BEFORE THE WASHINGTON

UTILITIES & TRANSPORTATION COMMISSION

WASHINGTON UTILITIES AND TRANSPORTATION COMMISSION,

Complainant,

v.

CASCADIA WATER, LLC

Respondent.

DOCKET UW-240151

**CROSS-EXAMINATION EXHIBIT OF MATTHEW J. ROWELL AND CULLEY J. LEHMAN
ON BEHALF OF THE
WASHINGTON STATE OFFICE OF THE ATTORNEY GENERAL
PUBLIC COUNSEL UNIT**

EXHIBIT MJR-CJL-__X

Cascadia Discovery Response to WCAW DR 47, Attachment 12
(W&B Waterworks 1 Project Report)

February 6, 2025

ARSENIC TREATMENT SYSTEM AND RESERVOIR DESIGN PROJECT REPORT

W&B WATERWORKS 1
PWS ID # 46670 3

Freeland, WA 98249

November 2022

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CERTIFICATE OF ENGINEER

Arsenic Treatment System and Reservoir Design for W&B Waterworks 1

The technical material and data contained within this report has been prepared by or under the direction of the following registered professional engineer(s), licensed in accordance with the laws of the State of Washington to practice in the State of Washington.

Exp: 04/20/2024

QUICK REFERENCE PROJECT INFORMATION

General Project Information

Water System Name	W&B Waterworks 1
Water System ID Number	46670 3
System Owner	Cascadia Water, LLC
Project Description	Storage Reservoir Design Pilot Testing Results and Arsenic Treatment System Design
Well Site	Island County Parcel R22922-370-5000
Sources	S01 – Well #1: DOE Tag: AGA932 S02 – Well #2: DOE Tag: AGA931 S03 – Well #3: DOE Tag: AGA930 S04 – Well #4: DOE Tag: AGA929
Reservoir and Pumphouse/Treatment Site	Island County Parcel R22922-376-5180
System Contact	Culley Lehman, General Manager, Cascadia Water
System Engineer	Jeff Tasoff, P.E. - Davido Consulting Group, Inc.

Project Summary

System Capacity	536 ERU (Q_i limiting factor)
SWI Approved Connections	521 ERU 478 ERUs W&B & 43 ERUs Del Bay
Proposed Storage	Reinforced Circular Concrete Reservoir (30' Diameter x 35' Tall) – 185,000-gallons
Treatment Objective	Iron and Manganese Removal
Proposed Treatment	225 gpm Oxidation/Filtration System
Reaction Vessels	(2) 30" diameter and 60" tall empty vessel contact tank (8) 30" diameter and 60" tall filters (4.91 ft^2 of surface area per filter)
Media	17.2 ft^3 (42" height) of AS-700 Series Filter Media per filter
Loading Rate	5.7 gpm/ft^2 of media surface area (28.1 gpm/filter)
Backwash Rate	137 gpm/filter (28 gpm/ft^2)
Filter Capacity	16 hours of filter runtime, 215,000 gallons (Well 4)
Proposed Sodium Hypochlorite Injection System	(2) 50- gallon polyethylene chemical storage tank Well 1, Well 2, and Well 3: LMI PD076-A40HI chemical injection pump, 4.5 ppm sodium hypochlorite dosing to achieve desired 1.0 ppm residual on outlet of treatment Well 4 LMI PD076-A40HI chemical injection pump, 5.4 ppm sodium hypochlorite dosing to achieve desired 1.0 ppm residual on outlet of treatment
Proposed Ferric Chloride Injection System	(1) 50- gallon polyethylene chemical storage tank Well 1, Well 2, and Well 3: LMI PD075-A30HI chemical injection pump, 1.5 ppm ferric chloride (equates to 0.51 ppm iron dosing) Well 4 LMI PD075-A30HI chemical injection pump, 2.2 ppm ferric chloride (equates to 0.77 ppm iron dosing)
Proposed Potassium Permanganate Injection System	1) 50- gallon polyethylene chemical storage tank LMI PD075-A30HI chemical injection pump, 0.1 ppm dosing
System Design Values	Average Day Demand (ADD) = 220 gpd/ERU Maximum Day Demand (MDD) = 570 gpd/ERU Peak Hour Demand = 447 gpm (at 536 ERUs)
Source Production	Source (Well ID / Well No) – Approved Capacity S01 (AGA932 / Well #1) – 50 gpm (52 gpm) S02 (AGA931 / Well #2) – 75 gpm S03 (AGA930 / Well #3) – 75 gpm S04 (AGA929 / Well #4) – 75 gpm (125 gpm)
Water Rights	Certificate – Instantaneous Withdrawal (Q_i) – Annual Withdrawal (Q_a) G1-22510C – (Q_i) 225-gpm – (Q_a) 45.0 Acre-Ft G1-24539C – (Q_i) 225-gpm – (Q_a) 105.0 Acre-Ft* G1-23683C – (Q_i) 37.5-gpm – (Q_a) 25.0 Acre-Ft ** * Supplemental to G1-22510 for a total of 150 acre-ft/yr. ** Water right to be transferred from Del Bay to W&B Waterworks 1

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1 PROJECT DESCRIPTION

1.1 Project Description

W&B Waterworks 1 (W&B), Public Water System Identification Number 46670 3, is a water system owned and operated by Cascadia Water located in the southern portion of Whidbey Island in Island County Washington. W&B is in the process of consolidating the Del Bay (ID: 18575K) system which will give W&B a total of 494 active connections. W&B currently has various deficiencies that Cascadia Water, the owner, would like to address to increase system capacity, improve reliability of service, and improve the quality of the provided water. The proposed improvements include the following items:

1. Replacement of storage reservoirs to increase storage capacity.
2. Relocation of storage reservoirs to improve system pressures.
3. Installation of an iron and manganese oxidation and filtration system.
4. Pumphouse installation for system maintenance and improved operations.

The analysis was done in compliance with the Washington State Department of Health (DOH) 2019 Water System Design Manual (Design Manual). The system was evaluated to verify that it meets the following requirements:

- Source & water right capacity
- Adequate standby storage volume for the temporary loss of one of the system's wells
- Adequate capacity to maintain 30 psi of pressure at each service connection.
- Adequate storage and distribution capacity to meet fire demands, while maintaining 20 psi at each service connection
- Reliable operation (not subject to pressure loss or back flow)
- Compliance with system's Water Right Permits/Certificates

The capacity and reservoir sizing calculations indicate that a 30-feet diameter by 35-feet tall concrete reservoir with a storage capacity of 185,000 gallons. This sizing will provide the required and recommended storage components for the System in excess of the listed capacity in this report.

1.2 Existing System Configuration

W&B is currently supplied by four wells. The wells are located on the system owned lot on Roy Road (Island County Parcel R22922-370-5000) at an elevation of approximately 255-feet above sea level. The wells function on a lead/lag orientation with Well 1, followed by Well 3, which is followed by Wells 2 and 4 running simultaneously. The well lot also contains two storage reservoirs and a booster pump for a small high-elevation service area adjacent to the reservoirs. Well operation is controlled by level floats in the one of the reservoirs. Wells 1, 2, and 4 pump into one of the reservoirs while Well 3 pumps into the other reservoir. The reservoirs are intertied and hydraulically equivalent. The system has water right certificates with a combined withdrawal rate of 225-gpm and annual withdrawal of 150 acre-feet per year. A fifth well from Del Bay which will soon be connected as an emergency source. Available information for each well is provided in Table 7.

The W&B water system was previously shown to have physical and legal capacity to serve up to 518 ERUs and is currently approved for 500 ERUs. The analysis in this report shows that, based on current water usage, the system has the capacity to supply 536 ERUs.

Past correspondence with the DOH noted that system capacity is subject to seawater intrusion review under Island County Code (ICC) 8.09.099. W&B is currently consolidating with the Del Bay Water System. As the combination of water systems will not result in a net increase in water removed from the aquifer, Sea Water Intrusion (SWI) limitations do not apply, and the additional approved connections associated with Del Bay will be added to the existing approved connections okayed by Island County for W&B. This will result in an approved number of connections at 521 ERUs (478 existing W&B ERUs and 43 approved from Del Bay). W&B will pursue the incorporation of the water right from Del Bay into the combined system following the consolidation of the systems. Section 3.4, and its associated subsections, provides a capacity analysis of W&B Waterworks 1 without the Del Bay water right which shows that the system has the capacity for a maximum of 536 ERUs (Equivalent Residential Units).

The source water from the system's wells have elevated levels of iron (Fe), manganese (Mn), and arsenic (As). The source water exceeds the secondary maximum contaminant level (SMCL) for Fe and Mn which are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. The source water does not exceed the MCL for arsenic, but the levels are considered elevated and Cascadia Water would like to proactively treat each of these contaminants. Table 1 includes the concentrations of Fe, Mn, and As taken from pilot tests or available source sample data. See Appendix E for the Pilot Test Report.

Table 1: Source Water Concentrations

Contaminant	MCL/SMCL	Well #1	Well #2	Well #3	Well #4
Iron (Fe)	0.3 mg/L	0.05 mg/L	0.07 mg/L	0.07 mg/L	0.15 mg/L
Manganese (Mn)	0.050mg/L	0.252 mg/L	0.143 mg/L	0.23 mg/L	0.381mg/L
Arsenic (As)	0.010 mg/L	0.0068 mg/L	0.007 mg/L	0.007 mg/L	0.0092 mg/L

2 W&B WATERWORKS 1 CAPACITY ANALYSIS

A capacity analysis was done on W&B to assess the physical capacity of the distribution system. This section provides analysis of the legal and physical capacity of the W&B distribution system The detailed capacity calculations are included in Appendix B. The factors involved in determining the W&B system's capacity include source capacity, existing storage volume, water rights, booster pump system and distribution system capacity. The Washington State Department of Health (DOH) requires that water systems comply with the following design standards:

- Provide peak demand flow rate while maintaining 30 pounds per square inch (psi) at each service connection.
- Have adequate source capacity to meet the maximum day demand.
- Have adequate equalizing storage (ES) volume to meet the peak hour demand (PHD) for 150 minutes.
- Have adequate stand-by storage volume for the temporary loss of the system's source(s)
- Maintain reliable operation (not subject to pressure loss or back flow).
- Comply with system's Water Right Permit(s) / Certificate(s).

The capacity analysis was done according to the standards set forth in the 2019 DOH Water System Design Manual which will be referred to as the Design Manual throughout this report. The analysis shows that W&B has the physical and legal capacity to serve 536 ERUs, limited by the treatment system capacity.

2.1 Water System Demands

Water usage and source production data from 2018 through 2020 was analyzed to determine current design values for the system. The W&B source production and usage is summarized in Table 2. Daily source meter readings were recording starting in 2020.Therefore the figure below indicated by * is the maximum daily source production.

Table 2: Water Production and Usage

Year	Annual Production (gallons)	Annual Usage (gallons)	ADD (gpd/ERU)	Max Monthly Production (gallons)	MMADD (gpd/ERU)	MDD (gpd/ERU)
2018	32,599,102	29,958,784	195	5,502,812	421	568
2019	31,092,287	28,355,939	213	4,750,548	358	484
2020	30,922,513	N/A	209	208,500*	n/a	457

2.1.1 Average Day Demand (ADD)

Average day demand (ADD) is defined as the average usage by a full-time ERU each day in the system. It is typically calculated by total volume of water produced in one year divided by the number of days in the year and the number of ERUs in the distribution system. Using water production data rather than consumption data gives an indication of the actual water required by the system to serve its consumers including distribution system leakage. Water production from 2016-2020 was analyzed to determine current design values for the system. The overall ADD of 213 gpd/ERU was found using data from the year 2019; this value was rounded up to be 220 gpd/ERU. See Table 2 for past water usage values and water system calculations.

