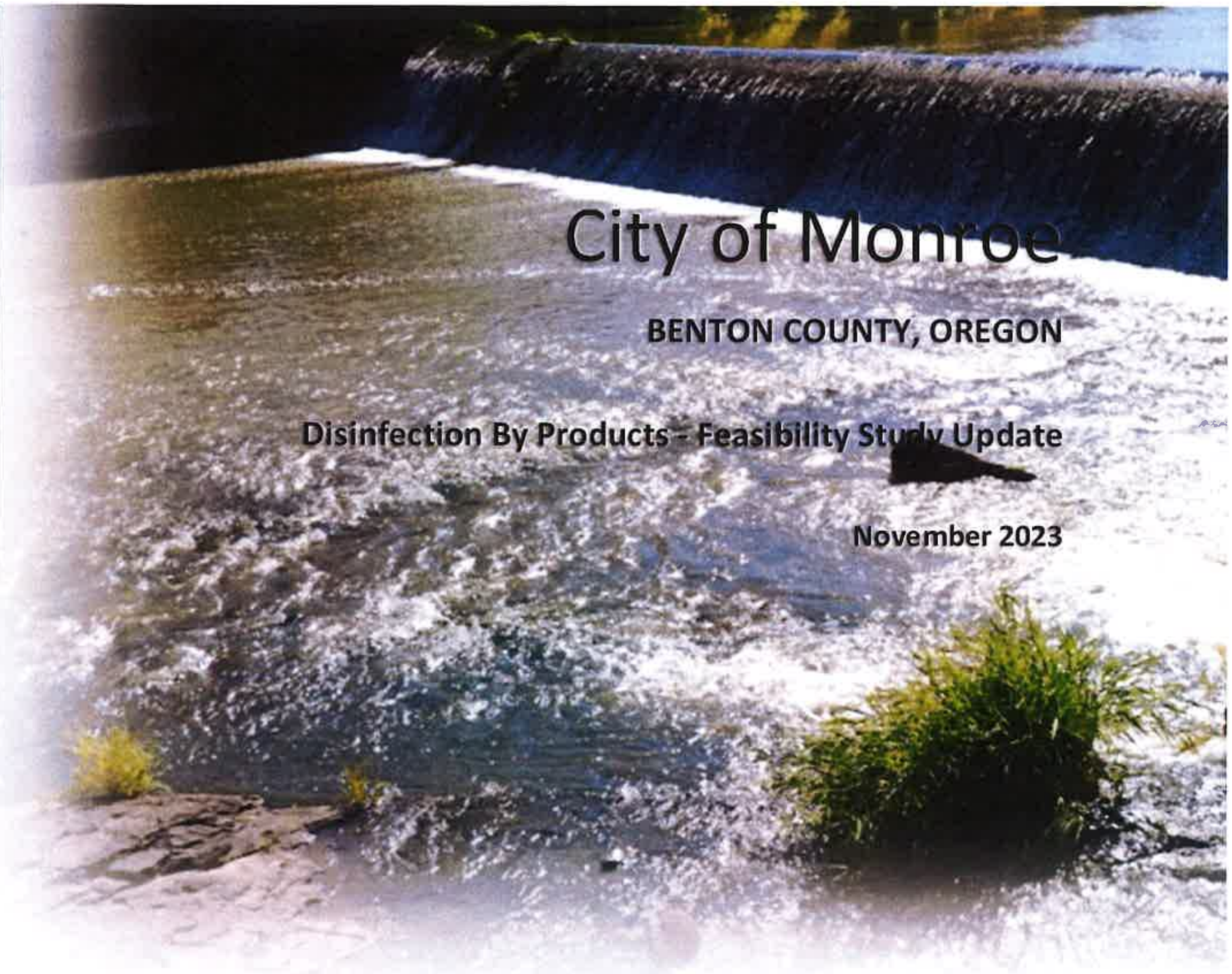

City of Monroe

BENTON COUNTY, OREGON

Disinfection By Products - Feasibility Study Update

November 2023

REGISTERED PROFESSIONAL ENGINEER
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OREGON
NOV. 10, 2009
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EXPIRATION DATE: 06/30/2024

Civil West
Engineering Services, Inc.

