PUBLIC HEALTH DIVISION
Drinking Water Services
Kate Brown, Governor

Oregon Health Authority

800 NE Oregon Street, #640
Portland, OR 97232-2162
Phone: 503-939-1322
Fax: 971-673-0694
healthoregon.org/DWS

December 8, 2022

Steve Martinenko
City of Monroe
Emailed

Re: City of Monroe (PWS ID# 00540)
Membrane Module Replacement with Evoqua S10N Modules
Conditional Approval – PR# 167-2022

Dear Steve:

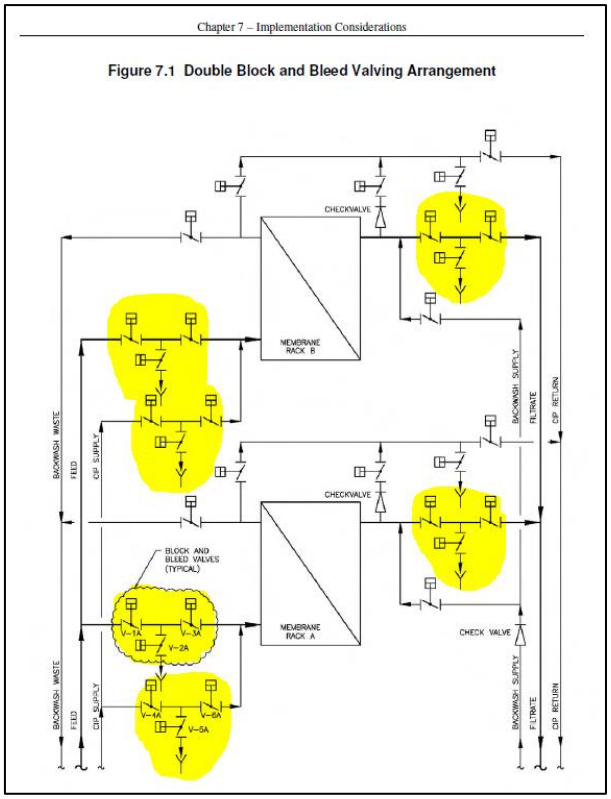
Thank you for submitting information regarding the membrane module replacement for the City of Monroe. On November 8, 2022 we received plans for replacing the existing Memcor S10V membrane modules with Memcor S10N modules. A plan review fee payment in the amount of $825 was received to cover the cost of the plan review. The project is/was assigned plan review (PR) #167-2022.

The project involves replacing the existing 48 Memcor S10V membrane modules with the newer Memcor S10N modules and programming the ambient log removal value ($LRV_{ambient}$) calculations into SCADA. The existing 48 S10N membranes in the other skid will have the same SCADA programming applied.

The Oregon Health Authority grants **Conditional Approval** for the project with the following conditions that will need to be met prior to granting Final Approval:

1. Direct integrity testing parameters will need to be verified and programmed into the PLC/SCADA system. These parameters include:
   a. A **direct integrity test pressure**, which is to be set no less than 11.4 psi;
   b. An **upper pressure decay control limit**, which is set no less than 0.95 psi/min that indicates a failure of the direct integrity test and prompts an automatic shut-down of the filtration skid; and
   c. An ongoing **log removal value ($LRV_{ambient}$)** reflective of particle and pathogen removal in the 3 micron or less size range that is calculated every 15 minutes based on current ambient operating conditions (a metric commonly referred to as $LRV_{ambient}$) and the most recent direct integrity test result. In summary, **$LRV_{ambient}$** is the performance indicator used to demonstrate the minimum 4.0-log (99.99%) *Cryptosporidium* removal that the membrane filters have been credited with.