2.1.2 Maximum Day Demand (MDD)

Maximum day demand (MDD) is ideally determined by meter readings and is the largest single-day usage of water based upon production. The maximum day demand (MDD) could only be determined for 2020 from actual water use data. For 208-2019 no daily source meter readings were available. Therefore, the meter readings for the system were analyzed to determine a maximum monthly average day demand (MMADD). The MMADD is then multiplied by a peaking factor of 1.35 to determine MDD per the Design Section 3.4.1. The design MDD for the system was found to be 568 gpd/ERU, which was rounded up to 570 gpd/ERU in the engineering calculations.

2.1.3 Peak Hour Demand

Equation 3-1 from the Design Manual was used to obtain the estimated PHD based upon the number of existing connections. The equation uses the MDD and the number of potential connections to determine the PHD flowrate.

Design Manual Equation 3-1:

$$PHD = \frac{MDD \cdot (C \cdot N + F)}{1440} + 18$$

Where *C* and *F* are coefficients based on system size. These coefficients are listed in Table 3, and the PHD values are provided in Table 4.

Table 3: Peak Hour Demand Calculation Coefficients

Range of ERUs	C	F
15-50	3.0	0
51-100	2.5	25
101-250	2.0	75
251-500	1.8	125
501+	1.6	225

Table 4: Peak Hour Demand

Scenario	MDD (gpd/ERU)	N (ERUs)	C	F	PHD (gpm)
Total current connections	570	456	1.8	125	392
System Capacity	570	536	1.6	125	447
Reservoir Design Max # Connections	570	550	1.6	225	447

W&B's future PHD based on the system capacity of 536 connections is 447 gpm.

2.1.4 Design Values

The design values used in determining the capacity of the system are provided in Table 5. A detailed compilation of production and usage data is provided in Appendix B.

Table 5: System Design Values

Parameter	Value
ADD	220 gpd/ERU
MDD	570 gpd/ERU
PHD	447 gpm

2.2 Water Rights

W&B Waterworks which currently has two (2) water rights permits. These water right permits are summarized in Table 6. The combined instantaneous withdrawal rate and annual withdrawal rate allowed by the water rights is 262.5 gpm and 175 acre-ft/yr, respectively. The water right certificates are included in Appendix A.

Table 6: Water Rights

Water Right No.	Name	Priority Date	Source	Instantaneous Withdrawal (gpm)	Annual Withdrawal (acre-ft/yr)
G1-22510P	W&B Waterworks	06/04/75	Well #1	225	45
G1-24539C	W&B Waterworks	08/24/84	Well #2	*225	105
			Total	**225**	**150**

*Non-Additive

The water rights for the wells allow for total instantaneous withdrawal of 225 gpm (Q_i) and an annual withdrawal of 150 acre-ft/yr (Q_a). Water Right Self-Assessment is included in Appendix C.

2.2.1 Water Right Capacity Based on Instantaneous Flow

The water rights for the System allows for an instantaneous pumping rate as of 250 gpm. Equation 4.4a from the Design Manual was used to determine the number of ERUs based upon Maximum Daily Demand (MDD) and water right. The number of ERUs that can be supported by the System's water right based on MDD is 518 ERUs.

Equation 4-4a:

$$\mathrm{N} = \frac{(Q_i)}{(ERU_{MDD}/1440)}$$

N = ERUs Supported
Q_i = Instantaneous Allowed Pumping Rate (gallons/minute)
ERU_{MDD} = MDD value per ERU

$$ERU = \frac{225\ gpm}{570\ gpd/1440} = 568\ ERUS$$

2.2.2 Water Right Capacity Based on Annual Volume

The water rights for the System allows for a specified annual withdrawal of 150 acre-feet/year. Equation 4-4b is provided in the Design Manual to determine the number of ERUs based upon Average Daily Demand (ADD) and water right. The number of ERUs that can be supported by the System's water right based on ADD is 608 ERUs.

Equation 4-4b:

$$\mathrm{N} = \frac{(Q_a)}{(ERU_{ADD})(365)}$$

N = ERUs Supported
Q_a = Annual Volume (gallons/year)
ERU_{ADD} = ADD value per ERU

$$ERU = \frac{48{,}874{,}320\ gallons\ per\ year}{220\ gpd\ per\ ERU * 365} = 609\ ERUS$$

2.3 Source Capacity

The W&B water system currently has four groundwater wells that serve the system. The wells are located on Island County Parcel R22922-376-5180 adjacent to Roy Road. Detailed source information for each well is provided in Table 7.

Table 7: Source Information

Parameter	Well 1	Well 2	Well 3	Well 4	Del Bay
Source (WFI)	S01	S02	S03	S04	S01
Use	Primary	Primary	Primary	Primary	Emergency
Drill Year	1973	1977	1984	1984	1962
Well Tag ID#	AGA932	AGA931	AGA930	AGA929	AGA812
WFI Listed Capacity	50 gpm	75 gpm	75 gpm	75 gpm	38 gpm
Depth	310 ft	301 ft	285 ft	264 ft	254 ft
Casing Diameter	6-in	6-in	6-in	8-in	6-in

Equation 4-3 from the Design Manual was used to determine the number of connections that can be served by all the non-emergency sources based on source capacity as follows:

Design Manual Equation 4-3:

$$N = \frac{V_T}{MDD}$$

$$N = \frac{275\ gpm * 1{,}200\ min/day}{570\ gpd/ERU} = 579\ ERUs$$

Where *N* is the total number of ERUs that can be served based on the source capacity, V_T is the total volume of water delivered from all nonemergency sources over a 24-hour period. V_T was assumed to be equal to the maximum source instantaneous flow rate over a 24-hour period. Section 3.10.4 of the Design Manual recommends against designs based on pumping 24-hours per day to meet future MDD (570 gpd/ERU). Rather, assessing source capacity based on an assumption of pumping a source no more than 20 hours (1,200 min) per day provides a factor of safety and an increased ability to meet unexpected demands. Therefore, V_T was found by multiplying the total well capacities (275 gpm) by 1,200 min/day. Therefore, the resulting source capacity was found to be 579 ERUs.

2.4 Booster Pumps

The W&B water system is primarily a gravity-fed system. There are a maximum of 11 connections near the reservoir that require pressurized service. A booster pump system will be installed to support these connections and provide backwash supply for the treatment system. The booster pump capacity is 80 gpm which equates to the capacity to supply 66 ERUs.

2.5 Storage

The proposed improvements below discuss the proposed replacement reservoir which will be sized based on a potential of 550 ERUs.

2.6 Capacity Summary

The number of connections that the W&B water system can support was estimated using the methods outlined in the Design Manual, Chapter 4. The components analyzed include the instantaneous water right, the annual water right, and the source capacity. The distribution system and booster system were also analyzed, but they are not considered to be factors that would limit the maximum capacity of the water system since they can be upgraded.

The analysis demonstrated that the System has the physical and legal capacity to serve up to 518 ERUs, limited by the water right. The capacity analysis summary is provided in Table 8 below and calculations are provided in Appendix B.

Table 8: System Capacity Summary

Component	Value	Component Capacity (N)	Equation for N
Instantaneous Water Right, Q_i	225 gpm	568 ERUs	Q_i /MDD
Annual Water Right, Q_a	150 ac-ft/yr	609 ERUs	Q_a /ADD
Source	275 gpm	579 ERUs	Q_s/MDD
Treatment	225 gpm	536 ERUs	Q_T/MDD

2.7 Seawater Intrusion Analysis

The Seawater Intrusion (SWI) Analysis provided in Appendix D indicates that there is medium risk for sea water intrusion into the system's wells and monitoring is required for all 4 wells. The maximum chloride levels measured in wells 1 through 4 are 25 mg/L, 23 mg/L, 27 mg/L, 25 mg/L respectively. Overall, all wells have had consistent chloride concentrations since their construction. Monitoring is required, but SWI does not appear to be a current concern.

Since the wells are indicated at being at medium risk Island County Hydrogeologist had previously resisted the number of approved connections below the physical capacity. The system was limited to 478 ERUs. With the combination of Del Bay which had existing approval for 43 ERUs the new SWI limited capacity is 521 ERUS.

3 PROPOSED SYSTEM IMPROVEMENTS

To proactively address arsenic concerns and to provide improved treatment of excesses of the SMCL, the water system is planning to install an oxidation/filtration system to reduce iron, manganese, and arsenic to less than half the SMCL and MCL. The proposed oxidation/filtration system will utilize ferric chloride and sodium hypochlorite chemical injection to precipitate arsenic out of the source water and a manganese dioxide-based filter media to filter out that precipitate. The treatment system will be installed in a proposed pump house located adjacent to a proposed reservoir site indicated in Figure 1.

Additionally, the system has two aging reservoirs that do not currently provide the DOH recommended level of standby storage. The system will construct a new reinforced concrete storage reservoir sized to provide the system's anticipated storage needs. The proposed reservoir will be placed at a higher elevation which should provide improved system pressures at the bottom of the equalizing storage.

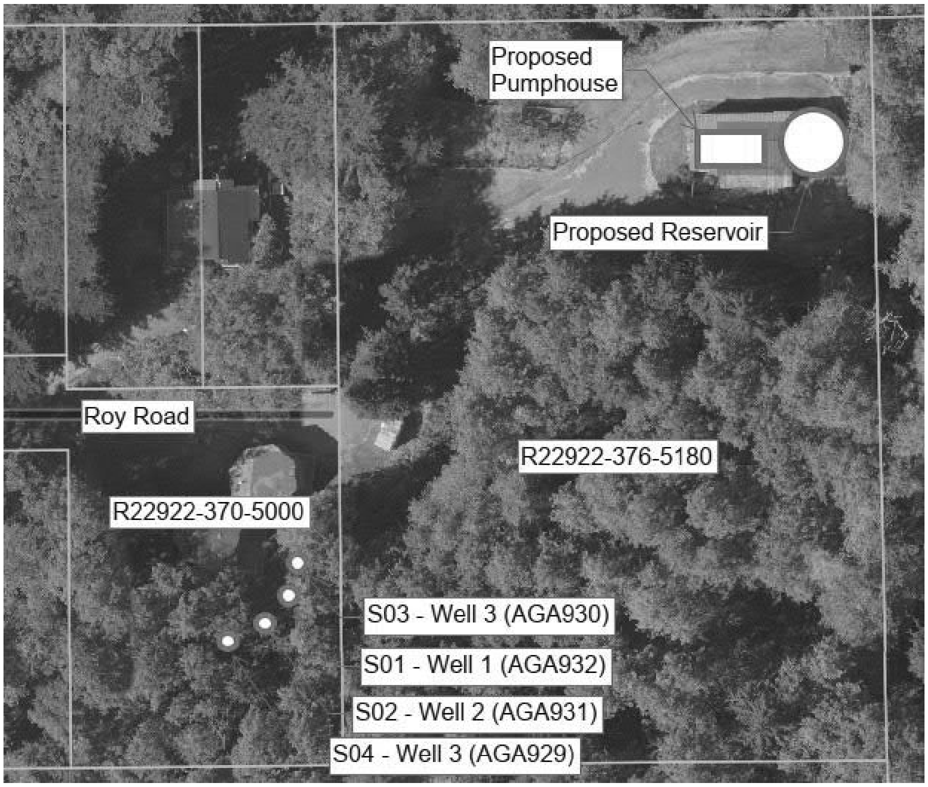

Figure 1: Project Location

4 RESERVOIR DESIGN

The System's existing 50,000-gallon reservoirs are octagonal and are constructed of reinforced concrete. They each have an effective diameter of 28.5 feet and a height of 12 feet. The total storage provided by the reservoirs does not meet the minimum recommended standby storage volume of 200 gpd/ERU as identified in the DOH *Water System Design Manual*, 2019 edition. Furthermore, the reservoirs are aging and are nearing the end of their useful lifespan.

