FEBRUARY 2025

MONTEREY ONE WATER
PURE WATER MONTEREY
GROUNDWATER REPLENISHMENT PROJECT

Engineering Report
Volume II

PREPARED BY:

LWA LARRY WALKER ASSOCIATES
science | policy | solutions

TODD GROUNDWATER

Trussell

PREPARED FOR:

Monterey One Water

APPENDICES: VOLUME II

APPENDIX A

National Water Research Institute Independent Advisory Panel Reports

NATIONAL WATER RESEARCH INSTITUTE

Draft Final Report

of the October 21-22, 2013, Meeting of the

Independent Advisory Panel

for

Monterey Peninsula Groundwater Replenishment Project

Prepared for:

Monterey Regional Water Pollution Control Agency
5 Harris Court, Building D
Monterey, California 93940

January 7, 2014

DISCLAIMER

This report was prepared by an NWRI Independent Advisory Panel, which is administered by the National Water Research Institute (NWRI). Any opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes.

ABOUT NWRI

A 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

For more information, please contact:

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Gina Melin Vartanian, Editor

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ACRONYMS

AF	Acre foot
AI	Aggressiveness Index
AOC	Assimilable organic carbon
AOP	Advanced oxidation processes
AWTP	Advanced water treatment plant
BAF	Biologically active filtration
Cal-Am	California American Water Company
CCPP	Calcium Carbonate Precipitation Potential
CDPH	California Department of Public Health
CEQA	California Environmental Quality Act
CPUC	California Public Utilities Commission
CSIP	Castroville Seawater Intrusion Project
EIR	Environmental Impact Report
GWR	Groundwater replenishment
LSI	Langlier Saturation Index
MF	Microfiltration
MPWMD	Monterey Peninsula Water Management District
MRWPCA	Monterey Regional Water Pollution Control Agency
NWRI	National Water Research Institute
RO	Reverse osmosis
TDS	Total dissolved solids
UV	Ultraviolet light
WPA	Water Purchase Agreement

1. PURPOSE AND HISTORY OF THE PANEL

In 2013, the National Water Research Institute (NWRI)[1] of Fountain Valley, California, a 501c3 nonprofit, appointed local and national water industry experts to an Independent Advisory Panel (Panel) to provide expert peer review of the proposed Monterey Peninsula Groundwater Replenishment (GWR) Project being considered by the Monterey Regional Water Pollution Control Agency (MRWPCA)[2] and its project partner, the Monterey Peninsula Water Management District (MPWMD).[3]

The GWR project is expected to create a sustainable source of water supply by using highly-treated water from a new advanced water treatment plant (AWTP) to augment local drinking water aquifers. Specifically, the project involves developing and conveying highly-treated water from the AWTP to the Seaside Basin using a series of shallow (i.e., vadose zone) and deep injection wells. Once injected into the Seaside Basin, the treated water would mix with the groundwater present in the aquifers and be stored for future use.

This additional supply would replenish the aquifers and increase the yield of the Seaside Basin for local pumpers, including the primary pumper, California American Water Company (Cal-Am). The GWR project will be designed to provide 3,500 acre-feet (AF) per year of high-quality replacement water to Cal-Am for delivery to its customers in the Monterey District service area, thereby enabling Cal-Am to reduce its diversions from the Carmel River system by the same amount.

The Panel is tasked with reviewing the proposed GWR project and providing findings and recommendations on project alternatives, alternative evaluation, and associated bench and pilot studies. Examples of issues that the Panel may address include public health and safety, advanced water treatment design issues, permitting and regulatory requirements, and public outreach and advocacy.

The Panel is made up of four experts in areas related to GWR projects, such as engineering, regulatory criteria, public health, hydrogeology, and other relevant fields. Panel members include:

- George Tchobanoglous, PH.D., P.E., NAE, University of California, Davis (Davis, CA)
- Jean-François Debroux, Ph.D., Kennedy/Jenks Consultants (San Francisco, CA)
- Martin B. Feeney, P.G., CHG, Consulting Hydrogeologist (Santa Barbara, California)
- Michael P. Wehner, MPA, REHS, Orange County Water District (Fountain Valley, California)

Background information about the NWRI Panel process can be found in Appendix A, and brief biographies of the Panel members can be found in Appendix B.

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[1] http://www.nwri-usa.org/.

[2] http://www.mrwpca.org/.

[3] http://www.mpwmd.dst.ca.us/.

2. PANEL MEETING

A 2-day meeting of the Panel was held on October 21-22, 2013, at the administrative offices of MRWPCA in Monterey, California. This meeting represents the first time the Panel has met to review the proposed GWR project.

2.1 Background Material

Prior to the meeting, the following background material and reports were provided to the Panel:

a) Draft Memorandum dated May 7, 2013, from Phyllis Stanin, Principal Geologist/Vice President of Todd Engineers, to Bob Holden, Principal Engineer at MRWPCA, providing details on GWR project elements in support of the Environmental Impact Report (EIR) process.

b) Document dated May 30, 2013, and titled "NOTICE OF PREPARATION: Monterey Peninsula Groundwater Replenishment Project Environmental Impact Report."

c) Document dated August 21, 2013, that details the following from a bifurcation motion:
    - Findings Required for GWR Decision Pursuant to Settlement Agreement.
    - Procedural Schedule and Scope Pursuant to Settlement Agreement.

d) Letter dated October 10, 2013, to Mayor Jason Burnett of the City of Monterey (California) from Keith Israel, General Manager of MRWPCA, providing a list of key impediments to the timely completion of GWR.

e) Letter dated October 10, 2013, to Bob Holden, Principal Engineer at MRWPCA, from Derrik Williams, President of HydroMetrics Water Resources, Inc., that discusses the modeling completed in support of GWR project development efforts.

f) A schedule of GWR project tasks and responsible parties from June 2014 to August 2014.

2.2 Meeting Agenda

Staff from NWRI and MRWPCA collaborated on the development of the agenda for the Panel meeting, which is included in Appendix C. The agenda was based on meeting the following specific objectives:

- Develop a working understanding of the proposed GWR project.
- Identify proposed project strengths and areas where more information is needed.
- After the meeting, prepare a brief summary of project questions and obstacles for use by the GWR project team.

The majority of the meeting was devoted to presentations made by MRWPCA staff and the project team. Time was provided for the Panel to ask questions and engage in discussion following each presentation. The presentations included:

- Panel Charge
- Overview of the Project Partners (MPWMD and MRWPCA)
- Overview of Related and Planned Projects
- GWR Project
- Bench Testing
- Pilot Testing and Sampling Plan
- Product Water Conveyance
- GWR Project – Injection
- Public Outreach

Once the presentations were concluded, the Panel met in a closed session to discuss the information presented and address questions provided by MRWPCA and the project team. Before the meeting adjourned, the Panel prepared a report outline and drafted preliminary findings and recommendations, which have been expanded upon in this report.

2.3 Meeting Attendees

All Panel members attended this meeting with the exception of George Tchobanoglous. Other attendees included NWRI staff, MRWPCA staff, MPWMD staff, project team members, representatives from agency partners, and regulators. A complete list of Panel meeting attendees is included in Appendix D.

3. OBSERVATIONS AND FINDINGS

The principal observations and findings derived from the material presented and discussed during the meeting are provided below. They are organized under the following categories:

- General
- Project Goals and Outcomes
- Schedule
- GWR Source Waters
- Treatment
- Monitoring
- Pilot Study
- Conveyance
- California Environmental Quality Act (CEQA)
- Groundwater Items
- Brine
- Public Outreach

3.1 General

The Panel compliments MRWPCA and the project team for their excellent presentations, which were well-prepared and professional. The Panel also appreciated the background documents provided by MRWPCA.

3.2 Project Goals and Outcomes

- It is critical that MRWPCA understand all the criteria to allow the California Public Utilities Commission (CPUC) to approve the Water Purchase Agreement (WPA). The Panel requests that MRWPCA provide its interpretation of the criteria in the settlement agreement. The interpretation should be accompanied by a plan, including a schedule to meet each criterion. It is not appropriate for the Panel to develop this interpretation.

  The Panel can evaluate MRWPCA's plan and progress in meeting these criteria. Once all the criteria are met, the Panel can provide a letter stating that the Panel believes MRWPCA has met the criteria as interpreted by MRWPCA.

- The Panel agrees that the GWR project is consistent with integrated water management planning as described in the California Water Plan.

- The Panel concurs that a draft engineer's report should be developed and incorporated into the schedule, as well as reviewed by the Panel. Allowing the California Department of Public Health (CDPH) to review the draft report would help in their conceptual approval of the project (which is necessary to satisfy CPUC's WPA approval).

- The Panel is concerned that the project (including conveyance and injection costs) could be greater than $3,000 per AF. Preliminary estimates may be useful.

- The variability and sustainability of influent flows are of concern in light of additional conservation efforts, impacts of higher rates, inflow and infiltration, agricultural practices, and so on. Additional analysis, including seasonal flows, would be helpful in determining future flows. A breakdown between Salinas and the peninsula may be useful. Also, what is the likelihood of acquiring rights to the identified sources?

- In a time of shortage, how would water be allocated between the Castroville Seawater Intrusion Project (CSIP) and GWR obligations?

- The Panel requests information on flow consistency and justification between source water availability, treatment, conveyance, and injection (e.g., why is injection well capacity being doubled?). The Panel recognizes that some items are upsized. It is possible to upsize all the items by similar amounts or to present a plan for upsizing components and long-term usage.

3.3 Schedule

- The Panel is aware of the tight schedule that MRWPCA is trying to meet. MRWPCA should coordinate Panel meetings with the review of GWR project tasks and milestones to expedite this schedule.

- The Panel would find it useful to have a numbered list of tasks, with a paragraph describing each task and Gantt chart to better understand how elements tie together, what the milestones are, what review is needed, and so on. This format will facilitate the Panel's review of MRWPCA's efforts related to GWR project tasks.

3.4 GWR Source Waters

- Regarding the presentation on the Blanco Drain, the Panel does not see a clear use of this water resource. MRWPCA should develop a plan for how Blanco Drain, if needed, is incorporated into the GWR project. In addition, a clear use for the 1/4 Reclamation Ditch water is not apparent.

- Regarding wastewater flows, is there a projection on when the reduction in flows will flatten out? Flows may drop more with increased water rates.

3.5 Treatment

- The Panel believes that ozone-biologically active filtration (BAF)-microfiltration (MF)-reverse osmosis (RO)-ultraviolet-based advanced oxidation processes (UV/AOP) to be appropriate to treat all sources that have gone through secondary treatment.

- To maintain appropriate levels of total dissolved solids (TDS) in the irrigation water, consider sending advanced treated water to the tertiary pond to control salinity if high TDS source water is sent to the plant headworks.

- MRWPCA should evaluate the possibility of the advanced treatment plant being larger than 3,500 AF. For example, a larger plant can treat water for the growers (rather than for economic growth) and could treat periods of high flows. Additional capacity in a larger advanced treatment plant could be used to offset the reduced availability of source water during dry years and droughts.

- Is the priority for source water treatment the following: Agricultural wash, Salinas stormwater, peninsula stormwater, 1/4 Reclamation Ditch, and Blanco Drain? A priority for the source waters should be established for the project.

- Is there a plan to stabilize the high-purity water before conveyance and injection? Is there a target finished water quality related to stability (e.g., Langlier Saturation Index [LSI], Aggressiveness Index [AI], and Calcium Carbonate Precipitation Potential [CCPP])? The appropriate stability index should be matched to the planned infrastructure materials and the prevention of metals mobilization in the aquifer.

- Is there an intent to maintain a chlorine residual in the finished water pipeline? The wells may perform better, especially if significant amounts of assimilable organic carbon (AOC) are present in the finished water.

3.6 Monitoring

- What is the rationale for quarterly monitoring of the source waters? Will the wet periods or specific crop washing be captured sufficiently?

- Regarding source water monitoring, the Panel recommends that MRWPCA provide a proposed list of constituents to change from quarterly monitoring to either annual monitoring or no monitoring. In addition, a brief narrative on the rationale to remove the constituents would be helpful for the Panel's review. The Panel would review the list and develop recommendations for submission to CDPH.

- Regarding monitoring for the pilot study, the Panel recommends that MRWPCA provide the proposed monitoring scheme for the pilot study, including constituents, locations, frequency, and related information. A brief narrative providing the project team's rationale would be helpful.

3.7 Pilot Study

- The Panel looks forward to seeing the early results from the pilot study.

- Will the pilot study results be used to determine if ozone and/or BAF are needed? Is this a goal of the pilot study?

3.8 Conveyance

- Due to the treatment employed, the stability of the water will need to be addressed with regards to pipeline material and corrosion. A stabilized water will be important for groundwater injection.

3.9 California Environmental Quality Act (CEQA)

- The Panel was impressed with the thoroughness of the CEQA efforts and encourages MRWPCA to continue these efforts as the project moves forward.

3.10 Groundwater Items

- The stability of the water will need to be evaluated for both aquifer systems (the Paso Robles and Santa Margarita formations).
- The groundwater sampling list will be forthcoming for Panel review. The Panel concurs that the list should include ordnance-related compounds, including perchlorate.
- The location analysis seems well handled in balancing all the components. The hydraulic modeling investigations (particle tracking) supported the analysis.
- Some sensitivity analysis on the modeling could be conducted on the reduced thickness of the Santa Margarita formation as the formation is not uniform.
- Costs for wells need to include costs for above-ground well facilities.
- The EIR should consider noise and visual impacts of the above-ground appurtenances.
- Is the use of one monitoring well in the Paso Robles because of the known heterogeneity? It would be helpful to justify the use of only one monitoring well.
- The well exploration program should include cased-hole geophysics, such as induction and gamma logging.
- Regarding the stability of RO source water quality: How will finished water quality impact wells? How will chemical reactions with aquifer materials be evaluated? Is there a need for geochemical modeling?

3.11 Brine

- MRWPCA should develop a brine management plan that includes discharge, seawater desalination brine, GWR brine, blending of brines, diffuser redesign, and so on.

3.12 Public Outreach

- The Panel recognizes that public outreach is a critical component of the project.

- Outreach to growers will be an important consideration as the project moves forward.

- It will be important to work with project partners and to understand the roles of each of the partners.

- Continued coordination between project proponents and tours of the Orange County Water District's Groundwater Replenishment System will be useful and beneficial.

- The communication plan should be finalized in coordination with project partners.

- There is a need to develop a consistent vocabulary and message for various agency representatives as they discuss the project at public meetings.

- As the timeline moves towards the completion of the project, the need for outreach efforts will intensify.

- There is a need to develop a visitor program for pilot facilities. The ability for visitors to view the pilot facilities would be useful, as observed in Orange County and San Diego.

- The use of a website and social media tools should be maintained throughout the effort.

- The Panel recommends that progress with the outreach program be reviewed at future Panel meetings.

APPENDIX A: PANEL BACKGROUND

About NWRI

For over 20 years, NWRI – a science-based 501c3 nonprofit located in Fountain Valley, California – has sponsored projects and programs to improve water quality, protect public health and the environment, and create safe, new sources of water. NWRI specializes in working with researchers across the country, such as laboratories at universities and water agencies, and are guided by a Research Advisory Board (representing national expertise in water, wastewater, and water reuse) and a six-member Board of Directors (representing water and wastewater agencies in Southern California).

Through NWRI's research program, NWRI supports multi-disciplinary research projects with partners and collaborators that pertain to treatment and monitoring, water quality assessment, knowledge management, and exploratory research. Altogether, NWRI's research program has produced over 300 publications and conference presentations.

NWRI also promotes better science and technology through extensive outreach and educational activities, which includes facilitating workshops and conferences and publishing White Papers, guidance manuals, and other informational material.

More information on NWRI can be found online at www.nwri-usa.org.

About NWRI Panels

NWRI also specializes in facilitating Independent Advisory Panels on behalf of water and wastewater utilities, as well as local, county, and state government agencies, to provide credible, objective review of scientific studies and projects in the water industry. NWRI Panels consist of academics, industry professionals, government representatives, and independent consultants who are experts in their fields.

The NWRI Panel process provides numerous benefits, including:

- Third-party review and evaluation.
- Scientific and technical advice by leading experts.
- Assistance with challenging scientific questions and regulatory requirements.
- Validation of proposed project objectives.
- Increased credibility with stakeholders and the public.
- Support of sound public-policy decisions.

NWRI has extensive experience in developing, coordinating, facilitating, and managing expert Panels. Efforts include:

- Selecting individuals with the appropriate expertise, background, credibility, and level of commitment to serve as Panel members.
- Facilitating hands-on Panel meetings held at the project's site or location.

- Providing written report(s) prepared by the Panel that focus on findings and recommendations of various technical, scientific, and public health aspects of the project or study.

Over the past 5 years, NWRI has coordinated the efforts of over 20 Panels for water and wastewater utilities, city and state agencies, and consulting firms. Many of these Panels have dealt with projects or policies involving groundwater replenishment and potable (indirect and direct) reuse. Specifically, these Panels have provided peer review of a wide range of scientific and technical areas related water quality and monitoring, constituents of emerging concern, treatment technologies and operations, public health, hydrogeology, water reuse criteria and regulatory requirements, and outreach, among others.

Examples of recent NWRI Panels include:

- **Groundwater Recharge Scientific Study** for the LOTT Clean Water Alliance (WA)
- **Groundwater Replenishment System Program Review** for the Orange County Water District (CA)
- **Examining the Criteria for Direct Potable Reuse** for Trussell Technologies (CA) and WateReuse Research Foundation (VA)
- **Evaluating Potable Reuse** for the Santa Clara Valley Water District (CA)
- **Indirect Potable Reuse/Reservoir Augmentation Project Review** for the City of San Diego (CA)
- **BDOC as a Surrogate for Organics Removal in Groundwater Recharge** for the California Department of Health Services (CA)
- **Effluent Master Plan** for Tucson Water (AZ)
- **Groundwater Replenishment Project Review** for the Los Angeles Department of Water and Power (CA)

More information about the NWRI Independent Advisory Panel Program can be found on the NWRI website at http://nwri-usa.org/Panels.htm.

APPENDIX B: PANEL BIOGRAPHIES

GEORGE TCHOBANOGLOUS, PH.D., P.E., NAE

Professor Emeritus
University of California, Davis (Davis, CA)

For over 35 years, wastewater expert George Tchobanoglous has taught courses on water and wastewater treatment and solid waste management at the University of California, Davis, where he is Professor Emeritus in the Department of Civil and Environmental Engineering. He has authored or coauthored over 500 publications, including 22 textbooks and eight engineering reference books. Tchobanoglous has been past President of the Association of Environmental Engineering and Science Professors and currently serves as a national and international consultant to both government agencies and private concerns. Among his honors, he received the Athalie Richardson Irvine Clarke Prize from NWRI in 2003, was inducted to the National Academy of Engineers in 2004, and received an Honorary Doctor of Engineering degree from the Colorado School of Mines in 2005. In 2012, he received the first Excellence in Engineering Education Award from AAEE and AEESP. In 2013, he was selected as the AAEE and AEESP Kappe Lecturer. Tchobanoglous received a B.S. in Civil Engineering from the University of the Pacific, an M.S. in Sanitary Engineering from the University of California, Berkeley, and a Ph.D. in Environmental Engineering from Stanford University.

JEAN-FRANÇOIS DEBROUX, Ph.D.

Director, Advanced Technologies Group
Kennedy/Jenks Consultants (San Francisco, CA)

At Kennedy/Jenks Consultants, Jean Debroux serves as Director of the Advanced Technologies Group, which was formed to solve technologically challenging problems. Part of this effort includes performing pilot and field studies for regulated and emerging contaminants and evaluates the cost impacts of complying with Safe Drinking Water Act regulations. A water quality expert, Debroux has extensive experience and expertise working with water utilities and research organizations in water treatment and water reuse issues, and is an active member of the WateReuse Foundation, where he serves on the Research Advisory Committee. Debroux received a B.S. in Chemical Engineering from the University of South Florida, and both an M.S. in Environmental Engineering and Ph.D. in Civil Engineering from the University of Colorado, Boulder. In addition, he attended the Environmental Management Institute at Tufts University and has served as a Post-Doctoral Research Fellow and Lecturer at Stanford University and as a Research Fellow at Université de Poitiers, France.

MARTIN B. FEENEY, P.G., CHG
Consulting Hydrogeologist (Santa Barbara, California)

Martin Feeney has been a consulting hydrogeologist since 1997, providing hydrogeologic consulting services to water agencies, private industry, and engineering firms. Prior to this, he served as hydrogeologist at various consulting firms such as Balanced Hydrologics, Inc. and Fugro West, Inc., where he provided analysis of groundwater basins, developed groundwater flow and transport, and developed saline groundwater source for desalination plants, injection wells/artificial recharge programs, and underground storage tank site assessment and remediation. He has also been involved in numerous groundwater resources and water well projects throughout California, working for groups such as Monterey County, Salinas Valley, Santa Clara Valley Water District, Ventura County, and various others. Feeney received a B.S. in Earth Sciences from the University of California, Santa Cruz and an M.S. in Environmental Planning (Groundwater) from California State University.

MICHAEL P. WEHNER, REHS, MPA
Assistant General Manager
Orange County Water District (Fountain Valley, California)

Mike Wehner has over 40 years of experience in water quality control and water resources management. He has been with the Orange County Water District (OCWD) since 1991, currently serving as Assistant General Manager. Among his responsibilities, he directly manages the Water Quality and Technology Group, including Laboratory, Water Quality, Hydrogeology, Research and Development, and Health and Regulatory Affairs Departments. He is also involved with numerous aspects with the Groundwater Replenishment System (the nation’s largest IPR project), including providing technical guidance on treatment and quality, as well as managing monitoring programs for the purification facility and receiving groundwater. He was also manager of OCWD’s 8-year Santa Ana River Water Quality and Health Study, which evaluated the impact of using effluent-dominated river waters for groundwater recharge. Prior to joining OCWD, Wehner spent 20 years with the Orange County Health Care Agency, where he managed the Water Quality Control Section of Environmental Health. He is a Registered Environmental Health Specialist in California and is an internationally recognized expert in water quality, public health, and advanced water treatment processes, serving on expert panels in the United Kingdom, Australia, and Singapore, as well as for California and U.S. agencies and foundations. He received a Masters of Public Administration from California State University Long Beach and a B.S. in Biological Sciences from the University of California, Irvine.

APPENDIX C: MEETING AGENDA

NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel Meeting for Monterey Regional Water Pollution Control Agency on Monterey Peninsula Groundwater Replenishment Project

Preliminary Meeting Agenda

October 21-22, 2013

Location
Monterey Regional Water Pollution Control Agency
Administrative Offices
5 Harris Court, Bldg. D
Monterey, CA 93940
(831) 372-3367

On-Site Contacts:
Jeff Mosher (NWRI)
Cell: (714) 705-3722
Mike McCullough (MRWPCA)
Office: (831) 594-2597

Meeting Objectives:

- Develop a working understanding of the Proposed Groundwater Replenishment Project.
- Identify proposed project strengths and areas where more information is needed.
- After the meeting, prepare a brief summary of project questions and obstacles for use by the GWR team.

Monday, October 21, 2013

10:00 am	**Welcome and Introductions** - CDPH (Jan Sweigert) - RWQCB (Harvey Packard) - MPWMD (Dave Stoldt) - MRWPCA (Keith Israel)	Jeff Mosher, NWRI Mike Wehner, Panel
10:30 am	Panel Charge - Goals and Objectives - Panel Outcomes	Keith Israel, MRWPCA
10:45 am	Overview of Partners: MPWMD and MRWPCA	Larry Hampson, MPWMD and Bob Holden, MRWPCA
11:00 am	Overview of Related and Planned Projects - Monterey County Water Situation (Bob Holden) - Water Solutions (Larry Hampson) o Deep Water Desal, People's Desal, and Other Desal o Monterey Peninsula Water Supply Project (Desalination, ASR, GWR)	Bob Holden and Larry Hampson

11:30 am	Groundwater Replenishment Project (GWR) - Source Water Characterization - Quantities and Locations (Bob Holden) - Qualities (Gordon Williams) o Secondary, Tertiary, Ag Wash Water, Blanco Drain, Reclamation Ditch o Sampling Plan	Bob Holden
12:30 - 1:00 pm	**WORKING LUNCH**	
1:00 pm	Bench Testing - Secondary, Ag Wash water, Blanco Drain, and Secondary + Ag Wash water	Gordon Williams, Trussell
2:00 pm	Pilot Testing and Sampling Plan - Secondary and Advanced treatment	Kevin Alexander, SPI
2:45 pm	**BREAK**	
3:00 pm	Product Water Conveyance	Alison Imamura, DDA
3:50 pm	Panel Deliberations	Mike Wehner, Panel
5:00 pm	**Adjourn**	

Tuesday, October 22, 2013

8:30 am	**Summary of Day 1**	Jeff Mosher, NWRI Mike Wehner, Panel
8:40 am	Groundwater Replenishment Project - Injection - Seaside Groundwater Basin - Injection Sites - Modeling - Monitoring Well - Injections Wells	Phyllis Stanin, Todd Engineers
9:45 am	**BREAK**	
10:00 am	Public Outreach	Keith Israel, MWRPCA
10:15 am	Questions and Discussions	
10:30 am	Panel Deliberations	Mike Wehner, Panel
12:00 noon	**Working Lunch**	
1:30 pm	Debrief with MWRPCA	All
2:00 pm	**Adjourn**	

APPENDIX D: MEETING ATTENDEES

Panel Members:

- Jean-François Debroux, Ph.D., Kennedy/Jenks Consultants (San Francisco, CA)
- Martin B. Feeney, P.G., CHG, Consulting Hydrogeologist (Santa Barbara, California)
- Michael P. Wehner, REHS, MPA, Orange County Water District (Fountain Valley, California)

National Water Research Institute:

- Jeff Mosher, Executive Director

Monterey Regional Water Pollution Control Agency:

- Garrett Haertel, P.E., Compliance Engineer
- Brad Hagemann, Assistant General Manager
- Karen Harris, Community Relations Specialist
- Robert Holden, P.E., Principal Engineer
- Keith Israel, General Manager
- Mike McCullough, Recycled Water Project Assistant

Monterey Peninsula Water Management District

- Larry Hampson, District Engineer
- Jonathan Lear, PG, CHg, Senior Hydrogeologist.
- Joe Oliver, PG, CHg, Water Resources Division Manager
- David J. Stoldt, General Manager

Project Team Members:

- Jim Brezack, Brezack and Associates Planning
- Jerry Cole, Consultant
- James Crook, Environmental Engineering Consultant (Retired CDPH)
- Denise Duffy, Denise Duffy & Associates
- Alison Imamura, Denise Duffy & Associates
- Margie Nellor, Nellor Environmental Associates (on phone)
- Phyllis Stanin, Todd Engineers
- Alex Wesner, Separation Processes Inc.
- Valerie J. Young, AICP, Environmental Planning and Water Reuse Consultant

California Department of Public Health:

- Randy Barnard (on phone)
- Brian Bernados
- Eugene Leung (on phone)
- Jan Sweigert

Regional Water Quality Control Board, Central Coast Region

- Harvey Packard

Monterey County Health Department

- Cheryl Sandoval (on phone)

NATIONAL WATER RESEARCH INSTITUTE

Draft Final Report

of the May 1-2, 2014, Meeting of the

Independent Advisory Panel

for

Pure Water Monterey Peninsula Groundwater Replenishment Project

Prepared for:

Monterey Regional Water Pollution Control Agency
5 Harris Court, Building D
Monterey, California 93940

June 23, 2014

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For more information, please contact:

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1. PURPOSE AND HISTORY OF THE PANEL

In 2013, the National Water Research Institute (NWRI)[1] of Fountain Valley, California, a 501c3 nonprofit, appointed local and national water industry experts to an Independent Advisory Panel (Panel) to provide expert peer review of the proposed Pure Water Monterey Peninsula Groundwater Replenishment (GWR) Project being considered by the Monterey Regional Water Pollution Control Agency (MRWPCA)[2] and its project partner, the Monterey Peninsula Water Management District (MPWMD).[3] Henceforth, MRWPCA, MPWMD, and their consultants will be referred to as the "Project Team."

The GWR project is expected to create a sustainable source of water supply by using highly-treated water from a new advanced water treatment plant (AWTP) to augment local drinking water aquifers. Specifically, the project involves developing and conveying highly-treated water from the AWTP to the Seaside Basin, where the water will be injected into the aquifer using a series of shallow (i.e., vadose zone) and deep wells. Once injected into the Seaside Basin, the treated water would mix with the groundwater present in the aquifers and be stored for future use.

This additional supply would replenish the aquifers and increase the yield of the Seaside Basin for local pumpers, including the primary pumper, California American Water (Cal-Am). The GWR project will be designed to provide 3,500 acre-feet (AF) per year of high-quality replacement water to Cal-Am for delivery to its customers in the Monterey District service area, thereby enabling Cal-Am to reduce its diversions from the Carmel River system by the same amount.

The Panel is tasked with reviewing the proposed GWR project and providing findings and recommendations on project alternatives, alternative evaluation, and associated bench and pilot studies. Examples of issues that the Panel may address include public health and safety, advanced water treatment design issues, permitting and regulatory requirements, and public outreach and advocacy.

The Panel is made up of four experts in areas related to GWR projects, such as engineering, regulatory criteria, public health, hydrogeology, and other relevant fields. Panel members include:

- George Tchobanoglous, PH.D., P.E., NAE, University of California, Davis (Davis, CA)
- Jean-François Debroux, Ph.D., Kennedy/Jenks Consultants (San Francisco, CA)
- Martin B. Feeney, P.G., CHG, Consulting Hydrogeologist (Santa Barbara, CA)
- Michael P. Wehner, MPA, REHS, Orange County Water District (Fountain Valley, CA)

Background information about the NWRI Panel process can be found in Appendix A, and brief biographies of the Panel members can be found in Appendix B.

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[1] http://www.nwri-usa.org/.
[2] http://www.mrwpca.org/.
[3] http://www.mpwmd.dst.ca.us/.

2. PANEL MEETING

A 2-day meeting of the Panel was held on May 1-2, 2014, at both the MRWPCA Regional Treatment Plant in Marina, California (May 1) and the MRWPCA administrative offices in Monterey, California (May 2). This meeting represents the second time the Panel has met to review the proposed GWR project.

2.1 Background Material

Prior to the meeting, the following background material and reports were provided to the Panel:

- Revised draft of the 29-page concept approval proposal, titled "Monterey Regional Water Pollution Control Agency Groundwater Replenishment Project: Proposal to Inject Highly-Treated Recycled Water into the Seaside Groundwater Basin" (dated April 23, 2014). The proposal was expected to be submitted to the California Department of Public Health (CDPH) by May 15, 2014.

2.2 Meeting Agenda

Staff from NWRI and the Project Team collaborated on the development of the agenda for the Panel meeting, which is included in Appendix C. The agenda was based on meeting the following specific objectives:

- Review the draft concept approval proposal to be submitted to CDPH for review.
- Develop a working understanding of the proposed GWR Project.
- Identify proposed project strengths and areas where more information is needed.
- After the meeting, prepare a brief summary of project questions and obstacles for use by the GWR team.

The majority of the meeting was devoted to presentations made by the Project Team. Time was provided for the Panel to ask questions and engage in discussion following each presentation. The presentations included:

- Water Quality, including:
    - Source Water Characterization
    - Pilot Facility Preliminary Results
    - Baseline Groundwater Basin Quality
    - Ongoing Vadose Zone Leaching Tests
- Outreach Update
- CEQA Status Report and Permits
- Water Rights Update
- Settlement Update
- Source Control Program
- Regulatory – Draft Concept Proposal
- GWR Panel Checklist: A Recap Items from October 21-21, 2013 Panel Meeting

In addition to the presentations, the Panel was given a tour of the Advanced Water Purification Demonstration Facility at the MRWPCA Regional Treatment Plant in Marina, California, and participated in a field trip to view possible water sources to be used as part of the project, including: Tembladero Slough, Blanco Drain, Reclamation Ditch, Salinas Pump Station, and the Industrial Ponds.

Once the presentations and tours were concluded, the Panel met in a closed session to discuss the information presented and address questions provided by the Project Team. Before the meeting adjourned, the Panel prepared a report outline and drafted preliminary findings and recommendations, which have been expanded upon in this report.

2.3 Meeting Attendees

All Panel members attended this meeting. Other attendees included NWRI staff, MRWPCA staff, MPWMD staff, consultants, representatives from agency partners, and regulators. A complete list of Panel meeting attendees is included in Appendix D.

3. OBSERVATIONS AND FINDINGS

The principal observations and findings derived from the material presented and discussed during the meeting are provided below. They are organized under the following categories:

- General
- Source Water
- Regional Treatment Plant
- Advanced Treatment
- Aquifer Injection
- Project Management
- Public Outreach
- Suggested Revisions to the Draft Concept Proposal

3.1 General

- The Panel compliments the Project Team for their excellent presentations, which were well-prepared and professional. The Panel also appreciated the background documents provided by the Project Team.

- The Panel concludes that the GWR project will contribute to the water supply portfolio of the Cal-Am's Monterey Peninsula service area by supplementing existing sources and providing a greater degree of independence, thus improving the reliability and sustainability of the region's water supplies.

- The Panel commends the Project Team for the significant amount of effort and progress that has been made in reaching project goals.

- The organization of the Panel meeting and field trip was both instructive and productive not only for Panel members, but for others in attendance, including regulators.

- The progress that the Project Team has made in their responsiveness to the previous Panel report is exemplary.

- The Panel concurs with the Project Team on the importance of securing water rights and associated contracts for the various source waters.

- The Panel has reviewed the draft project proposal to "Inject Highly-Treated Recycled Water into the Seaside Groundwater Basin" and believes that it represents a comprehensive description and assessment of the proposed GWR project and that it should be submitted to CDPH for early review.

3.2 Source Water

- Some probability distributions of the advanced treatment facility influent constituents would be important in terms of the operation of the ozone and membrane systems.

- The Panel has some concern that the quantity number projected for indoor water use in the future may be higher than should be anticipated, given current trends in conservation.

3.3 Regional Treatment Plant

- Because of excess capacity in the current trickling filter treatment process, it may be possible to operate one of the filters in a nitrifying mode. Such an operation may (1) eliminate the need for ozone (and reduce N-Nitrosodimethylamine [NDMA] formation potential), (2) further enhance the effectiveness of the ozone, and/or (3) produce an effluent that is significantly easier to filter (based on actual data from the Orange County Water District in Fountain Valley, California).

3.4 Advanced Treatment

- The Panel is concerned with the measures that have been taken to manage salinity. More specifically, is the goal of going from 750 to 799 milligrams of total dissolved solids per liter (TDS/L) in the recycled water realistic given the quantity and quality of the existing and new water sources?

- In assessing the chemistry of the stabilized product water from the reverse osmosis (RO) process, it will be important to check a number of indexes for both precipitation and corrosion in conjunction with the various pipe materials to be used.

- The remedies for stabilizing the water need to be consistent with the leaching or plugging potential of the final water on soils at the recharge area.

- Is chlorine addition (form of chlorine, e.g., chloramine or free) part of the chemical stabilization process?

- The methodology to be used to assess whether to include ozone and/or biologically active filtration (BAF) in the overall treatment process needs to be defined (e.g., water quality, treatability, cost, or a combination of factors).

3.5 Aquifer Injection

- Additional information needs to be developed on water movement in the Santa Margarita aquifer (e.g., the sensitivity to thickness of the highly conductive zone).

- To increase the travel time of the recharged water in the subsurface, consideration should be given to operating the existing aquifer storage and recovery (ASR) wells as only injection wells without recovery.

- Given that the vadose wells and injection wells will be co-located, it is recommended that the injection well be drilled first so that intervening clay layers can be characterized so that the vadose well design can be optimized.

3.6 Project Management

- Effective project coordination and management will be required to move forward in the very limited timeframe available for this project.

- Consideration should be given to the employment of an overall engineering project manager to coordinate the efforts of all sub-consultants.

3.7 Public Outreach

- The Panel commends the Project Team for the effort they have undertaken (e.g., educational visuals) to make the pilot facilities accessible and an educational experience.

- Given the noise level of the room in which the pilot facility is located, it would be helpful if some outdoor facilities, such as an open area tent with educational display materials and a place to sit and converse, would help occupy the visitors not touring the inside of the pilot facility.

- Because of the effectiveness of tours of the treatment facilities on public perception, it is recommended that the pilot facilities be retained and operated beyond the current study period. The pilot-scale facilities can also be used for operator training.

- The Panel is concerned that public outreach may be moving too far ahead of the actual project in terms of developing hand outs and visual materials. It appears by the public outreach materials that the project is a foregone conclusion.

- The Panel questions the usefulness and/or effectiveness of the proposed summit with the congressional delegation. The Panel would suggest that such a meeting might be appropriate once a concept approval letter has been received from CDPH.

3.8 Suggested Revisions to the Draft Concept Proposal

As noted in Section 2.1, the concept approval proposal, “Monterey Regional Water Pollution Control Agency Groundwater Replenishment Project: Proposal to Inject Highly-Treated Recycled water into the Seaside Groundwater Basin” (dated April 23, 2014), was to be submitted to CDPH by May 15, 2014. Because of the short turnaround time, the Panel provided comments and suggested revisions to the proposal during the Panel meeting. In this section, the Panel would like to formally document comments and recommendations made at the meeting. They include:

- The Panel commends the Project Team for a well-written, high-quality proposal.

- The Panel noted that the purpose of this proposal is to receive approval from CDPH to continue to move forward with evaluating the design and implementation of the proposed project. Therefore, it does not require detailed data and information, unlike (for instance) an engineer's report. In fact, the Panel cautions against sharing data in advance of efforts being undertaken through the California Environmental Quality Act (CEQA) process (including the development of the Environmental Impact Report [EIR]).

- A consistent term should be used throughout the report to refer to the end-product (for instance, "highly treated recycled water," "product water," or "purified water").

- In Section 4.3 "Public Outreach," it is important to include the activities and results of the re-branding effort that began in early 2014, such as changing the project's name to "Pure Water Monterey."

- Within Section 5 "Proposed Project Components," the Panel recommends adding a Section 5.4 on "Aquifer Recharge Facilities." In addition, a general statement that "recharge water may enter the vadose zone" could be added to the new Section 5.4.

- Section 7 "Seaside Groundwater Basin" and Section 8 "Injection Well Facilities" could be combined into one "Groundwater" section. The information on "Injection Well Facilities" could be expanded (by no more than a page) and should include work that has been conducted to-date to verify this effort. In addition, revise the groundwater injection map to reflect recent changes to well placement.

- Update Section 9.7 "Response Retention Time" with the new model run for Well Number 1.

APPENDIX A: PANEL BACKGROUND

About NWRI

For over 20 years, NWRI – a science-based 501c3 nonprofit located in Fountain Valley, California – has sponsored projects and programs to improve water quality, protect public health and the environment, and create safe, new sources of water. NWRI specializes in working with researchers across the country, such as laboratories at universities and water agencies, and are guided by a Research Advisory Board (representing national expertise in water, wastewater, and water reuse) and a six-member Board of Directors (representing water and wastewater agencies in Southern California).

Through NWRI's research program, NWRI supports multi-disciplinary research projects with partners and collaborators that pertain to treatment and monitoring, water quality assessment, knowledge management, and exploratory research. Altogether, NWRI's research program has produced over 300 publications and conference presentations.

NWRI also promotes better science and technology through extensive outreach and educational activities, which includes facilitating workshops and conferences and publishing White Papers, guidance manuals, and other informational material.

More information on NWRI can be found online at www.nwri-usa.org.

About NWRI Panels

NWRI also specializes in facilitating Independent Advisory Panels on behalf of water and wastewater utilities, as well as local, county, and state government agencies, to provide credible, objective review of scientific studies and projects in the water industry. NWRI Panels consist of academics, industry professionals, government representatives, and independent consultants who are experts in their fields.

The NWRI Panel process provides numerous benefits, including:

- Third-party review and evaluation.
- Scientific and technical advice by leading experts.
- Assistance with challenging scientific questions and regulatory requirements.
- Validation of proposed project objectives.
- Increased credibility with stakeholders and the public.
- Support of sound public-policy decisions.

NWRI has extensive experience in developing, coordinating, facilitating, and managing expert Panels. Efforts include:

- Selecting individuals with the appropriate expertise, background, credibility, and level of commitment to serve as Panel members.
- Facilitating hands-on Panel meetings held at the project's site or location.

- Providing written report(s) prepared by the Panel that focus on findings and recommendations of various technical, scientific, and public health aspects of the project or study.

Over the past 5 years, NWRI has coordinated the efforts of over 20 Panels for water and wastewater utilities, city and state agencies, and consulting firms. Many of these Panels have dealt with projects or policies involving groundwater replenishment and potable (indirect and direct) reuse. Specifically, these Panels have provided peer review of a wide range of scientific and technical areas related water quality and monitoring, constituents of emerging concern, treatment technologies and operations, public health, hydrogeology, water reuse criteria and regulatory requirements, and outreach, among others.

Examples of recent NWRI Panels include:

- **Development of Water Recycling Criteria for Indirect Potable Reuse through Surface Water Augmentation and the Feasibility of Developing Criteria for Direct Potable Reuse** for the California Department of Public Health (CA)
- **Developing Proposed Direct Potable Reuse Operational Procedures and Guidelines for New Mexico** for the New Mexico Environment Department (NM)
- **Monterey Peninsula Groundwater Replenishment Project** for the Monterey Regional Water Pollution Control Agency (CA)
- **Groundwater Recharge Scientific Study** for the LOTT Clean Water Alliance (WA)
- **Groundwater Replenishment System Program Review** for the Orange County Water District (CA)
- **Examining the Criteria for Direct Potable Reuse** for Trussell Technologies (CA) and WateReuse Research Foundation (VA)
- **Evaluating Potable Reuse** for the Santa Clara Valley Water District (CA)
- **Indirect Potable Reuse/Reservoir Augmentation Project Review** for the City of San Diego (CA)
- **BDOC as a Surrogate for Organics Removal in Groundwater Recharge** for the California Department of Public Health (CA)
- **Effluent Master Plan** for Tucson Water (AZ)
- **Groundwater Replenishment Project Review** for the Los Angeles Department of Water and Power (CA)

More information about the NWRI Independent Advisory Panel Program can be found on the NWRI website at http://nwri-usa.org/Panels.htm.

GEORGE TCHOBANOGLOUS, PH.D., P.E., NAE

Professor Emeritus
University of California, Davis (Davis, CA)

For over 35 years, wastewater expert George Tchobanoglous has taught courses on water and wastewater treatment and solid waste management at the University of California, Davis, where he is Professor Emeritus in the Department of Civil and Environmental Engineering. He has authored or coauthored over 500 publications, including 22 textbooks and eight engineering reference books. Tchobanoglous has been past President of the Association of Environmental Engineering and Science Professors and currently serves as a national and international consultant to both government agencies and private concerns. Among his honors, he received the Athalie Richardson Irvine Clarke Prize from NWRI in 2003, was inducted to the National Academy of Engineers in 2004, and received an Honorary Doctor of Engineering degree from the Colorado School of Mines in 2005. In 2012, he received the first Excellence in Engineering Education Award from AAEE and AEESP. In 2013, he was selected as the AAEE and AEESP Kappe Lecturer. Tchobanoglous received a B.S. in Civil Engineering from the University of the Pacific, an M.S. in Sanitary Engineering from the University of California, Berkeley, and a Ph.D. in Environmental Engineering from Stanford University.

JEAN-FRANÇOIS DEBROUX, Ph.D.

Director, Advanced Technologies Group
Kennedy/Jenks Consultants (San Francisco, CA)

At Kennedy/Jenks Consultants, Jean Debroux serves as Director of the Advanced Technologies Group, which was formed to solve technologically challenging problems. Part of this effort includes performing pilot and field studies for regulated and emerging contaminants and evaluates the cost impacts of complying with Safe Drinking Water Act regulations. A water quality expert, Debroux has extensive experience and expertise working with water utilities and research organizations in water treatment and water reuse issues, and is an active member of the WateReuse Foundation, where he served on the Research Advisory Committee for 7 years. Debroux received a B.S. in Chemical Engineering from the University of South Florida, and both an M.S. in Environmental Engineering and Ph.D. in Civil Engineering from the University of Colorado, Boulder. In addition, he attended the Environmental Management Institute at Tufts University and has served as a Post-Doctoral Research Fellow and Lecturer at Stanford University and as a Research Fellow at Université de Poitiers, France.

MARTIN B. FEENEY, P.G., CHG
Consulting Hydrogeologist (Santa Barbara, California)

Martin Feeney has been a consulting hydrogeologist since 1997, providing hydrogeologic consulting services to water agencies, private industry, and engineering firms. Prior to this, he served as hydrogeologist at various consulting firms such as Balanced Hydrologics, Inc. and Fugro West, Inc., where he provided analysis of groundwater basins, developed groundwater flow and transport, and developed saline groundwater source for desalination plants, injection wells/artificial recharge programs, and underground storage tank site assessment and remediation. He has also been involved in numerous groundwater resources and water well projects throughout California, working for groups such as Monterey County, Salinas Valley, Santa Clara Valley Water District, Ventura County, and various others. Feeney received a B.S. in Earth Sciences from the University of California, Santa Cruz and an M.S. in Environmental Planning (Groundwater) from California State University.

MICHAEL P. WEHNER, REHS, MPA
Assistant General Manager
Orange County Water District (Fountain Valley, California)

Mike Wehner has over 40 years of experience in water quality control and water resources management. He has been with the Orange County Water District (OCWD) since 1991, currently serving as Assistant General Manager. Among his responsibilities, he directly manages the Water Quality and Technology Group, including Laboratory, Water Quality, Hydrogeology, Research and Development, and Health and Regulatory Affairs Departments. He is also involved with numerous aspects with the Groundwater Replenishment System (the nation’s largest IPR project), including providing technical guidance on treatment and quality, as well as managing monitoring programs for the purification facility and receiving groundwater. He was also manager of OCWD’s 8-year Santa Ana River Water Quality and Health Study, which evaluated the impact of using effluent-dominated river waters for groundwater recharge. Prior to joining OCWD, Wehner spent 20 years with the Orange County Health Care Agency, where he managed the Water Quality Control Section of Environmental Health. He is a Registered Environmental Health Specialist in California and is an internationally recognized expert in water quality, public health, and advanced water treatment processes, serving on expert panels in the United Kingdom, Australia, and Singapore, as well as for California and U.S. agencies and foundations. He received a Masters of Public Administration from California State University Long Beach and a B.S. in Biological Sciences from the University of California, Irvine.

APPENDIX C: MEETING AGENDA

NATIONAL WATER RESEARCH INSTITUTE

Independent Advisory Panel Meeting for Monterey Regional Water Pollution Control Agency on Monterey Peninsula Groundwater Replenishment Project

Preliminary Draft Meeting Agenda

May 1-2, 2014

Location
Monterey Regional Water Pollution Control Agency
Regional Treatment Plant--THURSDAY
14811 Del Monte Blvd.
Marina, CA 93933
(831) 883-1118
Administrative Offices FRIDAY
5 Harris Court, Bldg. D
Monterey, CA 93940
(831) 372-3367

On-Site Contacts:
Jeff Mosher (NWRI)
Cell: (714) 705-3722
Mike McCullough (MRWPCA)
Cell: (831) 594-2597

Meeting Objectives:

- Develop a working understanding of the Proposed Groundwater Replenishment Project.
- Identify proposed project strengths and areas where more information is needed.
- After the meeting, prepare a brief summary of project questions and obstacles for use by the GWR team.

Thursday, May 1, 2014 – MRWPCA Regional Treatment Plant – NOTE LOCATION!

9:00 am	**Welcome and Introductions (RTP)**	Jeff Mosher, NWRI
9:10 am	All Things Water Quality - Source Water Characterization - Pilot Facility Preliminary Results - Baseline Groundwater Basin Quality - Vadose Zone Leaching Analysis	Gordon Williams, Trussell, Brad Reisinger, SPI, Phyllis Stanin, Todd Groundwater, Joe Oliver, MPWMD,
11:45 - 12:30 pm	**WORKING LUNCH - RTP**	
12:30 pm	Tour of Advanced Water Purification Demonstration Facility - Technical Hurdles – Gordon Williams - Building Eye Candy – Mark Millan	Gordon Williams, Trussell, Brad Reisinger, SPI
1:00 – 4:00 pm	FIELD TRIP	Mike McCullough,

	Tembladero Slough, Blanco Drain, Reclamation Ditch, Salinas Pump Station, Industrial Ponds, return to RTP	MRWPCA
4:00 pm	Outreach Update	Steve Thomas, Thomas Brand, Dave Stoldt, MPWMD, Karen Harris, MRWPCA,
4:20 pm	CEQA Status Report & Permits	Valerie Young
4:45 pm	Water Rights Update	Dave Stoldt & Larry Hampson, MPWMD
5:00 pm	Settlement Update	Bob Holden, MRWPCA
5:45 pm	**Adjourn**	

Friday, May 2, 2014 – MRWPCA Administration Offices – NOTE LOCATION!

8:30 am	**Summary of Day 1**	Jeff Mosher, NWRI George T., Panel
8:45 am	Source Control Program	Garrett Haertel, MRWPCA
9:00 am	Regulatory – Draft Concept Proposal	Jim Crook & Margie Nellor
9:45 am	**BREAK**	
10:00 am	GWR IAP Checklist - Recap Items from October 21-21, 2013 IAP meeting	Bob Holden, MRWPCA
10:30 am	Panel Deliberations	George T., Panel
12:00 noon	**Working Lunch**	
1:30 pm	Debrief with MRWPCA	All
2:00 pm	**Adjourn**	

APPENDIX D: MEETING ATTENDEES

Panel Members:

- CHAIR: George Tchobanoglous, PH.D., P.E., NAE, University of California, Davis (Davis, CA)
- Jean-François Debroux, Ph.D., Kennedy/Jenks Consultants (San Francisco, CA)
- Martin B. Feeney, P.G., CHG, Consulting Hydrogeologist (Santa Barbara, CA)
- Michael P. Wehner, REHS, MPA, Orange County Water District (Fountain Valley, CA)

National Water Research Institute:

- Jeff Mosher, Executive Director
- Gina Vartanian, Outreach and Communications Manager

Monterey Regional Water Pollution Control Agency:

- Garrett Haertel, P.E., Compliance Engineer
- Karen Harris, Community Relations Specialist
- Robert Holden, P.E., Principal Engineer
- Keith Israel, General Manager
- Mike McCullough, Recycled Water Project Assistant

Monterey Peninsula Water Management District

- Jonathan Lear, PG, CHg, Senior Hydrogeologist
- Joe Oliver, PG, CHg, Water Resources Division Manager

Project Team Members:

- Jim Brezack, Brezack and Associates Planning, LLC (on phone)
- Diana Buhler, Denise Duffy & Associates
- Jerry Cole, Consultant
- James Crook, Ph.D., P.E., Environmental Engineering Consultant (Retired CDPH)
- Denise Duffy, Denise Duffy & Associates
- Alison M. Imamura, AICP, Denise Duffy & Associates
- Mark Millan, Data Instincts, Inc.
- Margaret H. Nellor, P.E., Nellor Environmental Associates (on phone)
- Brad Reisinger, P.E., Separation Processes, Inc
- Bahman Sheikh, Ph.D., P.E., Water Resources and Reuse Specialist
- Phyllis Stanin, P.G., Todd Engineers
- Steve Thomas, Thomas Brand Consulting
- Gordon J. Williams, Ph.D., P.E, Trussell Technologies, Inc.
- Valerie J. Young, AICP, Environmental Planning and Water Reuse Consultant

California Department of Public Health:

- Brian Bernados, PE, Division of Drinking Water & Environmental Management

Regional Water Quality Control Board, Central Coast Region

- Peter Von Langen, Ph.D., Environmental Scientist

- Harvey Packard, Section Manager /Aquatic Habitat

Monterey County Health Department

- Cheryl Sandoval, Supervising Environmental Health Specialist, Drinking Water Protection Services

Pure Water Monterey
A Groundwater Replenishment Project

NWRI Independent Advisory Panel Meeting – Conference Call

February 5, 2015

Partners for Pure Water Solutions

MRWPCA

Monterey Peninsula Water Management District

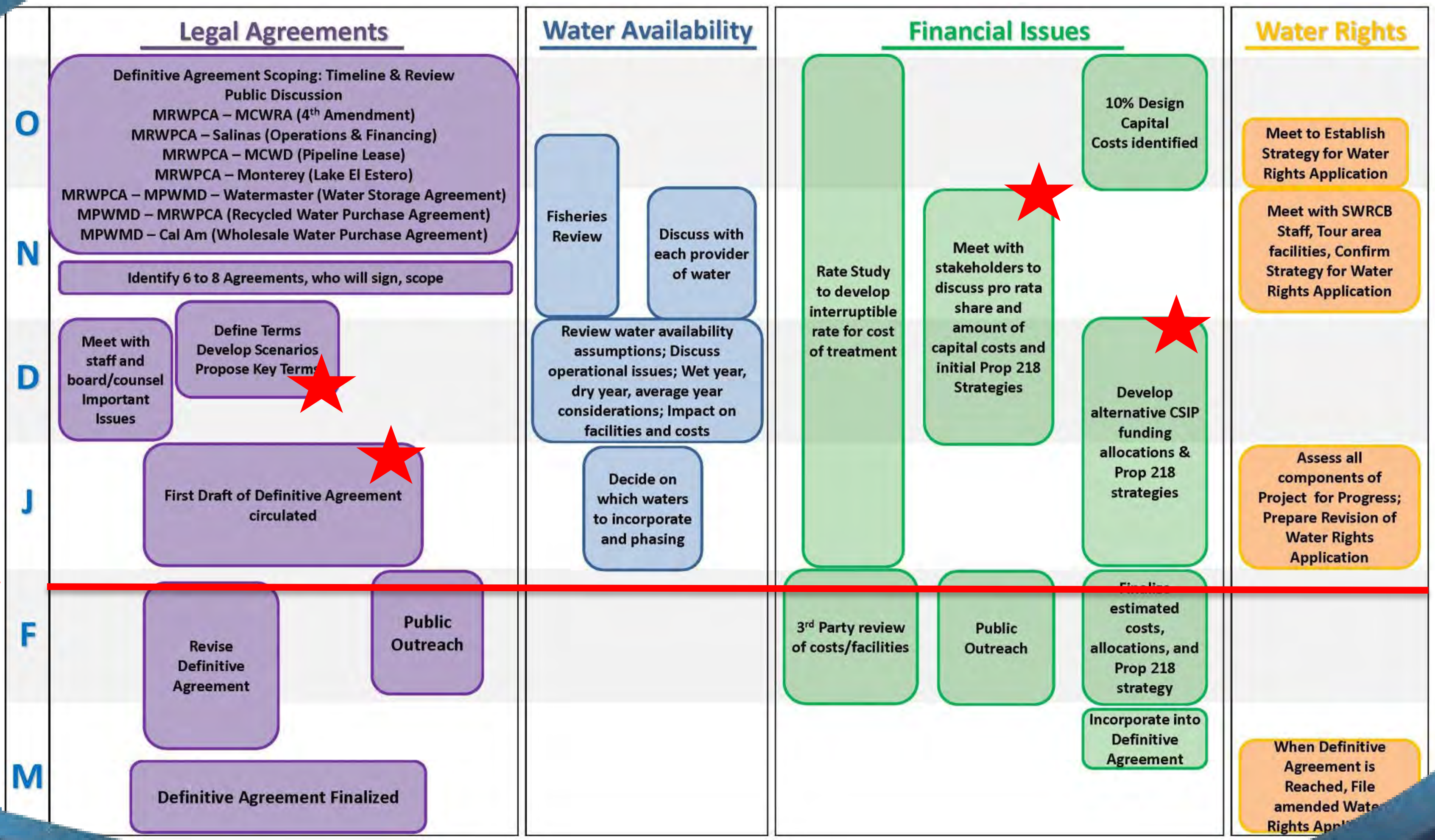
Pure Water Monterey
A Groundwater Replenishment Project

UPDATE ON TALKS/AGREEMENT WITH GROWERS

Dave Stoldt, MPWMD

Pure Water Monterey
A Groundwater Replenishment Project

Tasks for a Definitive Agreement



Legal Agreements

Definitive Agreement Scoping: Timeline & Review
Public Discussion
MRWPCA – MCWRA (4th Amendment)
MRWPCA – Salinas (Operations & Financing)
MRWPCA – MCWD (Pipeline Lease)
MRWPCA – Monterey (Lake El Estero)
MRWPCA – MPWMD – Watermaster (Water Storage Agreement)
MPWMD – MRWPCA (Recycled Water Purchase Agreement)
MPWMD – Cal Am (Wholesale Water Purchase Agreement)

Identify 6 to 8 Agreements, who will sign, scope

Meet with staff and board/counsel Important Issues

Define Terms
Develop Scenarios
Propose Key Terms ★

First Draft of Definitive Agreement circulated ★

Revise Definitive Agreement

Public Outreach

Definitive Agreement Finalized

Water Availability

Fisheries Review

Discuss with each provider of water

Review water availability assumptions; Discuss operational issues; Wet year, dry year, average year considerations; Impact on facilities and costs

Decide on which waters to incorporate and phasing

Financial Issues

Rate Study to develop interruptible rate for cost of treatment

10% Design Capital Costs identified

Meet with stakeholders to discuss pro rata share and amount of capital costs and initial Prop 218 Strategies ★

Develop alternative CSIP funding allocations & Prop 218 strategies ★

3rd Party review of costs/facilities

Public Outreach

Finalize estimated costs, allocations, and Prop 218 strategy

Incorporate into Definitive Agreement

Water Rights

Meet to Establish Strategy for Water Rights Application

Meet with SWRCB Staff, Tour area facilities, Confirm Strategy for Water Rights Application

Assess all components of Project for Progress; Prepare Revision of Water Rights Application

When Definitive Agreement is Reached, File amended Wate
Rights App

★ : Denotes little or no progress

Pure Water Monterey
A Groundwater Replenishment Project

Key Events Since We Got Started

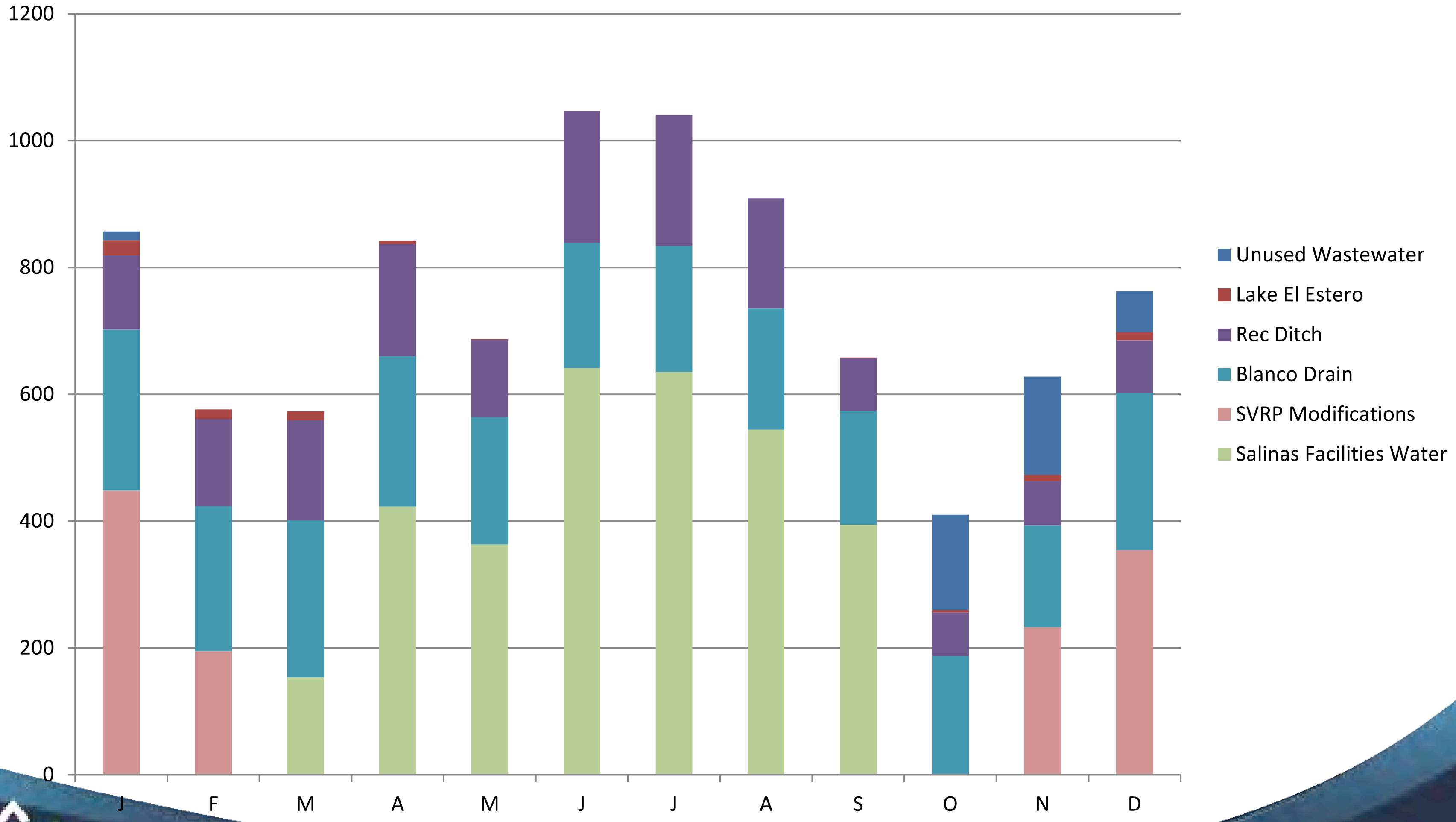
- Groundwater Sustainability Act signed into law and will require a Groundwater Sustainability Plan
- Regional Board letter "determined that MCWRA is a waste discharger and must file a report of waste discharge…for its activities in and around the Reclamation Ditch and Blanco Drain"
- Brown and Caldwell releases "State of the Salinas Groundwater Basin" report

Proposed Solution

Facilities	Cost	Water
Commence Immediately		
Salinas Ag Wash Water Facilities	$1,000,000	2,929
Salinas Stormwater Capture	$1,500,000	225
Salinas Emergency Sewage and Return Flows	MRWPCA	0
SVRP Modifications for Winter Ops	$1,228,000	1,230
Lake El Estero Intercept	$370,000	87
Winter Wastewater	$0	384
Wait Until Water Rights Granted		
Blanco Drain	$11,754,000	2,531
Reclamation Ditch	$1,335,000	1,604
Total	$17,187,000	8,990

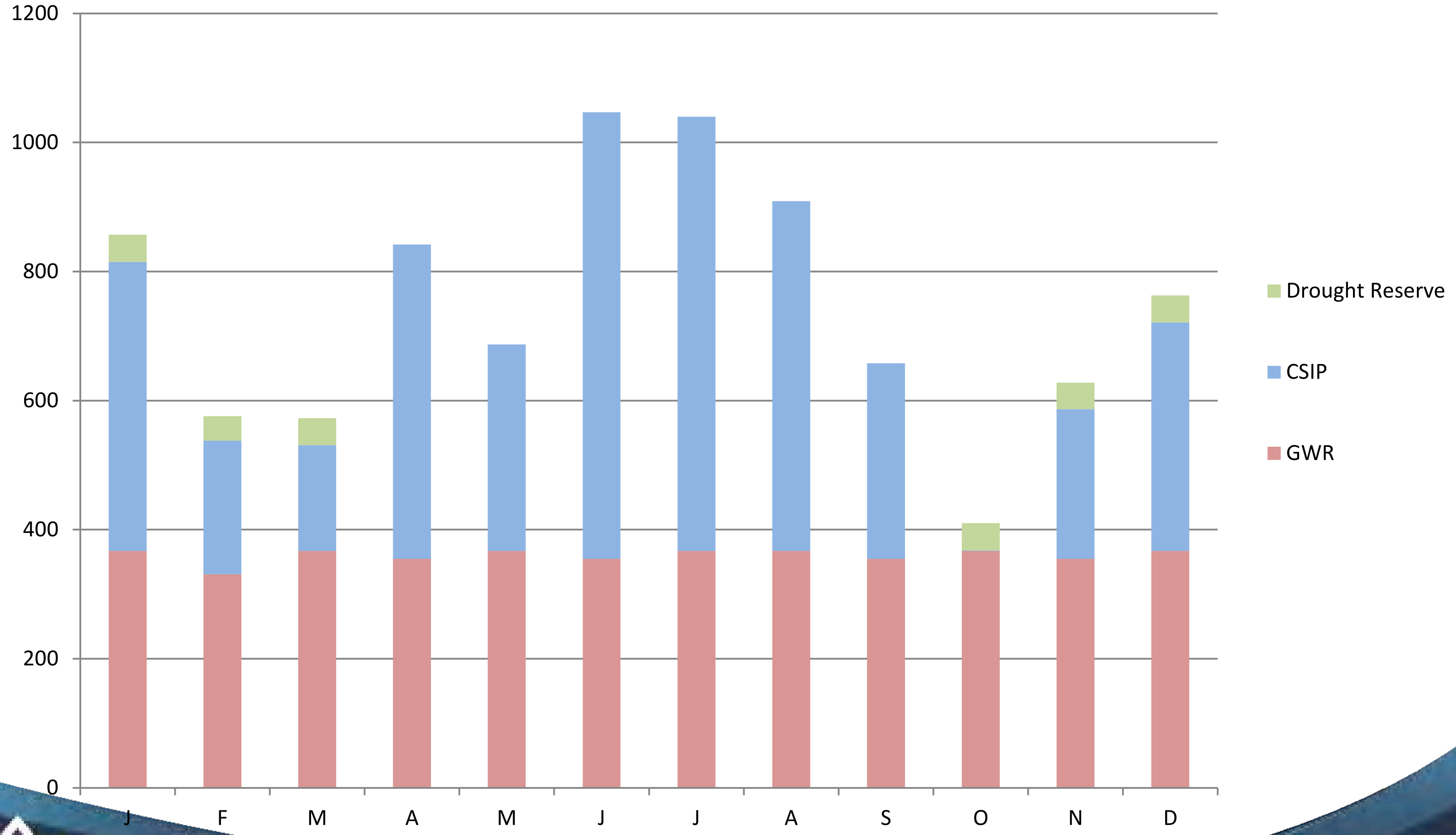
Tembladero Slough facilities eliminated due to water quality concerns

Proposed Solution - Sources



Pure Water Monterey
A Groundwater Replenishment Project

Proposed Solution - Uses



Pure Water Monterey
A Groundwater Replenishment Project

Next Steps – Financial Issues

- Next Step: Focus on Financial Plan
- Who Pays? Allocate CSIP portion like SVRP allocation for facilities, like CSIP allocation for O&M?
- Assign Blanco Drain facility costs to Storm Maintenance District #2? Other?
- How can CSIP only pay for facilities it needs now?
- Establish criteria for CSIP future “buy in”
- Try to structure around existing CSIP/SVRP loans?
- Role of grants, low cost loans, and contributions

Pure Water Monterey
A Groundwater Replenishment Project

CEQA UPDATE

Valerie Young, Hazen & Sawyer

Pure Water Monterey
A Groundwater Replenishment Project

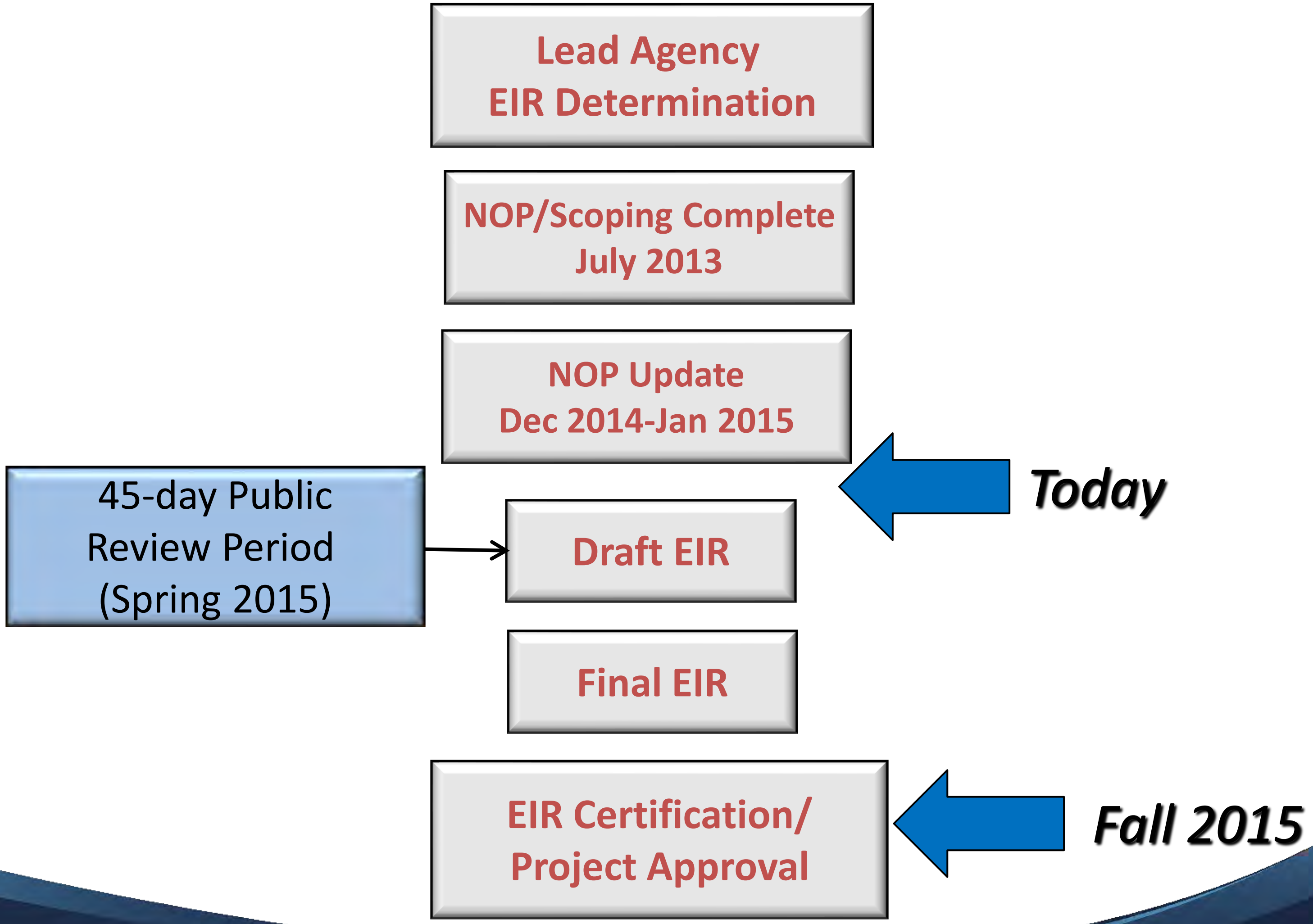
GWR CEQA PROCESS UPDATE
SINCE WE LAST MET……

- Substantial progress on EIR impact analysis
- Incorporate results of technical team reports
  - Water quality analysis (Trussell, Sheikh)
  - Groundwater analysis (Todd, Hydrometrics)
  - Regulatory compliance report (Nellor, Crook)
- Ongoing coordination with CPUC EIR team

SINCE WE LAST MET……

- Issued Supplement to CEQA Notice of Preparation on December 8, 2014
  - Updated project description to reflect results of source water negotiations (more H20 for growers)
  - Other project description changes from engineering and technical evaluations
- Normal part of CEQA process
- Provide opportunity for public/agency input
- Received 10 comment letters

GWR CEQA Process Timeline



Lead Agency
EIR Determination

NOP/Scoping Complete
July 2013

NOP Update
Dec 2014-Jan 2015

Today

45-day Public
Review Period
(Spring 2015)

Draft EIR

Final EIR

EIR Certification/
Project Approval

Fall 2015

Pure Water Monterey
A Groundwater Replenishment Project

BRINE MANAGEMENT (DETERMINING DISCHARGE COMPLIANCE)

Gordon Williams, Trussell Technologies

GWR Project and Ocean Discharge

GWR creates new discharge considerations

- New source waters may alter discharge water quality
- Addition of new waste stream: RO concentrate

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California Ocean Plan

WATER QUALITY CONTROL PLAN
OCEAN WATERS OF CALIFORNIA

Water Boards

CALIFORNIA OCEAN PLAN

2012

STATE WATER RESOURCES CONTROL BOARD
CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

Sets water quality objectives for:

- Protection of marine organisms
- Protection of human health

Objectives translated into MRWPCA discharge limits (NPDES permit)

- Objectives adjusted to credit blending with ocean water
  - "Zone of Initial dilution" (ZID)
  - $D_{m:}$ minimum probable initial dilution

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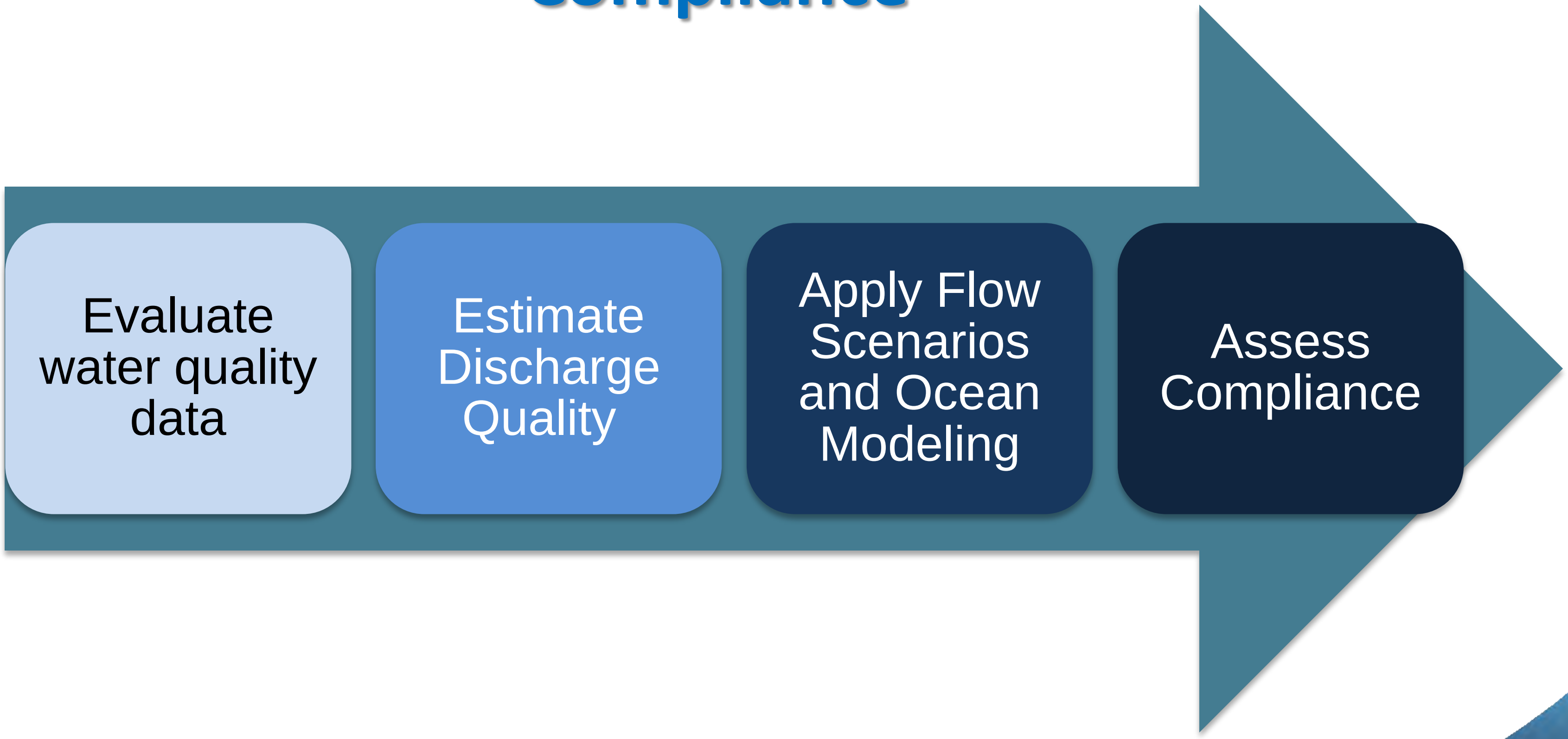
Process of Assessing Ocean Plan Compliance



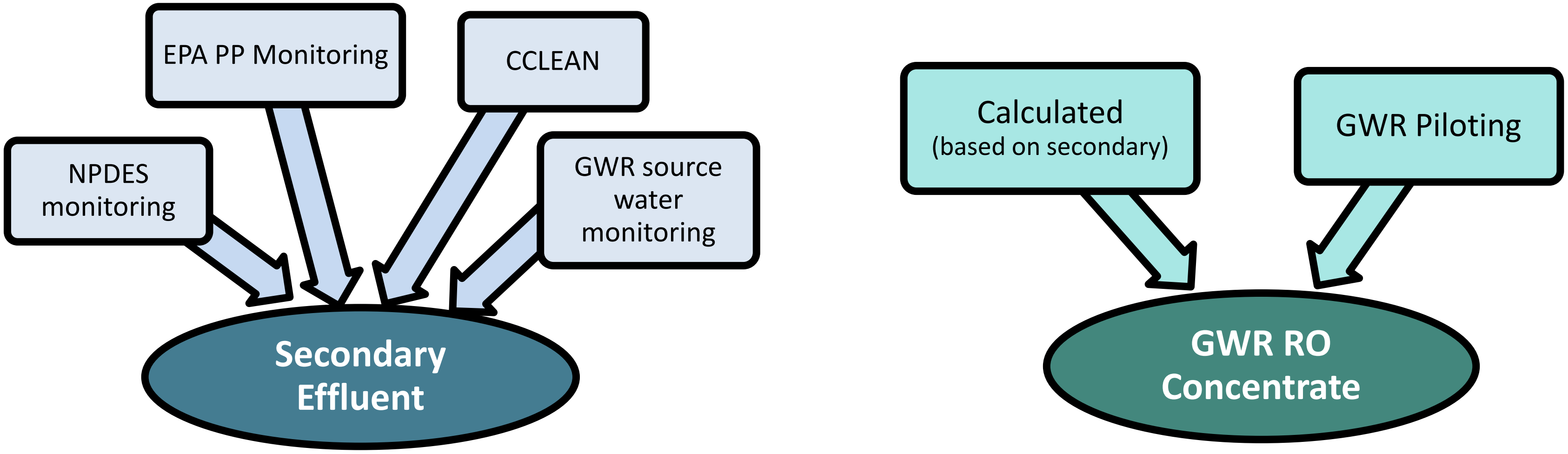
Evaluate water quality data

Estimate Discharge Quality

Apply Flow Scenarios and Ocean Modeling

Assess Compliance

Water Quality Data


EPA PP Monitoring

CCLEAN

NPDES monitoring

GWR source water monitoring

Secondary Effluent

Calculated (based on secondary)

GWR Piloting

GWR RO Concentrate

Assumed "worst-case" water quality based on *<u>maximum</u>* observed values

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Trade-offs Between Two Types of Dilution

“In-pipe” dilution

- Mixing of discharge waters (secondary + RO conc.)
- **More secondary → more “in-pipe” dilution of RO conc.**

“Ocean mixing” dilution

- Determined by ocean modeling (density, velocity, ocean conditions, etc.)
- **More secondary effluent → less dilution in ocean**

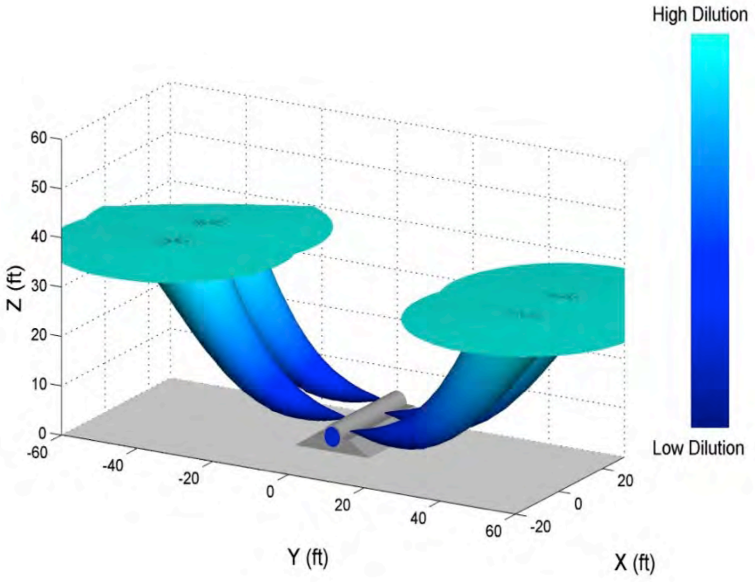

Figure from FlowScience, Inc. (2014)

Considered these factors in determining key discharge flow scenarios

Discharge Scenarios and Ocean Modeling

No.	Discharge Scenario (Ocean Condition)	Flows (mgd)			D_m
		Secondary effluent	RO concentrate	Hauled brine	
1	RTP Design Capacity (Oceanic)	24.7	0.94	0.1	150
2	RTP Capacity with Current Port Configuration (Oceanic)	23.7	0.94	0.1	137
3	Minimum Wastewater Flow (Oceanic)	0	0.94	0.1	523
4	Minimum Wastewater Flow (Davidson)	0.4	0.94	0.1	285
5	Moderate Wastewater Flow Condition (Davidson)	3	0.94	0.1	201

Assessing Ocean Plan Compliance

COMBINE:	**CALCULATE:**	**ASSSES COMPLIANCE:**
(1) Water quality data (2) Discharge scenarios (3) Ocean modeling	Estimated concentration at edge of ZID	Compare estimated ZID concentration with Ocean Plan Objectives

Ocean Plan Constituent		Assumed Water Quality				Concentration at Edge of ZID					Percentage of Ocean Plan Objective				
						Discharge Scenario					Discharge Scenario				
		RTP Secondary	Hauled Waste	GWR RO Conc.	Ocean Plan Objective	1	2	3	4	5	1	2	3	4	5
Objectives for protection of marine aquatic life															
Copper	ug/L	25.9	39	136	3	2.19	2.20	2.24	2.34	2.25	73%	73%	75%	78%	75%
Ammonia (as N)	ug/L	36,400	36,400	191,579	600	280	306	337	481	359	47%	51%	56%	80%	60%
Endrin	ug/L	7.8E-02	7.8E-02	4.1E-01	2.0E-03	6.0E-04	6.6E-04	7.2E-04	1.0E-03	7.7E-04	30%	33%	36%	52%	38%
Objectives for protection of human health - carinogens						0	0	0	0	0					
DDT	ug/L	0.0011	0.0219	0.0346	0.00017	0.00002	0.0000	0.0001	0.0001	0.0000	10%	10%	37%	50%	27%
Dieldrin	ug/L	0.0005	0.0056	0.0029	0.000040	0.00000	0.0000	0.0000	0.0000	0.0000	10%	11%	15%	21%	15%
TCDD Equivalents	ug/L	1.54E-07	1.54E-07	8.09E-07	3.90E-09	1.18E-09	1.30E-09	1.42E-09	2.03E-09	1.52E-09	30%	33%	37%	52%	39%

LEGEND	
▨	= Scenario not applicable
⬜	= Scenario expected to be below 80% of Ocean Plan Objective
🟨	= Scenario expected to be at or above 80% of Ocean Plan Objective
🟥	= Scenario expected to exceed Ocean Plan Objective

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A Groundwater Replenishment Project

Ocean Plan Compliance Findings

- **Based on assumptions, MRWPCA would still comply with Ocean Plan with addition of GWR project**
- **NPDES discharge permit revisions would be needed**
  - GWR project complexity will translate into a more complex permit

Pure Water Monterey
A Groundwater Replenishment Project

REGULATORY IMPLICATIONS FOR PROJECT CHANGE

Margie Nellor, Nellor Environmental Associates, Inc.

Substantive Changes From May 19, 2014 Draft Project Proposal

- Banked Drought Reserve Component: an additional 200 AFY of AWT recycled water for injection in wet and normal years up to a total of 1,000 AF
- New sources waters
  - Will still be mixed with municipal wastewater and treated at the RTP prior to treatment at the AWT Facility

Source Waters

Source Water	Avg. Monthly Flows Scenario Range AFY
Municipal Wastewater	18.4
Salinas agricultural wash water	2.6 - 2.8
Stormwater flows from the southwestern part of Salinas and the Lake El Estero	0
Tembladero Slough (surface water and agricultural tile drain water)	0 – 0.5
Salinas Reclamation Ditch (surface water and agricultural tile drain water)	0.5 – 0.8
Blanco drain (surface water and agricultural tile drain water)	0.4 – 1.4

Water Quality Ramifications New Source Waters

- **None** – Based on source water data, draft pilot testing, information for similar AWT facilities, relevant research, the AWT recycled water will meet GWR Regulations and Basin Plan objectives

- Pesticides – those present after AWT meet MCLs or are below detection levels
- CECs
  - Based on pilot testing, only 3 detected in RO permeate (Caffeine, Iohexal, Albuterol)
  - Concentrations orders of magnitude below relevant health levels (DWELs)
  - Al lwould be removed (up to 90%) by UV/peroxide AOP that will be part of the full-scale AWT Facility
  - Expect below detection after full-scale AWT

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Next Steps

- Start preparation of Draft Engineering Report – July 2015
- Discussions with RWQCB NPDES amendment - TBD

QUESTION FOR THE IAP/DDW/RWQCB

Concept Approval Letter - does it change based on the new conditions or can it be addressed in the Engineering Report?

WATER RIGHTS

Larry Hampson, MPWMD

SURFACE WATER RIGHTS APPLICATION

- MCWRA Application to SWRCB (April 2014)
  - 25,000 AFY, maximum diversion rate of 100 cfs
  - Source area includes Reclamation Ditch watershed, Tembladero Slough and Blanco Drain
  - There are no other applications or water rights for diversion/appropriation downstream of the proposed points of diversion for the GWR project
  - Several claims have been made to “underflow of the Salinas River” in reports filed with SWRCB
  - SWRCB has not determined whether water in the SVGB is percolating groundwater or water flowing in a definite channel

STATUS OF APPLICATION

- <u>SWRCB sent a letter describing application deficiencies (November 2014)</u>
  - MRWPCA, MPWMD, MCWRA, and SWRCB met in January 2015
  - Current application will likely be split into three applications
    - Reclamation Ditch @ Davis Road (2,000 AFY, 6 cfs)
    - Blanco Drain (3,000 AFY, 6 cfs)
    - Remainder permit (20,000 AFY, 88 cfs) with several potential points of diversion
  - Response to deficiencies in April or May 2015
  - SWRCB to notice applications
  - If there are no protests or protests can be resolved, staff can issue permit with no SWRCB hearing

POTENTIAL BASIS FOR PROTESTS

- Gabilan Creek (tributary to Reclamation Ditch) is designated critical habitat for steelhead
  - NMFS could request that SWRCB condition a permit to meet instream flow requirements
- Reclamation Ditch flows into Tembladero Slough
  - Surfrider Foundation may have concerns about effects to wetlands from flow diversions
- Blanco Drain flows into the Salinas River
  - Reductions in Salinas River flows could affect aquatic resources in the river and at the lagoon
- Note that waters proposed for diversion are listed as impaired due to nitrates, pesticides, and turbidity

OVERVIEW/COMMENTS

Bob Holden, MRWPCA

FINAL Panel Report

Meeting 4
Monterey One Water
Pure Water Monterey Project

Background

In 2013, the National Water Research Institute (NWRI) appointed local and national water industry experts to serve on an Independent Advisory Panel to provide expert review of the Pure Water Monterey Project (Project). The Project goal is to facilitate partnerships and interagency expertise to ensure reliable wastewater collection and conveyance, increase flows for beneficial reuse, and enhance regional surface water and groundwater quality.

NWRI is pleased to present this report on the findings and recommendations from Meeting 4 of the NWRI Independent Advisory Panel (Panel) held on October 3-4, 2018, in Monterey, California. The Panel previously met in person during October 2013 and May 2014 in Monterey and via web-enabled conference call during February 2015.

Pure Water Monterey Project

The Project is expected to create a sustainable water supply by using highly treated water from a new advanced water purification facility (AWPF) to augment local drinking water aquifers. This additional supply would replenish the aquifer and increase its yield for local pumpers, including the primary pumper, California American Water (Cal-Am).

The Project is designed to produce 3,500 acre-feet (AF) per year of purified recycled water for delivery to the Seaside Groundwater Basin where it can be used to serve customers in the Monterey District service area, thus enabling Cal-Am to make a corresponding reduction in water diverted from the Carmel River.

Despite the Monterey region's successful record as a leader in municipal and agricultural water reuse, the Project presents many complex issues, which include:

- The M1W Service Area is growing rapidly and is not served by the State or Federal water projects that deliver raw water to much of California.
- M1W spans two Integrated Regional Water Management planning areas: The Greater Monterey County Planning Area, which is focused on water quality, and the Monterey Peninsula Planning Area, which is focused on climate change adaptation and infrastructure enhancement.
- Four discrete source waters will contribute influent flow to the Project.
- Advanced water treatment, comprehensive process control, controlled plant operation, and in-plant side stream management are key elements of the project.
- There are multiple potential beneficial uses for recycled water in the service area.
- Constituent fate, transport, and mobilization dynamics in the aquifer are not fully understood.
- Responsibility for public health, groundwater quality, and management of the aquifer is allocated across multiple public agencies. Each agency is charged with a different operational mission and each has different legal authority.
- Support for the Project among public and private drinking water agencies, municipal and county governments, and other key stakeholders continues to evolve.

NWRI Panel Meeting

To ensure the success of Meeting 4, NWRI collaborated with the Pure Water Monterey Project Planning Team (PWM Team), the Panel Chair, and the Panel during August and September 2018. NWRI organized these coordination meetings to:

- Plan an effective process that meets all expectations of M1W and the Panel.
- Ensure good communication among the PWM Team, NWRI staff, and the Panel.
- Focus the Panel's scope of review.

Panel Members

The NWRI Panel members are:

- Jean Debroux, PhD, PE, Kennedy/Jenks Consultants
- Martin Feeney, PG, CEG, CHg (Consulting Hydrogeologist)
- George Tchobanoglous, PhD, PE, NAE, (Chair); University of California, Davis (Emeritus)
- Michael P. Wehner, MPA, Orange County Water District

All four panelists attended Meeting 4. Short biographies for each Panel member are provided in **Attachment A**. The agenda for Meeting 4 is included as **Attachment B,** and a list of Meeting 4 attendees is presented in **Attachment C**.

Panel Charge

The Panel was tasked with reviewing Project development since its last meeting in 2015 and providing findings and recommendations on:

- Project changes, status, and next steps.
- Public outreach and opinion.
- Operations planning activities.
- Permitting and compliance.

Organization of this report

The Panel report is organized into the following topics:

- Panel Feedback on Presentations
- Project Components, Changes, Status, and Next Steps
- Public outreach and Public Opinion
- Operations and Planning Activities
- Permitting and Compliance

Panel findings and recommendations are presented for each of the topics. Some final observations are presented in a section titled The Path Forward.

Panel Feedback on Presentations

The Panel appreciates the quality of the presentation materials prepared by the PWM Team and consultants. The Panel also recognizes the multiple challenges facing the Project and remains enthusiastic in its endorsement of M1W moving forward with safe and beneficial groundwater recharge in the Monterey Region.

Findings

Consistent with feedback provided by the Panel during the meeting, the Panel found certain slides presented at Meeting 4 difficult to read, analyze, and interpret in real time. Therefore, the Panel's review is necessarily limited to data clearly presented in the staff and consultant presentations.

To help clarify the path forward on this important Project, the Panel should have adequate time to review and consider technical information in advance of Panel meetings. NWRI's best practice is to prepare and distribute a package of pre-meeting reading materials at least one week before a meeting. This standard enables panelists to prepare more effectively for the meeting which, in turn, ensures that M1W maximizes the value of the Panel's input.

Recommendation

To optimize the value of future meetings of this Panel, M1W should provide pertinent technical memoranda, project reports, and relevant data to NWRI at least 10 business days before the meeting date. This lead time will ensure that Panel members have sufficient time to review the material before the meeting.

Project Components, Changes, Status, and Next Steps

The Project Team presented an overview of the four capital improvement projects that will make up the new infrastructure required to enable Project implementation.

Findings

The following findings are based on the presentations.

1. Source Waters Diversion Structures (55 percent complete as of October 4, 2018).
2. AWPF Construction (63 percent complete as of October 4, 2018).
3. Purified Recycled Water Conveyance and Reservoir (98 percent complete as of October 4, 2018).
4. Injection Wells Expansion. Work is proceeding and appears satisfactory.

Recommendation

Adherence to approved construction schedules prevents the cascade of risk that often arises from late delivery: disputes, change orders, and increased costs. The Panel encourages the PWM Team to identify and implement appropriate schedule recovery strategies.

Public Outreach and Public Opinion

The PWM Team update on outreach activities and challenges provided important context for the Panel. Given M1W's investments and activities aimed at successfully implementing the Project, the Panel discussed M1W's role in leading this project. The Panel applauds the proactive approach taken by the General Manager to engage with regulators, the community, Project partners, and stakeholders across the region.

Findings

The Panel learned that:

- The Monterey Peninsula Water Management District (MPWMD) now supports the Project as a direct result of the General Manager's outreach.
- The Marina Water District (Marina) only gets a fractional credit for recycled water that it would receive from the Project.
- Cal-Am is not a partner to the Project and the public just approved a local proposition (Measure J) to perform a study to evaluate the feasibility of public ownership of Cal-Am

assets by the Monterey Peninsula Water Management District.[1] The purpose of Measure J was to "ensure the long-term sustainability, adequacy, reliability, cost-effectiveness and quality of water service within the Monterey Peninsula Water Management District area, to lower the cost of service to ratepayers, to promote and practice sustainable water management measures, and to establish public ownership of water system assets by establishing regulations requiring the District to take affirmative action, to the extent financially feasible, to acquire the water system assets owned and operated by the California American Water Company that currently provide water service to the District and its ratepayers."

A fundamental lesson of early groundwater augmentation projects like the Orange County Water District's Groundwater Replenishment System is: the agency responsible for producing and delivering water to the aquifer should take the lead on water quality, groundwater quantity, groundwater resources management, and related communications. M1W is not responsible for managing the aquifer; however, the Panel believes this lead role is essential and that there is an opportunity for M1W to leverage this lesson-learned and become the authoritative source on groundwater quality and reliability within its service area.

Another early lesson is to employ standards as a tool to communicate a project's value to the community. Defining the most relevant standards around which to base communications is not easy and requires iteration to ensure continuing relevancy to the community. Standards tend to organize around water service reliability, water quality, environmental stewardship, affordability and rates, organizational efficiency, customer service, and communications and decision-making. The Panel is aware that the Utility Branding Network (UBN) has produced a variety of tools that provide practical advice for increasing trust, support and investment in water and wastewater utilities. These tools are available through the UBN and its website.

Recommendations

- The Panel recommends that M1W take the lead public-facing role on advanced water treatment, groundwater quality, groundwater resources management, and related communications by establishing an organizational unit dedicated to understanding,

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[1] The election in which Measure J passed took place after the panel meeting. The impact and ramifications of Measure J were not part of the panel meeting discussion.

managing, and improving groundwater quality in the Monterey region, and, communicating critical public health and water quality information directly to consumers and/or through their Project partners, as appropriate, using a standards-based approach.

- The Panel also noted that the data presented on source water quality and pesticides is now five years old and does not include the most current listings of chemicals of concern, such as perfluorinated compounds like PFOA and PFOS.
- Expand source water quality testing to include required virus, Giardia, and Cryptosporidium, and any chemical constituents for which there is an established federal or California maximum contaminant load (MCL) or public health notification level (NL).[2]

Operations Planning Activities

The Project builds on the Monterey region's success with water recycling.

Findings

The Project Team is using a Demonstration Project to understand AWPF operations and plan for the effective integration of the AWPF with the balance of the M1W wastewater treatment and conveyance infrastructure. The Panel finds that M1W's operational planning activities are developing consistent with overall Project implementation. M1W operations staff are already embedded within the AWPF Demonstration, which has now been successfully operating for three years. In addition, M1W staff are building cooperative relationships with other AWPFs in California.

M1W is investing in its laboratory so it can gain California Environmental Lab Accreditation Program (ELAP) certification for drinking water analysis. Interagency cooperation is growing and plans for all stakeholder public agencies to share an upgraded Supervisory Control and Data Acquisition (SCADA) System with end-to-end cybersecurity features.

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[2] National Primary Drinking Water Regulations are available at https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations.

California Drinking Water Notification Levels and Response Levels are available at https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/notificationlevels/notification_levels_response_levels_overview.pdf.

However, this Project will present new challenges for the M1W operations staff based on: the use of four discrete water sources that contribute influent flow to the Project; the Project's novel approach to advanced water treatment process control; and, significant changes to existing in-plant side streams. Figure 1 illustrates process flow for the Project.

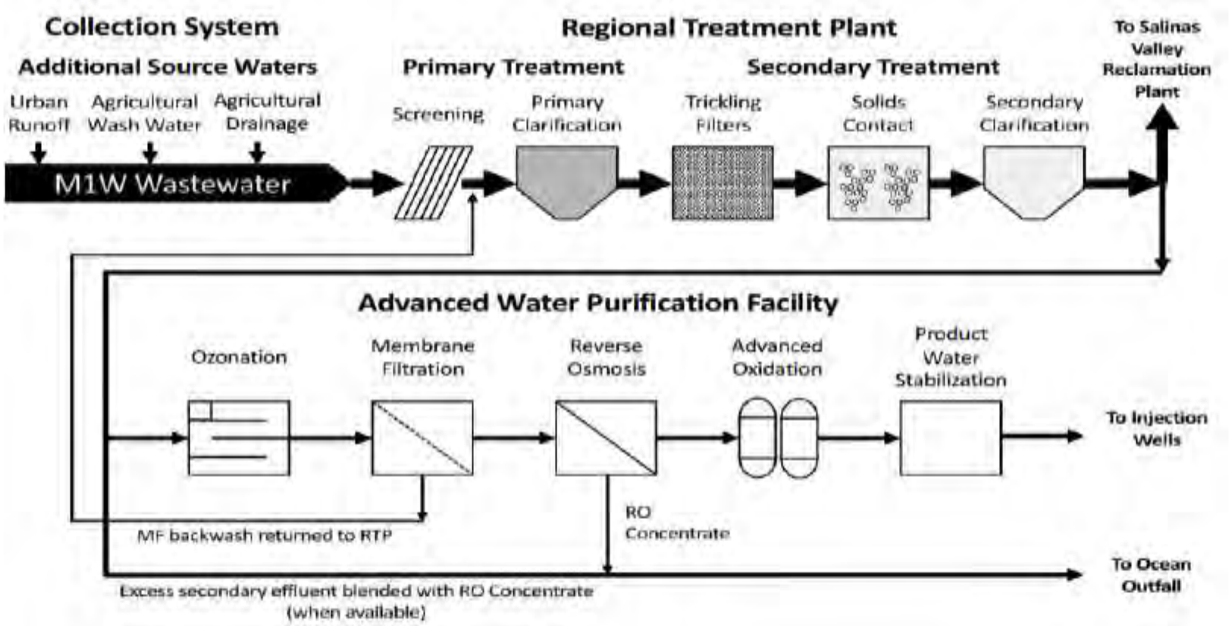

Figure 1. PWM Process Flow Chart. Source: Presentation by M1W Staff on October 4, 2018.

The Project Team is using the Demonstration Project to understand AWPF operations and plan for the effective integration of the AWPF with the balance of the M1W wastewater treatment and conveyance infrastructure.

Recommendations

The Panel has the following recommendations:

- Involve operations and management staff early in the planning process to ensure compliance and continuous improvement.
- Optimize the secondary treatment process. Develop key performance metrics to enable continuous monitoring of secondary treatment systems performance.
- Develop a timelier alternative methodology for assessing the performance of the reverse osmosis (RO) system's Total Organic Carbon (TOC) removal.
- There is concern that the performance of the secondary clarifiers may not be adequate to handle the sloughing of light organic particles from the trickling filters, which could exert

varying demands on the ozone system, and which, in turn, could result in the formation of colloidal and dissolved constituents that may be difficult to remove in the subsequent treatment processes. Ultimately, some form of filtration may be needed to optimize the performance of the advanced treatment system.

- Consider the potential for, and likely impacts of, the transmission of low molecular weight compounds through the RO membranes and formation of disinfection byproducts.
- Characterize, monitor, and manage all side streams and return flows at the WWTP to optimize the performance of the M1W wastewater treatment infrastructure. This will also help M1W manage contaminant slug loads and implement flow-paced operations where appropriate.
- Develop nominal alternative Project infrastructure operations scenarios and plans based on seasonal variation and foreseeable variabilities in source water constituency. Scenario based operations planning will also improve staffing projections.

Permitting and Compliance

The Panel understands that other regional authorities have important roles in the successful permitting of the Project, the targeted M1W service area extension, and then maintaining compliance with all applicable permits and regulations when the Project is operational. In fact, M1W spans two Integrated Regional Water Management planning areas: The Greater Monterey County Planning Area, which is focused on water quality, and the Monterey Peninsula Planning Area, which is focused on climate change adaptation and infrastructure enhancement.

Findings

The Panel appreciates the detailed analysis related to the commingled effluent that must be permitted through a National Pollution Discharge Elimination System (NPDES) permit reissuance process. The NPDES Permit protects the Pacific Ocean by requiring compliance with the Federal Ocean Plan. The Tentative Order to adopt an amended NPDES for the M1W Ocean Outfall was approved in June 2018. The Public Hearing in support of final order is scheduled for December 2018. The Panel notes that the Project is expected to reduce nitrogen loads to the Monterey Bay marine life protection area.

The Panel understands that Waste Discharge Requirements (WDR) were adopted by the Regional Water Quality Control Board in March 2017 to control inland discharges from the

Project's AWPF. The WDR requires the use of specific treatment processes, sets operational control monitoring and reporting requirements, and provides for Project compliance with applicable requirements of Title 22 and local Basin Plan objectives.

The Panel also appreciates the updated groundwater flow modeling but notes that the updated model challenges important theories related to the physical structures, characteristics, and flow patterns within and between the Paso Robles and Santa Margarita aquifers. If correct, these conclusions invalidate the current groundwater model because there is no confining layer to the Santa Margarita Aquifer. In any event, the Panel would need more than one e-log to reject accepted aquifer interface dynamics.

Recommendations

Looking forward, the Panel enthusiastically awaits an opportunity to review the revised engineering report and the tracer study, and offers the following recommendations:

- Revisit NPDES permit-related compliance and dilution analyses to reflect the effects of brine contributions by Cal-AM to the M1W Ocean Outfall under all four secondary effluent flow ranges.
- Seek to maximize aboveground Log Reduction Value (LRV) credits. The proposed underground retention time Virus LRV credit of 5.4, without additional LRV credit available to protect public health in the event of a loss of LRV credits in any treatment unit processes, is tenuous.
    - Priority opportunities to identify and secure additional LRV credits include: ozonation, chloramines, reverse osmosis (RO), and both primary and secondary processes at the M1W regional wastewater treatment plant.
    - Add sucralose to the analyte list in any analyses that are intended to track the path or fate of recycled water.
- The Panel was concerned about the reinterpretation of the stratigraphy of the basin because it conflicts with all previous interpretations and, more importantly, it conflicts with the geometry of the model that was used to perform the travel time estimates. This reinterpretation would change the boundary conditions and would require rebuilding and recalibrating the current model. An updated model capturing these postulated changes would likely result in significantly shorter travel times. Follow-up communication with the PWM team hydrogeologist revealed that the "cartoon" presented in the meeting was

exaggerated and was not correct, and that the working understanding by the project team is generally consistent with the model. Potential preferential flow pathways must be considered and should be evaluated with a tracer test.

- Design and execute a tracer test for this project. This test is challenging because of the injection zone, proximate pumping, and aquifer geometry. The variation and complexity of the potential project operational scenarios complicates the challenge, and the use of chlorides as an intrinsic tracer could potentially confound the analysis.
- Consider operating the full suite of trickling filters and evaluate the impacts of new arms with a focus on potential nitrification strategies and nitrite stabilization; definitively identify the source of nitrite concentrations.
- The ongoing RO Permeate TOC Study being conducted by Trussell Technologies may affect Project timing and viability, so approach DDW with any revisions to the proposed approach early to gain support.

The Path Forward

The Panel applauds M1W's emerging leadership on the Project. While the Panel had a limited amount of supporting technical data at their disposal, which limited the insights provided, suggestions for the path forward include:

- Making organizational investments and leveraging partnering arrangements in a manner that positions M1W as the drinking water quality and groundwater resources management experts.
- Establishing additional LRV credits with an emphasis on above-ground LRV credit opportunities to ensure sufficient LRV redundancy and to offset foreseeable unit process excursions.
- Identifying the sources of nitrite and establishing a strategy to mitigate its deleterious impacts.
- Exploring alternative Tracer Study approaches that do not include using an intrinsic tracer.
- Optimizing the performance of both the regional wastewater plant and AWPF operations according to a unified theory implemented via a scenario-based operating plan that protects

public health and achieves the Project's water quality, water supply reliability, and environmental benefits.

The Panel concludes that despite a variety of political, regulatory, and technical challenges, the Project remains an important element in the multi-jurisdictional effort to improve water reliability and enhance water quality in the Monterey region.

Prepared by

NWRI's Independent Advisory Panel for the Pure Water Monterey Project
Meeting 4; October 3 and 4, 2018, in Monterey, California

Prepared for

Monterey One Water
Monterey, California USA

Submitted by

National Water Research Institute, Fountain Valley, California USA

Disclaimer

This report was prepared by an Independent Advisory Panel that is administered by the National Water Research Institute. Opinions, findings, conclusions, or recommendations expressed in this report were prepared by the Panel. This report was published for informational purposes.

About NWRI

An IRC 501c3 nonprofit organization and California joint powers authority (JPA), the National Water Research Institute was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's JPA member agencies are: Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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Attachment A | Panel Member Biographies

Jean-Francois Debroux, PhD

Chief Technology Officer, Water/Infrastructure Business Unit

Kennedy/Jenks Consultants

At Kennedy/Jenks Consultants, Jean Debroux serves as the Chief Technology Officer for the Water/Infrastructure Business Unit. He and his team solve Kennedy/Jenks clients' most technologically challenging problems. Part of this effort includes performing pilot and field studies for regulated and emerging contaminants and evaluating the costs of complying with the Safe Drinking Water Act.

A water quality expert, Debroux has extensive experience and expertise working with water utilities and research organizations in water treatment and water reuse issues, and is an active member of the Water Research Foundation, where he serves on the Potable Reuse Issue Area Team.

Debroux received a BS in Chemical Engineering from the University of South Florida, and both an MS in Environmental Engineering and PhD in Civil Engineering from the University of Colorado, Boulder. In addition, he attended the Environmental Management Institute at Tufts University and has served as a Post-Doctoral Research Fellow and Lecturer at Stanford University and as a Research Fellow at Université de Poitiers, France.

Martin B. Feeney, PG, CEG, CHg

Consulting Hydrogeologist

Martin Feeney has more than 34 years of experience as a hydrogeologist. Since 1997, he has worked as an independent consulting hydrogeologist, providing services to water agencies, private industry, and engineering firms. Previously he worked at several consulting firms including Staal, Gardner, & Dunne, Inc.; Fugro Wes, Inc.; and Balance Hydrologics, Inc., where he provided analysis of groundwater basins, developed groundwater flow and transport models, sited and designed municipal wells, developed injection wells/artificial recharge programs, and performed underground storage tank site assessment and remediation.

Feeney has worked on developing subsurface seawater feedwater intakes for the cities of Oxnard, Ventura, Marina, and Monterey. He worked on the design of intake and reject disposal systems for the Sand City desalination facility, and on development of feedwater wells on numerous Caribbean islands.

Feeney is a member of the Hydrogeologic Working Group evaluating the proposed slant wells feedwater concept to support a 12 million gallon per day (MGD) desalination facility in the Monterey Bay area. He sat on the Independent Scientific Technical Advisory Panel that reviewed subsurface feedwater concepts for the proposed 50 MGD desalination facility in Huntington Beach, California, for the Coastal Commission and Poseidon. He received a BS in Earth Sciences from the University of California, Santa Cruz, and an MS in Environmental Planning from California State University.

George Tchobanoglous, PhD, PE (Panel Chair)

Professor Emeritus, UC Davis

For more than 35 years, wastewater expert George Tchobanoglous taught courses on water and wastewater treatment and solid waste management at University of California, Davis, where he is Professor Emeritus in the Department of Civil and Environmental Engineering. He has authored or coauthored more than 500 publications, including 22 textbooks and 8 engineering reference books. Tchobanoglous has been past President of the Association of Environmental Engineering and Science Professors and currently serves as a national and international consultant to both government agencies and the private sector.

Among his honors, Tchobanoglous received the Athalie Richardson Irvine Clarke Prize from NWRI in 2003, was inducted to the National Academy of Engineers in 2004, and received an Honorary Doctor of Engineering degree from the Colorado School of Mines in 2005. In 2012, he received the first Excellence in Engineering Education Award from AAEE and AEESP. In 2013, he was selected as the AAEES and AEESP Kappe Lecturer.

Tchobanoglous received a BS in Civil Engineering from the University of the Pacific, an MS in Sanitary Engineering from the University of California, Berkeley, and a PhD in Environmental Engineering from Stanford University.

Michael P. Wehner

Assistant General Manager, Orange County Water District

Mike Wehner has 40 years of experience in water quality control and water resources management. He spent 20 years with the Orange County Health Care Agency, and since 1991, he has worked for the Orange County Water District (OCWD), where he serves as Assistant General Manager.

His responsibilities include managing the Water Quality and Technology Group, which includes the Laboratory, Hydrogeology, Water Quality, Research and Development, and Health and Regulatory Affairs Departments. He is involved with numerous aspects of OCWD's Groundwater Replenishment System, which is the nation's largest indirect potable reuse project.

Wehner provides technical guidance on water treatment and quality, and he manages monitoring programs for the purification facility. He also managed OCWD's eight-year Santa Ana River Water Quality and Health Study, which evaluated the impact of using effluent-dominated river waters for groundwater recharge.

Wehner currently serves on independent advisory panels for potable reuse projects for Los Angeles Department of Water and Power, Monterey Regional Water Pollution Control Agency, City of San Diego, and Singapore Public Utilities Board. He received a Master of Public Administration from California State University, Long Beach, and a BS in Biological Sciences from University of California, Irvine.

Attachment B | Panel Meeting 4 Agenda

LOCATIONS:	**CONTACTS:**
WEDNESDAY October 3: Monterey One Water Plant 14811 Del Monte Blvd. Marina, CA 93933	**NWRI** Main Office: (714) 378-3278 (office) Kevin Hardy: (760) 801-9111 (mobile) Dawna Hernandez: (949) 345-9999 (mobile)
THURSDAY October 4: Monterey One Water Offices 5 Harris Ct., Building D Monterey, CA 93940	**Monterey One Water** Mike McCullough: (831) 645-4618 (office)

MEETING PURPOSE:
The National Water Research Institute (NWRI) is facilitating this independent advisory panel (Panel) on behalf of Monterey One Water (M1W). The purpose of this Panel is to provide independent and expert advice to M1W on responding to project development since the Panel's most recent meeting in May 2014 including: changes in project components; operational planning activities; and water quality permitting and compliance.

MEETING OBJECTIVES:

- Inspect the development at the Demonstration Facility since the Panel's last visit.
- Review current M1W Project elements and implementation status.
- Evaluate evolving public opinion and Project outreach efforts.
- Assess M1W with current staffing, systems integration, interagency cooperation, and source control planning.
- Review the schedule for issuance of the M1W NPDES Permit and the overall Project permitting and compliance timeline.
- Evaluate planned advanced water production facility optimization and log reduction approach for viruses and other pathogens of concern.
- Assess Groundwater Modeling Update.
- Review Groundwater Tracer Study Plan.

AGENDA DAY 1

Date: Wednesday, October 3, 2018
Location: Monterey One Water Plant
14811 Del Monte Blvd, Marina, CA 93933

Welcome, Overview of Project Activities since Last Meeting, and Demonstration Facility Tour	3:00 – 5:00 PM	Facilitator: Kevin Hardy, NWRI Paul Sciuto, PE, M1W General Manager George Tchobanoglous, PhD, Panel Chair Robert Holden, PE, M1W Principal Engineer
Panel Dinner	6:30 PM	Schooners, 400 Cannery Row Monterey, CA 93940

AGENDA DAY 2		
Date: Thursday, October 4, 2018 **Location:** Monterey One Water Offices 5 Harris Ct., Building. D, Monterey, CA 93940		
Continental Breakfast	7:30 – 8:00 AM	All Participants
Project Component Changes, Status, and Next Steps	8:00 – 9:00 AM	Dave Lindow, PE, GHD Robert Holden, PE, M1W Jennifer Gonzalez, PE, M1W
Outreach Efforts/Public Opinions	9:00 – 10:00 AM	Mike McCullough, M1W Rachel Gaudoin, M1W
Break	10:00 – 10:15 AM	All Participants
Operational Planning Activities a. Staffing b. System Integration and Interagency Coordination c. Source Control Program Updates	10:15 – 11:00 AM	David Lindow, PE, GHD Denise Conners, LWA
Water Quality Permitting and Compliance a. NPDES Permit Reissuance for RTP b. WDR/WRR for AWPF and Groundwater Replenishment • AWPF Optimization / Virus & Pathogen Reduction • Groundwater Quality Modeling Update and Tracer Study Plan c. Permitting and Compliance Schedule	11:00 – 12:00 PM	Alison Imamura and Sarah Stevens, M1W Denise Conners, LWA Elaine Howe, P.E. and John Kenny, PE, Trussell Technologies Ed Lin, PG, CHG, Principal Hydrogeologist, Todd Groundwater
Lunch	12:00 – 12:30 PM	All Participants
Closed Panel Deliberation	12:30 – 2:00 PM	Chair Tchobanoglous
Adjourn	2:00 PM	

MONTEREY ONE WATER PANEL CONTACT LIST

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Attachment C | Meeting Attendees

Facilitator: Kevin Hardy, NWRI

NWRI Panel

- Jean-Francois Debroux, PhD, Kennedy/Jenks Consultants
- Martin B. Feeney, PG, CEG, CHg, Consulting Hydrogeologist
- George Tchobanoglous, PhD, Panel Chair
- Michael P. Wehner, REHS, MPA, Orange County Water District

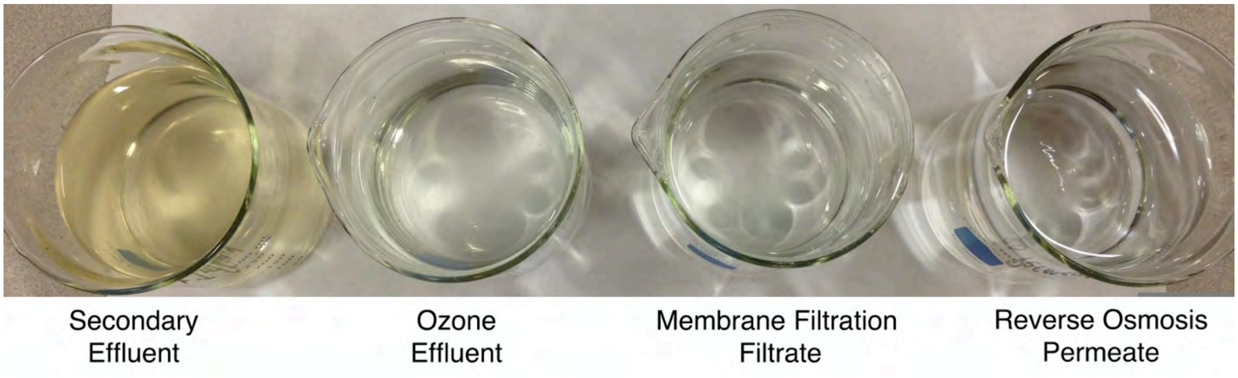
Agency Staff, Project Staff, and Other Participants

- Denise Conners, Larry Walker Associates
- Rachel Gaudoin, Monterey One Water
- Jennifer Gonzalez, PE, Monterey One Water
- Robert Holden, PE, Principal Engineer, Monterey One Water
- Elaine Howe, PE Trussell Technologies
- Alison Imamura, Monterey One Water
- John Kenny, PE, Trussell Technologies
- David Lindow, PE, GHD, Inc.
- Ed Lin, PG, CHG, Principal Hydrogeologist, Todd Groundwater
- Mike McCullough, MPA, Government Affairs Administrator, Monterey One Water
- Paul Sciuto, PE, General Manager, Monterey One Water
- Sarah Stevens, Monterey One Water

APPENDIX B

Pure Water Monterey Groundwater Replenishment Project: Advanced Water Treatment Facility Piloting Report

Pure Water Monterey Groundwater Replenishment Project: Advanced Water Treatment Facility Piloting



Draft Report - January 2016

Prepared for:

Partners for Pure Water Solutions

MRWPCA

Monterey Peninsula Water Management District

Prepared by:

Trussell Technologies, Inc.
John Kenny, P.E.
Gordon J. Williams, Ph.D., P.E.
Sarah Triolo

Separation Processes, Inc.
Alex Wesner, P.E.

Pure Water Monterey Groundwater Replenishment Project: Advanced Water Treatment Facility Piloting

DRAFT REPORT

Pure Water Monterey
A Groundwater Replenishment Project

January 2016

Prepared By:

Trussell Technologies, Inc.
John Kenny, P.E.
Gordon Williams, Ph.D., P.E.
Sarah Triolo

and

Separation Processes, Inc.
Alex Wesner, P.E.