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Contents

1. Introduction

The City of Monroe is located in the Willamette Valley, Benton County, approximately 18 miles south of Corvallis on 99W and 9 miles north of Junction City. The City of Monroe is primarily a residential and agricultural community with no major industries. The City owns and operates an ultrafiltration membrane surface water treatment plant that provides potable drinking water to approximately 615 persons via 273 service connections (OHA Drinking Water Data Online). The water system is comprised of the following primary assets:

- An intake structure and associated piping on the Long Tom River
- Several inactive wells
- Inactive spring sources outside of the UGB
- An ultrafiltration membrane technology-based surface water treatment plant
- One 1.0 MG potable water storage reservoir
- One pressure reducing valve station
- A distribution system including fire service
- Two off-line water storage reservoirs

Since 2019, the water system has had consistent problems with keeping their Disinfectant By Product (DBP) levels under the Maximum Contaminant Level (MCL). DBPs are formed as a byproduct of a disinfectant (primarily chlorine) interacting with organic matter to form trihalomethanes (TTHMs) and haloacetic acids (HAA5s). The formation of DBPs is dependent on the available chlorine, the presence of organics, and in the case of TTHMs the time (water age) that the two are in contact. The dangers of repeated exposure to elevated levels of DBP contaminants have adverse health effects including nervous system issues, cancer, and birth defects.

TTHMs

Total trihalomethanes (TTHMs) are a group of disinfection byproducts, namely trichloromethane (chloroform), dibromochloromethane, bromodichloromethane, and bromoform. The sum of these four chemicals is reported as TTHM and is compared to the State maximum contaminant level (MCL). The MCL for TTHM is 0.080 mg/L.

HAA5s

Similarly, haloacetic acids are measured as a group. Five haloacetic acids make up HAA5 group which is measured and compared to the State MCL. The five acids that make up HAA5 are dibromoacetic acid, dochloroacetic acid, monobromoacetic acid, monochloroacetic acid, and trichloroacetic acid. The State MCL for HAA5 is 0.060 mg/L.

DBPs at the City of Monroe have been recorded at an average of 0.090 mg/L for TTHMs and 0.054 mg/L for HAA5s since 2019. The average TTHM levels exceed the federal and state MCL of 0.080 mg/L. TTHMs at Monroe have been as high as 0.130 mg/L. The average HAA5 level is below the federal and state MCL of 0.060, but does frequently exceed the MCL up to 0.106 mg/L.

The following table displays the dates and results of the tests for TTHM and HAA5.