The proposed improvements will install a new, properly sized reservoir to meet the anticipated future system needs. The existing reservoirs will be kept in service until the storage reservoir proposed in this report is fully functional, at which time they will be removed from service. Installation of this new reservoir, and its associated yard piping, will be performed at the same time as the arsenic treatment system installation.

4.1 Reservoir Sizing

Reservoir sizing was completed according to DOH guidance in the *Water System Design Manual*, 2019 edition to provide the system with adequate storage capacity to meet system demand and provide a sufficient reserve for fire flow. The five following storage components were considered in the design process:

1. Operational Storage (OS)
2. Equalizing Storage (ES)
3. Dead Storage (DS)
4. Standby Storage (SB)
5. Fire Suppression Storage (FSS)

To size the proposed reservoir for future demands the sizing has been done for 550 ERUs and a corresponding PHD of 498 pgm. The proposed reservoir is a circular reinforced concrete with an internal diameter of 30 ft and a height of 35 ft. This equates to approximately 185,000 gallons of reservoir storage (V_R) and 5,285 gallons of storage per foot of reservoir height (V_f).

$$V_R = \pi \cdot (\frac{30\,ft}{2})^2 \cdot (35\,ft) \cdot (7.48\,gal/ft^3) = 185{,}000\,gallons$$

$$V_f = \frac{185{,}000\,gal}{35\,ft} = 5{,}290\,gal/ft$$

4.1.1 Operational Storage

Operational storage (OS) is the height difference between the water levels in the reservoir where the well pumps are turned on and off. Adequate operational storage will prevent excess cycling of the well pumps by minimizing the number of times they need to start. Additional operational storage will be provided to allow the filter to operate for a longer duration, to increase the percentage of time the filters are run at steady state condition. Four feet of elevation will be provided between the well pump on and off signal. Therefore, the operational storage is calculated as follows:

$$OS = 4.0\,ft \times 5{,}290\ \ gal/ft = 21{,}150\,gallons$$

This would allow for a minimum 94 minutes (=21,150/225 gpm) of filter run time. This should provide better filter performance.

4.1.2 Equalizing Storage

Equalizing storage (ES) is the volume of water that is needed to meet the peak demand period for the water system. Equalizing storage was calculated using Equation 7-1 from the DOH *Water System Design Manual*, 2019 edition as follows:

$$ES = (PHD - Q_s)(150\,minutes)$$

Where:
PHD = Peak Hour Demand
Q_s = Well Pump Capacity

$$ES = (455\,gpm - 225\,gpm)(150\,minutes) = 34{,}600\,gallons\,(6.5\,ft\,of\,storage)$$

4.1.3 Dead Storage

Dead storage (DS) is the unusable volume at the top (TDS) and bottom (BDS) of the reservoir. Six (6) inches of freeboard will be provided at the top of the reservoir over the well pump off water level. The reservoir outlet will be raised six inches above the bottom of the reservoir to prevent silt and other material that may collect in the reservoir from entering the distribution system. The booster pump low level shut off will be set to three inches above the reservoir outlet. Therefore, dead storage can be calculated as follows:

$$TDS = 0.75\ ft \times 5{,}290\ \ gal/ft = 3{,}970\ gallons$$

$$BDS = 0.75\ ft \times 5{,}290\ \ gal/ft = 3{,}970\ gallons$$

$$DS = TDS + BDS = 6{,}610\ gallons\ (1.5'of\ storage)$$

4.1.4 Standby Storage

Standby storage (SB) is the volume of water available to supply the system in case of abnormal operating conditions that prevent the source or treatment system from properly functioning. A standby storage volume of 200 gallons per ERU is recommended. This equates to 110,000 gallons for 550 ERUs as shown below:

$$SB_{Recommended} = 200\ gal/ERU \times 550\ ERUs = 110{,}000\ gallons$$

The standby storage provided by the proposed reservoir can be calculated as the remaining volume after operational storage, equalizing storage, and dead storage are accounted for. The provided standby storage is calculated as follows:

$$SB = V_R - (OS + ES + DS) = 185{,}000 gal - (21{,}150\ gal + 34{,}560\ gal - 6{,}610\ gal)$$

$$SB = 122{,}700\ (23.2\ ft\ of\ storage)$$

The proposed reservoir will provide sufficient standby storage to serve the current and projected future demands of the system.

4.1.5 Fire Suppression Storage

Fire suppression storage (FSS) requirements are set by Island County. The residential fire flow requirement is 500 gpm for 30 minutes, which equates to 15,000 gallons. Fire suppression storage may be nested with standby storage. Since the standby storage provided by the proposed reservoir is greater than 15,000 gallons, adequate fire suppression storage is provided. The provided storage volumes are summarized in Table 10.

Table 9: Storage Components

	Existing Reservoirs		Proposed Reservoir	
Storage Component	**Volume (gal)**	**Equivalent Height (ft)**	**Volume (gal)**	**Equivalent Height (ft)**
Top Dead Storage	4,776	0.5	3,970	0.75
Operational Storage	4,776	0.5	21,150	4.0
Equalizing Storage	32,973	3.5	34,560	6.5
Standby Storage	67,331	7.0	122,740	23.0
*Fire Suppression Storage	(15,000)	(3.1)	(15,000)	(2.8)
Bottom Dead Storage	4,776	0.575	3,970	0.75
Total	114,634	12.0	185,000	35.0

**Fire suppression storage is nested with standby storage.*

4.1.6 Reservoir Floats and Piping Levels

The proposed reservoir will be constructed with a finished floor of approximately 275 feet above sea level. The proposed reservoir will be located adjacent to the proposed pumphouse and treatment facilities. The proposed configuration will minimize the amount of dead storage and increase pressures in the distribution system. The height of the proposed reservoir overflow, inlet, outlet, and drain lines are provided in Table 11.

Table 10: Proposed Reservoir Piping Levels

Piping Component	Height Above Reservoir Bottom (ft)
Overflow (Pipe Invert)	34.65 (34'-8")
Inlet (Pipe Invert)	34.5 (34'-6")
Outlet	0.5 (0'-6")
Drain	0.0

A new control package will be provided in the proposed reservoir. This will include a pressure transducer controller interface in the proposed pumphouse. Well pumps will cycle on based on system needs. If the first pump is not adequate, a second and possible third well pump will activate. The primary and back up well pumps will alternate on each start up cycle. Reservoir set points for lead and lag well pump on/off levels, low and high level alarms, and booster pump shut off levels are summarized in Table 12.

Table 11: Reservoir Set Points

Reservoir Control Set Points	Height Above Reservoir Bottom (ft)
High Level Alarm	34.5 (34'-6")
Well Pumps Off	34.25 (34'-3")
Lead Well Pump On	31.75 (31'-9")
Lag Well Pump #1 On	31.00 (31'-0")
Lag Well Pump #2 On	30.25 (30'-3")
Low Level Alarm	20.0 (20'-0")
Booster Pump Shut Off	0.75 (0'-9")

4.1.7 Water Age

According to Section 7.6.1 of the DOH *Water System Design Manual*, 2019 edition, "long detention times in reservoirs can lead to loss of disinfectant residual, microbial growth, sediment accumulation, formation of disinfection byproducts, taste and odor problems, and other water quality issues." It is recommended in the manual that a complete turnover of water in a storage reservoir occur at least every three to five days to minimize these problems.

Water age before complete reservoir turnover was calculated for the proposed in operation together with the existing reservoir and the proposed reservoir operating by itself. The lowest recorded average daily demand of 195 gpd/ERU in 2018, a storage volume equal to the total reservoir volume minus top dead storage and lead well pump operational storage, and the current number of active connections were used for these calculations. Water usage data is available in Appendix B.

Water age with both reservoirs in operation:

$$Water\ Age = \frac{Total\ Storage\ Volume - TDS}{ADD} = \frac{(185{,}000\ - 3{,}970 - 13{,}225)\ gal}{195\ \ gpd/ERU \times 496\ ERUs} \cong 1.7\ days$$

The resulting water age for the reservoirs in operation is less than five days, meaning that the proposed reservoir is not expected to have any problems as a result of water age.

5 TREATMENT DESIGN

The source water from the all the wells have elevated levels of iron (Fe), manganese (Mn), and arsenic (As). The source water exceeds the secondary maximum contaminant level (SMCL) for Fe and Mn which are established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor. The source water does not exceed the MCL for As but the levels are considered elevated and Cascadia would like to proactively treat each of these contaminants.

5.1 Treatment Alternatives

Multiple treatment alternatives were reviewed to determine the best means of reducing the elevated levels of contaminants in the system. These alternatives are summarized in Table 14 and are discussed in greater detail below.

Table 12: Treatment Processes Alternatives

Treatment Type	Considerations
Iron Based Sorbents	High initial cost. High source water turbidity can decrease treatment efficiency and reduce media life.
Ionic Exchange Filter	Reduces water hardness. Complex operational requirements and high operating costs.
Oxidation/Filtration	Requires chlorination. Easy to maintain.

5.1.1 Iron Base Sorbents

Iron based sorbents function by chemisorption of arsenic onto an iron oxide media. Because the sorption is irreversible, the media is used until it is saturated and then disposed in a sanitary landfill. The filter tank is then recharged with fresh media. A lead/lag filter configuration is utilized to enable the media to run to the saturation point. Phosphates compete aggressively for adsorption sites, so complete water chemistry results are needed before determining the adequacy of this treatment option.

<u>Pros</u>:

- Ease of operation.

<u>Cons</u>:

- Lead/Lag configuration leads to higher initial cost.
- Turbidity interferes with efficiency, pre-filtration recommended.
- High turbidity decreases media life.

5.1.2 Ion Exchange

Ion exchange is a treatment process which directly removes soluble arsenic, iron, and manganese in solution without chemical change by replacing, or exchanging, the soluble arsenic, iron, and manganese ions with sodium or potassium ions. Ion exchange has the additional benefit of reducing water hardness.

A primary concern with ion exchange is chromatographic peaking, which can cause arsenic and nitrate levels in the treated water stream to exceed that of the raw water stream if the operation cycle is not properly maintained. This process requires highly skilled operators and frequent monitoring. Ion exchange treatment is appropriate for soluble ions only and most systems have some contaminants in their source water that are not soluble. Operational costs are high with this treatment option due to the large quantities of salt needed for operation. In addition, the wastewater discharge of the brine solution is problematic if the property is not connected to a municipal sewage disposal system. There is not a municipal sewage disposal system available at the project site. Based on these factors, ion exchange is not recommended as a suitable treatment alternative for this system.

Pros:

- Reduces water hardness.

Cons:

- Complex system operation and frequent monitoring needs.
- High operational costs.
- Disposal of brine solution wastewater.

5.1.3 Oxidation/Filtration with Catalytic Media

Oxidation/Filtration is a proven technology for removal of arsenic and other contaminates in groundwater sources. Iron and manganese in the source water are oxidized and converted to insoluble salts. Arsenic in the source water is also oxidized and absorbs onto the iron hydroxide insoluble salts. The insoluble salts (FeO_2 with bound $HAsO_4$ and MnO_2) are then filtered with a catalytic media.

