS:							
403	Handrail	490.40	LF	149.47	m	*$90.92*	$44,586	
404	Perforated Plate in Inlet Cell	618.89	SF	57.50	m2	*$108.25*	$66,998	
405	Perforated Plates in Serpentine Cells	1090.08	SF	101.27	m2	*$108.25*	$118,006	
406	3' x 3' SS Air Tight Checker Plate Covers Over Inlet Cells	8.00	EA			*$1,798.69*	$14,390	
407	3' x 3' SS Air Tight Checker Plate Covers Over Contactor Cells	12.00	EA			*$1,798.69*	$21,584	
408	Ladder	20.00	EA			*$1,915.27*	$38,305	
409	Stairway	78	Risers			*$495.92*	$38,682	
410	Allowance for Misc Items	10%				$342,550.71	$34,255	
411	Subtotal						$376,806	
412								
413	EQUIPMENT:							**Budgetary Quote: (CPES will automatically add Installation Factor)**
414	Ozone System (Including Ozone Generators, Diffusion System, Instrumentation & Valves, Ozone Destruct Units, and Cooling System for Closed Loop System)	6008.69	lb/d	2725.50	kg/d	***$1,810.82***	$10,880,670	
415	LOX Tanks and Vaporizers	126233	gal	477843.67	L	***$44.62***	$5,632,532	
416	Cooling Pumps for Open Loop Cooling System (Note: Cooling Pumps are included in OSS scope for Closed Loop system) (9.72 hp each)	4	EA			***$15,753.71***	$63,015	
417	Gates at Inlet	4	EA			***$9,614.74***	$38,459	
418	Gates at Outlet	4	EA			***$9,614.74***	$38,459	
419	Allowance for Misc Items	10%				$16,653,135.35	$1,665,314	
420	Subtotal						$18,318,449	
421								
422	INSTRUMENTS & CONTROLS:							
423	Instruments							
424	Inlet and Outlet Isolation Gate Actuator	8	EA			***$6,409.82***	$51,279	
425	Level Transmitters	4	EA			***$11,264.12***	$45,056	
426	Open Loop Cooling Water Flowmeters	1	EA			***$6,954.43***	$6,954	
427	Ozone Residual Analyzers	8	EA			***$6,954.43***	$55,635	
428	Pressure Transmitters (LOX)	3	EA					
429	Level Transmitters (LOX)	3	EA					
430	Isolation Valve Actuators (LOX)	3	EA					
431	Isolation Valve Actuators (GOX)	4	EA					
432	Control Valve Actuators (GOX)	3	EA					
433	Temperature Transmitters (GOX)	4	EA					
434	Pressure Transmitters (GOX)	1	EA					
435	Dewpoint Analyzers (GOX)	1	EA					
436	Flowmeter (GOX)	3	EA					
437	Dewpoint Analyzers (Nitrogen)	1	EA					
438	Nitrogen Compressor	2	EA					
439	Control Valve Actuators (Nitrogen)	1	EA					
440	Pressure Transmitters (Nitrogen)	1	EA					
441	Temperature Transmitters (Ozone)	3	EA					
442	Isolation Valve Actuators (Ozone)	3	EA					
443	Ozone Concentration Analyzers (Ozone)	3	EA					
444	Flowmeter (Ozone)	4	EA					
445	Control Valve Actuators (Ozone)	4	EA					
446	Ozone Concentration Analyzers (Off-gas)	6	EA					
447	Control Valve Actuators (Off-gas)	5	EA					
448	Isolation Valve Actuators (Off-gas)	5	EA					
449	Temperature Transmitters (Off-gas)	10	EA					
450	Pressure Differential Transmitters (Off-gas)	5	EA					
451	Destruct Blower	5	EA					
452	Closed Loop Cooling Water Pumps	3	EA					
453	Isolation Valve Actuators (Closed Loop Cooling)	6	EA					
