THE
Water
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WATEREUSE®

WRF/WateReuse Webcast

Advancing the Seawater Desalination Knowledge Base

March 14, 2019

Housekeeping Items

- Submit questions through the question box at any time! We will do a Q&A near the end of the webcast.
- Survey at the end of the webcast.
- Slides and a recording of the webcast will be available at www.waterrf.org.

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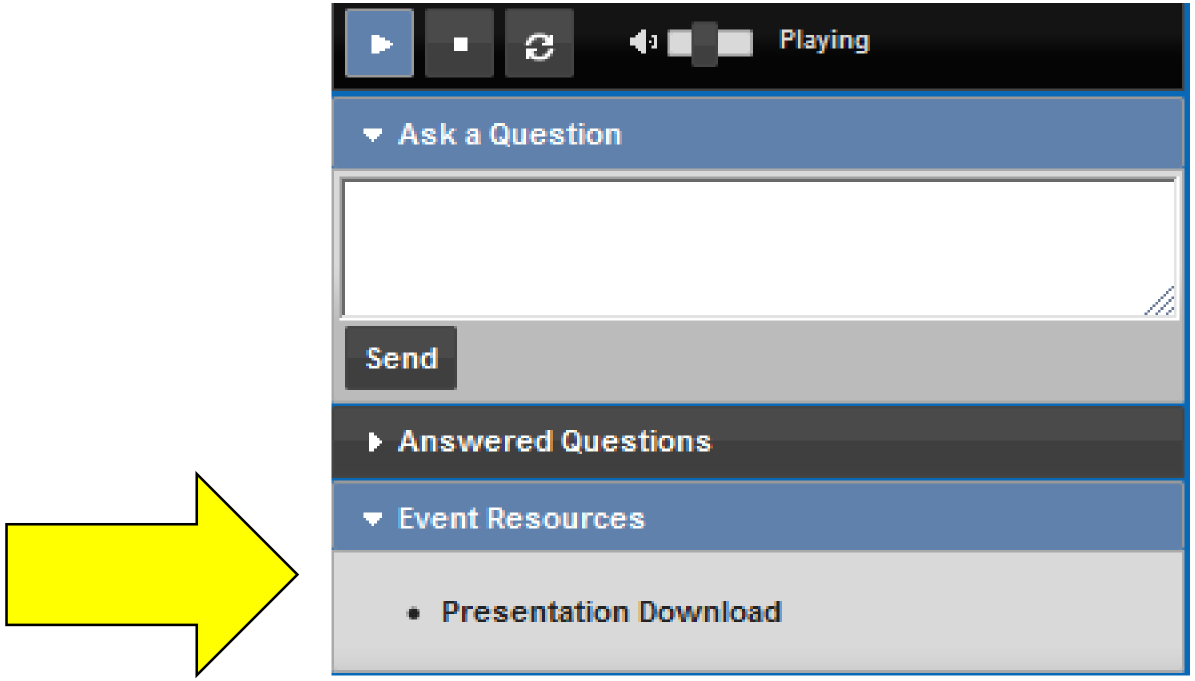
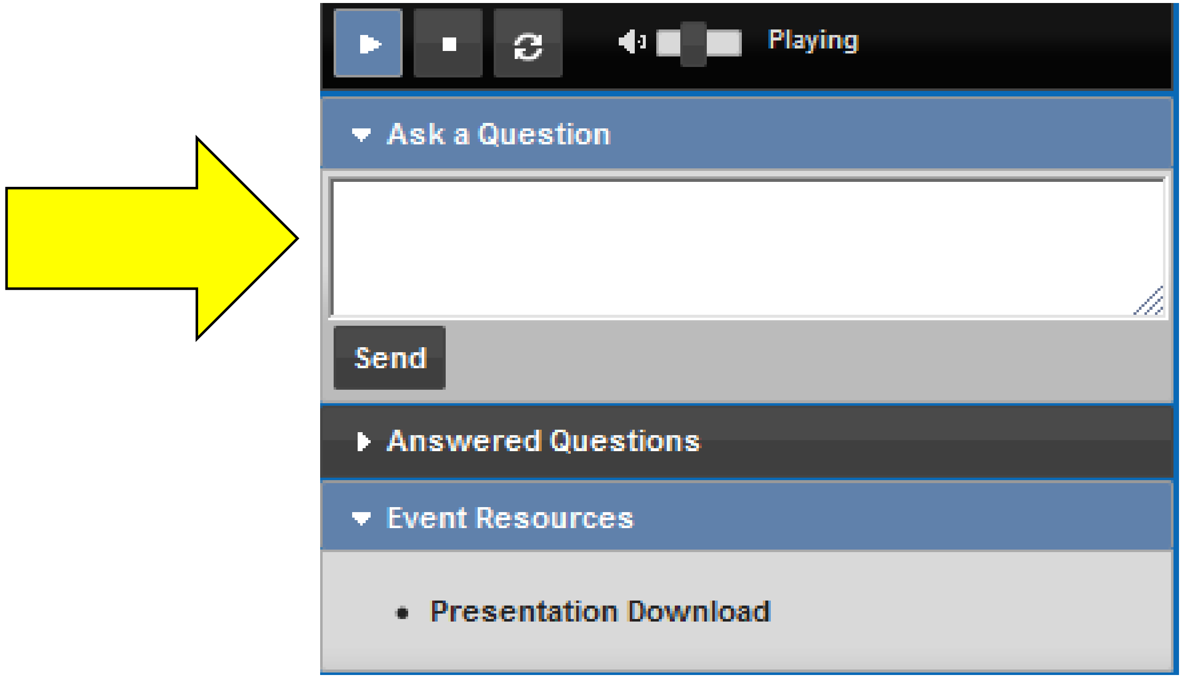


Slides and recording will be available to WRF subscribers WITHIN 24 hours after the webcast

Input your webinar questions here



Q&A at end of webinar

Webcast Agenda

Topic	**Speaker**	
Welcome, Introductions	Kristan VandenHeuvel, WRF	10 min
Pretreatment for Seawater Reverse Osmosis: Existing Plant Performance and Selection Guidance (Desal-14-07/4763)	Joe Jacangelo, Stantec	25 min
Carlsbad Desalinated Seawater Integration Study (Desal-15-06/4773)	Brent Alspach, Arcadis	25 min
Question and Answer	Kristan VandenHeuvel, WRF	30 min

Pretreatment for Seawater Reverse Osmosis: Existing Plant Performance and Selection Guidance

Joseph G. Jacangelo, PhD, REHS
Nikolay Voutchkov, PhD, PE, BCEE
Mohammad Badruzzaman, PhD, PE BCEE
Lauren A Weinrich, PhD

Presentation

- Background
- Research Approach
- Full-Scale Plant Questionnaire and Interview/Site Visit Results
- Pretreatment Planning Tool

Drivers for this Study

- Pretreatment is key to successful operation of seawater desalination.
- Long-term reliability of the downstream RO membranes impacted by the pretreatment systems has not been systematically reviewed and documented for full-scale plants.
- Influence of non-water quality parameters or non-process factors on the selection of the pretreatment systems has not been reported.

Parameter	Recommended Maximum Value
Turbidity	0.5 NTU
Total organic carbon (TOC)	2 mg/L
Iron	0.1 mg/L
Manganese	0.05 mg/L
Free chlorine	0.1 mg/L
Oil and grease	0.1 mg/L
SDI15 minutes	3
VOC	In mg/L range

Source: AMTA, 2012

Research Objectives

- Evaluate the impact of feed water quality on performance of pretreatment technologies and downstream RO processes.

- Collect full-scale data on the performance of various pretreatment technologies and operational data on RO process with pretreatment technology.

- More perspicuously identify and assess the criteria used for selecting pretreatment technologies at full-scale facilities.

- Based on information obtained, develop a tool that can provide guidance on pretreatment process selection and design.

Approa

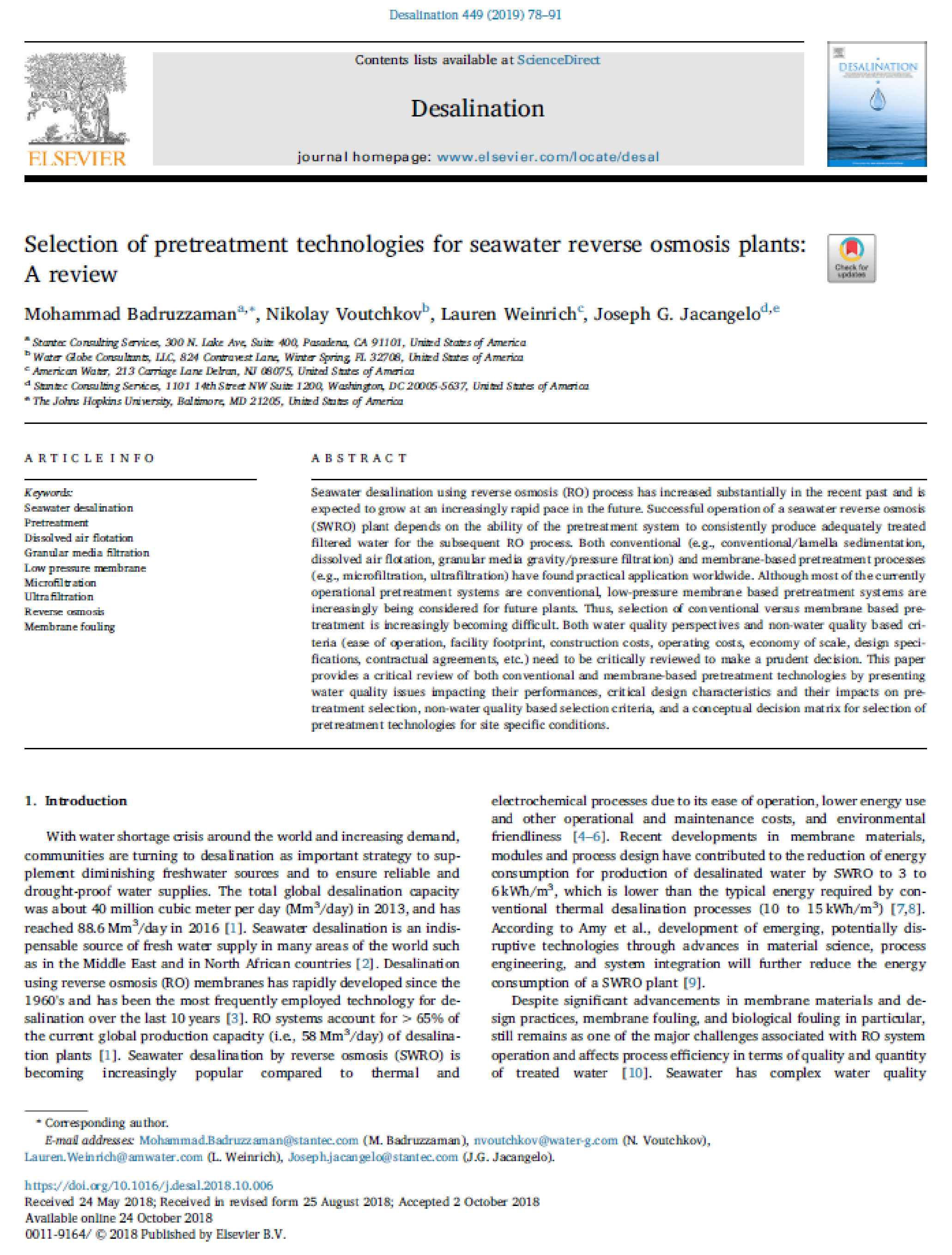
Task 1

Literature Review

Task 3

Facility

udits/Interview



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Selection of pretreatment technologies for seawater reverse osmosis plants: A review

Mohammad Badruzzaman[a,*], Nikolay Voutchkov[b], Lauren Weinrich[c], Joseph G. Jacangelo[d,e]

[a] Stantec Consulting Services, 300 N. Lake Ave, Suite 400, Pasadena, CA 91101, United States of America
[b] Water Globe Consultants, LLC, 824 Contravest Lane, Winter Spring, FL 32708, United States of America
[c] American Water, 213 Carriage Lane Delran, NJ 08075, United States of America
[d] Stantec Consulting Services, 1101 14th Street NW Suite 1200, Washington, DC 20005-5637, United States of America
[e] The Johns Hopkins University, Baltimore, MD 21205, United States of America

ARTICLE INFO

Keywords:
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Pretreatment
Dissolved air flotation
Granular media filtration
Low pressure membrane
Microfiltration
Ultrafiltration
Reverse osmosis
Membrane fouling

ABSTRACT

Seawater desalination using reverse osmosis (RO) process has increased substantially in the recent past and is expected to grow at an increasingly rapid pace in the future. Successful operation of a seawater reverse osmosis (SWRO) plant depends on the ability of the pretreatment system to consistently produce adequately treated filtered water for the subsequent RO process. Both conventional (e.g., conventional/lamella sedimentation, dissolved air flotation, granular media gravity/pressure filtration) and membrane-based pretreatment processes (e.g., microfiltration, ultrafiltration) have found practical application worldwide. Although most of the currently operational pretreatment systems are conventional, low-pressure membrane based pretreatment systems are increasingly being considered for future plants. Thus, selection of conventional versus membrane based pretreatment is increasingly becoming difficult. Both water quality perspectives and non-water quality based criteria (ease of operation, facility footprint, construction costs, operating costs, economy of scale, design specifications, contractual agreements, etc.) need to be critically reviewed to make a prudent decision. This paper provides a critical review of both conventional and membrane-based pretreatment technologies by presenting water quality issues impacting their performances, critical design characteristics and their impacts on pretreatment selection, non-water quality based selection criteria, and a conceptual decision matrix for selection of pretreatment technologies for site specific conditions.

1. Introduction

With water shortage crisis around the world and increasing demand, communities are turning to desalination as important strategy to supplement diminishing freshwater sources and to ensure reliable and drought-proof water supplies. The total global desalination capacity was about 40 million cubic meter per day (Mm^3/day) in 2013, and has reached 88.6 Mm^3/day in 2016 [1]. Seawater desalination is an indispensable source of fresh water supply in many areas of the world such as in the Middle East and in North African countries [2]. Desalination using reverse osmosis (RO) membranes has rapidly developed since the 1960's and has been the most frequently employed technology for desalination over the last 10 years [3]. RO systems account for > 65% of the current global production capacity (i.e., 58 Mm^3/day) of desalination plants [1]. Seawater desalination by reverse osmosis (SWRO) is becoming increasingly popular compared to thermal and electrochemical processes due to its ease of operation, lower energy use and other operational and maintenance costs, and environmental friendliness [4–6]. Recent developments in membrane materials, modules and process design have contributed to the reduction of energy consumption for production of desalinated water by SWRO to 3 to 6 kWh/m^3, which is lower than the typical energy required by conventional thermal desalination processes (10 to 15 kWh/m^3) [7,8]. According to Amy et al., development of emerging, potentially disruptive technologies through advances in material science, process engineering, and system integration will further reduce the energy consumption of a SWRO plant [9].

Despite significant advancements in membrane materials and design practices, membrane fouling, and biological fouling in particular, still remains as one of the major challenges associated with RO system operation and affects process efficiency in terms of quality and quantity of treated water [10]. Seawater has complex water quality

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* Corresponding author.
E-mail addresses: Mohammad.Badruzzaman@stantec.com (M. Badruzzaman), nvoutchkov@water-g.com (N. Voutchkov), Lauren.Weinrich@amwater.com (L. Weinrich), Joseph.jacangelo@stantec.com (J.G. Jacangelo).

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Apprc

Task 1

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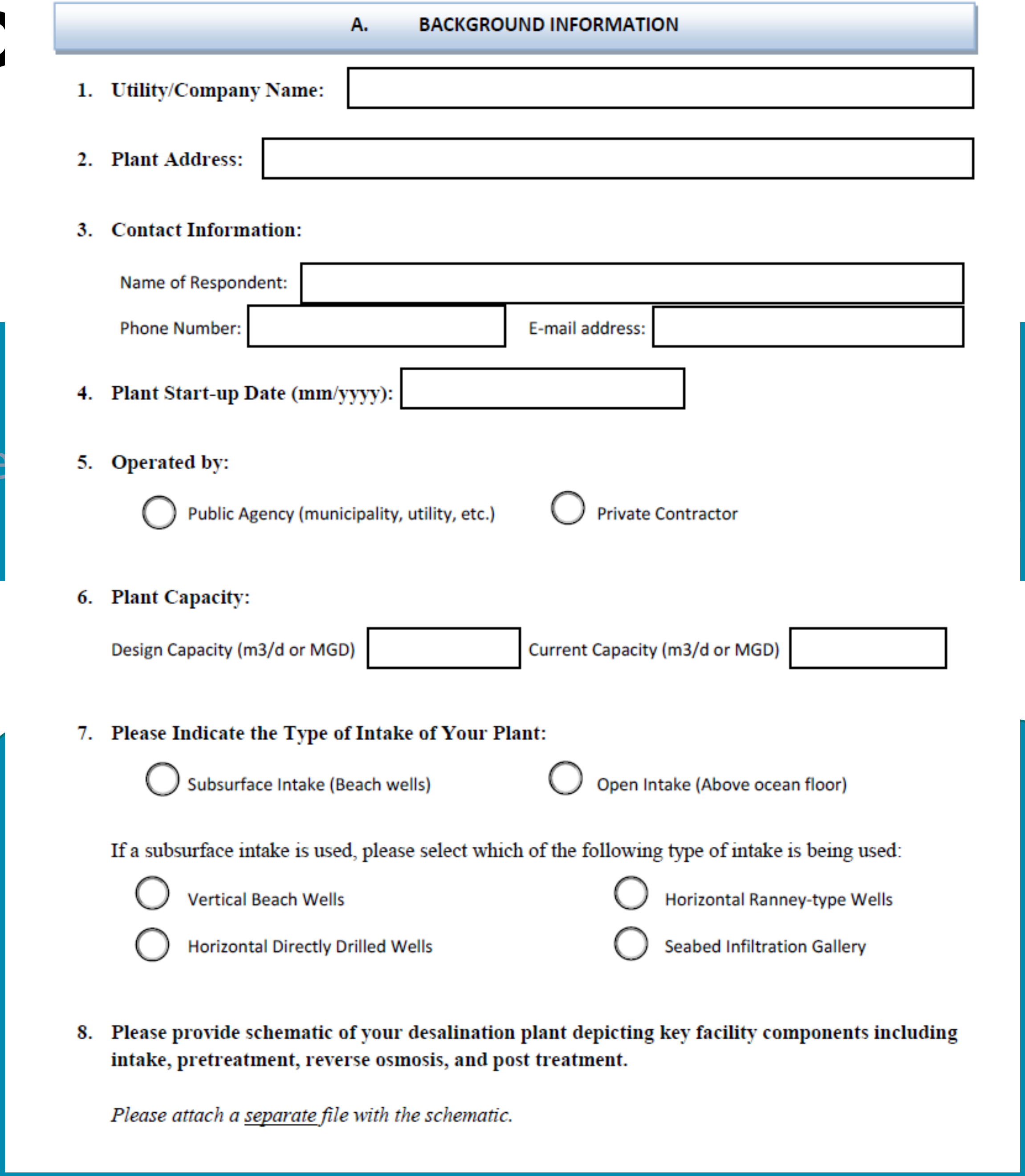
Facility

its/Interview



A. BACKGROUND INFORMATION

1. **Utility/Company Name:** ______

2. **Plant Address:** ______

3. **Contact Information:**

Name of Respondent: ______

Phone Number: ______ E-mail address: ______

4. **Plant Start-up Date (mm/yyyy):** ______

5. **Operated by:**

○ Public Agency (municipality, utility, etc.) ○ Private Contractor

6. **Plant Capacity:**

Design Capacity (m3/d or MGD) ______ Current Capacity (m3/d or MGD) ______

7. **Please Indicate the Type of Intake of Your Plant:**

○ Subsurface Intake (Beach wells) ○ Open Intake (Above ocean floor)

If a subsurface intake is used, please select which of the following type of intake is being used:

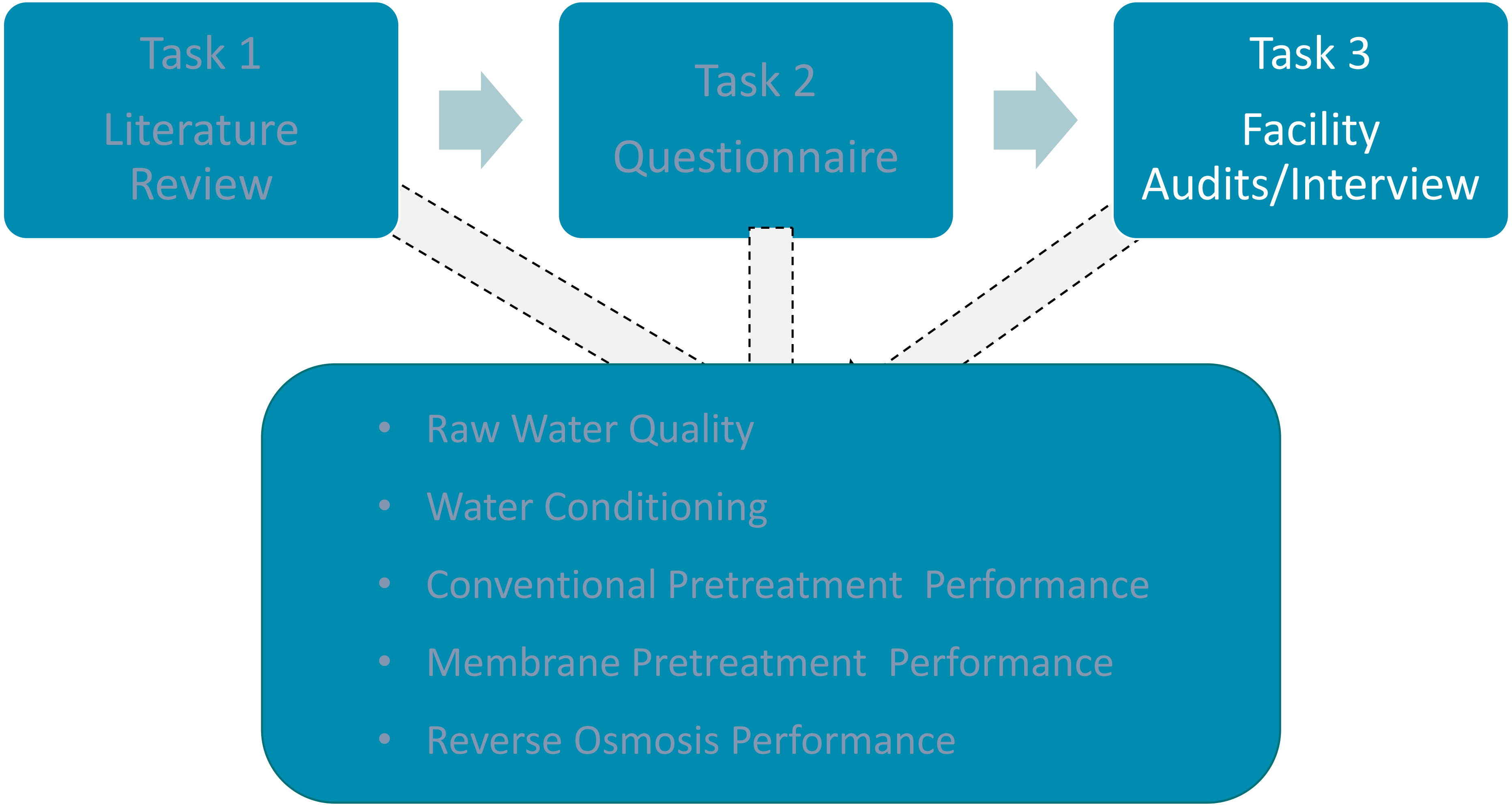
○ Vertical Beach Wells ○ Horizontal Ranney-type Wells

○ Horizontal Directly Drilled Wells ○ Seabed Infiltration Gallery

8. **Please provide schematic of your desalination plant depicting key facility components including intake, pretreatment, reverse osmosis, and post treatment.**

Please attach a separate file with the schematic.