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Acronyms

AAL	Archived Advisory Level
AOC	Assimilable Organic Carbon
AWTF	Advanced Water Treatment Facility
BAF	Biologically active filtration
BDOC	Biodegradable dissolved organic carbon
BOD	Biochemical oxygen demand
BPA	Bisphenol A
CEB	Chemically enhanced backwash
CEC	Contaminants of emerging concern
CEPT	Chemically enhanced primary treatment
CGWRRR	California Groundwater Replenishment Reuse Regulations
CIP	Clean in place
CO_2	Carbon dioxide
COD	Chemical oxygen demand
CT	Residual concentration times contact time
DBP	Disinfection by-product
DCP	1,3 dichloropropene
DCPA	Tetrachloroterephthalate
DDW	State Water Resources Control Board Division of Drinking Water
DO	Dissolved oxygen
DO_3	Dissolved ozone
DOC	Dissolved organic carbon
EEM	Excitation-emission matrices
EPA	Environmental Protection Agency
EPA PP	EPA Clean Water Act Priority Pollutants
GFD	Gallons per square foot per day
gpm	Gallons per minute
GWR	Groundwater Replenishment
HAA	Haloacetic acid
HRT	Hydraulic residence time
IPR	Indirect Potable Reuse
kDal	Kilodalton
LC-MS-MS	Liquid chromatography tandem mass spectrometry
LSI	Langelier saturation index
MCL	Maximum Contaminant Level
MF	Membrane filtration
MFI	Modified fouling index
mg-min/L	Milligram-minute per liter
mg-N/L	Milligrams as nitrogen per liter
mg-P/L	Milligrams as phosphorus per liter

mg/L	Milligrams per liter
mL	Milliliter
MPN	Most probable number
MPWMD	Monterey Peninsula Water Management District
MRWPCA	Monterey Regional Water Pollution Control Agency
mV	Millivolts
NaOCl	Sodium hypochlorite
NaOH	Sodium hydroxide
NDMA	N-Nitrosodimethylamine
NDPA	N-Nitrosodi-n-Propylamine
ng/L	Nanograms per liter
NL	Notification Level
nm	Nanometer
NTU	Nephelometric turbidity unit
O_3	Ozone
OCWD	Orange County Water District
ORP	Oxidation reduction potential
pCi/L	Picocuries per liter
PLC	Programmable logic controller
pMCL	Primary Maximum Contaminant Level
PNEC	Predicted no-effect concentration
POC	Particulate organic carbon
PoLI	Pesticides of local interest
ppm	Part per million
PSA	Pressure swing absorption
psi	Pounds per square inch
psi/min	Pounds per square inch per minute
PVC	Polyvinyl chloride
RO	Reverse osmosis
RTP	Regional Treatment Plant
SBS	Sodium bisulfite
SDI	Silt density index
SEC	Size-exclusion chromatography
SIWTF	Salinas Industrial Wastewater Treatment Facility
slpm	Standard liters per minute
SM	Standard Method for the Examination of Water and Wastewater
sMCL	Secondary Maximum Contaminant Level
SVRP	Salinas Valley Reclamation Plant
TDS	Total dissolved solids
THM	Trihalomethane
TI	Threshold Inhibitor
TKN	Total Kjeldahl Nitrogen
TMP	Transmembrane pressure

TOC	Total organic carbon
TOrC	Trace organic compound
TSS	Total suspended solids
UCMR	Unregulated Contaminant Monitoring Rule
UF	Ultrafiltration
UV	Ultraviolet
UV/AOP	UV light with hydrogen peroxide advanced oxidation process
UVT	Ultraviolet light transmittance
VFD	Variable frequency drive
VSS	Volatile suspended solids
µg/L	Microgram per liter
µS/cm	Microsiemens per centimeter

Executive Summary

The Monterey Regional Water Pollution Control Agency (MRWPCA) and the Monterey Peninsula Water Management District (MPWMD) are in the process of developing the Pure Water Monterey Groundwater Replenishment (GWR) Project. The GWR project involves treating secondary effluent from the Regional Treatment Plant (RTP) with an Advanced Water Treatment Facility (AWTF), injection into a groundwater aquifer, and subsequent withdraw to augment the potable water supply of the Monterey Peninsula. Additional source waters will be brought into the RTP to provide water for the AWTF. The AWTF will include the following major treatment processes:

- Preozonation (*i.e.*, ozonation),
- Upflow biologically active filtration (BAF; optional),
- Ultrafiltration (UF), otherwise known as membrane filtration (MF),
- Reverse osmosis (RO),
- Ultraviolet light with hydrogen peroxide advanced oxidation process (UV/AOP), and
- Product water stabilization.

Preozonation, MF, and RO were pilot tested during a nine-month long pilot testing program. The BAF process was not piloted, because it is an optional process, and the design of UV/AOP and product water stabilization systems do not require pilot testing. Pilot testing was conducted from mid-October, 2013 to mid-July, 2014, with extensive pilot water quality sampling from December 2013 to June 2014. Pilot testing follows the work of bench-scale testing, when a preliminary treatment train was developed and the treatability of various source waters was assessed (Trussell Technologies, 2014c); pilot testing occurred simultaneously with an extensive source water sampling campaign (Trussell Technologies, 2014d); and pilot testing informed the Basis of Design Report for the AWTF (Trussell Technologies and SPI, 2014b).

Secondary effluent from the RTP (non-nitrified trickling filter and solids contact effluent) was pumped into the former chlorine storage building, which was used as the pilot building. At times, additional source waters were shunted to the RTP collection system, and the resulting RTP secondary effluent was influenced by these source waters. The source waters tested during piloting consisted of City of Monterey stormwater from Lake El Estero and agricultural wash water that would otherwise go to the Salinas Industrial Wastewater Treatment Facility (SIWTF). Once within the pilot building, the secondary effluent was treated with sodium hypochlorite, ozone, MF, and RO. The ozone, MF, and RO pilot were procured from pilot equipment vendors. Two MF systems were procured to test two different MF configurations: inside-out and outside-in filtration. The RO permeate flow was 18 gallons per minute (gpm), with all product and waste flows drained to the holding pond next to the building and ultimately returned to the RTP headworks.

The objectives of the pilot testing were the following:

- Determine the preozonation ozone dose,
- Select MF technology (inside-out vs. outside-in),
- Determine sustainable MF flux,
- Determine sustainable RO recovery,
- Examine the impact of agricultural wash water shunting on RO fouling,
- Assess the product water quality, and
- Assess the water quality after each individual unit process.

These objectives were met by conducting a number of long- and short-term experiments, where operational conditions were changed and water quality and performance data were monitored. Operational conditions that were tested include the following:

- Lake El Estero and agricultural wash water shunt
- Chloramine residuals between 0 and 7 milligrams per liter (mg/L)
- Pre-ozone- and post-ozone-chloramination
- Ozone doses between 0 and 25 mg/L
- Ozone dose control methods utilizing oxidation reduction potential (ORP), dissolved ozone residual, and ultraviolet light transmittance (UVT)
- MF fluxes between 25 and 40 gallons per square foot per day (GFD)
- Inside-out MF and outside-in MF
- RO recovery of 81%
- RO feed pH setpoints of 6.0 to ambient (about 7.2)
- Phosphate precipitation in the RTP through ferric chloride addition

Pilot water quality sampling included sampling of the following parameters, before and after each unit process:

- General water quality parameters (*e.g.,* alkalinity, total organic carbon (TOC))
- Inorganics (*e.g.,* phosphate, ammonia)
- Disinfection by-products ([DBPs], *e.g.,* N-Nitrosodimethylamine [NDMA])
- Pathogens and pathogen indicators (*e.g.,* total coliforms, *Cryptosporidium*)
- Synthetic organic contaminants (*e.g.,* 1,4-dioxane, pesticides)

The following conclusions and recommendation are made based on the piloting results:

Preozonation conclusions and recommendations:

1. **Need for Preozonation:** Preozonation improved MF run times by a factor in the range of 4 to 8 by reducing membrane fouling. The reduction in fouling allows for a higher MF design flux, which would reduce the size and cost of the MF system. To realize these benefits, preozonation is recommended.
2. **Ozone Control:** Two ozone dose control methods were successfully demonstrated: (1) constant ozone dose with ORP control, and (2) ozone residual ozone dose

control. A third control method, UVT control, may provide the best ozone dose control of the three methods; however, further testing would be required, as the UVT equipment tested during piloting fouled too rapidly for use in a control system. Further testing of the UVT control method is recommended at either the pilot-scale demonstration facility or the full-scale facility to determine the benefits of the UVT control method.

3. **Ozone Dose:** An average transferred ozone dose of 9.5 mg/L (10 mg/L applied ozone dose at a transfer efficiency of 95%) provided sufficient preozonation. To provide this level of preozonation, an AWTF average transferred design dose of 9.5 mg/L is recommended. The AWTF maximum and minimum design transferred dose should account for the maximum and minimum design water quality.
4. **Secondary Performance and Ozone:** High TOC and nitrite concentrations in the RTP effluent contributed to the preozonation dose. RTP trickling filter operational changes may be able to reduce the nitrite concentration in the secondary effluent, which could reduce operational costs. If the nitrite concentration were reduced, it may be possible to reduce the design ozone dose and/or operational ozone dose.
5. **Ozone Disinfection:** Preliminary testing showed that disinfection credit might be possible at transferred ozone doses in the range of 15 to 19 mg/L. These doses led to ozone CTs (residual concentration times contact time) in the range of 1 to 2 mg-min/L.
6. **NDMA Formation:** Both pre-chloramination and post-chloramination yielded similar levels of NDMA formation. NDMA formation was about an order of magnitude lower than at West Basin Municipal Water District's Edward C. Little Facility, and it is expected that the NDMA concentration in the final product will be well below the 10 ng/L Notification Level.
7. **Bromate Formation:** Acceptable levels of bromate formation were observed through the ozonation process (maximum 9 micrograms per liter [μg/L], compared to the Maximum Containment Level (MCL) of 10 μg/L). The bromate formed during ozonation was consistently removed by the downstream RO process to levels below the detection limit (*i.e.,* less than 1 μg/L for all samples).
8. **Biologically Active Filtration:** A biological process (*e.g.,* upflow BAF) downstream of preozonation would improve the product water quality, and possibly improve AWTF operation by reducing the concentration of organics in ozone-BAF effluent, including TOC, NDMA, and contaminants of emerging concern (CECs, also known as chemical of emerging concern and constituents of emerging concern).
9. **High Ozone Doses:** High ozone doses (*e.g.,* an average of 20 mg/L, applied) increased the concentration of TOC and formaldehyde in the RO permeate for the waters tested. These high ozone doses are not recommended on a regular basis for the AWTF, unless a downstream biological process is included downstream of ozone.
10. **Impact on RO Validation Testing:** Preozonation interfered with measurements analogous to those required by the Division of Drinking Water (DDW) during RO membrane integrity testing in the first 20 weeks of operation. Due to this interference, the first 20 weeks of AWTF operation will likely have to be conducted without preozonation. Alternatively, it may be possible to develop an alterative RO membrane integrity test with DDW.

Membrane conclusions and recommendations (MF and RO):

1. **Technology Selection:** The outside-in MF technology dramatically outperformed the inside-out MF technology during piloting. An outside-in MF membrane technology is recommended for the AWTF.
2. **Chloramine Residual:** A chloramine residual (*e.g.,* 2 to 5 mg/L at the RO feed) was important for controlling organic fouling on the MF system. A chloramine residual of 2 to 5 mg/L at the RO feed is recommended at the AWTF.
3. **Design Flux:** The outside-in MF membrane filtered for more than 30 days at a flux of 30 GFD, with a constant applied ozone dose of 10 mg/L during the agricultural wash water shunt. An MF design flux of 30 GFD is recommended for the AWTF.
4. **MF Fouling and Secondary Performance:** The MF membranes experienced spikes in transmembrane pressure (TMP) associated with short-term episodes of degraded secondary effluent water quality (these spikes in TMP corresponded with higher coagulant needs at the Salinas Valley Reclamation Plant [SVRP]); however, they were able to recover without operational intervention.
5. **MF Filtrate Water Quality:** The MF provided suitable RO pretreatment, with 99.8% of the MF effluent turbidity measurements less than 0.05 Nephelometric Turbidity Units (NTU), and all silt density index (SDI) measurements less than 3.
6. **RO Membrane Fouling:** At a recovery of 81%, the RO membrane required only one cleaning over a test period of approximately seven months, including extended periods with elevated phosphate concentrations and a high RO feed pH setpoint (*e.g.,* 6.8). Based on this piloting work, a preliminary AWTF design RO recovery of 81% is recommended; however, further modeling is also recommended to ascertain the effect on the RO recovery of the source waters that were not tested during piloting (*e.g.,* the Blanco Drain).
7. **Need for Phosphate Control**: Elevated phosphate concentrations in the agricultural wash water may foul the RO membrane if the phosphate is not removed through the RTP, or if the formation of phosphate minerals is not controlled at the RO process (*e.g.,* through acid addition). Phosphate removal in the RTP can be enhanced via the addition of ferric chloride through the chemically enhanced primary treatment (CEPT) facilities, although an application more specific to the AWTF feed water or the agricultural wash water is recommended for the AWTF if this method of phosphate control is pursued (*e.g.,* adding ferric directly to the agricultural wash water).
8. **pH Control:** RO specific flux dropped dramatically when pH adjustment was stopped, and adjustments to pH control affected the RO specific flux (likely due to the formation of calcium phosphate minerals). pH adjustment facilities will be necessary for the AWTF (*e.g.,* sulfuric acid).
9. **RO Cleaning:** An acid clean, without the use of detergents, was sufficient to restore RO permeability after scaling developed. Other cleans may be needed during full-scale operation if RO performance is reduced by foulants not observed during piloting (*e.g.,* biological, silica).
10. **Effect of Agricultural Wash Water:** The agricultural wash water shunt did not discernibly increase the fouling of the MF or RO membranes under the conditions tested.

UV/AOP conclusions and recommendations:

1. **Design UVT water quality:** During pilot testing, the RO permeate UVT was measured at 95% or greater for almost all samples (one sample was measured at 94%, but this is likely due to a high residual chloramine concentration in the RO permeate). Accordingly, a design RO permeate UVT of 95% was assumed for preliminary full-scale UV/AOP design.
2. **1,4-dioxane removal:** 1,4-dioxane concentrations were below the detection limit in all RO permeate samples, and it was only detected in 4 of 11 secondary effluent samples (maximum concentration of 1.2 µg/L in the secondary effluent, whereas the notification level [NL] and the detection limit are both 1 µg/L). The UV/AOP system will be designed to achieve at least 0.5-log removal of 1,4-dioxane (*i.e.,* 68.4% removal), and thus the concentration of 1,4-dixoxane in the product water is expected to be consistently below the NL. The full-scale AWTF UV/AOP system will be challenge tested (by spiking 1,4-dioxane) during start-up to demonstrate at least 0.5-log removal of 1,4-dioxane.

Water quality conclusions and recommendations:

1. **Product Water Quality:** Pilot water quality sampling results indicate that the AWTF product water is expected to meet all applicable regulations in the California Water Recycling Criteria, including the groundwater replenishment regulations for subsurface application, MCLs, NLs, and Archived Advisory Levels (AALs). The RO permeate met all requirements, except for NDMA; the UV/AOP system will be designed to meet the 1,4-dioxane removal criteria and to reduce NDMA by at least 90%, which is expected to reduce the NDMA to an acceptable concentration.
2. **CEC Reduction:** Ozone and RO removed all but a few CECs to levels below their detection limits. Of the CECs that were not removed to below their detection limits, all were measured at concentrations well below any limits linked to health concerns and most will be well removed through the UV/AOP system.
3. **DBP Formation:** DBPs (*e.g.,* NDMA and bromate) were formed through ozonation and chloramination, but at levels that would be adequately addressed by the combination of RO and AOP. DBPs are not expected to be an issue for the final product water.
4. **Additional RO Modeling:** RO modeling that takes into account (a) the blending of all source waters in the RTP collection system, (b) removal of select constituents through the RTP, and (c) removal of selected constituents through upstream AWTF processes is recommended to assess the fouling potential of the source waters.
5. **Need for Ozone:** Ozone provides benefits to the water quality, including providing a barrier to many synthetic organic compounds.
6. **Need for RO membrane:** RO treatment is needed for removal of several constituents, and is the backbone of the AWTF treatment train.
7. **Need for UV/AOP**: AOP is needed to address NDMA and provide an additional barrier against CECs (such as 1,4-dioxane) and pathogens.

8. **Source Water Variability:** Based on the source water monitoring program, it is expected that the proposed treatment train will be sufficient to meet all product water quality requirements for all of the proposed source waters.

Other design considerations:

1. **Biologically Active Filtration**: While BAF design criteria may be estimated, pilot testing is recommended prior to full-scale implementation to determine site-specific design criteria. Additionally, pilot testing would also be recommended to determine the effect of a BAF system on the performance of the downstream MF system, if the BAF were to be included in the AWTF.
2. **UV/AOP impact on organics:** Some UV/AOP systems downstream of RO in water reuse applications increase the concentration of specific organic constituents (*e.g.,* formaldehyde). UV/AOP pilot-scale testing should be considered to quantify the impact of UV/AOP on organics for this water.
3. **UV/AOP pathogen and chemical removal:** Chemical (*e.g.,* 1,4-dioxane, NDMA) and pathogen removal varies between water reuse projects. The full-scale AWTF design can account for this variation by selecting conservative design criteria. Alternatively, additional testing (*e.g.*, collimated bench-scale testing) offers a potential for a more aggressive full-scale design (*i.e.,* a less conservative design).
4. **Additional Source Waters in the RTP collection system:** The addition of new source waters to the RTP collection system may impact the RTP and the AWTF design in ways that were not discussed in the Source Water and Pilot Water Quality Report (*e.g.*, nitrite formation, RO recovery)(Trussell Technologies, 2014d). RTP and AWTF modeling and demonstration-scale testing is recommended to reduce uncertainty during AWTF design and start-up.
5. **Additional Source Waters directly to the AWTF**: If any of the new source waters were brought directly to the AWTF, then additional testing would be required to determine if there were additional pre-treatment needs.
6. **Long-term MF testing:** Several flux conditions were tested during the piloting; if additional piloting were conducted, it would be beneficial to conduct long-term testing of the 30 GFD design flux to better characterize seasonal water quality impacts.

1 Background

1.1 Project background

The Monterey Regional Water Pollution Control Agency (MRWPCA) and the Peninsula Water Management District (MPWMD) are implementing a Groundwater Replenishment (GWR) Project to augment the Monterey Bay peninsula water supply through the design and construction of an Advanced Water Treatment Facility (AWTF). This AWTF will treat secondary effluent from the RTP, and will include the following processes:

- Ozonation,
- Upflow Biologically Active Filtration (BAF; optional),
- Membrane filtration (MF),
- Reserve osmosis (RO),
- Ultraviolet advanced oxidation process (UV/AOP), and
- Product water stabilization.

The RTP wastewater supply will be augmented to provide flow for the AWTF. To achieve this augmentation, additional water supplies will be brought into the collection system. These additional water sources may include agricultural wash water, urban runoff, and potentially irrigation runoff water. A schematic of the AWTF processes, the existing RTP processes, and the additional source waters is shown in Figure 1.1.

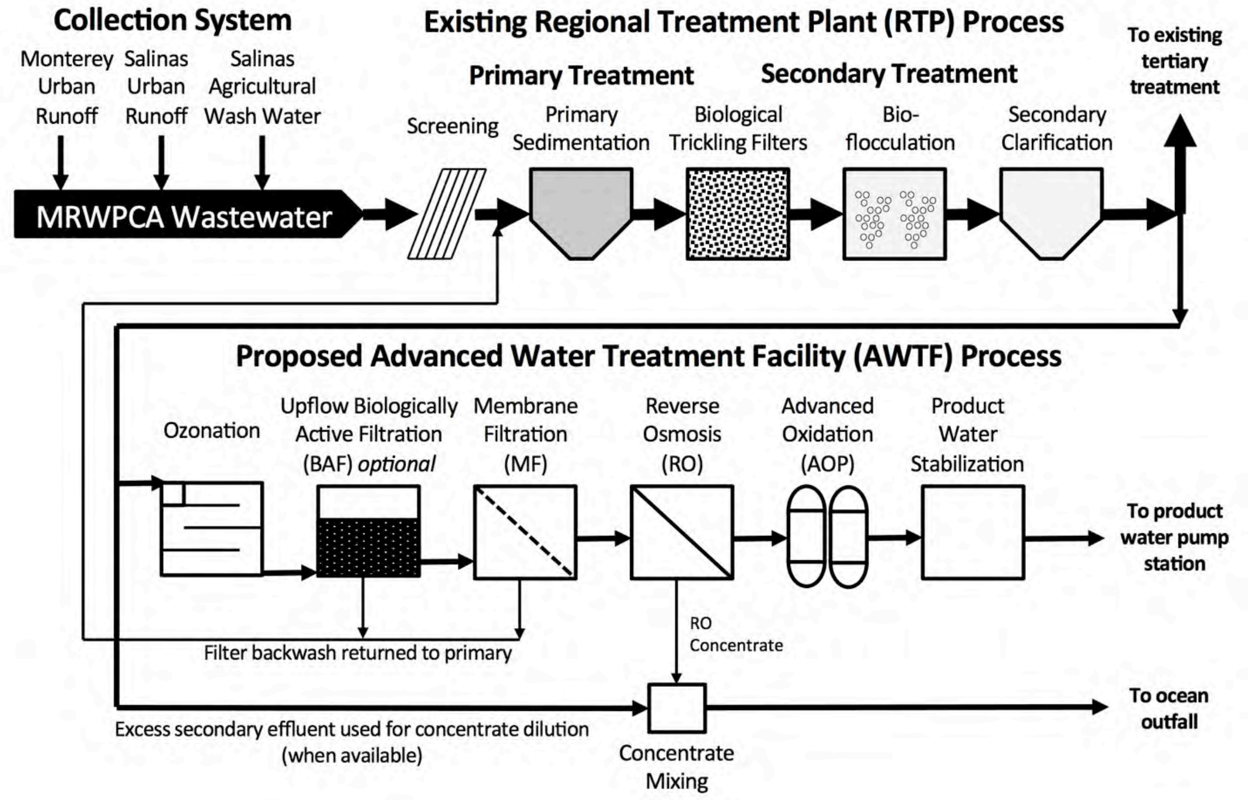

Figure 1.1 – Schematic of AWTF treatment processes

Pilot testing was conducted to develop design criteria for select unit processes (ozone, MF, and RO) and to collect water quality samples. The pilot testing began in October 2013 and was completed in July 2014. Both the design criteria results and the water quality results are discussed in this report. Bench-scale testing and source water quality sampling was also conducted to select the AWTF processes. A summary of the bench-scale testing and source water qualities is provided below.

1.2 Source water descriptions

Each of the additional water sources to the GWR Project has unique water quality signatures. These signatures are discussed in this section, as well as the identification of treatment requirements at the RTP, AWTF and any pre-treatment for these waters.

Unused wastewater

Secondary effluent in excess of the non-potable recycled water demands will be used as part of this project. This water is currently discharged to the Monterey Bay through the MRWPCA ocean outfall. The treatment process design for the AWTF was driven by the water quality of this existing secondary effluent. The primary water quality parameters that drive the treatment requirements for the secondary effluent are: (1) pathogens, (2) total organic carbon (TOC), (3) nitrogen species (ammonia, nitrate, and nitrite) (4) mineral quality (*e.g.,* dissolved solids including chloride, calcium, phosphate, silica), and (5) select unregulated contaminants. The concentrations of these parameters are all typical of a non-nitrified trickling filter effluent prior to disinfection.

Agricultural wash water

Agricultural wash water and wastewater from other agricultural processing operations throughout the City of Salinas will be diverted into the MRWPCA wastewater collection system at the MRWPCA Salinas Pump Station site. These waters are currently treated at the Salinas Industrial Wastewater Treatment Facility (SIWTF). From an organic loading perspective, this source water can be characterized as a low to moderate strength wastewater, with organic levels and pathogen concentrations lower than that of the raw municipal wastewater currently treated by MRWPCA at the RTP. This water contains elevated concentrations of phosphate and total dissolved solids (TDS), as compared with the existing RTP wastewater. These elevated phosphate concentrations (*e.g.*, 9 milligrams as phosphorus per liter [mg-P/L] compared with the existing 3 mg-P/L) will require additional controls to prevent calcium phosphate fouling on the RO membranes. Additional iron-based coagulant may be added in the collection system at the Salinas Area Pump Station or at the RTP headworks to enhance the phosphate removal through primary and secondary treatment. Further, bench-scale testing has indicated that this wash water (when mixed with the existing wastewater and treated through the RTP primary and secondary treatment) may have a measurable increase on the rate of fouling of the membrane filter; however, the degree of this impact was evaluated through pilot testing.

Monterey and Salinas stormwater and urban runoff

Urban runoff and stormwater from the cities of Monterey and Salinas will be diverted to provide this source water. Sampling of these sources indicates that elevated concentrations of TDS are the primary water quality consideration for the Monterey stormwater. However, the increase in TDS is minor from a treatability perspective, and it is not expected that the use of this water would require any changes to the process train. Once this water is mixed with the existing wastewater at the RTP, the resulting increase in TDS is expected to have a negligible impact on the final product water quality.

Agricultural drainage water

An additional type of source water that may be included in the project is agricultural drainage water from the Blanco Drain, Reclamation Ditch, and/or Tembladero slough (presently, the Blanco Drain and the Reclamation Ditch are included in the project, whereas the Tembladero Slough may be pursued at a later date). The Tembladero slough and Reclamation Ditch also include urban and non-urban runoff. Extensive source water monitoring of the Blanco Drain water has been conducted, including monitoring of pesticides; only low levels of a few pesticides were detected. Of the pesticides that were detected, most concentrations were orders of magnitude below applicable regulatory or advisory levels for drinking water (*i.e.,* State Water Resources Control Board Division of Drinking Water (DDW)[1] Maximum Contaminant Levels (MCLs) or Notification Levels (NLs)/Archived Advisory Levels (AALs)). Only two were at concentrations near applicable drinking water regulatory/advisory levels in the raw water: dieldrin and 1,3 dichloropropene (DCP). It is expected that both of these pesticides would be reduced to concentrations below detection through dilution with the wastewater alone. Further, the ozone, RO, and AOP processes would also be expected to provide a significant barrier for these contaminants. Other contaminants that would drive the treatment of drainage water are the elevated levels of dissolved solids and nitrate, both of which will be reduced to acceptable levels through the RO treatment. It is expected that no additional treatment would be needed for this water, beyond what is already proposed for treating the secondary effluent.

1.3 Bench-scale testing

Bench-scale pretreatment testing was conducted on the alternative GWR Project source waters to determine an appropriate pretreatment train and the treatability of the source waters. Testing was conducted on the RTP secondary effluent without blending, blended with the Blanco Drain, and blended with the agricultural wash water, and included pretreatment trains comprised of combinations of preozonation, coagulation and/or sedimentation. For these conditions the following parameters were measured:

- General water quality parameters
- Trace organic compounds (TOrCs)
- Excitation-emission matrices (EEMs)

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[1] On July 1, 2014, California's Drinking Water Program was moved from the California Department of Public Health (CDPH) to the State Water Resources Control Board (SWRCB), and as a result of the change they are now titled the Division of Drinking Water.

- Size-exclusion chromatography (SEC)
- Ultrafiltration (UF) fractionation
- Modified fouling index (MFI)
- Bacteriophage inactivation (bacteriophage MS2)
- Disinfection by-product formation (NDMA and bromate)

The pretreatment alternatives were evaluated by their impact on membrane fouling potential (EEM, SEC, UF fractionation, MFI), TOrC removal, virus inactivation, and disinfection by-product (DBP) formation.

The results from this testing were used to develop the AWTF process described below, which included preozonation as a method for reducing membrane fouling. This testing also indicated that the unused RTP secondary effluent would be the primary driver for the treatment process, with a secondary consideration coming from the high phosphate concentrations in the agricultural wash water.

1.4 AWTF process

DDW regulates GWR projects. The MRWPCA GWR Project falls under Subsurface Application DDW regulations for Indirect Potable Reuse (IPR). These regulations require advanced water treatment facilities to include RO and AOP, in addition to setting pathogen inactivation and chemical removal requirements. Membrane filtration is included to pretreat the RO feed water, and to remove pathogenic protozoa (*e.g., Cryptosporidium* and *Giardia*). Ozone is included to pretreat the MF feed water (*i.e.,* preozonation), and provide pathogen inactivation and destruction of Contaminants of Emerging Concern (CECs). The AOP process will be UV/AOP, which provides pathogen inactivation and CEC removal. Finally, product water stabilization treatment is necessary to increase the calcium concentration, alkalinity, and pH of the product water prior to conveyance, injection and distribution.

Product water stabilization and UV/AOP systems can be designed without pilot data and, thus, they were not included in the pilot program; however preozonation, MF, and RO system design criteria require piloting.

Low-pressure membrane (*e.g.,* MF systems) design fluxes must be empirically determined through pilot testing. These design fluxes are impacted by preozonation, and thus preozonation must be included in pilot testing. Lastly, some of the RO fouling mechanisms are not well understood, and piloting of the RO system is useful for demonstrating sustainable recoveries. Given these design constraints, pilot testing was conducted at the RTP on the ozone, MF, and RO processes.

1.5 Pilot objectives

The objectives of the pilot testing were the following:

- Determine the preozonation ozone dose,
- Select MF technology (inside-out vs. outside-in),

- Determine sustainable MF flux,
- Determine sustainable RO recovery,
- Examine the impact of agricultural wash water shunting on RO fouling,
- Assess the product water quality, and
- Assess the water quality after each individual unit process.

2 Pilot Facilities and Testing

The pilot facilities, processes, procedures, and schedules are discussed in the following sections.

2.1 Description of pilot facilities

The following treatment processes were included in the pilot testing to meet the pilot objectives:

- Screening
- Chloramination
- Preozonation
- Ultrafiltration
- Reverse osmosis

Screening was included to stop clogging of the ozone pump. Chloramination is required to minimize fouling of MF and RO systems. Each system is described in more detail in the following sections.

All pilot facilities were located in the building at the RTP that used to house the chlorine cylinders (a simplified process and instrumentation diagram (P&ID) is shown in Figure 2.1, layout shown in Figure 2.2, and a photo shown in Figure 2.3). The ozone equipment was procured from the ozone equipment supplier APTWater (now called Ultura), which included an ozone generation and contacting skid (HiPOx), an oxygen generation skid, and a chiller skid. Harn R/O Systems provided the membrane equipment on skids. These skids included an inside-out MF skid (Pentair module, an outside-in MF skid (Toray module), an RO skid (2:1 array, single pass; CSM membranes), an RO cleaning skid, and MF feed and filtrate tanks. Ancillary equipment was procured separately. Upflow BAF equipment (not used) was available onsite from the Filter Loading Evaluation for Water Reuse study. These facilities, and the source water, are discussed in more detail below.

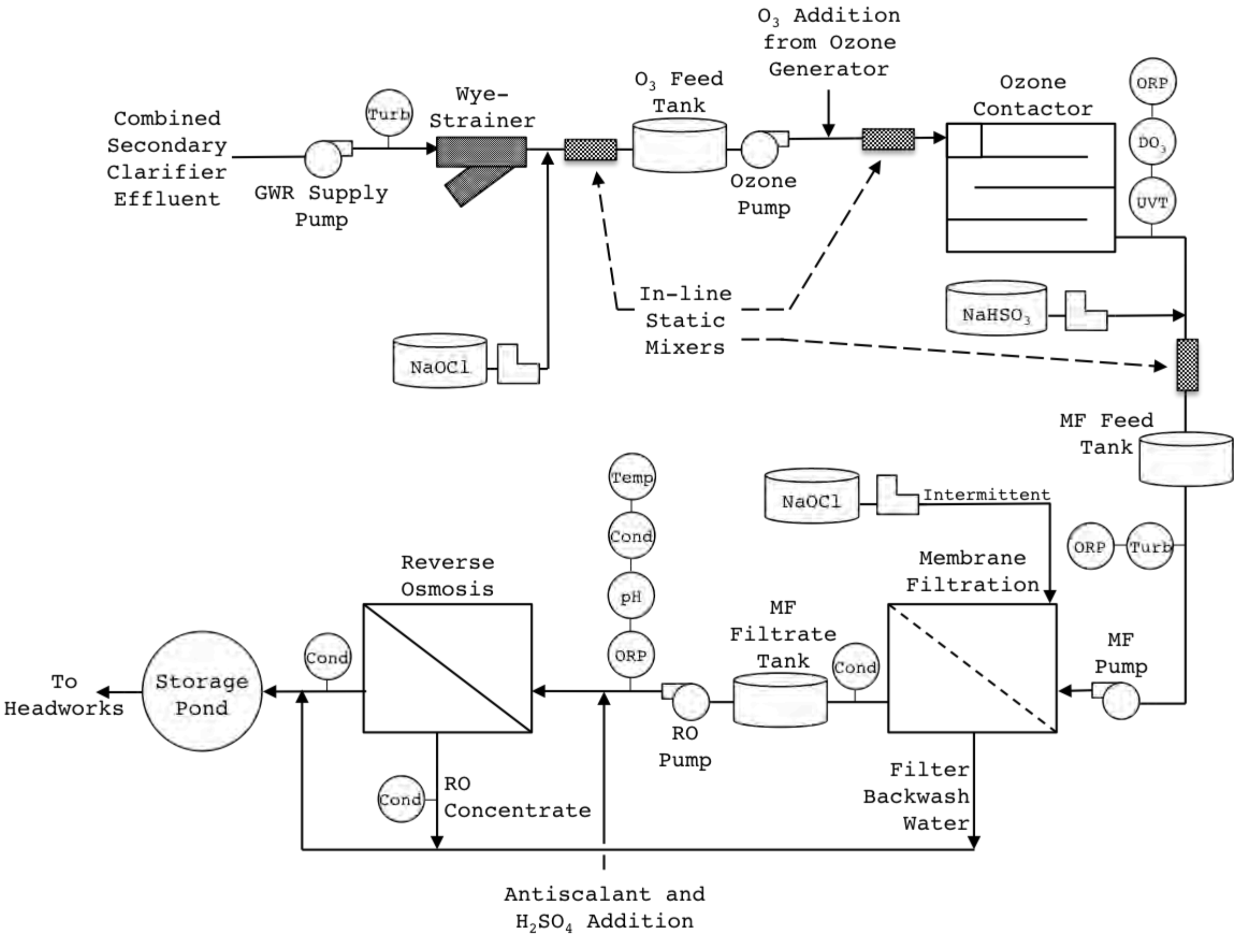

Figure 2.1 - Simple Pilot P&ID

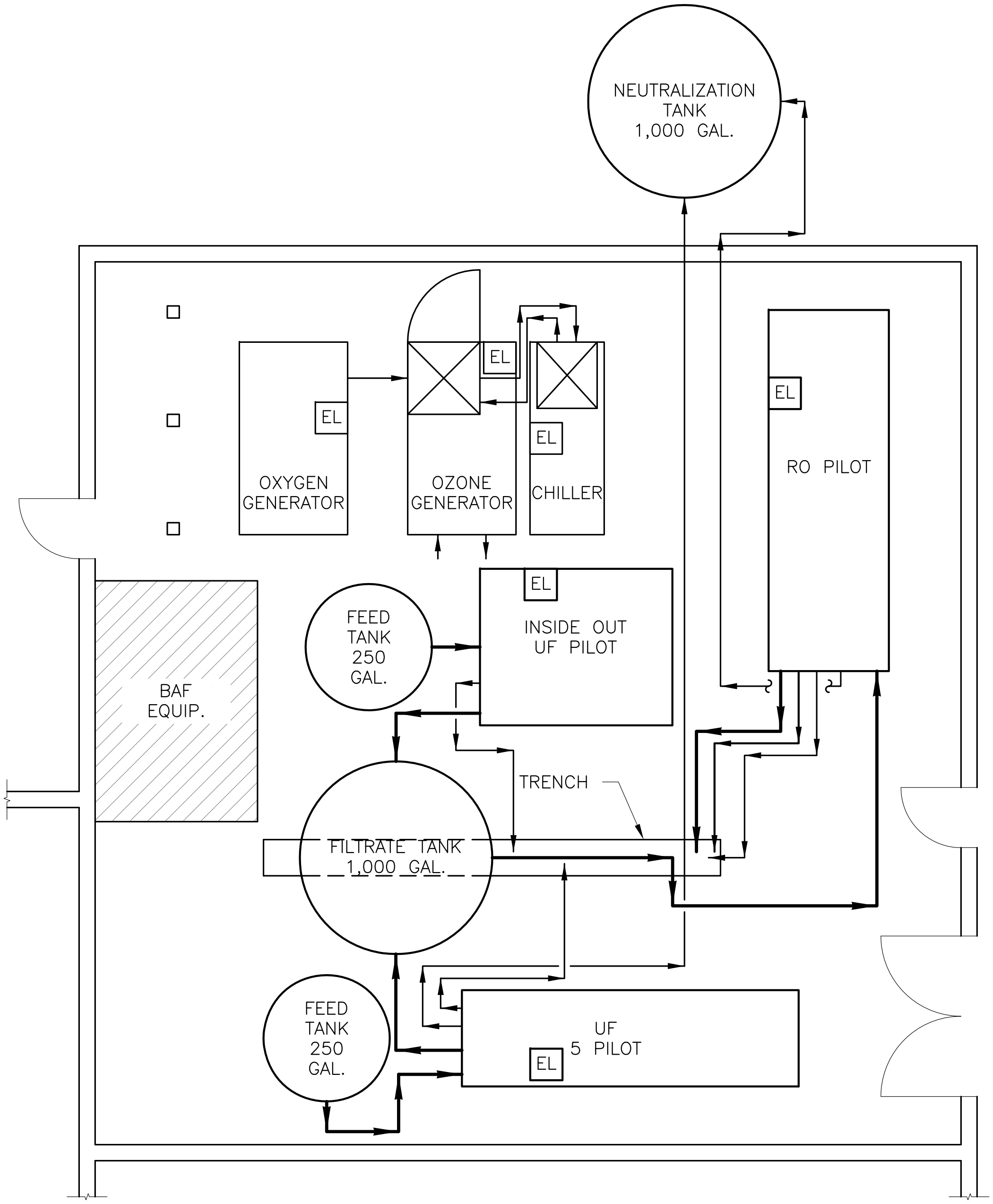

Figure 2.2 – MRWPCA GWR pilot layout

Figure 2.3 – Photo of pilot facilities. Outside-in MF front left; BAF equipment back left (not used); inside-out MF center; ozone back left; and RO right.

2.1.1 Source water

The pilot equipment received clarified secondary effluent from the RTP (non-nitrifying tricking filters, a solids contactor - also known as bioflocculation - and secondary clarifiers). A submerged pump, encased in a coarse screen[2] and located in the combined secondary clarifier effluent channel (GWR supply pump), pumped the secondary effluent through the pilot screens and into the ozone feed tank. The GWR supply pump pressurized the line leading to the ozone feed tank, where an automatic valve periodically opened and closed (about every 30 seconds) to keep the water level in the feed tank within a specified range. The GWR supply line flowed at about 60 gallons per minute (gpm) when the valve was open. After the secondary effluent entered the pilot building, it was pretreated with screening and sodium hypochlorite (discussed below).

Additional source waters were brought into the RTP collection system (also known as shunting) on two occasions during piloting (the timeline of these shunts are discussed later in the report). The first shunt consisted of Lake El Estero stormwater and it lasted for 56 hours. The second shunt was comprised of agricultural wash water and it was continued through the end of the pilot program.

2.1.2 Screening

Screening was included in the pilot process to remove snails from pilot influent. Early in the pilot program, occasional slugs of snails would enter the ozone pump and clog the closed impeller, reducing pilot flow. A Hayward wye-strainer with 1/16” perforated polyvinyl chloride (PVC) screens was used. This screen removes objects via physical straining (also known as size exclusion).

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[2] Pump encasement cleaned on May 6 to restore flow (from 24-35 gpm starting April 28 to 60 gpm)

2.1.3 Chloramination

Chloramination was included in the pilot process to reduce MF and RO fouling and to inhibit snail growth in the ozone feed tank. Chloramination effectively inhibits biological growth at low concentration, which can extend MF run times and decrease the frequency of RO cleanings. Sodium hypochlorite (12.5% neat) was dosed via a Pulsafeeder diaphragm pump upstream of the ozone system to achieve a chloramine residual of 2 to 5 mg/L at the RO feed[3]. Non-nitrified secondary effluents contain high concentrations of ammonia (approximately 30 mg/L as N at the RTP), and hypochlorous acid and hypochlorite ions from the sodium hypochlorite solution react with the ammonia to form chloramines.

The sodium hypochlorite solution was kept at one part neat sodium hypochlorite to one part tap water (1:1) to increase the pump frequency, which minimizes large pockets of sodium hypochlorite solution and thus breakpointing, while also maintaining sufficient storage. Immediately downstream of injection, in-line static mixers were used to rapidly mix the sodium hypochlorite solution with the secondary effluent to minimize the breakpoint reaction.

2.1.4 Preozonation

Ozone pretreatment provides a number of benefits to a potable reuse treatment system, which warranted its inclusion in the AWTF and pilot treatment processes. These benefits are as follows: (1) low-pressure membrane pretreatment, (2) CEC destruction, and (3) the potential for pathogen disinfection credit. These benefits are discussed in more detail below. Following this discussion, a description of the ozone equipment follows.

Low-pressure membrane pretreatment
Ozonation prior to low-pressure membrane filtration (*i.e.,* preozonation) can increase low-pressure membrane (*e.g.,* ultrafiltration [UF] membrane) run times and/or the flux for some waters. Non-nitrified secondary effluent (*e.g.,* RTP effluent) is only moderately oxidized and contains high concentrations of large organic molecules (*i.e.,* > 10 kilodaltons [kDa]), which rapidly foul MF membranes. Ozonation of these large organic molecules reduces their size (*e.g.,* < 1 kDa) via oxidation, and allows them to pass through the MF system with minimal fouling (the organic molecules are then well-rejected by the downstream RO system). With the fouling potential of the water reduced by preozonation, the MF system run times are increased and/or the MF system can be designed for higher fluxes. Long run times allow for less chemical usage and a greater recovery, while designing the MF system for a larger flux reduces the number of membrane modules required.

CEC destruction
Preozonation can reduce the concentration of CECs that are discharged to the environment through the RO concentrate. CECs, and other high molecular weight organics,

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[3] Field measurements made with Hach DR 890 using 25-mL total chlorine DPD packets

are typically well rejected by RO systems and thus concentrated in the RO concentrate. Ozone (O_3) can minimize the concentrating of CECs in the RO concentrate by reducing the concentration of some CECs in the RO feed. Ozone transforms CECs in the same way that it transforms MF-membrane-fouling organic molecules. CEC removal can be related to the ozone-to-TOC ratio (O_3:TOC), where larger ratios typically correlate more CEC removal (see Table 2.1 for a qualitative description of this relationship).

Table 2.1 – Relationship between O_3:TOC and typical CEC removal

O_3:TOC	Qualitative description of typical CEC removal
0.5	Easily removed CECs are destroyed
1	Many CECs are destroyed
1.5	All but recalcitrant CECs are destroyed

Pathogen disinfection credit

Preozonation can provide disinfection credit for viruses and bacteria (*e.g.,* 4 and 3 logs reduction credit, respectively, for an ozone CT of 1 milligram-minute per liter [mg-min/L]). In the same way that ozone transforms CECs and MF-fouling organic matter, ozone can destroy pathogenic viruses, bacteria, and protozoa. To claim disinfection credit, DDW requires an ozone residual be maintained at all times, such that a sufficient CT is demonstrated. If the water quality is highly variable, then the ozone system must be designed for the worst-case water quality in order to ensure disinfection at all times.

The ozone system was included in the process for both MF pretreatment and CEC removal. MRWPCA currently does not need disinfection credit from ozone (the DDW regulations require that the recycled water used as recharge water for a groundwater replenishment reuse project receives treatment that achieves at least 12-log enteric virus reduction, 10-log *Giardia* cyst reduction, and 10-log *Cryptosporidium* oocyst reduction, which are achieved through the MF, RO, and UV/AOP processes), so only preliminary testing was conducted with respect to disinfection design considerations.

Ozone generation and contacting skid

Ozone generation, injection, and contacting occurred at the ozone generation and contacting skid. Ozone was generated from high purity oxygen inside the ozone generator. High purity oxygen was received from the oxygen generation skid at approximately 15 standard liters per minute (slpm). After generation, the ozone/oxygen gas stream was injected into the screened secondary effluent. The ozone concentration in this gas stream was typically 8 to 12% ozone by weight, as measured by a Teledyne Instruments: Advanced Pollution Instrumentation gas-phase ozone analyzer. Injection was achieved with an injection quill, driven by a differential in the gas pressure compared to the liquid pressure. Mixing was achieved downstream of injection with four two-foot 1.5-inch diameter in-line static mixers (3 to 4 seconds; flow 25 to 45 gpm).

After injection and mixing, contact time was provided in the 6-inch serpentine pipeline contactor shown in Figure 2.4 (2 to 3 minute hydraulic residence time [HRT]). At the end of contacting, an air vent valve separated gas from the fluid stream. The gas stream passed through a thermally catalyzed ozone destruct to remove ozone in the off-gas. After the off-gas was removed, the ozonated secondary effluent passed through a number of sensors before quenching and final discharge to the MF feed tanks. An oxidation-reduction potential (ORP) sensor[4], dissolved ozone (DO_3) sensor[5], and an ultraviolet light transmittance (UVT, at 254 nm) sensor[6] were located at the end of the contactor, downstream of the air-vent valve. These sensors were used to control the ozone dose (described in subsequent sections).

A sodium bisulfite (SBS) solution was injected downstream of the instruments, as needed, to quench residual ozone (*i.e.,* to eliminate the ozone residual through reduction reactions). The downstream membranes are sensitive to ozone, and the ozone system was occasionally operated to produce an ozone residual at the contactor effluent. When operated this way, the ozone residual was quenched with SBS. A dilution of approximately one part SBS (neat strength of 25%) to thirty-two parts non-chlorinated tap water was made (1:33). This dilution ensured a rapid pump speed, which would not allow pockets of dissolved ozone to carry downstream without quenching. After quenching was accomplished on an as needed basis, the ozonated effluent flowed to the MF feed tanks.

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[4] George Fischer Signet +GF+, 277X series

[5] Emerson Process Management, Rosemount Analytical, 499A OZ

[6] AccUView online UV Transmission Analyzer, HF Scientific.

Figure 2.4 - Ozone generation skid (center), chiller skid (right), and oxygen generation skid (back left), during installation

Oxygen generation and chiller skids

Oxygen was generated on-site at the oxygen generation skid (see Figure 2.5). Generation equipment consisted of a screw press air compressor, an air drier, a coalescing filter, a pressure swing absorption (PSA) oxygen purifier, an oil-water separator, and receivers. Pressure swing absorption systems take advantage of pressure dependent nitrogen adsorption capabilities of zeolite media by operating in cycles. In the high-pressure cycle, nitrogen is removed from the chilled airflow by adsorption to the media. When the media is saturated with nitrogen, the flow shifts to a parallel PSA cell, while the saturated cell is depressurized. At the low pressures that come with depressurization, nitrogen desorbs from the media and is released to the atmosphere. The cells are rotated to achieve a constant production of high purity oxygen (approximately 94% oxygen by weight[7]).

Ozone generation produces excess heat, which must be cooled. Cooling was accomplished through a closed-loop chiller system, with a water-glycol mixture as the working fluid.

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[7] Ultura lab testing prior to deployment of the PSA system

Figure 2.5 - Oxygen generation skid, during installation

2.1.5 Membrane filtration

UF is a class of low-pressure membrane filtration (MF) systems that utilizes a pressure differential to drive liquids across a semipermeable membrane. MF is dead end filtration and is generally considered to consist of pores sized between 0.1 and 0.01 microns. The filtration mechanism is size exclusion.

For the MRWPCA GWR Pilot, the MF serves as pretreatment to the RO by removing solid particles larger than 0.01 to 0.04 micron. These include viruses, bacteria, and suspended solids. Two different hollow fiber MF systems were evaluated during the MRWPCA GWR Pilot. The first was a Pentair X-flow which has an inside to outside flow configuration, meaning the feed water is introduced to the *Lumen* or inside of the fiber and the product water or *Filtrate* flows across to the outside of the fiber. The other system tested was a Toray HFU-2020N that has an outside to inside flow configuration in which the feed water enters the fiber from the outside and the product water flows from the lumen side.

Pentair X-Flow System

The Pentair X-Flow unit was provided by Harn RO systems and is shown is Figure 2.6 below. The unit was equipped with 1 Pentair *X-Flow* UF module, feed and back wash pumps both with variable frequency drives (VFDs), 700-micron Y-Strainer, and an on-board programmable logic controller (PLC) that captured and recorded data every 2 minutes from on-board instruments.

Figure 2.6 - Pentair X-Flow Pilot Unit

The Pentair MF unit was started up on November 11, 2014 and testing officially concluded February 11, 2014. Several flux rates, ranging from 6 to 20 GFD, were attempted to identify the optimum operating point in terms of maximizing production and minimizing the cleaning frequency. At start-up, the Pentair unit was configured to automatically back wash every 25 minutes and to undergo daily Chemically Enhanced Backwash (CEB) cycles with a 200 mg/L sodium hypochlorite (NaOCl) solution followed by a Sulfuric Acid solution targeting pH 2 to 3. Throughout the pilot, a chloramine residual was maintained through the pilot system with the target of 2 to 5 mg/L at the RO feed.

Toray System

The Toray MF Pilot unit was provided by Harn RO systems and is shown in Figure 2.7 below. The unit was equipped with 2 Toray *HFU-2020N* UF modules, feed and back wash pumps both with VFDs, 100-micron Arkal self-backwashing pre-strainer, and an on-board PLC that captured and recorded data every 2 minutes from on-board instruments.

Figure 2.7 - Toray Pilot Unit

The Toray MF unit operated for just under 8 months, from November 18, 2013 through July 7, 2014. Several flux rates, ranging from 25 to 40 GFD, were attempted to identify the optimum operating point in terms of maximizing production and minimizing the cleaning frequency. While in operation, the Toray unit underwent daily CEB cycles with a 300-mg/L NaOCl solution. Throughout the pilot, a chloramine residual was maintained through the pilot system with the target of 2 to 5 mg/L at the RO feed.

2.1.6 Reverse Osmosis

RO is a class of medium- to high-pressure membrane filtration that utilizes a pressure differential to drive liquids across a semipermeable membrane. RO utilizes a pressure differential to overcome the osmotic pressure of the liquid. The precise mechanism of salt removal is not completely understood; however, there are primarily four theories. These include the *Sieve*, *The Wetted Surface*, the *Preferential Sorption-capillary,* and the *Solution-Diffusion Model* Mechanisms. It is the *Solution-Diffusion Model* that is most accepted.

The solution-diffusion model of transport assumes a non-porous, homogeneous membrane surface layer. Each component in a pressurized solution dissolves in the membrane and diffuses through the membrane. The flow of water and salt through the membrane is uncoupled (*i.e.,* they are independent of each other), and the water transports at a more rapid rate than the salt.

For the MRWPCA GWR Pilot, the RO serves to remove dissolved ions, bacteria, viruses, and CECs. The typical range of molecular weight cut off is less than 100 Daltons for RO membranes.

The Toray RO Pilot unit was provided by Harn RO systems and is shown below. The RO pilot unit was a two-stage configuration with 2 vessels in the first stage and one in the second. Each vessel contained seven *CSM RE4040-FE* 4-inch RO elements. The pilot unit was equipped with a booster pump, 10-micron cartridge filter, high pressure feed pump, and an interstate booster pump. Both the high-pressure feed and interstate booster pumps were controlled by VFDs. Recovery was manually controlled. Data was recorded automatically every 10 minutes via the on-board PLC.

Figure 2.8 - RO Pilot Unit

The chemical feed system consisted of Threshold Inhibitor (TI) and acid addition. The dose rate for both chemicals was manually controlled. The TI used was Avista Technologies *Vitec 4000* and was dosed at 5 mg/L through the entire pilot. 92% Sulfuric Acid was used for pH control.

2.2 Piloting procedures

Schedules and procedures necessary to meet the pilot objects are discussed in this section.

2.2.1 Test plan

A pilot test schedule was developed to meet the pilot objectives (see Table 2.2). The major components of this test plan were as follows:

- Inside-out versus outside-in MF filtration testing
- MF flux and preozonation dose testing
- RO recovery testing
- Shunt testing (Lake El Estero and agricultural wash water)
- Water quality sampling (process, product, and DBPs)

The details of the above experiments, and their results, are discussed in detail later in the report.

Table 2.2 – Pilot test schedule

Description	Month									
	10-13	11	12	1	2	3	4	5	6	7-14
Mobilization and start-up	■	■								
MF technology (inside-out vs. outside-in) selection			■	■	■	■				
Sustainable MF flux testing			■	■	■	■	■	■	■	■
Preozonation ozone dose testing			■	■	■	■	■	■	■	■
Sustainable RO recovery testing			■	■	■	■	■	■	■	■
Lake El Estero Shunt testing					■					
Agricultural wash water shunt testing							■	■	■	■
Individual treatment process water quality sampling			■	■	■	■	■	■	■	■
Product water quality sampling			■	■	■	■	■	■	■	■
Disinfection by-product water quality sampling			■	■	■	■	■	■	■	■
Demobilization										■

2.2.2 Bench-scale stabilization

Bench-scale stabilization of the RO permeate was conducted to prepare a sample for leach testing. TODD engineers extracted soil samples from the Seaside aquifer (where GWR injection will occur) during preliminary drilling. A sample of stabilized RO permeate was used to measure the leaching potential of the soil. Product water stabilization reduces aquifer leaching and mineral mobilization (*e.g.,* arsenic), among other things. At the time of this experiment, product water stabilization goals for the MRWPCA RO permeate had not yet been developed, and thus the product water stabilization goals of Orange County Water District (OCWD) were used (shown in Table 2.3).

Table 2.3 - GWR Bench-Scale Post-treatment Stabilization Goals

Parameter	Unit	Target Value
Langelier Saturation Index (LSI)	--	-0.1
Calcium	mg/L as $CaCO_3$	32
Alkalinity	mg/L as $CaCO_3$	40
pH	--	8.5

These goals were targeted with the following steps:

1. Strip carbon dioxide (CO_2) from the RO permeate with air stripping
2. Add calcium with calcium chloride dehydrate
3. Increase alkalinity with sodium hydroxide (NaOH)
4. Adjust the pH, as needed, with CO_2 injection

The above procedure was followed using pilot RO permeate and shipped to TODD engineers for leaching analysis.

2.2.3 Toxicity testing

The toxicity of the RO concentrate was analyzed and compared against the requirements of the California Ocean Plan. The sample was collected on April 19 and shipped to Pacific EcoRisk for analysis. Pacific EcoRisk tested the water for acute and chronic toxicity. The test species for acute toxicity was Inland silverside (*Menidia beryllina)*, and Giant Kelp (*Macrocystis pyrifera)* was used as the chronic toxicity test species. These test species are the same species used by the RTP for their regular compliance with the Ocean Plan. The results of this testing are reported in the Pacific EcoRisk toxicity report and attached Trussell Tech cover letter and the Source Water and Product Water Quality (Trussell Technologies, 2014d).

2.3 Water quality sampling scope

Two water quality sampling campaigns were conducted during the pilot test period: a source water sampling campaign and the pilot sampling campaign. The pilot sampling campaign was conducted to characterize the performance of specific processes and to evaluate the water quality of the RO permeate (*i.e.,* the AWTF process product water without UV/AOP and product water stabilization). The source water sampling campaign was conducted to evaluate the treatability of various sources in consideration for AWTF flow augmentation. The results from both of these sampling campaigns are useful when reporting the pilot results; however, this report focuses on the pilot water sampling results. A description of the source water campaign, including results, motivation, and methods, is described elsewhere (Trussell Technologies, 2014d). Select results from the source water sampling are reported in this Pilot Report when required for clarity or completeness. An overview of the source water campaign is presented below.

2.3.1 Source water quality sampling

A one-year monitoring program was started in July 2013 for five of the potential source waters. Regular monthly and quarterly sampling was carried out for the RTP secondary effluent, agricultural wash water, and Blanco Drain drainage water. Limited sampling of stormwater from Lake El Estero was performed due to seasonal availability, and there was one sampling event for the Tembladero Slough drainage water.

A full characterization of these source waters, as defined by DDW’s Policy Memo 97-005, was performed on these waters (RTP effluent, agricultural wash waster, and Blanco Drain on a quarterly basis; Lake El Estero and Tembladero slough one time each), with an expanded monitoring list for pesticides given the high levels of agricultural activity in the area. An all-inclusive approach was taken to the source characterization, where the full list of parameters was monitored in all sources. The types of constituents included in the GWR source water monitoring campaign are the following:

- General water quality parameters
- DDW MCLs
    - Inorganic chemicals
    - Organic chemicals

    - DBPs
    - Radionuclides
    - Microbiological parameters
- DDW NLs
- DDW Drinking Water AALs
- Environmental Protection Agency (EPA) Unregulated Contaminant Monitoring Rule (UCMR) Lists 1, 2 and 3
- EPA Clean Water Act Priority Pollutants (EPA PP)
- Pesticides of Local Interest (PoLI)
- CECs

See the Source Water and Product Water report for detail and results (Trussell Technologies, 2014d).

2.3.2 Pilot water quality sampling

Water quality sampling was conducted on a weekly basis during piloting. Source water sampling for the GWR project (including RTP effluent) was conducted on a monthly basis. The scope and full results of the source water sampling is discussed in the Source Water and Product Water Report (Trussell Technologies, 2014d), whereas the scope of the pilot water quality sampling is discussed in this report. Select results from the source water sampling campaign are also reported in this report when necessary. The sample locations at the pilot for the pilot water quality sampling campaign were the following:

- Pilot influent (secondary effluent)
- Ozone effluent (after quenching, when quenching was needed)
- MF effluent
- RO permeate
- RO concentrate
- MF backwash

These sample locations are highlighted in the process flow diagram shown in Figure 2.9.

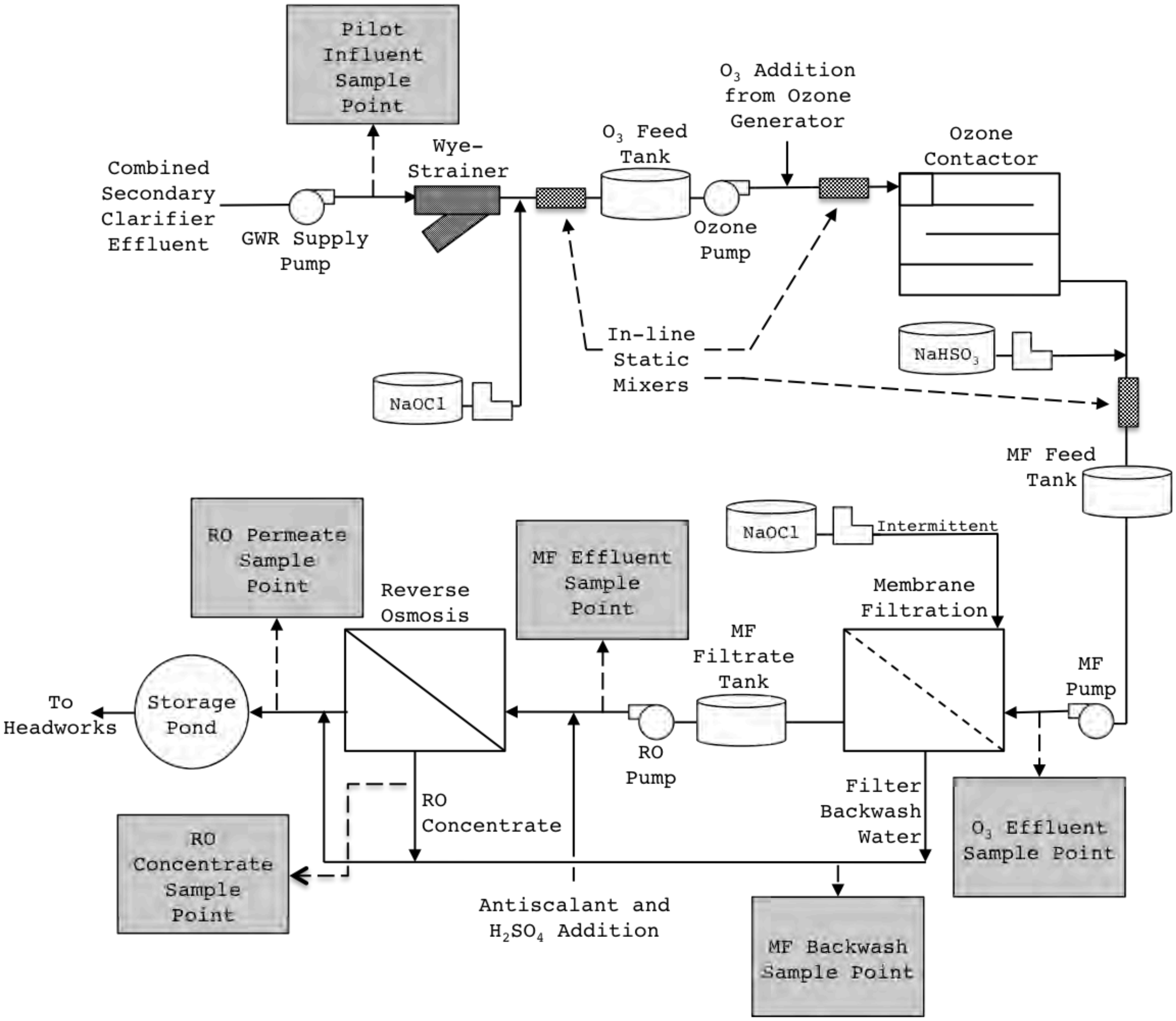

Figure 2.9 – Weekly water quality sampling locations

At locations listed above, samples were collected for the following water quality parameters:

- General water quality parameters (*e.g.,* alkalinity, TOC)
- Inorganics (*e.g.,* phosphate, ammonia)
- DBPS (*e.g.,* NDMA)
- Pathogens and pathogen indicators (*e.g.,* total coliforms, *Cryptosporidium*)
- Synthetic organic contaminants (*e.g.,* 1,4-dioxane, pesticides)

A detailed list of the water quality analysis performed for each sample location is shown in Table 2.5. Monterey Bay Analytical Services and Eurofins Eaton Analytical primarily performed the analysis, with sub-contactor labs as needed. A schedule of the sample events is shown in Table 2.4. Samples collected monthly were analyzed for the widest variety of parameters, while samples collected weekly were only analyzed for routine parameters. One sampling of the RO permeate was conducted for all MCLs, NLs, and AALs on April 8, 2014[8].

Table 2.4 - Regular Water Quality Sampling Events

Sample Date	Sample type
12/10/2013	Monthly
12/17/2013	Semi-monthly
12/23/2013	Weekly
12/30/2013	Weekly
1/7/2014	Weekly
1/14/2014	Monthly
1/21/2014	Weekly
1/28/2014	Semi-monthly
2/4/2014	Weekly
2/11/2014	Monthly
2/18/2014	Weekly
2/26/2014	Semi-monthly
3/4/2014	Weekly
3/11/2014	Monthly
3/18/2014	Weekly
3/25/2014	No sampling
4/2/2014	Semi-monthly
4/8/2014	Monthly
4/15/2014	Weekly
4/22/2014	Semi-monthly
4/30/2014	Weekly
5/6/2014	Weekly
5/13/2014	Monthly
5/21/2014	Weekly
5/27/2014	Semi-monthly
6/3/2014	Weekly
6/10/2014	Weekly[a]
6/17/2014	Weekly[a]
6/24/2014	Monthly[a]

[a] Reduced sampling; see appendix

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[8] Uranium (MCL), vanadium (NL), chlorate (NL), and N-Methyl dithiocarbamate (Metam sodium) (AAL) were omitted by the lab.

Table 2.5 – Constituents analyzed during regular water quality sampling events[a]

Parameter	RTP Raw	Pilot Inf	Ozone Eff.	MF Filtrate	RO Permeate	MF Backwash	RO Conc.
General Water Quality Parameters							
Alkalinity		2/M		2/M	2/M		2/M
Conductivity		2/M		2/M	2/M		2/M
Hardness - Total		2/M		2/M	2/M		2/M
pH		2/M		2/M	2/M		2/M
Temperature		2/M			2/M		
Total Dissolved Solids (TDS)		2/M		2/M	2/M		2/M
Total Suspended Solids (TSS)		2/M	2/M	2/M		2/M	
Turbidity		W	W	W	W	W	W
Dissolved Oxygen (DO)		W	W				
Oxidation/Reduction Potential (ORP)			2/M	2/M	2/M		
Biochemical Oxygen Demand (BOD)		2/M	2/M	2/M	2/M	2/M	2/M
Chemical Oxygen Demand (COD)		2/M	2/M	2/M	2/M	2/M	2/M
Biodegradable dissolved organic carbon (BDOC)		M	M		M		M
Dissolved organic carbon (DOC)		M	M				
Total Organic Carbon (TOC)		W	W	W	W		2/M
UV-254 Absorbance		W	W	W	W		2/M
Inorganics							
Ammonia		W	2/M	2/M	W		M
Nitrate		W	2/M	2/M	W		M
Nitrite		W	W	2/M	W		M
Total Kjeldahl Nitrogen (TKN)		W	2/M	2/M	W		M
Aluminum				2/M	2/M		M
Arsenic		2/M		2/M	2/M		M
Barium				2/M	2/M		M
Boron				2/M	2/M		M
Bromide		2/M	2/M	2/M	2/M		M
Calcium				2/M	2/M		M
Chloride				2/M	2/M		M
Cyanide		2/M		2/M	2/M		M
Fluoride				2/M	2/M		M
Iron		2/M		2/M	2/M		M
Magnesium				2/M	2/M		M
Manganese		2/M		2/M	2/M		M
Mercury				2/M	2/M		M
Molybdenum				2/M	2/M		M
Nickel				2/M	2/M		M
Phosphate (orthophosphate)		2/M		2/M	2/M		M
Potassium				2/M	2/M		M
Selenium				2/M	2/M		M
Silica				2/M	2/M		M
Sodium				2/M	2/M		M
Strontium				2/M	2/M		M
Sulfate				2/M	2/M		M
Sulfide				2/M	2/M		M
DBPs							
Total THMs and HAAs		2/M			2/M		M
Bromate		2/M	2/M		2/M		M
Nitrosamines		2/M	2/M	2/M	2/M		M
Microbiological Parameters							
Total coliform and *E. Coli*		W	W	W	W		
Cryptosporidium and *Giardia*	M	M	M	M			
Synthetic Organic Contaminants							
CECs (See Table 8)		M	M		M		M
1,4-Dioxane		M	M		M		M
Select pesticides (EPA 505 and 525.2)		M	M		M		M

[a] Weekly (W), twice per month (2/M), and monthly (M)

2.4 Timeline of piloting activities

Pilot equipment was onsite at the RTP from October 2013 to July 2014. During this time various changes were made to the piloting program. One change was the shunting of additional source water to the RTP headworks. Two shunts were conducted during piloting. Lake El Estero stormwater was shunted for 56 hours in February, and the agricultural wash water was shunted from April through the end of piloting. A summary of these shunt periods is shown in Figure 2.10.

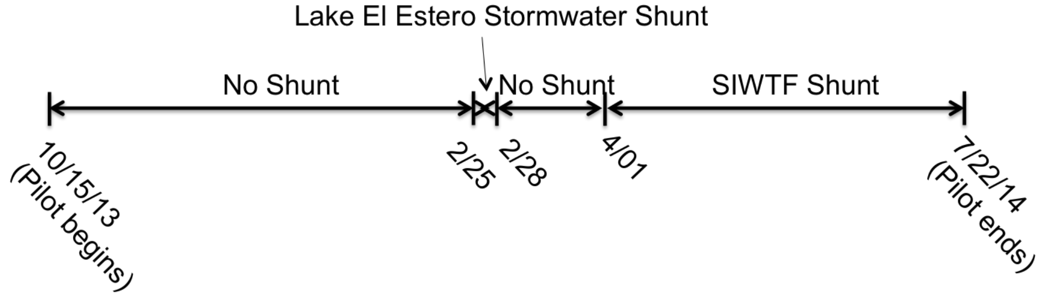
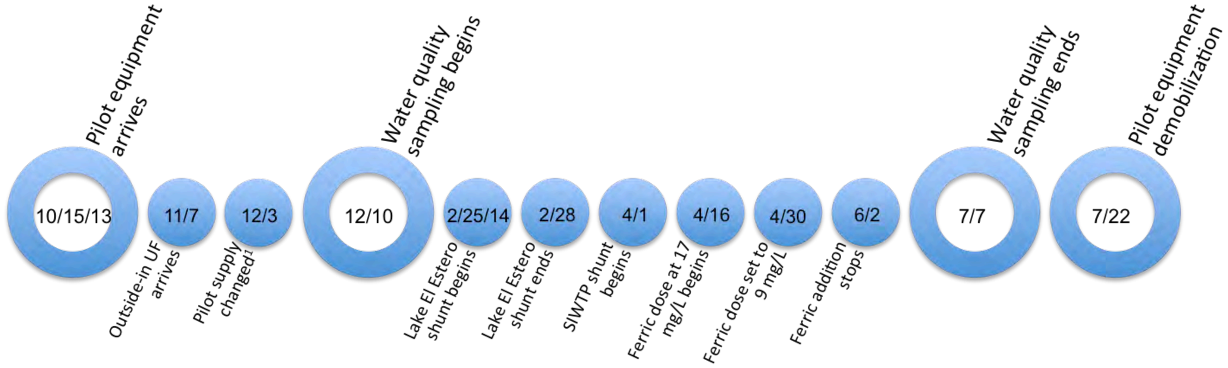


Figure 2.10 – Schedule of shunt testing during piloting

In addition to shunt water testing, another impact on the pilot feed water was the addition of ferric chloride to the RTP primary effluent. As phosphate concentrations in the RTP secondary effluent increased due to the agricultural wash water shunt, the RTP chemically enhanced primary treatment (CEPT) facilities were to add ferric to the primary effluent on an experimental basis. Over time, these doses were reduced to determine the impact of elevated concentration of phosphate on RO scaling. The ferric dose schedule, and other notable piloting events, are summarized in Figure 2.11.



[1] Supply changed from Class C sump basin to a submerged pump in combined secondary clarifier effluent channel due to concerns over the representativeness of the Class C sump station water

Figure 2.11 – Timeline of select piloting events

3 Operational results and discussion

Operational results are reported and discussed in this section. The section is divided into the major unit processes: ozone, MF, and RO. Results from the water quality sampling are reported and discussed in the following section.

3.1 Ozone

The ozone testing was conducted simultaneously with the MF flux and RO recovery testing. Ozone tests include determining an adequate ozone dose control method, testing the effect of moderate and high ozone doses on membrane fouling, and preliminary ozone CT testing. These tests and results are discussed in this section.

3.1.1 Dose control testing

The concentration of organics that cause membrane fouling and the ozone demand vary temporally in the secondary effluent. Ideally, the ozone dose is adjusted based on fluctuations in this concentration and demand. Alternatively, if the variability is low enough, a constant ozone dose may prove suitable, as the degree of under- and over-dosing may be minimal.

Three ozone dose control systems were explored during pilot testing: UVT at 254 nanometers (nm) control, ORP control, and dissolved ozone residual control. Of the three options, UVT control most accurately adjusts the ozone dose for some waters; however, UVT control at this pilot was unsuccessful due to instrumentation limitations with this feed water. Instead of UVT control, the pilot was successfully operated with both ORP and dissolved ozone residual control. These three control methods are discussed below.

UVT control

UVT is the most directly representative online metric available for the concentration of large organic molecules that foul low-pressure membranes (UF membranes), and thus controlling the ozone dose with UVT is ideal. In this control method, the ozone dose is adjusted to maintain a UVT effluent setpoint or a delta UVT setpoint (*i.e.,* the difference between the influent UVT and the effluent UVT). The UVT setpoint is empirically determined by observing the relationship between membrane fouling and various UVT setpoints.

At the pilot, the ozone effluent and delta UVT was measured during both moderate ozone dose testing (constantly applied ozone dose of 10 mg/L) and high ozone dose testing (variable ozone dose tied to ozone demand, with an average applied ozone dose of 20 mg/L) with weekly grab samples[9]. Both the moderate ozone and the high ozone doses successfully minimized membrane fouling, and thus these ozone effluent and delta UVT measurements represent preliminary UVT setpoints. The high ozone doses did not discernably decrease membrane fouling compared to the moderate ozone doses, thus the high ozone doses were likely achieving an upper limit on the oxidation of membrane

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[9] Thermo Scientific AQUAMATE

foulants. The average delta UVT during this maximum ozone testing, which likely represents a maximum delta UVT for this water, was 10% (9 to 11% for 10 samples; 1 sample at 15%). The average delta UVT for the moderate ozone doses was similar, albeit lower, at 8%, and contained higher variability (4 to 11% for 10 samples; 1 sample at 15%). The variability in the delta UVT during moderate ozone testing is likely due to regular underdosing. Regular overdosing must have also occurred (assuming variability in the ozone demand and concentration of membrane fouling organics), but the delta UVT ceiling (approximately 10 to 11%) curtailed data on the magnitude of this occurrence.[10] To minimize membrane fouling, the recommended delta UVT is 10%. This delta UVT was not consistently achieved with a constantly applied moderate ozone doses (*e.g.,* 10 mg/L), indicating that, on average, this dose is slightly lower than optimal. The high ozone doses (*e.g.,* 20 mg/L) achieved this delta UVT limit all the time, indicating that this dose is optimal or that it exceeds the optimal dose (possibly significantly exceeding the optimal dose).

Effluent UVT can also be used as a setpoint, however the ozonated effluent UVT exhibited more variability than the delta UVT. The variability seems to be due to varying concentrations of compounds in the secondary effluent that absorb UV at 254 nm, but which are not oxidized by ozone (and which may not foul membranes). The effluent and delta UVT for various ozone doses are summarized in Table 3.1.

Table 3.1 - Ozonated delta and effluent UVT[a]

Applied ozone dose	Average delta UVT at 254 nm (%, range)	Average effluent UVT at 254 nm (%, range)
Moderate (10 - 12 mg/L)	11 (9 – 15)	65 (59 – 70)
High (15 - 22 mg/L)	9 (4 – 15)	64 (62 – 68)

[a] Based on 13 and 11 high and moderate dose samples, respectively; control (*i.e.,* no ozone addition) showed a difference of -0.3 to 1% increase in UVT).

The UVT measurements reported above indicate that UVT control is suitable for this water if UVT can be measured continuously in the ozone effluent. Suitable online UVT analyzers may be available, but the sensor tested during piloting was unable to measure UVT continuously. The analyzer UVT decreased rapidly between cleans (*e.g.,* 10% over 12 to 24 hours), due to the deposition of a foulant on the flow-through cell surface. The foulant had a yellow-orange color and could be removed with either an acid solution or physical wiping. The analyzer had an ultrasonic cleaning feature, but this did not inhibit fouling. It is recommended that future piloting efforts test alterative UVT analyzers with built-in wipers that may remove the foulant (*e.g.,* Hach Company offers a UVT analyzer with a built-in wiper blade). Although the foulant was not analyzed, it appeared to be iron and manganese precipitate, which may have formed through the oxidization of reduced iron and manganese [Fe(II) and Mn(II)] in the pilot feed water.

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[10] Some variability is also due to variances in the chloramine residual concentration, which varied between 2 and 7 mg/L as Cl_2 at the ozone effluent during piloting.

Another consideration with UVT control is that the UVT sample point must be located downstream of the dissolved ozone residual dissipation or after the dissolved ozone residual has been quenched. Dissolved ozone absorbs UV at 254 nm, and may interfere with organic measurement.

Constant ozone dose with ORP control

Two other ozone dose control methods were tested due to challenges with UVT control. One successful control method was to set a constant ozone dose low enough such that the ozone residual decayed after a given contact time or sample location. The presence or absence of an ozone residual at the given contact time or sample location was measured with an ORP sensor. ORP sensors register the presence or absence of oxidants, such as ozone, and they are sensitive enough to distinguish been chloramines and dissolved ozone, even at very low ozone concentrations (0.1 mg/L dissolved ozone compared to 5 mg/L as Cl_2 chloramines). If a dissolved ozone concentration is detected at the ORP sensor, then the ozone dose is turned down until the ozone concentration is no longer detected. If the ORP sensor is located at the end of the ozone contactor, then this method of control limits the concentrations of dissolved ozone leaving the ozone system to rarely detectable concentrations.

The primary limitation to this control scheme is its inability to adjust the ozone dose when the loading of membrane-fouling organics fluctuates. Thus, the ozone dose is higher or lower than needed most of the time. This control scheme was successfully operated at the pilot scale to achieve the design MF flux of 30 GFD (with a constant applied ozone dose of 10 mg/L). The ORP electrode required cleaning (*e.g.,* rinsing with a dilute acid solution) on a weekly to twice a week basis to avoid biofilm and inorganic precipitate build-up. Example ORP measurements for this water are summarized in Table 3.2. The pilot was typically operated with an ORP upper limit setpoint of 480 millivolts (mV).

Table 3.2 – Example ORP values for various ozone residuals

Ozone residual (mg/L)	Chloramine residual (mg/L as Cl_2)	ORP (mV)
No ozone dosed	~5	110
0 (ozone dissipated)	No chlorine dosed	215
0 (ozone dissipated)	~5	375 – 450
0.1	~5	500
0.2 – 0.5	~5	700 - 900

A variation of this method was also tested where the constant ozone dose was paired with a dissolved ozone sensor and a quenching system instead of an ORP sensor. In this set-up, the dissolved ozone sensor detects the residual ozone concentration, and an appropriate chemical quenching dose is applied to quench the residual. Quenching the ozone residual (instead of avoiding it, as is practiced in the ORP sensor configuration) allows for a higher operating ozone dose compared to the ORP sensor configuration. The downside is that dissolved ozone sensors are less robust compared to ORP sensors. ORP electrodes require less frequent cleaning and they are less sensitive to damage.

Dissolved ozone residual control

The final ozone control system that was tested was the dissolved ozone setpoint method. In this method, the ozone dose is varied to reach an ozone setpoint at some location downstream. A dissolved ozone sensor measures the dissolved ozone, and this sensor must be located at some point where dissolved ozone is present at appropriate ozone doses. The dissolved ozone setpoint at a given sample location must be empirically determined by correlating the ozone setpoint with membrane run time. Ozone demand (ozone dose minus ozone residual) is not a direct measurement of the concentration of organics that foul membranes, but it is a function of those organics, as they contribute to ozone demand (among other compounds, such as nitrite). As the concentration of organics increase, the ozone demand increases, and the ozone dose increases correspondingly. Similarly, if the ozone demand increases for another reason (*e.g.,* due to increase in the nitrite concentration), the ozone demand will increase, and the ozone dose will increase. Although the concentration of organics is not increasing in this later case, more ozone is needed, because more will be consumed through reactions with the increased concentration of nitrite. Thus, a dissolved ozone residual control system varies the ozone dose as the ozone demand and the concentration of membrane-fouling organics fluctuates, similarly to UVT control.

This control system was employed during the high ozone dose testing. For these tests, the dissolved ozone sensor was located at the effluent of the ozone contactor (3-minute HRT), and the setpoint was maintained at 0.1 mg/L. This setpoint and location required an average applied ozone dose of 20 mg/L, with a range of 14 to 25 mg/L. The ozone demand varied diurnally, typically with two peaks per day: one at noon, and another at midnight (see Figure 3.1 for the applied ozone dose during an example week of testing). This ozone control method successfully reduced membrane fouling during pilot testing, and adjusted the ozone dose according to changes in ozone demand.

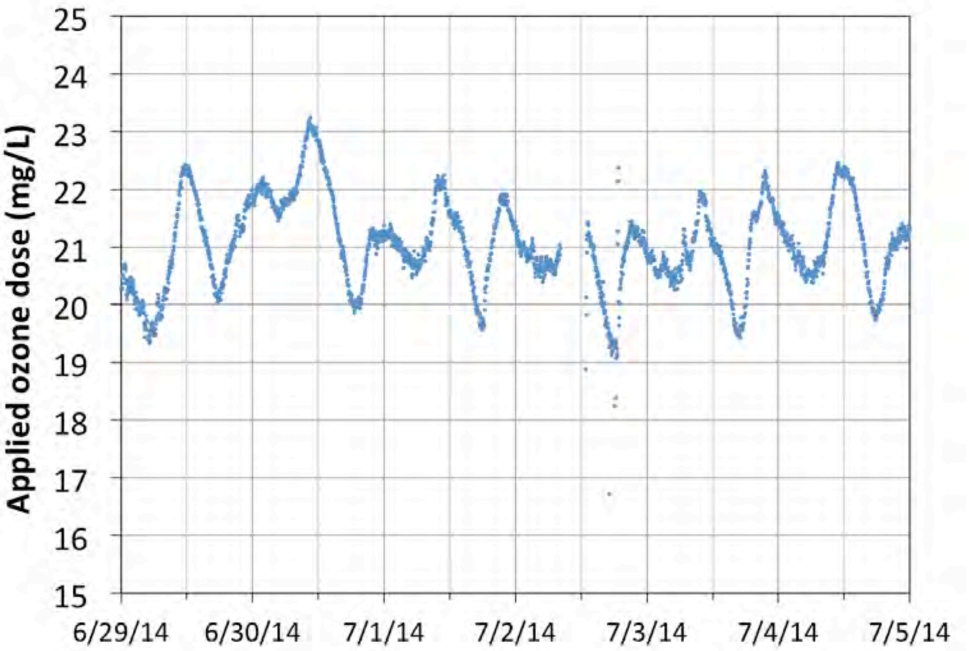

Figure 3.1 – Example of variability in applied ozone dose required to meet the 0.1 mg/L setpoint (ozone turned off in the afternoon of 7/2 for an experiment)

Dissolved ozone decays exponentially. To minimize this decay, sample tubing or piping that feeds a dissolved ozone sensor must have a minimal residence time. Once ozone reaches the sensor, it crosses a hydrophobic membrane and is reduced at the gold cathode. The gold cathode did not tarnish during piloting, but the membrane required frequent attention (daily examination), and at least weekly replacement. The membrane is very sensitive, and is easily torn by abrasion (*e.g.,* dabbing with a Kimwipe®). Air entrapment behind the membrane occurred occasionally, which diminished response time, and foulant accumulated on the surface. This foulant resembled the UVT flow-through cell foulant in appearance, and it was also susceptible dilute acid solutions. Over time, irreversible foulants accumulated on the membrane, and the membrane required replacement. These irreversible foulants had the same appearance as the foulants that were easily removed with dilute acid solutions, but they were amenable to acid treatment.

3.1.2 Ozone dose testing

Various ozone doses were tested to determine a design ozone dose for preozonation. This dose is a function of the water quality, including nitrite, TOC, and other constituents that contribute to ozone demand. During testing, the effect of ozone on foam formation was observed, as excessive foam formation may impact design. These tests and observations are discussed in this section.

Applied ozone dose

Ozone dose testing included extended testing at moderate and high ozone doses, as well as testing without ozone addition. These tests were performed to determine an appropriate preozonation design dose and to determine the impact of preozonation versus no ozone. Moderate ozone dose testing consisted of a constant applied ozone dose of 10 mg/L, whereas high ozone dose testing utilized the ozone residual control with a setpoint of 0.1 mg/L after a 3-minute HRT. This high ozone dose setpoint resulted in an average applied ozone dose of approximately 20 mg/L (ranging from 14 to 25 mg/L). Membrane flux was tested without ozone by turning off both the ozone and oxygen addition, but allowing the secondary effluent to travel through the ozone contactor (where it was dosed with sodium hypochlorite upstream of the contactor). A summary of the tests conducted is presented later in this section.

The impact of preozonation compared to the absence of ozonation was measured by comparing MF run times with and without ozone, while keeping the MF flux constant. This comparison shows that preozonation doses between 10 and 14 mg/L increase the MF run time by a factor of 4 to 8 (see Table 3.3). The factor of four increase represents a lower bound, as the chlorine pump used during daily MF CEBs was inadvertently turned off half way through the run (run #2). The factor of seven increase represents an upper bound, as the ozone doses were relatively high during this run (14 mg/L in run #1 compared to 10 mg/L in run #2). The longer run time observed during MF run #1, compared to run #2, may be due to the higher ozone dose (14 versus 10 mg/L, with the high dose possibly achieving a maximum UVT increase more consistently than the lower dose), the cessation of chlorinated CEBs half way through run #2, or to other seasonal variations in water quality.

Table 3.3 – Effect of preozonation on MF run time

MF Run Number	MF flux (GFD)	Run time (days)[a]	Applied ozone dose (mg/L; range)
1	25	36	14 (12 - 17)
2	25	17	10 (9 - 11)
3	25	5	0

[a] The no-ozone test began with eight days run time with ozone. These eight days were subtracted from the run times of each trial shown in this table.

The effect on transmembrane pressure (TMP) increase of preozonation versus non-ozonation is shown in Figure 3.2. Preozonation seems to oxidize organic material that is not easily removed during daily CEBs. During the tests without ozone, the pressure required to maintain the flux setpoint was not significantly reduced with the CEB (*i.e.*, the TMP recovery due to the CEB was minimal).

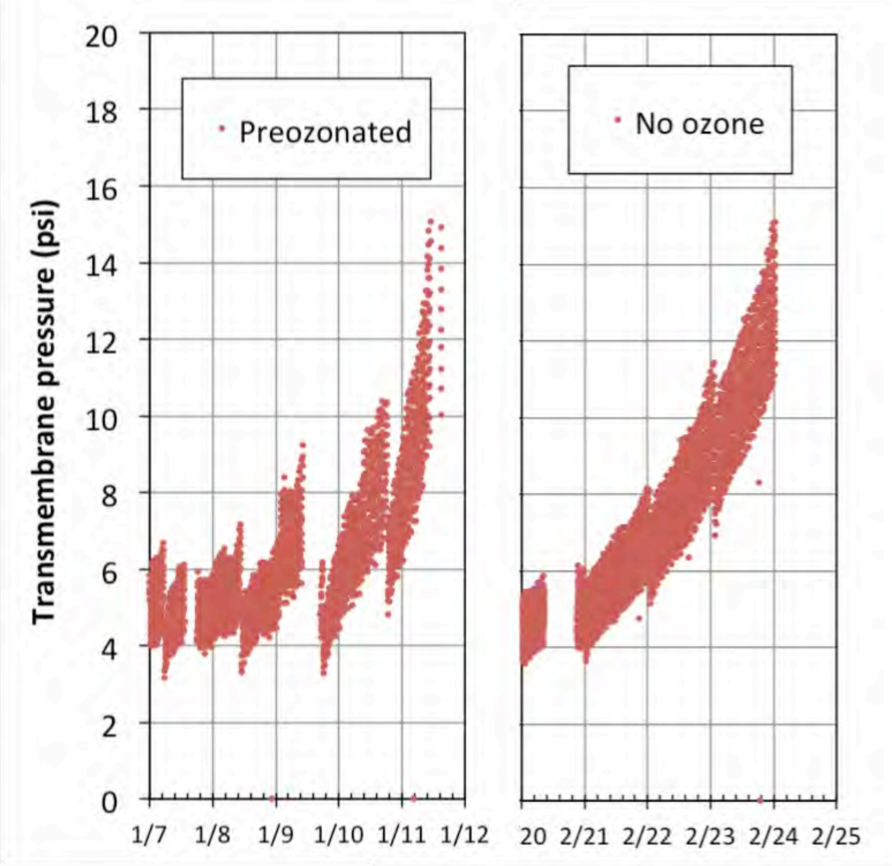

Figure 3.2 – Effect of ozonation on CEB TMP recovery (psi is pounds per square inch)

Moderate and high ozone testing was conducted to determine a recommended design ozone dose. Various combinations of ozone dose and MF flux were tested, with the goal of achieving the highest flux with a run time of approximately thirty days (summary of runs shown in Table 3.4). This goal was achieved with a moderate ozone dose (10 mg/L) and an MF flux of 30 GFD (run time 32 days at 30 GFD, with 3.5 days at a combination of 25 and 28 GFD). Subsequent testing explored higher MF fluxes, combined with higher ozone doses. This testing included a run at an MF flux of 35 GFD and a high ozone dose (20 mg/L average, 17 to 23 mg/L range) that achieved a run time of only 15 days (with an additional six days proceeding at 30 GFD) and a run at 32 GFD at high ozone doses (20 mg/L average, 17 to 22 mg/L range[11]) that lasted 22 days. During these experiments, run times greater than thirty days could not be achieved with fluxes of 32 GFD or greater. Given that the high ozone doses did not substantially increase the MF run time, designing for the high ozone dose to minimize MF fouling is not recommended.

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[11] Including about four hours of no ozone, to conduct a brief experiment

Table 3.4 – Summary of MF run conditions and results

MF Run Number	Date	MF flux (GFD)	Applied ozone dose (mg/L; range)	Run time (days)
1	11/15/13 – 01/12/14	25	14 (12 - 17)	44
2[b]	01/14 – 02/10	25	10 (9 - 11)	25
3[c]	02/10 – 02/25	25	10 (9 – 10), 0[a]	8, 5
4[d]	02/25 – 03/13	25	10 (10 - 11)	15
5	03/17 – 03/28	40	18 (17 - 18)	7
6	03/28 – 04/01	40	16 (15 - 17)	2
7	04/01 – 04/02	40	13 (13 – 13)	1
8	04/07 – 05/20	25, 28, 30[a]	10 (10 – 10)	1, 2, 32
9	05/20 – 06/12	30, 35	21 (17 - 23)	6, 15
10	06/12/14 – 07/07/14	32	19 (17 - 22)	22

[a] Run time corresponds to each condition shown, *e.g.,* during run 3, the system was run 8 days with a dose of 10 mg/L, and 5 days for a dose of 0 mg/L.
[b] No chlorine in CEB half way through the run
[c] No chlorine in CEB while ozone was applied
[d] Run terminated before terminal TMP reached

Water quality

Water quality greatly impacts the required ozone dose for membrane fouling minimization (transfer efficiency, mixing, and contact time also impact the required applied ozone dose). Specifically, higher ozone doses are needed for waters that contain higher concentrations of membrane fouling organics (*e.g.,* non-nitrified secondary effluents like MRWPCA), and for effluents with higher ozone demands. Ozone demand is a measurement of the reduction in dissolved ozone after time, after its application (analogous to chlorine demand and BOD), and represents concentrations of constituents that react with ozone. Some of these constituents are membrane-fouling organics, while others are not foulants. An example of a constituent that reacts rapidly with ozone, but that is not a membrane foulant is nitrite. Nitrite will react with ozone, making less ozone available for membrane-fouling organic oxidation. Another parameter that relates to ozone demand is TOC. TOC is a bulk measurement of all of the organic carbon in the water, including membrane-fouling organics, as well as non-fouling organics that react with ozone. The MRWPCA secondary effluent has high concentrations of both nitrite and TOC, which contribute to the high ozone dose required for membrane pretreatment.

Nitrite in the secondary effluent (pilot influent) was measured at the pilot through four different sampling campaigns, which are described below (see Figure 3.3 for data):

1. Grab samples collected and measured on site during piloting ("field grab")[12]
2. Grab samples collected during the pilot water quality sampling campaign ("pilot grab")[13]
3. 24-hour composite samples collected during source water quality sampling campaign ("source water 24-hr composite")[14]
4. 24-hour composite samples regularly collected by the RTP[15]. These data are displayed in the plot in two sets: (a) data collected while the pilot was in operation ("pilot"), and (b) all composites from 2008 to 2014 ("historical").

These data show unusually high concentrations of nitrite in the secondary effluent, which are indicative of partial nitrification in the secondary process. Ammonia measurements throughout the RTP treatment train indicate that this partial nitrification is typically occurring in the trickling filters (Trussell Technologies, 2014a). When ozone is applied to this water, the nitrite will consume 3.4 mg/L of ozone per mg/L of nitrite as N. For example, the average, weekly RTP effluent 24-hour composite nitrite concentration measured during piloting was about 0.73 mg/L as N, which would consume about 2.5 mg/L of ozone, while the largest weekly RTP effluent 24-hour composite nitrite concentration of 2.9 mg/L as N would consume 9.9 mg/L of ozone. The ozone that is consumed by nitrite is then unavailable for membrane-fouling organic oxidization. Therefore, the ozone dose needs to account for the nitrite concentration, ideally by maintaining a UVT setpoint or an ozone residual.

The design and operating ozone dose for the AWTF ozone system could be reduced if less nitrite was produced in the RTP. Nitrite production can occur in biological systems that partially nitrify. As mentioned previously, partial nitrification presently occurs in the RTP trickling filters. It may be possible to change the operation of the trickling filters to avoid this partial nitrification (*e.g.,* adjusting the recycle rate), and the production of nitrite. The average, weekly RTP effluent 24-hour composite nitrite concentration observed during piloting was 0.73 mg/L as N. If this concentration were 0.1 mg/L as N, instead of 0.73 mg/L as N, then the associated decrease in ozone demand would be 2.2 mg/L. This might allow for a decrease in the average transferred ozone dose from 9.5 mg/L to 7.3 mg/L, assuming that the nitrite would have reacted with ozone prior to the ozone reacting with the membrane fouling organics. Similarly, reducing the maximum expected nitrite concentration may be able to reduce the ozone design dose, and thus the size of the ozone system, by up to 30% (the cost of the ozone system does not scale linearly). The cost savings is potentially significant (*e.g.,* up to 1 million dollars of total project costs), and thus reducing nitrite formation in the secondary system is recommended.

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[12] Hach DR 890, NitriVer® 3 powder pillows, diluted 10:1 using Class A glassware with lab DI water, 11/7/13 to 7/2/14; 33 samples.

[13] Analyzed by Monterey Bay Analytical Services, SM 4500-NH_3 B&C or F/G, 12/10/13 to 6/24/14; 26 samples.

[14] Analyzed by Monterey Bay Analytical Services, SM 4500-NH_3 B&C or F/G, 9/9/13 to 6/10/14; 11 samples.

[15] 11/7/08 to 7/7/14, weekly, at a minimum, from May 2010 onward, as needed before; 245 samples.

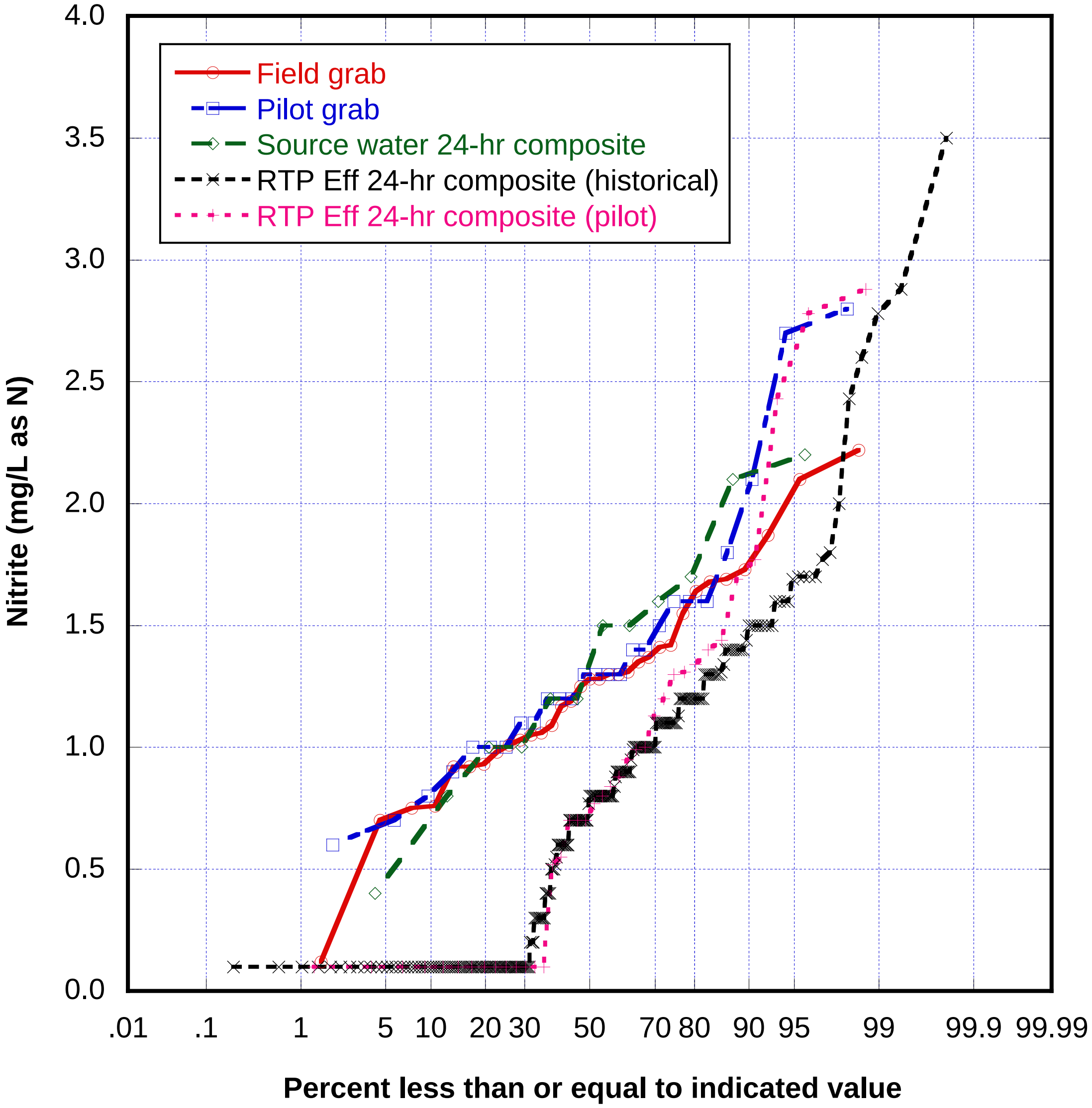

Figure 3.3 – Probability plot of nitrite measured during piloting and earlier

TOC was also measured through pilot and source water sampling campaigns, and estimated from RTP dissolved organic carbon (DOC) and total suspended solids (TSS) data (see Figure 3.4)[16]. Particulate organic carbon (POC) in the RTP samples was estimated from DOC and TSS data by assuming that 75% of the TSS were volatile suspended solids (VSS) and that 53% of the VSS were carbon[17]. The difference in TOC values between the RTP samples and pilot and source water samples is partially due to the method of estimation (16 to 32%, based on validating the method with pilot and source water data, respectively).

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[16] 23 pilot grab samples, 12 source water composite samples, 828 RTP samples from January 2, 2011 to May 15, 2014

[17] Assuming a generic cell chemical formula of $C_5H_7O_2N$

The rest of the difference is possibly due to differences in the TOC measurement method (Standard Method [SM] 5310B and SM5310C for the RTP and the source water composite samples, respectively), where SM5310B generally includes compounds that are chemically refractory and not measured by SM5310C and more efficiently oxidizes high concentrations of suspended organic carbon. Error may have also been introduced in the dilution step required for the SM5310C sample. Differences in TSS measurements may have been due to sedimentation in the sample carboys prior to pouring samples for TSS analysis. The difference between pilot grab samples and RTP composite samples may be due to diurnal variations in water quality. Given the difference between the two datasets, the higher, more conservative, TOC values are recommended for design purposes. Regardless of dataset, these TOC values are fairly typical for a non-nitrified trickling filter secondary effluent, and are high compared to nitrified secondary effluents. The high TOC concentrations increase the ozone demand of the water, and thus the doses necessary for membrane pretreatment.

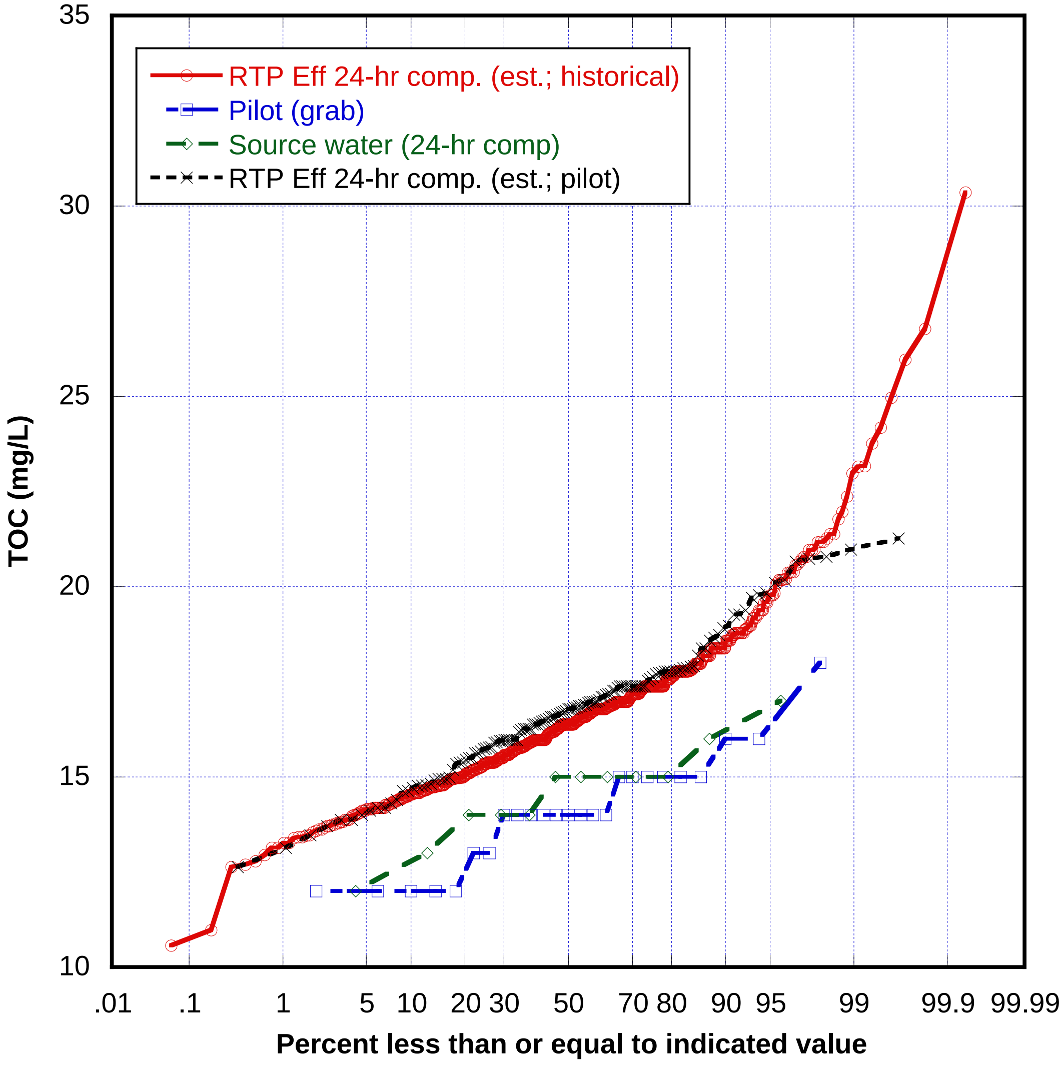

Figure 3.4 – Probability plot of TOC measured during piloting, and estimated TOC from RTP effluent sampling

Instantaneous ozone demand was measured during brief experiments with grab samples and continuously with online instrumentation (see Table 3.5). An ORP and dissolved ozone residual sensor were used to measure the ozone residual at the end of the ozone contactor (contact time of 3 minutes at a flow of 28 gpm). ORP readings were used to detect the presence or absence of ozone (indicating a concentration of zero, in the absence of ozone). Thirty-second ozone demand was calculated from 30-second ozone residual grab samples[18]. When a residual was detected, these 30-second residual concentrations were used to estimate the instantaneous ozone demand. These ozone demand values are typical for non-nitrified secondary effluents, high compared to typical ozone applications, and result in the preozonation doses that are higher than typical ozone applications.

Table 3.5 – Estimated and measured ozone demand

Transferred ozone dose (mg/L)	Number of measurements	Estimated instantaneous ozone demand (mg/L)[a]	30-second ozone demand (mg/L)[b]	~3-minute ozone demand (mg/L)
9	1	--	10	10
15 - 19	5	12 - 16	13 - 17	15 - 19
12 – 22	20,437	--	--	12 - 22
8 – 14	ca. 70,000	--	--	8 – 14

[a] Assuming first-order decay following instantaneous reactions (Rakness, 2008), which requires measurement of an ozone residual downstream of instantaneous reactions (*e.g.,* 30 seconds).

[b] Based on ozone residual measurements at 30 seconds

As mentioned previously, the applied ozone dose was varied to meet an ozone setpoint during the high ozone dose testing. A week of data from this phase of testing is shown again in Figure 3.5 with the addition of ozone influent online turbidity. The applied ozone dose correlates to the 3-minute ozone demand, when multiplied by transfer efficiency (88% during this period of testing). Within a week, the ozone demand varies by about 4 mg/L at these doses, with diurnal variations between 2 and 3 mg/L. These data also show that turbidity correlates somewhat with ozone demand, with turbidity spikes observed during most ozone demand spikes (although of differing magnitudes).

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[18] Hach AccuVac Ampules, low (0 to 0.25 mg/L) or high (0 to 1.50 mg/L), as needed; indigo method with DR 890.

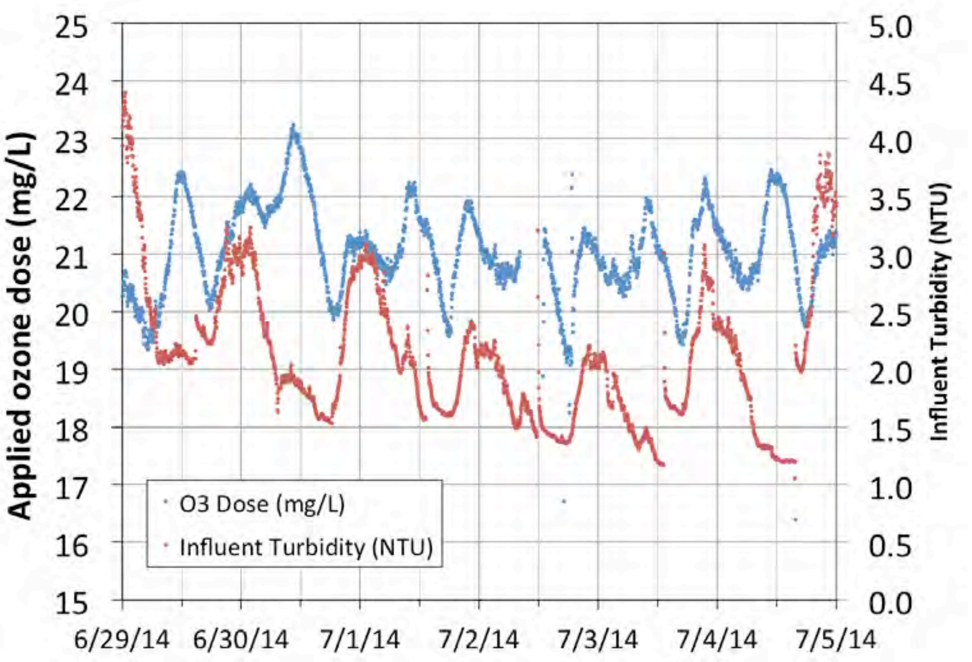

Figure 3.5 – Applied ozone dose to meet effluent setpoint of 0.1 mg/L and ozone influent turbidity

Turbidity was measured upstream of the ozone system with an online analyzer[19]. The average turbidity observed during piloting was 2.4 NTU (range of 0.9 to 6.2 NTU, at the 1st and 99th percentile, respectively). A probability plot of this data is shown in Figure 3.6, and a trend is shown in Figure 3.7. The high turbidity values observed in the probability plot may be due to slugs of high turbidity water that sheared from the sample tubing walls and passed through the analyzer, or from periodic cleanings. The overwhelming majority of the readings are between 0.9 and 6.2 NTU. The trend shows seasonal variation in the mean turbidity, and seasonal variation in the diurnal variation (*i.e.,* changes in the thickness of the band).

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[19] Hach 1720E Low Range Turbidimeter

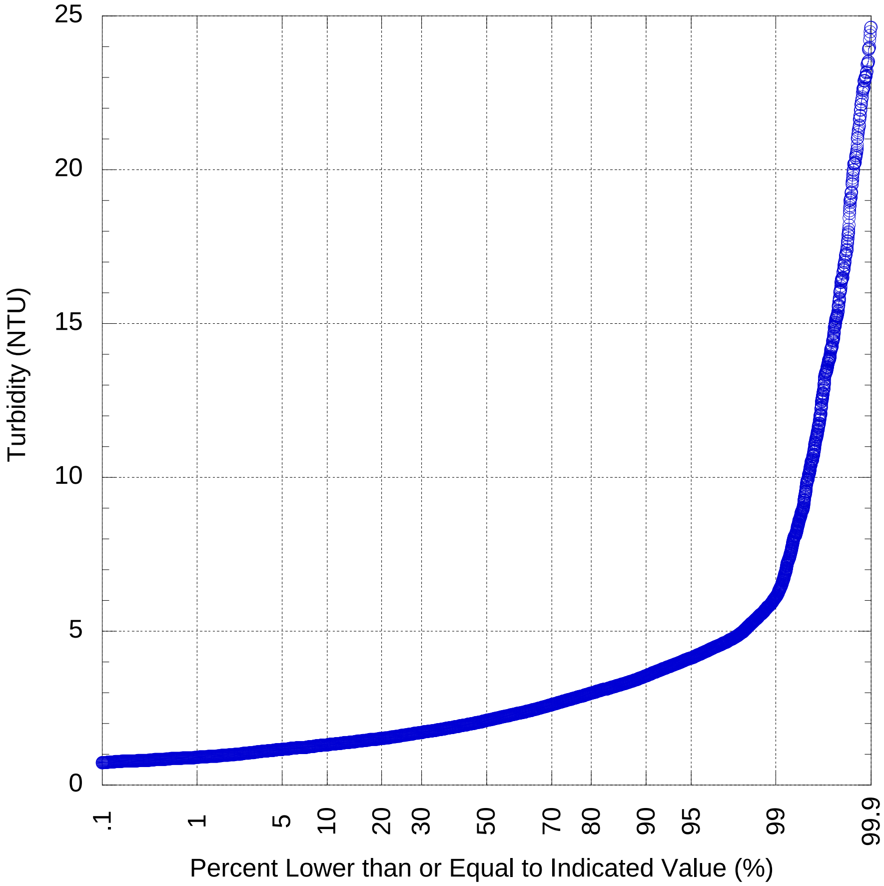

Figure 3.6 – Pilot influent (secondary effluent) turbidity probability plot

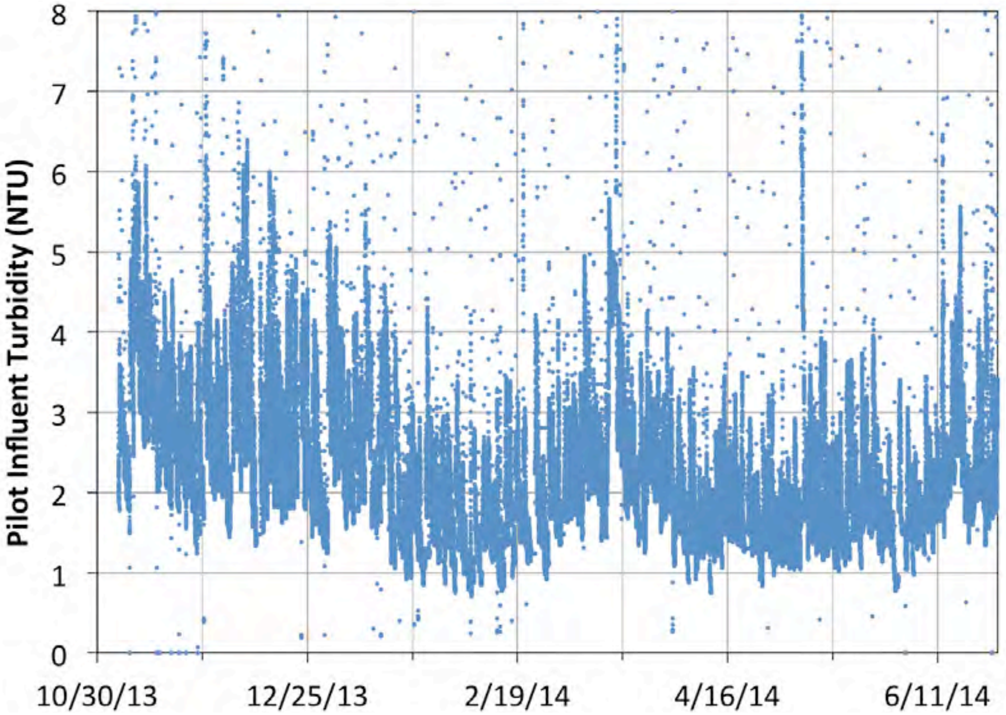

Figure 3.7 - Pilot influent (secondary effluent) turbidity trend plot

Foam

Foam creation was minimal through the ozone process during piloting. Qualitative observations could not distinguish between the volume of foam created with the application of ozone and the volume created without the application of ozone or high-purity oxygen. Thus, it appeared that foam was created from constituents in the secondary effluent, perhaps as the flow may have been aerated during the 5-foot drop, which was exposed to the atmosphere. Throughout the majority of pilot testing, the ozonated effluent flowed to MF feed tanks, which contained overflow pipes (2 to 3 inches) at different elevations. The lower elevation overflow pipe continuously drained ozonated effluent, and thus minimal foam accumulated in the MF feed tank with the lower elevation overflow pipe. The MF feed tank with the higher elevation overflow pipe accumulated 2 to 6 inches of foam. When this latter feed tank was modified to ensure that foam wasting did not even occur on an infrequent basis (*e.g.,* during daily CEBs), the foam depth did not change. Presumably, the foam breakdown rate limited the foam depth.

3.1.3 Transfer efficiency

Ozone transfer efficiency is the fraction of applied gaseous ozone that dissolves into the liquid phase (*e.g.,* 100% transfer efficiency equates to all of the applied ozone dissolving into the liquid). In practice, this is estimated with measurement of the ozone concentration in the off-gas and the applied gas, assuming no gas-phase ozone decay. Increasing ozone transfer efficiency decreases the ozone that is wasted (*i.e.,* sent to the ozone destruct). Transfer efficiency is used to calculate the transferred ozone dose from the applied ozone dose (the transferred ozone dose is the product of the applied ozone dose and the transfer efficiency). Given that transfer efficiencies will vary between ozone installations, or between pilot-scale and full-scale, the transferred ozone dose is useful for comparing systems, or translating pilot results to full-scale design. Transfer efficiency was measured at the pilot on a weekly basis. The results from these measurements are shown in Table 3.6 for both the moderate ozone dose testing, and the high ozone dose testing.

During piloting, transfer efficiency primarily correlated with ozone system flow. Mixing at the pilot was achieved through static mixers, which are a function of flow, and transfer efficiency is dependent on mixing. Thus low system flows resulted in lower transfer efficiencies. Due to pump capacity limitations, the ozone flow was increased or decreased at the pilot to achieve moderate and high doses, respectively. Thus, the transfer efficiency also correlates fairly well to ozone dose. Minor flow or head loss adjustments during the moderate dose testing lead to a wider range in transfer efficiencies (*i.e.,* 92 to 98%, with one measurement at 87% associated with low flow conditions as the GWR supply pump capacity dropped off due to clogging).

Table 3.6 – Pilot ozone transfer efficiency

Ozone test phase (applied dose)	Average transfer efficiency (%, range)
Moderate (10 mg/L)	95 (87 – 98)
High (20 mg/L, average)	88 (86 – 90)
Other (12 – 16 mg/L)	92 (91 – 93)

3.1.4 Disinfection CT preliminary testing

A potential use of preozonation is to achieve disinfection credit. This disinfection credit requires the maintenance of an ozone CT (*e.g.,* 1 mg-min/L) through the measurement of the ozone residual in the ozone contactor. The ozone residual must be measured in at least one location; however, measuring the ozone residual in multiple locations increases the resolution of the ozone decay curve, which may increase the reportable ozone CT. Methods for calculating the ozone CT include the following: (1) assuming that the ozone residual is constant between measurements, or (2) constructing an ozone decay curve, assuming first-order decay kinetics (Rakness, 2008). The latter method more accurately represents ozone decay, and yields higher CT values.

Preliminary measurements of the ozone CT were taken at the pilot for both the moderate ozone dose (10 mg/L, applied) and the high ozone dose (20 mg/L, average applied). At the high dose, CTs of 1 to 2 mg-min/L could be achieved with transferred ozone doses of approximately 15 to 19 mg/L (five sampling events; Table 3.7 for summary)[20]. At the moderate dose, no ozone residual was detected at the first sample point (one sampling event, triplicates). These preliminary data show that the high ozone doses (*e.g.,* transferred ozone dose of 18 mg/L) can achieve disinfection CTs (CT greater or equal to 1 mg-min/L). Further testing would be required to determine the transferred ozone dose necessary to sustain a disinfection CT on a continuous basis. A full-scale ozone disinfection design must be conservative enough to account for a wide range of water qualities that affect ozone demand.

Table 3.7 – Ozone CT measurements for various applied ozone doses

Applied ozone dose(s) (mg/L)[a]	Ozone CT (mg-min/L)[b]
21	1.9
20	1.4
18	0.8
17	1.2
19	1.4

[a] Transfer efficiency approximately 88%
[b] Calculated based on Rakness, 2008

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[20] The ozone residual was measured at four locations in the ozone contactor (approximate sample times of 0.5, 1.0, 1.5, and 2.5 minutes, assuming a 80% baffling efficiency).

3.1.5 Sodium Hypochlorite Dose Location experiment

The effect of the sodium hypochlorite dose location on NDMA formation was tested on 6/27/14. NDMA may form from chloramination and/or ozonation of secondary effluent. At the AWTF, both oxidants will be added to the secondary effluent for membrane pretreatment. The order that these oxidants are introduced into the secondary effluent may impact the total NDMA formation across both of these processes. For example, ozone NDMA precursors may not be the same as chloramine precursors, and one oxidant may oxidize the precursors of the other.

Two test conditions were examined (in triplicates) at the pilot to understand the effect of the sodium hypochlorite dose locations on NDMA formation: chlorine upstream of ozone (pre-chloramination) and chlorine downstream of ozone (post-chloramination). Two controls were also tested: only chlorine and only ozone. The results of these tests are shown in Table 3.8. The results show that pre-chloramination and post-chloramination produced essentially the same concentration of NDMA, at concentrations that are in agreement with other measurements of NDMA at the pilot. Both pre- and post-chloramination produced slightly less NDMA than the added effects of NDMA formation from the addition of only one of the oxidants (formation of 41 nanograms per liter [ng/L], range of 37 to 47 ng/L). Based on these results, either pre- or post-chloramination is expected to yield acceptable NDMA formation levels at the AWTF.

Table 3.8 - NDMA pre- and post-chloramination formation

Parameter	**Average NDMA (ng/L)[a] (Range)**		
Test condition	**Influent**	**Effluent**	**Formation**
Pre-chloramination[c]	11	49 (45 - 52)	38 (34 - 41)
Post-chloramination[c]	7.6	46 (44 - 48)	38 (36 - 40)
Only chloramination	6.7	17 (15 - 22)	11 (8 - 15)
Only ozonation	9.3	40 (36 - 44)	31 (27 - 35)

[a] Two hours contact time
[b] Ozone dose of 10 mg/L applied (approximately 90% transfer efficiency)
[c] Chlorine residual of 6.2 - 6.3 mg/L as Cl_2
[d] Samples collected at about 1 hour intervals between test conditions

3.1.6 TOC transformation experiment

The transformation of TOC through ozonation was measured at the pilot during an experiment conducted on July 2nd, 2014. Ozone typically increases assimilable organic carbon (AOC) in secondary effluents by transforming organic molecules that microorganisms cannot use as energy into smaller organic molecules that are more readily available to microorganisms. AOC is a measurement of the concentration of organic material in a sample that can be assimilated by microorganisms (AOC is truly only a measurement of the assimilability of the organic carbon to the species of microorganisms used in the AOC test). Ozone cannot increase the TOC of water (*i.e.,* it does not add carbon to the water), and it typically does not lower TOC (*i.e.,* it typically does not mineralize carbon). However, by transforming the chemical properties or size of the organic molecules, ozonation may impact the removal of TOC through downstream processes (*e.g.,* RO).