454	Temperature Transmitters (Closed Loop Cooling)	6	EA					
455	Flowmeters (Closed Loop Cooling)	6	EA					
456	Ambient Ozone Analyzers	2	EA					
457	Ambient Oxygen Analyzers	1	EA					
458	Number of Analog I/O Counts	178	EA			***$264.27***	$46,934	
459	Number of Digital I/O Counts	198	EA			***$62.59***	$12,393	
460	Number of Local Panels	1	EA			***$13,074.33***	$13,074	

	B	C	D	E	F	G	H	I
461	Number of PLC's	1	EA					
462	I&C Conduit & Wire	8,745	LF	2665.57	m	$12.06	$105,460	
463	Allowance for Misc Items	5%				$336,785.64	$16,839	
464	Subtotal						$353,625	
465								
466	MECHANICAL:							
467	Pipe:							
468	Influent Pipe-OZI (48-inch, Buried, Steel)	0.00	LF	0.00	m	$1,004.58	$0	
469	Effluent Pipe-OZW (48-inch, Buried, Steel)	0.00	LF	0.00	m	$1,004.58	$0	
470	Overflow Pipe-OF (96-inch, Buried, Steel)	0.00	LF	0.00	m	$2,009.15	$0	
471	LOX Pipe-LOX (1.5-inch, Exposed, Copper)	114.00	LF	34.75	m	$105.58	$12,036	
472	Total GOX Pipe Upstream of PRV-GOX (3-inch, Exposed, 304 SST)	62.00	LF	18.90	m	$109.49	$6,789	
473	Total GOX Pipe Downstream of PRV-GOX (6-inch, Exposed, 316 SST)	123.00	LF	37.49	m	$215.04	$26,450	
474	Individual GOX Pipe Downstream of PRV-GOX (4-inch, Exposed, 316 SST)	99.00	LF	30.18	m	$143.36	$14,193	
475	Header Ozone Gas PIpe-O3 (1-inch, Exposed, 316 SST)	51.00	LF	15.54	m	$35.84	$1,828	
476	Individual Ozone Generator Gas Pipe-O3 (6-inch, Exposed, 316 SST)	153.00	LF	46.63	m	$215.04	$32,901	
477	Individual Ozone Contactor Gas Pipe-O3 (4-inch, Exposed, 316 SST)	620.00	LF	188.98	m	$143.36	$88,884	
478	Nitrogen-N2 (3-inch, Exposed, Copper)	36.00	LF	10.97	m	$211.16	$7,602	
479	Ozone Off-Gas Pipe per Train-OZG (4-inch, Exposed, 316 SST)	200.00	LF	60.96	m	$143.36	$28,672	
480	Ozone Off-Gas Pipe Combined-OZG (8-inch, Exposed, 316 SST)	10.00	LF	3.05	m	$286.72	$2,867	
481	Ozone Off-Gas Pipe per Destruct Unit-OZG (4-inch, Exposed, 316 SST)	75.00	LF	22.86	m	$143.36	$10,752	
482	Total Cooling Water Pipe (open loop)-CWS/CWR (8-inch, Buried, Steel)	276.11	LF	84.16	m	$167.43	$46,228	
483	Individual Skid Cooling Water Pipe (open loop)-CWS/CWR (6-inch, Exposed, Steel)	70.00	LF	21.34	m	$125.57	$8,790	
484	Total Cooling Water Pipe (closed loop)-GCWS/GCWR (12-inch, Exposed, 304 SST)	88.00	LF	26.82	m	$437.98	$38,542	
485	Individual Generator Cooling Water Pipe (closed loop)-GCWS/GCWR (8-inch, Exposed, 304 SST)	123.00	LF	37.49	m	$291.99	$35,914	
486	Individual PSU Cooling Water Pipe (closed loop)-GCWS/GCWR (1.5-inch, Exposed, 304 SST)	108.00	LF	32.92	m	$54.75	$5,913	
487	Elbows							
488	LOX Pipe-LOX (1.5-inch, Exposed, Copper)	30.00	EA			$284.26	$8,528	
489	Total GOX Pipe Upstream of PRV-GOX (3-inch, Exposed, 304 SST)	3.00	EA			$568.52	$1,706	
490	Total GOX Pipe Downstream of PRV-GOX (6-inch, Exposed, 316 SST)	10.00	EA			$1,268.32	$12,683	