An iron to arsenic ratio in the source water of 100 to 1 is desired for optimal arsenic removal. Pilot testing results indicate a Well #1 iron concentration of 0.05 mg/L and an arsenic concentration of 0.0068 mg/L, or an approximate ratio of 7 to 1. Pilot testing results indicate a Well #4 iron concentration of 0.15 mg/L and an arsenic concentration of 0.0092 mg/L, or an approximate ratio of 16 to 1. As a result of the low iron to arsenic ratios in both wells, the addition of iron via ferric chloride injection prior to filtration is required for optimal arsenic removal. The added iron, with bound arsenic, would then be removed from the water by the filter media.

Upon review of these alternatives, oxidizing with sodium hypochlorite and filtering using a manganese dioxide-based filter media was selected as the desired treatment alternative. The manganese dioxide oxidation/filtration process was selected based on the chemistry of the source water and increased arsenic removal efficiencies with this media.

Manganese dioxide filtration systems use a natural mineral, pyrolusite, as the catalytic filter media. This filter media ranges from 50-80% manganese dioxide by weight. Consequently, the filter media has a substantially higher capacity to retain excess oxidant and adsorb arsenic, iron, and manganese. These properties translate to higher filter flow rates, greater capacity to sustain overfeeding or underfeeding of chemical oxidants, and a significantly longer filter bed life than other similar filtration systems such as manganese greensand when properly operated. Longer filter bed life allows fewer filter bed replacements over the system's life. Sodium hypochlorite is the recommended oxidant since the system operates better with chlorination.

Pros:

- Effective for arsenic, iron, and manganese reduction.
- Demonstrated success on Whidbey Island.
- Potential to operate at higher flow rates than alternatives.

Cons:

- Requires periodic backwashing to clean filters.

5.1.4 Treatment Selection for Pilot Testing

Upon review of the alternatives listed in Section 5.1 and summarized in Table 14, oxidation/filtration was selected as the preferred treatment alternative. ATEC Systems Associates was selected as the contractor to perform the pilot testing that confirms treatment effectiveness, to develop optimal design parameters, and to provide prefabricated filters. This company has completed pilot tests across the nation and has developed effective oxidation/filtration treatment systems for arsenic removal based on those pilot test results for 30 years. ATEC provides a simple, robust, and cost-effective treatment system with automated backwashing that meets the primary design goals of the treatment system. ATEC utilizes pyrolusite based filtration media, which is not subject to degradation during routine use. These systems are also equipped with a simple control panel for backwash operations that is suitable for this application. ATEC treatment systems typically operate with sodium hypochlorite as the lone oxidant; however, if a drop in the silica concentration is detected across the filter media, potassium permanganate will be required to protect the long-term functionality of the media.

5.2 Treatment Pilot Testing

A pilot study was undertaken to determine optimal operational parameters for the design of the arsenic water treatment system. An ATEC filtration system was determined to be a viable oxidation/filtration treatment alternative for the system based on the existing water chemistry, past success with this type of treatment, and the simplicity of operation. Based on this determination, a pilot test of the ATEC filtration system was completed on July 20th and 21st, 2021. The following sections summarize the details of the pilot testing, including an analysis of the test results. A copy of the Pilot Test Report is included in Appendix E

5.2.1 Objective

The objective was to determine the effectiveness of an ATEC treatment system in removing arsenic from the water of Wells #1 and #4. The pilot test also identified the required ATEC filtration equipment and the optimal operational settings to reliably remove arsenic to less than the MCL of 0.010 mg/L (10 parts per billion, ppb).

5.2.2 Pilot Test Description

Pilot testing was performed on both Wells 1 and 4 to determine the efficacy of removing iron, manganese, and arsenic. The source water quality between Table 13 includes the concentrations of those items in the source water taken during pilot testing; see Appendix E for the Pilot Test Report.

Table 13: Source Water Concentrations

Contaminant	MCL/SMCL	Well #1	Well #4
Iron (Fe)	0.3 mg/L	0.05 mg/L	0.15 mg/L
Manganese (Mn)	0.050mg/L	0.252 mg/L	0.381mg/L
Arsenic (As)	0.010 mg/L	0.0068 mg/L	0.0092 mg/L

As shown in Table 13, the concentration of contaminants in Well #4 surpasses that of Well #1. The concentration of manganese at 0.381 mg/L exceeds the secondary maximum contaminant level (SMCL), of 0.050 mg/L by 762%, set by the United States Environmental Protection Agency (EPA). In addition, the arsenic concentration of Well #4 at 0.0092 mg/L within 90% of the current maximum contaminant level (MCL) set by the EPA. Water quality tests results are included in the Pilot Testing Report (Appendix E). Arsenic is classified as a primary drinking water contaminant and is regulated for its potential adverse effects on human health. According to the Washington State Department of Health (DOH) *Publication*

#331-262, June 3, 2004, "Arsenic has a primary drinking water standard (of 0.010 mg/L) because it can cause skin lesions, circulatory problems, and nervous system disorders. Prolonged exposure also can cause various forms of cancer." The DOH *Water System Design Manual*, 2019 edition, states the established EPA arsenic MCL is "based on chronic health concerns, including carcinogenic and cardiovascular risks."

ATEC conducted a pilot test for blended water from Wells #1 and #4 on July 20 and 21, 2021. The pilot test was conducted by diverting a portion of the wells' production to the ATEC pilot filters. The filtered water was dumped to waste and not used for consumption by the system. The removal performance of the pilot filter was monitored as the operating parameters were adjusted to determine optimal sodium hypochlorite and ferric chloride dosing. The pilot filter system is designed to simulate actual operation of an ATEC filter system on a small scale in terms of contact time, media depth, flow per cubic foot of media, flow per square foot of media (loading rate), and so forth. See Appendix E for additional information on the equipment that was utilized for the pilot plant and a summary of the pilot testing conducted on each day.

5.2.3 Pilot Test Set-Up

In this test, sodium hypochlorite and ferric chloride were introduced to the influent immediately ahead of four 6-inch diameter filter columns with 60-inch filter sidewalls. The filters are manifolded together at the inlet and outlet and are filled with 42-inches of AS-700 Series Filter Media.

Filter loading rates, sodium hypochlorite feed rates, and ferric chloride feed rates were varied to determine the most economical filtration equipment necessary to meet treatment objectives. During the pilot testing, the pilot trailer's field lab was used to determine iron, manganese, and arsenic concentrations in the raw and finished water. The pilot test results are displayed in tables and graphically in Appendix E.

Pressure was measured on the influent and effluent manifold to determine head loss across the filters. The sodium hypochlorite and ferric chloride injection points were located as close to the filters as possible to simulate actual operation. Source water enters through a hose inlet in the wall, passes through a flow meter, past a sodium hypochlorite and ferric chloride injection point, through an in-line static mixer, into the inlet manifold, and down and through the filter media. See Appendix E for the flow path and for detailed information on the pilot test set-up.

The pilot-test on July 21st was run for approximately 6 hours and 30 minutes in total. The pilot-test on July 20th was run for approximately 5 hours and 30 minutes in total. On-site analysis was conducted for temperature, pH, total and free chlorine, iron, manganese, hydrogen sulfide, ammonia, silica, and arsenic. These parameters were monitored both before and after the filtration process using Hach sensors and spectrophotometer testing.

5.2.4 Pilot Filter Test Results and Analysis

During the pilot testing for Well #1, water was fed directly from the well at an average flow rate of 4.96 gpm from Well #1. Source water was metered using a totalizing flow meter. Sodium hypochlorite dosing was adjusted to an average of 2.18 mg/L to obtain a 1.16 mg/L average free chlorine residual and a 1.47 mg/L average total chlorine residual on the filter outlet. Ferric chloride was dosed at an average of 0.92 mg/L as iron. The water passed through the filter media with an average loading rate of 6.31 gpm/ft^2.

During pilot testing for Well #4, water was fed directly from the well at an average flow rate of 4.90 gpm from Well #4 and was also metered using a totalizing flow meter. Sodium hypochlorite dosing was adjusted to an average of 4.92 mg/L to obtain a 0.83 mg/L average free chlorine residual and a 1.83 mg/L average total chlorine residual on the filter outlet. Ferric chloride was dosed at an average of 1.11 mg/L as iron. The water passed through the filter media with an average loading rate of 6.24 gpm/ft^2. Pilot filter test results are provided in Appendix E and summarized in Table 15 for blended water from Well #1 and in Table 16 for Well #4.

The pilot test water quality testing for water from Well #1 indicates that the average influent (raw water) arsenic concentration is 6.8 ppb, or 68% of the MCL of 10 ppb. For the pilot testing, adequate removal is generally considered a reduction to less than 50% of the MCL, with non-detection being ideal. Following the oxidation-filtration treatment, the arsenic concentration was reduced to 3.4 ppb, or 34% of the MCL, which equates to 50% removal.

The pilot test water quality testing for Well #4 indicated that the influent arsenic concentration is 9.2 ppb, or 92% of the MCL of 10 ppb. Following the oxidation-filtration treatment, the arsenic concentration was reduced to 2.4 ppb, or 24% of the MCL, which equates to 74% removal.

The small difference between the free and total chlorine residuals in both pilot tests indicates that chloramine breakpoint, the point at which chloramines are no longer present in the water, was achieved in both cases. Chloramines are formed when chlorine, introduced via sodium hypochlorite injection, reacts with ammonia in the water. Further sodium hypochlorite injection introduces additional chlorine which breaks down the chloramines and converts them to nitrogen gas. Once the chloramines have been broken down, the free and total chlorine residual concentrations should be nearly equal. Pilot testing water quality results, included in Appendix E, indicate that no ammonia was present in the source water. Therefore, achieving chloramine breakpoint was probable.

The pilot test results for Well #1 and Well #4 indicate that effective removal of arsenic was obtained at an average loading rate of 6.31 gpm/ft^2 and 6.24 gpm/ft^2, respectively, of media surface area for blended water. Filtration was not extended to determine when the arsenic concentration started to rise in the filter effluent. This increase is referred to as filter breakthrough and relates to the total binding capacity of the filter media. During treatment validation testing, filter run time will be extended to filter breakthrough to determine optimal filter runtimes that will minimize the amount of water wasted to backwashing.

Table 14: Pilot Test Field Results from Well #1

		Chlorine (mg/L)		Iron (mg/L) SMCL: 0.30 mg/L		Manganese (mg/L) SMCL: 0.050 mg/L		Ammonia (mg/L) MCL: None		Arsenic (ppb) MCL: 10 ppb	
Date	**Time**	**Free**	**Total**	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**
7/20/2021	Start	2.35	2.84	0.16	-	0.27	-				
	10:30	1.93	2.23	0.08	-	0.22	-			6.8	4.8
	11:00	1.69	1.89	0.08	0.01	0.25	-	0.28	-		
	11:30	1.31	1.71	0.06	0.01	0.244	-				5.2
	12:00	1.29	1.62	0.08	0.01	0.258	0.001	0.26	-		
	12:30	1.27	1.54	0.06	-	0.249	-				
	13:00	0.8	1.11	0.02	-	0.242	-	0.28	-		1.1
	13:30	0.75	1.02	0.02	-	0.241	-				
	14:00	0.66	0.92	0.01	-	0.255	-				
	14:30	0.6	0.94	0.01	-	0.261	0.015				
	15:00	0.6	0.89	0.01	-	0.263	0.008			6.7	2.4
	15:30	0.61	0.9	0.02	-	0.265	0.01				
Average		**1.16**	**1.47**	**0.05**	**0.00**	**0.252**	**0.003**	**0.273**	**-**	**6.8**	**3.4**
Percent of SMCL/MCL		**-**	**-**	**16.9%**	**0.8%**	**503%**	**6%**	**-**	**-**	**68%**	**34%**

"-" : Non-Detect, counted as zero for averaging.
Empty cell indicates no test was performed.