Approach to Study



Task 1

Literature Review

Task 2

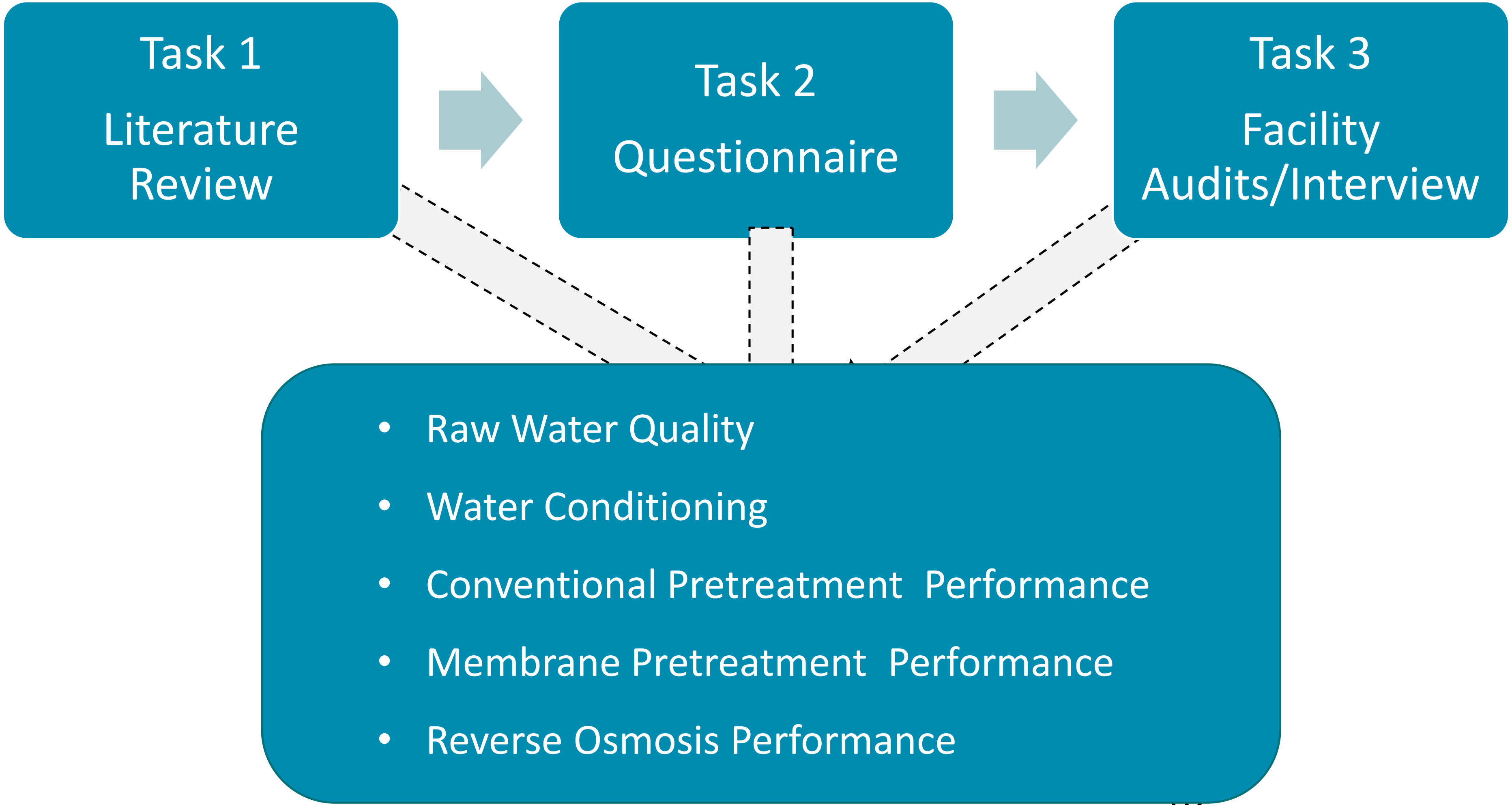
Questionnaire

Task 3

Facility Audits/Interview

- Raw Water Quality
- Water Conditioning
- Conventional Pretreatment Performance
- Membrane Pretreatment Performance
- Reverse Osmosis Performance

Approach to Study



Task 1

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Facility Audits/Interview

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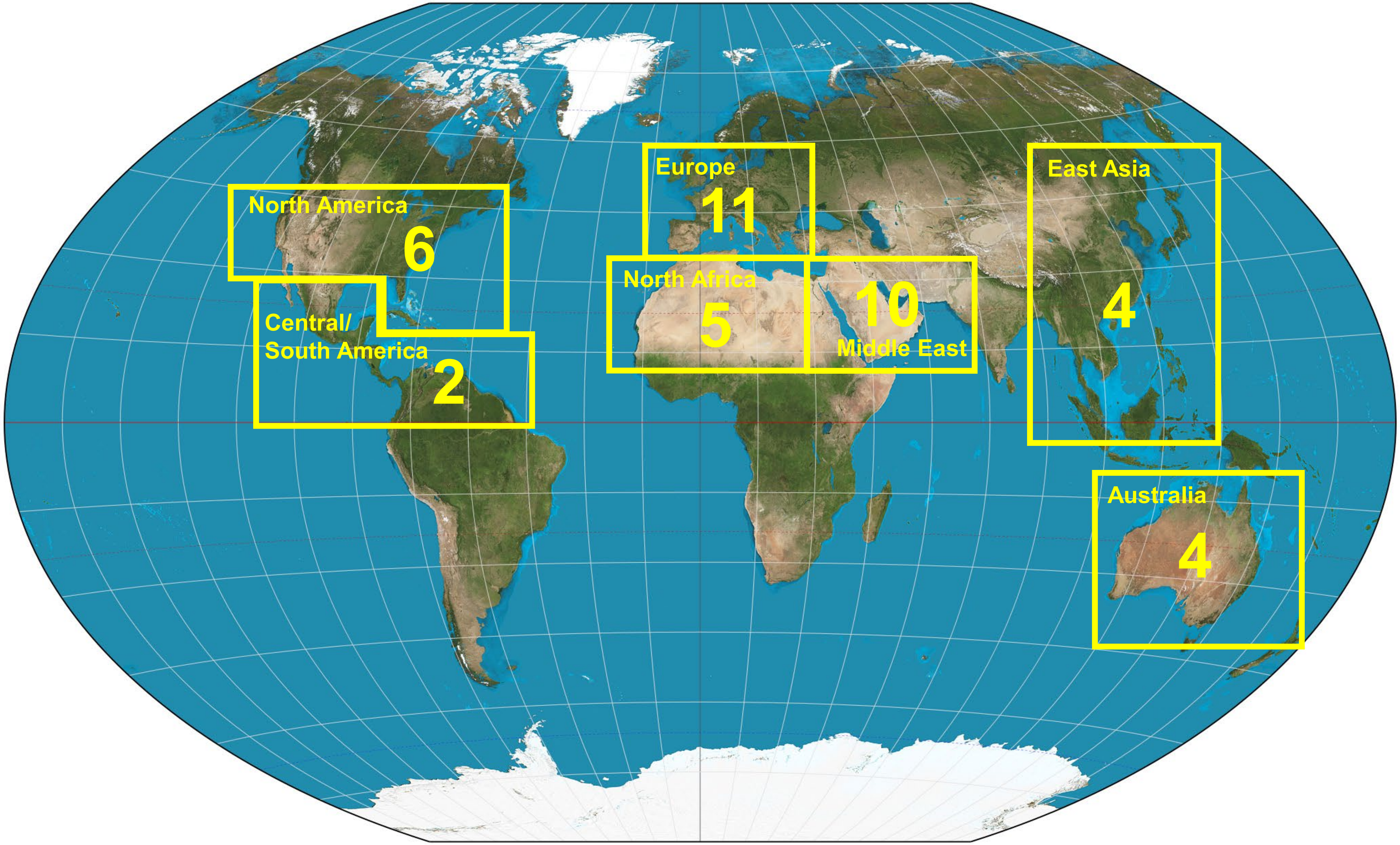
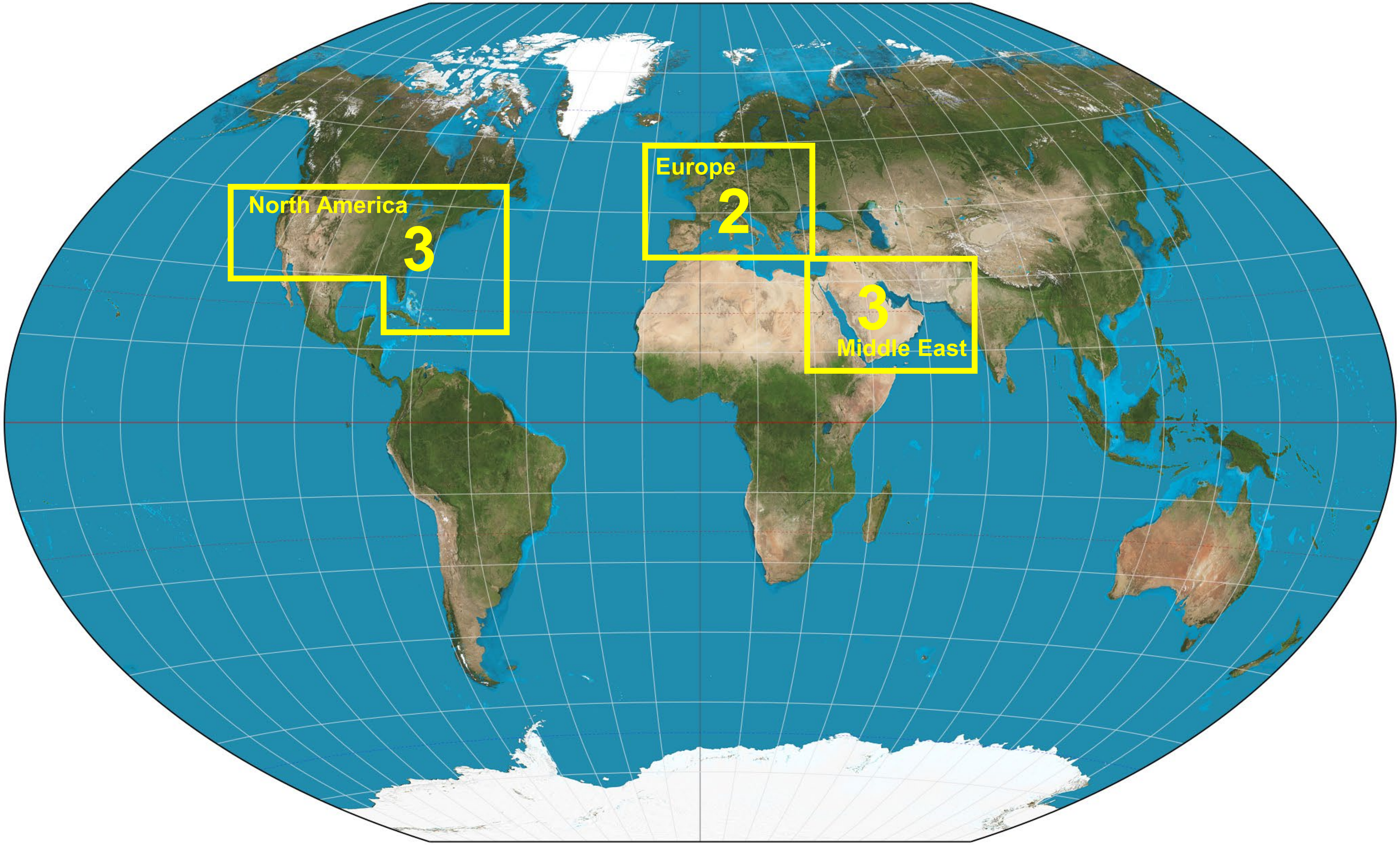
- Membrane Pretreatment Performance
- Reverse Osmosis Performance

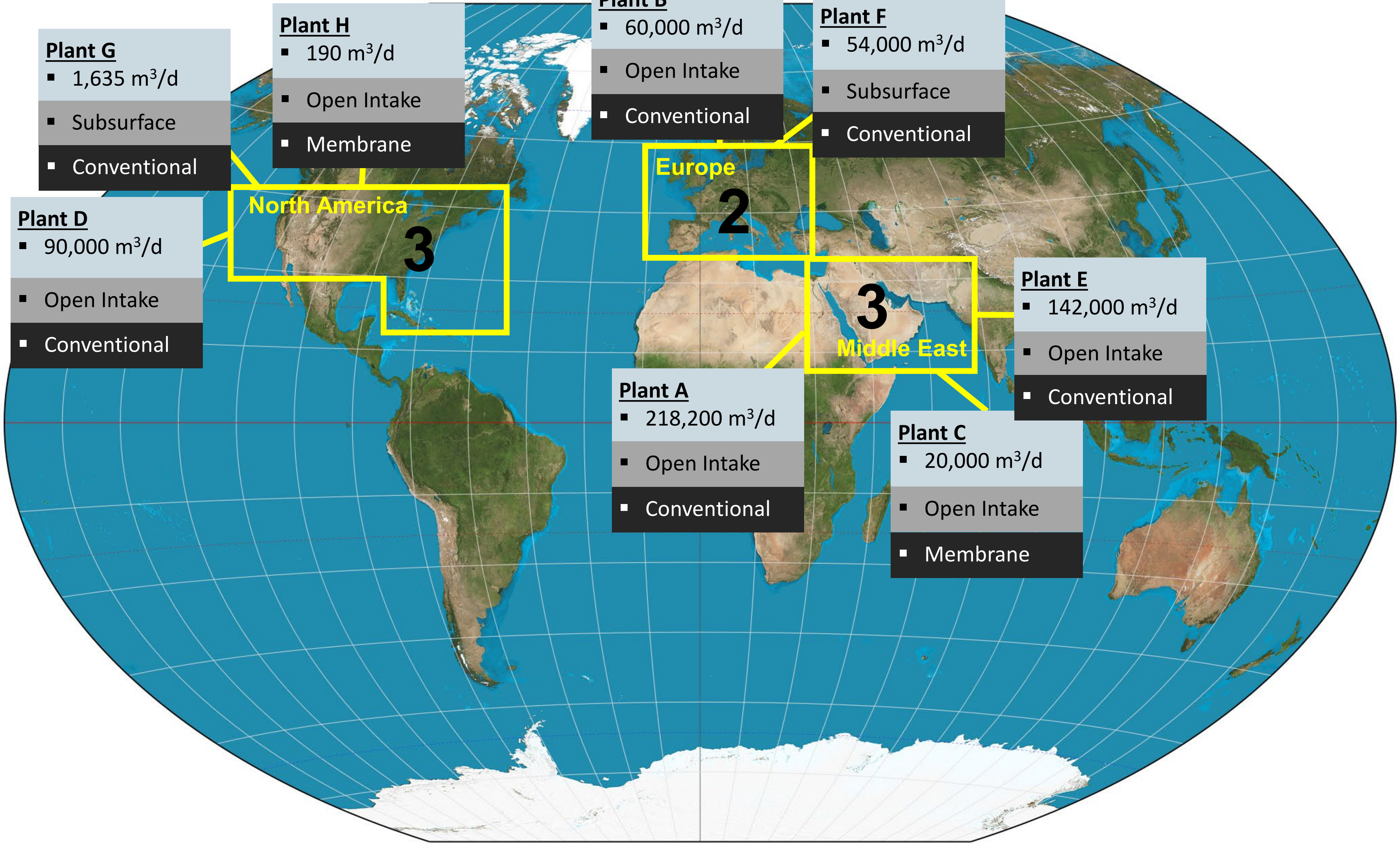
Forty-Two SWRO Plants Were Considered



Eight Plants Selected To Participate in Study



Description of Plants Participating in Study



Plant G
- 1,635 m^3/d
- Subsurface
- Conventional

Plant H
- 190 m^3/d
- Open Intake
- Membrane

Plant B
- 60,000 m^3/d
- Open Intake
- Conventional

Plant F
- 54,000 m^3/d
- Subsurface
- Conventional

Plant D
- 90,000 m^3/d
- Open Intake
- Conventional

Plant E
- 142,000 m^3/d
- Open Intake
- Conventional

Plant A
- 218,200 m^3/d
- Open Intake
- Conventional

Plant C
- 20,000 m^3/d
- Open Intake
- Membrane

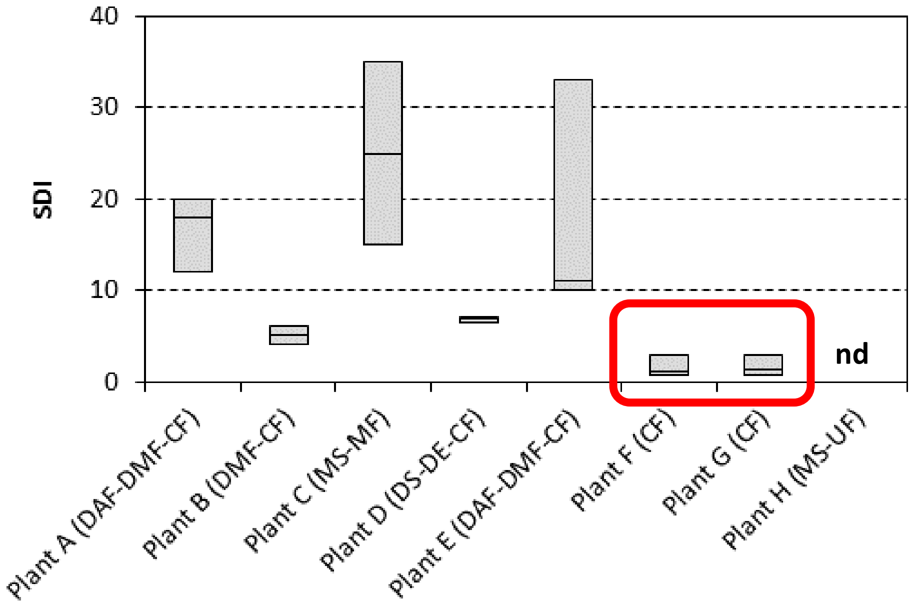
Pretreatment Processes of Seawater Desalination Plants Participating in Study

Plant ID	Pretreatment Category	Pretreatment Processes
Plant A (DAF+DMF+CF)	Conventional	Dissolved Air Flotation - Single Stage Dual Media Pressure Filter - 5 micron Cartridge Filter
Plant B (DMF+CF)	Conventional	Single Stage Dual Media Gravity Filter - 5 micron Cartridge Filter
Plant C (MS+MF)	Membrane	Microscreen - Microfiltration
Plant D (DynaSand® +DE+CF)	Conventional	Dynasan® Filtration - Diatomaceous Earth Filtration - 5 micron Cartridge Filter
Plant E (DAF+DMF+CF)	Conventional	Dissolved Air Flotation - Single Stage Dual Media Gravity Filter- 5 micron Cartridge
Plant F (CF)	Conventional	5 micron Cartridge Filter
Plant G (CF)	Conventional	5 micron Cartridge Filter
Plant H (MS+UF)	Membrane	Microscreen - Ultrafiltration

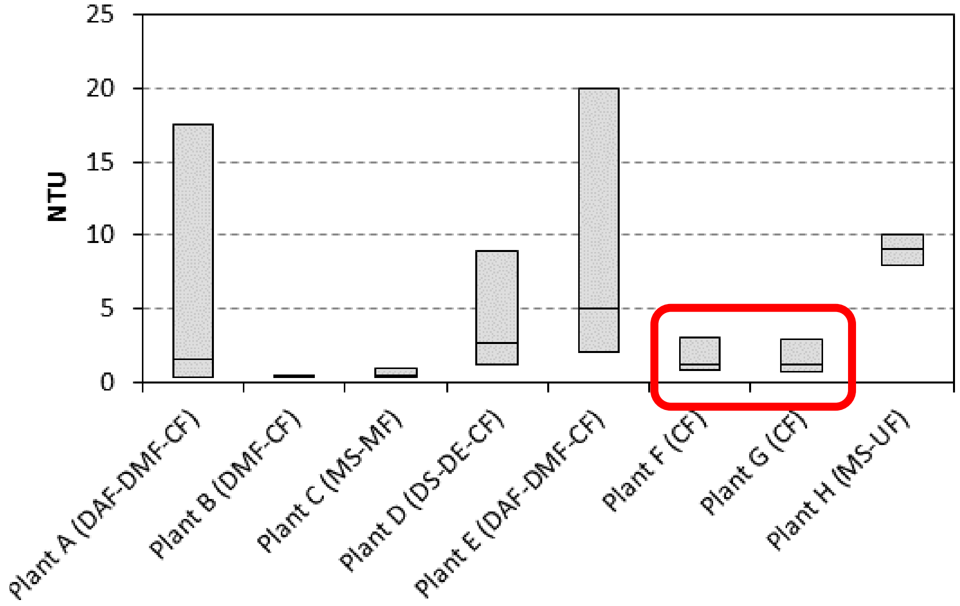
Water Quality

Feed Water Quality Parameters (SDI and Turbidity)

Subsurface Intakes

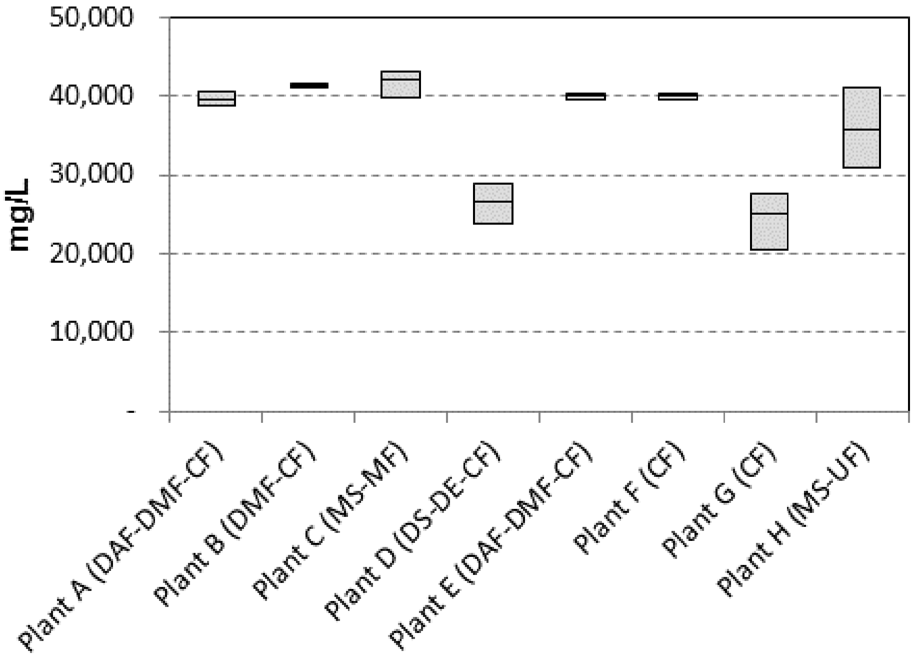


SDI

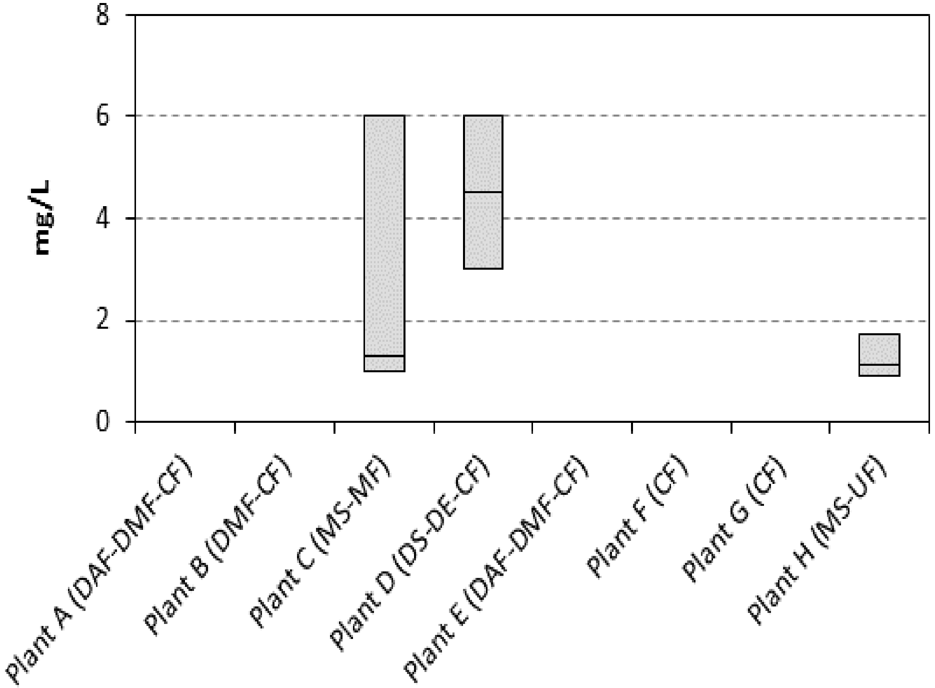


Turbidity

Feed Water Quality Parameters (TDS and TOC)