491	Individual GOX Pipe Downstream of PRV-GOX (4-inch, Exposed, 316 SST)	3.00	EA			$845.55	$2,537	
492	Header Ozone Gas PIpe-O3 (1-inch, Exposed, 316 SST)	1.00	EA			$211.39	$211	
493	Individual Ozone Generator Gas Pipe-O3 (6-inch, Exposed, 316 SST)	3.00	EA			$1,268.32	$3,805	
494	Individual Ozone Contactor Gas Pipe-O3 (4-inch, Exposed, 316 SST)	20.00	EA			$845.55	$16,911	
495	Nitrogen-N2 (3-inch, Exposed, Copper)	2.00	EA			$568.52	$1,137	
496	Ozone Off-Gas Pipe per Train-OZG (4-inch, Exposed, 316 SST)	12.00	EA			$845.55	$10,147	
497	Ozone Off-Gas Pipe per Destruct Unit-OZG (4-inch, Exposed, 316 SST)	15.00	EA			$845.55	$12,683	
498	Total Cooling Water Pipe (open loop)-CWS/CWR (8-inch, Buried, Steel)	2.00	EA			$1,113.60	$2,227	
499	Individual Skid Cooling Water Pipe (open loop)-CWS/CWR (6-inch, Exposed, Steel)	3.00	EA			$835.20	$2,506	
500	Individual Generator Cooling Water Pipe (closed loop)-GCWS/GCWR (8-inch, Exposed, 304 SST)	12.00	EA			$1,516.07	$18,193	
501	Individual PSU Cooling Water Pipe (closed loop)-GCWS/GCWR (1.5-inch, Exposed, 304 SST)	12.00	EA			$284.26	$3,411	
502	Tees							
503	LOX Pipe-LOX (1.5-inch, Exposed, Copper)	3.00	EA			$398.57	$1,196	
504	Total GOX Pipe Upstream of PRV-GOX (3-inch, Exposed, 304 SST)	4.00	EA			$797.14	$3,189	
505	Total GOX Pipe Downstream of PRV-GOX (6-inch, Exposed, 316 SST)	5.00	EA			$1,762.53	$8,813	
506	Header Ozone Gas PIpe-O3 (1-inch, Exposed, 316 SST)	7.00	EA			$293.76	$2,056	
507	Ozone Off-Gas Pipe Combined-OZG (8-inch, Exposed, 316 SST)	9.00	EA			$2,350.04	$21,150	
508	Total Cooling Water Pipe (open loop)-CWS/CWR (8-inch, Buried, Steel)	4.00	EA			$2,537.20	$10,149	
509	Total Cooling Water Pipe (closed loop)-GCWS/GCWR (12-inch, Exposed, 304 SST)	12.00	EA			$3,188.58	$38,263	
510	Individual Generator Cooling Water Pipe (closed loop)-GCWS/GCWR (8-inch, Exposed, 304 SST)	6.00	EA			$2,125.72	$12,754	
511	Crosses							
512	End Caps							
513	Valves							
514	Total Cooling Water Pipe (open loop)-CWS/CWR (8-inch, Buried, Steel)	8.00	EA			$8,144.58	$65,157	
515	Wall Pipes:							
516	Influent Pipe-OZI (48-inch, Buried, Steel)	4.00	EA			$10,045.76	$40,183	
517	Effluent Pipe-OZW (48-inch, Buried, Steel)	4.00	EA			$10,045.76	$40,183	
518	Overflow Pipe-OF (96-inch, Buried, Steel)	1.00	EA			$20,091.51	$20,092	
519	Total GOX Pipe Downstream of PRV-GOX (6-inch, Exposed, 316 SST)	1.00	EA			$2,150.42	$2,150	
520	Individual Ozone Contactor Gas Pipe-O3 (4-inch, Exposed, 316 SST)	4.00	EA			$1,433.61	$5,734	
521	Ozone Off-Gas Pipe Combined-OZG (8-inch, Exposed, 316 SST)	1.00	EA			$2,867.23	$2,867	

	B	C	D	E	F	G	H	I
522	Total Cooling Water Pipe (open loop)-CWS/CWR (8-inch, Buried, Steel)	1.00	EA			*$1,674.29*	$1,674	
523	Allowance for Misc Items	10%				$740,656.30	$74,066	
524	Subtotal						$814,722	
525								
526	ELECTRICAL:							