Sample Date	Location	TTHM (mg/L) MCL = 0.080	HAA5 (mg/L) MCL = 0.060
8/1/2022	575 S 5TH (TTHM)	**0.0922**	0.015
8/1/2022	575 N 8TH (HAA5)	**0.0917**	0.0425
6/6/2022	575 S 5TH (TTHM)	**0.0969**	**0.0709**
6/6/2022	575 N 8TH (HAA5)	0.0612	**0.106**
3/15/2022	575 S 5TH (TTHM)	0.0626	**0.0737**
3/15/2022	575 N 8TH (HAA5)	0.0606	**0.0705**
12/23/2021	575 S 5TH (TTHM)	**0.1013**	0.0188
12/23/2021	575 N 8TH (HAA5)	**0.1001**	**0.0608**
9/24/2021	575 S 5TH (TTHM)	**0.1071**	0.0088
9/24/2021	575 N 8TH (HAA5)	**0.1109**	0.0444
6/25/2021	575 S 5TH (TTHM)	**0.1236**	0.0342
6/25/2021	575 N 8TH (HAA5)	**0.108**	0.0507
3/25/2021	575 S 5TH (TTHM)	0.071	0.0546
3/25/2021	575 N 8TH (HAA5)	0.0646	**0.0717**
12/15/2020	575 S 5TH (TTHM)	**0.0825**	**0.0606**
12/15/2020	575 N 8TH (HAA5)	0.0777	0.0595
9/25/2020	575 S 5TH (TTHM)	**0.1292**	0.0474
9/25/2020	575 N 8TH (HAA5)	**0.1295**	**0.0813**
6/17/2020	575 S 5TH (TTHM)	**0.1133**	0.0353
6/17/2020	575 N 8TH (HAA5)	**0.1015**	0.0471
2/26/2020	575 S 5TH (TTHM)	0.063	**0.0661**
2/26/2020	575 N 8TH (HAA5)	0.0661	**0.0659**
11/14/2019	575 S 5TH (TTHM)	**0.0827**	0.0445
11/14/2019	575 N 8TH (HAA5)	**0.0808**	0.0432
9/5/2019	575 S 5TH (TTHM)	**0.13**	–
9/5/2019	575 N 8TH (HAA5)	–	**0.0746**
6/12/2019	575 S 5TH (TTHM)	**0.0802**	–
6/12/2019	575 N 8TH (HAA5)	–	0.043
2/21/2019	575 S 5TH (TTHM)	0.0502	–
2/21/2019	575 N 8TH (HAA5)	–	**0.0602**

Table 1.0 - DBP Reporting History

In the summer of 2020, the City entered into a Bilateral compliance agreement (BCA) with the Oregon Health Authority but was unable to make substantive changes to the water system to reduce DBPs. In April of 2022, the OHA, cancelled the BCA and issued a Notice of Violation and Administrative Order. Among the actions required to achieve compliance is for the City to submit a feasibility study and a revised action plan describing how the City will modify the water system to meet drinking water standards.

The Administrative Order with OHA is to complete the following tasks by their associated deadline:

ISSUE PUBLIC NOTICE	May 12, 2022 (Done)
SUBMIT COMPLETED FEASIBILITY STUDY	Nov 10, 2022
SUBMIT CORRECTIVE ACTION PLAN	Dec 29, 2022
BEGIN CONSTRUCTION	Apr 30, 2023
COMPLETE CONSTRUCTION	Jul 31, 2023
CORRECT WATER QUALITY DEFICIENCIES	Oct 10, 2024

1.1 Feasibility Study Objective

The purpose of this feasibility study is to identify infrastructure and process improvements which will reduce DBPs to levels deemed safe by the State and to recommend the improvements which will be most likely to reduce DBPs.

Principal plan objectives include:

- Identifying operational changes to reduce DBPs
- Identifying Capital Improvements to reduce DBPs
- Developing preliminary estimates of cost for proposed improvements
- Recommendation of improvements and operational changes

2 Existing Conditions – DBP Mitigation Strategies

The root cause of the DBP issues at Monroe is the high level of organic compounds in the raw water source. When ultrafiltration membranes are unable to filter out organics in the source water, they are chlorinated and form DBPs.

DBPs can be mitigated by two basic approaches;

(1) by controlling the quantity of the precursors (organics loading and sodium hypochlorite), or

(2) by removing the DBPs after they have been formed.

Generally, in water treatment, the earlier contaminants can be removed, the more efficient the treatment process is. This holds true with DBPs, as typically the most effective ways to reduce DBPs are to minimize their formation by reducing the organic loading in the raw water and to reduce the amount of disinfectant (chlorine) needed to treat the water. If a water system is unable to reduce DBPs by controlling the precursors, then they will need to remove the DBPs after they have formed. This section will review the existing water system and evaluate potential strategies for reducing DBPs in each step of the process.

2.1 Water Source

The intake is located adjacent to the WTP on the Long Tom River approximately 17 river miles downstream of the Fern Ridge Dam. The Fern Ridge Reservoir is a US Army Corps of Engineers (USACOE) operated site. The USACOE manages the release of water from the Fern Ridge Dam which feeds the downstream section of the Long Tom. Consequently, the downstream water quality of the Long Tom River is extremely variable due to the operation of the dam, with very high turbidity and organics loading spikes resulting from the abrupt changes to the dam's discharge.

