CITY OF OXNARD CALIFORNIA

MARCH 2017

Advanced Water Purification Facility

Indirect Potable Reuse Engineering Report

VOLUME 1 OF 2

carollo

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CITY OF OXNARD

ADVANCED WATER PURIFICATION FACILITY

INDIRECT POTABLE REUSE
POTABLE REUSE ENGINEERING REPORT

FINAL
VOLUME 1 OF 2

March 2017

CITY OF OXNARD
ADVANCED WATER PURIFICATION FACILITY

INDIRECT POTABLE REUSE
POTABLE REUSE ENGINEERING REPORT

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Note: *This version of the Engineering Report reflects comments received from the State Water Resources Control Board Division of Drinking Water, letter dated December 5, 2016 and a letter dated February 17, 2017. These letters were prepared in response to an October (2016) draft of this Engineering Report. This version of the report also reflects comments received from the State Water Resources Control Board Division of Drinking water, letter dated April 21, 2016. That letter was prepared in response to an October (2015) draft of this Engineering Report. Since the last submittal, extensive startup testing has been completed on the AWPF, demonstrating water quality in accordance with regulatory objectives, with the results presented within this report. Further, an Enhanced Source Control Program (ESCP) has been developed for Oxnard as they move into potable water reuse. That ESCP is also presented within this report.*

1.0 PROJECT OVERVIEW

The City of Oxnard (City) owns and operates a regional publicly-owned treatment works (POTW) that serves the City, City of Port Hueneme, Naval Base Ventura County and several surrounding unincorporated communities. It is comprised of the Oxnard Wastewater Treatment Plant (OWTP) and its associated wastewater collection system and outfall line. The OWTP is a secondary treatment facility with a design flow of 31.7 million gallons per day (mgd) and an average daily flow of 20 to 22 mgd.

The City's Advanced Water Purification Facility (AWPF) which, when placed into operation, will divert 8 to 9 mgd of biologically-treated secondary effluent for purification using three advanced treatment steps: microfiltration (MF), reverse osmosis (RO), and advanced oxidation with ultraviolet light and hydrogen peroxide (UV AOP). Because of reject streams, the 8 to 9 mgd of influent flow to the AWPF will result in 6.25 mgd of purified water. The MF reject and backwash wastewater produced at the AWPF will be returned to the OWTP headworks. The RO concentrate waste produced at the AWPF will be commingled with the OWTP secondary treated effluent and discharged to the Pacific Ocean.

This Engineering Report is submitted to the State Water Resources Control Board Division of Drinking Water (DDW) for review and approval. This Report is intended to provide the necessary information to permit indirect potable reuse (IPR) of up to 6.25 mgd of purified AWPF-treated product water. This first phase (Phase 1) will be IPR through Aquifer Storage and Recovery (ASR) in the Lower Aquifer System (LAS). For the ASR project, the City plans to inject the AWPF-treated recycled water into specific wells at the Campus Park location (at the corner of 5th and H Street in Oxnard), keep the water underground for a set period of time, then extract the water (from the same wells into which the water was injected) for potable and non-potable use.

1.1 Water in Oxnard

The City's current water supply comes from surface and groundwater sources. Fifty percent of the City's water supply is from northern California rainfall and snowmelt pumped through the Sacramento–San Joaquin Delta and imported to southern California via the State Water Project (SWP). This water is delivered by the Calleguas Municipal Water District (CMWD). Twenty-five percent of the City's water is regional groundwater supplied by the United Water Conservation District's (UWCD) spreading and pumping operations on the Santa Clara River and Oxnard Plain. Local, City owned and operated wells account for the remaining twenty-five percent of the City's water.

1.1.1 CMWD

The City receives SWP water from CMWD's Springville Reservoir (supplied by Metropolitan Water District of Southern California [MWDSC]) through the City's Oxnard and Del Norte conduits that feed five of the City's six water blending stations. Existing agreements between the City and CMWD do not guarantee the quantity of water the City may purchase. The City has a current MWDSC Tier 1 entitlement. Tier 1 water corresponds to the amount "contracted for" by the City. It is in essence a capacity reservation and includes the water being delivered to the Port Hueneme Water Authority (PHWA). MWDSC Tier 2 water is normally available to the City; however, the cost per acre-foot is higher. There is less availability and reliability of Tier 2 water in periods of drought.

1.1.2 Fox Canyon Groundwater Management Authority (FCGMA)

The FCGMA was created at the direction of the State Water Resources Control Board (SWRCB) to address ongoing overdraft and seawater intrusion into the Oxnard Plain Pressure Basin. The purpose of the FCGMA is to manage the region's groundwater supply by protecting the quantity and quality of local groundwater resources and by balancing the supply and demand for groundwater resources.

The FCGMA governs all extractions from the groundwater basin and, thus, the City's use of UWCD water and its own local wells is governed by the "safe yield" extraction volumes set by FCGMA.

In 2009 the City participated in the Ferro Pit Program, in which the City helped UWCD purchase an additional recharge basin, known as the Ferro Pit.

In 2016, the FCGMA issued a permit for the installation of the proposed Campus Park ASR well (letter dated June 24, 2016).

1.1.3 UWCD

UWCD currently provides a portion of the City's groundwater supply. This arrangement has been in place since 1954, and was formalized in the 1996 Water Supply Agreement for Delivery of Water through the O-H Pipeline. UWCD holds a pumping sub-allocation for all users of the O-H Pipeline, which includes the City, PHWA, and a number of small mutual water companies.

1.1.4 2002 Three-Party Agreement

The City, CMWD, and PHWA entered into a Three-Party Agreement in 2002, which provides PHWA with CMWD water through Oxnard's O-H pipeline. The City also supplied water to the Ocean View Municipal Water District (OVMWD) until 2008, when the OVMWD was dissolved and has since been managed and operated by the City. The OVMWD's distribution system is now referred to as the Ocean View System and the demand of the Ocean View customers is accounted for as part of the City's total demand, with much of the demand categorized as agricultural water use.

The City does not sell water to any other agencies. However, with the completion of Blending Station Number 6 in 2011, the City can provide desalted groundwater to PHWA in the case that PHWA's O-H pipeline supply becomes temporarily unavailable.

1.2 GREAT Program

To ensure a future reliable and affordable supply of high-quality water, the City has developed the Groundwater Recharge Enhancement and Treatment or GREAT program to be implemented and operated in two phases. Phase 1 (6.25 mgd, or 7,000 AFY) treatment facilities are now in operation for non-potable water reuse, whereas additional treatment will be constructed in the near future to 12.5 mgd, with a future final capacity of 25 mgd. At this time, regulatory approval is only sought for the 6.25 mgd flow. The objectives of the GREAT program are as follows:

- Increased reliability of water supply.
- Reduced cost of water supply.
- Improved dependability of water supply in accommodating existing needs and meeting planned growth and associated water demand.
- Enhanced stewardship of local water supply through recycling and reusing a substantial portion of the region's wastewater.

The GREAT program includes treating effluent from the OWTP and providing state-of-the-art MF, RO, and advanced oxidation with UV/H_2O_2 at the AWPF, schematically shown in Figure 1.

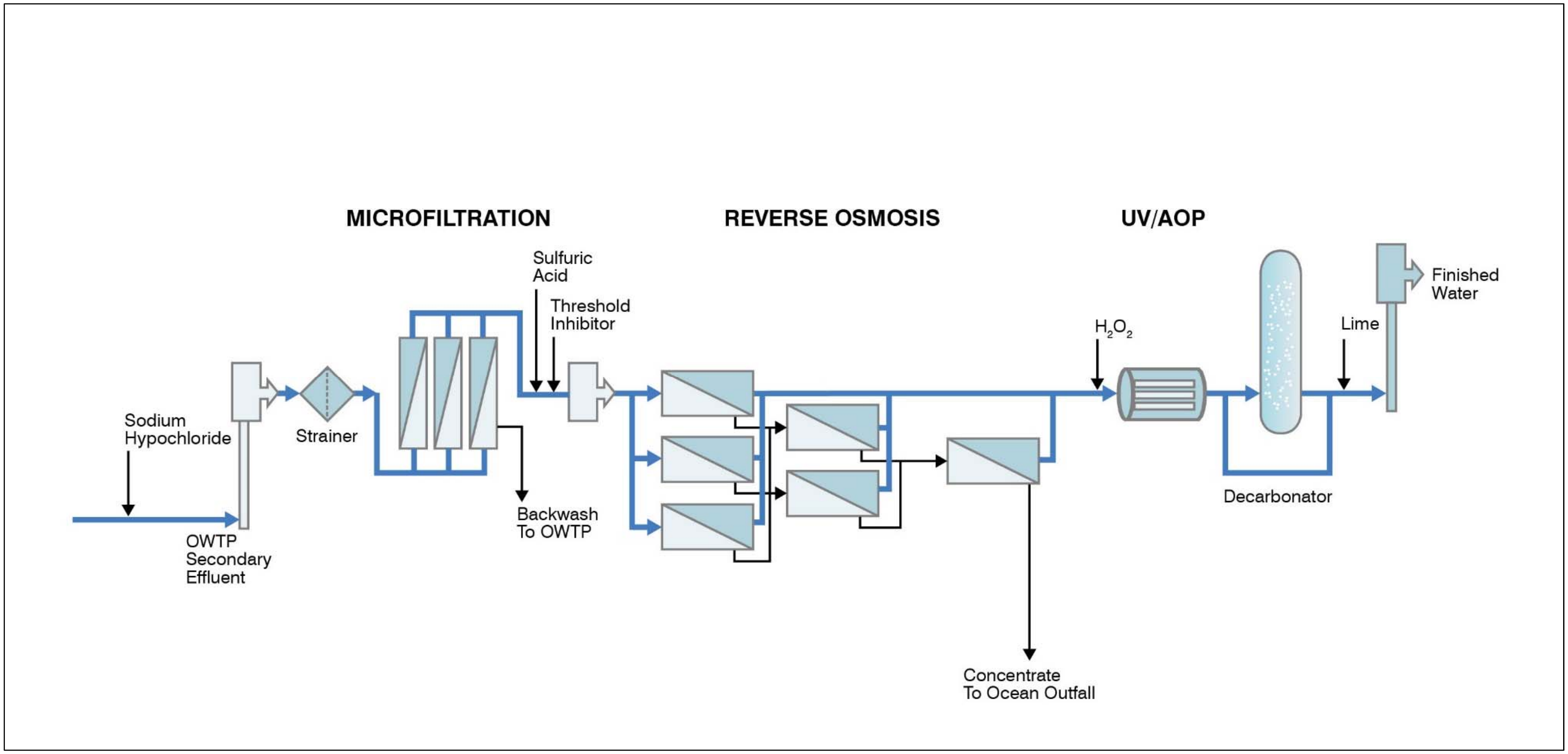

Figure 1 Advanced Treatment Schematic

Elements of the GREAT program are summarized as follows:

- Recycled Water Delivery System - Distributes recycled water for irrigation to agricultural users.
- Aquifer Storage and Recovery - Intended to help alleviate groundwater overdraft conditions and associated water quality problems, including coastal seawater intrusion. Will allow seasonal storage of potable water supplies to maximize use of the existing potable water distribution system.
- Regional Desalter - Membrane filter systems to remove dissolved minerals from groundwater, in order to reduce the levels of nitrates and total dissolved solids (TDS) in the groundwater basin.
- Blending Station No. 5 - Provides improved water supply infrastructure reliability, water quality, and hydraulic efficiencies. It also assists in meeting peak-hour and fire-flow water supply demands.
- Concentrate collection system from regional brine dischargers - Avoid discharge of high-salinity concentrate into City sanitary sewer system and Oxnard WWTP.
- Permeate Delivery System - Permeate delivery from regional desalter to industrial users.

All of the end uses (agricultural irrigation, landscape irrigation, injection into the aquifer, and industrial) will be served with a common water quality that meets the groundwater recharge (groundwater recharge) criteria for injection of purified recycled water. In exchange for the delivery of recycled water, agricultural customers would transfer their groundwater pumping allocations to the City on a one-for-one basis. The additional pumping by the City would be from the poor-quality Oxnard Aquifer, which would require additional treatment prior to delivery to the City's distribution system. The GREAT desalter constructed in 2007/2008 would provide this treatment. It does not increase the total water supply. It does, however, allow full use of the City's groundwater resources.

1.2.1 Project Site

The project site is Oxnard, California. The location of the AWPF and the ASR location are shown in Figure 2.

1.2.2 Existing Facilities and OMMP

The OWTP liquid processes include preliminary treatment, primary clarification, secondary treatment (biofiltration (trickling filters) followed by activated sludge), and chlorine disinfection in order to achieve an acceptable level of water quality for ocean discharge. The solids-handling processes include gravity thickening of primary sludge, dissolved air flotation thickening of secondary sludge, anaerobic digestion, and belt filter press dewatering.

Figure 2 Project Location

The AWPF is a standard MF/RO/UV AOP system to purify secondary effluent. It includes the following processes: automatic strainers, MF system (detailed below), equalization tank, RO transfer pumps, Cartridge filter, High pressure RO feed pump, Two-stage RO train (detailed below), UV disinfection system (detailed below), Decarbonator, lime stabilization, product water pumps, and chemical storage. The AWPF is located adjacent to the OWTP (Figure 3).

The three primary advanced treatment processes (MF, RO, and UV AOP) are designed to meet DDW performance criteria for indirect potable water reuse. A summary of each process is provided in Table 1.

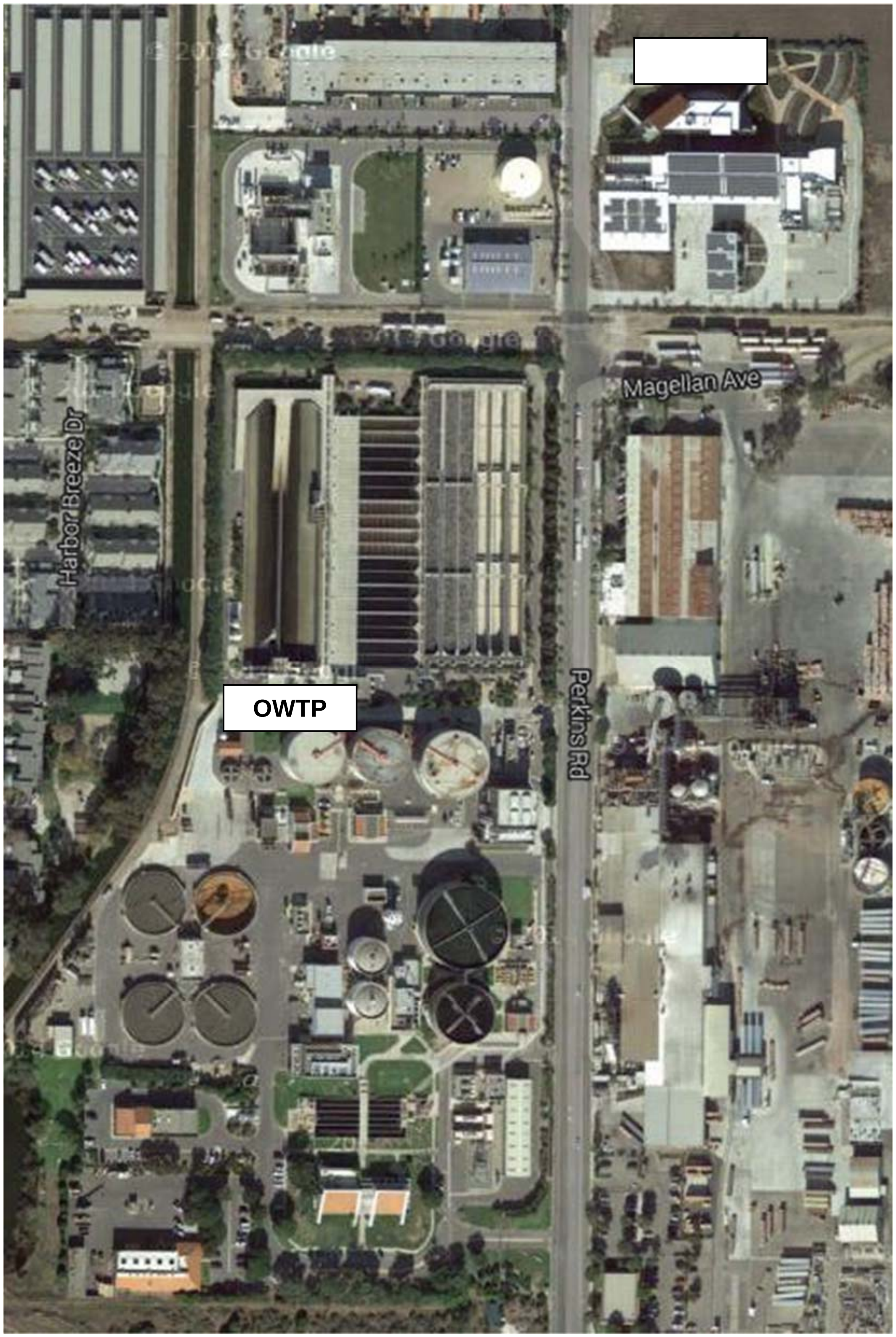

Figure 3 OWTP and AWPF

Table 1 Advanced Treatment Design Criteria
Advanced Water Purification Facility
City of Oxnard

Process	Performance Goal	Performance Monitoring
MF	Filtrate Nephelometric Turbidity Unit (NTU)<0.2 NTU.	Maintaining turbidity values of <0.2 NTU indicates no gross membrane failure. However, insufficient research exists to correlate MF filtrate turbidity with pathogen removal.
	Pressure Decay Test (PDT, also called membrane integrity test (MIT)) <0.3 pounds per square inch per 5 minutes (psi/5min).	Daily testing demonstrates MF integrity, allowing for 4-log protozoa credit.
RO	Each membrane element must achieve ≥99% rejection of sodium chloride, and average rejection of ≥ 99.2% sodium chloride.	Track and trend electrical conductivity (EC) reduction through the RO membrane. Pathogen reduction credits for RO based upon this measured value.
	RO permeate must have a total organic carbon (TOC) ≤ 0.25 mg/L greater than 95% of the time at startup and through 20 weeks of operation. Subsequently, RO permeate TOC must be ≤0.5 mg/L.	No online TOC metering is currently installed, but online TOC metering will be installed prior to IPR operation. It remains to be determined TOC will be installed just after RO, or before and after RO.
UV AOP	≥0.5-log reduction of 1,4-dioxane; at least one continuously monitored surrogate or operational parameter shall be established to reflect that the minimum 1,4-dioxane criterion is being met.	Startup testing documents 1,4-dioxane removal and correlates such removal with an online surrogate (UVI/Q).
	6-log reduction of adenovirus.	UVI/Q values correlate with N-Nitrosodimethylamine (NDMA) destruction, which maintains continuous documentation of a UV dose well in excess of 235 mJ/cm^2; which is the dose for 6-log adenovirus. This minimum dose will be maintained at all times.

1.2.2.1 MF System

The MF system (Figure 4) is an outside-in MF system (PALL Microza) and consists of MF feed strainers, MF feed water ORP, pH, turbidity, and total chlorine residual analyzers. The

MF is used to remove particulate and microbial contaminants, including turbidity, *Giardia,* and *Cryptosporidium* using a low-pressure filtration system. Upstream of RO, this system mitigates RO membrane fouling by reducing the level of particulates and larger colloids. MF also reduces the concentration of bacteria – particularly those that are particulate-associated. There are six treatment trains in parallel in the MF room with capacity for an additional six trains to be built if needed. One of the six trains can be out of service and the MF system will still maintain production of sufficient flow to result in 6.25 mgd of RO permeate.

Figure 4 MF Photos at the AWPF

1.2.2.2 RO System

RO units are furnished by H2O Innovation (Figure 5), and installed with Hydranautics ESPA2 membrane elements. The RO units are housed in their own room, with two identical skids running in parallel with individual production capacities of 3.125 mgd. Space for three additional RO skids of 6.25 mgd each is built into the room in for possible future needs. The RO system is monitored using online EC at the MF filtrate (RO feed) and several places on the RO. discharge; Stage 1, 2 and 3, total flow, and concentrate. These EC locations are at both trains. Currently there is no online TOC metering of this MF filtrate or RO permeate, though the City intends to install TOC monitors on the RO feed and RO permeate prior to operation.

Figure 5 RO Photos at the AWPF

1.2.2.3 UVOX System

Three Trojan UVPhox D72AL75 reactors are installed to provide additional treatment of the RO permeate (ROP) via AOP. These reactors operate with low-pressure high-output (LPHO) lamps and with dosed hydrogen peroxide (H_2O_2); based upon a target EEO sufficient for 0.5 log reduction of 1,4-dioxane. Startup testing, documented further on, demonstrates the dose capacity of this system and effective monitoring using a UVI/Q process. These three reactors each have two banks, for a total of six banks of UV lamps. Five of those banks are duty, and the sixth bank is redundant. Similar to the MF and RO systems, there is room to expand this UV system to meet future needs (Figure 6).

1.3 Public Outreach and Coordination Effort

The City has yet to initiate a formal outreach effort to the general public to discuss this IPR project. Stakeholders, however, are aware of this project and will be further informed as detailed below.

Figure 6 Photo of Similar UV Phox

1.3.1 Stakeholders

Key regional stakeholders are aware of this IPR project. These stakeholders include the CMWD, the UWCD, the FCGMA, and the City of Ventura. CMWD, UWCD, and FCGMA are directly involved in water supply to the City. Other regional stakeholders include various regulatory and governmental bodies, and several environmental organizations. The Program Environmental Impact Report (PEIR), completed in 2004, included the required public notice and engagement regarding the various aspects of the GREAT program, including potable reuse (CH2MHill, 2004).

Once this Engineer’s Report is submitted for review and approval by DDW and the Regional Water Quality Control Board (RWQCB), the City will re-engage with project stakeholders.

1.3.2 System Startup

As outlined in subsequent sections of this Engineer’s Report, extensive testing of the purification system has been completed to demonstrate compliance with DDW’s groundwater recharge regulations. This testing was done during the normal operation of the GREAT system for non-potable reuse applications. These tests are detailed in the following Chapter 17.

After the construction of the proposed IPR ASR well, a series of tests will be done on the background groundwater quality. This information, once it is thoroughly reviewed, will be presented to the various stakeholders and for regulatory review.

1.3.3 Public Hearing and Notifications

The City will follow the public hearing requirements specified in the DDW groundwater recharge regulations, which were adopted in June 2014 and are now included in the Division of Drinking Water (DDW) Water Recycling Criteria (CDPH, 2014). Section 60320.202 includes a review of the necessary public and regulatory notice requirements of the proposed project. In general, the following approach will be followed:

- The City will provide DDW and the RWQCB the information it intends to present at the hearing regarding this IPR project.
- After the Engineering Report has been approved, the City will post the Report on its website and make it available at the City's office at least 30-days prior to the hearing.
- The City will notify the public about the availability of the information and the public hearing, including how the public can provide comments and attend the hearing. This can be done through several media channels.
- The City will notify the first downgradient potable water well owner and well, which is the City of Oxnard.
- Further outreach will also occur once the draft tentative permit is issued. In accordance with California Water Code (CWC) Section 13167.5, the Los Angeles RWQCB (LARWQCB) must provide notice and a period of at least 30 days for public comment prior to adoption of a Waste Discharge Requirement (WDR) and/or Water Recycling Requirement (WRR). This is accomplished by providing a draft of the amendment to anyone who has requested a copy or by posting the draft on the LARWQCB website and providing an electronic notice to interested parties. After posting on the consent calendar, the LARWQCB will hold a public hearing that provides opportunity for further public comment.

1.3.4 California Environmental Quality Act (CEQA)

The CEQA compliance is summarized below under the "Environmental Compliance" section.

1.4 Environmental Compliance

The CEQA process for the GREAT treatment facilities has already been completed (CH2MHill, 2004). This process provided an open forum for public comment on the project at the time of that work (2004).

An addendum to that EIR was completed in January of 2015 by Hollee King to address the ASR well and monitoring wells (King, 2015). In a letter dated January 21, 2016, the Governor's Office of Planning and Research State Clearinghouse and Planning Unit issued a letter of compliance to Oxnard for the ASR project, stating "that you have complied with the State Clearinghouse review requirements for draft environmental documents, pursuant to the California Environmental Quality Act" (State of California, 2016).

1.5 Project Goal

The goal of the GREAT program is to ensure a future reliable and affordable supply of high-quality water. Phase 1 (6.25 mgd, or 7000 AFY) treatment facilities have been constructed and is now producing water for non-potable use. The City has plans to expand the production capability of this facility, and will provide details of this expansion at a future date.

1.6 Purpose of This Report

The purpose of this Title 22 Engineering Report is to provide detailed information on the design of the City's AWPF, describe the water reuse goals for the City, clearly indicate the means for compliance with DDW's groundwater recharge regulations and any other features specified by the RWQCB, and in total, gain approval for the City to implement an IPR groundwater recharge project.

This Engineering Report is in compliance with the State of California Water Recycling Criteria (CDPH, 2014) that requires the submission of an Engineer's Report to the RWQCB and DDW prior to any modification to an existing project or implementation of a new project.

2.0 PROJECT PARTICIPANTS

The City intends to recharge groundwater and extract groundwater from the same location. This operation, under the current plan, will not impact other utilities or entities. With that said, there are a number of key participants outside of the City that have had, and will have, a role in the successful implementation of IPR. The project participants, their role, and their contact information are listed below in Table 2.

3.0 REGULATORY REQUIREMENTS

The overarching regulatory requirements are summarized in this section. The specific parameters for monitoring and permit compliance are documented in Sections 9 and 15.

3.1 California Water Code (CWC)

The CWC stipulates that each RWQCB formulate and adopt Water Quality Control Plans (Basin Plans) for all areas governed by the board. These plans must contain water quality objectives for surface water and groundwater within the regions that provide reasonable protection of the beneficial uses of the waters. During the process of formulating such plans the RWQCBs must consult with and consider recommendations of affected state and local agencies. Such plans shall be periodically reviewed and may be revised (Section 13240).

Table 2 List of Key Project Participants
Advanced Water Purification Facility
City of Oxnard

Organization	Name	Contact Information	Project Role
City of Oxnard	David Lutz, AWPF Plant Manager	Desk: (805) 271-2203 Cell: (760) 415-2496 david.lutz@oxnard.org	Responsible for Daily Production of Purified Water and Operation of the ASR System.
City of Oxnard	Dan Rydberg, Director of Public Works	(805) 385-8055. Daniel.Rydberg@ci.oxnard.ca.us	Overall potable reuse program manager for the City.
City of Oxnard	Thien Ng, Wastewater Division Manager	(805) 432-3575 Thien.Ng@ci.oxnard.ca.us	Project Manager for this potable reuse project.
RWQCB	Elizabeth Erickson	(213)576-6665 Elizabeth.Erickson@waterboards.ca.gov	Lead RWQCB permitting authority for this project.
DDW	Jeff Densmore, District Engineer	(805)566-1326 Jeff.densmore@waterboards.ca.gov	Lead DDW permitting authority for this project.
DDW	Kurt Souza, South Field Branch Chief	(805)566-1326 Kurt.souza@waterboards.ca.gov	Regional oversight and perspective on potable reuse.
CalMWD	Kristine McCaffrey, Manager of Engineering	805-579-7173	Regional Stakeholder.
UWCD	Tony Morgan, GW Dept Manager Tony Emmert, Deputy GM	805-525-0621 805-317-8961	Regional Stakeholder.
FCGWMA	Gerhardt Hubner	805-654-5051	Regional Stakeholder.
City of Ventura	Shana Epstein, General Manager	805.652.4518 sepstein@venturawater.net	Adjacent City dealing with similar water supply concerns and potable reuse considerations.
Consultant Team			**Project Role**
Carollo Engineers	Tracy Clinton, Project Manager	(925)932-1710 tclinton@carollo.com	Project Manager for Water Reuse Permitting and Implementation, working for the City.
Carollo Engineers	Andrew Salveson, Project Engineer	(925)932-1710 asalveson@carollo.com	Engineer of Record for this Engineer's Report.
Hopkins Groundwater Consultants	Curtis Hopkins, Principal Hydrogeologist	(805)653-5306 chopkins.hgc@sbcglobal.net	Groundwater hydrogeologist of record for this Engineer's Report & Well Monitoring Plan
HLK Planning	Hollee L. King	(805)901- 2261 hollee@hlkplanning.com	CEQA Permitting Lead.
MV Engineering LLC	Mary Vorissis	(805) 217-8494 mary.vorissis@gmail.com	Operations and Maintenance Management Plan (OMMP)

In accordance with CWC Section 13260, all persons discharging waste within the region must file with the appropriate board, and provide information pertaining to their discharge. Within the region, it is not permitted for a person to construct, maintain, or use any waste well that interferes with a source for domestic water supply without proper permitting or exceptions (CWC Section 13540). “Recycling criteria” are the levels of constituents of recycled water, and means for assurance of reliability under the design concept which will result in recycled water safe from the standpoint of public health, for the uses to be made (CWC Section 13520). Section 13521 of the CWC states that the State Department of Public Health (now DDW) shall establish uniform statewide recycling criteria for each varying type of use of recycled water where the use involves the protection of public health.

