Recycled Water Use Plan
Individual Batch Process Production of Highly Purified Water for Beneficial Reuse
For Clean Water Services | NPDES Permit No. 101142 | File No. 90745
July 2019

INTRODUCTION

On April 15, 2015, the Oregon Environmental Quality Commission approved the use of high purity water for human consumption as an ingredient in the production of an alcoholic beverage. The proposed approach envisioned producing individual batches of high purity water to make home-brewed beer to use at specific professional events. The Environmental Quality Commission approval followed the recommendation from the Department of Environmental Quality (DEQ) staff (Agenda Item D, Action item: Authorization to allow human consumption of recycled water). The DEQ recommendation was based on the Clean Water Services' (District) proposal described in detail in the report Clean Water Services High Purity Water Project Direct Potable Water Reuse Demonstration in April 2015. The Oregon Health Authority (OHA) Public Health Division approved the proposed use of recycled water in the limited case as described in the proposal by letter from Dave Leland to Ron Doughten dated September 8, 2014. The District submitted a Recycled Water Use Plan to DEQ on April 24, 2015. The District is updating the Recycled Water Use Plan to allow commercial brewers or distillers to produce beer and other alcoholic beverages. The 2019 Recycled Water Use Plan also describes the trailer that houses the system that produces high purity water.

The District uses a proven advanced treatment process to produce batches of high purity water that exceed safety standards for drinking water and human consumption. The intent of this activity is to raise public awareness about advances in water purification and disinfection technology that provide groundbreaking opportunities to treat water to any desirable level. As water treatment technologies and monitoring have become more sophisticated and affordable, the District is promoting discussions about the potential uses of high purity water.

Background

Clean water is one of our most precious resources. The water we drink today has been used and reused many times because there is a finite amount of water on the planet. The District has one of Oregon's largest water reuse program and is exploring further options to address water needs within the Tualatin River Watershed. The District has been working with local and global interests for several years to advance public awareness and understanding of water as nature's amazing reusable resource. Whether it comes from a river, lake or melting snow pack, the water we drink is part of a closed system – part of one water.

On any given day, the District cleans millions of gallons of water and provides clean water for use on school grounds, wetlands, golf courses and sports fields, ecological restoration, and for environmental flows in the Tualatin River. There are now even greater opportunities for reuse of purified water for agricultural, industrial or urban uses. To continue the conversation and foster the growing awareness of this issue, the District has implemented this high purity water project.

The data presented in Appendix B was collected in January 2019 using the system upgrades described below. The data that appears in Appendix C was collected from batches of high purity water produced in 2015 to demonstrate the effectiveness of the treatment process. The results from both sets of testing clearly show the use of consistent, reliable technology produces consistent, reliable results. The monitoring employed for each batch of water intended for beneficial purposes is discussed below.

The District's goal is to utilize Pure Water Brew to change the conversation surrounding wastewater effluent and highlight the importance of using treated water as a resource. Through this effort, the District wishes to make a profound difference in our industry as well as with the general population. Ensuring the

security of a clean water supply is one of the most important issues we face.

High purity water will be produced in batches to produce alcoholic beverages for conferences, private venues, educational awareness and media events. The District will reuse or dispose unused high-purity water either for other permitted beneficial reuse (such as irrigation, facility operations, industrial use) or through appropriate municipal wastewater systems with no direct discharge of high purity water to waters of the state.

DESCRIPTION OF TREATMENT PROCESS

General

The effluent from Durham or Forest Grove wastewater treatment facility is treated with ultrafiltration membranes, reverse osmosis and disinfection/advanced oxidation ultraviolet (UV) disinfection to produce a very high quality water that is absent of trace pollutants and pathogens.

Forest Grove Wastewater Treatment Facility (Forest Grove)

Forest Grove receives an average dry weather flow of 2.46 MGD. The facility provides advanced secondary treatment followed by a vertical flow wetland and then by a natural treatment system. The average wet weather flow is 8 MGD. Flow consists of 92% domestic, 7.6% industrial and less than 1% commercial contributions. The industrial flow is mainly from food processing facilities and electronics manufacturing facilities. This facility does not accept septage.

Forest Grove has alarmed all vital equipment for major processes. When activated, the alarm system signals an auto-dialer (24-hour service) to notify District personnel. In addition, alarms are reported at the Rock Creek Advanced Wastewater Facility, which is staffed 24 hours a day, seven days a week.

Durham Advanced Wastewater Treatment Facility (Durham)

Durham receives an average dry weather flow of 19.6 MGD; the average wet weather flow is 24.4 MGD. Durham provides advanced wastewater treatment for Durham, King City, Sherwood, Tigard, Tualatin, portions of Beaverton, Lake Oswego and unincorporated Washington County. Flow consists of 93% domestic, 5% industrial and 2% commercial. The industrial flow is mainly from processing and electronic manufacturing facilities. Durham receives septage; fats, oil and grease; and has a separate RV waste receiving station.

Durham uses programmable logic controllers and a plant wide Supervisory Control and Data Acquisition System (SCADA). The control and monitoring system includes a large number of sensors and alarms, including alarms that will indicate process failures and emergency events. Plant staff will receive critical alarms over the Zeetron network by plant radio and should respond by going to any SCADA terminal to investigate the alarm.

PROCESSES SPECIFIC TO THE PRODUCTION OF HIGH PURITY WATER

Water purification treatment train for direct potable reuse: The water purification system selected for direct potable reuse incorporates multiple treatment steps to remove pathogens and chemical compounds from disinfected treated effluent to produce an ultra-pure finished water that is safe for human consumption. A brief overview of each process is provided here along with the purpose of each process in the water purification train. Greater detail is contained in the 2019 Technical Memorandum and Sampling Plan.

Ultrafiltration (UF): UF provides a physical barrier to remove particulate material from water through size exclusion. The UF membranes used in this treatment system have a nominal pore size of 0.03 *u*m and are expected to reduce the turbidity of the filtered water to near or below 0.1 Nephelometric Turbidity Units (NTU). Through the size exclusion mechanism, the UF membranes provide removal of bacteria, protozoan and viral pathogens. UF also provides pretreatment of the water prior to reverse osmosis.

Reverse Osmosis (RO): RO uses a semipermeable membrane to remove dissolved substances from water. Water passes through the RO membrane by diffusion facilitated by high pressure. Dissolved substances diffuse much more slowly through the RO membrane and are therefore removed from the water. RO is commonly used to remove salt from ocean water to create drinking water and will remove salts from the ultra-filtered water in this project. The RO process removes pathogens remaining in the water after UF and removes a significant portion of dissolved organic matter and trace chemical substances of human health concern.

Ultraviolet Light Advanced Oxidation Process (UV AOP) Disinfection System: Small, non-charged dissolved substances may pass through the RO membrane to some degree and require an additional unit process for removal. An example of a small non-charged dissolved substance is nitrosamines including NDMA (N-Nitrosodimethylamine). NDMA and other nitrosamines are effectively removed through photolysis with UV light. Additionally, other anthropogenic compounds may pass through the RO membrane in very trace concentrations. These compounds are broken down through chemical oxidation with hydrogen peroxide or free chlorine. The UV AOP is the combination of a UV light disinfection for photolysis with hydrogen peroxide addition for chemical oxidation. This combination ensures the final disinfection for the high purity water system

PURE WATER WAGON

The District has upgraded the treatment system with a similar unit process, but improved capacity, online monitoring and equipment with automated cleaning systems. The new system includes programmable logic controller-based controls and is capable of more automatic operation and control. As noted, the treatment uses the same proven process for purification and is therefore expected to provide the same level of purification.

The equipment is installed in an enclosed trailer that can be pulled by a conventional utility vehicle. The wagon is wrapped in signage that highlights the high purity water mission and contains educational material describing the unit processes and communicating the value of water and benefits of reuse. The wagon may be displayed at public events.

MONITORING STRATEGY

Monitoring includes system integrity and final quality monitoring, which are discussed below and in Table 11 of the 2019 Technical Memorandum and Sampling Plan. Results from testing in January 2019 are presented in Appendix B. There was no E. coli in 15 samples from January 2019. Additionally, sampling for a broad range of chemicals of emerging concern such as pharmaceuticals and personal care products were reduced to below detectable levels. The following parameters are monitored to test operational integrity:

Table 1: Monitoring parameters associated with system integrity testing

Treatment process	Monitoring during water production	Sample collection/results received after water production	Frequency
UF	Turbidity removal	Total coliform reduction	During operations
RO	Electrical conductivity removal	TOC removal	During operations
UV/H_2O_2 AOP	UVT, UVI and flow	NDMA removal	Intervals/annual
High Purity Water	Total coliform	Total coliform	During operation

SYSTEM INTEGRITY TESTING

System integrity testing includes both challenge testing and operational testing. Detail regarding the challenge testing and operational testing can be found in Appendix D.

Challenge testing using MS2 is done to verify the system achieves the log-removal expectations. Challenge testing conducted in January 2019 showed greater than 16 log removal; the anticipated log removal was 14.

Operational integrity testing is conducted to ensure the water treatment system for direct potable reuse is providing very high quality water that is absent of trace pollutants and pathogens. System integrity testing in the Pure Water Wagon includes both wet chemistry sampling and online sampling.

The District routinely checks the mechanical performance of each system during operation to make sure pressures and flows are in the design range.

The District conducts regular UF system performance testing to ensure proper UF membrane integrity. A pressure decay test is performed on the UF column before and after production to ensure there are no leaks in the membrane.

Online continuous monitoring provides real-time data to verify the quality of water that is being produced. Online monitors are routinely surveyed during operations to make sure the system is operating as required. They include:

Flow: The high purity water system has six continuous flow measuring devices on UF filtrate and backwash lines, RO product, recirculation and reject lines, and on the UV feed line. These devices are used to balance unit process flow to ensure treatment efficiency, manage unit process self-cleaning, and system protection.

Turbidity: The UF unit has two inline continuous turbidity meters located on the UF membrane inlet and filtrate lines to ensure all produced water is effectively treated through filtration.

Pressure Indicators: The UF and RO systems have pressure sensors and gauges to ensure treatment efficiency and to monitor the pressure across the filter and membrane columns.

Probes: The reverse osmosis system has inline pH, oxidation reduction potential and conductivity probes to ensure the protection and integrity of the reverse osmosis unit process. The final RO product water flows through an online total organic carbon (TOC) probe prior to UV AOP disinfection.

The District uses several metrics as indications of performance. If the metrics indicate performance is not optimal, the District will immediately evaluate operations, undertake any performance testing or in-place cleaning, and verify as appropriate with wet testing. If operations do not achieve operational expectations, production will be terminated and the batch of water returned to the treatment plant for treatment and discharge as provided by the NPDES permit.

Operational metrics include:

- A pressure drop greater than 0.2 bar in 10 minutes (2.9 psi in 10 minutes) within the UF membrane, which indicates that membrane fibers have been compromised and require repair or replacement.
- UF filtrate turbidity remains below turbidity target levels set by the California Regulations Related to Recycled Water of 0.2 NTU or less 95% of the time and to never exceed 0.5 NTU. This is a more restrictive limit than the Oregon criteria for membrane filtration (listed as other filtration technologies) of no more than 5 NTU with 95% of the monthly readings less than 1 NTU. The District chose this more restrictive operational threshold due to the January 2019 performance of the UF unit shown in Appendix D.