The City currently uses a simple screened intake and a 15 HP pump on the Long Tom River for the water supply. The raw water is "flash" mixed at the intake structure with coagulant (see photo 2.1) in the 350' long 8" pipe between the river intake and the WTP.

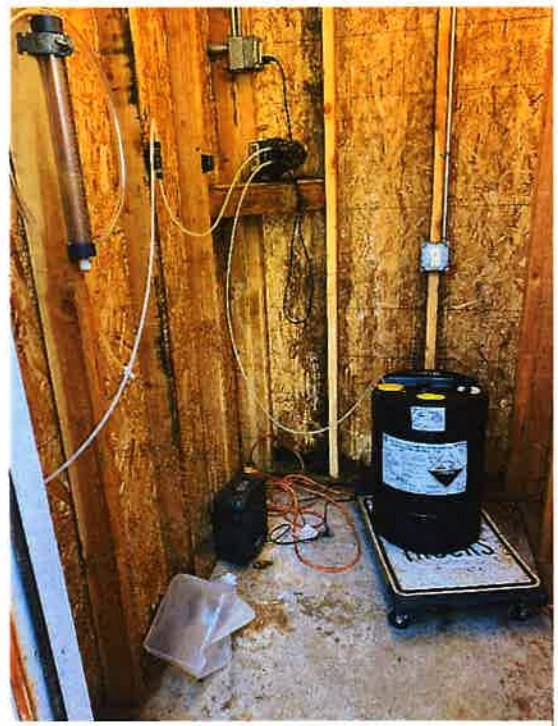

Photo 2.1 - Coagulant Injection - Intake

Since DBPs are formed when a strong oxidant such as sodium hypochlorite reacts with organic material in the water, removing or reducing the organic loading prior to disinfection will greatly reduce the formation of DBPs. The most common method to reduce organics in raw surface water sources, is to treat the raw water with an advanced coagulation process that will create floc particles that organics will bind to and then those floc particles are able to be settled out of the treated water. This would require either a settling basin or a clarification system, either of which would be sized to reduce the velocity of the water to the point where the heavier floc particles will drop out of the water column prior to the WTP's ultra-filtration (UF) membranes.

Another potential treatment solution would be to switch from the current UF membrane treatment to conventional filtration. UF membrane treatment systems inherently are not the best choice for organic laden waters, nor do they excel at treatment of high turbidity sources such as the Long Tom. Typically, UF membranes are not recommended for raw water turbidities in excess of 20 NTU, with AWWA recommending pretreatment on UF systems where influent turbidities exceed 10 NTU.

2.2 Water Treatment Plant

Photo 2.2 – Seimens Ultrafiltration System

The current population per the OHA Drinking Water Data Online website is 615 residents with 273 active water service connections. Population projections from the 2020 Water Master Plan push the population to 822 due both to recent development in the City combined with the Population Resource Center (PRC) at Portland State University's Average Annual Growth Rate Percentages. The 2020 WMP determined that Monroe uses on average 87 gallons per person per day. At the end of the master plan's 20-year planning period, this equates to an average daily demand of 64,000 gallons per day, or double that for a maximum daily demand at estimated 128,000 gallons per day. To meet these demands, the water treatment plant would need to run for about 4 hours to meet average daily demand in the wintertime (when water is cooler, the membrane plant has a maximum production rate of ~245 gpm). In the warmer months the plant can produce water up to 350 gpm and would require about 6 hours to meet the maximum daily demand of 128,000 gallons per day.