2. Alarm set points are updated to reflect the following operating limits which, if exceeded, prompt an automatic shut-down of the filter skid:
   a. Maximum flux of 80 gfd, or equivalent flow setpoint.
   b. Maximum transmembrane pressure (TMP) of 22.0 psi.
   c. Minimum $LRV_{ambient}$ of 4.0-log (calculated every 15 minutes and visible in SCADA)
   d. Maximum direct integrity test upper pressure decay rate (control limit) as determined upon commissioning.
   e. An alarm set point established to trigger a membrane unit shut down when the combined filter effluent turbidity exceeds 0.15 NTU for more than 15 minutes so that a direct integrity test can be performed on the affected unit.
3. SCADA programming should ensure that the variables and constants used to determine the pressure decay rate and $LRV_{ambient}$ are viewable to the operator for verification purposes.
4. Measures are taken to ensure that the membrane filter train is isolated during the clean in place (CIP). A double block-and-bleed system may be used to accomplish this as shown in the schematic to the right =>
5. An operation and maintenance manual is developed that includes membrane integrity testing or an "integrity verification program" and module fiber repair/pinning procedures.



The remainder of this letter includes:

1) Table 1 - Log removal credits (LRC) granted for the selected membrane modules.
2) Table 2 - Operating limits that help ensure that the log removal credits granted are met.
3) Appendix A - Explanation of operating limits and terms in Table 2.
4) Appendix B - Formulae and variables used in calculating the log removal value ($LRV_{ambient}$) of each membrane filter unit using current ambient operating conditions.
5) Appendix C – Product specifications for the selected modules.

When final approval is granted, each membrane filter unit will be granted log removal credits (LRCs) for pathogen removal as shown in Table 1. The LRCs are based on a verification of the Challenge Study Report for the S10N membrane modules.

Table 1 – Filter Log Removal Credit (LRC)

Pathogen	Removal Credit (log_{10})
Giardia lamblia	4.0
Cryptosporidium sp.	4.0
Viruses	0.0

The LRCs are only valid provided operations are within the limits shown in Table 2. Ensure SCADA/PLC programming accounts for the operating limits in Table 2 (e.g. set system alarms to ensure operating limits are met). **Some of the limits in Table 2 are yet to be determined as indicated by "TBD" and will need to be established prior to Final Approval.**

Table 2 – Operating Limits

Operating Parameter	Limit
Direct integrity test (DIT) frequency	Conduct at least 1 DIT each day of operation
DIT duration/hold time	4 minutes (240 Seconds)
DIT starting test pressure	16.5 psi
Minimum allowed DIT pressure	11.4 psi throughout the DIT duration
Maximum allowable pressure decay rate (PDR) upper control limit (UCL)	UCL = 0.95 $^{psi}/_{min}$
Minimum DIT pressure transducer accuracy for the established UCL[1]	$\pm$ 0.2 % of span (indicate span in psi)
Membrane Minimum Performance ($LRV_{ambient}$)	$LRV_{ambient}$ = 4.0-log (must be $\geq$ 4.0-log LRC)
DIT Sensitivity (LRV_{DIT})	4.8-log. LRV_{DIT} is the maximum LRV that can be reliably demonstrated by the DIT
Maximum transmembrane pressure (TMP)	22 psi at 20°C
Maximum allowed filtrate flux [gfd]	80 $^{gal/SqFt}/_{day}$ @ 20°C
Individual filter effluent (IFE) turbidity	IFE ≤ 0.15 NTU for ≥ 15 consecutive minutes
Combined filter effluent (CFE) turbidity	CFE ≤ 1 NTU in 95% of readings and always less than 5 NTU
Automatic Shutdown Conditions (i.e., shut filter unit down and conduct a DIT to demonstrate membrane integrity is intact)	○ PDR > UCL ○ $LRV_{ambient}$ < LRC ○ IFE > 0.15 NTU for > 15 min ○ CFE > 5.49 NTU (may prompt boil water notice)

[1] **Pressure transducer accuracy** is typically based on the manufacturer's stated accuracy (best fit straight line), expressed as % of span. The accuracy calculated in terms of [psi/min] must be less than or equal to the UCL in [psi/min]. Accuracy in terms of [psi/min] is calculated as follows:

Accuracy in psi/min = (% Accuracy x Max of span in psi) / DIT duration in minutes

$LRV_{ambient}$ is the best metric for demonstrating compliance with the log removal credit (LRC) granted. To remain in compliance, $LRV_{ambient}$ must be equal to or greater than the LRC for *Cryptosporidium* shown in Table 1. $LRV_{ambient}$ values displayed in SCADA should be calculated using the formulae and variables shown in Appendix B.