- Post-RO the TOC probe provides measurement below 0.5 mg/L TOC as set by the California Regulations Related to Recycled Water. This was listed in previous documents as 0.3 mg/L TOC, which is incorrect. The proper level of 0.5 mg/L TOC will be followed in the future.

RECYCLED WATER CHARACTERISTICS, MONITORING

The high purity water is monitored for chemicals identified by the National Water Resource Institute (NWRI) and by the OHA. Maximum contaminant levels (MCLs), action levels and monitoring requirements for public water systems providing water for human consumption are specified in the Oregon Administrative Rules (OAR), Oregon Health Authority, Public Health Division, Chapter 333, Division 61, Public Water Systems. These rules are consistent with EPA drinking water quality standards. Appendix A identifies the MCLs, action levels and chemical identified by NWRI monitoring requirements that must be met for high purity water projects. Further water quality goals are noted for some chemicals beyond what is specified in either the OAR or NWRI monitoring requirements, per recommendation of the OHA. For these chemicals, the District will follow the concentration limits suggested by OHA, compared to those in the OAR or NWRI monitoring requirements, to follow the most restrictive health criteria. The District will conduct water characteristic monitoring annually during periods that water is produced.

RECYCLED WATER STORAGE AND TRANSPORTATION

The purification system treats effluent with advanced water purification and disinfection technology to the point where it is suitable for human consumption and exceeds safe drinking water standards and additional water quality parameters recommended by the NWRI.

High purity water that is produced for drinking water will be stored in potable water containers approved by the Food and Drug Administration (FDA) that also meet National Sanitation Foundation 61 and ANSI standards. The District will follow the container manufacture guidelines for use of the containers for potable water. These containers will also follow the OHA's drinking water hauling guidelines for storage and transportation.

High purity water that is produced to be used as an ingredient in the production of alcoholic beverages will also be stored in FDA-approved potable water containers that also meet National Sanitation Foundation 61 and ANSI standards. Containers will be reused and will follow the OHA's drinking water hauling guidelines for sanitizing drinking water containers. When water is stored it will hold a residual free chlorine level of 0.2 mg/L. This will satisfy the minimum residual chlorine level for Oregon drinking water quality standards while compromising with brewers who prefer less chlorinated water.

BENEFICIAL USES

The goal is to communicate the benefits of reuse. High purity water will be used to produce an ingredient for making beer and other alcoholic beverages. Alcoholic beverages may be made by home brewers or by commercial brewers and distillers who provide opportunity for greater control and capacity when producing alcoholic beverages. The District will host events such as tastings at professional and organized public forums to raise awareness and advance the conversation of reuse. The District would like to consider the opportunity for limited commercial sale to the public at specific locations and times. District and manufacturers will make educational materials available.

RECORD KEEPING AND REPORTING

Record Keeping

The District's records for recycled water are kept on file at the Rock Creek facility and are available for inspection. The following records will be kept for high purity recycled water:

1. An up-to-date copy of the District's High Purity Water Use Plan.
2. Monitoring reports for high purity water.
3. Copy of Highly Purified Water annual report.

Annual Reporting

A report of water reuse activities for the previous calendar year is prepared and submitted to DEQ annually. The Highly Purified Water Annual Report will include:

1. Volume of high purity water produced.
2. Monitoring of the high purity water.
3. Intended use and venues served.
4. Volume and method of disposal or reuse of unused high purity water.

APPENDICES

A. High Purity Water: Monitoring Parameters
B. High Purity Water: 2019 Test Results
C. High Purity Water: 2015 Pilot Test Results
D. Technical Memorandum January 2019 Pure Water Summary

Appendix A: Monitoring Parameters

Table 2: Chemicals Identified in NWRI-2013-01

Chemical Group	Criterion	Rationale
Disinfection by-products		
Trihalomethanes (THMs)	80 ug/L	Prominent chlorination by-products
Halogenated acetic acids (HAA5)	60 ug/L	Polar group of chlorination by-products
N-nitrosodimethylamine (NDMA)	10 ng/L	By-product of chloramination
Bromate	10 ug/L	By-product of ozonation
Chlorate	800 ug/L	Reflective of hypochlorite use
Perfluoro-octanoic acid (PFOA)	0.4 ug/L	Known to occur, frequency unknown
Perfluoro-octane sulfonate (PFOS)	0.2 ug/L	Known to occur, frequency unknown
Perchlorate	15 ug/L 6 ug/L	Of interest, same analysis as chlorate and bromate
1,4-Dioxane	1 ug/L	Occurs at low frequency in wastewater, but likely to penetrate RO membranes
Ethinyl Estradiol	None, close to detection limit if established	Steroid hormone, should evaluate presence in source water
17-ß-estradiol	None, close to detection limit if established	Steroid hormone, should evaluate presence in source water
Cotinine/Primidone/ Dilantin	1/10/2 ug/L	Surrogate for low molecular weight, partially charged cyclics
Meprobamate/ Atenolol	200/4 ug/L	Occur frequently at the ng/L level
Carbamazepine	10 ug/L	Unique structure
Estrone	320 ng/L	Surrogate for steroids
Sucralose	150 mg/L	Surrogate for water soluble, uncharged chemicals of moderate molecular weight
Tris[2- chloroethyl]phosphate (TCEP)	5 ug/L	Chemical of interest
N,N-diethyl-meta-toluamide (DEET)	200 ug/L	Chemical of interest
Triclosan	50 ug/L	Chemical of interest

NWRI-2013-01 – National Water Research Institute, Examining the Criteria for Direct Potable Reuse.

Table 3: Inorganic Chemicals (as listed in Table 1 of OAR 333-061-0030)

Constituent	Units	MCL/Action Level, mg/L	MRL, mg/L
Antimony	mg/L	0.006	0.001
Arsenic	mg/L	0.01	0.001
Asbestos	MFL	7 MFL	0.2 MFL
Barium	mg/L	2	0.002
Beryllium	mg/L	0.004	0.001
Cadmium	mg/L	0.005	0.0005
Chromium	mg/L	0.1	0.001
Copper	mg/L	1.3	0.002
Cyanide	mg/L	0.2	0.025
Fluoride	mg/L	4	0.05
Lead	mg/L	0.015	0.0005
Mercury	mg/L	0.002	0.0002
Nickel[1]	mg/L	MCL being re-evaluated by EPA	0.005
Nitrate (as N)	mg/L	10	0.1
Nitrite (as N)	mg/L	1	0.44
Total Nitrate + Nitrite (as N)	mg/L	10	0.1
Selenium	mg/L	0.05	0.005
Thallium	mg/L	0.002	0.001
1) Additional constituents will be monitored at District discretion			

Table 4: Synthetic Organic Chemicals (as listed in Table 2 of OAR 333-061-0030)

Constituent	Units	MCL/Action Level, mg/L	MRL, mg/L
Alachlor	mg/L	0.002	0.00005
Atrazine	mg/L	0.003	0.00005
Benzo(a)pyrene	mg/L	0.0002	0.00002
Carbofuran	mg/L	0.04	0.0005
Chlordane	mg/L	0.002	0.0001
Dalapon	mg/L	0.2	0.001
Dibromochloropropane	mg/L	0.0002	0.00001
Dinoseb	mg/L	0.007	0.0002
Dioxin(2,3,7,8-TCDD)	mg/L	3.00E-08	5.00E-09
Diquat	mg/L	0.02	0.0004
Di(2-ethylhexyl) adipate	mg/L	0.4	0.0006
Di(2-ethylhexyl) phthalate	mg/L	0.006	0.0006
Endothall	mg/L	0.1	0.005
Endrin	mg/L	0.002	0.00001
Ethylene Dibromide	mg/L	0.00005	0.00001
Glyphosate	mg/L	0.7	0.006
Heptachlor	mg/L	0.0004	0.00001
Heptachlor epoxide	mg/L	0.0002	0.00001
Hexachlorobenzene	mg/L	0.001	0.00005
Hexachlorocyclopentadiene	mg/L	0.05	0.00005
Lindane	mg/L	0.0002	0.00004
Methoxychlor	mg/L	0.04	0.00005
Oxamyl(Vydate)	mg/L	0.2	0.0005
Picloram	mg/L	0.5	0.00004
Polychlorinated Biphenyls (TOTAL)	mg/L	0.0005	0.0001
Pentachlorophenol	mg/L	0.001	0.00005
Simazine	mg/L	0.004	0.0001
Toxaphene	mg/L	0.003	0.0005
2,4-D	mg/L	0.07	0.0002
2,4,5-TP Silvex	mg/L	0.05	0.0001

Table 5: Disinfection By-products (as listed in Table 3 of OAR 333-061-0030)

Disinfection By-product	Units	MCL/Action Level, mg/L	MRL, mg/L
Total Trihalomethanes (TTHM)	mg/L	0.08	0.0005
Haloacetic acids (five) (HAA5)	mg/L	0.06	0.002
Bromate	mg/L	0.010	0.001
Chlorite	mg/L	1.0	0.01
Chlorate[1]	mg/L	0.8	0.01
1. Chlorate is not listed in Table 3 of OAR 3330-61-0030.			

Table 6: Turbidity (as listed in OAR 333-061-0030 (3)(b)(D))

Constituent	Units	MCL/Action Level, mg/L	MRL, mg/L
Turbidity	NTU	95% of monthly readings less than 1 and no reading above 5	0.05

Table 7: VOCs (as listed in Table 4 of OAR 333-061-0030)

Constituent	Units	MCL/Action Level, mg/L	MRL, mg/L
Benzene	mg/L	0.005	0.0005
Carbon tetrachloride	mg/L	0.005	0.0005
cis-1,2-Dichloroethylene	mg/L	0.07	0.0005
Dichloromethane	mg/L	0.005	0.0005
Ethylbenzene	mg/L	0.7	0.0005
Monochlorobenzene (Chlorobenzene)	mg/L	0.1	0.0005
o-Dichlorobenzene	mg/L	0.6	0.0005
p-Dichlorobenzene	mg/L	0.075	0.0005
Styrene	mg/L	0.1	0.0005
Tetrachloroethylene (PCE)	mg/L	0.005	0.0005
Toluene	mg/L	1	0.0005
trans-1,2-Dichloroethylene	mg/L	0.1	0.0005
Trichloroethylene (TCE)	mg/L	0.005	0.0005
Vinyl chloride	mg/L	0.002	0.0003
Xylenes (total)	mg/L	10	0.0005
1,1-Dichloroethylene	mg/L	0.007	0.0005
1,1,1-Trichloroethane	mg/L	0.2	0.0005
1,1,2-Trichloroethane	mg/L	0.005	0.0005
1,2-Dichloroethane	mg/L	0.005	0.0005
1,2-Dichloropropane	mg/L	0.005	0.0005
1,2,4-Trichlorobenzene	mg/L	0.07	0.0005

Table 8: Microbiological Constituents

Constituent	Units	Criteria
Heterotrophic plate count (HPC)	MPN/100 mL	none[1]
Total Coliform	MPN/100 mL	zero
Legionella	CFU/mL	zero
Cryptosporidium	oocysts/L	zero
Giardia lamblia	cysts/L	zero

1) HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is. (http://water.epa.gov/drink/contaminants/#Microorganisms)

Table 9: Radionuclides (as listed in Table 5 of OAR 333-061-0030)

Constituent	MCL	MRL (units at left)
Gross Alpha (including Radium-226 but not Radon and Uranium)	15 pCi/L	3
Combined Radium-226 and Radium-228 (*226 + 228*)	5 pCi/L	2
Uranium	30ug/L	1
Beta/Photon emitters (gross beta tested)	4 mrem/yr	3