The pilot TOC transformation experiment was conducted at an applied ozone dose of 21 mg/L (transfer efficiency approximately 88%). Under this condition, TOC, ultraviolet light absorbance (UVA), AOC, and aldehyde samples were collected at the MF effluent and RO permeate. A control condition was also tested, where ozone (and oxygen) were not applied to the chloraminated secondary effluent. The results from the analysis of these samples are summarized in Table 3.9.

Table 3.9 – TOC transformation through the ozonation process

Sample Location[a]	**MF Effluent**		**RO Permeate**		**Unit**
Condition	**No Ozone**	**With Ozone**	**No Ozone**	**With Ozone**	
Bulk parameters:					
Total Organic Carbon[b]	7.5	8.6	ND (< 0.2)[c]	0.39	mg/L
Dissolved UV Abs. at 254 nm	0.189	0.107	ND (< 0.009)	0.011	cm^{-1}
Assimilable Organic Carbon	1400	2900	<10	50	µg/L
Aldehydes:					
Formaldehyde	20	130	9.2	71	µg/L
Acetaldehyde	9.4	55	2.7	17	µg/L
Benzaldehyde	2.6	3.9	1.2	1.3	µg/L
Crotonaldehyde	1.1	ND (< 1)	ND (< 1)	ND (< 1)	µg/L
Glyoxal	12	130	ND (< 10)	ND (< 10)	µg/L
Methyl glyoxal	ND (< 10)	27	ND (< 10)	ND (< 10)	µg/L
Butanal	ND (< 1)	5.7	ND (< 1)	ND (< 1)	µg/L
Decanal	ND (< 1)	ND (< 1)	ND (< 1)	ND (< 1)	µg/L
Heptanal	ND (< 1)	10	ND (< 1)	ND (< 1)	µg/L
Hexanal	ND (< 1)	13	1	1.2	µg/L
Nonanal	2.2	7.6	ND (< 1)	ND (< 1)	µg/L
Octanal	ND (< 1)	ND (< 1)	ND (< 1)	ND (< 1)	µg/L
Pentanal	ND (< 1)	ND (< 1)	ND (< 1)	ND (< 1)	µg/L
Propanal	3.1	15	ND (< 1)	5.1	µg/L

[a] ND (not detected, or below the detection limit; detection limit shown in parenthesis)
[b] Measured in triplicates in the RO permeate; average shown
[c] Measured as 0.21 mg/L by Trussell Technologies lab (0.20 - 0.23), hold time 35 days

The ozone dose tested during this experiment represents a high ozone dose. This high ozone dose was not used as the basis of design for the preliminary AWTF design (rather the 10 mg/L dose was used). Thus, these data should exaggerate what is expected at the AWTF, with the lower ozone doses (lower ozone doses will transform the organics to a lesser degree). With this high ozone dose, the RO permeate TOC concentration approximately doubled compared to without ozone (it increased by 70%, assuming the non-ozone test condition RO permeate TOC was at the detection limit and that RO TOC rejection is independent of influent TOC concentration).

The increase in RO permeate TOC is only partially explained by the increase in RO permeate AOC (21 to 26%, assuming the no-ozone test condition RO permeate TOC was at the detection limit), which means that the rest of the RO permeate TOC increase is due to organic molecules that were transformed such that they can pass through RO (*e.g.,* smaller), but not to the degree that they were assimilated during the AOC test (*i.e.,* 74 to 79% of the increase in TOC is recalcitrant). An increase in RO permeate AOC may foster biological growth in the downstream conveyance system, if sufficient chloramine concentrations are not present for inhibition. Given that the increase in AOC is small, a chloramine residual will be present in the conveyance system, and these data come from an experiment with ozone doses higher than the design AWTF dose, the AWTF is expected to meet all product water quality goals. The effect of the AWTF design ozone dose (*i.e.,* 10 mg/L applied pilot dose) on RO permeate TOC concentrations is further discussed in the product water quality section of this report.

Notable results from the aldehyde analysis are the formation of formaldehyde and acetaldehyde. As is discussed in the Source Water and Product Water Quality Report, the formaldehyde NL is 100 micrograms per liter (µg/L). Acetaldehyde does not have an NL, or any other regulatory level, but a Predicted No-effect Concentration (PNEC) has been developed, which is 23 µg/L (Anderson, 2010). The concentrations measured in the RO permeate during this experiment were somewhat close to these levels, but below them. This experiment was conducted at a high ozone dose (21 mg/L) and at a fairly high O_3:TOC ratio (approximately 1.4 with approximate nitrite effects taken into account). The AWTF will be designed for lower ozone doses (10 mg/L) and lower O_3:TOC ratios (*e.g.,* 0.5), which will result in lower formaldehyde and acetaldehyde production (26 and 5.1 µg/L of formaldehyde and acetaldehyde, respectively, measured during one sample event of the RO permeate with a secondary effluent TOC of 14 mg/L and transferred ozone dose of approximately 9.1 mg/L). Formaldehyde may increase slightly through the UV/AOP process; however, this increase is expected to be minor, such that AWTF product water formaldehyde concentration is not expected to exceed the NL. If further pilot testing is conducted, testing the effect of the UV/AOP process on the concentration of RO permeate organics should be considered to verify that the effect of UV/AOP on organic formation is minor.

3.2 Ultrafiltration

3.2.1 Pentair module testing (inside-out)

Several operational parameters were monitored and used to evaluate the Pentair MF system performance. These include *TMP*, *Flux,* and *Permeability*. *TMP* is the pressure differential between the feed and filtrate side of the membrane and is measured in pounds per square inch (psi). *Flux* is the volumetric flow rate across the membrane measured in gallons per square feet per day, GFD. *Permeability* is the flux divided by the TMP and is a measure of the ability of the membrane barrier to allow passage or diffusion of a substance. Data *Normalization* is a mathematical technique that allows the user to compare operation at a specific set of conditions to a reference set of conditions. This allows the user to determine whether changes in membrane performance are caused by fouling, damage to the membrane, or are just due to different operating conditions such as temperature.

Flux and transmembrane pressure testing
From start-up the Pentair X-Flow module had difficulties in this application. The membrane TMP along with the operating flux are plotted in Figure 3.8. Initially, the flux rate was set to 25 GFD; however, at this flux the membrane would rapidly approach the critical TMP within 2 to 3 days. The reason for the rapid TMP increase was originally thought to be caused by the relatively large 700-micron mesh size of the pre-strainer.

From December 16th, 2013 through January 18th, 2014 the flux rate was dramatically reduced to between 12 and 17 GFD. This was done primarily to keep the unit operational while the pre-strainer could be replaced with one similar to the Toray unit. On January 18th, a 100-micron pre-strainer was installed on the Pentair unit. On January 20th, the flux rate was increased from 17 to 20 GFD. Within a matter of hours, the TMP reached the critical value.

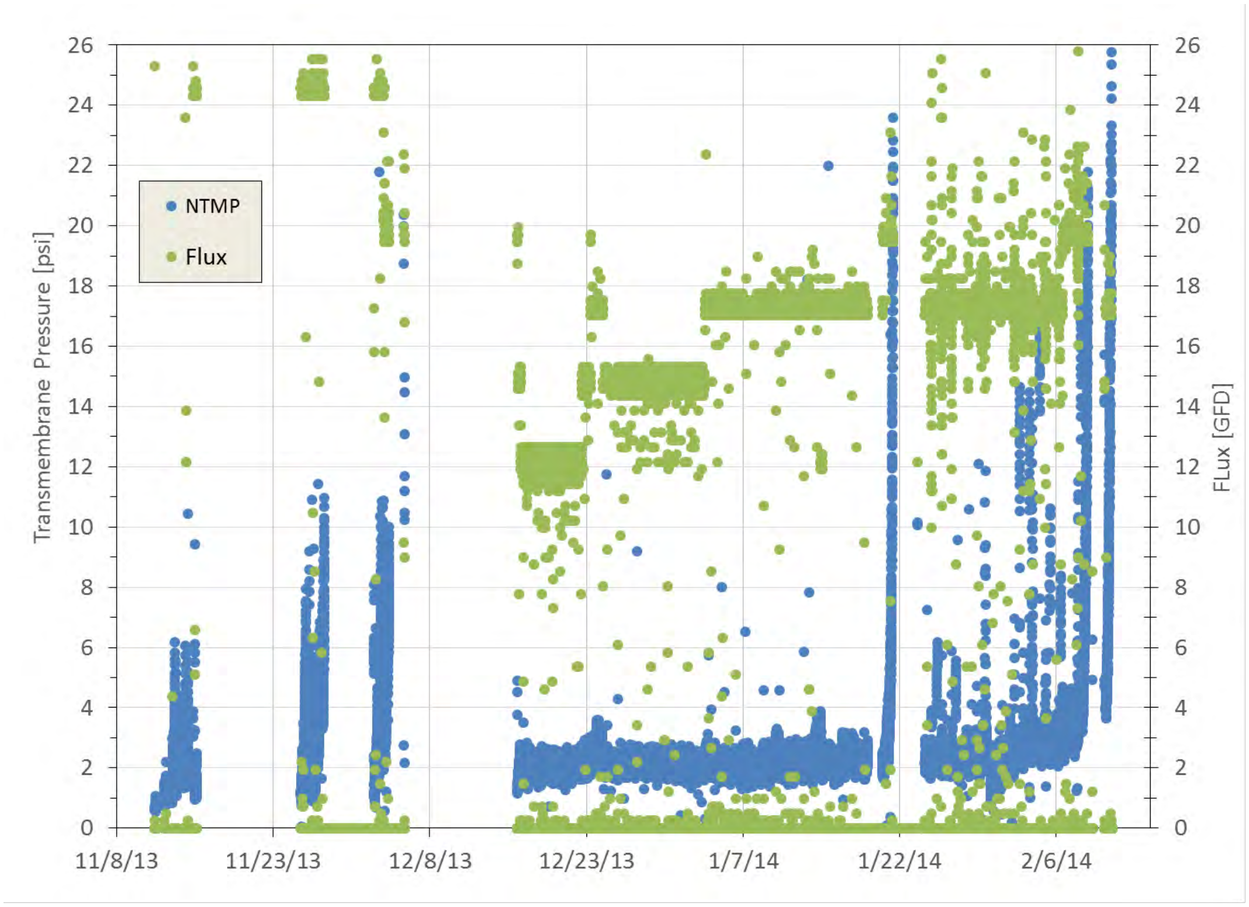

Figure 3.8 - Pentair TMP and Flux

A field technician from Harn RO systems performed a routine clean in place (CIP) on the Pentair unit on Jan 29th. The unit was returned to service at 17 GFD on January 30th, 2014. Following the CIP, the TMP was stable. One week after the CIP on Feb 6th, the flux rate was increased to 20 GFD. The TMP reached the critical value within three days. Because the Pentair unit was unable to maintain flux above 17 GFD, it was decided the inside out configuration was not suitable for this application.

3.2.2 Toray module Testing (outside-in)

Feed Water Quality

During piloting, the feed water quality remained relatively stable. Temperature, turbidity, and pH are plotted in Figure 3.9. The turbidity trend shows spikes in excess of 10 NTU. Fouling of the analyzer cuvette caused these spikes. The actual feed turbidity was never observed to be above 10 NTU.

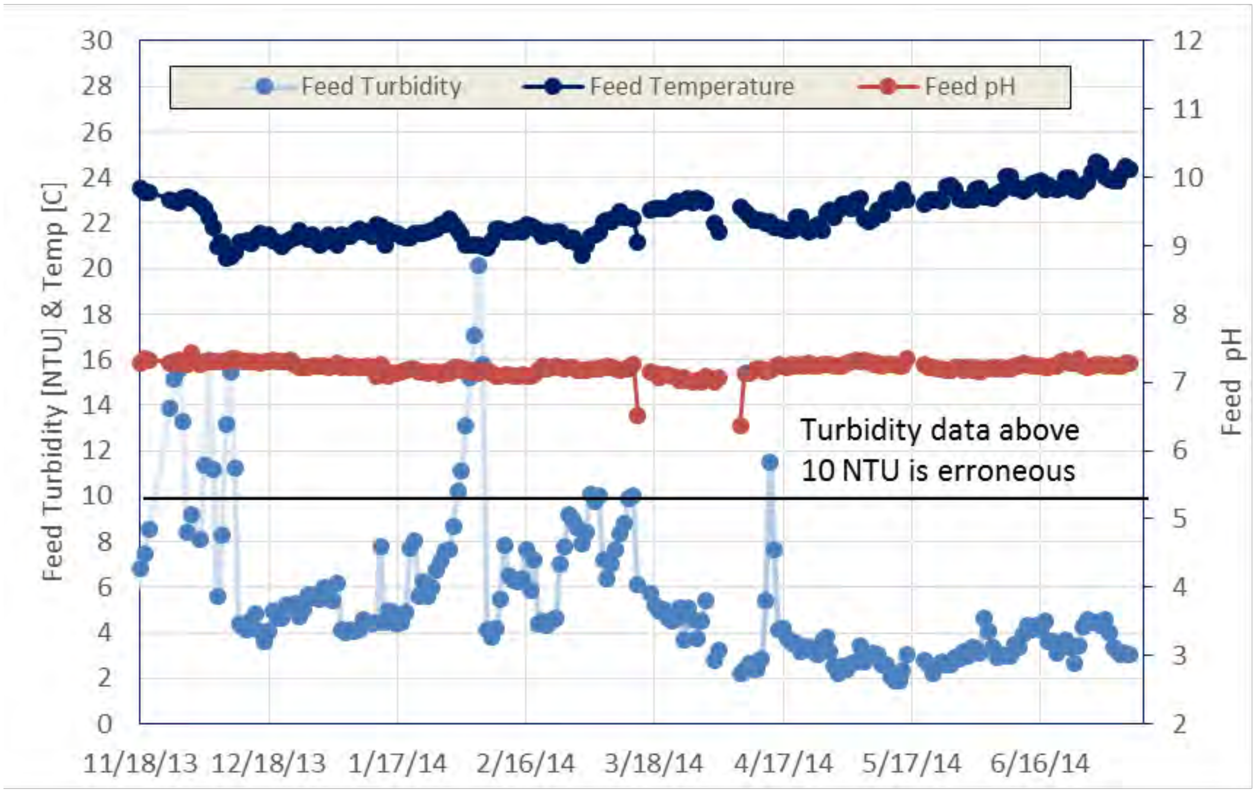

Figure 3.9 - Toray Feed Parameters

Flux and transmembrane pressure testing
Between the initial startup and shutdown, nine CIP cycles were performed on the Toray MF unit. The following section summarizes operating conditions and durations of each trial. For each trial, the total continuous run time is presented. The continuous run time neglected time off line resulting from periodic shutdowns of upstream equipment, such as repairs within the MRWPCA RTP and ozone system repairs.

TMP, flux, and permeability were operational parameters that were monitored and used to evaluate the Toray MF system performance (see Figure 3.10 for TMP and flux data).

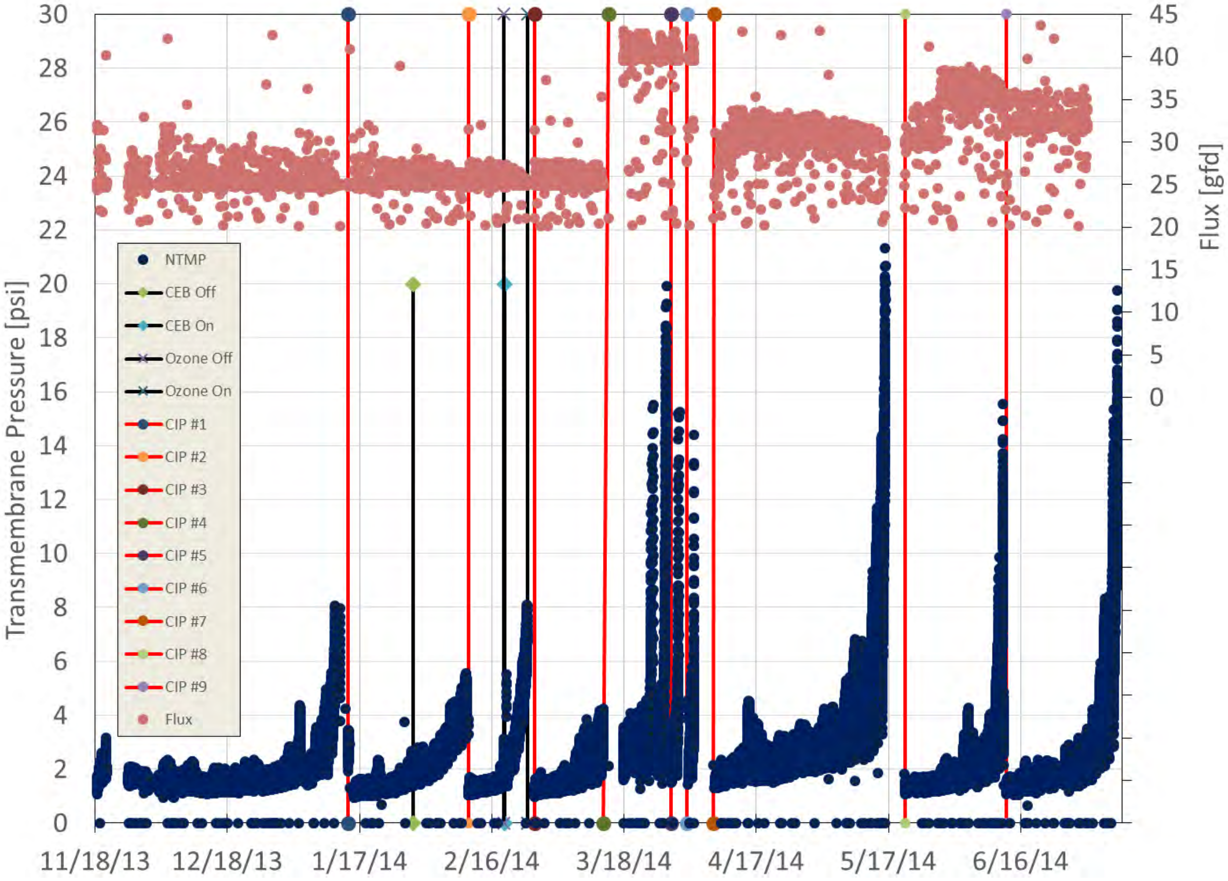

Figure 3.10 - Toray Transmembrane Pressure (Flux axis shown with truncated scale for ease of viewing the data)

Trial 1: 11/15/2013 – 01/12/2014

The first CIP was performed after 44 days (6.3 weeks) of continuous operation at a flux of 25 GFD and was done as a matter of routine maintenance. The TMP data shows a small spike that occurred on January 3rd, 2014. After an investigation of operations, it was determined that the chlorine feed used for chloramination went dry over a long holiday weekend. This is noted to exemplify the importance of controlling organic foulants. Once the chlorine system was returned to service, the MF system self-corrected.

Trial 2: 1/14/2014 – 2/10/2014

The second run yielded a shorter run time: 25 days (3.6 weeks) of continuous operation at 25 GFD. However, this run was likely abbreviated due to an inadvertent chemical feed pump shut down. The chemical pump that supplies NaOCl during the daily CEB was unintentionally disabled on Jan 29th. This was not discovered and corrected until Feb 18th. In addition to the lack of cleaning chemicals, the 2nd CIP was performed a few days early to ensure the system was fully operation for the monthly water quality sample scheduled for the second week of February (*i.e.,* the run could have lasted longer if the unit was allowed to reach the TMP shutdown setpoint of 21 psi).

Trial 3: 2/10/2014 – 2/25/2014
A planned ozone shut down was scheduled during this run. Once stable, MF operation was established at 25 GFD following the 2nd CIP, and the ozone system was taken off line to evaluate the corresponding effect to the membrane systems. Coincidentally, the same day the ozone was turned off, it was discovered that the chlorine pump was off and the regularly scheduled CEBs were resumed with the commencement of the no-ozone test. On February 18th the ozone system was turned off. The resulting TMP increase was very rapid, going from an average of 3 psi to the critical value within seven days. During trial 3, the Toray unit operated continuously for a total of 12.7 days (1.8 weeks) before reaching the critical TMP.

Trial 4: 2/25/2014 – 3/13/2014
Following the ozone shut down trial, the Toray unit was cleaned and returned to service at 25 GFD with the ozone system returned to service. After 15 days (2.1 weeks) of continuous operation, the unit was cleaned to prepare for the next trial, operating at an increased flux rate of 40 GFD. This CIP was performed as matter of preparation for the next phase of testing (*i.e.,* the CIP was not performed due to the module reaching the TMP shutdown setpoint).

Trial 5: 3/17/2014 – 3/28/2014
During the fifth trial, the MF flux rate was increased from 25 GFD to 40 GFD, and the ozone dose was increased from 10 mg/L to 18 mg/L. The TMP increase during the first 6 days was steady and moderate, from an average of 4.5 psi to 5.57. Then on the seventh day operating at 40 GFD, the TMP went from 5.75 to 29 psi in a matter of hours. The unit was returned to service by forcing several back-to-back backwash cycles followed by a CEB. These backwashes were undertaken to determine if the fouling event was due to a one-time surge in poor water quality. The unit was returned to service; however, it shut down on high TMP within two days. This trial yielded a substantial shorter run time of 8.2 days (1.2 weeks) of continuous operation.

Trial 6: 3/28/2014 – 4/1/2014
Initially it was not clear if the rapid fouling of the previous trial had resulted from the increased flux rate, inorganic fouling resulting from the increased Ozone dose, or simply an ineffective clean prior to the trial. The Toray unit was cleaned and returned to service under the same conditions, except that the ozone dose was decreased from 18 to 16 mg/L to reduce the likelihood of inorganic precipitation. This time the unit fouled in two days. The total continuous run time for this trial was 1.6 days.

Trial 7: 4/1/2014 – 4/2/2014
Following the 6th trial, the Toray unit was cleaned once again, and the ozone dose was lowered to 13 mg/L to further reduce the likelihood of inorganic precipitation. However within two days the critical TMP was reached. During Trial 7, the Toray unit operated continuously for 1.2 days at 40 GFD.

Trial 8: 4/7/2014 – 5/20/2014

Once it was established that 40 GFD was too aggressive, the flux rate was reduced. Following the 7th CIP, the unit was operated at 25 GFD for a day to verify the membrane module had not sustained irreversible fouling. The flux rate was then increased to 28 GFD for two more days. On the third day, April 11, the flux rate was increased to 30 GFD. The Ozone dose was 10 mg/L. During this trial, the Toray unit operated continuously for an additional 31.9 days (4.6 weeks) at 30 GFD. The total continuous run time for this trial was 35.4 days (5.1 weeks). On April 15th, the TMP rapidly jumped from 3 to 6 psi. Based on previous trials, it appeared the TMP was about to run away to the critical value. However, by the next day the TMP began to drop. Each consecutive day the TMP continued to drop until April 19th, when the TMP fell in line with a normal rate of increase. For the remainder of the trial, the rate of TMP increase was normal. This spike is explained in the following section.

Trial 9: 5/20/2014 - 6/12/2014

The 9th trial began by continuing to operate the Toray unit at 30 GFD for a week and changing the ozone dose to an average of 20 mg/L. During this time, the TMP showed no appreciable increase, less than 1 psi. In an effort to identify the upper limit to the sustainable operating flux, on May 28th the flux rate was increased to 35 GFD. On June 3rd, the TMP again took another unexpected jump. Once again, on the 4th the TMP dropped back in line with the normal rate of increase. The Toray unit operated continuously for 20.9 days (2.9 weeks), 15 days at 35 GFD.

Trial 10: 6/12/2014 - 7/7/2014

During the entire 10th trial, the Toray unit was operated at 32 GFD, while the ozone dose was maintained at an average of 20 mg/L. The Toray unit operated continuously for 22.2 days (3.2 weeks).

In addition to the TMP and Flux data, Figure 3.10 (introduced above) also shows Toray membrane testing milestones such as the CIPs, the chemical pump inactivation, and the ozone deactivation trial (indicated by vertical lines on the plot). An evaluation of the operating data over the course of the pilot operation period indicates the optimum operating flux rate is 30 GFD.

All the CIPs, except CIP number five, were performed in two steps, first with a 3,000 parts per million (ppm) NaOCl solution followed by a 3% Citric Acid solution. Each solution was recirculated for one hour, and then left to soak for three more hours. During the soak, the module was aerated for 30 seconds every 30 minutes. CIP number five had the acid portion performed first, followed by the NaOCl portion. With the exception of the chemical order, the chemical concentrations and sequences were identical to the other CIPs.

Over the course of the pilot, two unexpected TMP spikes were observed: one on April 15th 2014 and the other on June 4th 2014. Further investigation of the RTP revealed a decline in secondary effluent quality, which led to filtration difficulties at the Salinas Valley Reclamation Plant (SVRP; *i.e.,* SVRP required a significant increase in the coagulant dose to meet their effluent turbidity requirements)[21]. A plot of the TMP, along with the coagulant dose, is shown in Figure 3.11. The two TMP spikes are highlighted in red. A decline in MF performance is likely during times when the RTP secondary effluent water quality is low. However, the pilot unit recovered from these events without additional cleanings or operational effort.

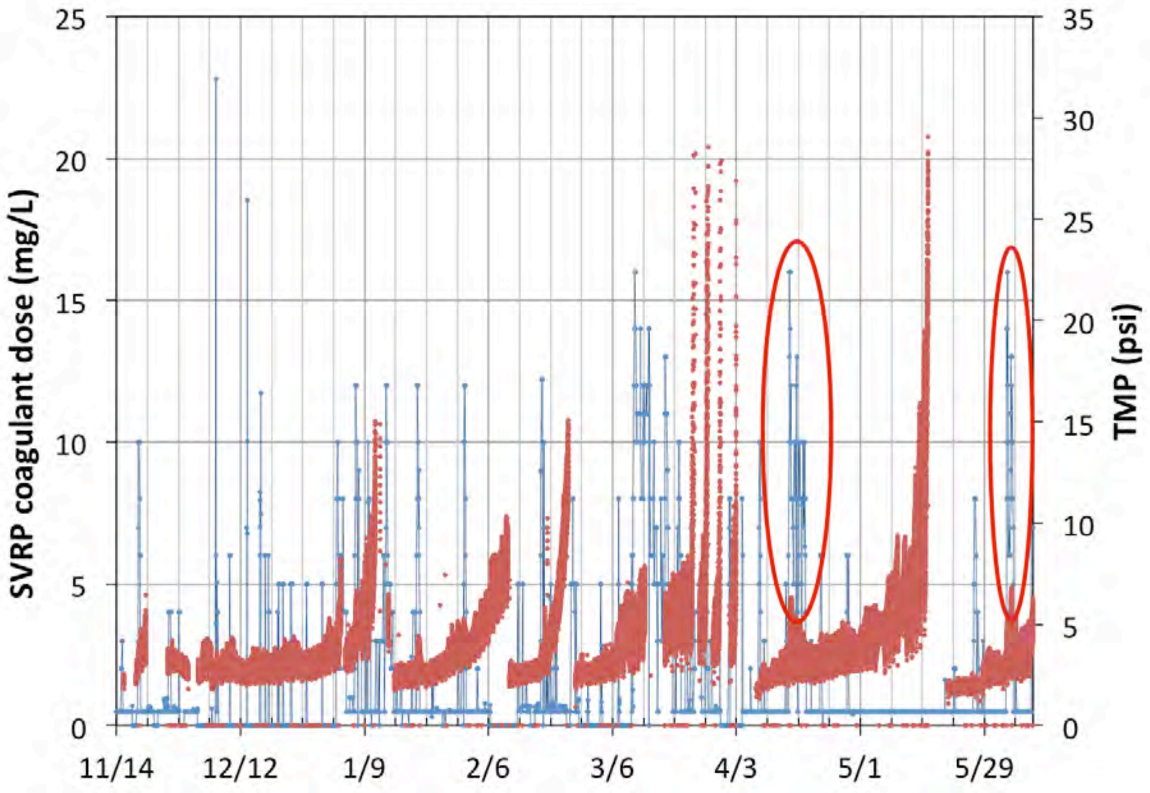

Figure 3.11 - Toray TMP and SVRP Coagulant Dose

Figure 3.12 below contains the plot of the normalized membrane permeability.

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[21] Coagulant is a polymer blend (JC-1676), and is added to the secondary effluent whenever the SVRP coagulant addition (also JC-1676) exceeds 10 mg/L (operator initiated). This coagulant may have also impacted filterability at the pilot (by increasing or decreasing the MF TMP).

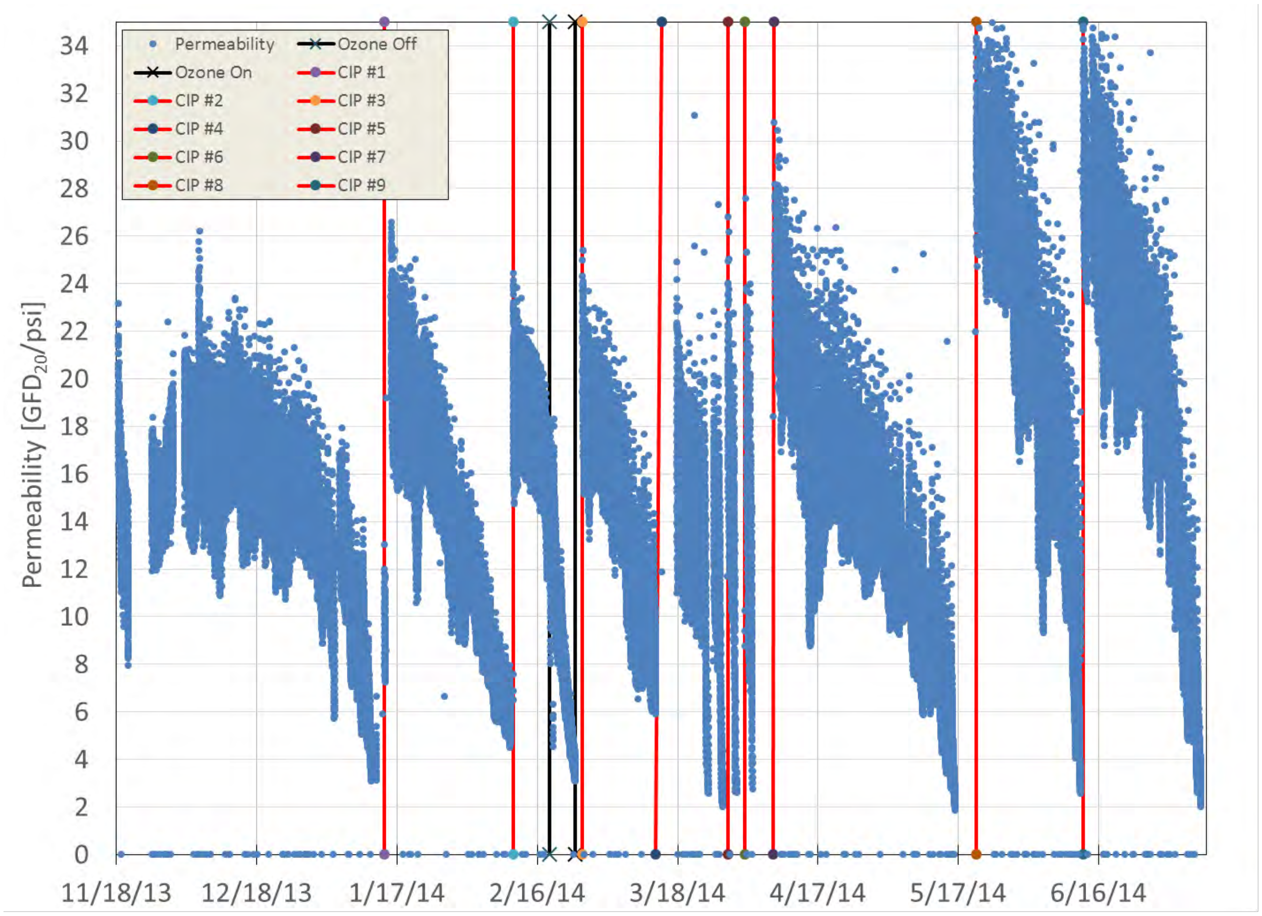

Figure 3.12 - Toray Normalized Permeability

A plot of the filtrate turbidity data is shown in Figure 3.13. 99.8% of the 134,600 data points collected were less than 0.05 NTU. Furthermore, all of the silt density index (SDI) results were less than 3.0. The PLC could not record daily membrane integrity test results; however, they never exceeded 0.1 pounds per square inch per minute (psi/min; *i.e.,* the alarm set point). In general, values below 0.5 psi/min indicate an integral membrane. Above 0.5 psi/min, membrane pinning may be required.

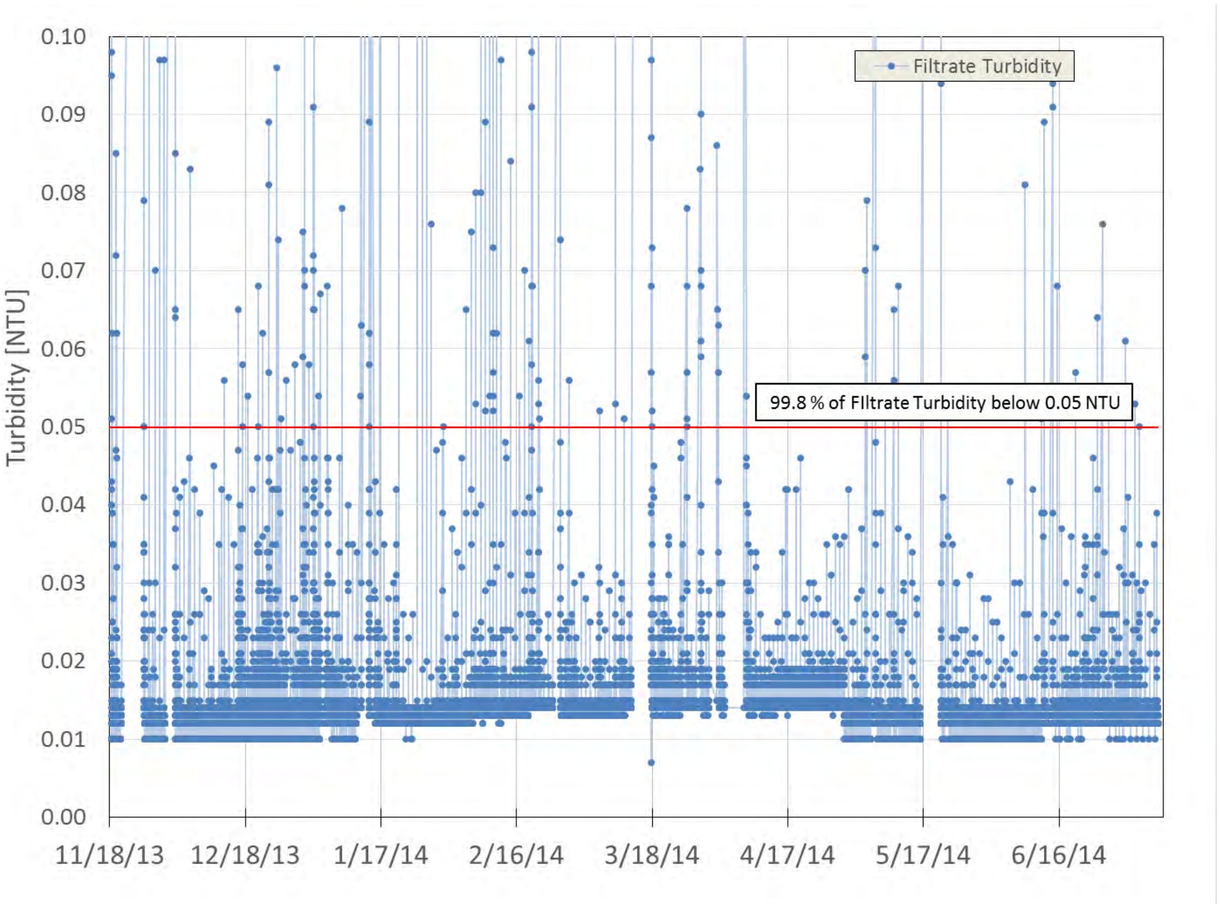

Figure 3.13 - Toray Filtrate Turbidity (the red line indicates the 99.8 percentile value)

3.3 Reverse osmosis

3.3.1 Performance testing

The feed parameters are plotted in Figure 3.14. The feed conductivity experienced two significant spikes, one in December of 2013 and the second in late February 2014. The cause of the first spike is unknown; however, the second spike resulted from the temporary introduction of Lake El Estero water between February 20th and March 1st for testing purposes. During the period of time between May 12 and June 3, 2014, the conductivity analyzer probe had malfunctioned; hence, there were no data collected through the PLC. During this time, the feed conductivity was measured manually and an average value of 1690 microsiemens per centimeter (µS/cm) was used for data normalization.

The feed temperature dropped suddenly from 22 °C to 20 °C in December 2013, then began to climb steadily to 24 °C by the conclusion of the pilot in June 2014. Overall, the water temperature was stable and did not cause any operational challenges.
At the onset of the pilot, the target pH was 6.8 with calcium phosphate being the primary constituent of concern. In late February, the feed pH began to increase unexpectedly.

Originally, the cause of the pH rise was unknown. In an effort to maintain the target 6.8 value, the acid dose was slowly increased. On April 21, 2014, it was discovered that the pH probe had been drifting high. The acid dose was adjusted and the actual pH was monitored manually with field measurements. The online data showed the pH between April 21 and June 13, 2014 to be around 8.0. The actual value was 6.8 through May 21, at which time the target pH was lowered to 6.0, shown with the red dashed line. The pH target was lowered on May 21st to target calcium phosphate because the RTP began receiving agricultural wash water, which contains elevated phosphorus levels.

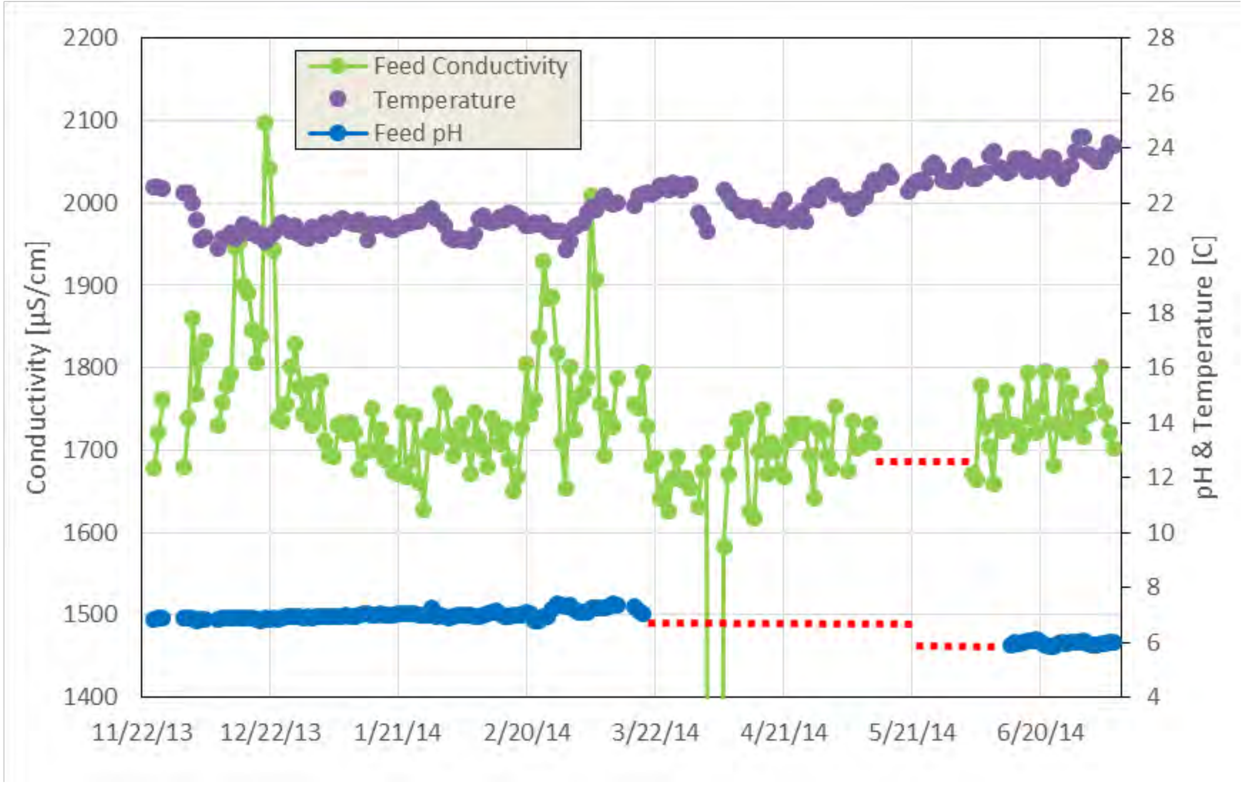

Figure 3.14 - RO Feed Parameters

The RO system performance was very stable from startup on November 25th, 2014, though shut down on July 7, 2014, after just over 7 months of operation. During the course of the pilot, the RO unit required only one CIP, which occurred on April 28th, 2014. Throughout the pilot testing, a chloramine residual was maintained through the pilot system with the target of 2 to 5 mg/L at the RO feed.

Several operational parameters were monitored and used to evaluate the RO system performance. These include: *Specific Flux, Normalized Differential Pressure, Feed Pressure, Normalized Rejection,* and *Normalized Permeate Conductivity.* The Specific Flux is the ratio of the Flux to the Net Driving Pressure, where the net driving pressure is the available feed pressure less the sum of the osmotic, train differential, and permeate back pressures. The differential pressure is a measure of the pressure drop from the feed to the concentrate and can be measured either across the entire train or across the individual train stages. Rejection is a measure of the total dissolved ions removed from the feed water.

The overall train normalized specific flux along with the ratio of individual specific flux for both stages are shown in Figure 3.15. The normalized specific flux is the specific flux normalized for temperature. The specific flux ratio is an indicator of any differential fouling or scaling between the two stages.

In mid-January, the specific flux began to decrease slightly, and continued to decrease while the ozone system was off line. However, immediately following the restart of the ozone, the RO specific flux began to recover slightly. While the lack of ozone likely played a role in the specific flux decrease, the exact cause is unknown. The specific flux decrease also coincides with the feed conductivity increase that occurred when the pilot received Lake El Estero water, which also likely had an effect on the RO performance.

On March 14, 2014, the overall specific flux dropped sharply. An evaluation of the second stage differential pressure (*i.e.,* the pressure drop between the feed and concentrate) also shows a sharp decrease during this time. Additionally, the permeate flow from the tail vessel also began to drop off during this time. All of these operational factors indicate scale formation in the tail end of the RO unit. The RO unit was taken off line on April 28 for the only CIP. The unit was cleaned with a 3.0% Citric Acid solution. The solution was heated to 100 °F. The solution was recirculated through the second stage for 30 minutes, and allowed to soak for 60 minutes. While the second stage was soaking, the CIP solution was recirculated through the first stage and allowed to soak for 60 minutes. The entire procedure was performed twice for a total of three hours of acid contact time per stage.

Following the clean, the specific flux data appeared to recover beyond that of the startup value. The days following the CIP continued to show increasing specific flux. An evaluation of the on-board instruments revealed the flow rates being recorded by the PLC were different than those reported on the respective flow meter displays. After trouble shooting the symptoms, it was determined that an analog input card in the PCL had failed. This card was replaced on May 15, 2014. Following the analog card replacement, the specific flux trend returned to the expected post-CIP value.

On May 28th, the sulfuric acid supply ran dry for approximately 20 hours (this is evident by the sudden drop in specific flux and the spike in the specific flux ratio). Immediately after it was discovered, the supply was refilled and the feed pH was dropped to 5.0 for approximately one hour. During this hour, the flow from the tail vessel was monitored and it slowly showed signs of recovery. It was decided to return the RO unit to service, monitor performance, and clean if necessary. Following this incident, the RO unit performance returned and maintained stable operation for the duration of the pilot.

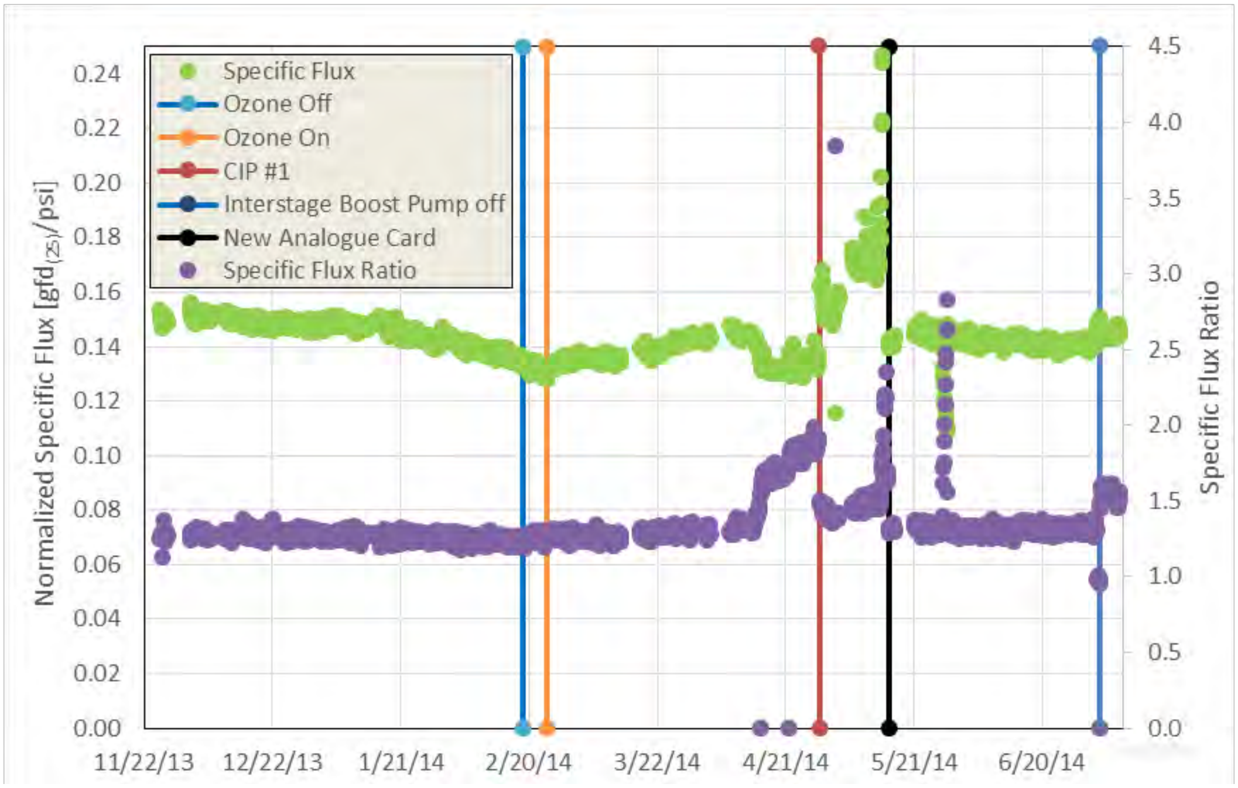

Figure 3.15 - RO Specific Flux and Specific Flux Ratio

The overall train normalized differential pressure plot is shown in Figure 3.16. The differential pressure remained very stable over the duration of the pilot. There was a slight decrease prior to the CIP, caused by a drop in the second stage differential pressure. In mid-June, 2014, there was a slight jump from about 27 to 29 psi.

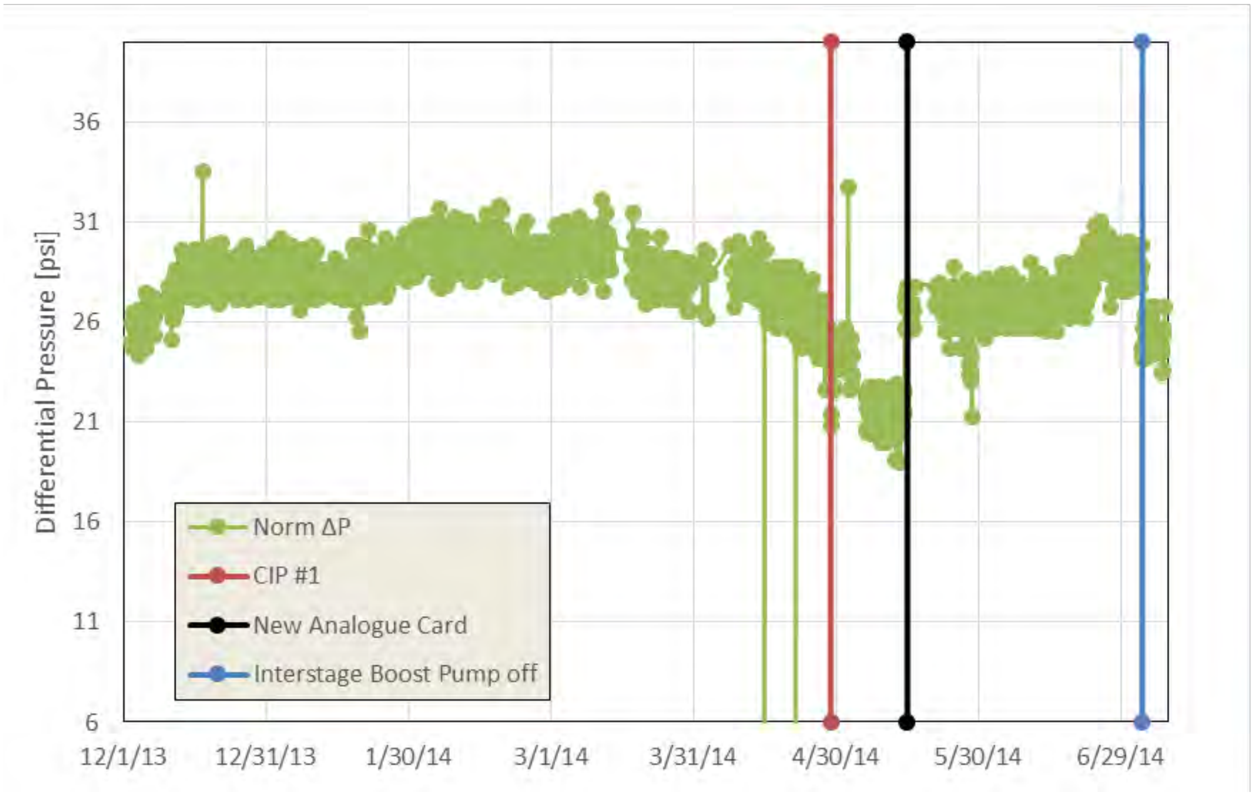

Figure 3.16 - Normalized Differential Pressure

The individual stage normalized differential pressures are shown in Figure 3.17. The second stage decrease prior to the clean is very evident here, while Stage 1 remained very stable.

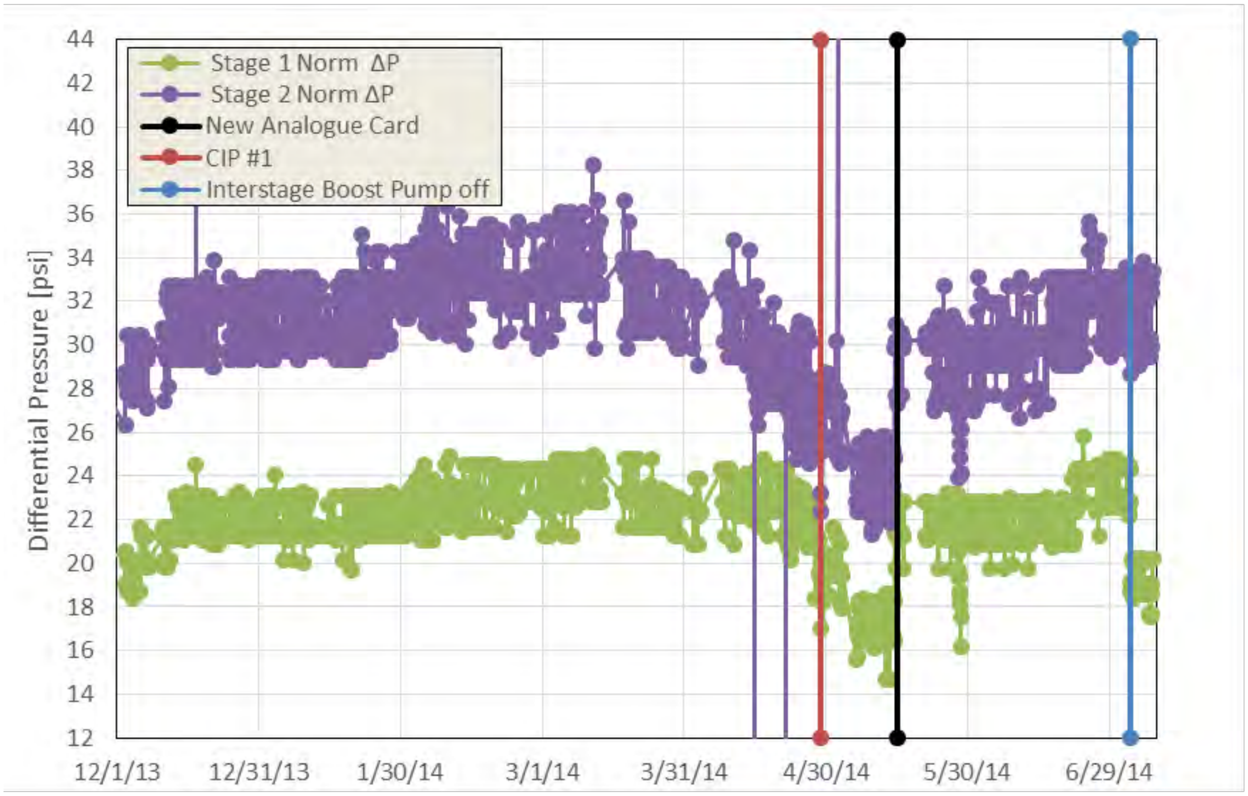

Figure 3.17 - Stage Normalized Differential Pressures

The actual feed pressures for both stages are shown in Figure 3.18. The red dashed lines were added to highlight post clean performance. The jump in the second stage feed pressure prior to the clean is another indicator of tail end element scaling. Following the clean and the analog card replacement, both stage feed pressures returned to normal levels relative to start-up values.

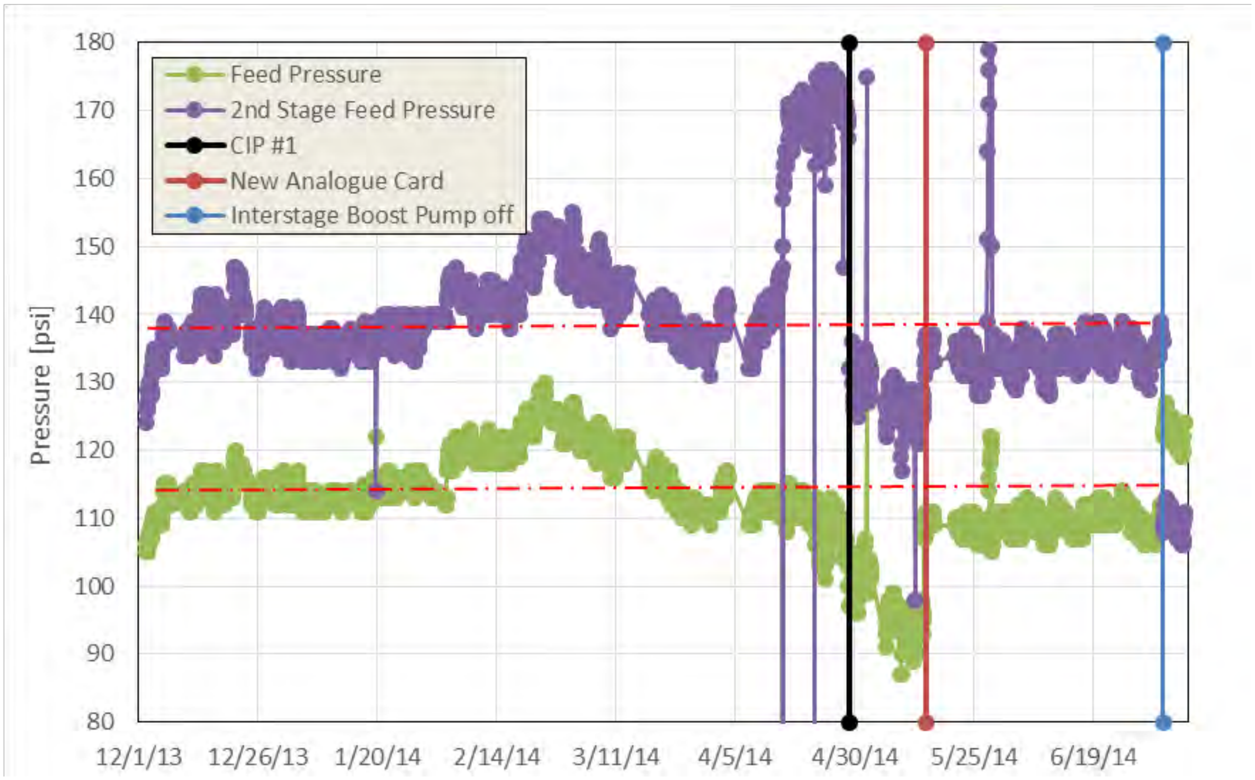

Figure 3.18 - Actual Stage Feed Pressure

The normalized salt rejection trend is shown in Figure 3.19. Overall, the data are very stable, exceeding 98.5%. The small spike shown prior to the analog card replacement is erroneous.

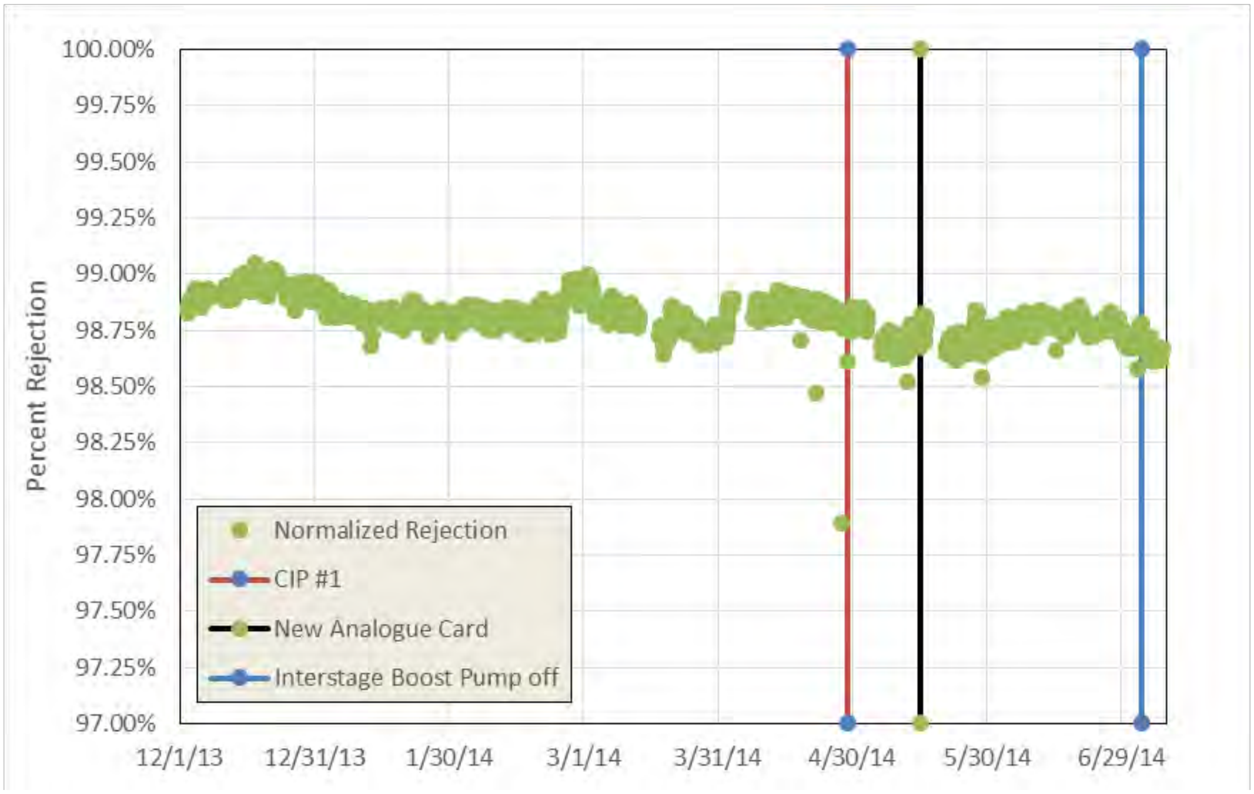

Figure 3.19 - Normalized Rejection

The normalized permeate conductivity trend is shown in Figure 3.20. While this data shows some fluctuation, the overall trend is very stable.

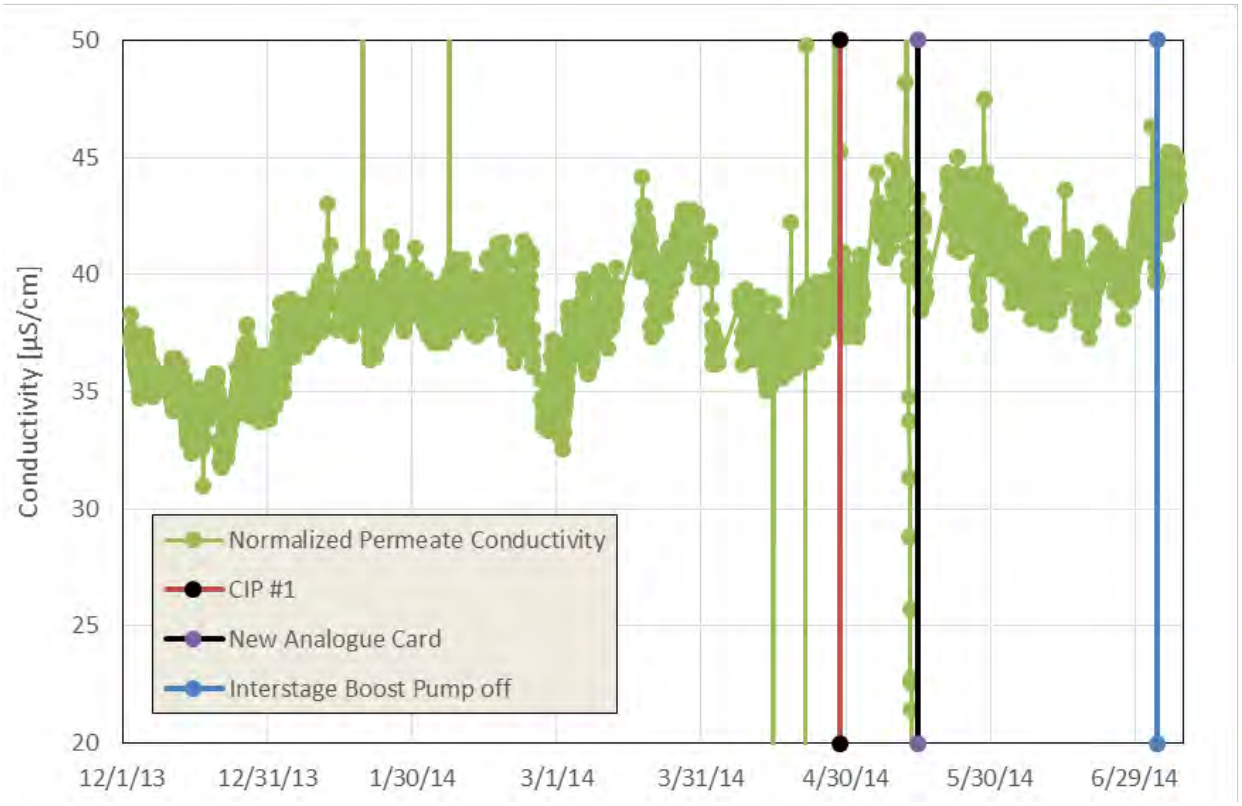

Figure 3.20 - Normalized Permeate Conductivity

3.3.2 Inorganic foulants

Phosphate minerals

Phosphate (mostly in the form of dihydrogen and hydrogen phosphate; also known as orthophosphate) is an ion of particular interest with respect to RO scaling, given the high concentrations of phosphate in the agricultural wash water. Hydrogen phosphate forms a sparingly soluble mineral with calcium when these constituents are at high enough concentrations. Phosphate is a salt of phosphoric acid, and the concentration of hydrogen phosphate is dependent upon pH (acid dissociation constants pK_2 and pK_3, 7.2 and 12.3, respectively). Given this dependence on pH, acid is one method of calcium phosphate control. The concentrations of these ions increase when they are retained on the RO concentrate side of the RO membrane. With an RO recovery of 81%, these ions are concentrated by a factor of 5.3 (assuming 100% rejection across the OR membrane). With the high feed concentrations associated with the agricultural wash water shunt (a high of 9 mg/L as P with the shunt compared to 4 mg/L as P without the shunt), the concentrating effect of the RO may cause scaling and fouling of the membrane, if adequate control measures are not employed (*e.g.,* pH adjustment). Phosphate concentrations measured in the secondary effluent of the RTP during piloting are shown in Figure 3.21. The samples were composited over a period of 24-hours (flow weighted), and passed through a 0.2-micron-pore-diameter filter prior to analysis.[22]

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[22] RTP Lab with ion chromatography; 0.2 micron filtration required due to capillary tubing size restrictions

Figure 3.21 – Phosphate concentration in the secondary effluent during piloting
(includes effect of CEPT control)

Although the elevated concentrations of phosphate in the secondary effluent during April and May were a concern, pH control seemed to stave off phosphate-related fouling. The RO feed pH was manually controlled at approximately 6.8 until May 21st, when the manual RO feed pH setpoint was set to 6.0 (manual control was necessary while a faulty pH sensor on the RO skid was replaced, and the feed pH was verified approximately weekly during this time period). While there may have been diurnal variations in the MF effluent pH (which would correspond to variations in the RO feed pH, given the manual control), the RO system did not discernably foul with these setpoints, under the high phosphate loads. On the other hand, the RO fouled rapidly when pH control was ceased (the RO recovered from this event after pH control was reinstated), and small perturbations to the RO feed pH appeared to impact the RO specific flux (an indicator that is typically used to monitor RO fouling). The one fouling event that required RO cleaning occurred prior to the higher phosphate concentrations associated with the agricultural wash water shunt (March 15, whereas the agricultural wash water shunt began on April 1). Another factor that may have contributed to the RO performance with these high phosphate loads is that the MF system may have filtered out sub-colloidal phosphate precipitates. The nominal pore size of the MF system was 0.01 microns, and any sub-colloids larger than this size would be well removed through the MF system. Although filtration through the MF system is possible, pH control likely played a key role in controlling phosphate-related mineral scaling, and thus pH control is recommended for the AWTF.

Phosphate removal at the RTP may occur through biological uptake and wasting, or through precipitation and sludge removal. Phosphorus typically makes up 1.5 to 2% of the dry weight of microbial cells. As cells increase in number through the secondary process, they remove dissolved phosphate from the wastewater. When these cells are settled out in the secondary clarifiers, the phosphorus is removed from the treated wastewater. Another method of phosphorus removal is chemical precipitation with metal salts (*e.g.,* ferric). With appropriate doses, ferric chloride can form sparingly soluble minerals with phosphate that settle out from the wastewater. A stoichiometric relationship between ferric dose and phosphate precipitation typically exists for high residual (effluent) phosphate concentrations (*i.e.,* when effluent dissolved phosphate concentrations are not low). As lower effluent phosphate concentrations are targeted, metal hydroxides form and the removal mechanism transitions from precipitation to adsorption to these metal hydroxides. This transition significantly increases the required ferric dose (Sedlak, 1991). A potential negative effect of a ferric chloride based phosphate control is the possibility of dissolved iron carryover into the RO feed. Iron is one of the many ions that contribute to RO scaling, and this carryover could possibly impact RO performance.

During the time period of elevated phosphate concentration in the RO feed (April through July), ferric chloride was experimentally used to control phosphate concentrations in the secondary effluent (see timing and magnitude of doses in Figure 3.22).[23] The starting ferric chloride dose of 18 mg/L had a statistically significant impact average on the phosphate concentration compared to the residual phosphate concentrations of the lower dose and no dose, after adjusting for variations in the RTP influent concentration (95% confidence). This high dose seems to have achieved residual phosphate concentrations that were similar to the secondary effluent concentrations prior to the agricultural wash water shunt. The lower dose of 9 mg/L did not yield a residual phosphate concentration that was statistically significant from the high dose or no ferric addition secondary effluent concentration.

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[23] Ferric chloride (41% strength ferric chloride) dosed through the RTP chemically enhanced primary treatment (CEPT) facilities

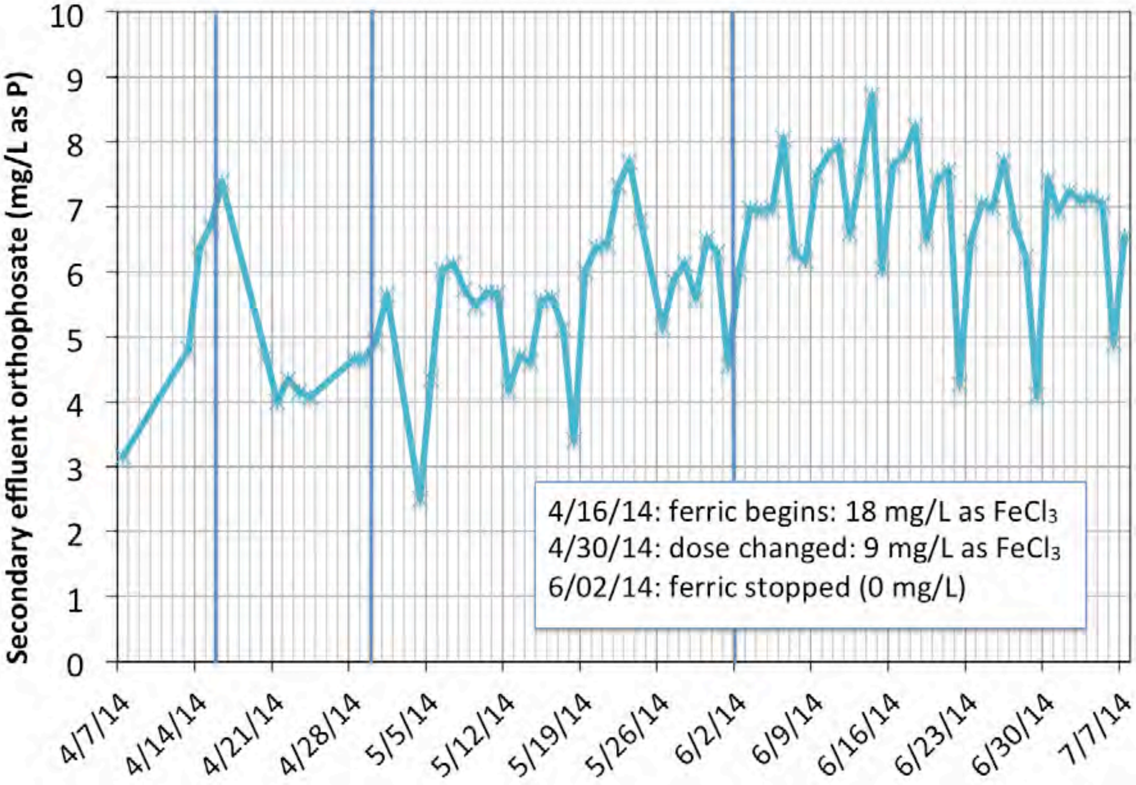

Figure 3.22 – Phosphate measurements during agricultural wash water shunt and ferric chloride doses

An approximate qualitative representation of the change in phosphorus concentration is shown in Figure 3.23. These data come from 24-hour composite samples at five locations in the RTP: RTP influent, primary influent (after recycle streams are included), primary effluent, trickling filter effluent, and secondary effluent. Although the difference in phosphate concentrations across neighboring sample locations was directly used to calculate the increase or decrease in phosphate as if all samples were collected over the same time period and with the same weighting scheme, the collection times and collection weighting schemes actually varied between sample locations.[24] Further, these data indicate an overall increase in phosphate concentrations through the RTP (*i.e.,* an increase in RTP influent compared to the secondary effluent; although not statistically significant at the 95% confidence interval). This increase may be due to suspended phosphate dissolving into the dissolved form (to pass through a 0.2-micron filter) through the RTP. With these caveats in mind, it may be possible to make broad observations from the data. First, these data seem to indicate a recirculation of phosphate through the recycling flow, presumably from the screw press pressate (three grab samples indicate 63 to 111 mg/L as P in late May). They also seem to show removal through biological clarification. Finally, the data appear to indicate that phosphate removal through primary sedimentation may have

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[24] RTP influent and secondary effluent were flow-weighted and collected from midnight to midnight; primary effluent and trickling filter were time-weighted, from approximately 7 am to 7 am; primary influent was time weighted up until 4/30/14, and flow-weighted after said date, from approximately 7 am to 7 am, regardless.

been negligible, although this observation may be skewed by absence of total phosphate data (including dissolved and suspended).

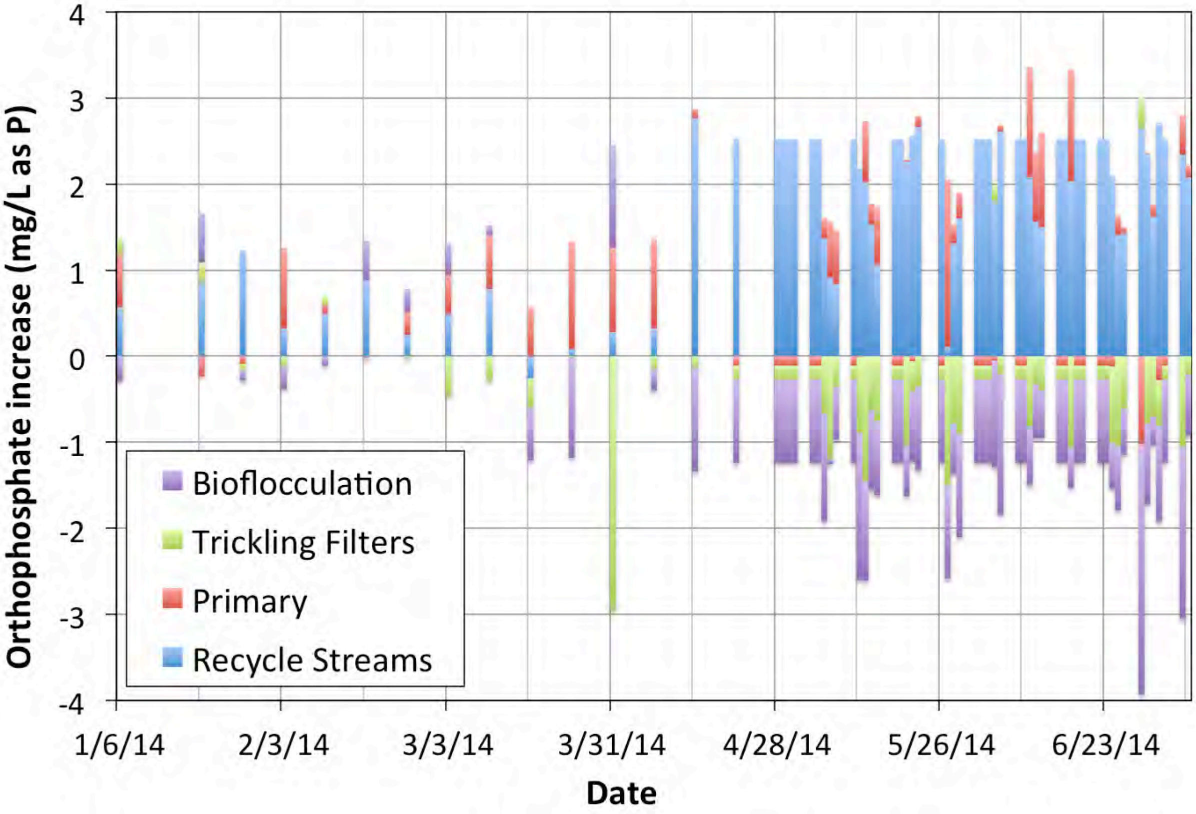

Figure 3.23 - Change in orthophosphate concentration through RTP (the mean of these changes across treatment processes are not statistically significant at the 95% confidence interval; all samples are 24-hour composites, but collection time periods and weighting schemes vary between sample locations)

Full-scale design, and later operation, of the AWTF should consider the costs and benefits of chemical precipitation (*e.g.,* ferric chloride), pH control (*e.g.,* sulfuric acid control at the RO feed), or other methods (*e.g.,* biological phosphorus removal) for controlling phosphate in the RO feed.

Other mineral foulants

In addition to calcium phosphate minerals, there are a number of other sparingly soluble minerals that may contribute to RO scaling (*e.g.,* aluminum silicates). The ions that constitute these sparingly soluble minerals were measured during piloting (see results of these measurements in Table 3.10; the probability plots of three ions with particularly high concentrations in this feed water are shown in Figure 3.24 and Figure 3.25). In some cases (*e.g.,* calcium phosphate minerals), the solubility of these minerals can be increased (*i.e.,* decrease the rate of mineral formation, or eliminate mineral formation) by decreasing the RO feed pH (*e.g.,* through acid addition). Lowering the pH, however, may have the opposite effect on some other minerals, where their solubility may decrease (*i.e.,* the rate of mineral formation may increase). Some RO scaling minerals are also amendable to anti-scalants (also known as anti-foulants or threshold inhibitors); however, anti-scalants are not available at this time for all minerals that may foul RO membranes in water reuse applications.

Table 3.10 – Inorganic parameters of concern with respect to RO fouling, measured in the RO feed water

Constituent (mg/L)	Median	Range[a]
Alkalinity	306	250-342
Aluminum	0.078	0.021-0.75
Calcium	58	51-65
Chloride	230	203-266
Fluoride	0.6	0.5-0.8
Phosphate	3.1	0.3-14
Magnesium	22	10-26
Manganese	0.052	0.043-0.078
Nitrate	19.9	<1-47
Silica	39	38-40
Sodium	152	149-173
Potassium	20	19-21
Iron	0.378	0.157-0.931
Barium	0.011	0.003-0.029
Sulfate	90	84-94
Strontium	0.378	0.360-0.396
TDS	808	757-897

[a] 13 samples, except for nitrate (12 samples), with approximately 6 samples during the agricultural wash water shunt

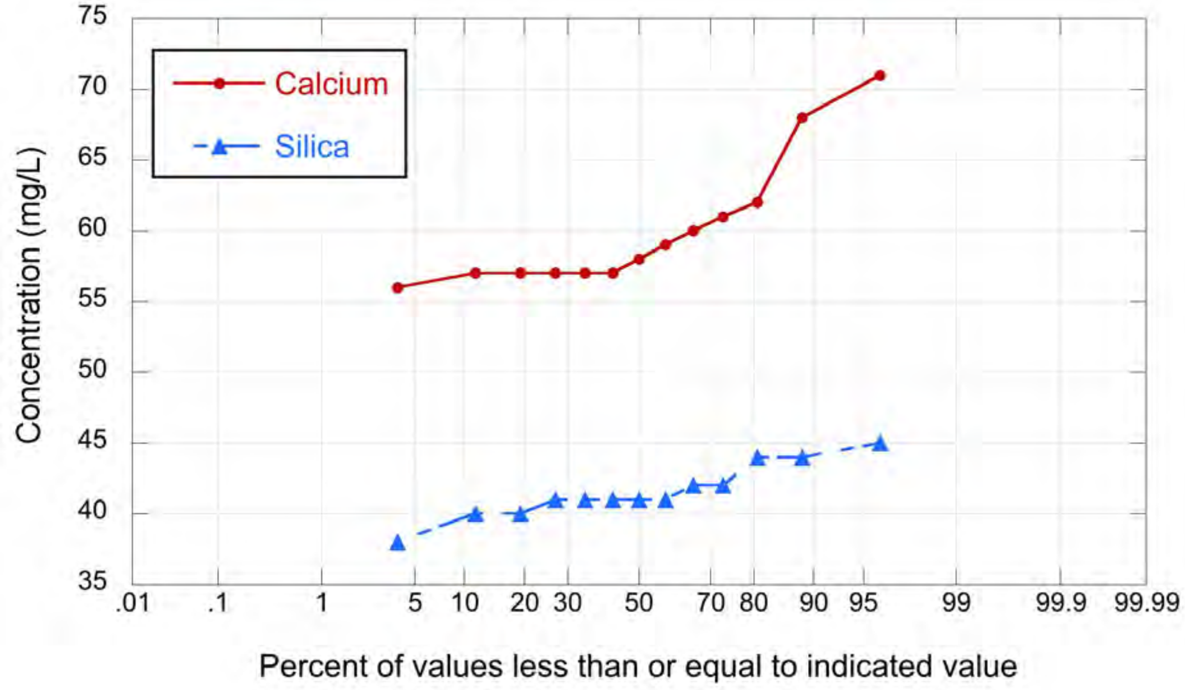

Figure 3.24 – Probability plot of calcium and silica concentrations in RO feed water

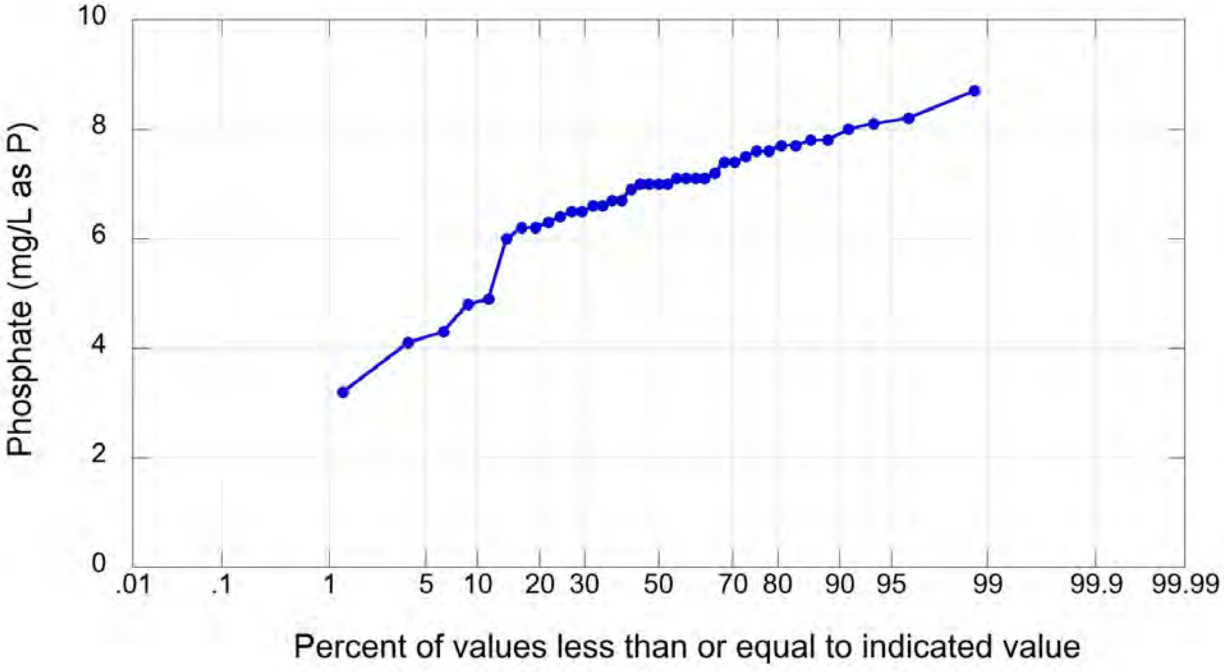

Figure 3.25 – Probability plot of phosphate concentrations in the RTP effluent after April 1, 2014, the date on which the agricultural wash water was routed into the RTP, and only when ferric chloride was not added at the RTP (*i.e.*, excluding dates 4/16 through 6/2)

Inorganic parameters of concern (*i.e.,* the ions that may form sparingly soluble minerals in RO membranes) were also measured during the source water sampling campaign (Trussell Technologies, 2014d). The results from this sampling effort are summarized in Table 3.11. Some of these ions are present in the source waters at concentrations that are of concern with respect to RO fouling (*e.g.,* iron, aluminum). However, these source waters will be blended and treated prior to entering the RO. They will blend together with municipal and industrial wastewater in the RTP collection system; they will undergo primary and secondary treatment through the RTP (where sedimentation of solid-bound ions, and biological update may occur); and they will receive chloramination, preozonation and MF treatment (where oxidative precipitation and removal may occur). Direct water quality samples are not available to characterize these effects, as select source water shunting occurred during the pilot program. If the final RO feed water quality can be estimated (after the effects of blending, RTP removal, and upstream AWTF removal), then RO modeling can be conducted to determine the impact of these constituents on RO fouling and RO recovery. An estimate of final RO feed water quality, and the associated RO modeling, is outside the scope of this pilot report; however, both of those tasks are recommended to ascertain the impact of the source water quality on the RO design and operation. The concentrations of some salts in the source waters may limit the RO recovery if they are not well removed by upstream processes, or sufficiently reduced through blending.

Table 3.11 – Observed median concentrations and ranges of inorganic parameters of concern for RO scaling. All concentrations in mg/L.

Parameter	RTP Effluent	Ag Wash Water	Blanco Drain	El Estero	Tembladero Slough
Alkalinity	316 (277-344)	168 (157-260)	356 (327-373)	185 (157-212)	363
Aluminum	0.048 (0.021-0.256)	0.237 (0.14-0.598)	0.77 (0.26-2.04)	0.296 (0.189-0.402)	1.54
Calcium	58 (54-62)	81 (76-100)	154 (128-169)	100 (77-122)	166
Chloride	217 (183-235)	237 (154-292)	274 (241-307)	423 (332-514)	394
Fluoride	0.56 (0.4-0.8)	0.3 (*<0.1*-31.9)	0.7 (0.66-0.9)	0.3	0.7
Phosphate (as P)	3.0 (2.2-13)	27.5 (10.5-47.2)	*<0.1* (*<0.1*-0.2)	*<0.1*	*<0.1*
Magnesium	22 (20-24)	34 (28-39)	146 (140-177)	42 (32-52)	159
Manganese	0.045 (0.034-0.051)	0.049 (0.039-0.051)	0.243 (0.06-0.449)	0.281 (0.219-0.342)	0.108
Nitrate	21.5 (*<1*-42)	22.5 (*<1.1*-28)	292 (70.3-352)	*<1*	255
Silica	40 (39-44)	44 (41-48)	30.5 (26-63)	*<0.5*	30
Sodium	161 (144-173)	177 (133-200)	241 (196-266)	235 (174-296)	333
Potassium	21 (19-22)	36 (32-42)	2.3 (1-2.7)	7.8 (6.2-9.3)	4.9
Iron	0.339 (0.175-0.537)	0.434 (0.3-0.875)	1.563 (0.639-3.891)	0.355 (0.202-0.508)	2.962
Barium	0.0115 (0.011-0.026)	0.096 (0.082-0.109)	0.068 (0.054-0.079)	0.086 (0.065-0.107)	0.119
Sulfate	88 (83-151)	170 (153-172)	523 (498-530)	157 (127-186)	412
Strontium	0.37 (0.29-0.74)	0.58 (0.51-1.30)	1.25 (0.99-2.20)	0.5	1.8
TDS	793 (771-803)	1282 (797-1591)	2003 (1822-2066)	1226 (946-1506)	1968

3.4 UV Hydrogen Peroxide Advanced Oxidation Process

Although this process was not piloted, results from the pilot water sampling campaign and the source water quality sampling campaign (see Trussell Technologies, 2014d for detailed report on the source water quality) inform the UV/AOP design. Design considerations are discussed in this section, after a brief introduction to the UV/AOP process in the AWTF.

At the AWTF, the UV/AOP will provide a final polishing step for pathogen disinfection and an additional chemical destruction barrier for the RO permeate. Hydrogen peroxide will be added to a reactor, which houses arrays of ultraviolet lamps. Ultraviolet light from these lamps react with hydrogen peroxide to form hydroxyl radicals, which, along with the ultraviolet light, oxidizes, destroys, or inactivates chemicals of concern and pathogens. The system sizing will be driven by the requirement in DDW's Groundwater Replenishment Regulations criteria for advanced oxidation (*i.e.,* NDMA and 1,4-dioxane removal requirements).

Although the RO is capable of removing the majority of organic and inorganic compounds, some particularly recalcitrant, low molecular weight compounds (especially neutrally charged compounds) are found in RO permeate (*e.g.,* NDMA and 1,4-dioxane). AOP systems are designed in this context to achieve required levels of NDMA and 1,4-dioxane removal, as removal of these compounds is indicatives removal of a wide variety of CECs. NDMA removal requirements are designed to achieve an effluent concentration less than the NL of 10 ng/L. The 1,4-dioxane removal requirements are stipulated by DDW in the Groundwater Replenishment regulations (0.5-log removal).

Secondary effluent NDMA concentrations are typically below the NL; however, NDMA is formed through ozonation and chloramination processes (see Figure 3.26). The ozone oxidant is short-lived, and thus NDMA formation from ozone is rapid. Chloramines are persistent, and NDMA formation may continue with residual chloramine if NDMA precursors are present (thus the NDMA concentration increases through the MF process). The RO process achieves measurable NDMA removal, but this removal is not sufficient to reach the NL. Given that NDMA can increase through the application of oxidants, the concentration of NDMA precursors in the source water is important in evaluating the RO feed NDMA concentration. The concentration of NDMA precursors of the RTP effluent combined with the agricultural wash water was empirically tested during piloting, by measuring NDMA after applying sodium hypochlorite and ozone (see Figure 3.26 and Figure 3.27), where the impact of the agricultural wash water shunt on the RO permeate concentration appears to be minimal. NDMA formation in the Blanco Drain water was minimal during bench scale testing after the application of ozone (Trussell Technologies, 2014b). Given that NDMA formation from other source waters is expected to be minimal, the maximum NDMA concentration observed during piloting was used as the basis of UV/AOP design (32 ng/L). Based on this maximum measurement, the UV/AOP system will be designed to achieve a 1.5-log reduction in NDMA, which will produce an effluent concentration of 1 ng/L, an order of magnitude below the NL.

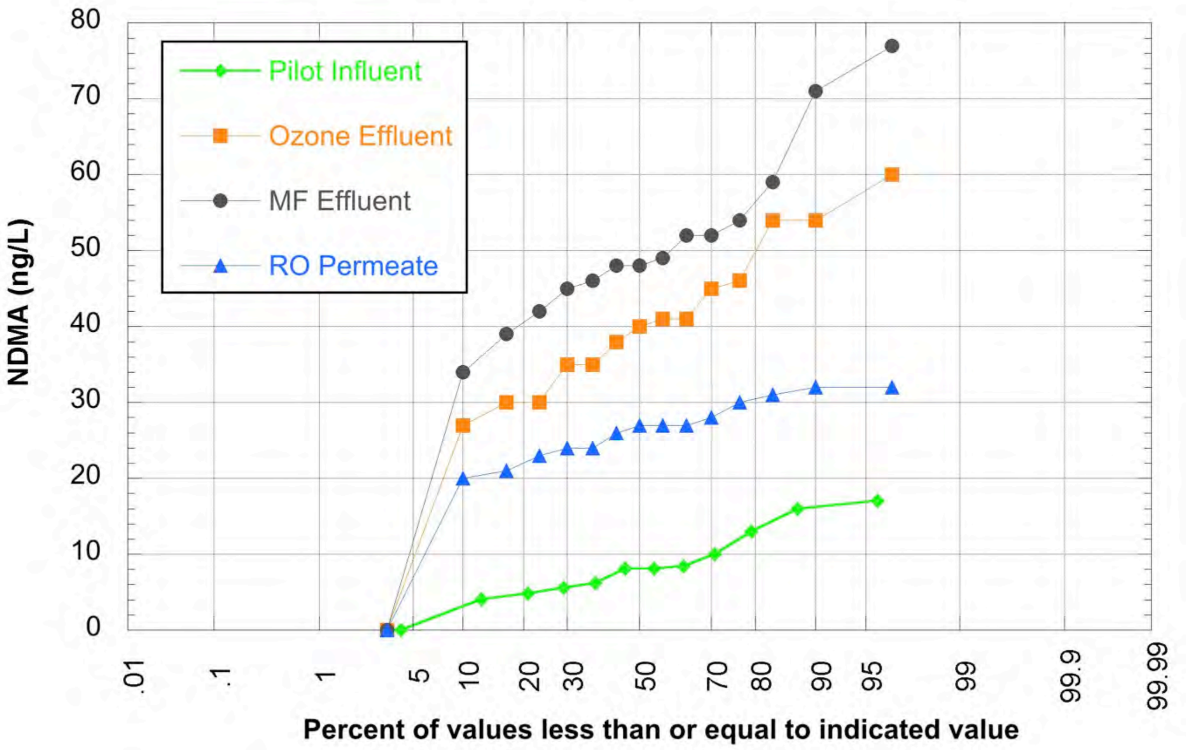

Figure 3.26 – Probability plot of NDMA concentrations through the pilot

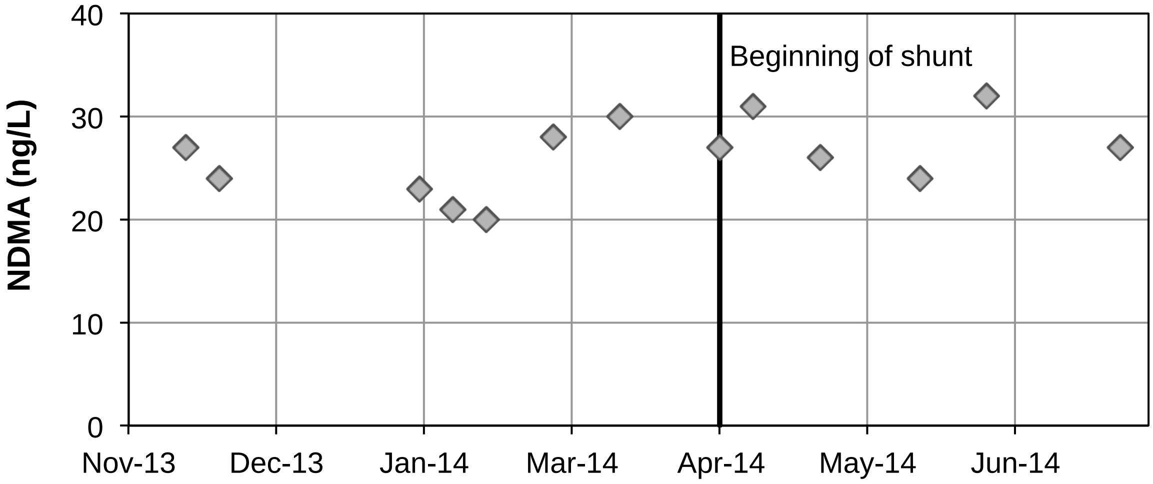

Figure 3.27 – NDMA concentrations in the pilot reverse osmosis permeate

1,4-dioxane has been detected in the RTP effluent at levels very close to the California NL of 0.001 mg/L, and it has not been detected in the other source waters (Table 3.12). As mentioned previously, the AOP will be designed to achieve 0.5-log removal of 1,4-dioxane, which will be demonstrated during start-up of the full-scale AWTF. This level of removal will bring the effluent concentration below the NL. Blending of the additional source waters is expected to reduce the UV/AOP 1,4-dioxane concentration even further, such that there is no measureable level in the UV/AOP feed.

Table 3.12 – 1,4-dioxane concentrations measured in potential source waters

	RTP Effluent	Ag Wash	Blanco Drain	El Estero	Tembladero Slough
1,4-dioxane (mg/L)	<0.001 (<0.001-0.0012)	<0.001	<0.001	<0.001	<0.001

UVT is another key parameter for the design of the AOP system. AOP systems rely on the formation of hydroxyl radicals, which are strong oxidants that react rapidly with organics. In a UV hydrogen peroxide AOP system, the formation of hydroxyl radicals is dependent on how much UV light reaches and reacts with the hydrogen peroxide. UVT is a measurement of how much UV light will be transmitted in a water matrix (*i.e.,* it is an indicator of how much UV light will reach hydrogen peroxide); thus UVT relates to hydroxyl radical production. A UVT of 95% or greater was initially specified for the AOP. UVT values greater than this design value were observed during the initial testing; however, the UVT dropped shortly after the start of the agricultural wash water shunt test at the start of April 2014 (Figure 3.28).

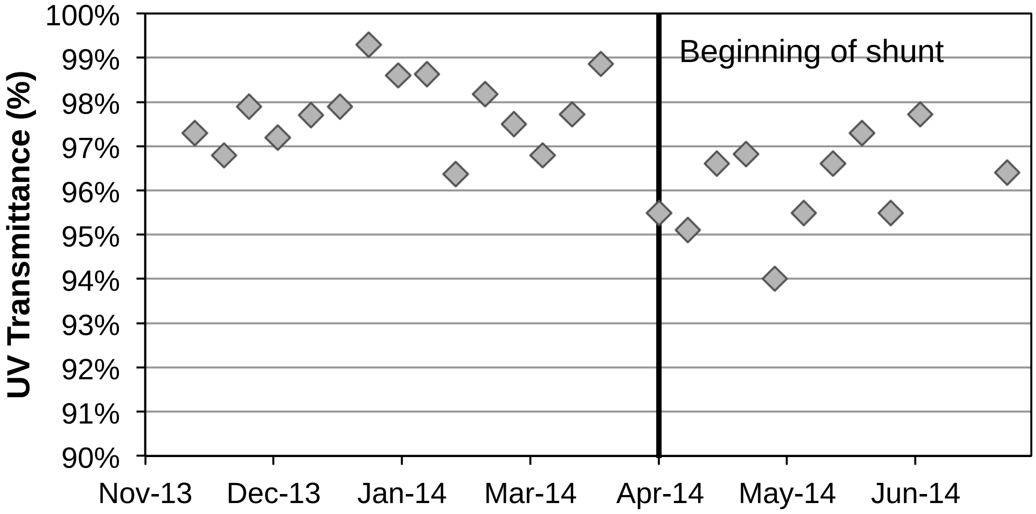

Figure 3.28 – UVT of the RO permeate over the duration of the pilot testing

Several process changes were occurring at the pilot facility from April through June 2014 (when the UVT dropped), including: the addition of ferric chloride as part of the CEPT, an increase in the chloramine residual used to prevent bio-fouling across the membrane processes, and an increase in the ozone dose associated with experimentation with higher MF flux rates. For the lowest UVT value observed in RO permeate (April 2014; 94%), the chloramine residual was approximately 7 mg/L, exceeding the target range of 2 to 5 mg/L. Chloramines reduce UVT (through the absorbance of UV light), and thus it is believed that this low UVT value is not realistic of future operating conditions (the AWTF will have better control over the chloramine residual, compared to the pilot facilities; see probability plot in Figure 3.29). Correspondingly, the UV/AOP system design was not based on a UVT of 94%; instead, the AOP process design UVT remains at 95%.

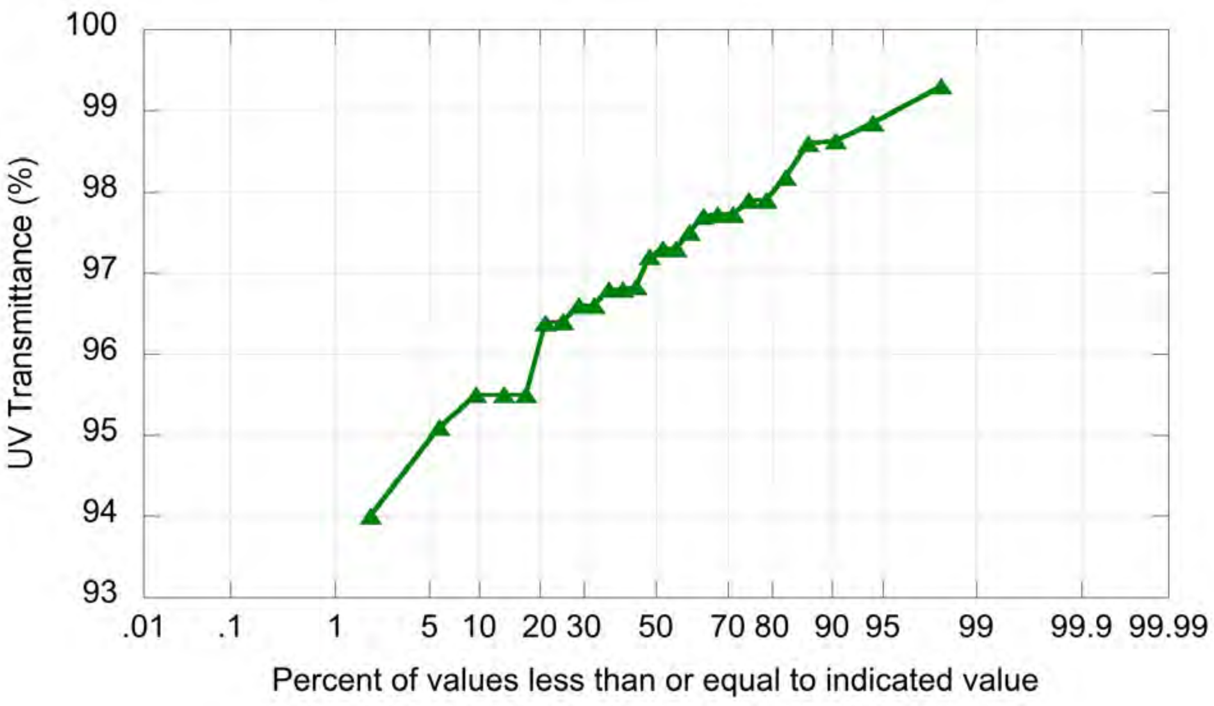

Figure 3.29 – Probability plot of UVT of the RO permeate

4 Product Water Quality

The results of the pilot testing, pilot water quality monitoring, and the source water monitoring (Trussell Technologies, 2014d) can be used to estimate the expected product water quality from the AWTF. The product water must be in compliance with all relevant regulations, and must also meet safe levels for other unregulated constituents such as pesticides and CECs. Where possible, worst-case product water qualities have been predicted based on piloting and source water monitoring; demonstrating that the AWTF can treat the worst-case water quality to levels below specified limits ensures consistent compliance and protection of public health.

4.1 Regulated Constituents

4.1.1 Total Nitrogen

The effluent limitation for total nitrogen is 10 mg N/L (DDW Groundwater Replenishment regulations), and the pilot plant consistently met this limit (Figure 4.1). After the addition of the agricultural wash water to the RTP in April 2014, the average pilot influent (RTP secondary effluent) total nitrogen decreased from 43.7 mg N/L to 34.8 mg N/L. This was expected because the wash water has a lower total nitrogen concentration compared to the RTP effluent.

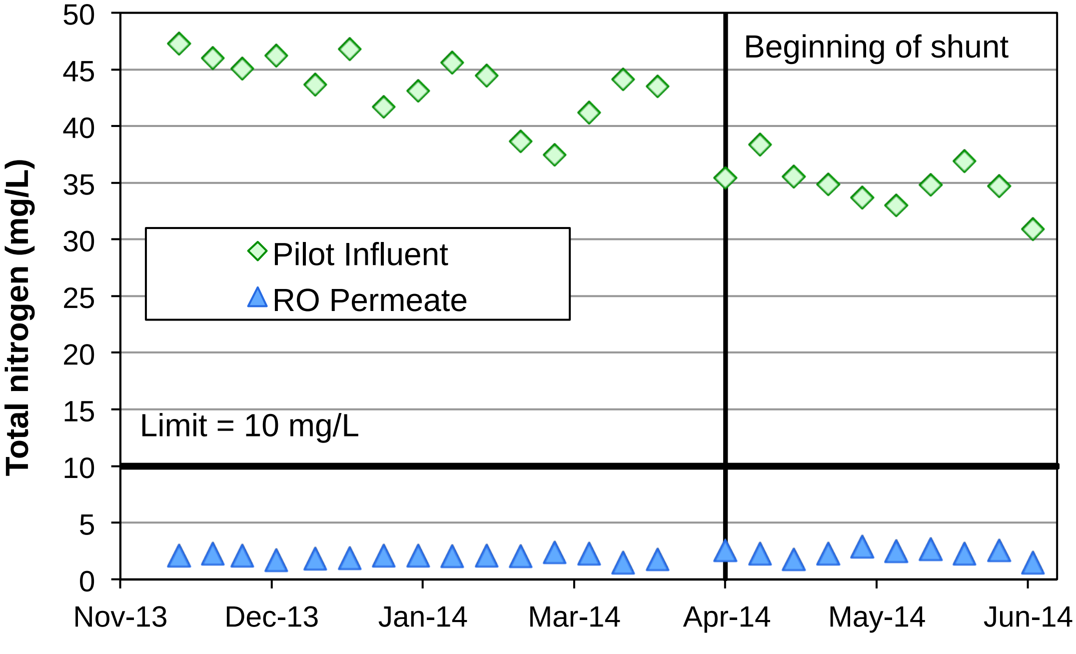

Figure 4.1 – Removal of total nitrogen through the pilot

The Blanco Drain has significantly elevated levels of nitrate – the median concentration observed during sampling was 68 mg/L as N, compared to the 5.4 mg/L as N seen in the RTP effluent during source water sampling. These high nitrate concentrations contribute to the high total nitrogen concentration observed in the Blanco Drain (70 mg/L as N), compared to the RTP effluent (44 mg/L as N, where the RTP effluent total nitrogen is mostly comprised of its high ammonia levels). The impact of the Blanco Drain on the RTP effluent total nitrogen concentration can be reasonably predicted because nitrogen removal is not expected in the RTP. Using the projected monthly flows, total nitrogen concentrations throughout the year were predicted. The results of the analysis are summarized in Table 4.1, including the highest monthly total nitrogen based on the median observed values and the maximum observed values. Despite the high nitrate levels in the Blanco Drain, the maximum predicted total nitrogen under median conditions is only about 5% higher than what has already been observed in the RTP effluent. The maximum predicted value, based on the maximum observed values, is only 8.5% higher than the observed maximum in the RTP effluent (without Blanco Drain blending).

Table 4.1 – Observed and predicted total nitrogen concentrations calculated using both median and maximum values. Observed concentrations are from RTP effluent; blended concentrations include RTP effluent, wash water, Blanco Drain, El Estero, and Tembladero Slough.

Parameter	**RTP Effluent (mg N/L)**	**Blended Source Waters (mg N/L)**
Median	44.4	46.5
Maximum	50.5	54.8

The average total nitrogen removal through the pilot was 94.3%. Assuming this removal, a blended source water total nitrogen concentration of 46.5 mg N/L would be reduced to 2.7 mg N/L and total nitrogen of 54.8 mg N/L would be reduced to 3.1 mg N/L. Both of these concentrations are still well below the limit of 10 mg N/L. Therefore, despite high nitrate levels (and corresponding high total nitrogen levels) in the Blanco Drain, the AWTF should have no problem meeting the 10 mg/L total nitrogen effluent limit.

4.1.2 Total Organic Carbon

TOC can be used as a surrogate for unregulated and unknown organic chemical contaminants. The project goal is to maintain RO permeate TOC concentrations below 0.5 mg/L (per the DDW Groundwater Replenishment regulations)[25]. Although the TOC in the wash water was measured at high concentrations compared the RTP effluent (Trussell Tech, 2014d), the wash water was measured prior to it receiving biological treatment. Primary and secondary treatment at the RTP is expected to significantly decrease the wash water TOC concentration. In fact, a significant decrease in the RTP effluent TOC was observed during the time period of the agricultural wash water shunt, compared with values observed before the shunt: 14.8 ± 0.7 mg/L and 13.0 ± 0.7 mg/L (mean ± 95% confidence interval), for before and after the shunt testing, respectively (see Figure 4.2). It is expected that the addition of low-TOC waters (*e.g.*, Blanco Drain, Tembladero Slough, Lake El Estero) would only further decrease the TOC.

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[25] For groundwater recharge by subsurface application, DDW requires that the applied recycled water TOC (24-hour composite sample, minimum once a week) not exceed 0.5 mg/L based on a 20-week running average of all TOC results and an average of the last four TOC results. Grab samples may be used in lieu of a 24-hour composite sample if it is demonstrated that a grab sample is representative of the water quality throughout a 24-hour period.

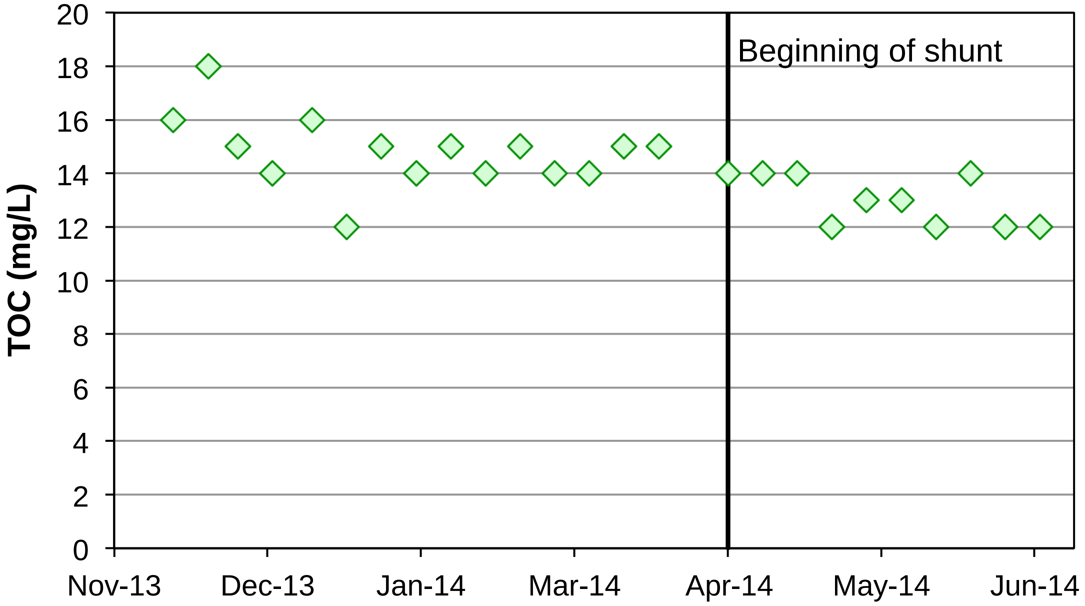

Figure 4.2 – TOC concentrations entering the pilot

The TOC concentrations in the RO permeate are impacted by the ozone dose. Sampling of the RO permeate at a time when ozone was not running indicates that ozone can significantly increase the TOC concentration in the RO permeate (RO permeate TOC concentrations of 0.39 mg/L and < 0.20 mg/L with and without ozone, respectively [ozone applied dose 21 mg/L]). In May 2014, the ozone dose in the pilot was increased to test the impact on the run-time of the MF unit; as illustrated in Figure 4.3, this increase caused the TOC in the RO permeate to increase, going above 0.5 mg/L three times. The design ozone dose chosen for the full-scale AWTF is the lower dose; this, coupled with the expected reduction in TOC from blending with other low-TOC source waters, indicates that an average RO permeate level of 0.5 mg/L TOC or less is consistently achievable.

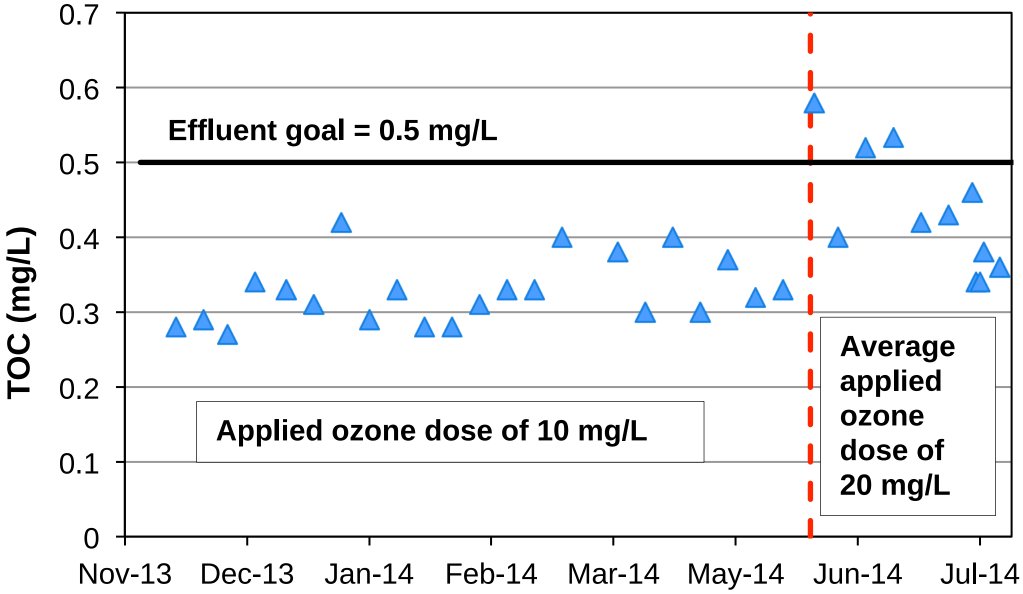

Figure 4.3 – TOC concentrations in the pilot RO permeate. Increase in ozone dose started on 5/20/14 and continued through the end of piloting

In addition to the ongoing product water TOC limit of 0.5 mg/L, DDW also maintains a stricter, temporary RO permeate TOC limit of 0.25 mg/L (95% of samples) for the first 20 weeks. While the ongoing limit is meant to continuously guarantee the quality of the product water, the temporary limit is one of two methods that DDW employs to ensure high quality RO membranes are procured for GWR projects (the other tool is sodium chloride rejection requirements). DDW has observed a relationship between the RO permeate TOC concentration during the first 20 weeks of RO operation and the quality of the RO membrane; however, this relationship was observed prior to the advent of preozonation. As discussed earlier, preozonation can increase the RO permeate TOC concentration from less than 0.25 mg/L (*e.g.,* 0.2 mg/L) to greater than 0.25 mg/L (*e.g.,* 0.4 mg/L), even in high quality RO membranes (*i.e.,* membranes that can meet the 0.25 mg/L TOC limit for 20 weeks without preozonation and that can meet the sodium chloride rejection requirements). Given this interference, RO membrane quality verification (the first 20 weeks of AWTF operation) will likely have to be conducted without preozonation. Alternatively, it may be possible to develop an alternative approach to RO membrane quality verification with DDW.

4.1.3 Pathogens

Pathogen removal to levels below detection (*i.e.,* below current detection limits) was observed through the pilot. The addition of other source waters is not expected to impact pathogen removal, since the other source waters have lower concentrations of pathogens, compared to the RTP. Additionally, the UV/AOP, which has not been piloted, will be designed for 6-logs of removal credit (*i.e.,* 99.9999% removal credit) for viruses, *Giardia* and *Cryptosporidium*. A summary of pathogen and pathogen indicator concentrations is shown in Table 4.2. A summary of expected log removal credits is shown in Table 4.3.

Measurement of *Giardia* and *Cryptosporidium* can present a particular challenge in the matrices samples at the RTP and the pilot plant. At this point in time, no standard method has been developed for the measurement of these species in wastewater and recycled water, which contain constituents that interfere with common methods of measurement. The best widely accepted method available at this time is EPA method 1623a, which was used for analysis of the treated wastewater. One of the separation steps in 1623a is a filtration step, and this step is infeasible for the high solids concentration of raw wastewaters (*e.g.,* RTP Influent). Draft EPA method 1693 omits this filtration step, and this method was employed for the raw wastewater samples. Despite these limitations, some general conclusions can be drawn from the data, such as those mentioned above.

Table 4.2 – Summary of pathogen removal observed through the pilot

Constituent/ sample location	**RTP Influent[d]**	**Pilot Influent (secondary effluent)**	**Ozone Effluent**	**MF Effluent**	**RO Permeate**
Cryptosporidium (oocysts/L) Recovery[c]	< 2 1 – 8 23%	< 0.35 (*<0.09*-0.9) 30%	*2.65*[a] *(0.3-23.3)* *92%*	*<0.09* *26%*	-- --
Giardia (cysts/L) Recovery[c]	8847 1634 – 13626 [e]	< 0.15 (*<0.09*-1.1) *<0.092%*	*<0.2*[a] *(<0.09-4.4)* *76%*	*<0.09* *50%*	-- --
Total coliform[b] (MPN/100 mL)	-- --	2.8x10^5 (2.4x10^3 – 1.6x10^6)	6.3x10^2 (5.5x10^1 – 3.1x10^3)	*<1*	*<1*
E. coli[b] (MPN/100 mL)	-- --	6.0x10^4 (4.9x10^2 – 3.3x10^5)	2.7x10^1 (*<1* – 5.5x10^2)	*<1*	*<1*

[a] There were consistently higher *Cryptosporidium* concentrations in the ozone effluent than the pilot influent (secondary effluent). This effect appears to be an artifact of the analysis; whereas the ozonation of the water likely increased the method recovery for *Cryptosporidium* and *Giardia*.

[b] Values are geometric means; MPN (most probable number)

[c] Recovery measured on one of the six samples

[d] Draft EPA method 1693, which omits the filtration step of EPA method 1623a (1623a used on other samples)

[e] ColorSeed not used, thus native *Giardia* interfered with matrix spike (recovery was 658%)

Table 4.3 – Anticipated pathogen log removal credit

Process	**Log reduction credits**		
	Enteric virus	***Giardia* cysts**	***Cryptosporidium* oocysts**
RTP (primary and secondary treatment)[a]	0	0	0
Ozone[a]	0	0	0
MF[b]	0	4	4
RO	1.5	1.5	1.5
AOP (UV/H_2O_2)	6	6	6
Final disinfection (free chlorine)[a]	0	0	0
Aquifer residence time[c]	5.4	0	0
Regulatory requirement	12	10	10
Total pathogen removal credit	12.9	11.5	11.5

[a] Not pursuing pathogen credit at this time
[b] Not pursuing virus removal credit at this time
[c] Based on modeling; actual residence time expected to exceed 6 months (actual residence time to be determined through tracer testing)

4.1.4 Maximum Contaminant Levels

One product water quality goal is to meet all of the DDW MCLs for drinking water. Results from the pilot testing indicate that the RO should produce a permeate that is in compliance with these MCLs; a summary of all compounds with an MCL that were detected at least once in the RO permeate is presented in Table 4.4. In this table sMCL and pMCL represent Secondary and Primary Maximum Contaminant Levels.

There are several constituents that have been measured above or close to their MCL in the source waters that were not included in the piloting testing for extended periods (*i.e.,* Blanco Drain, Lake El Estero, Tembladero Slough). However, because the best available treatment technologies are being used, and because high levels of removal in the pilot testing have been achieved, none of these constituents are expected to impact the ability of the AWTF to meet all MCLs.