Table 15: Pilot Test Field Results from Well #4

		Chlorine (mg/L)		Iron (mg/L) SMCL: 0.30 mg/L		Manganese (mg/L) SMCL: 0.050 mg/L		Ammonia (mg/L) MCL: None		Arsenic (ppb) MCL: 10 ppb	
Date	**Time**	**Free**	**Total**	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**	**Raw**	**Treated**
7/21/2021	Start	1.17	1.97	0.16	0.02	0.371	0.016				
	8:30	0.22	1.66	0.16	-	0.38	0.004	0.37	0.21		
	9:00	0.37	1.06	0.19	-	0.381	0.013			9.1	2.3
	9:30	0.32	1.58	0.17	-	0.383	0.013	0.34	0.13		
	10:00	0.34	1.89	0.16	-	0.38	0.003				
	10:30	1.13	1.97	-	-	0.387	0.003				2.4
	11:00	1.13	1.43	0.14	-	0.387	0.018				
	11:30	1.17	2.23	0.12	-	0.381	0.008				
	12:00	1.67	2.16	0.18	0.01	0.394	0.011	0.27	-		2.6
	12:30	0.78	2.02	0.13	0.01	0.373	0.004				
	13:00	0.82	2.02	0.17	0.01	0.377	0.01				
	13:30	0.8	1.92	0.16	0.04	0.379	0.012			9.2	2.1
Average		**0.83**	**1.83**	**0.15**	**0.01**	**0.381**	**0.010**	**0.327**	**0.113**	**9.2**	**2.4**
Percent of SMCL/MCL		**-**	**-**	**48.3%**	**2.5%**	**762%**	**19%**	**-**	**-**	**92%**	**24%**

“-“ : Non-Detect, counted as zero for averaging.
Empty cell indicates no test was performed.

5.2.5 Pilot Plant Results Summary

Based on the pilot test results, the ATEC AS-700 Series filter media-based oxidation/filtration treatment system has been identified as the appropriate technology for the effective removal of arsenic from the source water.

For Well #1, a ferric chloride dosing rate of 0.92 mg/L as Fe and a sodium hypochlorite dosing rate of 2.18 mg/L was shown to provide a 1.16 mg/L free chlorine residual, achieve chloramine breakpoint, and achieve arsenic reduction to 34% of the MCL.

For Well #4, a ferric chloride dosing rate of 1.11 mg/L as Fe and a sodium hypochlorite dosing rate of 4.92 gm/L was shown to provide a 0.83 mg/L free chlorine residual, achieve chloramine breakpoint, and achieve arsenic reduction to 24% of the MCL.

Hypochlorination treatment calculations are provided in Appendix F and based on pilot testing water chemistry and ferric chloride dosing rates, suggest that a dosing rate of 2.18 mg/L and 4.92 mg/L for Wells #1 and #4, respectively, of sodium hypochlorite will be adequate to achieve chloramine breakpoint and provide a minimum of 0.5 mg/L free chorine residual for both wells.

Well #1 experienced a drop in silica concentration of 0.90 mg/L across the pilot filters. It is recommended in the pilot study that a potassium permanganate feed system be included in the design to prevent silica from coating the filter media and reducing filter efficiency.

The system will be configured to allow treated water to provide water for backwash operations. A pressure sustaining solenoid valve will be installed in the pumphouse between the filter outlet and the reservoir inlet to provide adequate backpressure, prevent water from bypassing the filters during backwash operations by flowing directly to the reservoirs, and in doing so, provide an adequate flowrate to properly backwash the filters. This valve will normally be fully open and will only be activated by the ATEC control panel to increase backpressure during backwash operations. Treatment Engineering Calculations.

With the proposed system improvements, the wells will function on a lead/lag alternating orientation with Well 4 as the initial lead, followed by Well 1, Well 2, and Well 3 running simultaneously. To proactively address arsenic concerns and to provide improved treatment of excesses of the SMCL, the water system is planning to install an oxidation/filtration system to reduce iron, manganese, and arsenic to less than half the SMCL and MCL. The proposed oxidation/filtration system will utilize ferric chloride and sodium hypochlorite chemical injection to precipitate arsenic out of the source water and a manganese dioxide-based filter media to filter out that precipitate. The treatment system will be installed in a proposed pump house located adjacent to a proposed reservoir site indicated in Figure 1.

5.3 Water Quality, Quantity, & Water Rights

5.3.1 Water Quality Test Results

Following the installation of the treatment upgrades (and other water system upgrades), the four sources are proposed to be blended in the proposed new storage reservoir.

A mass balance calculation was performed to determine the expected concentration of arsenic, manganese, and iron based on the relative flow rates of the wells. Water quality data used in these calculations was based on the average concentrations from the Pilot Test. In typical operations the flow from Well #4 will alternate with the production from a combination of Wells 1, 2, and 3. The expected approximate concentrations of arsenic, manganese, and iron in the post-treatment blended water are provided in in Table 17. These concentrations can be used a datapoint for comparison of post-treatment, blended water quality. Should water quality testing values show concentrations reasonably higher than these expected values, further testing and investigation can be completed to determine if the unexpected water quality is due higher concentrations in the source water, or filter breakthrough/failure, etc.

Table 16: Post-Filtration Water Quality

Well	**Flow Rate (gpm)**	Finished Water Quality		
		As (mg/L)	**Fe (mg/L)**	**Mn (mg/L)**
1	55	0.0034	0.010	0.003
2*	75	0.0034	0.010	0.003
3*	75	0.0034	0.010	0.003
4	150	0.0024	0.010	0.010
MCL	-	0.010	0.30	0.050
Combined	**-**	**0.0029**	**0.010**	**0.007**

* Water quality calculated from Well 1 pilot test results.

5.4 Treatment Engineering Calculations

5.4.1 Treatment System

An oxidation/filtration treatment system has been identified as the appropriate technology for the removal of arsenic, iron, and manganese from the source water. Oxidation/filtration was selected as the treatment method because it has a history of success in removing arsenic from groundwater sources, is a proven and robust technology, and it is simple to operate and maintain. This treatment method involves dosing the source water with sodium hypochlorite and ferric chloride. The arsenic will bind with the iron that is present in the source water, as well as iron that is added in the form of ferric chloride, to form a precipitate that will then be filtered out of the water. The chlorine present in sodium hypochlorite will oxidize the manganese and the remaining iron to form another precipitate which will also be filtered out. The following is a summary of the materials and equipment that will be used in the treatment system:

Table 17: Treatment Component Summary

Component	Description
Pressure Vessels	(8) 30” (D) x 60” (H) filters (4.9 ft^2 filter bed area each) (2) 30” (D) x 60” (H) empty filter for contact tank
Filter Loading Rate	28 gpm/filter or 5.7 gpm/ft^2 of media surface area
Filter Bed	42” of ATEC Advantage filter media (17.2 ft^3/filter)
Backwash	5 minutes/filter at 137 gpm/filter (28 gpm/ft^2)
Hypochlorite Dosing	Well #1: 4.5 mg/L Well #4: 5.4 mg/L
Ferric Chloride Dosing	Well #1: 1.5 mg/L as iron Well #4: 2.2 mg/L as iron
Potassium Permanganate Dosing	0.1 ppm
Chlorine Residual	Target 1.0 ppm (0.5 ppm minimum)

5.4.2 Treatment Tank Sizing

Treatment production will be matched to the instantaneous water right rate of 225 gpm to maximize the capacity of the water system. Filter sizing is a balance between limiting the number of treatment vessels and providing an adequate flow rate to meet the backwash requirements of the filters. Treated water from the reservoir will be used to backwash the filters. A pressure sustaining solenoid valve on the ATEC filter outlet set to 30 psi will be used to maintain adequate pressure for backwashing. The proposed filter media has a recommended backwash flow rate of 28 gpm/ft^2 which equates to 137 gpm for the 30-inch diameter filters. Each filter is backwashed successively while the remaining filters can remain in treatment operation. A flow regulating valve on the ATEC filter backwash line will be set to regulate backwash flow to 137 gpm. Any flow beyond 137 gpm during backwash operations will be returned to the reservoirs.

ATEC’s Pilot Testing Report recommended a filter loading rate of approximately 5.7 gpm/ft^2. A 30” diameter filter provides approximately 4.9 ft^2 of media surface area. Using this loading rate, the system filter requirements can be calculated as follows:

$$225\ gpm\ \div 5.7\ gpm/ft^2 = \ 39.ft^2\ of\ filter\ area\ required$$

$$39\ ft^2 \div 4.9\ ft^2/filter = 8\ filters\ are\ required$$

To summarize, (8) 30” diameter filters will provide a sufficient surface area to treat the maximum withdrawal rate from the wells.

5.4.3 Pre-Filter Contact Time

Pre-filter contact volume is provided by a two 30” diameter by 60” tall contact tanks and the 18” of filter headspace above the filter media in each of the six diameter filter vessels. The volume of the contact tanks is calculated as follows:

$$Contact\ Tank\ Volume\ = 2 \cdot Height\ of\ Filter\ \cdot \pi \cdot (D\ /2)^2$$

$$Contact\ Tank\ Volume\ = 2 \cdot\ 60\ in\ \cdot\ \pi \cdot \left(\frac{30\ in}{2}\right)^2 = 84{,}823\ in^3 \cong 49\ ft^3 \cong 367\ gal$$

The volume of filter headspace in each filter vessel is calculated as follows:

$$Headspace\ Volume = Height\ of\ Headspace \cdot \pi \cdot (D/2)^2$$

$$Headspace\ Volume\ = 18\ in \cdot \pi \cdot \left(\frac{30\ in}{2}\right)^2 \cong 12{,}724\ in^3 \cong 7.36\ ft^3 \cong 55\ gal$$

Water will flow at 225 gpm through the contact tanks and at 28.1 gpm through each filter; therefore, the pre-filter contact time is calculated as follows:

$$Pre-filter\ Contact\ Time = 367\ gal/225\ gpm + 55\ gal/28\ gpm = 3.6\ min$$

5.4.4 Chemical Feed Equipment

Arsenic removal is accomplished by oxidizing arsenic in the water via the injection of a sodium hypochlorite solution, the binding of the oxidized arsenic to iron oxide, and the subsequent precipitation and filtration of the iron oxide with the bound arsenic. An iron to arsenic ratio of 100 to 1 in the incoming water is ideal for arsenic removal. When the ratio is lower, iron may need to be introduced via chemical injection of a ferric chloride solution. Iron and arsenic concentrations in Table 15 and Table 16 indicate an iron to arsenic ratio of 7:1 for Well #1 and 16:1 for Well #4. These ratios suggest ferric chloride dosing is required for adequate arsenic removal. Furthermore, as discussed in Section 5.2.3 and Section 5.2.4, pilot testing obtained adequate arsenic removal by dosing source water with ferric chloride. Therefore, ferric chloride dosing will be included in the proposed treatment system.

All the chemical injection pumps will be provided with a circuit to a magnetic pulse meter which will regulate the pump's dosing rate based on the flow rate of water to the treatment system. This is particularly important for Wells #1, #2, and #3 since the flow rate can vary depending on the pumps in service. The magnetic pulse meter will ensure there is no underdosing or overdosing of sodium hypochlorite or ferric chloride as operational values change.