527	# MCC Sections	10.00	EA			***$10,730.27***	$107,303	
528	Switchgear	0.00	EA			***$49,359.23***	$0	
529	Adjustable Frequency Drives							
530	Ozone Generators/Destruct (Active) (526 hp each)	0.00	EA			***$77,840.33***	$0	
531	Ozone Generators/Destruct (Standby) (526 hp each)	0.00	EA			***$77,840.33***	$0	
532	Cooling Water Pumps (Active) (6 hp each)	0.00	EA			***$9,717.06***	$0	
533	Cooling Water Pumps (Standby) (6 hp each)	0.00	EA			***$9,717.06***	$0	
534	Electrical Conduit & Wire	714.56	LF	217.80	m	*$12.06*	$8,617	
535	Allowance for Misc Items	10%				$115,919.49	$11,592	
536	Subtotal						$127,511	
537								
538	**USER DEFINED ESTIMATE ITEMS:**	**QUANT (ENGLISH)**	**UNIT (ENGLISH)**	**QUANT (METRIC)**	**UNIT (METRIC)**	**$/UNIT**	**TOTAL COST**	
539	Item 1 Description	0.00		0.00		0.00	$0	
540	Item 2 Description	0.00		0.00		0.00	$0	
541	Item 3 Description	0.00		0.00		0.00	$0	
542	Item 4 Description	0.00		0.00		0.00	$0	
543	Item 5 Description	0.00		0.00		0.00	$0	
544	Item 6 Description	0.00		0.00		0.00	$0	
545	Item 7 Description	0.00		0.00		0.00	$0	
546	Item 8 Description	0.00		0.00		0.00	$0	
547	Item 9 Description	0.00		0.00		0.00	$0	
548	Item 10 Description	0.00		0.00		0.00	$0	
549	Item 11 Description	0.00		0.00		0.00	$0	
550	Item 12 Description	0.00		0.00		0.00	$0	
551	Item 13 Description	0.00		0.00		0.00	$0	
552	Item 14 Description	0.00		0.00		0.00	$0	
553	Item 15 Description	0.00		0.00		0.00	$0	
554	Subtotal						$0	
555								
556	Subtotal						$23,910,721	
557								
558	ALLOWANCES:		**User Override**					
559	Finishes Allowance	2.00%		$25,989,914	$519,798.29			
560	I&C Allowance	2.00%		$25,989,914.37	$519,798.29			
561	Mechanical Allowance	2.00%		$25,989,914.37	$519,798.29			
562	Electrical Allowance	2.00%		$25,989,914.37	$519,798.29			
563								
564	**Facility Cost**	**4,006**	**lb/d Ozone**	**$6,488**	**$25,989,914**			
565	**Facility Cost with Standard Additional Project Costs Added**	**4,006**	**lb/d Ozone**	**$7,884**	**$31,582,164**			
566	**Facility Cost with Standard Additional Project Costs and Contractor Markups Added**	**4,006**	**lb/d Ozone**	**$13,523**	**$54,169,062**			
567	**Facility Cost, Contractor Markups, and Location Adjustment Factor Added (excluding ALL Additional Project Costs)**	**4,006**	**lb/d Ozone**	**$11,128**	**$44,577,354**			
568	**Facility Cost with Standard Additional Project Costs, Contractor Markups, and Location Adjustment Factor Added**	**4,006**	**lb/d Ozone**	**$13,523**	**$54,169,062**			

	B	C	D	E	F	G	H	I
1	***Filters***							
2								
3	**Is This Facility Included in My Project? Yes**							
4	Assumptions:							
5								
6	Based on Denver Water Reuse Project							
7	2 Basins @ 15 MGD each							
8	***If this is a Seawater Desalination Application, the materials in contact with seawater need to be corrosion resistant.***							