Section 13522 stipulates that if a contamination occurs as a result of recycled water, then procedures for abating this contaminant must be followed in accordance with the Health and Safety Code. The use of recycled water must not cause, constitute, or contribute to, any form of contamination. In order to comply with contamination prevention with recycled water use, any person recycling or proposing to recycle water must file for appropriate permitting with the regional board (Section 13522.5).

If a master recycling permit is granted, it must include at a minimum (Section 13523.1): waste discharge requirements(WDRs), a permittee statewide recycling criteria compliance requirement, recycled water producer end user rule enforcement requirement, requirement for a recycled water use quarterly report, periodic facility inspection requirement, and additional requirements given by the regional board in permit. Recycled water may only be used for the permitted purpose, as specified by the regional board (Section 13524).

3.2 DDW Requirements

DDW (formerly CDPH) has developed criteria for both non-potable uses of recycled water and groundwater recharge for subsequent potable use, with the most recent version updated as of June 2014 (CDPH, 2014). This Engineering Report deals specifically groundwater recharge for potable reuse.

This project will meet the requirements specified in the Water Recycling Criteria (CDPH, 2014). Key regulatory requirements related to groundwater recharge are summarized in Table 3.

3.3 RWQCB Requirements

The OWTP currently discharges to the Pacific Ocean under existing NPDES permit (CA0054097) Order No. R4-2013-0094 which was adopted on June 6, 2013 and became effective on July 26, 2013 (WW-16). The City also operates an AWPF under its GREAT Program, to produce non-potable water for reuse. The GREAT Program operates under a separate WRR and WDR Order No. R4-2008-99-0083 (WW-17), as amended by Order No. R4-2011-0079 and R4-2008-0083-A01.

**Table 3 List of Key Potable Reuse Regulatory Requirements for Groundwater Recharge
Advanced Water Purification Facility
City of Oxnard**

Issue	Regulation Citation	Regulatory Concept	Section in This Report
Alternate Source of Supply	60320.200(b)	The project proponent must have a plan for an alternative water supply in the event of a treatment process failure or unforeseen water quality event.	8
Background Groundwater Quality Sampling	60320.200(c)	Background groundwater quality must be documented to allow for a comparison with the recycled water.	12
Underground Retention Time for Recharged Water	60320.200(d)	The recycled water must be stored for a specific time prior to potable use to allow for monitoring of water quality and response in the event of water quality concerns.	6,7
Groundwater Flow Maps and Hydrogeology	60320.200(e, h)	The groundwater transport must be sufficiently and conservatively documented to provide confidence that a minimum specified travel time is obtained.	6
Treatment Process Performance	60320.200(f,g)	The proponent must demonstrate its ability to produce a high quality water protective of public health.	5,9
Advanced Treatment Criteria, RO	60320.201 (a,b)	The RO membranes must meet specific EC and TOC performance criteria and be monitored by a proven method to demonstrate continuous performance.	5
Advanced Treatment Criteria, Advanced Oxidation	60320.201 (d,e)	The advanced oxidation system must be sufficiently robust to provide specific log reduction of one or more trace pollutants and have a proven method for monitoring performance online.	5
Public Hearing	60320.202	The project proponent must provide notice to the public and stakeholders regarding the intent and implementation of the potable reuse project.	1
Wastewater Source Control	60320.206	A rigorous wastewater source control is required to minimize impacts to potable reuse water quality.	4
Pathogenic Microorganism Control	60320.208	Specific pathogen reduction targets must be met through a series of multiple treatment processes. The log reduction requirements for virus, *Giardia,* and *Cryptosporidium* are 12, 10, and 10, respectively.	5
Nitrogen Compounds Control	60320.210	A total nitrogen standard of ≤10 mg/L must be met at all times.	9
Regulated Contaminants and Physical Characteristics Control	60320.212	The recycled water must meet DDW drinking water regulations for MCLs and action levels for lead and copper.	9

Table 3 List of Key Potable Reuse Regulatory Requirements for Groundwater Recharge
Advanced Water Purification Facility
City of Oxnard

Issue	Regulation Citation	Regulatory Concept	Section in This Report
Diluent Water	60320.214	No diluent water is being proposed for this project.	10
Recycled Water Contribution (RWC)	60320.216	The RWC is the relative amount of recycled water compared to the total water being recharged. For this project, the RWC is 100 percent.	10
Total Organic Carbon	60320.218	TOC is used as a bulk surrogate for organics in the purified water. A maximum TOC value of 0.5 mg/L is required.	9
Additional Chemical and Contaminant Monitoring	60320.220	Monitoring of recycled water and groundwater is required for priority toxic pollutants, chemicals with notification levels, and other chemicals specified by DDW.	15
Operation Optimization and Plan	60320.222	Prior to operation, a detailed Operation Optimization Plan approved by DDW is required to operate, maintain, and monitor the project.	16
Response Retention Time	60320.224	The response retention time (RRT) is the time to monitor and respond to treatment process failures. The RRT must be less than the underground retention time of the stored purified water.	7
Monitoring Well Requirements	60320.226	Prior to operation, monitoring wells must be placed in appropriate locations to monitor the movement and water quality of the injected water.	6,11

This potable reuse project will require a reissuance of the WDR/WRR Order No. R4-2008-0083, including the Monitoring and Reporting Program No. 9456. A Report of Waste Discharge (ROWD) is required to initiate the permit application process.

The LARWQCB regulates groundwater recharge projects under numerous state laws and regulations, including the Water Quality Control Plan, Los Angeles Region (hereinafter, the Basin Plan) and SWRCB policies. The Basin Plan requirements include groundwater objectives for minerals and drinking water Maximum Contaminant Levels (MCLs). The Basin Plan also applies the state's Anti-degradation Policy, which has been further interpreted pursuant to the 2013 SWRCB Recycled Water Policy (SWRCB, 2013).

3.4 SWRCB Requirements

The SWRCB has two policies related to this proposed IPR project. They are the Anti-Degradation Policy and the Recycled Water Policy. While the full expectation for this IPR project is to improve groundwater quality through the injection of advanced-treated recycled water, the specific provisions of these two policies must be identified and met.

3.4.1 Anti-degradation Policy

Resolution 68-16 is the state's Anti-degradation policy, titled "Statement of Policy with Respect to Maintaining High Water Quality in California." The key components of this Resolution, listed here verbatim, are:

- "Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality water will be maintained until it has been demonstrated to the state that any change will be consistent with maximum benefit to the people of the state, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed in the policies."
- "Any activity which produces or may produce a waste or increased volume or concentration of waste and which discharges or proposes to discharge to existing high quality waters will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to ensure that (a) pollution or nuisance will not occur and (b) the highest water quality consistent with maximum benefit to the people of the State will be maintained."

3.4.2 Recycled Water Policy

The Recycled Water Policy was adopted by the SWRCB in 2009 and revised in 2013 (SWRCB, 2013). Relevant components of the Policy include Salt Nutrient Management Plans (SNMPs), Recycled Water Groundwater Recharge Projects (GRPs), anti-degradation, and monitoring constituents of emerging concern (CEC). Each of these is summarized below.

3.4.2.1 SNMPs

This element of the Recycled Water Policy requires SNMPs to be developed for every groundwater basin/sub-basin in California within five years of the Recycled Water Policy adoption (seven years with approved extensions). The objective of the SNMP is to manage salts and nutrients from all sources" on a basin-wide or watershed-wide basis in a manner that ensures attainment of water quality objectives and protection of beneficial uses." The SNMP includes the following tasks:

- Identify the SNMP work group and develop the SNMP work plan.
- Establish and manage a stakeholder process.
- Summarize/Characterize Water Management and Salt/Nutrient Management Goals and Objectives.
- Characterize Groundwater Basin Geology, Hydrology, and Hydrogeology.

- Summarize Existing Groundwater and Surface Water Monitoring Programs and Water Quality.
- Develop Salt and Nutrient Source Identification.
- Estimate Assimilative Capacity for Each Sub-Basin.

The City of Oxnard developed a preliminary draft SNMP for the Oxnard Plain (inclusive of the Oxnard Forebay) and Pleasant Valley groundwater basins (Carollo, 2016b). The preliminary draft was submitted to the LARWQCB and other stakeholders in July 22, 2016 for review and comment. The LARWQCB provided comments (email from Ginachi Amah, September 1, 2016). The United Water Conservation District provided comments regarding including potential use of purified water from the AWPF for recharge at UWCD facilities (personal communication, Dan Detmer UWCD). The City of Oxnard sent a response to comments to the LARWQCB in September 2016. The response to comments included the following request, related to allowing the City of Oxnard to obtain recycled water permits.

> *"The City of Oxnard respectfully requests that the RWQCB accept the Preliminary Draft Oxnard SNMP, as a draft document (with minor changes to accommodate TAG comments), with the understanding that the SNMP process is well underway, and that obtaining recycled water permits for the proposed projects identified in the Preliminary Draft Oxnard SNMP will not be impacted by delaying the development of a Final Oxnard SNMP. The City of Oxnard requests that the Final Oxnard SNMP be delayed to be coincident with the development of the Groundwater Sustainability Plan (GSP). It is envisioned that at that time, the involved stakeholders will determine the need for additional modeling and analysis based on the findings of the GSP."*

The Oxnard SNMP includes all of the required elements in the SNMP evaluation. Critical to the evaluation is the assessment of assimilative capacity and the evaluation of proposed projects.

The SNMP includes evaluation of existing groundwater quality and calculation of area weighted average TDS, chloride, and nitrate concentrations, by basin. Assimilative capacity for each constituent, which is a comparison of the existing groundwater quality with the target groundwater quality, summarized here. Note two things. First, the proposed ASR project is in the Oxnard Plain, which has assimilative capacity for chloride, TDS, and nitrate. Second, the purified water that will be used for groundwater recharge, will result in improved groundwater quality for all conditions.

- Oxnard Plain Excluding Coastal Saline Zone UAS (upper aquifer system)
  - Chloride Assimilative Capacity - YES
  - TDS Assimilative Capacity - YES
  - Nitrate Assimilative Capacity - YES

- Oxnard Plain Excluding Coastal Saline Zone LAS (lower aquifer system)
  - Chloride Assimilative Capacity - YES
  - TDS Assimilative Capacity - YES
  - Nitrate Assimilative Capacity - YES
- Oxnard Forebay
  - Chloride Assimilative Capacity - YES
  - TDS Assimilative Capacity - YES
  - Nitrate Assimilative Capacity - YES
- Pleasant Valley
  - Chloride Assimilative Capacity - YES - LIMITED
  - TDS Assimilative Capacity - NO
  - Nitrate Assimilative Capacity - YES

The City of Oxnard is planning to implement ASR in the Oxnard Plain. The purpose of the proposed ASR projects is to provide potable water supply. It is conservatively assumed that the proposed ASR project(s) would not necessarily lead to a reduction in groundwater pumping (via offsetting use of existing wells) or use of imported water, both of which would have potential groundwater quality benefits. The intent of the ASR project is to inject recycled water into a groundwater aquifer, allow it to remain within the aquifer for a specified retention time, and then extract the water for potable use.

Agricultural irrigation with recycled water from the AWPF may be delivered directly to agricultural areas east of the City of Oxnard and/or delivered to PVCWD. Use of recycled water would likely offset existing water supplies for agricultural irrigation (groundwater or other). Recycled water delivered directly to agricultural areas east of the City of Oxnard would recharge the Oxnard Plain. If recycled water from the AWPF is sold to PVCWD, then it would be comingled with PVCWD existing water supplies and delivered for agricultural irrigation within the PVCWD service area. Recycled water delivered to PVCWD would recharge the Oxnard Plain and the Pleasant Valley Basin.

The AWPF treatment facility will produce purified recycled water and includes MF, RO, and UV AOP. It is anticipated that lime will be added to restore the alkalinity and calcium to the water to minimize the corrosivity of the recycled water. Prior estimates for TDS and chloride of the reverse osmosis permeate was projected as 201 mg/L and 70 mg/L, respectively (Jensen Design and Survey 2015). Approximately 30 m/L of additional TDS was attributed to lime addition. Therefore, the predicted TDS, chloride and nitrate concentrations were 230 mg/L, 70 mg/L, and 0.7 mg/L as N, respectively. More recent numbers for the AWPF reverse osmosis permeate water suggest values of approximately 51 mg/L TDS, 14 mg/L chloride, and 0.11 mg/L as N of nitrate. Accounting for the additional TDS of lime addition, and adding in conservatism (factor of 2) to the estimates, it is assumed for this analysis that the recycled water from the AWPF has 160 mg/L TDS, 30 mg/L chloride, and 0.2 mg/L nitrate as N. The predicted water AWPF recycled water quality is well below the objectives and existing water quality in all systems of all basins within the study area.

As discussed, the City of Oxnard's proposed recycled water projects include potable reuse via ASR. In an ASR configuration, the recycled water is injected into an aquifer and extracted for use after some specified residence time. The purpose of the ASR projects is to provide water to meet increasing demands, and it is conservatively assumed that the water from the ASR project(s) will not offset existing groundwater pumping.

Relative to the time scales that are important in groundwater fate and transport, the residence time in an ASR configuration is relatively short. ASR effectively provides a relatively small and temporary additional load to the basin. There may be localized mixing of the injected water (desalted) and the groundwater aquifer during the residence time in the aquifer. However, any mixing that would occur would provide a diluting effect on existing groundwater, due to the superior quality of the AWPF recycled water as compared to existing groundwater quality. Therefore, if there is any effect of the temporary injection of AWPF water into aquifers in the Oxnard Plain, then it would be a beneficial effect of dilution. From a salt and nutrient loading perspective, ASR generates a no-net change to the existing system. Since ASR will effectively provide no change to groundwater quality (or possibly a benefit to groundwater quality) then it is reasonable to conclude that the proposed ASR project(s) are allowable under the SNMP framework and should proceed, provided that other regulatory requirements are met.

The SNMP evaluation of the City's proposed recycled water projects concluded that these projects can be implemented provided that all other regulatory requirements are met. It should be noted, that the SNMP includes management measures and a monitoring plan, and that the City will likely share the responsibility for implementing management measures and monitoring as part of future management and evaluation of groundwater quality in the Oxnard Plain and Pleasant Valley Basins.

3.4.2.2 Recycled Water Groundwater Recharge Projects

As listed in the Recycled Water Policy, approved GRPs must meet the following criteria:

- Compliance with regulations adopted by CDPH for groundwater recharge projects (CDPH, 2014).
- Implementation of a monitoring program for CECs and priority pollutants, consistent with recommendations from DDW.

Additionally, the Recycled Water Policy states that the “Regional Water Board” can implement “additional requirements for a proposed recharge project that has a substantial adverse effect on the fate and transport of a contaminant plume or changes the geochemistry of an aquifer thereby causing the dissolution of constituents, such as arsenic, from the geologic formation into groundwater.”

3.4.2.3 Anti-degradation

As stated in the Recycled Water Policy, “the proponent of a groundwater recharge project must demonstrate compliance with Resolution No. 68-16. Until such time as the City’s SNMP is completed, such compliance may be demonstrated as follows:

- A project that utilizes less than 10 percent of the available assimilative capacity in a basin/sub-basin (or multiple projects utilizing less than 20 percent of the available assimilative capacity in a basin/sub-basin) need only conduct an antidegradation analysis verifying the use of the assimilative capacity. For those basins/sub-basins where the Regional Water Boards have not determined the baseline assimilative capacity, the baseline assimilative capacity shall be calculated by the initial project proponent, with review and approval by the Regional Water Board, until such time as the salt/nutrient plan is approved by the Regional Water Board and is in effect. For compliance with this subparagraph, the available assimilative capacity shall be calculated by comparing the mineral water quality objective with the average concentration of the basin/sub-basin, either over the most recent five years of data available or using a data set approved by the Regional Water Board Executive Officer. In determining whether the available assimilative capacity will be exceeded by the project or projects, the Regional Water Board shall calculate the impacts of the project or projects over at least a ten-year time frame.
- In the event a project or multiple projects utilize more than the fraction of the assimilative capacity designated in subparagraph (1), then a Regional Water Board-deemed acceptable antidegradation analysis shall be performed to comply with Resolution No. 68-16. The project proponent shall provide sufficient information for the Regional Water Board to make this determination. An example of an approved method is the method used by the State Water Board in connection with Resolution No. 2004-0060 and the Regional Water Board in connection with Resolution No. R8-2004-0001. An integrated approach (using surface water, groundwater, recycled water, stormwater, pollution prevention, water conservation, etc.) to the implementation of Resolution No. 68-16 is encouraged.”

The regional groundwater quality is presented in Section 12 of this report. A review of anti-degradation and assimilative capacity is included in Section 14 of this report.

3.4.2.4 CEC Monitoring

The Recycled Water Policy addresses CECs and acknowledges that the state of knowledge on CECs is incomplete. CEC concentrations in finished water should be minimized through effective source control and treatment programs. The monitoring of specific CECs is required for groundwater recharge projects, and the CEC requirements for injection projects are reviewed in Section 9 of this Engineer’s Report.

3.5 Recycled Water Conveyance Pipeline

The advanced treated recycled water is pumped from the AWPF north in an existing recycled water backbone line and to the east to serve farmers. These lines are feeding recycled water to several non-potable applications. The line currently terminates near the River Park Development. Spurs from this line will be constructed to carry the recycled water to the West for the ASR application and to the North for future spreading operations.

3.6 Spreading Facilities

In addition to the proposed ASR application, the City has investigated potential potable reuse spreading applications at other locations within the City (Woolsey Pits, Ferro Pits). At this time, the City does not intend to pursue these alternatives.

3.7 Injection Facilities

The injection and monitoring facilities must meet the criteria of CDPH (2014), including section 60320.226. This section specifies:

- Prior to operating a Groundwater Replenishment Reuse Project (GRRP), a project sponsor shall site and construct at least two monitoring wells downgradient of the GRRP such that:
  - At least one monitoring well is located no less than two weeks but no more than six months of travel time from the GRRP, and at least 30 days upgradient of the nearest drinking water well.
  - At least one monitoring well is located between the GRRP and the nearest drinking water well.

For this project, sufficient monitoring wells are proposed that meet CDPH (2014), as detailed in Section 11.

4.0 SOURCE WATER FOR POTABLE REUSE

The production of purified water starts with an effective source control program and is followed by reliable primary and secondary treatment. Source water, and an enhanced source water control program, are detailed in the following report, which is intended as a stand-alone document, but also vital to this Engineering Report: *Indirect Potable Reuse Enhanced Source Water Control and Collection System Monitoring Program* (Carollo, 2016a); also attached here as Appendix A. Sections from that report are briefly summarized here.

The OWTP is permitted under Waste Discharge Requirements Order No. R4-2013-0094 (NPDES No. CA0054097), which was issued to the City in June 2013, and operates an EPA-approved industrial pretreatment program. That program is operating based upon an approved Local Limits program (from 1999). Oxnard is now updating that Local Limits program.

The regulatory requirements for wastewater source control are defined in Section 60320.206 of the regulations for groundwater recharge with recycled water (CDPH, 2014). For this project, the City must administer an industrial pretreatment and pollutant source control program that includes, at a minimum:

A. An assessment of the fate of Department-specified and RWQCB-specified chemicals and contaminants through the wastewater and recycled municipal wastewater treatment systems.

B. Chemical and contaminant source investigations and monitoring that focuses on Department-specified and RWQCB-specified chemicals and contaminants.

C. An outreach program to industrial, commercial, and residential communities within the portions of the sewage collection agency's service area that flows into the water reclamation plant subsequently supplying the GRRP, for the purpose of managing and minimizing the discharge of chemicals and contaminants at the source.

D. A current inventory of chemicals and contaminants identified pursuant to this section, including new chemicals and contaminants resulting from new sources or changes to existing sources, that may be discharged into the wastewater collection system.

E. Is compliant with the effluent limits established in the wastewater management agency's RWQCB permit.

The referenced report (*Indirect Potable Reuse Enhanced Source Water Control and Collection System Monitoring Program)*, included as Appendix A, is intended to address each of these items to the satisfaction of the Division of Drinking Water (DDW).

The Enhanced Source Control Monitoring Program (ESCMP) builds on the existing source control program already in place at the City of Oxnard; including:

- A source control program manager overseeing all data collection and regulatory issues relating to discharge from the first user to groundwater wells.
- More frequent sampling than required in the secondary effluent and AWPF finished water, including regulated, unregulated and industry-specific constituents.
- Use of historical and operationally collected online monitoring data required for operation to create baselines and predict trends in process performance.
- Heavily involved industrial outreach programs and residential outreach programs for potable reuse education and discharge initiatives.
- Mapping strategies for fast-acting collection system tracing of detected contaminants of health concern.

- Optional additions to discharge mapping, including hospitals.
- Ensure all SIUs report monthly and annual TTO monitoring results.
- Annual review of slug discharge control plans from SIUs.

5.0 PATHOGEN MICROORGANISM CONTROL

CDPH (2014) requires that potable reuse projects for groundwater recharge provide a combined level of treatment resulting in 12-log virus reduction, 10-log *Giardia* reduction, and 10-log *Cryptosporidium* reduction (12/10/10-log removal). No single process can receive more than 6-log reduction credit. CDPH (2014) also states that at least three processes must provide at least 1-log reduction. Beyond those three key processes, processes which provide <1-log reduction can be included within the analysis.

The step-by-step removal of pathogens, from raw wastewater to the production of potable water is reviewed below.

5.1 Primary and Secondary Treatment

Table 2-3 of USEPA (1986) lists less than 10 percent removal of total coliforms, 35 percent removal of fecal coliforms, and less than 10 percent removal of virus through primary treatment. Protozoa removal through primary treatment is not listed. The same Table (2-3) includes bacteria and virus removal percentages for secondary treatment (not including disinfection), indicating 90 to 99 percent removal of both total and fecal coliforms, and 76 to 99 percent removal of virus.

Francy *et al.* (2012) indicates 99 to 99.98 percent removal of bacteria and 88 to 99.9995 percent removal of various virus and coliphage. The single data set with any data below 90 percent removal, which was for adenovirus, showed removal ranging from 88 to 99.93 percent with a median removal of 99.8 percent.

One of the most recent DDW approval of pathogen removal credits for combined primary and secondary treatment, was obtained by the Water Replenishment District (WRD) (2013). That document relied upon risk analysis data presented in Olivieri *et al.* (2007) which was developed based upon Rose *et al.* (2004). Within Rose *et al.* (2004), the research team defined the range of bacteria, enterovirus, *Cryptosporidium*, and *Giardia* removal through six different full-scale wastewater treatment plants. The raw data from that work is reported in Olivieri *et al.* (2007). For WRD (2013), the pathogen removal credits for their secondary process were based upon the data from two of the six tested secondary process configurations. Specifically, two of the secondary process trains (Facilities C and D, with SRTs of 1.6-2.7 days and 3-5 days, respectively) had SRT values less than the secondary process feeding the WRD advanced treatment system (>9 days), and thus are presumed to be conservative estimates of performance. Per CDPH request, WRD (2013) used the lower 10th percentile values calculated for each pathogen, resulting in 2.06-log reduction of enterovirus, 1.42-log reduction of *Cryptosporidium*, and 2.42-log reduction of *Giardia.* Note that analysis of the same data set by Carollo Engineers found one data translation error, but the overall impact on the log reduction credits is minimal.

Interpretations of the data set (Rose *et al.,* 2004) suggest that longer SRT values result in increased pathogen removal. While this may be the case, the raw data from Rose *et al.* (2004) does not show this clearly (Table 4). For example, Facility F from that research with the longer SRT has reduced protozoa reduction than most of the other facilities, but also shows the best virus removal compared to the other facilities. The lowest virus removal occurs at Facility A, which has an SRT of 6 to 8 days, similar to the TIWRP. This data set is limited and making projections based upon SRT is speculative. Without site-specific data, our team recommends using the lower 10th percentile of the entire data set in Table 4, which results in 1.9-log reduction of virus, 1.2-log reduction of *Cryptosporidium*, and 0.8-log reduction of *Giardia*.

Table 4 Pathogen Reduction Values Through Primary and Secondary Treatment (from Rose *et al.*, 2004)
Advanced Water Purification Facility
City of Oxnard

Lower 10th Percentile Values		**Log Reduction**		
SRT	**Facility**	**Enterovirus**	***Giardia***	**Crypto**
1.6-2.7	C	1.8	2.6	1.25
3-5	D	2.05	1.35	1.4
3.5-6	B	1.95	2.45	1.6
6-8	A	1.65	0.8	0.7
8.7-13.3	E	1.75	2.6	1.9
8-16	F	2.6	0.9	0.25
1.6-16	**ALL**	**1.85**	**0.8**	**1.2**
7-8	***Projected for OWTP***	***1.9***	***0.8***	***1.2***
50th Percentile Values		**Log Reduction**		
SRT	**Facility**	**Enterovirus**	***Giardia***	**Crypto**
1.6-2.7	C	2.05	3.05	1.65
3-5	D	2.5	1.9	2.6
3.5-6	B	2.25	2.6	1.9
6-8	A	2.1	1.6	1.1
8.7-13.3	E	2.2	2.8	2.1
8-16	F	2.75	1.1	0.95
1.6-16	**ALL**	**2.3**	**2.6**	**1.6**
7-8	***Projected for OWTP***	***2.3***	***2.6***	***1.6***

As part of WateReuse Research Foundation Project 14-16, Oxnard has been researching the pathogen removal by the OWTP, in an effort to supplement, and potentially better understand, pathogen removal through the primary and secondary processes. The work, as of yet unpublished, examines a range of pathogens (*Giardia, Cryptosporidium*, norovirus, total culturable virus, *E. coli*), biological surrogates (enterococci, total coliform, male specific coliphage, somatic coliphage), chemical surrogates (UV Absorbance, TOC, DOC, BOD), and innovative monitoring (fluorescence). The laboratory work was done by Southern Nevada Water Authority (chemistry) and BioVir (biology). Spanning nearly 12 months, with sampling over 6 dates (four data sets are currently complete), the project team is developing an understanding of pathogen concentrations and removal (Figures 7, 8, and 9).