Table 4.4 – Constituents with MCLs detected in RO permeate

Constituent	**Unit**	**MCL**	**Median (Range)**[a]
Consumer Acceptance[b]			
Chloride	mg/L	250 (sMCL)	3 (<1 - 6)
Conductivity	µS/cm	900 (sMCL)	38 (32 - 46)
Sulfate	mg/L	250 (sMCL)	<1 (<1 – 1)
TDS	mg/L	500 (sMCL)	<10 (<10 – 26)
Turbidity	NTU	5 (sMCL)	<0.05 (<0.05 – 0.1)
Inorganics			
Aluminum	mg/L	0.2 (pMCL)	<0.01 (<0.01 – 0.045)
Arsenic	mg/L	0.01 (pMCL)	<0.001 (<0.001 – 0.002)
Chromium	mg/L	0.05 (pMCL)	0.005
Cyanide	mg/L	0.15 (pMCL)	<0.005 (<0.005 – 0.007)
Fluoride	mg/L	2 (pMCL)	<0.1 (<0.1 – 0.2)
Nitrate	mg/L as N	10 (pMCL)	<0.2 (<0.2 – 0.7)
Nitrite	mg/L as N	1 (pMCL)	<0.1 (<0.1 – 0.4)
Nitrate + Nitrite	mg/L as N	10 (pMCL)	0.55 (0.1 - 1.6)
Selenium	mg/L	0.1 (pMCL)	<0.002 (<0.002 – 0.01)
Synthetic Organic Compounds			
Total trihalomethanes	µg/L	80 (pMCL)	1.85 (0.68 – 5)
Radionuclides			
Radium-226	pCi/L	5 (pMCL)	0.298 ± 0.327

[a] 13 samples analyzed except for chromium and radium-226 (1 sample), total trihalomethanes (12 samples), turbidity (25 samples), and nitrate and nitrite (26 samples).
[b] Odor threshold was measured at 5 units (above the sMCL of 3) on one sample without dechlorination. The high odor threshold is almost surely due to the residual chloramines, and not due to other odorous compounds present in the water.

Bromate is a regulated ozone DBP that was closely monitored during the pilot testing (MCL 10 µg/L). Bromate formation during ozonation is shown in Figure 4.4, where the highest concentration observed (9 µg/L) was still below the 10 µg/L MCL. RO is one of the best available technologies for bromate reduction, and for all samples collected during the piloting, the RO reduced the product water bromate concentration to below detection (*i.e.,* less than 1 µg/L).

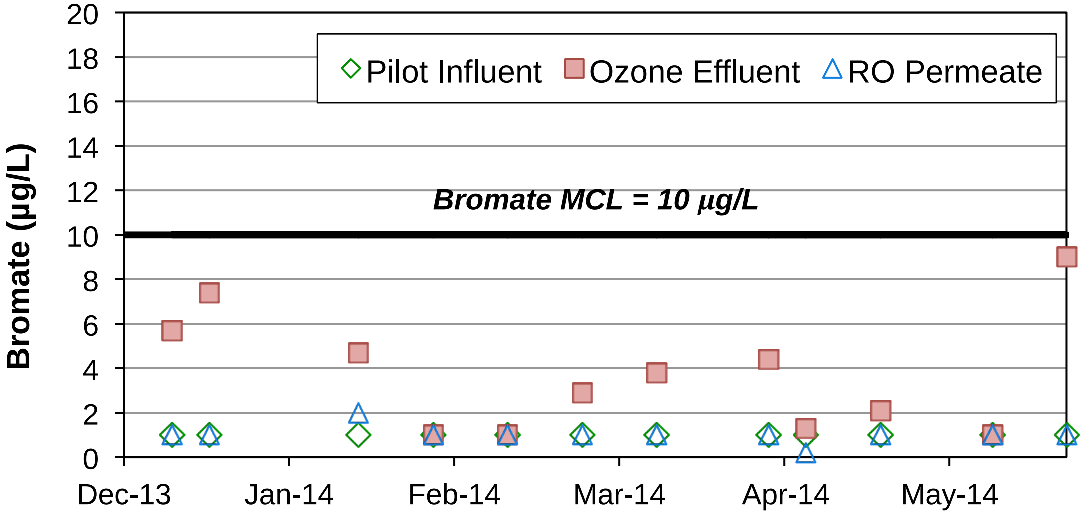

Figure 4.4 – Bromate formation through ozonation and removal through RO treatment

4.2 Unregulated Constituents

4.2.1 Notification Levels and Archived Notification Levels

The only constituent measured in the RO permeate above its DDW NL or DDW AAL was NDMA (see Table 4.5). However, the UV/AOP process is specifically design to achieve 1.5-log removal (*i.e.,* 96.8% removal) of NDMA. This level of removal will reduce the NDMA concentration to a range of approximately 0.63 to 1.0 ng/L (from the measured range of 20 to 32 ng/L present in the RO permeate), which is well below the NL. The detection limit for 1,4-dioxane makes it difficult to ascertain where the concentration in the RO permeate is in comparison to the NL (since the NL is equal to the detection limit). In addition to 1.5 log NDMA removal, the UV/AOP system will also be designed to achieve a minimum of 0.5 log removal of 1,4-dioxane to insure that the product water 1,4-dioxane concentration will be significantly below the NL (1,4-dioxane log removal will be demonstrated during start-up of the full-scale AWTF).

Table 4.5 – Constituents with NLs or AALs detected in RO permeate

Constituent	Unit	Limit	Median (Range)	Number of samples analyzed
Boron	mg/L	1 (NL)	0.18 (0.16 – 0.23)	13
Formaldehyde[a]	mg/L	0.1 (NL)	0.049 (0.026 – 0.071)	2
NDMA	ng/L	10 (NL)	27 (20 – 32)	14
N-Nitrosodi-n-Propylamine (NDPA)	ng/L	10 (NL)	<2 (<2 – 2.9)	14
Chloropicrin	µg/L	50 (AAL)	3.5	1
2,3,5,6-Tetrachloroterephthalate (DCPA)	mg/L	3.5 (AAL)	0.0001	1

[a] The high formaldehyde concentration was measured with a transferred ozone dose of approximately 18 mg/L, which is higher than the AWTF design transferred ozone dose

4.2.2 CEC Panel

The panel list of CECs measured by the Eurofins Eaton Analytical Liquid Chromatography Tandem Mass Spectrometry (LC-MS-MS) method (92 constituents) was measured monthly in the pilot influent, ozone effluent, and RO permeate. Ozonation consistently reduced the concentrations of many of the CECs to levels below detection (*e.g.*, bisphenol A (BPA) and several of the pharmaceuticals); on average, there were approximately 40 CECs detected in the pilot influent and 26 detected in the ozone effluent. With a few exceptions described below, the RO removed the remaining CECs to below detection. In addition, the AWTF will include UV/AOP, which would be used as an additional barrier to destroy chemicals and pathogens (UV/AOP was not piloted, and therefore no grab samples were collected on UV/AOP effluent). The CEC removals observed across the GWR pilot system are shown in Figure 4.5.

In three of the seven monthly sampling events, there were a few CECs detected in RO permeate (not including previously discussed NDMA). These compounds included erythromycin, caffeine, iohexal, albuterol, carbadox, fluoxetine, and quinolone. In all cases, these compounds were detected in only one sample, and it is likely that several of the detections were actually false positives due to contamination. Specifically, erythromycin and carbadox (both antibiotics) were not detected in either the pilot influent or the ozone effluent, and thus the RO permeate detection from these compounds was excluded from the analysis. For quinoline (a chemical found in cigarettes) and fluoxetine (an antidepressant), the RO permeate values exceeded the ozone effluent value, and it is strongly suspected that this is a false positive as well. The remaining compounds detected in the RO permeate, *i.e.,* caffeine (a simulant), iohexal (a contrast agent), and albuterol (an asthma medication), were detected at concentrations near the detection limit and it is unclear whether or not they are actual values. For all of these compounds, it is important to keep in mind that (1) the concentrations detected were many orders of magnitude below any demonstrated health related levels, and (2) these compounds have all been shown to be effectively removed by UV/AOP (*i.e.,* exceeding 90% for these compounds). In other words, it is expected that all of these compounds will be below current detection limits in the UV/AOP effluent.

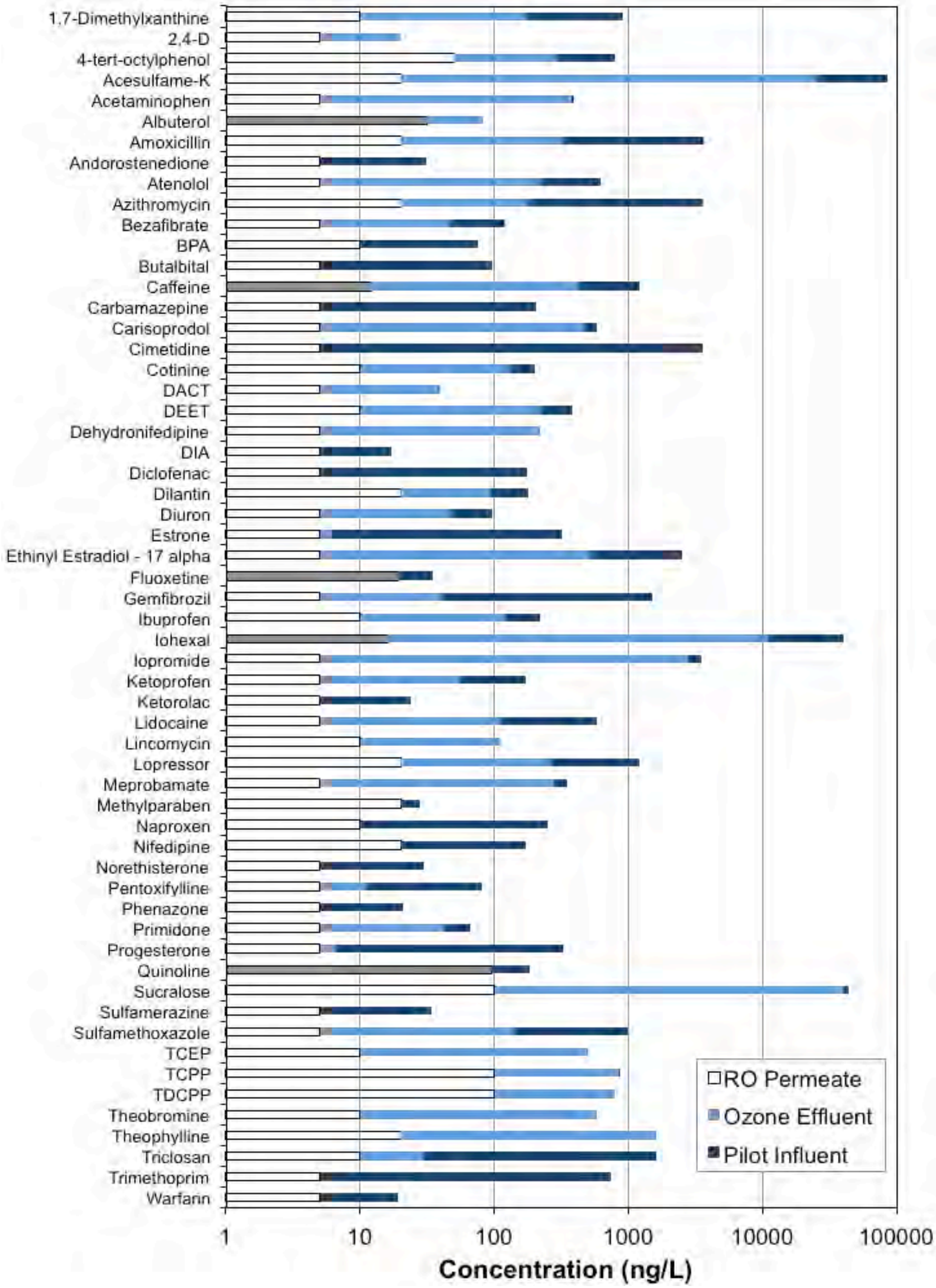

Figure 4.5 – CEC removal demonstrated during GWR pilot testing, through ozonation and reverse osmosis. Unfilled sections indicate results were below detection limit. All values shown are maximum detected values.

4.2.3 Dissolved solids

The concentration of dissolved solids on the feed and permeate side of the RO membrane were measured to determine their removal during the RO process. Select results from this effort are summarized in Table 4.6. The concentration of these dissolved solids in the RO permeate were typically below the detection limit, and thus the removal is often reported as greater than the indicated value. These data show robust removal of dissolved solids through the RO process, including a dramatic reduction in TDS.

Table 4.6 - Removal of select dissolved solids

Constituent	Average Removal[a]
TDS	>98.6%
Chloride	>98.8%
Sulfate[b]	>98.9%
Phosphate	>96.7%
Nitrate	>94.4%
Calcium	>99.1%
Magnesium	>97.8%
Sodium	97.2%
Potassium	>96.3%

[a] Removals calculated from 13 samples events with the exception of nitrate (12 sampling events)
b Sulfate was measured prior to sulfuric acid addition – removals including sulfate from sulfuric acid would be approximately >99.2 to >99.6%

4.2.4 Suspended solids

Aggregate solid parameters (*i.e.,* TSS and turbidity) and an organic parameter that includes solids bound organics (*i.e.,* TOC) were measured to determine removal through the MF system. Solids removal (*e.g.,* TSS and turbidity removal) in groundwater recharge projects is important for RO pretreatment and to avoid plugging of the aquifer. The median TSS and turbidity measured upstream and downstream of the MF system during piloting are shown in Figure 4.6. These data show that the MF system is a robust system for particle removal, and that it can provide an RO feed water low in turbidity. This solids removal correlated with a statistically significant reduction in the median TOC concentration across the MF process from 14 to 11 mg/L (95% confidence).

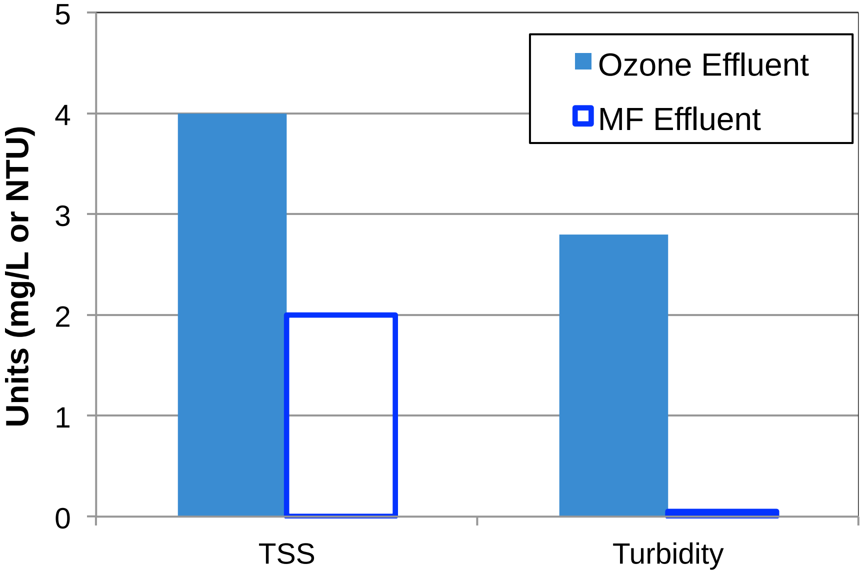

Figure 4.6 - Removal of solids through the MF process (median value shown; median MF effluent turbidity is less than the detection limit [0.05 NTU])

5 Conclusions and Recommendations

5.1 Design Conclusions

The following conclusions and recommendation are made based on the piloting results:

5.1.1 Preozonation conclusions and recommendations:

1. **Need for Preozonation:** Preozonation improved MF run times by a factor in the range of 4 to 8 by reducing membrane fouling. The reduction in fouling allows for a higher MF design flux, which would reduce the size and cost of the MF system. To realize these benefits, preozonation is recommended.
2. **Ozone Control:** Two ozone dose control methods were successfully demonstrated: (1) constant ozone dose with ORP control, and (2) ozone residual ozone dose control. A third control method, UVT control, may provide the best ozone dose control of the three methods; however, further testing would be required, as the UVT equipment tested during piloting fouled too rapidly for use in a control system. Further testing of the UVT control method is recommended at either the pilot-scale demonstration facility or the full-scale facility to determine the benefits of the UVT control method.
3. **Ozone Dose:** An average transferred ozone dose of 9.5 mg/L (10 mg/L applied ozone dose at a transfer efficiency of 95%) provided sufficient preozonation. To provide this level of preozonation, an AWTF average transferred design dose of 9.5 mg/L is recommended. The AWTF maximum and minimum design transferred dose should account for the maximum and minimum design water quality.
4. **Secondary Performance and Ozone:** High TOC and nitrite concentrations in the RTP effluent contributed to the preozonation dose. RTP trickling filter operational changes may be able to reduce the nitrite concentration in the secondary effluent, which could reduce operational costs. If the nitrite concentration were reduced, it may be possible to reduce the design ozone dose and/or operational ozone dose.
5. **Ozone Disinfection:** Preliminary testing showed that disinfection credit might be possible at transferred ozone doses in the range of 15 to 19 mg/L. These doses led to ozone CTs (residual concentration times contact time) in the range of 1 to 2 mg-min/L.
6. **NDMA Formation:** Both pre-chloramination and post-chloramination yielded similar levels of NDMA formation. NDMA formation was about an order of magnitude lower than at West Basin Municipal Water District's Edward C. Little Facility, and it is expected that the NDMA concentration in the final product will be well below the 10 ng/L Notification Level.
7. **Bromate Formation:** Acceptable levels of bromate formation were observed through the ozonation process (maximum 9 micrograms per liter [µg/L], compared to the Maximum Containment Level (MCL) of 10 µg/L). The bromate formed during ozonation was consistently removed by the downstream RO process to levels below the detection limit (*i.e.,* less than 1 µg/L for all samples).
8. **Biologically Active Filtration:** A biological process (*e.g.,* upflow BAF) downstream of preozonation would improve the product water quality, and possibly improve

AWTF operation by reducing the concentration of organics in ozone-BAF effluent, including TOC, NDMA, and contaminants of emerging concern (CECs, also known as chemical of emerging concern and constituents of emerging concern).

9. **High Ozone Doses:** High ozone doses (*e.g.,* an average of 20 mg/L, applied) increased the concentration of TOC and formaldehyde in the RO permeate for the waters tested. These high ozone doses are not recommended on a regular basis for the AWTF, unless a downstream biological process is included downstream of ozone.
10. **Impact on RO Validation Testing:** Preozonation interfered with measurements analogous to those required by the Division of Drinking Water (DDW) during RO membrane integrity testing in the first 20 weeks of operation. Due to this interference, the first 20 weeks of AWTF operation will likely have to be conducted without preozonation. Alternatively, it may be possible to develop an alterative RO membrane integrity test with DDW.

5.1.2 Membrane conclusions and recommendations (MF and RO):

1. **Technology Selection:** The outside-in MF technology dramatically outperformed the inside-out MF technology during piloting. An outside-in MF membrane technology is recommended for the AWTF.
2. **Chloramine Residual:** A chloramine residual (*e.g.,* 2 to 5 mg/L at the RO feed) was important for controlling organic fouling on the MF system. A chloramine residual of 2 to 5 mg/L at the RO feed is recommended at the AWTF.
3. **Design Flux:** The outside-in MF membrane filtered for more than 30 days at a flux of 30 GFD, with a constant applied ozone dose of 10 mg/L during the agricultural wash water shunt. An MF design flux of 30 GFD is recommended for the AWTF.
4. **MF Fouling and Secondary Performance:** The MF membranes experienced spikes in transmembrane pressure (TMP) associated with short-term episodes of degraded secondary effluent water quality (these spikes in TMP corresponded with higher coagulant needs at the Salinas Valley Reclamation Plant [SVRP]); however, they were able to recover without operational intervention.
5. **MF Filtrate Water Quality:** The MF provided suitable RO pretreatment, with 99.8% of the MF effluent turbidity measurements less than 0.05 Nephelometric Turbidity Units (NTU), and all silt density index (SDI) measurements less than 3.
6. **RO Membrane Fouling:** At a recovery of 81%, the RO membrane required only one cleaning over a test period of approximately seven months, including extended periods with elevated phosphate concentrations and a high RO feed pH setpoint (*e.g.,* 6.8). Based on this piloting work, a preliminary AWTF design RO recovery of 81% is recommended; however, further modeling is also recommended to ascertain the effect on the RO recovery of the source waters that were not tested during piloting (*e.g.,* the Blanco Drain).
7. **Need for Phosphate Control**: Elevated phosphate concentrations in the agricultural wash water may foul the RO membrane if the phosphate is not removed through the RTP, or if the formation of phosphate minerals is not controlled at the RO process (*e.g.,* through acid addition). Phosphate removal in the RTP can be enhanced via the addition of ferric chloride through the chemically

enhanced primary treatment (CEPT) facilities, although an application more specific to the AWTF feed water or the agricultural wash water is recommended for the AWTF if this method of phosphate control is pursued (*e.g.,* adding ferric directly to the agricultural wash water).

8. **pH Control:** RO specific flux dropped dramatically when pH adjustment was stopped, and adjustments to pH control affected the RO specific flux (likely due to the formation of calcium phosphate minerals). pH adjustment facilities will be necessary for the AWTF (*e.g.,* sulfuric acid).
9. **RO Cleaning:** An acid clean, without the use of detergents, was sufficient to restore RO permeability after scaling developed. Other cleans may be needed during full-scale operation if RO performance is reduced by foulants not observed during piloting (*e.g.,* biological, silica).
10. **Effect of Agricultural Wash Water:** The agricultural wash water shunt did not discernibly increase the fouling of the MF or RO membranes under the conditions tested.

5.1.3 UV/AOP conclusions and recommendations:

1. **Design UVT water quality:** During pilot testing, the RO permeate UVT was measured at 95% or greater for almost all samples (one sample was measured at 94%, but this is likely due to a high residual chloramine concentration in the RO permeate). Accordingly, a design RO permeate UVT of 95% was assumed for preliminary full-scale UV/AOP design.
3. **1,4-dioxane removal:** 1,4-dioxane concentrations were below the detection limit in all RO permeate samples, and it was only detected in 4 of 11 secondary effluent samples (maximum concentration of 1.2 μg/L in the secondary effluent, whereas the notification level [NL] and the detection limit are both 1 μg/L). The UV/AOP system will be designed to achieve at least 0.5-log removal of 1,4-dioxane (*i.e.,* 68.4% removal), and thus the concentration of 1,4-dixoxane in the product water is expected to be consistently below the NL. The full-scale AWTF UV/AOP system will be challenge tested (by spiking 1,4-dioxane) during start-up to demonstrate at least 0.5-log removal of 1,4-dioxane.

5.1.4 Water quality conclusions and recommendations:

1. **Product Water Quality:** Pilot water quality sampling results indicate that the AWTF product water is expected to meet all applicable regulations in the California Water Recycling Criteria, including the groundwater replenishment regulations for subsurface application, MCLs, NLs, and Archived Advisory Levels (AALs). The RO permeate met all requirements, except for NDMA; the UV/AOP system will be designed to meet the 1,4-dioxane removal criteria and to reduce NDMA by at least 90%, which is expected to reduce the NDMA to an acceptable concentration.
2. **CEC Reduction:** Ozone and RO removed all but a few CECs to levels below their detection limits. Of the CECs that were not removed to below their detection limits, all were measured at concentrations well below any limits linked to health concerns and most will be well removed through the UV/AOP system.

3. **DBP Formation:** DBPs (*e.g.,* NDMA and bromate) were formed through ozonation and chloramination, but at levels that would be adequately addressed by the combination of RO and AOP. DBPs are not expected to be an issue for the final product water.
4. **Additional RO Modeling:** RO modeling that takes into account (a) the blending of all source waters in the RTP collection system, (b) removal of select constituents through the RTP, and (c) removal of selected constituents through upstream AWTF processes is recommended to assess the fouling potential of the source waters.
5. **Need for Ozone:** Ozone provides benefits to the water quality, including providing a barrier to many synthetic organic compounds.
6. **Need for RO membrane:** RO treatment is needed for removal of several constituents, and is the backbone of the AWTF treatment train.
7. **Need for UV/AOP**: AOP is needed to address NDMA and provide an additional barrier against CECs (such as 1,4-dioxane) and pathogens.
8. **Source Water Variability:** Based on the source water monitoring program, it is expected that the proposed treatment train will be sufficient to meet all product water quality requirements for all of the proposed source waters.

5.1.5 Other design considerations:

7. **Biologically Active Filtration**: While BAF design criteria may be estimated, pilot testing is recommended prior to full-scale implementation to determine site-specific design criteria. Additionally, pilot testing would also be recommended to determine the effect of a BAF system on the performance of the downstream MF system, if the BAF were to be included in the AWTF.
8. **UV/AOP impact on organics:** Some UV/AOP systems downstream of RO in water reuse applications increase the concentration of specific organic constituents (*e.g.,* formaldehyde). UV/AOP pilot-scale testing should be considered to quantify the impact of UV/AOP on organics for this water.
9. **UV/AOP pathogen and chemical removal:** Chemical (*e.g.,* 1,4-dioxane, NDMA) and pathogen removal varies between water reuse projects. The full-scale AWTF design can account for this variation by selecting conservative design criteria. Alternatively, additional testing (*e.g.*, collimated bench-scale testing) offers a potential for a more aggressive full-scale design (*i.e.,* a less conservative design).
10. **Additional Source Waters in the RTP collection system:** The addition of new source waters to the RTP collection system may impact the RTP and the AWTF design in ways that were not discussed in the Source Water and Pilot Water Quality Report (*e.g.*, nitrite formation, RO recovery)(Trussell Technologies, 2014d). RTP and AWTF modeling and demonstration-scale testing is recommended to reduce uncertainty during AWTF design and start-up.
11. **Additional Source Waters directly to the AWTF**: If any of the new source waters were brought directly to the AWTF, then additional testing would be required to determine if there were additional pre-treatment needs.
12. **Long-term MF testing:** Several flux conditions were tested during the piloting; if additional piloting were conducted, it would be beneficial to conduct long-term

testing of the 30 GFD design flux to better characterize seasonal water quality impacts.

6 Reference

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7 Appendix

The following attachments are included in the appendix:

- June Pilot Water Quality Constituent sample frequency table
- Pilot Water Quality Sampling Campaign Summary sheets

Constituents analyzed during reduced sampling events (6/10 through 6/24): M is monthly and W is weekly

Parameter	RTP Raw	Pilot Inf	Ozone Eff.	MF Filtrate	RO Permeate	MF Backwash	RO Conc.
General Water Quality Parameters							
Alkalinity		M		M	M		
Conductivity		M		M	M		
Hardness - Total							
pH							
Temperature							
Total Dissolved Solids (TDS)				M	M		
Total Suspended Solids (TSS)							
Turbidity							
Dissolved Oxygen (DO)							
Oxidation/Reduction Potential (ORP)							
Biochemical Oxygen Demand (BOD)							
Chemical Oxygen Demand (COD)							
Biodegradable dissolved organic carbon (BDOC)							
Dissolved organic carbon (DOC)							
Total Organic Carbon (TOC)				W	W		
UV-254 Absorbance				W	W		
Inorganics							
Ammonia		W			W		
Nitrate		W			W		
Nitrite		W			W		
Total Kjeldahl Nitrogen (TKN)		W			W		
Aluminum				M	M		
Arsenic				M	M		
Barium				M	M		
Boron				M	M		
Bromide				M	M		
Calcium				M	M		
Chloride				M	M		
Cyanide				M	M		
Fluoride				M	M		
Iron				M	M		
Magnesium				M	M		
Manganese				M	M		
Mercury				M	M		
Molybdenum				M	M		
Nickel				M	M		
Phosphate (orthophosphate)				M	M		
Potassium				M	M		
Selenium				M	M		
Silica				M	M		
Sodium				M	M		
Strontium				M	M		
Sulfate				M	M		
Sulfide				M	M		
DBPs							
Total THMs and HAAs							
Bromate							
Nitrosamines		M	M	M	M		
Microbiological Parameters							
Total coliform and *E. Coli*					W		
Cryptosporidium and *Giardia*							
Synthetic Organic Contaminants		M	M		M		
CECs (See Table 8)							
1,4-Dioxane							
Select pesticides (EPA 505 and 525.2)							

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
General Water Quality Parameters														
Alkalinity	--	SM 2330B	mg/L as CaCO$_3$	--	306 (260-342)	13 / 13			298 (257-344)	13 / 13	10 (8-26)	13 / 13	875 (402-1289)	12 / 12
Ammonia	--	SM 4500NH3F,G	mg/L as N	--	32.1 (25.5-45.1)	26 / 26	29.9 (22.5-41.1)	12 / 12	29.5 (22.4-41.5)	12 / 12	1.4 (0.9-2.1)	26 / 26	125 (122-177)	6 / 6
Biochemical Oxygen Demand, 5-day @ 20ºC (BOD)	--	SM 5210B	mg/L	-	91 (52-119)	12 / 12	32 (7-116)	12 / 12	11 (<2-104)	11 / 12	<2 (<2-4)	3 / 12	22 (11-226)	7 / 7
Bromide	--	EPA 300.0	mg/L	--	0.2 (0.1-0.3)	12 / 12	0.2 (0.1-0.2)	12 / 12	0.2 (0.1-0.2)	13 / 13	<0.1	0 / 13	0.6 (0.5-1.2)	6 / 6
Calcium	--	EPA 200.7	mg/L	--	58 (51-65)	9 / 9			58 (56-71)	13 / 13	<0.5 (<0.5-1)	1 / 13	254 (234-291)	11 / 11
Chemical Oxygen Demand (COD)	--	EPA 410.4/Hach 8000	mg/L	--	95 (36-174)	12 / 12	79 (22-134)	12 / 12	73 (1-111)	12 / 12	3.5 (<2-6)	1 / 12	259 (<10-462)	11 / 12
Chloride	sMCL	EPA 300.0	mg/L	250	230 (203-266)	3 / 3			234 (134-266)	13 / 13	3 (<1-6)	12 / 13	1007 (962-1030)	6 / 6
Color	sMCL	SM 2120B	units	15							<3	0 / 1		
Conductivity (Specific Conductance)	sMCL	SM 2510B	µS/cm	900	1608 (1490-1717)	13 / 13			1630 (1543-1763)	13 / 13	38 (32-46)	13 / 13	6250 (5580-7200)	12 / 12
Copper	sMCL, EPA PP	EPA 200.8	mg/L	1.3/1.0							<0.004	0 / 1		
Dissolved organic carbon (DOC)	--	SM 5310C	mg/L	--	13 (11-14)	6 / 6	14 (13-16)	6 / 6					<3	0 / 1
Biodegradable Disssolved Organic Carbon	--	Allgeier, 1996	mg/L	--	<3	0 / 6	<6 (<6-6.4)	1 / 6			0.46 (<0.3-1)	5 / 6	<15	0 / 6
Dissolved oxygen (DO)	--	Field/SM4500-O	mg/L	--	4.89 (3.82-6.2)	20 / 20	>20 (15.7-38)	17 / 23						
Foaming Agents (MBAS)	sMCL	SM 5540C	mg/L	0.5							<0.05	0 / 1		
Iron	sMCL	EPA 200.7	mg/L	0.3	0.378 (0.157-0.931)	12 / 12			0.055 (0.042-0.082)	13 / 13	<0.01	0 / 13	0.25 (0.183-0.3)	6 / 6
Magnesium	--	EPA 200.7	mg/L	--	22 (10-26)	11 / 11			22 (20-28)	13 / 13	<0.5	0 / 13	100 (89-125)	11 / 11
Manganese	sMCL, NL	EPA 200.8	mg/L	0.5/0.5	0.052 (0.043-0.078)	12 / 12			0.04 (0.032-0.052)	13 / 13	<0.01 (<0.01-0.01)	1 / 13	0.163 (0.15-0.206)	6 / 6
Nitrate	pMCL	EPA 300.0	mg/L as NO$_3$	45	19.9 (<1-47.0)	25 / 26	25.9 (5.8-55)	12 / 12	26.7 (5.3-57.0)	12 / 12	<1 (<1-3.1)	17 / 26	118 (39-238)	6 / 6
Nitrite	pMCL	EPA 300.0	mg-N/L	1	1.3 (0.6-2.8)	26 / 26	<0.1 (<0.1-0.3)	9 / 25	<0.1 (<0.1-0.2)	3 / 12	<0.1 (<0.1-0.4)	20 / 26	<0.1	0 / 6
Nitrate+Nitrite	--	EPA 300.0	mg-N/L	--	5.6 (0.8-12.1)	26 / 26	7 (1.5-12.4)	11 / 11	7.4 (1.4-13.7)	12 / 12	0.6 (0.1-1.6)	23 / 23	46.5 (8.9-60.7)	5 / 5
Odor-Threshold	sMCL	SM 2150B	units	3							5	1 / 1		
Oxidation Reduction Potential (ORP)	--	Field	mV	--	270	1 / 1	343 (162-394)	13 / 13	321 (256-448)	13 / 13	586 (402-645)	12 / 12		
pH (field)		Field	pH		7.24 (7.16-7.38)	7 / 7	7	1 / 1	7.31 (7.28-7.43)	9 / 9	5.22 (5.04-6.05)	9 / 9	6.92 (6.6-7.58)	8 / 8
pH (laboratory)	--	SM 2330B/SM4500H+ B	pH	--	7.51 (7.42-7.8)	3 / 3	6.88	1 / 1	7.5 (6.9-7.7)	12 / 12	5.6 (5.3-6.87)	11 / 11	7.2 (6.8-7.6)	9 / 9
Phosphate	--	EPA 300.0	mg/L as P	--	3.05 (0.3-14.0)	12 / 12			3.1 (1.63-14.00)	13 / 13	<0.1 (<0.1-0.1)	1 / 13	13.2 (11.4-22.2)	6 / 6
Potassium	--	EPA 200.7	mg/L	--	20 (19-21)	3 / 3			22 (19-24)	13 / 13	0.6 (<0.5-3.2)	12 / 13	98 (82-112)	6 / 6
Silica	--	EPA 200.7	mg/L	--	39 (38-40)	3 / 3			41 (38-45)	13 / 13	<0.5 (<0.5-1)	4 / 13	175 (167-191)	6 / 6
Silver	sMCL, EPA PP	EPA 200.8	mg/L	0.1							<0.01	0 / 1		
Sodium	--	EPA 200.7	mg/L	--	152 (149-173)	3 / 3			178 (129-199)	13 / 13	5 (4-6)	13 / 13	744 (532-880)	6 / 6
Sulfate	sMCL	EPA 300.0	mg/L	250	90 (84-94)	3 / 3			92 (88-103)	13 / 13	<1 (<1-1)	1 / 13	918 (619-1098)	6 / 6

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
Sulfide	--	SM4500SD	mg/L	--					<0.05 (<0.05-0.063)	1 / 13	<0.05	0 / 13	<0.05	0 / 6
Temperature	--	Field/SM 2550B	°C	--	21.6 (9.9-23.5)	15 / 15	19.9 (18.6-21.4)	3 / 3	20.6 (19.4-22.5)	3 / 3	22.2 (19.9-24.2)	15 / 15	21.6 (20.6-22.5)	2 / 2
Total Dissolved Solids (TDS)	sMCL	EPA 160.1/SM 2540C	mg/L	500	808 (757-897)	12 / 12			828 (794-931)	13 / 13	<10 (<10-26)	4 / 13	3797 (3230-4766)	12 / 12
Total Hardness	--	SM 2340B	mg/L as CaCO$_3$	--	235 (169-269)	12 / 12			239 (232-293)	12 / 12	<10 (<10-2)	1 / 4	1070 (951-1241)	12 / 12
Total Kjeldahl Nitrogen (TKN)	--	EPA 351.2/SM 4500B,C	mg/L	--	33.4 (26.6-42.2)	26 / 26	32 (25.5-42.8)	12 / 12	30.9 (20.1-42.1)	12 / 12	1.7 (1.1-2.8)	26 / 26	133 (121-177)	6 / 6
Total Nitrogen	--	calculation	mg/L	--	40.9 (30.9-47.3)	26 / 26	40.8 (33.1-47.5)	11 / 11	37.9 (29.5-46.7)	12 / 12	2.1 (1.5-2.9)	25 / 25	171.7 (141-196.9)	6 / 6
Total Organic Carbon (TOC)	--	SM 5310C	mg/L	--	14 (12-18)	25 / 25	14 (12-16)	25 / 25	11 (10-13)	28 / 28	0.34 (0.27-0.58)	33 / 33	52 (46-55)	11 / 11
Total Phosphorus as P	--	SM 4500-PE/EPA 365.1	mg/L	--							<0.02	0 / 1		
Dissolved Phosphorus	--	SM 4500-PE/EPA 365.1	mg/L	--							<0.02	0 / 1		
Total Suspended Solids (TSS)	--	SM 2540D	mg/L	--	5.5 (<2-9)	11 / 12	4 (2-10)	12 / 12	<2	0 / 12	<2	0 / 1		
Turbidity	sMCL	EPA 180.1	NTU	5	2.9 (1.6-5.7)	25 / 25	2.8 (1.2-4.7)	25 / 25	<0.05 (<0.05-0.1)	20 / 25	<0.05 (<0.05-0.1)	2 / 25	0.2 (0.1-6.2)	25 / 25
UV-254 Absorbance	--	SM 5910	cm^{-1}	--	0.204 (0.172-0.226)	25 / 25	0.14 (0.11-0.196)	25 / 25	0.131 (0.105-0.177)	26 / 26	0.012 (0.003-0.027)	26 / 26	0.541 (0.232-0.715)	12 / 12
UV Transmittance	--	calculation	%	--	63% (59%-67%)	25 / 25	72% (64%-78%)	25 / 25	74% (67%-79%)	26 / 26	97% (94%-99%)	26 / 26	29% (19%-59%)	12 / 12
Zinc	sMCL, EPA PP	EPA 200.8	mg/L	5							<0.01	0 / 1		
Microbiological Quality														
Cryptosporidium	--	EPA 1623	oocysts/L	TT	0.35 (<0.09-0.9)	4 / 6	2.7 (0.3-23.3)	6 / 6	<0.09	0 / 6				
Giardia	--	EPA 1623	cysts/L	-	0.15 (<0.09-1.1)	3 / 6	0.2 (<0.09-4.4)	4 / 6	<0.09	0 / 6				
Total coliform[1]	pMCL	SM 9223B	MPN/100 mL	TT	2.8x10^{5} (2.4x10^{3}-1.6x10^{6})	21 / 22	6.3x10^{2} (5.5x10^{1}-3.1x10^{3})	22 / 25	<1	0 / 25	<1	0 / 26		
E. coli[1]	pMCL	SM 9223B	MPN/100 mL	TT	6.0x10^{4} (4.9x10^{2}-3.3x10^{5})	22 / 22	2.7x10^{1} (<1-5.5x10^{2})	20 / 25	<1	0 / 25	<1	0 / 26		
DDW Drinking Water Maximum Contaminant Levels (MCLs) - primary MCLs (pMCLs) and secondary MCLs (sMCLs)														
MCLs - Inorganics														
Aluminum	pMCL, sMCL, EPA CCL	EPA 200.8	mg/L	1/0.2	0.078 (0.021-0.75)	3 / 3			<0.01 (<0.01-0.105)	6 / 13	<0.01 (<0.01-0.045)	2 / 13	0.047 (0.011-0.556)	6 / 6
Antimony	pMCL, EPA PP	EPA 200.8	mg/L	0.006							<0.001	0 / 1		
Arsenic	pMCL, EPA PP	EPA 200.8	mg/L	0.01	0.003 (0.002-0.045)	12 / 12			0.003 (0.002-0.003)	13 / 13	<0.001 (<0.001-0.002)	7 / 13	0.009 (0.008-0.012)	6 / 6
Asbestos	pMCL, EPA PP	EPA 100.2	MFL	7							<0.2	0 / 1		
Barium	pMCL	EPA 200.8	mg/L	1	0.011 (0.003-0.029)	3 / 3			<0.01 (<0.01-0.04)	1 / 13	<0.01	0 / 13	0.033 (0.017-0.039)	6 / 6
Beryllium	pMCL, EPA PP	EPA 200.8	mg/L	0.004							<0.001	0 / 1		
Cadmium	pMCL, EPA PP	EPA 200.8	mg/L	0.005							<0.0005	0 / 1		
Chromium	pMCL, EPA PP, UCMR 3	EPA 200.8	mg/L	0.05							0.005	1 / 1		
Cyanide	pMCL, EPA PP	SM 4500CN-F	mg/L	0.15	0.022 (<0.005-0.054)	10 / 12			0.014 (<0.005-0.095)	11 / 13	<0.005 (<0.005-0.007)	2 / 13	0.056 (0.006-0.143)	6 / 6
Fluoride	pMCL	SM 4500F-C/EPA 300.0	mg/L	2	0.6 (0.5-0.8)	3 / 3			0.8 (0.6-1.1)	13 / 13	<0.1 (<0.1-0.2)	1 / 13	3.5 (3.1-3.8)	6 / 6
Mercury	pMCL, EPA PP	EPA 245.1	mg/L	0.002	<0.0002	0 / 1			<0.0002	0 / 13	<0.0002	0 / 13	0.00034 (<0.0002-0.00051)	5 / 6

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
Nickel	pMCL, EPA PP	EPA 200.8	mg/L	0.1	*<0.01*	**0 / 3**			*<0.01*	**0 / 13**	*<0.01*	**0 / 13**	**0.0205 (0.016-0.023)**	**6 / 6**
Perchlorate	pMCL, UCMR 1	EPA 314	mg/L	0.006							*<0.002*	**0 / 1**		
Selenium	pMCL, EPA PP	EPA 200.8	mg/L	0.1	**0.003 (0.002-0.003)**	**3 / 3**			**0.004 (0.003-0.006)**	**13 / 13**	*<0.002* (*<0.002*-**0.01**)	**7 / 13**	**0.013 (0.01-0.017)**	**6 / 6**
Thallium	pMCL, EPA PP	EPA 200.8	mg/L	0.002							*<0.001*	**0 / 1**		
MCLs - Volatile Organic Chemicals (VOCs)														
1,1-Dichloroethane	pMCL, EPA PP, UCMR 3	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
1,1-Dichloroethylene	pMCL, EPA PP	EPA 524.2	mg/L	0.006							*<0.0005*	**0 / 1**		
1,1,1-Trichloroethane	pMCL, EPA PP	EPA 524.2	mg/L	0.2							*<0.0005*	**0 / 1**		
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	pMCL	EPA 524.2	mg/L	1.2							*<0.0005*	**0 / 1**		
1,1,2-Trichloroethane	pMCL, EPA PP	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
1,1,2,2-Tetrachloroethane	pMCL, EPA PP	EPA 524.2	mg/L	0.001							*<0.0005*	**0 / 1**		
1,2-Dichlorobenzene	pMCL, EPA PP	EPA 524.2	mg/L	0.6							*<0.0005*	**0 / 1**		
1,2-Dichloroethane	pMCL, EPA PP	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
1,2-Dichloropropane	pMCL, EPA PP	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
1,2,4-Trichlorobenzene	pMCL, EPA PP	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
1,3-Dichloropropene	pMCL, PoLI, EPA PP	EPA 524.2	mg/L	0.0005							*<0.0005*	**0 / 1**		
1,4-Dichlorobenzene	pMCL, EPA PP	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
Benzene	pMCL, EPA PP	EPA 524.2	mg/L	0.001							*<0.0005*	**0 / 1**		
Carbon Tetrachloride	pMCL, EPA PP	EPA 524.2	mg/L	0.0005							*<0.0005*	**0 / 1**		
cis-1,2-Dichloroethylene	pMCL	EPA 524.2	mg/L	0.006							*<0.0005*	**0 / 1**		
Dichloromethane	pMCL, EPA PP	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
Ethylbenzene	pMCL, EPA PP	EPA 524.2	mg/L	0.3							*<0.0005*	**0 / 1**		
Methyl-tert-butyl ether (MTBE)	pMCL, sMCL, UCMR 1	EPA 524.2	mg/L	0.013/0.005							*<0.0005*	**0 / 1**		
Monochlorobenzene	pMCL	EPA 524.2	mg/L	0.07							*<0.0005*	**0 / 1**		
Styrene	pMCL	EPA 524.2	mg/L	0.1							*<0.0005*	**0 / 1**		
Tetrachloroethylene	pMCL, EPA PP	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
Toluene	pMCL, EPA PP	EPA 524.2	mg/L	0.15							*<0.0005*	**0 / 1**		
trans-1,2-Dichloroethylene	pMCL	EPA 524.2	mg/L	0.01							*<0.0005*	**0 / 1**		
Trichloroethylene	pMCL, EPA PP	EPA 524.2	mg/L	0.005							*<0.0005*	**0 / 1**		
Trichlorofluoromethane	pMCL	EPA 524.2	mg/L	0.15							*<0.0005*	**0 / 1**		
Vinyl Chloride	pMCL, EPA PP	EPA 524.2	mg/L	0.0005							*<0.0003*	**0 / 1**		
Xylenes	pMCL	EPA 524.2	mg/L	1.75							*<0.0005*	**0 / 1**		
MCLs - Non-Volatile Synthetic Organic Chemicals (SOCs)														
2,4-D	pMCL	EPA 515.4	mg/L	0.07							*<0.0001*	**0 / 1**		
Alachlor	pMCL, UCMR 2	EPA 505	mg/L	0.002	*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**
Atrazine	pMCL	EPA 525.2	mg/L	0.001	*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**			*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**
Bentazon	pMCL	EPA 515.4	mg/L	0.018							*<0.0005*	**0 / 1**		
Benzo(a)pyrene	pMCL, EPA PP	EPA 525.2	mg/L	0.0002	*<0.005*	**0 / 6**	*<0.00002*	**0 / 6**			*<0.00002*	**0 / 6**	*<0.00002*	**0 / 6**
Carbofuran	pMCL	EPA 531.2	mg/L	0.018							*<0.0005*	**0 / 1**		
Chlordane	pMCL, EPA PP	EPA 505	mg/L	0.0001	*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**
Dalapon	pMCL	EPA 515.4	mg/L	0.2							*<0.001*	**0 / 1**		
Di(2-ethylhexyl)adipate	pMCL	EPA 525.2	mg/L	0.4	*<0.0006*	**0 / 6**	*<0.0006*	**0 / 6**			*<0.0006*	**0 / 6**	*<0.0006*	**0 / 6**
Di(2-ethylhexyl)phthalate	pMCL, EPA PP	EPA 525.2	mg/L	0.004	**0.0012** (*<0.0006*-**0.078**)	**5 / 6**	**0.00082** (*<0.0006*-**0.0014**)	**5 / 6**			*<0.0006*	**0 / 6**	*<0.0006*	**0 / 6**
Di(2-ethylhexyl)phthalate	pMCL, EPA PP	EPA 8720C	mg/L	0.004							*<0.004*	**0 / 1**		

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
Dibromochloropropane	pMCL	EPA 551.1	mg/L	0.0002							*<0.00001*	**0 / 1**		
Dinoseb	pMCL	EPA 515.4	mg/L	0.007							*<0.0002*	**0 / 1**		
Diquat	pMCL, PoLI	EPA 549.2	mg/L	0.02							*<0.0004*	**0 / 1**		
Endothall	pMCL	EPA 548.1	mg/L	0.1							*<0.005*	**0 / 1**		
Endrin	pMCL	EPA 505	mg/L	0.002	*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**			*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**
Ethylene Dibromide	pMCL	EPA 551.1	mg/L	0.00005							*<0.00001*	**0 / 1**		
Glyphosate	pMCL, PoLI	EPA 547	mg/L	0.7							*<0.006*	**0 / 1**		
Heptachlor	pMCL, EPA PP	EPA 505	mg/L	0.00001	*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**			*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**
Heptachlor Epoxide	pMCL, EPA PP	EPA 505	mg/L	0.00001	*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**			*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**
Hexachlorobenzene	pMCL	EPA 525.2	mg/L	0.001	*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**			*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**
Hexachlorocyclopentadiene	pMCL	EPA 525.2	mg/L	0.05	*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**			*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**
Lindane	pMCL, PoLI	EPA 505	mg/L	0.0002	*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**			*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**
Methoxychlor	pMCL	EPA 505	mg/L	0.03	*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**			*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**
Molinate	pMCL, UCMR 1	EPA 525.2	mg/L	0.02	*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**
Oxamyl	pMCL, PoLI	EPA 531.2	mg/L	0.05							*<0.001*	**0 / 1**		
Pentachlorophenol	pMCL, EPA PP	EPA 525.2	mg/L	0.001	*<0.00004*	**0 / 6**	*<0.001*	**0 / 6**			*<0.001*	**0 / 6**	*<0.001*	**0 / 6**
Picloram	pMCL	EPA 515.4	mg/L	0.001							*< 0.0001*	**0 / 1**		
Polychlorinated Biphenyls	pMCL	EPA 505	mg/L	0.0005	*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**
Simazine	pMCL, PoLI	EPA 525.2	mg/L	0.004	*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**			*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**
Thiobencarb	pMCL, sMCL, PoLI	EPA 525.2	mg/L	0.07/0.001	*<0.0002*	**0 / 6**	*<0.0002*	**0 / 6**			*<0.0002*	**0 / 6**	*<0.0002*	**0 / 6**
Toxaphene	pMCL, EPA PP	EPA 505	mg/L	0.003	*<0.0005*	**0 / 6**	*<0.0005*	**0 / 6**			*<0.0005*	**0 / 6**	*<0.0005*	**0 / 6**
2,3,7,8-TCDD (Dioxin)	pMCL, EPA PP	EPA 1613	mg/L	3.00E-08							*<1.96E-9*	**0 / 1**		
2,4,5-TP (Silvex)	pMCL	EPA 515.4	mg/L	0.05							*<0.0002*	**0 / 1**		
MCLs - Radionuclides														
Gross Alpha Particle (excluding radon and uranium)	pMCL	EPA 900.0	pCi/L	15							**3**	**1 / 1**		
Beta/photon emitters (K40 adjusted)	pMCL	EPA 900.0	pCi/L	50							< 2.51	**0 / 1**		
Radium-226	pMCL	EPA 903.1	pCi/L	5 (Combined)							**0.298±0.327**	**1 / 1**		
Radium-228	pMCL	EPA 904.0	pCi/L								*<0.78±0.395*	**0 / 1**		
Strontium-90	pMCL	EPA 905.0	pCi/L	8							*<0.589±0.268*	**0 / 1**		
Tritium	pMCL	EPA 906.0	pCi/L	20,000							*<216±125*	**0 / 1**		
MCLs - Disinfection By-Products (DPBs)														
Total trihalomethanes (TTHM)	pMCL	EPA 551.1	mg/L	0.08	**0.00053** **(***<0.0005***-0.002)**	**7 / 12**					**0.0019** **(0.00068-0.005)**	**12 / 12**	**0.012** **(0.0037-0.039)**	**6 / 6**
Total Haloacetic acids (HAAs)	pMCL	SM6251B	mg/L	0.06	**0.0042** **(***<0.002***-0.0089)**	**10 / 12**					*<0.002*	**0 / 12**	**0.094** **(0.063-0.11)**	**6 / 6**
Trichloroacetic acid	-	SM6251B	mg/L	--	**0.0037** **(0.0013-0.0069)**	**12 / 12**					*<0.001*	**0 / 12**	**0.025** **(0.012-0.036)**	**6 / 6**
Dichloroacetic acid	-	SM6251B	mg/L	--	*<0.001* *(<0.001-***0.002***)*	**3 / 12**					*<0.001*	**0 / 12**	**0.044** **(0.026-0.058)**	**6 / 6**
Bromate	pMCL	EPA 317	mg/L	0.01	*<0.001*	**0 / 12**	**0.0034** **(***<0.001***-0.009)**	**9 / 12**			*<0.001*	**0 / 12**	**0.0053** **(***<0.001***-0.011)**	**4 / 6**
Chlorite	pMCL	EPA 300.1	mg/L	1							*<0.01*	**0 / 1**		
DDW Drinking Water Notification Levels (NLs)														
Boron	NL	EPA 200.7	mg/L	1	**0.29** **(0.29-0.3)**	**3 / 3**			**0.29** **(0.27-0.38)**	**13 / 13**	**0.18** **(0.16-0.23)**	**13 / 13**	**0.63** **(0.58-0.87)**	**6 / 6**
n-Butylbenzene	NL	EPA 524.2	mg/L	0.26							*<0.0005*	**0 / 1**		
sec-Butylbenzene	NL, EPA CCL	EPA 524.2	mg/L	0.26							*<0.0005*	**0 / 1**		
tert-Butylbenzene	NL	EPA 524.2	mg/L	0.26							*<0.0005*	**0 / 1**		

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
Carbon disulfide	NL	EPA 524.2	mg/L	0.16							*<0.0005*	**0 / 1**		
2-Chlorotoluene	NL	EPA 524.2	mg/L	0.14							*<0.0005*	**0 / 1**		
4-Chlorotoluene	NL	EPA 524.2	mg/L	0.14							*<0.0005*	**0 / 1**		
Diazinon	NL, UCMR 1, PoLI	EPA 525.2	mg/L	0.0012	*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**
Dichlorodifluoromethane (Freon 12)	NL	EPA 524.2	mg/L	1	*<0.0005*	**0 / 1**								
1,4-Dioxane	NL, UCMR 3	EPA 522	mg/L	0.001	*<0.001*	**0 / 1**	*<0.001*	**0 / 6**			*<0.001*	**0 / 6**	**0.0032** **(0.0029-0.0042)**	**6 / 6**
Ethylene glycol	NL	EPA 8270C	mg/L	14							*<0.04*	**0 / 1**		
Formaldehyde	NL, EPA CCL	EPA 556	mg/L	0.1							**0.026**	**1 / 1**		
HMX (or Octogen)	NL	LC-MS-MS	mg/L	0.35							*<0.0001*	**0 / 1**		
Isopropylbenzene	NL	EPA 524.2	mg/L	0.77							*<0.0005*	**0 / 1**		
Methyl isobutyl ketone (MIBK)	NL	EPA 524.2	mg/L	0.12							*<0.005*	**0 / 1**		
Naphthalene	NL	EPA 524.2	mg/L	0.017							*<0.0005*	**0 / 1**		
N-Nitrosodiethyamine (NDEA)	NL, UCMR 2	EPA 521	ng/L	10	**2.3** **(***<2***-4.4)**	**8 / 10**	*<2* (*<2*-**2.7**)	**4 / 14**	*<2* (*<2*-**3**)	**5 / 14**	*<2*	**0 / 14**	**5.4** **(***<2***-7.1)**	**4 / 6**
N-Nitrosodimethylamine (NDMA)	NL, EPA PP, UCMR 2	EPA 521	ng/L	10	**8.1** **(4.1-17)**	**11 / 11**	**41** **(27-60)**	**14 / 14**	**49** **(34-77)**	**14 / 14**	**27** **(20-32)**	**14 / 14**	**120** **(84-150)**	**6 / 6**
N-Nitrosodi-n-propylamine (NDPA)	NL, EPA PP, UCMR 2	EPA 521	ng/L	10	*<2* (*<2*-**76**)	**3 / 10**	*<2* (*<2*-**66**)	**4 / 14**	*<2* (*<2*-**78**)	**6 / 14**	*<2* (*<2*-**2.9**)	**1 / 14**	*<2* (*<2*-**19**)	**2 / 6**
Propachlor	NL	EPA 525.2	mg/L	0.09	*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**			*<0.00005*	**0 / 6**	*<0.00005*	**0 / 6**
n-Propylbenzene	NL	EPA 524.2	mg/L	0.26							*<0.0005*	**0 / 1**		
RDX (Hexahydro-1,3,5-trinitro-1,3,5-tr	NL, UCMR 1&2	LC-MS-MS	mg/L	0.0003							*<0.0001*	**0 / 1**		
Tertiary butyl alcohol (TBA)	NL	EPA 524.2m	mg/L	0.012							*<0.002*	**0 / 1**		
1,2,3-Trichloropropane (1,2,3-TCP)	NL	EPA 524.2m	mg/L	5.00E-06							*<0.0005*	**0 / 1**		
1,2,4-Trimethylbenzene	NL, EPA PP	EPA 524.2	mg/L	0.33							*<0.0005*	**0 / 1**		
1,3,5-Trimethylbenzene	NL	EPA 524.2	mg/L	0.33							*<0.0005*	**0 / 1**		
2,4,6-Trinitrotoluene (TNT)	NL, UCMR 2	LC-MS-MS	mg/L	0.001							*<0.0001*	**0 / 1**		
DDW Drinking Water Archived Advisory Levels (aNLs)														
Aldicarb	aNL	EPA 531.2	mg/L	0.007							*<0.0005*	**0 / 1**		
Aldrin	aNL	EPA 505	mg/L	0.000002	*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**			*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**
Baygon	aNL	EPA 531.2	mg/L	0.03							*<0.0005*	**0 / 1**		
alpha-BHC	aNL	EPA 8081A	mg/L	0.01*/ 0.000015							*<0.00005*	**0 / 1**		
beta-BHC	aNL	EPA 8081A	mg/L	0.05*/ 0.000025							*<0.00005*	**0 / 1**		
Captan	NL, EPA CCL, Pol	EPA 8081/8082	mg/L	0.015							*<0.00005*	**0 / 1**		
Carbaryl	aNL, PoLI	EPA 531.2	mg/L	0.7							*<0.0005*	**0 / 1**		
Chloropicrin	aNL, PoLI	EPA 551.1	mg/L	0.05							**0.0035**	**1 / 1**		
Chloropropham (CIPC)	aNL	EPA 8321	mg/L	1.2							*<0.002*	**0 / 1**		
1,3-Dichlorobenzene	aNL	EPA 8270C	mg/L	0.6							*<0.005*	**0 / 1**		
Dieldrin	aNL, EPA PP	EPA 525.2	mg/L	0.000002	*<0.0002*	**0 / 6**	*<0.00001*	**0 / 6**			*<0.0002*	**0 / 6**	*<0.0002*	**0 / 6**
Dieldrin	EPA PP, aNL	EPA 505	mg/L	0.000002	*<0.00001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.00001*	**0 / 6**	*<0.00001*	**0 / 6**
Dimethoate	aNL, UCMR 2, PoLI	EPA 525.2	mg/L	0.001	*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**
2,4-Dimethylphenol	aNL, EPA PP	EPA 8270C	mg/L	0.1							*<0.005*	**0 / 1**		
Diphenamide	aNL	EPA 8141	mg/L	0.2							*<0.0001*	**0 / 1**		
Ethion	aNL	EPA 8141	mg/L	0.004							*<0.0001*	**0 / 1**		
Malathion	aNL, PoLI	EPA 525.2	mg/L	0.16	*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**
Methylisothiocyanate	aNL	EPA 131	mg/L	0.19							*<0.001*	**0 / 1**		
Methyl parathion	aNL	EPA 8141	mg/L	0.002							*<0.0001*	**0 / 1**		

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
Parathion	aNL	EPA 525.2	mg/L	0.04	*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**			*<0.0001*	**0 / 6**	*<0.0001*	**0 / 6**
Pentachloronitrobenzene	aNL	EPA 8270C	mg/L	0.02							*<0.01*	**0 / 1**		
Phenol	aNL, EPA PP	EPA 8270C	mg/L	4.2							*<0.005*	**0 / 1**		
2,3,5,6-Tetrachloroterephthalate (DCF	aNL	EPA 515.4	mg/L	3.5							**0.0001**	**1 / 1**		
Trithion	aNL	EPA 8081/8082	mg/L	0.007							*< 0.00005*	**0 / 1**		
EPA Unregulated Contaminant Monitoring Rule (UCMR) Lists 1 through 3														
Acetochlor	UCMR 1&2	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
EPTC	UCMR 1, PoLI	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Metolachlor	UCMR 2	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Molybdenum	UCMR 3	EPA 200.8	µg/L	--	**58** **(5-110)**	**2 / 2**			**6** **(4-13)**	**13 / 13**	*<1*	**0 / 13**	**23** **(20-59)**	**6 / 6**
N-nitroso-di-n-butylamine (NDBA)	UCMR 2	EPA 521	ng/L	--	**2.7** (*<2*-**6.7**)	**5 / 10**	*<4* (*<4*-**9.4**)	**4 / 14**	*<4* (*<4*-**4.2**)	**4 / 14**	*<4* (*<4*-**3.1**)	**1 / 14**	*<4* (*<4*-**4.7**)	**2 / 6**
N-nitroso-methylethylamine (NMEA)	UCMR 2	EPA 521	ng/L	--	*<2*	**0 / 10**	*<2*	**0 / 14**	*<2*	**0 / 14**	*<2*	**0 / 14**	*<2* (*<2*-**3**)	**1 / 6**
N-Nitrosopyrrolidine (NPYR)	UCMR 2	EPA 521	ng/L	--	*<2* (*<2*-**2.7**)	**4 / 10**	*<2* (*<2*-**3.3**)	**7 / 14**	**2.4** (*<2*-**3.6**)	**10 / 14**	*<2*	**0 / 14**	**2.7** (*<2*-**6.3**)	**4 / 6**
Strontium	UCMR 3	EPA 200.8	µg/L	--	**378** **(360-396)**	**2 / 2**			**356** **(318-426)**	**13 / 13**	*<5* (*<5*-**3**)	**4 / 13**	**1557** **(1452-1710)**	**6 / 6**
Terbacil	UCMR 1	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
EPA Clean Water Act Priority Pollutants (PPs)														
2,4-dinitrotoluene	EPA PP, UCMR 1	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
2,6-dinitrotoluene	EPA PP, UCMR 1	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
4,4-DDD	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
4,4-DDE	EPA PP, UCMR 1	EPA 525.2	µg/L	--	*<0.1* (*<0.1*-**0.021**)	**1 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
4,4-DDT	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Acenaphthene	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Acenaphthylene	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Aldrin	EPA PP	EPA 525.2	µg/L	--	*<0.01*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Alpha-BHC	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Alpha-endosulfan	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Anthracene	EPA PP	EPA 525.2	µg/L	--	*<0.02*	**0 / 6**	*<0.02*	**0 / 6**			*<0.02*	**0 / 6**	*<0.02*	**0 / 6**
benzo(a) anthracene	EPA PP	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Benzo(b) fluoranthene	EPA PP	EPA 525.2	µg/L	--	*<0.02*	**0 / 6**	*<0.02*	**0 / 6**			*<0.02*	**0 / 6**	*<0.02*	**0 / 6**
Benzo(ghi) perylene	EPA PP	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Benzo(k) fluoranthene	EPA PP	EPA 525.2	µg/L	--	*<0.02*	**0 / 6**	*<0.02*	**0 / 6**			*<0.02*	**0 / 6**	*<0.02*	**0 / 6**
Beta-BHC	EPA PP	EPA 525.2	µg/L	--	*<0.1* (*<0.1*-**0.15**)	**1 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Beta-endosulfan	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Bromoform	EPA PP	EPA 551.1	µg/L	--	*<0.5*	**0 / 12**					*<0.5*	**0 / 11**	*<0.5*	**0 / 6**
Butyl benzyl phthalate	EPA PP	EPA 525.2	µg/L	--	*<0.5*	**0 / 6**	*<0.5*	**0 / 6**			*<0.5*	**0 / 6**	*<0.5*	**0 / 6**
Chlorodibromomethane	EPA PP	EPA 551.1	µg/L	--	*<0.5*	**0 / 12**					*<0.5*	**0 / 11**	*<0.5* (*<0.5*-**0.56**)	**1 / 5**
Chloroform	EPA PP	EPA 551.1	µg/L	--	**0.53** **(***<0.5***-2)**	**7 / 12**					**1.6** **(0.68-4.2)**	**11 / 11**	**11** **(3.7-38)**	**6 / 6**
Chrysene	EPA PP	EPA 525.2	µg/L	--	*<0.02*	**0 / 6**	*<0.02*	**0 / 6**			*<0.02*	**0 / 6**	*<0.02*	**0 / 6**
Delta-BHC	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Di-N-Butyl Phthalate	EPA PP	EPA 525.2	µg/L	--	*<10*	**0 / 6**	*<1*	**0 / 6**			*<1*	**0 / 6**	*<1*	**0 / 6**
Di-n-octyl phthalate	EPA PP	EPA 525.2	µg/L	--	*<10*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
Dibenz(a,h) anthracene	EPA PP	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Dichlorobromomethane	EPA PP	EPA 551.1	µg/L	--	*<0.5*	**0 / 12**					*<0.5*	**0 / 11**	*<0.5* (*<0.5*-**0.96**)	**2 / 5**
Diethyl Phthalate	EPA PP	EPA 525.2	µg/L	--	*<0.5*	**0 / 6**	*<0.5*	**0 / 6**			*<0.5*	**0 / 6**	*<0.5*	**0 / 6**
Dimethyl phthalate	EPA PP	EPA 525.2	µg/L	--	*<0.5*	**0 / 6**	*<0.5*	**0 / 6**			*<0.5*	**0 / 6**	*<0.5*	**0 / 6**
Endosulfan sulfate	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Endrin	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.2*	**0 / 6**			*<0.2*	**0 / 6**	*<0.2*	**0 / 6**
Endrin aldehyde	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Fluoranthene	EPA PP	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Fluorene	EPA PP	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Hexachlorocyclopentadiene	EPA PP	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Indeno (1,2,3-cd) pyrene	EPA PP	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Isophorone	EPA PP	EPA 525.2	µg/L	--	*<0.5*	**0 / 6**	*<0.5*	**0 / 6**			*<0.5*	**0 / 6**	*<0.5*	**0 / 6**
Naphthalene	EPA PP	EPA 525.2	µg/L	--	*<0.3*	**0 / 6**	*<0.3*	**0 / 6**			*<0.3*	**0 / 6**	**0.161** (*<0.3*-**0.022**)	**2 / 6**
PCB–1016 (Arochlor 1016)	EPA PP	EPA 505	µg/L	--	*<0.08*	**0 / 6**	*<0.08*	**0 / 6**			*<0.08*	**0 / 6**	*<0.08*	**0 / 6**
PCB–1221 (Arochlor 1221)	EPA PP	EPA 505	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
PCB–1232 (Arochlor 1232)	EPA PP	EPA 505	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
PCB–1242 (Arochlor 1242)	EPA PP	EPA 505	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
PCB–1248 (Arochlor 1248)	EPA PP	EPA 505	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
PCB–1254 (Arochlor 1254)	EPA PP	EPA 505	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
PCB–1260 (Arochlor 1260)	EPA PP	EPA 505	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Phenanthrene	EPA PP	EPA 525.2	µg/L	--	*<0.04*	**0 / 6**	*<0.04*	**0 / 6**			*<0.04*	**0 / 6**	*<0.04*	**0 / 6**
Pyrene	EPA PP	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Pesticides of Local Interest (PoLI)														
Chlorothalonil (Draconil, Bravo)	PoLI	EPA 525.2	µg/L	--	*<0.1*	**0 / 6**	*<0.1*	**0 / 6**			*<0.1*	**0 / 6**	*<0.1*	**0 / 6**
Chlorpyrifos	PoLI	EPA 525.2	µg/L	--	*<0.05*	**0 / 6**	*<0.05*	**0 / 6**			*<0.05*	**0 / 6**	*<0.05*	**0 / 6**
Contaminants of Emerging Concern (CECs)														
1,7-Dimethylxanthine	CECs	LC-MS-MS	ng/L	--	**24** (*<10*-**900**)	**4 / 7**	*<10* (*<10*-**170**)	**3 / 7**			*<10*	**0 / 6**	*<10* (*<10*-**240**)	**2 / 6**
2,4-D	CECs	LC-MS-MS	ng/L	--	*<5* (*<5*-**6.7**)	**1 / 7**	*<5* (*<5*-**20**)	**1 / 7**			*<5*	**0 / 7**	*<5* (*<5*-**98**)	**2 / 6**
4-nonylphenol - semi quantitative	CECs	LC-MS-MS	ng/L	--	*<100*	**0 / 7**	*<100*	**0 / 7**			*<100*	**0 / 7**	*<100*	**0 / 6**
4-tert-octylphenol	CECs	LC-MS-MS	ng/L	--	**280** (*<50*-**790**)	**5 / 7**	**120** (*<50*-**290**)	**5 / 7**			*<50*	**0 / 7**	**335** (*<50*-**810**)	**5 / 6**
Acesulfame-K	CECs	LC-MS-MS	ng/L	--	**33000** **(14000-85000)**	**7 / 7**	**21000** **(2700-25000)**	**7 / 7**			*<20*	**0 / 7**	**77500** **(14000-130000)**	**6 / 6**
Acetaminophen	CECs	LC-MS-MS	ng/L	--	**94** (*<5*-**390**)	**5 / 7**	**6.9** (*<5*-**890**)	**4 / 7**			*<5*	**0 / 7**	**58** (*<5*-**420**)	**3 / 6**
Albuterol	CECs	LC-MS-MS	ng/L	--	**18** (*<5*-**72**)	**5 / 7**	*<5* (*<5*-**83**)	**2 / 7**			*<5* (*<5*-**31**)	**1 / 7**	**5.7** (*<5*-**16**)	**3 / 6**
Amoxicillin (semi-quantitative)	CECs	LC-MS-MS	ng/L	--	**2300** **(1200-3700)**	**7 / 7**	*<20* (*<20*-**320**)	**3 / 7**			*<20*	**0 / 7**	**33** (*<20*-**820**)	**4 / 6**
Andorostenedione	CECs, UCMR 3	LC-MS-MS	ng/L	--	*<5* (*<5*-**26**)	**1 / 7**	*<5*	**0 / 7**			*<5*	**0 / 7**	*<5* (*<5*-**11**)	**2 / 6**
Atenolol	CECs	LC-MS-MS	ng/L	--	**460** **(310-620)**	**7 / 7**	**110** **(21-220)**	**7 / 7**			*<5*	**0 / 7**	**265** **(120-460)**	**6 / 6**
Atrazine	CECs	LC-MS-MS	ng/L	--	*<5*	**0 / 7**	*<5*	**0 / 7**			*<5*	**0 / 7**	*<5*	**0 / 6**
Azithromycin	CECs	LC-MS-MS	ng/L	--	*<20* (*<20*-**3600**)	**1 / 7**	*<20* (*<20*-**180**)	**1 / 7**			*<20*	**0 / 7**	*<20* (*<20*-**670**)	**1 / 6**
Bendroflumethiazide	CECs	LC-MS-MS	ng/L	--	*<5*	**0 / 7**	*<5*	**0 / 7**			*<5*	**0 / 7**	*<5*	**0 / 6**
Bezafibrate	CECs	LC-MS-MS	ng/L	--	**69** **(54-120)**	**7 / 7**	**12** (*<5*-**46**)	**5 / 7**			*<5*	**0 / 7**	**116** **(27-250)**	**6 / 6**

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
BPA	CECs	LC-MS-MS	ng/L	--	<10 (<10-66)	2 / 7	<10	0 / 7			<10	0 / 7	16 (<10-38)	3 / 6
Bromacil	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<200	0 / 7			<200	0 / 7	<200	0 / 6
Butalbital	CECs	LC-MS-MS	ng/L	--	<5 (<5-91)	2 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Butylparben	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5 (<5-8.3)	1 / 6
Caffeine	CECs	LC-MS-MS	ng/L	--	580 (110-1200)	7 / 7	190 (<5-430)	6 / 7			<5 (<5-12)	1 / 6	895 (55-1700)	6 / 6
Carbadox	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5 (<5-11)	1 / 7	<5	0 / 6
Carbamazepine	CECs	LC-MS-MS	ng/L	--	130 (120-200)	7 / 7	<5	0 / 7			<5	0 / 7	<5 (<5-5.3)	1 / 6
Carisoprodol	CECs	LC-MS-MS	ng/L	--	82 (<5-580)	5 / 7	71 (<5-470)	6 / 7			<5	0 / 7	260 (<5-2500)	5 / 6
Chloramphenicol	CECs	LC-MS-MS	ng/L	--	<10	0 / 7	<10	0 / 7			<10	0 / 7	<10	0 / 6
Chloridazon	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Chlorotoluron	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Cimetidine	CECs	LC-MS-MS	ng/L	--	190 (<5-3600)	5 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Clofibric Acid	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Cotinine	CECs	LC-MS-MS	ng/L	--	100 (25-200)	7 / 7	69 (21-130)	7 / 7			<10	0 / 7	180 (44-550)	6 / 6
Cyanazine	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
DACT	CECs	LC-MS-MS	ng/L	--	<5 (<5-6.9)	1 / 7	<5 (<5-40)	2 / 7			<5	0 / 7	<5 (<5-10)	1 / 6
DEA	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5 (<5-9.5)	2 / 6
DEET	CECs	LC-MS-MS	ng/L	--	300 (93-380)	7 / 7	95 (<10-220)	6 / 7			<10	0 / 7	390 (<10-1000)	5 / 6
Dehydronifedipine	CECs	LC-MS-MS	ng/L	--	67 (5.7-120)	7 / 7	100 (5.2-220)	7 / 7			<5	0 / 7	370 (99-610)	6 / 6
DIA	CECs	LC-MS-MS	ng/L	--	<5 (<5-12)	1 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Diazepam	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	7.1 (<5-11)	4 / 6
Diclofenac	CECs	LC-MS-MS	ng/L	--	58 (<5-170)	5 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Dilantin	CECs	LC-MS-MS	ng/L	--	120 (82-180)	7 / 7	58 (29-94)	7 / 7			<20	0 / 7	240 (170-270)	6 / 6
Diuron	CECs	LC-MS-MS	ng/L	--	31 (<5-96)	5 / 7	<5 (<5-47)	3 / 7			<5	0 / 7	37 (<5-280)	3 / 6
Erythromycin	CECs, EPA CCL	LC-MS-MS	ng/L	--	<10 (<10-120)	2 / 7	<10	0 / 7			<10 (<10-13)	1 / 7	15 (<10-43)	4 / 6
Estradiol	CECs, UCMR 3	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Estrone	CECs, UCMR 3	LC-MS-MS	ng/L	--	29 (12-320)	7 / 7	<5 (<5-6.2)	1 / 7			<5	0 / 7	<5 (<5-7.8)	2 / 6
Ethinyl Estradiol - 17 alpha	CECs, UCMR 3	LC-MS-MS	ng/L	--	<5 (<5-2500)	1 / 7	<5 (<5-520)	1 / 7			<5	0 / 7	<5 (<5-3400)	1 / 6
Ethylparaben	CECs	LC-MS-MS	ng/L	--	<20	0 / 7	<20	0 / 7			<20	0 / 7	<20	0 / 6
Flumeqine	CECs	LC-MS-MS	ng/L	--	<10	0 / 7	<10	0 / 7			<10	0 / 7	<10	0 / 6
Fluoxetine	CECs	LC-MS-MS	ng/L	--	18 (<10-27)	6 / 7	<10 (<10-11)	1 / 7			<10 (<10-19)	1 / 7	<10	0 / 6
Gemfibrozil	CECs	LC-MS-MS	ng/L	--	1200 (1000-1500)	7 / 7	<5 (<5-41)	1 / 7			<5	0 / 7	9 (<5-460)	3 / 6
Ibuprofen	CECs	LC-MS-MS	ng/L	--	46 (<10-220)	4 / 7	35 (<10-120)	5 / 7			<10	0 / 7	195 (<10-510)	4 / 6
Iohexal	CECs	LC-MS-MS	ng/L	--	9800 (7800-40000)	7 / 7	7600 (5400-11000)	7 / 7			<10 (<10-16)	1 / 7	29000 (3000-40000)	6 / 6

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
Iopromide	CECs	LC-MS-MS	ng/L	--	1600 (960-3500)	7 / 7	1100 (570-2800)	7 / 7			<5	0 / 7	4250 (2200-9400)	6 / 6
Isobutylparaben	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5 (<5-13)	1 / 6
Isoproturon	CECs	LC-MS-MS	ng/L	--	<100	0 / 7	<100	0 / 7			<100	0 / 7	<100	0 / 6
Ketoprofen	CECs	LC-MS-MS	ng/L	--	73 (39-170)	7 / 7	31 (<5-55)	6 / 7			<5	0 / 7	130 (89-160)	6 / 6
Ketorolac	CECs	LC-MS-MS	ng/L	--	10 (<5-19)	4 / 7	<5	0 / 7			<5	0 / 7	<5 (<5-7)	1 / 6
Lidocaine	CECs	LC-MS-MS	ng/L	--	250 (100-580)	7 / 7	16 (<5-110)	5 / 7			<5	0 / 7	78 (<5-340)	4 / 5
Lincomycin	CECs	LC-MS-MS	ng/L	--	46 (<10-74)	5 / 7	<10 (<10-110)	2 / 7			<10	0 / 7	<10	0 / 6
Linuron	CECs, PoLI	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5 (<5-12)	1 / 6
Lopressor	CECs	LC-MS-MS	ng/L	--	580 (350-1200)	7 / 7	<20 (<20-260)	3 / 7			<20	0 / 7	95 (<20-370)	4 / 6
Meclofenamic Acid	CECs	LC-MS-MS	ng/L	--	<5 (<5-280)	1 / 6	<5	0 / 7			<5	0 / 7	<5	0 / 6
Meprobamate	CECs	LC-MS-MS	ng/L	--	220 (130-350)	7 / 7	180 (87-280)	7 / 7			<5	0 / 7	335 (260-680)	6 / 6
Metazachlor	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Methylparaben	CECs	LC-MS-MS	ng/L	--	<20 (<20-28)	1 / 7	<20 (<20-20)	1 / 7			<20	0 / 7	<20	0 / 6
Metolachlor	CECs	LC-MS-MS	ng/L	--	<5	0 / 6	<5	0 / 7			<5	0 / 7	<5	0 / 6
Naproxen	CECs	LC-MS-MS	ng/L	--	28 (<10-240)	4 / 7	<10	0 / 7			<10	0 / 7	<10	0 / 6
Nifedipine	CECs	LC-MS-MS	ng/L	--	<20 (<20-150)	2 / 7	<20	0 / 7			<20	0 / 7	<20 (<20-66)	1 / 6
Norethisterone	CECs	LC-MS-MS	ng/L	--	<5 (<5-25)	2 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Oxolinic Acid	CECs	LC-MS-MS	ng/L	--	<10	0 / 7	<10	0 / 7			<10	0 / 7	<10	0 / 6
Pentoxifylline	CECs	LC-MS-MS	ng/L	--	11 (<5-80)	5 / 7	<5 (<5-11)	2 / 7			<5	0 / 7	<5 (<5-51)	3 / 6
Phenazone	CECs	LC-MS-MS	ng/L	--	<5 (<5-16)	1 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Primidone	CECs	LC-MS-MS	ng/L	--	49 (31-66)	7 / 7	24 (11-42)	7 / 7			<5	0 / 7	100 (<5-180)	5 / 6
Progesterone	CECs	LC-MS-MS	ng/L	--	<5 (<5-330)	2 / 7	<5 (<5-6.6)	1 / 7			<5	0 / 7	7 (<5-11)	3 / 6
Propazine	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Propylparaben	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Quinoline	CECs, EPA CCL	LC-MS-MS	ng/L	--	<5 (<5-130)	1 / 7	<5 (<5-41)	1 / 7			<5 (<5-94)	1 / 7	<5	0 / 6
Simazine	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Sucralose	CECs	LC-MS-MS	ng/L	--	37000 (26000-44000)	7 / 7	33000 (20000-40000)	7 / 7			<100	0 / 7	150000 (<100-180000)	5 / 6
Sulfachloropyridazine	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Sulfadiazine	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Sulfadimethoxine	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Sulfamerazine	CECs	LC-MS-MS	ng/L	--	<5 (<5-29)	1 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Sulfamethazine	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Sulfamethizole	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Sulfamethoxazole	CECs	LC-MS-MS	ng/L	--	800 (350-990)	7 / 7	32 (<5-140)	6 / 7			<5	0 / 7	104 (<5-490)	4 / 6
Sulfathiazole	CECs	LC-MS-MS	ng/L	--	<5	0 / 7	<5 (<5-5)	1 / 7			<5	0 / 7	<5	0 / 6

Sampling Constituent	Contaminant List	Analytical Method	Units	DDW MCL/NL	Pilot Influent (Secondary Effluent)		Ozone Effluent		MF Effluent		RO Permeate		RO Concentrate	
					Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured	Median (Range)	Detected / Measured
TCEP	CECs	LC-MS-MS	ng/L	--	290 (100-440)	7 / 7	320 (120-500)	7 / 7			<10	0 / 7	1200 (580-2000)	6 / 6
TCPP	CECs	LC-MS-MS	ng/L	--	470 (280-860)	7 / 7	340 (240-850)	7 / 7			<100	0 / 7	1550 (1200-2200)	6 / 6
TDCPP	CECs	LC-MS-MS	ng/L	--	460 (180-800)	7 / 7	300 (220-800)	7 / 7			<100	0 / 7	1450 (720-1700)	6 / 6
Testosterone	CECs, UCMR 3	LC-MS-MS	ng/L	--	<5 (<5-18)	1 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6
Theobromine	CECs	LC-MS-MS	ng/L	--	<10 (<10-310)	2 / 7	<10 (<10-580)	2 / 7			<10	0 / 7	<10 (<10-920)	2 / 6
Theophylline	CECs	LC-MS-MS	ng/L	--	430 (<20-1300)	5 / 7	<20 (<20-1600)	3 / 7			<20	0 / 7	135 (<20-1000)	3 / 6
Triclosan	CECs	LC-MS-MS	ng/L	--	140 (11-1600)	7 / 7	<10 (<10-30)	3 / 7			<10	0 / 7	11 (<10-92)	3 / 6
Trimethoprim	CECs	LC-MS-MS	ng/L	--	400 (200-730)	7 / 7	<5	0 / 7			<5	0 / 7	<5 (<5-21)	1 / 6
Warfarin	CECs	LC-MS-MS	ng/L	--	<5 (<5-14)	2 / 7	<5	0 / 7			<5	0 / 7	<5	0 / 6

[1] Values for total coliform and *E. coli* are in the format geometric mean (range)

SM is Standard Methods for the Examination of Water and Wastewater; LC-MS-MS is Liquid Chromatography, tandem Mass Spectrometry; mg is milligram; L is Liter; µg is microgram; ng is nanograms; EPA is Environmental Protection Agency
NTU is Nephelometric Turbidity Units; cm is centimeter; MPN is Most Probable Number; mL is milliliter; MFL is Million Fibers per Liter; pCi is picocuries; TT is Treatment Technique; UV is ultraviolet

APPENDIX C

AOP Revalidation Acceptance and Report

CALIFORNIA
Water Boards

Gavin Newsom
GOVERNOR

Yana Garcia
SECRETARY FOR
ENVIRONMENTAL PROTECTION

State Water Resources Control Board
Division of Drinking Water

July 18, 2023

James Bishop
Central Coast Regional Water Quality Control Board
895 Aerovista Place, Suite 101
San Luis Obispo, CA 93401

DIVISION OF DRINKING WATER CONDITIONAL ACCEPTANCE OF MONTEREY ONE WATER PURE WATER MONTEREY GROUNDWATER REPLENISHMENT PROJECT ADVANCED OXIDATION PROCESS REVALIDATION REPORT (2790002-707)

Dear Mr. Bishop,

The State Water Resources Control Board Division of Drinking Water (DDW) staff has reviewed the Monterey One Water (M1W) Pure Water Monterey Groundwater Replenishment Project (Project) Advanced Oxidation Process Revalidation Report (Report) transmitted on May 15, 2023. The revalidation test was conducted in February 2023 based on a test plan approved by DDW in October 2022.

The purpose of the test is to optimize the current advanced oxidation process (AOP) operating requirements of 14,300 mJ-mg/cm^2/L UV-H_2O_2 dose product, which was based on testing conducted in June 2020 and was accepted by DDW on December 8, 2020. M1W is proposing a modified sidestream 1,4-dioxane injection system (compared to the June 2020 testing) and eight (8) test conditions at 1.3 mgd flow and UV transmittance of 95% through UV reactor #6 for a range of UV dose and H_2O_2 dose.

Section 5 of the Report proposes the revised AOP operating requirements and operating setpoints modifications. DDW accepts the operating requirements and setpoints below.

- Operating requirements
    - Reactor flowrate of 1.4 mgd or less
    - Influent UVT of 95% or greater
    - H_2O_2 dose of 2.2 mg/L or greater
    - UV- H_2O_2 dose product of 8,455 mJ-mg/cm^2-L or greater

- Operating setpoints

Parameter	Current Operation	Setpoint Revision
Reactor Flowrate	High-high alarm at 1.4 mgd High alarm at 1.3 mgd	Raise high alarm setpoint to 1.35 mgd
Influent UVT	Low-low alarm at 95%	No change
H_2O_2 dose	Target setpoint: 5.0 mg/L Low alarm: 4.7 mg/L High alarm: 7.0 mg/L	1) Add low-low alarm at 2.2 mg/L 2) Remove low alarm at 4.7 mg/L 3) Remove target setpoint 4) No change to high alarm setpoint
UV-H_2O_2 dose product	Operating Setpoint: 15,730 mJ-mg/cm^2-L Low alarm: 15,000 mJ-mg/cm^2-L Low-low alarm: 14,300 mJ-mg/cm^2-L	1) Reduce operating setpoint to 9,300 mJ-mg/cm2-L 2) Reduce low alarm setpoint to 8,880 mJ-mg/cm2-L 3) Reduce low-low alarm setpoint to 8,455 mJ-mg/cm2-L

M1W must submit an updated OOP section(s), Appendix I, and if applicable, any proposed change to the monitoring report forms, to reflect the DDW accepted operating requirements and setpoints.

If you have any questions regarding this letter, please contact Sherly Rosilela at (916) 341-5578 or via email at Sherly.Rosilela@waterboards.ca.gov or me at (818) 551-2046 or via email at Ginachi.Amah@waterboards.ca.gov.

Sincerely,

Ginachi Amah, P.E., D.Env.
Recycled Water Unit Supervisor
Division of Drinking Water

cc: Jonathan Weininger, DDW (via email)
Stefan Cajina, DDW (via email)
Randy Barnard, DDW (via email)
Brian Bernados, DDW (via email)

Jennifer Epp, Central Coast Regional Water Quality Control Board (via email)

Alison Imamura, Monterey One Water (via email)
Tamsen McNarie, Monterey One Water (via email)
Mike McCullough, Monterey One Water (via email)

Bryce McFerrin, Trussell Technologies (via email)
Keel Robinson, Trussell Technologies (via email)

RWU files

Trussell

DAVID ROBERT HOKANSON
C 70254
EXP. 9/30/24
CIVIL

ADVANCED OXIDATION PROCESS RE-VALIDATION REPORT

Monterey One Water

Pure Water Monterey Advanced Water Purification Facility

Date: May 12, 2023

Recipients: State Water Resources Control Board, Division of Drinking Water, Recycled Water Unit: Sherly Rosilela, Brian Bernados, Ginachi Amah

Authors: Monterey One Water: Alison Imamura, Jose Guzman
Trussell: Bryce McFerrin, Aleks Pisarenko, Ph.D., Keel Robinson, David Hokanson, Ph.D., P.E.

Subject: Advanced Oxidation Process Re-Validation Report

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1. INTRODUCTION

Monterey One Water (M1W) produces 3,700 acre-feet per year of purified recycled water for groundwater replenishment through the Advanced Water Purification Facility (AWPF) as part of the Pure Water Monterey (PWM) project. The AWPF has a permitted capacity of 5 million gallons per day (mgd) and was commissioned in February 2020. M1W has designed an expansion of the AWPF facilities that would increase peak capacity to 7.6 mgd and allow for production of 5,950 (acre-feet per year) afy.

The AWPF receives secondary effluent from M1W's Regional Treatment Plant. The AWPF treatment processes include chloramination, ozonation, membrane filtration (MF), reverse osmosis (RO), an advanced oxidation process (AOP) with ultraviolet light (UV) and hydrogen peroxide, post treatment stabilization and chloramination. The purified recycled water is injected into the Seaside Groundwater Basin using primarily deep injection wells and later extracted for potable water supply. The UV reactors are Xylem's Wedeco LBX1500e reactors.

M1W's AOP validation was approved by the State Water Resources Control Board, Division of Drinking Water, Recycled Water Unit on December 8, 2020. The approval was based on testing conducted in June 2020, which included unexpected results. A conservative operating requirement was established at a 14,300 mJ-mg/cm^2-L UV-peroxide dose product, which required higher UV and hydrogen peroxide doses than assumed during the design of the facility (Monterey One Water, 2020). The high doses incur high operational costs, require operating near 100% power, and limit flow capacity through the reactors. Operating setpoints, alarms, and responses were also updated in the current Operation Optimization Plan (OOP) dated January 2021.

M1W evaluated the AOP performance in a spot-check 1,4-dioxane challenge test in February 2022 with improved test methods to determine if errors in the June 2020 testing could be identified and minimized. The results showed that improved test methods could eliminate unexpected variation and yield results that better aligned with other projects and previous experience (Monterey One Water, 2022). The February 2022 results indicated the potential for significant cost savings and ease of operations while also ensuring public health protection via the 0.5 log removal value (LRV) requirement for 1,4-dioxane. M1W developed a test plan to support re-validation of the AOP process. The test conditions below describe the testing that M1W conducted in February 2023 to re-validate the AOP process in accordance with the test plan reviewed and approved by DDW on October 31, 2022. The test conditions summary is followed by an analysis of the test results and recommendations for a new minimum UV-peroxide dose product.

2. TEST CONDITIONS

The actual test conditions during the re-validation were similar to those described in the test plan reviewed and approved by DDW on October 31, 2022. Testing was conducted on UV reactor #6, which was the same vessel tested in June 2020 and February 2022 during prior 1,4-dioxane challenge test. The same influent and effluent samples ports were used to collect samples for various lab analyses. Marked up drawings in **Appendix A: Sampling Locations** show the location of the influent and effluent sample ports. The influent sample port is located just after the riser coming off the influent header. The effluent sample port is located on the effluent header between UV reactor #6's and UV reactor #5's discharge. UV reactor #5 was kept offline to ensure the effluent sample port location represents UV reactor #6 effluent only. UV reactors #3 and #4 were online during testing to achieve the target AWPF flowrate of 4 mgd throughout testing. Similar to the June 2020 and February 2022 testing, the AWPF product water was diverted to the Salinas Valley Reclamation Project storage pond during testing and subsequently pumped back to the headworks of the RTP for treatment.

2.1 Dioxane Sidestream Injection System

The same improved sidestream injection system was used to dose 1,4-dioxane into the RO permeate (ROP) header as was used in the February 2022 testing. As detailed in the re-validation test plan, the new sidestream injection system improved the 1,4-dioxane dose accuracy of the dosing system from 19% to 89% and improved the average replicate sample coefficient of variation (COV) from 15% and to 3% relative to the June 2020 testing (Trussell 2022). The same target 1,4-dioxane dose of 14 µg/L was used, which was achieved using the same 1,4-dioxane solution concentration, sidestream flow, and process flow. Figure 1 below shows the schematic of the 1,4-dioxane dosing system.

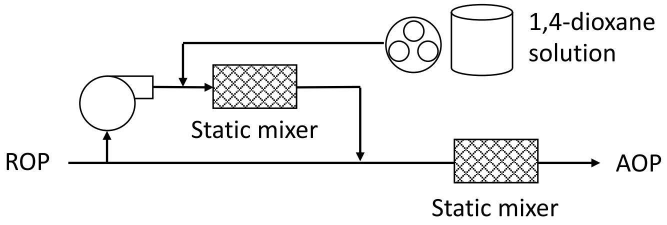


Figure 1. February 2022 Sidestream Injection System

Two 1,4-dioxane batches were made up during testing: one batch for tests #2 through #7 and another batch for tests #0 and #1. For each batch, approximately 50 mL of pure 1,4-dioxane was added to approximately 5 gallons of ROP and mixed well. The resulting concentration of this diluted 1,4-dioxane solution was calculated to be approximately 2,729 mg/L.

The diluted 1,4-dioxane solution was injected and mixed into the sidestream at a rate of 54 mL/min. The flowrate of the peristaltic pump was confirmed by conducting a drawdown test using ROP prior to mixing the first 1,4-dioxane batch. The sidestream was then injected and mixed into the AOP influent flow of 4 mgd. This sidestream injection method resulted in a well-mixed AOP influent 1,4-dioxane concentration of approximately 14 µg/L.

2.2 Target Test Conditions

The target test conditions were established in the proposed test plan that was reviewed and approved by DDW on October 31, 2022. The target test conditions included an influent UVT of 95% (the existing permit limit), which was achieved by increasing the chloramine dose upstream of the ozone system. The target test conditions also included a reactor flowrate of 1.3 mgd, UV ballast power ranging from 50% to 100%, peroxide doses ranging from 2.1 to 7.5 mg/L, UV doses ranging from 1,524 to 1,915 mJ/cm^2, and UV-peroxide dose products ranging from 3,200 to 14,300 mJ-mg/cm^2-L. An additional “zero run” was also included where the UV dose was set to zero by turning off the UV lamps. Table 1 summarizes the target test conditions.

Table 1. February 2023 Test Plan Conditions

Test	UVT (%)	Flow (mgd)	UV Ballast Power (%)	UV dose (mJ/cm^2)	H_2O_2 dose (mg/L)	Dose product (mJ-mg/cm^2-L)
0	95	1.3	0	0	2.1	0
1	95	1.3	50	1,524	2.1	3,200
2	95	1.3	58	1,586	3.1	4,900
3	95	1.3	67	1,657	4.0	6,600
4	95	1.3	75	1,719	4.8	8,300
5	95	1.3	84	1,790	5.8	10,300
6	95	1.3	92	1,852	6.6	12,300
7	95	1.3	100	1,915	7.5	14,300

3. TEST RESULTS

The complete table of online measurements, field measurements, and laboratory data are attached in **Appendix B: February 2023 Data**. The test methods associated with the lab and field measurements are provided in **Appendix C: Water Quality Methods**. The actual test conditions were similar to the proposed test conditions with some minor differences, which are described in the following section. Furthermore, the water quality during the re-validation testing was similar to the conditions tested in the June 2020 validation study and the February 2022 testing, as shown in Table 2 below.

Table 2. RO Permeate Water Quality

Parameter	June 2020	February 2022	February 2023
pH	5.3	5.3	5.3
Alkalinity (mg/L as $CaCO_3$)	15	24	21
Temperature (°C)	23	21	19
Total Organic Carbon (mg/L)	0.18	0.20	0.25
Nitrite (mg/L as N)	< 0.02	0.02	0.05

3.1 Actual Test Conditions

For Tests #1 through #7, the ultraviolet light transmittance (UVT) varied between 94.7% and 95.2% compared to the target of 95%; the reactor flow varied between 1.33 and 1.36 mgd compared to the target of 1.3 mgd; the UV ballast power ranged from 50% to 100% compared to the targets of 50% to 100%; the UV dose ranged from 1,555 to 1,927 mJ/cm^2 compared to the targets of 1,524 to 1,915 mJ/cm^2; the hydrogen peroxide dose ranged from 2.2 to 8.0 mg/L compared to the targets of 2.1 to 7.5 mg/L; and UV-peroxide dose products ranged from 3,403 to 15,375 $mJ\text{-}mg/cm^2\text{-}L$ compared to the targets of 3,200 to 14,300 $mJ\text{-}mg/cm^2\text{-}L$. For the zero run (Test #0), all UV lamps were turned off to demonstrate no log-removal of 1,4-dioxane under zero dose product conditions. The flow during Test #0 had to be reduced for M1W's operators to run the vessel in maintenance mode without UV lamp power. The reduced flow should not impact the grab sample results for 1,4-dioxane when no UV dose is being applied. Table 3 below summarizes the actual test conditions for each test run.

Table 3. February 2023 Actual Test Conditions

Test	UVT (%)	Flow (mgd)	UV Ballast Power (%)	UV dose (mJ/cm^2)	H_2O_2 dose (mg/L)	Dose product ($mJ\text{-}mg/cm^2\text{-}L$)
0	95.0	0.96	0	0	2.2	0
1	95.1	1.35	50	1,555	2.2	3,403
2	95.2	1.35	53	1,583	3.3	5,254
3	95.2	1.35	64	1,640	4.3	7,043
4	95.1	1.3	71	1,709	5.2	8,822

5	94.9	1.35	80	1,771	6.2	10,911
6	94.8	1.33	91	1,840	7.0	12,873
7	94.7	1.36	100	1,927	8.0	15,375

The UVT data was recorded at the time of sampling from the online meter located downstream of the peroxide injection that measures UVT at the inlet to the UV reactors. Marked up drawings in **Appendix C: Water Quality** Methods indicate the location of the sample line that feeds the online UVT meter. The flow data was recorded from the Reactor #6 flowmeter at the time of sampling. The UV ballast power and UV dose from Reactor #6 were recorded at the time of sampling from the online SCADA values. The peroxide dose was calculated using the peroxide flowrate and total flowrate recorded at the time of sampling. The UV-peroxide dose product is the product of the recorded UV dose and peroxide dose.

3.2 1,4-Dioxane Lab Results

For each test condition, three influent and three effluent samples were collected and sent to Eurofins, an outside lab, to be analyzed for 1,4-dioxane. The results from the replicate samples in each test condition were averaged and used to calculate the 1,4-dioxane LRV. Table 4 below shows the 1,4-dioxane results and corresponding LRVs.

Table 4. February 2023 1,4-Dioxane Lab Results

Test	Influent (µg/L)					Effluent (µg/L)					LRV	Dose Product (mg-mJ/ L-cm^2)
	1	2	3	AVG	COV	1	2	3	AVG	COV		
0	15	15	15	15.0	0%	15	16	16	15.7	4%	-0.02	0
1	16	16	16	16.0	0%	9.3	9.1	9.4	9.3	2%	0.24	3403
2	11	12	11	11.3	5%	5.8	-	6.3	6.1	6%	0.27	5254
3	12	13	12	12.3	5%	4.7	4.9	5.0	4.9	3%	0.40	7043
4	12	12	12	12.0	0%	3.8	3.7	3.9	3.8	3%	0.50	8822
5*	13.5	12.5	15.0	13.7	9%	3.2	3.4	-	3.3	4%	0.65	10911
6	13	12	10	11.7	13%	2.3	1.5	1.6	1.8	24%	0.81	12873
7	11	11	11	11.0	0%	1.3	1.3	1.3	1.3	0%	0.93	15375

*Results are an average of duplicate measurements for each sample result

The influent results ranged from 10-16 µg/L with an average of 13 µg/L. The COVs for the replicate sample sets ranged from 0-24% with an average COV of 5%. Additionally, the Test #0 results demonstrate no significant 1,4-dioxane LRV under a zero UV-peroxide dose product condition.

For Test #2, the effluent 2 sample result of 2.6 µg/L varied greatly from the other Test #2 effluent replicate results and the effluent 2 sample was accompanied by two QA/QC flags in Eurofins' sample analysis report. For this sample, a matrix spike (MS) sample and matrix spike duplicate (MSD) sample were prepared and analyzed in addition to the test sample. The

MS/MSD results indicated 4% recovery and 432% recovery, respectively, which fall far outside of the acceptable limits of 70-130%. There was no additional sample volume remaining for re-testing, and the lab admitted there was most likely human error associated with the preparation of the samples that caused the erroneous results. Trussell and M1W propose to exclude the Test #2 effluent 2 sample result from the analysis due to the high likelihood of human error. Furthermore, removing the effluent sample 2 result yields a more conservative (lower) 1,4-dioxane LRV for Test #2.

For Test #5, the initial effluent sample results of 1.8, 6.3, and 5.5 µg/L contained a high degree of variation (COV of 53%) when compared to the COV for most other effluent sample sets (≤ 6%). Trussell and M1W requested a re-test of the Test #5 influent and effluent samples. One of the effluent samples (effluent 3) from Test #5 did not have enough sample volume remaining for re-testing. The re-testing was completed at another Eurofins lab location and each of the five samples were run with duplicate injections to demonstrate consistency of the re-test results on each replicate sample. The results reported in Table 4 are the average of the duplicate results for each of the re-tested samples from Test #5. The influent triplicate sample re-test contained a COV of 9% and the effluent duplicate sample re-test contained a COV of 4%, which indicated a degree of variation similar to what was observed in the other test runs. Since the results of the Test #5 re-test indicated more consistency between replicate samples, Trussell and M1W propose to use the data from Test #5 re-testing for analysis.

For Test #6, the effluent 2 and effluent 3 samples were flagged in Eurofins' sample analysis report with accompanying internal standard (ISTD) responses outside of acceptable limits. The ISTD responses for these samples were initially 133% and 132%, respectively, compared to the acceptable limits of 70-130%. The samples were re-extracted with passing ISTD responses, but surrogate recoveries outside of acceptable limits (61% and 63%, respectively, compared to the acceptable limits of 70-130%). No sample remained for additional re-testing. Trussell and M1W propose to keep the re-extracted sample results for analysis since the surrogate recoveries were only just outside the acceptable limits and no sample remained for re-testing.

4. ANALYSIS

4.1 Minimum UV-Peroxide Dose Product Requirement

As expected, and similar to the test results from February 2022, the 1,4-dioxane LRV results exhibited a linear relationship with respect to UV-peroxide dose product. A linear regression was applied to the observed data with a corresponding R^2-value of 0.991, indicating an excellent fit over the range of tested conditions. Figure 2 shows the 1,4-dioxane LRV results with a linear regression applied to the data along with the corresponding linear regression equation.

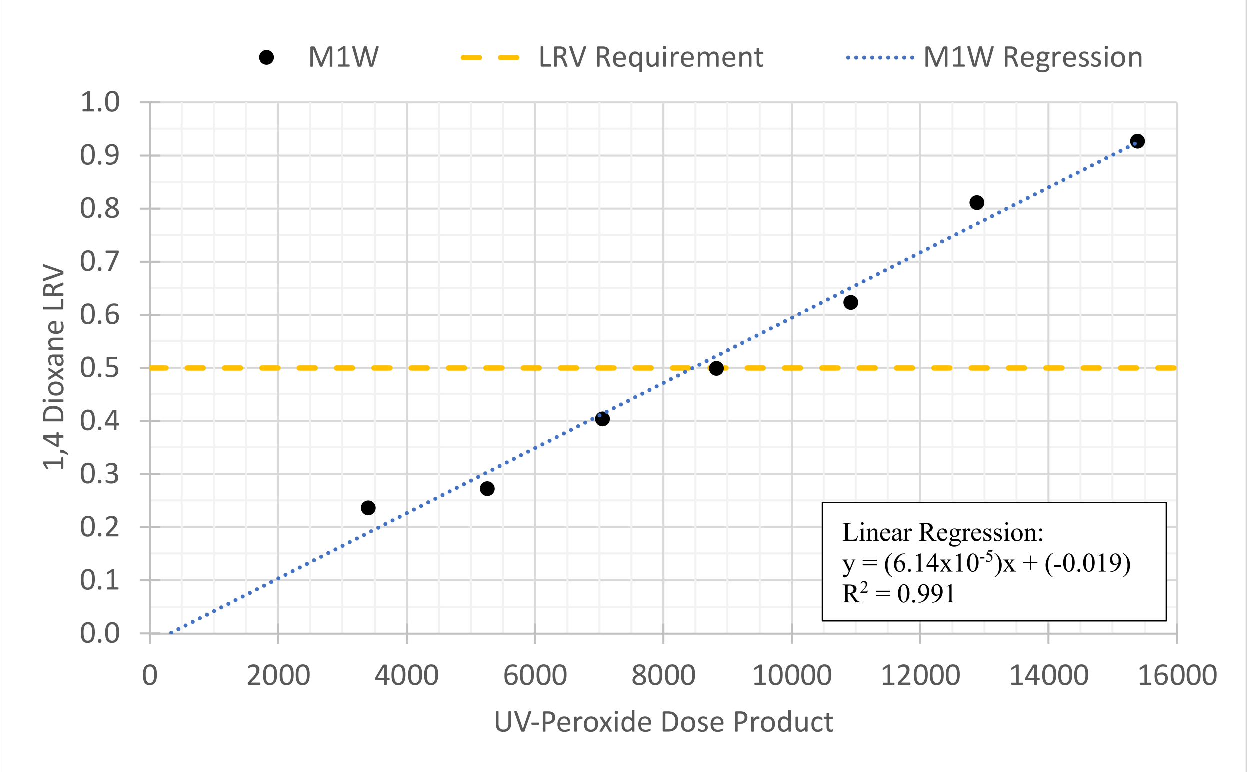


Figure 2. UV-Peroxide Dose Product Regression

The linear regression equation indicates an excellent fit over the UV-peroxide dose product range of 3,403 to 15,375 mJ-mg/cm^2-L, which was achieved with the following range of conditions: UV doses ranging from 1,555 to 1,927 mJ/cm^2, peroxide doses ranging from 2.2 to 8.0 mg/L. By demonstrating linearity of the 1,4-dioxane LRV versus UV-peroxide dose product with varying peroxide and UV doses, the 1,4-dioxane LRV can be confidently predicted (using these results) for any combination of peroxide dose and UV dose as long as the UV-peroxide dose product is at least 3,403 mJ-mg/cm^2-L (the lowest tested UV-peroxide dose product). Based on this linear dose-response of the tested conditions, operating at a peroxide dose of 2.2 mg/L or greater should ensure reproducible 1,4-dioxane LRV results consistent with the operating conditions tested during re-validation.

Using the linear regression equation, the minimum UV-peroxide dose product required to achieve a 0.5 LRV of 1,4-dioxane is estimated to be 8,455 mJ-mg/cm^2-L. By operating at a UV-peroxide dose product of at least 8,455 mJ-mg/cm^2-L, M1W will ensure at least a 0.5 LRV of 1,4-dioxane is achieved.

In operation, a peroxide dose setpoint and a UV dose setpoint are selected and input into SCADA to achieve a target UV-peroxide dose setpoint. M1W's UV dose control system automatically controls ballast power to achieve a UV dose 10% higher than the operator-specified UV dose setpoint; therefore, a 10% UV-peroxide dose product safety factor is designed into M1W's control system. For example, a UV dose setpoint of 1,691 mJ/cm^2 along with a peroxide dose product setpoint of 5.0 mg/L means M1W's control system will apply a UV dose of 1,860 mJ/cm^2 and a peroxide dose of 5.0 mg/L. The resulting UV-peroxide dose product would be 9,300 mJ-mg/cm^2-L. Thus, a recommended minimum UV-peroxide dose product of 8,455 mJ-mg/cm^2-L means M1W would operate with an effective operational UV-peroxide dose product setpoint of 9,300 mJ-mg/cm^2-L. The 10% safety factor operating line is depicted in Figure 4.

To compare M1W's 10% safety factor to an alternative approach to a conservative safety factor, two 1-sided lower confidence intervals (CI) (90% and 95%) were evaluated for the linear regression line. The 1-sided lower confidence intervals for the regression were calculated using Equation 1 and Equation 2 below. The results from calculations are plotted in Figure 3 alongside the linear regression and the 10% safety factor operating line for comparison.

Equation 1:

$$90\%\ CI = Y + (t_{0.1})(SE_{res})\sqrt{\frac{1}{n} + \frac{(X - X_{avg})^2}{SS_{xx}}}$$

Equation 2:

$$95\%\ CI = Y + (t_{0.05})(SE_{res})\sqrt{\frac{1}{n} + \frac{(X - X_{avg})^2}{SS_{xx}}}$$

Where,
Y = predicted y-value (LRV) from the regression
X = x-value (dose product) corresponding to predicted y-value
$t_{0.1} = -1.44$ = t-value corresponding to 90% confidence
$t_{0.05} = -1.94$ = t-value corresponding to 95% confidence
$SE_{res} = 0.032$ = standard error of residual variation in y-values
$n = 8$ = number of data points
$X_{avg} = 7{,}960$ = sample mean of x-values
$SS_{xx} = 180{,}859{,}939$ = sum of squared deviations in x-values

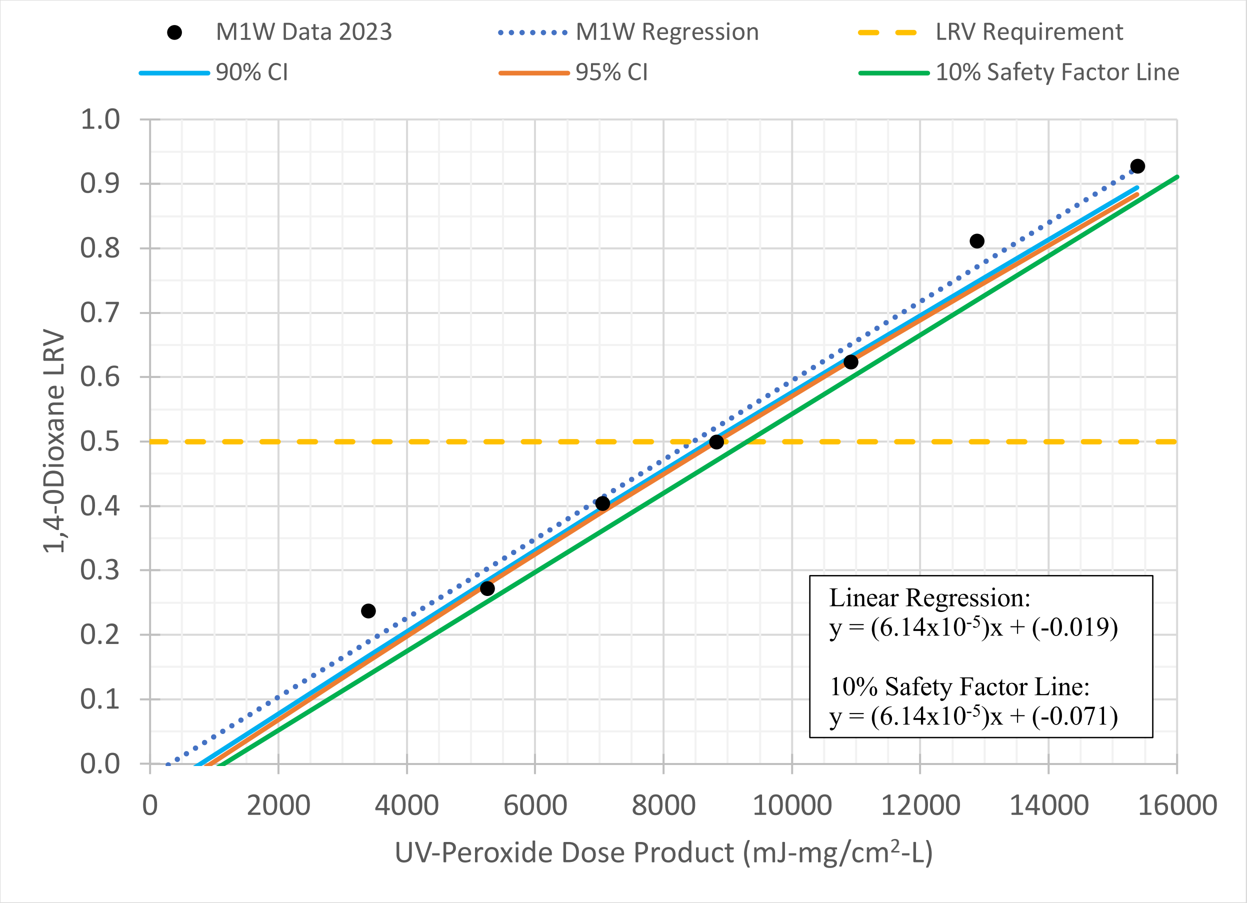


Figure 3. UV-Peroxide Dose Product Regression and Operating Line

As shown in Figure 3, the 10% safety factor already incorporated in M1W's control scheme is more conservative than both the 90% and 95% confidence interval approach. Thus, M1W's proposed 10% safety factor provides adequate conservatism to the proposed minimum UV-peroxide dose product of 8,455 mJ-mg/cm^2-L.

5. RECOMMENDATIONS

Based on results of the revalidation test described above, the following minimum conservative operating conditions for the M1W Advanced Water Purification Facility advanced oxidation reactors provide the required minimum 0.5-log reduction of 1,4-dioxane:

- Reactor flowrate of 1.4 mgd or less
- Influent UVT of 95% or greater
- Peroxide dose of 2.2 mg/L or greater
- UV-Peroxide dose product of 8,455 mJ-mg/cm^2-L or greater

In M1W's current OOP, the minimum and maximum operating conditions are associated with low-low or high-high alarms, respectively. High-high and low-low alarms trigger an automated response such as an off-spec diversion or unit shut down, or other corrective action as described in the approved OOP. High and low alarm setpoints are associated with operator warnings to alert when conditions are nearing the high-high or low-low limits. The alarm conditions associated with the recommended minimum conservative operating conditions are summarized in Table 5.

Table 5. Recommended Operating Setpoints for M1W AWPF UV/AOP

Parameter	Current Operation (Current OOP)	Recommendation
Reactor Flowrate	High-high alarm at 1.4 mgd High alarm at 1.3 mgd	Raise high alarm setpoint to 1.35 mgd to allow for operation at 1.3 mgd per reactor without alarm
Influent UVT	Low-low alarm at 95%	No change
Peroxide Dose	Target setpoint: 5.0 mg/L Low alarm: 4.7 mg/L High alarm: 7.0 mg/L	1) Add low-low alarm at 2.2 mg/L 2) Remove low alarm at 4.7 mg/L 3) Remove target setpoint 4) Remove high alarm setpoint
UV-Peroxide Dose Product	Operating Setpoint: 15,730 Low alarm: 15,000 Low-low alarm: 14,300	1) Reduce operating setpoint to 9,300 mJ-mg/cm^2-L 2) Reduce low alarm setpoint to 8,880 mJ-mg/cm^2-L 3) Reduce low-low alarm setpoint to 8,455 mJ-mg/cm^2-L

Since the minimum regulatory requirement is imposed on UV-peroxide dose product, there are ranges of UV dose and peroxide dose that will meet the UV-peroxide dose product requirement. Table 6 shows a few examples of UV dose and peroxide dose setpoint combinations that could be used to achieve at least 0.5-log reduction of 1,4-dioxane using the proposed conservative operating conditions. M1W operations may select the combination that best minimizes the operating costs while ensuring compliance with the UV-peroxide dose product setpoint at the given operating conditions (based on flow and UVT).

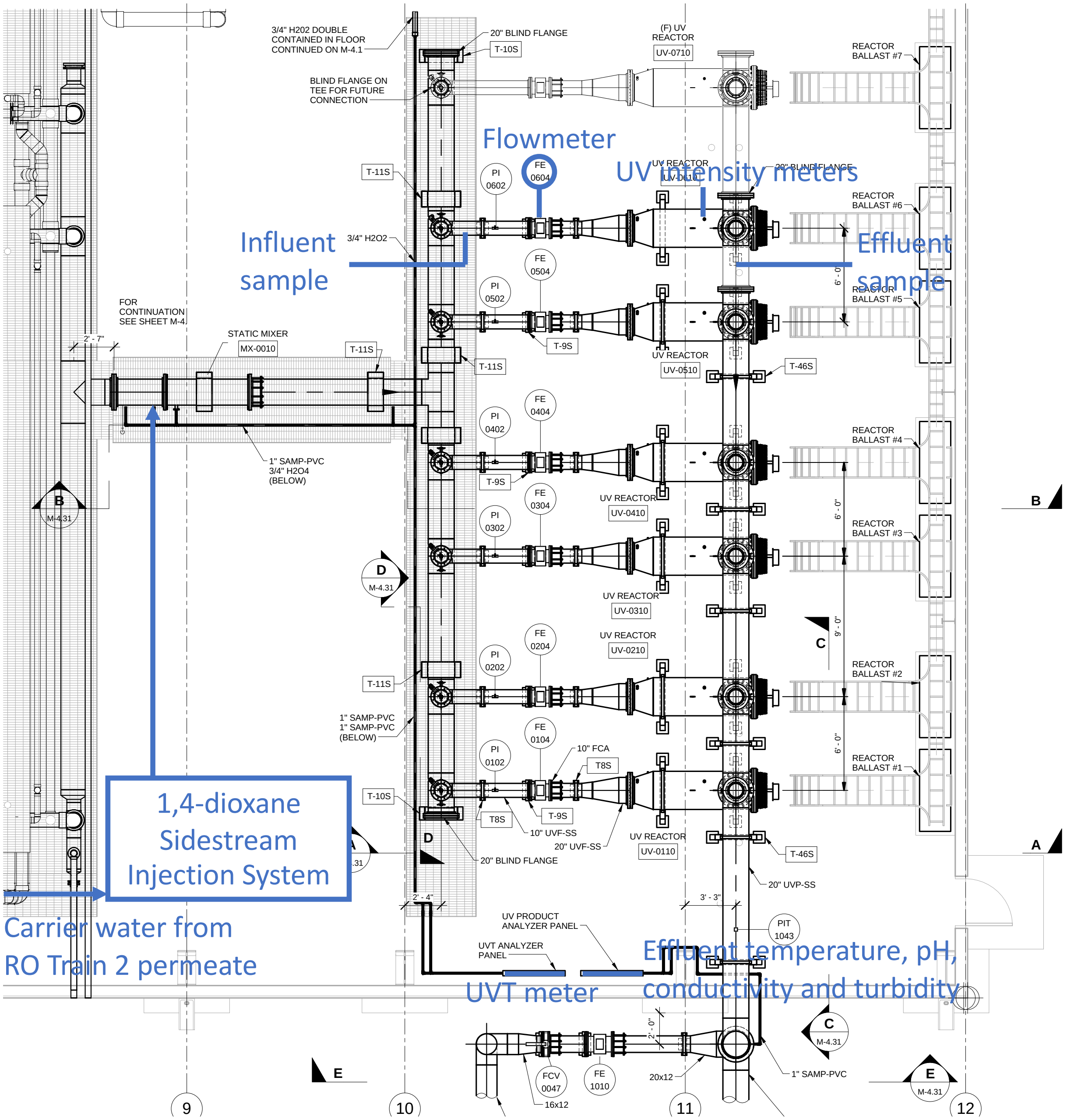
Table 6. UV Dose and Peroxide Dose Example Combinations to Achieve Required UV-Peroxide Dose Product

UV-Peroxide Dose Product Regulatory Limit (mJ-mg/cm^2-L)	Peroxide Dose Setpoint (mg/L)	UV Dose Setpoint (mJ/cm^2)	Applied UV Dose with 10% Safety Factor (mJ/cm^2)	Applied UV-Peroxide Dose Product (mJ-mg/cm^2-L)
8,455	2.2	3,843	4,228	9,300
8,455	3.0	2,818	3,100	9,300
8,455	4.0	2,114	2,325	9,300
8,455	5.0	1,691	1,860	9,300
8,455	6.0	1,409	1,550	9,300

REFERENCES

Monterey One Water. (2020). *UV AOP Test Report.*
Monterey One Water. (2022). *AOP Re-validation Test Plan.*

APPENDIX A: SAMPLING LOCATIONS



Note that UV reactor 7 has not been installed.