9	FILTER PARAMETRIC DESIGN APPROACH							
10	BASIS: DENVER REUSE PLANT, HDPE DUAL LATERAL UNDERDRAIN WITH MEDIA SUPPORT CAP, FRONT FLUME, & CONSTANT EFFLUENT FLOW CONTROL							
11								
12								
13	**Process User Inputs:**	**Value (English)**	**Unit (English)**	**Value (Metric)**	**Unit (Metric)**	**Name**	**Red Flags**	**Comment**
14	Is this a Seawater Desalination Application?	**No**	Y/N					
15	Has the USER Contacted Equipment Suppliers to Obtain Equipment Quotes?	**No**	Y/N				Fixed	
16	Input Filtration System Maximum Design Flow Rate	**160.00**	mgd	**605.67**	ML/d	Q		
17	Input Filtration System Minimum Design Flow Rate	**30.00**	mgd	**113.56**	ML/d			
18	Select HDPE Underdrain System Type	**LS**	Type			UT		LSL = Leopold Type SL; LS = Leopold Type S; TLP = Tetra Type LP; NP = IDI or GF Nozzle/Plenum Type
19	Calculate Underdrain Profile Depth	1.08	ft	329.18	mm	UPD		LSL = 0.67 ft; LS = 1.08 ft; TLP = 0.75 ft; NP = 2.5625.
20	Input Bottom Media Effective Size	**0.55**	mm			BMES		
21	Input Bottom Media Uniformity Coefficient	**1.40**	#			BMUC		
22	Input Bottom Media Depth	**12.00**	in	**304.80**	mm	BMD		
23	Select Bottom Media Material	**Sand**	Type					
24	Input Middle Media Effective Size	**1.10**	mm			MMES		
25	Input Middle Media Uniformity Coefficient	**1.50**	#			MMUC		
26	Input Middle Media Depth	**0.00**	in	**0.00**	mm	MMD		
27	Select Middle Media Material	**Anthracite**	Type					
28	Input Top Media Effective Size	**1.10**	mm			TMES		
29	Input Top Media Uniformity Coefficient	**1.50**	#			TMUC		
30	Input Top Media Depth	**60.00**	in	**1,524.00**	mm	TMD		
31	Select Top Media Material	**Anthracite**	Type					
32	Calculate Total Media Depth	6.00	ft	1828.80	mm	MD		
33	Input GAC Replacement Frequency, if Applicable (number per year)	**0.00**	#					
34	Input GAC Apparent Density (Bulk Density), if Applicable	**29.00**	lb/cf	**464.54**	kg/m3			Typically about 29 lb/cf for most GAC products.
35	Input Maximum Design Filtration Hydraulic Loading Rate	**6.00**	gpm/sf	**14.67**	m/h	FHLR		Typical Range: 3 - 10 gpm/sf
36	Input Minimum Design Filtration Hydraulic Loading Rate	**2.00**	gpm/sf	**4.89**	m/h			
37	Calculate Active Filter Area	18,518.52	sf	1720.43	m2	AFA		
38	Calculate Emtpy Bed Contact Time at Maximum Design Filtration Hydraulic Loading Rage	7.48	min			EBCT		
39	Calculate Emtpy Bed Contact Time at Minimum Design Filtration Hydraulic Loading Rage	39.90	min			EBCT		
40	Input Number of Active Filters with Maximum Design Flow Rate	**20**	#			#AF		Typical Range: ≥ 3.
41	Calculate Individual Filter Area	925.93	sf	86.02	m2	IFA		
42	Calculate Individual Filter Dimension in Direction of Underdrain Lateral	24.83	ft	7569.20	mm	IFW		For Leopold Type SL (LSL), IFW < 16 ft; For Leopold Type S (LS), IFW < 48 ft; For Tetra Type LP (TLP), IFW < 30 ft.