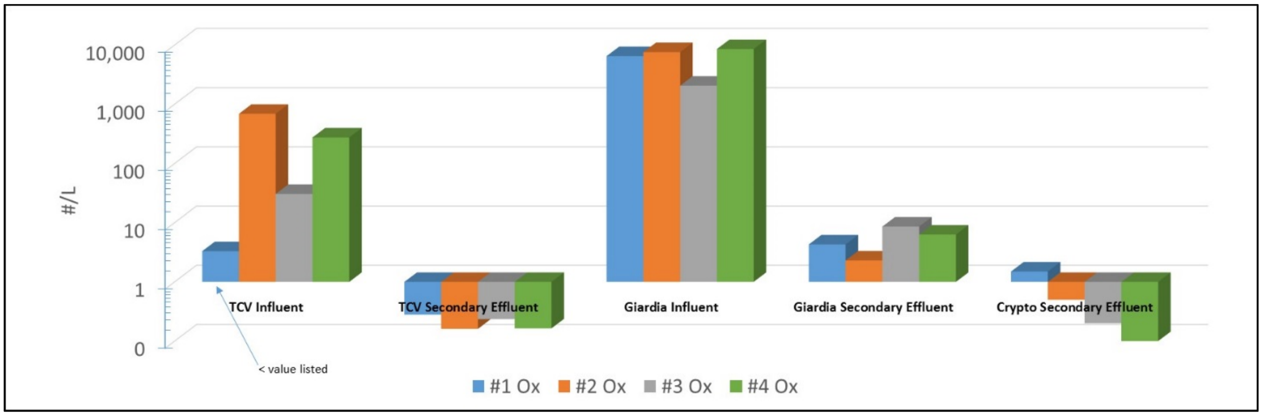

Figure 7 Total Culturable Virus, *Giardia*, and *Cryptosporidium* Concentrations in Raw Wastewater and Secondary Effluent for Oxnard

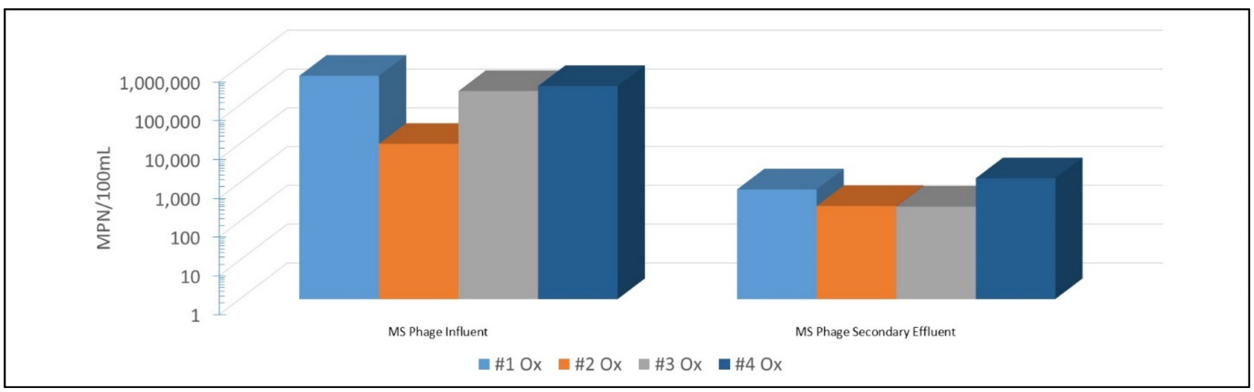

Figure 8 Male Specific Phage Concentrations in Raw Wastewater and Secondary Effluent for Oxnard

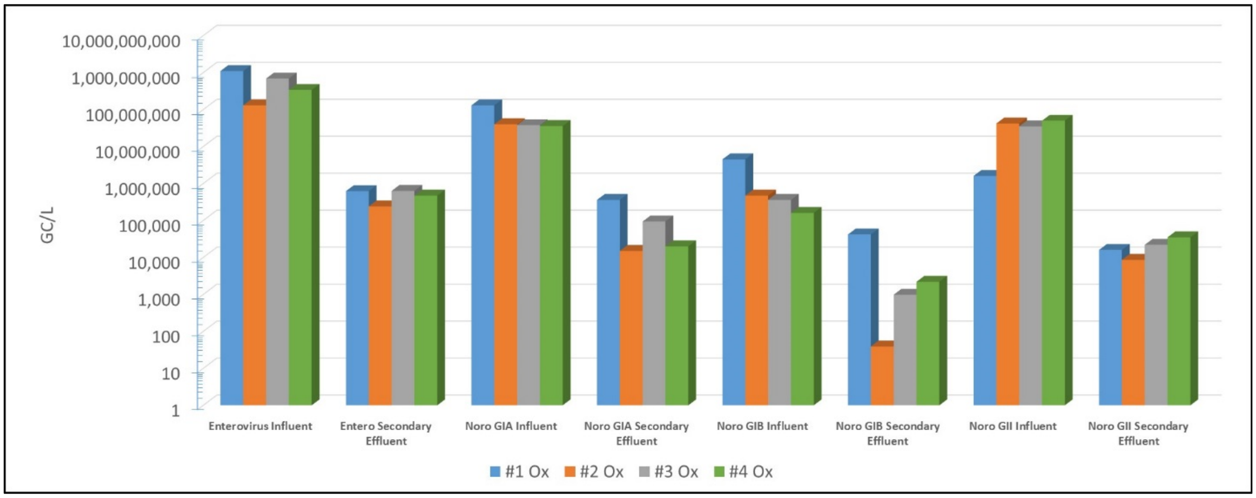

Figure 9 Enterovirus and Norovirus Concentrations in Raw Wastewater and Secondary Effluent for Oxnard

Analytical difficulty with *Cryptosporidium* enumeration inhibited calculation of log reduction for this organism. Log removal values (LRVs) for all other organisms were:

- Male Specific Phage - 1.6 to 2.98 LRV, with an average value of 2.47 LRV.
- Giardia - 2.38 to 3.52 LRV, with an average value of 3.05 LRV.
- Enterovirus - 2.7 to 3.2 LRV, with an average value of 2.97 LRV.
- Total Culturable Virus - 2.1 to 3.6 LRV, with an average value of 2.99 LRV.
- Norovirus Type GIA - 2.6 to 3.4 LRV, with an average value of 2.96 LRV.
- Norovirus Type GIB - 1.9 to 4.1 LRV, with an average value of 2.63 LRV.
- Norovirus Type GII - 2.0 to 3.7 LRV, with an average value of 3.01 LRV.

While raw wastewater and secondary effluent were sampled on the same day, the samples were not time-coupled, meaning that they do not necessarily represent the same drop of water and thus the average log reductions are likely more representative of performance compared to individual numbers. Using the lowest average for all virus removal and the average for Giardia removal, reasonable LRVs for protozoa and virus are 3-log and 2.5 log, respectively. **If we were to assume accuracy in the individual sample events and use the lowest measured reductions for protozoa and virus (not coliphage), we would result in 2.4-log and 1.9-log, respectively.** DDW, in a letter dated December 5, 2016, acknowledged the value of this new research to the industry, but raises important concerns regarding the lack of a surrogate to monitor log removal performance. As a result, DDW has stated that they will only approve the lower log removal values from Rose et al (2004); 1.9-log reduction of virus, 1.2-log reduction of *Cryptosporidium*, and 0.8-log reduction of *Giardia*.

The concentrations of the organisms in the secondary effluent also allow for an analysis of risk. Water treatment regulations for pathogens are predicated on reducing the risk of infection to minimal levels. For this project, the team has targeted the concentration end goals for pathogens that correspond to a modeled, annual risk of infection of 1 in 10,000 or less (Trussell *et al.*, 2013). DDW used this risk level to develop their pathogen criteria (CDPH, 2014a) and NWRI used this risk level to develop their pathogen criteria (NWRI, 2013). This risk level corresponds to the following potable water concentrations:

- *Giardia* - 6.80E-06 cysts/L.
- Cryptosporidium - 3.00E-05 oocysts/L.
- Enteric virus - 2.22E-07 MPN/L.

Giardia and *Cryptosporidium* results varied from 2.3 to 8.6 #/L and <0.1 to 1.5 #/L, respectively. Taking the highest count for each *Giardia* and *Cryptosporidium* results in a need for 6.1-log and 4.7-log of additional treatment following the secondary process to meet the risk-based levels above. Considering that subsequent MF treatment will provide 4-log protozoa removal, the subsequent RO will provide 1 to 2-log protozoa removal, and subsequent UV will provide 6-log protozoa removal, protozoa in the finished water does not represent a health concern.

For virus, there are many more data sets to evaluate. Total culturable virus concentrations in secondary effluent were 0.16 to 0.28 MPN/L. Taking the highest count results in a need for 6.1-log of additional treatment following the secondary process to meet the risk-based levels above. Considering that subsequent RO will provide 1 to 2-log virus removal and subsequent UV will provide 6-log virus removal, total culturable virus concentrations in the finished water does not represent a health concern.

Enterovirus, norovirus GIA, norovirus GIB, and norovirus GII had concentrations of 240,000 to 630,000, 15,000 to 360,000, 39 to 42,000, and 8,600 to 35,000 GC/L, respectively. ***An important difference*** between the total culturable virus test and the other tests is the use of a culture to measure viable organisms in the former, while the measurement of gene copies in the latter. Gene copy numbers do not necessarily correlate to viable pathogens and this is a current topic of research within our industry. A highly conservative approach would be to assume all gene copies to be viable pathogens. Following that approach and using the highest GC/L counts, an additional 11 to 12-log removal of virus would be needed through subsequent processes. Considering that subsequent RO will provide 1 to 2-log virus removal, subsequent UV will provide 6-log virus removal, and groundwater recharge can provide up to 6-log virus removal (depending upon travel/storage time), the finished water does not represent a health concern.

5.2 MF

Reardon *et al.* (2005) reported numerous studies showing bacteria rejection of 3 to 9 logs, protozoa rejection of 4 to 7 logs, and unreliable rejection of virus. The AWPF utilizes Pall Microza MF membranes, which are credited by CDPH for 4-log protozoa removal and 0.5-log virus removal (95 percent of the time), as documented by CDPH (2011). According to the Supplier's documentation, which cites USEPA (2003) and Sethi (2002) to calculate a maximum allowable pressure decay test (PDT) result that correlates to a specific protozoa log reduction.

Pall's approach is to use the maximum allowable TMP, the minimum feed water temperature, the maximum filtrate flow (27.2 gfd based upon the maximum flux in the Pall Operating Protocol and as measured in their 2011 Initial Performance Test), and a default VCF of 1.08. The result is that a PDT of 0.16 psi/min equates to a protozoa LRV of 4, which equates to a PDT of 0.80 psi/5min. Details on Pall's approach can be found in Appendix C.

Extensive SCADA data exists demonstrating compliance with this maximum PDT. As part of start-up demonstration testing of Oxnard's purification processes in April, May, and June of 2016, Carollo staff recorded a handful of PDTs and turbidity values, as shown below.

- **4/27/2016:** Rack 2 - 0.2, Rack 3 - 0.2, Rack 4 - 0.18, Rack 5 - 0.18, Rack 6 - 0.20
- **5/2/2016:** Rack 1 - 0.31, Rack 2 - 0.2, Rack 3 - 0.17
- **5/3/2016:** Rack 1 - 0.26, Rack 4 - 0.17, Rack 5 - 0.15, Rack 6 - 0.16
- **6/3/2016:** Rack 1 - 0.25, Rack 2 - 0.20, Rack 3 - 0.18, Rack 4 - 0.18, Rack 5 - 0.16, Rack 6 - 0.22
- **Influent Turbidity:** 3.48 to 5.09
- **Effluent Turbidity:** 0.04 to 0.10

During the May site visit and inspection, MF influent and effluent samples were also collected to analyze the particle size distribution (PSD). The analysis was done with Carollo's optical particle sizer/counter (PSS AccuSizer 780/SIS), with a sensitivity down to approximately 1 micron (Figure 10). The goal of the PSD testing was to set a baseline of performance for particle removal, focusing on the size range of protozoa (4 to 15 microns). The results demonstrate >3-log removal of particles in the 4 and 5 micron range, affirming the PDT performance shown above.

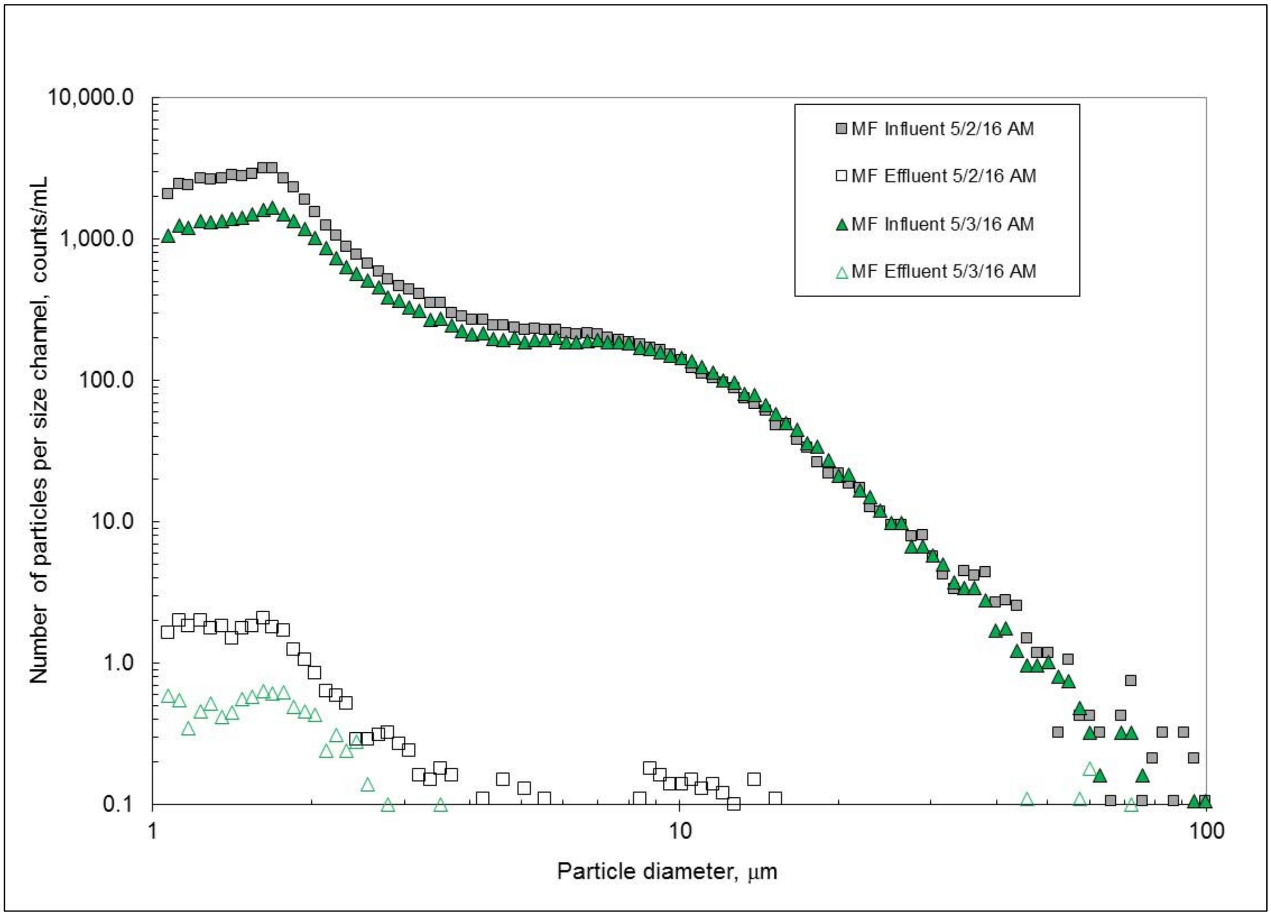

Figure 10 Particle Size Distribution for MF Influent and Effluent (5/2/16 and 5/3/16)

Online turbidity and PDT measurements for December 2014 through June 2016 are shown as Figures 11 and 12, respectively. The online results back demonstration results previously presented, showing the MF in normal operation at Oxnard is able to consistently achieve the PDT target. Online microfiltration filtrate turbidity measurements confirm a required effluent turbidity limit of <0.2 NTU is consistently met. Exceedances of 0.2 NTU in the MF filtrate were seen when 1) the online turbidimeter requires cleaning and calibration or 2) when the plant is cycling through a startup period and flow has not yet stabilized. Influent turbidity concentrations from secondary effluent, typically range between 1 - 6 NTU. Benchtop and online turbidimeter measurements during testing showed consistency when compared.

Overall, the City proposes to use 0-log virus reduction credit and 4-log protozoa reduction credit for this Pall membrane. No virus credit is sought because PDTs do not have sufficient resolution to measure virus removal performance.

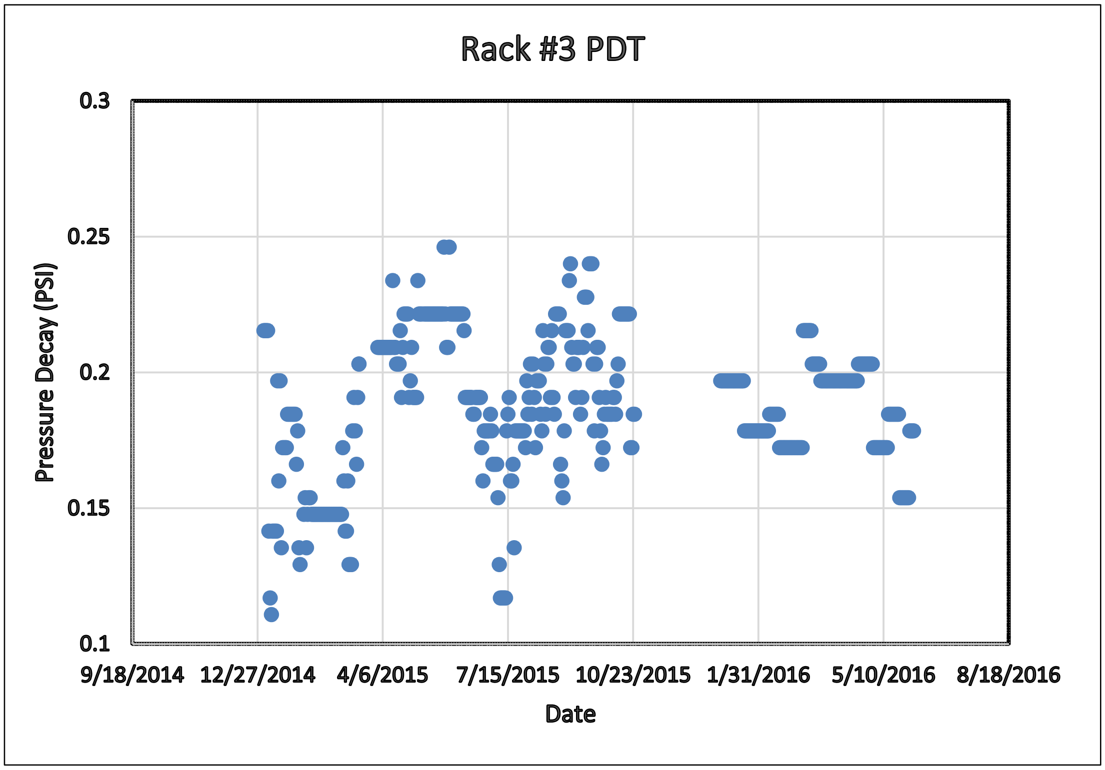

Figure 11 MF Online PDT Results for December 2014 through June 2016

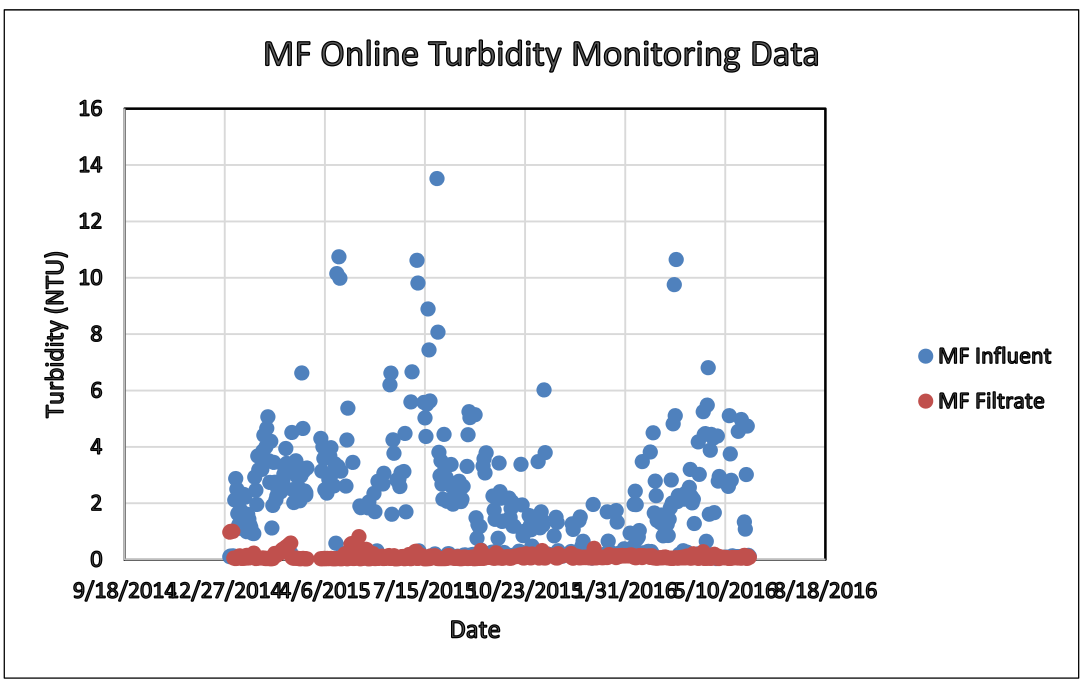

Figure 12 MF Influent and Filtrate Online Turbidity Data for December 2014 through June 2016

5.3 Reverse Osmosis

RO process performance for pathogen rejection is not governed by the ability of an intact membrane to reject pathogens but by the ability to monitor process integrity (Reardon *et al.* (2005) and Schäfer *et al.* (2005)). The monitoring tools currently used, electrical conductivity meters and total organic carbon (TOC) meters, can measure 99 percent or less removal of both parameters through the RO process. Recently, the CDPH granted 1.5-log reduction credit for all pathogens (i.e., virus, *Giardia*, and *Cryptosporidium*) for RO (WRD, 2013), based upon a requirement to continuously monitor TOC reduction across RO.

Currently, the City only measures EC across the RO membranes. During the Carollo performance demonstration testing and site audit, our team collected EC data.

- **5/2/2016:** Influent EC 2693 to 2787 µS/cm, Effluent EC 107 to 134 µS/cm.
- **EC LRV is 1.3 to 1.4.**

Monitoring and performance data showing online EC measurements of the RO system from March - May 2016 are displayed in Figure 13, with the average, minimum and maximum LRV results by train shown in Table 5 and Figure 14. The online data confirms The site inspection results from Carollo, showing an average of 1.47 LRV from a 3 month period, with a minimum LRV of ~1.29. These online results indicate consistent and reliable LRV of EC, that can be confidently correlated to pathogen removal credits.

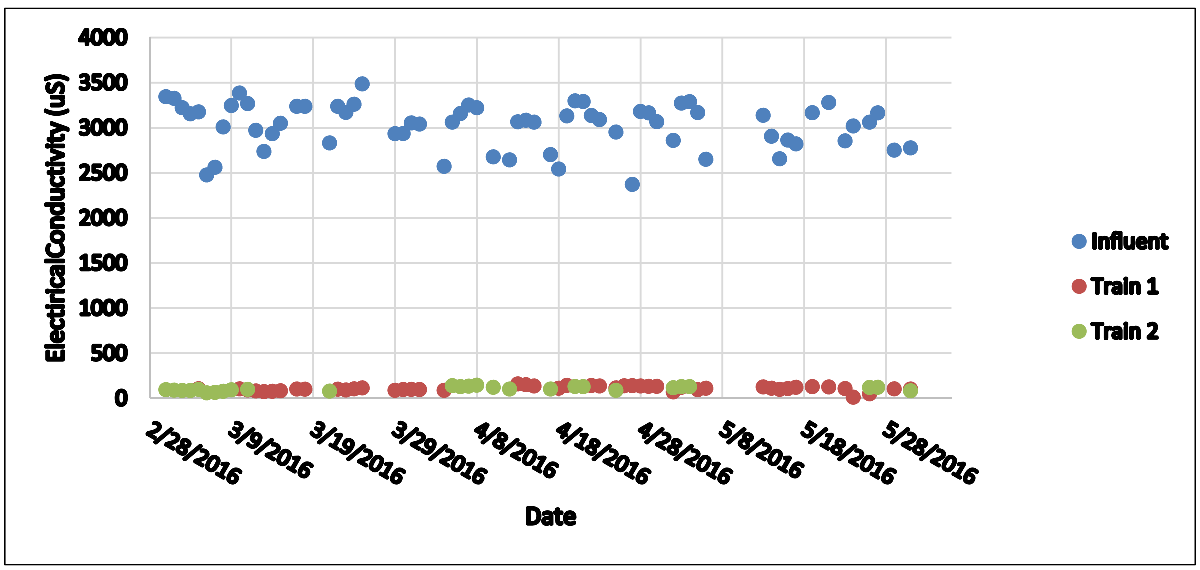

Figure 13 Influent and Effluent Historical (March 2016 - May 2016) Electrical Conductivity Online Data

Table 5	Average, Minimum and Maximum EC LRV through RO treatment March 2016 - May 2016 Advanced Water Purification Facility City of Oxnard		
	Train 1 LRV	**Train 2 LRV**	**Total Perm LRV**
Average	1.47	1.47	1.47
Min	1.23	1.34	1.29
Max	2.44	1.62	2.03

Figure 14 EC LRV Online Monitoring Data March 2016 - May 2016

The AWPF does not have online TOC meters, though intends to install them in the near future prior to operation. Grab samples were taken during the May Carollo inspection to document TOC removal across the RO process. TOC concentrations in the RO feed was 16 mg/L (on both 5/2 and 5/3), whereas RO permeate TOC concentrations were at the detection limit of 0.3 mg/L or below detection (again on 5/2 and 5/3). The LRV for this limited TOC data set is 1.7, suggesting that TOC reduction may be a more sensitive monitoring tool for RO performance and RO LRV credits.

In the April 2016 letter from DDW to the City, DDW stated that "online EC can show log reduction value (LRV) of approximately 0.5 to 1.0". The data collected here demonstrates a higher level of performance monitoring, with a minimum of 1.3 LRV. The City proposed to use the 1.3-log reduction value for all pathogens for RO at this time and use EC to monitor the performance of the system. DDW, in a letter dated December 5, 2016, approved a credit of 1-log based upon EC monitoring. *In the future, the AWPF intends to install TOC meters and potentially demonstrate higher LRV credits using this or other advanced monitoring (such as online fluorescence) resulting higher pathogen removal credit.*

5.4 UV Advanced Oxidation

The UV advanced oxidation process (AOP) provides three primary values:

- Disinfection.
- NDMA Destruction by Photolysis.
- Trace Chemical Destruction Through Advanced Oxidation (1,4-dioxane).

Following RO treatment, advanced oxidation is accomplished through the use of UV and hydrogen peroxide (H_2O_2), with an H_2O_2 dose of up to 6 mg/L. The UV system is the D72AL75, which has gone through extensive validation for non-potable water reuse applications and is the same reactor as the ones used at the OCWD for the Groundwater Replenishment System. For the AWPF, there are three D72AL75 reactors in series (stacked). The “D” in “D72AL75 means “dual”, as each reactor actually has two banks of lamps within it. This system is designed with redundancy, with five banks of lamps required for operation and the sixth bank of lamps for redundancy.

Note: The discussion here, which is in the disinfection section of this report, focuses upon all three components of performance, disinfection, NDMA destruction, and 1,4-dioxane destruction; as each of the three data sets are necessary to fully understand UV AOP performance and the recommended controls.

5.4.1 Current UV System Controls

Historically, UV AOP systems have been controlled to provide a target EEO, or electrical energy use per order of magnitude destruction of a target pollutant. UVI and a pure "dose" based control has yet to be implemented for the various installed UV AOP systems for potable water reuse in California (e.g., OCWD, WBMWD, WRD), but will soon be implemented for the City of Los Angeles' Terminal Island facility.

The target of the City's UV AOP control system is to provide sufficient power to achieve a required level of treatment (removal) of the target compound, NDMA. The control system calculates the target power for a UV system via the EE/O metric. EE/O as a function of flow rate and UVT is computed by the system, and adjusted for a Lamp Efficiency Factor (LEF), based on the target contaminant removal setpoint. The power modulation can be described as:

Power = a x f(flow, UVT, LEF*), where

a = Trojan-specific empirical factor, and

LEF = f(lamp age, temperature, power level efficiency)

The present power (summation of all power output by the system at any timepoint) is then compared to the target power (based on a LRV contaminant setpoint), to allow for power reduction in times of low flow or high UVT as the present power should be greater than the target power.

The current target NDMA LRV setpoint for Oxnard is 1.0. As part of startup testing, the Carollo/Oxnard team obtained SCADA data to document the performance of the existing control system to meet the 1.0 NDMA LRV metric. Actual system LRV outputs and UVT values are recorded by plant staff directly from the UV system monitoring screen every 4 hours. Data provided by plant staff from 9/27 and 9/28/16 show the system's response to changes in UVT in terms of LRV achieved (Figure 15). All LRV values were above the setpoint of 1.0, showing the system was meeting the target setpoint at all times during the two days analyzed.

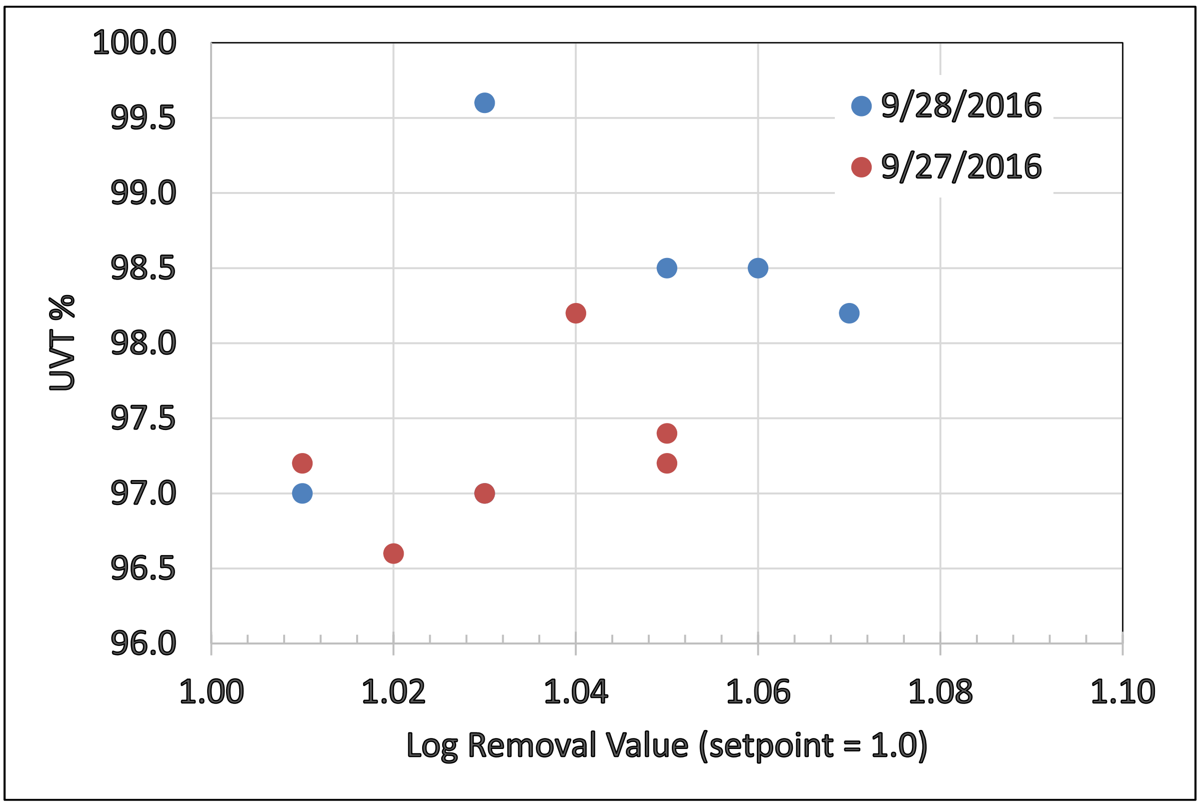

Figure 15 Percent UVT and corresponding Log Removal Values for 9/27 and 9/28/2016

The LRV-based control takes into account changes in flow rate and UVT. Additional data was collected showing the system's response to UVT and flow for the same 9/27 - 9/28/2016 dates, Figure 16. This result confirms the system's control philosophy is functioning as intended.