The ferric chloride injection will consist of a chemical injection pump shared by Wells #1, #2, and #3 with a separate chemical injection pump for Well #4. All the wells can share a polyethylene chemical storage tank as the dilution of the chemical will be kept consistent. The ferric chloride solution for all wells will consist of one part 39% ferric chloride diluted with 9 parts water. The chemical injection pump for Wells #1, #2, and #3 will be set to provide a flow rate of 0.46 gph and an initial dosing rate of 0.58 mg/L of iron (Ferric chloride dose of 1.5 mg/L). Well #4 will be set to provide a flow rate of 0.43 gph and an initial dosing rate of 0.92 mg/L of iron (Ferric chloride dose of 2.2 mg/L).

New chemical feed equipment will also be used to inject a sodium hypochlorite solution to oxidize raw incoming water for arsenic removal. The chemical injection system will be composed of a shared chemical injection pump and polyethylene chemical storage tank for Wells #1, #2, and #3 with a separate chemical injection pump and polyethylene chemical storage tank for Wells #4. Wells #1, #2, and #3 will use a sodium hypochlorite solution of one part 12.5% sodium hypochlorite diluted with 2 parts water. The chemical injection pump will be set to provide a flow rate of 1.14 gph and an initial dosing of 3.9 mg/L of sodium hypochlorite. Well #4 will use a sodium hypochlorite solution of two parts 12.5% sodium hypochlorite diluted with 3 parts water. The chemical injection pump will be set to provide a flow rate of 0.73 gph and an initial dosing of 4.9 mg/L of sodium hypochlorite.

The initial parameters for all four chemical injection pumps are summarized in Table 19.

Table 18: Initial Parameters for Chemical Injection Pumps

	Wells #1 #2 and #3		Well #4	
Solution Type	**Sodium Hypochlorite**	**Ferric Chloride**	**Sodium Hypochlorite**	**Ferric Chloride**
Raw Solution Strength	12.5%	39%	12.5%	39%
Raw Solution to Water Ratio	1 to 2	1 to 9	1 to 2	1 to 9
Pump Rate	1.3 gph	0.46 gph	0.97 gph	0.43 gph
Dosing Rate	4.5 mg/L	1.5 mg/L	5.4 mg/L	2.2 mg/L

A dedicated electrical outlet will be provided for each chemical injection pump that is energized when the corresponding well pump(s) are turned on. Each chemical injection pump's stroke frequency will be manually adjusted by the operator in the field to obtain the desired dosing rates and ensure adequate arsenic removal and chlorine residual. A single, shared polyethylene chemical storage tank will be used for both sodium hypochlorite injection pumps. See Appendix G for chemical injection pump specifications and Appendix F for sodium hypochlorite and ferric chloride dosing calculations.

5.4.5 Filter Vessel Capacity and Backwash Frequency

The filter media capacity is based on a potassium permanganate demand equivalent of 10,000 mg per cubic foot of media. The following table lists the potassium permanganate demand equivalent for each chemical species.

Table 19: $KMnO_4$ Equivalents

		Well #1/2/3		Well #4	
Contaminant	**Equivalence**	**Concentration (mg/L)**	**Effective Conc. (mg/L)**	**Concentration (mg/L)**	**Effective Conc. (mg/L)**
Iron*	1:1	0.58	0.58	0.92	0.92
Manganese	2:1	0.25	0.50	0.38	0.76
Total	-	-	1.1	-	1.68

** Iron concentration is the sum of iron in the raw water and iron added via injection of ferric chloride.*

The iron and manganese concentrations in Table 20 were used to determine the theoretical number of gallons the filter media can treat prior to backwashing. With a media depth of 42 inches, the eight filter vessels combined will contain a total of 137.4 cubic feet of media. The theoretical filter media capacity and volume of production from Well #1 before backwash is calculated as:

$$137.4\ ft^3 \cdot \frac{10{,}000\ mg}{ft^3} \cong 1{,}374{,}000\ mg \text{ total binding capacity}$$

$$1{,}374{,}000\ mg \cdot \frac{L}{1.1\ mg} \cdot \frac{gal}{3.79\ L} \cong 330{,}000 \text{ gallons of source water}$$

$$\frac{330{,}000\ gal}{200\ gal/min} \cdot \frac{1\ hour}{60\ minutes} \cong 27.5 \text{ hours of production}$$

The theoretical filter media capacity and volume of production from Well #4 before backwash is calculated as:

$$137.4\ ft^3 \cdot \frac{10{,}000\ mg}{ft^3} \cong 1{,}374{,}000\ mg \text{ total binding capacity}$$

$$1{,}374{,}000\ mg \cdot \frac{L}{1.68\ mg} \cdot \frac{gal}{3.79\ L} \cong 216{,}000 \text{ gallons of source water}$$

$$\frac{216{,}000\ gal}{125\ gal/min} \cdot \frac{1\ hour}{60\ minutes} \cong 28.8 \text{ hours of production}$$

The theoretical time before backwash for Wells #1 and #4 were calculated to be about 28 hours. However, the Pilot Test Report done by ATEC recommends an initial back wash frequency of 12 hours. Treated water quality will be monitored during treatment validation testing to determine the filter breakpoint. The backwash frequency will be set to ensure that backwashing occurs prior to filter breakpoint. It is anticipated that filter runtime may be extended to 24 hours past the 12 hours recommended in the Pilot Testing Report. Longer runtimes will decrease the total volume of water used for backwash.

5.4.6 Backwash Volume

Each filter will be sequentially backwashed at 28 gpm/ft^2, or 137 gpm, for five minutes. Treated water from the reservoir will be pressurized via booster pumps to provide adequate flow for backwash of the system. A pressure sustaining solenoid valve will be installed on the treated water outlet and will be activated during backwashing operations to ensure that an adequate flow of water is forced through the filter being backwashed. Backwash quantities for each production cycle are as follows:

$$137 \frac{gpm}{filter} \times 5\ minutes = 685\ gallons/filter$$

$$685\ \frac{gallons}{filter} \times 8\ filters = 5{,}480\ gallons$$

Based on pilot test results, the recommended backwash frequency is every 12 hours of production, equating to 90,000 gallons at the production rate of 125 gpm. The percentage of water lost to backwashing is therefore estimated at:

$$\frac{5{,}480\ gallons}{90{,}000\ gallons} = 6\%\ of\ production\ water\ lost\ to\ backwashing$$

Filter performance should be monitored for effectiveness. Adjustment to the backwash frequency, duration, or flowrate may be desired or necessary to minimize water loss or increase filter performance. Decreasing the cycle time between backwashes would result in increased water loss while increasing the cycle time may result in reduced filter performance. A backwash infiltration area near the treatment building will be needed for the disposal of backwash water.

5.4.7 Backwash Infiltration Area

The filter backwash water will be routed to an infiltration area near the treatment building. The infiltration facility was sized using the Island County Soil Survey included in Appendix H. The project area is underlain with Indianola-Useless Bay complex. The Indianola soil type is classified as hydraulic soil group A, and has a typical profile of 1 inch of slightly decomposed plant material and 58 inches of loamy sand and sand. Table 2.4 of the Department of Ecology Stormwater Manual, Volume III, lists long term infiltration rates for Group A soils as greater than 0.30 inches per hour. However, information from Onsite Sewage Evaluations of neighboring parcels shows infiltration rates of 0.50 inches per hour. Therefore, 0.50 inches per hour was used as the design infiltration rate for the backwash infiltration facility.

The MDD of 570 gpd/ERU was used to size the backwash infiltration facility. An overflow to a drainage ditch adjacent to the site will be provided to prevent the infiltration area from flooding. An infiltration rate of 0.50 inches per hour produces a required infiltration area of 1,500 square feet as shown below.

$$Backwash\ Frequency\ at\ MDD = \frac{144{,}000\ gal}{570\ \ gpd/ERU \times 528\ ERUs} \cdot \frac{24\ hr}{day} \cong 11.5\ hr$$

$$\frac{5{,}480\ gallons}{11.5\ hours} \cdot \frac{1\ ft^3}{7.48\ gal} \cdot \frac{12\ in}{1\ ft} \cdot \frac{1\ hour}{.5\ in} \cong 1{,}500\ ft^2$$

A 25-foot by 60-foot infiltration area with a depth of 6 inches will be provided. This equates to 1,500 square feet and a volume of 5,610 gallons.

6 CONSTRUCTION DRAWINGS

The proposed reservoir will be located at the site of the water system's existing reservoir and pumphouse. The proposed arsenic treatment system will be located inside of the pumphouse. Construction drawings have been prepared and are included in Appendix I.

7 OPERATION AND MAINTENANCE CONSIDERATIONS

The system is currently operated by Cascadia Water LLC, who will be responsible for system upkeep and maintenance. A system operation & maintenance manual will be provided by the treatment equipment supplier.

ATEC treatment systems typically require little operator involvement besides maintaining the proper chemical dosing. The chlorine residual will be measured after treatment to ensure that proper oxidant dosing is occurring. Arsenic and iron concentrations will also be taken after treatment to ensure they are adequately removed. The sodium hypochlorite and ferric chloride chemical storage tanks will need to be replenished on a routine basis. The filter media should last 20 years or more based on current field reports.

The water system will need to maintain and periodically clean the reservoir. The required frequency of reservoir cleaning and line flushing operations should decrease with the addition the proposed treatment system because manganese and iron will be removed in addition to arsenic.

Appendix B: Capacity Analysis Calculations

WATER SYSTEM INFORMATION

Date Printed: 11/8/2022

System:	W&B Waterworks 1
PWS ID:	46670-3
Location:	Whidbey Island, Washington
Owner:	Cascadia Water
Operator:	Cascadia Water

Operating Permit	
Issue Date	9/1/2019
Color	Green

Water Facilities Inventory (WFI) Form	
Date Printed	8/23/2019
Active Residential Connections	456
Active Residential Population	1048
Active Non-Residential Connections	0
Average Non-Residential Population	0
Approved Connections	471

WATER USAGE DATA

2016

Month	Days	Usage (Cubic Feet)	Usage (Gallons)	GPD/ERU	% Change from Previous Year
January / February	60	301,368	2,254,233	82	
March / April	61	314,611	2,353,290	85	
May / June	61	884,152	6,613,457	238	
July / August	62	1,294,333	9,681,611	342	
September / October	61	758,345	5,672,421	204	
November / December	61	291,558	2,180,854	78	
SYSTEM TOTAL	**366**	**3,844,367**	**28,755,865**	**172**	

2017

Month	Days	Usage (Cubic Feet)	Usage (Gallons)	GPD/ERU	% Change from Previous Year
January / February	59	340,389	2,546,110	95	11.5%
March / April	61	301,419	2,254,614	81	-4.4%
May / June	61	714,250	5,342,590	192	-23.8%
July / August	62	1,717,980	12,850,490	455	24.7%
September / October	61	859,961	6,432,508	231	11.8%
November / December	61	286,267	2,141,277	77	-1.8%
SYSTEM TOTAL	**365**	**4,220,266**	**31,567,590**	**190**	**8.9%**

2018

Month	Days	Usage (Cubic Feet)	Usage (Gallons)	GPD/ERU	% Change from Previous Year
January / February	59	367,333	2,747,651	102	7.3%
March / April	61	281,048	2,102,239	76	-7.2%
May / June	61	943,006	7,053,685	254	24.3%
July / August	62	1,471,340	11,005,623	389	-16.8%
September / October	61	664,019	4,966,862	179	-29.5%
November / December	61	278,439	2,082,724	75	-2.8%
SYSTEM TOTAL	**365**	**4,005,185**	**29,958,784**	**180**	**-5.4%**