43	Optionial: Input Individual Filter Dimension in Direction of Underdrain Lateral (overwrites above calculation)		ft		mm			Only enter override value when matching existing conditions or accomodating site constraints.
44	Calculate Individual Filter Dimension Perpendicular to Underdrain Lateral	37.25	ft	11353.80	mm	IFL		
45	Input Number of Standby Filters with Maximum Design Flow Rate	**2**	#			#SF		Typically 1 minimum
46	Calculate Total Number of Filters	22	#			#TF		Should be even number. If not, add active or standby filter
47	Input Desired Filter Bed Expansion During Backwash	**25.00%**				BEX		Typically 20-30%.
48	Calculate Media Expansion Depth	1.20	ft	365.76	mm	EXD		
49	Input Maximum Water Temperature	77.00	degrees F	**25.00**	degrees C	MWT		
50	Input Maximum Backwash Supply Hydraulic Loading Rate	**25.00**	gpm/sf	**61.12**	m/h	BWSHLR		Calculate from CH2M Backwash Rate Program
51	Calculate Maximum Backwash Supply Flow Rate	33.30	mgd	126.06	ML/d	BWSFR		
52	Input Filter Media Clean Bed Head Loss at Maximum Design Filtration Hydraulic Loading Rate	**2.50**	ft	**762.00**	mm	CBH		Calculate from CH2M HILL Clean Bed Head Loss Program
53	Input Underdrain Head Loss at Maximum Design Filtration Hydraulic Loading Rate	**0.50**	ft	**152.40**	mm	UDH		Determine from CH2M HILL Filter Design Guide. Typically 1-foot

	B	C	D	E	F	G	H	I
54	Input Filter Effluent Piping Head Loss from Seal Weir Back to Filter Box with FE FCV 80% Open	1.50	ft	457.20	mm	FPH		Calculate from WinHydro. Typically 2 to 4 feet
55	Input Filter Influent/Backwash Wastewater Gullet Channel Width	5.00	ft	5.00	mm	GCW		Typically 4 ft. minimum for access
56	Input Filter Influent Channel / Backwash Wastewater Channel Width	5.00	ft	5.00	mm	FI/BWCW		Typically 4 ft. minimum for access
57	Calcualte Filter Influent Isolation Gate Width	42.00	in	1066.80	mm			Typically requires 9 inches of concrete on both sides of gate.
58	Calculate Number of Isolation Gates	2	#					
59	Input Distance from Bottom of Wash Trough to Top of Expanded Media	12.00	in	304.80	mm	DTM		Typically 3 inches minimum
60	Input % Area of Wash Trough Coverage per Filter	25.00%				WT%A		Typically 25%
61	Calculate Wash Trough Coverage per Filter = IFW * IFL * WT%A / 100	231.26	sf	21.48	m2	WTC		
62	Input Wash Trough Width	3.00	ft	914.40	mm	WTW		Typically 1.5 ft minimum
63	Select Wash Trough Type	Media Retaining	Type			WTYP		Conventional or Media Retaining Type
64	Calculate Number of Wash Troughs per Filter	3	#			#WT		
65	Calculate Depth of Wash Trough	2.24	ft	683.37	mm	WTD		Includes 0.25 feet freeboard and 0.25 feet trough bottom thickness
66	Calculate Distance Between Troughs	9.42	ft	2870.20	mm	DBT		Full Size Space between each trough, and Half Size Space between each end trough and wall.
67	Calculate Distance from Top of Media to Top of Trough	4.74	ft	1445.37	mm	TMTT		
68	Calculate Ratio Distance Between Troughs: Distance from Top of Media to Top of Trough	1.99	:1			RATIO		Typically between 1.0 to 2.0 (If error, change percent coverage or trough width)
69	Select Backwash Design Basis	Time	Type					Time = Based off backwash duration. Filter Box Volumes = Based off # of filter vessel volumes for BW cycle.