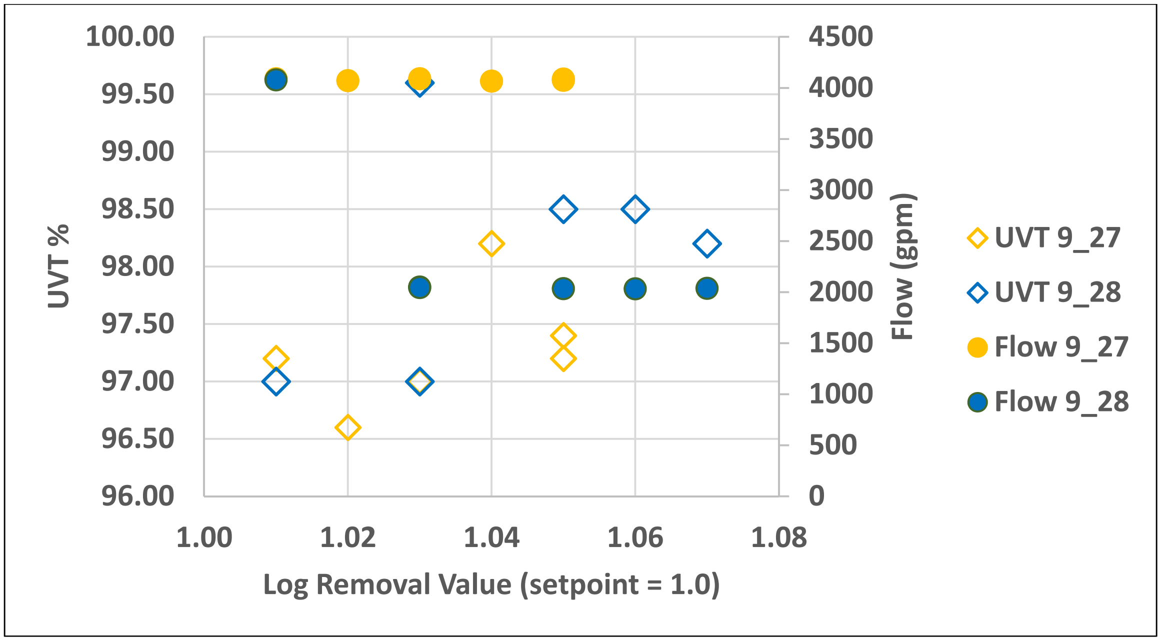

Figure 16 UV Log Removal Value as a Function of UVT and Flow

Power modulation is the final step in the UV AOP control strategy. The apparent power and target power across the UV system was analyzed for consistency across 9/27 and 9/28 operation (Figure 17). This consistency shows the UV system's ability to modulate the power to limit the energy input to the system to only what is necessary to meet the target power at any given time based on the UVT and flow.

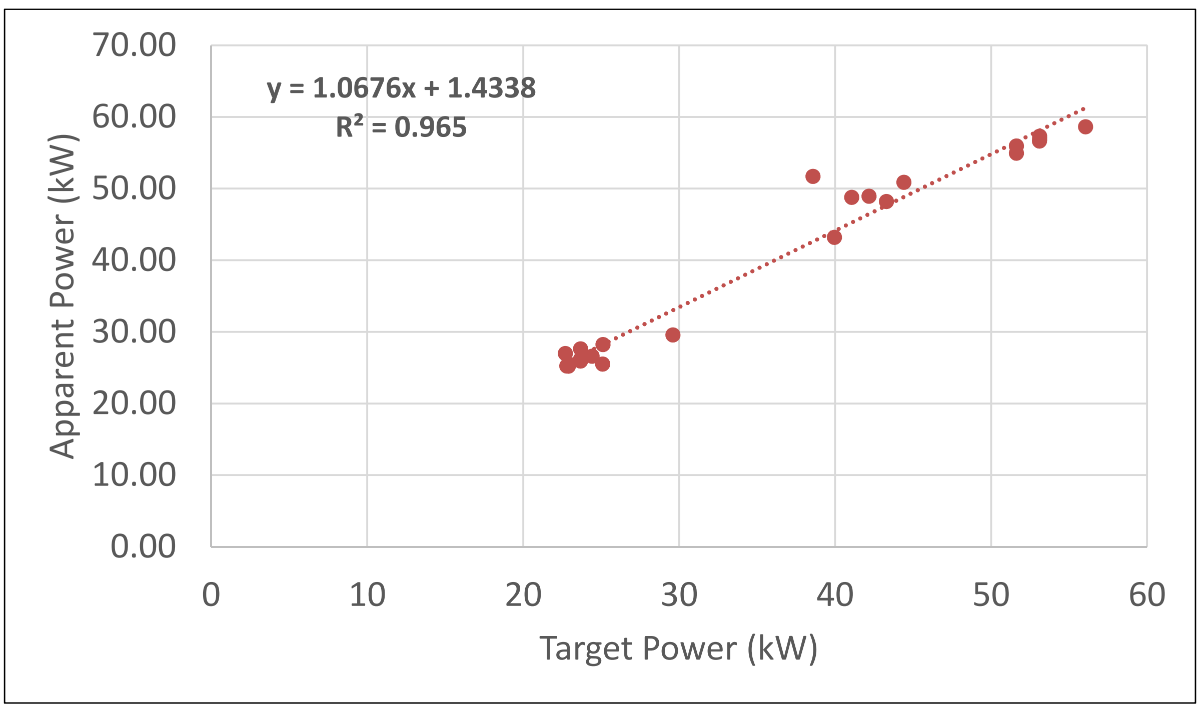

Figure 17 Apparent Power vs. Target Power (data collected 9/25 - 9/28/16)

The sections and analysis that follows evaluates the capacity of the installed UV AOP to destroy NDMA, pathogens, and 1,4-dioxane; then determine if the existing control system (as defined above) is sufficient or if it needs some level of adjustment.

5.4.2 UV Sensor Performance

Though UVI is not an active control within the UV system (at this time), the Carollo project team did a preliminary analysis of sensors for the installed 6-bank UV system. The orientation of the reactor sets the naming of the reactors and the corresponding UVI sensors, as shown in Figure 18 below; LWR LFT (lower left), MID RHT (middle right), and HGH LFT (high left) are three naming examples. Note that in the figure below, the terms "left" and "right" refer to the direction of flow (with flow going from left to right), not the visual location of the banks.

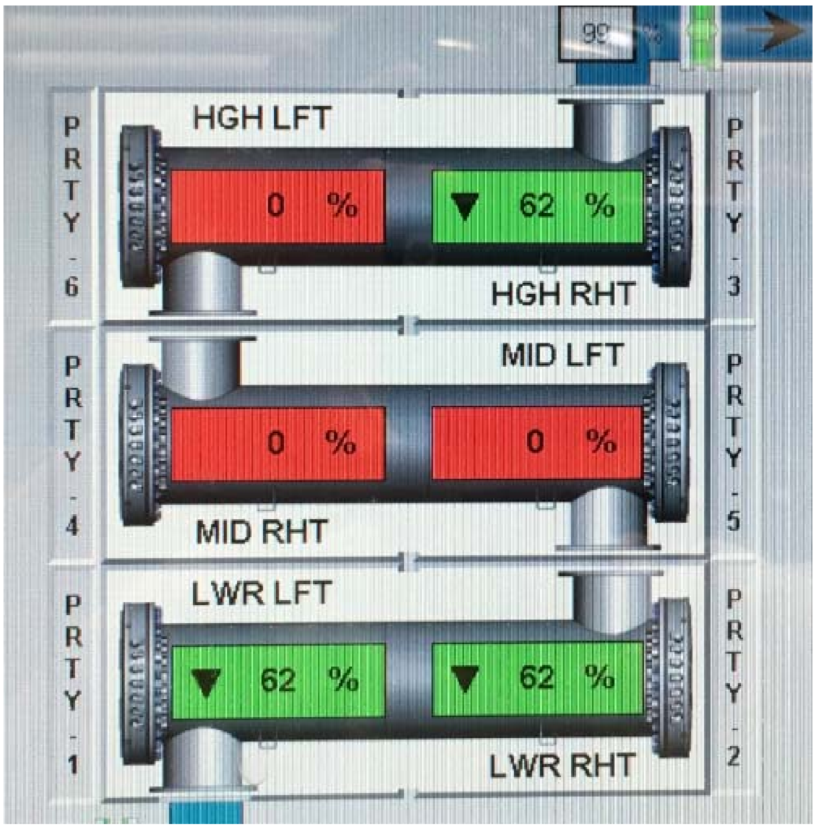

Figure 18 Screenshot of Trojan HMI at Oxnard

Through twenty-two different tests, different flow, different UVT, different # of reactors, and different reactor power settings were used. UVT transmittance readings were taken from an online meter, from a calibrated bench-top meter, and with laboratory grab sampling with subsequent analysis. Samples were taken before and after UV. For this analysis, only samples from the influent side of the UV were used, and only the results from the calibrated bench-top meter were used. The logic of this approach is based upon our team's confidence in the accuracy of the bench-top meter coupled with the future method of system monitoring, which is UVT on the influent to the UV system.

The sensor results are shown in Figure 19 below. Substantial sensor variability was shown. At a basic level, the sensors did track changes in UVT and power.

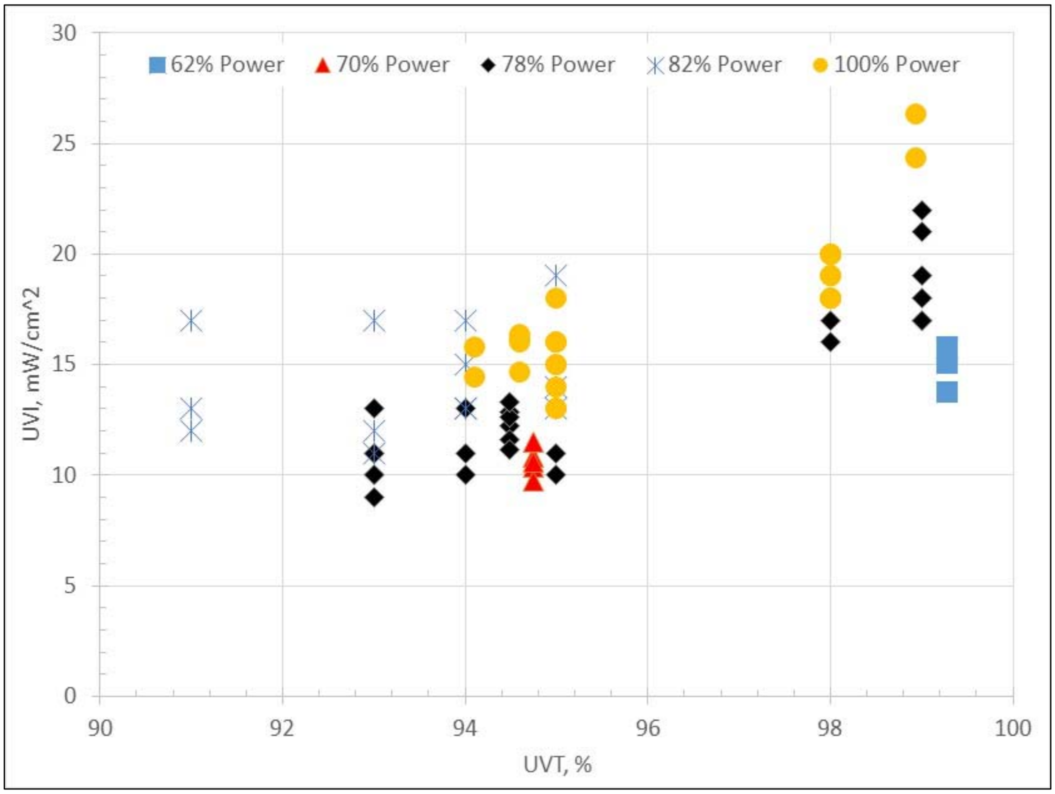

Figure 19 Sensor Values for Different UVT and Power Values

Using the sensor data points, a predictive formula was developed for the sensors. Sensor intensity is a function of UV absorbance (UVA) and ballast power (BP), as follows:

$$S = 10^{A} \times UVA^{B} \times BP^{C}$$

Where:

A = -1.27979

B = -0.25179

C = 1.02881

This formula results in an R^2 value of 0.92, which indicates a good measure of data variability. The prediction residuals are shown in Figure 20, demonstrating the accuracy of the predictive formula to be plus or minus 20 percent.

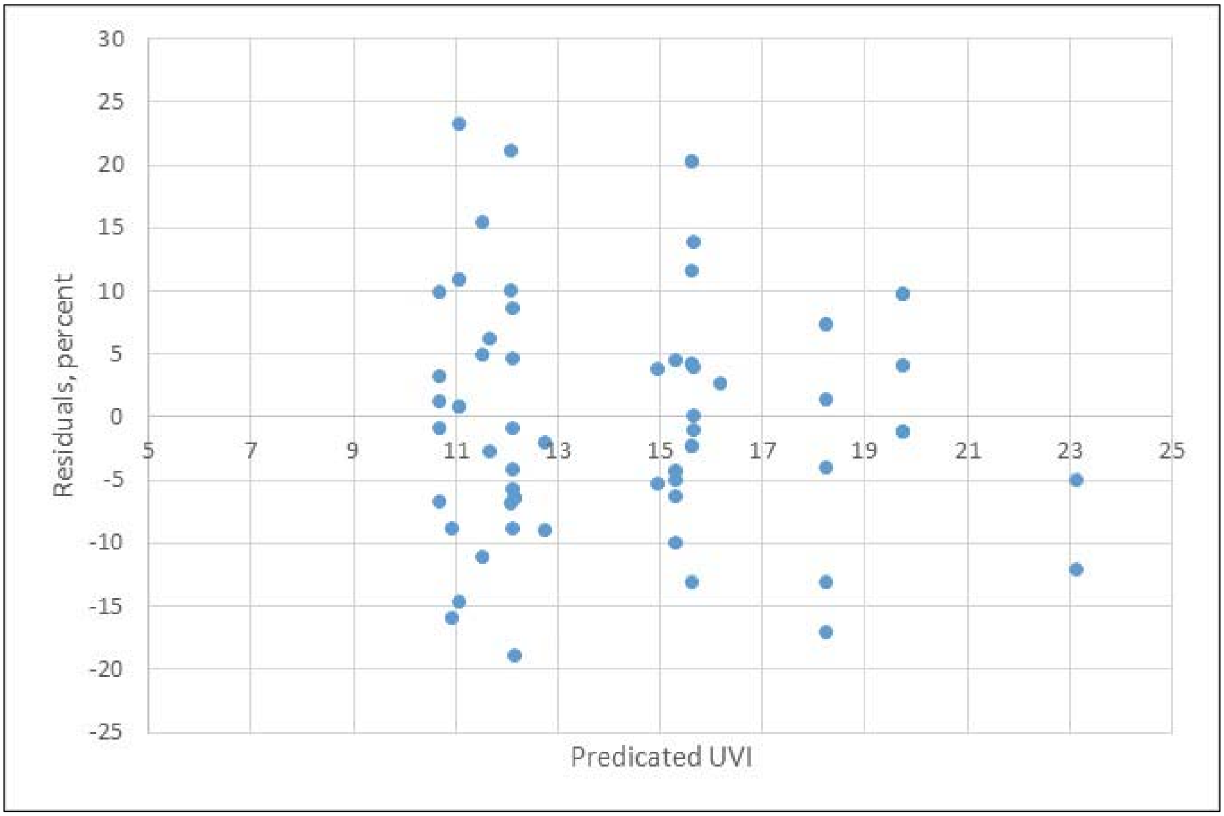

Figure 20 Sensor Residuals

5.4.3 **Disinfection Performance**

The D72AL75 validation is documented in Carollo (2009). That work documented reactor performance over a range of flow (1.05 to 7.3 mgd) and over a range of UV transmittance (UVT) (41.4 to 80.8 percent), with the data analyzed in accordance with National Water Research Institute Ultraviolet Disinfection Guidelines for Drinking Water and Water Reuse (NWRI, 2003) but not NWRI (2012). The validation of the D72AL75 is based upon the dose delivery per reactor, recognizing that there are two 72 lamp banks within each reactor. Note that the Oxnard UV AOP system is controlled based upon the use of each bank, so three reactors results in a total of 6 banks of UV light. For this application at the AWPF, the flow per reactor is 6.25 mgd (as all three reactors are in series). As the UVT in ROP is greater than 95 percent, the validation formula from Carollo (2009) is conservative. Using the maximum validated UVT of 80.8 percent the dose of five banks of lamps from the three D72AL75 reactors (leaving one bank in standby) is >250 mJ/cm^2.

As this is a potable reuse application, disinfection credit for UV should be based upon adenovirus disinfection. Adenoviruses comprise a large group of serologically different viruses that can cause a broad spectrum of diseases with varying severity (USEPA, 2010). Research on the dose-response relationship of Adenoviruses, using Low Pressure (LP) UV radiation on a bench-scale collimated beam setup, is mainly limited to Adenovirus types 2, 40, and 41. The dose response relationship at high UV doses (>200 mJ/cm^2) is more widely published for Adenovirus type 2 (Ad2), and shows that 6-log reduction of Ad2 may be obtained at a dose of 235 mJ/cm^2 (Gerba *et al.*, 2002). The dose response relationship of Ad2 as well as other viruses is shown in Figure 21, demonstrating that Ad2 is a conservative surrogate for a wider range of virus.

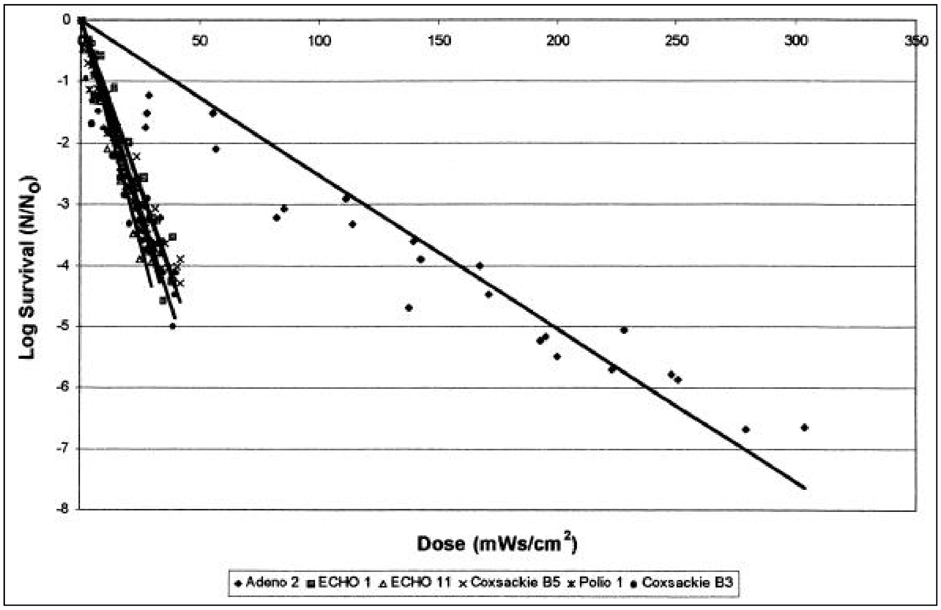

Figure 21 LP UV Dose Response Relationship of Ad2

USEPA (2010) published a dose-response equation for Ad2 of:

$$\text{Log Reduction} = 0.0262 \times \text{UV Dose} + 0.2774$$

This dose response relationship is based on a dose range between 20 and 160 mJ/cm^2 (USEPA, 2010). Other studies have shown similar dose responses, consistently indicating that a 6-log reduction of Ad2 is met with a LP UV dose of up to 235 mJ/cm^2.

Pertaining directly to Oxnard and their Trojan D72AL75, the following can be said:

- The system, with five banks in series, results in a predicted UV dose of >250 mJ/cm^2 at a UVT of 80.8 percent. For a UVT of 95 percent or higher, as is the case for potable reuse projects using RO permeate, the UV dose will be substantially higher.
- 6-log adenovirus can be obtained based upon a UV dose of 235 mJ/cm^2. Because MS2 is more sensitive to UV light than adenovirus, using an MS2-based validation conservatively estimates dose for adenovirus. The underlying concept for this conclusion is found in the discussion of RED bias in USEPA (2006).
- USEPA (2006) (Table 6 below) provides data on the dose required for up to 4-log reduction, but did not go further as such higher reductions are not required for drinking water disinfection applications.

- In total, the UV system, operating at a UV dose in excess of 250 mJ/cm^2, installed at the AWPF is sufficient to provide 6-log reduction of both virus and protozoa.

Table 6 UV Dose Targets for Log Inactivation Credit, mJ/cm^2 (USEPA, 2006)
Advanced Water Purification Facility
City of Oxnard

Target	0.5-log	1.0-log	1.5-log	2.0-log	2.5-log	3.0-log	3.5-log	4.0-log
Crypto	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3	5.2	7.7	11	15	22
Adenovirus	39	58	79	100	121	143	163	186

5.4.4 NDMA Destruction Performance and Correlation to Disinfection Performance

While this section of the report is focused on disinfection credits, the destruction of NDMA provides a clear documentation of high UV dose delivery, and thus a high level of disinfection.

NDMA destruction is required to reduce RO permeate NDMA concentrations to below the DDW notification level of 10 ng/L (ppt). NDMA destruction has a proven correlation with UV dose, as shown in Figure 22, below. Using the information below, 1-log reduction of NDMA correlates to a UV dose in the range of ~700 to ~1100 mJ/cm^2. Such a wide variation does require further refinement by the industry. However, remembering that our disinfection target dose is 235 mJ/cm^2, there is a margin of comfort that dose sufficient to meet NDMA targets will also be sufficient to provide disinfection. Using the NDMA destruction dose/response from Sharpless and Linden (2003), the results of 22 NDMA destruction test runs at Oxnard can be evaluated for dose delivery and accuracy of system control, as shown in Figures 23 and 24, below.

Note: The NDMA data was collected over four different days, and the influent concentrations to the UV AOP system was consistent on each specific day, but varied from one day to the next. Thus, the NDMA destruction analysis utilized the average of influent NDMA concentrations for each day. Daily influent numbers are shown below:

- 5/4/2016 - 32, 23, 29, 25, 23, 28.
- 6/20/2016 - 28, 32.
- 6/21/2016 - 24, 22, 19, 23, 20.
- 6/22/2016 - 11, 12, 13, 12.

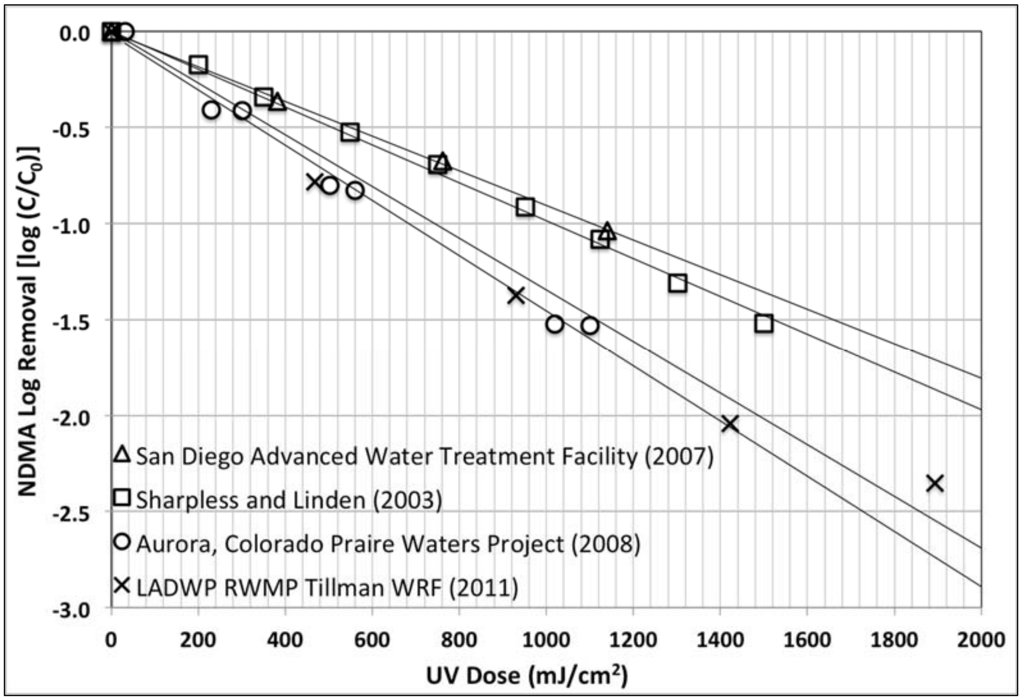

Figure 22 Collimated Beam Bench Testing Results for NDMA Collected in different Studies (Sources of Data: City of San Diego, 2007; Sharpless and Linden, 2003; Swaim et al., 2008; Hokanson et al., 2011). The Colorado Prairie Waters Project in Aurora, Colorado is the only reference study that used hydrogen peroxide (5 mg/L). The results shown for the other three studies used UV photolysis (graphic credit: Trussell Technologies).

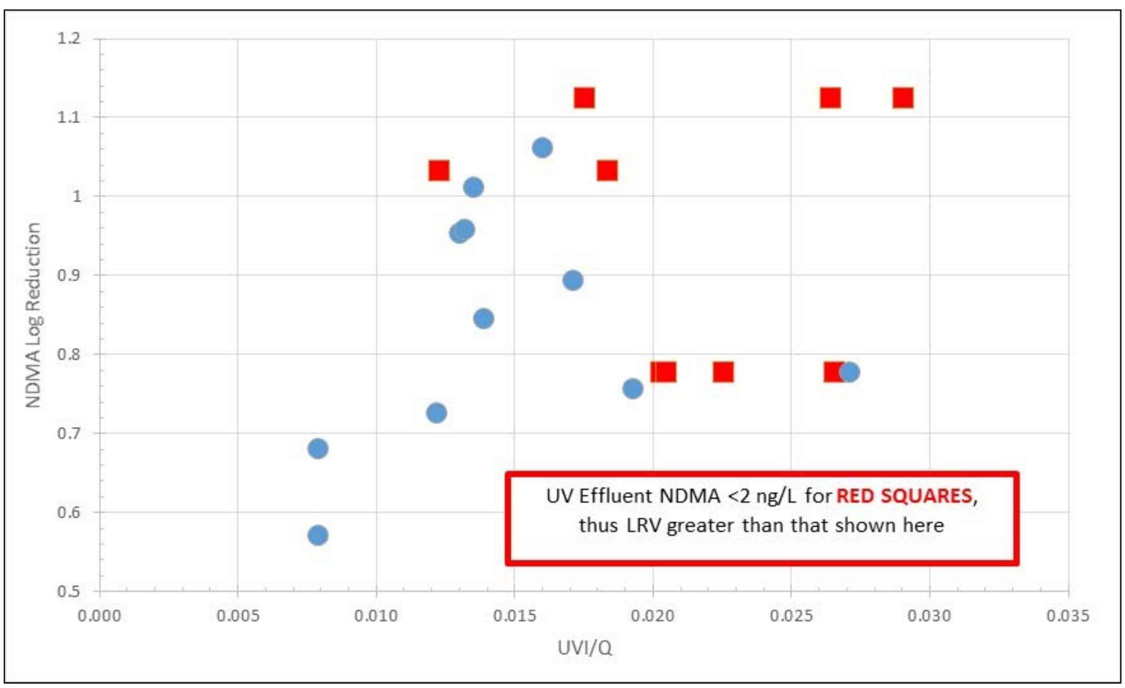

Figure 23 NDMA Destruction as a Function of UVI/Q

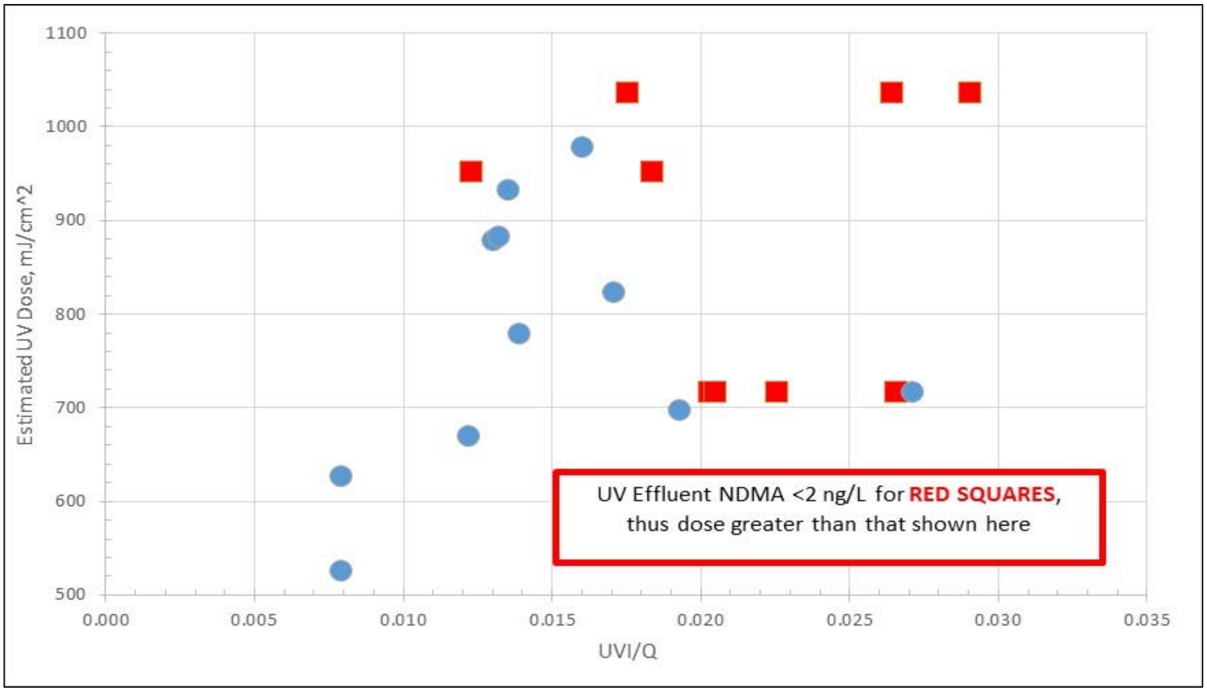

Figure 24 UV Dose as a Function of UVI/Q

The data in the figure above cannot be trended because a large number of the test events had NDMA below detection (<2 ng/L) in the UV effluent. However, this information can be used as a set-point control or alarm system for both disinfection and NDMA destruction based upon the following approach:

- NDMA concentrations in the RO permeate, through limited testing, have been in the range of 11 to 32 ng/L. Using the highest measured influent concentration (32 ng/L), and targeting the NDMA notification level of 10 ng/L, a minimum NDMA destruction of 0.5 could be required.
  - Assuming that NDMA levels in the RO permeate will vary from the measured numbers, and understanding that some level of operational safety factor is warranted to meet the 10 ng/L target, a finished water NDMA target of 5 ng/L is recommended, resulting in a need for an NDMA reduction target of 0.8-log.
  - 0.8-log NDMA destruction, based upon the collected data, can be obtained at a UVI/Q of 0.014 (with UVI being the sum of all UVI for operational reactors and Q being the total flow to the system in gpm).
- Regarding UV dose, the UVI/Q of 0.014 correlates to a UV dose of >800 mJ/cm^2, well in excess of the dose needed for 6-log reduction of all known pathogens.