Currently, the plant is typically run for 8 – 12 hours to replenish the water levels in the reservoir and is then offline for 2-3 days until it needs to be ran again to "fill" the reservoir. During extended periods of time when the plant is not being run, the clearwell and reservoir are sitting stagnant with nearly zero mixing. We feel that if the plant was run every day to meet the daily demand, mixing would improve, which should in turn lower DBP concentrations in distribution. Ideally, the functionality of the WTP's automation should be restored via SCADA upgrades to allow the plant to run autonomously and more frequently. The plant could potentially run on one of the two membrane banks at a time to further slow the plant's output which will in turn allow for increased mixing in the reservoir and clearwell.

Sodium hypochlorite injection at the WTP is presently done with a simple, non-flow paced peristaltic pump. The dosing pump is dosing hypochlorite at a constant rate irrespective to the WTP's variable effluent flow rate into the clearwell. This can lead to both over and underdosing of sodium hypochlorite, in the case of overdosing, the plant will be accelerating the formation of DBPs.

2.3 Water Storage

The City of Monroe currently uses a 1.0 MG reservoir for water storage. Per the 2020 Water Master Plan, the City needs to store approximately 800,000 gallons currently and 850,000 gallons at the end of the design period (2040) to meet storage needs for equalization, emergency, and fire reserves. Bearing this in mind, the reservoir cannot simply be "drained down" to shorten water age to address DBP formation without losing fire flow capacity.

An aerating mixer could be installed in the reservoir (photo 2.3) to both decrease stagnation and increase off-gassing of TTHMs. While aerating mixers can be effective at decreasing volatile TTHMs, they have little to no effect on HAA5s. Since the City of Monroe struggles with both TTHMs and HAA5s, this would only be a viable solution if the HAA5s were able to be controlled by some other means and TTHMs continued to be an issue independent of the HAA5s.

Photo 2.3 - 1.0 MG Reservoir

2.4 Water Distribution System

The existing water distribution system at the City of Monroe begins at the outlet of the reservoir. Most of the City is fed through a Pressure Reducing Valve (PRV) (photo 2.4). From there the distribution system is generally a well-looped grid consisting of mostly 8-inch and 10-inch PVC water mains, with a small amount of 4-inch and 6-inch scattered around the periphery. The layout of the existing water system is adequate to deliver the required flowrates to the community, with most lines being looped back into the system. Looped distribution lines allow the use of smaller diameter pipes and improves both the reliability and the redundancy of the system, as the water can reach the point of demand by more than one path.

Photo 2.4 - Pressure Reduction Valve

DBP problems can be compounded by distribution systems that have high chlorine demand. Particulate matter can settle out in the distribution mains if not periodically flushed, this can lead to high chlorine demand in the distribution system. To maintain sufficient free chlorine residual throughout the system, the water system will be forced to use a much higher free chlorine residual at the entry point. Historically, the distribution system at the City of Monroe has not been regularly flushed. We strongly recommend that the City either begin a monthly water line flushing program, or budget to hire a third party to flush the water lines.

3 System Improvement Alternatives

3.1 Water Source Improvements

Currently the pre-treatment coagulant at the City of Monroe's raw water intake is injected via a peristaltic pump whenever the raw water pump is on. There are no means to flow pace the injection of coagulant with the rate on water pumped by the raw water pump. There is also no way to remotely adjust the coagulant dosing from the water treatment plant. The existing dosing pump is only adjustable manually from a rotary dial on the pump itself.

To adequately upgrade the raw water pumping station the City will need to expand its SCADA system to communicate with the raw water pump(s). This will require metering and SCADA communications to the raw water pump station. We are anticipating that chemical dosing will be moved to the WTP, so costs associated with that are shown in section 3.2.

The cost estimate below includes two new VFD controllable raw water pumps, a new raw water meter, and SCADA integration/communication to the WTP.