Table 10: Secondary Constituents (as listed in Table 6 of OAR 333-061-0030)

Secondary Constituent	Units	MCL/Action Level (units at left)	MRL (units at left)
Color	ACU	15 color units	3
Corrosivity (below)[1]		Non-corrosive	-
Langelier Index - 25 degrees C[2]	-	Non-corrosive	-
Langelier Index at 60 degrees C[2]	-	Non-corrosive	-
Agressiveness Index-Calculated[2]	-	Non-corrosive	0.1
pH of CaCO3 saturation(25C) [2]	units	Non-corrosive	0.1
pH of CaCO3 saturation(60C) [2]	units	Non-corrosive	0.1
Bicarb. Alkalinity as HCO3,calc[2]	mg/L	Non-corrosive	2
Foaming agents (Surfactants)	mg/L	0.5	0.05
pH (analyzed past holding time)	SU	6.5-8.5	0.1
Hardness (as CaCO3)	mg/L	250	3
Odor (SM 2150B - Odor at 60 C (TON))	TON	3 (Threshold Odor Number)	1
Total dissolved solids(TDS)	mg/L	500	10
Aluminum	mg/L	0.05-0.2	0.02
Chloride	mg/L	250	1
Copper	mg/L	1	0.002
Fluoride	mg/L	Primary= 4.0, Secondary= 2.0	0.05
Iron	mg/L	0.3	0.02
Manganese	mg/L	0.05	0.002
Silver	mg/L	0.1	0.0005
Sulfate	mg/L	250	0.5
Zinc	mg/L	5	0.02

1) Corrosivity and pH are to be measured, but action levels are only applicable if the water is transported through a piped distribution system. Since a piped system is not used for delivery of the batched high purity water corrosivity measurements are applicable
2) Additional constituents will be monitored at District discretion

Table 11: Maximum Residual Disinfectant Levels

Constituent	Units	MCL	MRL, mg/L
Chlorine (as Cl_2)	mg/L	4.0	0.1
Chloramines (as Cl_2)	mg/L	4.0	0.1
Chlorine dioxide (as ClO_2)	mg/L	0.8	0.24

Table 12: Trace Compounds Specified by NWRI (2013)

Contaminant	Units	Criteria	MRL (units at left)
N-Nitrosodimethylamine (NDMA)	ng/L	(see note 1)	2
1,4- Dioxane	ug/L	1 ug/L	0.07
Perfluoro-octanoic acid (PFOA)	ug/L	0.4 ug/L	0.0025
Perfluoro-octane sulfonate (PFOS)	ug/L	0.2 ug/L	0.0025
Perchlorate	ug/L	6 ug/L	0.5
Ethinyl Estradiol	ug/L	-	0.005
17-b-estradiol (reported as Estradiol)	ug/L	-	0.005
Cotinine	ug/L	1 ug/L	0.01
Dilantin	ug/L	1 ug/L	0.02
Primidone	ug/L	1 ug/L	0.005
Atenolol	ug/L	4 ug/L	0.005
Meprobamate	ug/L	4 ug/L	0.005
Carbamazepine	ug/L	10 ug/L	0.005
Estrone	ug/L	0.32 ug/L	0.005
Sucralose	ug/L	150,000 ug/L	0.1
Tris[2-chloroethyl]phosphate (TCEP)	ug/L	5 ug/L	0.01
N,N-diethyl-meta-toluamide (DEET)	ug/L	200 ug/L	0.01
Triclosan	ug/L	50 ug/L[2]	0.01
1) There is no EPA MCL for NDMA. California Dept. of Public Health lists a 10^{-6} Risk Level of 3 ng/L, a notification level of 10 ng/L, and a response level of 300 ng/L. (http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/NDMA.shtml) EPA risk assessments indicate that the drinking water concentration representing a 1 x 10^{-6} cancer risk level for NDMA is 0.7 ng/L (EPA IRIS 1993).			
2) Minnesota Department of Health's short-term non-cancer health based value of 50 ug/L for triclosan			

Table 13: Chemicals to be tested per OHA's recommendations

Contaminant	Recommended Goal	Source
Perfluoro-octanoic acid (PFOA)	0.07 ug/L (individually or in combination with PFOS)	EPA lifetime health advisory (LTHA) 2016
Perfluoro-octane sulfonate (PFOS)	0.07 ug/L (individually or in combination with PFOA)	EPA LTHA 2016
Perfluorohexane sulfonic acid (PFHxS)	0.52 ug/L	ASTDR Intermediate EMEG for adults 2018
Perfluoronanoic acid (PFNA)	0.078 ug/L	ASTDR Intermediate EMEG for adults 2018
1-Butanone (MEK)	4,000 ug/L	EPA LTHA 1987
Copper	260 ug/L	ASTDR Intermediate EMEG for adults 2004
NDMA	0.01 ug/L	California Department of Public Health Notification level
Nickel	100 ug/L	EPA LTHA 1995
Zinc	2,000 ug/L	LTHA 1993

LTHA - Lifetime health advisory

ASTDR - Agency for Toxic Substances and Disease Registry

EMEG - environmental media evaluation guides

Appendix B: 2019 Test Results

In January 2019 two samples sets were collected and analyzed after treatment in the Pure Water Wagon. Data continues to demonstrate a high purity water with no constituent approaching drinking water criteria.

Table 13: 2019 Summary Data from Monitoring with Applicable MCL, Action or Reference Level

Observed High Purity Water Trailer Data with Applicable MCL, Action or Reference Level for all Contaminants observed in previous and current sampling											
Contaminant	Nitrate (as N)	Total Nitrate + Nitrite (as N)	Total Trihaolmethanes (TTHM)	Turbidity	Gross Alpha (Including Combined Radium 226 and Radium 228)	Odor (SM 2150B - Odor at 60 C) (Threshold Odor Number)	Total Dissolved Solid (TDS)	Chloride	Flouride	Chlorine	Chloramines
Units	mg/l	mg/l	mg/l	mg/l	Pci/l	TON	mg/l	mg/l	mg/l	mg/l	mg/l
MCL / Action Level	10	10	0.08	0.3	15pCi/L	3	500	250	2	4	4
Sample 1	0.3	0.336	<DL	<DL	<DL	1	<DL	0.53	<DL	0.14	0.11
Sample 2	0.256	0.287	<DL	<DL	<DL	1	<DL	0.56	<DL	0.16	0.15

These results demonstrate the effectiveness of the processes that the District uses to treat the water, and as noted is consistent with a proven process. Finished high purity water is analyzed by NELAP-accredited laboratories for all applicable constituents specified for any source in OAR 333-061 (Appendix A). Finished water is also analyzed for trace compounds specified by the National Water Research Institute, Examining the Criteria for Direct Potable Reuse (2013).

Samples collected in January 2019 were collected at the start and end of the batching process, production water will be collected in sanitized food grade totes, chlorinated (~0.20 mg/L of free chlorine), and stored indoors up to one year until used as an ingredient for the brewing or other process. Greater detail is contained in the 2019 Technical Memorandum and Sampling Plan.

In addition to the constituents shown in Appendix A, the analytical methods also reported results for approximately 135 additional constituents, mostly organic compounds. With the exception of sodium (FW#1 = 1.3 mg/L, FW#2 = 1.2 mg/L), none of these constituents was observed.

Table 14: 2019 Data from Monitoring with Applicable MCL, Action or Reference Level

HIGH PURITY WATER - ANALYTICAL RESULTS SUMMARY - Pure Water Wagon - January 9, 2019 Production Run
The following tables are generated from the analytical results of samples collected from the Pure Water Wagon water production run on 1/9/2019.
"ND" means the constituent was analyzed for, but was not detected at or above the listed minimum analytical Quantitation Level (QL).
Maximum Contaminant Levels (MCL) and Action Levels are specified in the Oregon Administrative Rules for Public Water Systems, OAR 333-061-0030
The analytical methods used for the samples produced results for additional unregulated constituents that are not included in the tables below.
UV-006A = Finished water collected at the start of the production run
UV-006B = Finished water collected at the end of the production run

Inorganic Chemicals (as listed in Table 1 of OAR 333-061-0030)						
Constituent	**Units**	**UV-006A**	**UV-006B**	**MCL/Action Level, mg/l**	**QL, mg/L**	**Method**
Antimony	mg/L	ND	ND	0.006	0.001	EPA 200.8
Arsenic	mg/L	ND	ND	0.01	0.001	EPA 200.8
Asbestos	MFL	ND	ND	7 MFL	0.2 MFL	EPA 100.2
Barium	mg/L	ND	ND	2	0.002	EPA 200.8
Beryllium	mg/L	ND	ND	0.004	0.001	EPA 200.8
Cadmium	mg/L	ND	ND	0.005	0.0005	EPA 200.8
Chromium	mg/L	ND	ND	0.1	0.001	EPA 200.8
Copper	mg/L	ND	ND	1.3 *(Action Level)*	0.002	EPA 200.8
Cyanide	mg/L	ND	ND	0.2	0.025	SM 4500CN-F
Fluoride	mg/L	ND	ND	4	0.05	SM 4500F-C
Lead	mg/L	ND	ND	0.015 *(Action Level)*	0.0005	EPA 200.8
Mercury	mg/L	ND	ND	0.002	0.0002	EPA 245.1
Nickel	mg/L	ND	ND	MCL being re-evaluated by EPA	0.005	EPA 200.8
Nitrate (as NO3)	mg/L	1.33	1.13	44.3	0.44	EPA 300.0
Nitrate (as N)	mg/L	0.300	0.256	10	0.1	EPA 300.0
Nitrite (as N)	mg/L	0.0364	0.0310	1	0.01	EPA 300.0
Total Nitrate + Nitrite (as N)	mg/L	0.336	0.287	10	0.1	EPA 300.0
Selenium	mg/L	ND	ND	0.05	0.005	EPA 200.8
Thallium	mg/L	ND	ND	0.002	0.001	EPA 200.8