TDS



TOC

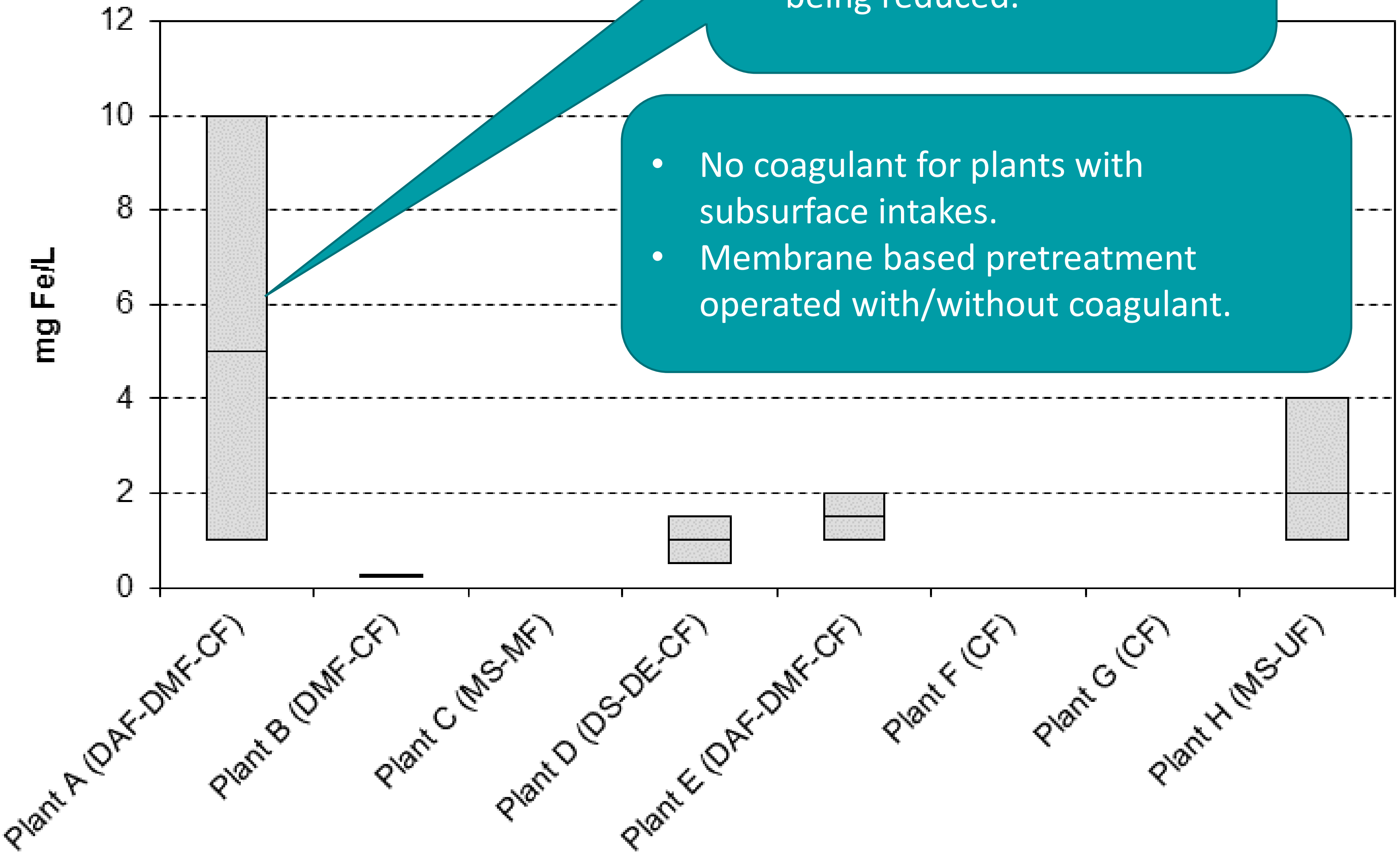
(only three plants monitored)

Water Conditioning Practiced at Plants

Source Water Conditioning is Often a Critical Pretreatment for Controlling Fouling Potential

- Coagulation and flocculation to control the fouling potential of the source seawater.
- Pre-chlorination to control the growth of sea organisms/microorganisms.
- Antiscalant for scaling prevention.
- Addition of reducing agent to quench excess chlorine.

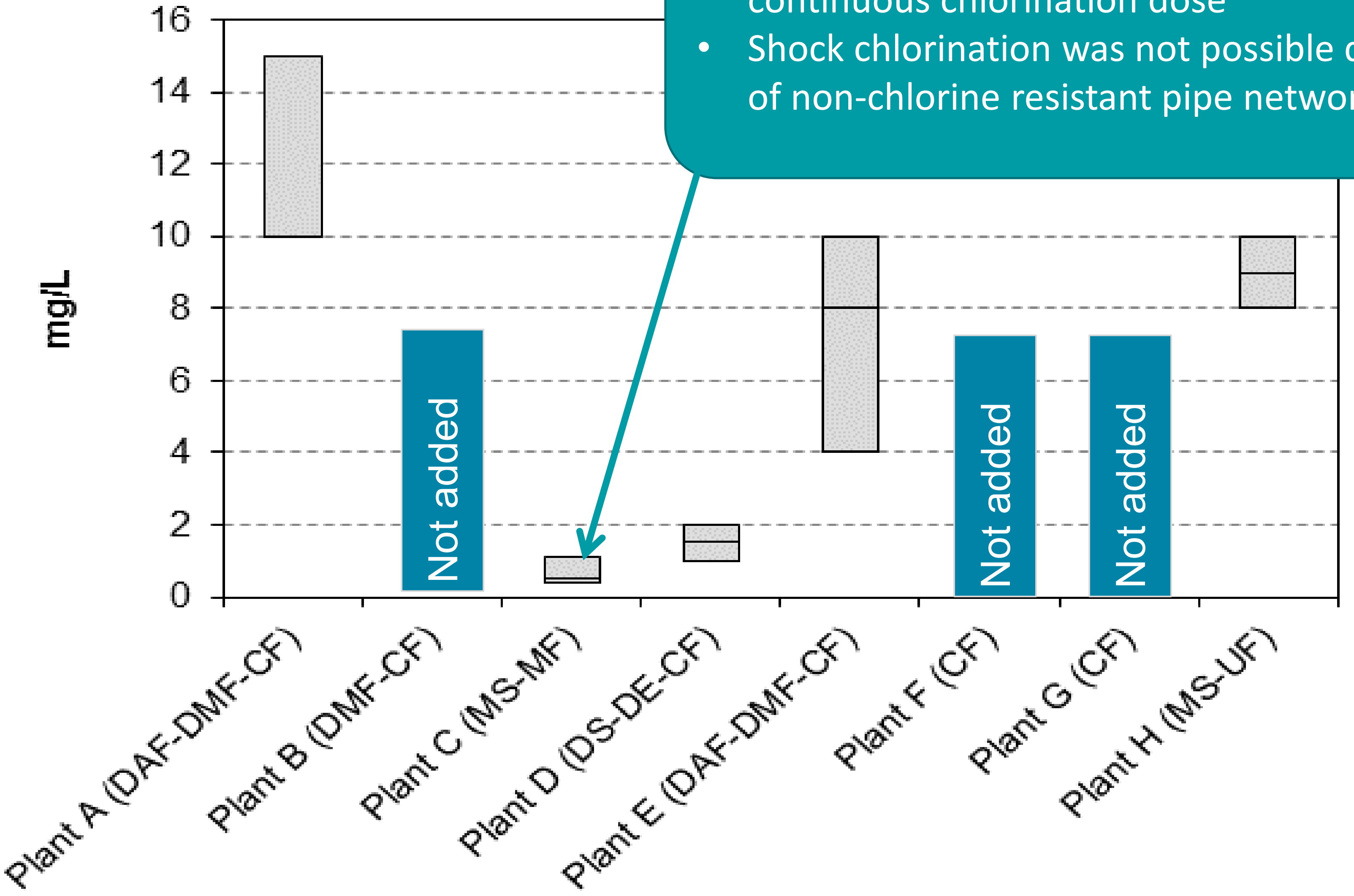
Coagulant and Floc by Plants Participating



- About 0.3 mg/L of polymer being used.
- Coagulant dose is currently being reduced.

- No coagulant for plants with subsurface intakes.
- Membrane based pretreatment operated with/without coagulant.

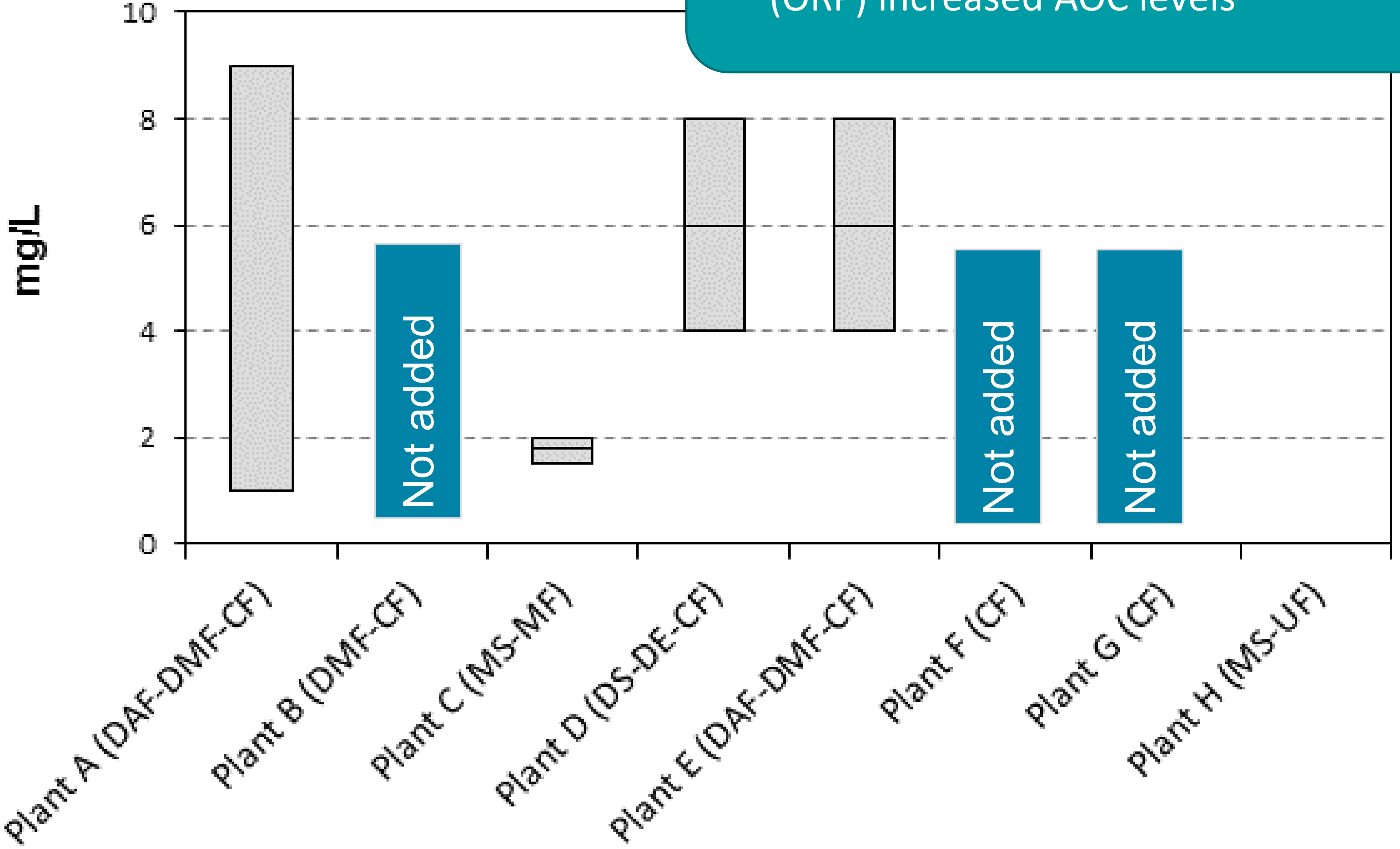
Pre-Chlorination (Shock, Intermittent, Continuous) Practice



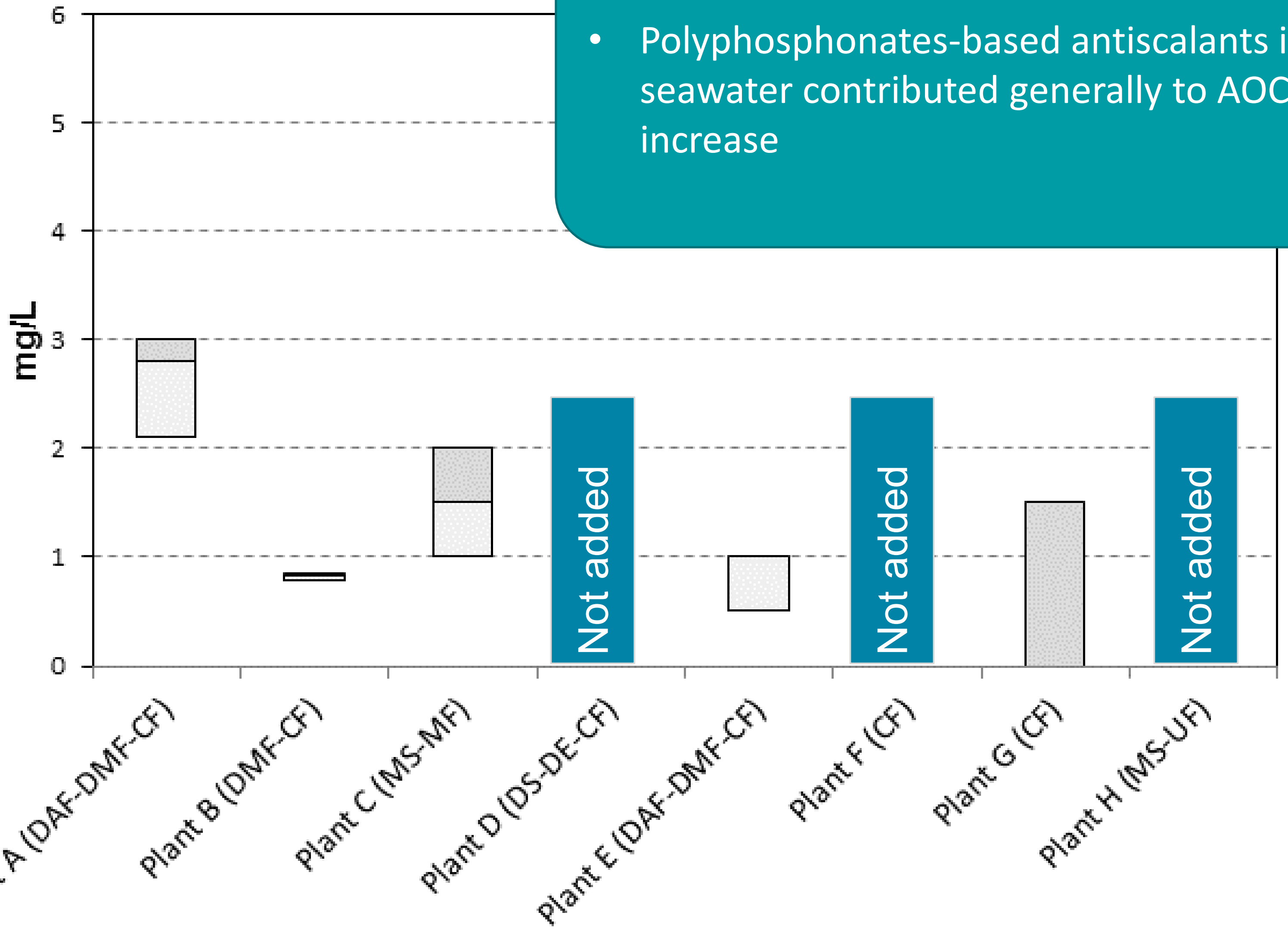
- Organisms appeared to get acclimated with continuous chlorination dose
- Shock chlorination was not possible due to use of non-chlorine resistant pipe network

Addition of Sodium Bisulfite for SWRO Protection by Plants

- Overdosing sodium bisulfite as a control practice for the oxidation-reduction potential (ORP) increased AOC levels



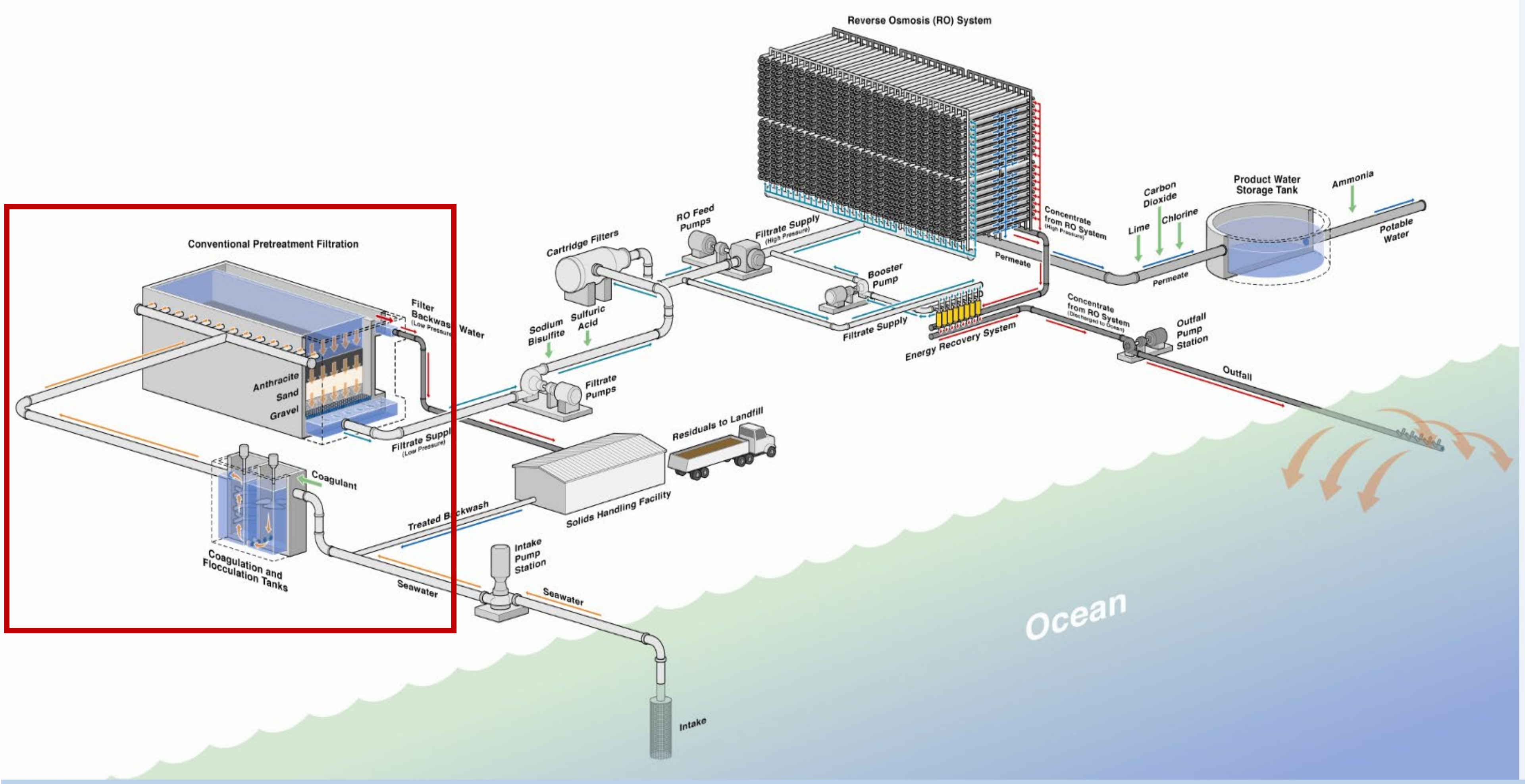
Antiscalant Addition Practice by Plants Participating in Study



- Polyphosphonates-based antiscalants in seawater contributed generally to AOC increase

Conventional and Membrane Pretreatment Systems

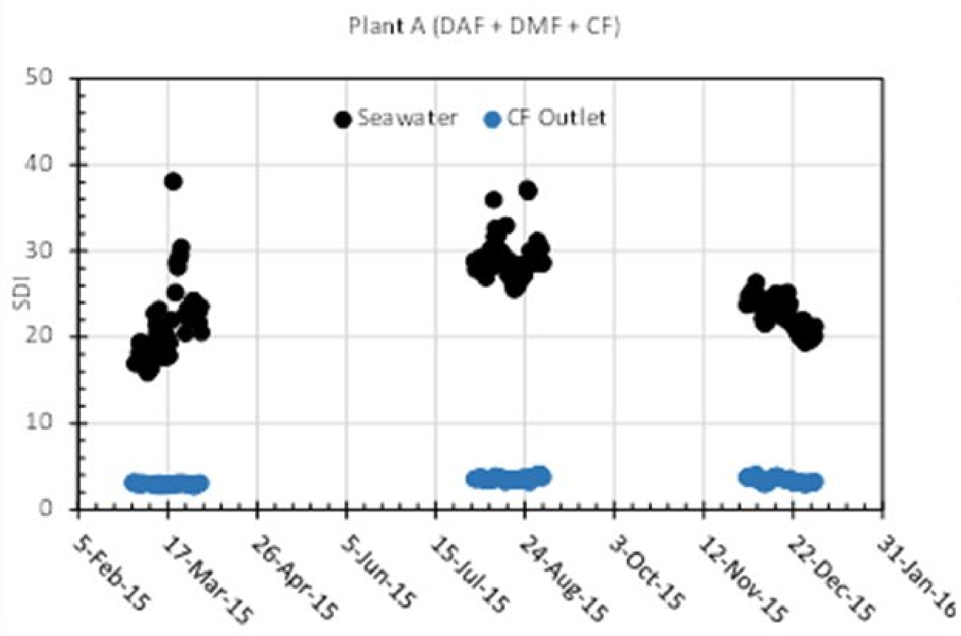
Conventional Pretreatment

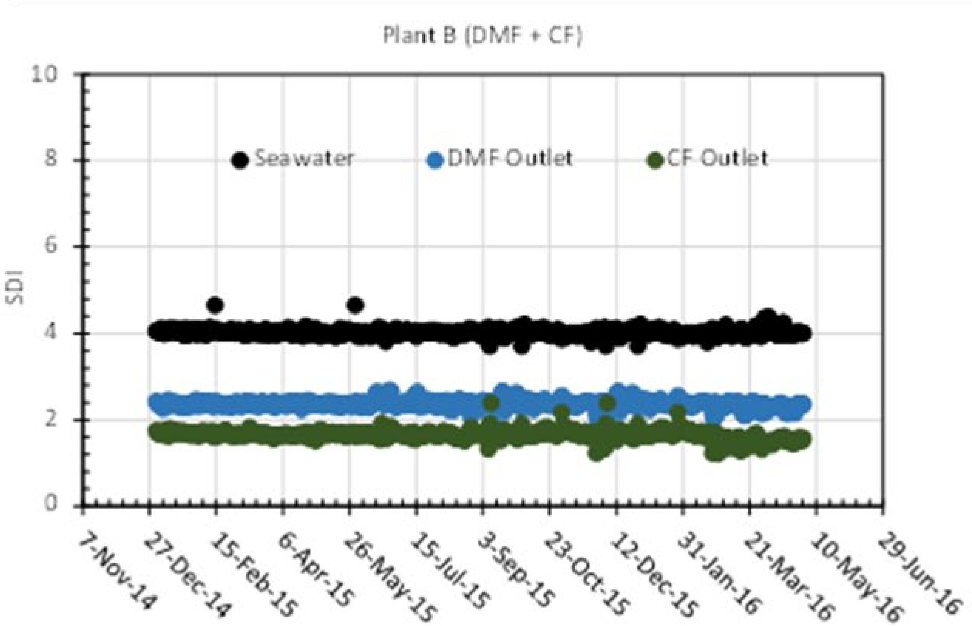


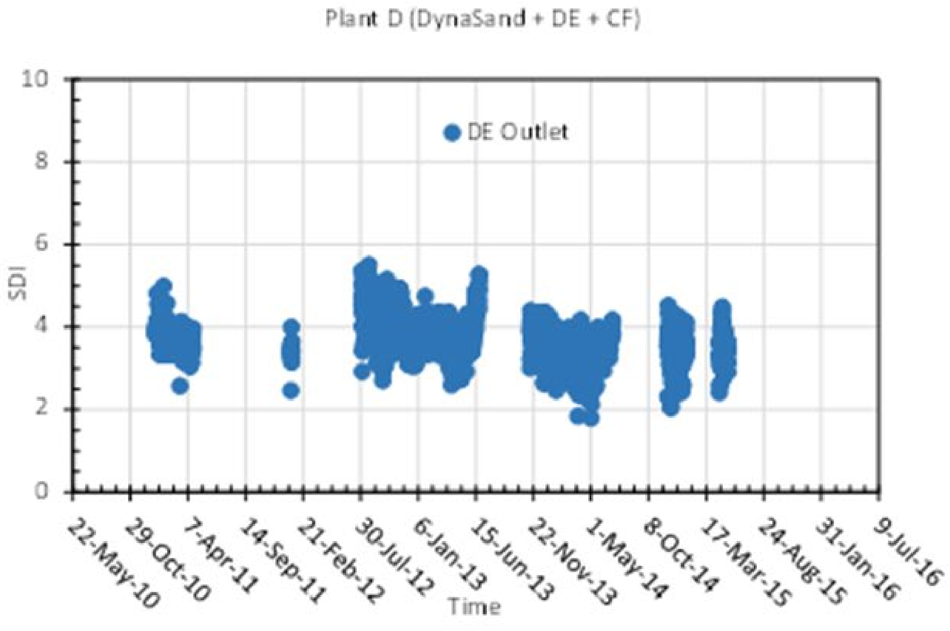
Design Characteristics of Granular Media Filtration