An important question thus exists on the capacity of the UV system under reduced UVT conditions, as detailed in Table 7 below, which predicts the UVI based upon the sensor equation and data detailed previously. As shown, even at a much reduced UVT of

95 percent, the UV system is projected to attain a UVI/Q of 0.018, which is greater than the minimum desired value of 0.014.

Table 7 UV Capacity to Meet NDMA Target of 5 ng/L
Advanced Water Purification Facility
City of Oxnard

UVT	Q, mgd (gpm)	UVI for One Bank, mW/cm^2	# Banks in Operation at 100% Power	Combined UVI, mW/cm^2	UVI/Q
Ambient (~99%)	6.25 (4,340)	23.6	5	118	0.027
Reduced (95%)	6.25 (4,340)	15.6	5	78	0.018

5.4.5 1,4-Dioxane Destruction Performance

The UV AOP system, per CDPH (2014) must demonstrate 0.5-log reduction of 1,4-dioxane, or demonstrate destruction of a wider range of trace pollutants. Similar to ongoing and recently completed work for the City of LA (LA Sanitation, LASAN) and the Santa Clara Valley Water District (SCVWD), Seeding and destruction of 1,4-dioxane is the most precise method for such performance demonstration. Testing was completed over a range of H_2O_2 (hydrogen peroxide, peroxide) doses to demonstration 0.5-log reduction of 1,4-dioxane. Values for UVT, UV intensity, and UV reactor power were recorded. Testing was performed in triplicate, with all seeding and sampling done over a two-day period, with results shown in Figures 25 and 26.

Recognizing that analytical and sampling variability may account for some data variability, the analysis of the data using the Peroxide Weighted Dose concept, then back-calculating the minimum UVI/Q, may be more appropriate. Figure 26 indicates that a minimum UVI/Q should be in the range of 0.072 to 0.088; resulting in a tapered peroxide dose based upon the target UVI/Q. Assuming the more conservative peroxide weighted dose of 0.088, the following target UVI/Q values are recommended:

- Peroxide dose of 3 mg/L - *Minimum* UVI/Q = 0.029;
- Peroxide dose of 4 mg/L - *Minimum* UVI/Q = 0.022;
- Peroxide dose of 5 mg/L - *Minimum* UVI/Q = 0.018.

Understanding that the installed system has a set UV system capacity, the recommended approach is to utilize a peroxide dose of 6 mg/L and maintain a minimum UVI/Q of 0.018 to meet the required 0.5-log reduction of 1,5-dioxane.

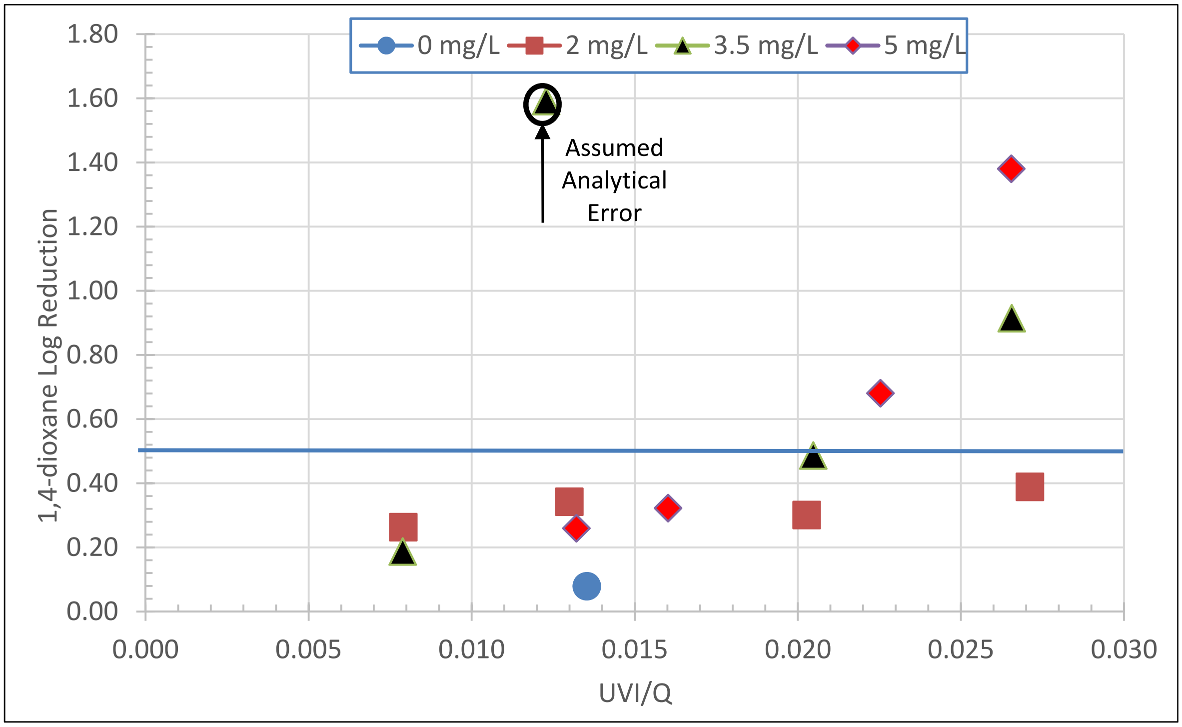

Figure 25 1,4-dioxane Destruction as a Function of UVI/Q and peroxide dose

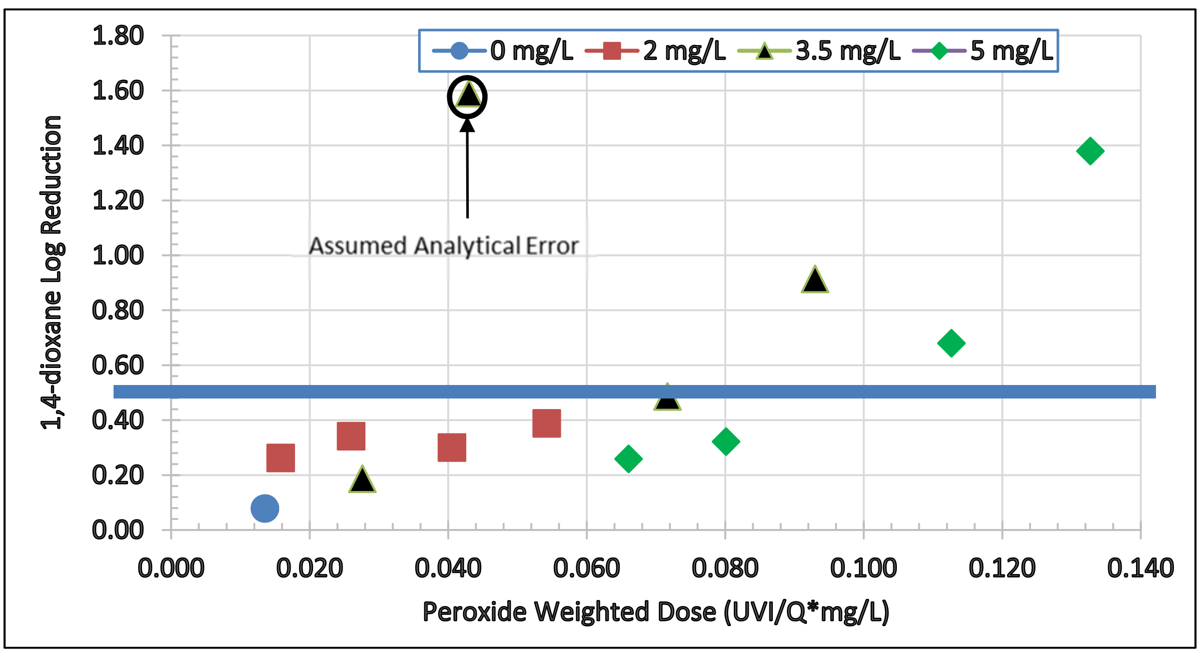

Figure 26 1,4-dioxane Destruction as a Function of Peroxide Weighted Dose

Based upon Figure 25, for a peroxide dose of 3.5 mg/L, the minimum UVI/Q should be 0.021; whereas for a peroxide dose of 5 mg/L the minimum UVI/Q should be 0.020. Recommendations on UV AOP Control Based Upon Disinfection, NDMA, and 1,4-Dioxane Performance Targets

The recommended UVI/Q to reliably below the 10 ng/L NDMA notification level is 0.014. This correlates to a minimum NDMA log reduction of 0.8, which also correlates to a UV dose well in excess of 235 mJ/cm² (the minimum UV dose for 6-log adenovirus disinfection). The use of 6 mg/L peroxide allows for the use of a minimum UVI/Q of 0.018 for 1,4-dioxane destruction. As shown in Table 7 (above), at a UVT of 95 percent, with 5 of 6 reactors in service, the installed system is projected to be able to attain the target 0.018 UVI/Q value; while still allowing for maintaining one UV reactor as redundant. **Thus, the key conclusion is that the installed system has sufficient capacity to meet disinfection, NDMA destruction, and 1,4-dioxane destruction at peak flow (6.25 mgd) and at a reduced UVT (95%).**

The remaining focus is the determination of what NDMA LRV setpoint is necessary to maintain the target UVI/Q of 0.018. As part of startup testing, the project team collected the necessary data to compare UVI/Q with the NDMA LRV setpoint, as shown in Figure 27. With one exception, the existing control system maintained a UVI/Q at or above ~0.013, which is noticeably below the recommended target of 0.018. **Accordingly, our recommendation is to adjust the NDMA LRV setpoint from 1.0 to 1.0*0.018/0.013, which results in a NDMA LRV setpoint of 1.4.**

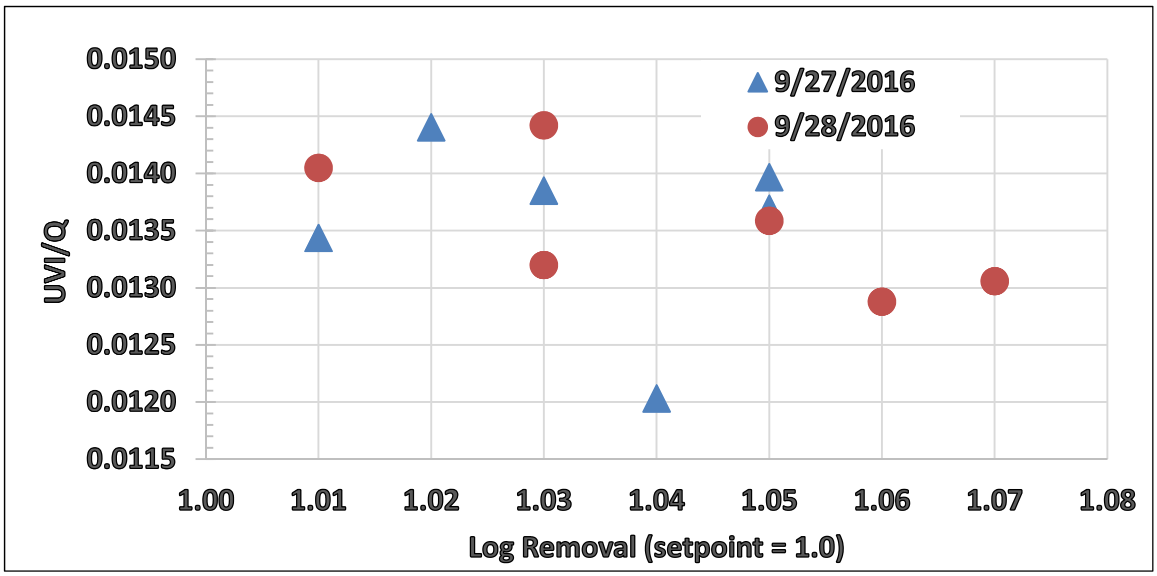

Figure 27 UVI/Q and NDMA LRV Control System Comparison

As a final point of comparison, DDW has become accustomed to the EEO concept for system control and permitting. Figure 28, below, plots the calculated EEO as a function of UVI/Q, presented here for information only. This data suggests that an EEO target would be in excess of 0.230 for Oxnard's particular application.

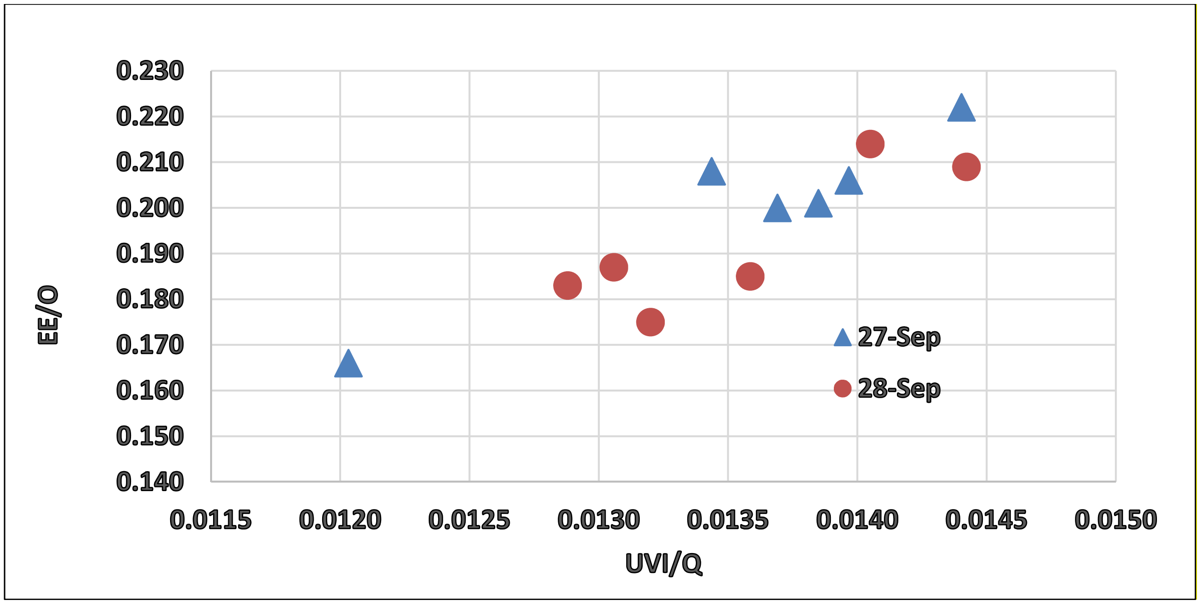

Figure 28 UVI/Q and EEO Comparisons

5.5 Subsurface Pathogen Removal Credit

Per CDPH (2014), utilities employing groundwater injection are granted 1-log virus removal credit per month of subsurface travel time, but are currently not granted credit for protozoa removal. Recent work by the WateReuse Research Foundation (led by Jorg Drewes) has documented the subsurface die-off rate of *Cryptosporidium* at 0.025 to 0.072-log reduction per day, with a mean of 0.039-log reduction per day (Drewes *et al.*, 2014). For 6-months of underground storage, the work by Drewes suggests 7-logs of die-off. Peng *et al.* (2008) reported 85 to 268 days of time to result in 1-log die-off of *Cryptosporidium* in sterile water at 4 degrees C. For 6-months of underground storage, the work by Peng suggests 0.7 to 2.1-log die-off. Per the April 2016 letter from DDW to the City, the DDW is not ready to allow protozoa removal credits based upon the referenced literature.

For the proposed groundwater recharge projects (Phase 1 – ASR and Phase 2 – conventional injection and Downgradient extraction) the water will be in the subsurface for a minimum subsurface retention time of 2 months, though longer periods may be required to attain the full 12-log virus credit requirement. Based upon current virus credits documented in Table 8, below, the minimum subsurface time is 3.1 months.

5.6 Findings for Disinfection Credit

When taken together, the treatment processes discussed in Section 5.1 have the ability to meet (and exceed) the 12/10/10 pathogen log reduction requirements specified in the groundwater recharge regulations, as shown in Table 8. The total pathogen log reduction credits are 12.0/11.8/12.2 for a groundwater recharge project with 3.1 months of subsurface storage time.

Table 8 Total Pathogen Log Reduction Credits Advanced Water Purification Facility City of Oxnard			
Process	**Virus**	***Giardia***	***Crypto***
Primary/Secondary Treatment	1.9	0.8	1.2
MF	0.0	4.0	4.0
RO	1.0	1.0	1.0
UV Advanced Oxidation	6	6	6
Groundwater Retention Time	3.1	0.0	0.0
Totals	***12.0***	***11.8***	***12.2***
DDW Requirements	***12***	***10***	***10***

6.0 GROUNDWATER RECHARGE OPERATIONAL STRATEGY

As mentioned previously, the City proposes one groundwater recharge operation at this time. This operation is proposed with 100 percent recycled water (i.e., no blending with diluent water). The City plans to inject the purified water into specific wells at the Campus Park location into aquifer zones within the Lower Aquifer System (LAS), keep the water underground for a minimum of 3.1 months (or the required response retention time [RRT]), then extract the water from the same ASR well for potable and non-potable use. In the future, should the City implement more advanced monitoring for the RO system and gain greater credits, the minimum time of 3.1 months may be reduced to 2 months.

This summary is based upon Hopkins (2016) study, which is included as Appendix B – Hydrogeological Study Report. The Hopkins report is provided to comply with regulations pursuant to section 60320.200(h), with a short summary provided here.

The City's long-term plan is to inject up to 6.5 mgd (4,500 gpm) of recycled water into several wells at the Campus Park location. The first ASR well location is proposed to ultimately include two adjacent wells (3 if necessary), each with an injection capacity of up to 2,000 gpm (totaling 4,000 gpm for this first application). This first pair of wells will inject purified water into a discrete aquifer zone(s) in the LAS and subsequently facilitate groundwater extraction after the required RRT is achieved and regulatory approval is granted.

The Campus Park location is ideal, as the ASR wells and monitoring wells can all be placed on City property, thus firmly controlling the use of groundwater in this area. Further, the proposed injection is into the LAS, whereas nearby potable wells are all in the Upper Aquifer System (UAS), and thus hydraulically isolated from the LAS. The closest well to the proposed ASR location that is constructed within the LAS is located nearly 1 mile to the east and is owned and operated by the City.

For the fully expanded ASR project, the Campus Park location would host several pairs of ASR wells, with each pair recharging discrete aquifers. A pair of wells is anticipated to be necessary to fully utilize the operational capacity of each aquifer zone available for replenishment and reuse at the Campus Park site. This concept is described in detail by Hopkins (2016).

The construction of ASR well facilities in discrete aquifer zones uses the isolation of natural clay layers to allow simultaneous operation of replenishment, retention, and reuse without mutual interference. Wells located in Aquifer 1 are by design isolated from wells located in Aquifer 2 and 3. Utilization of the confined aquifer system in this manner will allow optimization of a continual ASR operation and full utilization of the wellfield location. Utilization of discrete aquifer zones also serves to preservation of the replenished water quality and minimizes mixing with native groundwater. This type of operation will require validation that the minimum time requirement is in compliance prior to the distribution of recycled water.

The ASR operation, upon full execution, will involve recharge of some wells concurrent with extraction of water from other wells. This process is intended to be flexible to allow the City to maximize recharge of the groundwater. One potential example of operation is as follows:

- Recharge ASR Well No. 1 in confined Aquifer 1 at flows up to 2,000 gpm. The period of recharge time must be sufficient so that recharged water does not migrate to off-site potable water wells. The duration of injection may range from 3.1 months to 6 months or greater.
- After the allocated time, stop recharge of ASR Well No. 1. Hold water in Aquifer 1 for a minimum of 3.1 months or the required RRT starting from the time the last drop of water entered the ASR well.
- Extract Water from ASR Well 1 at a rate of up to 3,000 gpm.
- Repeat the three steps described above in rotation for all operational ASR wells to allow a continual IPR operation.

Though this operation is fully intended as an ASR operation, in the event that some recharged water is not extracted and migrates toward drinking water wells, the time to the nearest downstream potable water supply well must be determined and documented to be more than 3.1 months of time for this project, though regulations allow for as little as 2 months of travel time as long as all pathogen reduction criteria are met.

Utilizing a conservative estimation of soil porosity (15 percent), an average hydraulic conductivity value of (125 feet /day), and the range of groundwater gradients calculated from available data, Hopkins (2016) used the average linear flow velocity equation to predict the subsurface travel time caused by the seasonal gradients in the aquifer system.

During normal to wet years, the groundwater gradient is toward the southwest away from the Oxnard Forebay, the primary area of aquifer recharge (Hopkins, 2016). During dry years, the groundwater gradient is predominantly westward toward the area of greatest agricultural use (Hopkins, 2016). During a drought with repeated dry years where the groundwater levels in the aquifer system fall below sea level, the groundwater gradient migrates to the north toward inland pumping and away from the ocean where offshore storage is located in the aquifer system. The movement of groundwater caused by the regional gradient is slow and results in very little movement of the injected purified water plume, with an estimated travel time of between 0.17 and 0.92 feet per day.

The injection of purified water at 2,000 gpm results in a purified plume at a ~1,000 foot radius and ~1,500 foot radius after 3 months and 6 months of continuous injection, respectively (Hopkins, 2016). Using the 0.17 to 0.92 ft/day travel time, the purified water will move 30 to 165 feet in the direction of groundwater flow (to the Southwest or to the North) over a period of six months (during 3 months of injection and 3 months of retention). DDW regulations (CDPH, 2014) require a safety factor of 4 times the distance for groundwater calculations using Darcy's law methods (0.25 log credit for virus and 0.25-month response time credit per month of transport using Darcy's law methods). This results in a projected movement of 120 to 660 feet after the completion of a 180-day injection and retention period. This distance is significantly short of the distance to the nearest potable wells, both municipal and private wells.

After the 2-year injection period at 2,000 gpm, the area of the displaced volume is predicted by Hopkins (2016) to not reach the nearest potable supply well (City Well No. 20, located in the LAS). **Note: until tracer studies document otherwise, the maximum proposed injection period is 90 days.**

The proposed monitoring well locations and related hydrogeology are also documented by Hopkins (2016). These well locations are intended to track the travel time of the injected water (greater than 2 weeks and less than 6 months, in accordance with CDPH (2014)). As proposed, the three monitoring wells will sufficiently define the groundwater gradient in Aquifer 1. The location of Monitoring Well No. 2 is between the proposed ASR well and the City municipal supply Well No. 20. The differential well spacing will generate data through tracer testing to confirm the displacement rate of native groundwater. As detailed by Hopkins (2016), Monitoring Well No. 1 is anticipated to see the recharge bubble within 2 weeks while Monitoring Well No. 2 should see the recharge bubble at around 60 days. If our estimates are accurate, Monitoring Well No. 3 will not see the recharge bubble prior to the end of 90 days of recharge.

7.0 MONITORING AND RESPONSE RETENTION TIME

Over time, detection of trace pollutants in the monitoring wells and reduced treatment performance may occur. Depending upon the issue, the City may handle the issue internally, or, in the event of a regulatory exceedance, the City must provide the appropriate notification to DDW and RWQCB staff. These meetings and discussions will determine if the produced water remains protective of public health or if some form of mitigation is required. The need for and magnitude of response from the City will be based upon the following analysis:

- **Analytical detection of a pollutant above a regulated value.** The City will resample the groundwater and concurrently evaluate the AWPF performance. Should resampling still demonstrate non-compliance, appropriate remediation measures will be taken, which may include shutting down production wells or installation of well-head treatment for wells that may extract inadequately treated water. For the ASR operation, the ASR wells can be put into extraction mode and water can be pumped and used for non-potable applications.
- **Analytical detection of a pollutant below a regulated value.** The City will evaluate the occurrence, cause, and significance of the trace pollutant at the AWPF and may take corrective measures to reduce the concentration of the pollutant, either through source control or through treatment process modification.
- **Process failures or online metering/process monitoring failures above regulated values.** The City will evaluate the potential impact on treatment performance, both in terms of pathogen reduction and trace pollutant reduction.
- Included in the analysis by City and regulatory staff is the potential impact of dilution and attenuation of the pollutant of concern in the groundwater basin. Because the ASR operation is intended to be a fill and draw operation with minimal loss of injected water, dilution is not anticipated to be significant.

For the purpose of the RRT, the City anticipates a time period of 4 to 6 weeks for resampling, analysis of treatment processes, and regulatory consultation, as detailed below. This time value is less than the proposed minimum RRT of 3.1 months, as reviewed below.

7.1 Proposed RRT Concept

The ASR operations will follow the requirements of CDPH (2014), Sections 60320.200(b) and 60320.224. For the ASR project, the RRT is based entirely upon City operation of the well. The minimum time of storage for this ASR operation will be 3.1 months to meet the pathogen credits for potable reuse. In the event of a stoppage in ASR operation, the travel distance to the nearest potable water well (City Well #20) is ~4,000 feet. As shown by Hopkins (2016), two years of continuous recharge does not reach City Well #20. As only a 3-month to 6-month recharge period is originally proposed, and as DDW requires a 4X safety factor for Darcy's Law estimations, a 6-month RRT is readily achieved without having the purified water reach a potable well.

For this project, a RRT of three months is more than sufficient to:

- Gain 3-log virus credit through subsurface storage time.
- Identify a treatment failure or detect an inadequately-treated constituent.
- Consider appropriate actions to protect public health.
- Implement corrective measures.

7.1.1 Online Process Control Monitoring

The AWPF controls are designed to maintain water quality that is protective of public health. The AWPF will have both continuous online monitoring and periodic monitoring of treatment performance. Production of water for IPR applications may cease based upon the process monitoring approaches listed in Table 9 below. The RRT for each of these monitoring approaches is also included within Table 9.

The OMMP (OMMP, KEH, 2015)[1] provides further details on the operations and control concepts for the production of water for non-potable and potable reuse.

7.1.2 Offline Analytical Monitoring

Details on the required water quality monitoring and the proposed sampling plan are included in Sections 9 and 17, respectively. This section provides information on the RRT for sampling, analytical monitoring, and response.

The monitoring and control of the MF, RO, and UV AOP systems focuses on process performance to maximize pathogen reduction, plus additional monitoring of trace constituent removal or destruction. The offline monitoring program focuses on chemicals that could present a chronic risk. Most of the monitored constituents are regulated based on conservative estimates of the lifetime health risk associated with chronic exposure. Accordingly, the RRT must be sufficient to respond to acute health concerns such as pathogens as well as several specific chemicals (e.g., nitrate, nitrite), but need not necessarily account for the response time for constituents with long term chronic concerns.