Source - Raw Water Pumps and SCADA Improvements					
Item No.	**Description**	**Unit**	**Quantity**	**Unit Cost**	**Item Cost**
1	Mobilization - Bonds, Insurance (10%)	LS	1	$ 18,250.00	$ 18,250.00
2	Construction Facilities and Temporary Controls	LS	1	$ 3,500.00	$ 3,500.00
3	Demo and Site Prep	LS	1	$ 5,500.00	$ 5,500.00
4	New Raw Water Pumps (200 gpm), VFDs	EA	2	$ 45,000.00	$ 90,000.00
5	New Raw Water Meter	EA	1	$ 8,000.00	$ 8,000.00
6	Piping and Appurtenances	LS	1	$ 17,500.00	$ 17,500.00
7	SCADA Integration and Comunication System	LS	1	$ 50,000.00	$ 50,000.00
8	Electrical	LS	1	$ 8,000.00	$ 8,000.00
			Estimated Construction Cost:	**$**	**200,750.00**
	Administrative/Legal (5%)			$	10,037.50
	Contingency (20%)			$	40,150.00
	Engineering (20%)			$	40,150.00
			Estimated Project Total Cost:	**$**	**291,087.50**

3.2 Water Treatment Plant Improvements

To reduce the organic loading of the raw water, the treatment system must use some form of optimized flocculation/coagulation. This can be achieved with either a clarification and sedimentation process, or by switching to a conventional treatment system.

One way to reduce DBPs at the City of Monroe is the addition of a sedimentation basin and clarifier upstream of the UF membrane water treatment plant. With the extremely variable turbidity that the City of Monroe's WTP sees daily, the addition of a pre-filter to the membrane plant will allow the membrane plant to run for much longer between backwash cycles. The clarifier also adds the benefits of the conventional sedimentation process, which when coupled with the appropriate coagulants and water chemistry will allow for treatment of NOM along with a significant turbidity reduction prior to the UF membranes. Removal of DBP precursor is the preferred method of mitigation of a DBP issue.

As described in the previous section, two of the major issues plaguing the WTP are the lack of automation and the accuracy of the metering and dosing systems. We feel that if the plant was run every day to meet the daily demand, mixing would improve, which should in turn lower DBP concentrations in distribution. Pre-treatment chemical addition (alkalinity & coagulant) will be dosed from the WTP. The chlorine dosing pump will be upgraded to a variable output pump that can flow pace with the WTP's output flowrate to ensure that a consistent chlorine dose is administered to the finished water without the possibility of dosing chlorine in excess. Below you will find cost estimates to add clarification and SCADA upgrades to the existing membrane plant.

Water Treatment Plant - Clarifier and SCADA Upgrades					
Item No.	**Description**	**Unit**	**Quantity**	**Unit Cost**	**Item Cost**
1	Mobilization - Bonds, Insurance (10%)	LS	1	$ 123,565.00	$ 123,565.00
2	Construction Facilities and Temporary Controls	LS	1	$ 10,000.00	$ 10,000.00
3	Demo and Site Prep	LS	1	$ 6,500.00	$ 6,500.00
4	Membrane Filter Station Control	EA	2	$ 100,000.00	$ 200,000.00
5	Clarifiers	EA	2	$ 225,000.00	$ 450,000.00
6	Clarifier Station Controls	EA	2	$ 50,000.00	$ 100,000.00
7	Housing for Clarifiers	EA	2	$ 30,000.00	$ 60,000.00
8	Upgraded Meters	EA	3	$ 7,800.00	$ 23,400.00
9	Chemical Dosing Pump Skids	EA	3	$ 26,500.00	$ 79,500.00
10	Piping and Appurtenances	LS	1	$ 65,000.00	$ 65,000.00
11	Pump Station Integration	EA	2	$ 20,000.00	$ 40,000.00
12	Electrical	LS	1	$ 45,000.00	$ 45,000.00
13	Elevated Reinforced Concrete Pad	CY	100	$ 1,500.00	$ 150,000.00
14	Site Restoration	LS	1	$ 6,250.00	$ 6,250.00
			Estimated Construction Cost:	**$**	**1,359,215.00**
	Administrative/Legal (5%)			$	67,960.75
	Contingency (20%)			$	271,843.00
	Engineering (20%)			$	271,843.00
			Estimated Project Total Cost:	**$**	**1,970,861.75**

Treatment of high turbidity and high organic laden raw water like what is seen of the source at the City of Monroe is best suited for a conventional style of treatment plant. A conventional treatment plant relies on flocculation/coagulation and settlement of particles prior to filtering with a media filter. These filters can be backwashed periodically and are then good for a new cycle. The cost to backwash and to occasionally replace media is significantly less than the replacement of the City's current UF membranes.