APPENDIX B: FEBRUARY 2023 DATA

Test	Date	Time	UVT	Flow	Power	UV Dose	H_2O_2 Dose	Dose Product	Online Process Data						
									UVI 1	UVI 2	Temp	EC	Turb	MF Filt Cl_2	PW TOC
			(%)	(mgd)	(%)	(mJ/cm^2)	(mg/L)	(mg-mJ/ L-cm^2)	(mW/cm^2)	(mW/cm^2)	(ºC)	(µS/cm)	(NTU)	(mg/L)	(µg/L)
7	2/15/23	8:07	94.7	1.36	100	1927	8.0	15,375	54.67	54.08	18.8	57.9	0.03	4.2	258
6	2/15/23	9:08	94.8	1.33	91	1840	7.0	12,873	53.02	51.19	18.9	57.4	0.03	4.2	248
5	2/15/23	9:53	94.9	1.35	80	1771	6.2	10,911	50.19	47.07	18.9	56.9	0.03	4.2	249
4	2/15/23	10:32	95.1	1.36	71	1709	5.2	8,822	46.67	45.29	18.9	57.0	0.03	4.1	251
3	2/15/23	11:11	95.2	1.35	64	1640	4.3	7,043	43.15	43.98	19.0	56.7	0.03	4.2	250
2	2/15/23	11:50	95.2	1.35	53	1583	3.3	5,254	40.91	39.47	19.1	56.9	0.05	4.3	249
1	2/15/23	13:07	95.1	1.35	50	1555	2.2	3,403	39.37	39.92	19.3	57.1	0.05	4.5	252
0	2/15/23	13:40	95.0	0.96	0	0	2.2	0	0	0	19.4	56.8	0.04	4.5	254

Test	UV Dose	H_2O_2 Dose	Dose Product	1,4-Dioxane Concentration (µg/L)								
	(mJ/cm^2)	(mg/L)	(mg-mJ/ L-cm^2)	INF-1	INF-2	INF-3	Avg	EFF-1	EFF-2	EFF-3	Avg	LRV
7	1927	8.0	15,375	11	11	11	11.0	1.3	1.3	1.3	1.3	0.93
6	1840	7.0	12,873	13	12	10	11.7	2.3	1.5	1.6	1.8	0.81
5	1771	6.2	10,911	13	12	17	14.0	3.2	3.1	-	3.2	0.65
5-DUP	1771	6.2	10,911	14	13	13	13.3	3.1	3.6	-	3.4	0.60
5-AVG*	1771	6.2	10,911	13.5	12.5	15.0	13.7	3.15	3.35	-	3.25	0.62
4	1709	5.2	8,822	12	12	12	12.0	3.8	3.7	3.9	3.8	0.50
3	1640	4.3	7,043	12	13	12	12.3	4.7	4.9	5.0	4.9	0.40
2	1583	3.3	5,254	11	12	11	11.3	5.8	-	6.3	6.1	0.27
1	1555	2.2	3,403	16	16	16	16.0	9.3	9.1	9.4	9.3	0.24
0	0	2.2	0	15	15	15	15.0	15	16	16	15.7	-0.02

*5-AVG is the average of Test 5 and Test 5-DUP data

Test	UV Dose	H_2O_2 Dose	Dose Product	M1W Lab Data							
				Alkalinity		Ammonia		Nitrite		Nitrate	
				(mg/L as $CaCO_3$)		(mg/L as N)		(mg/L as N)		(mg/L as N)	
	(mJ/cm^2)	(mg/L)	(mg-mJ / L-cm^2)	INF	EFF	INF	EFF	INF	EFF	INF	EFF
7	1927	8.0	15,375	21	13	1.8	1.3	0.05	<0.02	0.17	0.43
6	1840	7.0	12,873	21	14	1.8	1.3	0.06	<0.02	0.17	0.41
5	1771	6.2	10,911	20	14	1.8	1.3	0.06	<0.02	0.16	0.41
4	1709	5.2	8,822	21	14	1.7	1.3	0.06	<0.02	0.17	0.42
3	1640	4.3	7,043	20	9	1.7	1.3	0.06	<0.02	0.18	0.41
2	1583	3.3	5,254	21	14	1.6	1.3	0.07	<0.02	0.23	0.43
1	1555	2.2	3,403	22	15	1.7	1.4	<0.1	<0.02	0.26	0.44
0	0	2.2	0	21	21	1.8	1.8	0.06	0.06	0.22	0.20

Test	UVT	UV Dose	H_2O_2 Dose	Dose Product	Field Grab Data																			
					pH		Temperature		Conductivity		UVT		Total Chlorine		Mono-chloramine		Free Ammonia		Nitrite		H_2O_2	
							(°C)		(µS/cm)		(%)		(mg/L as Cl_2)		(mg/L as Cl_2)		(mg/L as N)		(mg/L as N)		(mg/L)	
	(%)	(mJ/cm²)	(mg/L)	(mg-mJ/L-cm²)	INF	EFF	INF	EFF	INF	EFF	INF	EFF	INF	EFF	INF	EFF	INF	EFF	INF	EFF	INF	EFF
7	94.7	1927	8.0	15,375	5.18	5.03	18.5	18.6	50.7	53.8	94.4	98.2	3.9	1.8	3.68	0.53	0.72	0.31	0.005	0.027	8.78	7.33
6	94.8	1840	7.0	12,873	5.25	5.08	18.4	18.5	49.2	53.0	94.4	98.1	4.0	1.6	3.60	0.30	0.92	0.90	0.003	0.025	7.90	6.52
5	94.9	1771	6.2	10,911	5.25	5.08	18.4	18.5	49.2	53.0	94.6	98.1	4.0	1.6	3.60	0.30	0.92	0.90	0.003	0.025	6.95	5.84
4	95.1	1709	5.2	8,822	5.33	5.04	18.4	18.8	49.2	52.1	94.9	98.2	3.9	1.7	3.88	0.57	0.96	0.87	0.003	0.024	5.67	4.89
3	95.2	1640	4.3	7,043	5.32	5.12	18.4	18.7	48.9	52.1	94.8	98.2	3.9	1.7	3.88	0.78	0.92	1.17	0.005	0.021	4.96	4.29
2	95.2	1583	3.3	5,254	5.30	5.03	18.5	18.9	49.0	52.0	94.9	98.1	4.2	1.6	3.96	0.93	0.92	1.23	0.004	0.024	4.02	3.54
1	95.1	1555	2.2	3,403	5.29	5.14	18.8	19.1	49.6	52.4	95.0	98.3	4.2	1.6	4.08	0.93	1.12	1.14	0.001	0.020	2.73	2.43
0	95.0	0	2.2	0	5.24	5.25	19.1	19.1	49.2	49.2	94.9	94.9	4.2	4.3	4.00	3.84	0.96	0.99	0.003	0.001	2.80	2.70

APPENDIX C: WATER QUALITY METHODS

Table A1. Field Water Quality Methods

Parameter	Method
UVT	RealTech UV_{254} Field Meter
H_2O_2	Titanium oxalate
Total Chlorine	Hach DPD
Monochloramine	Hach ChemKey
Conductivity	Hach MP-6p Portable Meter
pH	Hach MP-6p Portable Meter
Temperature	Hach MP-6p Portable Meter
Free Ammonia	Hach ChemKey
Nitrite	Hach ChemKey

Table A2. Laboratory Water Quality Methods

Parameter	Method	RDL
1,4-dioxane	EPA 522	0.07 mg/L
Alkalinity	SM 2320 B	3 mg/L
Ammonia	SM 4500-NH3 C	0.4 mg/L
Nitrite	EPA 300.0	0.02 mg/L
Nitrate	EPA 300.0	0.02 mg/L

APPENDIX D

Justification for Additional Pathogen Removal Credits

TECHNICAL MEMORANDUM

Draft Date: March 28, 2019
Final Date: April 2, 2019

Authors: Elaine W. Howe, P.E., BCEE
John D. Kenny, P.E.

Reviewers: R. Shane Trussell, PhD, P.E., BCEE

Subject: Justification for Additional Pathogen Treatment Credit for Monterey One Water's Advanced Water Purification Facility

EXECUTIVE SUMMARY

Monterey One Water (M1W) is following recommendations from the National Water Research Institute's (NWRI) Independent Advisory Panel (IAP) to maximize pathogen treatment credit through its existing wastewater Regional Treatment Plant (RTP) and the Advanced Water Purification Facility (AWPF) that will be operational this summer. The IAP recommended credit through the (1) the RTP, (2) ozonation, (3) enhanced RO credit, and (4) chlorination, noting that these credits will provide redundancy to offset unforeseen unit process excursions.

M1W's previously submitted (November 2017) Title 22 Engineering Report showed 12.4-log virus (V), 11-log *Giardia* cyst (G), and 11-log *Cryptosporidium* oocyst (C) treatment credit, which exceeded the 12/10/10 log regulatory requirements for V/G/C. As a first step towards implementing additional pathogen treatment credit, M1W is proposing a three-surrogate membrane integrity monitoring approach—based on strontium, total organic carbon (TOC) and/or electrical conductivity (EC) rejection—consistent with the approach used at the City of San Diego's North City Pure Water Facility for which DDW recently granted conditional approval. Using this approach, M1W expects to achieve a minimum of 2.5-log V/G/C removal credit for the RO system, which increases the overall treatment credit to 13.9/12.5/12.5 log V/G/C.

This technical memorandum (TM) provides justification for the three-surrogate approach for RO integrity monitoring to achieve the increased treatment credit, as well as an estimate of treatment credit for the other processes included in the IAP recommendation. M1W may pursue credit for the other processes in the future, following demonstration validation testing for DDW approval.

1 - BACKGROUND

Monterey One Water (M1W) is implementing the Pure Water Monterey (PWM) groundwater replenishment project (Project) that will provide (1) purified recycled water for replenishment of the Seaside Groundwater Basin that serves as a drinking water supply; (2) purified recycled water for landscape irrigation by the Marina Coast Water District (MCWD); and (3) additional tertiary disinfected recycled water to augment the Castroville Seawater Intrusion Project's (CSIP) agricultural irrigation supply. M1W's Advanced Water Purification Facility (AWPF) is currently under construction and expected to startup in the summer of 2019, with a production capacity of 5 MGD.

The Project will enable the California American Water Company (CalAm) to reduce its diversions from the Carmel River system by 3,500 acre-feet per year (AFY) by injecting the same amount of product water into the Seaside Basin. The first 1,000 AF will constitute an operational reserve, which will be augmented to 1,750 AF over the first years of operation. An additional 200 AFY of purified water may be injected for development of a drought reserve for the CSIP for a maximum drought reserve of 1,000 AF.

M1W contracted with the National Water Research Institute (NWRI) to coordinate an Independent Advisory Panel (IAP) to provide expert peer review of the technical, scientific, regulatory, policy, and outreach aspects of the Project. The most recent meeting of the IAP was October 3 and 4, 2018. At this meeting, additional pathogen crediting alternatives were presented to the IAP, including crediting the primary and secondary process of the Regional Treatment Plant, ozonation, reverse osmosis (RO) using total organic carbon (TOC) and strontium, and chloramine disinfection in the conveyance pipeline. The Panel recommended maximizing pathogen treatment credit through the RTP and the AWPF in order to provide pathogen credit redundancy to offset unforeseen unit process excursions, and to prioritize the four alternatives presented. These alternatives utilize existing treatment processes.

In September 2016, the Division of Drinking Water (DDW) approved the Engineering Report for M1W's 4 MGD AWPF. Since that time, M1W entered into an agreement with MCWD to provide 600 AFY of purified water from the product water conveyance pipeline. In order to provide the additional production, the capacity of the AWPF was revised from 4 MGD to 5 MGD. The pathogen treatment credit approved by DDW in the initial 4 MGD Engineering Report (shown in **Table 1)**, was not impacted by the capacity increase as the treatment train remained the same and the injection flowrate did not increase.

M1W updated the Engineering Report in November 2017 to address the AWPF production increase, final design, and waste discharge and water recycling reporting requirements. The updated Engineering Report included the pathogen crediting table from the September 2016 version. As indicated, the pathogen treatment credit exceeded the required credit for virus, *Giardia* cysts, and *Cryptosporidium* oocysts. Per the IAP's recommendation, and due to uncertainty with the underground retention time, since the required tracer test has not yet been conducted, M1W is pursuing additional pathogen treatment credit for processes that are presently under-credited but that are known to effective treat (remove and/or deactivate) pathogens and viruses.

This technical memorandum provides justification for receiving higher pathogen reduction credit through the RO membranes based on rejection of additional surrogates besides electrical conductivity (EC). DDW has already conditionally approved this crediting option at another advanced treatment potable reuse facility—the City of San Diego's North City Pure Water Facility—as will be discussed in this technical memorandum (TM).

Table 1. Pathogen Log Reduction Credit in M1W's Approved September 2016 and Draft November 2017 Engineering Reports

Treatment Process	**Treatment Confirmation**	**Log Reduction Credits**		
		Virus	*Giardia*	*Crypto*
Regional Treatment Plant, Primary and Secondary	Credit not pursued	0	0	0
Ozone	Credit not pursued	0	0	0
Membrane Filtration (MF)	Pressure decay test; filtrate turbidity	0	4	4
Reverse Osmosis (RO)	Electrical conductivity removal	1	1	1
UV/AOP	UV dose	6	6	6
Disinfection with Chlorine	Credit not pursued	0	0	0
Underground Residence Time in Aquifer	Modeled underground time with 0.5 modeling credit factor	5.4	0	0
Total Expected Credit		**12.4**	**11**	**11**
Required Credit		**12**	**10**	**10**

2 - PATHOGEN REMOVAL THROUGH REVERSE OSMOSIS

Pure Water Monterey has been approved for a log removal credit of 1 through the RO system, using daily average reduction of EC, with the option for using TOC as an alternate surrogate parameter. Through this TM, M1W is providing justification and requesting DDW approval to use a three-surrogate monitoring approach, like what DDW approved for the Pure Water San Diego (PWSD) Project—that is, the use of strontium, TOC, and EC.

The Pure Water San Diego Program has a philosophy of exceeding minimum pathogen log removal value (LRV) requirements for improved operational reliability, and sought to enhance the awarded pathogen removal credit for processes that are potentially under credited, such as reverse osmosis. Typically, reverse osmosis integrity monitoring via TOC or EC provides no greater than 2-logs of treatment credit, yet studies have shown that RO membranes can reject as much as 6-logs of virus, the smallest in size of the regulated pathogens. Microbial surrogates, specifically male-specific bacteriophage (MS2), are often used to validate pathogen removal across RO membranes due to their similarities to enteric virus (Pype et al., 2016a). **Table 2** provides a summary of recent studies evaluating removal of MS2 by RO membranes.

Table 2. Log removal values of studies evaluating removal of MS2 by RO

MS2 Log Removal Value (LRV)	Reference
3 – 4.8	Kruithof et al. (2001)
4	Lozier et al. (2003)
5.4	Mi et al. (2004)
7	Casani et al. (2005)
4.2 – > 6	Pype et al. (2016b)
> 6.2	Antony et al. (2016)
4.6 – 7.3	Trussell Technologies (2017)

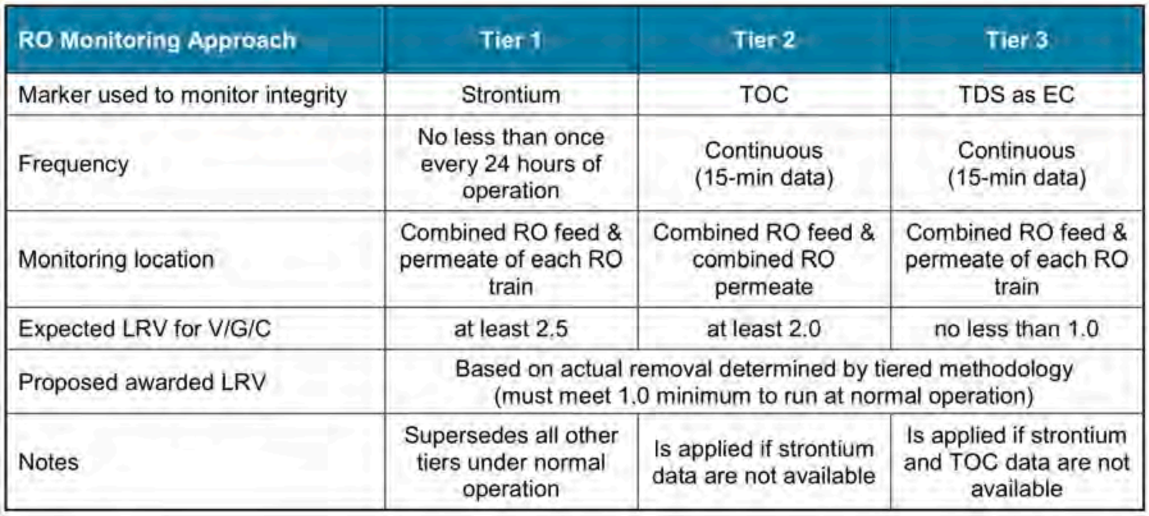
Demonstrating pathogenic microorganism control in the RO process involves the use of surrogate parameters for performance and integrity monitoring. Most facilities measure TOC or electrical conductivity (EC) reduction across the RO membranes as surrogates for pathogen log reduction.

The City of San Diego recently completed a monitoring program at their 1 MGD North City Demonstration Pure Water Facility (NCDPWF) to test alternative surrogate molecular markers for RO integrity monitoring and pathogen crediting. This demonstration testing showed that strontium rejection through the RO membranes provided a conservative assessment of MS2 virus rejection under both intact and compromised conditions, while providing higher log removal values (LRVs) than the typical surrogates EC and TOC. This demonstration testing used the Hydranautics ESPA2 LD RO elements, which are the same membranes being installed in the PWM AWPF.

As a result of the City of San Diego's monitoring program, a three-tiered RO approach for integrity monitoring and pathogen reduction crediting (for virus, *Giardia* cysts and *Cryptosporidium* oocysts) was included in its Title 22 Engineering Report for the North City Pure Water Facility for the Pure Water San Diego (PWSD) Project (City of San Diego, June 2018). As discussed in the PWSD Engineering Report, the first tier of pathogen credit will be based on strontium rejection as measured once daily in the combined RO feed and the permeate of each RO train. The second tier of pathogen credit will be based on TOC rejection calculated from continuous online monitoring of the combined RO feed and the combined RO permeate. The third and last tier for pathogen credit will be based on continuous on-line EC monitoring of the combined RO feed and combined RO permeate of each RO train.

The City of San Diego's ranking of tier priority for Virus/*Giardia*/*Cryptosporidium* (V/G/C) LRV credit is (1) Tier 1 strontium rejection, (2) Tier 2 TOC rejection and (3) Tier 3 EC rejection. Tier 1 supersedes all other tiers under normal operation. Tier 2 is applied if strontium data are not available. Tier 3 is applied if both strontium and TOC data are not available. PWSD was given conditional approval of this pathogen crediting approach from DDW. The expected LRV credit for V/G/C at the NCPWF is shown in **Table 3**.

Table 3. Tiered Pathogen Crediting Approach for the City of San Diego's NCPWF (City of San Diego, June 2018)



RO Monitoring Approach	Tier 1	Tier 2	Tier 3
Marker used to monitor integrity	Strontium	TOC	TDS as EC
Frequency	No less than once every 24 hours of operation	Continuous (15-min data)	Continuous (15-min data)
Monitoring location	Combined RO feed & permeate of each RO train	Combined RO feed & combined RO permeate	Combined RO feed & permeate of each RO train
Expected LRV for V/G/C	at least 2.5	at least 2.0	no less than 1.0
Proposed awarded LRV	Based on actual removal determined by tiered methodology (must meet 1.0 minimum to run at normal operation)		
Notes	Supersedes all other tiers under normal operation	Is applied if strontium data are not available	Is applied if strontium and TOC data are not available

To provide justification for implementing a similar three-surrogate approach at the AWPF, M1W has conducted parallel sampling of EC, TOC, and strontium rejection across the ESPA2 LD RO elements at its Demonstration Facility for the past 8 months. Conductivity and strontium results were based on grab samples, while RO permeate TOC values were based on an online TOC analyzer. Results are presented in **Figure 1**. Monitored LRVs can be summarized as follows:

- Strontium LRVs were all greater than 2.5-log, and ranged from 2.6-log to greater than 3.4-log. EPA Method 200.8 was used for strontium analyses, with a lab determined Reporting Limit of 0.15 µg/L.
- TOC LRVs were always greater than 1.5-log, and ranged from 1.6-log to 2.3-log.
- EC LRVs were always greater than the currently approved minimum of 1.0-log, and ranged from 1.3-log to 1.5-log.

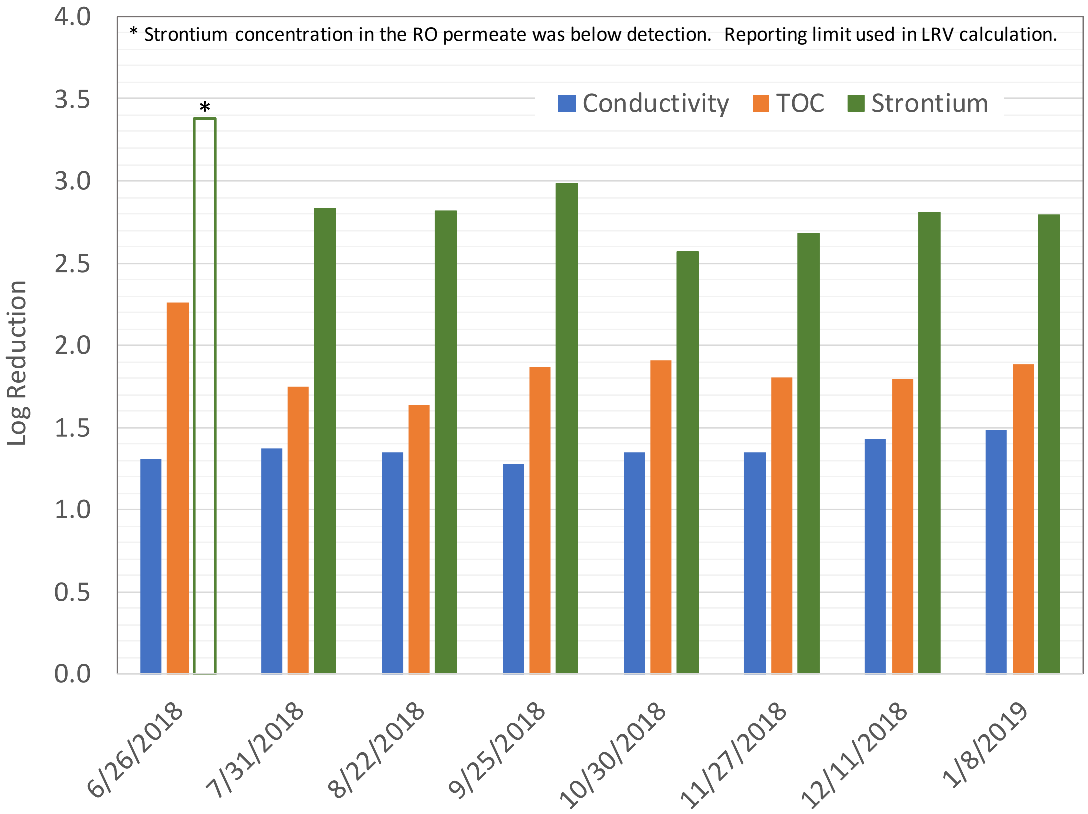


Figure 1. Log Removals for EC, TOC and Strontium Measured at M1W's Demonstration Facility with ESPA2 LD RO Elements

Like what was use for PWSD, M1W will monitor rejection of all three surrogates—strontium, TOC and conductivity—across the RO membranes. M1W proposes to report LRVs for all three surrogates, as long as data is available, and to receive pathogen removal credit for the largest measured LRV.

Strontium rejection across the RO system will be calculated based on measured strontium concentrations, from grab samples collected once daily in the RO feed and the combined permeate of each RO train. Concurrently, pathogen credit will be calculated from TOC rejection across the RO system, as determined from continuous online monitoring of the RO feed and the combined RO permeate. The third measure of membrane integrity and pathogen LRV will be based on continuous on-line EC monitoring of the RO feed and combined RO permeate of each RO train. Log reduction will be reported to DDW for all three surrogates (unless data is not available for the other surrogate(s)) and the surrogate that provides the largest log reduction will be used for calculating pathogen LRV. Where LRV is measured and calculated for each RO train (e.g., strontium), the lowest per train LRV will be reported. The expected minimum pathogen LRV for each surrogate is (a) at least 2.5 log for strontium rejection, (b) 1.5 log for TOC rejection, and (c) 1.0 log for EC rejection.

A summary of M1W's proposed pathogen LRV crediting approach for the Title 22 Engineering Report is provided in **Table 4**. The revised table of pathogen log reduction credit for M1W's revised Engineering Report, including RO LRV credit based on strontium rejection, is provided in **Table 5**.

Table 4. Proposed Pathogen Crediting Approach for M1W's AWPF RO System

RO Monitoring Approach	Strontium	Total Organic Carbon (TOC)	Electrical Conductivity (EC)
Marker used to monitor integrity	Strontium, TOC and EC if data is available for all surrogates		
Frequency	No less than once every 24 hours of operation	Continuous (15-min data)	Continuous (15-min data)
Monitoring location	Combined RO feed and permeate of each RO train	Combined RO feed and combined RO permeate	Combined RO feed, permeate of each RO train, and combined RO permeate
Expected LRV for V/G/C	at least 2.5	at least 1.5	at least 1.0
Proposed awarded LRV	The maximum calculated LRV based on strontium, TOC and EC rejection, from available data		
Notes	LRV based on the minimum per train strontium rejection	LRV based on continuously measured combined RO feed and combined RO permeate	

Table 5. Proposed Pathogen Log Removal Expectations for the PWM Project's Engineering Report

Treatment Process	Treatment Confirmation	Log Reduction Credits		
		Virus	*Giardia*	*Crypto*
Regional Treatment Plant, Primary and Secondary	Credit not pursued	0	0	0
Ozone	Credit not pursued	0	0	0
Membrane Filtration (MF)	Pressure decay test; filtrate turbidity	0	4	4
Reverse Osmosis (RO)	Electrical conductivity removal	2.5	2.5	2.5
UV/AOP	UV dose	6	6	6
Disinfection with Chlorine	Credit not pursued	0	0	0
Underground Residence Time in Aquifer	Modeled underground time with 0.5 modeling credit factor	5.4	0	0
Total Expected Credit		**13.9**	**12.5**	**12.5**
Required Credit		**12**	**10**	**10**

3 - FUTURE DEMONSTRATION OF PATHOGEN TREATMENT CREDIT

In the future, M1W may decide to pursue additional pathogen credit for above-ground treatment that is already in place, as recommended by the IAP. This additional treatment credit will provide a buffer so that M1W does not have to divert water or shutdown the AWPF for treatment excursions that might prevent M1W from achieving the required 12/10/10 credit for virus/Giardia/Cryptosporidium log removal. Additionally, having this additional pathogen treatment buffer in place is advantageous since results of the tracer test of underground residence time (and associated virus credit) are currently unknown since it cannot begin until the AWPF starts up and injection of purified water begins, and to facilitate future AWPF expansion should the additional capacity of purified water be needed to meet regional water demands.

The following treatment alternatives are considered in this TM for future additional credit:

- Wastewater treatment credit through the RTP for virus, *Giardia* cyst and *Cryptosporidium* oocyst removal credit
- Preozonation disinfection credit for virus
- Chloramine disinfection credit in the conveyance pipeline for virus and *Giardia* cyst credit

These treatment alternatives make use of existing facilities by characterizing them as pathogen treatment barriers. Pathogen log removal credit for these options, however, may require validation study, either at the full-scale facilities or M1W's AWPF Demonstration Facility, for DDW approval. The purpose of this section of this TM is to provide an estimate of the pathogen treatment credit that M1W could claim for in-place treatment processes, contingent upon validation demonstration and DDW approval.

3.1 Pathogen Removal through M1W's Regional Treatment Facility

While pathogen densities in drinking water have been well characterized, there have not been strong drivers to investigate pathogens in wastewaters. Accordingly, few studies have been conducted to date aimed at characterizing pathogens such as enteric virus, *Giardia* cysts, or *Cryptosporidium* oocysts through wastewater treatment facilities. A 2004 study conducted by Dr. Joan Rose and colleagues under a collaborative Water Environment Research Foundation (WERF) research effort has been used as a benchmark for potable reuse projects in the state of California (Rose, 2004). Agencies have proposed estimates of pathogen removal based on values within the literature. More recently, agencies have also conducted pathogen monitoring programs involving measurements of pathogen concentrations (or approved surrogates) through wastewater treatment. Wastewater pathogen crediting approaches must be reviewed by DDW on a case-by-case basis.

3.1.1 Literature-Based Crediting in California

Potable reuse projects in CA have historically requested wastewater pathogen credit based on the Rose et al. (2004) study. This study surveyed six water reclamation facilities in the U.S., with five to six samples collected at each facility. Capacities ranged from 0.9 to 25 mgd, and treatment included conventional activated sludge and nitrification-denitrification. Due to the limited applicability of these results, DDW is moving away from granting significant credit based on these data.

3.1.2 Estimated Removal of Pathogenic Microorganisms at M1W's RTP

The removal of pathogenic microorganisms at M1W's RTP has been studied during two projects: the Recycled Water Food Safety Study ("Food Safety Study") and the Pure Water Monterey Advanced Water Purification Pilot Study ("AWP Pilot Study"). The Food Safety Study was conducted by Bahman Sheikh (consultant), Bob Cooper (University of California at Berkeley and BioVir Laboratories), and Rick Danielson (BioVir Laboratories) from 1997 to 1998 and included seven samples collected on the raw wastewater entering the RTP and from the secondary effluent, and enumerated for *Giardia* cysts[1], *Cryptosporidium* oocysts[1], and fecal coliform. The AWP Pilot Study (conducted 2013 to 2014) included six samples collected from the raw wastewater entering the RTP and six samples from the secondary effluent, with enumeration of *Giardia* cysts[2] and *Cryptosporidium* oocysts[2] on each sample. No virus data were collected during either of these studies. The results from these studies are plotted in **Figures 2 and 3**.

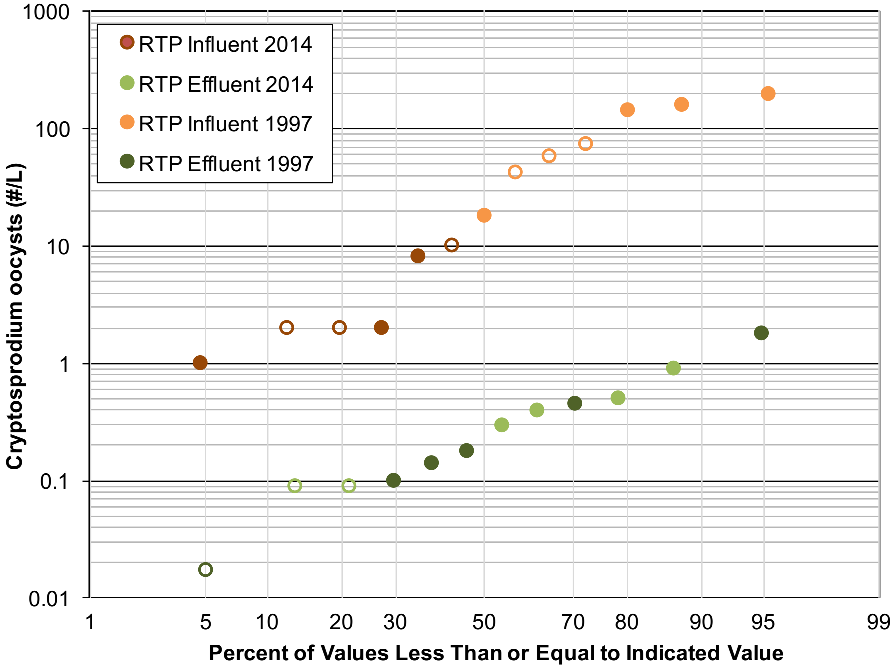


Figure 2. RTP *Cryptosporidium* oocyst distributions (open circles indicate the concentration was below the plotted value, which was the detection limit)

---

[1] *Giardia* cysts and *Cryptosporidium* oocysts were enumerated using USEPA Information Collection Request (ICR) methodologies (1996), which used phase separation with a Percoll-sucrose solution rather than the immunomagnetic separation (IMS) technique in USEPA method 1623.

[2] Laboratory analyses were conducted by BioVir, using the fluorescent microscopy analysis detailed in USEPA Method 1623 and USEPA Method 1693

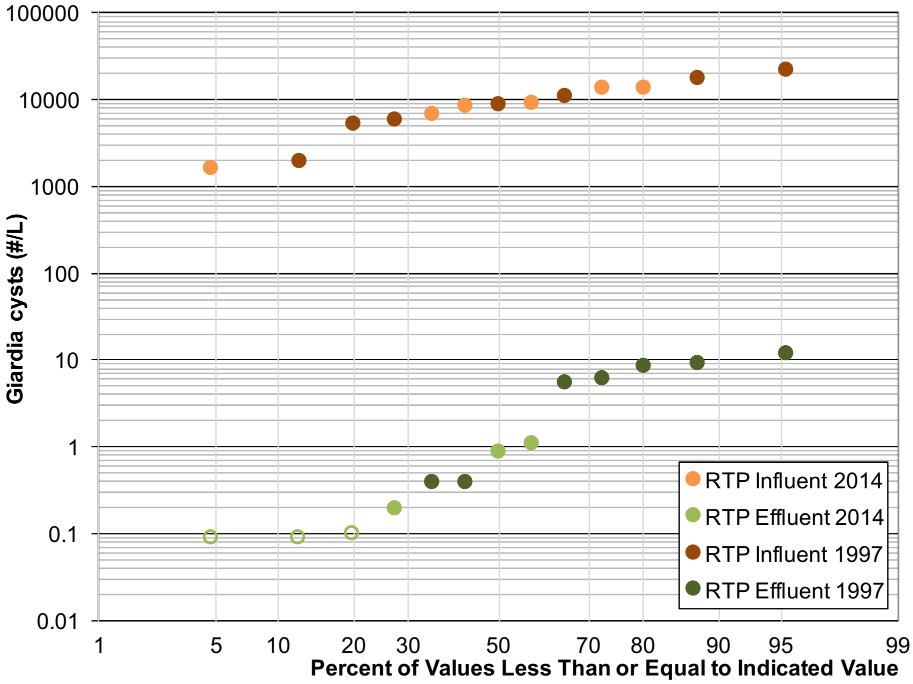


Figure 3. RTP *Giardia* cyst distributions (open circles indicate the concentration was below the plotted value, which was the detection limit)

Two recent potable reuse pathogen monitoring studies at wastewater treatment facilities in California, conducted for the purpose of pathogen crediting, include site-specific work for the City of San Diego's Pure Water Program ("San Diego Pathogen Study") and the City of Oceanside's Pure Water Oceanside project ("Oceanside Pathogen Study"). The Pure Water Oceanside work was conducted at the San Luis Rey Water Reclamation Facility (SLRWRF) and the City of San Diego work was conducted at the North City Reclamation Plant (NCWRP). Process summaries for the SLRWRF and NCWRP (with RTP for reference) are shown in **Table 6**.

Table 6. Process details for wastewater treatment plants with site-specific monitoring studies

Plant	Capacity (mgd)	Primary Clarifiers	Biological Treatment	Solids Retention Time (d)
SLRWRF	13.5	Yes	Conventional Activated Sludge	2-4
NCWRP	30	Yes	Nitrification-Denitrification	10
RTP	29.6	Yes	Trickling Filters + Solids Contact	1-2

Through involvement with both the Oceanside Pathogen Study and San Diego Pathogen Study, Trussell Technologies has been engaged with DDW regarding site-specific monitoring for wastewater pathogen reduction credit. A statistical analysis approach has been presented to and approved by DDW as an acceptable methodology for calculating LRVs through secondary treatment. This approach has required the use of DDW-approved assays, a minimum number of samples, and a Monte Carlo simulation and statistical analysis of the resulting data.

Using this method, credit values have been estimated for the RTP and summarized alongside results from San Diego, Oceanside and Rose et al. (2004) facilities, as shown in **Table 7**. For this analysis, both cases considering (a) all facilities from Rose et al. (2004) as well as (b) only the facilities with flows larger than 10 MGD were analyzed. The analysis for the RTP was performed by combining data from the Food Safety Study and AWPF Pilot Study. These data provide insights into an estimation of the pathogen reduction that could be achieved through M1W's RTP.

The RTP is observed to achieve better levels of *Giardia* cyst and *Cryptosporidium* oocyst removal than the Rose et al. (2004) facilities. Data from Oceanside and San Diego suggest that virus removals up to 2 logs may be achievable; thus, the RTP might demonstrate 0.7-log to 2.0-log reduction of enteric virus if a well-run monitoring study was conducted at the facility.

Table 7. Pathogen LRVs through secondary treatment at M1W, San Diego, Oceanside, and facilities from Rose et al. (2004) via the statistical analysis approach accepted by DDW

Pathogen	RTP (M1W)	NCWRP (San Diego)	SLRWRF (Oceanside)	Rose et al. (2004)[4]	Rose et al. (2004)[5]
Enteric virus[1]	No data	0.8	2.0[2]	0.4	0.7
Giardia cysts[1]	2.5[2,3]	3.2	2.5[2]	0.2	0.9
Cryptosporidium oocysts[1]	0.3[2,3]	1.0	0.6[2]	0	0.2

1 – All non-detects are included in the analysis at the detection limit
2 – Deviates from the DDW-approved approach since a minimum of 20 samples was not taken
3 – Deviates from the DDW-approved approach since non-USEPA Method 1623/1693 data is included
4 – For reference; all facilities were analyzed
5 – For reference; only facilities larger than 10 mgd were analyzed

3.2 Pathogen Disinfection through Ozonation

Ozonation is increasingly being used for non-potable and potable reuse due to its ability to simultaneously disinfect and oxidize wastewater for chemical abatement/pretreatment. The USEPA's Surface Water Treatment Rule (SWTR) has established procedures for accounting for pathogen disinfection credit using ozone for drinking water applications. These guidelines require monitoring of ozone residual through the ozone contactor and calculating the corresponding CT (residual concentration x time) to determine pathogen inactivation credit from the USEPA's CT tables (USEPA, 1990). With ozone, the CT approach accounts for the rapid decay of ozone by allowing integration under the ozone decay curve to determine measured CT.

Applying this CT approach to potable reuse is challenging for secondary and tertiary wastewater matrices. One challenge is that ozone demand in wastewater is high, so it can be difficult to sustain the dissolved ozone residual necessary for CT calculation. A second challenge is that the high ozone doses necessary to generate sufficient residuals can form disinfection by-products (e.g., bromate, NDMA, formaldehyde).

M1W's AWPF design ozone dose does not yield significant ozone residuals, so attempting to apply the drinking water CT concept would require an increase in ozone dose, with associated drawbacks. Instead, the ozone system was designed based around an ozone to total organic carbon (O_3:TOC) ratio, which correlates to CEC destruction and improvement of water quality for downstream membrane operations, as determined from pilot testing. Based on these design assumptions, the AWPF ozonation system will initially be operated at an O_3:TOC ratio of approximately 0.5 g/g including correction for additional ozone demand exerted by nitrite[3]. This O_3:TOC ratio was determined to be sufficient to minimize fouling of microfiltration membranes while also providing significant removal of constituents of emerging concern (CECs).

The O_3:TOC ratio has also been shown to relate to virus inactivation, which offers a potential alternative to the traditional CT approach. Wedeco, the ozone system supplier for the PWM AWPF, conducted a disinfection validation study in 2014 and 2015 that was submitted to DDW for review and approval (Xylem, 2015). The report evaluated virus inactivation as a function of O_3:TOC ratio, and compared the 2014/2015 results with past validation studies done by Wedeco, APTwater, and H2O Engineering in California. A correlation was found to exist between virus inactivation and O_3:TOC ratio (see **Figure 4**), and it was confirmed that significant virus inactivation occurs rapidly, before generating a measurable CT.

Gamage, et al. (2013), did a similar study on filtered secondary effluents from five wastewater treatment plants in the U.S. This study was conducted at the bench-scale and their results were similar to the pilot-scale Wedeco study results, with MS2 inactivation ranging from approximately 5-log to 7.5-log with an O_3:TOC ratio of 0.5.

Therefore, it can be estimated that M1W's AWPF ozonation system will provide approximately 5-log to 7-log inactivation of MS2, at the design O_3:TOC ratio of 0.5. If M1W were to pursue virus inactivation credit for the AWPF ozonation system based on the applied O_3:TOC ratio, validation testing would be performed either at the full-scale AWPF or at its Demonstration Facility, depending on test conditions and test organism (e.g., native phage or MS2). Test results would be submitted to DDW for review and approval of the requested virus inactivation credit.

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[3] Nitrite exerts an immediate ozone demand on a 1:1 stoichiometric basis.

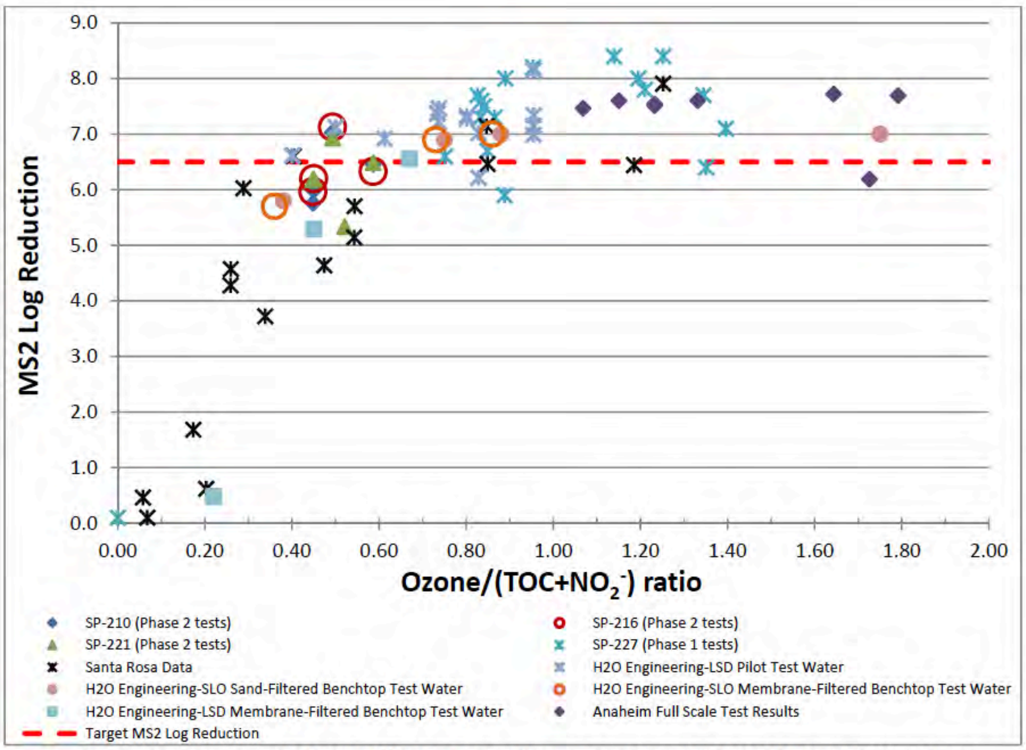

Figure 4. Compilation of Ozone Validation Studies for MS2 Inactivation as a Function of O3:TOC Ratio (Xylem, 2015)

3.3 Disinfection Credit through the Transmission Pipeline

The USEPA's Surface Water Treatment Rule (SWTR) requires potable water treatment facilities using a surface water as its source water to achieve a minimum of 4-log virus removal/inactivation and 3-log *Giardia* cyst removal/inactivation through treatment. The companion SWTR Guidance Manual (USEPA, 1990) defines conditions for receiving treatment credit for virus and *Giardia* cyst inactivation with commonly used water treatment disinfectants, such as free chlorine and combined chlorine (i.e., chloramines). Disinfection requirements are defined by the required CT_{10} that must be achieved for a specified log inactivation, as a function of water temperature and pH, where CT_{10} is the product of disinfectant residual concentration (C) and hydraulic detention time (T) multiplied a baffle factor (T_{10}/T[4]) which accounts for short-circuiting in a basin or pipeline.

The 5 MGD AWPF design includes provisions for use of chloramines in the conveyance system to control biological growth at the wellhead. Sodium hypochlorite will be dosed into the secondary effluent, which is rich in ammonia, forming

---

[4] T_{10} is the time for which 90 percent of the water has been in contact with at least the disinfectant residual concentration, C. A pipeline will have plug flow conditions, with an applicable baffle factor of 1.0 (USEPA, 1990).

chloramines. Chloramines will be carried through the ozone, MF, RO, and UV/H_2O_2 process, with provisions for boosting both the chlorine residual and the ammonia concentration, as needed, prior to the product water pump station and conveyance pipeline. The target wellhead residual combined chlorine concentration is 2 to 4 mg/L as Cl_2, as shown in **Table 8**. The relative location of the PWM injection wellfield to the AWPF PWPS is shown in **Figure 5**. The conveyance pipeline from the PWPS to the injection wellfield is 46,500 feet long (8.8 miles) and made up of pipe segments ranging in diameter from 24-inches to 16 inches.

Table 8. Design Total Chlorine and pH Targets, and Range of Expected Temperature, for the Purified Water at M1W's Injection Wellfield.

Parameter	Unit	Value
Temperature	°C	16 - 24
pH	pH units	7.5 - 8.5
Total Chlorine Residual	mg/L as Cl_2	2 - 4
AWPF Production Capacity	MGD	1.2 – 5.0

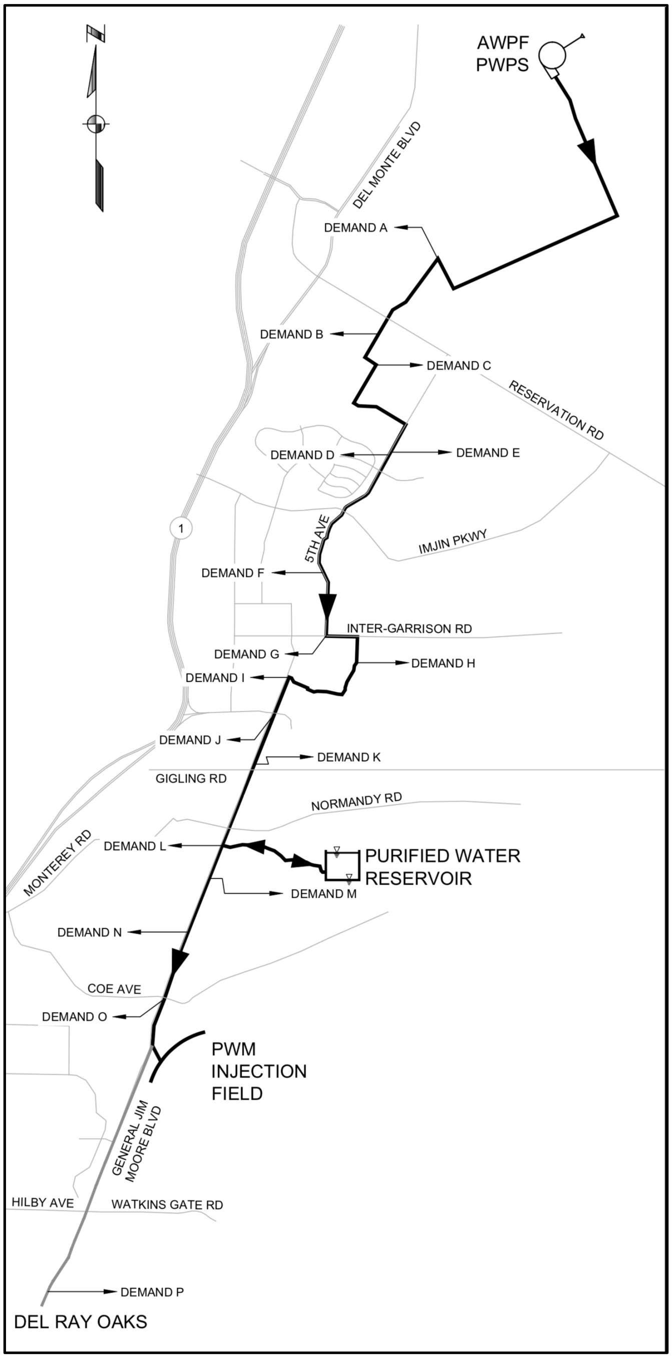

Figure 5. Schematic of the Relative Location of the AWPF Product Water Pump Station and the Purified Water Injection Wellfield, Along the Conveyance Pipeline

The USEPA's SWTR Guidance Manual includes the following caveat regarding use of the USEPA's chloramine CT requirements:

> *For systems applying ammonia ahead of chlorine or preformed chloramines, the EPA recommends that the system demonstrate effective virus inactivation according to the protocol in Appendix G, since the CT values for virus inactivation in Table E-13 only apply to the addition of chlorine prior to ammonia.*

Therefore, in order to claim pathogen inactivation credit for disinfection with chloramines in the conveyance pipeline, M1W will need to consider implementing one of the following two options:

- Add sodium hypochlorite to breakpoint the chloramines to free chlorine at the product water pump station, and then add ammonia at the entry of the conveyance pipeline to form chloramines. This option would allow use of the USEPA's chloramine CT tables for the conveyance pipeline, as well as potentially take advantage of free chlorine CT credit in the AWPF.
- Conduct a virus inactivation study in accordance with the protocol required by the USEPA's SWTR Guidance Manual (USEPA, 1990, Appendix G), using the recommended MS2 bacteriophage, to demonstrate virus inactivation that would be achieved in the conveyance pipeline with chloramines, given that ammonia is present prior to chlorine addition in the AWPF design.

Disinfection credit using the USEPA CT tables was estimated assuming breakpoint chlorination upstream of adding ammonia. Disinfection credit through the conveyance pipeline was calculated for the range of target purified water chlorine residual and pH conditions, temperatures, and flows. Although a pipeline should exhibit plug flow conditions, with a baffle factor close to 1.0, a conservative baffle factor of 0.9 was assumed in the LRV calculations shown in **Table 9**. The maximum virus and *Giardia* cyst credits available under the SWTR Guidance Manual are 4 logs 3 logs, respectively. Additional virus inactivation credit could be available during breakpoint chlorination.

Table 9. Virus and Giardia LRVs Available to PWM for Disinfection with Chloramines in the Conveyance Pipeline

Total Chlorine Residual at Injection Wellfield (mg/L as Cl_2)	Purified Water Production (MGD)	Hydraulic Detention Time[2] (hours)	Water Temp = 15ºC		Water Temp = 25ºC	
			Virus LRV (log)	Giardia LRV (log)	Virus LRV (log)	Giardia LRV (log)
2	1.2 (minimum)	21	4[1]	3[1]	4[1]	3[1]
4			4[1]	3[1]	4[1]	3[1]
2	5.0 (maximum)	5.1	2.4	1.1	4[1]	2.2
4			4[1]	2.2	4[1]	3[1]

[1] Limited by credits available in the Surface Water Treatment Rule Guidance Manual

[2] Conservatively assumes bypassing the Purified Water Reservoir

4 - REFERENCES

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APPENDIX E

Chloramine Inactivation Acceptance and Report

5 Harris Court Bldg. D
Monterey, Ca 93940

Regional Treatment Plant
14811 Del Monte Blvd.
Marina, Ca 93933
Direct: 831.883.6183
Mobile: 831.905.0838
Fax: 831.883.0516
Monterey One Water
Providing Cooperative Water Solutions

From: Bernados, Brian@Waterboards <Brian.Bernados@waterboards.ca.gov>
Sent: Wednesday, January 5, 2022 4:46 PM
To: Alison Imamura <Alison@my1water.org>; Ortiz, Aide@Waterboards <Aide.Ortiz@waterboards.ca.gov>; Amah, Ginachi@Waterboards <Ginachi.Amah@waterboards.ca.gov>; Barnard, Randy@Waterboards <Randy.Barnard@waterboards.ca.gov>
Cc: Joanne Le <joanne@my1water.org>; Mike McCullough <MikeM@my1water.org>; Jose Guzman <joseg@my1water.org>; johnk@trusselltech.com
Subject: RE: Chloramine Virus Inactivation Study Protocol

I have reviewed the report and it is acceptable.

The following equation appears to predict the 95th percentile virus LRV credit via chloramine disinfection.

$$\mathrm{LRV} = 3.62\log((X\ \mathrm{mg/L})(1.06\ \mathrm{Mgal})(1440\ \mathrm{min/day})(0.9)2\hat{}((Y{}^\circ\mathrm{C}-20{}^\circ\mathrm{C})/10{}^\circ\mathrm{C})/(Z\ \mathrm{MGD}))-8.$$

There are a number of variables that need to be monitored online including the following:
- Temperature (degrees C)
- Flow (MGD)
- Chlorine residual (mg/L)

Please provide a description of where these will be monitored.
By residual, is it total chlorine?
Describe the setpoints for each of the 3 variables. Each should have 3 setpoints including the following:
- operational goal
- low alarm warning
- low low shutdown alarm

The Operation Optimization Plan must be updated.

Brian Bernados, Sr. Sanitary Engineer

From: Alison Imamura <Alison@my1water.org>
Sent: Wednesday, December 8, 2021 11:41 AM
To: Ortiz, Aide@Waterboards <Aide.Ortiz@waterboards.ca.gov>; Amah, Ginachi@Waterboards

From: **John Kenny** Johnk@trusselltech.com
Subject: Fwd: Chloramine Virus Inactivation Study Protocol
Date: January 11, 2022 at 2:41 PM
To: Elaine Howe Elaineh@trusselltech.com
Cc: Emily Darby emilyd@trusselltech.com

> Begin forwarded message:
>
> **From:** Jose Guzman <joseg@my1water.org>
> **Subject:** **RE: Chloramine Virus Inactivation Study Protocol**
> **Date:** January 11, 2022 at 1:27:12 PM PST
> **To:** "Bernados, Brian@Waterboards" <Brian.Bernados@waterboards.ca.gov>, Alison Imamura <Alison@my1water.org>, "Ortiz, Aide@Waterboards" <Aide.Ortiz@waterboards.ca.gov>, "Amah, Ginachi@Waterboards" <Ginachi.Amah@waterboards.ca.gov>, "Barnard, Randy@Waterboards" <Randy.Barnard@waterboards.ca.gov>
> **Cc:** Joanne Le <joanne@my1water.org>, Mike McCullough <MikeM@my1water.org>, "johnk@trusselltech.com" <johnk@trusselltech.com>, Tamsen McNarie <tamsen@my1water.org>
>
> Hi Brian,
>
> Here are answers to your questions:
>
> - Temperature and chlorine residual are monitored at the injection wellfield
>
> - Flow is monitored at the Product Water Pump Station
>
> - Chlorine residual is total chlorine residual
>
> - Temperature low alarm warning setpoint: 15°C (expected range 17-27°C)
>
> - Flow high alarm warning: 5.5 mgd (control setpoint range is 1.2 to 5 mgd)
>
> - Chlorine residual operational goal: 2-4 mg/L
>
> - Chlorine residual low alarm warning: 1 mg/L
>
> - Low low shutdown alarms are based on AWPF LRVs
>
> We're expecting to get you the OOP updates in about two weeks.
>
> We're planning to start reporting chloramine LRVs in the January monthly report.
>
> Best,
>
> **Jose O. Guzman**
> Chief Plant Operator
> joseg@my1water.org
>
> Monterey One Water

5 Harris Court Bldg. D
Monterey, Ca 93940

Regional Treatment Plant
14811 Del Monte Blvd.
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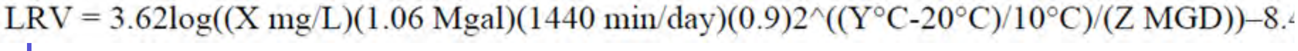

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- Chlorine residual (mg/L)

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Cc: Joanne Le <joanne@my1water.org>; Mike McCullough <MikeM@my1water.org>; Jose Guzman <joseg@my1water.org>;johnk@trusselltech.com
Subject: FW: Chloramine Virus Inactivation Study Protocol

EXTERNAL:

Aide, Ginachi, and Brian,
Would you be willing to have a brief, small-group phone call about the attached study results?
We are starting to implement the SCADA and reporting procedures to put this into effect for our system.
We would really like to receive your approval on the report so we can implement the virus crediting change by the end of the year, if possible.
Thank you!

Alison Imamura, PE, AICP
Principal Engineer

5 Harris Court, Building D
Monterey, CA 93940
Mobile: (831)915-6630

Monterey One Water
Providing Cooperative Water Solutions
www.montereyonewater.org

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To: Ortiz, Aide@Waterboards <Aide.Ortiz@waterboards.ca.gov>; Bernados, Brian@Waterboards <Brian.Bernados@waterboards.ca.gov>; Weininger, Jonathan@Waterboards <jonathan.weininger@waterboards.ca.gov>; Moltrup, Querube@Waterboards <Querube.Moltrup@waterboards.ca.gov>; Rosilela, Sherly@Waterboards <Sherly.Rosilela@waterboards.ca.gov>; Amah, Ginachi@Waterboards <Ginachi.Amah@waterboards.ca.gov>
Cc: Tamsen McNarie <tamsen@my1water.org>; Jennifer Gonzalez <Jennifer@my1water.org>; Jose Guzman <joseg@my1water.org>; Joanne Le <joanne@my1water.org>; Jonathan Mungcal <jonathan@my1water.org>; Mike McCullough (MikeM@my1water.org)

<MikeM@my1water.org>; Paul Sciuto <paul@my1water.org>; davidl@my1water.org; John Kenny <Johnk@trusselltech.com>; 'Conners Denise' <denisec@lwa.com>; Elaine W. Howe (elaineh@trusselltech.com) <elaineh@trusselltech.com>; Jonathan Lear <jlear@mpwmd.net>; 'Maureen Hamilton' <mhamilton@mpwmd.net>; Bishop, James@Waterboards <James.Bishop@Waterboards.ca.gov>; Epp, Jennifer@Waterboards <Jennifer.Epp@waterboards.ca.gov>
Subject: Chloramine Virus Inactivation Study Protocol

Dear Aide and DDW staff,

With this email, M1W is submitting the Chloramine Virus Inactivation Protocol study results report and requesting DDW approval to assign chloramine disinfection virus log reduction credit in the conveyance pipeline based on the results of the inactivation study and the crediting and reporting approach proposed in the attached.

By way of a reminder:

- on August 18, 2021, M1W submitted the Chloramine Virus Inactivation Protocol
- on September 30, 2021, M1W submitted the Engineering Report Addendum that proposed providing virus log reduction credits with chloramines in the conveyance system (see pages 5-3 to 5-4 and 5-14).
- on October 1, 2021, DDW approved the protocol authorizing commencement of the bench scale test.

Thank you so much for your time and effort to review the above and provide prompt approval of the attached and above-listed documents.

Please don't hesitate to reach out to me or Jose Guzman, if you have any questions or need additional information.

Alison Imamura, PE, AICP
Principal Engineer
Phone (mobile): (831)915-6630
Monterey One Water
Providing Cooperative Water Solutions

CHLORAMINE VIRUS INACTIVATION STUDY RESULTS

Pure Water Monterey

Monterey One Water

Date: December 3, 2021

To: Aidé Ortiz, PE and Sherly Rosilela, PE, Division of Drinking Water

From: John Kenny, PE, Elaine Howe, PE (NM), BCEE, Chao Yang, and Rhodes Trussell, PhD, PE, BCEE, NAE, Trussell Technologies, Inc., and Alison Imamura, PE, Joanne Le, and Jose Guzman, Monterey One Water

Subject: Chloramine Virus Inactivation Study Results

EXECUTIVE SUMMARY

Monterey One Water (M1W) operates the Advanced Water Purification Facility (AWPF) as part of the Pure Water Monterey (PWM) Groundwater Replenishment Reuse Project (Project). The AWPF was designed for 5 MGD production and is permitted to inject 3,700 acre-feet per year (AFY) into the Seaside Groundwater Basin. A recently completed intrinsic tracer study revealed shorter than anticipated underground retention times, which is expected to yield less virus reduction credit. M1W is conducting an added tracer study. M1W is also pursuing additional virus reduction credit with chloramines through the conveyance pipeline that carries purified water from the AWPF to the injection wellfield.

Chloramine disinfection CT (disinfectant residual multiplied by contact time) tables are provided for drinking water in the Surface Water Treatment Rule (SWTR) Guidance Manual (USEPA 1991); however, these CT tables assume chlorine is applied ahead of ammonia. Ammonia is present upstream of sodium hypochlorite addition at the AWPF. For cases like this, the SWTR Guidance Manual recommends an inactivation study with bacteriophage MS2 to determine CT values for virus reduction credit. The State Water Resource Control Board Division of Drinking Water (DDW) approved virus inactivation bench testing on October 1, 2021 (Trussell, 2021).

Bench tests were conducted using weekly samples collected from the AWPF. Twenty conditions were tested in triplicate for a total of sixty CT data points. The results demonstrated up to 3.5 log virus reduction with chloramines, depending on flowrate, chloramine residual, and temperature.

M1W requests DDW approval to credit chloramines disinfection through the conveyance pipeline with virus inactivation as proposed herein.

1 INTRODUCTION

Monterey One Water (M1W) operates the Advanced Water Purification Facility (AWPF) as part of the Pure Water Monterey (PWM) Groundwater Replenishment Reuse Project (Project) and began injecting purified water into the Seaside Basin in March 2020. The AWPF treats non-nitrified secondary effluent from the Regional Treatment Plant with ozone, ultrafiltration (UF), reverse osmosis (RO), an ultraviolet light advanced oxidative process with hydrogen peroxide (UV/AOP), post-treatment and chloramines.

The AWPF was designed for 5 MGD production and is permitted to inject 3,700 acre-feet per year (AFY) into the Seaside Groundwater Basin (M1W recently submitted an amended Title 22 Engineering Report associated with a request to increase purified water injection by an additional 600 AFY). The Project recently completed an intrinsic tracer study, and associated groundwater modeling revealed shorter than anticipated underground retention times. The shorter underground retention times are expected to yield less virus reduction credit after review by the State Water Resources Control Board Division of Drinking Water (DDW). M1W is conducting an added tracer study to improve virus log reduction and response time crediting. M1W is also pursuing additional virus reduction credit with chloramines through the conveyance pipeline that carries purified water from the AWPF to the injection wellfield.

The Surface Water Treatment Rule (SWTR) Guidance Manual offers a framework for chloramine virus reduction crediting (USEPA 1991). However, the chloramine CT (disinfectant residual multiplied by contact time) tables in the Guidance Manual assume chlorine is applied ahead of ammonia. For systems with ammonia upstream of sodium hypochlorite addition, as is the case for the AWPF, the SWTR Guidance Manual recommends an inactivation study with bacteriophage MS2 to determine CT values for virus reduction credit. Guidelines for the study are provided in the SWTR Guidance Manual.

The chloramine disinfection process at the AWPF is shown in Figure 1. Sodium hypochlorite is added to the partially decarbonated UV/AOP effluent following sodium hydroxide, calcium chloride, and ammonium sulfate addition (if needed). The partially decarbonated UV/AOP effluent contains chloramines and free ammonia. Operations controls the sodium hypochlorite dose to target a residual of 2 to 4 mg/L as Cl_2 at the end of the conveyance pipeline, for biofouling control. Operations controls the sodium hydroxide to target a pH of 8.0 to 8.5 at the end of the conveyance pipeline. Product water temperature ranges from 17 to 27°C. Online total chlorine, pH and temperature analyzers (Hach CL10s) are installed at the end of the conveyance pipeline and connected to the Project's Supervisory Control and Data Acquisition (SCADA) system. Blackhorse reservoir "floats" on the conveyance pipeline pressure. The shortest conveyance pipeline residence time is when the reservoir level is static.

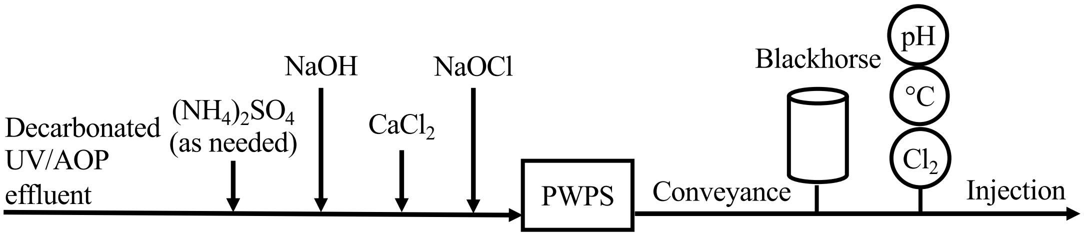


Figure 1. Chloramine Disinfection Process at the AWPF

M1W submitted a chloramine virus inactivation study protocol on August 18, 2021 (Trussell 2021) and received DDW approval of the study protocol on October 1, 2021. This report presents the results of the inactivation study and proposed method for assigning virus reduction credit to the chloramine disinfection process.

2 INACTIVATION STUDY

The chloramine virus inactivation study protocol followed the guidelines described in the SWTR Guidance Manual (USEPA 1991). Test procedures, materials and methods were provided in the August 2021 protocol. A summary is provided below.

2.1 Sample Collection

Starting the first week of October, five-gallon samples of stabilized, partially decarbonated UV/AOP effluent, without sodium hypochlorite addition, were collected on a weekly basis, over a four week period. The AWPF calcium chloride pump failed during week 2's sample collection, and week 4 was added to make up for week 2. Sodium hypochlorite injection to the stabilized water was temporarily halted during sample collection since sodium hypochlorite was added in the lab after MS2 seeding.

Samples were stored in coolers with ice packs and shipped overnight to Trussell Tech's Pasadena laboratory. Upon arrival in the lab, the samples were brought to room temperature, and initial water quality measurements were made. The pH of the samples was within the expected range of 8.0 to 8.5, without adjustment.

2.2 Test Conditions

The following conditions were tested. Test data is provided in Appendix A.

Contact Time: Contact times including 5.1, 6.7, and 21 hours, which correspond to the hydraulic residence time (HRT) of the conveyance pipeline at AWPF flowrates of 5, 3.8, and 1.2 mgd. Contact times of 1.5, 2.3, 2.6, 3.0 and 3.7 hours were also tested.

Chlorine Residual: Chlorine residuals ranging from 0.9 to 4.5 mg/L.

Temperature: Temperatures ranging from 20 to 24°C.

pH: Initial pH values between 8.3 and 8.4.

2.3 Test Procedures

Testing followed these general steps:

1. Upon arrival in the lab, the sample's total chlorine, ammonia, pH, hydrogen peroxide, calcium and alkalinity concentrations were measured and recorded.
2. Dilute chemical stock solutions were prepared the morning of testing. MS2 spiking solution was prepared by diluting the MS2 stock from approximately 1×10^{11} PFU/mL to approximately $1\text{-}5 \times 10^{8}$ PFU/mL.
3. The water sample was brought to temperature.
4. Each 400 to 800 mL water sample was inoculated with 1 to 2 mL of the diluted MS2 stock, and initial samples were taken for MS2 enumeration.
5. Sodium hypochlorite was dosed to achieve the target total chlorine residual at the end of each sample's holding time. Chloramine decay curves were developed using a sample of AWPF UV/AOP water the week prior to disinfection testing.
6. The samples were stirred for the duration of the contact time.

7. At the end of the contact time, aliquots were collected for total chlorine and MS2 analyses. Aliquots collected for MS2 analysis were quenched to stop additional inactivation. Final temperature and pH were also measured and recorded.

2.4 Inactivation Data

The data used in the analysis described in this report are provided in Appendix A. Up to three dilutions were plated for each condition and replicate to target 20 to 200 plaque forming units (PFU). Samples were replated if the original plates were not within range.

3 DATA ANALYSIS

Inactivation is temperature dependent, and all CT values were temperature corrected to 20ºC from the test temperatures which ranged from 20ºC to 24ºC. The SWTR Guidance Manual CT-temperature relationship of a two-fold decrease in CT for every 10ºC temperature increase was used, as the following:

$$CT_{20^\circ C} = CT_{Temp^\circ C}\, 2^{\left(\frac{Temp^\circ C - 20^\circ C}{10^\circ C}\right)}$$

The temperature corrected CT values were modeled against LRV with the Collins-Selleck model (Selleck, et al., 1978). The Collins-Selleck model characterizes pathogen disinfection as a linear relationship between LRV and log(CT). A least squares regression with the Collins-Selleck model is shown in Figure 2. Upper and lower bounds were selected by adjusting the intercept to capture the lowest point. The model is shown in Figure 3 as LRV versus CT.

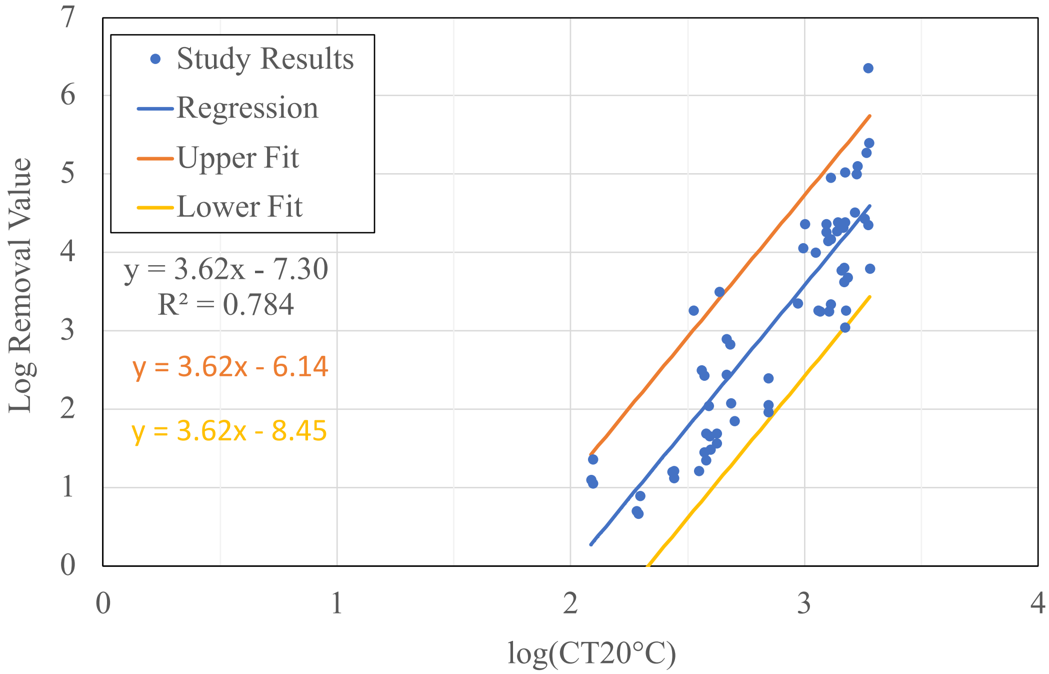


Figure 2. Collins-Selleck Model of Inactivation Study Results: LRV versus Log(CT20°C)

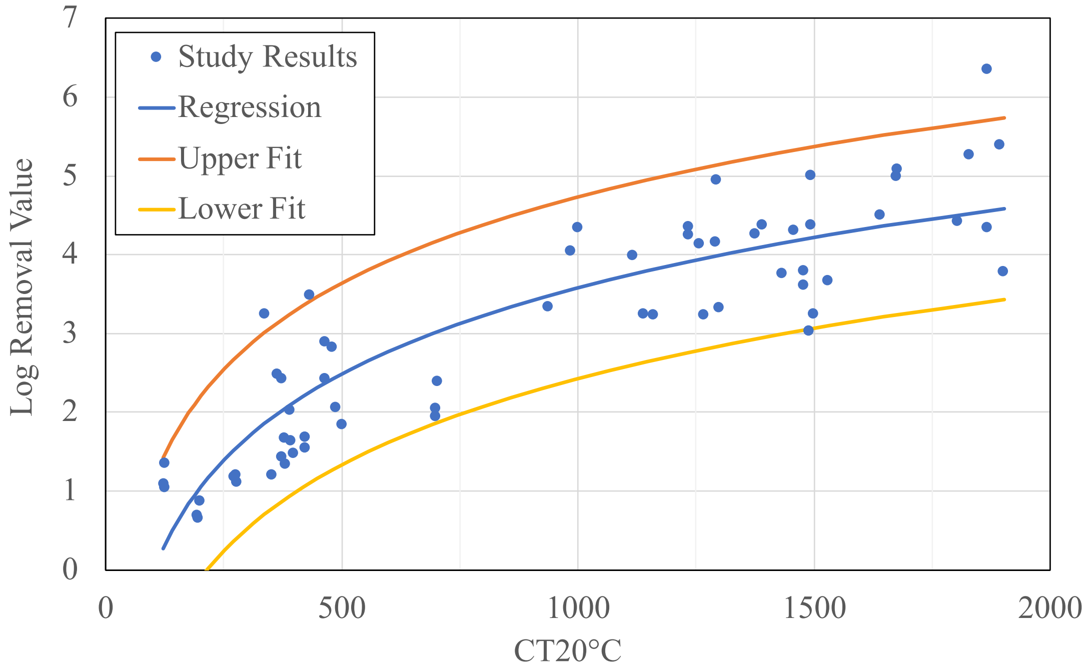


Figure 3. Collins-Selleck Model of Inactivation Study Results: LRV versus CT20°C

4 VIRUS INACTIVATION CREDITING

The proposed chloramine virus reduction approach is described in this section.

The conveyance pipeline from the PWPS to the injection wellfield is 8.8 miles long and consists of pipe segments ranging in diameter from 16 inches to 24 inches. Pipeline characteristics and HRTs are shown in Table 1.

Table 1. Conveyance Pipeline Characteristics

Parameter	Value	Units
Length	46,500	ft
Diameter	16-24	in.
L/D, weighted average	24,630	ft/ft
Volume	1.06	MG
HRT, 5 MGD	305	min
HRT, 3.8 MGD	402	min
HRT, 1.2 MGD	1,272	min
T_{10} baffle factor, assumed	0.9	min/min

Total chlorine residual, water temperature, and pH are continuously monitored at the injection wellfield and flow is continuously monitored at the PWPS. Two amperometric analyzers (1 duty and 1 standby) are installed at the site of deep injection well No. 4 (DIW-4). DIW-4 is the first

DIW off the conveyance pipeline and the sample tap is located on the conveyance pipeline. These continuously monitored parameters are recorded in M1W's Historian.

Trussell and M1W propose crediting chloramine virus log reduction based on the lower model fit, with temperature correction, as shown in the following equation (an example calculation is provided in the Appendix):

$$LRV = 3.62 \log\left(CT_{10} 2^{\frac{Temp - 20°C}{10°C}}\right) - 8.45$$

Where CT_{10} is CT multiplied by the assumed T_{10} baffling factor of 0.9.

M1W will program the virus LRV calculation into SCADA so that LRV can be calculated using paired temperature and chlorine residual measurements. M1W proposes to report the daily minimum chloramine virus LRV, based on 15-minute rolling averages, in the monthly compliance reports.

M1W requests DDW approval to assign chloramine disinfection virus log reduction credit in the conveyance pipeline based on the results from the inactivation study documented herein and the crediting and reporting approach proposed herein.

5 REFERENCES

Crittenden, J. C., R. R. Trussell, D. W. Hand, K. J. Howe and G. Tchobanoglous (2012). Water Treatment: Principles and Design, Third Edition, John Wiey & Sons, Inc.

Selleck, R. E., B. M. Saunler, H. F. Collins (December 1978). "Kinetics of Bacterial Deactivation with Chlorine." Journal of the Environmental Engineering Division, 1197-1212.

Trussell (August 2021). Chloramine Virus Inactivation Study Protocol to Division of Drinking Water.

USEPA (March 1991). Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources. Office of Drinking Water.

APPENDIX A

Chloramine Bench Test Data Tables

Table A.1 – Raw Water Quality

Round	**1**	**2**	**3**
pH	8.3, 8.4	8.3	8.4
H_2O_2 (mg/L)	5.9	5.4	5.6
Total Chlorine (mg/L Cl_2)	0.40	0.19	0.22
Ammonia (mg/L N)	2.1	1.9	2.0
Temperature (°C)	--	22	21
Calcium (mg/L as $CaCO_3$)	--	43	38
Alkalinity (mg/L as $CaCO_3$)	--	32	35

Table A.2 - Week 1 MS2 Disinfection Test Data (October 5)

				Chem Addition			Initial Water Quality							Final Water Quality										
									MS2 at dilution of 1 mL (PFU)									MS2 at dilution of 1 mL (PFU)						
Label	**Target Chlorine Dose**	**Contact Time (hr)**	**Replicate**	**NaOH Dose (mg/L)**	**NaOCl Dose (mg/L Cl2)**	**NH3 Dose (mg/L N)**	**Initial Cl2 (mg/L Cl2)**	**Initial H2O2 (mg/L)**	**-1**	**3**	**4**	**5**	**Initial MS2 (PFU/mL)**	**Final pH**	**Final H2O2 (mg/L)**	**Final Cl2 (mg/L Cl2)**	**Final Temp (°C)**	**-1**	**0**	**1**	**2**	**3**	**4**	**Final MS2 (PFU/mL)**
1-5-1	1	5.1 (306 min)	1	0	0.88	0				127	15	2	1.27E+05	7.9	5.6	0.9	22.8			7	1	0		7.00E+01
1-5-2			2	0	0.88	0				157	19	3	1.57E+05	8.0		1.0	22.8			58	3	0		5.80E+02
1-5-3			3	0	0.88	0				128	17	0	1.28E+05	7.9		1.0	22.4			41	5	0		4.10E+02
1-6-1		6.7 (402 min)	1	0	0.88	0				127	15	2	1.27E+05	7.9	3.7	0.9	22.5			4 (0)	0	0		4.00E+01
1-6-2			2	0	0.88	0				157	19	3	1.57E+05	8.0		1.0	22.5			23	2	1		2.30E+02
1-6-3			3	0	0.88	0				128	17	0	1.28E+05	7.9		1.0	22.0			16	2	0		1.60E+02
1-21-1		21 (1260 min)	1	0	1.4	0				123	10	1	1.23E+05	7.9	5.2	1.0	21.4	50	7	2				5.00E+00
1-21-2			2	0	1.4	0				129	10	1	1.29E+05	7.9		0.9	21.2	71	3	2				7.10E+00
1-21-3			3	0	1.4	0				143	10	2	1.43E+05	7.9		0.9	21.2	61	31	2				6.10E+00
4-5-1	4	5.1 (306 min)	1	0	4.8	0				127	13	2	1.27E+05	7.9	4.9	3.7	21.9	14	3					1.40E+00
4-5-2			2	0	4.8	0				122	10	0	1.22E+05	7.9		3.8	21.5	82	8					8.20E+00
4-5-3			3	0	4.8	0				134	15	0	1.34E+05	8.0		4.1	21.3	71	10					7.10E+00
4-6-1		6.7 (402 min)	1	0	4.8	0				127	13	2	1.27E+05	7.9	3.1	3.7	21.7	10	2					1.00E+00
4-6-2			2	0	4.8	0				122	10	0	1.22E+05	7.9		3.8	21.3	12	0					1.20E+00
4-6-3			3	0	4.8	0				134	15	0	1.34E+05	8.0		3.8	21.0	41	4					4.10E+00
C4-6-1	4	6.7 (402 min)	1	0	4.8	0			0				0.00E+00	8.0	3.0	3.4	21.8	0						0.00E+00
C4-6-2			2	0	4.8	0			0				0.00E+00					0						0.00E+00
C4-6-3			3	0	4.8	0			0				0.00E+00					0						0.00E+00
C0-6-1	0 (control quench)	6.7 (402 min)	1	0	0	0	0	0.12		151	23	3	1.51E+05	7.7	0.1	0	21.6				TNTC	92	17	9.20E+04
C0-6-2			2	0	0	0				139	16	1	1.39E+05								TNTC	106	15	1.06E+05
C0-6-3			3	0	0	0				143	30	2	1.43E+05								TNTC	121	12	1.21E+05

Note 1: Final Cl2 can be higher than NaOCl dose because initial Cl2 was greater than zero

Note 2: Grey shading under Initial Water Quality MS2 at dilution of 1 mL (PFU) indicates that the MS2 values are copied from the cells above, since the final effluent MS2 samples were taken from shared reactors

Note 3: MS2 counts next to parentheses indicates recounts and MS2 counts in parentheses indicate original counts

Note 4: TNTC is Too Numerous To Count

Table A.3 - Week 3 MS2 Disinfection Test Data (October 19)

Label	Target Chlorine Dose	Contact Time (hr)	Replicate	Chem Addition			Initial Water Quality					Final Water Quality										
				NaOH Dose (mg/L)	NaOCl Dose (mg/L Cl2)	NH3 Dose (mg/L N)	Initial Cl2 (mg/L Cl2)	Initial H2O2 (mg/L)	MS2 at dilution of 1 mL (PFU)		Initial MS2 (PFU/mL)	Final pH	Final H2O2 (mg/L)	Final Cl2 (mg/L Cl2)	Final Temp (°C)	MS2 at dilution of 1 mL (PFU)						Final MS2 (PFU/mL)
									-1	4						-1	0	1	2	3	4	
1-1.5-1	1	1.5 (90 min)	1	0	1.2	0				82	8.20E+05	8.0	5.4	1.23	21.4				TNTC	65	7	6.50E+04
1-1.5-2			2	0	1.2	0				86	8.60E+05	8.0		1.25	21.4				TNTC	37	5	3.70E+04
1-1.5-3			3	0	1.2	0				100 (34)	1.00E+06	8.0		1.25	21.4				TNTC	88	7	8.80E+04
1-5-1		5.1 (306 min)	1	0	1.2	0				82	8.20E+05	7.8	5.3	1.12	21.4			TNTC	169			1.69E+04
1-5-2			2	0	1.2	0				86	8.60E+05	7.8		1.15	21.4			TNTC	78			7.80E+03
1-5-3			3	0	1.2	0				100 (34)	1.00E+06	7.8		1.16	21.4			TNTC	222			2.22E+04
1-6-1		6.7 (402 min)	1	0	1.2	0				82	8.20E+05	7.9	5.3	1.05	22.0			TNTC	69			6.90E+03
1-6-2			2	0	1.2	0				86	8.60E+05	7.8		1.03	21.6			TNTC	31			3.10E+03
1-6-3			3	0	1.2	0				100 (34)	1.00E+06	7.8		1.12	21.5			TNTC	140			1.40E+04
1-21-1		21 (1260 min)	1	0	1.5	0				98	9.80E+05	7.8	5.1	0.94	21.3	TNTC	TNTC	45	4			4.50E+02
1-21-2			2	0	1.5	0				109	1.09E+06	7.8		0.93	21.1	TNTC	TNTC	62	4			6.20E+02
1-21-3			3	0	1.5	0				28 (55)	2.80E+05	7.8		0.91	21.3	0	2	0	0			2.00E+00
4-3-1	4	3 (180 min)	1	0	5.3	0				84	8.40E+05	7.9	4.7	4.4	22.4		235	37	3			3.70E+02
4-3-2			2	0	5.3	0				23 (43)	2.30E+05	8.0		4.5	23		1	1	0			1.00E+01
4-3-3			3	0	5.3	0				81	8.10E+05	8.0		4.5	22.8		71	5	1			7.10E+01
4-5-1		5.1 (306 min)	1	0	5.3	0				84	8.40E+05	7.8	4.5	4.1	21.9	TNTC	141	17				1.41E+02
4-5-2			2	0	5.3	0				23 (43)	2.30E+05	7.9		4.0	22.5	93	4	6				9.30E+00
4-5-3			3	0	5.3	0				81	8.10E+05	7.9		4.2	22.5	77	18	1				7.70E+00
4-6-1		6.7 (402 min)	1	0	5.3	0				84	8.40E+05	7.8	4.7	4.0	22.4	TNTC	135	14				1.35E+02
4-6-2			2	0	5.3	0				23 (43)	2.30E+05	7.9		3.9	22.5	1	0	0				1.00E-01
4-6-3			3	0	5.3	0				81	8.10E+05	7.9		3.9	22.7	32	3	0				3.20E+00
C4-6-1	4	6.7 (402 min)	1	0	5.3	0			0		0.00E+00	7.9	4.7	3.5	22.0	0						0.00E+00
C4-6-2			2						0		0.00E+00					0						0.00E+00
C4-6-3			3						0		0.00E+00					0						0.00E+00
C0-6-1	0 (control quench)	6.7 (402 min)	1	0	0	0	0.00	0.03		55	5.50E+05	7.7	0.0	0.0	20.8						14	1.40E+05
C0-6-2			2							51	5.10E+05										20	2.00E+05
C0-6-3			3							73	7.30E+05										17	1.70E+05

Note 1: Final Cl2 can be higher than NaOCl dose because initial Cl2 was greater than zero

Note 2: Grey shading under Initial Water Quality MS2 at dilution of 1 mL (PFU) indicates that the MS2 values are copied from the cells above, since the final effluent MS2 samples were taken from shared reactors

Note 3: MS2 counts next to parentheses indicates recounts and MS2 counts in parentheses indicate original counts

Note 4: TNTC is Too Numerous To Count

Table A.4 - Week 4 MS2 Disinfection Test Data (October 26)

					Chem Addition			Initial Water Quality					Final Water Quality										
Label	Target Chlorine Dose	Contact Time (hr)	Replicate	Temp (°C)	NaOH Dose (mg/L)	NaOCl Dose (mg/L Cl2)	NH3 Dose (mg/L N)	Initial Cl2 (mg/L Cl2)	Initial H2O2 (mg/L)	MS2 at dilution of 1 mL (PFU)		Initial MS2 (PFU/mL)	Final pH	Final H2O2 (mg/L)	Final Cl2 (mg/L Cl2)	Final Temp (°C)	MS2 at dilution of 1 mL (PFU)						Final MS2 (PFU/mL)
										-1	4						-1	0	1	2	3	4	
1-2-1	1	2.58 (155 min)	1	20.5	0	1.2	0				145	1.45E+06	8.1	5.5	1.06	22.2				TNTC	234	29	2.90E+05
1-2-2			2	20.2	0	1.2	0				163	1.63E+06	8.0		1.10	22.1				TNTC	229	21	2.10E+05
1-2-3			3	20.3	0	1.2	0				131	1.31E+06	8.0		1.09	22.0				TNTC	177	28	2.80E+05
1-3-1		3.67 (220 min)	1		0	1.2	0				145	1.45E+06	8.0	5.7	1.06	22.4			TNTC	TNTC	109		1.09E+05
1-3-2			2		0	1.2	0				163	1.63E+06	8.0		1.08	22.1			TNTC	TNTC	99		9.90E+04
1-3-3			3		0	1.2	0				131	1.31E+06	7.9		1.07	22.0			TNTC	TNTC	83		8.30E+04
1-5-1		5.1 (306 min)	1		0	1.2	0				145	1.45E+06	7.9	5.6	1.02	21.7			TNTC	TNTC	89		8.90E+04
1-5-2			2		0	1.2	0				163	1.63E+06	7.9		1.04	22.2			TNTC	TNTC	58		5.80E+04
1-5-3			3		0	1.2	0				131	1.31E+06	7.9		1.04	22.5			TNTC	TNTC	58		5.80E+04
1-6-1		6.7 (402 min)	1		0	1.2	0				145	1.45E+06	7.8	5.5	0.96	20.4			TNTC	TNTC	47		4.70E+04
1-6-2			2		0	1.2	0				163	1.63E+06	7.9		1.02	20.4			TNTC	TNTC	33		3.30E+04
1-6-3			3		0	1.2	0				131	1.31E+06			1.01	20.5			TNTC	TNTC	36		3.60E+04
1-21-1		21 (1260 min)	1	21.1	0	1.5	0				169	1.69E+06	7.9	5.6	1.02	22.1	TNTC	TNTC	152				1.52E+03
1-21-2			2	21.1	0	1.5	0				143	1.43E+06	7.9		1.02	22.2	TNTC	TNTC	78				7.80E+02
1-21-3			3	21.3	0	1.5	0				119	1.19E+06	8.0		1.02	21.8	TNTC	57	7				5.70E+01
4-2-1	4	2.25 (135 min)	1	20.5	0	5.4	0				132	1.32E+06	8.0	5.2	4.4	22.3		TNTC	TNTC	116			1.16E+04
4-2-2			2	20.6	0	5.4	0				154	1.54E+06	8.0		4.2	22.3		TNTC	TNTC	168			1.68E+04
4-2-3			3	20.5	0	5.4	0				149	1.49E+06	8.1		4.2	22.4		TNTC	TNTC	59			5.90E+03
4-3-1		3.67 (220 min)	1		0	5.4	0				132	1.32E+06	8.0	5.3	4.2	23.0	TNTC	TNTC	73	10			7.30E+02
4-3-2			2		0	5.4	0				154	1.54E+06	8.0		4.1	23.6	TNTC	TNTC	86	11			8.60E+02
4-3-3			3		0	5.4	0				149	1.49E+06	8.0		4.0	23.4	TNTC	150	15	1			1.50E+02
4-5-1		5.1 (306 min)	1		0	5.4	0				132	1.32E+06	7.9	5.3	4.0	22.7	TNTC	203	9				2.03E+02
4-5-2			2		0	5.4	0				154	1.54E+06	8.0		3.9	23.2	TNTC	191	32				1.91E+02
4-5-3			3		0	5.4	0				149	1.49E+06	8.0		3.8	22.7	TNTC	139	35				1.39E+02
4-6-1		6.7 (402 min)	1		0	5.4	0				132	1.32E+06	7.9	4.9	3.9	22	TNTC	48					4.80E+01
4-6-2			2		0	5.4	0				154	1.54E+06	7.9		3.8	22.5	TNTC	68					6.80E+01
4-6-3			3		0	5.4	0				149	1.49E+06	7.9		3.7	22.2	78	12					1.20E+01
C4-6-1	4	6.7 (402 min)	1	20.7	0	5.4	0			0		0.00E+00	7.9	5.0	4.1	20.6	0						0.00E+00
C4-6-2			2							0		0.00E+00					0						0.00E+00
C4-6-3			3							0		0.00E+00					0						0.00E+00
C0-6-1	0 (control quench)	6.7 (402 min)	1	20.8	0	0	0	0.00	0.00		141	1.41E+06	7.8	0.2	0.0	20.8						28	2.80E+05
C0-6-2			2								133	1.33E+06										22	2.20E+05
C0-6-3			3								126	1.26E+06										21	2.10E+05

Note 1: Final Cl2 can be higher than NaOCl dose because initial Cl2 was greater than zero

Note 2: Grey shading under Initial Water Quality MS2 at dilution of 1 mL (PFU) indicates that the MS2 values are copied from the cells above, since the final effluent MS2 samples were taken from shared reactors

Note 3: TNTC is Too Numerous To Count

APPENDIX B

Sample Calculations for Chloramine Virus LRV

Parameters:

- Water flow rate: 5 MGD
- Chlorine residual at the injection wellfield: 2 mg/L as Cl_2
- Water temperature: 22ºC
- Pipeline volume: 1.06 MG
- T_{10}/T: 0.9

Equations:

LRV = 3.62log((X mg/L)(1.06 Mgal)(1440 min/day)(0.9)2^((Y°C-20°C)/10°C)/(Z MGD))–8.45

LRV = 3.62log((2 mg/L)(1.06 Mgal)(1440 min/day)(0.9)2^((22°C-20°C)/10°C)/(5 MGD))–8.45

LRV = 1.7

APPENDIX F

Groundwater Model Calibration and Simulation of Operational Scenarios

Groundwater Model Calibration and Simulation of Operational Scenarios

Prepared by Eugene B. Yates, PG, CHG
Todd Groundwater
January 24, 2025

M1W uses a numerical groundwater flow and transport model to extend the results of tracer studies to conditions other than those present during the tracer studies. The alternative injection/extraction conditions include operation of future wells and various rates and locations of injection and extraction among existing wells. By this means, the results of tracer studies can be extrapolated to the PWM Expansion and patterns of injection can be identified that reliably achieve the target underground residence time of 4 months.

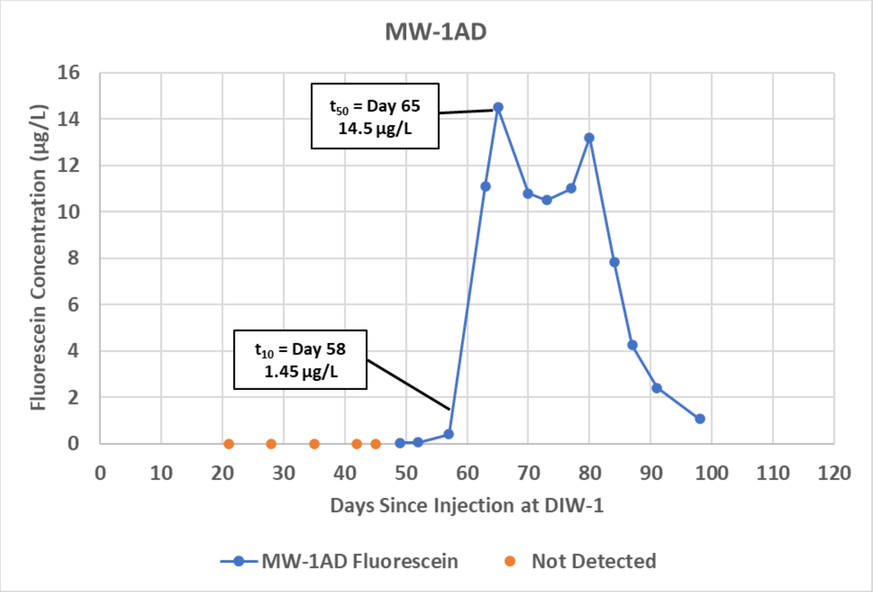
The Seaside Basin regional groundwater flow model was originally developed in 2009 for the Seaside Basin Watermaster (HydroMetrics, 2009). It covers an area larger than the adjudicated Seaside Groundwater Basin, extending east and north of the basin boundary into the Salinas Valley. The model simulates five geologic layers, which from top to bottom are the Aromas Red Sands, upper Paso Robles Aquifer, middle Paso Robles Aquifer, lower Paso Robles Aquifer, and Santa Margarita Sandstone/Purisima Formation. The model simulates the interaction of groundwater in the study area with the Pacific Ocean, as well as the interaction with the adjacent Salinas Groundwater Basin. The 3-D groundwater flow model is built on the USGS MODFLOW-2005 numerical modeling code (Harbaugh, 2005) with transport modeling performed using the MODPATH advective transport particle tracking code. It was updated for simulations used in the April 2019 PWM Engineering Report and the 2022/23 Draft Addendum to the PWM Engineering Report. The model is herein referred to as the Watermaster Model.

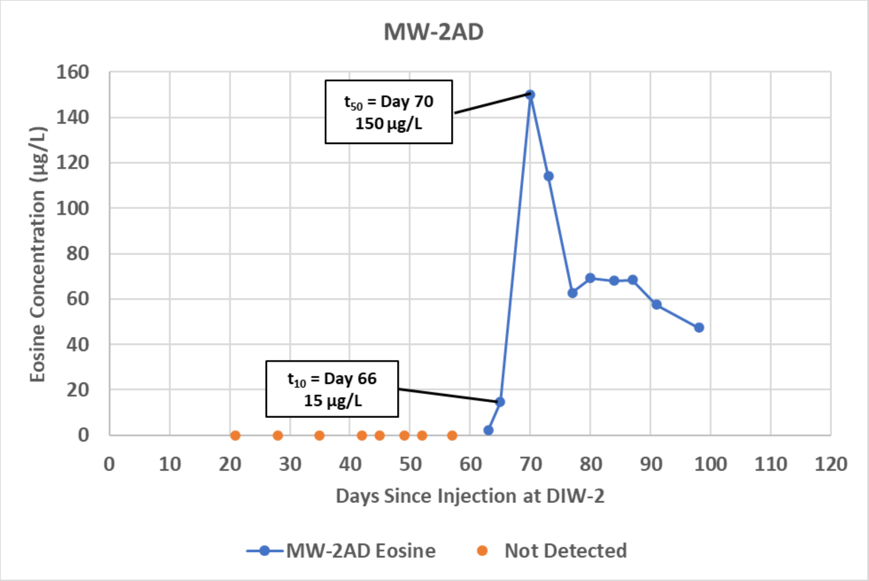
Model Calibration

The Watermaster Model was initially calibrated to the results of the intrinsic tracer study implemented for the DIW-1 and DIW-2 wells during the first year of PWM operation, between March 2020 and March 2021 (Montgomery & Associates, 2021). The low specific conductance of PWM water was used as the intrinsic tracer, and the results of downgradient monitoring are presented in **Appendix G** of the 2024 PWM Engineering Report. The model parameter used to calibrate simulated travel times was effective porosity. Groundwater velocity is proportional to hydraulic conductivity and flow thickness and inversely proportional to effective porosity. Effective porosity was selected as the calibration variable because flow thickness in the model is fixed, and altering hydraulic conductivity would tend to disrupt the calibration to water levels. Values of effective porosity in unconsolidated materials are typically equal to or greater than specific yield (a dimensionless fraction of total volume), which depends on sediment texture. A value of 0.08 was needed in the model to match the observed travel times to MW-1AD and Paralta. This value was applied globally throughout the modeled flow domain.

An extrinsic tracer study was conducted at DIW-1 and DIW2 from October 2021 through April 2022. Only a minor adjustment to effective porosity was made when the intrinsic tracer study calibrated model results were compared with results from the extrinsic tracer study. That work was documented in a technical memorandum (Montgomery & Associates, 2022a), and the results are summarized here. The dye breakthrough curves at MW-1AD, MW-2AD and Paralta provided the clearest results for calibration purposes and are shown in **Figure F-1**. Slightly decreasing the global effective porosity value to 0.062

achieved a simulated peak travel time from DIW-1 to Paralta of 169 days, or 95 percent of the measured travel time. Erring slightly on the side of fast simulated travel was a deliberate choice to ensure that simulated travel times were conservatively fast throughout the model. This value worked equally well for all three of the calibration wells.





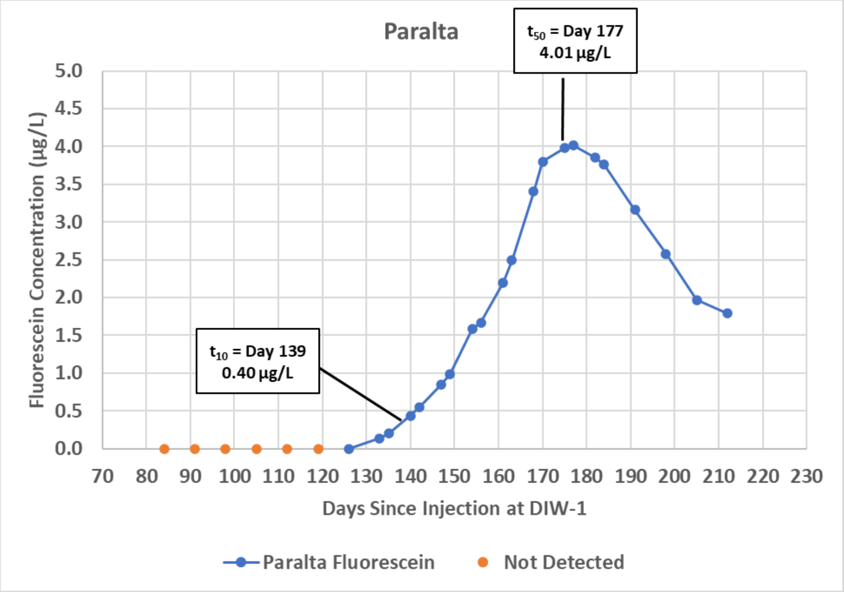


Figure F-1. Dye Concentrations Measured at Downgradient Wells (MW-1AD, MW-2AD, Paralta) during the DIW-1 and DIW-2 Extrinsic Tracer Study

The particle tracking method simulates the travel time of the center of mass of the injected water, which in the context of the tracer studies is assumed to equal the travel time for the peak concentration (t_{peak}). Travel time specified in the groundwater replenishment reuse projects (GRRP) regulations is the time when the concentration reaches 10% of its peak concentration, referred to here as the t_{10} travel time (Title 22 Section 60320.208(d)). Data from the extrinsic tracer results showed the relationship between t_{10} and t_{peak}. As the tracer moved through the aquifer, its breakthrough curve became broader and more gradual due to dispersion, which is the effect of differences in flow path velocities at microscopic and macroscopic scales as water moves through an aquifer. The amount of dispersion in the breakthrough curve increases with distance traveled and the increase is theoretically proportional to distance. A linear relationship of t_{10}/t_{peak} based on data from this tracer study is shown in **Figure F-2** (Montgomery & Associates, 2022). Simulated t_{peak} travel times from the particle tracking algorithm in the model were post-processed using this relationship to estimate t_{10} travel times between injection-extraction well pairs of various distances.

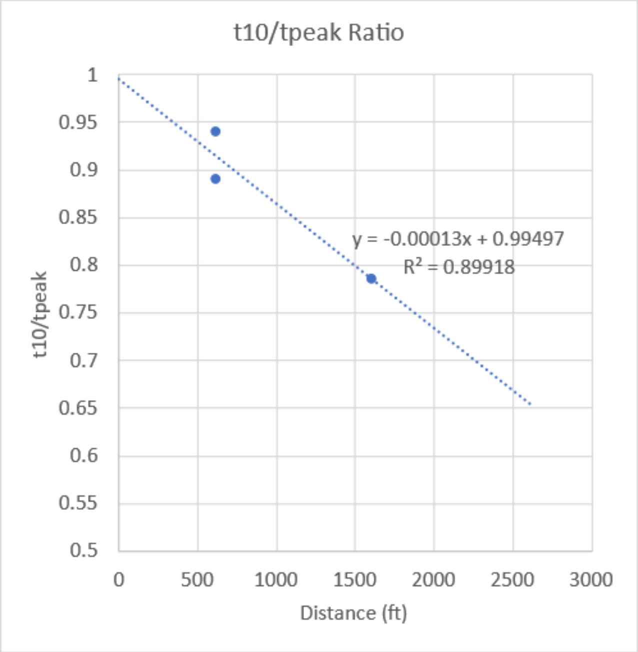


Figure F-2. Linear Relationship Between Observed t_{10}/t_{peak} Ratio and Distance from Injection Well

Model Verification

A second extrinsic tracer test offered an opportunity to check the model calibration that was based on the first study. Fluorescent dye was injected into DIW-3 and DIW-4 in October 2022 and concentrations are continuing to be measured at downgradient extraction wells as of January 2024. Details of the tracer test are documented in **Appendix G**. Simulated t_{peak} travel times are compared with dye observations to date (through month 14.1) in **Table F-1**. The peak concentration at ASR-1 has not yet occurred, but data thus far are consistent with a peak occurring around the time of the simulated t_{peak}. The simulated t_{peak} for Ord Grove 2 was much earlier than the observed t_{peak} (7.1 versus 12.2 months, or a ratio of 0.58). However, the difference can be explained by assumptions in the modeling that were known to be conservative with respect to travel time and that are now confirmed to be too conservative. The first conservative assumption was that the hypothesized partial flow barrier associated with the anticline northeast of DIW-4 and Ord Grove 2 was completely impermeable. Sensitivity tests showed that assumption resulted in travel times 0.83 as long as simulated travel times without the barrier, because the barrier confined the DIW-4 injection plume into a narrow corridor. The second conservative assumption was that all of the water extracted by Ord Grove 2 derives from the Santa Margarita Aquifer. Recent comparisons of chloride and total dissolved concentrations for the two aquifers and the well water indicates about 30 percent of Ord Grove 2 water is from the Paso Robles Aquifer. This contributes a factor of 0.7 to the discrepancy because travel time is proportional to pumping rate. Together, those two factors account for the ratio of simulated to observed t_{peak} (0.83 x 0.70 = 0.58).

Table F-1. Observed and Simulated t_{peak} Travel Times for the DIW-3 and DIW-4 Extrinsic Tracer Study

Source Well	Downgradient Well	t_{peak} travel time (months)		Simulated/ Observed	Notes
		Observed	Simulated		
DIW-3	ASR-3	14.3	13.4	0.94	Simulated t_{peak} is shorter than observed; model is conservative.
DIW-3	Paralta	>15	>24	--	Very gradual rising trend since month 10.9
DIW-4	Ord Grove 2	12.2	7.1	0.58	Discrepancy likely due to overestimated partial flow barrier effect (0.83 factor) and overestimated fraction of Ord Grove 2 pumping from Santa Margarita Aquifer (0.71 factor).
DIW-4	Seaside Muni #4	>15	>24	--	Dye not yet detected

In summary, data from the DIW-3 and DIW-4 extrinsic tracer study verified that the simulated travel times are either accurate or conservatively fast relative to observed travel times.

Simulation of Operational Scenarios

The groundwater model was used to simulate the effects of the Expanded Project in conjunction with several possible patterns of Cal-Am extraction. Model inputs and results for the scenarios are described in **Section 5.3** of the 2024 PWM Engineering Report, and additional details are documented here.

The model was used to simulate Project injection and Cal-Am extraction over a 3-year period nominally starting in 2025, after DIW-5, DIW-6, and new Cal-Am wells are expected to become operational. The 2019 PWM Engineering Report used a 25-year simulation period to test the extent to which ASR operations and wet and dry years affect water levels and travel times and to evaluate the long-term impact of the project on water levels in the Seaside Groundwater Basin. That modeling showed the shortest travel times occur during periods of prolonged drought with no ASR injection of Carmel River water. As a result, the current set of simulations conservatively assumes no ASR injection. Because of its location, ASR injection tends to slow the movement of injected water from DIW-1 and DIW-2 to Paralta, which is the nearest downgradient drinking water well. Extrinsic tracer tests and subsequent model calibration showed the shortest underground retention times are more than four months. Therefore, it is not necessary to complete a 25-year simulation with variable hydrology to calculate travel times.

Injection at Project Deep Injection Wells – Normal Operating Conditions

Simulations of Project operation require that monthly amounts of injection at the Project wells be specified. The Expanded PWM will add deep injection wells DIW-5 and DIW-6 (see **Figure 3-9** for well locations) and increase annual injection to an average of 5,750 AFY, plus an additional 200 AFY in wet years when the operating and drought reserves/storage volumes will be increased. Because travel time is proportional to the combined injection and extraction rates for a well pair, it was conservatively assumed in all scenarios that annual injection was at the higher amount (5,950 AFY). The annual total was divided spatially among the DIWs and varied seasonally among the months of the year.

The Project has substantial flexibility regarding the allocation of injection among the DIWs. If all six of the DIWs were operated at their physical capacities, they could inject about 53 percent more than the maximum annual injection volume of 5,950 AFY. The difference between injection capacity and actual injection for the scenario simulations is shown in **Figure F-3**. In the case of DIW-1, the injection rate is constrained by the travel time to Paralta, which in all of the scenarios was the fastest travel time from any DIW to any downgradient extraction well. The remaining overall surplus injection capacity provides flexibility in the event that one or two injection wells are out of service for maintenance or other issues. In the process of simulating various Cal-Am extraction patterns, it was determined there are scenarios of injection distribution to the DIWs that can achieve more than the target of 4 months of t_{10} travel time. This applies to all DIWs and for all the Cal-Am operational configurations considered. The shortest travel time for all scenarios was 4.5 months from DIW-1 to Paralta. That distribution was not unique, similar distributions could also achieve >4 months travel time for all scenarios.

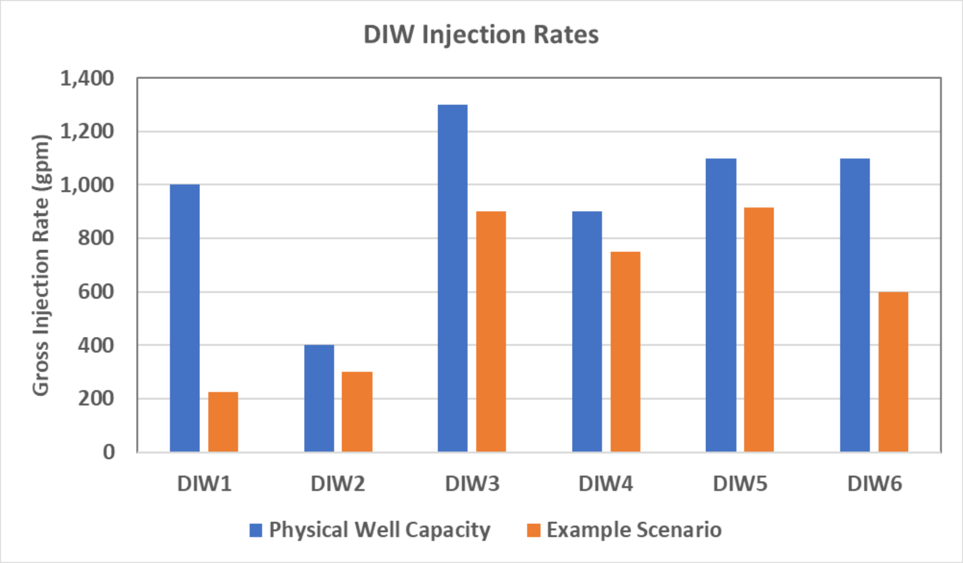


Figure F-3. Injection Rates at Deep Injection Wells

The amount of injection to the DIWs will vary seasonally in a pattern opposite that of Cal-Am's extraction. There is sufficient capacity at the AWPF and at the injection wells to support seasonal variations in injection. Travel time between an injection well and extraction well is proportional to the sum of their pumping rates. Cal-Am's extraction rates follow the seasonal pattern of water demand: high in summer and low in winter. The Project's water production and injection were designed to be low in summer and high in winter, due to high demands for M1W irrigation water customers in the summer. The seasonal pattern used in all scenarios is shown in **Figure F-4**. The maximum winter month injection volumes (637 AF) are 81 percent of the combined physical capacities of the deep injection wells, so the assumed seasonality pattern retains some flexibility to rearrange injection among the wells in the event one well is out of service or to manage travel times. The maximum monthly injection volume in the wintertime equals a continuous flow of 6.8 mgd, which is close to the 7.6 mgd peak AWPF capacity.

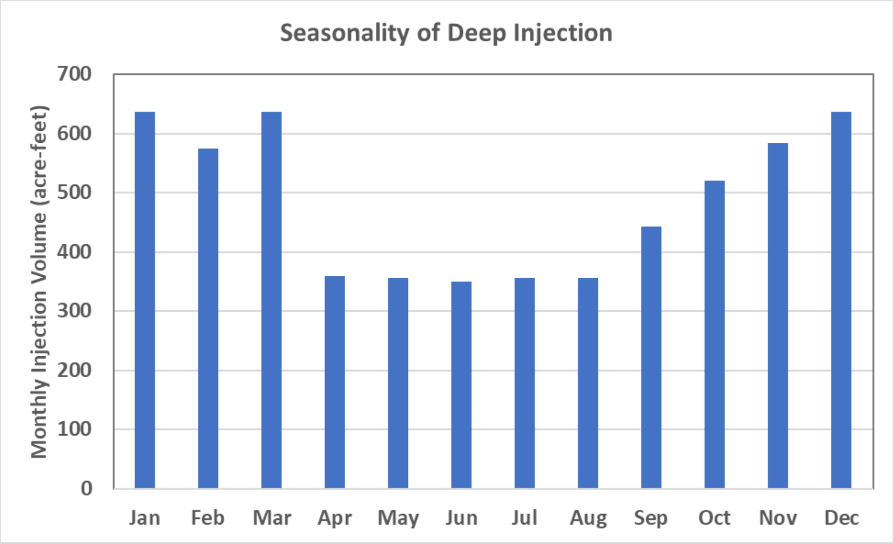


Figure F-4. Seasonality of Deep Injection

Monthly injection rates at the DIWs were the same for all scenarios and are listed in **Table E-2**. This is not the only feasible set of injection rates. It is simply one set that achieved t_{10} travel times to Cal-Am extraction wells greater than 4 months in all of the scenarios. Also, DIW-5 was assumed to inject more than DIW-6 for a conservative estimate of travel time since it is closer to the extraction wells. The distribution to DIW5 and DIW-6 could be reversed or modified pending pump test results to further increase travel time.

Table F-2. Injection Rates for Deep Injection Wells in All Scenarios

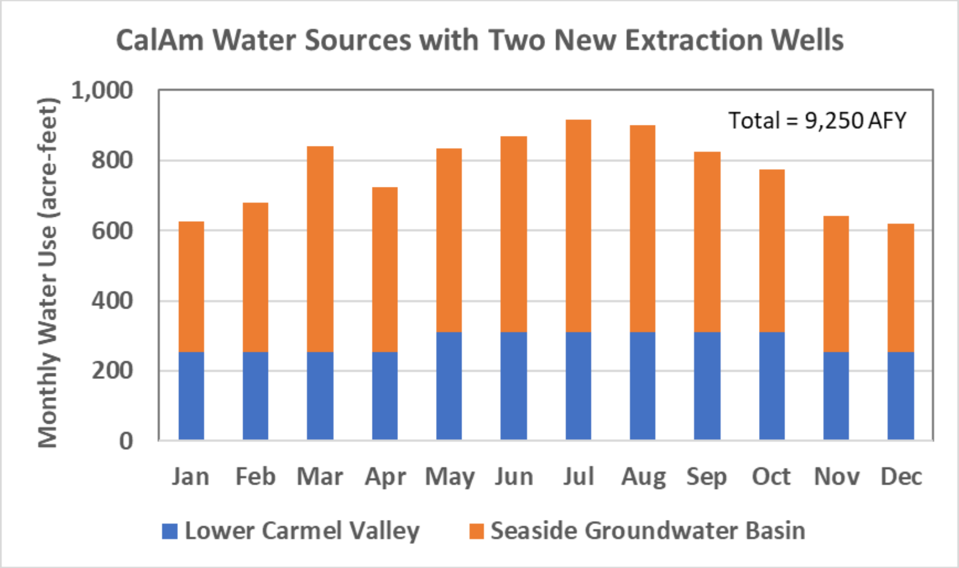
Month	Monthly Net Injection (acre-feet)						
	DIW1	DIW2	DIW3	DIW4	DIW5	DIW6	Total
Jan	38.8	51.8	155.1	129.4	157.9	103.5	**636.5**
Feb	35.1	46.8	140.1	116.9	142.6	93.5	**575.0**
Mar	38.8	51.8	155.1	129.4	157.9	103.5	**636.6**
Apr	21.9	29.2	87.5	73.0	89.1	58.4	**359.2**
May	21.7	29.0	86.8	72.4	88.4	57.9	**356.3**
Jun	21.3	28.4	85.2	71.1	86.7	56.9	**349.5**
Jul	21.7	29.0	86.8	72.4	88.4	57.9	**356.3**
Aug	21.7	29.0	86.8	72.4	88.4	57.9	**356.3**
Sep	27.0	36.1	108.0	90.1	109.9	72.1	**443.2**
Oct	31.7	42.2	126.5	105.6	128.8	84.5	**519.4**
Nov	35.6	47.8	142.2	118.7	144.8	95.0	**584.1**
Dec	38.8	51.8	155.1	129.4	157.9	103.5	**636.6**
Total	**354.3**	**472.4**	**1,415.3**	**1,181.0**	**1,440.8**	**944.8**	**5,808.7**

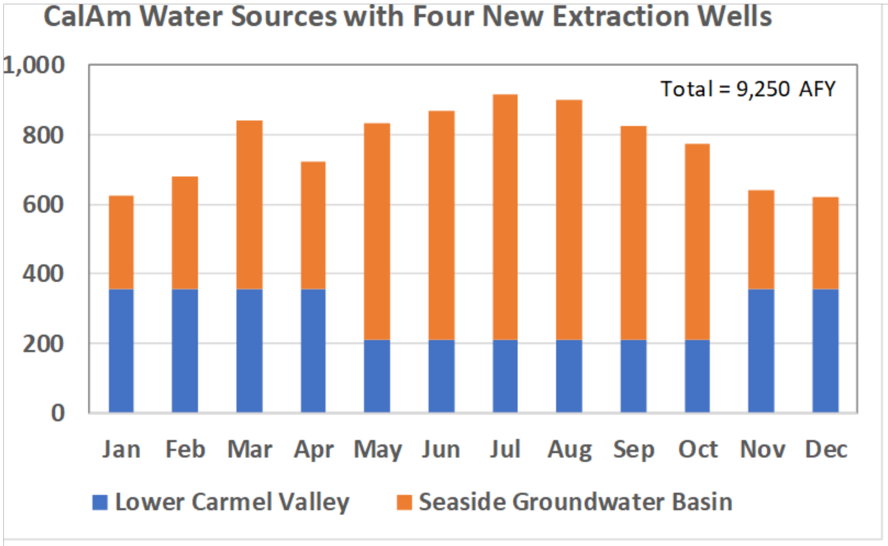
Extraction at Cal-Am Wells- – Normal Operating Conditions

Cal-Am wells included four planned extraction wells: EW-1 through EW-4 (see **Figure 3-9** in 2024 PWM Engineering Report for well locations). It is anticipated the Cal-Am wells will be installed in pairs, so some scenarios included only EW-1 and EW-2 while others included all four EWs.

Annual Cal-Am extraction from the Seaside Groundwater Basin was assumed to be 5,850 AFY in all scenarios. This equals Cal-Am's total annual water use since January 2022 (9,250 AFY) minus the amount of water obtained from its lower Carmel Valley wells (3,400 AFY). Cal-Am has been fully compliant with the Cease and Desist Order limiting diversions from the Carmel River system since January 2022. Cal-Am also has upper Carmel Valley wells, but diversions from those are contingent on the presence of relatively high Carmel River flows. For this analysis, it was conservatively assumed that no water was available from the upper Carmel Valley wells.

The seasonal pattern of Cal-Am extraction depends on available well capacity. With only its existing wells and two new extraction wells (EW-1 and EW-2), Cal-Am will need to take more of its Carmel Valley allocation during the summer months when water demand is highest. With four new extraction wells, more of the summer demand can be supplied by the Seaside Groundwater Basin wells. This allows the Carmel Valley diversions to be shifted more toward the winter months, thereby reducing impacts on summer flows in the Carmel River. **Figure F-5** shows the seasonal pattern of water sources for these two conditions. The two likely scenarios of Seaside Groundwater Basin use (i.e., availability of two or four new Cal-Am wells) affects simulated travel times of injected Project water and thus both are modeled. Without any new extraction wells, Cal-Am would not be able to extract the increased injection volumes enabled by the expansion of PWM; thus, that scenario is not modeled.





Note: Excludes water from the Sand City desalination plant, upper Carmel Valley wells, and Table 13, which are relatively small or conservatively assumed to be zero in the scenarios.

Figure F-5. Seasonal Pattern of Cal-Am Water Use (with 2 or 4 New Extraction Wells)

Cal-Am has some flexibility for distributing groundwater extraction among its wells, more so when all four new extraction wells are constructed. The simulated scenarios tested extraction patterns that were most likely to produce fast travel times of water injected into the deep injection wells. Cal-Am has two key pressure zones fed by the Seaside Groundwater Basin wells. The Seaside Pressure Zone is in and near the City of Seaside and is supplied by the Paralta, Ord Grove 2, Luzern, Playa #3 and Plumas #4 wells. Of those, the Paralta and Ord Grove 2 wells have the highest capacities and are closest to the Project injection wells. It was conservatively assumed that the Playa #3 and Plumas #4 wells supplied no water and that all demand was met by the Paralta, Ord Grove 2, and Luzern wells (in that order of priority). This extraction distribution for the Seaside Pressure Zone wells was the same in all scenarios.

The Monterey Peninsula pressure zones are supplied by the Paralta, ASR-3 and ASR-4 wells and the four new Cal-Am extraction wells, all of which are located along General Jim Moore Boulevard. The scenarios tested several extraction distributions, each focusing extraction in one geographic area (for example, at ASR-3 and ASR-4, or EW-1 and EW-2, or EW-3 and EW-4) to the extent possible to test for fast travel times. **Table F-3** lists the ranges of Cal-Am extraction rates tested in the scenarios. Results for two scenarios are presented to illustrate the range of simulated travel times.