With the above context, the project team examined the RRT for different analytical parameters that represent a chronic concern (Table 10). Because the groundwater storage time for this ASR project is at least 3.1 months, there is more than sufficient RRT to address any potential issues related to regulated and non-regulated constituents.

[1] This document, which has previously been reviewed by DDW, can be provided upon request.

Table 9 RRT Values for Online and Periodic Treatment Process Control
Advanced Water Purification Facility
City of Oxnard

Process	Monitoring	Regulatory Requirement	Issue	Evaluation Approach	Operational Response	*RRT*
MF	Online filtrate turbidity	0.2 NTU.	A properly functioning MF should produce a filtrate with a turbidity of <0.2 NTU.	• Calibrate online meter using bench-scale results. • Examine trend turbidity with time, watch for increasing filtrate turbidity with time, indicative of loss of membrane performance.	• Shut down out of compliance train. Bring on redundant MF train if turbidity continues to exceed 0.2 NTU. • Reduce or shut down water production if insufficient MF capacity to meet turbidity standards. • Perform DIT and repair membranes.	Minutes to Hours
MF	Daily pressure decay testing (also called DIT)	Performance requirement of <0.8 psi/5min.	DIT failure suggests breach in MF, resulting in reduced a removal of particulates (including protozoa) by MF.	No evaluation, see Operational Response.	• Shut down out of compliance train. Bring on redundant train. • Reduce or shut down water production if insufficient MF capacity exists. • Repair membranes.	One day if DIT done daily. Shorter RRTs if DITs done more frequently.
RO	Online EC	• Either EC or TOC online monitoring required to document performance. • Log reduction of EC across RO can be used to prove pathogen credits.	Log reduction of EC across RO is trending down, indicating RO membrane decay or some other leak.	• Verify/calibrate online EC meters with bench-scale testing. • Profile RO vessels to find damaged membrane or seal.	Replace damaged RO membranes or seals.	Hours to Days
RO	Online or periodic TOC	• For the first 20 weeks of operation, ROP TOC must be ≤0.25 mg/L 95% of the time based upon weekly or more frequent sampling. • Subsequent to 20 weeks, ROP TOC must be ≤0.5 mg/L. • Log reduction of TOC can be used to continuously measure RO performance.	• High TOC in ROP suggests either a breach in the RO membrane or the existence of low molecular weight compounds that can pass through RO. • Log reduction of TOC across RO is trending down, indicating RO membrane decay or some other leak.	• Verify/calibrate online TOC meters with bench-scale testing. • Sample RO influent and ROP for analysis of a wide range of trace organic and regulated compounds. • Profile RO vessels to find damaged membrane or seal. Profile to be done using EC, as above.	Depending upon the results of the evaluation: • Replace damaged RO membranes or seals. • Implement a source control solution.	Days to Weeks
UV AOP	Online UVT	No set value. ROP typically has a UVT of 98 to 99%. The UV system is designed to provide a target dose based upon an assumed UVT value of 95%.	• Trending of UVT down suggests either the passage of low molecular weight organics through the RO or suggests damage to the RO process. • Reduced UVT will impact the ability of the existing UV system to deliver the proper UV dose.	• Verify/calibrate online UVT meter with bench-scale testing. • Sample RO influent and ROP for analysis of a wide range of trace organic and regulated compounds. • Profile RO vessels to find damaged membrane or seal. Profile to be done using EC, as above.	Depending upon the results of the evaluation: • Replace damaged RO membranes or seals. • Implement a source control solution.	Days to Weeks
UV AOP	NDMA LRV Based Upon a Target UVI/Q	UV intensity is used to measure the combined impact of lamp output decay and sleeve fouling. UV intensity can also be used as part of UV reactor dose control. For this project, the UVI/Q is recommended as a daily verification of performance to support the NDMA LRV-based operation.	Reduced UV intensity suggests one of several issues: • Aged lamps that must be replaced. • Fouled sleeves that must be cleaned. • Reduced UVT.	• Verify accuracy of online UVT meter (above). • Verify that UV intensity sensor is properly seated in sensor port. • Check UV intensity sensor accuracy with reference sensor(s). • Remove and replace UV intensity sensor with a standby sensor. • Pull representative quartz sleeve, clean, and replace. Alternatively, clean all sleeves. Recheck sensor intensity.	• Depending upon the results of the evaluation: • Replace sensor. • Clean all sleeves. • Replace lamp(s). • Calibrate UVT meter.	Hours to Days

Table 10 RRT Examples for Analytical Monitoring of AWPF and Monitoring Wells
Advanced Water Purification Facility
City of Oxnard

Location	Parameter	Frequency	Performance Requirement	Issue	Evaluation Approach	Operational Response	RRT
Monitoring Wells	Primary MCLs	Quarterly	Varies	Primary MCLs are typically met in secondary effluent. Detection of pollutants near, at, or above the MCLs suggests a high pollutant load at the OWTP and a lack of performance through the AWPF.	• Resample compliance point in question. • If detection was at the monitoring well, sample finished water at the AWPF. • Profile OWTP and AWPF systems as needed.	• Repair process components. • Evaluate other sources of pollutant that may be contributing to the pollutant at the monitoring well.	Sampling is quarterly. Response time, including repeat samples and analysis is a minimum of two weeks. Reasonable RRT is 16 weeks.
Monitoring Wells	Total Coliform	Quarterly (wells)	≤2 MPN/100mL	Total coliform detection at the AWPF is likely sample contamination or sampling from a line with regrowth. Legitimate breakthrough of total coliform suggests a large performance failure.	• Resample compliance point in question. • Concurrently sampling for fecal coliform. • Evaluate treatment processes for compliance with various operating criteria.	• Repair process components. • Evaluate other sources of pollutant that may be contributing to the pollutant at the monitoring well.	Sampling is quarterly for the monitoring wells. Response time, including repeat samples and analysis is a few days. Reasonable RRT is 13 weeks.
AWPF Finished Water	NDMA	Quarterly	≤10 ng/L	Values in excess of 10 ng/L suggest either reduced UV performance or increased levels of NDMA in the secondary effluent.	• Sample finished water at the AWPF. • Sample RO influent and RO permeate. • Determine if the problem is UV performance or increased NDMA at the OWTP.	Depending upon the results of the evaluation: • Shut down water production or bring redundant treatment processes online. • Evaluate NDMA formation in the OWTP or increased NDMA loadings in the collection system.	Sampling is quarterly. Response time, including repeat samples and analysis is a minimum of two weeks. Reasonable RRT is 16 weeks.
AWPF Finished Water	Total Coliform	Daily	ND-≤2.2 MPN/100mL	Total coliform should be removed after RO and after UV AOP. Existence of total coliform at the monitoring well suggests sample contamination or a much larger treatment process failure.	• Resample monitoring well. • Sample finished water at the AWPF. • Sample RO influent and RO permeate. • Concurrently sampling for fecal coliform.	Depending upon the results of the evaluation: • Shut down water production or bring redundant treatment processes online. • Evaluate other methods for total coliform contamination of the monitoring well.	Days
AWPF Finished Water	Total Nitrogen	Weekly	<10 mg/L	Maintaining TN <10 mg/L assures that nitrate levels are also <10 mg/L. Nitrate is an acute health concern.	• Resample monitoring well. • Sample finished water at the AWPF. • Sample RO influent and RO permeate.	• Shut down water production until TN<10 mg/L.	Sampling is twice weekly, no more than 3 days between sampling events. Response time, including repeat samples and analysis is a minimum of three weeks. Reasonable RRT is four weeks.

7.2 Water Quality Failure Decision Protocol

In the event of a suspected water quality failure, in which water was continuously produced and recharged into the groundwater basin that was suspected to be non-compliant (e.g., control system failure, alarm failure), or in the case of detections of pollutants in the groundwater monitoring wells, City staff will follow a detailed decision protocol to evaluate the situation and determine if the finished water quality presents a risk to public health.

The objectives of the decision protocol are as follows:

- Provide a mechanism to verify water quality in a rigorous and measured way. Effort also will minimize questions and concerns from City stakeholders and interested parties through effective communication of the sampling results and their implications.
- Have the City communicate with a single voice to deliver a clear and consistent message.
- Insure that the City is openly communicating water quality information.
- Provide an organized process for data evaluation and follow-up activities.

The first step in such a water quality situation is to shut down all water production for potable reuse (non-potable reuse would remain in operation as long as non-potable water quality standards are met). Figure 29 illustrates an example protocol that would follow cessation of production for potable water reuse[2]. Central to this protocol are two teams:

- The “Engineering/Operations Staff.”
- The “Decision Committee.”

This protocol will be adopted by the City prior for the production of recycled water for potable reuse.

7.3 Proposed RRT

The proposed RRT here is based upon responding to acute concerns, which are those associated with pathogens and a few chemical constituents (e.g., nitrate, nitrite). Thus, the proposed RRT can be calculated as follows:

> RRT = *Sample Collection (daily to twice per week[3]), Analysis and Regulatory Consultation Time (4 weeks) + Time to Provide Relief Measure or Alternative Source of Water (4 weeks) = 9 weeks.*

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[2] Modeled after the SCVWD’s Water Quality Response Protocol. The City and Carollo appreciates the use of this information.
[3] DDW requirements for TN (which provides a conservative measure for nitrate) is twice per week.

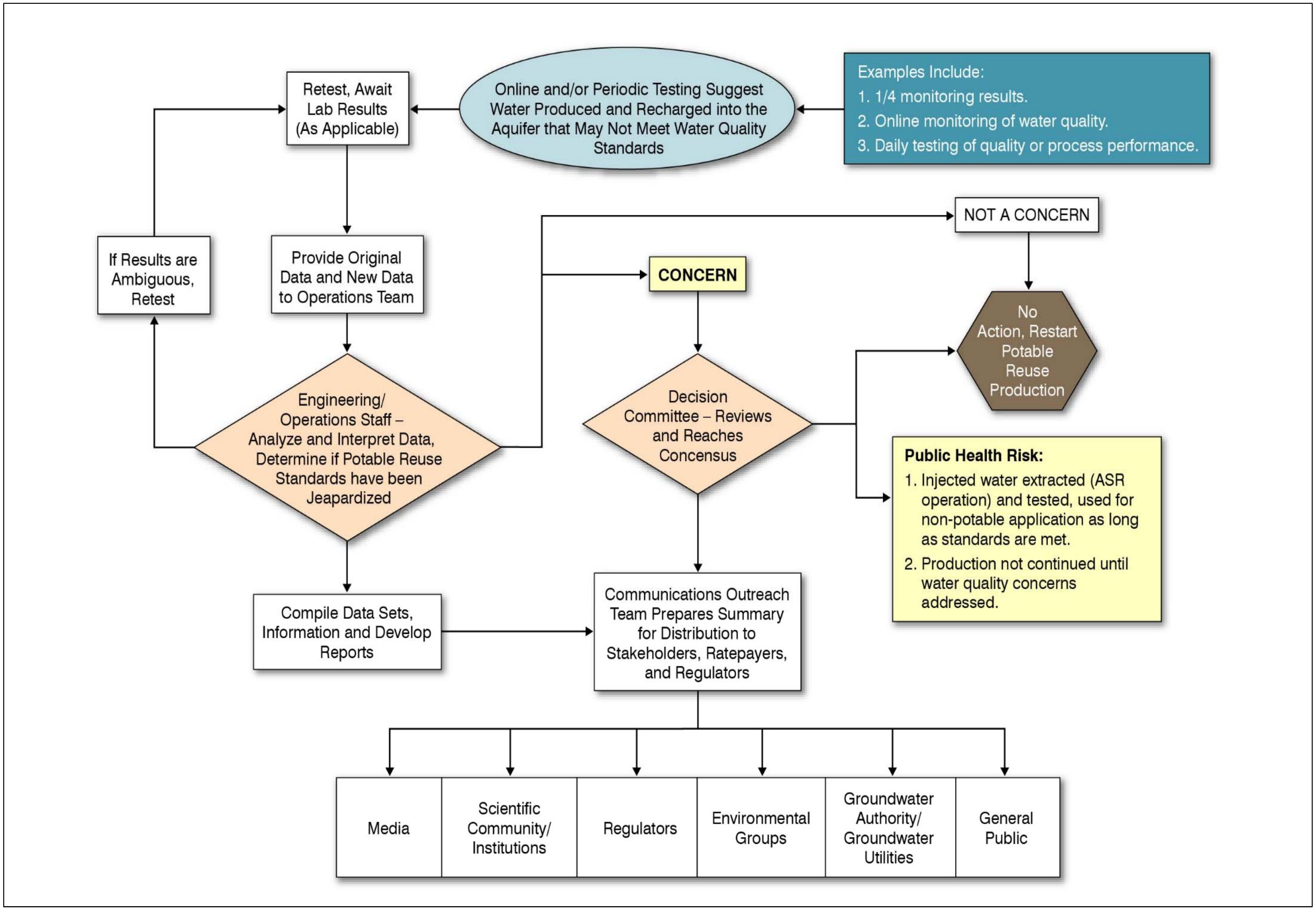

Figure 29 Emergency Response Schematic

As detailed in Hopkins (2016) and in accordance with CDPH (2014) Section 60320.224, groundwater residence/travel times to the nearest potable well are estimated at more than 2 years for the ASR application. As the ASR fill and draw times are controlled, and the proposed project will leave the water in the ground for a minimum of 3.1 months, the RRT of 9 weeks will be reliably met.

Upon commencement of the project, these travel and residence times will be demonstrated through the use of intrinsic or added tracers, potentially TDS, chloride, and sulfate. Further details on startup testing, which includes the groundwater residence time demonstrations, is included in Section 17 of this report.

8.0 NEED FOR ALTERNATIVE SOURCES OF WATER

Long-term sustainable capture and reuse of water supplies is the goal of the City. However, the City's short term water supply remains reliable and interruptions in the production of water from potable reuse do not constitute an emergency or short term problem. Thus, for failures in monitoring or process performance, or detection of pollutants in the groundwater monitoring network, the AWPF can be simply shut down and not produce water.

For ASR operations, if improperly treated water is injected into the aquifer, or if groundwater monitoring results do not meet regulatory limits, the water will be extracted from the ASR location, and one of the following will occur.

- If the water quality meets the requirements for non-potable reuse, the water will be sent off-site for non-potable reuse operations.
- If the water quality does not meet the requirements for non-potable reuse, well-head treatment will be employed to bring the non-compliant water to non-potable water reuse standards.

As the ASR wells are intended to extract the majority of injected water, and as the current groundwater analysis shows limited groundwater migration at the proposed ASR site, migration of injected water to off-site potable wells is not anticipated. With that said, DDW has requested that this report address such off-site migration. As illustrated in Hopkins (2016), the nearest potable water well to the proposed ASR location is City Well No. 20. In the event of contamination of that well, well-head treatment would be initiated, with the treatment based upon the type of contaminant. For pathogens, installation of a UV system and/or free chlorination could be employed. For trace pollutants, the use of activated carbon or advanced oxidation (which could be a UV-based process) could be employed. For nitrate contamination, ion exchange treatment would be employed.

9.0 POTABLE REUSE WATER QUALITY

There are no federal regulations pertaining to water reuse, and water reuse regulations are developed at the state level. The main regulatory agency for water reuse in the State of California is the SWRCB. The SWRCB is separated into nine different RWQCBs that regulate water reuse projects in conformance with the regulations adopted by the CDPH, which is now part of the SWRCB as the Division of Drinking Water (DDW). The City is located within the LARWQCB.

The water quality limits for groundwater recharge with recycled water and the projected water quality for the AWPF are reviewed below.

9.1 Water Quality Requirements

Tables 11 through 16 constitute the required water quality performance, consistent with CDPH (2014). The tables of constituents referenced in CDPH (2014) are found in CDPH (2014a). Within each table is a specific reference to the table within the regulation (e.g., Primary MCLs are listed in a table below and also found in Table 64431-A). In addition to the CDPH (2014) water quality requirements provided in the following tables, the advanced treated recycled water from the AWPF facility will be required to satisfy the discharge limits included in the revised GREAT permit (R4-2011-0079-A01 and R4-2008-0083-A01) prior to injection.

Table 11 Inorganics with Primary MCLs(1)
Advanced Water Purification Facility
City of Oxnard

Constituents	Primary MCL (in mg/L)	Constituents	Primary MCL (in mg/L)
Aluminum	1.0	Fluoride	2
Antimony	0.2	Lead	0.015(4)
Arsenic	0.006	Mercury	0.002
Asbestos	7 (MFL)(2)	Nickel	0.1
Barium	1	Nitrate (as NO_3)	45
Beryllium	0.004	Nitrite (as N)	1
Cadmium	0.005	Total Nitrate/Nitrite (as N)	10
Hexavalent Chromium	0.010	Selenium	0.05
Copper	1.3(3)	Thallium	0.02
Cyanide	0.15		

Table 11 Inorganics with Primary MCLs[1]
Advanced Water Purification Facility
City of Oxnard

Constituents	Primary MCL (in mg/L)	Constituents	Primary MCL (in mg/L)

Notes:
(1) Based on **Table 64431-A.**
(2) MFL = Million fibers per liter, with fiber lengths > 10 microns.
(3) Regulatory Action Level; if system exceeds, it must take certain actions such as additional monitoring, corrosion control studies and treatment, and for lead, a public education program; replaces MCL.
(4) The MCL for lead was rescinded with the adoption of the regulatory action level. The action level is like a MCL except it also requires additional testing. If more than 10% of samples collected at the point of delivery exceed the action level, the water distributor must take steps to reduce the corrosivity and/or lead concentrations of the delivered water and notify the public about steps they should take to protect their health.

Table 12 Constituents/Parameters with Secondary MCLs
Advanced Water Purification Facility
City of Oxnard

Constituents[1]	MCL (in mg/L)	Constituents[2]	MCL (in mg/L)
Aluminum	0.2	TDS	500
Color	15 (units)	Specific Conductance	900 *u*S/cm
Copper	1	Chloride	250
Foaming Agents (MBAS)	0.5	Sulfate	250
Iron	0.3		
Manganese	0.05		
Methyl-tert-butyl-ether (MBTE)	0.005		
Odor Threshold	3 (units)		
Silver	0.1		
Thiobencarb	0.001		
Turbidity	5 (NTU)		
Zinc	5		

Notes:
(1) Based on **Table 64449-A.**
(2) Based on **Table 6449-B.**

Table 13	**Radioactivity[1] Advanced Water Purification Facility City of Oxnard**		
Constituents	**MCL (in pCi/L)**	**Constituents**	**MCL (in pCi/L)**
Uranium	20	Gross Beta particle activity	50[2]
Combined radium-226 & 228	5	Strontium-90	8[2]
Gross alpha particle activity	15	Tritium	20,000[2]

Notes:
(1) Based on **Tables 64442 and 64443**.
(2) MCLs are intended to ensure that exposure above 4 millirem/yr does not occur.

Table 14	**Regulated Organics[1] Advanced Water Purification Facility City of Oxnard**		
Constituents	**MCL (in mg/L)**	**Constituents**	**MCL (in mg/L)**
Volatile Organic Compounds			
Benzene	0.001	Monochlorobenzene	0.07
Carbon Tetrachloride	0.0005	Styrene	0.1
1,2-Dichlorobenzene	0.6	1,1,2,2-Tetrachloroethane	0.001
1,4-Dichlorobenzene	0.005	Tetrachloroethylene	0.005
1,1-Dichloroethane	0.005	Toluene	0.15
1,2-Dichloroethane	0.0005	1,2,4 Trichlorobenzene	0.005
1,1-Dichloroethylene	0.006	1,1,1-Trichloroethane	0.2
cis-1,2-Dichloroethylene	0.006	1,1,2-Trichloroethane	0.005
trans-1,2-Dichloroethylene	0.01	Trichloroethylene	0.005
Dichloromethane	0.005	Trichlorofluoromethane	0.15
1,3-Dichloropropene	0.0005	1,1,2-Trichloro-1,2,2-Trifluoroethane	1.2
1,2-Dichloropropane	0.005	Vinyl chloride	0.0005
Ethylbenzene	0.3	Xylenes	1.75
Methyl-tert-butyl ether (MTBE)	0.013		
SVOCs			
Alachlor	0.002	Hexachlorobenzene	0.001

Table 14	Regulated Organics[1] Advanced Water Purification Facility City of Oxnard		
Constituents	**MCL (in mg/L)**	**Constituents**	**MCL (in mg/L)**
Atrazine	0.001	Hexachlorocyclopentadie ne	0.05
Bentazon	0.018	Lindane	0.0002
Benzo(a) Pyrene	0.0002	Methoxychlor	0.03
Carbofuran	0.018	Molinate	0.02
Chlordane	0.0001	Oxamyl	0.05
Dalapon	0.2	Pentachlorophenol	0.001
Dibromochloropropane	0.0002	Picloram	0.5
Di(2-ethylhexyl)adipate	0.4	Polychlorinated Biphenyls	0.0005
Di(2-ethylhexyl)phthalate	0.004	Pentachlorophenol	0.001
2,4-D	0.07	Picloram	0.5
Dinoseb	0.007	Polychlorinated Biphenyls	0.0005
Diquat	0.02	Simazine	0.004
Endothall	0.1	Thiobencarb	0.07/0.001[2]
Endrin	0.002	Toxaphene	0.003
Ethylene Dibromide	0.00005	2,3,7.8-TCDD (Dioxin)	$3x10^{-8}$
Glyphosate	0.7	2,4,5-TP (Silvex)	0.05
Heptachlor	0.00001		
Heptachlor Epoxide	0.00001		

Notes:
(1) Based on Table 64444-A.
(2) Second value is listed as a Secondary MCL.

Table 15	Disinfection By-Products[1] Advanced Water Purification Facility City of Oxnard		
Constituents	**MCL (in mg/L)**	**Constituents**	**MCL (in mg/L)**
Total Trihalomethanes	0.080	Bromate	0.010
Total haloacetic acids	0.060	Chlorite	1.0

Notes:
(1) Based on **Table 64533-A.**

Table 16	**Constituents with Notification Levels(1) Advanced Water Purification Facility City of Oxnard**		
Constituents	**NL (in μg/L)**	**Constituents**	**NL (in μg/L)**
Boron	1000	Manganese	500
n-Butylbenzene	260	Methyl isobutyl ketone (MIBK)	120
sec-Butylbenzene	260	Naphthalene	17
tert-Butylbenzene	260	N-Nitrosodiethylamine (NDEA)	0.01
Carbon disulfide	160	N-Nitrosodimethylamine (NDMA)	0.01
Chlorate	800	N-Nitrosodi-n-propylamine (NDPA)	0.01
2-Chlorotoluene	140	Propachlor**	90
4-Chlorotoluene	140	n-Propylbenzene	260
Diazinon	1.2	RDX	3
Dichlorodifluoromethane (Freon 12)	1000	Tertiary butyl alcohol (TBA)	12
1,4-Dioxane	1	1,2,3-Trichloropropane (1,2,3-TCP)	0.005
Ethylene glycol	14000	1,2,4-Trimethylbenzene	330
Formaldehyde	100	1,3,5-Trimethylbenzene	330
HMX	350	2,4,6-Trinitrotoluene (TNT)	1
Isopropylbenzene	770	Vanadium	50

Notes:

(1) Based on http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/notificationlevels/notificationlevels.pdf.
The web link above also contains the levels of the pollutants in this table that must result in a removal of the water source from service.

9.2 CEC Monitoring

SWRCB (2013) lists specific compounds for monitoring for groundwater injection projects (Table 17). The initial monitoring program is intended to be quarterly, followed by semi-annual monitoring for the duration of the project.

Table 17 Monitoring Trigger Levels for Groundwater Recharge, as Listed in SWRCB (2013)
Advanced Water Purification Facility
City of Oxnard

Constituents	Relevance/ Indicator Type/ Surrogate	Monitoring Trigger Level (in μg/L)	Removal Percentages (%)
17B-estradiol	Health	0.0009	--
Caffeine	Health & Performance	0.35	>90
NDMA	Health & Performance	0.01	25-50, >80(1)
Triclosan	Health	0.35	--
DEET	Performance	--	>90
Sucralose	Performance	--	>90
Electrical Conductivity	Surrogate	--	>90
TOC	Surrogate	--	>90

Notes:
(1) 25 to 50 % removal by RO, >80% removal by RO followed by UV, depending upon the UV dose.

The LARWQCB requires specific monitoring for CECs. The Monitoring and Reporting Program of the revised GREAT permit will specify the monitoring program for this project.

9.3 Basin Plan

The Basin Plan Objectives for ground water quality for the LA region are divided into five groups: bacteria, chemical constituents and radionuclides, minerals, nitrogen, and taste and odor. Excluding the chemical constituents and radionuclides, the objectives are summarized as follows:

- **Bacteria -** Concentration of coliform organisms shall be < 1.1/100 mL over any 7-day period.
- **Minerals:** TDS - (1200 mg/L (confined aquifers), 3000 mg/L (unconfined aquifers), Sulfate (600 mg/L (confined aquifers), 1000 mg/L (unconfined aquifers), Chloride (150 mg/L (confined aquifers), 500 mg/l (unconfined aquifers), Boron (1 mg/L).
- **Nitrogen –** 10 mg/L (NO_3-N + NO_2-N), 45 mg/L (NO_3), 10 mg/L (NO_3-N), 1 mg/L (NO_2-N).
- **Taste and Odor -** Ground waters shall not contain taste or odor-producing substances in concentrations that cause nuisance or adversely affect beneficial uses.

Additionally, the Basin Plan specifies compliance with Table 64431-A, Table 6444-A, and Tables 64442 and 64443 of CDPH (2014a). The constituents in these tables are provided in Tables 12, 14, and 15 of this report.

9.4 Current Water Quality

The City's AWPF is now in operation, producing high quality water for non-potable reuse. Detailed water quality and performance testing has been completed and is documented here. Secondary Effluent, RO permeate, and UV AOP final effluent were sampled for MCLs, NLs, Secondary MCLs and CECs, results are show in Tables 18 through 25. Consistent contaminant removal was seen throughout the MF/RO/UVAOP process, with the AWPF treatment train finished water meeting all health goals (MCLs, secondary MCLs, and NLs). CEC concentrations were either ND or below the recommended health levels according to literature sources. ***Of important note, only 8 contaminants tested for were detected above the health-based goal/limit in the secondary effluent (as highlighted in yellow in the tables below).*** All 8 constituents were fully removed to below the detection level or health target/limit in the finished water, and most were removed prior to UV AOP treatment, as demonstrated both by the RO effluent sampling, and the RO concentrate contaminant concentrations.

9.4.1.1 TOC

The CDPH (2014) requirement for total organic carbon (TOC) is a maximum of 0.5 mg/L, and new membranes are required to meet a value of 0.25 mg/L. Grab samples taken as part of the startup testing all resulted in RO permeate TOC levels below detection at <0.3 mg/L.

9.4.1.2 Total Nitrogen

The CDPH groundwater recharge requirement for total nitrogen (TN) is ≤10 mg/L. As listed in the tables above, the finished water has low nitrate + nitrite (as N) of <0.2 mg/L. Recent (6/22/2016) ammonia concentrations (RO feed = 33 mg/L, UV AOP feed = 2.8 mg/L, Finished water = 2.1 mg/L) coupled with the low nitrate and nitrite numbers indicate a low TN result of ~3 mg/L.

10.0 DILUENT WATER

No diluent water is proposed for the ASR project. The water that will be used for recharge will be 100 percent recycled water that has received advanced treatment (MF/RO/UV AOP). Any dilution in the subsurface (due to groundwater underflow) will not be counted toward TOC credits or for meeting pollutant or pathogen levels.

Table 18 MF/RO/UV AOP Finished Water Quality for MCLs- Inorganic Chemicals per Table 64431-A and Table 64432-A (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Constituent	Unit	RO INF	RO CONC	UV INF	Finished Water	MCL/Action Level	MRL (units shown at far left)
		5/2/16	5/2/16	11/12/15	5/20/16		
Aluminum	ug/L	ND	87	ND	ND	200	20
Antimony	ug/L	ND	3.9	ND	ND	6	1
Arsenic	ug/L	1	8.1	ND	ND	10	1
Asbestos	MFL[(2)]	ND	ND	ND	ND	7	0.2
Barium	ug/L	18	120	ND	ND	1,000	2
Beryllium	ug/L	ND	ND	ND	ND	4	1
Cadmium	ug/L	ND	ND	ND	ND	5	0.5
Chromium	ug/L	1.2	5.9	ND	ND	50	1
Copper	ug/L	5.4	36	ND	ND	1,300 *(Action Level)*	2
Cyanide	mg/L	0.04	0.18	ND	ND	150	0.025
Fluoride	mg/L	0.78	3.6	ND	ND	2	0.05
Hexavalent Chromium[(1)]	ug/L	--	--	--	--	10	0.5
Lead	ug/L	ND	ND	ND	ND	15 *(Action Level)*	0.5
Mercury	ug/L	ND	ND	ND	ND	2	0.2
Nickel	ug/L	6.2	46	ND	ND	100	5
Nitrate (as NO_3)	mg/L	ND	ND	ND	0.12	45	0.013
Nitrite (as N)	mg/L	ND	ND	ND	0.072	1	0.013
Perchlorate	ug/L	32	200	ND	ND	6	2
Nitrate + Nitrite (as N)	mg/L	ND	ND	ND	0.192	10	0.055

Table 18 MF/RO/UV AOP Finished Water Quality for MCLs- Inorganic Chemicals per Table 64431-A and Table 64432-A (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Constituent	Unit	RO INF 5/2/16	RO CONC 5/2/16	UV INF 11/12/15	Finished Water 5/20/16	MCL/Action Level	MRL (units shown at far left)
Selenium	ug/L	5.7	28	ND	ND	50	5
Thallium	ug/L	ND	ND	ND	ND	2	1

Notes:
(1) Laboratory error, hexavalent chromium not analyzed for.
(2) MFL = million fibers per liter longer than 10 *u*m.
(3) Hexavalent chromium was not tested due to a sampling error, however, total chromium was analyzed.