Due to the construction of the current plant, which was designed for housing the relatively smaller and lighter UF membranes above the clearwell, the floor is likely not designed for the larger and heavier conventional package units. The clearwell would likely need to be reinforced with stainless steel columns to support the additional weight of the heavier conventional treatment units.

Costs to move to a conventional style water treatment plant are comparable to the upgrades required to add clarification upstream of the existing UF membrane treatment plant. Long term operations and maintenance costs for upgrading to a clarifier and retaining the existing plant are likely far more than the operations and maintenance costs of a conventional style water treatment plant. Below you will find our cost estimate to change the existing membrane plant to conventional filtration.

Water Treatment Plant - New Conventional Treatment and SCADA Upgrades					
Item No.	**Description**	**Unit**	**Quantity**	**Unit Cost**	**Item Cost**
1	Mobilization - Bonds, Insurance (10%)	LS	1	$ 124,090.00	$ 124,090.00
2	Construction Facilities and Temporary Controls	LS	1	$ 10,000.00	$ 10,000.00
3	Demo and Site Prep	LS	1	$ 6,500.00	$ 6,500.00
4	New Raw Water Pump Station	LS	1	$ 80,000.00	$ 80,000.00
5	New 120 gpm Convention Treatment Units	EA	3	$ 250,000.00	$ 750,000.00
6	Upgraded Meters	EA	3	$ 7,800.00	$ 23,400.00
7	Chemical Dosing Pump Skids	EA	3	$ 26,500.00	$ 79,500.00
8	Pump Station Integration	EA	2	$ 20,000.00	$ 40,000.00
9	Clearwell Structural Support for Treatment Units	LS	1	$ 200,000.00	$ 200,000.00
10	Piping and Appurtenances	LS	1	$ 28,000.00	$ 28,000.00
11	Electrical	LS	1	$ 22,000.00	$ 22,000.00
12	Site Restoration	LS	1	$ 1,500.00	$ 1,500.00
			Estimated Construction Cost:	**$**	**1,364,990.00**
	Administrative/Legal (5%)			$	68,249.50
	Contingency (20%)			$	272,998.00
	Engineering (20%)			$	272,998.00
			Estimated Project Total Cost:	**$**	**1,979,235.50**

Aside from infrastructure upgrades, the City of Monroe should budget for having the clearwell cleaned and inspected. There may be significant buildup of fine sediments in the clearwell that could be harboring biological activity and hence greater chlorine demand. Many surface water treatment plants suffer from this issue, and it would be prudent for the City to eliminate the potential for such demand in their clearwell with periodic cleanings.

Further, the City should budget to have a CT Study performed on the clearwell to ensure that the proper contact time is being used for CT calculations. If the CT Study shows that the clearwell is performing better than the estimated contact time from OHA, the City should be able to lower their chlorine dosage and consequently their DBPs.

In addition to the WTP project cost, a certified operator with a current license will need to be employed to comply with the OAR (Oregon Administrative Rule) requirement of a Direct Responsible Charge (DRC). Since no one in the community currently has the qualifications to perform this service, the City should continue to budget to hire outside of City staff to DRC the water treatment plant.

3.3 Water Storage Improvements

Due to the ongoing issues with DBPs the City has not been able to fill their 1.0 MG reservoir without the threat of exceeding the MCL for DBPs. Per the 2020 Water Master Plan, the City needs to store approximately 800,000 gallons currently and 850,000 gallons at the end of the design period (2040) to meet storage needs for equalization, emergency, fire reserves.