Table F-3. Extraction Rates for Cal-Am Wells in Normal Operating Scenarios

Month	Luzern			Ord Grove 2			Paralta		
	Example Scenario (AF/mo)	Range Tested (AF/mo)		Example Scenario (AF/mo)	Range Tested (AF/mo)		Example Scenario (AF/mo)	Range Tested (AF/mo)	
		Min	Max		Min	Max		Min	Max
Jan	0.00	0.00	0.00	40.64	40.64	40.64	137.00	137.00	137.00
Feb	1.29	0.00	1.29	98.99	95.86	98.99	123.74	123.74	128.16
Mar	14.77	14.77	14.77	109.60	109.60	109.60	137.00	137.00	137.00
Apr	0.00	0.00	0.00	95.59	95.59	95.59	132.58	132.58	132.58
May	0.00	0.00	0.00	82.31	82.31	82.31	137.00	137.00	137.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	132.58	132.58	132.58
Jul	0.00	0.00	0.00	29.13	29.13	29.13	137.00	137.00	137.00
Aug	0.00	0.00	0.00	96.07	96.07	96.07	137.00	137.00	137.00
Sep	0.00	0.00	0.00	76.25	76.25	76.25	132.58	132.58	132.58
Oct	0.00	0.00	0.00	81.09	81.09	81.09	137.00	137.00	137.00
Nov	0.00	0.00	0.00	29.69	29.69	29.69	132.58	132.58	132.58
Dec	0.00	0.00	0.00	29.99	29.99	29.99	137.00	137.00	137.00

Month	ASR-3			ASR-4			EW-1		
	Example Scenario (AF/mo)	Range Tested (AF/mo)		Example Scenario (AF/mo)	Range Tested (AF/mo)		Example Scenario (AF/mo)	Range Tested (AF/mo)	
		Min	Max		Min	Max		Min	Max
Jan	171.24	0.00	171.24	20.84	0.00	20.84	0.00	0.00	0.00
Feb	154.67	0.00	154.67	45.27	0.00	45.27	0.00	0.00	14.34
Mar	171.24	0.00	171.24	152.14	0.00	152.14	0.00	0.00	117.89
Apr	165.72	0.00	165.72	75.63	0.00	75.63	0.00	0.00	42.48
May	171.24	0.00	171.24	134.05	0.00	134.05	0.00	0.00	99.80
Jun	165.72	0.00	165.72	165.72	0.00	165.72	0.00	0.00	198.86
Jul	171.24	0.00	171.24	171.24	0.00	171.24	0.00	0.00	205.49
Aug	171.24	0.00	171.24	171.24	0.00	171.24	0.00	0.00	151.40
Sep	165.72	0.00	165.72	139.34	0.00	139.34	0.00	0.00	106.19
Oct	171.24	0.00	171.24	72.70	0.00	72.70	0.00	0.00	38.46
Nov	165.72	0.00	165.72	57.20	0.00	57.20	0.00	0.00	24.05
Dec	171.24	0.00	171.24	26.91	0.00	26.91	0.00	0.00	0.00

Month	EW-2			EW-3			EW-4		
	Example Scenario (AF/mo)	Range Tested (AF/mo)		Example Scenario (AF/mo)	Range Tested (AF/mo)		Example Scenario (AF/mo)	Range Tested (AF/mo)	
		Min	Max		Min	Max		Min	Max
Jan	0.00	0.00	192.09	0.00	0.00	91.09	0.00	0.00	0.00
Feb	0.00	0.00	192.24	0.00	0.00	98.94	0.00	0.00	0.00
Mar	0.00	0.00	205.49	0.00	0.00	205.49	0.00	0.00	16.89
Apr	0.00	0.00	198.86	0.00	0.00	140.35	0.00	0.00	0.00
May	0.00	0.00	205.49	0.00	0.00	205.49	0.00	0.00	200.80
Jun	92.98	92.98	198.86	0.00	0.00	198.86	0.00	0.00	198.86
Jul	96.28	96.28	205.49	0.00	0.00	205.49	0.00	0.00	205.49
Aug	14.40	14.40	205.49	0.00	0.00	205.49	0.00	0.00	205.49
Sep	0.00	0.00	198.86	0.00	0.00	198.86	0.00	0.00	198.86
Oct	0.00	0.00	205.49	0.00	0.00	205.49	0.00	0.00	139.46
Nov	0.00	0.00	198.86	0.00	0.00	121.92	0.00	0.00	0.00
Dec	0.00	0.00	198.16	0.00	0.00	97.16	0.00	0.00	0.00

Other Scenario Input Assumptions

Two injection/extraction assumptions were common to all scenarios. One assumption was that ASR injection did not occur during the simulation period. Although a year with no ASR injection has happened only once since 2010 (see **Table 10-1** in the 2024 PWM Engineering Report), ASR injection may not occur in an extreme dry year when Carmel River flows do not reach thresholds specified in the diversion permit. ASR injection will always occur in wet and normal hydrologic years. The ASR-1 and ASR-2 wells are located between Project wells (DIW-1 and DIW-2) and the nearest Cal-Am extraction well (Paralta). Injection creates a mound in groundwater levels that tends to deflect the flow of water from DIW-1 and DIW-2 to Paralta, forcing it into longer and slower, less direct flow paths. Thus, for the purpose of ensuring that Project operation meets travel time requirements, it was conservatively assumed that ASR injection was not occurring. The second assumption is that extraction from Seaside Muni #4 well is the same in all years and all scenarios at amounts equal to recent historical pumping. The City of Seaside has not announced plans to alter operation of that well, but has begun its planning for a replacement well in coordination with M1W and MPWMD, and respecting the most recent mapped zone of control for drinking water well construction.

Results of Normal Operating Conditions Scenario Simulations

The key results from the operational scenario simulations are the underground travel times of injected water to the nearest downgradient drinking water wells and the delineation of zones of control for construction of future drinking water wells.

Simulated travel times were first converted from average travel time (t_{50}) to 10th-percentile travel time (t_{10}) to compare them with regulatory requirements for underground retention time. The process is described in **Section 5.3.** of the 2024 PWM Engineering Report.

The results of the particle tracking analysis for an operational scenario with only two new Cal-Am extraction wells are shown in **Figure F-6**. Each colored trace emanating from a DIW represents the movement of a particle of water from a set of starting locations surrounding the well. The color bands along the length of the traces represent one month of travel. This scenario assumed Cal-Am extraction was focused at ASR-3 followed by ASR-4 and EW-2. This was expected to produce fast travel times from DIW-3 and did indeed produce the fastest simulated travel times from DIW-3 to ASR-3 (t_{10} = 5.6 months), but they were still longer than the travel times from DIW-3 to Paralta (5.2 months) or from DIW-1 to Paralta (4.5 months).

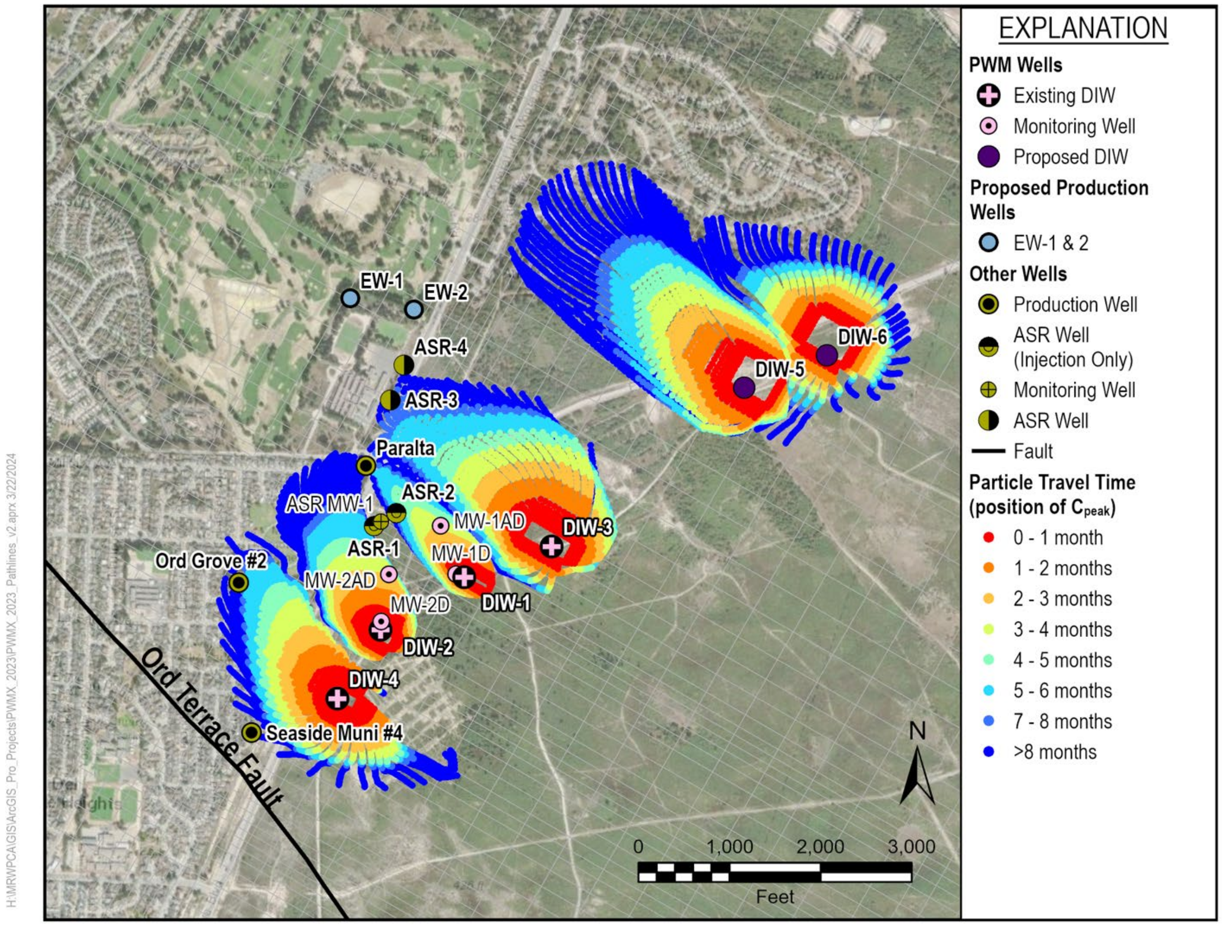


Figure F-6. Simulated Particle Traces for Normal Operating Conditions Scenario with Two New Cal-Am Extraction Wells

To illustrate the ability of the Project to maintain the target travel time of greater than 4 months under a wide range of Cal-Am extraction patterns, particle traces for a second operational scenario are shown in **Figure F-7**. That scenario included the two additional Cal-Am extraction wells (EW-3 and EW-4) and assumed Cal-Am extraction was focused on EW-3, EW-4, and EW-2 (in order of priority). This was expected to produce the fastest travel times from DIW-5 and DIW-6 to those wells. The simulated travel time from DIW-5 to EW-3 was 7.4 months, much longer than the 4-month target. Because of interference from the DIW-5 plume, travel time from DIW-6 to EW-3 was twice as long as the travel time from DIW-5. Travel time was long in spite of relatively high injection at DIW-5 simply because the distance to EW-3 is large: over twice the distance between DIW-1 and Paralta.

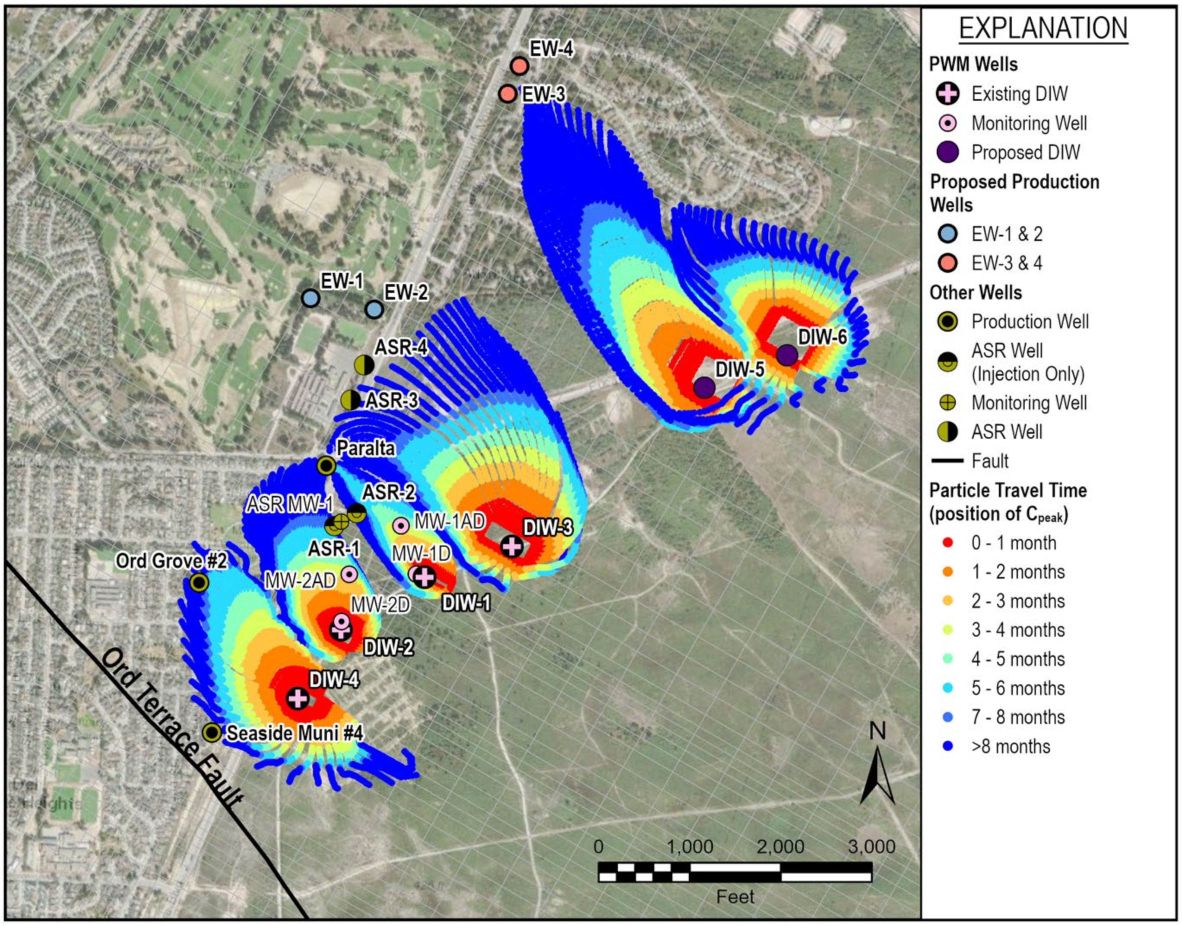


Figure F-7. Simulated Particle Traces for Normal Operating Conditions Scenario with Four New Cal-Am Extraction Wells

A key finding of the scenario simulations was that a single set of monthly deep injection well volumes—including the distribution among the six wells and the seasonal variation in injection—was able to achieve a t_{10} travel time of 4.4 months or greater for all DIWs under every Cal-Am extraction scenario. The injection allocations and resulting travel times are summarized in **Table F-4**. This simplifies Project operation, because adjustments to the injection pattern will be needed only in unusual circumstances, such as when one of the wells is out of service. The "extra" 0.4 month of simulated travel time (4.4 versus the target of 4.0 months) provides additional assurance that there is flexibility to implement variations in the injection pattern without causing travel times of less than 4 months. The shortest travel time for any well pair at any point in any "Normal Operating Condition" scenario was 4.4 months from DIW-1 to Paralta. Travel times were 5.4 months or more for all of the other well pairs.

Table F-4. Injection Rates and Simulated Travel Times for Operational Scenarios

	DIW-1	DIW-2	DIW-3	DIW-4	DIW-5	DIW-6	Total
Annual Injection[1]							
Acre-Feet	354	472	1,415	1,181	1,441	945	5,809
% of Total	6.1%	8.1%	24.4%	20.3%	24.8%	16.3%	100%
Maximum Winter Injection[1]							
Gallons Per Minute	289	385	1,155	963	1,175	770	4,737
Acre-feet Per Month	40	53	158	132	161	106	649
% of Capacity[2]	29%	96%	89%	107%	107%	70%	82%
Minimum t_{10} Travel Time							
Nearest Extraction Well[3]	Paralta	Paralta	ASR-3	Ord Grove 2	EW-3 & 4	EW-3 & 4	
Average Injection Rate (AF/month)[4,6]	36	46	126	112	117	81	518
Average Injection Rate (% of capacity)	28%	88%	74%	94%	81%	56%	68%
Average Extraction Rate (AF/month)[4,7]	136	133	167	70	282	179	653
Average Extraction Rate (% of capacity)[7]	72%	71%	83%	53%	70%	44%	70%
T_{10} Travel Time (months)[4]	4.4	5.5	5.4	6.6	7.5	15.4	

Notes:

1. Injection amounts are net after backflushing and also do not include Vadose zone well injection.
2. The injection-apportioning algorithm resulted in two instances with injection slightly above the well's long-term capacity. Because travel time exceeded 4 months even at those high rates of injection, the simulation was not revised to have a slightly different injection allocation.
3. The nearest extraction well is based on travel time, not map distance.
4. Injection and extraction amounts are averages over the number of months equal to the t_{50} travel time that corresponds to the reported t10 travel time. All months are assumed to be 365/12 = 30.4 days long when converting from AF/day to AF/month.
5. The listed travel times are the shortest times between a well pair among the six simulated scenarios.
6. Total annual and monthly injection volumes at DIW wells were the same in all scenarios, as was the distribution among the deep injection wells.
7. Total CalAm production and capacity is for the downgradient wells: Paralta, ASR-3, Ord Grove 2, EW-3 and EW-4.

n.a. = not applicable

All travel times apply to purified recycled water injection into the Santa Margarita Aquifer. The Project injects small amounts of recycled water into vadose zone wells VZW-1 and VZW-2 which are located next to DIW-1 and DIW-2. The capacities of the vadose zone wells injecting into the Paso Robles Aquifer proved to be substantially smaller than expected, with injection rates of 20 to 35 gpm. Recycled water has not yet been positively identified as having arrived in any Paso Robles monitoring wells (i.e., MW-1S, MW-1AS and MW-2AS). Water injected into the vadose zone must first percolate downward to the water table, mixing with surface percolation which dilutes the product water, then horizontally through the Paso Robles Aquifer being further diluted with native groundwater as it travels. In 2019, during project design activities, the vertical travel time was estimated to be at least half a year and the horizontal travel time to off-site shallow monitoring wells was estimated to be approximately one year. Given that actual vadose zone well injection rates are an order of magnitude smaller than the rates assumed in 2019, the horizontal travel time is now estimated to be in excess of two years.

Travel Times at Maximum Injection and Extraction Rates – Extraction Emergency Operating Conditions

The operational scenarios described above include conservative assumptions that produce relatively fast travel times but are within the range of "normal operating conditions". Title 22 Section 60320.224(c) requires that extrinsic tracer studies demonstrating retention time underground are to be implemented under "normal operating conditions." Under emergency conditions due to a well or pipeline being out of service, Cal-Am could conceivably need to operate one or more of the extraction wells at their maximum physical capacities for a prolonged period of time. This would produce faster travel than the scenario results for normal operating conditions described above.

DDW requested simulations of travel time under maximum extraction conditions for the DIW-1/Paralta well pair and the DIW-4/Ord Grove 2 well pair. For the other well pairs, the travel times from the scenario simulations were sufficiently long and/or the injection and extraction rates were sufficiently close to the maximum physical capacities that it was clear travel times would exceed 4 months even at maximum capacity.

Paralta Well Maximum Capacity Simulation

The simulation of Paralta pumping at maximum capacity incorporates the following conservative assumptions that have essentially no chance of occurring concurrently:

- No Upper Carmel Valley water supply available to Cal-Am.
- No ASR injection.
- Paralta extracting at 1,400 gpm (6.19 AF/d), which is only possible when it is supplying the high pressure zone continuously.
- Paralta extracting at maximum capacity for 12 months continuously.
- ASR-3 concurrently extracting at maximum capacity for 12 months continuously (ASR-3 is located close to Paralta and in line with the DIW-1 to Paralta flow path, and ASR-3 extraction consequently accelerates travel from DIW-1 to Paralta slightly).

The maximum capacity simulations were implemented in the same manner as the normal operating scenario simulations, with a sequence of injection-extraction assumptions each implemented for a period of 3 years. **Figure F-8** shows the time series of injection and extraction rates for all wells during the simulation. For the DIW-1/Paralta simulation, Paralta and ASR-3 were assumed to extract year-round at their maximum physical capacities. Injection at DIW-1 was incrementally decreased from 100 percent of its physical capacity to 75, 50, and 25 percent, each for a period of 3 years. For Cal-Am extraction, the high rates of extraction at Paralta and ASR-3 were balanced by reduced extraction at ASR-4 and Ord Grove 2 such that total Cal-Am production still equaled the demand. The incremental changes in DIW-1 injection were balanced by changes in injection at DIW-5 and DIW-6, which are far enough away that injection does not affect travel time from DIW-1 to Paralta.

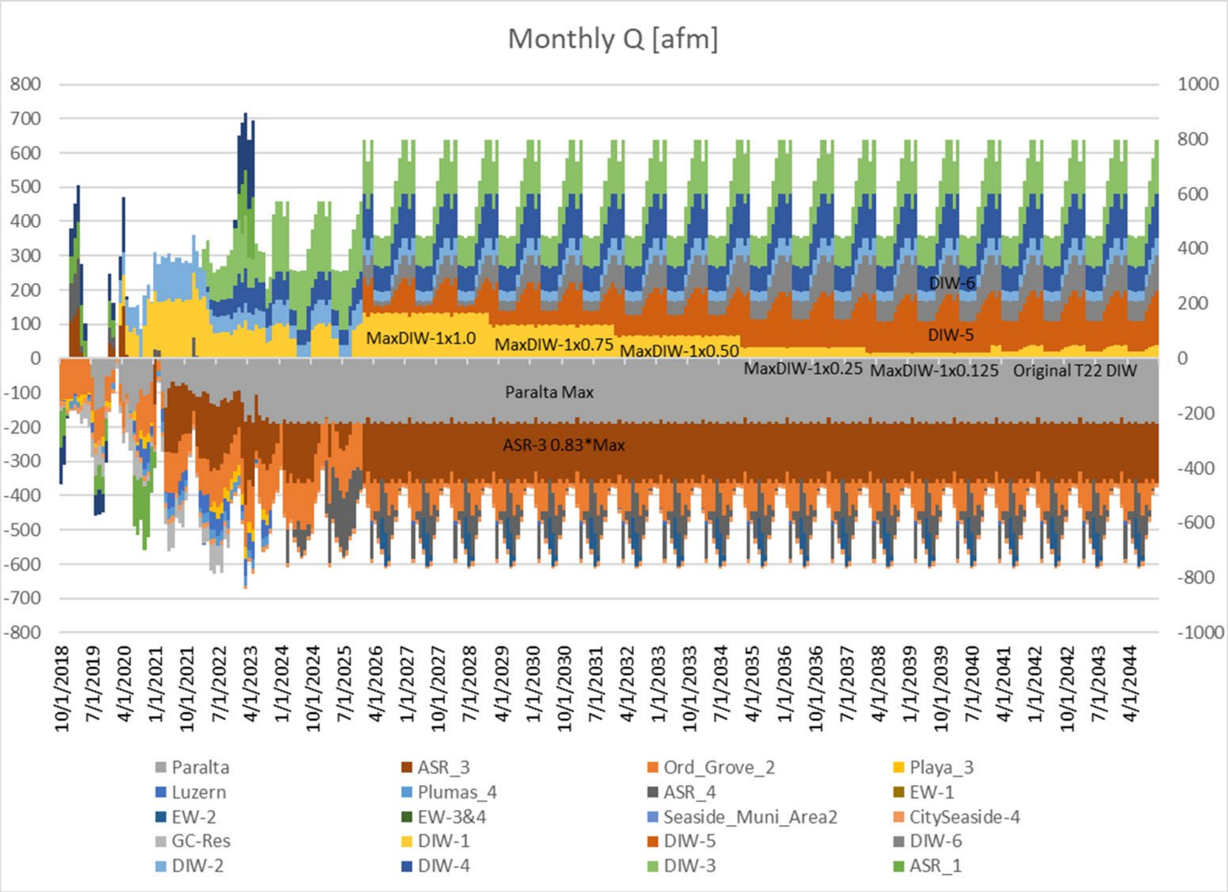


Figure F-8. Injection and Extraction Rates by Well for Paralta Well Maximum-Capacity Simulation

The results of the simulation are shown in **Figure F-9**, which plots travel time versus the sum of DIW-1 injection rate and Paralta extraction rate. Travel time is proportional to this sum, so the data points create a linear pattern. Paralta extraction is constant at 6.19 acre-feet per day (AF/d), which equals a pumping rate of 1,400 gpm. From left to right, the data points are the fastest t_{10} travel time for any month of the simulation for DIW-1 injection at 25, 50, 75 and 100 percent of capacity.

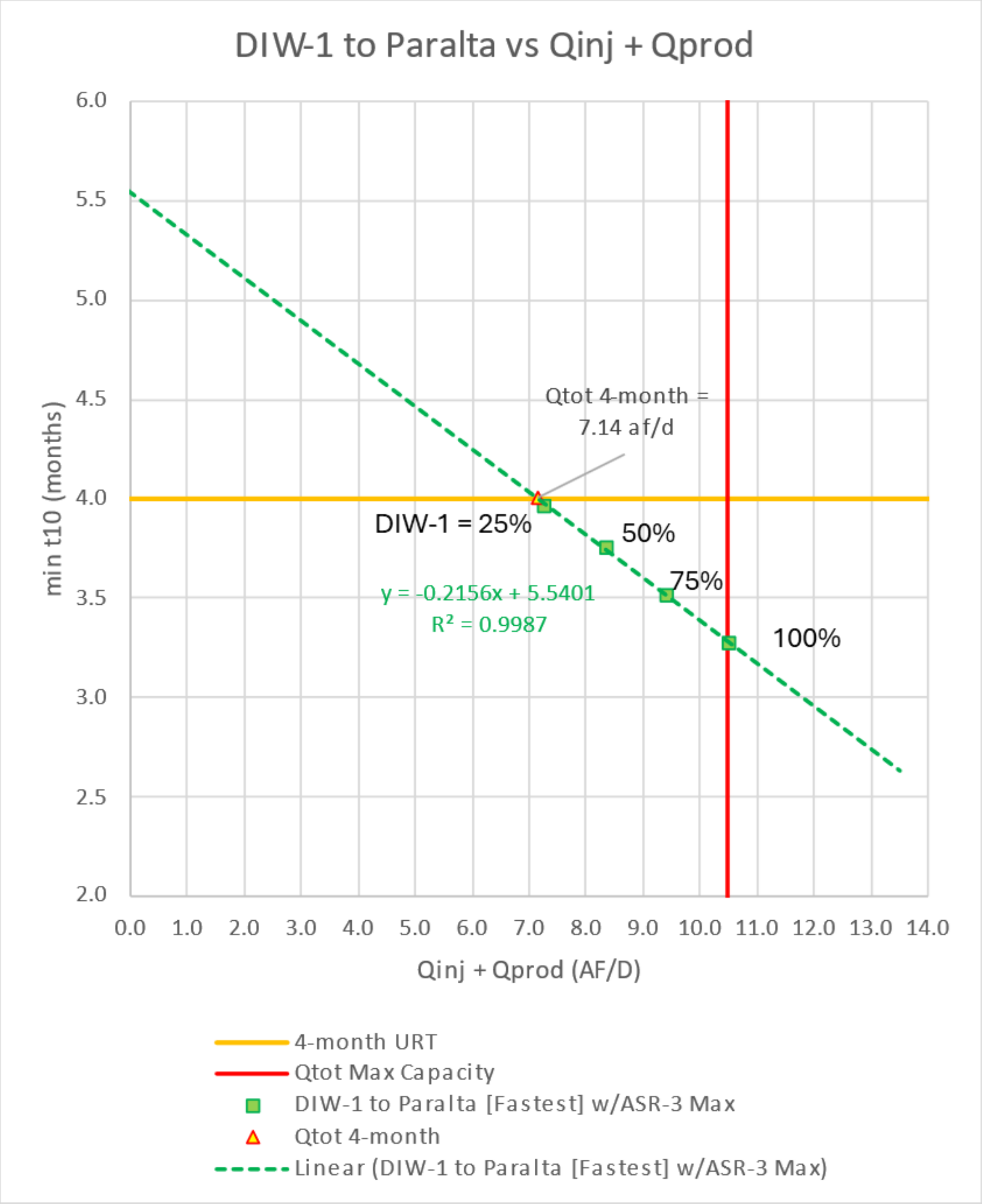


Figure F-9. Relationship of Travel Time and Combined Injection and Extraction Rate (DIW-1 to Paralta)

The line through the datapoints crosses the 4-month travel time threshold at a combined injection-plus-extraction rate equal to 7.14 AF/d. Thus, for any Paralta 4-month average extraction rate, the 4-month average DIW-1 injection rate that will still meet the 4-month travel time target is:

DIW-1 ≤7.14 – Paralta
(all rates in acre-feet per day, representing 4-month average flow)

Brief periods of above-average injection or extraction can be balanced by other periods with below-average injection or extraction over the course of the four months. If Paralta is extracting at its maximum physical capacity (6.19 AF/d), the maximum DIW-1 injection rate would be 0.95 AF/d. This corresponds to 215 gpm, or 22 percent of its physical capacity (after accounting for backflush cycles).

The above equation can be expressed in units of acre-feet per month as follows:

$$\text{DIW-1} \leq 217 - \text{Paralta}$$

(all rates in acre-feet per month, representing 4-month average flowrate)

In these units, Paralta maximum capacity is 188 AF/mo and DIW-1 maximum capacity is 131 AF/mo.

The same equation indicates the Paralta extraction rate below which DIW-1 can inject at its full capacity is 217 – 131 = 86 AF/mo, or 640 gpm. During 2022-2024, Paralta extracted at 86 AF/mo or less 16 percent of the time. This indicates DIW-1 would need to inject at less than its physical capacity 84 percent of the time, by varying amounts depending on concurrent Paralta extraction.

Ord Grove 2 Maximum Capacity Simulation

The same exercise was applied to the DIW-4 and Ord Grove 2 well pair. Previous modeling, water level monitoring, and tracer studies have confirmed that travel times for this well pair are not significantly affected by injection and extraction at other wells. Injection and extraction rates for all wells over the course of the simulation are shown in **Figure F-10**. Ord Grove 2 extraction was held at its current physical capacity of 990 gpm (equals 4.38 AF/d or 133 AF/mo). DIW-4 injection capacity is 3.88 AF/d (118 AF/mo). In the simulation DIW-4 injection was tested at 100, 75, 50, and 25 percent of its capacity in a sequence of 3-year periods.

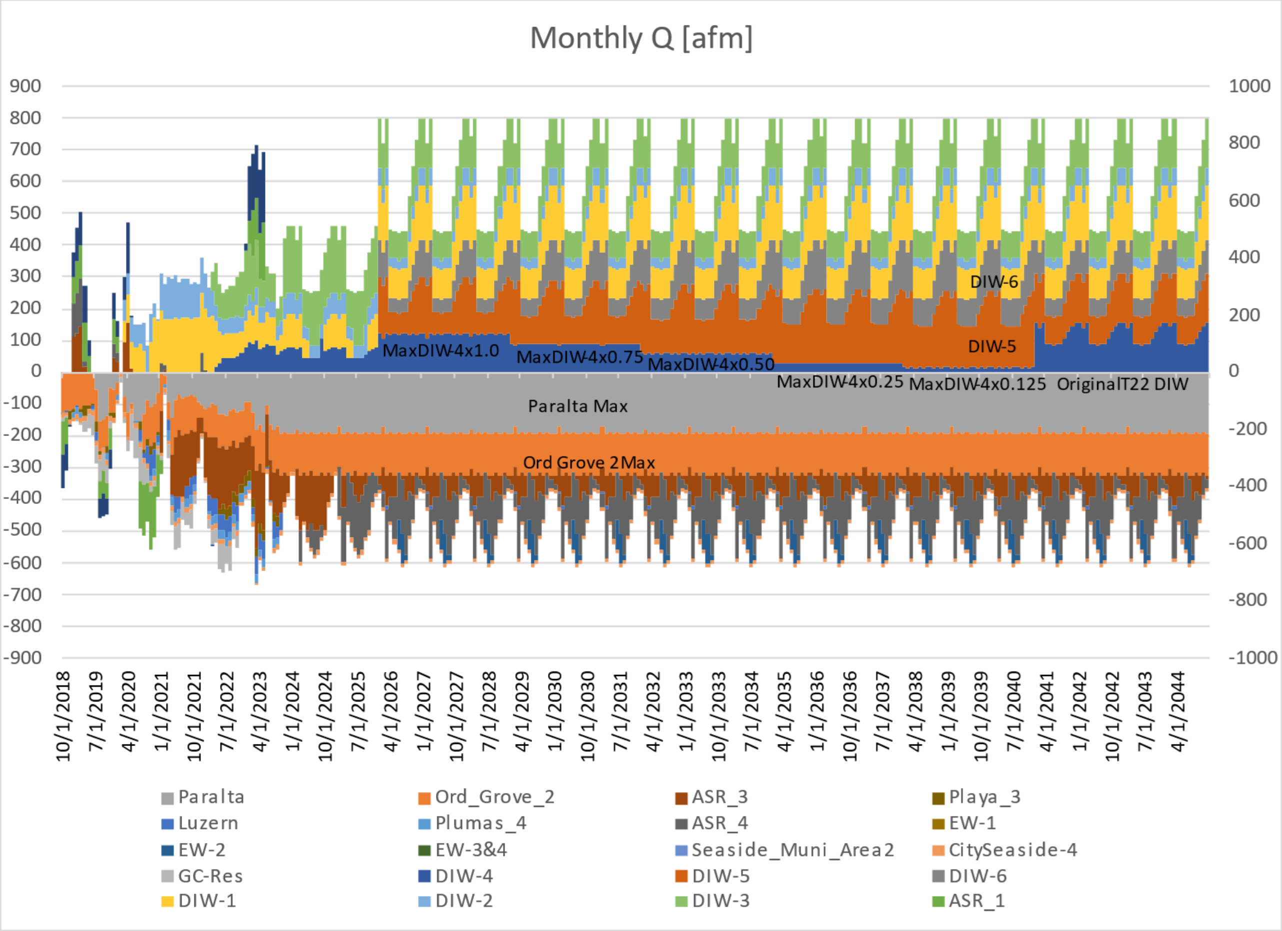


Figure F-10 Injection and Extraction Rates by Well for Ord Grove 2 Well Maximum-Capacity Simulation

The results of the simulation are summarized in **Figure F-11**, which plots travel time versus the sum of DIW-4 injection and Ord Grove 2 extraction.

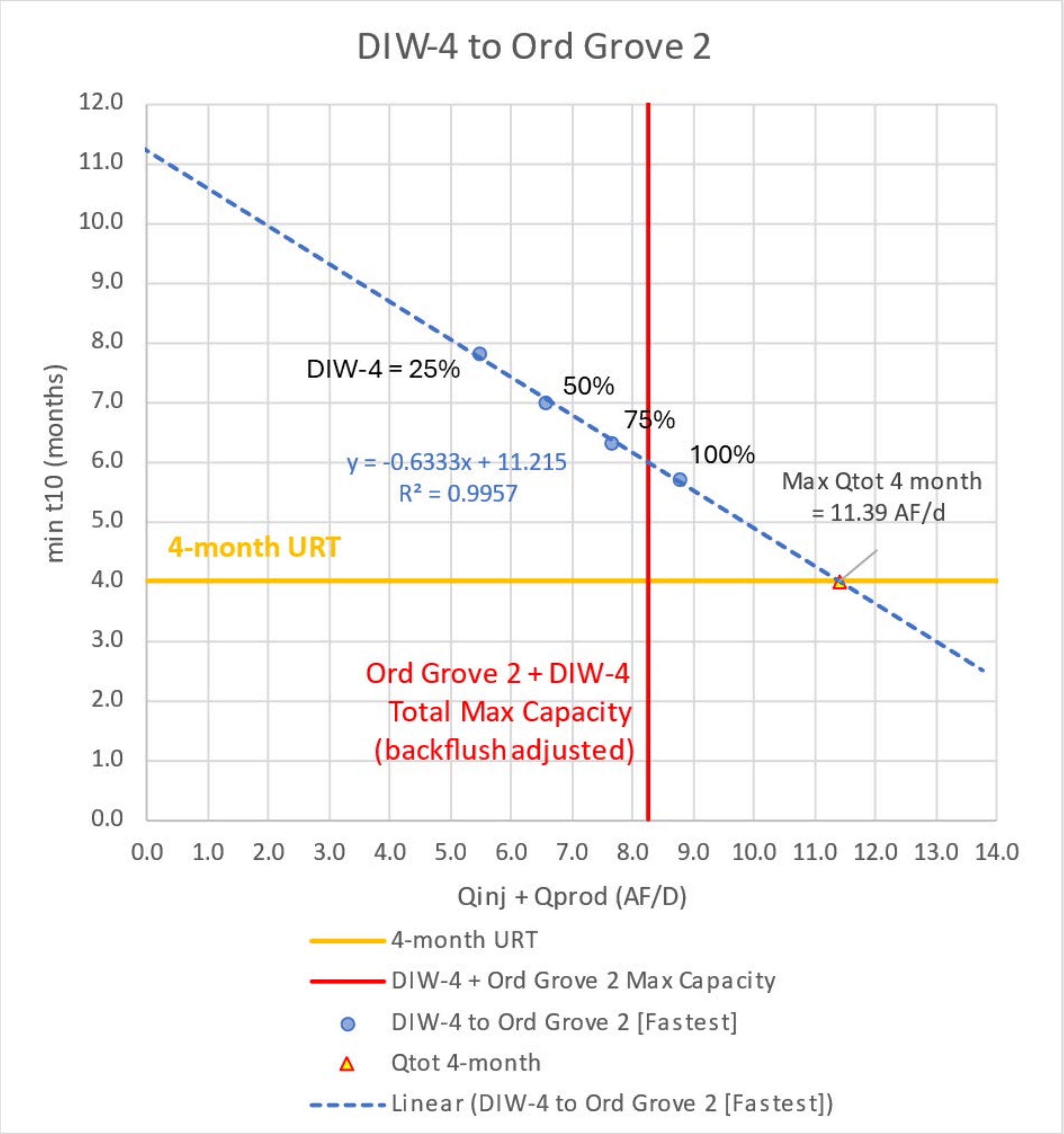


Figure F-11 Relationship of Travel Time and Combined Injection and Extraction Rate (DIW-4 to Ord Grove 2)

For this well pair, the regression line through the datapoints intersects the 4-month travel time threshold at a combined injection plus extraction rate of 11.39 AF/d. This exceeds the combined capacities of the two wells, which is 8.25 AF/mo. This means that DIW-4 can inject up to its physical capacity regardless of the amount of extraction at Ord Grove 2 and still achieve more than 4 months of travel time.

The following tables include the well combinations, prioritization, and injection/extraction scenarios for each operational configuration that was modeled.

Operational Configuration #1: **2 new EW's, Production Prioritization: EW-2 > EW-1 > ASR-4**

Monthly Municipal Seaside Production (acre-feet)

	Luzern	Ord Grove 2	Paralta	ASR-3	ASR-4	EW-1	EW-2	EW-3	EW-4	Seaside Muni #4
Jan	0	41	137	0	0	0	192	0	0	11
Feb	1	99	124	0	0	14	186	0	0	13
Mar	15	110	137	0	0	118	205	0	0	13
Apr	0	96	133	0	0	42	199	0	0	13
May	0	82	137	0	0	100	205	0	0	16
Jun	0	0	133	0	27	199	199	0	0	14
Jul	0	29	137	0	28	205	205	0	0	8
Aug	0	96	137	0	0	151	205	0	0	15
Sep	0	76	133	0	0	106	199	0	0	14
Oct	0	81	137	0	0	38	205	0	0	15
Nov	0	30	133	0	0	24	199	0	0	12
Dec	0	30	137	0	0	0	198	0	0	12

PWM Monthly Injection Rates (acre-feet)

	DIW-1	DIW-2	DIW-3	DIW-4	DIW-5	DIW-6
Jan	112	52	171	104	102	97
Feb	101	47	154	94	92	87
Mar	112	52	171	104	102	97
Apr	63	29	96	58	57	55
May	63	29	96	58	57	54
Jun	62	28	94	57	56	53
Jul	63	29	96	58	57	54
Aug	63	29	96	58	57	54
Sep	78	36	119	72	71	67
Oct	92	42	139	84	83	79
Nov	103	47	157	95	93	89
Dec	112	52	171	104	102	97

Operational Configuration #1: **2 new EW's, Production Prioritization: EW-2 > EW-1 > ASR-4**

Simulated Minimum t10 Travel Times (months)

Well	Paralta	ASR-3	ASR-4	Ord Grove 2	Seaside Muni #4	EW-1	EW-2	EW-3&4	Grand Min
DIW-1	5.2								5.2
DIW-2	7.8	37.2	41.5				37.8		7.8
DIW-3	5.8	8.2	8.3				9.5		5.8
DIW-4	38.5	49.5		5.2	7.1				5.2
DIW-5		47.0	53.1			11.6	10.6		10.6
DIW-6			41.3				14.2		14.2
Grand Min	5.2	8.2	8.3	5.2	7.1	11.6	9.5		5.2

Operational Configuration #2: **2 new EW's, Production Prioritization: EW-2 > ASR-4 > ASR-3**

Monthly Municipal Seaside Production (acre-feet)

	Luzern	Ord Grove 2	Paralta	ASR-3	ASR-4	EW-1	EW-2	EW-3	EW-4	Seaside Muni #4
Jan	0	41	137	0	0	0	192	0	0	11
Feb	1	99	124	0	14	0	186	0	0	13
Mar	15	110	137	0	118	0	205	0	0	13
Apr	0	96	133	0	42	0	199	0	0	13
May	0	82	137	0	100	0	205	0	0	16
Jun	0	0	133	60	166	0	199	0	0	14
Jul	0	29	137	62	171	0	205	0	0	8
Aug	0	96	137	0	151	0	205	0	0	15
Sep	0	76	133	0	106	0	199	0	0	14
Oct	0	81	137	0	38	0	205	0	0	15
Nov	0	30	133	0	24	0	199	0	0	12
Dec	0	30	137	0	0	0	198	0	0	12

PWM Monthly Injection Rates (acre-feet)

	DIW-1	DIW-2	DIW-3	DIW-4	DIW-5	DIW-6
Jan	112	52	171	104	102	97
Feb	101	47	154	94	92	87
Mar	112	52	171	104	102	97
Apr	63	29	96	58	57	55
May	63	29	96	58	57	54
Jun	62	28	94	57	56	53
Jul	63	29	96	58	57	54
Aug	63	29	96	58	57	54
Sep	78	36	119	72	71	67
Oct	92	42	139	84	83	79
Nov	103	47	157	95	93	89
Dec	112	52	171	104	102	97

Operational Configuration #2: **2 new EW's, Production Prioritization: EW-2 > ASR-4 > ASR-3**

Simulated Minimum t10 Travel Times (months)

Well	Paralta	ASR-3	ASR-4	Ord Grove 2	Seaside Muni #4	EW-1	EW-2	EW-3&4	Grand Min
DIW-1	5.1								5.1
DIW-2	7.7	32.8							7.7
DIW-3	5.7	7.4	7.3				9.0		5.7
DIW-4	33.7	39.1		5.2	7.3		61.9		5.2
DIW-5		29.7	26.6				10.2		10.2
DIW-6			30.6				14.1		14.1
Grand Min	5.1	7.4	7.3	5.2	7.3		9.0		5.1

Operational Configuration #3: **2 new EW's, Production Prioritization: EW-2 > ASR-3 > ASR-4**

Monthly Municipal Seaside Production (acre-feet)

	Luzern	Ord Grove 2	Paralta	ASR-3	ASR-4	EW-1	EW-2	EW-3	EW-4	Seaside Muni #4
Jan	0	41	137	0	0	0	192	0	0	11
Feb	0	96	128	8	0	0	192	0	0	13
Mar	15	110	137	118	0	0	205	0	0	13
Apr	0	96	133	42	0	0	199	0	0	13
May	0	82	137	100	0	0	205	0	0	16
Jun	0	0	133	166	60	0	199	0	0	14
Jul	0	29	137	171	62	0	205	0	0	8
Aug	0	96	137	151	0	0	205	0	0	15
Sep	0	76	133	106	0	0	199	0	0	14
Oct	0	81	137	38	0	0	205	0	0	15
Nov	0	30	133	24	0	0	199	0	0	12
Dec	0	30	137	0	0	0	198	0	0	12

PWM Monthly Injection Rates (acre-feet)

	DIW-1	DIW-2	DIW-3	DIW-4	DIW-5	DIW-6
Jan	112	52	171	104	102	97
Feb	101	47	154	94	92	87
Mar	112	52	171	104	102	97
Apr	63	29	96	58	57	55
May	63	29	96	58	57	54
Jun	62	28	94	57	56	53
Jul	63	29	96	58	57	54
Aug	63	29	96	58	57	54
Sep	78	36	119	72	71	67
Oct	92	42	139	84	83	79
Nov	103	47	157	95	93	89
Dec	112	52	171	104	102	97

Operational Configuration #3: **2 new EW's, Production Prioritization: EW-2 > ASR-3 > ASR-4**

Simulated Minimum t10 Travel Times (months)

Well	Paralta	ASR-3	ASR-4	Ord Grove 2	Seaside Muni #4	EW-1	EW-2	EW-3&4	Grand Min
DIW-1	4.9								4.9
DIW-2	7.2	24.4							7.2
DIW-3	5.5	6.2	8.3				9.6		5.5
DIW-4	28.8	37.7		4.9	9.1		44.2		4.9
DIW-5		14.6	14.2				10.9		10.9
DIW-6		16.6	17.6				16.6		16.6
Grand Min	4.9	6.2	8.3	4.9	9.1		9.6		4.9

Operational Configuration #4: **2 new EW's, Production Prioritization: ASR-3 > ASR-4 > EW-2**

Monthly Municipal Seaside Production (acre-feet)

	Luzern	Ord Grove 2	Paralta	ASR-3	ASR-4	EW-1	EW-2	EW-3	EW-4	Seaside Muni #4
Jan	0	41	137	171	21	0	0	0	0	11
Feb	1	99	124	155	45	0	0	0	0	13
Mar	15	110	137	171	152	0	0	0	0	13
Apr	0	96	133	166	76	0	0	0	0	13
May	0	82	137	171	134	0	0	0	0	16
Jun	0	0	133	166	166	0	93	0	0	14
Jul	0	29	137	171	171	0	96	0	0	8
Aug	0	96	137	171	171	0	14	0	0	15
Sep	0	76	133	166	139	0	0	0	0	14
Oct	0	81	137	171	73	0	0	0	0	15
Nov	0	30	133	166	57	0	0	0	0	12
Dec	0	30	137	171	27	0	0	0	0	12

PWM Monthly Injection Rates (acre-feet)

	DIW-1	DIW-2	DIW-3	DIW-4	DIW-5	DIW-6
Jan	112	52	171	104	102	97
Feb	101	47	154	94	92	87
Mar	112	52	171	104	102	97
Apr	63	29	96	58	57	55
May	63	29	96	58	57	54
Jun	62	28	94	57	56	53
Jul	63	29	96	58	57	54
Aug	63	29	96	58	57	54
Sep	78	36	119	72	71	67
Oct	92	42	139	84	83	79
Nov	103	47	157	95	93	89
Dec	112	52	171	104	102	97

Operational Configuration #4: **2 new EW's, Production Prioritization: ASR-3 > ASR-4 > EW-2**

Simulated Minimum t10 Travel Times (months)

Well	Paralta	ASR-3	ASR-4	Ord Grove 2	Seaside Muni #4	EW-1	EW-2	EW-3&4	Grand Min
DIW-1	4.5								4.5
DIW-2	6.9								6.9
DIW-3	5.2	5.6	7.9				9.9		5.2
DIW-4	33.7			4.8	8.6				4.8
DIW-5			15.1				13.3	8.8	8.8
DIW-6								17.3	17.3
Grand Min	4.5	5.6	7.9	4.8	8.6		9.9	8.8	4.5

Operational Configuration #5: **4 new EW's, Production Prioritization: EW-3 > EW-2 > EW-4**

Monthly Municipal Seaside Production (acre-feet)

	Luzern	Ord Grove 2	Paralta	ASR-3	ASR-4	EW-1	EW-2	EW-3	EW-4	Seaside Muni #4
Jan	0	41	137	0	0	0	0	91	0	11
Feb	1	99	124	0	0	0	0	99	0	13
Mar	15	110	137	0	0	0	17	205	0	13
Apr	0	96	133	0	0	0	0	140	0	13
May	0	82	137	0	0	0	201	205	0	16
Jun	0	0	133	0	0	0	199	199	128	14
Jul	0	29	137	0	0	0	205	205	129	8
Aug	0	96	137	0	0	0	205	205	47	15
Sep	0	76	133	0	0	0	199	199	8	14
Oct	0	81	137	0	0	0	139	205	0	15
Nov	0	30	133	0	0	0	0	122	0	12
Dec	0	30	137	0	0	0	0	97	0	12

PWM Monthly Injection Rates (acre-feet)

	DIW-1	DIW-2	DIW-3	DIW-4	DIW-5	DIW-6
Jan	112	52	171	104	102	97
Feb	101	47	154	94	92	87
Mar	112	52	171	104	102	97
Apr	63	29	96	58	57	55
May	63	29	96	58	57	54
Jun	62	28	94	57	56	53
Jul	63	29	96	58	57	54
Aug	63	29	96	58	57	54
Sep	78	36	119	72	71	67
Oct	92	42	139	84	83	79
Nov	103	47	157	95	93	89
Dec	112	52	171	104	102	97

Operational Configuration #5: **4 new EW's, Production Prioritization: EW-3 > EW-2 > EW-4**

Simulated Minimum t10 Travel Times (months)

Well	Paralta	ASR-3	ASR-4	Ord Grove 2	Seaside Muni #4	EW-1	EW-2	EW-3&4	Grand Min
DIW-1	5.3								5.3
DIW-2	7.7								7.7
DIW-3	6.5						9.3	16.9	6.5
DIW-4	35.1			5.0	7.3				5.0
DIW-5								7.6	7.6
DIW-6								15.5	15.5
Grand Min	5.3			5.0	7.3		9.3	7.6	5.0

Operational Configuration #6: **4 new EW's, Production Prioritization: EW-3 > EW-4 > EW-2**

Monthly Municipal Seaside Production (acre-feet)

	Luzern	Ord Grove 2	Paralta	ASR-3	ASR-4	EW-1	EW-2	EW-3	EW-4	Seaside Muni #4
Jan	0	41	137	0	0	0	0	91	0	11
Feb	1	99	124	0	0	0	0	99	0	13
Mar	15	110	137	0	0	0	0	205	17	13
Apr	0	96	133	0	0	0	0	140	0	13
May	0	82	137	0	0	0	0	205	201	16
Jun	0	0	133	0	0	0	128	199	199	14
Jul	0	29	137	0	0	0	129	205	205	8
Aug	0	96	137	0	0	0	47	205	205	15
Sep	0	76	133	0	0	0	8	199	199	14
Oct	0	81	137	0	0	0	0	205	139	15
Nov	0	30	133	0	0	0	0	122	0	12
Dec	0	30	137	0	0	0	0	97	0	12

PWM Monthly Injection Rates (acre-feet)

	DIW-1	DIW-2	DIW-3	DIW-4	DIW-5	DIW-6
Jan	112	52	171	104	102	97
Feb	101	47	154	94	92	87
Mar	112	52	171	104	102	97
Apr	63	29	96	58	57	55
May	63	29	96	58	57	54
Jun	62	28	94	57	56	53
Jul	63	29	96	58	57	54
Aug	63	29	96	58	57	54
Sep	78	36	119	72	71	67
Oct	92	42	139	84	83	79
Nov	103	47	157	95	93	89
Dec	112	52	171	104	102	97

Operational Configuration #6: **4 new EW's, Production Prioritization: EW-3 > EW-4 > EW-2**

Simulated Minimum t10 Travel Times (months)

Well	Paralta	ASR-3	ASR-4	Ord Grove 2	Seaside Muni #4	EW-1	EW-2	EW-3&4	Grand Min
DIW-1	5.3								5.3
DIW-2	7.7								7.7
DIW-3	6.7						11.2		6.7
DIW-4				4.9	7.5				4.9
DIW-5								7.4	7.4
DIW-6								14.5	14.5
Grand Min	5.3			4.9	7.5		11.2	7.4	4.9

Monterey One Water
Pure Water Monterey Groundwater Replenishment Project
Engineering Report

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APPENDIX G

Assumptions, Data, and Results of Tracer Studies

Assumptions, Data, and Results of Tracer Studies

Prepared by Eugene B. Yates, PG, CHG
Todd Groundwater
February 12, 2024

M1W has measured underground retention time by conducting two intrinsic and two extrinsic tracer studies during startup and ongoing operation of the Project. This memo documents the test procedures, injection and extraction rates during the studies, and the measured tracer concentrations at downgradient wells. Briefly, an intrinsic tracer study using electrical conductivity as the tracer was implemented for DIW-1 and DIW-2 over the first year of project operation (March 2020-March 2021). It provided initial indications of mean subsurface velocity and the amount of dispersion that occurs around the mean. An extrinsic (added) trader study using fluorescent dyes was conducted at DIW-1 and DIW-2 from October 2021 to April 2022. That study tightened the estimate of travel times because it avoided the confounding effects of low electrical conductivity of Carmel Valley water injected at the ASR wells located between the injection and extraction wells used for the intrinsic tracer study. Electrical conductivity was also used as an intrinsic tracer for water injected into DIW-3 and DIW-4 following their start-up in March-April 2022. Finally, an extrinsic tracer test was initiated at DIW-3 and DIW-4 by injecting fluorescent dyes in October 2022. Monitoring for the DIW-3 and DIW-4 tests is nearing completion and has supported some revised underground retention time conclusions.

Injection and Extraction Rates during the Tracer Studies

Injection rates at DIWs and extraction rates at CalAm and Seaside municipal wells are key variables that influence travel time from injection wells to extraction wells. In this case, injection at ASR wells also strongly influences travel times for water injected using DIW-1, DIW-2, and DIW-3. **Figure G-1** shows monthly extractions at CalAm wells (upper plot) and monthly injections at Project and ASR wells (lower plot) during March 2020-September 2023. ASR-3 injected some Carmel Valley water in the first two months of the period, but thereafter it was used only as a CalAm municipal supply well. ASR-1 also changed roles during this period. It was used as a CalAm municipal supply well in 2020 but converted to injection-only use when early tracer and modeling results indicated travel times from DIW-1 would be close to the regulatory minimum at higher injection rates that were anticipated in later project operational phases. ASR-4 was not permitted as a municipal supply well until late 2023, and CalAm expects to use it as a supply well beginning in 2024.

Two injection/extraction patterns evident in **Figure G-1** are particularly relevant to observed travel times during the tracer tests. First, DIW-1 and DIW-2 were operated at high rates of injection until March 2022, when DIW-3 and DIW-4 came on-line. Those rates exceeded the recommended injection rate, which is half of the extraction rate during backflushing. But the high rates tested the aquifer under conditions conducive to the fastest plausible travel times. Second, there was a large amount of ASR injection during the DIW-3 DIW-4 tracer tests because the winter of 2023 was exceedingly wet. All of the injection occurred at ASR-1 and ASR-2, which are located between the DIWs and the downgradient CalAm supply wells (Paralta, and to some extent ASR-3). ASR injection creates a hydraulic mound that tends to deflect Project water into longer, slower peripheral flow paths. Note that travel time from DIW-4 to Ord Grove 2 is not significantly affected by ASR injection because those wells are farther to the south of the ASR wells.

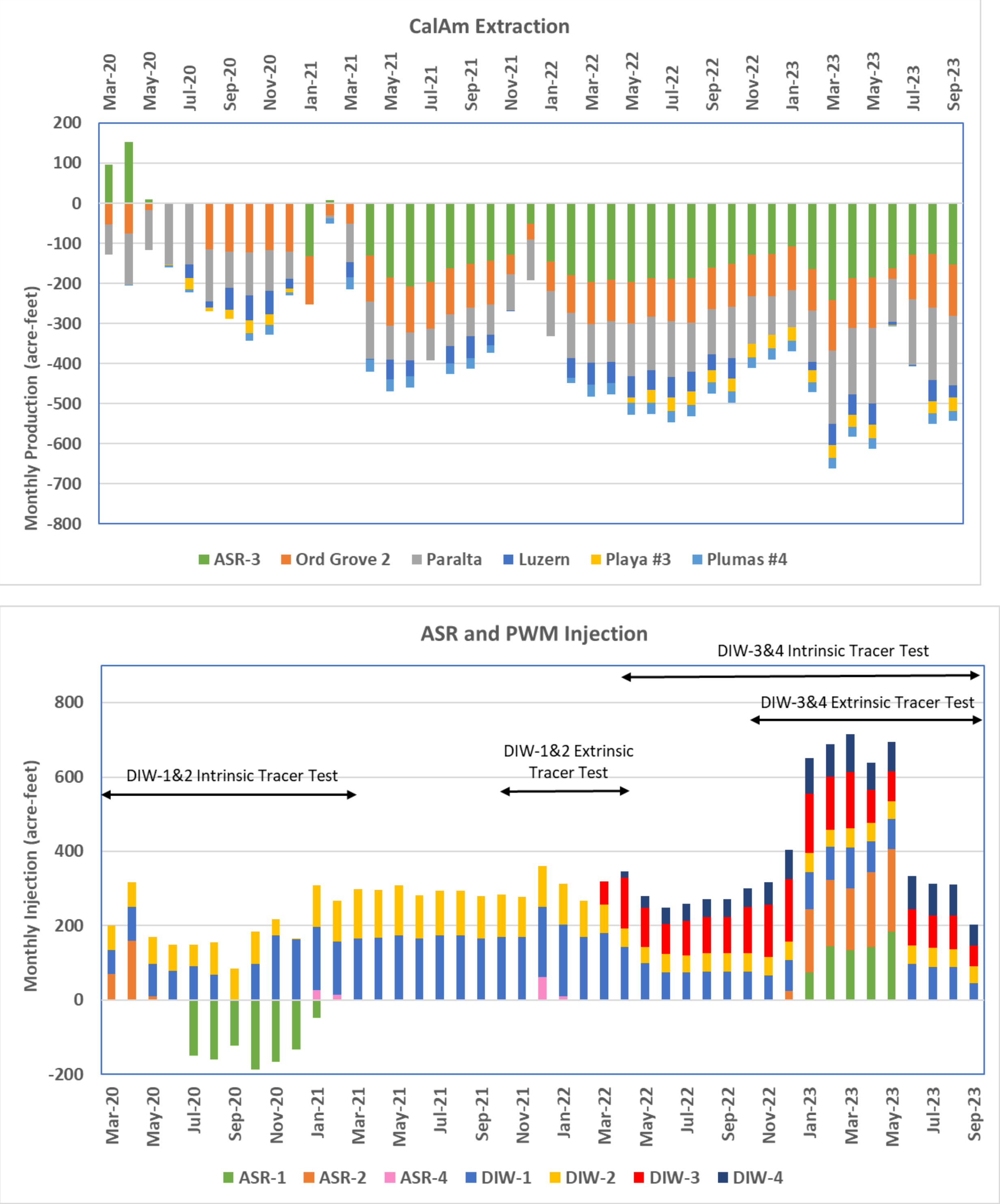


Figure G-1. Monthly Injection and Extraction, March 2020-September 2023

DIW-1 and DIW-2 Intrinsic Tracer Study Results

The results of the DIW-1 and DIW-2 intrinsic tracer study were documented in a technical memorandum (Todd Groundwater, 2021). The low specific conductance (electrical conductivity) of the purified recycled water was used as the intrinsic tracer. The most important results were the time-concentration plots of specific conductance at nearby monitoring wells, which are shown in **Figure G-2**. The decrease in specific conductance at the onsite monitoring wells (MW-1D and MW-2D) was rapid and abrupt. At the more distant monitoring wells (MW-1AD and MW-2AD) it occurred later and more gradually. The travel times for arrival and breakthrough of injected water are listed in **Table G-1**. In the table, “arrival” is used to indicate the time when injected water was first detected at the downgradient well, and “breakthrough” is used to indicate when the concentration of a constituent in the downgradient sample reached 10% of the peak concentration measured at the downgradient well. With continuous injection, the peak concentration manifests as the stabilized long-term concentration associated with the steady blend of injected water and ambient groundwater. The time to the 10th percentile concentration is the travel time to which underground retention time regulations apply. Specifically, Title 22 Section 60320.208(d) states “The retention time shall be the time representing the difference from when the water with the tracer is applied at the GRRP to when ... ten percent (10%) of the peak tracer unit value observed at the downgradient monitoring point reached the monitoring point.”

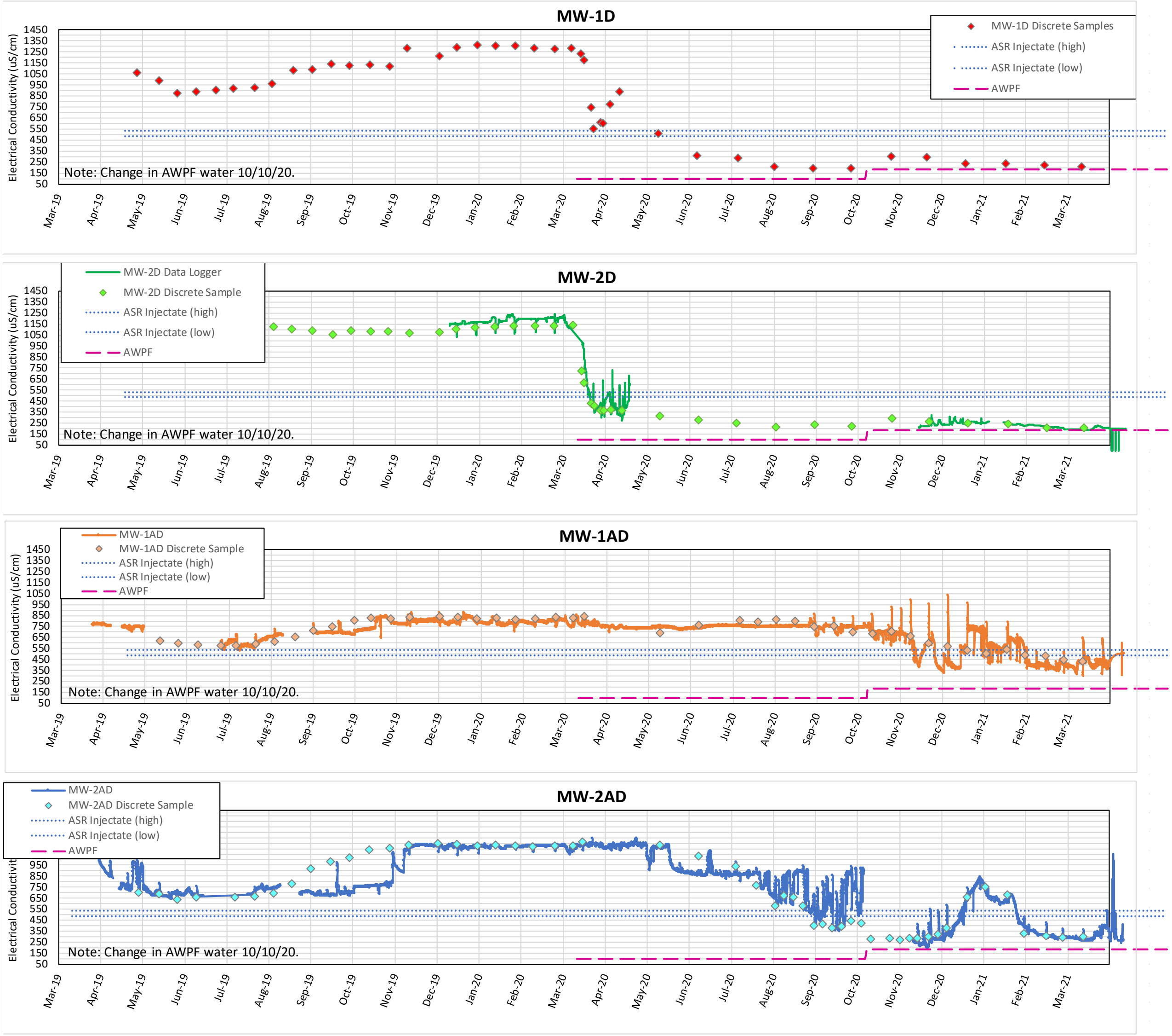


Figure G-2. Specific Conductance at Monitoring Wells DIW-1 and DIW-2 Intrinsic Tracer Study

Table G-1. Arrival and Breakthrough Travel Times for DIW-1 and DIW-2 Intrinsic Tracer Study

Monitoring Well	Distance from Nearest Injection Well (feet)	Date of Arrival	Elapsed Time to Arrival (days)	Date of Breakthrough	Elapsed Time to Breakthrough (days)
MW-1D	95	3/24/2020	11	3/24/2020	11
MW-1AD	615	8/1/2020	138	8/18/2020	155
MW-2D	95	3/17/2020	4	3/17/2020	4
MW-2AD	610	5/20/2020	65	6/7/2020	83

Interpretation of the specific conductance data was somewhat confounded by concurrent injection of ASR water early in the test period. The specific conductance of Carmel Valley water injected at the ASR wells is lower than that of ambient groundwater but higher than the specific conductance of the purified recycled water (490-520 µS/cm versus 185 µS/cm). Measured specific conductance at MW-1AD and MW-2AD could not positively be attributed to Project injection until it dropped below the value for Carmel Valley water.

DIW-1 and DIW-2 Extrinsic Tracer Study Results

After the initial intrinsic tracer study, an extrinsic (or added) tracer study was implemented at DIW-1 and DIW-2 pursuant to a work plan approved by DDW (Todd Groundwater, 2021b). On October 26, 2021, 20 pounds of fluorescein dye was injected into DIW-1 and 50 pounds of eosine dye was injected into DIW-2. Details of the mixing and injection were documented in the tracer study report (Todd Groundwater, 2022a). Dye concentrations were measured at MW-1AD, MW-2AD, SMTIW MW-1, Paralta, and Ord Grove 2 from November 16, 2021 through May 26, 2022. Time concentration plots at those wells are shown in **Figure G-3**. Dye was never detected at Ord Grove 2, so data for that well are not shown.

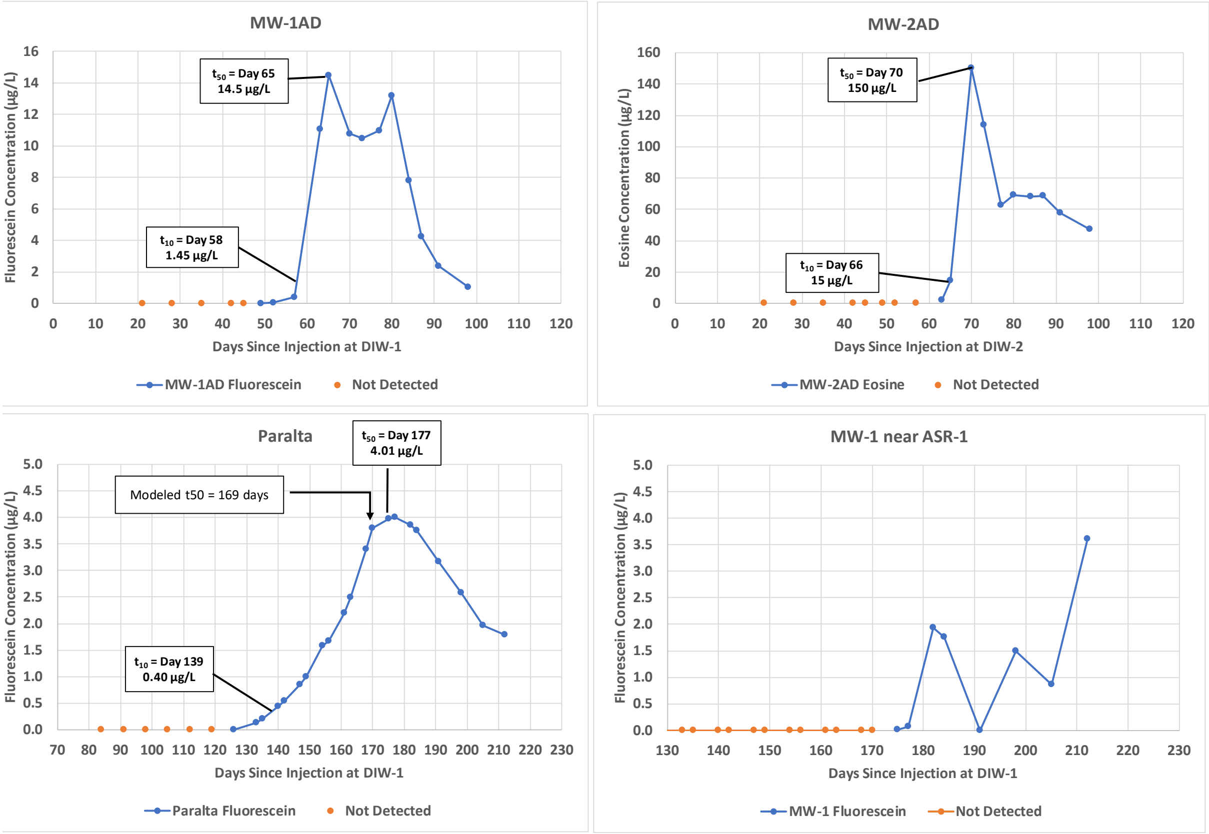


Figure G-3. Dye Concentrations at Downgradient Wells for DIW-1 and DIW-2 Extrinsic Tracer Test

The t_{10} and t_{peak} travel times are labeled on the plots. As expected, fluorescein arrived at MW-1AD and eosine arrived at MW-2AD relatively quickly, and the rising limbs of the breakthrough curves were abrupt. Peak concentrations occurred at 65 and 70 days after injection, respectively, and the 10th percentile concentrations occurred after 58 and 66 days, respectively. A more gradual and symmetrical breakthrough curve was measured at Paralta. These characteristics are due to its greater distance from DIW-1 and the fact that it is a production well with a high pumping rate. The well captured all the dye over a large capture-zone radius and blended it with ambient groundwater entering the well from other directions. The t_{10} and t_{peak} travel times were 139 and 177 days, respectively. The erratic data and relatively low concentrations measured at SMTIW MW-1 (near ASR-1) were attributed to the well's location in a low-velocity zone between the DIW-1 and DIW-2 plumes, as indicated by numerical groundwater modeling.

The extrinsic tracer results provided a basis for estimating the ratio of t_{10} to t_{peak} at other locations and under different injection/extraction conditions. The ratio represents dispersion due to differences in flow path velocities at microscopic and macroscopic scales as water moves through an aquifer. The amount of spread (dispersion) in the breakthrough curve increases with distance traveled, and the increase is theoretically proportional to distance. A linear relationship of t_{10}/t_{peak} based on data from this tracer study is shown in **Figure G-4** (Montgomery & Associates, 2022a).

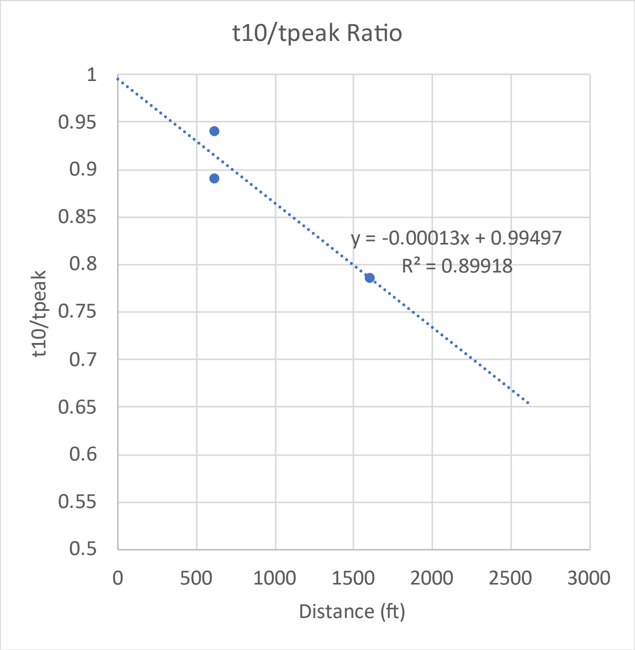


Figure G-4. Linear Relationship Between Observed t_{10}/t_{peak} Ratio and Distance from Injection Well

DIW-3 and DIW-4 Intrinsic Tracer Study Results

An intrinsic tracer study similar to the one conducted for DIW-1 and DIW-2 was implemented for DIW-3 and DIW-4 when those wells began injecting recycled water in spring 2022. DIW-3 began normal injection on March 15, 2022 and DIW-4 began normal injection on April 7, 2022. As in the previous intrinsic tracer study, the low specific conductance of the purified recycled water was used as the intrinsic tracer. Specific conductance was measured at the ASR-3, Paralta, Ord Grove 2 and Seaside Muni #4 wells weekly beginning in early September 2022. Measurements have continued up to the date of preparing this report (January 2024). A preliminary data interpretation memo was prepared in November 2022 (Todd Groundwater, 2022c). However, that memorandum is superseded by the results shown here.

Figure G-5 shows measured specific conductance before and during the intrinsic tracer test for the monitored downgradient wells, and also for the purified recycled water during the tracer study period. The upper plot shows all of the data, and the lower plot expands the time scale for recent data during the test period. DIW-3 began injecting in mid-March 2022, and specific conductance at ASR-3 began declining around the beginning of January 2023, approximately 9.5 months later. DIW-4 began injecting in early April 2022, and specific conductance at Ord Grove 2 similarly began declining around the middle of January 2023, approximately 9.5 months later. Ignoring occasional high outliers (probably measurement errors), the data for Seaside Muni #4 did not exhibit a trend, consistent with modeling results that showed it outside the path of flow from DIW-4.

In contrast to the other municipal wells, Paralta began experiencing a prominent increasing trend in specific conductance beginning in mid-January 2023. The timing and direction of this change suggest that Carmel Valley groundwater injected at ASR-1 and ASR-2 began displacing recycled water that had been arriving from DIW-1 and DIW-2. Prior to the increase, Paralta specific conductance was near the very bottom of its historical range. This was likely due to the introduction of recycled water beginning in March 2020. Carmel Valley groundwater has a higher specific conductance than recycled water, so if it replaced recycled water upgradient of Paralta, the specific conductance at Paralta would increase. There was a substantial amount of ASR injection in winter 2023, commencing about one month before the start of the rising trend in specific conductance at Paralta. So the direction and timing of the trend are consistent with the expected effects of ASR injection.

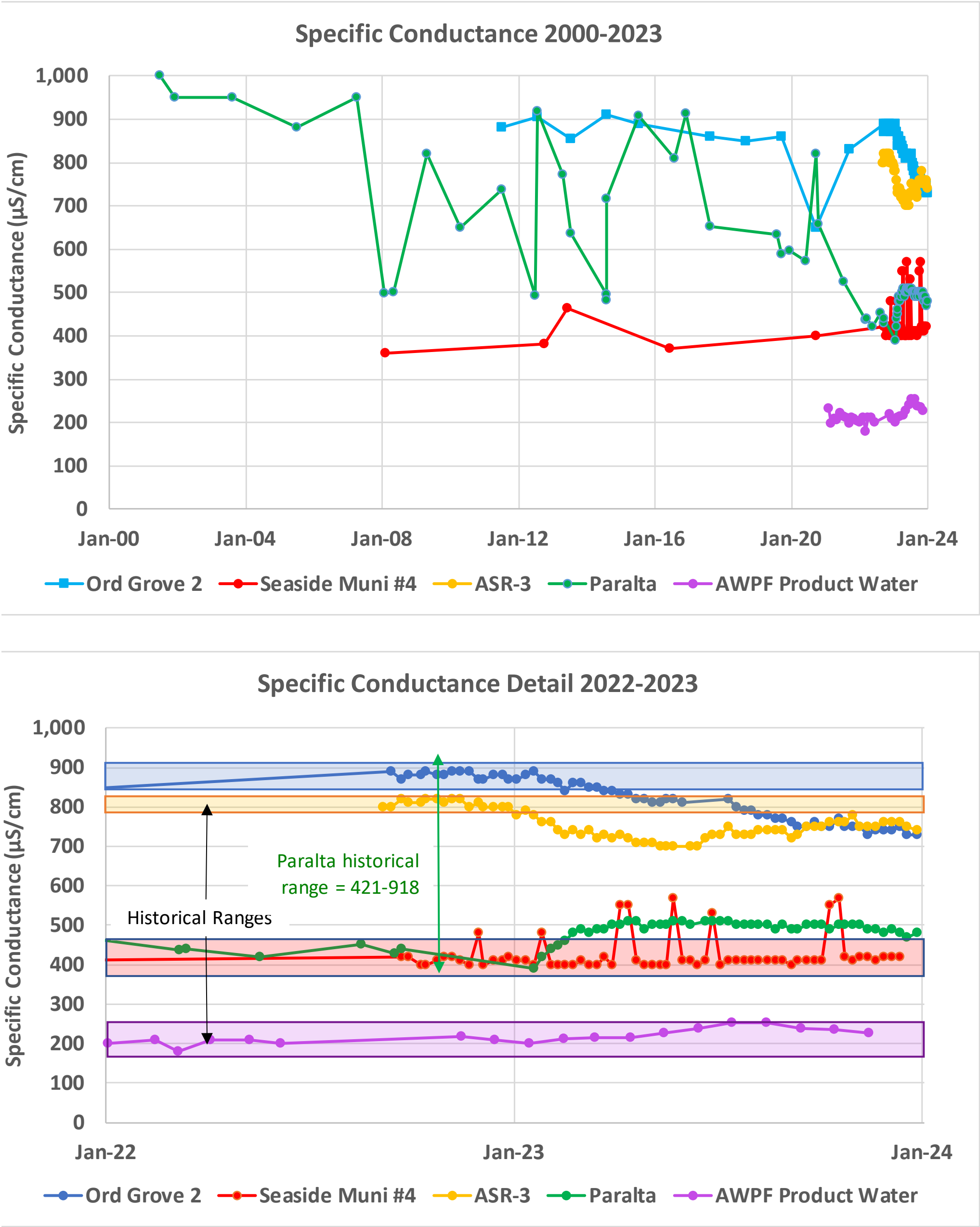


Figure G-5. Specific Conductance in Municipal Supply Wells, 2000-2023

DIW-3 and DIW-4 Extrinsic Tracer Study Results

A second extrinsic tracer study was initiated on October 25, 2022 pursuant to a work plan approved by DDW (Todd Groundwater, 2022c). Twenty pounds of fluorescein dye was injected into DIW-4 and 40 pounds into DIW-3 (to allow for greater dispersion over the longer travel distance). Concentrations were monitored weekly at the ASR-3, Paralta, Ord Grove 2 and Seaside Muni #4 wells starting 72 days after injection. Monitoring is ongoing as of January 2024, and results to date are shown in **Figure G-6**. Water from the Paralta well was also analyzed for eosine to see if water injected at DIW-2 during the first extrinsic tracer study had finally arrived. That proved to be the case, and eosine monitoring at Paralta continued throughout the second extrinsic tracer study.

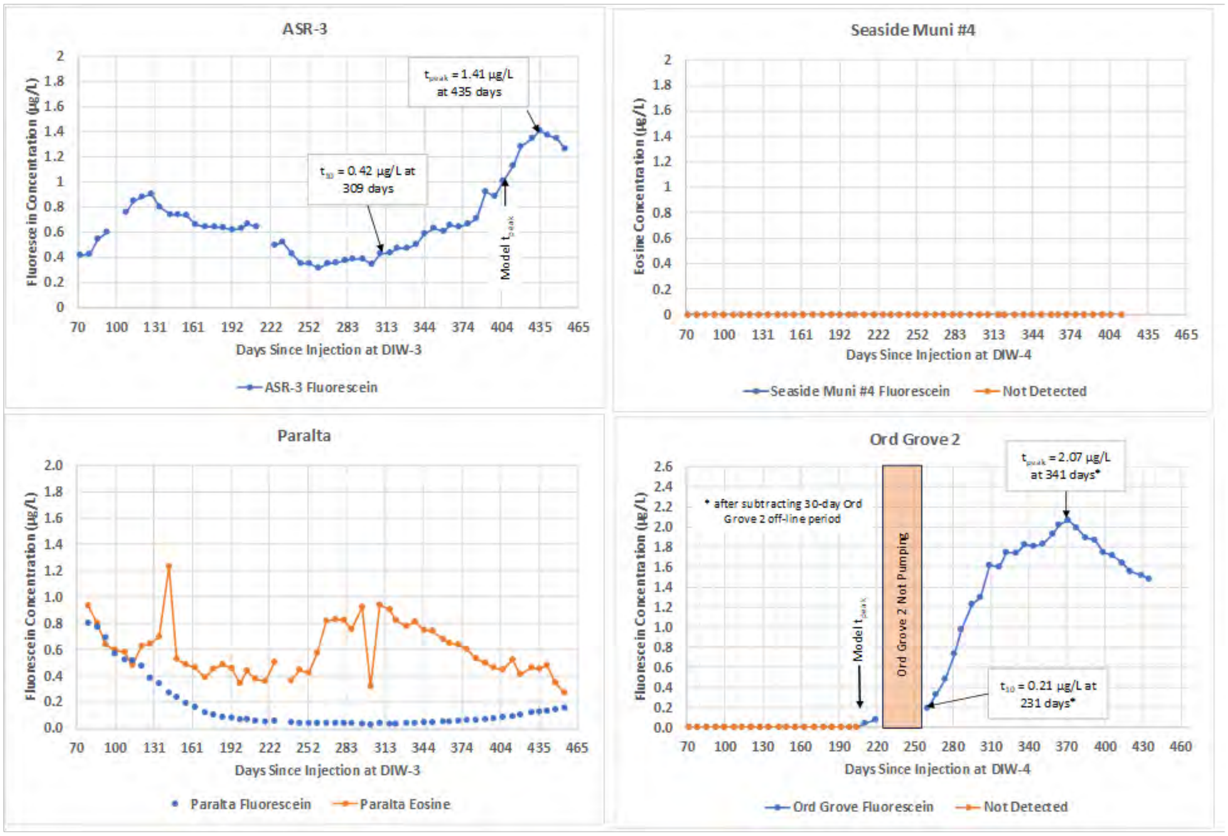


Figure G-6. Downgradient Dye Concentrations during the DIW-3, DIW-4 Extrinsic Tracer Study

Fluorescein has been detected at ASR-3 throughout the monitoring period, but the detections early in the study period are residual dye from the first extrinsic tracer study (that is, dye injected into DIW-1 during the previous year). Dye from the first study was expected to eventually reach ASR-3, and its presence at the very start of the monitoring period for the second extrinsic tracer study was too soon to plausibly be dye injected at DIW-3 for that study. The peak concentration that occurred 441 days (14.5 months) after injection was from dye injected at DIW-3. That almost exactly matched the peak time of 445 days (14.6 months) indicated by simulations prior to the test, confirming the accuracy of the model. The t10 travel time was calculated by assuming the first arrival of fluorescein from DIW-3 was when the concentration curve shifted from declining to ascending, at day 260 of the test. Taking the 10th percentile of the difference between the concentration at that time (0.193 µg/L) and the peak concentration (1.41 µg/L) produced a t_{10} travel time of 309 days (10.2 months).

As expected, no dye has been detected at Seaside Muni #4. This well is off to the side of the flow path connecting DIW-4 and Ord Grove 2. Prior modeling showed that with relatively high rates of injection at DIW-4, injected water would spread to the vicinity of Seaside Muni #4 only slowly through transverse dispersion. The tracer study results have thus far confirmed those results.

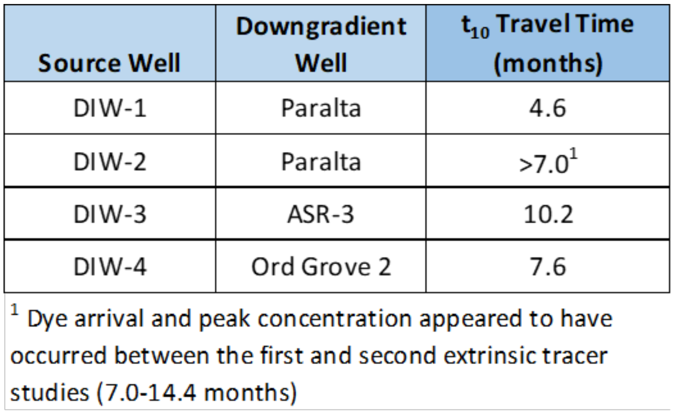
Fluorescein was detected at Paralta at low, declining levels during the first half of the monitoring period. That fluorescein was residual dye from the DIW-1 and DIW-2 extrinsic tracer study. As described in **Section 5.3** of the 2024 PWM Engineering Report, modeling of Project operational scenarios showed that under most conditions, water injected at DIW-3 would reach ASR-3 before it reached Paralta due to the influence of the adjacent injection plume from DIW-1. Flourescein peaked at ASR-3 on day 441 of the test, and there appears to be a very gradual increase in fluorescein at Paralta that started around day 340. The latter could be dye injected at DIW-3 for the second extrinsic tracer study.

Eosine has been present at Paralta throughout the second extrinsic tracer study monitoring period and exhibited a peak on August 23, 2023, or 21.9 months after injection for the first (DIW-1 and DIW-2) tracer study. This is roughly three times longer than the expected t_{peak} travel time based on model simulations. This peak might be a delayed secondary peak representing flow through a less permeable part of the aquifer. The eosine concentration was declining for the first 4 months of monitoring for the second tracer study, suggesting that a prior peak had occurred between the monitoring periods for the first and second tracer studies. That prior peak might have corresponded more closely to the simulated travel time.

A well-defined fluorescein breakthrough curve occurred at Ord Grove 2 with a peak at 371 days (12.2 months). However, Ord Grove 2 was off-line for one month in summer 2023, so under normal circumstances the t_{50} travel time would have been about 341 days (11.2 months).

Table G-2 summarizes the t_{10} travel times between each DIW and its nearest downgradient drinking water well obtained from the extrinsic tracer studies. The shortest measured travel time was 4.6 months between DIW-1 and the Paralta well. The t_{10} travel times for the other well pairs were all greater than 7 months.

Table G-2. T_{10} Travel Times from Extrinsic Tracer Studies



Source Well	Downgradient Well	t_{10} Travel Time (months)
DIW-1	Paralta	4.6
DIW-2	Paralta	>7.0[1]
DIW-3	ASR-3	10.2
DIW-4	Ord Grove 2	7.6

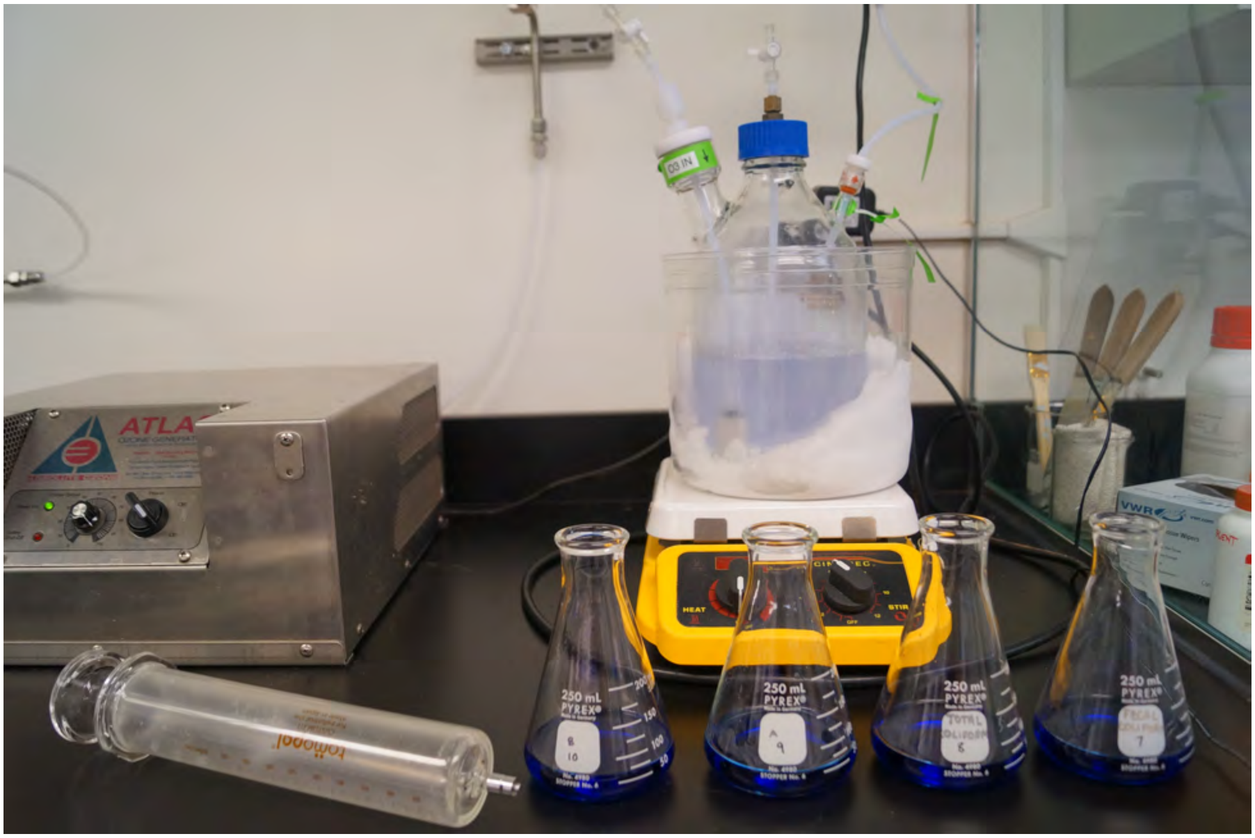
[1] Dye arrival and peak concentration appeared to have occurred between the first and second extrinsic tracer studies (7.0-14.4 months)

APPENDIX H

Dieldrin and DDx Removal Testing for the Pure Monterey Groundwater Replenishment Project

Dieldrin and DDx Removal Testing for the Pure Water Monterey Groundwater Replenishment Project

FINAL REPORT



Prepared for:

Monterey Regional Water Pollution Control Agency &
Monterey Peninsula Water Management District

July 2016

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TECHNOLOGIES INC

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EXECUTIVE SUMMARY

The Monterey Regional Water Pollution Control Agency (MRWPCA) is in the process of developing the Pure Water Monterey (PWM) project to help address potable water needs on the Monterey Peninsula. As part of this project, MRWPCA is designing an Advanced Water Treatment Facility (AWTF), which will include ozonation, membrane filtration (MF), reverse osmosis (RO) and further treatment. The AWTF will receive secondary effluent from the Regional Treatment Plant (RTP), which will receive additional diversions of water sources for the PWM project. One additional water that will be diverted to the RTP is the Blanco Drain, which has elevated levels of dieldrin and DDx.

The California Ocean Plan (COP) has water quality objectives for dieldrin and DDx that are used to develop discharge limits. A by-product of RO treatment is a concentrate stream, which will be discharged through the RTP ocean outfall. The discharge of RO concentrate, along with secondary effluent, has been evaluated for compliance with COP objectives. This assessment concluded that removal of dieldrin and DDx through the RTP, ozone, and MF may be required to meet COP objectives. This report summarizes an effort to evaluate dieldrin and DDx removal through these processes.

Removal of dieldrin and DDx through the RTP, ozone, and MF were evaluated through sampling and bench-scale testing. Samples were collected from the RTP and analyzed with low-detection limit methods to assess removal of ambient dieldrin and DDx through the RTP. Bench-scale testing was conducted on blends of Blanco Drain water and samples from the RTP. Tests included ozonation, membrane filtration, and bench-scale approximations of RTP processes.

Significant dieldrin and DDx removal occurred through the RTP, ozonation, and filtration (see summary of results, with respect to COP compliance of the RTP and the AWTF processes, in Table E-1). Removal through the RTP alone was sufficient to meet COP objectives. Removal through ozonation and MF offer additional layers of redundancy and robustness.

Table E-1: Dieldrin and DDx removals through RTP and AWTF processes

Constituent	Qualifier	Removal (%)			
		RTP	Ozone	MF	Total
Dieldrin	Required for COP	--	--	--	61% - 78%
	Observed or estimated	84%	44% - 63%	1% - 98%	91% - 99.9%
DDx	Required for COP	--	--	--	58% - 71%
	Observed or estimated	93%	36% - 48%	2% - 94%	96% - 99.8%

1 INTRODUCTION

1.1 Background

Pending reductions in Carmel River water diversions are spurring the development of additional potable water supplies on the Monterey peninsula. The Monterey Peninsula Water Management District (MPWMD) and the Monterey Regional Water Pollution Control Agency (MRWPCA) are developing the Pure Water Monterey (PWM) Groundwater Replenishment (GWR) project to help address the water shortage. The project includes diversion of additional waters to the Regional Treatment Plant (RTP), which produces both a secondary treated wastewater and tertiary treated wastewater. A portion of the secondary effluent will be diverted to an Advanced Water Treatment Facility (AWTF), while the remaining secondary effluent will be treated at the Salinas Valley Reclamation Plant (SVRP) for non-potable recycled water or discharged to the Monterey Bay through the ocean outfall. The AWTF will produce high quality recycled water suitable for groundwater replenishment. The main components of the RTP and AWTF treatment train are the following:

- **Regional Treatment Plant (RTP):** screening, primary clarification, optional Chemically Enhanced Primary Treatment (CEPT), non-nitrifying trickling filters, bio-flocculation (solids contact basins), and secondary clarification; and,
- **Advanced Water Treatment Facility (AWTF)**: chloramination, ozonation, membrane filtration (MF), reverse osmosis (RO), advanced oxidation (AOP) with hydrogen peroxide and ultraviolet (UV) light, and product water stabilization.

Additional raw water sources will be diverted to the RTP collection system including agricultural wash water and industrial wastewater from the Salinas Industrial Wastewater Treatment Facility (SIWTF), and agricultural tile drainage and runoff waters from the Blanco Drain, Reclamation Ditch, and stormwater from the City of Salinas. Source water monitoring was conducted from July 2013 to June 2014 to characterize the proposed new source waters for the GWR project (Trussell Technologies, 2014). Two legacy pesticides that have been banned for decades, dieldrin and 4,4'dichlorodiphenyldichloroethylene (4,4'DDE), were detected during the monitoring of the Blanco Drain. The median concentration of dieldrin detected in the Blanco Drain samples was 17 nanograms per liter (ng/L), with a range of less than 10 (below the method detection limit) to 31 ng/L; 4,4'DDE was detected once, at a concentration of 21 ng/L.

DDE is a breakdown degradate of dichlorodiphenyltrichloroethane (DDT), and exists as one of two congeners: 4,4'DDE or 2,4'DDE. Although only one of the congeners was detected in the source water monitoring, all six congeners of DDT (2,4'DDT, 4,4'DDT, 2,4'DDE, 4,4'DDE, 2,4'dichlorodiphenyldichloroethane (DDD), and 4,4'DDD) have been included in this investigation, and will be collectively referred to as DDx. The RTP effluent and the SIWTF were also sampled, in addition to the Blanco Drain, during the source water monitoring. Dieldrin and DDx were not detected in the RTP effluent and the SIWTF (utilizing methods with method reporting limits as low as 10 ng/L).

Both dieldrin and DDx have established water quality objectives in the 2012 California Ocean Plan (COP), as well as the draft 2015 version (State Water Resources Control Board, 2012 and 2015). Ocean discharges in California must meet the water quality objectives described in the

COP. The AWTF will produce an RO concentrate that will be discharged through an ocean outfall, along with varying quantities of secondary treated wastewater. The concentrations of dieldrin and DDx in this RO concentrate are of concern due to the potential to exceed COP water quality objectives.

Modeling of AWTF RO concentrate and secondary effluent discharge suggests that an overall removal of 61% to 78% and 58% to 71% would be required through the RTP and ozone for dieldrin and DDx, respectively, in order for future discharges to comply with the COP objectives. Compliance assessment efforts (Trussell Technologies, 2015b) have estimated concentrations of dieldrin and DDx in the RO concentrate for purpose of evaluating compliance with COP objectives. These efforts assumed that removal through ozone was 90% for dieldrin and 70% for DDx, based on scientific literature (Ormad, 2008). An additional 20% removal of dieldrin and DDx was assumed to occur through the RTP, based on limited sampling that identified the portions of dieldrin in the Blanco Drain that were dissolved or suspended (*i.e.*, filtered or retained on a 0.45-µm glass fiber filter). These assumptions for RTP and ozone removals equate to overall assumed removals of 92% for dieldrin and 76% for DDx.

The objective of this testing was to verify these previously used assumptions for dieldrin and DDx removal prior to RO by measuring dieldrin and DDx removal through the RTP, ozonation, and simulated membrane filtration.

1.2 Test Protocol

Testing was conducted following the bench test plan (attached as Appendix B[1]). Major components of testing were the following:

- RTP sampling,
- RTP bench testing, and
- AWTF bench testing.

Bench testing was conducted on the following three blends of samples from the RTP and the Blanco Drain in order to simulate treatment with this new source water through the RTP:

- Primary influent mixture: primary influent sample and Blanco Drain sample,
- Solids contactor effluent mixture: solids contactor effluent sample and filtered Blanco Drain sample, and
- Secondary effluent or AWTF feed mixture: secondary effluent sample and filtered Blanco Drain sample.

The filtered Blanco Drain sample was produced by filtering the Blanco Drain sample first through the 100-µm filter, then the 45-µm, and lastly the 10-µm filter, to simulate RTP treatment. The mixtures contained 12% Blanco Drain water, which is the maximum contribution projected for the RTP source water blends. The mixtures were subjected to treatment processes that simulate treatment processes in the RTP and the AWTF (treatment processes shown Table 1-1).

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[1] Test conditions may have changed from the experimental plan, as warranted during actual testing. Procedures used during testing are described in detail in the main body of this report.

Bench-scale filtration was used to mimic primary, secondary, and membrane filtration treatment. For primary and secondary treatment, a 100-µm hydrophilic nylon net filter (“100-µm filter”) was used as a pre-filter, followed by a 45-µm hydrophobic polypropylene filter (“45-µm filter”) as another pre-filter, and then by a 10-µm hydrophobic polypropylene filter (“10-µm filter”). To mimic membrane filtration, either a 0.7-µm glass fiber filter (“7-µm filter”) or the 10-µm filter was used to pre-filter the samples, followed by a 0.45-µm hydrophilic nitrocellulose membrane (“0.45-µm”) as another pre-filter, and then by a 0.1-µm hydrophilic polyethersulfone membrane filter (“0.1-µm filter”).

Table 1-1: Bench-scale treatment processes used to simulate full-scale treatment processes

RTP or AWTF treatment process	Bench-scale treatment process
Primary clarification (RTP)	Filtration through 100-, 45- and 10-µm filters
Secondary clarification (RTP)	Filtration through 100-, 45- and 10-µm filters
Ozonation (AWTF)	Solution ozone test (SOT)
Membrane filtration (AWTF)	Filtration through 0.7-µm or 10-, 0.45- and 0.1-µm filter

The solution ozone test (SOT) is a bench-scale ozonation test conducted with a stable stock of ozone solution. Deionized water is ozonated to make a stock of ozone solution that is stable at low temperatures over short time scales. The stock solution concentration is measured using the indigo method[2] and the sample is dosed with the ozone stock solution. Indigo solution was prepared the day of testing and the ultraviolet absorbance (UVA) at 600 nanometers (nm) was checked for quality control (*i.e.*, UVA greater than or equal to 0.2 per centimeter). SOTs were conducted at three ozone-to-total-organic-carbon (O_3:TOC) ratios, after accounting for initial nitrite demand of the sample, where the middle ratio represented the AWTF design O_3:TOC ratio.

RTP sampling was conducted for two purposes: (1) to provide samples for the mixtures that were used in bench testing (blends of RTP samples and Blanco Drain sample), and (2) to measure ambient dieldrin and DDx removal across the RTP. The locations of the RTP sampling and the water qualities simulated during bench-scale testing are shown in Table 1-2.

Table 1-2: RTP and AWTF sample and bench-test water qualities

Facility	**RTP**				**AWTF**		
Sample location	Primary influent	Primary effluent	Solids contact effluent	Secondary clarifier effluent		Ozone effluent	Membrane filtration filtrate
RTP sampling	Sample	--	Sample	Sample		--	--
Bench-scale testing	Blend	Filtered	Blend	Filtered	Blend	SOT	Filtered

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[2] Standard Methods 4500-O_3 B Indigo Colorimetric Method

Samples from the Blanco Drain and RTP were collected by Monterey Bay Analytical Services (MBAS) and MRWPCA on February 9, 2016, and shipped to Eurofins Eaton Analytical and Vista Analytical Laboratories for analysis and to the Trussell Technologies Pasadena Laboratory for bench-scale testing. The SOT bench-scale testing was conducted the following day (February 10), and RTP bench-scale testing was completed February 11. Both laboratories received all samples within the method hold time based on the initial sample collection of February 9.

Dieldrin and DDx were analyzed by two laboratories: Vista Analytical Laboratories (VAL) and Eurofins Eaton Analytical (EEA). Low detection limit methods were used at VAL to ensure detection of dieldrin and DDx through treatment; EEA was used for continuity with previous source water sampling for dieldrin. Environmental Protection Agency (EPA) method 1699 was used at VAL, with dieldrin and DDx congener minimum quantification limits (also known as method reporting limits) of 30 picograms per liter (pg/L) when no interferences are present and method detection limits (MDLs) ranging from 1 to 5 pg/L. EPA method 505 was used at EEA with a dieldrin method reporting limit (MRL) of 10,000 pg/L and an MDL of 5,000 pg/L. Unless otherwise specified, sample results are total concentrations of dieldrin and DDx (suspended plus dissolved). VAL filtered one sample through a 0.7-µm filter to measure the fraction retained and filtered; EEA filtered one sample through a 0.45-µm filter to measure the suspended and dissolved fraction.

2 SAMPLING RESULTS

2.1 Comparison to Previous Measurements

Dieldrin and DDx concentrations measured in the Blanco Drain sample and the secondary effluent sample are compared to historical measurements below.

The comparison between the dieldrin and DDx concentrations in the Blanco Drain sample and previous Blanco Drain source water sampling is presented in Table 2-1, which shows that concentrations in the water used for bench testing were similar to previous levels.

Dieldrin concentrations were toward the high end of those observed during previous source water sampling (compared to nine low detection limit samples previously). 2,4-DDE and 2,4-DDD were at higher concentrations than previously observed (compared to one sample for each previously), resulting in a higher DDx concentration in this sample than seen previously. Results from 4,4-DDx and 2,4-DDT were consistent with previous sampling results. The somewhat elevated concentrations of dieldrin and DDx may have been due to rain in the preceding weeks, which may have washed dieldrin- and DDx-bound sediment into the Blanco Drain.

Table 2-1: Blanco drain sample results compared to historical source water sampling

Constituent	2/9/2016 sample (pg/L)[1]	7/14 to 6/15 source water sampling (pg/L)[2]
Dieldrin	28,800 & 27,000	< 10,000 – 31,000
4,4-DDD	5,260	< 10,000
4,4-DDE	1,130	21,000
4,4-DDT	3,320	< 10,000
2,4-DDD	20,900	< 5,000
2,4-DDE	87,600	< 5,000
2,4-DDT	9,700	< 10,000
DDx	127,910	< 61,000

[1] All results from EPA method 1699 except for dieldrin result of 27,000, which was from EPA method 505

[2] Lowest MRL of EPA methods 505, 8081, 608, and 525.2 reported from source water sampling; sampling events were typically twice quarterly for dieldrin and typically quarterly for 4,4-DDx; lowest detection limit methods, including 2,4-DDx, were conducted for one sampling event for DDx

A comparison between the concentration of dieldrin retained on a 0.45-µm glass fiber filter (suspended fraction) and the concentration that passed through the filter (dissolved fraction) in the Blanco Drain sample and an earlier source water sampling event is shown in Table 2-2. Dieldrin is highly hydrophobic; accordingly, it was suspected that a large fraction would be retained with the solids and organics on the filter. The relatively low suspended fraction in the 2014 sample compared with the higher suspended fraction in the 2016 sample suggests that dieldrin may absorb to relatively small organic molecules that pass through 0.45-µm filters with moderately high efficiency. The size of these molecules may vary in the Blanco Drain with time, which may partially explain the difference in split results (*i.e.*, dissolved and suspended fractions) between the two dates. Additionally, the concentration of suspended solids varies in the Blanco Drain, particularly due to rain events, which may affect the split between dissolved and suspended.

Table 2-2: Blanco Drain split sample of dieldrin compared to historical source water sampling

Date	February 9, 2016[1]	July 24, 2014[1]
Dissolved fraction (%)	44%	81%
Suspended fraction (%)	56%	19%

[1] EPA method 505

A comparison between dieldrin and DDx concentrations measured in the secondary effluent sample and historical levels is shown in Table 2-3. The dieldrin and DDx concentrations were within the range of previously observed levels.

Table 2-3: Dieldrin and DDx concentrations in the RTP secondary effluent compared to historical final effluent concentrations

Constituents	2/9/2016 sample[1] (pg/L)	2008 to 2015 CCLEAN[2] (pg/L)
Dieldrin	366	163 - 629
DDD (2,2 & 4,4)	202	109 - 951
DDE (2,2 & 4,4)	802	214 - 343
DDT (2,2 & 4,4)	240	Below detection - 120
DDx	1244	387 - 1362

[1] EPA method 1699

[2] Data collected by the Central Coast Long-Term Environmental Assessment Network (CCLEAN) on the final effluent, which may include hauled brine

Note that the World Health Organization (WHO) drinking water guidance level for DDT is 1,000,000 pg/L, several orders of magnitudes higher than the concentrations observed in the RTP secondary effluent and the Blanco Drain samples.

2.2 Regional Treatment Plant

2.2.1 Removal Through Regional Treatment Plant

Dieldrin and DDx were measured in all samples collected from the RTP, allowing for determination of ambient dieldrin and DDx removal through the RTP (results are shown in Figure 2-1). Removals of 84% and 93% were observed through the RTP for ambient dieldrin and DDx, respectively, which are greater than the required removals for COP compliance. The increase in dieldrin and DDx in the solids contactor effluent is discussed in the next section.

The RTP secondary effluent was filtered by Vista Analytical Laboratories to further investigate the amount of dieldrin and DDx found in the particulate and dissolved phases (0.7-µm filter). Removals of 29% and 80% were observed for dieldrin and DDx, respectively through the filtering process. Removal through the AWTF membrane filter (MF) is expected to be greater than through the 0.7-µm filter, as the design nominal MF pore size is smaller (0.1-µm to 0.01-µm).

The RTP was operating under typical conditions when samples were collected for dieldrin and DDx (see Table A.6-1 in Appendix A for RTP water quality data and operational setpoints from the date water samples were collected).

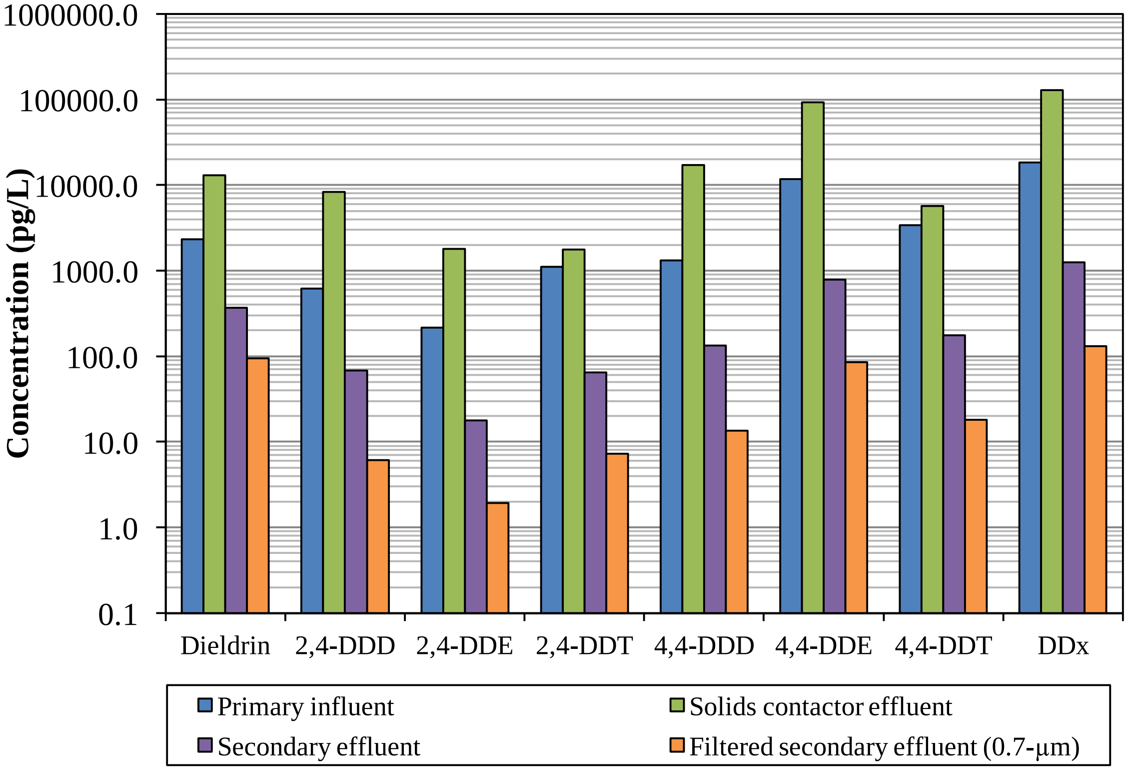

Figure 2-1: RTP dieldrin and DDx congener sampling results

2.2.2 Removal and Volatile Suspended Solids

Dieldrin and DDx concentrations were correlated with volatile suspended solids (VSS) concentration through the RTP (see Figure 2-2; relationship to DDx congeners is shown in Figure A-1 in Appendix A), which suggests that VSS may provide a surrogate for dieldrin and DDx removal through the RTP and operational changes that impact VSS removal may also impact dieldrin and DDx removal.

DDx and dieldrin have a strong affinity to absorb to organics due to their nonpolar structure, minimal hydrogen bonding, and relatively high molecular weight[3]. VSS is comprised of organic matter, such as biological matter in the trickling filter and solids contact process, and the correlation between VSS and dieldrin and DDx appears to be due to the strongly hydrophobic nature of dieldrin and DDx.

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[3] Log octanol-water partition coefficients typically measured in the range of 5.9 to 6.9; *i.e.*, the concentration of dieldrin and DDx in an octanol phase of a two phase octanol-water system tends to be 790,000 to 7,900,000 times higher than in the water phase, where octanol is an organic solvent

Dieldrin and DDx concentrations are higher in the solids contact process (Figure 2-1) where a reserve of biological mass is grown and stored to meet carbon removal and solids retention time (SRT) targets. Subsequent clarification and wasting of waste activated sludge (WAS) removes biological mass, including any dieldrin and DDx that may be absorbed to the organic mass. Given this apparent relationship, dieldrin and DDx removal is dependent on secondary clarification removal efficiency.

The primary influent VSS has a similar affinity to dieldrin and DDx as the solids contactor effluent and secondary clarifier effluent VSS. The primary influent contains recycle streams, including the clarified backwash wastewater from SVRP. The solids in the secondary contactor effluent and the secondary clarifier effluent are similar in composition, as both are primarily bacteria from the solids contact and trickling filter processes. The clarified backwash wastewater from SVRP may also be similar in composition, as it contains bacteria removed from the secondary effluent. Presumably, organic runoff with absorbed dieldrin and DDx enter the collection system. These organics may then be oxidized or desorbed by bacteria in the trickling filter-solids contact process or become part of the mixed liquor volatile suspended solids (MLVSS). Influent dieldrin and DDx loading is greater than dieldrin and DDx associated removal through solids wasting (SRT of 33 hours and solid contactor average hydraulic residence time (HRT) of 3.8 hours), which allows for the elevated, equilibrium levels of dieldrin and DDx in the solids contactors.

Although the relationship between dieldrin and DDx may vary with the constitution of organic matter in the RTP influent, trickling filters, and solids contactors, it offers a potential predictive tool as a process surrogate for dieldrin and DDx removal, which suggest that required dieldrin and DDx removals can still be achieved even if VSS concentrations increase with the PWM project. The PWM project is expected to increase the RTP influent flow to a maximum monthly average of 27.8 million gallons per day (MGD). This flowrate is significantly higher than wastewater flows have been in recent years (*e.g.*, the flow as 17.7 MGD on the day of sampling). The increased flowrate may impact the ability of the RTP to remove VSS, dieldrin and DDx, as primary and secondary clarifier loading rates will be increased, among other operational impacts; however, the potential increase in dieldrin and DDx concentrations is expected to be within the range where removal through the RTP, ozone, and MF can maintain compliance with the COP water quality objectives.

The secondary effluent total suspended solids (TSS) concentration was one-third of the National Pollutant Discharge Elimination System (NPDES) permit monthly average limit during sampling (10 milligrams per liter during sampling compared to a limit of 30 milligrams per liter). Assuming a “worst-case” three-fold increase in TSS, and corresponding increase in VSS, dieldrin, and DDx, the observed DDx removal in the RTP would be sufficient to meet COP objectives, and dieldrin COP objectives would be met if ozone and MF achieved a removal of 23%, or greater (bench-scale ozone and MF removals exceeded 23% by approximately a factor of two; see Bench-scale testing results section).

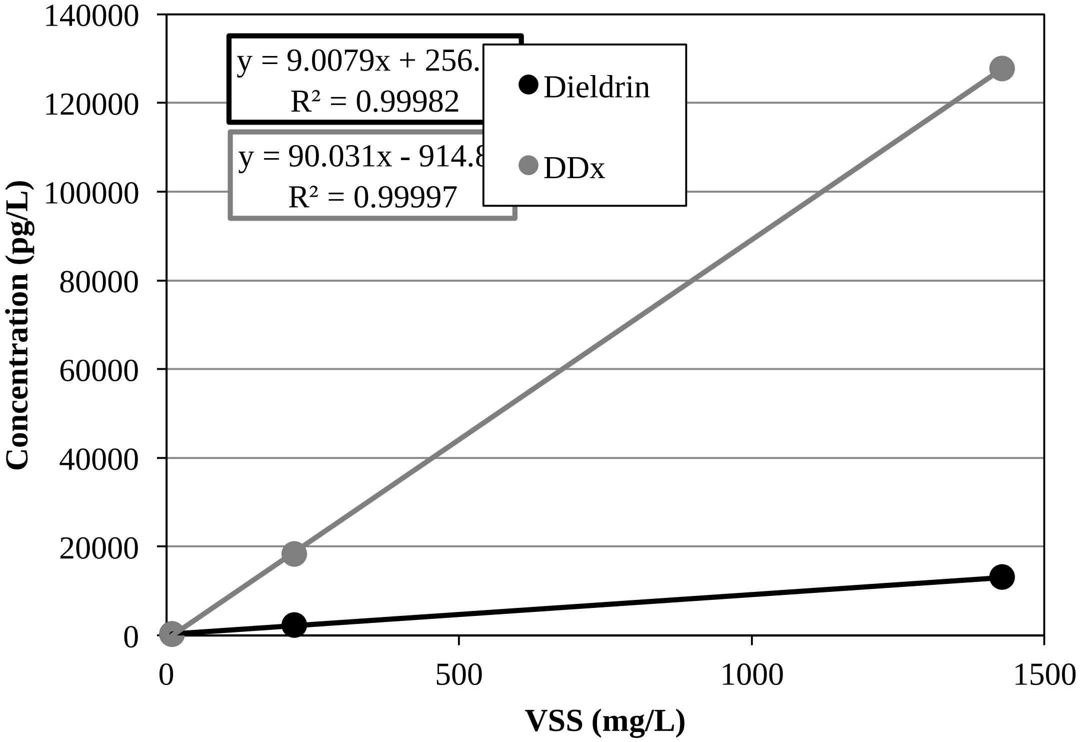

Figure 2-2: Relationship between VSS and total dieldrin and DDx in the RTP (samples points from left to right: secondary effluent, RTP influent, solids contactor effluent)

3 BENCH-SCALE TESTING RESULTS

3.1 Regional Treatment Plant

The removal of dieldrin and DDx through bench-scale testing of RTP processes is shown in Figure 3-1. The bench-scale removals (which included Blanco Drain water) match those observed through the RTP (which did not include Blanco Drain water), suggesting that dieldrin and DDx in the Blanco Drain may be removed similarly to ambient dieldrin and DDx in the RTP influent. The bench-scale removals were 84% and 93% for dieldrin and DDx, respectively, which is greater than the required removals for COP compliance.

The concentrations of the solids contactor effluent mixture Blanco Drain portion were numerically adjusted to account for the dieldrin and DDx accumulation that was observed during RTP sampling. Removals observed through filtration of the solids contactor effluent mixture were applied to the adjusted solids contactor effluent mixture to develop the estimate of the secondary effluent concentrations (unadjusted removals are shown in Appendix A).

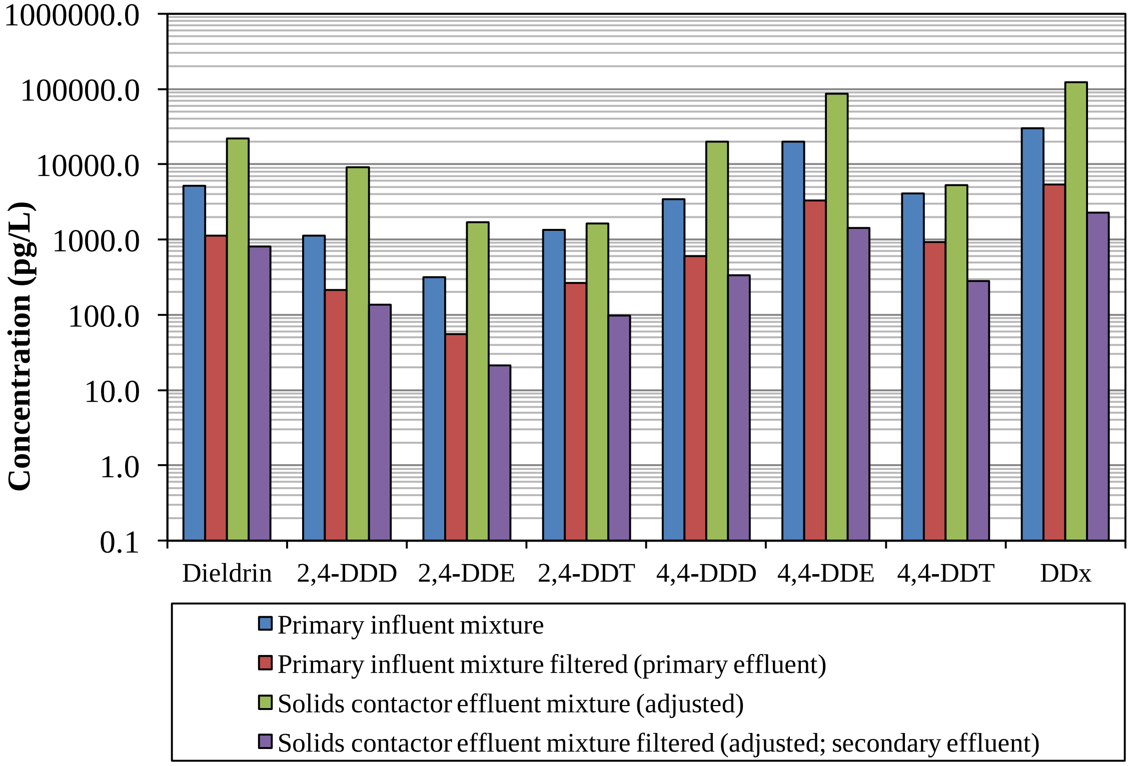

Figure 3-1: Removal of dieldrin and DDx congeners through RTP bench-scale testing
(mixtures are blends of RTP and Blanco Drain samples; Blanco Drain contribution adjusted for accumulation of dieldrin and DDx observed at the RTP)

3.2 Solution Ozone Test

Removal of 44% to 63% and 36% to 48% were observed through bench-scale ozonation for dieldrin and DDx, respectively, with higher levels of removal observed with higher ozone doses (see Figure 3-2). While the ozonation removal alone was not sufficient to maintain COP compliance, it does add an additional layer of redundancy and robustness to dieldrin and DDx removal through the RTP and the AWTF. Removal of dieldrin and DDx through ozonation occurs via a chemical oxidation process, which does not occur in the RTP.