70	Input Backwash Duration	8.00	min					Typically 8 to 30 minutes.
71	Input Number of Filter Box Volumes per Backwash	3.00	#					Typically target at least 3 filter box volumes.
72	Calculate Typical Backwash Volume per Event	185,008.33	gal	700.33	m3			
73	Calculate Backwash Duration		min					Typically 8 to 30 minutes.
74	Calculate Number of Filter Box Volumes per Backwash	2.49	#				**Warning! Consider increasing BW duration.**	Typically target at least 3 filter box volumes.
75	Include Filter Drain-Down?	Yes	Y/N					
76	Calculate Filter Drain-Down Volume per Event	36,418.97	gal	137.86	m3			
77	Input Distance from Top of Wash Trough to Top of Gullet Channel Wall	4.00	ft	1,219.20	mm	DTG		Typically 0.5 to 6 feet
78	Input Terminal Filter Head Loss Build-Up	10.00	ft	3,048.00	mm	THL		Typically 8 to 12 feet, confirm with hydraulic analysis
79	Input Freeboard Above Operating Water Surface	2.00	ft	2.00	mm	FB		Typically 1 to 3 feet
80	Calculate Gullet Channel Height	15.82	ft	4822.55	mm	GCH		
81	Calculate Gullet Channel Fill Height	2.58	ft	786.38	mm	GCF		
82	Calculate Filter Box Depth Based on Filter Seal Weir Set at the Same Elevation as the Top of the Filter Underdrain	19.08	ft	5815.58	mm	FBD		Setting Seal Weir and Top of Underdrain at Same Elevation Assures No Negative Pressure & Filter Air Binding
83	Calculate Backwash Waste Channel Height	12.32	ft	3755.75	mm	BWWCH		
84	Calculate Backwash Waste Channel Fill Height	2.58	ft	786.38	mm	BWWCF		
85	Calculate Filter Influent Channel Height	5.76	ft	1755.03	mm	FICH		Assumes top of filter influent valve = top of gullet channel
86	Input Filter Seal Weir Head	1.50	ft	1.00	mm	SWH		Typically < 2 feet
87	Calculate Filter Seal Weir Length	40.47	ft	12334.13	mm	SWL		Typically Use Trough Style Weirs to Reduce Area of Seal Weir Box
88	Input Length of Each Seal Weir Trough	2.00	ft	10.00	mm	SWTL		Typically < 20 feet to avoid intermediate structural support
89	Calculate Number of Seal Weir Troughs	10	#			#SWT		
90	Input Seal Weir Trough Width	2.00	ft	609.60	mm	SWTW		Typically 1.5 ft minimum
91	Calculate Depth of Wash Trough	3.41	ft	1040.19	mm	SWTD		Includes 0.25 feet freeboard and 0.25 feet trough bottom thickness
92	Calculate Seal Weir Box Width	40.00	ft	12192.00	mm	SWBW		
93	Calculate Seal Weir Box Depth	24.41	ft	7440.99	mm	SWBD		
94	Calculate Filter Flume Depth Below Underdrain Floor	5.00	ft	1524.00	mm	FFD		
95	Input Clear Distance Between Filter Effluent Piping in Gallery for Access	12.00	ft	3,657.60	mm	GCD1		Typically 8 ft minimum
96	Input Clear Distance Between Filter Effluent Piping & Filter Box in Gallery for Access	4.00	ft	1,828.80	mm	GCD2		Typically 3 ft minimum
97	Input Clear Distance Between Filter Effluent Piping & Filter End Wall for Access	6.00	ft	6.00	mm	GCD3		Typically 6 ft minimum
98	Calculate Filter Gallery Width	34.80	ft	10608.06	mm	FGW		
99	Input Clear Distance Between Filter Effluent Piping & Gallery Floor	2.00	ft	609.60	mm	GCD4		Typically 1 to 3 feet
100	Include Filter to Waste?	Yes	Y/N					
101	Input Filter to Waste Duration	15.00	min					Typically 10 to 30 minutes
102	Calculate Filter to Waste Volume per Event	83,333.33	gal	315.45	m3			