Thank you for your cooperation during this process and if you have any questions on the information above, or would like this information in an alternate format, please contact me at (503) 939-1322 or via e-mail at keith.male@oha.oregon.gov.

Sincerely,

Keith Male, EIT
Regional Engineer
Oregon Health Authority - Drinking Water Services

ec: Chuck Sholz, City of Monroe
Shawn Stevenson, OHA-DWS,

Appendix A - Explanation of operating limits and terms in Table 2.

The ability of membranes to filter out pathogens (referred to as **membrane integrity**) is to be tested in two ways:

1) Continuously using a turbidimeter that monitors the effluent turbidity from each membrane unit, often called **individual filter effluent (IFE)** turbidity monitoring, and

2) Once a day using a more direct pressure decay or "air hold" test, often called a **"Direct Integrity Test" (DIT)** because the air hold test is a direct test for leaks or broken membrane fibers.

Direct Integrity Testing (DIT):
Like checking for leaks in a car tire, the membranes are pressurized with air and held for a set amount of time. Air hold times are generally 2 – 10 minutes. A pressure sensor then detects a drop in the held pressure. This pressure drop is called a pressure decay, measured in psi. How fast the pressure drops (or decays) is called the **pressure decay rate (PDR)**, measured in psi/minute. The pressure decay rate is the drop in pressure (psi) divided by the air hold time (minutes) expressed in psi/minute. In some cases, the SCADA will display only the pressure decay in psi and it is up to the operator to know the hold time and determine the decay rate in psi/minute.

Demonstrating compliance:
Should individual filter effluent turbidity exceed 0.15 NTU for more than 15 consecutive minutes, the membrane unit needs to be taken out of service and undergo a direct integrity test. Turbidity is an indirect indicator of membrane integrity and a direct integrity test (DIT) is needed to explicitly determine membrane integrity.

In order for a DIT to be able to demonstrate that the membranes are intact (do not have holes or broken fibers), the membrane needs to be pressurized to a certain minimum pressure (the **minimum direct integrity test pressure**) and the pressure decay rate needs to be under a specified upper limit or **"Upper Control Limit" (UCL)**.

The results of the DIT can be used to calculate a pathogen removal efficiency under ambient operating conditions achieved by the membranes. This log removal value is termed **"$LRV_{ambient}$"** and can be used to demonstrate compliance by directly comparing this performance metric to the log removal credit (**LRC**) *Cryptosporidium* awarded in Table 1.

More detail on the terms introduced above and the operating limits (e.g., upper control limit, etc.) in Table 2 are further described as follows:

- DIT Turbidity Trigger (IFE > 0.15 NTU for > 15 min): A direct integrity test (DIT) must be performed on each filter unit if the individual filter effluent (IFE) turbidity is greater than 0.15 NTU for more than 15 minutes. This must be programmed into the SCADA system. Should the IFE turbidity exceed 0.15 NTU for more than 15 minutes, the membrane unit must be taken out of service and undergo a DIT. The membrane unit must not be placed back into service unless it passes the DIT (see Upper Control Limit below). Membrane fiber repair/pinning is often needed to remedy this situation.