2019

Month	Days	Usage (Cubic Feet)	Usage (Gallons)	GPD/ERU	% Change from Previous Year
January / February	59	319,633	2,390,855	89	-14.9%
March / April	61	351,071	2,626,011	94	19.9%
May / June	61	1,013,073	7,577,786	272	6.9%
July / August	62	1,270,200	9,501,096	336	-15.8%
September / October	n/a	n/a	n/a	n/a	n/a
November / December	n/a	n/a	n/a	n/a	n/a
SYSTEM TOTAL	**243**	**2,953,977**	**22,095,748**	**199**	**-3.7%**

Month	2016	2017	2018	2019
January				
February	2,254,233	2,546,110	2,747,651	2,390,855
March				
April	2,353,290	2,254,614	2,102,239	2,626,011
May				
June	6,613,457	5,342,590	7,053,685	7,577,786
July				
August	9,681,611	12,850,490	11,005,623	9,501,096
September				
October	5,672,421	6,432,508	4,966,862	n/a
November				
December	2,180,854	2,141,277	2,082,724	n/a
Total	28,755,865	31,567,590	29,958,784	22,095,748
ADD	172	190	180	199
Summer usage	16,295,068	18,193,080	18,059,308	17,078,882
ADD (Summer*)	291	324	322	305
max usage	9,681,611	12,850,490	11,005,623	9,501,096
MADD (Summer*)	342	455	389	336

* May through August

Date	S01 Reading	S01 Gallons	S02 Reading	S02 Gallons	S03 Reading	S03 Gallons	S04 Reading	S04 Gallons	Days	Total Gallons	Gallons per Day
1/28/2020	649,418	0	1,000	0	177,769	0	50,007,215	0	-	0	-
1/31/2020	743,087	93,669	1,000	0	177,769	0	50,007,215	0	3	93,669	31,223
2/3/2020	827,123	84,036	3,506	2,506	180,731	2,962	50,021,401	14,186	3	103,690	34,563
2/7/2020	957,455	130,332	3,506	0	180,731	0	50,021,401	0	4	130,332	32,583
2/11/2020	1,090,397	132,942	3,506	0	189,912	9,181	50,021,401	0	4	142,123	35,531
2/14/2020	1,188,329	97,932	3,506	0	206,535	16,623	50,021,401	0	3	114,555	38,185
2/18/2020	1,263,676	75,347	3,506	0	318,695	112,160	50,021,401	0	4	187,507	46,877
2/21/2020	1,371,748	108,072	3,506	0	326,809	8,114	50,021,401	0	3	116,186	38,729
2/25/2020	1,452,432	80,684	3,506	0	460,467	133,658	50,021,401	0	4	214,342	53,586
2/28/2020	1,478,426	25,994	3,506	0	581,337	120,870	50,021,401	0	3	146,864	48,955
3/3/2020	1,543,311	64,885	3,506	0	712,708	131,371	50,021,401	0	4	196,256	49,064
3/6/2020	1,582,089	38,778	3,506	0	822,387	109,679	50,021,401	0	3	148,457	49,486
3/10/2020	1,641,777	59,688	3,506	0	976,769	154,382	50,021,401	0	4	214,070	53,518
3/13/2020	1,681,209	39,432	3,506	0	1,080,471	103,702	50,021,401	0	3	143,134	47,711
3/20/2020	1,825,803	144,594	3,506	0	1,328,111	247,640	50,021,401	0	7	392,234	56,033
3/23/2020	1,903,065	77,262	3,506	0	1,419,645	91,534	50,021,401	0	3	168,796	56,265
3/27/2020	2,005,531	102,466	3,506	0	1,563,851	144,206	50,040,075	18,674	4	265,346	66,337
3/31/2020	2,106,707	101,176	3,506	0	1,710,129	146,278	50,040,075	0	4	247,454	61,864
4/3/2020	2,191,011	84,304	3,506	0	1,814,813	104,684	50,040,075	0	3	188,988	62,996
4/6/2020	2,262,783	71,772	3,506	0	1,903,371	88,558	50,072,785	32,710	3	193,040	64,347
4/9/2020	2,344,321	81,538	3,506	0	2,016,855	113,484	50,073,176	391	3	195,413	65,138
4/13/2020	2,444,416	100,095	3,506	0	2,161,080	144,225	50,119,555	46,379	4	290,699	72,675
4/17/2020	2,565,515	121,099	3,506	0	2,294,610	133,530	50,207,031	87,476	4	342,105	85,526
4/20/2020	2,660,545	95,030	3,506	0	2,382,227	87,617	50,301,727	94,696	3	277,343	92,448
4/29/2020	2,963,377	302,832	3,506	0	2,691,795	309,568	50,440,790	139,063	9	751,463	83,496
5/4/2020	3,135,769	172,392	3,506	0	2,868,862	177,067	50,519,010	78,220	5	427,679	85,536
5/11/2020	3,352,845	217,076	102,065	98,559	3,070,473	201,611	50,797,043	278,033	7	795,279	113,611
5/15/2020	3,475,736	122,891	102,065	0	3,180,481	110,008	50,965,239	168,196	4	401,095	100,274
5/21/2020	3,605,199	129,463	102,065	0	3,275,824	95,343	51,366,256	401,017	6	625,823	104,304
5/29/2020	3,806,041	200,842	102,065	0	3,451,618	175,794	51,875,269	509,013	8	885,649	110,706
6/1/2020	3,904,187	98,146	102,065	0	3,552,817	101,199	51,945,022	69,753	3	269,098	89,699
6/8/2020	4,102,590	198,403	102,065	0	3,771,354	218,537	52,167,311	222,289	7	639,229	91,318
6/29/2020	4,700,010	597,420	140,777	38,712	4,400,843	629,489	52,717,197	549,886	21	1,815,507	86,453
7/3/2020	4,931,023	231,013	189,015	48,238	4,514,976	114,133	52,852,809	135,612	4	528,996	132,249
7/17/2020	5,373,869	442,846	300,440	111,425	4,878,381	363,405	53,855,817	1,003,008	14	1,920,684	137,192
7/21/2020	5,505,118	131,249	461,165	160,725	4,958,847	80,466	54,102,736	246,919	4	619,359	154,840
7/23/2020	5,570,554	65,436	539,678	78,513	4,997,366	38,519	54,220,021	117,285	2	299,753	149,877
7/31/2020	5,838,146	267,592	867,271	327,593	5,209,413	212,047	54,868,276	648,255	8	1,455,487	181,936
8/3/2020	5,938,305	100,159	985,875	118,604	5,299,731	90,318	55,142,752	274,476	3	583,557	194,519
8/6/2020	6,038,045	99,740	1,108,920	123,045	5,401,605	101,874	55,443,476	300,724	3	625,383	208,461
8/14/2020	6,316,137	278,092	1,448,910	339,990	5,633,845	232,240	56,071,741	628,265	8	1,478,587	184,823

8/17/2020	6,413,209	97,072	1,567,790	118,880	5,746,777	112,932	56,364,119	292,378	3	621,262	207,087
8/20/2020	6,513,412	100,203	1,690,036	122,246	5,843,769	96,992	56,614,083	249,964	3	569,405	189,802
8/31/2020	6,879,699	366,287	2,128,261	438,225	6,179,730	335,961	57,484,466	870,383	11	2,010,856	182,805
9/14/2020	7,333,067	453,368	2,523,207	394,946	6,635,025	455,295	58,644,712	1,160,246	14	2,463,855	175,990
9/18/2020	7,460,543	127,476	2,523,207	0	6,775,789	140,764	58,997,931	353,219	4	621,459	155,365
9/22/2020	7,585,533	124,990	2,523,207	0	6,895,376	119,587	59,297,041	299,110	4	543,687	135,922
9/25/2020	7,674,402	88,869	2,525,721	2,514	6,972,642	77,266	59,497,098	200,057	3	368,706	122,902
9/28/2020	7,762,536	88,134	2,529,543	3,822	7,025,081	52,439	59,635,533	138,435	3	282,830	94,277
10/12/2020	8,164,621	402,085	2,541,665	12,122	7,216,611	191,530	60,188,405	552,872	14	1,158,609	82,758
10/29/2020	8,638,590	473,969	2,921,292	379,627	7,216,611	0	60,188,405	0	17	853,596	50,212
11/2/2020	8,745,383	106,793	3,021,786	100,494	7,216,611	0	60,188,405	0	4	207,287	51,822
11/5/2020	8,828,889	83,506	3,095,991	74,205	7,216,611	0	60,188,405	0	3	157,711	52,570
11/10/2020	8,956,264	127,375	3,239,534	143,543	7,216,611	0	60,188,405	0	5	270,918	54,184
11/17/2020	9,148,567	192,303	3,427,461	187,927	7,223,092	6,481	60,212,015	23,610	7	410,321	58,617
11/20/2020	9,238,815	90,248	3,490,752	63,291	7,223,092	0	60,212,015	0	3	153,539	51,180
11/23/2020	9,315,825	77,010	3,573,911	83,159	7,223,092	0	60,212,015	0	3	160,169	53,390
11/30/2020	9,513,419	197,594	3,776,669	202,758	7,223,092	0	60,212,015	0	7	400,352	57,193
12/7/2020	9,699,034	185,615	3,959,774	183,105	7,224,345	1,253	60,217,035	5,020	7	374,993	53,570
12/7/2020	9,703,921	4,887	3,984,181	24,407	7,235,078	10,733	60,217,035	0	0	40,027	0
12/14/2020	9,895,978	192,057	4,137,907	153,726	7,237,319	2,241	60,257,113	40,078	7	388,102	55,443
12/18/2020	10,018,264	122,286	4,236,509	98,602	7,237,319	0	60,265,823	8,710	4	229,598	57,400
										MDD	208,461

CONNECTIONS BASED ON WATER USE DATA

Date Printed: 11/8/2022

System: W&B Waterworks 1
PWS ID: 46670-3
Location: Whidbey Island, Washington

Year	Active Connections	Active Metered	Active Unmetered	Ready to Serve	Committed Connections
2016	456	456	0		
2017	456	456	0		
2018	456	456	0		
2019	456	456	0		
2020	456	456	0		
2021	456	456	0		

Proposed Connections 471

WATER RIGHTS SUMMARY

Date Printed: 11/8/2022

System: W&B Waterworks 1
PWS ID: 46670-3
Location: Whidbey Island, Washington

Certificate #	Name	Priority Date	Source Name	Primary or Supplemental	Q_i (gpm) Additive	Q_i (gpm) Non-Additive	Q_a (acre-ft) Additive	Q_a (acre-ft) Non-Additive	
G1-22510P	W&B Waterworks	06/04/75	4 Wells	Primary	225		45		
G1-24539C	W&B Waterworks	08/24/84	4 Wells	Primary		225	105		
				Total	225		150		Total
				max flow per day (gal)	162,000		6,534,000		annual water rights (CF/yr)
				max flow per year (gal)	59,130,000		48,874,320		annual water rights (gal/yr)
							133,902		avg available daily water rights (gal)

Q_i = Maximum Instantaneous Flow Rate
V_a = Maximum Annual Withdrawal

Conversion Factors	
square feet per acre	43,560
gallons per CF	7.48
days per year	365
hours per day	24

Pump	
pump cycles per hour	6
pump run per hour (min)	30
pump run per day (min)	720