Table 19 MF/RO/UV AOP Finished Water Quality for MCLs- Radionuclides per Table 64442 AND 64443 (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Constituent	Unit	RO INF 5/02/16	RO CONC 5/02/16	UV INF 5/02/16	Finished Water 5/20/16	MCL	MRL (units shown at far left)
Gross Alpha (including Radium-226 but not Radon and Uranium)	pCi/L	5.7	29.1		ND	15	1.5
Radium-226	pCi/L	<0.889	0.354	<0.733	ND	-	0.889
Radium-228	pCi/L	<0.661	<0.593	<0.804	ND	-	0.661
Combined Radium-226 and Radium-228 (*226 + 228*)	pCi/L	ND	0.354	ND	ND	5	
Strontium 90	pCi/L	<0.968	<1.92	<0.908	<0.654	8	0.968
Uranium	pCi/L	5.2	37	ND	ND	20	0.7
Tritium	pCi/L	<267	<265	<264	<279	20,000	267
Beta/Photon emitters (gross beta tested)	pCi/L	38	210	5.3	<1.80	4	2.42

Table 20 MF/RO/UV AOP Finished Water Quality for MCLs- Synthetic Organic Chemicals - SVOCS per Table 64444-A (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Constituent	Unit	RO INF 5/02/16	RO CONC 5/02/16	UV INF 5/0216	Finished Water 5/20/16	MCL/Action Level	MRL(units shown at far left)
Alachlor	ug/L	ND	ND	ND	ND	2	0.05
Atrazine	ng/L	ND	9.3	ND	ND	1	5
Benzo(a)pyrene	ug/L	ND	ND	ND	ND	0.2	0.02
Carbofuran	ug/L	ND	ND	ND	ND	40	0.5
Chlordane	ug/L	ND	ND	ND	ND	2	0.1
Dalapon	ug/L	ND	1.1	ND	ND	200	1
Dibromochloropropane	ug/L	ND	ND	ND	ND	0.2	0.01
Dinoseb	ug/L	ND	ND	ND	ND	7	0.2
Dioxin(2,3,7,8-TCDD)	pg/L	ND	ND	ND	ND	3.00E-08	5
Diquat	ug/L	ND	0.65	ND	ND	20	0.4
Di(2-ethylhexyl) adipate	ug/L	ND	ND	ND	ND	400	0.6
Di(2-ethylhexyl) phthalate	ug/L	ND	ND	ND	ND	6	0.6
Endothall	ug/L	ND	ND	ND	ND	100	5
Endrin	ug/L	ND	ND	ND	ND	2	0.2
Ethylene Dibromide	ug/L	ND	ND	ND	ND	0.05	0.01
Glyphosate	ug/L	ND	ND	ND	ND	700	6
Heptachlor	ug/L	ND	0.033	ND	ND	0.04	0.01
Heptachlor epoxide	ug/L	ND	ND	ND	ND	0.02	0.01
Hexachlorobenzene	ug/L	ND	ND	ND	ND	1	0.05
Hexachlorocyclopentadiene	ug/L	ND	ND	ND	ND	50	0.05
Lindane	ug/L	ND	ND	ND	ND	0.2	0.04

Table 20 MF/RO/UV AOP Finished Water Quality for MCLs- Synthetic Organic Chemicals - SVOCS per Table 64444-A (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Constituent	Unit	RO INF	RO CONC	UV INF	Finished Water	MCL/Action Level	MRL(units shown at far left)
		5/02/16	5/02/16	5/0216	5/20/16		
Methoxychlor	ug/L	ND	ND	ND	ND	40	0.1
Oxamyl(Vydate)	ug/L	ND	ND	ND	ND	200	0.5
Picloram	ug/L	ND	ND	ND	ND	500	0.1
Polychlorinated Biphenyls (TOTAL)(1)	ug/L	ND	ND	ND	ND	0.5	0.0005
Pentachlorophenol	ug/L	ND	ND	ND	ND	1	0.04
Simazine	ng/L	20	76	ND	ND	4	5
Toxaphene	ug/L	ND	ND	ND	ND	3	0.5
2,4-D	ug/L	0.25	2.3	ND	ND	70	0.1
2,4,5-TP Silvex	ug/L	ND	ND	ND	ND	50	0.2
Bentazon	ug/L	ND	0.78	ND	ND	18	0.5
Molinate	ug/L	ND	ND	ND	ND	20	0.1
Thiobencarb	ug/L	ND	ND	ND	ND	1	0.2

Notes:
(1) Polychlorinated Biphenyls (TOTAL) includes: PCB 1016, PCB 1221, PCB 1232, PCB 1242, PCB 1248, PCB 1254 and PCB 1260."

Table 21 MF/RO/UV AOP Finished Water Quality for MCLs- Volatile Organic Chemicals - VOCS per Table 64444-A (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Constituent	Unit	RO INF	RO CONC	UV INF	Finished Water	MCL/Action Level	MRL
		5/02/16	5/02/16	5-02-16	5/2016		
Benzene	ug/L	ND	ND	ND	ND	1	0.5
Carbon tetrachloride	ug/L	ND	ND	ND	ND	0.5	0.5
cis-1,2-Dichloroethylene	ug/L	ND	ND	ND	ND	6	0.5
Dichloromethane	ug/L	ND	ND	ND	ND	5	0.5
Ethylbenzene	ug/L	ND	ND	ND	ND	300	0.5
Monochlorobenzene (Chlorobenzene)	ug/L	ND	ND	ND	ND	70	0.5
o-Dichlorobenzene	ug/L	ND	ND	ND	ND	600	0.5
p-Dichlorobenzene	ug/L	ND	ND	ND	ND	5	0.5
Styrene	ug/L	ND	ND	ND	ND	100	0.5
Tetrachloroethylene(PCE)	ug/L	ND	ND	ND	ND	5	0.5
Toluene	ug/L	ND	ND	ND	ND	150	0.5
trans-1,2-Dichloroethylene	ug/L	ND	ND	ND	ND	10	0.5
Trichloroethylene (TCE)	ug/L	ND	ND	ND	ND	5	0.5
Vinyl chloride	ug/L	ND	ND	ND	ND	0.5	0.3
Xylenes (total)	ug/L	ND	ND	ND	ND	1,750	0.5
1,1-Dichloroethylene	ug/L	ND	ND	ND	ND	6	0.5
1,1,1-Trichloroethane	ug/L	ND	ND	ND	ND	200	0.5
1,1,2-Trichloroethane	ug/L	ND	ND	ND	ND	5	0.5
1,2-Dichloroethane	ug/L	ND	ND	ND	ND	0.5	0.5

Table 21 MF/RO/UV AOP Finished Water Quality for MCLs- Volatile Organic Chemicals - VOCS per Table 64444-A (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Constituent	Unit	RO INF 5/02/16	RO CONC 5/02/16	UV INF 5-02-16	Finished Water 5/2016	MCL/Action Level	MRL
1,2-Dichloropropane	ug/L	ND	ND	ND	ND	5	0.5
1,2,4-Trichlorobenzene	ug/L	ND	ND	ND	ND	5	0.5
1,1-Dichloroethane	ug/L	ND	ND	ND	ND	5	0.5
1,3-Dichloropropene	ug/L	ND	ND	ND	ND	0.5	0.5
Methyl-tert-butyl ether (MTBE)	ug/L	ND	ND	ND	ND	135 (Secondary MCL)	0.5
1,1,2,2-Tetrachloroethane	ug/L	ND	ND	ND	ND	1,200	0.5
Trichlorofluoromethane	ug/L	ND	ND	ND	ND	150	0.5
1,1,2-Trichloro-1,2,2-Trifluoroethane	ug/L	ND	ND	ND	ND	1,200	0.5

Table 22 MUF/RO/UV AOP Finished Water Quality for MCLs- Disinfection Byproducts per Table 64533-A (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Disinfection Byproduct	Unit	RO INF 5/02/16	RO CONC 5/02/16	UV INF 5/02/16	Finished Water 5/20/16	MCL/Action Level	MRL
Total Trihalomethanes (TTHM)	ug/L	2.3	11	1.5	0.89	80	0.5
Haloacetic acids (five) (HAA5)(1)	ug/L	20	85	ND	ND	60	2
Bromate	ug/L	ND	1.8	ND	ND	10	1
Chlorite	mg/L	ND	ND	ND	ND	1.0	0.01
Chlorate	ug/L	350	1600	16	ND	800	10

Note:
(1) Haloacetic acids (five) includes: Bromoacetic Acid, Chloroacetic Acid, Dibromoacetic Acid, Dichloroacetic Acid and Trichloroacetic Acid.

Table 23 MF/RO/UV AOP Finished Water Quality for Secondary MCLs per Tables 64449-A and 64449-B (DDW, 2015)
Advanced Water Purification Facility
City of Oxnard

Secondary Constituent	Unit	RO INF	RO CONC	UV INF	Finished Water	MCL/Action Level (units shown at far left)	MRL (units shown at far left)
		5/02/16	5/02/16	5/02/16	5/20/16		
Color	ACU	40	300	ND	5	15 color units	3
Corrosivity (below)*:						Non-corrosive	
Langelier Index - 20 degrees C	-	-3	-4.9	-2.4	5.4	Non-corrosive	-
Langelier Index at 60 degrees C	-	NA	NA	NA	NA	Non-corrosive	-
Aggressiveness Index-Calculated	-	8.7	6.8	9.3	7.4	Non-corrosive	-
pH of CaCO3 saturation(25C)	Units	6.6	5	10	10	Non-corrosive	0.1
pH of CaCO3 saturation(60C)	Units	6.2	4.6	9.9	9.9	Non-corrosive	0.1
Bicarb. Alkalinity as HCO3, calc	mg/L	650	4200	ND	ND	Non-corrosive	3
Foaming agents (Surfactants)	mg/L	0.2	0.89	ND	ND	0.5	0.1
pH	Units	8	7.8	6.7	6.5	6.5-8.5	0.1
Hardness (as CaCO3)	mg/L	650	4,200	ND	ND	250	3
Odor (SM 2150B - Odor at 60 C (TON))	TON	200	200	3	ND	3 (Threshold Odor Number)	1
Total dissolved solids(TDS)	mg/L	2,000	11,000	68	64	500	10
Aluminum	ug/L	ND	87	ND	ND	50-200	20
Chloride	mg/L	610	3,700	26	17	250	1
Copper	ug/L	5.4	36	ND	ND	1,000	2
Fluoride	mg/L	0.78	3.6	ND	ND	2	0.05
Iron	mg/L	0.13	0.87	ND	ND	0.3	0.02
Manganese	ug/L	95	680	ND	ND	50	2
Silver	ug/L	ND	ND	ND	ND	100	0.5
Sulfate	mg/L	510	3400	ND	0.55	250	0.5
Turbidity	NTU	0.17	0.5	ND	0.14	5	0.1
Specific Conductance	umho/cm	3400	18,000	140	110	900	2
Zinc	ug/L	21	140	ND	ND	5,000	20

Table 24 MF/RO/UV AOP Finished Water Quality for Drinking Water NLs per DDW, 2015a
Advanced Water Purification Facility
City of Oxnard

Secondary Constituent	Unit	RO INF	RO CONC	UV INF	Finished Water	MCL/Action Level (units shown at far left)	MRL (units shown at far left)
		5/02/16	5/02/16	5/02/16	5/20/16		
Boron	mg/L	1.1	2.1	0.82	0.77	1	0.05
n-Butylbenzene	ug/L	ND	ND	ND	ND	260	0.5
sec-Butylbenzene	ug/L	ND	ND	ND	ND	260	0.5
tert-Butylbenzene	ug/L	ND	ND	ND	ND	206	0.5
Carbon disulfide	ug/L	ND	ND	ND	ND	160	0.5
Chlorate	ug/L	350	1,600	16	ND	800	10
2-Chlorotoluene	ug/L	ND	ND	ND	ND	140	0.5
4-Chlorotoluene	ug/L	ND	ND	ND	ND	140	0.5
Diazinon	ug/L	ND	ND	ND	ND	1.2	0.1
Dichlorodifluoromethane (Freon 12)	ug/L	ND	ND	ND	ND	1,000	0.5
1,4-Dioxane	ug/L	1.4	7	ND	ND	1	1
Ethylene glycol	mg/L	ND	ND	ND	ND	14	10
Formaldehyde	ug/L	36	100	20	17	100	5
HMX	ug/L	ND	ND	ND	ND	350	0.1
Isopropylbenzene	ug/L	ND	ND	ND	ND	770	0.5
Manganese	ug/L	95	680	ND	ND	500	2
Methyl isobutyl ketone (MIBK)	ug/L	ND	ND	ND	ND	120	5
Naphthalene	ug/L	ND	ND	ND	ND	17	0.5
N-Nitrosodiethylamine (NDEA)	ng/L	2.9	25	ND	ND	10	2
N-Nitrosodimethylamine (NDMA)	ng/L	33	90	32	5	10	2

Table 24 MF/RO/UV AOP Finished Water Quality for Drinking Water NLs per DDW, 2015a
Advanced Water Purification Facility
City of Oxnard

Secondary Constituent	Unit	RO INF	RO CONC	UV INF	Finished Water	MCL/Action Level (units shown at far left)	MRL (units shown at far left)
		5/02/16	5/02/16	5/02/16	5/20/16		
N-Nitrosodi-n-propylamine (NDPA)	ng/L	ND	ND	ND	ND	10	2
Propachlor**	ug/L	ND	ND	ND	ND	90	0.05
n-Propylbenzene 0.26	ug/L	ND	ND	ND	ND	260	0.5
RDX	ug/L	ND	ND	ND	ND	0.3	0.1
Tertiary butyl alcohol (TBA)	ug/L	2.1	19	ND	ND	12	2
1,2,3-Trichloropropane (1,2,3-TCP)	ug/L	ND	0.017	ND	ND	0.005	0.005
1,2,4-Trimethylbenzene	ug/L	ND	ND	ND	ND	330	0.5
1,3,5-Trimethylbenzene	ug/L	ND	ND	ND	ND	330	0.5
2,4,6-Trinitrotoluene (TNT)	ug/L	ND	ND	ND	ND	1	0.1
Vanadium	ug/L	ND	11	ND	ND	50	3

Table 25 MF/RO/UV AOP Finished Water Quality for CECs
Advanced Water Purification Facility
City of Oxnard

Constituent	Unit	RO INF 5/02/16	RO CONC 5/02/16	UV INF 5/02/16	Finished Water 5/2016	MRL
Gemfibrozil	ng/L	1200	16000	ND	ND	5
Naproxen	ng/L	130	230	ND	ND	10
Triclosan	ng/L	230	2000	12	ND	10
Ibuprofen	ng/L	ND	5200	ND	ND	10
Acetaminophen	ng/L	150	240	45	ND	5
Sucralose	ng/L	47,000	310,000	ND	ND	100
Triclocarban	ng/L	ND	ND	ND	ND	5
Sulfamethoxazole	ng/L	1,600	15,000	ND	ND	5
Atenolol	ng/L	320	3700	5.5	ND	5
Trimethoprim	ng/L	320	3500	ND	ND	5
Caffeine	ng/L	3500	31000	23	21	5
Fluoxetine	ng/L	35	220	ND	ND	10
Meprobamate	ng/L	ND	930	ND	ND	5
Carbamazepine	ng/L	140	1000	ND	ND	5
Primidone	ng/L	94	260	ND	ND	5
DEET	ng/L	94	260	ND	ND	5
TCEP	ng/L	200	1100	ND	ND	10
PFOA	ug/L	0.0057	0.035	ND	0.0051	0.0025
PFOS	ug/L	0.0042	0.035	ND	ND	0.0025
Estrone	ng/L	9.4	51	ND	ND	0.002
Estradiol	ng/L	ND	ND	ND	ND	5
Ethynylestradiol	ug/L	ND	0.0052	ND	ND	0.0009
Testosterone	ug/L	0.0019	0.0090	ND	ND	0.0001
Progesterone	ng/L	ND	ND	ND	ND	5

11.0 ASR FACILITIES

The proposed ASR concept is to inject highly-treated recycled water for a minimum period of 3.1 months and possibly for up to 6 months, hold the water in the designated aquifer for 3.1 months, and then withdraw the water from the same wells into which the water was injected for potable and/or non-potable use. The proposed ASR operation is summarized in Section 6 and detailed by Hopkins (2016).

12.0 GROUNDWATER BASINS

12.1 Existing Water Quality

At this time, the project team has extensive groundwater data provided by the UWCD for the "Lower Aquifer System," or LAS (shown in Figure 30 below). The LAS extends throughout the area and groundwater quality is anticipated to be similar underneath the proposed ASR location. Table 26 is lists local groundwater quality data obtained from UWCD.

**Table 26 List of UWCD Groundwater Quality
Advanced Water Purification Facility
City of Oxnard**

Constituent (mg/L unless otherwise stated)	Comparative Groundwater Quality Well IDs			Nearest Well to Proposed ASR Location
	01N22W03F05S	02N22W30F03S	02N22W20L03S	(1N22W04F04)[1]
Alk as CaCO3	213	484	608	520
Temperature (C)				
pH	7.38	7.40	7.46	7.6
TDS	996			958
Turbidity (NTUs)	0.04		0.42	
Nitrate-N				4.3
Potassium	5	7	5	6
Sodium	102	93	140	93
Magnesium	47	37	54	44
Calcium	141	135	155	135
Bicarbonate	239	255	286	249
Sulfate	470	435	594	418
Boron (µg/L)	700	600	620	600
Chloride	50	54	66	49
Fluoride	0.62	0.50	0.60	0.7

Notes:
(1) Data from 1960 to 1989.

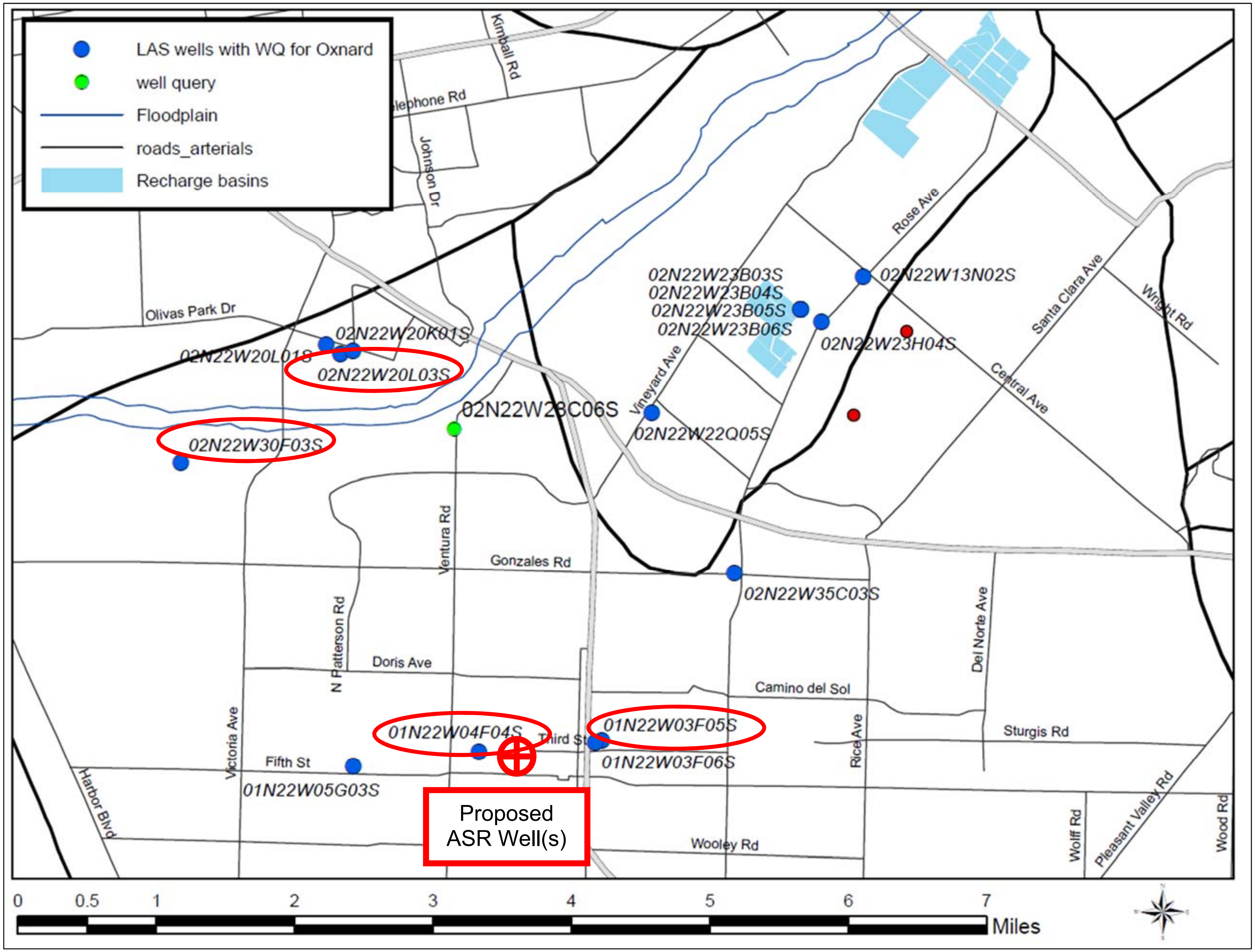

Figure 30 Oxnard Map of UWCD Well Locations (provided by UWCD)

12.2 Groundwater Model

No groundwater model exists for the project area.

13.0 DOMESTIC WATER SUPPLY PRODUCTION WELLS

13.1 Production Wells Near the Project

The Campus Park site is located within the City where all potable water is provided by the City municipal supply system. The nearest production well to the project is a domestic well located southeast of the site that is used for off-site irrigation. The next closest production wells are domestic wells located to the northwest of the site in the County. These wells, ***all in the UAS***, supply residential uses. The next closest wells are located to the east at City Blending Station No. 1. See Hopkins (2016) for more details.

13.2 Closest Domestic Supply Well

The closest existing domestic supply wells are located over 2,000 feet northwest of the site and are constructed in the Oxnard Aquifer, the uppermost member of the upper aquifer system. See Hopkins (2016) for more details.

13.3 Domestic Water Supply Production Wells – Water Quality

The water quality in regional water supply wells is summarized in Section 12.

14.0 GROUNDWATER RECHARGE IMPACTS

14.1 Regional Geologic and Hydrogeologic Framework

The subsurface geology that controls groundwater flow in the study area is differentiated into two primary geologic units that include; the Holocene and late Pleistocene alluvium, and the San Pedro Formation. The first unit is comprised largely of unconsolidated sedimentary deposits and includes all older and recent alluvial deposits. These shallower units are coarse-grained sand and gravel layers that form the Oxnard and Mugu Aquifers and comprise the UAS in the Oxnard Plain Basin (see Hopkins (2016), Appendix D, Plates 3, and 4). The San Pedro Formation consists of consolidated marine and nonmarine clay, silt, sand, and gravel deposits that comprise the Hueneme and Fox Canyon Aquifers that are designated as the LAS. The low permeability geologic formations underlying the San Pedro Formation are generally considered to be non-water-bearing and effectively define the base of fresh water.

The groundwater in the Oxnard Plain Basin LAS is isolated from overlying land uses by the laterally extensive aquitard (silt and clay) layers that separate and confine the Hueneme and Fox Canyon Aquifer zones. The conceptual subsurface profile (shown in Figure 11) uses the geophysical survey (electric log) from the proximate (destroyed) City Well No. 13 to show the anticipated geology and aquifer zones beneath the Campus Park GRRP site. The aquifer zones shown in Figure 11 are discretely separated by clay layers that are laterally continuous and appear as marker beds in other well logs shown by Hopkins (2016) in Appendix D, Plates 3 and 4. The significance of the highly confined condition that results from the discretely layered aquifer system is that wells located in close proximity (50 feet apart) but producing from different aquifer layers, do not have hydraulic connectivity with each other (no interference).

Recharge into the LAS will store water in aquifer zones that receive significantly less groundwater recharge than the UAS because of the regional confined aquifer conditions. The UAS readily receives groundwater recharge derived from natural percolation of rainwater and Santa Clara River flows in the Oxnard Forebay Basin, as well as from river flow diversions into the engineered recharge facilities operated by UWCD.

14.1.1 Other Existing or Proposed GWRS Project that Could Impact the ASR

There are no other planned groundwater recharge projects in the vicinity.

14.1.2 Cumulative Impact on Water Quantity and Quality With and Without the Proposed GWRS Project

The water quality in the aquifer zones that will be used for replenishment in the LAS was previously described in Chapter 12. The groundwater is typically a calcium sulfate-barcarbonate chemical character with a TDS concentration of approximately 1,000 mg/l. Water quality degradation has been occurring in the overdrafted basin and results from poorer quality groundwater seeping out of the fine-grained silt and clay layers that are interbedded with the sand and gravel aquifer zones along with seawater intrusion. Without the project, regional groundwater quality will continue to degrade largely as a result of these 2 mechanisms.

With the project, the regional and local water quality impacts are beneficial. The regional benefit occurs when the aquifer is replenished and the groundwater levels rise. The rising water levels lessen any landward gradient and effectively slow the rate of seawater intrusion in the aquifer zones used for storage. This regional benefit remains until the stored volume is entirely removed. After removal there is no impact, in that the groundwater levels return to pre-recharge conditions.

The localized benefit to water quality will occur from flushing and mixing with the superior water quality of the purified water. Any water left behind will blend with the local native groundwater and improve its quality for downgradient users.

14.2 Predicted Recycled Water Retention Time

As detailed previously, the retention time is fully controlled by the City because of the ASR operation. The minimum retention time will be 3.1 months but can vary specifically as chosen by the City as long as all pathogen credit requirements are met.

14.3 Recycled Water Contribution

As there is no proposed dilution, the recycled water contribution (RWC) is 1.0, or 100 percent.

14.4 Antidegradation Assessment – Predicted Groundwater Quality Post Recharge and Utilization of Available Assimilative Capacity of Basin

14.4.1 MCLs, Secondary MCLs, NLs, and CECs

As detailed in WRD (2013), the purified recycled water from an AWPF is expected to improve groundwater quality and thus improve the assimilative capacity. Demonstration of such improved water quality, comparing the water quality at the proposed recharge locations with the water quality of the finished water from the AWPF, has not yet been done. Such work will be done as detailed in Section 17.

14.4.2 Recharge of Purified Water and Groundwater Chemistry Concerns

The LARWQCB has requested more information regarding the change in groundwater chemistry that can result from injection of a purified water. The following perspective comes from OCWD (2014).

- The finished water from Groundwater Replenishment System (GWRS) is stabilized prior to injection via decarbonation and lime addition. Initially the target pH was set at 9.0, but this has been progressively reduced to 8.0 in an effort to mitigate arsenic mobilization while also maintaining pipeline integrity. Ambient groundwater pH is approximately 7.5, and previous literature indicates elevated pH in laboratory experiments can mobilize certain arsenic species. More recent laboratory experiments conducted by Stanford University on behalf of OCWD have shown pH to be a secondary factor in mobilization behavior, with the relatively poorly-buffered finished GWRS water rapidly taking on the pH of the soil column. The effect of reducing the GWRS finished water pH on field-observed arsenic mobilization has been inconclusive to date.

- The literature indicates that low alkalinity and low ionic strength of the finished water may alter the surface charge of aquifer mineral surfaces, affecting arsenic sorption. However, recent laboratory experiments conducted by Stanford University on behalf of OCWD have indicated that neither of these parameters is of significant importance in shallow unconfined aquifer sediments collected near OCWDs recharge area;

instead the concentration of divalent cations, primarily magnesium and secondarily calcium, have been the most important inorganic controls on arsenic desorption.

- The high oxidation reduction potential (ORP) of the finished water may affect the oxidation state of arsenic and increase its solubility or release it via the oxidation of host minerals (e.g., iron sulfides) in the aquifer. This phenomena has been observed at some ASR project sites. In a second phase of work, Stanford University is currently conducting laboratory experiments on the addition of GWRS finished water to deep aquifer sediments collected from a geochemically reducing environment targeted for potential future injection.

- Field observations indicate a complex, non-linear relationship between the proportional GWRS water in the subsurface and resulting arsenic mobilization, governed by significant spatial and temporal variability. The majority of monitoring wells showing GWRS arrival demonstrate little or no mobilization of arsenic. A majority of those wells showing mobilization behavior have resulting arsenic concentrations below levels of regulatory concern (i.e., the 10 ug/L MCL) and/or have shown declining trends after an initial increase.