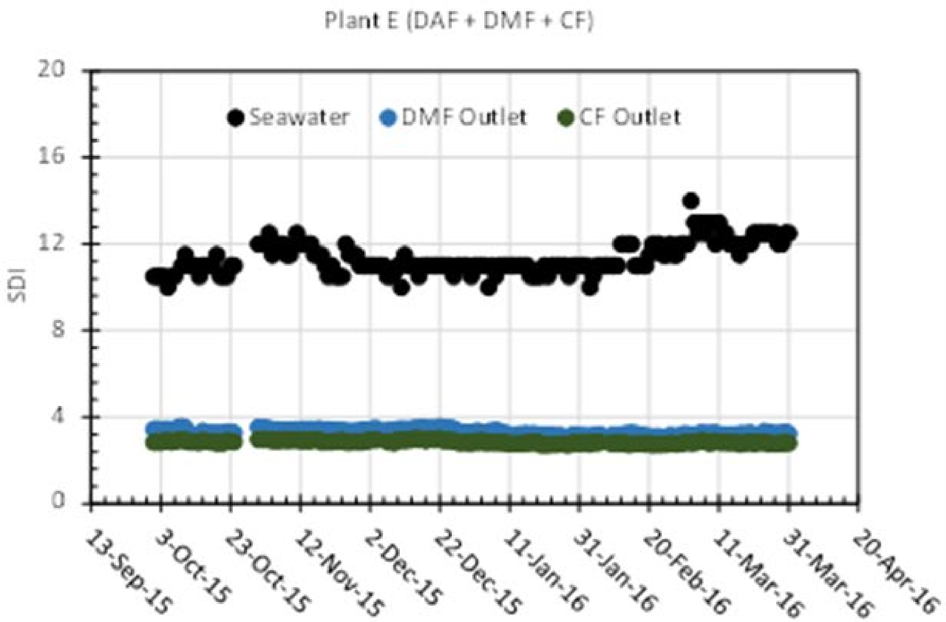
Design Parameter	Plant A (DAF-DMF-CF)		Plant B (DMF-CF)		Plant D (DS-DE-CF)	Plant E (DAF-DMF-CF)	
	Stage 1		Stage 1		DynaSand	Stage 1	
Media type	Anthracite	Sand	Gravel/Sand	Anthracite	Fine sand	Sand	Pumice
Media depth (m)	0.55	0.45	0.2/0.5	0.5	2.74	0.4	0.7
Surface loading rate (m3/m2/hr)	14		6.3		8	9.13	
Backwash frequency (hrs)	36 to 48		70		Continuous	24	
Waste stream volume (% of feed flow)	4%		2.2%		5-10%	3.2%	

SDI Values for Conventional Plants

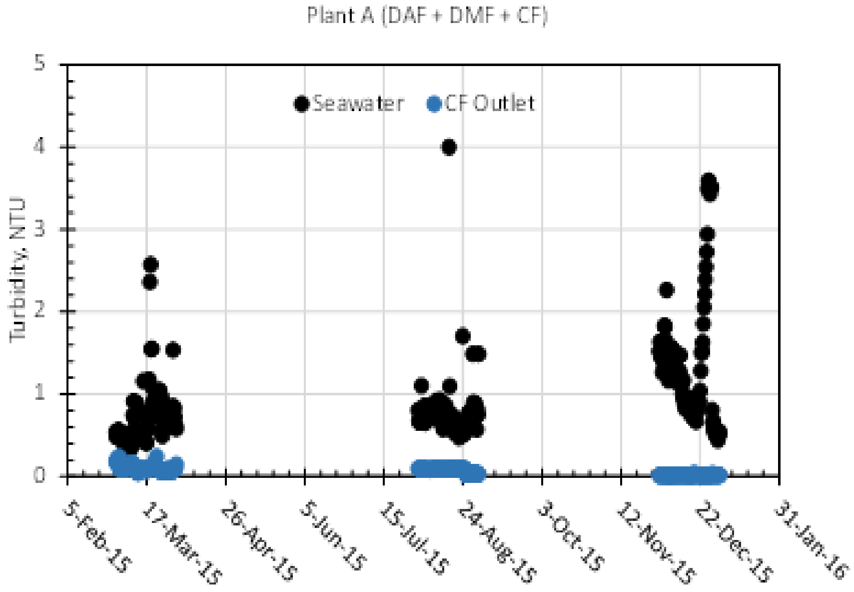

Plant A (DAF + DMF + CF)

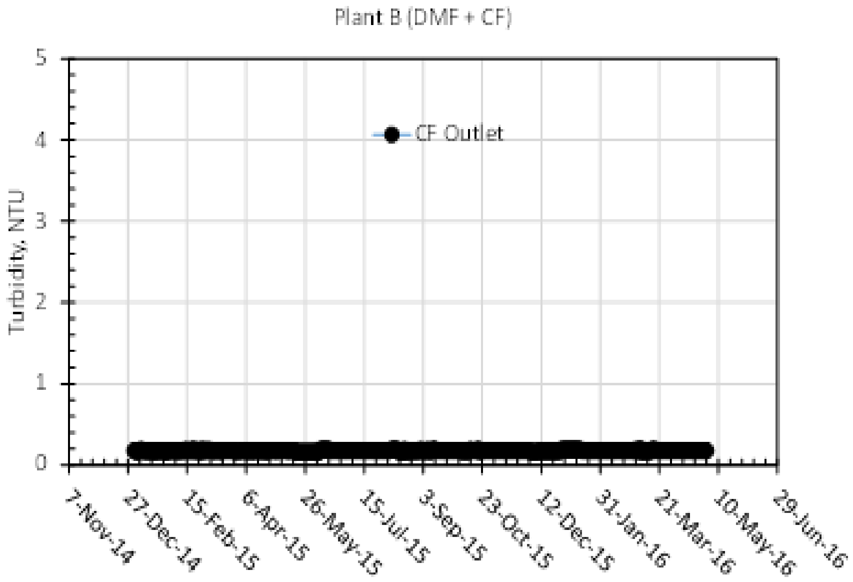

Plant B (DMF + CF)

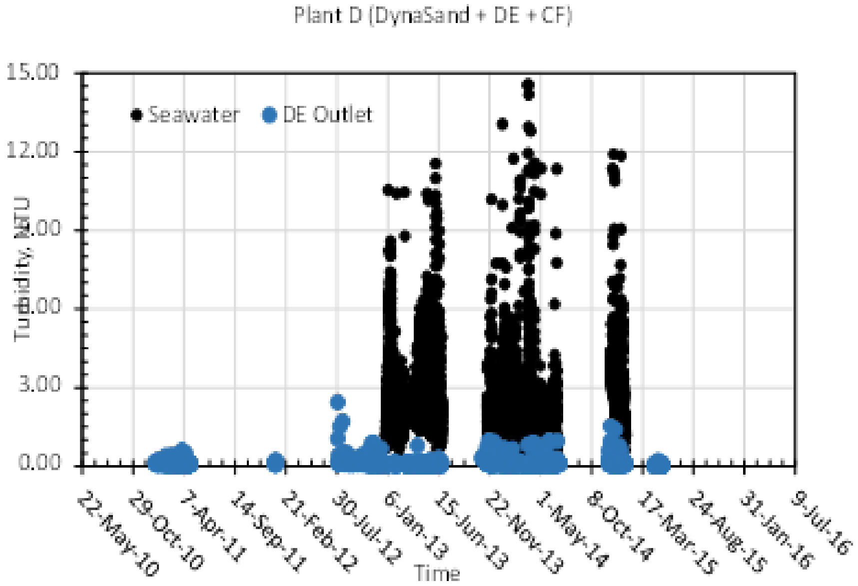

Plant D (DynaSand + DE + CF)

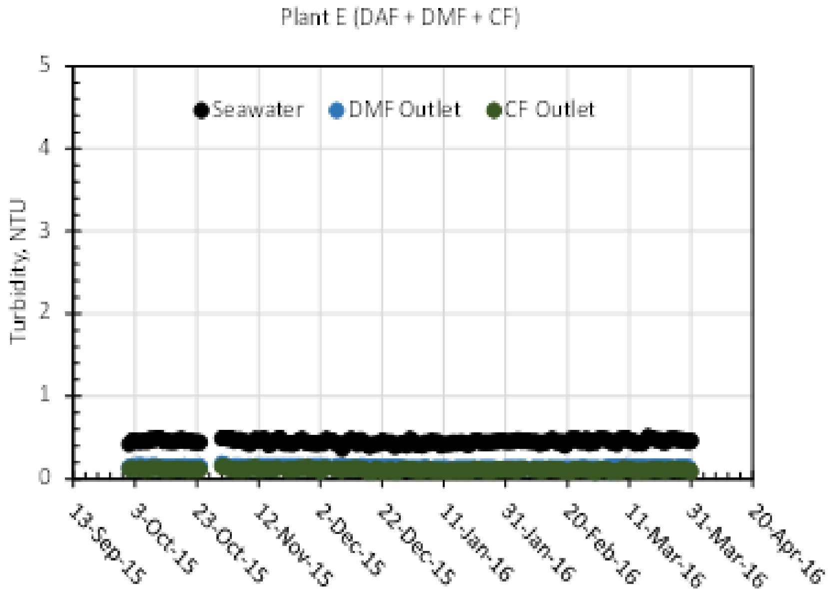

Plant E (DAF + DMF + CF)

Turbidity Removal by Conventional Plants

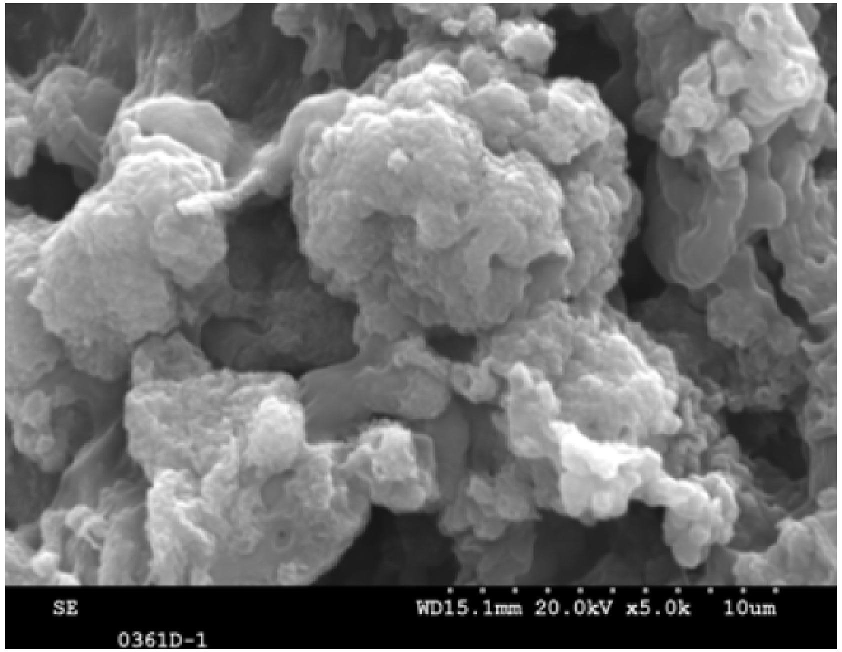


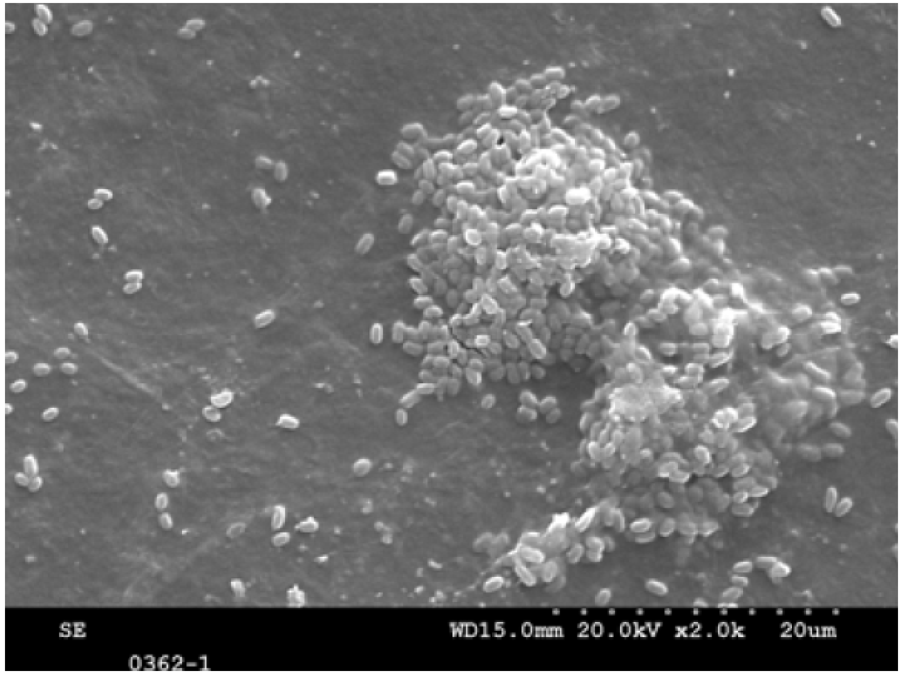


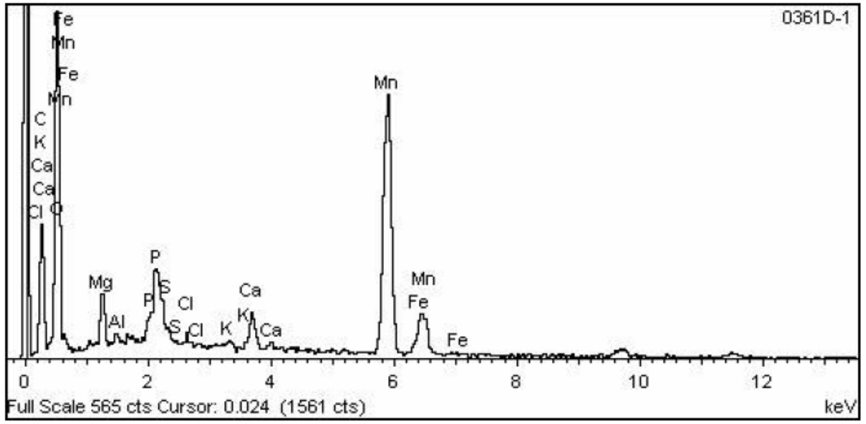


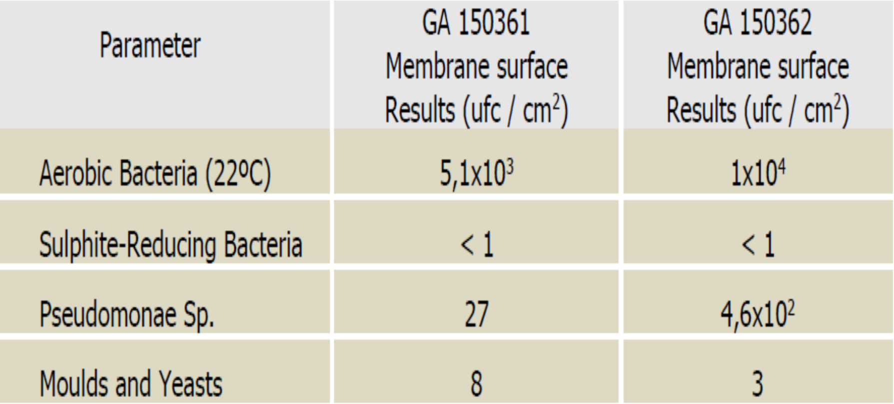


Impact of the DMF System on the SWRO Membrane (Plant A: DAF- DMF- CF)



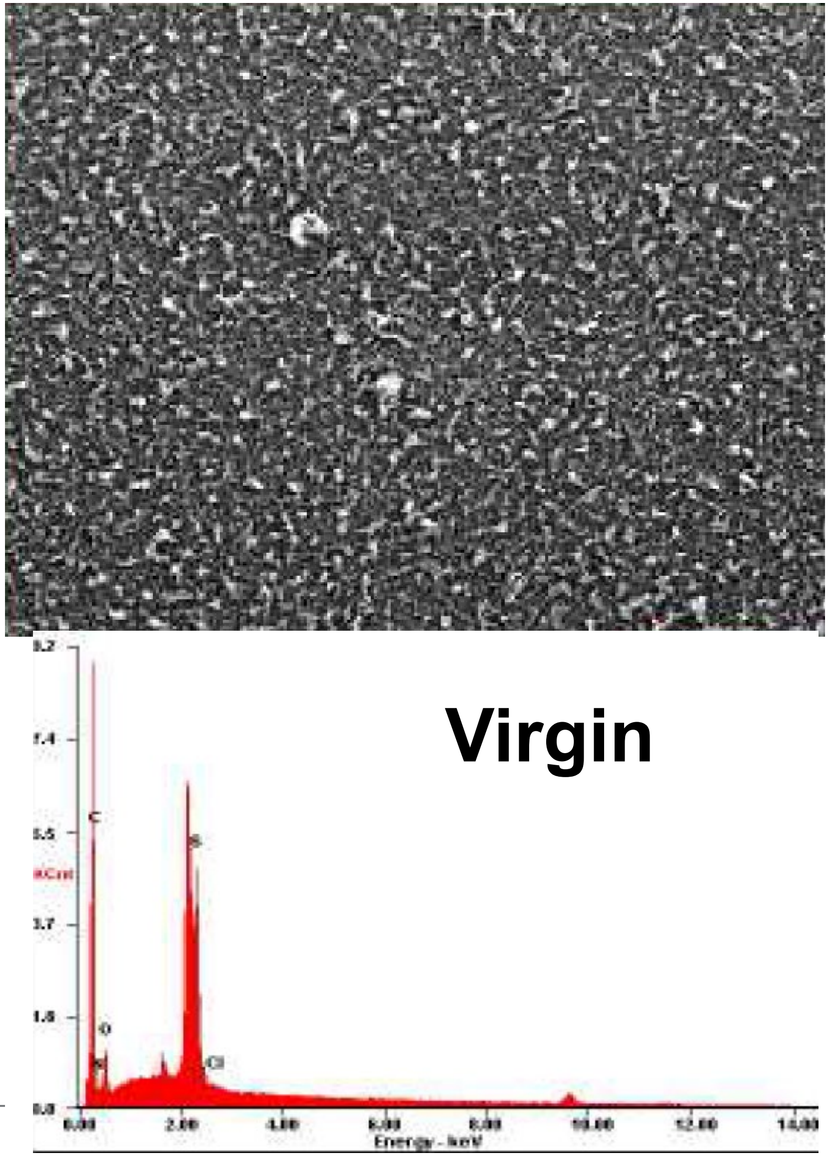




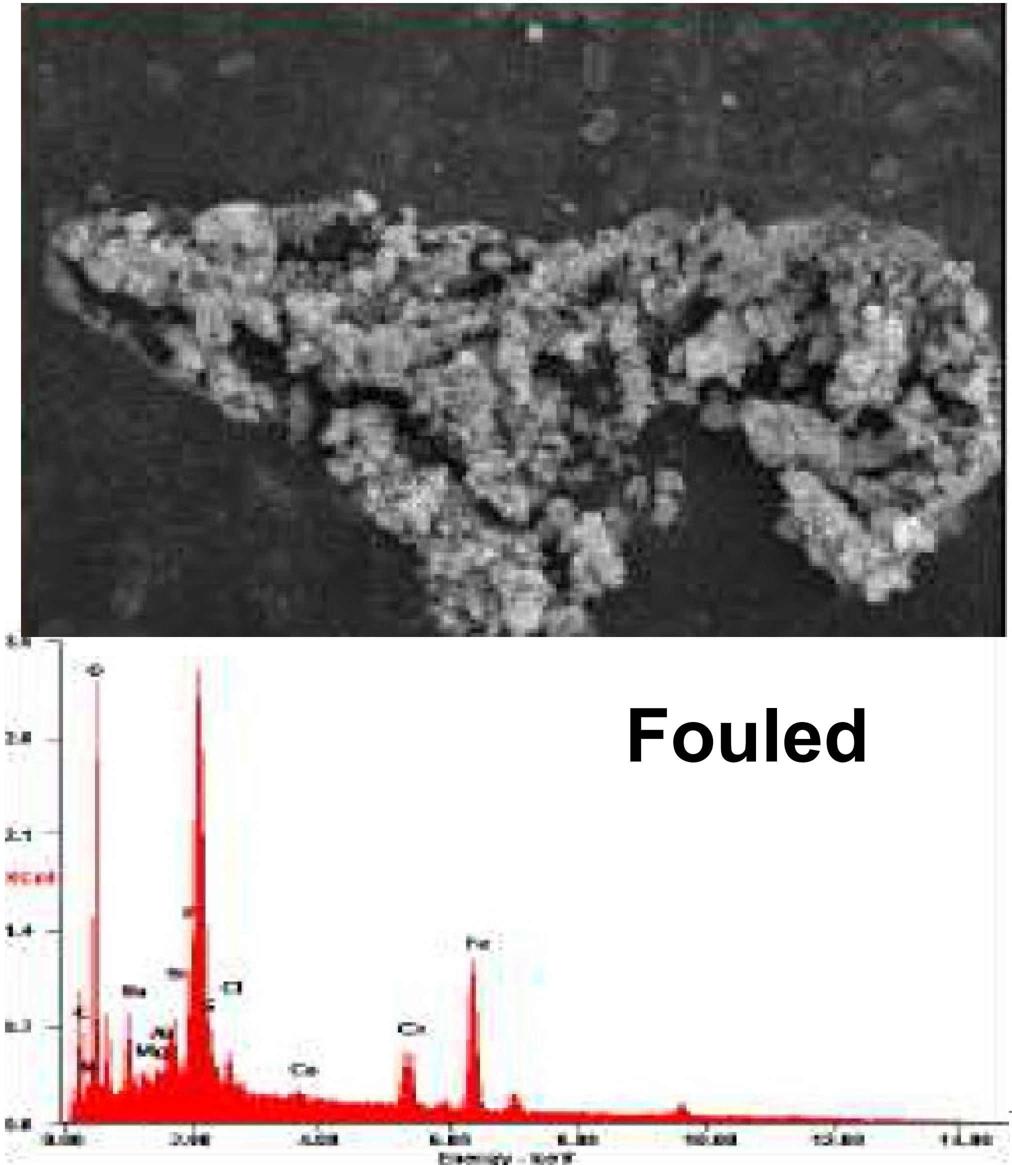


Parameter	GA 150361 Membrane surface Results (ufc / cm^2)	GA 150362 Membrane surface Results (ufc / cm^2)
Aerobic Bacteria (22ºC)	5,1x10^3	1x10^4
Sulphite-Reducing Bacteria	< 1	< 1
Pseudomonae Sp.	27	4,6x10^2
Moulds and Yeasts	8	3