Synthetic Organic Chemicals (as listed in Table 2 of OAR 333-061-0030)						
Constituent	Units	UV-006A	UV-006B	MCL/Action Level, mg/l	QL, mg/L	Method
Alachlor	mg/L	ND	ND	0.002	0.0001 & 0.00005	EPA 505 & EPA 525.2
Atrazine	mg/L	ND	ND	0.003	0.00005	EPA 525.2
Benzo(a)pyrene	mg/L	ND	ND	0.0002	0.00002	EPA 525.2
Carbofuran	mg/L	ND	ND	0.04	0.0005	EPA 531.2
Chlordane	mg/L	ND	ND	0.002	0.0001	EPA 505
Dalapon	mg/L	ND	ND	0.2	0.001	EPA 515.4
Dibromochloropropane	mg/L	ND	ND	0.0002	0.00001	EPA 551.1
Dinoseb	mg/L	ND	ND	0.007	0.0002	EPA 515.4
Dioxin(2,3,7,8-TCDD)	mg/L	ND	ND	0.00000003	0.000000005	EPA 1613B
Diquat	mg/L	ND	ND	0.02	0.0004	EPA 549.2
Di(2-ethylhexyl) adipate	mg/L	ND	ND	0.4	0.0006	EPA 525.2
Di(2-ethylhexyl) phthalate	mg/L	ND	ND	0.006	0.0006	EPA 525.2
Endothall	mg/L	ND	ND	0.1	0.005	EPA 525.2
Endrin	mg/L	ND	ND	0.002	0.00001	EPA 505
Ethylene dibromide	mg/L	ND	ND	0.00005	0.00001	EPA 551.1
Glyphosate	mg/L	ND	ND	0.7	0.006	EPA 547
Heptachlor	mg/L	ND	ND	0.0004	0.00001	EPA 505
Heptachlor epoxide	mg/L	ND	ND	0.0002	0.00001	EPA 505
Hexachlorobenzene	mg/L	ND	ND	0.001	0.00005	EPA 525.2
Hexachlorocyclopentadiene	mg/L	ND	ND	0.05	0.00005	EPA 525.2
Lindane	mg/L	ND	ND	0.0002	0.00001	EPA 505
Methoxychlor	mg/L	ND	ND	0.04	0.00005	EPA 505
Oxamyl (Vydate)	mg/L	ND	ND	0.2	0.0005	EPA 531.2
Picloram	mg/L	ND	ND	0.5	0.0001	EPA 515.4
Polychlorinated Biphenyls (TOTAL)	mg/L	ND	ND	0.0005	0.0001	EPA 505
Pentachlorophenol	mg/L	ND	ND	0.001	0.00004	EPA 515.4
Simazine	mg/L	ND	ND	0.004	0.00005	EPA 525.2
Toxaphene	mg/L	ND	ND	0.003	0.0005	EPA 505
2,4-D	mg/L	ND	ND	0.07	0.0001	EPA 515.4
2,4,5-TP Silvex	mg/L	ND	ND	0.05	0.0002	EPA 515.4

Disinfection Byproducts (as listed in Table 3 of OAR 333-061-0030)						
Disinfection Byproduct	Units	UV-006A	UV-006B	MCL/Action Level, mg/L	QL, mg/L	Method
Total Trihalomethanes (TTHM)	mg/L	ND	ND	0.08	0.0005	EPA 524.2
Haloacetic Acids (five)(HAA5)	mg/L	ND	ND	0.06	0.002	SM 6251B
Bromate	mg/L	ND	ND	0.01	0.001	EPA 317
Chlorite	mg/L	ND	ND	1.0	0.01	EPA 300.0

Turbidity as listed in OAR 333-061-0030 (3)(b)(A)						
Constituent	Units	UV-006A	UV-006B	MCL/Action Level, mg/L	QL, NTU	Method
Turbidity	NTU	ND	ND	1 & ≤ 0.3 in 95% per month	0.1	EPA 180.1

VOCs (as listed in Table 5 of OAR 333-061-0030)						
Constituent	Units	UV-006A	UV-006B	MCL/Action Level, mg/L	QL, mg/L	Method
Benzene	mg/L	ND	ND	0.005	0.0005	EPA 524.2
Carbon tetrachloride	mg/L	ND	ND	0.005	0.0005	EPA 524.2
cis-1,2-Dichloroethylene	mg/L	ND	ND	0.07	0.0005	EPA 524.2
Dichloromethane	mg/L	ND	ND	0.005	0.0005	EPA 524.2
Ethylbenzene	mg/L	ND	ND	0.7	0.0005	EPA 524.2
Monochlorobenzene (Chlorobenzene)	mg/L	ND	ND	0.1	0.0005	EPA 524.2
o-Dichlorobenzene	mg/L	ND	ND	0.6	0.0005	EPA 524.2
p-Dichlorobenzene	mg/L	ND	ND	0.075	0.0005	EPA 524.2
Styrene	mg/L	ND	ND	0.1	0.0005	EPA 524.2
Tetrachloroethylene(PCE)	mg/L	ND	ND	0.005	0.0005	EPA 524.2
Toluene	mg/L	ND	ND	1	0.0005	EPA 524.2
trans-1,2-Dichloroethylene	mg/L	ND	ND	0.1	0.0005	EPA 524.2
Trichloroethylene (TCE)	mg/L	ND	ND	0.005	0.0005	EPA 524.2
Vinyl chloride	mg/L	ND	ND	0.002	0.0003	EPA 524.2
Xylenes(total)	mg/L	ND	ND	10	0.0005	EPA 524.2
1,1-Dichloroethylene	mg/L	ND	ND	0.007	0.0005	EPA 524.2
1,1,1-Trichloroethane	mg/L	ND	ND	0.2	0.0005	EPA 524.2
1,1,2-Trichloroethane	mg/L	ND	ND	0.005	0.0005	EPA 524.2
1,2-Dichloroethane	mg/L	ND	ND	0.005	0.0005	EPA 524.2
1,2-Dichloropropane	mg/L	ND	ND	0.005	0.0005	EPA 524.2
1,2,4-Trichlorobenzene	mg/L	ND	ND	0.07	0.0005	EPA 524.2

Microbiological Constituents, including those listed in listed in OAR 333-061-0030						
Constituent	Units	UV-006A	UV-006B	Criteria	QL (units at left)	Method
Heterotrophic (or Standard) plate count (HPC) [1]	CFU/ml	ND	ND	500 [1]	1	SM 9215B
Total Coliform	MPN/100 mL	ND	ND	zero	1	SM 9223B
E. coli	MPN/100 mL	ND	ND	zero	1	SM 9223B
Legionella	MPN/100 mL	ND	ND	zero	10 / 0 PW [2]	IDEXX Legiolert
Cryptosporidium	Oocysts/L	ND	ND	zero	<0.091/<0.089	EPA 1623
Giardia lamblia	Cysts/L	ND	ND	zero	<0.091/<0.089	EPA 1623
1) HPC has no specific health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is (http://water.epa.gov/drink/contaminants/#Microorganisms). The 500 criteria is from EPA's surface water treatment rules.						
2) PW = Positive Wells. Both samples had 0 positive large and small wells using the IDEXX Legiolert method.						

Radionuclides (as listed in Table 6 of OAR 333-061-0030)						
Constituent	Units	UV-006A	UV-006B	MCL	QL / MDA[1] (units at left)	Method
Gross Alpha (including Radium-226 but not Radon and Uranium)	pCi/L	ND	ND	15 pCi/L	3 / 2.4	SM 7110B
Radium-226	pCi/L	ND	ND	-	1 / 0.39	SM 7500Ra B
Radium-228	pCi/L	ND	ND	-	1 / 0.73	SM 7500Ra D
Combined Radium-226 and Radium-228 (*226 + 228*)	pCi/L	ND	ND	5 pCi/L	1 / 0.73	SM 7500Ra B & SM 7500Ra D
Uranium	ug/L	ND	ND	30ug/L	1	EPA 200.8
Beta/Photon emitters (gross beta tested)	pCi/L	ND	ND	4 mrem/yr[2]	3 /2.5	SM 7110B
1) Minimum Detectable Activity (MDA95) shall be that concentration which can be counted with a precision of plus or minus 100% at the 95% confidence level.						
2) The screening level for beta is 15 or 50 pCi/L, depending on the source water. *Average Annual Concentrations Assumed to Produce a Total Body or Organ Dose of 4 Mrem/Yr =* *Radionuclide* / *Critical organ* / *pCi per liter*: *Tritium* / *Total body* / *20,000*; *Strontium-90* / *Bone Marrow* / *8*						

Secondary Constituents (as listed in Table 7 of OAR 333-061-0030)						
Secondary Constituent:	Units	UV-006A	UV-006B	MCL/Action Level (units at left)	QL (units at left)	Method
Color	ACU	ND	ND	15 color units	3	SM 2120B
Corrosivity (below)				Non-corrosive		SM 2330B
Langelier Index - 25 degrees C	none	-5.0	-5.1	Non-corrosive		SM 2330B
Langelier Index at 60 degrees C	none	-4.6	-4.6	Non-corrosive		SM 2330B
Aggressiveness Index-Calculated	-	6.9	6.8	Non-corrosive	0.1	SM 2330B
pH of CaCO3 saturation(25C)	units	11	11	Non-corrosive	0.1	SM 2330B
pH of CaCO3 saturation(60C)	units	11	11	Non-corrosive	0.1	SM 2330B
Bicarb. Alkalinity as HCO3,calc	mg/L	4.3	3.8	Non-corrosive	2	SM 2320B
Foaming Agents (Surfactants)	mg/L	ND	ND	0.5	0.1	SM 5540C/EPA 425.1
pH (analyzed past holding time)	SU	6.1	6.1	6.5-8.5	0.1	SM 4500H-B
Hardness (as CaCO3)	mg/L	ND	ND	250	3	SM 2340B
Odor (SM 2150B - Odor at 60 C (TON))	TON	1	1	3 (Threshold Odor Number)	1	SM 2150B
Total Dissolved Solids(TDS)	mg/L	ND	ND	500	10	SM 2540C
Aluminum	mg/L	ND	ND	0.05-0.2	0.02	EPA 200.8
Chloride	mg/L	0.53	0.56	250	0.5	EPA 300.0A
Copper	mg/L	ND	ND	1	0.002	EPA 200.8
Fluoride	mg/L	ND	ND	Primary= 4.0, Secondary= 2.0	0.05	SM 4500F-C
Iron	mg/L	ND	ND	0.3	0.02	EPA 200.7
Manganese	mg/L	ND	ND	0.05	0.002	EPA 200.8
Silver	mg/L	ND	ND	0.1	0.0005	EPA 200.8
Sulfate	mg/L	ND	ND	250	0.5	EPA 300.0
Zinc	mg/L	ND	ND	5	0.02	EPA 200.8

Maximum Residual Disinfectant Levels (as listed in Table 8 of OAR 333-061-0030)						
Constituent	Units	UV-006A	UV-006B	MCL	QL, mg/L	Method
Chlorine (as Cl2)[1]	mg/L	0.14	0.16	4.0	0.1	SM 4500CL-G
Chloramines (as Cl2)[1]	mg/L	0.11	0.15	4.0	0.1	SM 4500CL-G Hach
Chlorine dioxide (as ClO2)[1]	mg/L	ND	ND	0.8	0.24	SM 4500CL-G Hach
1) Analyzed past method holding time						

Trace Compounds Specified by NWRI (2013)						
Constituent	**Units**	**UV-006A**	**UV-006B**	**Criteria**	**QL (units at left)**	**Method**
N-Nitrosodimethylamine (NDMA)	ng/L	ND	ND	(see note 1)	2.1 / 2.2 ng/L	EPA 521
1,4- Dioxane	ug/L	ND	ND	1	0.07	EPA 1613B
Perfluoro-octanoic acid (PFOA)	ug/L	ND	ND	0.4	0.002	EPA 537
Perfluoro-octane sulfonate (PFOS)	ug/L	ND	ND	0.2	0.002	EPA 537
Perchlorate	ug/L	ND	ND	6	0.5	EPA 331.0
Ethinyl Estradiol	ug/L	ND	ND	-	0.005	LC-MS-MS
17-b-estradiol (reported as Estradiol)	ug/L	ND	ND	-	0.005	LC-MS-MS
Cotinine	ug/L	ND	ND	1	0.01	LC-MS-MS
Dilantin	ug/L	ND	ND	1	0.02	LC-MS-MS
Primidone	ug/L	ND	ND	1	0.05	LC-MS-MS
Atenolol	ug/L	ND	ND	4	0.005	LC-MS-MS
Meprobamate	ug/L	ND	ND	4	0.005	LC-MS-MS
Carbamazepine	ug/L	ND	ND	10	0.005	LC-MS-MS
Estrone	ug/L	ND	ND	0.32	0.005	LC-MS-MS
Sucralose (common artificial sweetener)	ug/L	ND	ND	150,000	0.1	LC-MS-MS
Tris[2-chloroethyl]phosphate (TCEP)	ug/L	ND	ND	5	0.01	LC-MS-MS
N,N-diethyl-meta-toluamide (DEET)	ug/L	ND	ND	200	0.01	LC-MS-MS
Triclosan	ug/L	ND	ND	50 [2]	0.02	LC-MS-MS
1) There is no EPA MCL for NDMA. California Dept. of Public Health lists a 10^{-6} Risk Level of 3 ng/L, a notification level of 10 ng/L, and a response level of 300 ng/L (http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/NDMA.shtml) EPA risk assessments indicate that the drinking water concentration representing a 1 x 10-6 cancer risk level for NDMA is 0.7 ng/L (EPA IRIS 1993).						
2) Minnesota Department of Health's short-term non-cancer health based value of 50 ug/l for Triclosan						