As part of this project, it is proposed to pilot test the ASR system and measure the impacts. The pilot test would include detailed monitoring of intrinsic tracers (dissolved minerals) as summarized in Section 17.

Because of the ASR operation, injected water will be extracted for both potable and non-potable reuse applications. If there are groundwater chemistry changes that are of public health significance for drinking water, the extracted water can be used exclusively for non-potable applications.

14.5 Impact of Groundwater Recharge Project on Contaminant Plumes

Groundwater recharge projects that utilize surface water spreading or injection in an unconfined groundwater basin can potentially effect the movement or cause movement of existing groundwater contamination. A preliminary search of the State operated GeoTracker web site indicated that there are 4 leaky underground storage tank sites located within 2,000 feet of the Campus Park site. The contamination was either contained in the soil or found in the shallow semi-perched aquifer zone which is isolated from the underlying Oxnard Aquifer by an extensive clay layer. The aquifer zones targeted by the ASR recharge project are isolated by multiple clay layers and aquifer zones beneath the semi-perched aquifer and prevent the project from having a potential impact on shallow groundwater contamination. Furthermore, all 4 sites have been remediated and are closed.

15.0 PROPOSED MONITORING AND REPORTING PROGRAM

This proposed monitoring and reporting program (MRP) was developed to conform to the DDW groundwater recharge regulations (CDPH, 2014).

15.1 General Monitoring Provisions

The following are general monitoring provisions:

- The City proposes to monitor the following according to the manner and frequency specified in this MRP:
  - Influent flow rate and quality to the AWPF.
  - AWPF finished water flow rate and quality.
  - Receiving groundwater quality, both background monitoring and monitoring after start of recharge project.
  - Production well (ASR wells) flow rate and quality.
- Compliance with the requirements of the LARWQCB WDRs will be evaluated based on the analytical monitoring data. Monitoring reports will include, but not be limited to, the following:
  - Analytical results.
  - Location of each sampling station where representative samples can be obtained, including a map that clearly identifies the locations of all injection wells, monitoring wells, and production wells (detailed in Hopkins, 2016).
  - Analytical test methods used and the corresponding method reporting limits (MRLs).
  - Name(s) of the laboratory that conducted the analyses.
  - Copy of the laboratory certifications by the DDW's Environmental Laboratory Accreditation Program (ELAP).
  - Quality assurance and control information.

15.1.1 Sampling and Analytical Protocols

Though not required to be included in the monitoring reports unless specifically requested by DDW or the LARWQCB, the City will have in place sampling protocols including procedures for handling, storing, testing, and disposing of purge and decontamination waters generated from sampling events.

For groundwater monitoring, the sampling protocols will outline the methods and procedures for: measuring water levels; purging wells; collecting samples; decontaminating equipment; containing, preserving, and shipping samples; and maintaining appropriate documentation.

The samples will be analyzed using analytical methods described in 40 CFR Part 141; or where no methods are specified for a given pollutant, by methods approved by the DDW, LARWQCB, and/or SWRCB. The City will select the analytical methods that provide MRLs lower than the limits prescribed in the WDR or as low as possible that will provide reliable data.

The City will instruct its contract laboratories to establish calibration standards so that the MRLs (or its equivalent if there is a different treatment of samples relative to the calibration standards) are the lowest calibration standard. At no time will analytical data derived from extrapolation beyond the lowest point of the calibration curve be used.

For all bacterial analyses, sample dilutions will be performed so the range of values extends from 1 to 800. The detection methods used for each analysis will be reported with the results of the analyses.

15.1.2 QA/QC Procedures

The LARWCB, DDW and the SWRCB Quality Assurance Program, may establish MRLs in any of the following situations:

- When the pollutant has no established method under 40 CFR 141.
- When the method under 40 CFR 141 for the pollutant has a MRL higher than the limit specified in the WDR.
- When the City proposes to use a test method that is more sensitive than those specified in 40 CFR Part 141.

For regulated constituents, the laboratory conducting the analyses will be certified by ELAP or approved by the DDW, LARWQCB, and/or SWRCB for a particular pollutant or parameter.

Samples will be analyzed within allowable holding time limits as specified in 40 CFR Part 141. All QA/QC analyses will be run on the same dates that samples are actually analyzed. The City will retain the QA/QC documentation in its files and make those files available for inspection and/or submit them when requested by the LARWQCB or the DDW. Proper chain of custody procedures will be followed and a copy of this documentation will be submitted with the quarterly report.

15.1.3 Unregulated Chemical Procedures

For unregulated chemical analyses, the City will select methods according to the following approach:

- Use drinking water methods, if available.
- Use DDW-recommended methods for unregulated chemicals, if available.
- If there is no DDW-recommended drinking water method for a chemical, then City staff will utilize the method that results in the lowest MRL for that chemical.
- If there is more than a single USEPA-approved method available, use the most sensitive of the USEPA-approved methods.
- If there is no USEPA-approved method for a chemical, and more than one method is available from the scientific literature and commercial laboratory, after consultation with DDW, use the most sensitive method.

- If no approved method is available for a specific chemical, the City's laboratory (or contract laboratory) may develop methods or use its own methods and will provide the analytical methods to DDW for review. Those methods may be used until DDW-recommended or USEPA-approved methods are available.

15.2 RO Permeate and AWPF Finished Water Monitoring Requirements

CDPH (2014) outlines a number of monitoring requirements for various process parameters and constituents that can determine performance of the system and compliance of the AWPF finished water in relation to the WDR. Section 60320.201 of CDPH (2014) states the following general requirements by process:

RO:

- On-going performance monitoring (EC or TOC) that indicates when the process has been compromised.
  - Online monitoring of EC in the RO permeate is proposed for this project, and the measurement of EC removal across RO will be determined at the AWPF.
  - DDW has requested that TOC monitoring also be used to determine TOC reduction across RO. Oxnard will install TOC metering upstream and downstream of the RO process.
- Minimum of one (1) form of continuous monitoring as well as associated surrogate and/or operational parameter limits and alarm settings that indicate when the integrity has been compromised.
  - As listed above, the RO permeate EC and log removal of EC across RO will be continuously monitored. The log removal of EC is a conservative surrogate for pathogen removal. Once the initial background log reduction of EC is established, a level below the background noise will be alarmed to indicate a reduction in RO performance. DDW, in a letter dated 12/5/2016, recommended setting alarm points similar to OCWD, with a blended EC target of 95 uS/cm and an individual train EC target of 110 uS/cm. As noted above, the baseline EC in the RO permeate will first be monitored before settling on specific EC targets.
  - As listed above, DDW has recommended the use of TOC as an additional monitoring method for RO performance. TOC meter(s) will be installed by the City.

Advanced Oxidation:

- Perform an occurrence study on municipal wastewater that includes indicator compounds and select a total of at least nine indicator compounds, with at least one from each of the functional groups. Or, as an alternative, demonstrate 0.5-log reduction of 1,4-dioxane by the AOP (in this case, UV AOP).
  - Demonstration testing of 1,4-dioxane destruction by AOP was performed at startup and was documented previously in this report.

- Occurrence study protocol, as well as subsequent results and chosen indicator compounds should be submitted for DDW review and approval.
  - 1,4-dioxane demonstration work was done in lieu of this requirement.
- During full-scale operation, the surrogate and or/operational parameter identified should be continuously monitored.
  - As detailed here, demonstration testing was done to show a correlation between the existing control philosophy (NDMA LRV) and 1,4-dioxane destruction.
- Monthly (grab or composite) samples representative of the finished water of the advanced treatment process will be analyzed for contaminants having MCLs and notification levels (NLs). After 12-consecutive months with no results exceeding MCL or NL, a reduction in monitoring frequency can be applied for (minimum quarterly). Monitoring conducted in this subsection can be used in lieu of monitoring (for the same contaminants) in CDPH (2014), Sections 60320.212 and 60320.220.

Table 27 provides more detail on the key analytical monitoring requirements specified in the DDW regulations (CDPH, 2014) as they pertain to the direct injection of purified water. This summary will serve as the basis for the monitoring and testing recommendations set forth within this MRP.

15.3 AWPF Influent Monitoring Requirements

OWTP effluent is the feed to the AWPF. Monitoring of OWTP quality allows for a better understanding of AWPF performance. OWTP effluent will be monitored in accordance with the current NPDES permit and based upon the Enhanced Source Control Program (Appendix A).

For this potable reuse project, recommended minimum monitoring of OWTP effluent is shown below in Table 28.

15.4 Advanced Treatment Online Monitoring

Online monitoring of process performance is critical to maintain the proper barrier to pathogens and trace pollutants. Table 9, presented earlier in this report provides information on the proposed monitoring and response procedures to produce high quality water and the necessary response retention time.

15.5 Reporting Requirements

The reporting requirements included in this section are proposed requirements and not the final requirements. The final reporting requirements for IPR will be specified in the revised Order.

Table 27 Master Table for Analytical Monitoring Requirements Required by CDPH (2014)
Advanced Water Purification Facility
City of Oxnard

Treatment Process	Parameter	Location		Frequency	Further Information	CDPH (2014) Reference
		Influent to Process	Effluent from Process			
RO	Electrical Conductivity	X	X	Continuous	Effluent concentration and log reduction.	60320.201 (b)
	Total Organic Carbon	X	X	Weekly (24-hour composite)	Effluent concentration only. TOC<0.25 mg/L 95% of the time for first 20 weeks. TOC<0.5 mg/L thereafter. City will be installing online TOC meters influent and effluent to RO.	60320.201 (b) / 320.218 (a)
UV AOP	1,4-dioxane	X		One-Time	Seeding and destruction of 1,4-dioxane, ≥ 0.5-log.	60320.201 (d)
	NDMA LRV control with UVI/Q inspections		X	Continuous	NDMA LRV based control system correlates well with 1,4-dioxane destruction, NDMA destruction, and pathogen disinfection	60320.201 (e)
	MCLs, NLs (Inorganics, Radionuclides, Organics, Disinfection By-Products, Lead and Copper)		X	Monthly for 12 months, then transition to Quarterly	Contaminants with MCLs and NLs.	60320.201 (i) / 60320.212 (a)
	Secondary MCLs		X	Yearly[2,3]	Secondary DW MCLs defined in Table 13.	60320.212 (c)
	CECs		X	Annually	CECs defined in Table 19.	60320.220 (d)
	Nitrogen Compounds		X	2 x week, 3 days apart	TN<10 in RO finished water.	60320.210 (a)
	Priority Toxic Pollutants		X	Quarterly	Chemicals listed in 40 CFR Part 131.38.	60320.220
	Chemicals analyzed as part of Source Control		X	Annually	Appendix A	60320.220 & 60320.206
Monitoring Wells		All Monitoring Wells		2 background samples before operation followed by Quarterly Samples	Chemicals listed in 40 CFR Part 131.38. Secondary DW MCLs. Total Nitrogen, nitrate, nitrite. Additional contaminants named by the Department.	60320.220 / 60320.226

Table 28 Influent Monitoring Requirements Advanced Water Purification Facility City of Oxnard			
Constituents	**Units**	**Type of Sample**	**Minimum Frequency of Analysis**
Total Flow	mgd	Online Recorder	Continuous(1)
pH	--	Online Recorder	Continuous(1)
Turbidity	NTU	Online Recorder	Continuous(1)
TSS	mg/L	24-hour comp	Daily
TDS	mg/L	24-hour comp	Daily
BOD_5, 20°C	mg/L	24-hour comp	Weekly
TOC	mg/L	24-hour comp	Weekly
EC	µS/cm	Online Recorder	Continuous(1)
NDMA	ng/L	Grab	Monthly

Notes:

(1) For those constituents that are continuously monitored, the City will report the monthly minimum, maximum, and daily average values.

15.5.1 Report Submittals

The City will submit the required compliance monitoring reports, as outlined in the following paragraphs to the SWRCB's GeoTracker database and to the DDW by the dates listed in Table 29.

Table 29 Summary of Compliance Report Submittals and their Due Dates Advanced Water Purification Facility City of Oxnard		
Report	**Description**	**Due**
Occurrence / Surrogate Study Report	Provide summary of occurrence study and subsequent surrogate monitoring effectiveness.	60 days after initial 12-months of monitoring during full-scale operation.
Quarterly Monitoring Reports	Provide discussion of previous quarter's analytical results and graphical and tabular summaries of monitoring data (see detailed description below).	May 15 (for Jan – Mar) Aug 15 (for Apr – Jun) Nov 15 (for Jul – Sep) Feb 15 (for Oct – Dec)
Annual Summary Report	Provide discussion of previous year's analytical results and graphical and tabular summaries of monitoring data (see detailed description below).	April 15 (for previous year).

Table 29 Summary of Compliance Report Submittals and their Due Dates Advanced Water Purification Facility City of Oxnard		
Report	**Description**	**Due**
Operations, Maintenance and Monitoring Plan	Description of operation, maintenance, and monitoring activities related to the AWPF.	Initial prior to operation Amended: After 6 months of operation.
Five-year Engineering Report	Provide and update to the Engineer's Report.	Every 5th year from date of approval of this Engineer's Report.
Notes: (1) All reports will be submitted to SWRCB's GeoTracker as well as to the DDW.		

15.5.2 Requirements for Reports

15.5.2.1 Analytical Reporting Details

For the purposes of reporting compliance with numerical limitations, analytical data will be reported using the following reporting protocols:

- Sample results greater than or equal to the MRL must be reported 'as measured' by the laboratory (i.e., the measured chemical concentration in the sample).
- Sample results less than the MRL, but greater than or equal to the laboratory's method detection limit (MDL), will be reported as "Detected, but not Quantified", "DNQ", or "J". The laboratory will write the estimated chemical concentration of the sample next to "DNQ" or "J."
- Sample results less than the laboratory's MDL will be reported as "Non-Detected," or ND.

If the City (or their consultants/contractors) samples and performs analyses (other than for process/operational control, startup, research or equipment testing) on any sample more frequently than required in this MRP using approved analytical methods, the results of those analyses will be included in the report. The results will be reflected in the calculation of the average used in the demonstrating compliance with average effluent limitations.

The quarterly report will be prepared by an engineer licensed in the State of California and experienced in the fields of wastewater treatment and public water supply.

The LARWQCB may request supporting documentation, such as daily logs of operations.

15.5.2.2 Occurrence / Surrogate Study Report

As detailed in Section 17, the performance of the system will be documented at startup, including the use of online surrogates for performance monitoring.

Within 60-days after completing the initial 12-months of monitoring during the full-scale operation, the City will submit a report to the DDW and LARWQCB that includes:

- The results of combined chlorine destruction monitoring across the UV AOP.
- The results on online EC reduction across RO.
- The results on online measurements of UV intensity and UVT.
- The results of MF DIT results and turbidity compliance.
- A description of actions taken, or those that would be taken, if the indicator compound removal did not meet the associated design criteria, the continuous surrogate monitoring failed to correspond to the indicator compound removal percentage, or the surrogate and/or operation parameter established was not met.

15.5.2.3 Quarterly Report

The quarterly compliance monitoring reports will, at a minimum, include the following information:

- The volume of recycled water used for non-potable and potable reuse applications. If no recycled water was used/spread/injected, the report shall so state.
- The date and time of all sampling and analyses.
- All analytical results of samples collected during the monitoring period, as listed in previously in this Section.
- Records of any operational problems, plant upset, and equipment breakdowns or malfunctions and any diversion(s) of off-specification recycled water and the location(s) of final disposal.
- Discussion of compliance, non-compliance, or violation of requirements.
- All corrective or preventative action(s) taken or planned with schedule of implementation, if any.
- Certification by the City that no groundwater for drinking water purposes has been pumped from wells within the boundary representing the greatest of the horizontal and vertical distances reflecting 3.1 months of RRT.
- Verification of compliance with the 20-week running average TOC in numerical graphic formats.
- Monitoring results associated with the evaluation of pathogenic microorganism removal as described in Section 5 of this Engineering Report.

15.5.2.4 Annual Report

The annual compliance monitoring reports will, at a minimum, include the following information:

- The volume of purified water used for non-potable and potable reuse applications. If no recycled water was used/spread/injected, the report shall so state.
- Tabular and graphical summaries of the monitoring data (influent, recycled water, and groundwater) obtained during the previous calendar year.
- A summary of compliance status, and for any non-compliance, a description of:
  - The date, duration, and nature of the violation.
  - A summary of any corrective actions and/or suspensions of surface and sub-surface application of recycled water resulting from a violation.
  - If uncorrected, a schedule for and summary of all remedial actions.
- Information pertaining to the vertical and horizontal migration of the recharge water plume.
- Observed trends in the monitoring wells.
- DDW drinking water quality data for the nearest domestic water supply well.
- A description of any changes in the operation of any unit processes or facilities.
- A description of any anticipated changes, along with an evaluation of the expected impacts of those changes on subsequent unit processes or facilities.
- A list of the analytical methods used for each test and associated laboratory quality assurance/quality control procedures; the report will identify the laboratories used by the City to monitor compliance with the WDR, their status of certification and provide a summary of proficiency test.
- A summary of measures taken by the City to comply with wastewater source control program and the effectiveness of the implementation measures.
- Evaluation of the ability of the City to comply with all regulations and provisions.
- List of current operating personnel, their responsibilities, and their corresponding grade of certification.

The annual report will be prepared by an engineer licensed in the State of California and experienced in the fields of wastewater treatment and public water supply.

15.5.2.5 Operations, Maintenance and Monitoring Plan

The Operations, Maintenance, and Monitoring Plan (OMMP) has been prepared under separate cover (KEH (2015)). The OMMP describes:

- Operation and control methodologies of the facility.
- Routine maintenance procedures.

- The monitoring and reporting plan (as included herein).
- Analytical methods for constituent analysis.

As detailed in Section 16, the OMMP needs to be updated prior to operation for potable water reuse. Looking forward, after 6-months of optimizing treatment processes during actual operation, the OMMP will be further updated and amended and will be submitted to the SWRCB's GeoTracker.

15.5.2.6 Five-Year Report

A five-year Engineering Report update will address any project changes and will include, but not be limited to:

- Evidence that the requirements associated with retention time in Section 60320.108, if applicable, and Section 60320.124 of CDPH (2014) have been met.
- A description of any inconsistencies between previous groundwater model predictions and the observed and/or measured values. For this requirement, the City will summarize the groundwater flow and transport including injection and extraction operations for the project during the previous five calendar years. This summary will also use the most current data for the evaluation of the transport of recycled water; such evaluations will include, at a minimum, the following information:
  - Total quantity of water injected into each major aquifer.
  - Estimates of the rate and path of flow of the injected water within each major aquifer.
  - Projections of the arrival time of the recycled water at the closest extraction well and the percent of recycled water at the wellheads.
  - Clear presentation on any assumptions and/or calculations used for determining the rates of flow and for projecting arrival times.
  - A discussion of the underground retention time of recycled water, a numerical model, or other methods used to determine the recycled water contribution to each aquifer.
  - A revised flow and transport model to match actual flow patterns observed within the aquifer if the flow paths have significantly changed.
  - Revised estimates, if applicable, on hydrogeologic conditions including the retention time and the amount of the recycled water in the aquifers and at the production well field at the end of that calendar year. The revised estimates will be based upon actual data collected during that year on recharge rates (including recycled water, native water, and potable water), hydrostatic head values, groundwater production rates, basin storage changes and any other data needed to revise the estimates of the retention time and the amount of the recycled water in the aquifers and at the production well field. Significant differences, and the reasons for such differences, between the original

estimates presented in the Engineer's Report, and the revised estimates, will be clearly presented. Additionally, the City will use the most recently available data to predict the retention time of recycled water in the substance.

The 5-year report will be prepared by an engineer licensed in the State of California and experienced in the fields of wastewater treatment and public water supply.

16.0 GENERAL OPERATIONS PLAN

Details of the AWPF operation, including chemical use and complimentary process details are provided in the Operations and Maintenance Management Plan (OMMP, KEH, 2015).

The DDW commented on this OMMP on February 19, 2015 (DDW, 2015); providing the following important comments, followed by responses from the City on April 14, 2015 (Oxnard, 2015). Prior to operational for potable water reuse, the OMMP needs to be updated to reflect these comments and recommended changes to system operation and monitoring (e.g., TOC implementation as one example).

- **DDW Comment (General)-** DDW "strongly encourages OWD to train additional staff on the operation of the AWPF to allow more flexibility in staffing…OWD shall not put an unnecessary strain on existing drinking water operations staffing…DDW requests more detail on the recycled water distribution staffing." **City Response:** The City is cross-training OWTP staff to assist the two current AWPF operators. The City also intends to limit AWPF operation, at this time, "to daytime hours when dedicated operators are manning the facility." The City intends to "add another position for a dedicated AWPF operator as well as increase Water Quality and Cross Connection staffing, by two."
- **DDW Comment (on IPR) -** "Conductivity will have a water quality trigger level at greater than 60 umho/cm. Will there be an alarm triggered instantly if this level is sustained for a period of time? What is the response time for the confirmation sample? Are operators able to respond afterhours quickly? What would their response time be?" **City Response:** "The SCADA system will be programmed to have a water quality conductivity levels above 60 umho/cm trigger an alarm after a sustained period of 10 minutes. If the AWPF is unmanned when an alarm is triggered, operators at the OWTP would respond. The OWTP has operates 24-hours per day that will be trained to respond to AWPF alarms. The response times would be less than 30 minutes. **Additional Comments based upon this Engineer's Report:** The recommended approach needs to be incorporated into the OMMP.
- **DDW Comment -** "The UV system is expected to achieve 0.9-log NDMA destruction. DDW comments on previous studies which show this corresponds to an EEO of approximately 0.20 kWhr/kgal." **City Response:** Comment Noted. **Additional Comments based upon this Engineer's Report:** Extensive startup work has been performed and documented in this report which illustrate the proper UV system

control to meet NDMA targets with a high degree of reliability. The recommended approach needs to be incorporated into the OMMP.

- **DDW Comment -** "Number four on the list of parameters monitored by SCADA is conductivity monitoring of the RO permeate. For IPR applications, DDW strongly encourages OWD to use an online TOC analyzer." **City Response:** "An online TOC analyzer will be added to the AWPF." **Additional Comments based upon this Engineer's Report:** At this time, no TOC analyzer has been added to the AWPF. The City intends to install a TOC meter, and the OMMP must then be amended to include TOC monitoring and calibration.
- **DDW Comment -** "Please explain what is meant by dose and how this set point is calculated. OMWD should propose a minimum EED." **City Response:** "A minimum EED will be identified…". **Additional Comments based upon this Engineer's Report:** See comment above regarding startup testing of the UV system. The recommended approach needs to be incorporated into the OMMP.
- **DDW Comment -** "The set point for the UV system should be…set [to] a level to always achieve 0.9-log NDMA destruction, which in previous studies corresponds to an EED of approximately 0.2 kWhr/kgal." **City Response:** Comment Noted. **Additional Comments based upon this Engineer's Report:** See comment above regarding startup testing of the UV system. The recommended approach needs to be incorporated into the OMMP.
- **DDW Comment -** OWD shall submit more details on tracer studies, monitoring wells, etc. as they become available. Additionally, please propose a detailed procedure for monitoring leakage between aquifers." **City Response:** Comment noted, the City will provide requested information to DDW. **Additional Comments based upon this Engineer's Report:** No further information in this Engineer's Report.

In the event of a process failure that impacts water quality (potentially or confirmed), the decision making process for protection of public health, detailed in Section 7, will be followed.

17.0 STARTUP TESTING

17.1 DDW Testing Requirements

In discussions with DDW, the City's engineering team reviewed how this project will not use dilution water and will use 100 percent recycled water for recharge. Additionally, the groundwater hydrogeology analyzed within this report is basic, with no tracer work yet performed. As such, extensive testing has been done on the AWPF, as detailed in Sections 5 and 9. These results demonstrate the ability of the AWPF to meet all regulated water quality standards, including for chemical pollutants and for pathogen log reduction.

The single missing information that still must be gathered is the travel time of injected water as it pertains to nearby drinking water wells (detailed in Hopkins, 2016). The analysis within this report of groundwater movement is simplistic. While the analysis methods are conservative, demonstration of groundwater movement (speed and direction) is required. For the ASR project, the ASR well will be put into temporary operation to track the movement of the injected water. Finished water and water from all monitoring wells will be sampled weekly (at a minimum) for TDS, chloride, and sulfate. The time of transport with these intrinsic tracers will be compared to the estimated values and the necessary RRT documented within this report.

The results from the testing above will be submitted to DDW and the RWQCB for review and approval prior to IPR operation.

17.2 LARWQCB Testing Requirements

Several key items must be demonstrated in advance of potable reuse:

- **Background Groundwater Quality –** Upon completion of the monitoring wells, the City will perform sampling required for regulated drinking water projects and the requirements in the Basin Plan for bacteria, minerals, nitrogen, and taste and odor. This testing will be done twice for each groundwater monitoring location. Results will be compared to the AWPF finished water quality detailed in Section 9.
- **Groundwater Chemistry Impacts –** The LARWQCB is concerned about changes in groundwater chemistry that may occur due to the addition of purified water into the groundwater basin. The primary example of this concern is the release of bound arsenic as a result of changes in groundwater chemistry (as reviewed in Section 14 of this report). Upon completion of the initial recharge demonstration period and the response retention, the groundwater will be recovered and placed into the recycled water system for irrigation uses. Groundwater will be sampled weekly for laboratory testing for potential contaminants of concern including for pH, alkalinity, arsenic, magnesium, calcium, and iron sulfides. In addition, water analyses for general minerals, metals, and radionuclides will be conducted on the recovered groundwater toward the beginning, the middle, and the end of the recovery period to assess its suitability as a potable supply.

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LIST OF ACRONYMS

-A-	
ASR	Aquifer Storage and Recovery
AWPF	Advanced Water Purification Facility
-B-	
bgs	below ground surface
BOD	Biological Oxygen Demand
-C-	
CEC	Constituents of Emerging Concern
CEQA	California Environmental Quality Act
City	The City of Oxnard
CIUs	Categorical Industrial Users
CMWD	Calleguas Municipal Water District
CWC	California Water Code
-D-	
DDW	Division of Drinking Water
DIT	Direct Integrity Test
-E-	
EC	Electrical Conductivity
EDCs	Endocrine Disrupting Compounds
ELAP	Environmental Laboratory Accreditation Program
-F-	
FCGMA	Fox Canyon Groundwater Management Authority
-G-	
GRPs	Groundwater Recharge Projects
GRRP	Groundwater Replenishment Reuse Project
GWRS	Groundwater Replenishment System
-H-	
H_2O_2	Hydrogen Peroxide
-I-	
IPR	Indirect Potable Reuse
-L-	
LARWQCB	Los Angeles RWQCB
LAS	Lower Aquifer System
LASAN	LA Sanitation
LPHO	Low-Pressure High-Output
-M-	
MCLs	Maximum Contaminant Levels
MDL	Method Detection Limit
MF	Microfiltration
MRP	Monitoring and Reporting Program

MWDSC	Metropolitan Water District of Southern California
-N-	
ND	Non-Detected
NLs	Notification Levels
NOV	Notice of Violation
NWRI	National Water Research Institute
-O-	
OMMP	Operations, Maintenance, and Monitoring Plan
ORP	Oxidation Reduction Potential
OVMWD	Ocean View Municipal Water District
OWTP	Oxnard Wastewater Treatment Plant
-P-	
PDT	Pressure Decay Test
PEIR	Program Environmental Impact Report
PHWA	Port Hueneme Water Authority
POTW	Publicly-Owned Treatment Works
PPCP(s)	Pharmaceuticals and Personal Care Products
-Q-	
QAPP	Quality Assurance Project Plan
-R-	
RO	Reverse Osmosis
ROP	RO Permeate
ROSA	Reverse Osmosis System Analysis
ROWD	Report of Waste Discharge
RRT	Response Retention Time
RWC	Recycled Water Contribution
RWQCB	Regional Water Quality Control Board
-S-	
SCVWD	Santa Clara Valley Water District
SIU(s)	Significant Industrial User(s)
SNMP(s)	Salt Nutrient Management Plan(s)
SWP	State Water Project
SWRCB	State Water Resources Control Board
-T-	
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TSS	Total Suspended Solids
TSP-SC	Technical Services Program – Source Control
TTO	Total Toxic Organics
-U-	
UAS	Upper Aquifer System
UV AOP	Ultraviolet Light and Hydrogen Peroxide

UVT	UV Transmittance
UWCD	United Water Conservation District’s
-W-	
WDR(s)	Waste Discharge Requirement(s)
WRD	Water Replenishment District
WRR	Water Recycling Requirement

APPENDIX A – INDIRECT POTABLE REUSE ENHANCED SOURCE WATER CONTROL AND COLLECTION SYSTEM MONITORING PROGRAM

APPENDIX A - LOCATED IN VOLUME 2

APPENDIX B – PRELIMINARY HYDROGEOLOGICAL STUDY REPORT, CITY OF OXNARD GREAT PROGRAM, CAMPUS PARK GROUNDWATER REPLENISHMENT AND REUSE PROJECT

APPENDIX B - LOCATED IN VOLUME 2

APPENDIX C - LOCATED IN VOLUME 2

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