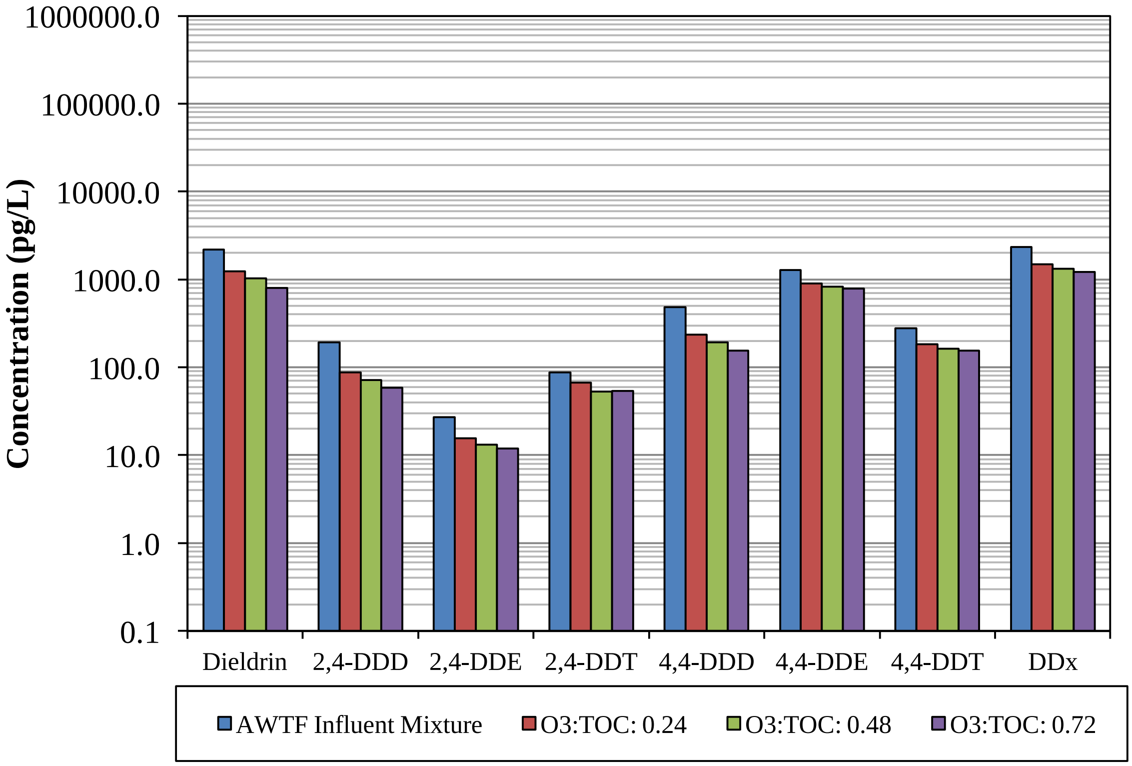

Figure 3-2: Dieldrin and DDx congener removal through ozonation of Blanco Drain-RTP effluent mixture

The water quality of the secondary effluent and Blanco Drain mixture prior to and after bench-scale ozonation are shown in Table 3-1. Three O_3:TOC ratios were tested, where the middle test condition (O_3:TOC wt./wt. ratio of 0.48) represents the AWTF design O_3:TOC ratio. The nitrite concentration was within the range typically observed in the secondary effluent, albeit on the low side. Nitrification may have occurred in the sample bottle prior to measurement (*e.g.*, 1.28 mg/L of DO could have facilitated the conversion of 1.12 mg/L as N of nitrite to nitrate, if the necessary bacterial population were present); however, the method utilized for comparing O_3:TOC ratios accounts for nitrite, likewise accounting for any changes in nitrite concentrations that may have occurred. Turbidity, TOC, and temperature were within typical ranges.

Table 3-1: General water quality of the solution ozone test samples

Parameter	Units	Values		
O_3 dose[1]	mg/L	4.2	7.9	11.6
O_3:TOC ratio[2]	gO_3/gC	0.24	0.48	0.72
Before ozonation				
Nitrite	mg/L as N	0.161		
TOC[4]	mg/L	15.4		
pH	--	8.06	8.06	8.06[2]
Temperature	°C	26.7	26.7	22.7
Turbidity	NTU	3.72		
After ozonation				
TOC[4, 1]	mg/L	14.6	15.2	15.4
pH	--	7.89	7.83	7.96
Temperature	ºC	25.0	25.0	21.4
UVT_{254nm}[1]	%	56%	61%	63%

[1] Accounts for dilution from O_3 stock (results were corrected for dilution to show value without effects of dilution)
[2] Accounts for immediate nitrite demand
[3] At 26.7°C
[4] General Electric (GE) Sievers 5310C

The apparent changes in TOC values due to ozonation are likely due to limited accuracy of the method, as the greatest degree of mineralization, if any, would be expected at the largest ozone dose, which did not exhibit a change in TOC. The decrease in pH is presumably due to both the dilution of the samples with the ozone stock solution and oxidation of organics. The ultraviolet light transmittance (UVT) increased with increasing ozone dose, a phenomenon that was observed at the pilot and elsewhere.

The impact of O_3:TOC ratios on dieldrin and DDx removal is shown in Figure **3-3** (removal for DDx congeners is shown in Figure A-3). The relationship between removal and O_3:TOC ratio was linear under the ranges tested; however, it appears that there may be an initial rapid removal of dieldrin and DDx at lower ozone doses, prior to the linear range, as lines fit to the data do not intersect the origin.

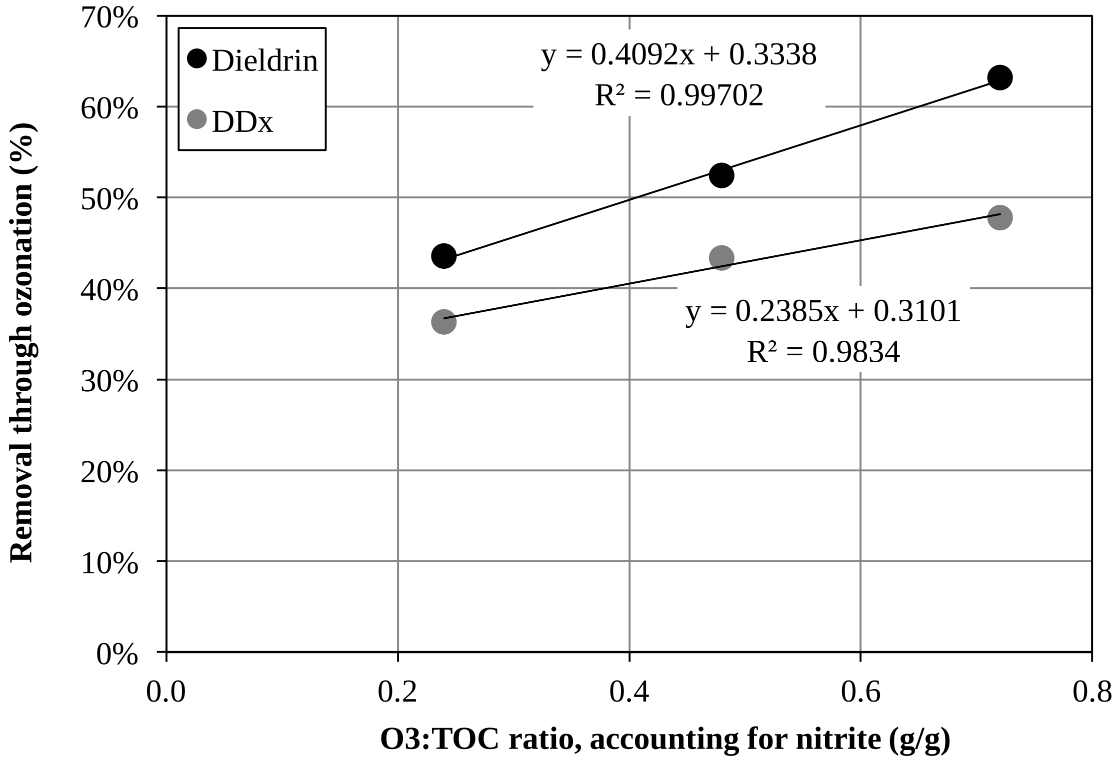

Figure 3-3: Impact of O_3:TOC ratio on dieldrin and DDx removal in Blanco Drain-RTP effluent mixture

3.3 Membrane Filtration

The results from membrane filtration of select ozonated mixtures are shown in Figure 3-4. Removals of 97% to 98% and 92% to 94% were observed for dieldrin and DDx, respectively. These removals may be more representative of full-scale MF removal than the removal observed through the 0.7-µm filter on the non-ozonated secondary effluent described earlier. When no secondary effluent is discharge to the ocean, the MF system, following ozonation, can significantly reduce discharges of dieldrin and DDx to the ocean by removing dieldrin and DDx in the AWTF feed water with high efficiencies.

Dieldrin and DDx adsorbed to organics and particulates that are captured on the MF membrane will be returned to the RTP headworks during regular backwashes and clean-in-places (CIP) events. This recycling of waste backwash water slightly increases the concentrations of dieldrin and DDx in the RTP influent and may marginally increase concentrations in RTP effluent; however, the overall removal of dieldrin and DDx is expected to increase, as recycling increases the amount of dieldrin and DDx removed through the RTP and the ozone system. The increase in dieldrin and DDx concentrations, and the increase in the amount of dieldrin and DDx removed through the RTP and ozone, is a function of flowrates through the RTP and the AWTF and removals through the RTP, ozone and MF. The average increase is expected to be approximately

4% and 2%, or less, for dieldrin and DDx, respectively, based on removals observed during this study and design conditions.[4]

When no secondary effluent is recycled through the SVRP (*i.e.*, when more secondary effluent is being discharged through the ocean outfall), removal through the MF system contributes to a reduction in dieldrin and DDx discharged to the ocean by the increase in dieldrin and DDx removed through the RTP and ozone. Assuming no increase in removal efficiency of the recycled dieldrin and DDx, the decrease in dieldrin and DDx discharged would range from approximately 1% and 2% to 28% and 31% for dieldrin and DDx, respectively, depending on the proportion of secondary effluent and AWTF RO concentrate in the discharge stream to the ocean outfall.[5]

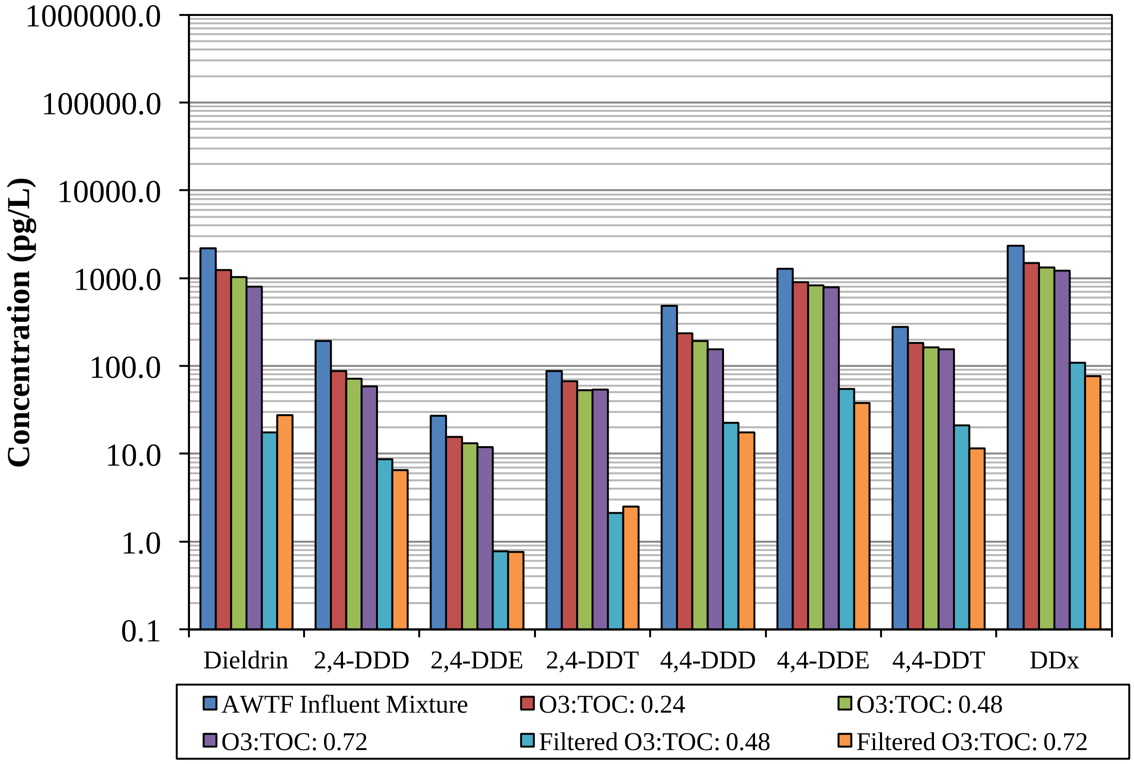

Figure 3-4: Dieldrin and DDx congener removal through membrane filtration of Blanco Drain-RTP effluent mixture

The removal of dieldrin through various size filters for different water qualities is shown in Figure 3-5. From these data, it appears that (1) there may have been negligible interference from dieldrin and DDx adsorption onto the filter material, (2) finer filters result in more dieldrin and DDx removal for low VSS concentrations, and (3) filters removal may be increased if VSS

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[4] Low projected average monthly RTP flow of 15 MGD, high AWTF feed flows of 6.85 MGD, high observed removals through 0.1-µm filters, low ozone removal through 0.24 O_3:TOC ratio.

[5] Based on the observed removals through RTP and RTP bench-scale testing, the range of removals observed through bench-scale ozonation and membrane filtration (including through the 0.7-µm filter), and flowrates of 15 to 28 MGD through the RTP and 1.6 to 6.9 MGD through the AWTF.

concentrations were to increase during an upset. The data exhibit a log-linear relationship between filter size and removal for water relatively low in solids and/or for filter sizes of 0.7-µm or less (left size of graph). This relationship appears to be independent of filter material, suggesting negligible adsorption of dieldrin and DDx onto the filters (*i.e.*, that the hydrophobic polypropylene 0.1-µm filters behaved similarly to the hydrophilic glass fiber filters). The AWTF MF membranes will be thermally induced phase separation (TIPS) polyvinylidene fluoride (PVDF), which are moderately hydrophobic. These membranes are expected to behave similarly.

The data in Figure 3-5 also suggest that removal is dependent on another variable besides filter size for samples with relatively high concentrations of solids when filtering through the 10-µm filter (right size of graph). Figure 3-6 shows that better removal was observed for samples with more solids. The increased removal is presumably due to cake filtration, where large material is removed on the filter (e.g., VSS) which in turn can either effectively reduces the pore size, thereby increasing dieldrin and DDx removal, or increase adsorption sites for removal of dieldrin and DDx. Removal through cake filtration can evidently be significant and equivalent to removal through filters with nominal pore sizes 100 times smaller (e.g., compare “solids contactor effluent & 10-µm filtered Blanco Drain” mixture to the mixtures filtered through 0.1-µm filters).

In the event of a process upset at the RTP, where higher concentrations of VSS, and possibly associated higher levels of dieldrin and DDx, enter the AWTF, these data suggest that MF removal may be well fortified through cake filtration, thereby maintaining low dieldrin and DDx concentrations in the MF filtrate (*i.e.*, RO feed).

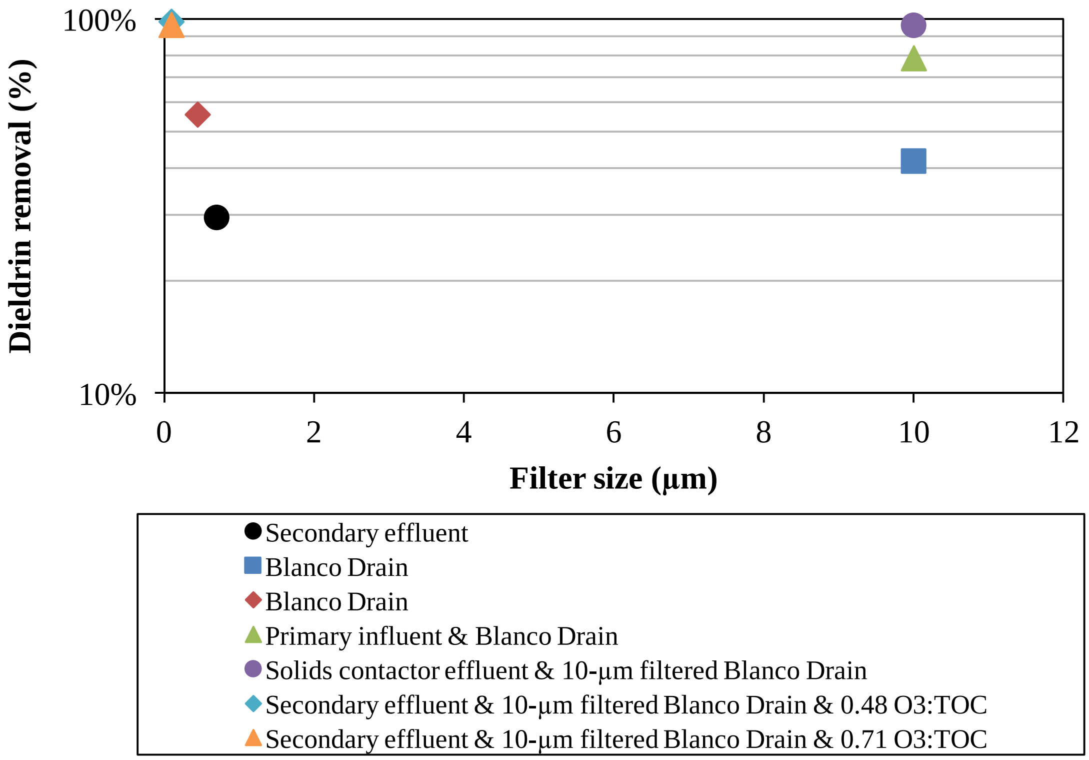

Figure 3-5: Dieldrin removal through filtration as function of filter size and water quality

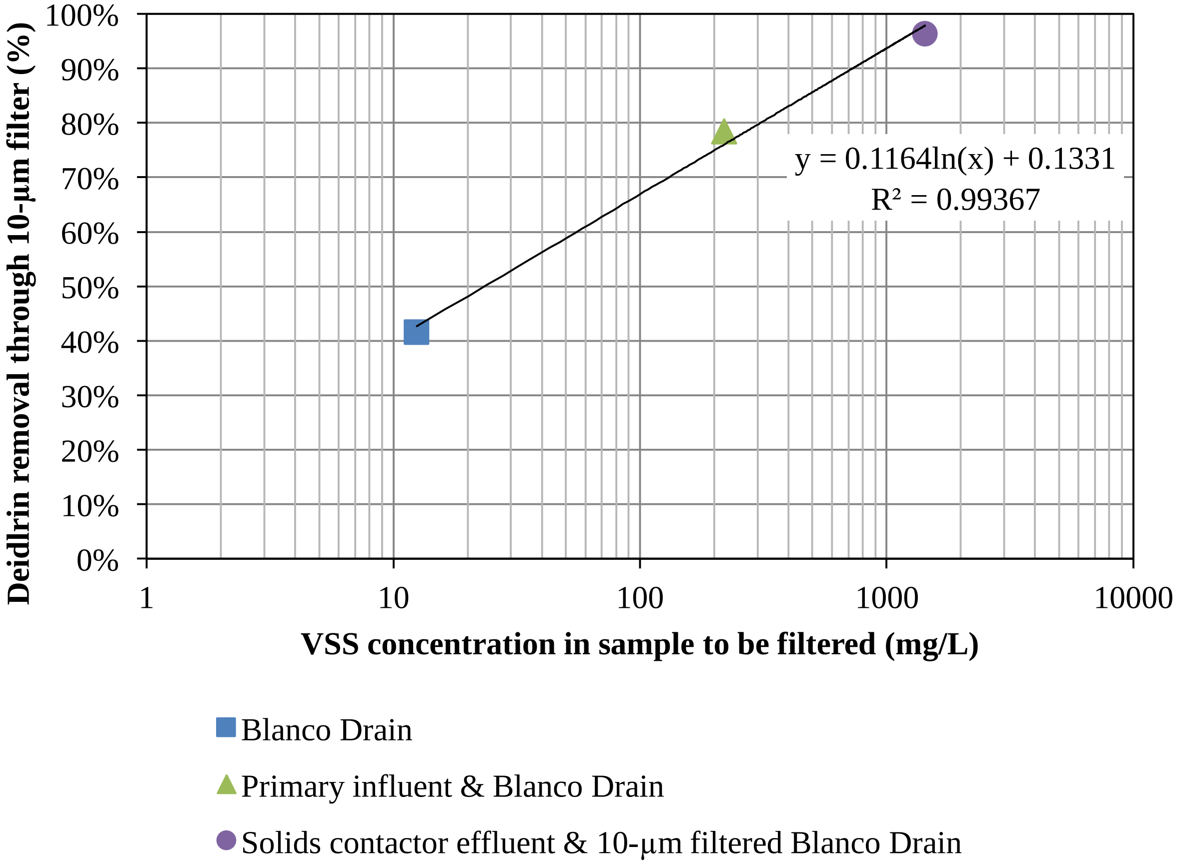

Figure 3-6: 10-µm filter removal of dieldrin and VSS concentration

4 SUMMARY AND CONCLUSIONS

A summary of removals observed through full-scale sampling of the RTP and bench-scale testing is shown in Table 4-1. A summary of removals previously assumed for COP compliance, required for COP compliance, and observed through the RTP sampling and bench-scale testing with respect to COP compliance and RTP and AWTF processes is shown in Table 4-2.

Table 4-1: Summary of dieldrin and DDx removals observed through full-scale sampling and bench-sale testing

Process	Test	Removal (%)	
		Dieldrin	DDx
RTP	Full-scale sampling	84%	93%
RTP[1]	Bench-scale (RTP-Blanco blend)	84%	93%
Ozone[2]	Bench-scale (RTP-Blanco blend)	44% - 63%	36% - 48%
Membrane filtration	Bench-scale (RTP-Blanco blend)	97% - 98%	92% - 94%

[1] Blanco Drain contribution adjusted for accumulation of dieldrin and DDx observed at the RTP

[2] O_3:TOC ratios of 0.24 to 0.71 gO_3:gC, accounting for nitrite demand

Table 4-2: Summary of dieldrin and DDx removals through RTP and AWTF processes related to COP compliance

Constituent	Qualifier[1]	Removal (%)			
		RTP[2]	Ozone[3]	MF[4]	Total
Dieldrin	DEIR assumption	20%	90%	--	92%
	Required for COP	--	--	--	61% RTP or 78% O_3
	Observed	84%	44% - 63%	1% - 98%	91% - 99.9%
DDx	DEIR assumption	20%	70%	--	76%
	Required for COP	--	--	--	58% RTP or 71% O_3
	Observed	93%	36% - 48%	2% - 94%	96% - 99.8%

[1] "Draft Environmental Impact Report (DIER) assumption" refers to previous COP analysis (Trussell Technologies, 2015b); "Required for COP" refers to the values needed to meet COP objectives, where the requirements depend on where the removal is achieved; and "Observed" refers to removals observed through RTP sampling and bench-scale testing for RTP and AWTF processes relating to COP compliance

[2] Ambient dieldrin and DDx removal observed through RTP and adjusted RTP bench-scale removals

[3] O_3:TOC ratios of 0.24 to 0.71 gO_3:gC, accounting for nitrite demand

[4] Considering the recycling of backwash solids to the head of the RTP: additional removal through RTP and ozone processes when 26.2 MGD of secondary effluent (max flow) is discharged through the ocean outfall with 1.6 MGD going to the AWTF, 0.7-µm glass fiber filtration of ambient dieldrin and DDx in secondary effluent assumed for MF removal and the high-end ozone removal assumed to 0.1-µm filtration of ozonated Blanco Drain-RTP secondary effluent mixture, accounting for potential increases in dieldrin and DDx concentrations, where the latter represents the case where no secondary effluent is discharged through the ocean outfall (see discussion in 3.3).

The following conclusions can be drawn from the sampling and bench-scale testing:

- Significant dieldrin and DDx removal occurred through the RTP, ozonation, and filtration;
- Removal through the RTP alone was sufficient to meet COP objectives (based on previous COP compliance analysis); and

- Removal through ozonation and MF offer additional layers of redundancy and robustness.

5 REFERENCES

Ormad et al. (2008). *Pesticides removal in the process of drinking water production*. Chemosphere, 71, 97-106.

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Trussell Technologies, 2016. *Bench-Top Dieldrin and DDT Removal Testing for the MRWPCA Groundwater Replenishment Project*. Technical Memorandum. January 2016.

APPENDIX A – ADDITIONAL FIGURES AND TABLES

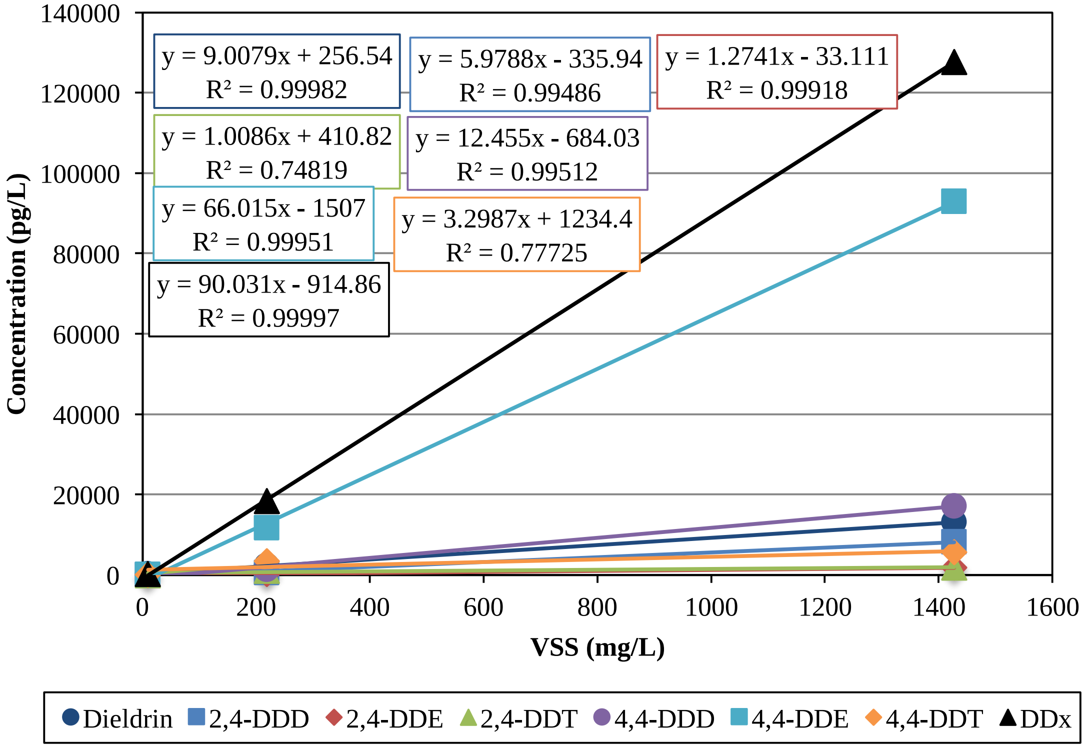


Figure A-1: Relationship between VSS and dieldrin and DDx congeners

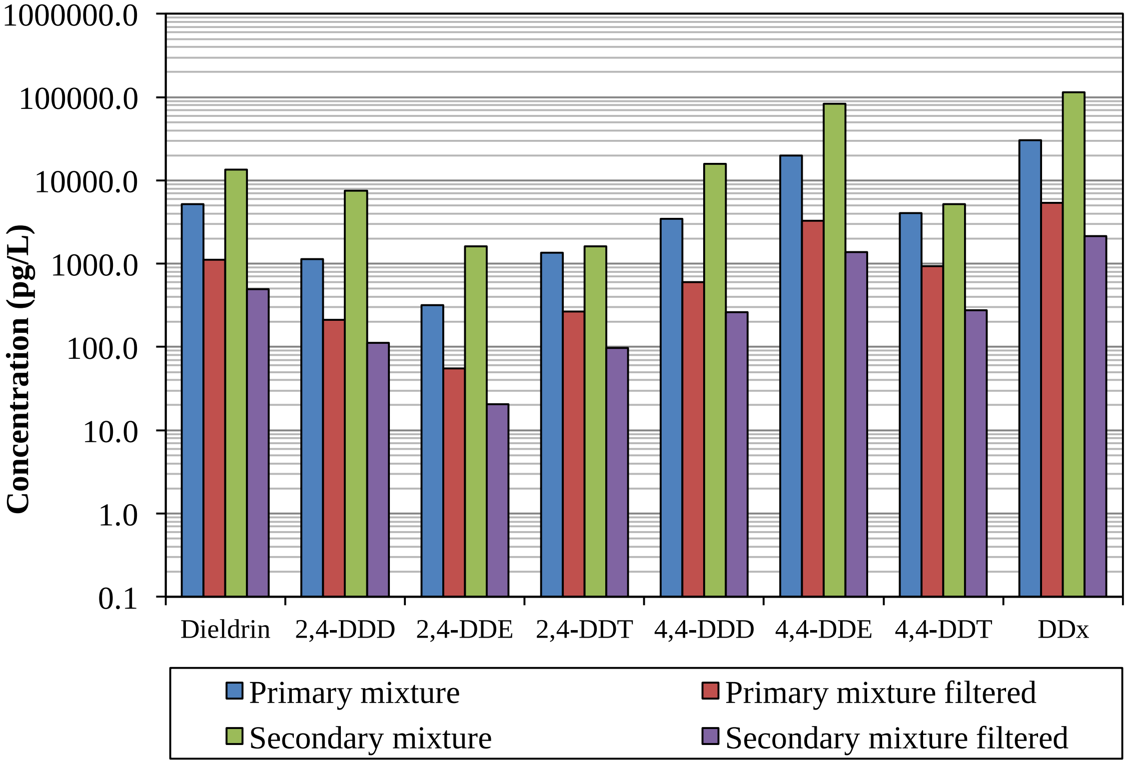


Figure A-2: RTP bench testing dieldrin and DDX congener removal without adjusting for accumulation of the Blanco Drain dieldrin and DDx in the secondary process (mixtures are blends of RTP and Blanco Drain samples**)**

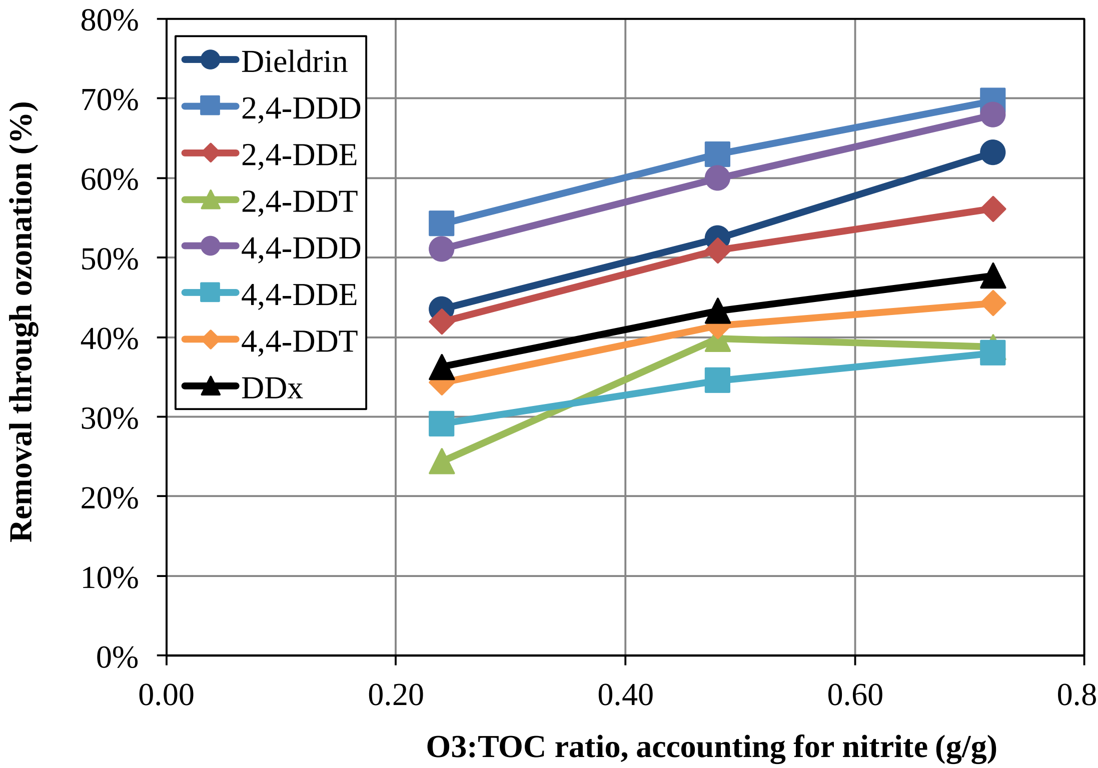


Figure A-3: Relationship between O_3:TOC ratio and dieldrin and DDx congener removal

Table A-1: General quality parameters and operational conditions at RTP during sampling

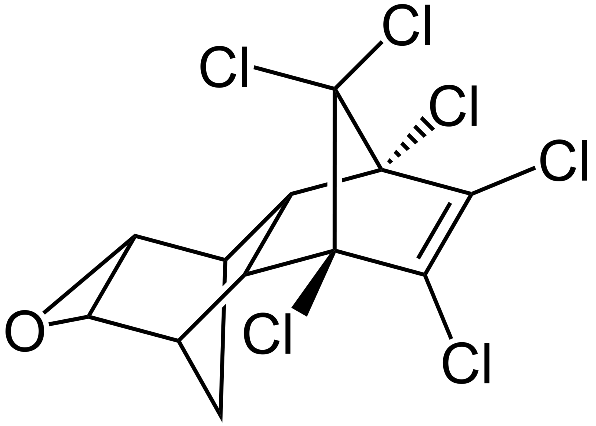
Collect Date	Parameter	Site							Units	Sample Type	Reporting Limit	Method
		Blanco Drain	Salinas Pump Station	Monterey Pump Station	RTP Headworks	Primary Influent	Solids Contact Eff (MLSS)	Sec Eff				
09-Feb-16	CBOD	4.5	--	--	--	310	810	9	mg/L	Grab	1	SM 5210 B
09-Feb-16	COD	38.6	--	--	--	740	2303	61.6	mg/L	Grab	--	Hach 8000
09-Feb-16	pH	7.7	--	--	--	6.99	7.26	7.44	--	Grab	--	SM 4500-H+ B
09-Feb-16	TBOD	1.2	--	--	--	314	1274	31.3	mg/L	Grab	--	SM 5210 B
09-Feb-16	TDS	2380	--	--	--	876	810	883	mg/L	Grab	20	SM 2540 C
09-Feb-16	Temperature	11.7	--	--	--	18.9	17.5	19.2	°C	Grab	--	SM 2550 B
09-Feb-16	TSS	89	--	--	--	248	1830	10	mg/L	Grab	1	SM 2540 D
09-Feb-16	Turbidity	52.9	--	--	--	200	869	5	NTU	Grab	0.4	SM 2130 B
09-Feb-16	VSS	14	--	--	--	88	78	94	%	Grab	--	SM 2540 E
09-Feb-16	Ferric Dose	--	21	235	0	--	--	--	mg/L	Composite	--	Meter Reading
09-Feb-16	Flow Rate	--	10.91	2.65	17.7	--	--	--	MGD	Composite	--	Meter Reading

Notes:
1. SIWTF shunted into the RTP collection system during sampling
2. Average primary clarifier surface loading rate of 623 gallons per day per square foot (gpd/sf), with maximum and minimum of 1001 and 247, respectively
3. Trickling filter recycle ratio of 5%
4. Solids contact SRT of 1.38 days
5. Solids contact dissolved oxygen (DO) of 1.28 mg/L
6. Average secondary clarifier overflow rate of 10225 gallons per day per foot (gpd/ft), with maximum and minimum of 16442 and 4053, respectively

APPENDIX B – EXPERIMENTAL PLAN

Bench-Top Dieldrin and DDT Removal Testing for the MRWPCA Groundwater Replenishment Project

TEST PROTOCOL



Prepared for:
Monterey Regional Water Pollution Control Agency &
Monterey Peninsula Water Management District

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1 Introduction

1.1 Background

Pending reductions in Carmel River water diversions are spurring the development of additional potable water supplies on the Monterey peninsula. The Monterey Peninsula Water Management District (MPWMD) and the Monterey Regional Water Pollution Control Agency (MRWPCA) are developing the Pure Water Monterey Groundwater Replenishment (GWR) Project to help address the water shortage. The project includes diversion of additional waters to the Regional Treatment Plant (RTP), which produces a secondary treated wastewater that would be the influent to an Advanced Water Treatment Facility (AWTF). The AWTF will produce high quality recycled water suitable for groundwater replenishment. The main components of the RTP and AWTF treatment train are the following:

- **Headworks and primary treatment** (RTP): screening, primary clarification, and optional Chemically Enhanced Primary Treatment (CEPT);
- **Secondary treatment (RTP)**: non-nitrifying trickling filters, bio-flocculation (solids contact basins), and secondary clarification; and,
- **Advanced treatment (AWTF)**: ozonation, membrane filtration (MF), reverse osmosis (RO), advanced oxidation (AOP) with hydrogen peroxide and ultraviolet (UV) light, and product water stabilization.

Additional raw water sources would be diverted to the RTP collection system including agricultural wash water, agricultural tile drainage and runoff waters, which could include waters from the Blanco Drain, Reclamation Ditch, and/or Tembladero Slough. Source water monitoring was conducted from July 2013 to June 2014 to characterize the proposed new source waters for the GWR Project (Trussell Technologies, 2014). Two legacy pesticides that have been banned for decades, dieldrin and Dichlorodiphyenyldichloroethylene (DDE), were detected during the monitoring in the Blanco Drain water. The median concentration of dieldrin detected was 17 ng/L, with a range of <10 to 31 ng/L; 4,4’DDE was detected once in four samples at a concentration of 21 ng/L.

DDE is a breakdown degradate of dichlorodiphenyltrichloroethane (DDT), and exists as one of two congeners: 4,4’DDE or 2,4’DDE, where the 4,4’DDE isomer was the isomer detected in the Blanco Drain. Although only one of the congeners of DDT was detected in the source water monitoring, all six congeners of DDT (2,4’DDT, 2,4’DDE, 2,4’DDD, 4,4’DDT, 4,4’DDE, 4,4’DDD) will be included in this investigation, and will be referred to as DDx.

Both dieldrin and DDx have established water quality objectives in the 2012 California Ocean Plan (“Ocean Plan”) (State Water Resources Control Board, 2012)[1]. Ocean discharges in California must meet the water quality objectives described in the Ocean Plan. The AWTF would produce an RO concentrate that would be discharged along with different quantities of secondary treated wastewater. Modeling efforts of the various discharge scenarios related to the GWR Project have indicated that the future discharges would comply with the COP objectives

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[1] DDT in the Ocean Plan is the sum of the two DDT congeners and the congeners of the DDT byproducts, DDE and dichlorodiphenyldichloroethanet (DDD), 4,4’DDT, 2,4’DDT, 4,4’DDE, 2,4’DDE, 4,4’DDD, and 2,4’DDD.

(Trussell Technologies, 2015); however, the estimated concentrations of dieldrin and DDx congeners in the RO concentrate were estimated using assumed removals (90% reduction of dieldrin and 30% reduction of DDx) from scientific literature (Ormad 2008).

The overall objective of this test protocol is to verify these previous assumptions used for dieldrin and DDx removal from a blend of Blanco Drain water and wastewater through sedimentation, ozonation, and membrane filtration.

1.2 Literature Review

The existing literature on dieldrin and DDx removal through the relevant treatment processes (i.e., adsorption, sedimentation, filtration and ozone destruction) was reviewed; however, conflicting results were observed for ozone oxidation. Certain factors will likely influence the destruction of these pesticides via ozone, specifically the type of water (*i.e.* source water quality) and the applied ozone doses. Two studies conducted by Ormad et al. on pesticides removal through oxidation yielded different results. Using the same ozone to total organic carbon (TOC) ratio for both studies of 0.14, and the same initial dieldrin concentration of 500 ng/L, the first study cited a removal efficiency of 90% with ozonation (Ormad et al., 2008), whereas the second study reported only 20% removal (Ormad et al., 2010). The ozone to TOC ratio is typically used in ozonation studies to normalize the effects of ozonation across differing water qualities. An investigation by Westerhoff et al., using ozone to TOC ratios between 0.63 and 1, cited minimal oxidation in the presence of ozone (<20%) (Westerhoff et al., 2005).

Both dieldrin and DDx are very hydrophobic, with K_{OW} values of 5.40 for dieldrin and between 6.02 and 6.91 for the congeners of DDx (Westerhoff, 2005). Therefore, significant removal (55%) of dieldrin and DDx through adsorption and sedimentation with enhanced coagulation and then filtration has also been reported (Robeck et al., 1965). Due to the differences observed in the level of destruction, and the variability of removal rates based on influent water quality, treatment processes and ozone dose, it was decided that bench-scale testing specific to the GWR project would be conducted.

1.3 Protocol Objectives

The objectives of this protocol are the following:

1. Determine the removal of dieldrin and DDx through adsorption onto particulate material and then course filtration (10 µm), which will be used to estimate removal through primary and secondary treatment at the RTP;
2. Determine dieldrin and DDx degradation through bench-scale ozone testing, using the design ozone to TOC ratio[2] for the proposed AWTF, to estimate the removal through the future ozone system; and,
3. Determine the remaining dissolved component of dieldrin and DDx after ozonation by filtering the ozonated water through a membrane disk filter (0.1 µm), which will be used to estimate removal through an MF filter.

Testing will be conducted at the Trussell Tech Laboratory in Pasadena, CA, using a laboratory blend of filtered (10 µm filter to represent solids removal during RTP treatment) Blanco Drain

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[2] The design ozone to TOC ratio incorporates immediate nitrite demand based on the detected nitrite concentration prior to ozonation.

water with RTP secondary effluent at a ratio that represents the highest expected future contribution of agricultural drainage water to the wastewater collection system. Additionally, testing will be conducted on a blend of Blanco Drain water and RTP primary influent at the same ratio to investigate the potential of dieldrin and DDx adsorption onto organic solids. Bench testing, including the membrane filtration and solution ozone test, will be conducted by Trussell Tech, and the dieldrin and DDx analyses will be performed by commercial laboratories (Eurofins and Vista Laboratories).

2 Experimental Design

Water samples from the RTP will be collected, put on ice and shipped overnight to the Trussell Tech laboratory in Pasadena, CA. Water samples from the Blanco Drain will be shipped overnight to three different locations to minimize handling times prior to analysis: Eurofins Eaton Analytical Laboratory ("Eurofins"), Vista Laboratory ("Vista") and the Trussell Tech laboratory. MRWPCA staff will collect samples from the RTP, and Monterey Bay Analytical Services (MBAS) will be contracted to collect the water sample from the Blanco Drain. Trussell Tech staff will conduct the filtration and ozonation tests described in detail below. Throughout the bench-scale test, untreated samples (*i.e.*, non-filtered and non-ozonated Blanco Drain samples) and treated samples (*i.e.*, filtered and ozonated) will be collected and shipped to a certified laboratory for dieldrin and DDx analysis.

2.1 Sample Collection and Preparation

Trussell Tech performed an assessment of the impact the brine discharge, including the additional source waters, could have on the Monterey Bay in relation to the California Ocean Plan Objective (Trussell Technologies, 2015). For this assessment, water quality data for several types of discharge waters were used to estimate the future combined water quality in the ocean outfall discharge, including consideration of (1) different flow scenarios that varied based on time of year and/or drought conditions, (2) variation in the volume of water from each new source water, and (3) an estimate of the highest concentrations of Ocean Plan constituents from all data received during the source water monitoring. From this analysis, a worst-case scenario concerning dieldrin and DDx was identified to occur during times of maximum contribution from the Blanco Drain, which was determined to be 12% of the total influent water volume based on 2019 projected RTP flows.

To estimate the removal of dieldrin and DDx through the RTP and proposed AWTF, water samples will be collected from the Blanco Drain, RTP primary influent, solids contactor effluent and RTP secondary effluent. The amount of water collected will be as follows:

- 12 L from Blanco Drain,
- 5 L from RTP primary influent autosampler,
- 4.5 L from RTP solids contactor effluent, and
- 14 L from RTP secondary effluent.

These water samples will then be shipped overnight to Vista Laboratories, Eurofins, Caltest and the Trussell Tech laboratory. The temperature of the water will be recorded on the Chain of Custody when the samples are received. The samples will be stored at 6 degrees Celsius for a maximum of 24 hours.

Prior to the start of testing, the water will be brought to room temperature (similar to expected temperature of the wastewater) so that results are not impacted by slower reaction kinetics associated with lower temperatures. Three test mixtures will then be created:

1. **Primary:** 0.26 L Blanco Drain water combined with 2.14 L RTP primary influent,
2. **Secondary:** 0.26 L filtered Blanco Drain water combined with 2.14 L RTP solids contactor effluent, and
3. **AWTF Influent:** 1.32 L filtered Blanco Drain water combined with 10.68 L RTP secondary effluent.

The Primary mixture will be used to focus on the removal of dieldrin and DDx through adsorption and subsequent sedimentation during primary treatment at the RTP. Therefore, this mixture will only be filtered (see Section 2.2) and not subjected to ozonation. The average residence time through the RTP's primary treatment process will be applied during the bench-scale testing to mimic the time available for adsorption to occur. Therefore, the Primary mixture will be filtered after the respective residence time for primary treatment has passed.

The Secondary mixture will be used to estimate the removal of dieldrin and DDx through adsorption and subsequent sedimentation during secondary treatment at the RTP.

The AWTF Influent mixture most accurately represents the proposed AWTF influent water quality, and so it will be used to study the impacts of ozonation and membrane filtration on dieldrin and DDx destruction and removal. Specifically, the amount of total organic carbon (TOC) present in the AWTF Influent mixture will be more similar to the actual RTP effluent water. This is important because the ozone to TOC ratio can significantly impact the ozone demand of the water, which could affect the observed dieldrin and DDx destruction.

2.2 Filtration

Filtration will be used to mimic primary, secondary, and membrane filtration treatment. Several filtration scenarios will be done to investigate the amount of dieldrin and DDx removal attributable to adsorption of the constituents onto suspended solids and subsequent removal through sedimentation and straining. A 10-micron filter will be used to simulate primary and secondary treatment, and a 0.1-micron filter will be used for membrane filtration.

The Primary mixture testing will involve first combing the Blanco Drain and RTP primary influent waters as specified in Section 2.1. The mixed water will then be filtered through a 10-micron filter. For the Secondary mixture, Blanco Drain water will first be filtered through a 10-micron filter, and then will be mixed with the RTP solids contactor effluent water. The Blanco Drain water is filtered separately in this scenario because in the full-scale plant, this water will first go through primary treatment prior to membrane filtration, and the RTP solids contactor effluent water collected will have already gone through this treatment. Similarly, the AWTF Influent mixture will be made with filtered Blanco Drain water (10-micron) mixed with RTP secondary effluent water.

The AWTF Influent mixture only will receive ozone treatment, to simulate the first process in the AWTF treatment train. Ozonation procedures are discussed in Section 2.3. Following ozonation, the AWTF Influent mixture will be filtered through a 0.1-micron filter to simulate membrane filtration. Depending on the final design of the full-scale AWTF, there will either be a microfiltration (0.1 – 10 micron pore size) or an ultrafiltration (0.01 – 0.1 micron pore size) treatment step. To be conservative, a pour size similar to a typical microfiltration membrane was chosen for this study.

2.3 Ozonation

The first step of the proposed AWTF will be ozonation to control the amount of fouling on the downstream membranes, and allow a higher operating flux. The degree of fouling is related to the amount of TOC in the membrane influent water, and so the ozone dose required to be effective at preventing fouling is based on the ozone to TOC ratio. The ozonation test in this study will be performed using the AWTF Influent mixture to most accurately mimic the AWTF influent water quality, specifically the amount of TOC and nitrite present. Once the AWTF Influent mixture has been made, approximately 200 mL will be sampled and used for TOC and nitrite analysis, which will be conducted in the Trussell Tech laboratory. Once the results have been obtained, a transferred ozone dose will be selected such that the ozone to TOC ratio (accounting for nitrite demand) matches the ratio that will be targeted at the AWTF, which is 0.48 (w./w.). Two additional ozone doses will also be tested, +/- 50% of the design ozone to TOC ratio, to determine degradation based on a range of ozone doses.

Trussell Tech staff will then perform the Solution Ozone Test (SOT) method to mimic full-scale ozonation. This method utilizes a stock ozone solution, which will be prepared by bubbling ozone through deionized water (apparatus shown in Figure 1). The ozone concentration will be quantified using the gravimetric indigo method, as described by Rakness (2005). The results from the TOC analysis will be used to calculate the ozone dose required to produce an ozone to TOC ratio of 0.48. A known volume of the stock ozone solution will then be added to the water sample of interest to deliver the dose associated with the target ozone to TOC ratio.

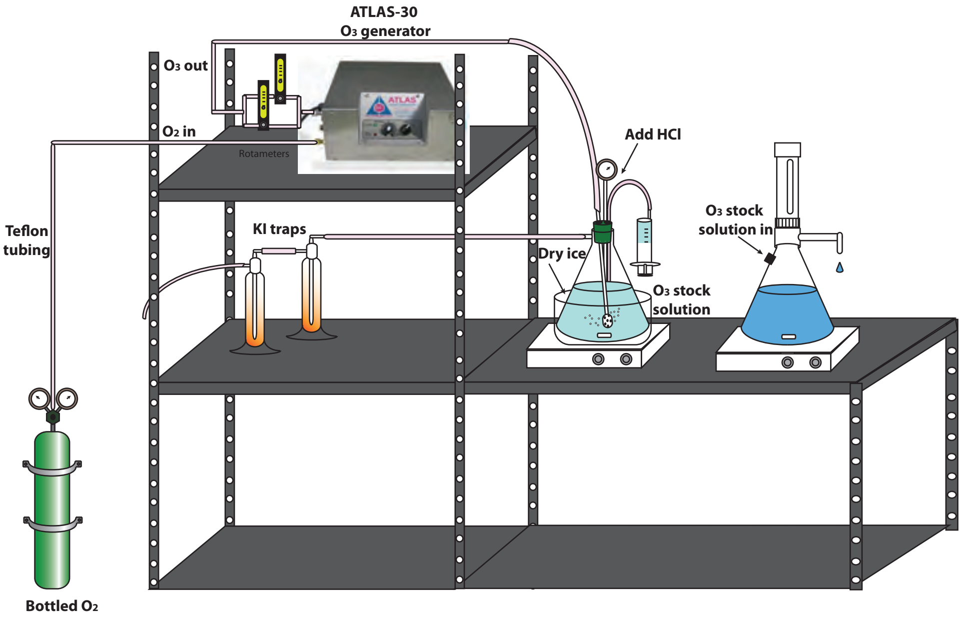

Figure 1 - Solution Ozone Test apparatus

2.4 Laboratory Analysis

Certified laboratories will be contracted for the analysis of dieldrin and DDx throughout the filtration and ozonation steps described above. Eurofins Eaton Analytical ("Eurofins") is a California certified laboratory that will be consulted for the analysis of dieldrin in the particulate and dissolved phases using EPA Method 505. This method has a method-reporting limit (MRL) of 0.012 ug/L, and requires six 40-mL vials, or a total of 240-mL per sample for analysis of both phases. Caltest Analytical Laboratory ("Caltest") will be consulted for the analysis of DDx using EPA Method 608, which will also be used to analyze the samples for particulate and dissolved phases separately. These methods have MRLs ranging from 0.005 – 0.01, depending on the congener, and require two 1-L bottles, or a total of 8-L per sample. DDE was found in one sample at a concentration of 21 ng/L and dieldrin was found in the Blanco drain at a median concentration of 17 ng/L; therefore, these laboratory methods will only be used on the initial raw water sample of Blanco Drain water, and will not be used to analyze the Primary, Secondary and AWTF Influent mixtures due to the MRL.

Vista Laboratories ("Vista") is another California certified laboratory that will be contracted for the low-detection limit analysis of dieldrin and DDx using EPA Method 1699. This method has an MRL of 40 pg/L and 80 pg/L for dieldrin and DDx respectively, and the sample volume required per analysis is 2 L. Method 1699 will be used to analyze all of the initial source waters, and all of the samples once the mixtures have been made, which will include the samples collected from the following:

1. Primary influent raw water;

2. Solids contactor effluent raw water;
3. Secondary effluent raw water;
4. Blanco Drain raw water;
5. Primary mixture after filtration through the 10-micron filter;
6. Blanco Drain raw water after filtration through the 10-micron filter;
7. Secondary mixture after filtration through the 10-micron filter;
8. The AWTF Influent mixture:
    a. After ozonation (3 samples), and
    b. After filtration through the 0.1-micron filter (2 samples).

2.5 Testing Supplies

The following supplies will be obtained and prepared in advance of testing:

- Sample bottles, cooler, gel-ice and Chain of Custody documentation (delivered to sampling location),
- Filtration equipment,
- 47-mm diameter filters with 10-micron and 0.1-micron pore sizes,
- TOC, turbidity and nitrite analysis equipment, and
- SOT apparatus.

2.6 Laboratory Procedure

The testing and sampling procedure is described in this section and graphically shown in Figure 2.

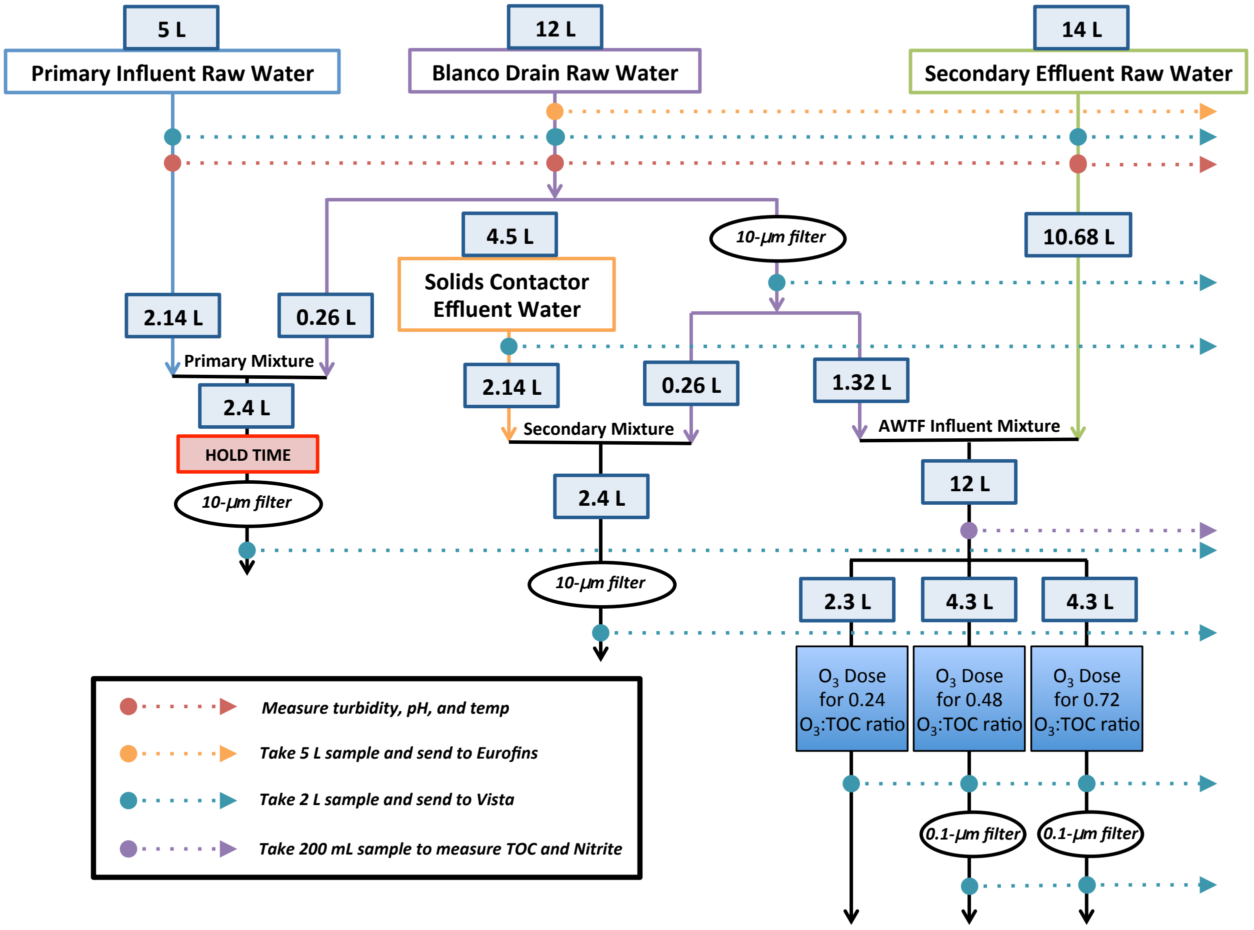

Figure 2 - Testing and sampling procedure. Note: the O_3:TOC ratio accounts for nitrite demand

Field:

Collect water samples as follows:

- **Blanco Drain:** fill six 40-mL amber glass vials for EPA Method 505, four 1-L amber glass bottles for EPA Method 608. Send these bottles directly to Eurofins. Fill two 1-L amber glass bottles for EPA Method 1699 and send directly to Vista. Fill four 1-L amber glass bottles and send to Trussell Tech laboratory in Pasadena, CA.
- **RTP Primary Influent:** Fill two 1-L amber glass bottles from the auto-sampler for the primary influent and send to Vista. Fill three 1-L amber glass bottles and send to Trussell Tech laboratory.
- **RTP Solids Contactor Effluent:** Fill two 1-L amber glass bottles from the solids contactor effluent water and send to Vista. Fill three 1-L amber glass bottles and send to Trussell Tech laboratory.
- **RTP Secondary Effluent:** Fill two 1-L amber glass bottles from the secondary effluent and send to Vista. Fill twelve 1-L amber glass bottles and send to Trussell Tech laboratory.

Lab:

1. Take a 10-mL water sample from each source and measure turbidity, pH and temperature.

2. Combine 2.14-L RTP primary influent water with 0.26-L Blanco Drain water to create the Primary mixture.
3. After the simulated primary treatment residence time (1.7 hours), filter the Primary mixture through a 10-micron pore size filter.
4. Fill two 1-L Vista laboratory analysis bottles with the Primary mixture filtered water, set aside.
5. Filter 3.7-L Blanco Drain water through a 10-micron filter.
6. Combine 0.26-L filtered Blanco Drain water with 2.14-L RTP solids contactor effluent water to create the Secondary mixture.
7. Filter the Secondary mixture through a 10-micron pore size filter.
8. Fill two 1-L Vista laboratory bottles with the Secondary mixture filtered water, set aside.
9. Combine 1.32-L of the remaining filtered Blanco Drain water with 10.68-L RTP secondary effluent water to create the AWTF Influent mixture.
10. Fill two 1-L Vista laboratory analysis bottles with the filtered Blanco Drain water, set aside.
11. Take a 40-mL sample of the AWTF Influent mixture and measure the total organic carbon and take a 20-mL sample and measure the total nitrite. Determine the ozone doses needed for ozone:TOC ratios of 0.24, 0.48 and 0.72 accounting for nitrite demand.
12. Divide the AWTF Influent mixture into three separate beakers labeled A, B and C containing 2.3 L, 4.3 L and 4.3 L respectively.
13. Once waters have reach room temperature, perform the SOT on the three filtered AWTF Influent mixtures:
    A. 2.3 L AWTF Influent mixture = ozone:TOC of 0.24
    B. 4.3 L AWTF Influent mixture = ozone:TOC of 0.48
    C. 4.3 L AWTF Influent mixture = ozone:TOC of 0.72
14. From tests A through C of the ozonated AWTF Influent mixtures, fill two 1-L Vista laboratory analysis bottles and set aside.
15. Filter the ozonated mixtures from tests B and C through a 0.1-micron filter.
16. Fill two 1-L Vista laboratory analysis bottles with the filtered AWTF Influent mixtures of tests B and C, set aside.
17. Send the 16 reserved Vista analysis bottles to Vista labs for analysis.

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APPENDIX I

Projected Arsenic Fate Post-Injection within Pure Water Monterey One Water Replenishment System

July 8, 2022

Projected Arsenic Fate Post-Injection within Pure Water Monterey One Water Replenishment System

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Controlling Geochemistry of Arsenic

Arsenic is a common, rock-derived element present within aquifers globally. Arsenic is liberated from sediments into groundwater through a combination of biogeochemical processes (linked to hydrologic factors) that can broadly be grouped into four categories: (1) ion displacement (principally induced by phosphate), (2) pH promoted desorption of As(V) from Fe(III) and other minerals at pH values > 8.5, (3) reductive dissolution of As(V) and Fe(III) (typically from As(V) adsorbed on Fe(III) minerals) under anaerobic conditions, and (4) oxidative dissolution of As-bearing (iron) sulfide minerals. The latter process (sulfide oxidation) typically leads to an ephemeral pulse of dissolved arsenic that is ultimately quenched by As(V) adsorption onto sediments, and in particularly Fe(III) oxides and hydroxides formed by Fe sulfide oxidation; thereafter, the dissolved concentrations of As are controlled by factors promoting (or limiting) adsorption (mostly pH).

Retention of arsenic onto soil solids is foremost dependent on its oxidation state, and two oxidation states of arsenic, As(V) and As(III), predominate in surface and near-surface environments. In general, As(V) binds extensively and strongly to most mineral constituents of soils and sediments, while As(III) retention is weaker and leads to both greater dissolved concentrations and migration. As a result of the strong partitioning of As(V) on Fe(III) oxides and hydroxides (along with other metal oxides and clay minerals) within oxygenated (aerated) soils and sediments, total As levels often correlate with Fe content (Smedley and Kinniburgh, 2002).

Within oxygen-limited environments where sulfide is present, As(III) can adsorb on or precipitate with sulfide minerals. In fact, As(III) concentrations are often controlled by sulfide precipitates in regions where sulfidogenesis (biological production of sulfide) occurs, limiting As(III) concentrations (Moore et al., 1988). Under hydrothermal conditions with high Fe^{2+}, sulfides may coprecipitate with Fe and As as arsenopyrite (FeAsS) or arsenic-rich (arsenian) pyrite [$Fe(S,As)_2$]; at lower levels of ferrous-iron, orpiment (As_2S_3) or realgar (AsS) may form. Iron sulfide minerals are, in fact, often the host of arsenic within aquifer sediments of marine origin when deposited under anoxic conditions.

Processes of Leading to Arsenic Release

Processes that reverse or limit arsenic retention result in groundwater arsenic contamination. The most common, albeit not exclusive, process leading to high arsenic levels in waters occurs under (non-sulfidic) anaerobic conditions whereby As(V) and Fe(III)-minerals undergo reductive dissolution. Organic matter in the water or sediments leads to O_2 consumption by aerobic microorganisms; when consumption exceeds supply rates, the prevailing anoxic conditions lead to anaerobic metabolisms. The consequence of anaerobic conditions is the production of Fe(II) and As(III) with a concomitant increase in dissolved As concentrations. The second most common conditions leading to arsenic release occurs under oxygenated conditions when the pH values exceed 8.5. Such pH values occur most commonly in arid environments with low calcium concentrations (limiting formation of $CaCO_3$ that buffers the pH around 8.2) such as the highlands of the Andes. However, advanced treatment of recycled water followed by a sodium hydroxide and calcium chloride polishing step can yield pH values exceeding 8.5 as well. The third possible release mechanism is when and anion of comparative binding strength displaces As(V) from mineral surfaces; phosphate is of particular concern in this regard (Manning and Goldberg, 1996; Dixit and Hering, 2003), and regions where fertilizer or pesticide runoff and leaching occurs are specifically at risk for this mobilization pathway (Peryea and Kammerack, 1997). Both dissolved silicate and organic acids can also competitively limit arsenic adsorption or promote desorption (Grafe et al., 2002). Other anions, such as Cl^-, SO_4^{2-}, and NO_3^-, have minimal direct impact on arsenic retention. As noted above, arsenic may also reside in (or on) sulfide minerals, particularly in marine deposits, that can be dissolved (destroyed) by oxidative reaction with oxygen or nitrate. The oxidation process, however, also creates Fe(III) oxides and hydroxides that then serve as scavengers of As(V)—also formed during oxidation—and the consequential decrease in dissolved arsenic concentrations. Thereafter, if the Fe(III) oxides are not reduced, pH values remain below 8.5, and phosphate is not introduced, dissolved arsenic concentrations will typically reside below drinking water standards.

Evaluation of Monterey One Water Geochemical Conditions

The drill logs, known lithology for the Salinas Valley, and studies associated with the ASR project offer insights into the potential origins and thus threats of arsenic. However, it is important to note that to gain the most accurate assessment of arsenic, direct measurement of arsenic concentrations in sediments (of each strata) and, ideally, its chemical state and controlling mineralogy-geochemistry would be required. Nevertheless, the color, particle size, and known deposition, and general mineralogical analysis of the Santa Margarita Aquifer provide important insights into the geochemistry of the sediments. The combination of alluvial sediments mixed with marine deposits give rise to variations in mineralogy and geochemistry. Light (including yellow) colored to orange-red tinted sediments largely signal oxidizing conditions, with yellows-oranges-reds indicative of Fe(III) oxides and hydroxides. An example is noted in the well logs for ASR-1 that denote reddish brown, moderately well sorted fine-medium sands at *ca.* 40-50 ft below ground surface. If arsenic is present in sediments with these colorings, it would likely be in the form of As(V) and associated with iron minerals. Gray, dark-gray and green(ish)-blue(ish) sediments generally signify a chemically reduced state that resulted from anaerobic conditions. Examples are the olive-green clayey sands at ca. 700-750 ft in ASR-3 and the Monterey shale/formation noted in ASR-1, MW-1AD, and MW-2AD. If sulfidic conditions persisted within these strata, such as in marine or estuarian deposits, and arsenic is present, it will commonly be associated with sulfide minerals such as pyrite. The abundant phases noted by X-ray diffraction analysis do not reveal pyritic or arsenic-bearing phases (Murphy, 2007), but trace pyrite was postulated from inverse geochemical modeling of the Santa Margarita Aquifer for the ASR project (wells SMTIW#2, aka ASR-2, and SMTIW#1, aka ASR-1) (Short, 2008)

Considering the potential arsenic sources within the sediments, it is next important to cover the geochemical conditions that high-purity water injections create in the subsurface, and then to place these in relation to how they will affect arsenic—specifically whether dissolution/desorption is likely to transpire. The injection water is high purity, oxygenated water. The translation is that it should neither induce competitive ions that displace arsenic nor the onset of low-oxygen conditions that could result in the reductive dissolution of arsenic from iron oxides. On the latter point, the water has very low dissolved organic carbon and is oxygenated, leading to oxidizing and not reducing conditions. Thus, two of the possible release mechanisms (reductive dissolution and competitive displacement) are unlikely upon delivery of the aerated, high-purity water.

The next possibility we need to consider is the pH of the injection water. Within oxidized sediments, if arsenic is present it will typically exist as As(V), and dissolved concentrations will be controlled by its adsorption on mineral surfaces, with iron oxides playing a particularly strong role. For conditions where As(V) adsorption controls arsenic partitioning, if the pH of the system increases above pH 8.5, As(V) will undergo progressive desorption, leading to concomitant increases in groundwater concentrations. Examining the (laboratory) measured pH of AWPF effluent, the pH exceeded pH 8.5 only upon the onset of injection (February 2020); thereafter, the pH decreased for the next 4 months, reaching a low around 6.5, and then increased to 8 in September 2020. It is possible that the short period of high pH in February (2020) release arsenic from sediments, but re-adsorption as the pH decreased should be rapid and limit dissolved concentrations in the subsequent periods. The rapid response of dissolved arsenic to changes in pH (causing arsenic to desorb or adsorb) within managed aquifers is well illustrated for the mid-basin injection system of Orange County Water District (Fahkreddine et al., 2020).

The last possibility is the oxidation of arsenic-bearing sulfides. While we do not have chemical and mineralogical data that will allow definitive assessment of arsenic-bearing sulfides, the color and known depositional history along with inverse modeling of the ASR geochemistry can provide insight into the possible form of arsenic if it is present. Shales of the Monterey Formation, for example, would likely have arsenic within arsenian pyrite (again, if arsenic is present). In general, the olive-green to dark gray sediments have optical properties consistent with reduced conditions that could include sulfidic arsenic forms. Accordingly, upon receiving oxygenated water, Fe(II)-sulfides will undergo oxidative dissolution, releasing other elements in co-association. Again, if arsenic is present, it will thus be released to solution. However, the dual oxidation of arsenic to As(V) and formation of Fe(III) hydroxides and oxide minerals will lead to the repartitioning of arsenic back to the solid phase.

Observed Impacts of Injection on Water Chemistry

A small arsenic pulse within the groundwater is noted for well MW-2D (Figure 1). Importantly, the water chemistry thus indicates that there is a source of arsenic within the alluvial-marine sediments. Further, the pulse itself tells us that there are two possible pathways of arsenic release. The first possibility is that the temporary change in pH above the critical value of 8.5 induced by the initial injection water resulted in desorption from minerals within the aquifer; the change in pH of lower values (less than 8) then led to the re-adsorption of arsenic back onto the aquifer sediments. The pH-displacement is a possible source of arsenic, but in comparing the pH to dissolved arsenic concentrations, the lack of correlation coupled with the known rapid geochemical response (adsorption and desorption) to pH leads me to suspect that pH was not a major contributor to dissolved arsenic. In a similar aquifer system associated with OCWD, dissolved arsenic concentrations rapidly changed with pH (Fahkreddine et al., 2020). Thus, we should look to a second geochemical alternative that would explain the pulse of arsenic. The alternative explanation is that injection of oxygenated water induced the displacement or dissolution of a finite quantity of arsenic likely via oxidative dissolution of arsenic-bearing sulfide minerals (such as arsenian pyrite). Arsenic dissolution was then followed by the formation of secondary iron hydroxide minerals that re-adsorbed arsenic. The combination of arsenic release followed by re-adsorption and flushing is consistent with a small quantity of As-bearing sulfides undergoing oxidative dissolution and explains the approximately 5-month period of elevated arsenic within MW-2D. The small pulse is also consistent with only trace quantities of pyrite. X-ray diffraction analysis of Santa Margarita Sandstones failed to detect pyrite or other mineral

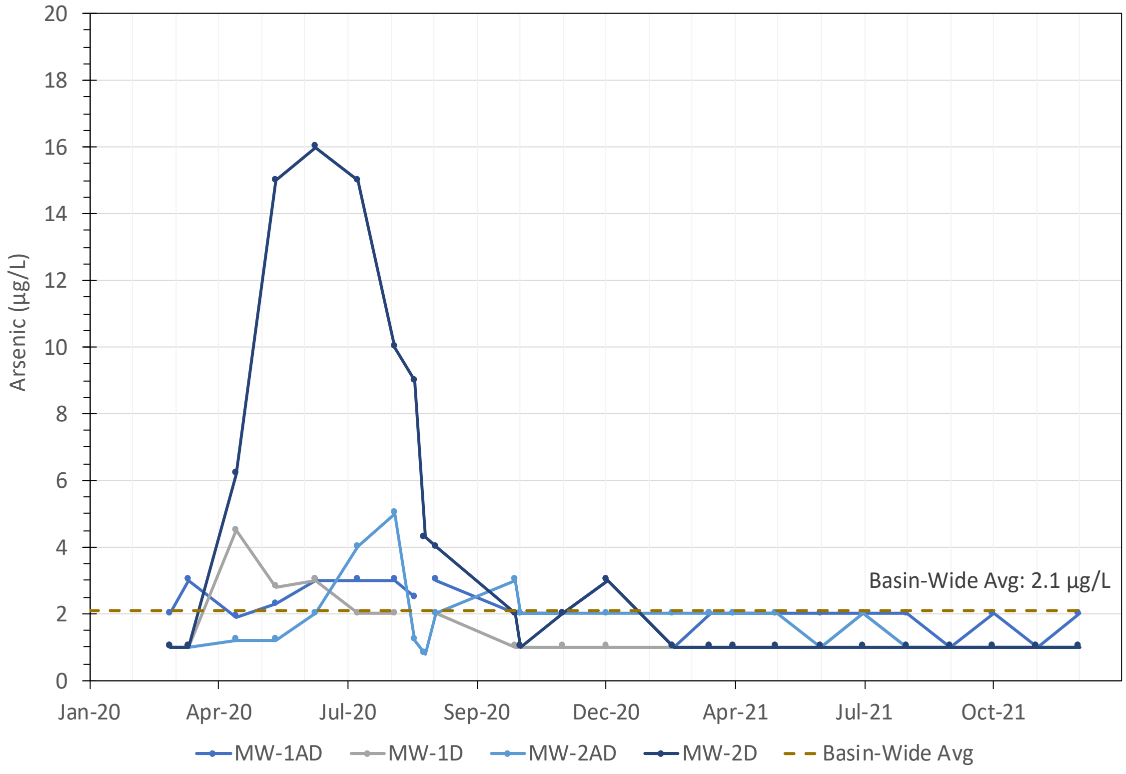

Figure 1. Dissolved arsenic concentrations within AWPF effluent and monitoring wells post injection.

sulfide (Murphy, 2007), and total sulfur analysis shows the possibility for trace levels (Tanner and Short, 2019), with inverse geochemical modeling inferring small quantities of pyrite in the Santa Margarita ASR aquifer (Short, 2008). Further, the observations here are similar to those observed for OCWD's injection of high purity water into aquifers containing arsenian pyrite (Fahkreddine et al., 2020). In the case of OCWD, after oxidative dissolution, the fate of arsenic was controlled by the pH of the injection water and advective displacement/dilution of arsenic. At pH values less than 8.5, arsenic released during oxidative dissolution was subsequently readsorbed on newly formed iron hydroxides, limiting dissolved concentrations (Fahkreddine et al., 2020). There is also the possibility of a small, finite quantity of arsenic adsorbed on clay minerals through weak electrostatic forces that is displaced by the injectate, as was seen for spreading basins within OCWD (Fahkreddine et al., 2015). In the case of the OCWD spreading basins, arsenate anions were bound to negatively charged clay mineral through Ca^{2+} or Mg^{2+} bridging ions (meaning that the divalent cations bind to the mineral surface and the arsenate anion binds to the extra positive charge of the cation) that are easily displaced. Arguing against this possibility, however, is a highly localized (single well) signature of elevated dissolved arsenic.

Recommendations and Future Assessment

On the basis of existing data (inclusive of monitoring well water chemistry, well logs, known depositional strata and ASR well data), arsenic is likely partitioned as As(V) onto aquifer solids. In the case of the aquifer strata upstream of MW-2D, arsenic was likely released from arsenic-bearing mineral sulfides and subsequently partially repartitioned onto newly formed Fe(III) minerals.

Recommendation 1

With As(V) adsorption now controlling the dissolved concentrations in the Pure Water Monterey aquifer system, maintaining a pH less than 8.5 for the injection water will prevent (pH-induced) desorption of As(V) from minerals within the sediments.

Recommendation 2

Prolonging injection of aerated water into aquifer will limit the potential rebound of arsenic noted in MW2D during the initial period of injection—the longer the period of injection, the smaller and less likely a rebound will occur.

Explanation of Recommendation 2 and Projections

Within the upstream sediments of MW2D, and only in this specific zone, a small quantity of arsenic appears to have been mobilized by oxidative dissolution of arsenic-bearing sulfides and either repartitioned onto newly formed Fe(III) minerals upon receiving oxygenated water or flushed from the aquifer—or a combination of both processes. While the phase is likely an arsenian pyrite (i.e., pyrite with trace quantities of arsenic substituting for sulfur, $FeS_{2-x}As_x$), I use arsenopyrite to illustrate the reactions controlling arsenic upon oxygenation.

$$FeAsS + 3\frac{1}{2}O_2 + 4H_2O \Rightarrow Fe(OH)_3 + SO_4^{2-} + H_2AsO_4^{2-} + 3H^+$$

Generation of $Fe(OH)_3$ then should adsorb the As(V) (existing as $H_2AsO_4^-$ or $HAsO_4^{2-}$), leading to its repartitioning to the solid phase (i.e., removal from the groundwater). Here, the reaction shows

$$\boldsymbol{Fe(OH)_3 \equiv OH} + H_2AsO_4^- \Rightarrow \boldsymbol{Fe(OH)_3 \equiv H_2AsO_4} + OH^-$$

the solid phase (bold, left side) having a hydroxyl ion displaced by the As(V) molecule, leading to the adsorbed complex (bold, right side). The strong complexation of As(V) then limits its dissolved concentration provide the pH is maintaining below ~8.5.

However, it is possible that the strata originally hosting the sulfide minerals may contain organic matter that could result in oxygen being depleted and arsenic release through reductive dissolution or As(V)-bearing Fe(III) minerals. Under oxygen-limiting conditions, microorganisms have the capacity to use alternate electron acceptors (to oxygen) in respiration. The general sequence of electron acceptors is O_2 followed by nitrate, manganese dioxides, iron hydroxides, sulfate, and then methanogenesis (Kocar and Fendorf, 2009). Nitrate and manganese dioxide minerals thus help to buffer against microbial utilization of Fe(III) and As(V). Yet, once both are utilized, microbial reduction of As(V) and Fe(III) (as AsV-$Fe(OH)_3$), will transpire. Thus, microbially driven oxidation of organic carbon coupled to the dissimilatory reductive dissolution of As-bearing Fe oxides causes the transfer of arsenic from sediment solids to groundwater (Fendorf et al., 2010), as shown below:

$$CH_2O + 4\mathbf{FeOOH\text{-}(H_2AsO_4)_x} + (7+3x)H^+ \Leftrightarrow 4Fe^{2+} + HCO_3^- + (6+x)H_2O + xH_3AsO_3$$

where CH_2O generically represents organic carbon within the sediments and may include other fermentation products such as $H_{2(aq)}$, As(V) (as arsenate) is bound to Fe oxide (goethite as written in reaction 1) and x is the stoichiometric coefficient of As content associated with the Fe oxides. Dissimilatory As(V)/Fe(III) reduction requires anaerobic conditions with low sulfate supply and microbially available organic carbon, and the rate is further dependent on the reactivity (toward microbial reduction) of the As-Fe solid phase complex.

The aquifer appears sulfur limited (for reformation of As-bearing iron sulfides), and thus the extent and rate of microbial reductive dissolution of arsenic will depend primarily on the available organic carbon within the sediments. Stimulating microbial oxidation of organic carbon thus helps to mitigate future reduction by promoting the aerobic consumption of organic carbon, again represented here as the simplified sugar CH_2O.

$$CH_2O + O_{2\,(aq)} \rightarrow HCO_3^- + H^+$$

With aerobic microbial respiration being both faster and more complete (meaning a greater set of compounds can be decomposed) than anaerobic conditions, continued injection will help deplete the microbially available carbon. The projected outcome, while only verifiable through experimentation, is that at a minimum the rate of arsenic released due to a reductive dissolution rebound will decrease proportionally to the period of injection. In Figure 2, I illustrate the dissolved concentration of arsenic that would result for a similar zone of interaction that resulted during the oxidative release of 2020 noted in MW2D. For the sake of the illustration, I show results for a flow rate in the absence of injection being half that during the injection—slower flow rates will yield higher concentrations; the same concentration curve would result, however, if the release rate were one-fifth the rate in 2020 but the flow rate decreased to one-fifth that occurring during injection. The primary purpose of the figure is to illustrate how a decrease in organic matter over the period of injection due to aerobic microbial respiration will lead to progressively slower release rates of arsenic upon termination of injection.

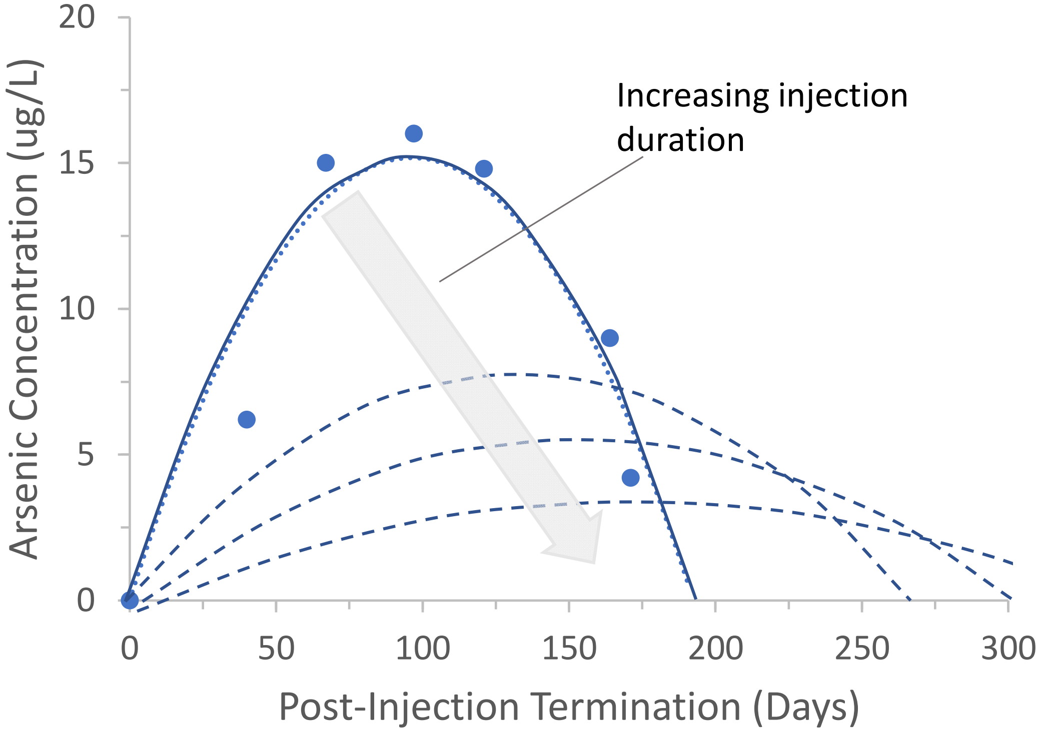

Figure 2. Projected aquifer (dissolved) arsenic concentrations after the termination of Pure Monterey One injection in the vicinity of MW2D (assuming a similar zone of interaction). The solid line represents the concentration projected for a reductive dissolution rate half the observed (2020) oxidative release rate but with half the flow rate; the same result would occur if the reaction rate decreased to one-fifth the 2020 value but the flow rate is one-fifth of that occurring during injection. Importantly, successively decreasing rates of release resulting from increased duration of inject due to the burnout of organic carbon, illustrated by dashed lines.

It is also worth noting that arsenic concentrations are unlikely to exceed the drinking water standards given expected reaction rates, and, most importantly, become less likely to do so with increasing duration of injection.

To reiterate the primary point of the second recommendation, continuing to run the Pure Water Monterey injection will lead to decreasing risk of arsenic within the aquifer that could result from a reductive dissolution rebound.

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APPENDIX J

AWPF Demonstration Facility

DRAFT - MRWPCA Pure Water Monterey Demo Ops Water Quality Monitoring Schedule

Operator readings

Parameter	Method	Location of Sample	Sample Type	Frequency	Reason	Level of Concern
Conductivity	Handheld Meter (Myron L Comp. UltraMeter II)	RO Feed	Grab	Monthly	Meter Verification†	+/- 10% of analyzer value
		RO Permeate	Grab	Monthly	Meter Verification†	+/- 10% of analyzer value
		UV/AOP Effluent	Grab	Weekly	Verify calcite filter performance	Difference of 200 +/- 100
		Faucet	Grab	Weekly	Verify calcite filter performance	
Dissolved Ozone	Hach DR900	DO$_3$ #1 Sample Line	Grab	Daily*	Meter Verification†	+/- 10% of analyzer value
		Ozone Effluent	Grab	Daily*	Meter Verification†	>0.05 mg/L or +/-10% of analyzer value
H_2O_2	Hach DR900	UV Reactor Feed Water	Grab	Weekly	Verify peroxide dose	< 2 mg/L
Nitrite	Hach DR900	Secondary Effluent	24-h Comp.	Daily*	Understanding ozone demand	n/a
		Ozone Influent	Grab	Daily*	Understanding ozone demand	n/a
ORP	Handheld Meter (Myron L Comp. UltraMeter II)	UF Feed	Grab	Weekly	Meter Verification†	+/- 10% of analyzer value
pH	Handheld Meter (Myron L Comp. UltraMeter II)	UF Feed	Grab	Monthly	Meter Verification†	+/- 10% of analyzer value
		RO Feed	Grab	Daily*	Meter Verification†	+/- 10% of analyzer value
		UV/AOP Effluent	Grab	Weekly	Verify calcite filter performance	Differential of 1 +/- 0.5
		Faucet	Grab	Weekly	Verify calcite filter performance	
Temperature	Hand held thermometer	UF Feed	Grab	Monthly	Meter Verification†	+/- 10% of analyzer value
		RO Feed	Grab	Monthly	Meter Verification†	+/- 10% of analyzer value
		UV/AOP Effluent	Grab	Weekly	Verify calcite filter performance	Difference of 5 +/- 2
		Faucet	Grab	Weekly	Verify calcite filter performance	
Total Cl_2	Hach DR900	UF Feed	Grab	Daily*	Verify Chlorine Dose	Outside 3-5 mg/L
Turbidity	Hach 2100Q field meter	UF Feed	Grab	Monthly	Meter Verification†	+/- 10% of analyzer value
		UF Filtrate	Grab	Monthly	Meter Verification†	+/- 10% of analyzer value
UVT	Portable RealTech	UV/AOP Feed	Grab	Weekly	Meter Verification†	+/- 10% of analyzer value

*Daily is 5 days per week

†Record meter reading when sample is collected to compare to WQ result

Lab readings

Alkalinity	Titration (SM2320B)	UV/AOP Effluent	Grab	Weekly	Verify calcite filter performance	dAlk < 40 mg/L as $CaCO_3$
		Faucet	Grab	Weekly	Verify calcite filter performance	
Calcium	IC	UV/AOP Effluent	Grab	Weekly	Verify calcite filter performance	dCa < 40 mg/L as $CaCO_3$
		Faucet	Grab	Weekly	Verify calcite filter performance	
TDS	Filtration method (SM2540C)	UV/AOP Effluent	Grab	Weekly	Verify calcite filter performance	difference of 50 +/- 40
		Faucet	Grab	Weekly	Verify calcite filter performance	
TOC	TOC Analyzer (SM5310B)	Ozone Influent	Grab	3/week	Understanding TOC variability	n/a
		Faucet	Grab	3/week	Understanding future regulatory compliance	> 0.5 mg/L
Total coliform	Colilert QT (UF Filtrate)	UF Filtrate	Grab	Weekly	Verify UF performance	Detactable
	Colilert P/A (Faucet)	Faucet	Grab	Weekly	Verify stabilization sterility	Detactable
Total Nitrogen	Nitrite (IC), Nitrate (IC) and TKN	Faucet	Grab	Weekly	Understanding future regulatory compliance	>10 mg/L

DRAFT - MRWPCA Pure Water Monterey Demo Ozone & Pre-treatment Ops Sheet

Date	Time	Ops	Applied ozone dose (mg/L)	Ozone transfer efficiency (%)	Transferred ozone dose (mg/L)	Ambient ozone (ppm)	Oxygen flowrate (scfh)	Generator power (%)	Applied ozone concentration (g/Nm^3)	Flowrate (gpm)	Venturi suction pressure (psi)	Degas ozone concentration (g/Nm^3)	DO3 #1 (mg/L)	DO3 #2 (mg/L)	ORP (mV)	Confirm water separator drainage flow	Sample conditioner coalescer water level	South & north LOX dewar level (in. H_2O)		Hypo tank level (% full)	Pressure reading upstream & downstream of strainers (psi)		Chloramine residual at UF influent (mg/L as Cl_2)
Level of concern	--	--	Atypical (Ex: < 5 or > ~20)	< 80%	Atypical (Ex: < 5 or > ~20)	> 0.10	±1 of setpoint	Atypical (Ex: 0%, < ~40% or 100%)	Atypical (Ex: < ~40)	< 30 if pump valve open	> 20	Atypical (Ex: > ~10)	±0.2 of setpoint	> 0.05 (if DO$_3$ #1 used for control)	> ~500 (if setpoint at 475)	No flow	Empty as needed	Replace when empty		Fill as needed	dP > ~5 psi		< 3
Example	*9:00*	*JDK*	*14.4*	*90.9%*	*12.7*	*0.03*	*60*	*49%*	*52.5*	*34.0*	*9*	*5.0*	*0.26*	*0.00*	*420*	✓	*10%*	*47.5*	*20*	*30%*	*32*	*32*	*4*

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UF System - Operations Log For Monterey, CA

UF System Unit Must be Running For Several Minuets Before Recording Readings

Operators Initials	Date	Time	UF Status at Time of Sample	Time Remaining at Time of Sample	UF Feed Pump Pressure (PI-1005)	UF Membrane Feed Pressure (PI-1016)	UF Filtrate Pressure (PI-1028)	UF Feed Temp (TIT-1004)	UF Filtrate Flow (FIT-1023)	UF Feed Turbidity (AE-1010)	UF Filtrate Turbidity (AE-1036)	TMP from Screen	Prefilter Delta P from Screen	Hours to Next Chlorine/Caustic Mini-CIP (if ON)	Hours to Next Acid Mini-CIP (if ON)	Hours to Next Chlorine/Caustic TMC (if ON)	Hours to Next Acid TMC (if ON)	Dsuring Backwash Filtrate Flow (FIT-1023)	During Backwash Air Scour Flow (FIT-1040)	pH Reading on Screen (AIT-1026)

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Reverse Osmosis - Log For Monterey, CA

Reverse Osmosis Unit Must be Running For Several Minuets Before Recording Readings

Operators Initials	Date	Time	Pre-filter Press. (PI-2012)	Post filter Press. (PI-2017)	Pump Inlet Pressure (PI-2032)	Pump Outlet Pressure (PI-2036)	RO Feed Pressure (PI-2039)	Interstage Pressure (PI-2042)	Conc. Pressure (PI-2045)	Final Pressure (PI-2052)	Permeate Pressure (PT-2065)	Inlet Hardness	Inlet Chlorine (free)	Inlet ORP (AE-2023)	Inlet Temperature (AE-2023)	Inlet pH (AE-2024)	Permeate Flow (FE-2061)	Concentrate Flow (FE-2054)	Inlet Cond. (AE-2027)	Permeate Cond. (AE-2068)	Pre-filter's Changed

DRAFT - MRWPCA Pure Water Monterey Demo UV/AOP Ops Sheet

Date	Time	Ops	Flowrate (gpm)	UVT (%)	NDMA log removal	1,4-dioxane log removal	Power (kW)	H_2O_2 pump rate on HMI (gph)	H_2O_2 dose (mg/L)	UV intensity (mW/cm^2)	BLP (%)	H_2O_2 tank level (pad)	H_2O_2 pump rate on pump (gph)	H_2O_2 in H_2O_2 skid sump	H_2O_2 line pressures (psi)	UVT analyzer humidity (%)	UVT analyzer temperature (°C)	H_2O_2 kit result after H_2O_2 dosing, A (mg/L)	RO permeate chloramine residual, B (mg/L as CL_2)	Calculated H_2O_2 residual = A - B*34/71 (mg/L)
Level of concern	--	--	> 18 < ~5	< 95%	< 1.2	< 0.5	Atypical	Atypical (Ex: < 0.0088)	Atypical (Ex: < 4)	Atypical	Atypical	Fill/replace as needed	If ≠ HMI	If H_2O_2 present	Atypical (Ex: > ~10)	> 25%	--	NA	NA	< 4
Example	*14:30*	*JDK*	*15.0*	*97.0%*	*1.58*	*0.57*	*0.94*	*0.011*	*5*	*25.18*	*92%*	*Full*	*0.0113*	*Empty*	*4, 4*	*13%*	*31*	*6.0*	*2.0*	*5.0*

DRAFT - MRWPCA Pure Water Monterey Demo Stabilization Ops Sheet

Date	Time	Ops	UV lamp on/off	Check flowrate	Calcite level	Chiller on/off	Pre-stabilized pH	Pre-stabilized temperature (°C)	Pre-stabilized conductivity (µS/cm)	Faucet pH	Faucet temperature (°C)	Faucet conductivity (µS/cm)
Level of concern	--	--	off	< 0.3 gpm per faucet (replace cartridge filter as needed)	TBD (fill as needed)	off	> 6.0 < 5.0	Atypical	> 60	< 6.0	> 24	< 50
Example	*15:30*	*JDK*	*on*	✓	*~90%*	*on*	*5.60*	*24.7*	*39.3*	*7.10*	*19.8*	*565*

Pure Water Monterey Pre-Tour Checklist (Day of Tour)

No.	Item							
	Date	10/13						
	Initials	JDK						
Ozone System								
1	DO$_3$ #1 Sensor ≥ 0.1 mg/L?	✓						
2	Effluent clear in color?	✓						
3	Ambient ozone concentration < 0.1 ppm?	✓						
UF System								
1	DIT LRV: ≥ 4 logs?	✓						
2	Filtrate turbidity < 0.2 NTU?	✓						
RO System								
1	Conductivity rejection ≥ 96.8%?	✓						
2	Permeate conductivity < 60 µS/cm?	✓						
3	Feed pH ≥ 5.8?	✓						
UV/AOP System								
1	NDMA log removal ≥ 1.20?	✓						
2	1,4-dioxane log removal ≥ 0.50?	✓						
3	UVT ≥ 95%?	✓						
Stabilization System								
1	UV power on?	✓						
2	Product water conductivity > 150 µS/cm?	✓						
3	Product water temperature < 22°C?	✓						
Water Quality Sampling								
1	Chloramine residual at UF influent ≥ 3 mg/L as Cl_2?	✓						
2	H_2O_2 residual at UV/AOP reactor influent ≥ 4 mg/L?	✓						

APPENDIX K

Pure Water Monterey Project: Sensitivity Analysis of Simulated Subsurface Travel Time from DIW-4 to Ord Grove 2

TODD
GROUNDWATER

October 24, 2024

MEMORANDUM

To: Sherly Rosilela, DDW

From: Gus Yates, PG, CHG, Senior Hydrologist
Pascual Benito, Montgomery & Associates

Re: Pure Water Monterey Project: Sensitivity Analysis of Simulated Subsurface Travel Time from DIW-4 to Ord Grove 2

Groundwater modeling and tracer studies were completed to estimate subsurface travel times between the Pure Water Monterey (PWM) Project deep injection wells and the nearest downgradient municipal supply wells. The results of those studies are presented in the 2024 PWM Engineering Report, and travel times exceeded 4 months for all six of the existing and planned deep injection wells under a broad range of extraction patterns at the downgradient municipal supply wells. In the case of deep injection well DIW-4, however, simulated travel times to the Ord Grove 2 supply well were faster than observed travel times measured using a tracer study between the two wells. This memorandum documents a sensitivity analysis of the model which demonstrated that two conservative assumptions originally incorporated into the model caused most of the discrepancy between simulated and observed travel times.

DIW-4 is located 1,600 feet upgradient of municipal well Ord Grove 2 at the southwestern end of the Pure Water Monterey project area. **Figure 1** shows a time series of fluorescein dye concentrations measured at Ord Grove 2 for the 14 months following the dye injection into DIW-4 on October 25, 2022. The time concentration plot forms a classic bell-shaped breakthrough curve pattern, with a pause when Ord Grove 2 was off-line for one month in summer 2023. The peak concentration occurred 371 days (12.2 months) after injection.

The injection rate at DIW-4 averaged 834 gallons per minute (gpm) during the tracer test period, and the Ord Grove 2 extraction rate also averaged 834 gpm. Those rates are representative of normal operating conditions. The model simulations showed peak concentration arrival of PWM water at 215 days after injection, or 58 percent of the observed 371-day peak concentration travel time.

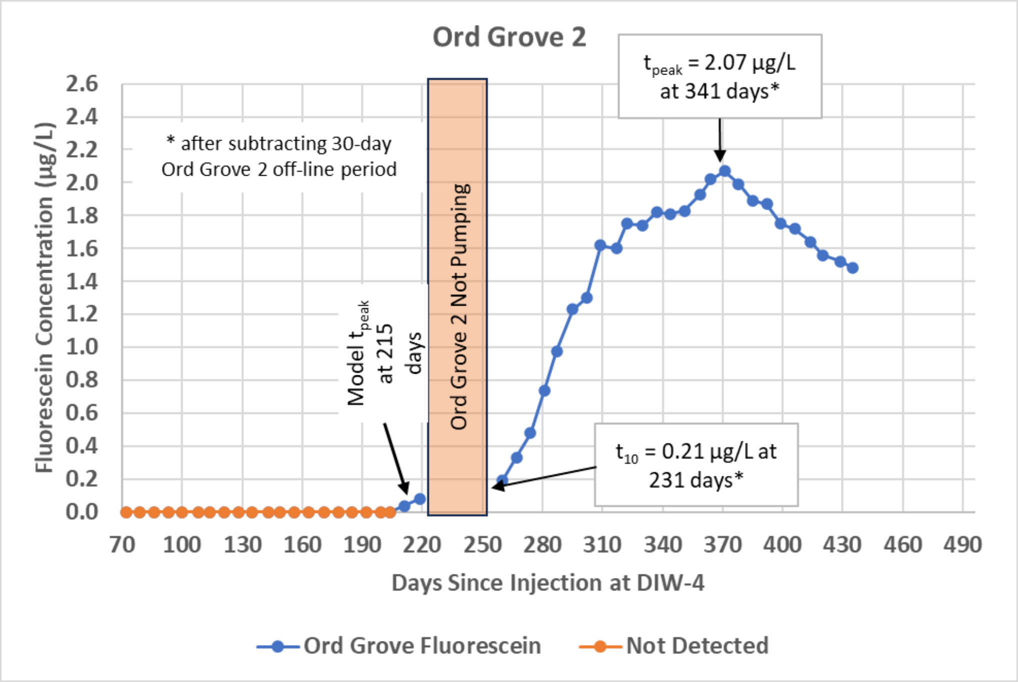

Figure 1. Fluorescein Dye Concentration Measured at Ord Grove 2 Well

These initial results demonstrate that the current model is overly conservative with respect to simulated travel times between DIW-4 and Ord Grove 2 and suggest that two assumptions incorporated into the model could be adjusted to better match the observed longer travel time between the well pair. The first assumption relates to how the simulated pumping from Ord Grove 2 is distributed between the Paso Robles and Santa Margarita Aquifers in the model, and the second relates to the incorporation of an assumed hydraulic barrier adjacent to Ord Grove 2 and DIW-4. These two assumptions were modified in a new simulation to test the sensitivity of simulated travel time to the assumptions.

As originally implemented, the model assumed that 100 percent of the water extracted from Ord Grove 2 was being drawn from the Santa Margarita Aquifer, which is the same aquifer into which DIW-4 injects purified water. More recent analysis of well logs and water quality data suggests that Ord Grove 2 is actually screened across both the deeper confined Santa Margarita Aquifer and the lower portion of the shallower Paso Robles Aquifer. The Paso Robles Aquifer water quality signature is lower in dissolved solids and chloride concentrations than the Santa Margarita Aquifer water quality signature. A water quality mixing analysis indicated that only between 60-80 percent of the water produced by Ord Grove 2 is from the Santa Margarita Aquifer, with 20-40 percent coming from the Paso Robles Aquifer. For the sensitivity analysis, pumping was redistributed with 70 percent from the model layer representing the Santa Margarita Aquifer and 30 percent from the layer representing the Paso Robles Aquifer.

The second assumption is the presence of a hypothesized anticline acting as a partial flow barrier between the DIW-4/Ord Grove 2 well pair and other injection and extraction wells to the north. The presence of this partial flow barrier was inferred from:

1. the absence of observed water-level drawdown or draw-up response between wells on opposite sides of the inferred barrier, and

2. the absence of water quality changes over the past 15 years indicating that neither the Phase 1 injected Pure Water Monterey water nor the injected Carmel River ASR water arrived at Ord Grove 2.

The model conservatively assumed the anticline acts as a complete barrier to groundwater flow and was simulated as completely impermeable. This assumption was expected to shorten the simulated travel time between DIW-4 and Ord Grove 2 because all of the water injected at DIW-4 would be constrained to a relatively narrow corridor between that well and Ord Grove 2, resulting in a steeper hydraulic gradient between the wells. For the sensitivity analysis, the effect of the flow barrier was removed by setting its transmissivity equal to the transmissivity of the aquifer material on either side.

Sensitivity Simulation. The results of the sensitivity simulation confirmed that these two assumptions are conservative and can account for most of the discrepancy between simulated and measured tracer travel time between the DIW-4/Ord Grove 2 well pair. The simulated peak tracer travel time increased from 215 days to 307 days, or 83 percent of the travel time measured with the extrinsic tracer. This result confirms that relaxing these two excessively conservative assumptions eliminated most of the discrepancy between simulated and measured travel times. These results validate the conclusion that the simulated underground retention time (t_{10}) between DIW-4 and Ord Grove 2 presented in the 2024 PWM Engineering Report are conservative and that the expected actual underground retention time from DIW-4 will be substantially longer, 6.6 months instead of 4.8 months (on the order of 1.4 times longer).

The two adjustments to the model for the sensitivity simulation also impacted travel times between DIW-1, DIW-2, DIW-3 and their respective nearest downgradient potable supply wells. The changes in t_{10} travel times ranged from a decrease of 1.4 months from DIW-2 to Paralta (from 6.9 to 5.5 months) to an increase of 0.7 months from DIW-3 to Paralta (5.2 to 5.5 months).[1] In all cases, simulated t_{10} travel times still exceeded 4 months.

The sensitivity analysis also confirmed that the discrepancy between simulated and measured travel time between DIW-4 and Ord Grove 2 was largely attributable to excessively conservative assumptions regarding the vertical distribution of pumping at Ord Grove 2 and the effects of a hypothesized flow barrier north of that well pair. Furthermore, adjustments implemented for the sensitivity analysis did not alter the conclusion that travel

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[1] The t_{10} travel time is used for regulatory compliance and is the time when the concentration at the downgradient extraction well reaches 10 percent of the eventual peak concentration.

times from the other deep injection wells meet the target of 4 months or more under a wide range of assumptions regarding municipal well extraction.

Model Calibration & Performance. The flow and transport model used to the support the 2024 PWM Engineering Report was calibrated to the measured tracer travel times between DIW-1 and Paralta, DIW-1 and MW-1AD and between DIW-2 and MW-2AD that were observed during the initial added tracer study that ran for 224 days from October 2021 to May 2022 (M&A, 2022). The simulated travel times between those well pairs matched the measured travel times to within 4%. This same version of the model was used to simulate the more recent added tracer study initiated in October 2022 (DIW-3 to ASR-3 and DIW-4 to Ord Grove 2 and to Seaside Municipal). From these results, the simulated tracer arrival times were compared with the measured tracer arrival times to assess how well the model predicts tracer test results and to ensure the model is biased towards underestimating underground travel times between those well pairs. For these simulations, the reported PWM injection and Cal-Am and City of Seaside municipal pumping rates for the tracer study periods were applied in the model.

The results of this comparison and the results of the initial model calibration are shown on **Figure 2.** The horizontal axis of the plot represents the travel time between an injection well and a monitoring well or production well as measured during the tracer study and the vertical axis represents the simulated tracer travel time. If the simulated travel time between an injection and production or monitoring well pair exactly matches the measured travel time, then the point plots exactly on the diagonal dotted 1:1 line. If the model overestimates the travel time between the well pair (e.g., model simulates a longer underground retention time), then the point will fall above the 1:1 line. Conversely if the simulated travel time is shorter than the measured travel time (e.g., model simulates a shorter underground retention time), then the point will fall below the 1:1 line. For the DIW-2 to Paralta well pair, a horizontal line segment, rather than a single point, is used to represent the potential range of the t_{10} and t_{peak} tracer arrival times because the eosine dye tracer injected at DIW-2 arrived at Paralta sometime after the end of the 224 day October 2021 tracer study, but before the start of the October 2022 tracer study.

An important conclusion can be made from the observations; namely, all of the simulated travel times between an injection well and a municipal supply well are either very close to the 1:1 line or are below the 1:1 line. This tells us that the model, as currently set up and calibrated, is conservative with respect to simulating underground retention times from DIW-4 to Ord Grove 2 and from DIW-1 to ASR-3. For well pairs where the simulated travel time does not match the measured travel time, the model is biased towards simulating travel times that are shorter than the actual travel times, and not vice-versa. For example, in the case of the travel time from DIW-4 to Ord Grove 2, the model simulates a t_{10} travel time that is around 40% shorter than the actual underground retention time. As described in the DIW-4 to Ord Grove 2 sensitivity analysis presented above, this bias is likely structural and a function of a combination of assumptions, such as how pumping is distributed between the Santa Margarita and Paso Robles formations for multi-aquifer wells, the hydraulic properties assigned in the model, and assumptions related to the inferred flow barrier between DIW-4 and DIW-2. This indicates that not only are the simulated tracer arrival times conservatively underestimated, but the projected future underground retention times for the expansion operational scenarios will also be simulated conservatively rather than over-estimated.

The comparison with measured travel times demonstrates that the underground retention times simulated by the model to these wells are conservative and support the conclusion presented in the 2024 PWM Engineering Report that project injection wells will operate to maintain a minimum underground retention time of 4 months or greater.

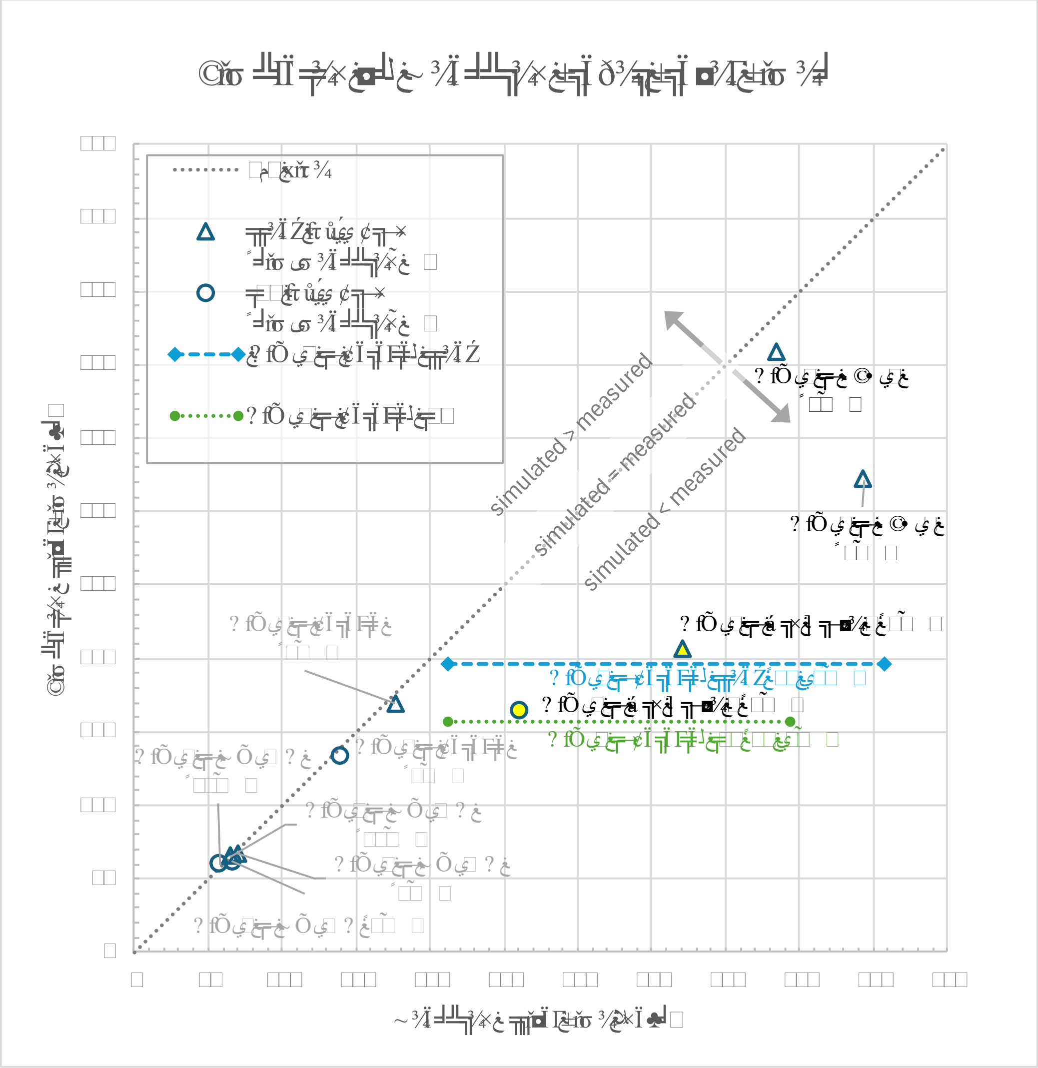

Figure 2. Simulated Versus Measured Extrinsic Dye Tracer Study Travel Times.[2]

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[2] Seaside Municipal Well is not shown in the figure because the tracer dyes that were added to the deep injection wells in October 2021 (DIW-1, DIW-2) and October 2022 (DIW-3 and DIW-4) have not been detected at that well.

REFERENCES

Montgomery & Associates, Inc. (M&A), 2022. Technical Memorandum, PWM Added Tracer Study Analysis & Operational Scenario Modeling, June.

APPENDIX L

Toray Low-Pressure Reverse Osmosis Membrane Element Datasheet

Product Datasheet

TORAY
Innovation by Chemistry

TMG(D) Series

Low-Pressure Brackish Water Reverse Osmosis (RO) Membrane Element with Enhanced Chemical Tolerance

Toray's reverse osmosis membrane technology applies decades of R&D and precision automated manufacturing under ISO 9001 for consistency in product quality. State-of-the-art cross-linked fully aromatic polyamide composite membranes produce high-quality permeate and robust membrane chemistry for improved performance and longer membrane life.

Product Specifications	Unit	TMG10D	TMG20D-400	TMG20D-440
Size		4040	8040	8040
Membrane Area	ft^2 (m^2)	87 (8)	400 (37)	440 (41)
Nominal Salt Rejection	%	99.7	99.7	99.7
Minimum Salt Rejection	%	99.5	99.5	99.5
Product Flow Rate	gpd (m^3/d)	2,650 (10.0)	12,100 (45.8)	13,300 (50.3)
Minimum Product Flow Rate	gpd (m^3/d)	2,120 (8.0)	10,300 (39.0)	11,200 (42.4)
Feed spacer thickness	mil	34	34	28

Test Conditions: Feed water pressure 150 psi (1.03 MPa); Feed water temperature 77 °F (25°C); Feed water concentration 2,000 mg/L as NaCl; Recovery rate 15%; Feed water pH 7

Applications

Municipal drinking water, Industrial process water, Water reuse

Products manufactured at our U.S. facility (TMUS) are certified to NSF/ANSI 61 for drinking water applications.

FeedWater Permeate ConcentratedBrine

Flow direction →

Figure 1: 4040 elements

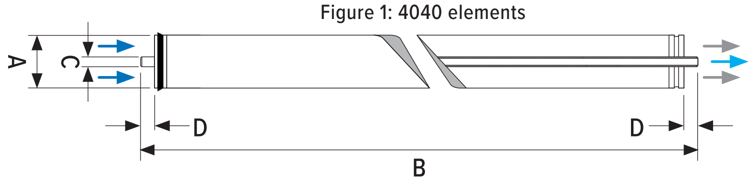
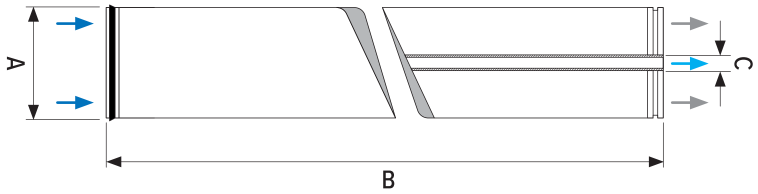


Figure 2: 8040 elements



Dimensions in. (mm)		
Size	4040	8040
A	4.0 (101)	7.9 (201)
B	40 (1,016)	40 (1,016)
C	0.75 (19)	1.125 (29)
D	1.05 (26)	—

TMG(D) Series

Low Pressure Brackish Water Reverse Osmosis (RO) Membrane Element with Enhanced Chemical Tolerance

Operating Limits		Unit	Value
Maximum operating pressure[6,7]		psi (MPa)	600 (4.1)
Maximum feed water temperature		°F (°C)	113 (45)
Maximum feed water SDI_{15}			5
Feed water chlorine concentration		ppm	< 0.1
Feed water pH range	Continuous operation		2–11
	Chemical cleaning		1–13
Maximum pressure drop per element		psi (MPa)	15 (0.10)
Maximum pressure drop per vessel		psi (MPa)	50 (0.34)

Operating Information

1. Please consult the latest Toray technical bulletin, design guidelines, computer design program, or call an application specialist for the recommended design range. Not strictly following the operating limits stated in this bulletin will void and nullify the Limited Warranty.
2. All RO elements are wet tested treated with a 1 percent by weight sodium bisulfite storage solution. Afterward, the RO elements are vacuum packed in oxygen barrier bags or treated with a tested feed water solution, and then vacuum sealed in oxygen barrier bags with deoxidant inside. Toray recommends flushing Toray RO elements for 30 to 60 minutes once every two days with sufficient quality flushing water, such as pre-treated feed water, to prevent biological growth during system shutdown. Please refer to the Toray RO Handling Manual for suggested flushing water quality.
3. The presence of free chlorine and other oxidizing agents under certain conditions, such as heavy metals that act as oxidation catalysts in the feed water, will cause unexpected oxidation of the membrane. Toray strongly recommends removing these oxidizing agents contained in feed water before operating the RO system.
4. Permeate from the first hour of operation shall be discarded.
5. The customer is fully responsible for the effects of chemicals that are incompatible with the elements. Their use will void the element Limited Warranty.
6. Recommended process / operation pressure is < 2.0 MPa (for details, and in special cases, please consult the projection design guideline or contact your membrane supplier).
   a) Low-pressure elements will perform best with low salinity brackish water
   b) Maintain the above pressure range at low temperatures.
7. Maximum operating pressure will vary depending on feed temperature. Please ask for detailed information from Toray if needed.

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For more info, please visit
water.toray

APPENDIX M

M1W, Cal-Am, MCWD October 16, 2024 Meeting Notes

MCWD/Cal-Am Intertie
Meeting Minutes

October 16, 2024
11am to 12pm
Microsoft Teams Meeting

Participants:

Alison Imamura, Sarah Stevens, Matt Thompson (M1W)
Jon Lear, Maureen Hamilton (MPWMD)
Tim O'Halloran, Spencer Vartanian, Scott Ottmar, Mike Magretto (Cal-Am)
Garett Haertel, Derek Cray (MCWD)
Andy Sterbenz (Schaaf & Wheeler)
Denise Conners (LWA)
Samantha Terrell (Valentine Engineering)

Purpose of Meeting*:* Review status of MCWD/Cal-Am Intertie and plans for finalizing the MCWD/Cal-Am Agreement. Discuss the updated Pure Water Monterey Notification and Response Plan.

I. Introductions, Review Meeting Agenda and Purpose (Denise/Alison)

II. Status of Intertie (MCWD, Cal-Am)

Garrett shared that MCWD and Cal-Am met and discussed potential options for the Intertie but that more clarity was needed regarding DDW requirements and objectives. MCWD will be the operator of the Intertie.

Tim added that preliminary design is complete and it can deliver 800 gpm. He asked how this volume would help provide provide capacity if drinking water wells are impacted, and what the objectives of the interconnection were. If the goal is to provide a full replacement supply, the Intertie would not suffice.

Maureen noted that MPWMD has a meeting with Cal-Am next week to discuss the source capacity and maximum daily demand (MDD) assumptions, but 800 gpm is a sufficient replacement volume for now. She clarified that if a well is impacted from Pure Water Monterey (PWM) operations, it would be only one well at a time so the Intertie would replace the supply from just that one well.

Alison explained there is a 1 in a million chance of injecting off-spec water based on redundant treatment processes, use of continuous monitoring devices, and multiple alarms. In the off chance off-spec water is produced, all groundwater modeling conducted for the Base and Expanded PWM Project showed there will never be less than 4 months of underground retention time. As a result, there will always be greater than 4 months to respond.

With the Expanded PWM Project, DIW-5 and DIW-6 will provide additional capacity and allow M1W to cease injection into DIW-1 (the injection well with the shortest travel time to nearest production well). Operation of DIW-5 and DIW-6 (without DIW-1) will extend underground travel times to 6-8 months due to their location (further away from downgradient wells) and well capacities (higher than current high-performance DIWs). This additional time will allow agencies to coordinate and bring the Intertie online if necessary. DDW wants to ensure Cal-Am has redundancy in their system and the Intertie is a way to replace the supply if one drinking water well is impacts and pulled out of operation.

Alison noted the groundwater modeling results are in the revised Draft Title 22 Engineering Report (T22 ER) which M1W can share for those who are interested. M1W is meeting with DDW (Recycled Water Unit, Monterey District), RWQCB, and other agencies to describe responses to DDW comments and the revised T22 ER. The groundwater modeling results will be presented as well, but can be distributed to today's participants, if interested. The quarterly Monterey Peninsula Water Operations (MP Water Ops) meeting will be next week. MP Water Ops is another venue to be informed about PWM operations and other water supply projects in the Seaside Basin. MPWMD (Jon) presents the previous quarter's PWM travel times based on actual Cal-Am extraction and PWM injection rates, and future projected travel times based on the quarterly water budget provided to MPWMD by Cal-Am.

Tim asked if it would help satisfy DDW concerns about impacted wells and limited supply if Cal-Am could switch production to the new EW-1 and EW-2. Alison said she thought it would be an acceptable backup source. Tim said this seems like a much simpler solution, especially now that construction of the two new wells (which are much farther from the PWM well field) is underway and EW-1 will be operable in October 2025.