- DIT Daily Trigger: A DIT is also required each day of operation. If the pressure decay rate (PDR) drops below the upper control limit (UCL in $^{psi}/_{minute}$), then the DIT is considered to have failed and the unit must be automatically taken off-line, repaired, and retested to show that it passes a DIT before being placed back into service. In other words, should the PDR of the daily PDT (or "air hold test") exceed the UCL, this should indicate a "failed" DIT and the membrane must be taken out of service and may not be placed into service until it passes a DIT. **A new DIT may be immediately run after a DIT failure, or repairs may be needed first (e.g., fibers pinned, leaks at pipe fittings repaired, etc.) followed by passing a new DIT.**

- DIT test pressure: The minimum DIT pressure (i.e., the test pressure at the end of the DIT) must not drop below the minimum DIT pressure stated in Table 2. **Should the pressure during a DIT drop below the level in Table 2, the DIT is considered invalid or "failed" and must be repeated. Test pressures are often established (with consultation with the membrane manufacturer) above the minimum DIT pressure to ensure that the test is valid.**

- Upper Control Limit (UCL) in $^{psi}/_{min}$
  Every membrane system has an Upper Control Limit (UCL) measured in $^{psi}/_{min}$. The UCL is the highest **p**ressure **d**ecay **r**ate (PDR) allowed during a direct integrity test (DIT). Exceeding the UCL indicates DIT failure. The failing membrane unit shall not operate until it passes a DIT. Ensure that the SCADA/PLC system is programmed to account for this UCL.

- Membrane Performance ($LRV_{ambient}$): The results of the direct integrity test will be used to determine the log removal value of *Cryptosporidium* that is based on ambient or

current operating conditions ($LRV_{ambient}$). The main difference between LRV_{DIT} and $LRV_{ambient}$ is the use of the current operating flow when calculating $LRV_{ambient}$. Lower flows could yield a lower (less conservative) LRV value. Since the pathogen removal credit is in terms of a log removal value, membrane performance must be determined to demonstrate compliance with the pathogen credit awarded using the same unit of measure [log]. Formulae and variables used to calculate $LRV_{ambient}$ are included in Appendix B of this letter. In summary, $LRV_{ambient}$ is the metric for demonstrating compliance. $LRV_{ambient}$ must be equal to or greater than the log removal credit for *Cryptosporidium* shown in Table 1.

- TMP: The transmembrane pressure or "TMP" is the pressure drop across the membranes and must not exceed that indicated in Table 2. The log removal credit is awarded based on this TMP as it reflects the operating conditions at the time of the challenge study conducted to demonstrate the membrane's ability to remove *Cryptosporidium*.

- Flux: The flux ($^{flow}/_{filter\ feed\ area}$) is the flow per square feet of membrane surface area on the feed or inlet side of the membranes per day [$^{gal/SqFt}/_{day}$]. The flux must not exceed that indicated in Table 2. The log removal credit is awarded based on this flux as it reflects the operating conditions at the time of the challenge study conducted to demonstrate the membrane's ability to remove Cryptosporidium.

- Automatic Shutdown Conditions: **The filters must be taken off-line or otherwise shut down, repaired and/or re-tested if any of the following occurs:**

    1. PDR > UCL. The DIT PDR exceeds the UCL in Table 2.
    2. $LRV_{ambient}$ < LRC. The $LRV_{ambient}$ is less than the log removal credit (LRC) in Table 1
    3. IFE > 0.15 NTU for > 15 min. The individual filter effluent (CFE) turbidity exceeds 0.15 NTU for more than 15 minutes.
    4. Combined Filter Effluent (CFE) turbidity exceeds 5.49 NTU (your regulator should be contacted as a boil water notice may be required)

- DIT Sensitivity (LRV_{DIT}): The results of the direct integrity test (commonly a pressure decay rate or "PDR" is the DIT of choice) and the design flow can be used to determine the DIT sensitivity, expressed as a log removal value of *Cryptosporidium* (LRV_{DIT}). This LRV_{DIT} must be equal to or greater than the log removal credit (LRC) shown in Table 1.

Appendix B - Formulae and variables used in calculating the log removal value ($LRV_{ambient}$) of each membrane filter unit using current ambient operating conditions.