An aerating mixer could be installed in the reservoir to both decrease stagnation and increase off-gassing of TTHMs. While aerating mixers can be effective at decreasing volatile TTHMs, they have little to no effect on HAA5s. Since the City of Monroe struggles with both TTHMs and HAA5s, this would only be a viable solution if the HAA5s were able to be controlled by some other means and TTHMs continued to be an issue independent of the HAA5s.

Reservoir - Mixing/Aeration Upgrades for TTHM Control					
Item No.	**Description**	**Unit**	**Quantity**	**Unit Cost**	**Item Cost**
1	Mobilization - Bonds, Insurance (10%)	LS	1	$ 4,120.00	$ 4,120.00
2	Construction Facilities and Temporary Controls	LS	1	$ 2,500.00	$ 2,500.00
3	Mixer/Aerator	LS	1	$ 12,500.00	$ 12,500.00
4	Aeration System and Compressor	LS	1	$ 12,000.00	$ 12,000.00
4	Active Ventilation	LS	1	$ 10,000.00	$ 10,000.00
5	Electrical	LS	1	$ 4,200.00	$ 4,200.00
			Estimated Construction Cost:	**$**	**45,320.00**
	Administrative/Legal (5%)			$	2,266.00
	Contingency (20%)			$	9,064.00
	Engineering (20%)			$	9,064.00
			Estimated Project Total Cost:	**$**	**65,714.00**

3.4 Water Distribution Improvements

As discussed in an earlier section, DBP problems can be compounded by distribution systems that have high chlorine demand and thus necessitate elevated residual at the EP to maintain residual throughout the distribution system. Particulate matter can settle out in the distribution mains if not periodically flushed, this can lead to high chlorine demand in the distribution system. We strongly recommend that the City either begin a monthly water line flushing program, or budget to hire a third party to flush the water lines. The cost estimate below provides for 25% of the distribution system being flushed monthly by an outside service and the engineering to determine the most advantageous flushing locations.

Distribution - Citywide Waterline Flushing					
Item No.	**Description**	**Unit**	**Quantity**	**Unit Cost**	**Item Cost**
1	Monthly Flushing 25% of System	EA	12	$ 2,400.00	$ 28,800.00
			Estimated Construction Cost:	**$**	**28,800.00**
	Administrative/Legal (5%)			$	1,440.00
	Contingency (20%)			$	5,760.00
	Engineering (20%)			$	5,760.00
			Estimated Project Total Cost:	**$**	**41,760.00**

4 Project Timeline

We anticipate once the feasibility study is approved by OHA, that the design work can begin shortly after. Design for the proposed projects should be able to be done in three to four months. The project should be able to go out for bids in two months after plan review approval with OHA. The construction phase should take approximately six months from notice to proceed until substantial completion.

5 Recommendation

5.1 Water Source Recommendations

To provide more consistent water to the plant, we recommend new raw water pumps and VFDs and chemical dosing as described in section 3.1. Estimated cost $291,087.50.

5.2 Treatment Recommendations

The water treatment system for the City of Monroe requires improvements to meet OHA water quality standards. Given the similar upfront costs for:

- adding a clarifier to the existing system and
- replacement of the existing system with a conventional treatment system

the recommended improvements are to replace the existing treatment system with a conventional treatment system. The conventional system will be much less complex than a clarifier/membrane system, and the conventional system will have much lower operations and maintenance costs in the long term. Estimated cost $1,979,235.50.

5.3 Storage Recommendations

Although HAA5 cannot be off-gassed as TTHMs can, it is recommended to install a mixer in the reservoir to reduce some of the DBPs. Estimated cost $65,714.00.

5.4 Distribution Recommendations

A water main flushing program is also strongly recommended to routinely flush the waterlines to mitigate high levels of DBPs and sedimentation that occur in the larger water mains. Estimated cost $41,760 for the first year and $28,800 annually afterwards.

6 Conclusion

We are confident that the various recommended projects will be able to reduce DBPs below the MCL and will provide the residents, employees, and visitors to the City higher quality drinking water.

The total estimated cost of these improvements is $2,377,797.00.