Alison said DDW District staff have expressed concerns that EW-1 and EW-2 aren't pending operable wells, so we will need to provide assurance to them regarding capacity and the implementation timeline. Maureen circled back to her earlier comment that these concerns are related to the MDD, which is the subject of the meeting with next week with Cal-Am. Jon said he does not believe DDW will want to move away from the Intertie even if there is enough capacity from EW-1, EW-2. Alison added that DDW District staff do not want to be issuing permits in an emergency, so having permits to deliver from ASR 4 and EW-1 and EW-2 would certainly help our case.

Jon asked that we keep in mind that in the unlikely event off-spec water injection, it will be diluted underground as it travels to a production well and it will be monitored atmultiple locations (project monitoring wells), so it would be extremely unlikely MCL exceedances will occur at the production wells. He cautioned that even if we're convinced there's enough redundancy when EW-1 and EW-2 are online, we will still need to convince the regulators and we don't know what they will need.

Alison stated that the good news is that the Intertie is essentially ready to implement. Andy confirmed that the valve and meter are in place, but still need permission to operate the Intertie (i.e., MCWD, Cal-Am agreement). Derek asked if the existing Water Wheeling Agreement would suffice since it covers existing physical connections between MCWD and Cal-Am. Maureen said she would review the Wheeling Agreement to make that determination. Alison said it may be enough and that she will explore that angle in discussions with MPWMD.

Tim mentioned that if a well goes offline, the ASR system won't work. Maureen stated the priority will always be to deliver water to the public. Alison suggested Cal-Am could deliver Carmel River water rather than injecting it in the winter under some of the other water rights. Jon confirmed that if Cal-Am were to produce water during winter from the Carmel River and deliver it, it could not be counted against the 2808A or C water rights that support ASR because they designate the usage point as the injection wells. It would, however, come out of Table 13 or 3306 rights as Alison suggested.

Jon said DDW wants the Intertie physically in place and this group to agree on its. They want adequate assurances this source could be called upon if an issue occurs. Alison restated that DDW doesn't necessarily need the physical solution in place but simply wants the agencies to be in agreement that it will be implemented if needed. Derek echoed this interpretation citing language in DDW's comment letter on the T22ER.

M1W could just submit the Water Wheeling Agreement to DDW and state in the T22 ER that the physical intertie infrastructure is in place. This agreement, coupled with the minimum 4 months underground travel time, and future operability of EW-1 should help address DDW's concerns. In addition, outcomes of the source capacity meeting next week will be communicated to DDW and relevant information will be included in the revised T22 ER.

III. Updated Notification and Response Plan (Alison)

Alison said the T22 ER includes the Notification and Response Plan (NRP) requested by DDW to ensure M1W is communicating with all stakeholders. DDW has been calling it an Emergency Response Plan (ERP), but foreseeable problems with the PWM Project should not be considered emergencies since there will always be at least 4 months to respond. Nisha Patel is no longer with City of Seaside. We will use Monty Miller (Water System Operator) as the point of contact for Seaside with Andreas Beare (Engineer) as backup. The revised NRP was included as an attachment to the meeting invite. Please review and provide comments by the middle of next week (10/23/24).

IV. Questions, Action Items

Action	Who
Review the Wheeling Agreement and determine ability to use.	M1W / MPWMD (Alison & Maureen)
Assuming the Wheeling Agreement can be used, include it in the T22 ER as an appendix and discuss as appropriate.	LWA / M1W (Denise & Alison)
Explain in the T22 ER that EW-1 will be operable by ~October 2025.	LWA (Denise)
Meet to discuss outcome of the source capacity between MPWMD and Cal-Am.	MPWMD / M1W / Cal-Am
Discuss bacteria detection method and necessary updates to the draft Notification and Response Plan (NRP).	M1W / LWA (Sarah M, Alison / Denise)
Review the draft NRP and provide comments by next week (10/23), if possible.	All

APPENDIX N

MCWD and Cal-Am Potable Water Wheeling Agreement (executed April 8, 2009)

M0916

MARINA COAST WATER DISTRICT

and

CALIFORNIA-AMERICAN WATER COMPANY

POTABLE WATER WHEELING AGREEMENT

Dated as of March 10, 2009

TABLE OF CONTENTS

THIS POTABLE WATER WHEELING AGREEMENT, dated as of April 8, 2009 ("Agreement"), is between the MARINA COAST WATER DISTRICT, a County Water District organized and operating under the County Water District Law, Sections 30000 and following of the California Water Code ("MCWD"), having an address at 11 Reservation Road, Marina, CA 93933, and CALIFORNIA-AMERICAN WATER COMPANY, a California corporation and regulated public utility ("CAW"), having an address at 511 Forest Lodge Road, Suite 100Pacific Grove, CA 93950.

RECITALS:

A. MCWD provides water and wastewater service within a service area that includes the former Fort Ord. As an element of such service, MCWD plans to install a pipeline and appurtenances (the "water conveyance facility") to convey water along and within an existing public road, Gen. Jim Moore Boulevard, as part of the Fort Ord Reuse Plan. The installation will be made in accordance with the Mitigated Negative Declaration approved by the Fort Ord Reuse Authority on September 9, 2005, based on the Environmental Assessment/Initial Study (EA/IS) dated March 2005, for The General Jim Moore Boulevard and Eucalyptus Road Improvement Project.

B. CAW provides water service within its Monterey District, in a service area adjacent to MCWD's service area. As an element of such service, CAW plans to undertake a project for aquifer storage and recovery of water in the Seaside Groundwater Basin, based on the authority provided under various water right entitlements, including but not limited to, State Water Resources Control Board, Permit 20808A, and based further on the environmental review undertaken by the State Water Resources Control Board for Permit 20808A, the Environmental Impact Report and Environmental Assessment (EIR/EA) for the Monterey Peninsula Water Management District's Phase 1 Aquifer Storage and Recovery (ASR) Project, and the Notice of Exemption by MPWMD for the Water Right Change Petition for Phase 2 Seaside Basin Groundwater Aquifer Storage and Recovery Project, and the Amended Decision in the Seaside Basin Groundwater Adjudication, and further pursuant to Section 15261(b) of the CEQA Guidelines for any exercise by CAW of pre-1914 water rights for CAW's ASR project.

C. CAW wants to use a portion of the capacity of a portion of MCWD's water conveyance facility, as shown diagrammatically and generally on Exhibit A to this Agreement ("the Subject Facility"), to transfer water for CAW's ASR project. The Subject Facility is the potable water pipeline extending southwards from the inter-tie location within General Jim Moore Boulevard just south of Coe Avenue and all appurtenant devices and fittings on the main transmission pipe itself. The Subject Facility boundary is immediately outside the flanged connection point of any fitting that allows water to enter or exit the main transmission pipe; in other words, the valves commonly attached to the flanged connection points on the main transmission pipeline are not considered part of the Subject Facility. The ownership of the valve(s) that control the exit and entrance of water to the main transmission pipeline from any branch pipeline or turn-out will be determined by the ownership of the pipe segments extending away from the valves outside the Subject Facility. MCWD wants to cooperate with CAW to enable joint use of the Subject Facility pursuant to sections 1810 through 1813 of the Water

Code. This Agreement is intended to provide the terms and conditions for construction, financing, operation and maintenance, scheduling, quality requirements, term, priorities, and fair compensation for CAW's joint use of the Subject Facility.

D. CAW and MCWD intend and have determined that CAW's use of the water conveyance facility may be made without injuring any legal user of water and without unreasonably affecting fish, wildlife, or other instream beneficial uses and without unreasonably affecting the overall economy or the environment of Monterey County.

NOW, THEREFORE, MCWD and CAW hereby agree. in consideration of the mutual covenants in this Agreement, the sufficiency of which are hereby acknowledged and agreed, as follows:

1. Wheeling of Potable Water

1.1 Wheeling of Potable Water. As and when agreed by the Parties as provided in (and subject to the provisions of) this Agreement, MCWD will wheel potable water on behalf of CAW through the Subject Facility to mutally-agreed points of delivery. CAW will be responsible for further distribution of the transported water received at a point of delivery, including operation and maintenance costs for delivery to CAW's end users.

1.2 Priority of Service. CAW shall have the first right to use the Subject Capacity in accordance with the terms and conditions of this Agreement to convey water for CAW's ASR project.

1.3 Scheduling and Ordering. The Parties will mutually agree from time to time, on a monthly basis or otherwise, on a water delivery schedule, including periodic water quality testing at each entry point on the Subject Facility for water being transferred by CAW through the Subject Facility. A schedule and protocol shall be memorialized in a writing signed by MCWD's General Manager and an Authorized Officer of CAW prior to CAW's use of the Subject Facility, subject to periodic revision as otherwise described in this paragraph.

1.4 Interruptions and Curtailments. The wheeling of water pursuant to this Agreement is subject to interruptions, curtailments or schedule changes related to (a) emergencies, operational constraints, or unplanned necessary maintenance and repairs of the Subject Facility; (b) degradation of the quality of water introduced into the Subject Facility or received from CAW's sources of supply; or (c) the availability of water to convey. Interruptions or curtailments will be allocated in accordance with the priority of service.

2. Billing and Payment

2.1 Upon execution of this Agreement, as a condition precedent to MCWD's performance of MCWD's obligations under this Agreement, CAW shall pay to MCWD One Million Three Hundred Thousand Dollars ($1,300,000.00), as a deposit against all costs incurred and to be incurred by MCWD in planning, engineering and constructing the Subject Capacity. MCWD shall create a separate holding account for the deposit and shall report to CAW monthly on all funds placed into and withdrawn from the account, including the date, purpose and payee of each withdrawal. The minimum deposit held in this account shall be $5,000.00. If the account balance falls below the minimum deposit balance before all of MCWD's costs are paid, CAW will pay to MCWD within 7 days from time of request an amount estimated by MCWD to be sufficient to pay the balance of MCWD costs through completion of the Subject Capacity. MCWD shall refund to CAW any balance remaining in the holding account after the payment of all of MCWD's costs through the date of completion of the Subject Capacity.

2.2 Wheeling Charges. On a monthly basis, MCWD will invoice CAW $2,000.00 per month for each month CAW wheels water into and through the Subject Facility. MCWD may, but shall not be required to, adjust the monthly charge on July 1 of each year, based on MCWD's costs for the fiscal year ending on the June 30 before the adjustment and MCWD's budgeted costs for the fiscal year beginning on July 1. MCWD shall provide CAW with any proposed change and the justification for the change not less than 60 days before the change becomes effective. Upon CAW's request, MCWD shall provide CAW with an invoice for an entire year's wheeling charges in advance. Such invoice shall be paid in accordance with Paragraph 2.3, provided that late charges shall be assessed only for those months where payment is in arrears.

2.3 Payment by CAW. CAW will pay amounts invoiced pursuant to Section 2.1 or 2.2 within thirty (30) days of the date of the invoice. Any delinquent invoices past 30 days will be subject to interest charge at the rate of 18% per annum.

2.4 Water Accounting. CAW will provide a monthly report regarding the amounts of potable water wheeled pursuant to this Agreement.

2.5 Metering. CAW will install and maintain meters at the points of entry to the Subject Facility and at the CAW points of delivery for purposes of measuring the amount of water wheeled pursuant to this Agreement. CAW will pay the cost of meter installation in addition to the costs under Section 2.1 and shall maintain the meters in accordance with accepted water industry practices.

2.6 Removal of Connections at Termination of Agreement. CAW agrees to remove, at CAW expense, all points of connection to the Subject Facility that are under CAW control upon termination of this Agreement. At MCWD's preference, this removal may take the form of accepting ownership, with CAW's concurrence, of all valving and appurtenant devices that control the entrance or exit of water from the Subject Facility or by CAW installing, to MCWD standards, an appropriate blind flange fitting at the boundary of the Subject Facility.

3. Conveyance Capacity

3.1 Upon execution of this Agreement, CAW will provide to MCWD sufficient information to enable MCWD's engineers to determine and describe with particularity the Subject Facility, including all points of entry and all points of discharge for water being transferred by CAW, and to calculate the capacity required in the subject portion for CAW's ASR project. Upon receiving the deposit from CAW pursuant to section 2.1 of this Agreement, using the information supplied by CAW, MCWD and CAW will determine the unused capacity required and available in the Subject Facility for CAW's proposed use and sections 1810 through 1813 of the Water Code.

3.2 MCWD will cause the Subject Facility to be sized and constructed such that space is available within the operational limits of the conveyance system and that MCWD is not using during the period for which CAW proposes to use the Subject Facility (the "Subject Capacity") and that such space is sufficient to carry the quantity of water proposed to be transferred by CAW.

3.3 MCWD will cause the Subject Facility to be built in accordance with the Approved Plans and will allow CAW to inspect and approve the Subject Facility before MCWD begins operating the water conveyance facility.

3.4 MCWD will control, operate and maintain the whole water conveyance facility, including the Subject Facility and the Subject Capacity, subject to the terms and conditions of this Agreement, in compliance with laws and regulations, or accepted industry Best Operating Practices, governing operation and use of the Subject Facility.

3.5 MCWD shall have no responsibility for or control of the following:

(a) Any facilities used by CAW to convey water to or away from the Subject Facility;

(b) Any use of water transferred by CAW through the Subject Facility.

3.6 Nothing in this Agreement shall be construed as obligating MCWD to construct any facilities or other improvements or to take any other action to expand or increase the unused capacity of either the water conveyance facility or the Subject Facility beyond that contemplated in this Agreement.

4. Term

4.1 Except as otherwise provided in section 4 of this Agreement, CAW's right to use the Subject Capacity shall begin on the date MCWD determines the Subject Capacity is ready to convey water and shall continue from that date for thirty (30) years (the "Basic Term"), unless sooner terminated or extended as hereinafter provided.

4.2 So long as no Event of Default shall have occurred and be continuing on the last day of the Basic Term, CAW may elect to extend the term of this Agreement beyond the Basic Term for one (1) additional term of thirty (30) years ("Extended Term"). CAW may exercise its election to extend this Agreement by delivering written notice to MCWD not less than ninety (90) days prior to the expiration of the Basic Term.

4.3 CAW may terminate this Agreement at any time after paying all sums to be paid by CAW under section 2.1 of this Agreement, by delivering written notice of termination to MCWD at least 60 days before the termination date. CAW shall be liable to MCWD for any costs incurred in connection with the Subject Capacity before the termination date.

5. Use. CAW may use the Subject Capacity only to convey potable water meeting all statutory and regulatory quality requirements for human domestic use and consumption. The commingling of water transferred by CAW shall not result in a diminution of the beneficial uses or quality of the water conveyed by MCWD in the water conveyance facility.

6. Compliance with Laws. MCWD and CAW will cooperate to take the actions and execute the documents necessary to comply with laws and regulations governing the construction, operation and use of the Subject Facility.

7. Liens. MCWD shall use its best efforts to prevent the filing of any liens on or against the Subject Facility. During the Basic Term and Extended Term MCWD will promptly, but no later than sixty (60) days after its Actual Knowledge of the filing thereof, at its own expense remove and discharge of record, by bond or otherwise, any Lien (other than Permitted Encumbrances) upon the Subject Facility which arises solely out of MCWD's possession, use, operation and occupancy of the Subject Facility.

8. Indemnification; Fees and Expenses

8.1 During the Basic Term and Extended Term, and subject to the other limits in this Agreement , CAW shall indemnify and defend MCWD and other applicable Indemnified Parties against all liabilities, obligations, losses, actions, suits and causes of action, or claims, of any kind or nature, (the foregoing, collectively, "Losses", and, individually, a "Loss") arising from the acts or omissions of CAW in the use of the Subject Facility, including but not limited to CAW's introduction into the Subject Facility of water that does not meet all applicable health and safety standards for potable use.

8.2 CAW shall not be required pursuant to this Agreement to indemnify: (i) MCWD or any other Indemnified Party for any property or other damage that is covered or should have been covered by the insurance to be maintained by MCWD; (ii) MCWD or any particular Indemnified Party for any Losses resulting from, arising out of or which would not have occurred but for MCWD's or such other Indemnified Party's own negligence, fraud or willful misconduct; (iii) MCWD or any particular Indemnified Party for any Losses resulting from, arising out of or which would not have occurred but for a breach by MCWD or such Indemnified Party of any representation, warranty or covenant made by MCWD or such Indemnified Party in this Agreement or any other related document; (iv) any Indemnified Party for any taxes; (v) any Indemnified Party for any losses resulting from the authorization or giving or withholding of any future amendments, supplements, waivers or consents with respect to the Agreement or the Subject Capacity by such Indemnified Party other than such as have been consented to in writing by the CAW; (vi) any Indemnified Party for any Losses resulting, from, arising out of or which would not have occurred but for acts or events solely with respect to any portion of the Subject Facility that occur after this Agreement terminates and CAW ceases to use the Subject Facility; or (vii) for Loss or Losses arising from a defect in the design or construction of the Subject Facility.

8.3 MCWD shall indemnify CAW against all liabilities that are solely a result of a defect in the design or construction of the Subject Facility.

8.4 Nothing in this Article 7 or in Article 8 hereof shall be construed to give rise to any third party beneficiary rights with respect to any Person who is not an Indemnified Party.

9. Condemnation and Casualty. If the Subject Facility, or any part thereof shall be damaged or destroyed by fire or earthquake or other casualty, MCWD shall proceed with diligence and promptness to carry out any necessary demolition and to restore, repair, replace, and/or rebuild the Subject Facility in order to restore the Subject Facility to a condition and fair market value, utility and remaining useful life not less than the condition and fair market value, utility and remaining useful life thereof immediately prior to such casualty. Unless CAW elects to terminate this Agreement, MCWD and CAW shall meet and confer regarding casualty repairs, including but not limited to, the nature of the repairs, the replacement equipment, contractor qualifications, potential disruptions to operations, and schedule; No repair work done by MCWD pursuant to this section shall violate the terms of any restriction, easement, condition or covenant or other matter affecting title to the Subject Facility, and all repair work done by MCWD pursuant to this Article 9 shall be undertaken and completed in a good and workmanlike manner and in compliance in all material respects with all Legal Requirements then in effect with respect to the Subject Facility. If the proceeds of any casualty insurance policy maintained by MCWD are less than the estimated cost of restoring, replacing or rebuilding the Subject Facility to the condition and fair market value required above in this Article 9, then CAW shall share and pay any such deficiency in the same proportion that the Subject Capacity bears to the total capacity of the Subject Facility.

10. Insurance.

10.1 Prior to the commencement of the Basic Term, MCWD shall procure and maintain with respect to MCWD's use and operation of the Subject Facility valid and enforceable insurance of the following character:

(a) Commercial General Liability Insurance or Comprehensive General Liability Insurance with Broad Form CGL endorsement with limits of not less than $1,000,000 each occurrence and $2,000,000 general aggregate. Equivalent insurance through the ACWA JPIA will satisfy MCWD's obligation under this sub-section.

(b) Worker's Compensation Insurance as required by laws and regulations applicable to and covering employees performing under this. Agreement. Employer's Liability Insurance protecting employer against common law liability, in the absence of statutory liability, for employee bodily injury arising out of the master-servant relationship with a limit of not less than $1,000,000 each accident, $1,000,000 disease-policy limit, $1,000,000 disease-each employee.

(c) All-Risk Property Insurance with a limit equal to the replacement cost of the Subject Facility during the Basic Term. Equivalent insurance through the ACWA JPIA will satisfy MCWD's obligation under this sub-section.

10.2 During the Basic Term, CAW also shall be responsible for maintaining the type of insurance described in clause 10.1(a) and 10.1(b).

10.3 In addition to the foregoing, every insurance policy maintained in accordance with this Article 10 shall: (i) name the other party as additional loss payee as its interest may appear with respect to 10.1(c); (ii) provide that the issuer waives all rights of subrogation against MCWD or CAW or any other person insured under such policy, (iii) provide that thirty (30) days advance written notice of Cancellation, material modification. termination or lapse of coverage shall. be given to MCWD and CAW; and (iv) be primary relative to the respective party's liability and without right or provision of contribution as to any other insurance carried by MCWD or CAW or any other interested party.

10.4 CAW and MCWD shall deliver' to the other prior to the Basic Term certificates of insurance, reasonably satisfactory to MCWD and CAW, evidencing all of the insurance required under section 10.1 of this Article 10, provided, however, that CAW shall not be obligated to deliver such certificates of insurance with respect to required insurance coverages as to which CAW has retained the risk of loss (self-insured). After the expiration of any required insurance policy, the primary insured shall deliver to the other party certificates of insurance evidencing the renewal of any such policy. CAW shall provide MCWD with written notice of any determination to self-insure with respect to any risk theretofore covered by externally procured insurance.

10.5 CAW and MCWD shall comply with all of the terms and conditions of each insurance policy maintained pursuant to the terms of this Agreement to the extent necessary to avoid invalidating such insurance policy or impairing the coverage available thereunder.

10.6 The limits of insurance contained in this Article 10 shall not be construed as limits on the indemnification obligations set forth in Article 8.

11. Quiet Enjoyment. So long as no Event of Default under this Agreement shall have occurred and be continuing, MCWD covenants that CAW shall and may at all times peaceably and quietly use the Subject Capacity during the Term without hindrance by MCWD or any Person claiming through or under MCWD.

12. Assignment.

12.1 Neither this Agreement nor the Subject Facility shall be mortgaged or pledged as security by CAW. Any such mortgage or pledge shall be null and void.

12.2 CAW may only assign its interest in this Agreement in connection with the consolidation or merger of CAW into any other Person or the sale, Agreement or other transfer or disposal of all or substantially all of CAW's assets in the Monterey Peninsula area (whether in one transaction or in a series of related transactions), if and only if (i) the assignee of CAW's interest, or the corporation or other Person which results from any such consolidation, merger, acquisition, sale, Agreement, transfer and/or disposition of assets. if not CAW, assumes all of CAW's obligations, duties and liabilities under this Agreement; and (ii) any such assignment, consolidation, merger, acquisition, sale, transfer and/or disposition of assets would not result in a violation of any regulatory requirement applicable to MCWD, including but not limited to any and all licensing requirements applicable to the operator of the Subject Facility.

13. Events of Default and Remedies.

13.1 Any of the following occurrences or acts shall constitute an event of default under this Agreement (each an "Event of Default"):

(a) if CAW defaults in making payment on any invoice from MCWD under section 3.2. which default continues for thirty (30) days after the same first becomes due and payable; or

(b) if CAW or MCWD defaults in the performance of any covenant, agreement or obligation on the part of CAW or MCWD, as applicable, to be performed under this Agreement, and such default continues for a period of, thirty (30) days after written notice thereof is received by the defaulting party, unless such default is curable and the defaulting party shall be diligently proceeding to correct such default (but in no event for a total period of longer than ninety (90) days after the receipt of such notice as provided above); or

(c) if CAW or MCWD files a petition in bankruptcy or for reorganization or for an arrangement pursuant to the Bankruptcy Code,' or is adjudicated bankrupt or become insolvent or makes an assignment for the benefit of its creditors, or shall admit in writing its inability to pay its debts generally as such debts become due, or dissolves, or suspends payment of its obligations, or takes any corporate action in furtherance of any of the foregoing; or

(d) if a petition or answer is filed proposing the adjudication of CAW or MCWD as bankrupt, or proposing its reorganization pursuant to the Bankruptcy Code, and (A) CAW or MCWD, as applicable, consents to the filing thereof, or (B) such petition or answer is not discharged or denied within sixty (60) days after the filing thereof; or

(e) if a receiver, trustee or liquidator (or other similar official) is appointed for, or takes possession or charge of, CAW or MCWD, or of all or substantially all of the business or assets of CAW or MCWD or its estate or interest in the Subject Facility, and such official shall not be discharged within sixty (60) days thereafter, or if CAW or MCWD consents to or acquiesce in such appointment; or

(f) if, as of the time when the same shall have been made, any representation or warranty of CAW or MCWD set forth herein, or in any consent, notice, certificate, demand, request or other instrument delivered by or on behalf of CAW or MCWD, as applicable, in connection with or pursuant to this Agreement shall prove to have been incorrect or untrue in any material respect as of the time when made, and the condition or circumstance giving rise to such incorrect or untrue representation or warranty shall continue for a period of thirty (30) days after CAW or MCWD has Actual Knowledge thereof, unless such condition or circumstance is curable and CAW or MCWD shall be diligently proceeding to correct such condition or circumstance (but in 'no event for a total period of longer than one hundred eighty (180) days after CAW or MCWD has Actual Knowledge thereof); or

13.2 This Agreement and the term are subject to the limitation that, whenever an Event of Default shall have occurred and be continuing, the non-defaulting party may, at its option, elect to exercise any one or more of the rights and remedies set forth in the following paragraphs.

(a) Terminate this Agreement upon giving an additional 30 days written notice and in the case of default by CAW, MCWD may close the Subject Facility to water from CAW upon termination. Such notice shall specify the date of such termination, and the Term with respect to the Subject Facility shall expire by limitation at midnight on, the date specified in such notice as fully and completely as if said date were the date herein originally fixed for the expiration of the Term hereby granted, and CAW shall cease using the Subject Facility and the Subject Capacity.

(b) Sue to collect damages caused by the breach by the other party, including, if applicable, following a default by CAW, make a claim for accrued unpaid costs invoiced to CAW.

13.3 The non-defaulting party may exercise any other 'right or remedy which may be available to it under applicable law or at equity, including, without limitation, bringing a suit for specific performance, and the non-defaulting party may proceed by appropriate court action to enforce the terms hereof or to recover damages for the breach hereof or to rescind this Agreement.

13.4 If an action shall be brought for the enforcement of any provision of this Agreement in which it is found that an Event of Default has occurred, the non-defaulting prevailing party shall be entitled to seek reimbursement of its attorneys' fees and expenses.

13.5 No right or remedy herein is intended to be exclusive of any other right or remedy, and every right and remedy shall be cumulative and in addition to any other legal or equitable right or remedy given hereunder, or at any time existing hereunder or at law. The failure of MCWD or CAW to insist upon the strict performance of any provision or to exercise any option, right, power or remedy contained in this Agreement shall not be construed as a waiver or a relinquishment thereof for the future.

14. Dispute Resolution.

14.1 Scope of Section. This Section governs the resolution of all disputes that arise under this Agreement.

14.2 Good Faith Negotiations. A Party that believes a dispute exists under this Agreement will first refer the dispute to the Representatives for resolution. The Representatives of each Party will personally meet and attempt in good faith to resolve the dispute. If the Representatives cannot resolve the dispute within fifteen (15) days, the matter will be referred to senior management of the Parties for resolution. If these persons are unable to resolve the dispute within fifteen (15) days thereafter, a Party that still believes a dispute requires resolution may avail itself of the provisions of paragraph 14.3.

14.3 Non-Binding Mediation. If said dispute cannot be settled through normal contract negotiations, the Parties agree to first endeavor to settle the dispute in an amicable manner, using mandatory non-binding mediation under the rules of JAMS before having recourse in a court of law. The expenses of witnesses for either side shall be paid by the party producing such witnesses. All other expenses of the mediation, including required travel and other expenses of the mediator, and the cost of any proofs or expert advice produced at the direct request of the mediator, shall be borne equally by the Parties. unless they agree otherwise. Any resultant agreements from mediation shall be documented in writing. All mediation proceedings, results, and documentation shall be inadmissible for any purpose in any legal proceeding (pursuant to California Evidence Codes sections 1115 thru 1128), unless such admission is otherwise agreed upon in writing by both parties. Mediators shall not be subject to any subpoena or liability, and their actions shall not be subject to discovery. The mediator must have substantial experience with the water utility industry. Mediation shall be completed within 30 days after request for the mediation by either Party.

14.4 Remedies. The preceding paragraphs of this Section are intended to set forth the primary procedure to resolve all disputes under this Agreement. It is expected that all disputes that would traditionally be resolvable by a court of law would be resolvable under this procedure. However, the Parties recognize that certain business relationships could give rise to the need for one or more of the Parties to seek equitable remedies from a court that were traditionally available from an equity court, such as emergency, provisional or summary relief, and injunctive relief. Immediately following the issuance of any such equitable relief. the Parties will stay any further judicial proceeding pending mediation of all underlying claims between the Parties.

15. Representatives: Notices.

15.1 Authorized Representatives. Each Party will designate at least one individual officer or employee who will be its representative and will be authorized to act on behalf of the Party for all purposes in performing the provisions of this Agreement ("Representative"). Each Party will also designate an alternate Representative who will serve in the place of (and with the same authority as) the Representative if the latter is unavailable. A Party may also designate more than one Representative. The designation may be changed from time to time. The designation must be made in a writing delivered to the other Party.

15.2 No Release. Each Party is responsible for the acts or omissions of its Representative(s). The designation of a Representative by a Party does not release the Party from responsibility for performance of its obligations under this Agreement.

15.3 Notice. All notifications, notices, demands, requests and other communications herein provided for or made pursuant hereto shall be in writing and shall sent by (i) registered or certified mail, return receipt requested, and the giving of such communication shall be deemed complete on the third (3rd) Business Day after the same is deposited in a United States Post Office with postage charges prepaid, (ii) reputable overnight delivery service, and the giving of such communication shall be deemed complete on the immediately succeeding Business Day after the same is deposited with such delivery service or (iii) legible fax with original to follow in due course (failure to send such original shall not affect the validity of such fax notice) and the giving of such communication shall be complete when such fax is received.

(a) if to MCWD, addressed to such party at its address set forth in the first paragraph of this Agreement, or at such other address in the continental United States as MCWD may furnish to CAW in writing, or

(b) if to CAW, addressed to such party at its address set forth in the first paragraph of this Agreement, or at such other address in the continental United States as CAW may furnish to MCWD in writing, with a copy to the Western States Divisional General Counsel at such address in the continental United States as CAW will furnish to MCWD in writing.

16. Cessation of Use. Upon the expiration or earlier termination of the Term, CAW shall cease using the Subject Facility and MCWD may act to prevent CAW's water from entering the Subject Facility.

17. Limitation on Recourse. All obligations of CAW under this Agreement shall be 'on a non-recourse basis to its shareholders, officers, and directors and their respective parent companies, subsidiaries and affiliates (other than CAW). The sole recourse of MCWD or any other Person for any obligation of CAW under this Agreement shall be to CAW and its assets, provided that the limitation on recourse set forth in this Article 18 shall not limit any rights of MCWD or any other Person under applicable law relating to fraudulent transfers or voidable preferences.

18. Force Majeure.

18.1 If by reason of "force majeure," as defined in this Article 19, a party is rendered unable, wholly or in part, to carry out its obligations under this Agreement, and if such party gives notice and reasonably full particulars of such force majeure in writing to the other party promptly after the occurrence of the cause relied on, the affected party, and only so far as and to the extent that it is affected by such force majeure, shall be excused from performance hereunder without liability; provided, however, such cause shall be remedied with all reasonable dispatch.

18.2 For purposes of this Agreement, "force majeure" shall mean an event that creates an inability to perform that could not be prevented or overcome by the due diligence of the affected party, including but not limited to, any act, omission or circumstance occasioned by or in consequence of any acts of God, strikes, lockouts, acts of the public enemy, wars, sabotage, blockades, insurrections, riots, epidemics, landslides, lightning, earthquakes, fires, storms, hurricanes, tornadoes, floods, washouts, civil disturbances, explosions, power outages the failure or inability to obtain any necessary governmental authorization which has been sought or requested, as the' case may be, in good faith by all reasonable legal means, and any other cause, whether of the kinds herein enumerated or otherwise, not reasonably within the control of the affected party. In the event the production from the extraction wells, falls below the level needed to operate the Project at a capacity sufficient to supply water for new and expanded water hookups in Sand City due to depletion of the aquifer or some other natural cause, then such event shall be considered as a "force majeure" event.

19. Miscellaneous.

19.1 Integration. This Agreement embodies the entire agreement between MCWD and CAW relating to the subject matter hereof and supersedes all prior agreements and understandings, written or oral, relating to such subject matter.

19.2 Successor and Assigns. This Agreement shall be binding upon, and shall inure to the benefit of and be enforceable by, the parties hereto and their respective successors and assigns permitted hereunder.

19.3 Amendments or Waivers. No term or provision hereof or Appendix, Exhibit or Schedule hereto may be amended, changed, waived, discharged, terminated or replaced orally except by a written instrument, in accordance with applicable terms and provisions hereof, executed by each of the. parties hereto.

19.4 Waivers. No failure, delay, forbearance or indulgence on the part of any party in exercising any right, power or privilege hereunder shall operate as a waiver thereof, or as an acquiescence in any breach, nor shall any single or partial exercise of any right, power or remedy hereunder preclude any other or further exercise thereof or the exercise of any other right, power or privilege.

19.5 Severability. Any provision of this Agreement which is prohibited or unenforceable in any jurisdiction shall, as to such jurisdiction, be ineffective to the extent of such prohibition or unenforceability without invalidating the remaining provisions hereof, and any such prohibition or unenforceability in any jurisdiction shall not invalidate or render unenforceable such provision in any other jurisdiction.

19.6 Neutral Construction. This Agreement is the product of negotiation between the Parties. No Party is deemed the drafter of this Agreement.

19.7 No Third Party Beneficiaries. Nothing in this Agreement, express or implied, is intended to confer any rights or remedies under or by reason of this Agreement on any persons other than the Parties. Nothing in this Agreement is intended to relieve or discharge the obligation or liability of any third person to any Party. This Agreement does not create any duty, liability or standard of care to any person who is not a Party.

19.8 Relationship of Parties. Each Party is an independent entity. This Agreement will not constitute either Party as the agent of the other Party, except as otherwise provided in this Agreement or as otherwise agreed by the Parties. This Agreement will not constitute the Parties as partners or joint venturers (or as co-owners of a business entity) for common law purposes, federal, state or local income tax purposes, or otherwise. The Parties will not conduct business under a common name, execute an agreement identifying any or all of them as partners, shareholders or members of a business entity, or otherwise hold out their co-ownership of the Plant as a partnership or other form of business entity (nor will the Parties hold themselves out as partners, shareholders, or members of a business entity).

19.9 Controlling Law; Conflicts of Law. This Agreement shall be construed, governed and applied in accordance with the laws of the State of California, without regard to the conflicts of law principles thereof.

19.10 Venue. In connection with this Agreement, CAW and MCWD hereby agree that any action, proceeding, or dispute regarding this Agreement shall be filed in the Superior Court of the State of California, in and for the County of Monterey. Nothing in this section shall be construed as a waiver of CAWs' rights under California Code of Civil Procedure section 394.

19.11 Counterparts. This Agreement may be executed in any number of counterparts, each of which shall be an original, and such counterparts together shall constitute but one and the same instrument.

IN WITNESS WHEREOF, MCWD and CAW hereto have each caused this Agreement to be duly executed and delivered in their name and on their behalf, respectively, as of the day and year first written above.

MARINA COAST WATER DISTRICT

By: ____________________
Name: HOWARD GUSTAFSON
Title: BOARD PRESIDENT

By: ____________________
Name: JIM HEITZMAN
Title: GENERAL MANAGER

CALIFORNIA AMERICAN WATER COMPANY,

By: B. Kent
Name: B. Kent Turner
Title: President
4/8/09

APPROVED AS TO FORM:

Noland, Hamerly, Etienne & Hoss,
A Professional Corporation,
Legal Counsel to MCWD

By: ______________________
Lloyd W. Lowrey, Jr., Esq.

____
Tim Miller
Corporate Counsel
California American Water

ATTACHMENT 1

Definitions

"Actual Knowledge" means actual knowledge of (i) an Authorized Officer or (ii) any other officer or official whose responsibilities include administration of the' transactions contemplated by time Agreement.

"Affiliate" of any specified Person means any other Person directly or indirectly controlling or controlled by or under direct or indirect common control with such specified Person or, in the case of a specified Person which is a partnership, any general partner of such partnership. For purposes of this definition, "control" when used with respect to any specified Person means the power to direct the management and policies of such 'Person, directly or indirectly, whether by contract, through the ownership of voting securities or the power to appoint and remove directors or trustees, or otherwise; and the terms "controlling" and "controlled" have meanings correlative to the foregoing.

"Approved Plans" means the plans for the Subject Facility, in the form existing as of the date hereof, a copy of which have been received and approved by CAW.

"Authorized Officer" means with respect to CAW, President, the chief financial officer. 'any vice president, the treasurer or any assistant treasurer of the CAW, or any other person of the CAW designated by the CAW as an Authorized Officer of the CAW from time to time, including but not limited to any person granted authority by the American Water Delegation of Authority, and with respect to MCWD, any official or any officer whose responsibilities include Administration of this transaction.

"Bankruptcy Code" means Title 11 of the United States Code, as amended, or any successor statutory provisions.

"Basic Term" has the meaning set forth in Article 4 of the Agreement.

"Basic Term Commencement Date" means the Completion Date or, if such day is not the first day of a calendar month, the first day of the calendar month next succeeding the Completion Date.

"Business Day" means a day when banks are open for business in California.

"CAW" means California-American Water Company.

"Code" means the Internal Revenue Code of 1986, as amended from time to time, or any successor statute.

"Complete" or "Completion" means that (a) the materials and equipment for the Subject Facility have been installed and checked for alignment, lubrication, rotation and hydrostatic and pneumatic pressure integrity, (b) the electrical systems have been installed and tested, (c) the electrical continuity and ground 'fault tests and mechanical tests and calibration have been completed, (d) the instrumentation has been loop checked, (e) the Subject Facility has been flushed and cleaned out as necessary, (1) the Subject Facility is ready to commence start-up and testing, (g) the Subject Facility has been constructed substantially in accordance with the Approved Plans, including, without limitation, the specifications applicable thereto, and (h) the Subject Facility is capable of operating safely. The following shall not prevent certification of Substantal Completion, but shall be remedied, cured or resolved within sixty (60) days after the Basic-Term Commencement Date:

(i) any redundant part or piece of equipment which is missing or inoperable which does not affect the safe operation of the Project Improvements;

(ii) any' disputed contract issue which has been submitted for arbitration;

(iii) any non-conforming item which has been agreed to be corrected and the material placed on order which does not affect the . safe operation of the Project Improvements or

(iv) any punchlist items which will not prevent use of the Subject Facility.

"Completion Date" means the date, if any, on or before the Outside Completion Date, on which the following have occurred:. (i) Substantial Completion has been achieved, and (ii) MCWD has satisfactorily completed all start-up commissioning for the Subject Facility.

"Fair Market Rental Value" means an amount equal to the fair market rental value that would be obtained in an arm's length transaction between an informed and willing MCWD and an informed and willing CAW, in either case under no compulsion to rent, and neither of which is related to the MCWD, calculated as the value of the Agreementd Premises for its use at its present location determined on the basis of the value of the Land Parcel subject to existing governmental zoning and use restrictions and with regard to the value of the Project Improvements.

"FASB" means the Financial Accounting Standards Board, or any successors thereto that perform substantially similar functions'.

"Final Determination" means, with respect to a private letter ruling or a. technical advice memorandum of the Internal Revenue Service, written notice thereof in a proceeding in which the CAW had an opportunity to participate and otherwise means written notice of a determination from which no further right of appeal exists or from which no appeal is timely filed with any court of competent jurisdiction in the United States in a proceeding to which the CAW was a party or in which the CAW had the opportunity to participate.

"GAAP" means generally accepted accounting principles as in effect in the United States of America at the time of application.

"Governmental Action" means all permits, authorizations, registrations, consents, approvals, waivers, exceptions, variances, orders, judgments, decrees, licenses, exemptions, publications, filings, notices to and declarations of or with, or required by, any Governmental Authority, or required by any Legal Requirements, and shall include, without limitation, all citings, environmental and operating permits and licenses that are required for the use, occupancy, zoning and operation of the Project Improvements.

"Governmental Authority" means any foreign or domestic federal, state, county, municipal or other governmental or regulatory authority, agency, board, body, commission, instrumentality, court or quasi-governmental authority or any political subdivision thereof.

"Hazardous Substances" means (i) those substances included within the definitions of or identified as "hazardous substances", "hazardous materials", or "toxic substances" in or pursuant to, without limitation, the Comprehensive Environmental Response Compensation and Liability Act of 1980 (42 U.S.C. § 9601 et seq.) ("CERCLA"), as amended by Superfund Amendments and Reauthorization Act of 1986 (Pub. L. 99-499, 100 Stat. 1613) ("SARA"), the Resource Conservation and Recovery Act of 1916 (42 U.S.C. § 6901 et. seq.) ("RCRA"), the Occupational Safety and Health Act of 1970 (29 U.S.C. § 651 et seq.) ("OSHA"), and the Hazardous Materials Transportation Act, 49 U.S.C. § 1801 et. seq. and in the regulations promulgated pursuant to said laws, all as amended; (ii) those substances listed in the United States Department of Transportation Table (40 CFR 172.101 and amendments thereto) or by the Environmental Protection' Agency (or any successor agency) as hazardous substances (40 CFR Part 302 and amendments thereto); (iii) any material, waste or substance which is or contains (A) asbestos, (B)polychlorinated biphenyls, (C) designated as "hazardous substance" pursuant to Section 311 of the Clean Water Act, 33 U.S.C. § 1251 (33 U.S.C. § 1321) or listed pursuant to Section 307 of the Clean Water Act (33 U.S.C. § 1317); (D) flammable explosives; (E) petroleum products and substances; '(F) radioactive materials; and (iv) such other substances, materials and wastes which are or become regulated as hazardous, toxic or "special wastes" under applicable local, state or federal law, or the United States government, or which are classified as hazardous, toxic or as "special wastes" under federal, state or local laws or regulations.

"Indemnified Parties" means MCWD or CAW, as applicable, and all shareholders, officers, directors, employees, attorneys and agents of any of the foregoing, and any Person holding any beneficial interest in any of the foregoing.

"Legal Requirements" means all applicable laws, rules, orders, ordinances, regulations and requirements and conditional permissions now existing .or (except to the extent any exemption or so called "grandfathering" provision is available) hereafter enacted or promulgated, of every government and municipality and of any agency thereof having jurisdiction over CAW, MCWD or the Subject Facility, relating to the ownership, use, occupancy, maintenance or operation of the Subject Facility, or the improvements thereon, or the facilities or equipment thereon or therein, or the streets, sidewalks, vaults, vault spaces, curbs and gutters adjoining the Subject Facility, or the appurtenances to the Subject Facility, or the franchises and privileges connected therewith or the transactions contemplated by the Agreement, including but not limited to the operation of the Subject Facility in the manner described in Article 4 and including, without limitation, all applicable' building laws, health codes, safety rules, handicapped access, zoning and subdivision laws and regulations and Environmental Laws.

"Lien" means any mortgage, pledge, security interest, production payment, encumbrance, lien or charge of any kind whatsoever. For the purposes of the Agreement, any Person shall be deemed to own subject to a Lien any asset which it has acquired or holds subject to the interest of a MCWD or vendor under any capital Agreement or other title retention agreement relating to such asset.

"MCWD" means Marina Coast Water District.

"Outside Completion Date" has the meaning set forth in Article 2 of the Agreement.

"Permitted Encumbrances" means, with respect to the Subject Facility: (a) rights reserved to or vested in any municipality or public authority to condemn, appropriate, recapture or designate a purchaser of the Subject Facility; (b) any Liens thereon for taxes,' assessments and other governmental charges and any Liens of mechanics, materialmen and laborers for work or services performed or material furnished in connection with the Subject Facility, which are not due' and payable, or the amount or validity of which are being contested as permitted by Article 6 of the Agreement; and (c) Liens granted by MCWD in connection with any bonds issued to fund the Project, as long as such lender receiving such lien has granted CAW satisfactory rights of nondisturbance.

"Person" means an individual, a corporation, a partnership, an association, a joint stock company, a trust, an unincorporated organization, a governmental body or a political subdivision, a municipal corporation, a public corporation or any other group or organization of individuals.

"<u>Prudent Industry Practices</u>" means any of the practices, methods and acts engaged in or approved by a significant portion of the municipal water treatment and supply industry operating in the immediate area surrounding the Subject Facility during the Term of this Agreement. Prudent Industry Practices are not to be interpreted, construed or limited to the optimum industry practices, methods or acts, but rather as a range of acceptable practices, methods or acts consistent with the duties and obligations of Contractor under this Agreement.

"Regulations" means the applicable proposed, temporary or final Income Tax Regulations promulgated under the Code, as such regulations may be amended and/or supplemented from time to time.

"Renewal Term" has the meaning set forth in paragraph (b) of Article 2 of the Agreement.

"Subsidiary" means any corporation or other entity of which securities or other ownership interests having ordinary voting power to elect a majority of the board of directors or other persons performing similar functions are at the time directly or indirectly owned by CAW.

"Subject Capacity" means the unused capacity in the Subject Facility to be used by CAW pursuant to the Agreement.

"Subject Facility" means the water conveyance facility, consisting of a water pipeline and appurtenances, to be located along and within Gen. Jim Moore Blvd on the former Ft. Ord, to be used jointly by CAW and MCWD.

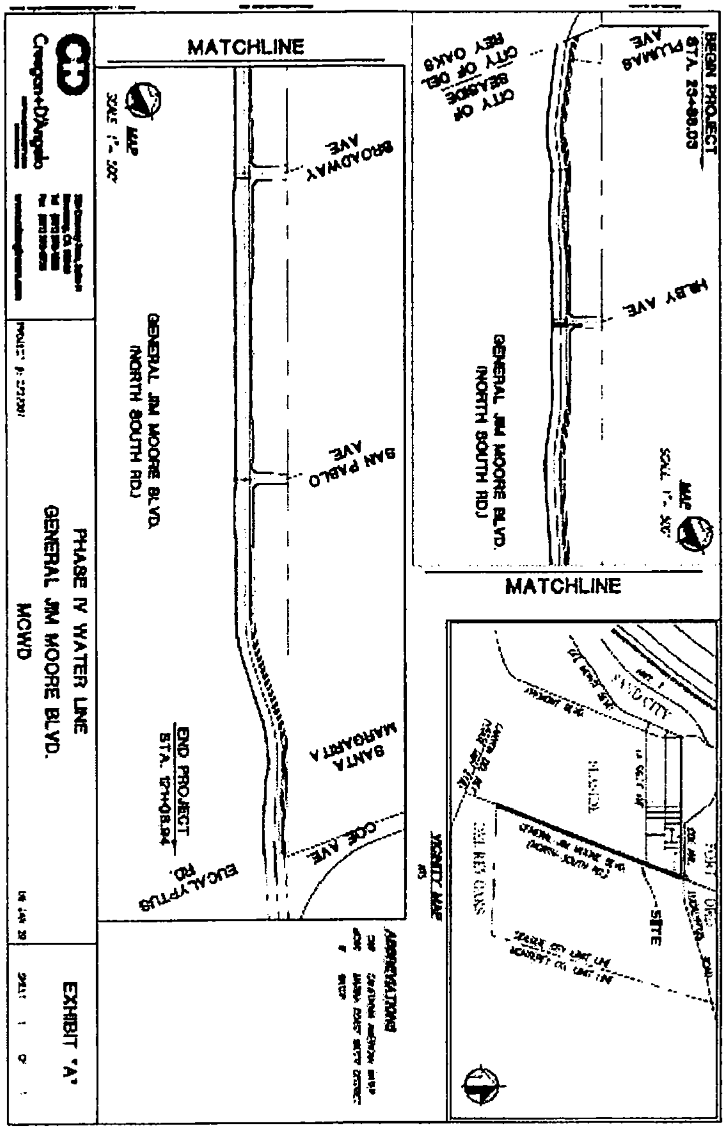
"Term" means (a) the Basic Term and Extended Term which may be effected pursuant to Article 2 of the Agreement or (b) such shorter period as may result from earlier termination of the Agreement as provided therein.

"Term Termination Date" means the last day of the Basic Term or a Renewal Term, as applicable.

"Termination Date" has the meaning set forth in Article 2 of the Agreement.

EXHIBIT A

DIAGRAM OF SUBJECT FACILITY



APPENDIX O

Amended and Restated Water Purchase Agreement for Pure Water Monterey Project (executed March 31, 2023)

AMENDED AND RESTATED
WATER PURCHASE AGREEMENT FOR
PURE WATER MONTEREY PROJECT

THIS AMENDED AND RESTATED WATER PURCHASE AGREEMENT ("Agreement") is made this 31st day of March, 2023 (the "Effective Date") by and between California-American Water Company, a California corporation, hereinafter referred to as the "Company," Monterey One Water (formerly the Monterey Regional Water Pollution Control Agency), hereinafter referred to as the "Agency," and Monterey Peninsula WaterManagement District, hereinafter referred to as the "District." The Company, the Agency, and the District are hereinafter referred to individually as a "Party" and collectively as the "Parties."

RECITALS

A. The Company has a statutory duty to serve water in certain cities on the Monterey Peninsula and in a portion of Monterey County for its service area, the boundaries of which are shown in Exhibit A attached hereto and incorporated herein.

B. The Company has been ordered by the State Water Resources Control Board in orders WR 95-10, WR 2009-0060, and WR 2016-0016 to find alternatives to the Carmel River to fulfill its duty to serve, and to reduce Carmel River diversions to authorized limits by December 31, 2021.

C. In 2012, the Company filed application 12-04-019 with the California Public Utilities Commission ("CPUC"), seeking an order issuing a Certificate of Public Convenience and Necessity ("CPCN") for the construction of the Monterey Peninsula Water Supply Project ("MPWSP") and authorizing the recovery of the costs for such construction in rates. The Company proposed the MPWSP as either a 9.6 million gallons per day ("mgd") production capacity desalination plant or a reduced capacity 6.4 mgd production capacity desalination plant combined with a water purchase agreement for 3,500 acre-feet per year of product water from the Agency's Groundwater Replenishment Project (also known as the Pure Water Monterey Project).

D. In 2013, multiple parties, including the Company, the Agency, and the District, entered into a Comprehensive Settlement Agreement, providing for the development, construction, operation and financing of the MPWSP, and recovery of costs in rates for a desalination plant sized at either 9.6 mgd or 6.4 mgd.

E. In 2016, in Decision 16-09-021, the CPUC authorized a water purchase agreement for the 3,500 acre-feet per year of product water from the Pure Water Monterey Project to be delivered to the Company.

F. On September 20, 2018, the CPUC issued Decision 18-09-017, certifying the combined Final Environmental Impact Report/Environmental Impact Statement for the MPWSP and authorizing a CPCN for the MPWSP at a desalination plant size of 6.4 mgd. The Decision declined to adopt the Comprehensive Settlement Agreement, but adopted the framework set forth therein, including a cost cap, operations and maintenance financing provisions, ratemaking provisions, and contingency provisions.

G. Between 2012 and the present, the Company incurred costs, including environmental review, permitting, and other costs, in proceeding with development of the MPWSP to provide a permanent, reliable water supply and allow reduction of unauthorized Carmel River and Seaside Basin diversions. Many of these costs were reviewed and discussed among the parties Since July 2013, the Company has provided these incurred costs as part of its quarterly newsletter filings that are served on all parties in the CPUC proceeding.

H. In September 2017, at the CPUC's request the Agency proposed expansion of the Pure Water Monterey Project to provide an additional incremental supply of 2,250 acre-feet per year of product water to be made available to the Company for delivery to its customers.

I. In Decision 18-09-017, the CPUC required the Company to file an application if it sought to enter into a water purchase agreement for additional water supply to be provided by an expansion of the Pure Water Monterey Project.

J. In Decision 18-09-017, the CPUC set forth the requirements for any water purchase agreement application to be filed with the CPUC for acquiring water from the Pure Water Monterey Expansion Project if the MPWSP desalination plant was delayed beyond December 31, 2021, stating: "To the extent Cal-Am files (or the Commission directs Cal-Am to file) an application seeking approval of a PWM expansion WPA, the application shall include sources of supply water, development costs, prices for sales of the developed water, contractual details, environmental effects, potential to obtain necessary permits, water quality, sources of funding, possible related facilities (e.g., additional pipelines or pump stations), and any other information relevant and necessary for the Commission to make an informed, just and reasonable decision including details as to supply and production including not only during average rainfall years but also during a multi-year drought and the timing of expanded production. The application will be considered only to the extent the desalination plant authorized in this decision (i.e., 6.4 million gallons per day) is delayed to the point that sufficient source water capacity is more likely than not to be unavailable after the December 31, 2021, deadline set by the State Water Resources Control Board in its amended CDO."

K. Approval by the California Coastal Commission of a coastal development permit necessary for the MPWSP desalination plant slant wells was delayed, such that the desalination plant authorized by the CPUC will not be operational by December 31, 2021.

L. At this time, the Company desires to buy advanced treated recycled water from the Pure Water Monterey Project, and the Pure Water Monterey Expansion project, from the District for the purpose of fulfilling its duty to serve its customers within its service area and the District is willing to sell advanced treated recycled water to the Company for this purpose on the terms and conditions provided for herein.

M. The Company believes, based on expert advice, that the water available from the Pure Water Monterey Project and the Pure Water Monterey Expansion Project provides insufficient supplies to meet customer demand without the desalination component of the MPWSP and, therefore, intends to continue to seek all necessary approvals for development, construction and operation of the MPWSP desalination plant. Nevertheless, water supplied by the Pure Water Monterey Expansion Project will likely be available before the desalination plant is operational and would help meet current demand after December 31, 2021.

N. The District believes, also based on expert advice and peer review, that supplies without the desalination plant are sufficient to satisfy customer demand for a couple decades if the Pure Water Monterey Expansion Project is built, and, therefore, supports entering into an agreement with the Company for water purchases from the Pure Water Monterey Expansion Project.

O. The Agency will be responsible for the design, construction, operation, and ownership of facilities for the production, delivery, and injection of advanced treated recycled water into the Seaside Groundwater Basin, such facilities to be part of the Pure Water Monterey groundwater replenishment project.

P. The District will buy advanced treated recycled water from the Agency for purpose of securing the financing of and paying the operating costs of the project. The District will sell the advanced treated recycled water to the Company subject to the terms of this Agreement.

Q. The Company desires to buy advanced treated recycled water from the District for the purpose of fulfilling its duty to serve its customers within its service area and the District is willing to sell advanced treated recycled water to the Company for this purpose on the terms and conditions provided for herein.

R. The Agency contends, and has so advised the District and the Company, that based on advice of counsel, (1) Agency assets and revenue derived from Agency ratepayers are not available for satisfying claims and judgments for any liability arising from this water project Agreement, and (2) therefore, the single source for so satisfying is insurance coverage described as Required Insurance in this Agreement.

S. The Agency has separately entered into an agreement with the Monterey County Water

Resources Agency in Section 4.05 of which, the Monterey County Water Resources Agency may request additional irrigation water from Agency sources. Pursuant to that agreement the Agency has committed to produce no more than 200 acre-feet per year, up to a total quantity of 1,000 acre-feet, for delivery to the District as a drought reserve. When such a request is made, the District may make available to the Company Drought Reserve Water in order to satisfy the Company Allotment. Additionally, in order to ensure delivery of the Company Allotment in the event of an interruption in project operations, the District has established an Operating Reserve. Together the two reserves are called the Reserve Account and will be paid for by the District until deemed delivered to the Company if needed at a future date.

NOW, THEREFORE, the Parties agree as follows:

1. Purpose of Agreement.

The purpose of this Agreement is to provide for the sale of advanced treated recycled water from the Agency to the District and from the District to the Company derived from the Pure Water Monterey groundwater replenishment project owned and operated by the Agency, and to serve the Company's customers within its service area. The Parties confirm that this Agreement constitutes a contractual right to purchase advanced treated recycled water, that no water right is conferred to the Company, and that no additional rights in the Seaside Groundwater Basin are conferred to the District or the Agency.

2. Definitions

The following terms shall, for all purposes of this Agreement have the following meanings:

"Additional Project Participant" means any public district, agency, or entity, or any private water company, other than the Company, that executes a water purchase agreement in accordance with Section 19 hereof, together with its respective successors or assigns.

"Affected Party" means a Party claiming the occurrence of a Force Majeure Event and seeking relief under this Agreement as a result thereof.

"Agreement" means this Amended and Restated Water Purchase Agreement, as the same may be amended from time to time.

"Applicable Law" means any federal, state or local statute, local charter provision, regulation, ordinance, rule, mandate, order, decree, permit, code or license requirement or other governmental requirement or restriction, or any interpretation or administration of any of the foregoing by any governmental authority, which applies to the services or obligations of any of the Parties under this Agreement.

"AWT Facilities" means the advanced water treatment facilities portion of the Project that provides advanced treatment to source water that has undergone secondary treatment at the

Regional Treatment Plant, including any advanced water treatment facilities constructed as part of the Expansion.

"AWT Water" means advanced treated recycled water produced by the AWT Facilities. "Company Account" means the account managed by the District and the Company that tracks and records the quantity of Company Water delivered to the Delivery Point.

"Company Allotment" means 3,500 acre-feet of AWT Water until the Expansion Performance Start Date, after which it shall mean 5,750 acre-feet, or another quantity of AWT Water as agreed to, in writing, by the Parties.

"Company Facilities" means the necessary facilities funded and constructed by the Company for purposes of supporting water deliveries from the Project and other Company water supplies, including (a) injection/extraction wells and related appurtenances, (b) pipelines and transmission mains, and (c) real property, all as additionally described in Exhibit B.

"Company Water" means the AWT Water delivered to the Delivery Point to be used and owned by the Company and will be counted toward the Company Allotment.

"Company Water Payments" means payments made by the Company to the District pursuant to Section 16 hereof for the furnishing of Company Water.

"Company Water Rate" means the dollar amount per acre-foot of Company Water that the Company pays the District for delivery of Company Water, as calculated pursuant to Section 16.

"Company Water Shortfall" is measured in acre-feet and, for each Fiscal Year, means the Company Allotment (with respect to Section 20(c)(5)) or the Minimum Allotment (with respect to Section 20(c)(6)), as applicable, minus the quantity of Company Water delivered by the Agency or the District to the Delivery Point in the applicable Fiscal Year. With respect to an Event of Default under Section 20(c)(5), the Company Water Shortfall shall be an amount equal to the cumulative sum of the shortfall in each of the three consecutive Fiscal Years. With respect to an Event of Default under Section 20(c)(6), the Company Water Shortfall shall be an amount equal to the cumulative sum of the shortfall in each of the two consecutive Fiscal Years.

"CPUC" means the California Public Utilities Commission.

"Delivery Point" means any of the metered points of delivery identified in Exhibit C.

"Delivery Start Date" means the date that the District commences delivery of AWT Water to the Delivery Point.

"District Shortfall Payment" means a payment made by the District to the Company pursuant to Section 16 hereof.

"Drought Reserve" means one of the two sub-accounts that comprise the Reserve Account.

"Drought Reserve Minimum" means 1,000 acre-feet of Drought Reserve Water in the Drought Reserve.

"Drought Reserve Water" means Excess Water in the Drought Reserve Account at any given time.

"Event of Default" means each of the items specified in Section 20 which may lead to termination of this Agreement upon election by a non-defaulting Party.

"Excess Water" means a quantity of AWT Water in excess of the Company Allotment delivered by the District to the Delivery Point in any given Fiscal Year.

"Expansion" means the Pure Water Monterey groundwater replenishment project expansion, including (a) expansion to AWT Facilities, (b) additional Product Water Facilities, and (c) additional Injection Facilities, all as additionally described in Exhibit B.

"Expansion Delivery Start Date" means the date that the District commences delivery of AWT Water from the Expansion to the Delivery Point.

"Expansion Performance Start Date" means the date set forth in a written notice provided by the District to the Company upon which the District's performance obligations with respect to the Water Availability Guarantee, the Water Delivery Guarantee, and the Water Treatment Guarantee shall commence with respect to the Expansion, such date not to be more than twelve months following the Expansion Delivery Start Date.

"Fiscal Year" means a twelve-month period from July 1 through June 30. Any computation made on the basis of a Fiscal Year shall be adjusted on a pro rata basis to take into account any Fiscal Year of less than 365 or 366 days, whichever is applicable.

"Fixed Project Costs" means all pre-construction, development, and capital costs of the Project, including debt service and reserves for the payment of debt service, incurred by the Agency or District in accordance with Section 6 hereof; provided, however, Fixed Project Costs shall not include any damages or other amounts paid by the Agency or the District to the Company as indemnification payments pursuant to Section 22 of this Agreement.

"Force Majeure Event" means any act, event, condition or circumstance that (1) is beyond the reasonable control of the Affected Party, (2) by itself or in combination with other acts, events, conditions or circumstances adversely affects, interferes with or delays the Affected Party's ability to perform its obligations under this Agreement, and (3) is not the fault of, or the direct result of the willful or negligent act, intentional misconduct, or breach of this Agreement by, the Affected Party.

"Injection Facilities" means the injection wells and appurtenant facilities portion of the Project used to inject AWT Water into the Seaside Basin.

"Minimum Allotment" means 2,800 acre-feet of AWT Water until the Expansion Performance Start Date, after which it shall mean 4,600 acre-feet.

"Operating Reserve" means one of the two sub-accounts that comprise the Reserve Account.

"Operating Reserve Minimum" means (a) 1,000 acre-feet of Operating Reserve Water in the Operating Reserve prior to the date that is three (3) years following the Performance Start Date, (b) 1,750 acre-feet of Operating Reserve Water in the Operating Reserve after the date that is three (3) years following the Performance Start Date but prior to the Expansion Performance Start Date, and (c) 2,875 acre-feet of Operating Reserve Water in the Operating Reserve after the date that is three (3) years following the Expansion Performance Start Date.

"Operating Reserve Water" means Excess Water in the Operating Reserve at any given time.

"Performance Start Date" means the date set forth in a written notice provided by the District to the Company upon which the District's performance obligations with respect to the Water Availability Guarantee, the Water Delivery Guarantee, and the Water Treatment Guarantee shall commence, such date not to be more than six months following the Delivery Start Date.

"Product Water Facilities" means the product water conveyance facilities portion of the Project used to transport the AWT Water from the AWT Facilities to the Injection Facilities.

"Project" means the Pure Water Monterey groundwater replenishment project, including (a) Source Water Facilities, (b) AWT Facilities, (c) Product Water Facilities, and (d) Injection Facilities, all as additionally described in Exhibit B. The Project also includes the Expansion beginning on the Expansion Delivery Start Date.

"Project Operation and Maintenance Expenses" means all expenses and costs of management, operation, maintenance, repair, replacement, renovation, or improvement of the Project incurred by the Agency and the District, including overhead costs, and properly chargeable to the Project in accordance with generally accepted accounting principles, including, without limitation (a) salaries, wages, and benefits of employees, contracts for professional services, power, chemicals, supplies, insurance, and taxes; (b) an allowance for depreciation, amortization, and obsolescence; (c) all administrative expenses; and (d) a reserve for contingencies, in each case incurred by the Agency or District with respect to the Project; provided, however, Project Operation and Maintenance Expenses shall not include any damages or other amounts paid by the Agency or the District to the Company as indemnification payments pursuant to Section 22 of this Agreement.

"Regional Treatment Plant" means the Agency's Regional Wastewater Treatment Plant.

"Replenishment Assessment Rate" means a dollar value equal to the greater of (1) the

Replenishment Assessment amount, as defined in the Seaside Basin Amended Decision, as of the last day of the Fiscal Year for which a District Shortfall Payment becomes due, or (2) $3,500 per acre-foot.

"Required Insurance" means, with respect to the Agency and the District, the insurance each Party is required to obtain and maintain during the term of this Agreement as set forth in Exhibit D.

"Reserve Account" means the account managed by the District that tracks and records (a) quantities of Excess Water delivered to the Delivery Point, and (b) quantities of Reserve Water debited from the Reserve Account to satisfy the Company Allotment.

"Seaside Basin" means the Seaside Groundwater Basin.

"Seaside Basin Amended Decision" means the Amended Decision of the Superior Court of the State of California in and for the County of Monterey, Case No. M66343, dated February 9, 2007.

"Service Area" means the Company's service area as of the Effective Date of this Agreement, as shown in Exhibit A, and as amended from time-to-time by the CPUC.

"Storage and Recovery Agreement" means the storage and recovery agreement among the Company, the District and the Watermaster that allows for injection of AWT Water into the Seaside Basin for purposes of continued storage or withdrawal.

"Source Water Facilities" means the source water diversion and conveyance facilities portion of the Project used to divert and convey new source waters to the Regional Treatment Plant.

"Watermaster" means the Seaside Groundwater Basin Watermaster.

"Water Availability Guarantee" means the water availability guarantee set forth in Section 13.

"Water Delivery Guarantee" means the water delivery guarantee set forth in Section 12.

"Water Treatment Guarantee" means the water treatment guarantee set forth in Section 14.

OPERATIVE PROVISIONS

3. <u>Commencement of Service</u>.

The Performance Start Date occurred on September 1, 2020. The Expansion Delivery Start Date shall be no later than February 1, 2025, or other date as agreed to in writing by the Parties. Failure of the Agency and the District to meet this deadline shall constitute an Event of Default upon which the Company may terminate this Agreement in accordance with Section 20. The Company shall not incur anycosts or be responsible for any payments under this Agreement prior to the Performance Start Date. The Company shall not incur any costs or be responsible for any payments under this Agreement relating to the Expansion prior to the Expansion Delivery Start

Date.

4. Term of Agreement.

This Agreement shall be effective as of the Effective Date and shall remain in effect until the date that is thirty (30) years after the Expansion Performance Start Date (the "Expiration Date"), unless earlier terminated as provided in this Agreement.

5. Option for Continued Service.

The Company may extend the Expiration Date of this Agreement for one or more periods not to exceed ten (10) years, in total. The Company shall notify the Agency and the District, in writing at least 365 days prior to the then-applicable Expiration Date, of its intent to extend the Expiration Date and such notice shall indicate the new Expiration Date. At the election of any Party, the Parties will meet and confer to consider the Parties' interest in any additional extension or renewal of an arrangement similar to this Agreement. Such meet-and-confer sessions should take place approximately five (5) years prior to the then-applicable Expiration Date; provided, however, if pursuant to an extension under this Section 5 the new Expiration Date is less than five (5) years following the Company's notification of the extension, the Parties will meet and confer within a reasonable time prior to the new Expiration Date.

6. Agency and District to Develop Project and Expansion.

Subject to all terms and conditions of the Agency's water rights, permits and licenses, and all agreements relating thereto, the Agency and District will cause and complete the design, construction, operation, and financing of the Project and the Expansion, the production and delivery of AWT Water, the obtaining of all necessary authority and rights, consents, and approvals, and the performance of all things necessary and convenient therefor. The Agency will own and operate the Project and the Expansion.

As consideration for funding environmental, permitting, design, and other pre-construction costs, as well as for pledging revenues for repayment of future costs under this Agreement in the event Company Water Payments are insufficient, the District shall (i) own AWT Water for sale and delivery to the Company, (ii) have the right to sell AWT Water to the Company or any Additional Project Participant (if approved by the Company pursuant to Section 19), (iii) have the right to bill the Company for Company Water Payments or to bill any Additional Project Participant for AWT Water, and (iv) have the right to apply all Company Water Payments to payment of Fixed Project Costs and Project Operation and Maintenance Expenses.

7. Obligation to Pay Design and Construction Costs.

The Agency shall be solely responsible for the design, construction, implementation and performance of the Project, and shall bear all costs associated with such design, construction, implementation and performance. Title to the structures, improvements, fixtures, machinery, equipment, materials, and pipeline capacity rights constituting the Project and the Expansion shall remain with the Agency as described in Exhibit B. The Agency shall bear all risk of loss concerning such structures, improvements, fixtures, machinery, equipment, and materials.

At the request of the Agency, the Company may assist the Agency in obtaining financing for Fixed Project Costs for the Project. Any such assistance will be evidenced in a writing agreed to by the Company and the Agency.

8. Obligation to Pay Operation and Maintenance Costs.

The Agency shall be solely responsible for the operation, maintenance, repair and replacement of the Project, and shall bear all costs associated with such operation, maintenance, repair and replacement.

9. Point of Delivery and Ownership of AWT Water.

All AWT Water shall be delivered to the Delivery Point. Water utilized to backflush an injection well that percolates into the ground is considered delivered AWT Water.

The Agency shall own the AWT Water until the point it leaves the AWT Facilities. The District shall own the AWT Water from the point it leaves the AWT Facilities to the Delivery Point. After the Delivery Point, if the water is Company Water, it will be owned by the Company. If, however, the water is Excess Water after the Delivery Point, then ownership of such water shall remain with the District. The District shall own any water in the Reserve Account, until such time as Operating Reserve Water or Drought Reserve Water is used to satisfy the Water Availability Guarantee at which point it shall become Company Water and beowned by the Company.

The Company recognizes and agrees that it acquires no interest in or to any portion of the District's system or any Agency facilities.

Delivery by the District and withdrawal by the Company shall be governed by the Storage and Recovery Agreement.

10. Points of Withdrawal.

All AWT Water furnished pursuant to this Agreement shall be taken from storage by the Company at the points of withdrawal controlled by the Company and permitted by the California Department of Public Health. The Company shall be solely responsible for operating and maintaining all of its facilities for withdrawal of water.

11. Measurement.

All AWT Water furnished pursuant to this Agreement shall be measured by the Agency at the

Delivery Point. Such measurement shall be with equipment chosen by the Agency, installed by the Agency on Agency facilities, and approved by the District and Company in writing. All measuring equipment shall be installed, maintained, repaired and replaced by the Agency. The Agency will provide annual meter calibration by an outside contractor and provide a copy of resultsof such calibrations to District and Company. The Agency shall have the primary obligation to measure the quantity of AWT Water delivered to the Delivery Point. The Company may request,at any time, investigation and confirmation by the District or Agency of the measurement being made as well as the charges associated with those measurements. Errors in measurement and charges discovered by the investigation will be corrected in a timely manner by the Agency and the District. The Company may, at its own expense, at any time, inspect the measuring equipmentand the record of such measurements for the purpose of determining the accuracy of the equipment and measurements.

12. Water Delivery Guarantee.

(a) Beginning on the Performance Start Date and in every Fiscal Year throughout the term of this Agreement, the Agency shall use its best efforts to deliver AWT Water to the District in quantities at least equal to the Company Allotment.

(b) Beginning on the Performance Start Date and in every Fiscal Year throughout the term of this Agreement, the District shall use its best efforts to deliver Company Water to the Delivery Point in quantities at least equal to the Company Allotment.

(c) Beginning on the Performance Start Date and in every Fiscal Year throughout the term of this Agreement, the Agency shall deliver AWT Water to the District in quantities at least equal to the Minimum Allotment (the "Water Delivery Guarantee").

(d) Beginning on the Performance Start Date and in every Fiscal Year throughout the term of this Agreement, the District shall deliver Company Water to the Delivery Point in quantities at least equal to the Minimum Allotment (also, the "Water Delivery Guarantee").

(e) All AWT Water delivered by the District to the Delivery Point between the Delivery Start Date and the Performance Start Date shall be deemed Operating Reserve Water and allocated to the Operating Reserve. The Performance Start Date shall not occur until the Operating Reserve Minimum has been allocated to the Operating Reserve. Beginning on the Performance Start Date and in every Fiscal Year throughout the term of this Agreement, all AWT Water delivered to the Delivery Point each Fiscal Year shall be Company Water until an amount equal to the Company Allotment has been delivered.

13. Water Availability Guarantee.

(a) Beginning on the Performance Start Date and throughout the term of this Agreement, the

Agency must deliver enough AWT Water to the District so that the Company may draw AWT Water (including Company Water, Operating Reserve Water, and Drought Reserve Water released by the District to the Company) from the Seaside Basin every Fiscal Year in an amount at least equal to the Company Allotment (the "Water Availability Guarantee").

(b) Beginning on the Performance Start Date and throughout the term of this Agreement, the District must deliver enough AWT Water to the Delivery Point so that the Company may draw AWT Water (including Company Water, Operating Reserve Water, and Drought Reserve Water released by the District to the Company) from the Seaside Basin every Fiscal Year in an amount at least equal to the Company Allotment (also, the "Water Availability Guarantee").

(c) If in any Fiscal Year the District delivers Excess Water, any such amount shall be credited to the Reserve Account. The Reserve Account will have two sub-accounts: the Operating Reserve and the Drought Reserve. The District will allocate all Excess Water into either the Operating Reserve or the Drought Reserve as it shall determine in its sole discretion.

(d) If the amount of Operating Reserve Water in the Operating Reserve at any time is less than the Operating Reserve Minimum, then all Excess Water in a Fiscal Year must be allocated to the Operating Reserve until the Operating Reserve Minimum is achieved, except for up to 200 acre-feet of Excess Water that may, at the District's election, be allocated to the Drought Reserve but only if the balance in the Drought Reserve is lessthan the Drought Reserve Minimum. In no instance shall the District reduce CompanyWater deliveries to make available additional irrigation water to the Monterey County Water Resources Agency from Agency sources in an amount exceeding the balance available in the Drought Reserve.

(e) If in any Fiscal Year the District delivers Company Water to the Delivery Point in quantities less than the Company Allotment, the Company shall have the right, but not the obligation, to draw Operating Reserve Water from the Operating Reserve to make up for any such shortfall in Company Water. In addition, if a shortfall still exists after Operating Reserve Water is drawn by the Company, the District may, in its sole discretion, use Drought Reserve Water available in the Drought Reserve to satisfy the Water Availability Guarantee.Upon the occurrence of the Expiration Date, or the earlier termination of this Agreement as contemplated herein, the Company shall have the right to draw Drought Reserve Water from the Drought Reserve.

(f) At least every three (3) months during the term of this Agreement, beginning on the Performance Start Date, the District will report to the Company the balances and activity in the OperatingReserve and Drought Reserve. In addition, the District shall, with ten (10) days following the Company's request, provide to the Company the balances and activity in the Operating Reserve and Drought Reserve.

14. Water Treatment Guarantee.

All AWT Water delivered by the Agency to the District and by the District to the Delivery Point must meet the water quality requirements set forth in Applicable Law (the "Water Treatment Guarantee"). If at any time the Agency or the District fails to meet the Water Treatment Guarantee, the Agency or the District shall give the Company immediate notice thereof and shall promptly meet with the Company to discuss the circumstances of such failure and the District's and the Agency's proposed action plan for remediation so that the Water Treatment Guarantee will be met. AWT Water delivered by the Agency to the District or by the District to the Delivery Point that does not meet the Water Treatment Guarantee shall not be considered Company Water or Excess Water.

15. Budgeting.

Not later than May 1 each year, the Fixed Project Costs and Project Operation and Maintenance Expenses shall be estimated by the Agency and the District for the following Fiscal Year. Such estimates shall be made available for review by the Parties at least fifteen (15) days prior to adoption by the Agency's or District's respective boards.

16. Rate of Payment for Company Water.

For Company Water furnished to the Company under this Agreement, the Company shall pay Company Water Payments to the District on a monthly basis determined as the Company Water Rate multiplied by the quantity of Company Water delivered the previous month. The Company shall not pay for deliveries to the Operating Reserve and the Drought Reserve until such reserves are designated by the Company or the District, as applicable, as Company Water.

The Company Water Rate in each Fiscal Year of the Agreement shall be the sum of the Fixed Project Costs and Project Operation and Maintenance Expenses budgeted for production and delivery of AWT Water in such Fiscal Year, divided by the amount of AWT Water expected to be produced during such Fiscal Year. The Parties agree that the fundamental rate-setting principles of this Agreement shall be (a) the Company does not pay for water it does not receive, (b) the cost of water shall only reflect the true cost of service consistent with California public agency laws and regulations, and (c) the Company shall pay only its proportionate share of the costs of the Agency and the District producing AWT Water.

In the first year following the Performance Start Date, the Company Water Rate shall not exceed $1,720 per acre foot (the "Soft Cap"). Prior to the Performance Start Date, if the first-year Company Water Rate as calculated is expected to exceed the Soft Cap, the Company shall apply to the CPUC through a Tier 2 advice letter for approval of such rate before the Company shall be required under this Agreement to pay an amount greater than the Soft Cap as the Company Water Rate. Unless and until the CPUC approves a Company Water Rate in an amount greater than the

Soft Cap, the Company shall only be required to pay an amount equal to the Soft Cap as the Company Water Rate. In no circumstance shall the District's or the Agency's obligations under this Agreement to deliver Company Water to the Company be affected by the pendency of the Company's application to the CPUC for approval of a rate greater than the Soft Cap or a decision by the CPUC to deny any such application.

As Project Operation and Maintenance Expenses are projected or budgeted for an upcoming Fiscal Year, the Parties agree there will be a "true-up" or reconciliation at the end of every Fiscal Year following the Performance Start Date to ensure the principles set forth in this section are met. Such "true-up" shall mean: if actual Project Operation and Maintenance Expenses are more or less than budgeted Project Operation and Maintenance Expenses used to calculate the Company Water Rate paid during the Fiscal Year, a corresponding adjustment (up or down) will be provided against the subsequent Fiscal Year budget and computed Company Water Rate for that Fiscal Year.

The Parties agree that, given the status of the Agency and the District as governmental agencies and the requirements under law that they incur only reasonable and prudent costs and expenses for purposes related to their governmental duties and the fact that such costs and expenses are subject to public review and scrutiny, all Fixed Project Costs and Project Operation and Maintenance Expenses incurred by the Agency and/or the District in compliance with the terms of this Agreement shall reflect only the actual cost of service consistent with California public agency laws and regulations and shall be subject to CPUC review consistent with that used for existing water purchase agreements by CPUC-regulated Class A investor-owned water utilities.

The District covenants and agrees to pay to the Agency the revenues received from the Company from the Company Water Payments provided, however, it will reduce the payment amount by any portion of the Fixed Project Costs and Project Operation and Maintenance Expenses directly paid or incurred by the District.

In addition to any other right or remedy available pursuant to this Agreement, if an Event of Default should occur under Section 20(c)(5) or Section 20(c)(6) at any time after the Expansion Performance Start Date, then the District shall pay a District Shortfall Payment to the Company determined as the Replenishment Assessment Rate multiplied by the cumulative Company Water Shortfall for each applicable Fiscal Year. The District shall pay the District Shortfall Payment to the Company within sixty days following last day of the Fiscal Year for which such payment becomes due. The Company, in its sole discretion, may elect any District Shortfall Payment to be credited against any Company Water Payment payable to the District pursuant to Section 17.

17. Time and Method of Payments.

The District shall send the Company a detailed monthly statement of charges due for all Company Water delivered to the Delivery Point during the preceding month as measured by the Agency meters, which shall be read on a monthly basis, and all Operating Reserve Water and Drought Reserve Water used to satisfy the Water Availability Guarantee, The Company shall not be billed for Excess Water that goes into the Reserve Account.

The Company shall pay to the District all undisputed portions of statements, within forty-five (45) days after receipt. Statements shall be mailed to the Company at the following address:

California American Water Company
Director of Operations
511 Forest Lodge Rd # 100
Pacific Grove, CA 93950

The Agency shall send the District a monthly statement of charges due for all AWT Water actually delivered to the District during the preceding month as measured by the meters, which shall be read on a monthly basis. The District shall pay all statements within forty-five (45) days after receipt. Statements shall be mailed to the District at the following address:

Monterey Peninsula Water Management District
Administrative Services Division Manager
5 Harris Court, Building G
Monterey, CA 93940

If payment of any amount due hereunder is not made when due, excluding disputed amounts, simple interest will be payable on such undisputed amount at the legal rate of interest charged on California judgments, as provided in California Code of Civil Procedure Section 685.010, and shall be calculated on the basis of a 365-day year from the date such payment is due under this Agreement until paid.

The Company is obligated to pay to the District the undisputed amounts becoming due under this Agreement, notwithstanding any individual default by its water users or others in the payment to the Company of assessments or other charges levied by the Company.

GENERAL PROVISIONS

18. CPUC Rate Recovery Process.

All costs that the Company pays to the District pursuant to this Agreement shall be considered purchased water costs that are a pass-through to customers to be recovered via the Modified Cost Balancing Account ("MCBA") mechanism.

At least six (6) months prior to the Performance Start Date, at least one time between May 1 and June 1 of every year thereafter, and at any time throughout the term of this Agreement the District deems necessary, the District shall provide the Company with written notice of the Company Water Rate, supported by detailed information relating to the Fixed Project Costs and the estimated Operation and Maintenance Expenses to be incurred in the upcoming Fiscal Year that were used to determine the Company Water Rate. Within sixty (60) days following receipt of the written notice containing the Company Water Rate, the Company shall file a Tier 1 advice letter for rate recovery with the CPUC to update its rates and tariffs, and in doing so establish a surcharge rate to reflect the Company Water Rate.

All changes to the Company Water Rate resulting from annual increases or decreases to the FixedProject Costs or Project Operation and Maintenance Expenses, as reflected in the Company WaterRate, shall be requested for rate recovery through a Tier 1 advice letter in accordance with Section 3.2 of Water Industry Rules in General Order 96-B, as amended from time to time, for processingexpense offset rate changes. The rate change will be applied to the surcharge to ensure that the Company's customer rates remain aligned with the Company Water Rate under the Agreement.

The Company shall have no obligation to make Company Water Payments unless and until the CPUC approves payment and recovery of those payments in rates through the process set forth in General Order 96-B, including a Tier 1 advice letter, which is effective upon filing pending CPUC approval, or another process resulting in CPUC approval of such costs, which shall be diligently pursued by the Company. Failure of the Company to pay amounts in excess of the amount approved by the CPUC shall not constitute a breach, and the District and Agency shall not be relieved of any obligations hereunder as a result thereof.

Access to the books and records of the Agency and the District will be made available to the Company for purposes of reviewing the accuracy and reasonableness of all costs relating to the Project and determination of the Company Water Rate.

Notwithstanding the Company's commitments under this Agreement, the Company intends to implement the MPWSP as authorized by the CPUC. Neither the District nor the Agency shall oppose the Company's efforts to obtain CPUC approval to recover in rates the Company's costs incurred relating to the MPWSP on or prior to August 31, 2019. Neither the District nor the Agency is currently taking a position relating to the Company's efforts to obtain CPUC approval to recover in rates the Company's costs incurred relating to the MPWSP after August 31, 2019.

19. <u>Additional Project Participants</u>.

After giving sixty (60) days' prior written notice to the Company, the District and Agency may enter into water purchase agreements for AWT Water with Additional Project Participants subsequent to the Effective Date of this Agreement to the extent the District determines sufficient capacity exists (after accounting for the need to maintain the Operating Reserve Minimum and the Drought Reserve Minimum), to the extent there is no additional cost to the Company as a result of any such agreement, and to the extent any such agreement does not adversely affect the Agency's or the District's ability to meet their performance obligations under this Agreement.

In order to not diminish the source waters available to produce AWT Water under this Agreement, the Company shall have the right, prior to the District or the Agency entering into any water purchase agreement for AWT Water and in the Company's sole discretion, to approve or not approve in writing any Additional Project Participants deriving water from the water sources identified for the Project, specifically source waters identified in Sections 1.04 and 2.02 of the Amended and Restated Water Recycling Agreement between the Agency and Monterey County Water Resources Agency, dated November 3, 2015.

The Company shall not have the right to approve Additional Project Participants deriving water from prior existing rights to wastewater flows to the Regional Treatment Plant pursuant to Section 4.01 of the Agency's agreement with Monterey County Water Resources Agency or from future additional sources, as yet unidentified, such as wastewater systems annexed to the Agency's service area.

Any Additional Project Participant will pay for all additional capital costs necessitated by existence of the new water purchase agreement, its proportionate share of both the unamortized capital costs of the Project, and its proportionate share of future operation and maintenance expenses of the Project. The District and Agency will provide supporting documentation to the Company to ensure the Company Water Payments do not include any costs properly allocable to an Additional Project Participant.

20. <u>Breach, Event of Default and Termination</u>.

(a) Remedies for Breach – The Parties agree that, except as otherwise provided in this section with respect to termination rights, if any Party breaches this Agreement, any other Party may exercise any legal rights it may have under this Agreement and under Applicable Law to recover damages or to secure specific performance. No Party shall have the right to terminate this Agreement for cause except upon the occurrence of an Event of Default. If a Party exercises its rights to recover damages upon a breach of this Agreement or upon a termination due to an Event of Default, such Party shall use all reasonable efforts to mitigate damages. If a Force Majeure Event occurs, the Affected Party shall be entitled to relief from determination of a breach pursuant to Section 23 of this Agreement.

(b) If the District fails to exercise, and diligently pursue, any legal rights it may have against the Agency pursuant to subsection (a) of this section 20 within forty-five (45) days after the Company's written request that the District do so, the District shall be deemed to have assigned to the Company all such legal rights. The Agency shall not object to any such assignment, but shall not waive any defense it may otherwise assert to any claim brought by the Company.

(c) Event of Default – The following shall each constitute an "Event of Default" under this Agreement:

(1) The Delivery Start Date does not occur on or before July 1, 2019[1];

(2) The Performance Start Date does not occur on or before January 1, 2020[2];

(3) The Expansion Delivery Start Date does not occur on or before February 1, 2025;

(4) The Expansion Performance Start Date does not occur on or before February 1, 2026;

(5) The failure of the Agency or the District to deliver Company Water to the Delivery Point in quantities at least equal to the Company Allotment in each of three consecutive Fiscal Years;

(6) The failure of the Agency or the District to meet the Water Delivery Guarantee in each of two consecutive Fiscal Years;

(7) The failure of the Agency or the District to deliver Company Water to the Delivery Point in quantities at least equal to 2,960 acre-feet in any Fiscal Year;

(8) The failure of the Agency or the District to meet the Water Availability Guarantee in any Fiscal Year;

(9) The failure of any Party to perform any material term, covenant, or condition of this Agreement, and the failure continues for more than thirty (30) days following the defaulting Party's receipt of written notice of such default from a non-defaulting Party; provided, however, that if and to the extent such default cannot reasonably be cured with such thirty (30) day period, and if the defaulting Party has diligently attempted to cure the same within such thirty (30) period and thereafter continues to diligently attempt to cure the same, then the cure period provided for herein shall be extended from thirty (30) days to one-hundred twenty (120) days;

(10) The failure of the Agency or the District to meet the Water Treatment Guarantee on a repeated basis; and

(11) The Company no longer has a statutory duty to serve water in the Service Area.

(d) Termination for Event of Default – If an Event of Default occurs, any non-defaulting Party may terminate this Agreement immediately upon written notice to the other Parties. A non-

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[1] This Event of Default occurred prior to execution of this Amended and Restated Agreement and shall no longer be a basis for termination under Section 20(d).

[2] This Event of Default occurred prior to execution of this Amended and Restated Agreement and shall no longer be a basis for termination under Section 20(d).

defaulting Party may enforce any and all rights and remedies it may have against a defaulting Party under Applicable Law.

21. Dispute Resolution.

Representatives from each Party shall meet and use reasonable efforts to settle any dispute, claim, question or disagreement (a "Dispute") arising from or relating to this Agreement. To that end, the Parties' representatives shall consult and negotiate with each other in good faith and, recognizing their mutual interests, attempt to reach a just and equitable solution satisfactory to the Parties. If the Parties do not reach such a solution within a period of thirty (30) days after the first notice of the Dispute is received by the non-disputing Parties, then the Parties shall pursue non-binding mediation to be completed within one-hundred twenty (120) days after the notice of the Dispute is received by the non-disputing Parties. If the Parties do not settle the Dispute within the one-hundred twenty (120) day period, any Party may pursue any and all available legal and equitable remedies.

22. Indemnification.

Each Party (an "Indemnifying Party") shall fully indemnify the other Parties and their respective officers, directors, employees, consultants, contractors, representatives and agents (the "Indemnified Persons") against, and hold completely free and harmless from, all liability and damages including any cost, expense, fine, penalty, claim, demand, judgment, loss, injury and/or other liability of any kind or nature, including personal or bodily injury, death or property damage, that are incurred by or assessed against the Indemnified Persons and directly or indirectly caused by, resulting from, or attributable to the fault, failure, breach, error, omission, negligent or wrongful act of the Indemnifying Party, or its officers, directors, employees, consultants, contractors, representatives and agents, in the performance or purported performance of the Indemnifying Party's obligations under this Agreement, but only to the extent of and in proportion to the degree of fault, failure, breach, error, omission, negligent or wrongful act of the Indemnifying Party, or its officers, directors, employees, consultants, contractors, representatives and agents.

23. Force Majeure Event Relief.

(a) If a Force Majeure Event occurs, the Affected Party shall be entitled to (1) relief from its performance obligations under this Agreement to the extent the occurrence of the Force Majeure Event prevents or adversely affects Affected Party's performance of such obligations, and (2) an extension of schedule to perform its obligations under this Agreement to the extent the occurrence of the Force Majeure Event prevents or adversely affects Affected Party's ability to perform such obligations in the time specified in this Agreement. The occurrence of a Force Majeure Event shall not, however, excuse or delay the other Parties' obligation to pay monies previously accrued and owing to Affected Party under this Agreement, or for Affected Party to perform any obligation under this Agreement not affected by the occurrence of the Force Majeure Event.

(b) Upon the occurrence of a Force Majeure Event, Affected Party shall notify the other Parties in accordance with the notice provisions set forth herein promptly after Affected Party first knew of the occurrence thereof, followed within fifteen (15) days by a written description of the Force Majeure Event, the cause thereof (to the extent known), the date the Force Majeure Event began, its expected duration and an estimate of the specific relief requested or to be requested by the Affected Party. Affected Party shall use commercially reasonable efforts to reduce costs resulting from the occurrence of the Force Majeure Event, fulfill its performance obligations under the Agreement and otherwise mitigate the adverse effects ofthe Force Majeure Event. While the Force Majeure Event continues, the Affected Party shall give the other Parties a monthly update of the information previously submitted. TheAffected Party shall also provide prompt written notice to the other Parties of the cessationof the Force Majeure Event.

24. Amendments.

No change, alteration, revision or modification of the terms and conditions of this Agreement shall be made, and no verbal understanding of the Parties, their officers, agents or employees shall be valid, except through a written amendment to this Agreement duly authorized and executed by the Parties.

25. Remedies Not Exclusive.

The use by any Party of any remedy for the enforcement of this Agreement is not exclusive and shall not deprive the Party using such remedy of, or limit the application of, any other remedy provided by law.

26. Mitigation of Damages.

In all situations arising out of this Agreement, the Parties shall attempt to avoid and minimize the damages resulting from the conduct of another Party.

27. Failure of CPUC Approval.

If this Agreement is not approved by the CPUC in a manner acceptable to the Parties, any Party may, within sixty (60) days after the effective date of the decision or order of the CPUC relating to the approval of this Agreement, give written notice to the other Parties that the Agreement will terminate ten (10) days after receipt of such notice. Those acts and obligations that are to be performed on or after the Execution Date shall be discharged and no Party shall thereafter be obligated to continue to perform this Agreement or any provision hereof. Whether this Agreement is approved by the CPUC in a manner acceptable to the Parties or not, those acts and obligations performed prior to the date of termination shall be final and no party shall have any claim to be restored to its pre-Execution Date status with regard to any of those acts or obligations.

28. Insurance.

The Agency and District will each obtain the applicable Required Insurance, as set forth in Exhibit D. If insurance proceeds fail to satisfy the obligations of the Agency or the District under this Agreement, the District and the Agency will utilize their own resources, including Prop 218 revenue raising capacity, to the extent allowable by law, to satisfy their obligations.

29. No Waiver.

Failure by a Party to insist upon the strict performance of any of the provisions of this Agreement by another Party, irrespective of the length of time for which such failure continues, shall not constitute a waiver of such Party's right to demand strict compliance by such other Party in the future. No waiver by a Party of any default or breach shall affect or alter this Agreement, and each and every covenant, term, and condition hereof shall continue in full force and effect to any existing or subsequent default or breach.

30. Successors in Interest, Transferees, and Assignees.

(a) This Agreement and all the rights and obligations created by this Agreement shall be in full force and effect whether or not any of the Parties to this Agreement have been succeeded by another entity, or had their interests transferred or assigned to another entity, and all rights and obligations created by this Agreement shall be vested and binding on any Party's successor in interest, transferee, or assignee. If the Company, the Agency or the District is succeeded by another entity, it shall assign this Agreement to its successor. If the District ceases to exist, the Agency and the Company shall continue their obligations hereunder in a manner that will substantively comply with the intent of this Agreement. Except as provided in subsection (b) of this Section 30, no succession, assignment or transfer of this Agreement, or any part hereof or interest herein, by a Party shall be valid without the prior written consent of the other Parties, such consent not to be unreasonably withheld.

(b) In the event of the creation of a local governmental agency duly established for the sole purpose of succeeding to, assuming, and performing all obligations and rights of Agency or District created by this Agreement, Agency or District may assign this Agreement and all those obligations and rights to such local governmental agency without consent, written or otherwise, of any other Party.

31. Covenants and Conditions.

All provisions of this Agreement expressed either as covenants or conditions on the part of the

District, Agency, or the Company shall be deemed to be both covenants and conditions.

32. Governing Law.

This Agreement and the rights and obligations of the Parties shall be governed, controlled and interpreted in accordance with the laws of the State of California.

33. Headings.

All headings are for convenience only and shall not affect the interpretation of this Agreement.

34. Construction of Agreement Language.

The provisions of this Agreement shall be construed as a whole according to its common meaning and purpose of providing a public benefit and not strictly for or against any Party. The Agreement shall be construed consistent with the provisions hereof, in order to achieve the objectives and purposes of the Parties. Wherever required by the context, the singular shall include the plural and vice versa, and the masculine gender shall include the feminine or neutral genders or vice versa.

35. Drafting Ambiguities.

This Agreement is the product of negotiation and preparation between the Parties. The Parties and their counsel have had the opportunity to review and revise this Agreement. The Parties waive the provisions of Section 1654 of the Civil Code of California and any other rule of construction to the effect that ambiguities are to be resolved against the drafting Party, and the Parties warrant and agree that the language of this Agreement shall neither be construed against nor in favor of any Party unless otherwise specifically indicated.

36. Partial Invalidity; Severability.

If any provision of this Agreement is held by a court of competent jurisdiction to be invalid, void or unenforceable, the remaining provisions will nevertheless continue in full force without being impaired or invalidated in any way.

37. No Third Party Beneficiaries.

Nothing in this Agreement is intended to create any third Party beneficiaries to the Agreement, and no person or entity other than the Parties and the permitted successors, transferees and assignees of either of them shall be authorized to enforce the provisions of this Agreement.

38. Relationship of the Parties.

The relationship of the Parties to this Agreement shall be that of independent contractors. Each Party shall be solely responsible for any workers compensation, withholding taxes, unemployment insurance, and any other employer obligations associated with the described work or obligations assigned to them under this Agreement.

39. Signing Authority.

The representative of each Party signing this Agreement hereby declares that authority has been obtained to sign on behalf of the Party such person is representing.

40. Further Acts and Assurances.

The Parties agree to execute, acknowledge and deliver any and all additional papers, documents and other assurances, and shall perform any and all acts and things reasonably necessary in connection with the performance of the obligations hereunder and to carry out the intent of the Parties.

41. Opinions and Determinations.

Where the terms of this Agreement provide for action to be based upon opinion, judgment, approval, review or determination of any Party hereto, such terms are not intended to be and shall never be construed as permitting such opinion, judgment, approval, review or determination to be arbitrary, capricious or unreasonable.

42. Interpretation of Conflicting Provisions.

If there is any conflict, discrepancy or inconsistency between the provisions of this Agreement and the provisions of any exhibit or attachment to this Agreement, the provisions of this Agreement shall prevail and control.

43. Integration.

This Agreement, including the exhibits, represent the entire Agreement between the Parties with respect to the subject matter of this Agreement and shall supersede all prior negotiations, representations, or agreements, either written or oral, between the Parties as of the Effective Date.

44. Counterparts.

All signatures need not appear on the same counterpart of this Agreement and all counterparts of this Agreement shall constitute one and the same instrument.

45. Notices.

All notices to a Party required or permitted under this Agreement shall be in writing and shall be deemed delivered (i) when delivered in person; (ii) on the third day after mailing, if mailed, postage prepaid, by registered or certified mail (return receipt requested); or (iii) on the day after mailing if sent by a nationally recognized overnight delivery service which maintains records of the time, place, and recipient of delivery. Notices to the Parties shall be sent to the following addresses or to other such addresses as may be furnished in writing by one Party to the other Parties:

Monterey Peninsula Water Management District
5 Harris Court, Building G
Monterey, CA 93940
Attention: General Manager

Monterey One Water
5 Harris Court, Building D
Monterey, CA 93940
Attention: General Manager

California American Water
Attn: President
655 W. Broadway, Suite 1410
San Diego, CA 92101

SIGNATURE PAGE FOLLOWS

IN WITNESS WHEREOF, the Parties hereto have executed this Agreement as of the date first above written.

MONTEREY ONE WATER,

By: Thomas P. Moore

Printed Name: Thomas P. Moore

Board Chair, Agency Board of Directors

MONTEREY PENINSULA WATER MANAGEMENT DISTRICT,

By:

Printed Name: Mary L. Adams.

Chair, District Board of Directors

CALIFORNIA-AMERICAN WATER COMPANY,

By:

Printed Name: Kevin A. Tilden.

President

EXHIBIT A

Service Area

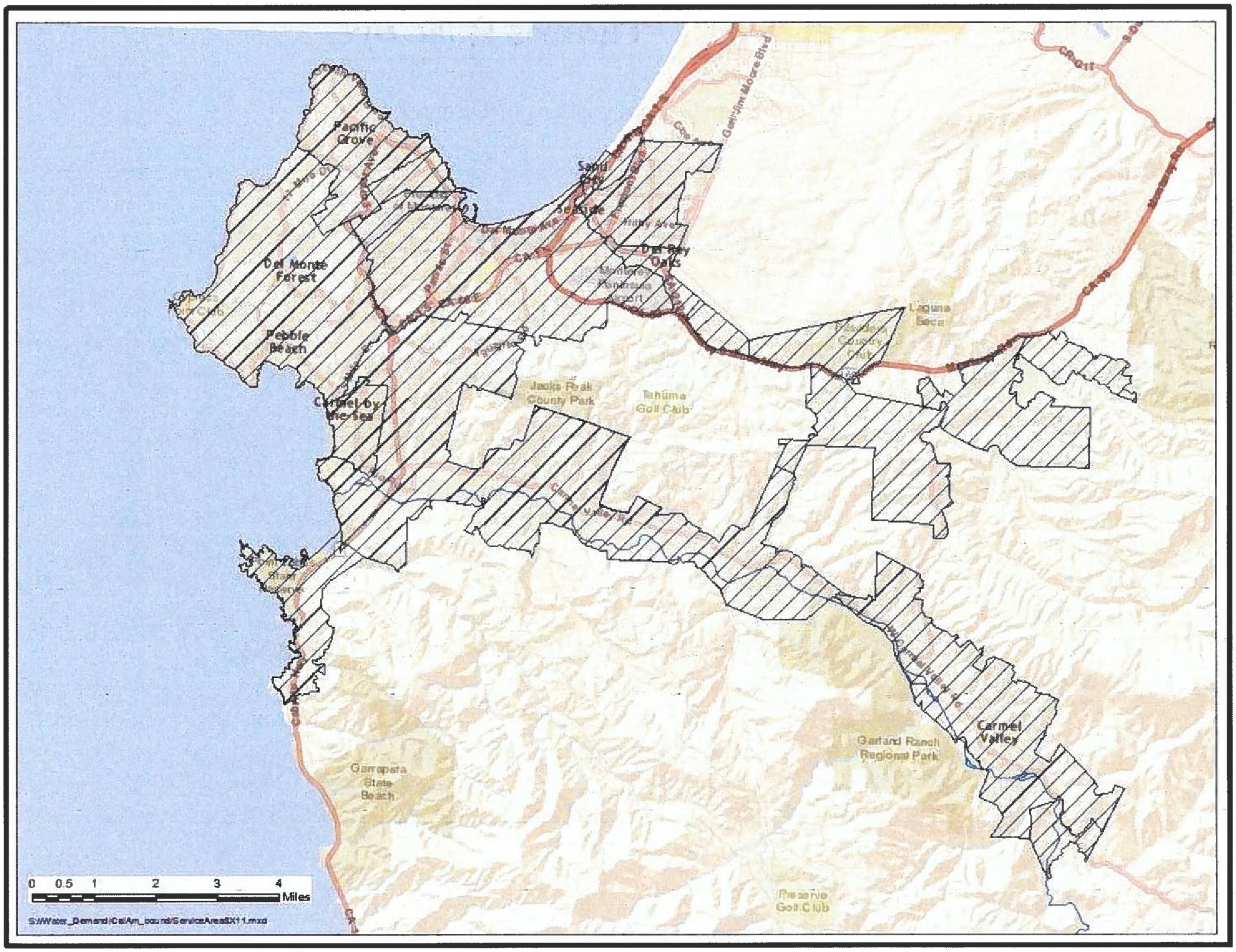

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EXHIBIT B

Description of Project

Source Water Facilities – facilities to enable diversion of new source waters to the existing municipal wastewater collection system and conveyance of those waters as municipal wastewater to the Regional Treatment Plant to increase availability of wastewater for recycling. Modifications would also be made to the existing Salinas Industrial Wastewater Treatment Facility to allow the use of the existing treatment ponds for storage of excess winter source water flows and later delivery to the Regional Treatment Plant for recycling.

AWT Facilities – use of existing primary and secondary treatment facilities at the Regional Treatment Plant, as well as new pre-treatment, advanced water treatment (AWT), product water stabilization, product water pump station, and concentrate disposal facilities.

Product Water Facilities – new pipelines, pipeline capacity rights, booster pump station(s), appurtenant facilities along one of two optional pipeline alignments to move the product water from the Regional Treatment Plant to the Seaside Groundwater Basin injection well facilities.

Injection Facilities – new deep and vadose zone wells to inject Proposed Project product waterinto the Seaside Groundwater Basin, along with associated back-flush facilities, pipelines, electricity/ power distribution facilities, and electrical/motor control buildings.

Description of Expansion

"Expansion" means the Pure Water Monterey groundwater replenishment project expansion, including (a) expansion to AWT Facilities, (b) additional Product Water Facilities, and (c) additional Injection Facilities. The proposed expansion to AWT Facilities will include additions of equipment, pipelines, and appurtenances to the approved and existing buildings and concrete/asphalt areas at the Advanced Water Purification Facility (also referred to herein as AWT Facilities).

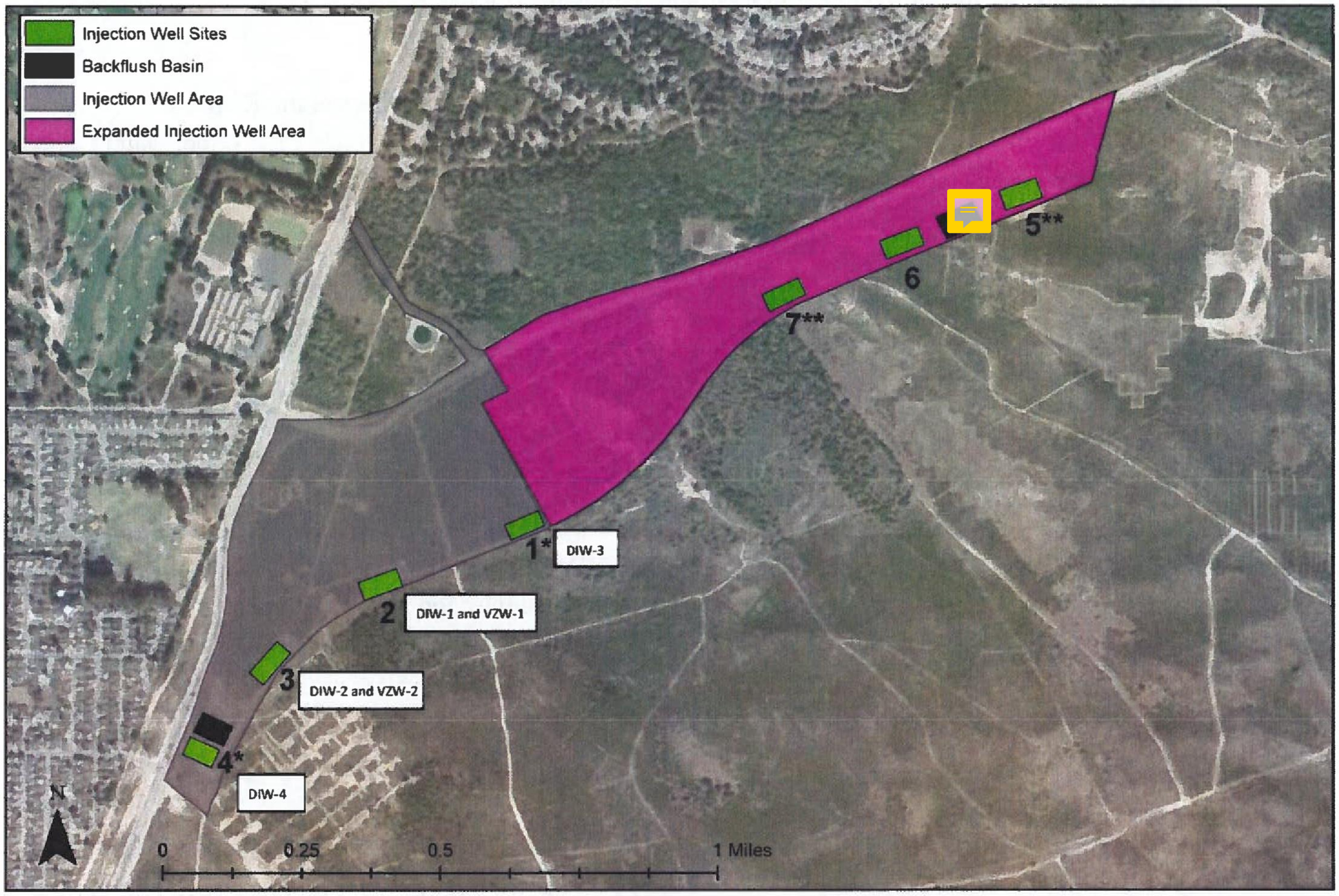
Description of Company Facilities

"Company Facilities" means the necessary facilities funded and constructed by the Company for purposes of supporting water deliveries from the Project and other Company water supplies, including (a) injection/extraction wells and related appurtenances, (b) pipelines and transmission mains, and (c) real property, including up to two extraction wells near Fitch Park on Presidio of Monterey property and two extraction wells just north of the Seaside Middle School, in the City of Seaside, conveyance pipelines serving the extraction wells and interconnecting with the Company distribution system in General Jim Moore Boulevard, and potential treatment facilities.

EXHIBIT C

Delivery Point

AWT Water will be injected into the Seaside Groundwater Basin using existing and new injection wells. Theproposed Injection Well Facilities will be located east of General Jim Moore Boulevard, south of Eucalyptus Road in the City of Seaside, including injection wells (deep injection wells, vadose zone wells, as identified in the figure below), plus monitoring wells, and back-flush facilities.



Well sites 1-4 have been approved and constructed. Well site 6 is the primary site for expansion, but sites 5 and 7 may be made available for redundancy or future replacement.

EXHIBIT D

Required Insurance

As provided in Section 28 of this Agreement, Agency and District shall, to the extent it continues to be available and applicable to the insured risk, obtain and keep in force during the term of this Agreement the following minimum insurance limits and coverage (or greater where required by Applicable Law). Such coverage will be in place not later than the inception of the covered activity, or such time as the Agency's and the District's insurable interest exists.

The cost of Project insurance obtained pursuant to this Exhibit is a Project Operation and Maintenance Expense as defined in Section 2 of this Agreement.

Upon request, Agency and District will provide Company with a certificate of insurance or memorandum of coverage as to any Project insurance and/or complete copies of policies.

Company shall be provided at least 30 days' written notification of cancellation, material reduction in coverage or reduction in limits.

Project insurance may be issued by a public agency Joint Powers Authority Program or insurance companies authorized to do business in California with a current A. M. Best rating of A or better.

All commercial general liability insurance, including completed operations-products liability, automobile liability, and pollution liability insurance obtained pursuant to this Agreement shall designate Company, its parent and affiliates, their respective directors, officers, employees and agents, as additional covered parties. All such insurance should be primary and non-contributory, and is required to respond and pay prior to any other insurance or self-insurance available to Company. In addition to the liability limits available, such insurance will pay on behalf or will indemnify Company for defense costs. Any other coverage available to Companyapplies on a contingent and excess basis. All such insurance shall include appropriate clauses pursuant to which the insurance companies shall waive their rights of subrogation against Company, its parent and affiliates, their respective directors, officers, employees and agents.

Agency shall require that the contractors and subcontractors of all tiers as appropriate provide insurance during the pre-construction and construction (as covered activities begin) of the AWT Facilities as described in "Pure Water Monterey – Insurance Requirements for Construction and Design Professional Contracts," attached to this Exhibit D as Attachment 1. Approval of any deviation or exception from these insurance requirements resides solely with the Agency.

Coverages:

i. The Agency will provide coverage as follows:

(a) General liability insurance, including coverage for auto, errors and omissions and employment practices, and for the Water Delivery Guarantee, Water Availability Guarantee, and Water Treatment Guarantee at Sections 12, 13, and 14, respectively, of this Agreement. Total general and excess liability coverage limits shall be no less than $15,000,000 per occurrence.

(b) "All Risk" Property Insurance (including coverage for Builders' Risk, with additional coverage for loss or damage by water, earthquake, flood, collapse, and subsidence) with a total insured value equal to replacement cost of the AWT Facilities during the term of this Agreement

(c) Cyber Liability Insurance with $2,000,000 coverage limits for first and third party limits.

(d) (1) Public Entity Pollution Liability (claims made and reported) with coverage limits in the amounts of $25,000,000 policy aggregate and $2,000,000 per pollution condition with a $75,000 per pollution condition retention; (2) Pollution & Remediation Legal Liability with coverage limits in the amounts of $1,000,000 each pollution condition and $5,000,000 aggregate liability limits including a self-insured retention not to exceed $25,000 each pollution condition; and (3) TankAdvantage Pollution Liability with coverage limits in the amounts of $1,000,000 each claim and $2,000,000 aggregate.

(e) Workers' Compensation/Employers' Liability. Workers' Compensation and Employer's Liability insurance and excess insurance policy(s) shall be written on a policy form providing workers' compensation statutory benefits as required by California law. Employers' liability limits shall be no less than one million dollars ($1,000,000) per accident or disease.

ii. The District will provide coverage as follows:

(a) General Liability Coverage: $10,000,000 per Occurrence
Personal injury and Property Damage Coverage

(b) Automobile Liability Coverage: $10,000,000 per Occurrence
Personal Injury and Property Damage Coverage

(c) Workers' Compensation Coverage
    A. Statutory Workers Compensation Coverage;
    B. Employers' Liability Coverage: $5,000,000 each Occurrence

(d) Public Officials' and Employees Errors and Omissions: $10,000,000 per Occurrence

(e) Property Coverage: $1,000,000,000 (pooled limit)
Includes Fire, Theft and Flood Coverage with property replacement values

(f) Public Entity Pollution Liability with coverage limits in the amounts of $10,000,000 per occurrence with a not-to-exceed $75,000 per-pollution-condition retention; and (2) Pollution & Remediation Legal Liability with coverage limits in the amounts of $10,000,000 per occurrence including a self-insured retention not to exceed $25,000 each pollution condition.

Attachment 1

Pure Water Monterey
Proposed Insurance Requirements for Construction and Design Professional Contracts

Contractors and design professionals (as that term is used in California Civil Code §2782.8) shall procure and maintain for the duration of the contract, and for twelve (12) years thereafter, insurance against claims for injuries to persons or damages to property which may arise from or in connection with the performance of the work hereunder by the contractor or design professional,his/her agents, representatives, employees, or subcontractors.[1]

MINIMUM SCOPE AND LIMIT OF INSURANCE

Coverage shall be at least as broad as:

1. **Commercial General Liability (CGL):** Insurance Services Office Form CG 00 01 covering CGL on an "occurrence" basis, including products and completed operations, property damage, bodily injury and personal & advertising injury with limits no less than $5,000,000 per occurrence. If a general aggregate limit applies, either the general aggregatelimit shall apply separately to this project/location or the general aggregate limit shall be twice the required occurrence limit.

2. **Automobile Liability:** Insurance Services Office Form Number CA 0001 covering Code 1 (any auto), with limits no less than $5,000,000 per accident for bodily injury and property damage.

3. **Workers' Compensation** insurance as required by the State of California, with Statutory Limits, and Employers' Liability insurance with a limit of no less than $1,000,000 per accident for bodily injury or disease.

4. **Builder's Risk (Course of Construction)** insurance utilizing an "All Risk" (Special Perils) coverage form, with limits equal to the completed value of the project and no coinsurance penalty provisions.

5. **Surety Bonds** as described below.

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[1] The coverages herein are understood to be representative only and the Agency and District retain the right to modify the insurance and indemnity requirements based upon the scope of services for any engagement.

6. **Professional Liability** (for all design professionals and contractors for design/build projects), with limits no less than $2,000,000 per occurrence or claim, and $4,000,000 policy aggregate.

7. **Contractors' Pollution Legal Liability and Errors and Omissions** (if project involves environmental hazards) with limits no less than $2,000,000 per occurrence or claim, and $4,000,000 policy aggregate.

If the contractor or design professional maintains higher limits than the minimums shown above, the Entity[2] requires and shall be entitled to coverage for the higher limits maintained by the contractor or design professional. Any available insurance proceeds in excess of the specified minimum limits of insurance and coverage shall be available to the Entity.

Deductibles and Self-Insured Retentions

Any deductibles or self-insured retentions must be declared to and approved by the Entity. At the option of the Entity, either: the contractor shall cause the insurer to reduce or eliminate such deductibles or self-insured retentions as respects the Entity, its officers, officials, employees, and volunteers; or the contractor or design professional shall provide a financial guarantee satisfactory to the Entity guaranteeing payment of losses and related investigations, claim administration, and defense expenses.

The insurance policies are to contain, or be endorsed to contain, the following provisions[3]:

1. The Entity, its officers, officials, employees, and volunteers are to be covered as additional insureds on the CGL policy with respect to liability arising out of with respect to liability arising out of work or operations performed by or on behalf of the Contractor including materials, parts, or equipment furnished in connection with such work or operations and automobiles owned, leased, hired, or borrowed by or on behalf of the Contractor. General liability coverage can be provided in the form of an endorsement to the Contractor's insurance (at least as broad as ISO Form CG 20 10 10 93, CG 00 01 11 85 or both CG 20 10 10 01 and CG 20 37 10 01 forms if later revisions used).

2. For any claims related to this project, the Contractor's insurance coverage shall be primary insurance as respects the Entity, its officers, officials, employees, and volunteers. Any insurance or self-insurance maintained by the Entity, its officers, officials, employees, or volunteers shall be excess of the Contractor's insurance and shall not contribute with it.

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[2] The term "Entity" as used herein means the Agency or the District.

[3] The term "Contractor" as used herein also means Design Professional in context of an agreement for services by a design professional as that term is used in CA CC 2782.8.

3. Each insurance policy required by this clause shall provide at least thirty (30) days' written notification of cancellation, material reduction in coverage or reduction in available limits.

Builder's Risk (Course of Construction) Insurance

Contractor may submit evidence of Builder's Risk insurance in the form of Course of Construction coverage. Such coverage shall name the Entity as a loss payee as their interest may appear.

If the project does not involve new or major reconstruction, at the option of the Entity, an Installation Floater may be acceptable. For such projects, a Property Installation Floater shall be obtained that provides for the improvement, remodel, modification, alteration, conversion or adjustment to existing buildings, structures, processes, machinery and equipment. The Property Installation Floater shall provide property damage coverage for any building, structure, machinery or equipment damaged, impaired, broken, or destroyed during the performance of the Work, including during transit, installation, and testing at the Entity's site.

Claims Made Policies

If any coverage required is written on a claims-made coverage form:

1. The retroactive date must be shown, and this date must be before the execution date of the contract or the beginning of contract work.

2. Insurance must be maintained and evidence of insurance must be provided for at least twelve (12) years after completion of contract work.

3. If coverage is canceled or non-renewed, and not replaced with another claims-made policy form with a retroactive date prior to the contract effective, or start of work date, the Contractor must purchase extended reporting period coverage for a minimum of five (5) years after completion of contract work.

4. A copy of the claims reporting requirements must be submitted to the Entity for review.

5. If the services involve lead-based paint or asbestos identification/remediation, the Contractors Pollution Liability policy shall not contain lead-based paint or asbestos exclusions. If the services involve mold identification/remediation, the Contractors Pollution Liability policy shall not contain a mold exclusion, and the definition of Pollution shall include microbial matter, including mold.

Acceptability of Insurers

Insurance is to be placed with insurers authorized to do business in California with a current A.M. Best rating of no less than A: VII, unless otherwise acceptable to the Entity.

Waiver of Subrogation

Contractor hereby agrees to waive rights of subrogation which any insurer of Contractor may acquire from Contractor by virtue of the payment of any loss. Contractor agrees to obtain any endorsement that may be necessary to affect this waiver of subrogation. The Workers' Compensation policy shall be endorsed with a waiver of subrogation in favor of the Entity for all work performed by the Contractor, its employees, agents and subcontractors.

Verification of Coverage

Contractor shall furnish the Entity with original certificates and amendatory endorsements, or copies of the applicable insurance language, effecting coverage required by this contract. All certificates and endorsements are to be received and approved by the Entity before work commences. However, failure to obtain the required documents prior to the work beginning shall not waive the Contractor's obligation to provide them. The Entity reserves the right to require complete, certified copies of all required insurance policies, including endorsements, required by these specifications, at any time.

Subcontractors

Contractor shall require and verify that all subcontractors maintain insurance meeting all the requirements stated herein, and Contractor shall ensure that Entity is an additional insured on insurance required from subcontractors. For CGL coverage subcontractors shall provide coverage with a format least as broad as CG 20 38 04 13.

Surety Bonds

Contractor shall provide the following Surety Bonds:

1. Bid bond
2. Performance bond
3. Payment bond
4. Maintenance bond

The Payment Bond and the Performance Bond shall be in a sum equal to the contract price. If the Performance Bond provides for a one-year warranty a separate Maintenance Bond is not necessary. If the warranty period specified in the contract is for longer than one year a Maintenance Bond equal to 10% of the contract price is required. Bonds shall be duly executed by a responsible corporate surety, authorized to issue such bonds in the State of California and secured through an authorized agent with an office in California.

Special Risks or Circumstances

Entity reserves the right to modify these requirements, including limits, based on the nature of the risk, prior experience, insurer, coverage, or other circumstances.

Hold Harmless - Contractor

To the fullest extent permitted by law, Contractor shall hold harmless, immediately defend, and indemnify Entity and its officers, officials, employees, and volunteers from and against all claims, damages, losses, and expenses including attorney fees arising out of the performance of the work described herein, caused in whole or in part by any negligent act or omission of the Contractor, any subcontractor, anyone directly or indirectly employed by any of them, or anyone for whose acts any of them may be liable, except to the extent caused by the active negligence, sole negligence, or willful misconduct of the Entity.

Hold Harmless – Design Professional

To the fullest extent permitted by law, Design Professional shall hold harmless, immediately defend, and indemnify Entity and its officers, officials, employees, and volunteers from and against all claims, damages, losses, and expenses including attorney fees that arise out of, pertain to, or relate to the negligence, recklessness, or willful misconduct of the Design Professional, or its employees, agents or subcontractors, except to the extent caused by the active negligence, sole negligence, or willful misconduct of the Entity.