Impact of the DMF System on the SWRO Membrane (Plant E: DAF- DMF- CF)



Virgin

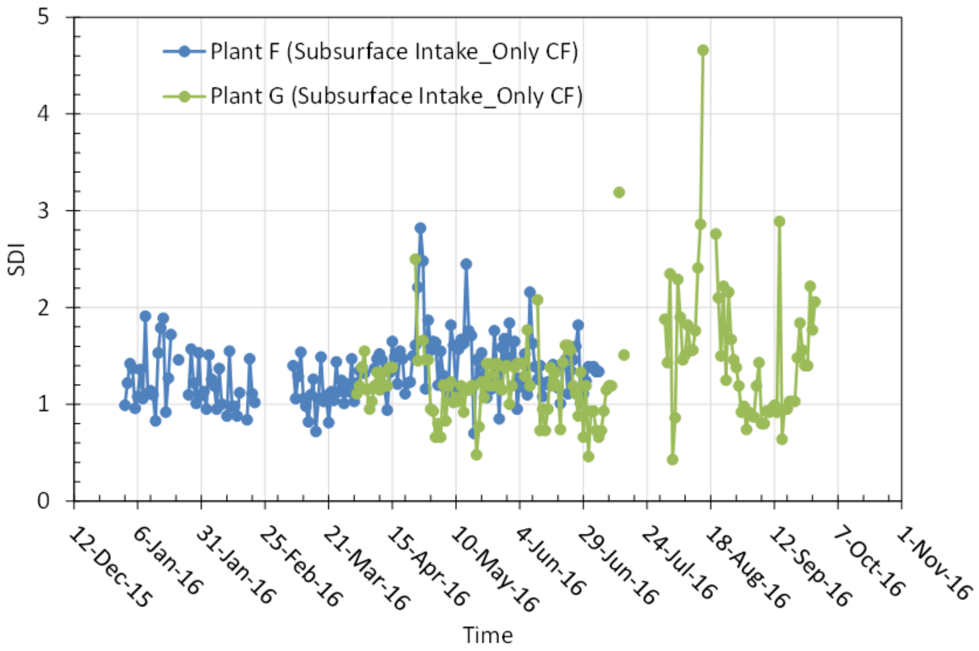


Fouled

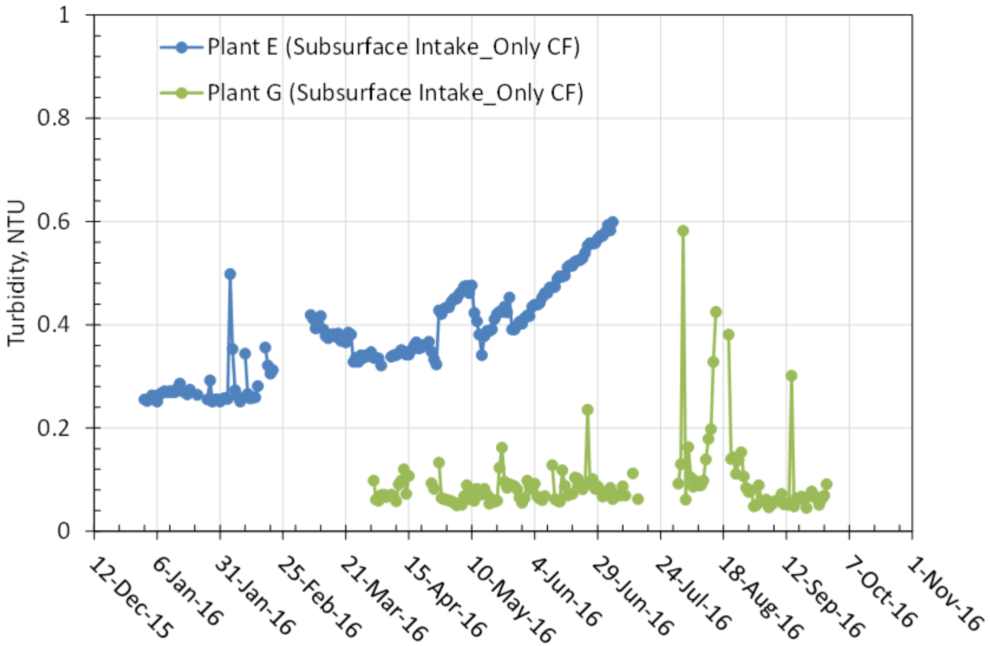
Pretreatment Systems for Subsurface Intake Plants

- Plant F and Plant G utilize beach wells as intake.
- Plants only use cartridge filters as pretreatment.
- SDI values in the feed water are typically less on 3.0.
- Hydro-geologic conditions play an important role as the presence of Fe and Mn might impact the RO performance.

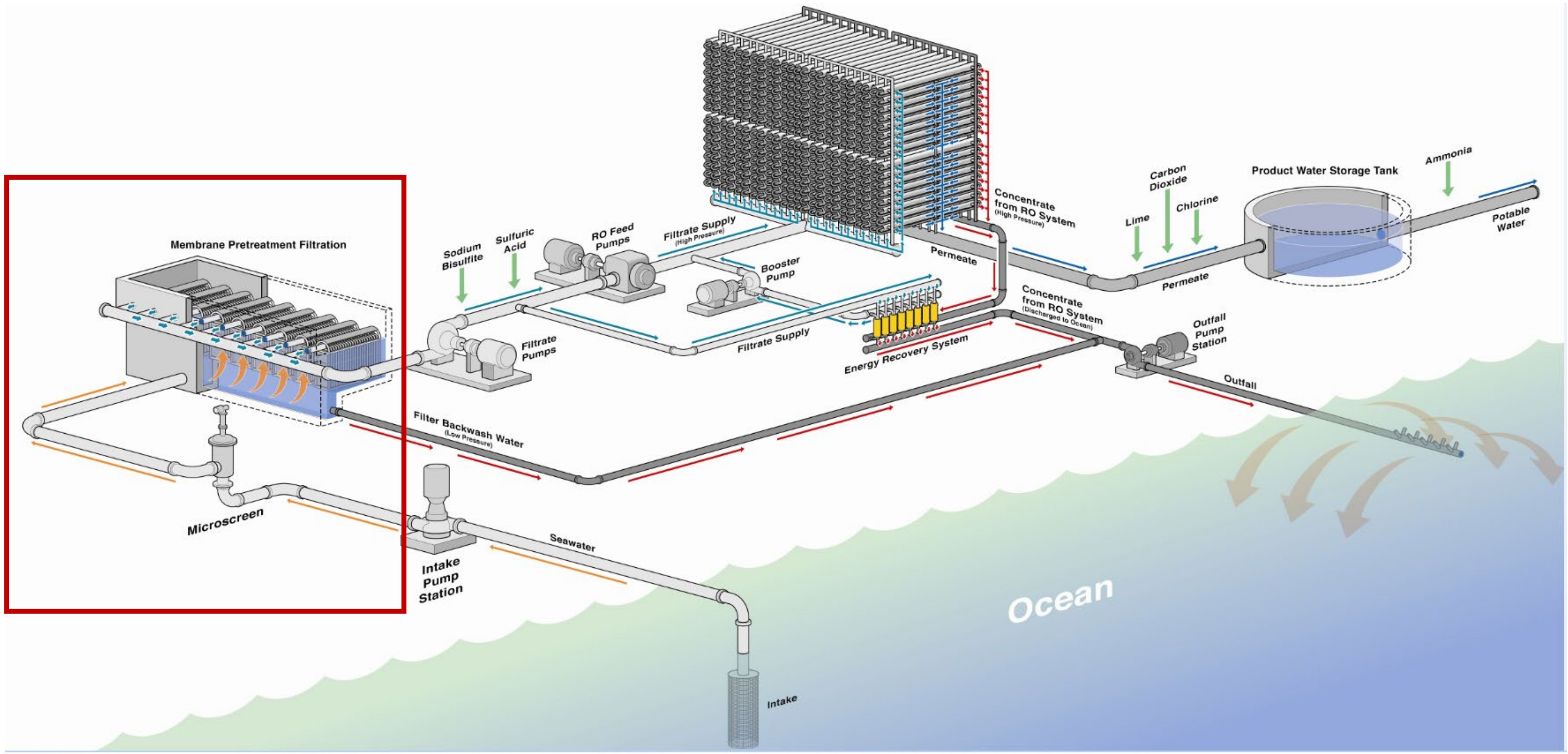
SDI Values and Turbidity for Plants F &G (Only CF)



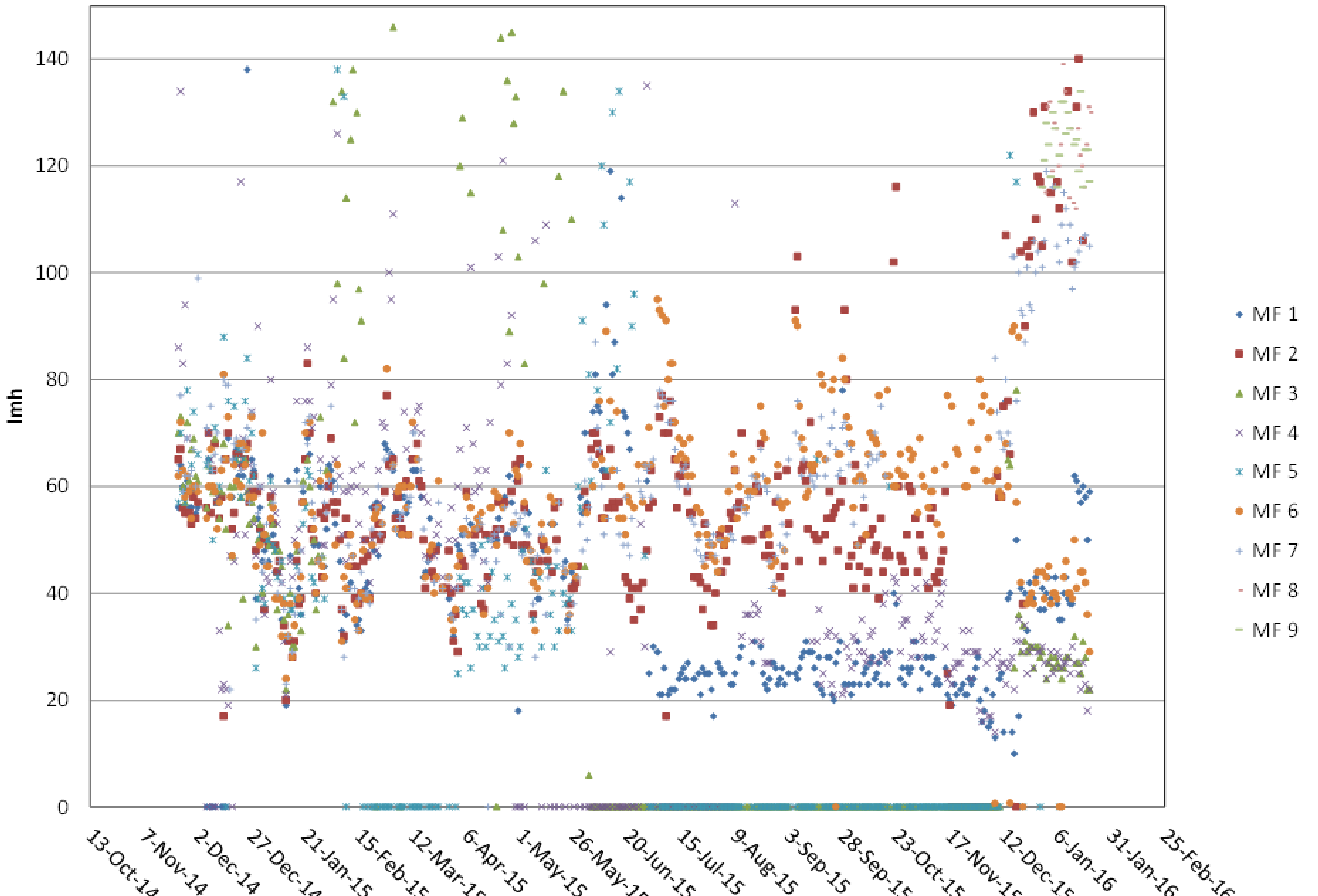
- Plant G monitors the SDI values and the color of the SDI filtration pads to determine which well should be selected to minimize iron loading on the RO system.



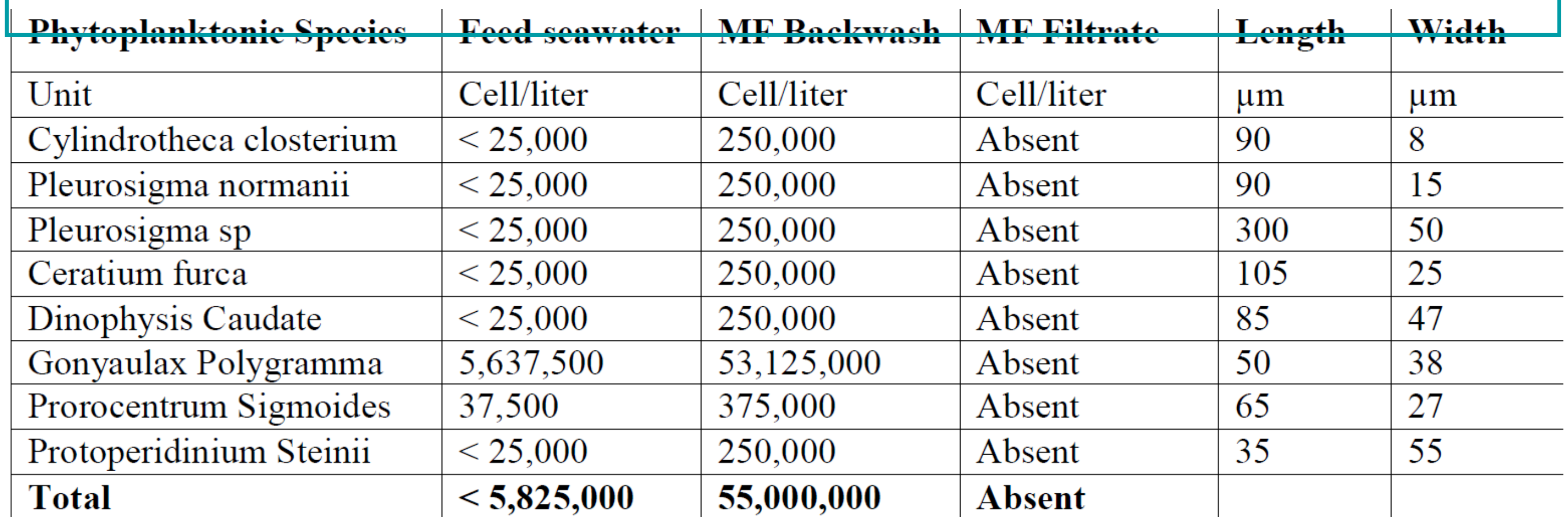
Low-Pressure Membranes Employed as a Pretreatment



Transmembrane Flux Profile at Plant C (Membrane-based Pretreatment)

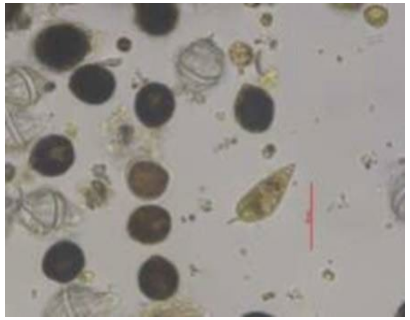


HABs and Silt Content Impact the Performance: Plant C



Phytoplanktonic Species	**Feed seawater**	**MF Backwash**	**MF Filtrate**	**Length**	**Width**
Unit	Cell/liter	Cell/liter	Cell/liter	µm	µm
Cylindrotheca closterium	< 25,000	250,000	Absent	90	8
Pleurosigma normanii	< 25,000	250,000	Absent	90	15
Pleurosigma sp	< 25,000	250,000	Absent	300	50
Ceratium furca	< 25,000	250,000	Absent	105	25
Dinophysis Caudate	< 25,000	250,000	Absent	85	47
Gonyaulax Polygramma	5,637,500	53,125,000	Absent	50	38
Prorocentrum Sigmoides	37,500	375,000	Absent	65	27
Protoperidinium Steinii	< 25,000	250,000	Absent	35	55
Total	**< 5,825,000**	**55,000,000**	**Absent**		

Gonyaulax Polygramma



Prorocentrum Sigmoides

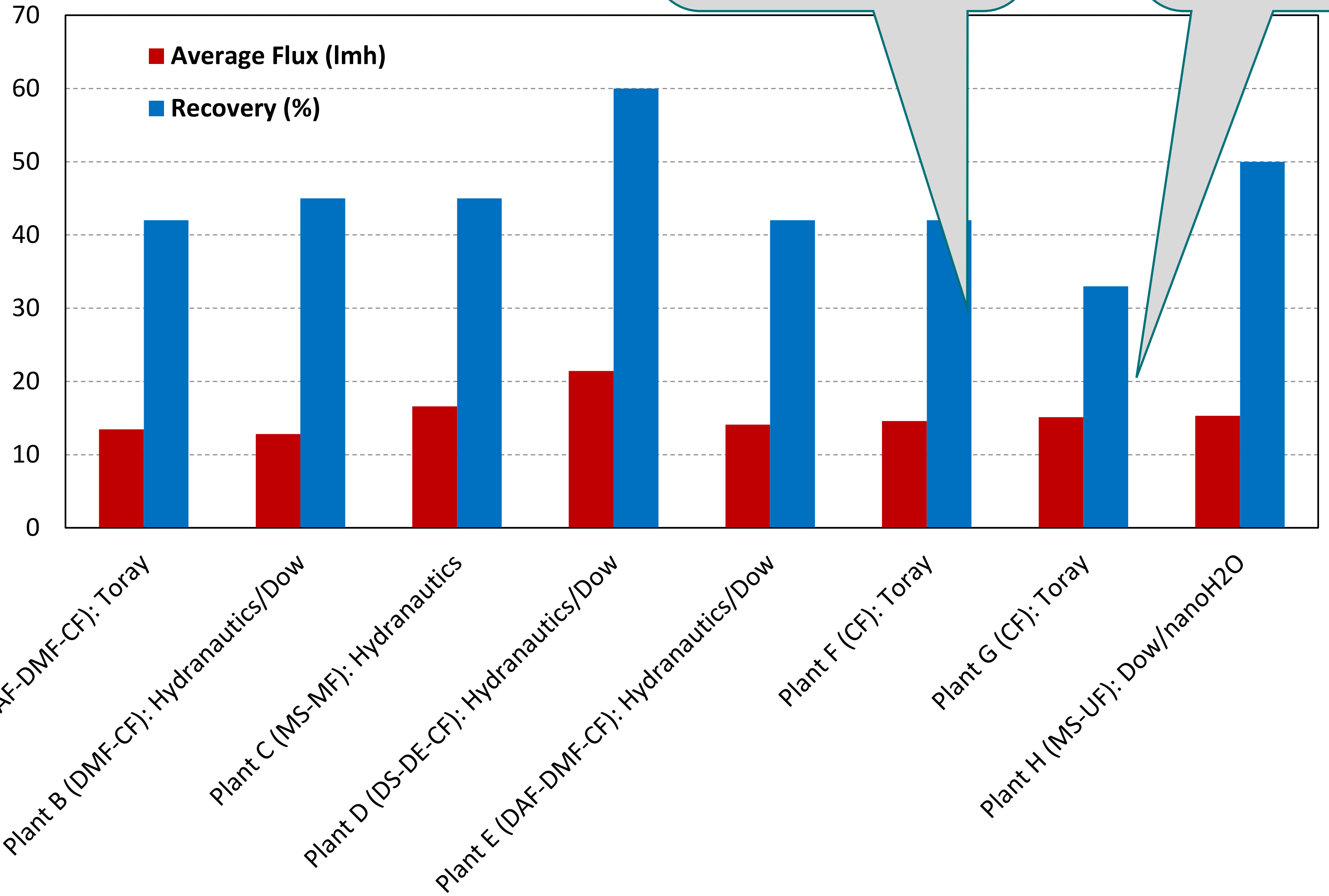
MF Backwash during Algal Bloom

RO Performance at Plants

First Stage SWRO ent

NanoH2O was recently selected recently primarily for boron rejection

Low recovery was driven by concentrate discharge limits



Impacts of Pretreatment on SWRO Operations

Plant Name	Membrane Cleaning Frequency (months)	Cartridge Filter Replacement Frequency (months)	Membrane Replacement Frequency (% per year)
Plant A (DAF-DMF-CF): Toray	6	2 to 3	10 to 12
Plant B (DMF-CF): Hydranautics/Dow	3	3	< 10
Plant C (MS-MF): Hydranautics	0.5	No CF	< 10
Plant D (DS-DE-CF): Hydranautics/Dow	2 to 3	12	14.3
Plant E (DAF-DMF-CF): Hydranautics/Dow	2 to 3	2	10 to 12
Plant F (CF): Toray	6	1.25	5
Plant G (CF): Toray	4 to 5	2 to 3	25
Plant H (MS-UF): Dow/NanoH2O	N/A	N/A	N/A

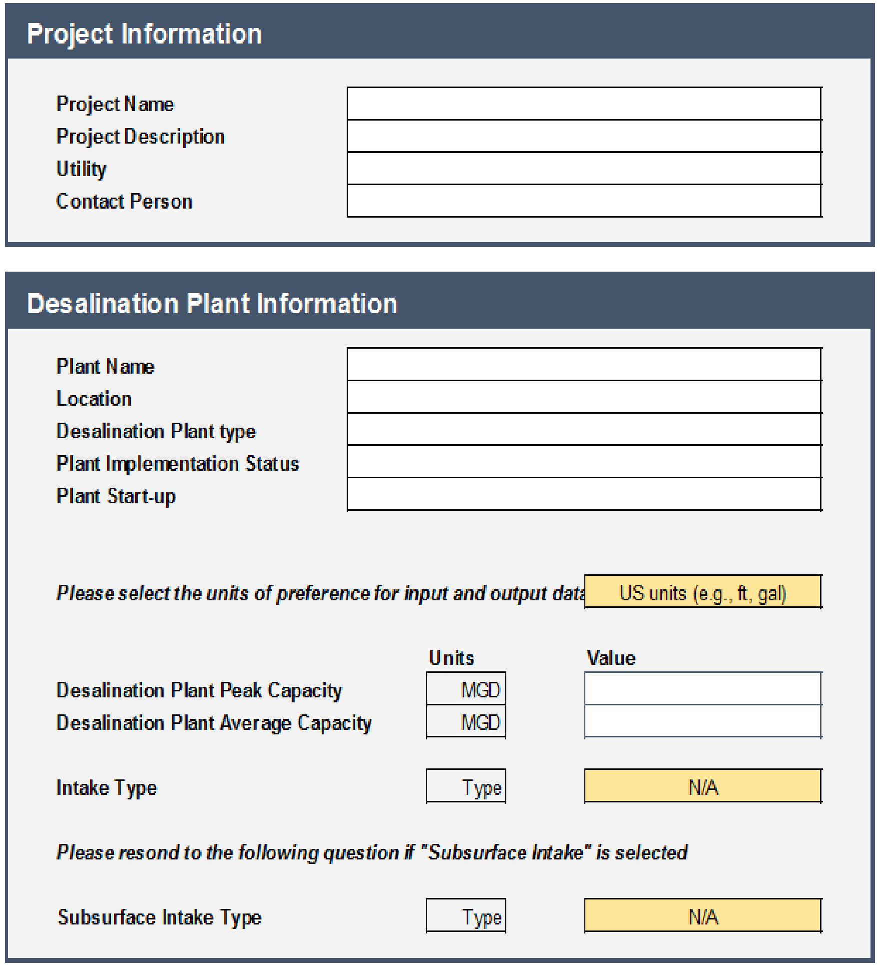
Pretreatment Selection Guidance Tool

Objective: To assist water utilities in the selection of various seawater pretreatment systems.