Table B. Formulae and variables used in the $LRV_{ambient}$ programming

Specification	Value
$LRV_{ambient}$ equation	$LRV_{ambient} = \log_{10}(\frac{Q_P \bullet ALCR \bullet P_{atm}}{\Delta P_{test} \bullet V_{sys} \bullet VCF})$
ALCR equation	$ALCR_{laminar} = \frac{527 * \Delta P_{eff} * (175 - 2.71 * T + 0.0137 * T^2)}{TMP * (460 + T)}$
▲P_{eff}	$\Delta P_{eff} = [P_{test} - BP] * \left[\frac{(P_{test} + P_{atm}) + (BP + P_{atm})}{2 * (BP + P_{atm})}\right] * \left[\frac{(BP + P_{atm})}{P_{atm}}\right]$
P_{Test} equation	P_{Test} = (0.193 • κ• σ • cos ɵ) + BP_{max}
Volume of pressurized air in module during direct integrity testing [gallons and liters]	0.4227 $^{gallons}/_{module}$ (1.6 $^{liters}/_{module}$)
V_{sys}, Total volume of pressurized air in the unit during direct integrity testing [gallons and liters]	62 gallons (234.7 liters)
VCF, Volumetric Concentration Factor [dimensionless]	1
VCF for backwash units in which filtrate goes to clearwell	N/A
P_{atm}, Atmospheric pressure [psia]	14.7
Y, Net Expansion Factor [dimensionless]	N/A
d, Lumen diameter [mm]	0.54 mm I.D. (1.03 mm O.D.)
L, Potting depth or defect length [mm]	N/A
κ, Pore shape correction factor [dimensionless]	1
σ, surface tension at 0°C, N/m [$^{dyne}/_{cm}$]	0.0749 N/m (74.9 dyne/cm)
ɵ, Liquid-membrane contact angle [degrees]	50 °
Q_p, Maximum design flow rate per module [$^{gal}/_{min}$]	13.89 gpm (52.6 L/min)
BP_{max}, Maximum backpressure during the DIT [psi]	2.0 psi (55.4 inches of water)
P_{Test}, Applied direct integrity test pressure [psi] (*Should be ≥ minimum test pressure in Table 2*)	16.5 psi starting test pressure target 11.4 psi lowest ending test pressure
D_{base}, Baseline diffusive loss expected through fully intact membrane filter unit [psi/min]	0 psi/min (for membrane units of this size)

[1] Crane Co. 1988. *Flow of fluids through valves, fittings, and pipe*. Technical Paper No. 410. Stamford, CT.

Appendix C – Product specifications for the Evoqua S10N membrane modules

Table A. Membrane Filter Module Specifications

Specification	Value
Membrane Manufacturer	Evoqua
Membrane Model Number	S10N
Challenge test standard (ANSI/NSF 419-YY, ETV, etc.)	40 CFR §141.719
Challenge test report date	December 2012
$LRV_{C\text{-}Test}$	4.0-log
OHA-DWS Challenge Study Verification Information Assumes a 2.0 psi maximum backpressure (BP_{max}) =>	Date Verified = May 26, 2015 LRC = 4.0-log (*Giardia*/*Crypto*) Max Flux = 80 GFD @ 20°C Max TMP = 22 psi Minimum DIT Pressure = 11.4 psi
ANSI/NSF Standard 61 certification (yes/no)	Yes
Membrane type (*e.g.*, hollow fiber, etc.)	Hollow fiber
Number of fibers per module	6.800
Fiber inside (lumen) diameter	0.54 mm
Fiber wall thickness	0.245 mm
Active fiber length (length of fibers not in potting)	1050 mm
Potting depth	90 mm
Membrane classification (*e.g.,* ultra- or micro-filtration)	Ultrafiltration
Nominal membrane pore size (*e.g.*, 0.01 µm, etc.)	0.04 µm
Membrane material (*e.g.*, PVDF, polysulfone, etc.)	PVDF
Roughness coefficient	N/A
Feed side membrane filtration area (ft^2)	250 ft^2 (23.23 m^2)
Filtration Flow Direction (*i.e.*, inside-out or outside-in)	Outside-in
Hydraulic configuration (*i.e.*, deposition or suspension)	Deposition
Submerged or Pressurized	Submerged