Miscellaneous Non-Regulated Constituents						
Constituent	**Units**	**UV-006A**	**UV-006B**	**Criteria**	**QL (units at left)**	**Method**
Aluminum	mg/L	ND	ND	-	0.02	EPA 200.8
Calcium	mg/L	ND	ND	-	1	EPA 200.7
Magnesium	mg/L	ND	ND	-	0.1	EPA 200.7
Silica	mg/L	ND	ND	-	0.5	EPA 200.7
Sodium	mg/L	ND	ND	-	1	EPA 200.7
Zinc	mg/L	ND	ND	-	0.02	EPA 200.8
Total Organic Carbon	mg/L	ND	ND	-	0.3	SM 5310 C
Specific Conductance, 25 C (RO unit effluent)	uS/cm	13.08	13	-	2	SM 2510 B
2-Butanone (MEK)	ug/L	ND	ND	-	5	EPA 524.2
Chloroform	ug/L	ND	ND	0.08 (from TTHM in Table 3)	0.0005	EPA 524.2

Bioassay (UC Davis)				
Constituent	**Sample**	**Result**	**Discussion**	**Method**
Human estrogen receptor (ER) alpha responsive breast cancer cell bioassay for detection of estrogenic chemicals (VM7Luc4E2 cells) Results indicate stimulation of estrogen receptor alpha-responsive luciferase reporter gene activity in VM7Luc4E2 cells by test samples. Result is expressed as % Luciferase Activity relative to the 100% control	17b Estradiol Positive control	100 ± 11.98*	Results in this figure demonstrate that 1 uL of either Production A or Production B water samples does not contain a chemical(s) that can activate estrogen receptor alpha-dependent gene expression in VM7Luc4E2 cells, compared to that of negative controls (DMSO and Method Blank) and that of the positive control, 17beta Estradiol. **Thus, both the Production A and B water samples contains no estrogenic chemicals.**	Recombinant Cell Bioassay Protocol by He et al. (2012)
	Method Blank	1.50 ± 3.04		
	UV-006A	-1.59 ± 4.25		
	UV-006B	-3.26 ± 1.21		
Mouse Ah (dioxin) receptor (AhR)-responsive liver cancer cell bioassay for AhR active chemicals (H1L6.1c3 cells) Results indicate stimulation of Ah receptor-responsive luciferase reporter gene activity in H1L6.1c3 cells by test samples. Result is expessed as % Luciferase Activity relative to the 100% control	TCDD Positive control	100 ± 9.10*	Results in this figure demonstrate that 1 uL of either Production A or Production B water samples do not contain a chemical(s) that can activate Ah receptor-dependent gene expression in H1L6.1c3 cells, compared to that of negative controls (DMSO and Method Blank) and that of the positive control, TCDD. **Thus, both the Production A and B water samples contain no AhR active chemicals.** **Cytotoxicity.** No cytotoxicity (cell death) was visually observed in any cell bioassay with any of the water extracts, method blanks, negative or positive controls and thus, any negative results (i.e. no induction) are not biased by adverse effects produced by the extracts. **Thus, extracts of the Production A and B water samples do not contain chemicals that are directly toxic to the cells.**	Recombinant Cell Bioassay Protocol by He et al. (2012)
	Method Blank	1.55 ± 0.67		
	UV-006A	0.78 ± 0.70		
	UV-006B	0.96 ± 0.80		

Appendix C: High Purity Water – 2015 Pilot Test Results

Results of the sampling from the pilot test in 2015 are presented in the table below. Most of the data has been reported at below minimum detection levels for the multiple samples analyzed. Those analytes with an MCL, Action or reference levels that were observed in previous monitoring are presented below. The full data set was provided previously. The data demonstrates a high purity water with no constituent approaching drinking water criteria.

Table 15: 2015 Sampling Results

Summary Observed Data with Applicable MCL, Action or Reference Level												
Contaminant	Nitrate (as N)	Total Nitrate + Nitrite (as N)	Total Trihalome thanes (TTHM)	Turbidity	Gross Alpha (including Radium-226 but not Radon and Uranium)	Combined Radium-226 and Radium-228	Odor (SM 2150B - Odor at 60 C) (Threshold Odor Number)	Total dissolved solids (TDS)	Chloride	Fluoride	Chlorine*	Chloramines *
units	mg/L	mg/L	mg/L	NTU	pCi/L	pCi/L	TON	mg/L	mg/L	mg/L	mg/L	mg/L
MCL/Action Level	10	10	0.08	0.3	15 pCi/L	5 pCi/L	3	500	250	2	4.0 (as Cl2)	4.0 (as Cl2)
N	10	10	10	5	9	10	10	10	10	10	10	10
Minimum	< DL	0.123	<DL	< DL	< DL	< DL	<DL	<DL	<DL	<DL	< DL	< DL
Median	0.175	0.225	<DL	0.074	<Dl	<DL	<DL	<DL	<DL	<DL	0.505	0.475
Maximum	0.731	0.745	0.047	0.081	1.5	1.9	1	11	0.14	0.054	0.89	0.84

Appendix D: Technical Memorandum January 2019 Pure Water Summary

Clean Water Services

Clean Water Services
Potable Water Reuse Demonstration Update

Technical Memorandum
JANUARY 2019 PURE WATER SUMMARY

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Clean Water Services
Potable Water Reuse Demonstration Update

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Abbreviations

%	percent
µS	microsecond
AWPF	advanced water purification facility
CDPH	California Department of Public Health
DDW	Division of Drinking Water
gpm	gallons per minute
HRT	hydraulic residence time
LRV	log removal value
MIT	membrane integrity testing
PDT	pressure decay testing
PFU/mL	plaque forming units per milliliter
psi	pounds per square inch
RO	reverse osmosis
TM	technical memorandum
UF	ultrafiltration
UV AOP	Advanced oxidation process
WQL	Water quality lab

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Section 1

OVERVIEW

Carollo Engineers, Inc. oversaw and verified the performance of the Clean Water Services demonstration-scale advanced water purification facility (AWPF) in January 2019. Clean Water Services staff ran the facility and performed some of the necessary testing. Any testing performed by an outside lab is identified in subsequent sections. The system purified secondary wastewater effluent to potable water standards and provided robust disinfection and chemical removal. This technical memorandum (TM) summarizes key performance and water quality data from three processes, ultrafiltration (UF), reverse osmosis (RO), and ultraviolet disinfection with an advanced oxidation process (UV AOP).

The full Test Plan for the AWPF (Clean Water Services, 2019), includes substantial details on the treatment components, monitoring systems, and planned testing, which is not repeated here. The three key process components, which are reviewed in this Memo, are:

- UF: DOW SFP2860XP
- RO: DOW LCHR-4040
- UV: WEDECO Spektron 30e

Section 2

ULTRAFILTRATION PATHOGEN REMOVAL PERFORMANCE

The primary value of UF is pathogen removal; which is measured in three ways for this project, as summarized below.

2.1 Turbidity

Turbidity is an indirect and online method to document membrane integrity. For both potable and non-potable water reuse projects, the State of California Division of Drinking Water (DDW) requires low pressure membrane systems (such as UF) to maintain an effluent turbidity of 0.2 NTU or less 95% of the time and to never exceed 0.5 NTU (DDW, 2018).

During the January 2019 production run, a total of 38 on-line turbidimeter readings were hand recorded on the CWS data log sheets, which are summarized in Table 1. As shown, average UF effluent turbidity was 0.05 NTU and ranged for 0.04 to 0.05 NTU; again sufficiently below the standards set by California for membranes used for potable water reuse.

Table 1 Summary of Turbidity Removal via Ultra Filtration

Sample ID	Sample Date	Sample Time	Turbidity (NTU)	
			UF001 (before UF)	UF002 (after UF)
1	1/8/2019	23:26	1.88	0.04
2	1/8/2019	23:41	1.88	0.05
3	1/9/2019	0:28	1.86	0.04
4	1/9/2019	0:43	1.86	0.04
5	1/9/2019	0:58	1.86	0.04
6	1/9/2019	1:36	1.86	0.05
7	1/9/2019	1:51	1.86	0.05
8	1/9/2019	2:07	1.89	0.05
9	1/9/2019	2:22	1.87	0.05
10	1/9/2019	2:48	1.86	0.05
11	1/9/2019	3:03	1.86	0.05
12	1/9/2019	3:18	1.86	0.05
13	1/9/2019	3:33	1.86	0.05
14	1/9/2019	4:13	1.86	0.05
15	1/9/2019	4:28	1.84	0.05
16	1/9/2019	4:43	1.84	0.05
17	1/9/2019	4:58	1.84	0.05
18	1/9/2019	5:37	1.84	0.05
19	1/9/2019	5:52	1.84	0.05
20	1/9/2019	6:07	1.84	0.05
21	1/9/2019	6:22	1.84	0.05
22	1/9/2019	6:37	1.84	0.05
23	1/9/2019	7:07	1.83	0.05
24	1/9/2019	7:22	1.83	0.05
25	1/9/2019	7:37	1.83	0.05
26	1/9/2019	7:52	1.82	0.05
27	1/9/2019	8:07	1.8	0.05
28	1/9/2019	8:22	1.82	0.05
29	1/9/2019	8:42	1.82	0.05
30	1/9/2019	8:58	1.82	0.05
31	1/9/2019	9:14	1.8	0.05
32	1/9/2019	9:30	1.7	0.05
33	1/9/2019	9:45	1.86	0.05
34	1/9/2019	10:00	1.91	0.05

Table 1 Summary of Turbidity Removal via Ultra Filtration (Continued)

Sample ID	Sample Date	Sample Time	Turbidity (NTU)	
			UF001 (before UF)	UF002 (after UF)
35	1/9/2019	10:15	1.97	0.05
36	1/9/2019	10:30	1.97	0.05
37	1/9/2019	10:45	1.97	0.05
38	1/9/2019	11:00	1.95	0.05
		Ave	**1.86**	**0.05**
		Min	**1.7**	**0.04**
		Max	**1.97**	**0.05**

2.2 Pressure Decay Testing

While turbidity removal through membrane processes is a gross indication of process performance, referred to as "continuous indirect integrity monitoring" by the U.S. EPA (2005), pressure decay testing (PDT) is a "direct integrity test" U.S. EPA (2005). The PDTs are designed to measure if there is membrane damage sufficient to pass a 3 µm particle, which is the lower bound of the *Cryptosporidium* size range (U.S. EPA, 2005).