- General plant information (Input File)
- Influent water quality Information (Input File)
- Recommended conventional or membrane-based pretreatment alternatives (Output File)
- Effluent water quality information specific for intake type and selected pretreatment alternative (Output File)
- System design information (Output File)
- Comparison of alternatives based on non-water quality related information (Output File)
- Guidance worksheets on various water quality aspects, system design and operation (Output File)

Pretreatment Selection Guidance Tool

General Description Worksheet



Project Information

Project Name	
Project Description	
Utility	
Contact Person	

Desalination Plant Information

Plant Name	
Location	
Desalination Plant type	
Plant Implementation Status	
Plant Start-up	

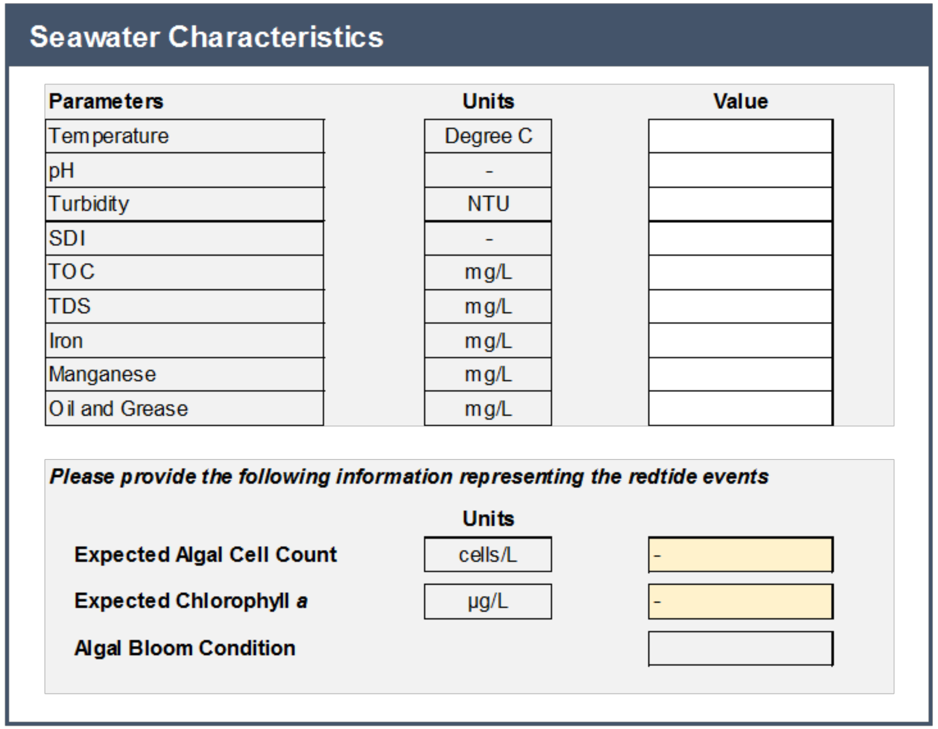
Please select the units of preference for input and output data US units (e.g., ft, gal)

	Units	Value
Desalination Plant Peak Capacity	MGD	
Desalination Plant Average Capacity	MGD	
Intake Type	Type	N/A

Please resond to the following question if "Subsurface Intake" is selected

Subsurface Intake Type	Type	N/A

Water Quality Input Worksheet



Seawater Characteristics

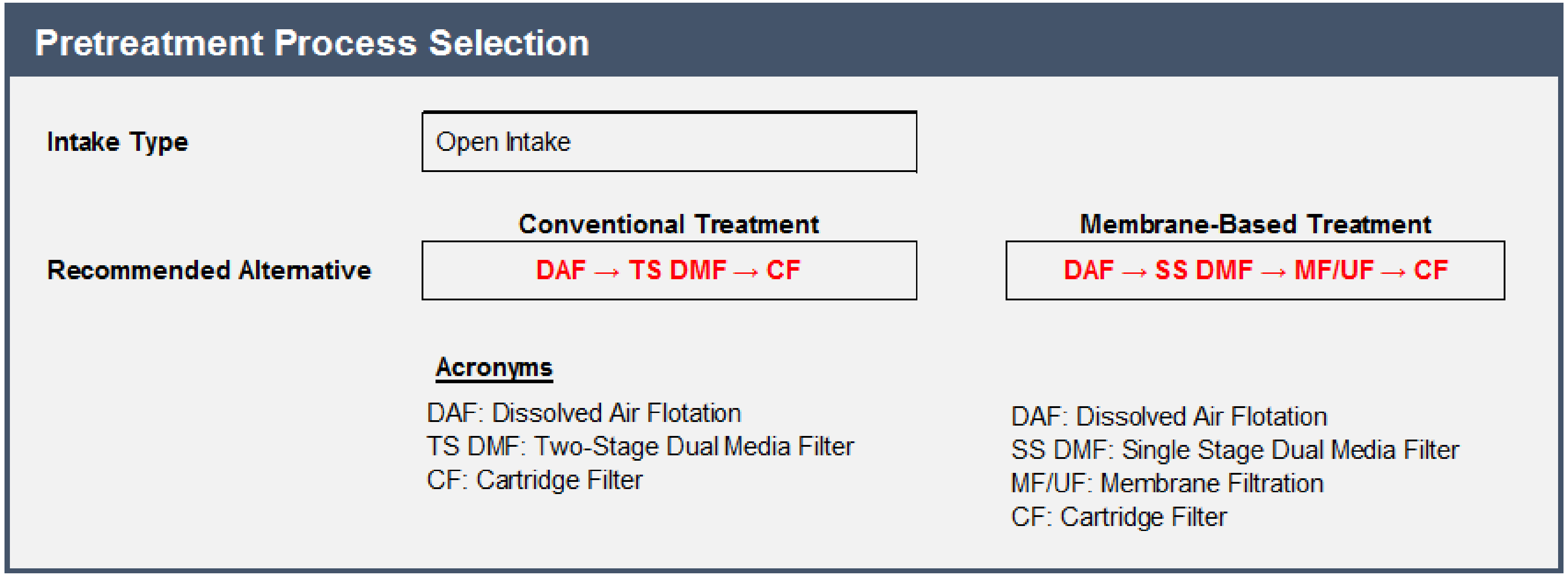
Parameters	Units	Value
Temperature	Degree C	
pH	-	
Turbidity	NTU	
SDI	-	
TOC	mg/L	
TDS	mg/L	
Iron	mg/L	
Manganese	mg/L	
Oil and Grease	mg/L	

Please provide the following information representing the redtide events

	Units	
Expected Algal Cell Count	cells/L	-
Expected Chlorophyll *a*	µg/L	-
Algal Bloom Condition		

Pretreatment Selection Guidance Tool

Recommended Pretreatment Alternatives Worksheet



Pretreatment Process Selection

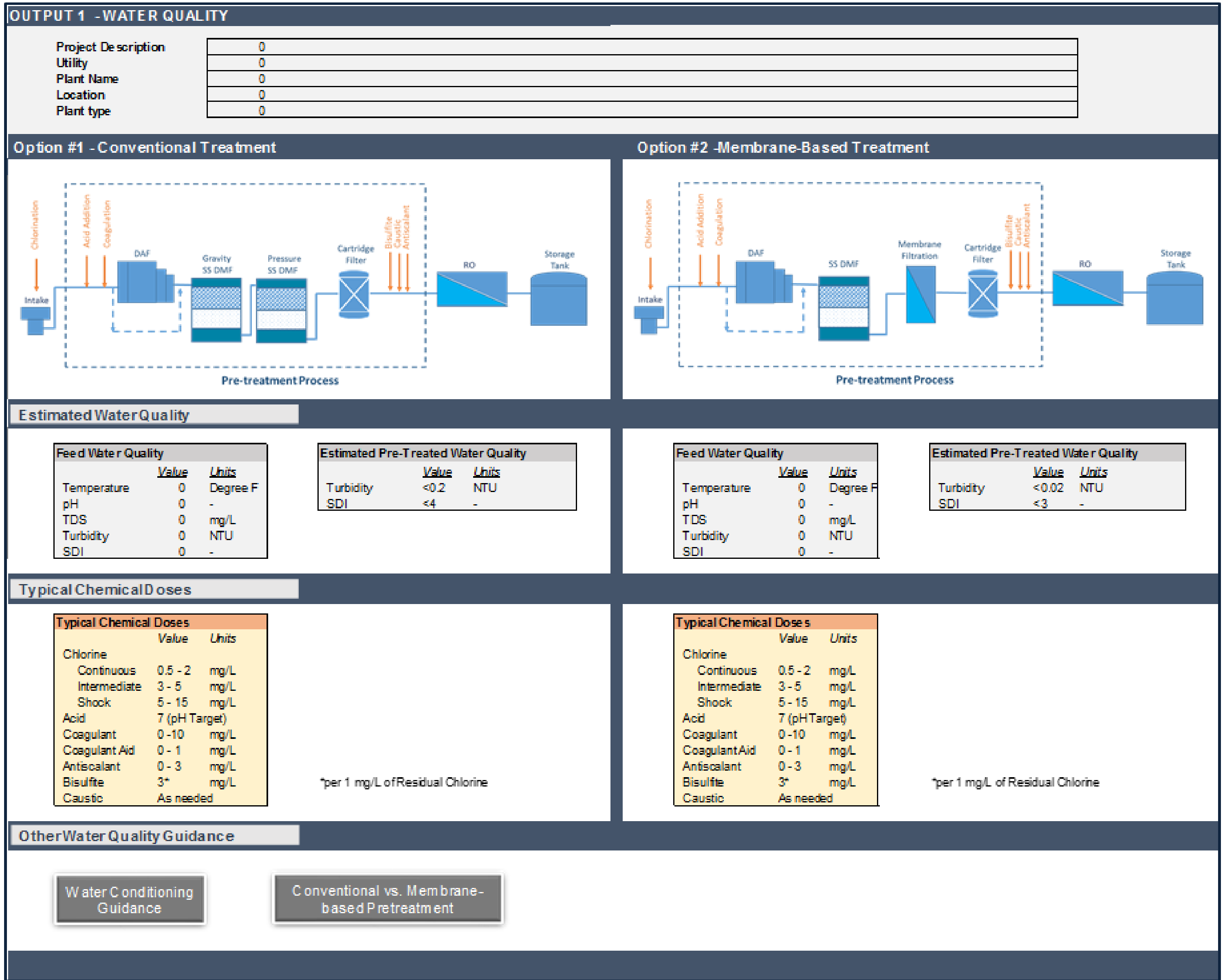
Intake Type	Open Intake	
	Conventional Treatment	**Membrane-Based Treatment**
Recommended Alternative	**DAF → TS DMF → CF**	**DAF → SS DMF → MF/UF → CF**

Acronyms

DAF: Dissolved Air Flotation
TS DMF: Two-Stage Dual Media Filter
CF: Cartridge Filter

DAF: Dissolved Air Flotation
SS DMF: Single Stage Dual Media Filter
MF/UF: Membrane Filtration
CF: Cartridge Filter

Pretreatment Selection Guidance Tool



OUTPUT 1 - WATER QUALITY

Project Description	0
Utility	0
Plant Name	0
Location	0
Plant type	0

Option #1 - Conventional Treatment

Option #2 -Membrane-Based Treatment

Estimated Water Quality

Option #1:

Feed Water Quality	Value	Units
Temperature	0	Degree F
pH	0	-
TDS	0	mg/L
Turbidity	0	NTU
SDI	0	-

Estimated Pre-Treated Water Quality	Value	Units
Turbidity	<0.2	NTU
SDI	<4	-

Option #2:

Feed Water Quality	Value	Units
Temperature	0	Degree F
pH	0	-
TDS	0	mg/L
Turbidity	0	NTU
SDI	0	-

Estimated Pre-Treated Water Quality	Value	Units
Turbidity	<0.02	NTU
SDI	<3	-

Typical Chemical Doses

Option #1:

Typical Chemical Doses	Value	Units
Chlorine		
Continuous	0.5 - 2	mg/L
Intermediate	3 - 5	mg/L
Shock	5 - 15	mg/L
Acid	7 (pH Target)	
Coagulant	0 -10	mg/L
Coagulant Aid	0 - 1	mg/L
Antiscalant	0 - 3	mg/L
Bisulfite	3*	mg/L
Caustic	As needed	

*per 1 mg/L of Residual Chlorine

Option #2:

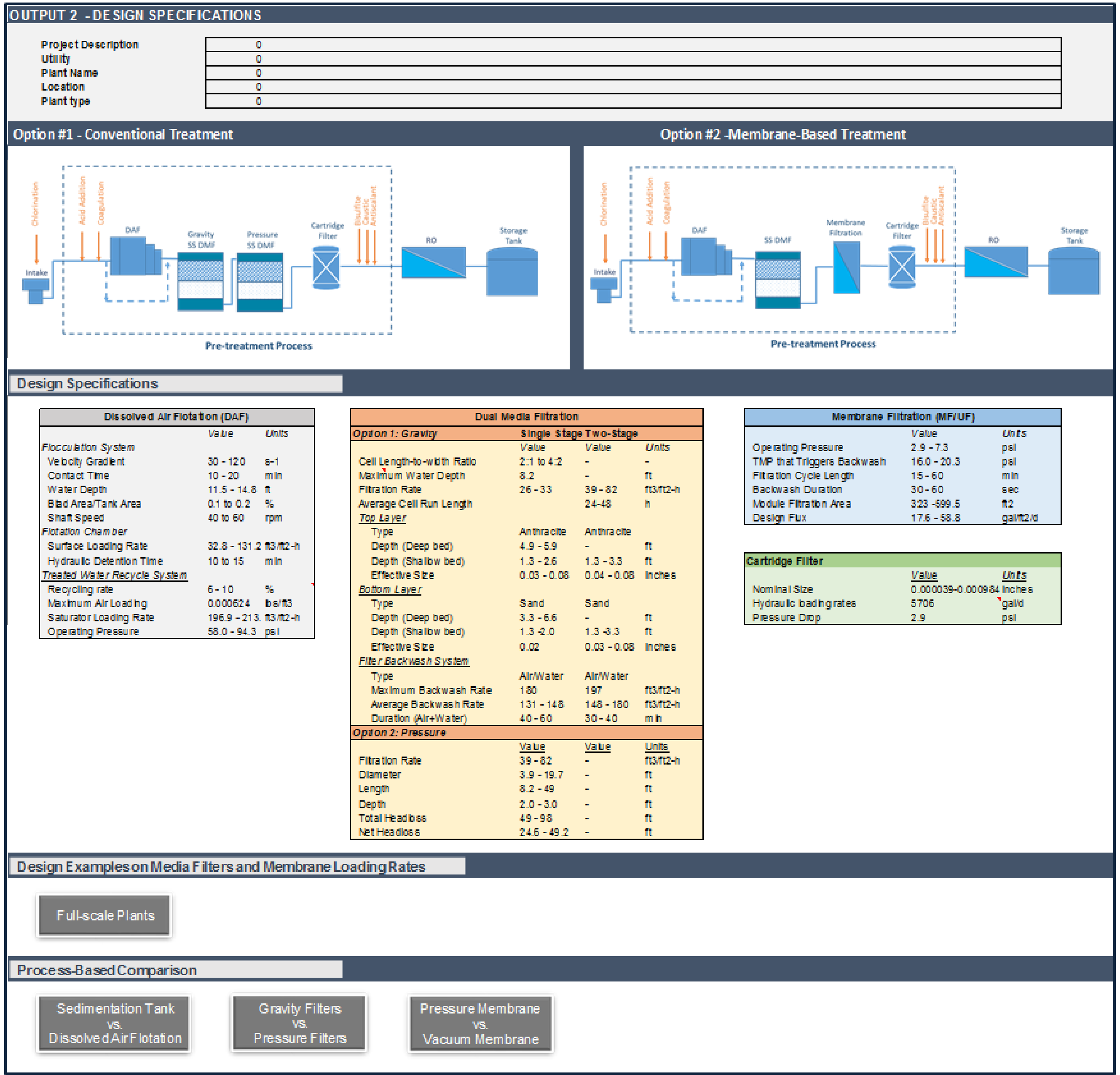
Typical Chemical Doses	Value	Units
Chlorine		
Continuous	0.5 - 2	mg/L
Intermediate	3 - 5	mg/L
Shock	5 - 15	mg/L
Acid	7 (pH Target)	
Coagulant	0 -10	mg/L
Coagulant Aid	0 - 1	mg/L
Antiscalant	0 - 3	mg/L
Bisulfite	3*	mg/L
Caustic	As needed	

*per 1 mg/L of Residual Chlorine

Other Water Quality Guidance

Recommended Pretreatment Alternatives Worksheet

Pretreatment Selection Guidance Tool



OUTPUT 2 - DESIGN SPECIFICATIONS

Project Description	0
Utility	0
Plant Name	0
Location	0
Plant type	0

Option #1 - Conventional Treatment

Option #2 -Membrane-Based Treatment

Design Specifications

Dissolved Air Flotation (DAF)		
	Value	*Units*
Flocculation System		
Velocity Gradient	30 - 120	s-1
Contact Time	10 - 20	min
Water Depth	11.5 - 14.8	ft
Blad Area/Tank Area	0.1 to 0.2	%
Shaft Speed	40 to 60	rpm
Flotation Chamber		
Surface Loading Rate	32.8 - 131.2	ft3/ft2-h
Hydraulic Detention Time	10 to 15	min
Treated Water Recycle System		
Recycling rate	6 - 10	%
Maximum Air Loading	0.000624	lbs/ft3
Saturator Loading Rate	196.9 - 213.	ft3/ft2-h
Operating Pressure	58.0 - 94.3	psi

Dual Media Filtration			
Option 1: Gravity	**Single Stage**	**Two-Stage**	
	Value	*Value*	*Units*
Cell Length-to-width Ratio	2:1 to 4:2	-	-
Maximum Water Depth	8.2	-	ft
Filtration Rate	26 - 33	39 - 82	ft3/ft2-h
Average Cell Run Length		24-48	h
Top Layer			
Type	Anthracite	Anthracite	
Depth (Deep bed)	4.9 - 5.9	-	ft
Depth (Shallow bed)	1.3 - 2.6	1.3 - 3.3	ft
Effective Size	0.03 - 0.08	0.04 - 0.08	Inches
Bottom Layer			
Type	Sand	Sand	
Depth (Deep bed)	3.3 - 6.6	-	ft
Depth (Shallow bed)	1.3 -2.0	1.3 -3.3	ft
Effective Size	0.02	0.03 - 0.08	Inches
Filter Backwash System			
Type	Air/Water	Air/Water	
Maximum Backwash Rate	180	197	ft3/ft2-h
Average Backwash Rate	131 - 148	148 - 180	ft3/ft2-h
Duration (Air+Water)	40 - 60	30 - 40	min
Option 2: Pressure			
	Value	Value	Units
Filtration Rate	39 - 82	-	ft3/ft2-h
Diameter	3.9 - 19.7	-	ft
Length	8.2 - 49	-	ft
Depth	2.0 - 3.0	-	ft
Total Headloss	49 - 98	-	ft
Net Headloss	24.6 - 49.2	-	ft

Membrane Filtration (MF/UF)		
	Value	*Units*
Operating Pressure	2.9 - 7.3	psi
TMP that Triggers Backwash	16.0 - 20.3	psi
Filtration Cycle Length	15 - 60	min
Backwash Duration	30 - 60	sec
Module Filtration Area	323 -599.5	ft2
Design Flux	17.6 - 58.8	gal/ft2/d

Cartridge Filter		
	Value	*Units*
Nominal Size	0.000039-0.000984	Inches
Hydraulic loading rates	5706	gal/d
Pressure Drop	2.9	psi

Design Examples on Media Filters and Membrane Loading Rates

Process-Based Comparison

Design Specification Worksheet

Summary

- Selection of pretreatment was a function of feed water quality, intake system, and membrane fouling propensity.
- Iron and manganese, DOC/AOC were key parameters involved in fouling of RO membranes.
- Plant delivery and operations contracts played a key role on design and operational performance of membranes.
- An excel-based pretreatment process selection tool can be useful as a first step when considering

Acknowledgement

- Funding: Water Research Foundation (Project #WRRF-14-07)
- Research Manager: Kristan VandenHeuvel - WRF
- Project Advisory Committee (PAC) Members: Con Pelekani, SA Water; Jonathan Dietrich, Dietrich Consulting; John Tonner, Consolidated Water; Neil Callahan, Louis Berger; Robert Cheng, CVWD; Sohail Murad, U of Illinois, Chicago
- Participating SWRO Plants and the utility personnel responding to the questionnaire

Thanks!

joseph.jacangelo@stantec.com

Carlsbad Desalinated Seawater Integration Study

Desal-15-06 / 4773

Brent Alspach, PE, BCEE
Director of Applied Research
Arcadis

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Research Team

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Greg Imamura	Arcadis
Dr. Jerry Speitel	U. of Texas

ARCADIS

TEXAS
The University of Texas at Austin

Water Research Foundation

- Kristan VandenHeuvel, PM

THE Water Research FOUNDATION

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Project Advisory Committee

Wendy Chambers	Irvine Ranch Water District
Dr. Robert Cheng	Coachella Valley Water District
Dr. Christine Owen	Hazen and Sawyer
Nikolay Voutchkov	Water Globe Consulting
Justin Pickard	Water Systems Consulting

Acknowledgements

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Partner Agencies

Carlsbad Municipal Water District

City of San Diego

Helix Water District

Olivenhain Municipal Water District

Otay Water District

Poseidon Water

Rincon del Diablo Municipal Water District

San Diego County Water Authority

Sweetwater Authority

Vallecitos Water District

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Vallecitos Water District

Owner of the Carlsbad Desalination Plant (CDP)

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Vallecitos Water District

Regional wholesaler and sole purchaser of CDP water

Acknowledgements

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Sweetwater Authority

Vallecitos Water District

SDCWA
Member Agencies

Background

WRF-15-06: What You Need to Know

High-Level Project Synopsis

- Collect data over a 3-year window
  - Two pre-CDP baseline years: **2014-15**
  - First year of CDP operation: **2016**
- Focus on water quality data collected during routine system operation
- Utilize existing monitoring locations

WRF-15-06: What You Need to Know

SDCWA Treated Water Supplies

- Imported treated water, from MWD's Skinner WTP
- Imported raw water, treated locally at the Twin Oaks Valley WTP
- CDP desalinated seawater

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- CDP desalinated seawater

Combined sources of Colorado River Water (CRW) & State Project Water (SPW)

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Complex blending

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Water Quality Focus Areas

Water Quality Focus Areas

Categories

- General Physical / Chemical Parameters
- Salinity and Chloride
- Disinfectant Residual
- Nitrification
- Disinfection By-Products
- Corrosion
- Boron and Sodium Adsorption Ratio (SAR)

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WateReuse California Annual Conference

March 25-27, 2018

Water Quality Focus Areas

Categories

- General Physical / Chemical Parameters
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AWWA Annual Conference

June 11-14, 2018

Water Quality Focus Areas

Categories

- General Physical / Chemical Parameters
- **Salinity and Chloride**
- Disinfectant Residual
- Nitrification
- Disinfection By-Products
- Corrosion
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WateReuse Association
Annual Symposium
September 9-12, 2018

Water Quality Focus Areas

Categories

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- Salinity and Chloride
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- Nitrification
- Disinfection By-Products
- Corrosion
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AWWA Water Quality Technology Conference

November 11-15, 2018

Water Quality Focus Areas

Categories

- General Physical / Chemical Parameters
- Salinity and Chloride
- Disinfectant Residual
- Nitrification
- Disinfection By-Products
- Corrosion
- Boron and Sodium Adsorption Ratio (SAR)

The WRF-15-06 report provides an extensive discussion of the water quality influences pertaining to each of these categories.

Water Quality Focus Areas

Categories

- General Physical / Chemical Parameters
- Salinity and Chloride
- Disinfectant Residual
- Nitrification
- Disinfection By-Products
- Corrosion
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TODAY:

Temperature Influence

Key Water Quality Findings

1. Ocean water temperature exerts a significant influence on SWRO finished water quality, and by extension, the treated water blends delivered to SDCWA member agencies.
2. The potential for bromide-induced chloramine residual decay was successfully mitigated.
3. The introduction of SWRO supplies seemed to decrease fluctuation in several interrelated water quality parameters pertaining to chloramine residual and nitrification.