SOURCE INFORMATION

System: W&B Waterworks 1
PWS ID: 46670-3
Location: Whidbey Island, Washington

Source						
Status	Active					Emergency
Source ID	Well 1	Well 2	Well 3	Well 4		
IC Hydrogeo ID						
DOE Well Tag	AGA932	AGA931	AGA930	AGA929		
Category	Well	Well	Well	Well		
Use	Permanent	Seasonal	Permanent	Seasonal		
Treatment	None	None	None	None		
Capacity (gpm)	50	75	75	75		
Depth to First Interval (ft)	300	291	270	307		
Casing (in)						
Screen Diameter (in)						
Location						
1/4, 1/4	SE NE	SE NE	SE NE	SE NE		
Section	22	22	22	22		
Township	29N	29N	29N	29N		
Range	02E	02E	02E	02E		

DEMAND BASED ON WATER USE DATA

System: W&B Waterworks 1
PWS ID: 46670-3
Location: Whidbey Island, Washington

Year	Active Connections	Annual Withdrawal (gal)	Annual Withdrawal (ac-ft)	Annual Usage (gal)	Summer* Usage (gal)	Maximum Month Usage (gal)	DSL / Unauthorized Use (gal)	Annual ADD (gpd)	Summer* ADD (gpd)	Maximum Month ADD (gpd)	Annual ADD (gpd/ERU)	Summer* ADD (gpd/ERU)	MMADD (gpd/ERU)	MDD** (gpd/ERU)
2018	456	32,599,102	100.0	29,958,784	18,059,308	5,502,812	2,640,318	88,727	158,715	191,887	195	348	421	568
2021	456	31,092,287	95.4	28,355,939	17,078,882	4,750,548	n/a	98,541	150,477	166,073	216	330	364	492
2020	456	30,922,513	94.9	n/a	n/a	5,889,050	n/a	95,146	-	189,969	209	n/a	417	457
	Average	31,537,967	96.8	29157361.4	17569095.1	5380803.2	2640318.2	94138.1	154596.3	182643.1	206.4	339.0	400.5	506
	Minimum	30,922,513	94.9	28355939.0	17078882.0	4750548.0	2640318.2	88726.7	150477.3	166072.8	194.6	330.0	364.2	492
	Maximum	32,599,102	100.0	29958783.8	18059308.1	5502811.6	2640318.2	98541.5	158715.4	191887.2	216.1	348.1	420.8	568

* May through August
** MDD = 1.35(MMAD)

	Proposed		
ADD	220	gpd/ERU	
MDD	570	gpd/ERU	Based on MDD

SOURCE-BASED PHYSICAL CAPACITY

System: W&B Waterworks 1
PWS ID: 46670-3
Location: Whidbey Island, Washington

WATER RIGHT CALCULATIONS

Based on Annual Volume & Average Day Demand (Eqn 4-4b):

$N = Q_a/(365*ADD)$

Where: N = Number of Service Connections, ERUs
Q_a = Annual Volume of Water Available from All Sources, as limited by Water Right (gallons/year)
ADD = Average Daily Demand per ERU (gpd/ERU)

	V_a (gal/year)	ADD (gpd/ERU)	N (ERUs)
Potential Connections	48,874,320	220	**609**

Based on Instantaneous Flow & Maximum Day Demand (Eqn 4-4a):

$N = V_d/MDD = (Q_i*t_d)/MDD$

Where: N = Number of Service Connections, ERUs
V_d = Total Volume of Water Available for Maximum Day's Demand (gpd)
MDD = Maximum Daily Demand per ERU (gpd/ERU)
Q_i = Instantaneous Maximum Water Right Flow Rate (gpm)
t_d = Time that source operates per day (minutes/day)

	Q_i (gpm)	Minutes Pumped/Hr	t_d (min/day)	MDD (gpd/ERU)	N (ERUs)
Potential Connections	225	60	1440	570	**568**

SOURCE CALCULATIONS

Individual Source Capacity (Eqn 4-1):

$V_j = Q_j*t_j$

Where: Vj = Total volume for source "j" over a specified period of time (gal/specified time period)
Qj = Delivery rate of source (gal/unit time)
tj = Time that flow (Qj) was delivered from source "j"

Total Source Capacity (Eqn 4-2):

$V_T=sum(Q_j*T_j)$

Where: V_T = Total volume of water available to the system over a specified period of time (gal/specified time period)
Q_j = Delivery rate of source (gal/unit time)
t_j = Time that flow (Q_j) was delivered from source "j"

Source ID	Well 1	Well 2	Well 3	Well 4	
Q_j Delivery Rate (gpm)	50	75	75	75	
Max Pump Time (min/day)	1200	1200	1200	1200	
Max Days Pumped (days/yr)	365	365	365	365	
V_j Source Capacity (gal/yr)	21,900,000	32,850,000	32,850,000	32,850,000	

Q_s = 275 gpm

V_T = 120,450,000 gal/yr

Based on Source Capacity & Average Day Demand (Eqn 4-4b)

$N = V_T/(365*ADD)$

Where: N = Number of Service Connections, ERUs
V_T = Annual Volume of Water Available from All Sources, except Emergency Sources (gallons/year)
ADD = Average Daily Demand per ERU (gpd/ERU)

	V_T (gal/year)	ADD (gpd/ERU)	N (ERUs)
Potential Connections	120,450,000	220	**1,500**

Based on Source Production & Maximum Day Demand (Eqn 4-3):

$N = V_T/MDD = (Q_s*t_d)/MDD$

Where: N = Number of Service Connections, ERUs
V_T = Total Volume of Water Available for Maximum Day's Demand (gpd)
MDD = Max Daily Demand per ERU (gpd/ERU)
Q_s = Total Well Production Flow rate (gpm)
t_d = Time that source operates per day (minutes/day)

	Q_s (gpm)	Minutes Pumped/Hr	t_d (min/day)	MDD (gpd/ERU)	N (ERUs)
Potential Connections	275	50	1200	570	**579**

SOURCE-BASED PHYSICAL CAPACITY

System: W&B Waterworks 1
PWS ID: 46670-3
Location: Whidbey Island, Washington

BOOSTER PUMP CALCULATIONS

Based on Booster Pump Production & Maximum Day Demand:

N= [(PHD - 18)1440/MDD -F]/C

Where: N = Number of Service Connections, ERUs
PHD = Peak Hour Demand (gallons/minute) (Booster Pump Capacity)
MDD =Maximum Daily Demand per ERU (gpd/ERU)
F = PHD Coefficient from Table 3-1
C = PHD Coefficient from Table 3-1

	Q_B (gpm)	C	F	MDD (gpd/ERU)	N (ERUs)
Potential Connections	80	2.5	25	570	**66**

*The booster pumps only serve 11 connections on Roy Road.

TREATMENT CALCULATIONS

Based on Treatment Max Design Flow & Maximum Day Demand (Eqn 4-4a):

N = V_d/MDD = (Q_t*t_d)/MDD)

Where: N = Number of Service Connections, ERUs
V_d = Total Volume of Water Available for Maximum Day's Demand (gallons/day)
MDD = Maximum Daily Demand per ERU (gpd/ERU)
Q_t = Treatment System Maximum Design Flow Rate (gpm)
t_d = Time that source operates per day (minutes/day)

	Q_t (gpm)	Minutes Pumped/Hr	t_d (min/day)	MDD (gpd/ERU)	N (ERUs)
Potential Connections	225	57	1358	570	**536**

SUMMARY

ERUs	Condition	Limiting Factor
609	Water Right	V_a & ADD
568	Water Right	Q_i & MDD
1,500	Source	V_T & ADD
579	Source	Q_s & MDD
66	Booster Pump (Pressurized Zone)	Q_B & MDD
536	Treatment	Q_t & MDD

System Capacity: **536** ERUs
* 101 connections max. in pressurized zone
Limited by: **Qt & MDD** *Treatment*
Proposed connections: **536** ERUs

PEAK HOUR DEMAND (PHD) CALCULATION

Date Printed: 11/8/2022

System: W&B Waterworks 1
PWS ID: 46670-3
Location: Whidbey Island, Washington

From DOH Water System Design Manual (Section 3.4.2)

Equation 3-1: PHD = (MDD/1440)[(C)(N) + F] + 18

Where:
PHD = Peak Hourly Demand, (gpm)
C = Coefficient Associated with Ranges of ERUs
N = Number of Service Connections, ERUs
F = Factor Associated with Ranges of ERUs
MDD = Maximum Day Demand, (gpd/ERU)

Table 3-1:

Range of N (ERUs)		C	F
15	50	3.0	0
51	100	2.5	25
101	250	2.0	75
251	500	1.8	125
501	1,000,000	1.6	225

MDD (gpd/ERU)	N (ERUs)	C	F	PHD (gpm)	
570	456	1.8	125	**392**	2020 ERUs
570	472	1.8	125	**404**	2026 ERUs
570	550	1.6	225	**455**	Reservoir Design Min.
570	471	1.8	125	**403**	Current DOH Approved
570	536	1.6	225	**447**	Max ERUs

STORAGE CAPACITY CALCULATIONS

System: W&B Waterworks 1
ID No.: 46670-3
Location: Whidbey Island, Washington

Demands	
N (ERUs)	550
ADD (gpd/ERU)	220
MDD (gpd/ERU)	570
PHD (gpm)	455

Sources		
Source ID	**Delivery Rate (gpm)**	
Well 1	50	
Well 2	75	
Well 3	75	
Well 4	75	
Q_s =	275	
Q_s =	225	*water right limited*
Q_L =	75	*largest source*

Reservoirs						
Reservoir ID	**Diameter (ft)**	**Area (ft^2)**	**Height (ft)**	**Base Elevation (ft)**	**Volume (gal)**	**VF (gal/ft)**
Reservoir	30	706.9	35	280	185,056	5,287
				Total	185,056	5,287

Top Dead Storage (TDS)	
Depth (ft)	**Volume (gal)**
0.75	3,965

Operational Storage (OS)	
Depth (ft)	**Volume (gal)**
4.0	21,149

Treatment Run Time *94* *minutes* *(desire 60 miutes or more)* 70.50
7930.95

Required Equalizing Storage (ES)			
PHD (gpm)	**Q_s (gpm)**	**Volume (gal)**	**Depth (ft)**
455	225	34,559	6.5

*ES = (PHD-Q_s)*150 or Zero*

Recommended Standby Storage (SB)			
Recommended SB per Connection (gal/ERU)	**N (ERUs)**	**Rcommended SB Volume (gal)**	**Depth (ft)**
200	550	110,000	20.8

SB_{TMS} = (200)(N) or (100)(N) when reduction is applied (see section 7.1.1.3 of the Manual)

Available Standby Storage (SB)			
Storage Provided (gal/ERU)	**N (ERUs)**	**Volume (gal)**	**Depth (ft)**
200	607	121,416	23.0

SB = Total Storage Volume -TDS-OS -ES-BDS

STORAGE CAPACITY CALCULATIONS

System: W&B Waterworks 1
ID No.: 46670-3
Location: Whidbey Island, Washington

Fire Suppression Storage (FSS)		
Fire Flow (gpm)	**t_m (min)**	**Volume (gal)**
500	30	15,000

FSS = FFt_m*   *Where: FF = Required fire flow rate (gpm)*
t_m = Duration of FF rate (minutes)

Bottom Dead Storage (BDS)	
Depth (ft)	**Volume (gal)**
0.75	3,965

Available Storage Summary		
Component	**Volume (gal)**	**Depth of Storage Component (ft)**
TDS	3,965	0.75
OS	21,149	4.0
ES	34,559	6.5
SB/FSS	121,416	23.0
BDS	3,965	0.75
Total	185,056	35.0

Is the available SB/FSS…	
greater than recommended SB?	greater than required FSS?
yes	yes