Through size exclusion, the UF membranes remove bacteria, protozoan, and viral pathogens (Cheryan, 1998, USEPA, 2005). The DDW, formerly the California Department of Public Health (CDPH)) has previously granted virus removal credit for UF (CDPH, 2014), approving "at least 1-log" virus removal while also approving 4-log protozoa removal. However, DDW currently does not grant virus credit due to the lack of a continuous or daily method to verify membrane integrity to the level sufficient to remove virus.

PDT is sometimes referred to as membrane integrity testing (MIT) through which the integrity of the membrane is determined based upon an air pressure test in which the membranes are pressurized with air, then put in a "hold" mode and the air slowly leaks from the membranes. Too fast a leak means that the membrane has been compromised. The Quality Control Release Value (QCRV) is minimum quality standard established by the manufacturer that ensures the module will attain the targeted log removal value. For the AWPF installed UF membrane, QCRV is 0.29 psi/min.

A summary of these tests in shown in Table 2 and indicated that in all cases the pressure decay rates were less than 0.2 psi/min, which is lower than the recommended target of 0.29 psi/min and thus represents an in-tact barrier for 4+ log removal value (LRV) of protozoa.

Table 2 Summary of Pressure Decay Testing

Date	Start time	End Time	Test Period	Starting pressure (psi)	Ending Pressure (psi)	Duration (min)	Pressure drop rate (psi/min)	Pass/ Fail?
1/2/2019	13:38	13:48	Pre-Production	28.5	28	10	0.05	Pass
1/7/2019	2:49	2:59	Pre-Production	29	27	10	0.20	Pass
1/7/2019	17:41	17:51	Pre-Production	28	27	10	0.10	Pass
1/8/2019	7:16	7:26	Challenge Testing	28	27	10	0.10	Pass
1/8/2019	13:00	13:10	Challenge Testing	28	28	10	0.00	Pass
1/8/2019	22:39	22:49	Pre-Production	28	27	10	0.10	Pass
1/9/2019	11:17	11:27	Post-Production	28	27	10	0.10	Pass

Notes:
(1) Sample time not reported.

The information from a PDT (or MIT) can be taken one step further, to specifically calculate the LRV for the specific UF membrane (DOW SFD-2860 XP) by using the equation specified in the USEPA Long Term 2 Enhanced Surface Water Treatment Rule (40 CFR 141.719(b)(3)(iii)(A)), which is given below.

$$LRV_{DIT} = \log\left(\frac{Q_p \times ALCR \times P_{atm}}{\Delta P_{test} \times V_{sys} \times VCF}\right)$$ Eqn. 4.9 of EPA (2005)

$$ALCR = 170 \times Y \times \sqrt{\frac{(P_{test} - BP) \times (P_{test} + P_{atm})}{(460 + T) \times TMP}}$$ Eqn. C.4 of EPA (2005)

$$Y \propto \left[\frac{1}{\left(\frac{P_{test} - BP}{P_{test} + P_{atm}}\right)}, K\right]$$ Eqn. C.5 of EPA (2005)

$$K = f \times \frac{L}{d_{fiber}}$$ Eqn. C.6 of EPA (2005)

The definitions of the various parameters in the equations above are summarized in Table 3.

Table 3 Terms and Definitions in Expression for Direct Integrity Testing Log Removal Credit According to EPA (2005)

Term [1]	Definition [1]
LRV_{DIT}	direct integrity test sensitivity in terms of LRV
Q_P	membrane unit design capacity filtrate flow (gpm)
P_{atm}	atmospheric pressure (psia)
ΔP_{test}	smallest rate of pressure decay that can be reliably measured and associated with a known integrity breach during an integrity test (psi/min)
V_{sys}	volume of pressurized air in the system during the test (gal)
VCF	volumetric concentration factor (dimensionless)
ALCR	air liquid conversion ratio
Y	net expansion factor for compressible flow through a pipe to a larger area (dimensionless)
P_{test}	direct integrity test pressure (psi)
T	water temperature (°F)
TMP	trans-membrane pressure (psi)
K	flow resistance coefficient
f	friction factor
L	length of defect (mm)
d_{fiber}	fiber diameter (mm)
LRC	log removal credit (as awarded by the State; 4 for Toray HFU membranes)
UCL	upper control limit in terms of airflow (psi/min)

Notes:
(1) Terms and definitions from EPA (2005).

A summary of UF operating conditions during the challenge testing conducted on January 8, 2019 is provided in Table 4, which shows the parameters necessary to estimate the LRV_{DIT}. An assumption was made for the overall pressurized system volume that was based on the manufacturer's stated system volume of 9.3 gallons with added volume of piping under pressure for the PDT of 1.2 gallons for a total estimated system volume of 10.5 gallons. Water temperature was estimated to be 70 F and a representative value of Y, described in Table 3, of 0.74 was used. An average pressure drop during the two PDTs test conducted on January 8, 2019, shown in Table 2 during the time of challenge testing was 0.05 psi/min; this value was used to estimate the LRVs shown in Table 4. The estimated average LRV for this test was 3.93. A sensitivity analysis showed very little dependence on the assumed values of the parameters, so the calculated LRV of 3.93 seems representative for the challenge testing period.

Table 4 Summary of UF Operating Conditions and Estimated LRV during Challenge Testing

$Q_{filt.}$ (gpm)	PDT (psi/min)	ALCR	P_{atm}	Sys Vol (gal)	VCF	PDT Starting Pressure (psi)	Temp (F)	TMP (psi)	BP (psi)	LRV
8.7	0.05	39.3	14.7	10.5	1	28	70	19	5	3.98
9	0.05	41.9	14.7	10.5	1	28	70	16	6	4.02
7.6	0.05	35.0	14.7	10.5	1	28	70	25	4	3.87
7.3	0.05	33.7	14.7	10.5	1	28	70	27	4	3.84

2.3 MS2 Coliphage Challenge

MS2 coliphage is widely used as a biological surrogate for UV disinfection processes due to its' relative resistance and reproducible sensitivity to exposure to UV light. However, it is also an ideal direct measure of the ability of membranes (such as UF and RO) to remove viruses, bacteria and protozoan cysts due to size exclusion. MS2 is a viron (viral particle) composed of proteins encasing genomic RNA that is about 27 nm in diameter. It can be grown in high concentrations up to $5x10^{11}$ plaque forming units per milliliter (PFU/mL). It can be accurately detected at concentrations as low as 0.1 PFU/mL. This makes MS2 an ideal surrogate to confirm membrane integrity for removal over many orders of magnitude (>6 Logs) of particles larger than approximately 27 nm in diameter, which include all protozoal cysts, bacteria and many enteric viruses (as shown in Table 5).

Table 5 Pathogen Size

Pathogen	Size (Brock *et al.*, 1997, Strauss and Sinsheimer, 1963, McCuin and Clancy, 2006, Meyer and Jarroll, 1980, Singleton, 1999)
Protozoa	2 to 200 (*Giardia* - 6 to 14 μm) (*Cryptosporidium* – 3 to 8 μm)
Bacteria	0.1 to 15 (*E. coli* 0.25 μm dia X 2 μm long) (Salmonella 0.7-1.5 μm dia X 2-5 μm long)
Enteric Virus	0.01 μm to 0.1 μm
MS-2	0.027 μm

Notes:
(1) The nominal pore size of the DOW SFP 2860XP membrane tested for this project is 0.03µm.

MS2 coliphage challenge testing was conducted for each unit process in the AWPF as discussed below and in subsequent sections of this Memo. The basic procedure included identifying an injection point upstream of each unit process into which a concentrated stream of MS2 coliphage was injected into the process flow at a known flow rate. Target MS2 concentrations in the process water upstream of each unit process was $1 x10^8$ PFU/mL. MS2 was fed into the process water until a hydraulic steady stead had been reached, at which time 5 replicate samples were collected upstream and downstream of each unit process. The samples were shipped via overnight courier to GAP Enviromicrobial Services in London Ontario, CA for analysis.

Prior to the challenge testing in August 2018, tracer testing was conducted on each unit process at the design process flow rate using a UV absorber as a tracer. The UV absorber was feed into the process water upstream of each unit process, and the UV absorbance of the unit process effluent tap was monitored over time until a steady state UV absorbance was reached. The time

required to reach steady state was evaluated in terms of hydraulic residence times. As an example, the results of tracer testing conducted on the UV reactor system is shown in Figure 1 for a process flow of 5 gpm, which shows the UV absorbance at the effluent sample tap as a function of time. This figure shows that 1 hydraulic residence time (HRT) can be estimated at 2.5 minutes based on the breakthrough of 50% of the tracer. After 5 minutes, a steady state has been achieved. During all MS2 challenge tests of all processes, a conservative feed time of 5 HRTs was employed from the time of MS2 feed to the time of sampling.

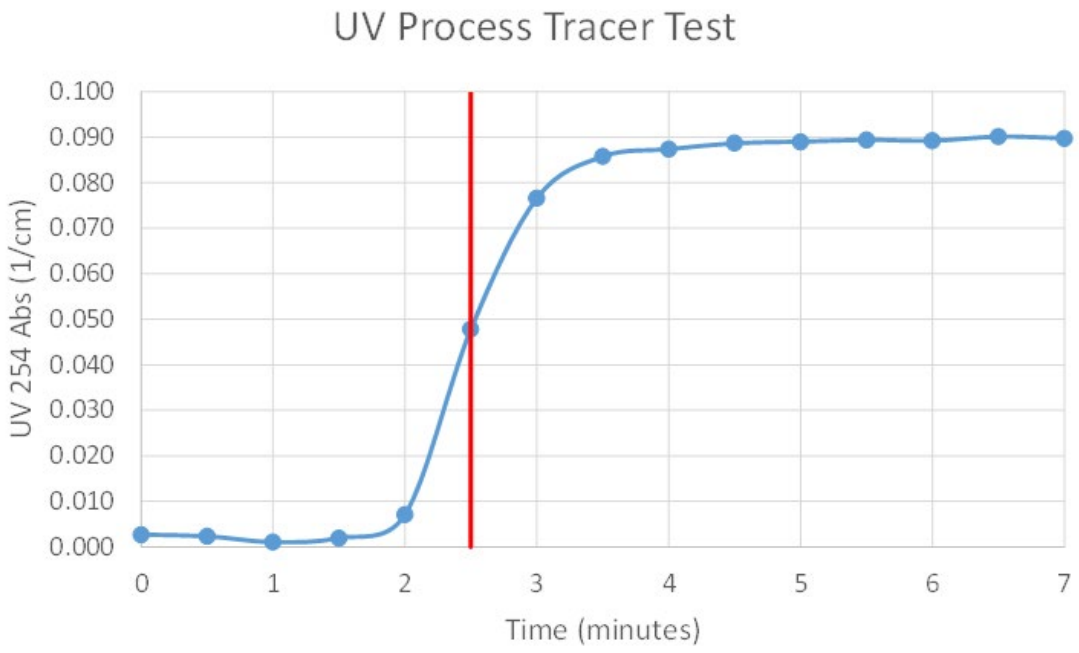

Figure 1 Example Tracer Test for UV Process

The results of MS2 challenge testing are summarized in Table 6.

LRV is calculated using Equation 1 below,

$$LRV = \log(Counts_{inlet}) - \log(Counts_{outlet}) \quad \text{Eqn. 1}$$

As shown the overall UF LRV 4.5 logs, indicating robust removal of virus, protozoa, and bacteria.