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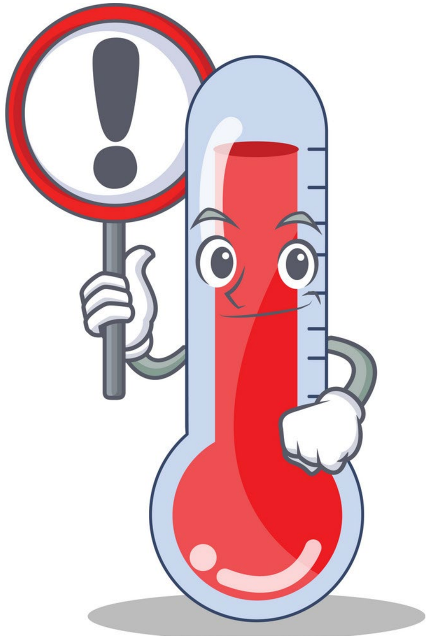

Detailed analysis shown today is not directly addressed in the Desal-15-06 report.

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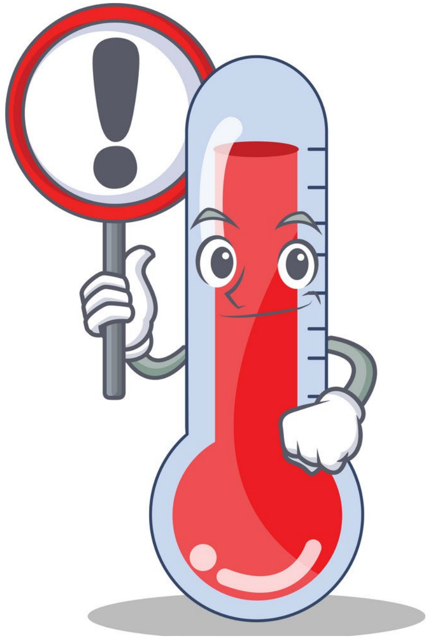

Demonstrated effect on numerous parameters

Chloride
TDS
Boron
Sodium

SAR
CSMR
CCPP
LSI

Key Water Quality Findings

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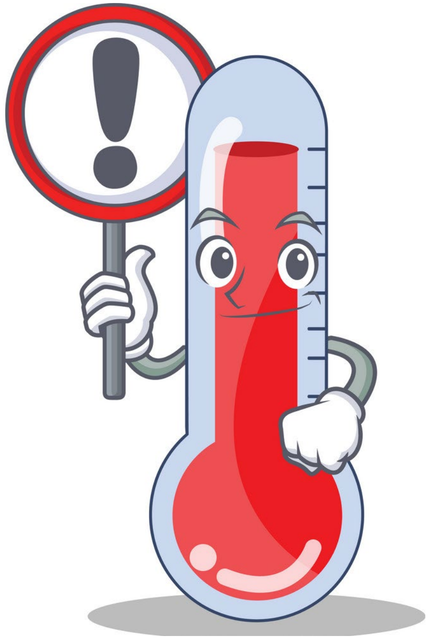
Demonstrated effect on numerous parameters



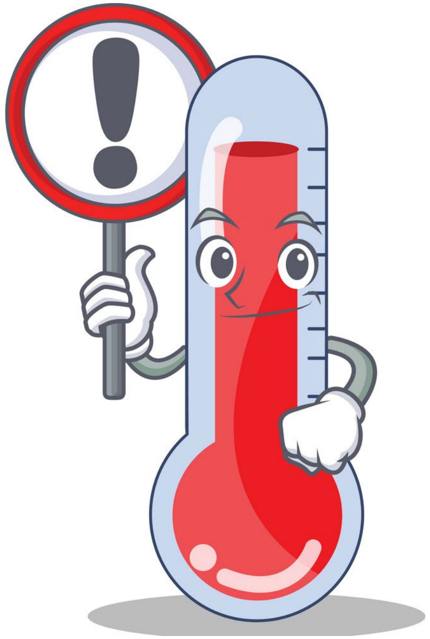
Temperature factors into the formulae for calculation.

Chloride	SAR
TDS	CSMR
Boron	**CCPP**
Sodium	**LSI**

Key Water Quality Findings

1. Ocean water temperature exerts a significant influence on SWRO finished water quality, and by extension, the treated water blends delivered to SDCWA member agencies.

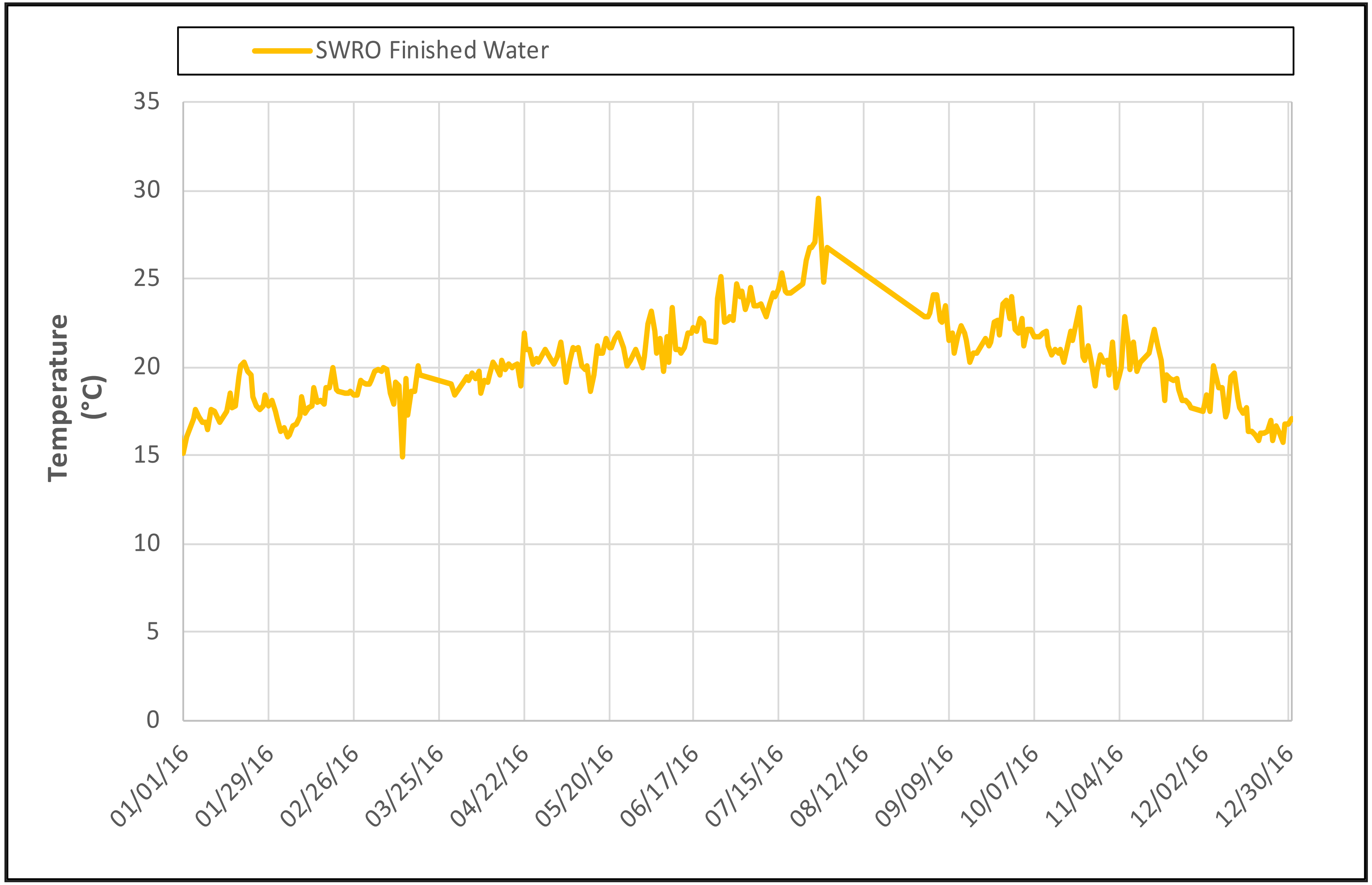
Demonstrated effect on numerous parameters



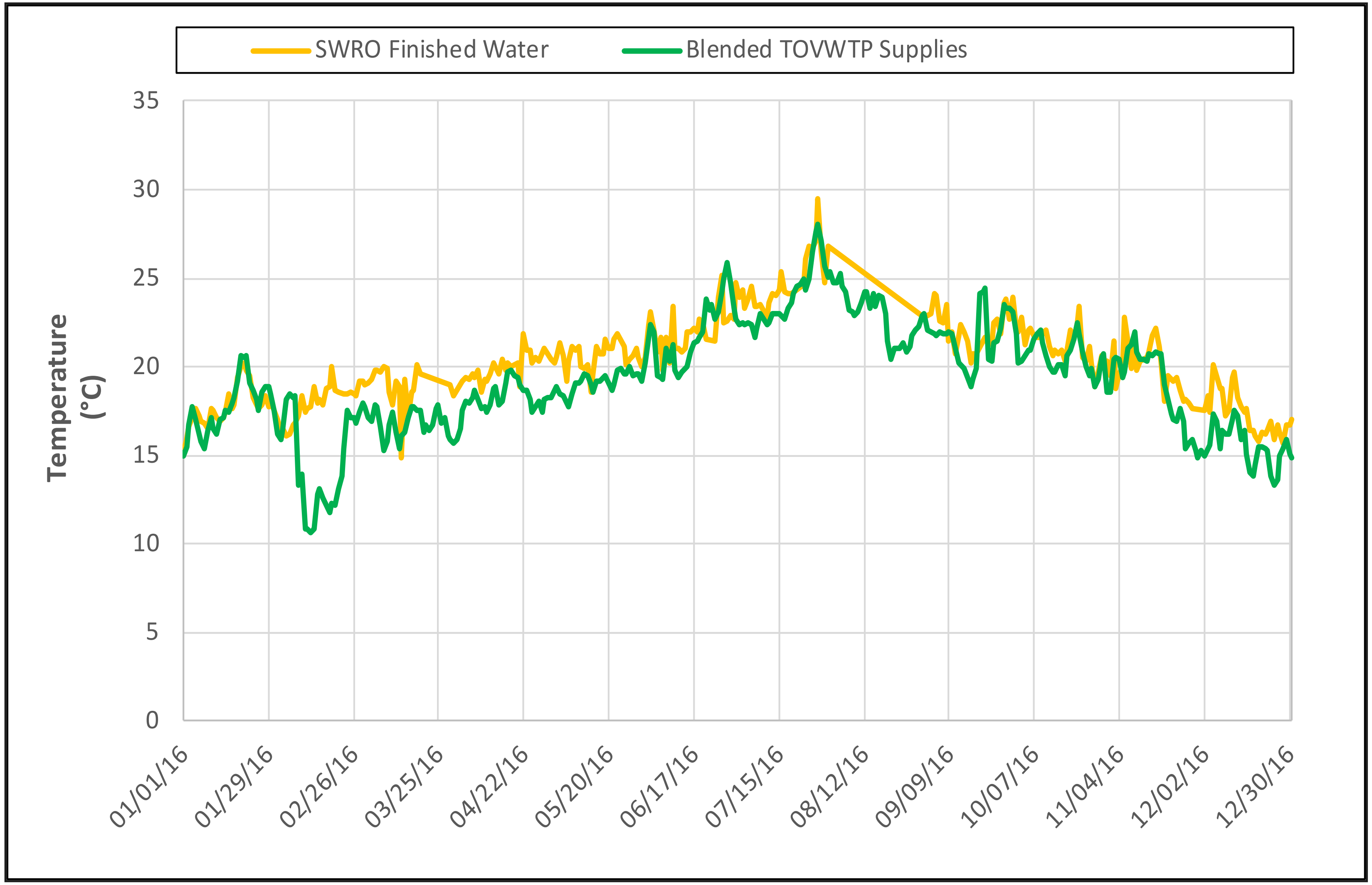
Temperature influences RO rejection characteristics

Chloride	**SAR**
TDS	**CSMR**
Boron	CCPP
Sodium	LSI

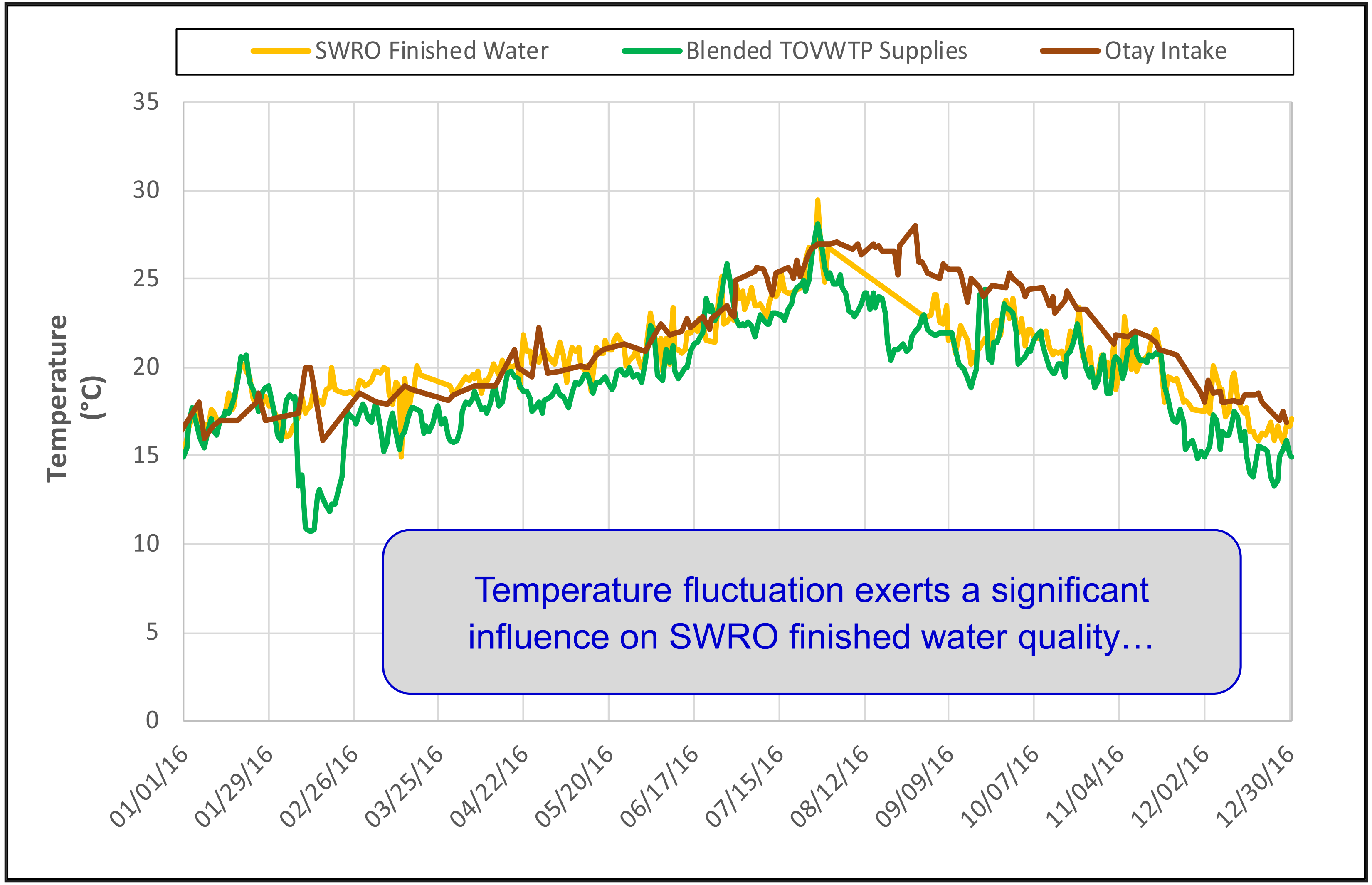
Temperature



Temperature



Temperature

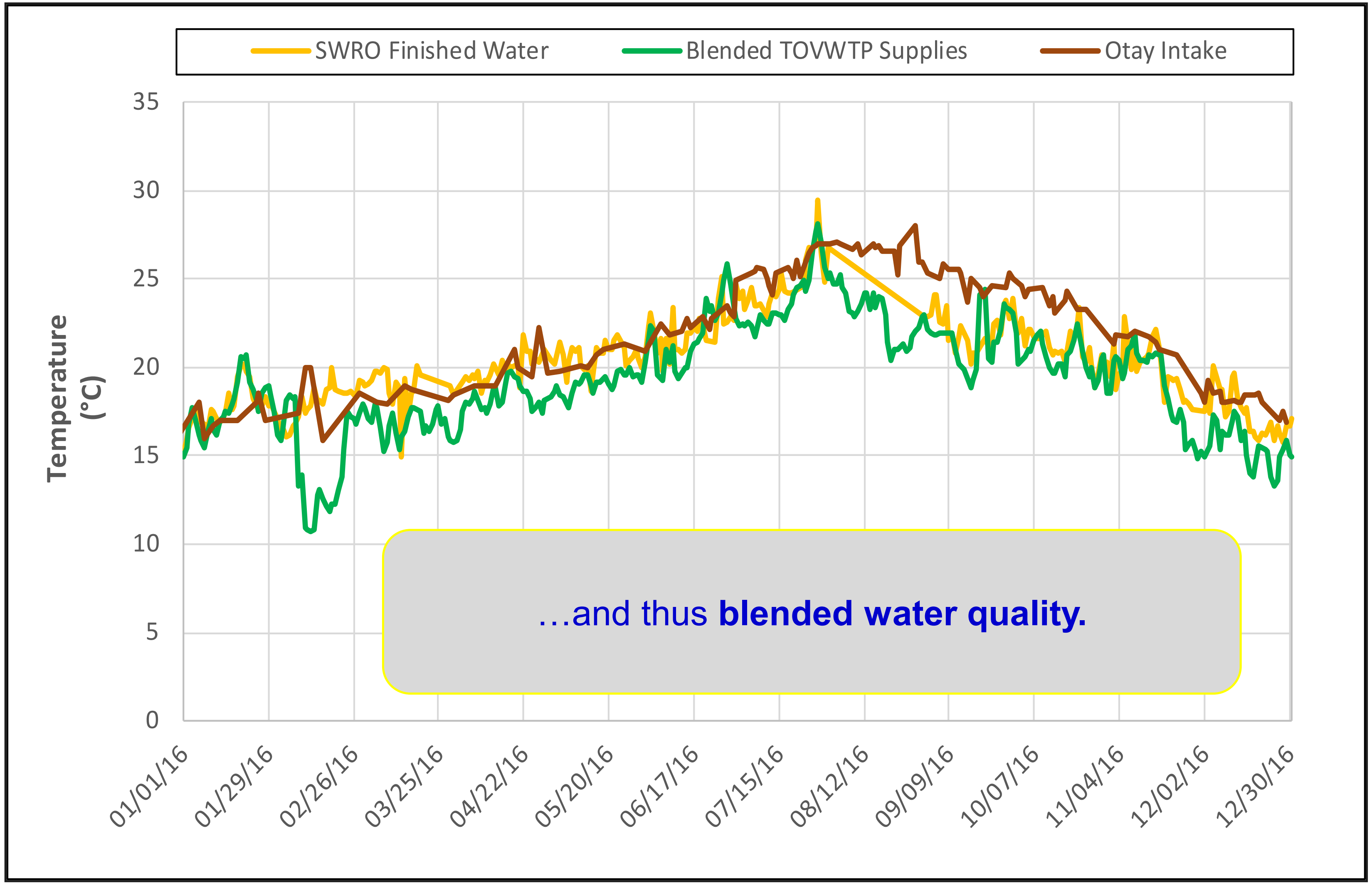


Temperature fluctuation exerts a significant influence on SWRO finished water quality…

Key Points:

- Seasonal changes in ocean water and imported water temperature track closely…
- …purely by coincidence.
- Temperature increases slightly within the SDCWA regional conveyance (as expected).
- Range of temperature fluctuation: **~10 °C**

Temperature



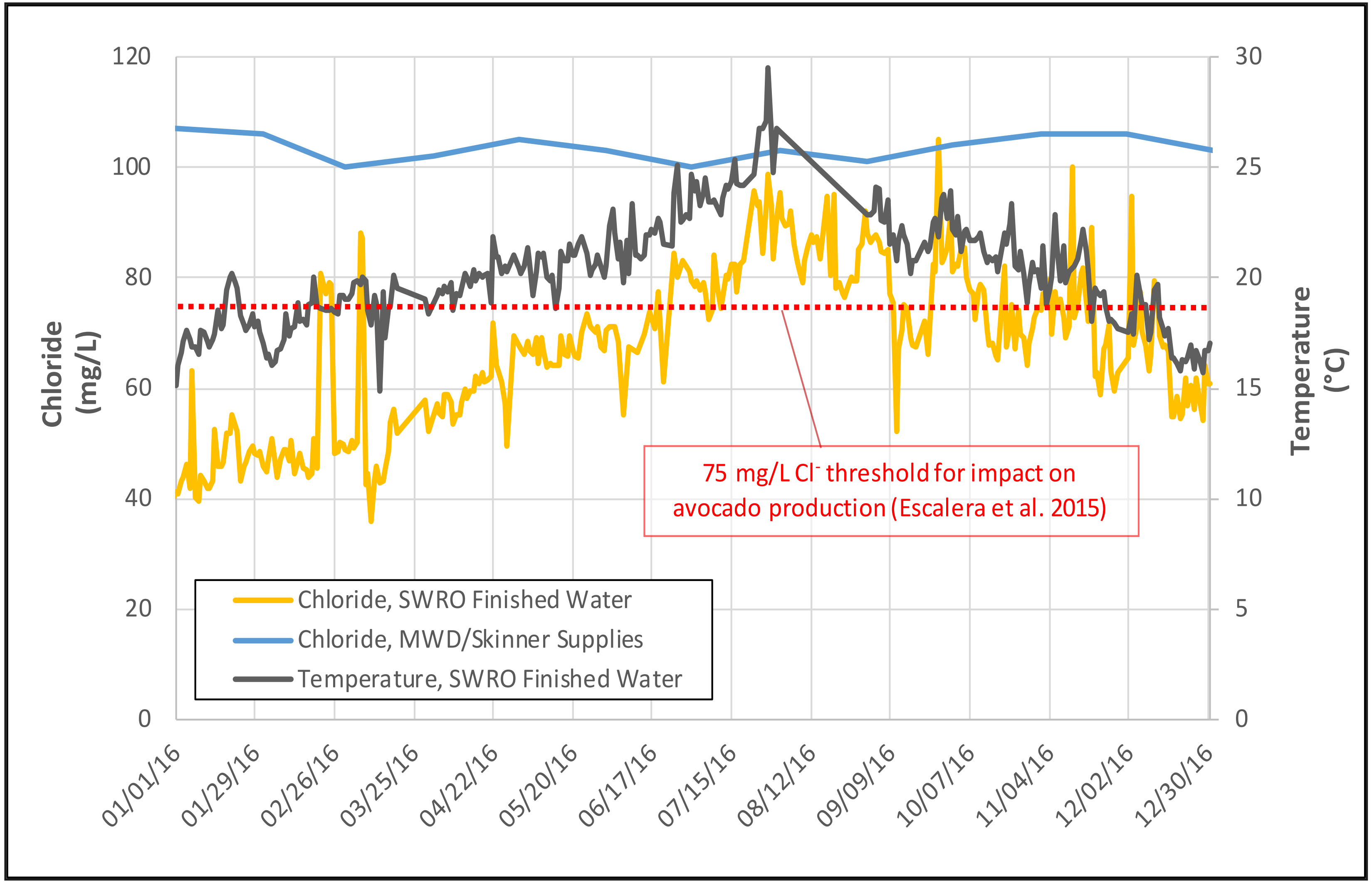
…and thus **blended water quality.**

Key Points:

- Seasonal changes in ocean water and imported water temperature track closely…
- …purely by coincidence.
- Temperature increases slightly within the SDCWA regional conveyance (as expected).
- Range of temperature fluctuation: **~10 °C**

Important implications!