Table 6 Summary of MS2 Challenge Testing on the UF Process

Sample[(1)]	Date	Replicate 1 PFU/mL	Replicate 2 PFU/mL	Average (PFU/mL)	Log Concentration	Average Log Concentration	Overall UF LRV
UF001	1/8/2019	9.80E+07	9.40E+07	9.60E+07	7.98	7.96	4.5
UF001	1/8/2019	8.90E+07	1.03E+08	9.60E+07	7.98		
UF001	1/8/2019	8.00E+07	8.90E+07	8.45E+07	7.93		
UF001	1/8/2019	7.80E+07	7.80E+07	7.80E+07	7.89		
UF001	1/8/2019	1.23E+08	9.60E+07	1.10E+08	8.04		
UF002	1/8/2019	2.70E+03	3.22E+03	2.96E+03	3.47	3.44	
UF002	1/8/2019	2.06E+03	2.56E+03	2.31E+03	3.36		
UF002	1/8/2019	3.24E+03	2.62E+03	2.93E+03	3.47		
UF002	1/8/2019	3.18E+03	3.00E+03	3.09E+03	3.49		
UF002	1/8/2019	2.76E+03	2.48E+03	2.62E+03	3.42		

Notes:
(1) UF001 in ultrafilter inlet and UF002 is ultrafilter outlet.

Section 3

REVERSE OSMOSIS PATHOGEN AND CHEMICAL REMOVAL PERFORMANCE

RO provides a robust barrier to both pathogens and chemical pollutants, as summarized below.

3.1 Total Organic Carbon Removal

For potable water reuse projects, the State of California DDW requires RO systems to maintain, on average, an RO permeate Total Organic Carbon (TOC) level of <0.5 mg/L (DDW, 2018). Reducing TOC to this level (or below) is considered an important barrier to reduction of chemical pollutants. Further, DDW allows for the reduction of TOC across RO to be a conservative surrogate for both virus and protozoa removal (Los Angeles, 2018).

For CWS, a summary of TOC removal via RO for challenge testing and production runs conducted is provided in Table 5. In September 2018, on-line TOC monitoring was added to the system (CarboVis 705 IQ, manufactured by YSI). A total of 40 on-line readings were recorded from 23:06PM January 8 to 11:01AM on January 9, 2019. All of these readings showed a TOC concentration of zero in the RO permeate, and are not presented in Table 7. The minimum detection level for the on-line TOC meter was determined as 0.2 mg/L through the calibrations process utilized by CWS

January production and challenge testing results indicated average RO feed TOC of 11.5 mg/L and RO permeate TOC of < 0.13 mg/L. LRV were calculated using Equation 1 substituting TOC concentration for Counts. The average LRV was >1.95 log. The LRV is expressed as a greater than (>) number because the resulting effluent average TOC was based on some values that were below the detection limit.

Table 7 Summary of TOC Removal through Reverse Osmosis

Date	Time	Test	TOC (mg/L)[3]			LRV
			Sample Location			
			RO FEED (RO-003)	RO Permeate (RO-004)	RO Permeate RO-004[2]	
1/8/2019	23:06	Pre-Production	11	0.157	0.141	1.68
1/8/2019	8:25	MS2 Challenge	11.7	0.109		2.03
1/8/2019	8:28	MS2 Challenge	11.6	<.100		>2.06
1/8/2019	9:17	MS2 Challenge	11.4	NR[1]		NR
1/8/2019	9:19	MS2 Challenge	11.4	<.100		>2.06
1/9/2019	11:01	Post-Production	11.8	0.111	0.119	1.84

Notes:
(1) Data not reported.
(2) Second sample for RO-004 indicates replicate sample was collected.
(3) TOC measurements reported during challenge MS2 challenge testing were collected during times when MS2 feed was not turned on, as such any contribution to TOC from MS2 is not present in these reported values.

3.2 Electrical Conductivity Removal

For potable reuse projects, the State of California DDW allows for the reduction of Electrical Conductivity (EC) across RO to be a conservative surrogate for both virus and protozoa removal (Oxnard, 2018).

The results for electrical conductivity removal during the January production runs, and the Challenge testing are summarized in Table 8 and 9, respectively. LRVs during the January 2019 production, calculated using equation 1, substituting conductivity for counts, averaged 1.6 logs. During the MS2 challenge testing the average LRV was 1.6 logs.

Table 8 Summary of Electrical Conductivity removal by Reverse Osmosis during January 2019 Production Run

Sample ID	Sample Date	Sample Time	Conductivity (µS/cm^2)		LRV
			RO-003 (RO Feed)	RO-004 (RO Permeate)	
1	1/8/2019	23:26	484	13	1.57
2	1/8/2019	23:41	484	13	1.57
3	1/9/2019	0:28	481	13	1.57
4	1/9/2019	0:43	481	13	1.57
5	1/9/2019	0:58	481	13	1.57
6	1/9/2019	1:36	481	13	1.57
7	1/9/2019	1:51	481	13	1.57
8	1/9/2019	2:07	481	13	1.57
9	1/9/2019	2:22	484	13	1.57
10	1/9/2019	2:48	490	13	1.58
11	1/9/2019	3:03	493	13	1.58
12	1/9/2019	3:18	490	13	1.58
13	1/9/2019	3:33	487	13	1.57
14	1/9/2019	4:13	481	13	1.57
15	1/9/2019	4:28	481	13	1.57
16	1/9/2019	4:43	481	13	1.57
17	1/9/2019	4:58	478	13	1.57
18	1/9/2019	5:37	478	13	1.57
19	1/9/2019	5:52	478	13	1.57
20	1/9/2019	6:07	481	13	1.57
21	1/9/2019	6:22	487	13	1.57
22	1/9/2019	6:37	487	13	1.57
23	1/9/2019	7:07	487	13	1.57
24	1/9/2019	7:22	484	13	1.57
25	1/9/2019	7:37	481	13	1.57

Table 8 Summary of Electrical Conductivity removal by Reverse Osmosis during January 2019 Production Run

Sample ID	Sample Date	Sample Time	Conductivity (µS/cm2)		LRV
			RO-003 (RO Feed)	RO-004 (RO Permeate)	
26	1/9/2019	7:52	481	13	1.57
27	1/9/2019	8:07	481	13	1.57
28	1/9/2019	8:22		13	
29	1/9/2019	8:42	478	13	1.57
30	1/9/2019	8:58	474	13	1.56
31	1/9/2019	9:14	474	13	1.56
32	1/9/2019	9:30		13	
33	1/9/2019	9:45	452	11	1.61
34	1/9/2019	10:00	452	13	1.54
35	1/9/2019	10:15	465	13	1.55
36	1/9/2019	10:30	471	13	1.56
37	1/9/2019	10:45	474	12	1.60
38	1/9/2019	11:00	474	13	1.56
		Ave	**479.4**	**12.9**	**1.6**
		Min	**452**	**11**	**1.5**
		Max	**493**	**13**	**1.6**

Table 9 Summary of Conductivity Removal during MS2 Challenge Testing

Date	Time	Conductivity (µS/cm^2)		LRV
		RO-003 (RO Feed)	RO-004 (RO Permeate)	
1/8/2019	8:25	465	13	1.55
1/8/2019	8:28	465	13	1.55
1/8/2019	9:17	459	12	1.58
1/8/2019	9:19	462	12	1.59
	Ave	**508.4**	**17.2**	**1.6**

3.3 Chemical Pollutant Removal

Substantial work was performed to document the removal of chemical pollutants, including regulated chemicals, unregulated trace level chemicals, and tissue culture bioassays to examine "unknowns". These results, which demonstrated robust chemical removal and high quality water, are not included in this document.

3.4 MS2 Coliphage Challenge

As previously discussed for the ultrafiltration process above, MS2 challenge testing was conducted for the RO system. MS2 phage was fed into the RO feed stream at a target concentration of 1x10^8 pfu/mL. After a period of 10 minutes (5 HRTs), five replicate samples were

collected at the RO feed and RO permeate sample taps. To prevent degradation of MS2 phage in RO permeate, each 50mL sample bottle received 62.5 µL of a 10 percent Butterfield Buffer solution (a pH stabilized sodium dihydrogen phosphate solution).

The results are summarized in Table 10. As shown the overall RO LRV was 3.0 logs.

Table 10 Summary of MS2 LRV during Challenge Testing

Sample[(1)]	Date	Replicate 1 PFU/mL	Replicate 2 PFU/mL	Average (PFU/mL)	Log Concentration	Average Log Concentration	Overall UF LRV
RO003	1/8/2019	1.10E+08	1.18E+08	1.14E+08	8.06	8.09	3.0
RO003	1/8/2019	1.35E+08	1.31E+08	1.33E+08	8.12		
RO003	1/8/2019	1.40E+08	1.28E+08	1.34E+08	8.13		
RO003	1/8/2019	1.29E+08	1.02E+08	1.16E+08	8.06		
RO003	1/8/2019	1.27E+08	1.24E+08	1.26E+08	8.10		
RO004	1/8/2019	9.70E+04	9.60E+04	9.65E+04	4.98	5.09	
RO004	1/8/2019	1.15E+05	1.15E+05	1.15E+05	5.06		
RO004	1/8/2019	1.44E+05	1.43E+05	1.44E+05	5.16		
RO004	1/8/2019	1.64E+05	1.25E+05	1.45E+05	5.16		
RO004	1/8/2019	1.02E+05	1.32E+05	1.17E+05	5.07		

Notes:
(1) R003 is RO feed sample point, R004 is RO permeate sample point.

Section 4

UV DISINFECTION PATHOGEN AND CHEMICAL REMOVAL PERFORMANCE

UV systems for potable water reuse are credited with up to 6-log reduction of virus and protozoa, while also providing for destruction of NDMA (via photolysis) and trace organic chemicals (via advanced oxidation), as documented by permitted potable water reuse projects (Los Angeles (2018), Oxnard (2018)). Performance of the UV reactor for CWS was documented based upon several specific metrics, as reviewed below.

As previously discussed for the ultrafiltration and reverse osmosis processes above, MS2 challenge testing was conducted for the UV system. MS2 phage was fed into the RO permeate upstream of the UV system at a target concentration of $1x10^8$ pfu/mL. After a period of 12.5 minutes (5 HRTs), five replicate samples were collected at the UV inlet and UV outlet sample taps. To prevent degradation of MS2 phage in the high purity RO permeate, each 50mL sample bottle received 62.5 µL of a 10 percent Butterfield Buffer solution (a pH stabilized sodium dihydrogen phosphate solution).

Following sample collection, hydrogen peroxide was added at a dose of 6 mg/L to the RO permeate upstream of the UV reactors, and downstream of the MS2 injection point. During MS2 challenge testing, all samples with peroxide residual were collected in sample bottles that contained sodium thiosulfate to quench the hydrogen peroxide residual.

The results are summarized in Table 11. Values reported as "nd" indicated samples that had non-detect MS2 counts, and as such, the log of the concentration is reported as < the detection limit. The calculation the overall LRV (using Equation 1) for samples that have non-detect MS2 counts must take into account the indeterminate nature of these values where removal results in below detection. Therefore, the average log concentration values and the overall LRVs shown in Table 11 indicate less than and greater than values, respectively.

As shown the overall UV LRV >9.09 logs, and the overall UV-Peroxide LRV was >7.48 logs. Calculation of LRVs over a greater than nine order of magnitude range is very difficult and requires a combination of high MS2 counts in the influent, few or no MS2 counts in the effluent samples and a low effluent sample detection limit. During the UV only testing MS2 inlet counts were 8.09 logs. Effluent concentration included non-detect values and are reported as <-1.0. These levels result in LRVs of approximately 9.09 logs. However, UV peroxide testing shows lower overall LRVs, which is counterintuitive; LRVs should be at least as high as those for UV only. The primary factor impacting the lower LRVs for UV peroxide testing is the lower inlet samples. For all challenge tests, MS2 was fed into the process water at a target concentration of 8 logs, and these target vales were achieved for UV only testing. The addition of peroxide prior to UV likely resulted in some degradation of the inlet MS2 concentrations by the reported 1.5 log difference between the target and measured MS2 UV inlet concentrations.

UV transmittance (UVT) and UV sensor intensity were monitored during the challenge testing. Grab samples for UVT were measured using a RealTech model P300. UV intensity readings were recorded from the Wedeco UV reactor PLC display.

Grab samples for UVT taken during challenge testing, along with UV sensor intensity values are summarized in Table 12. RO permeate samples had an average UVT of 99.87%. The addition of H_2O_2 resulted in a drop in UVT of approximately 1 % to an average of 98.80%. The addition of MS2 phage during the UV only testing reduced UVT by approximately 0.5% to 99.1%.

UV sensor intensity values ranged from 184.4 to 194.1 mW/cm^2. Lower values were associated with the reduced UVT resulting from the presence of H_2O_2.

Table 11 Summary of MS2 LRV by UV and UV Peroxide during MS2 Challenge Testing

Sample	Date	Replicate 1 PFU/mL	Replicate 2 PFU/mL	Average (PFU/mL)	Detection Limit (PFU/mL)	Log Conc.(1)	Average Log Conc.	Overall UF LRV
UV INF 1	1/8/2019	1.28E+08	1.16E+08	1.22E+08	1.0	8.09	8.09	>9.09
UV INF 2	1/8/2019	1.23E+08	1.23E+08	1.23E+08	1.0	8.09		
UV INF 3	1/8/2019	1.22E+08	1.23E+08	1.23E+08	1.0	8.09		
UV INF 4	1/8/2019	1.19E+08	1.16E+08	1.18E+08	1.0	8.07		
UV INF 5	1/8/2019	1.36E+08	1.14E+08	1.25E+08	1.0	8.10		
UV EFF 1	1/8/2019	0.00E+00	0.00E+00	nd	0.1	<-1.0	<-1.0	
UV EFF 2	1/8/2019	0.00E+00	0.00E+00	nd	0.1	<-1.0		
UV EFF 3	1/8/2019	0.00E+00	0.00E+00	nd	0.1	<-1.0		
UV EFF 4	1/8/2019	0.00E+00	0.00E+00	nd	0.1	<-1.0		
UV EFF 5	1/8/2019	0.00E+00	0.00E+00	nd	0.1	<-1.0		
UVP INF 1	1/8/2019	3.75E+06	2.65E+06	3.20E+06	0.5	6.51	6.39	>7.48
UVP INF 2	1/8/2019	1.45E+06	9.50E+05	1.20E+06	0.5	6.08		
UVP INF 3	1/8/2019	3.15E+06	2.55E+06	2.85E+06	0.5	6.45		
UVP INF 4	1/8/2019	2.90E+06	2.30E+06	2.60E+06	0.5	6.41		
UVP INF 5	1/8/2019	4.05E+06	2.50E+06	3.28E+06	0.5	6.52		
UVP EFF 1	1/8/2019	0.00E+00	1.00E-01	5.00E-02	0.1	-1.30	<-1.09	
UVP EFF 2	1/8/2019	1.00E-01	0.00E+00	5.00E-02	0.1	-1.30		
UVP EFF 3	1/8/2019	0.00E+00	3.00E-01	1.50E-01	0.1	-0.82		
UVP EFF 4	1/8/2019	0.00E+00	0.00E+00	nd	0.1	<-1.0		
UVP EFF 5	1/8/2019	0.00E+00	0.00E+00	nd	0.1	<-1.0		

Notes:
(1) nd is not detected.

Table 12 Summary of UVT and UV Sensor Intensity Readings

Date	Time	Sample Location	Condition	UVT (%/cm)	UV Sensor Intensity (mW/cm^2)[1]
1/8/2019	7:35	RO permeate	w/o MS2	99.91	
1/8/2019	7:35	UV inlet	w H_2O_2 w/o MS2	98.47	
1/8/2019	7:35	UV Effluent	w H_2O_2 w/o MS2	99.1	
1/8/2019	7:45	RO permeate	w/o MS2	99.83	184.4
1/8/2019	7:45	UV Effluent	w H_2O_2 w/o MS2	98.96	184.4
1/8/2019	7:45	RO permeate	w H_2O_2 w/o MS2	99.38	184.4
1/8/2019	7:57	UV inlet	w H_2O_2 and MS2	98.07	
1/8/2019	8:03	UV inlet	w/o MS2 and H_2O_2	99.88	194.1
1/8/2019	8:03	UV Effluent	w/o MS2 and H_2O_2	99.39	194.1
1/8/2019	8:04	UV inlet	w/o MS2 and H_2O_2	99.84	194.2
1/8/2019	8:04	UV Effluent	w/o MS2 and H_2O_2	99.89	194.2
1/8/2019	8:14	UV inlet	w MS2 only	99.1	
1/8/2019	8:21	UV inlet	w/o MS2	98.98	192.6
1/8/2019	8:21	UV Effluent	w/o MS2	98.88	194.1

Notes:
(1) Readings from Wedeco UV reactor PLC display taken at the midpoint of the UV reactor between UV inlet and UV effluent sample taps.

4.1 NDMA Destruction

High UV doses on the order of 900 mJ/cm^2 can provide 90% (1 log, or LRV=1) reduction of NDMA (Sharpless and Linden, 2003). The results of NDMA samples collected during challenge testing period are summarized in Table 13 and indicate an average LRV of >0.77 log, suggesting a UV dose of approximately 700 mJ/cm^2. This high dose far exceeds the UV dose necessary for 6-log reduction of adenovirus, which is 235 mJ/cm^2 (Gerba et al., 2002).

Table 13 Summary of NDMA Removal in January 2019

Date	Time	Sample[(1)]	NDMA Concentration (ng/L)	MRL
1/9/2019	00:23	RO 004	13	2
1/9/2019	10:29	**RO-004**	**11**	2
1/9/2019	01:45	**UV 006**	**ND**	2.1
1/9/2019	9:55	UV-006	ND	2

Notes:
(1) RO 004: RO Permeate.
(2) UV 006: UV Effluent.

Section 5

SUMMARY

This TM documents the pathogen removal ability of the CWS demonstration-scale AWPF in January 2019. The AWPF is composed of three core treatment barriers, UF, RO, and UV AOP.

- UF:
  - Reliable turbidity removal, with an average UF filtrate turbidity of 0.1 NTU.
  - Protozoa rejection of 3.93 LRV based upon PDT results.
  - Seeded virus (MS2 coliphage) rejection of 4.5 LRV, which is the lower of two test runs.
- RO:
  - Reliable reduction of TOC to <0.5 mg/L, with a minimum LRV of 1.3.
  - Reliable reduction of EC, with a minimum LRV of 1.3.
  - Seeded virus (MS2 coliphage) rejection of 3.0 LRV, which is the lower of two test runs. Virus rejection can conservatively be applied to protozoa rejection.
- UV AOP:
  - Robust disinfection of seeded virus (MS2 coliphage), with >5.3 LRV.
  - Repeatable UVI readings, showing stability of performance between the two test periods.
  - Destruction of NDMA to below detection (<2 ng/L) resulting in >0.94 LRV, indicative of a UV dose of >900 mJ/cm^2, a dose far greater than necessary to provide 6 LRV of all known pathogens.

Chemical removal performance, pertaining to regulated chemical pollutants and unregulated trace level chemicals, is not detailed in this TM.

In total, the results from this project demonstrate a high level of pathogen removal, as indicated in summary table below, noting that the highest LRV reported is based either on the measured value or 6 LRV, whichever is lower and in accordance with DDW (2018).

Table 14 AWPF Performance Summary

Water Quality Target	UF	RO	UV/AOP
Virus LRV	4.5	3	6
Protozoa LRV	3.9	3	6
Total Organic Carbon Concentration and LRV	7.7 to 11.8 mg/L	<0.5 mg/L, 1.3 LRV	-
Electrical Conductivity LRV		1.3	
NDMA Concentration and LRV	-	11-13 ng/L	<2 ng/L, >0.77 LRV

Section 6

REFERENCES

Brock, T., Madigan, M. ,Martinko, J., and Parker, J., 1997. *Biology of Microorganisms*. Prentice Hall International, London.

California Department of Public Health (CDPH), 2014. *Groundwater Replenishment Reuse FINAL Regulation,* dated June, 2014.

Cheryan, M., 1998 "Ultrafiltration and Microfiltration Handbook." CRC Press, Boca Raton, FL.

Clean Water Services (2019). Clean Water Services High Purity Water Update Technical Memorandum and Sampling Plan. April 2019.

Division of Drinking Water (DDW), 2018, California Regulations Related to Recycled Water. California Code of Regulation Title 22, Division 4, Chapter 3. California State Water Resources Control Board Division of Drinking Water. Published October 8, 2018.

Gerba, C.P, Gramos, D.M, and Nwachukwu, N. Comparative Inactivation of Enteroviruses and

Adenovirus 2 by UV Light. Appl Environ Microbiol. Oct 2002; 68(10): 5167–5169.

10.1128/AEM.68.10.5167-5169.2002.

Los Angeles (2018). Demonstration of Water Quality for Potable Reuse Report. Terminal Island Advanced Water Purification Facility Expansion: Dominguez Gap Barrier Project. A report by Carollo Engineers, Inc. for the City of Los Angeles and the State of California Division of Drinking Water. March 2018.

McCuin, R. and Clancy, J. 2006. "*Occurrence of Cryptosporidium oocysts in US Wastewaters*." Journal of Water and Health 2006.

Meyer E. and Jarroll, E. 1980. *Giardiasis.* Am. J. Epidemiol*. 111:1–12.*

Oxnard (2018). Engineering Report for Groundwater Replenishment Reuse Project. A report prepared by Carollo Engineers, Inc. for Oxnard California and the State of California DDW. December 2018.

Sharpless, C. and Linden, K. 2003. Experimental and Model Comparisons of Low- and Medium-Pressure Hg Lamps for the Direct and H2O2 Assisted UV Photodegradation of N-Nitrosodimethylamine in Simulated Drinking Water. Environ. Sci. Technol (2003). 37, 1933-1940.

Singleton, P., 1999. *Bacteria in Biology, Biotechnology and Medicine* (5th ed.). Wiley. pp. 444–454.

USEPA, 2005. *Membrane Filtration Guidance Manual;* EPA 815-R-06-009; Office of Water, U.S. Environmental Protection Agency, Cincinnati OH, 2005.

USEPA, 2005. *Membrane Filtration Guidance Manual;* EPA 815-R-06-009; Office of Water, U.S. Environmental Protection Agency, Cincinnati OH, 2005.

USEPA. (1989). *Surface Water Treatment Rule. 40 CFR 141.70-141.* 719(b)(3)(iii)(A)