Temperature Influence: Chloride



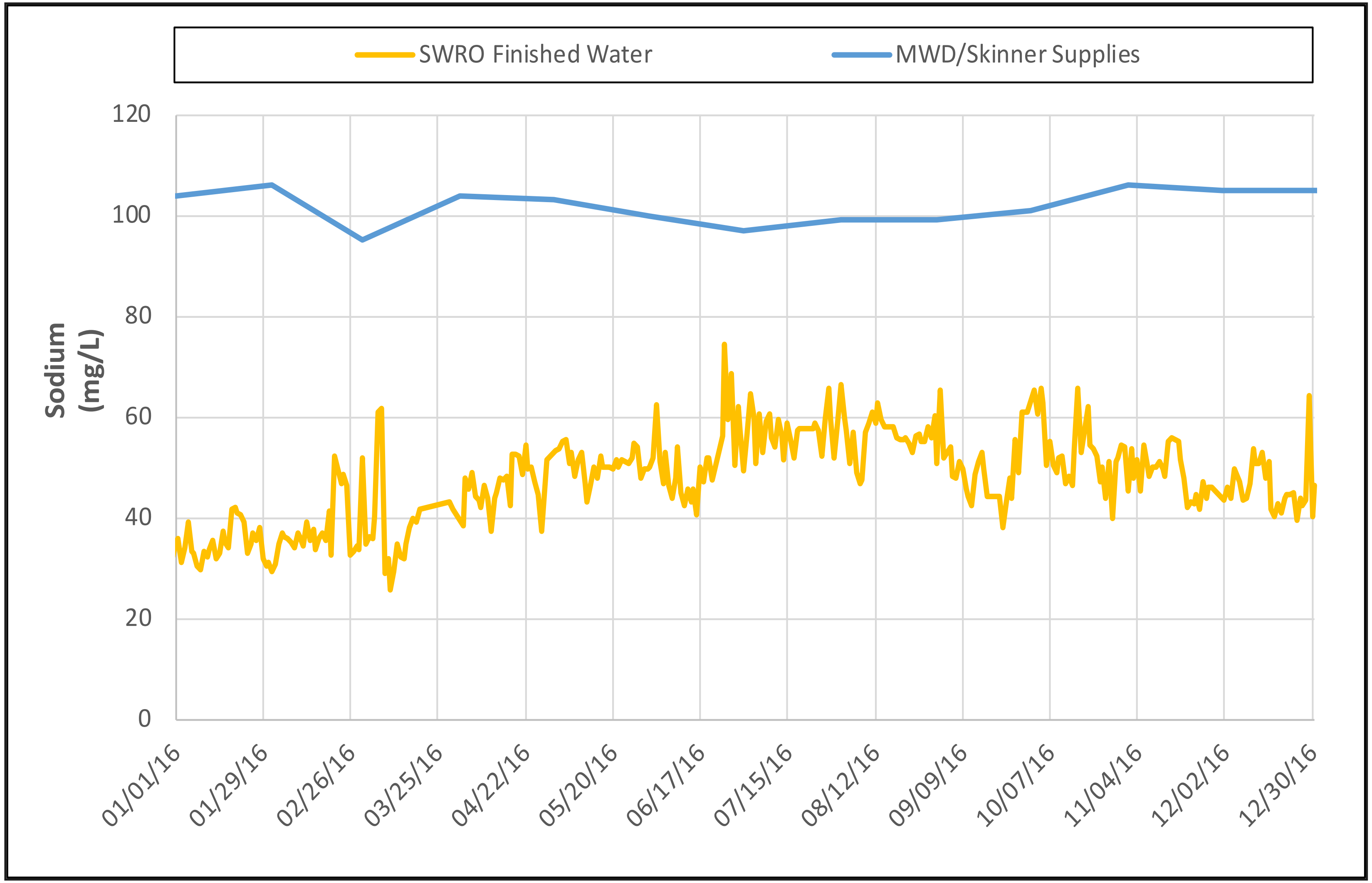
75 mg/L Cl^- threshold for impact on avocado production (Escalera et al. 2015)

Key Points:

- SWRO water chloride levels exhibit seasonal variation with temperature due to fluctuations in RO rejection.
- The magnitude of seasonal variation in SWRO water chloride levels is significant: **~ 40-100 mg/L (2.5x)**

→ SWRO supplies reduced chloride in treated water blends in 2016.

Temperature Influence: Sodium

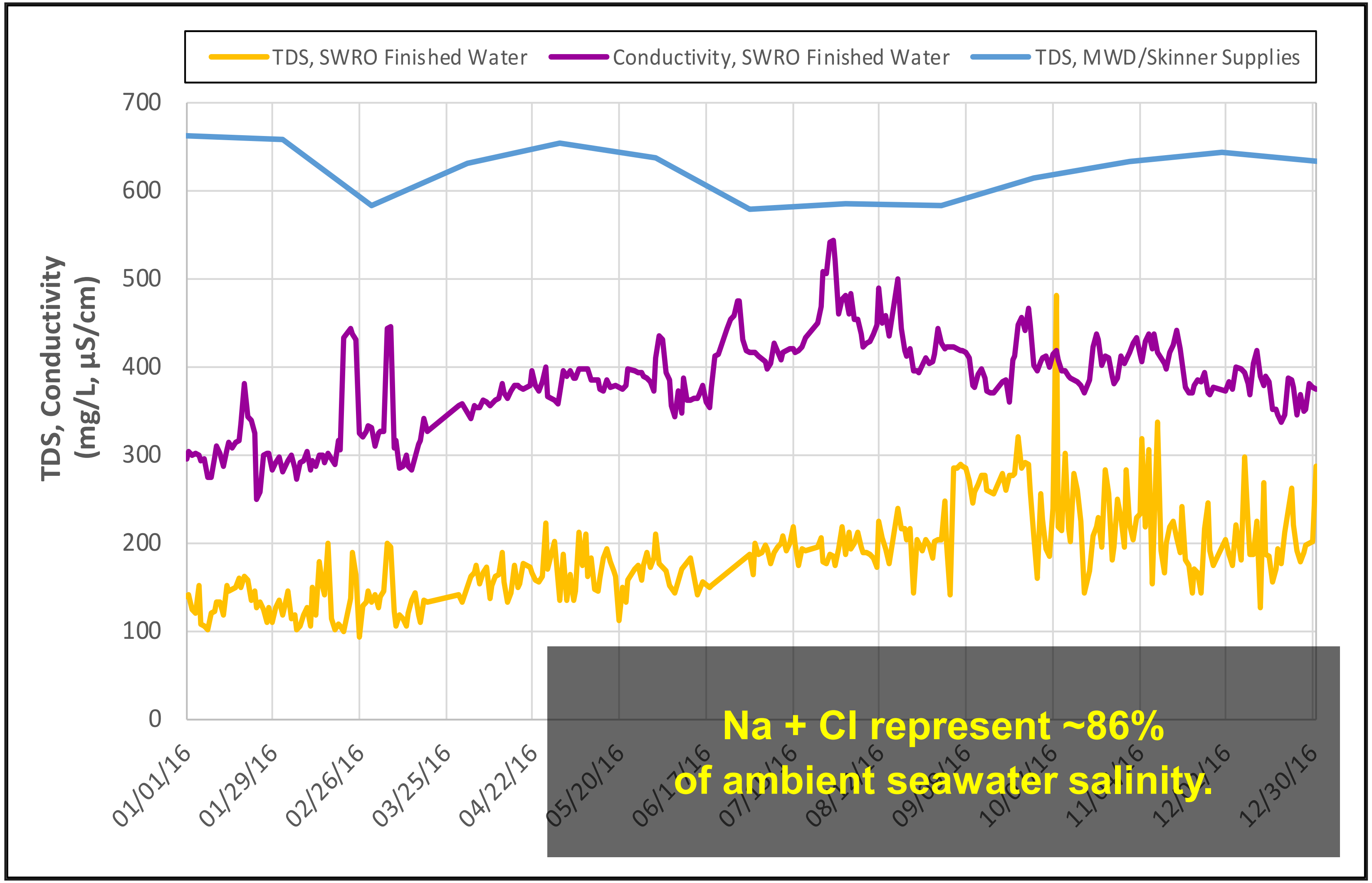


Key Points:

- SWRO water sodium levels exhibit seasonal variation with temperature due to fluctuations in RO rejection.
- The magnitude of seasonal variation in SWRO water sodium levels is significant: **~ 25-75 mg/L (3x)**

→ **SWRO supplies reduced sodium in treated water blends in 2016.**

Temperature Influence: TDS



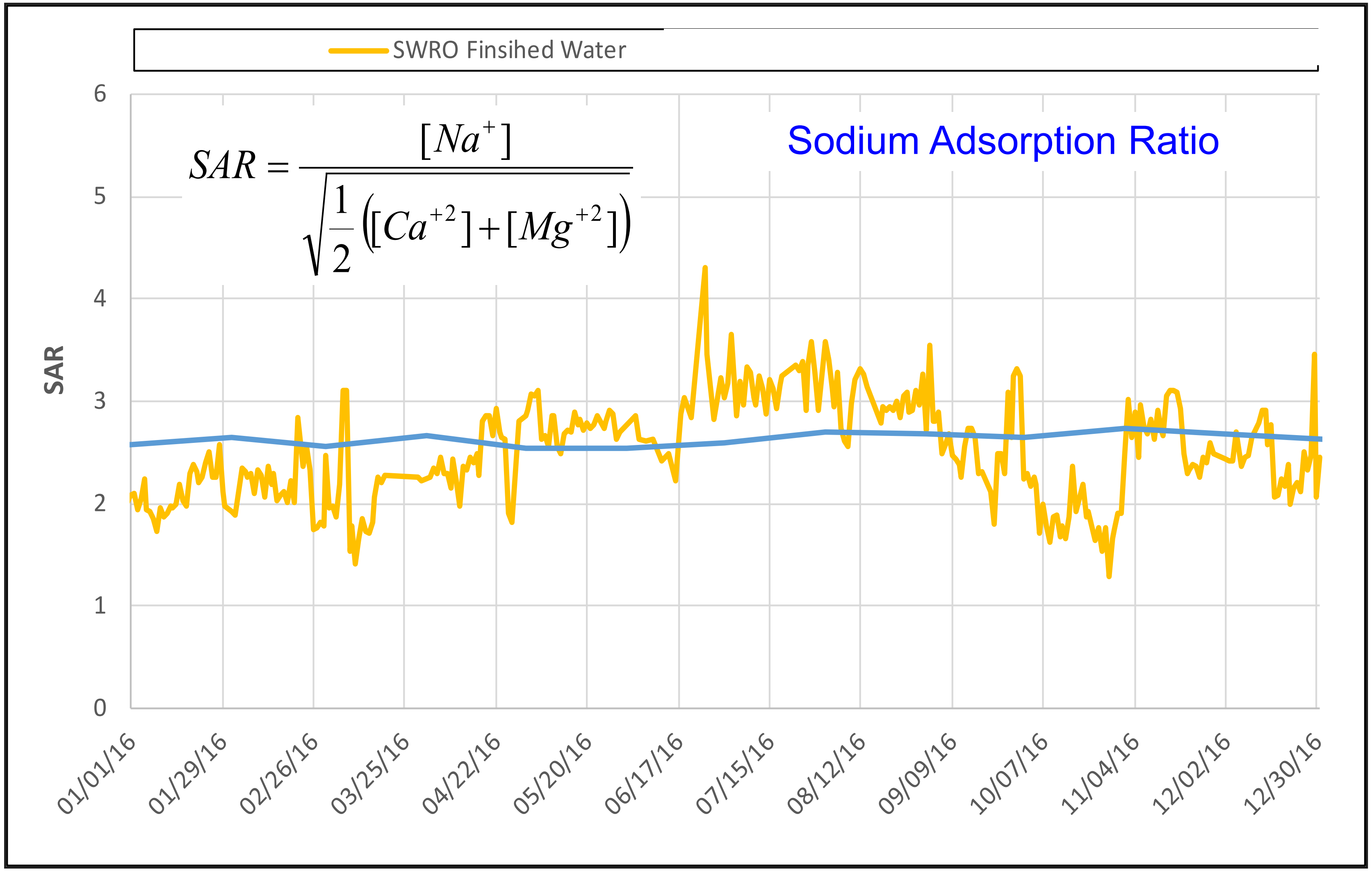
Na + Cl represent ~86% of ambient seawater salinity.

Key Points:

- The peak SWRO water TDS (~300 mg/L) is about ½ imported water TDS in 2016.
- The magnitude of seasonal variation in SWRO water TDS levels is significant: **~ 100-300 mg/L (3x)**
- At points of greatest differential in 2016, SWRO water is ~20% that of imported water.

→ SWRO supplies reduced both potable water salinity and regional salinity loading.

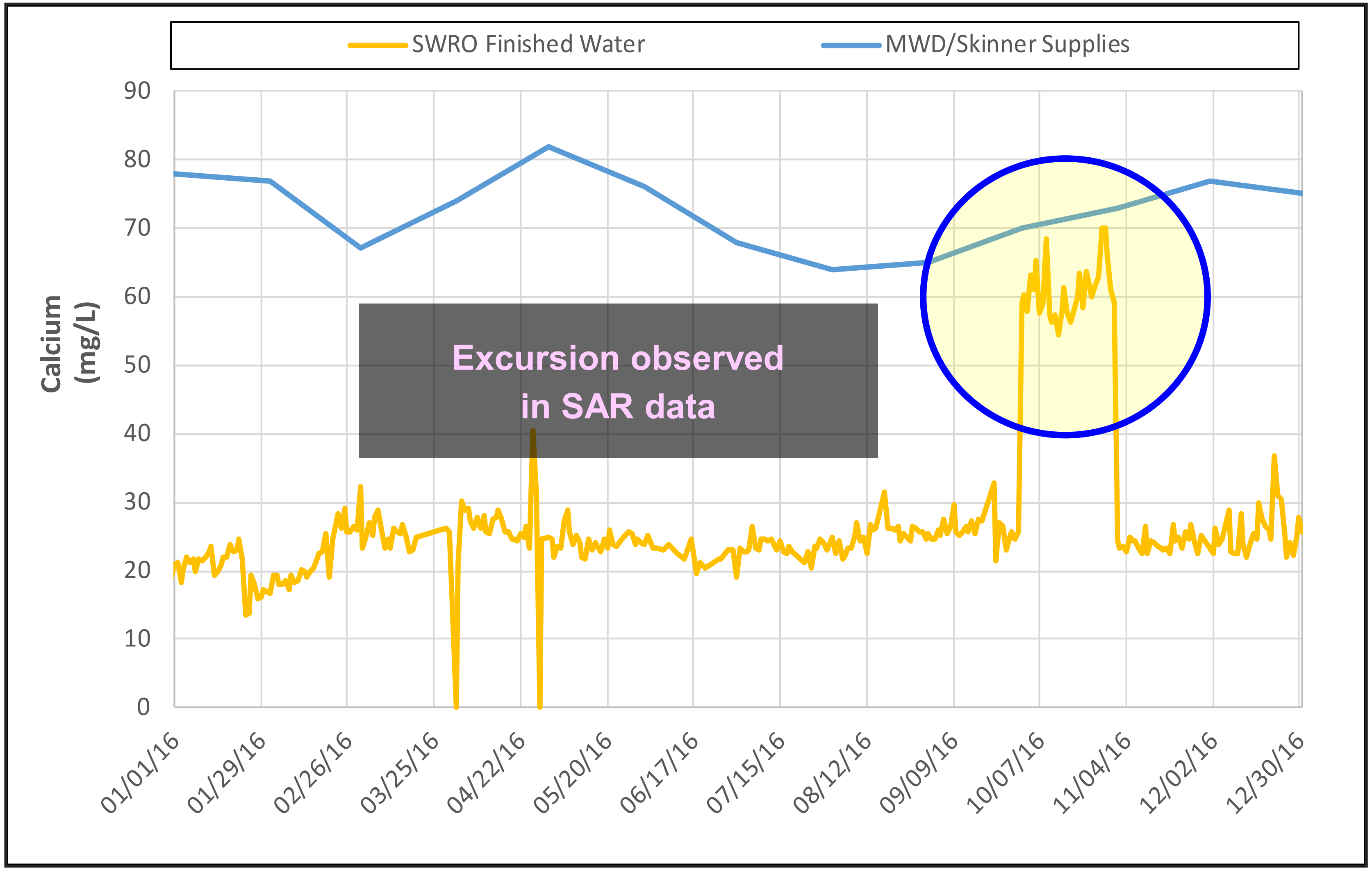
Temperature Influence: **SAR**



$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{1}{2}\left([Ca^{+2}]+[Mg^{+2}]\right)}}$$

Sodium Adsorption Ratio

Temperature Influence: Calcium

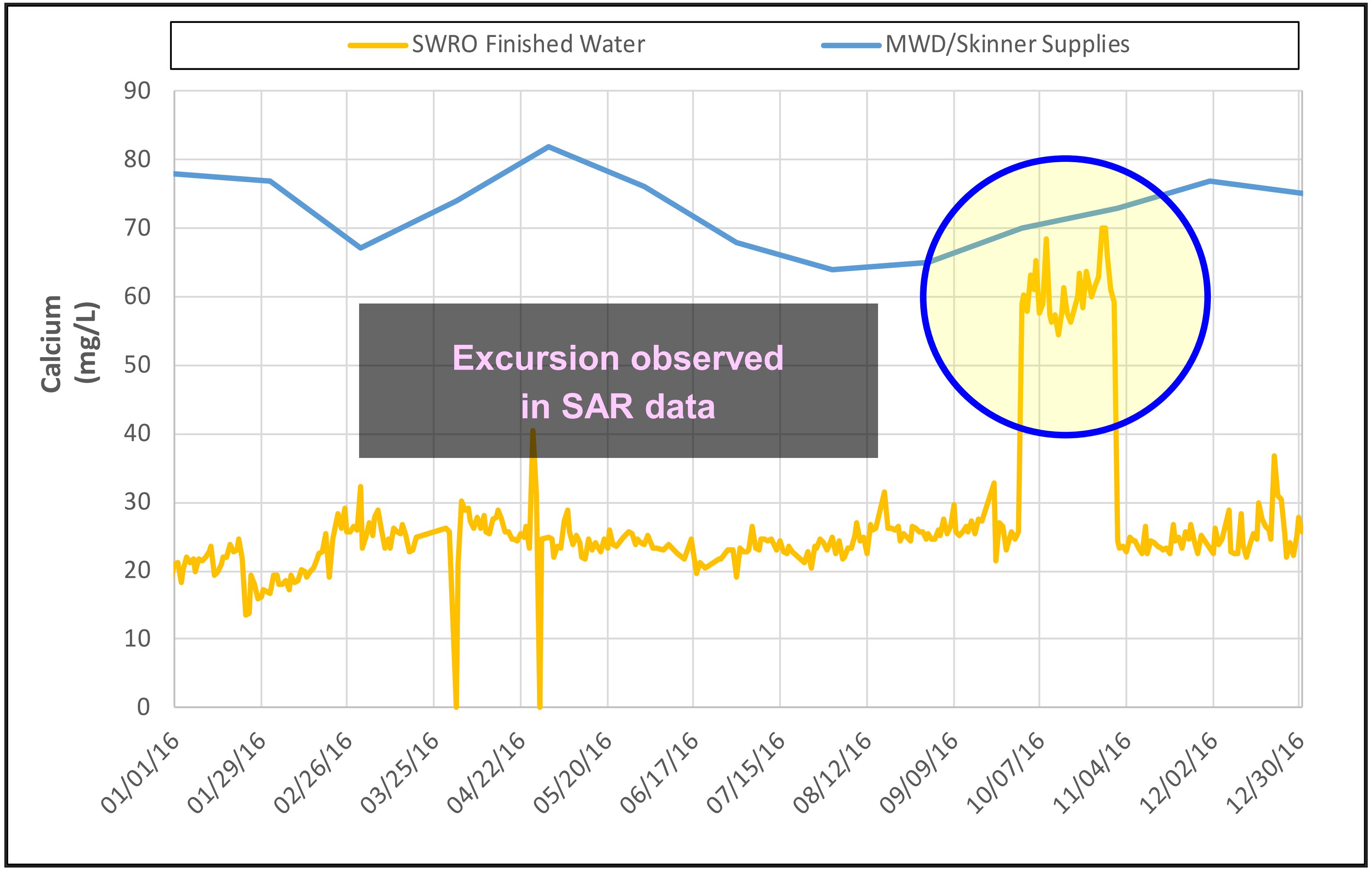


~~Temperature Influence~~: Calcium

Key Points:

- The divalent calcium ion is more efficiently rejected by SWRO membranes; thus, fluctuation of permeate levels with seasonal temperature is not observed.
- Calcium levels are about 3.5x higher in imported supplies vs. SWRO water.

→ **SWRO supplies reduced calcium in treated water blends in 2016.**

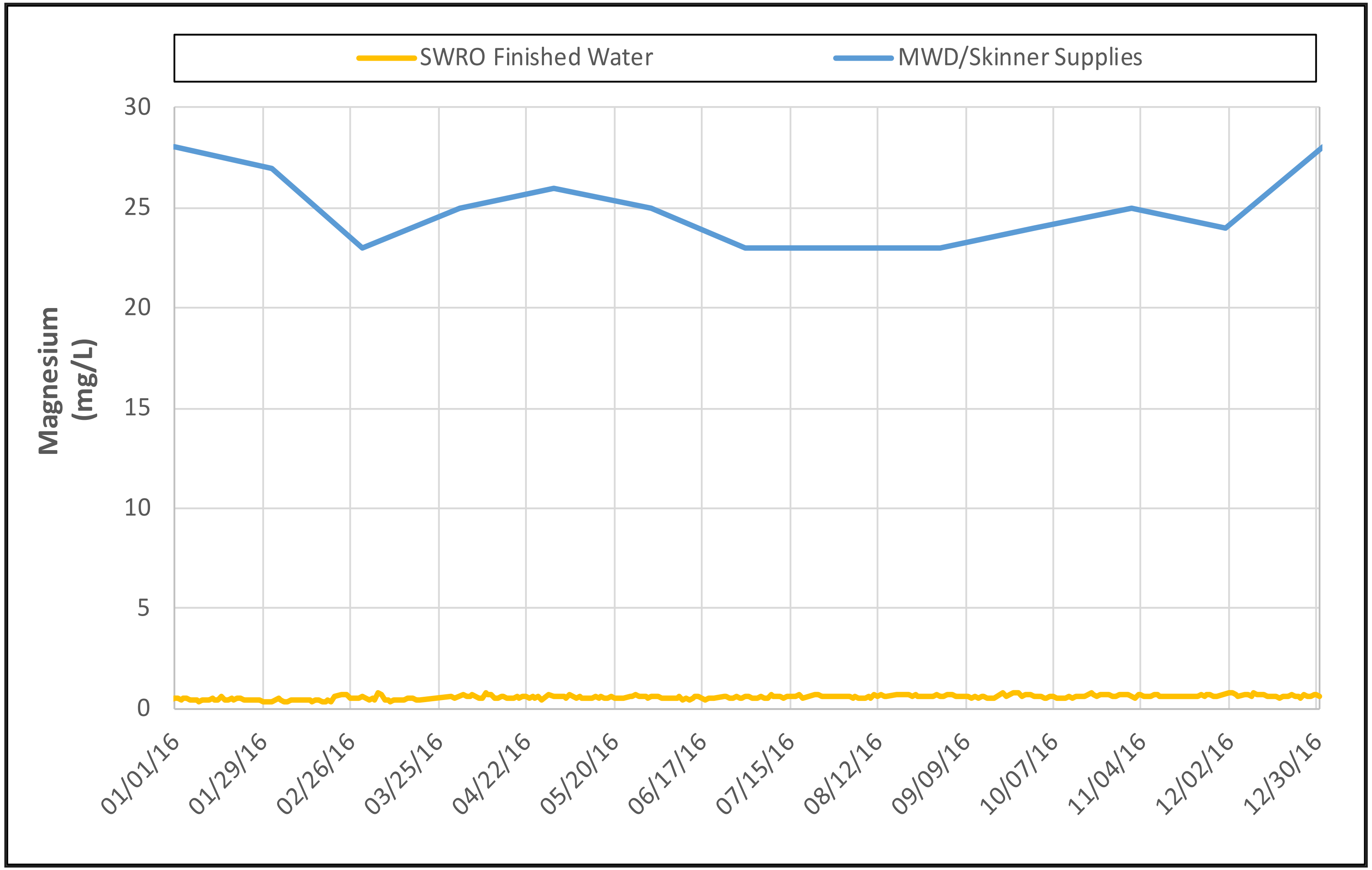


~~Temperature Influence~~: Magnesium

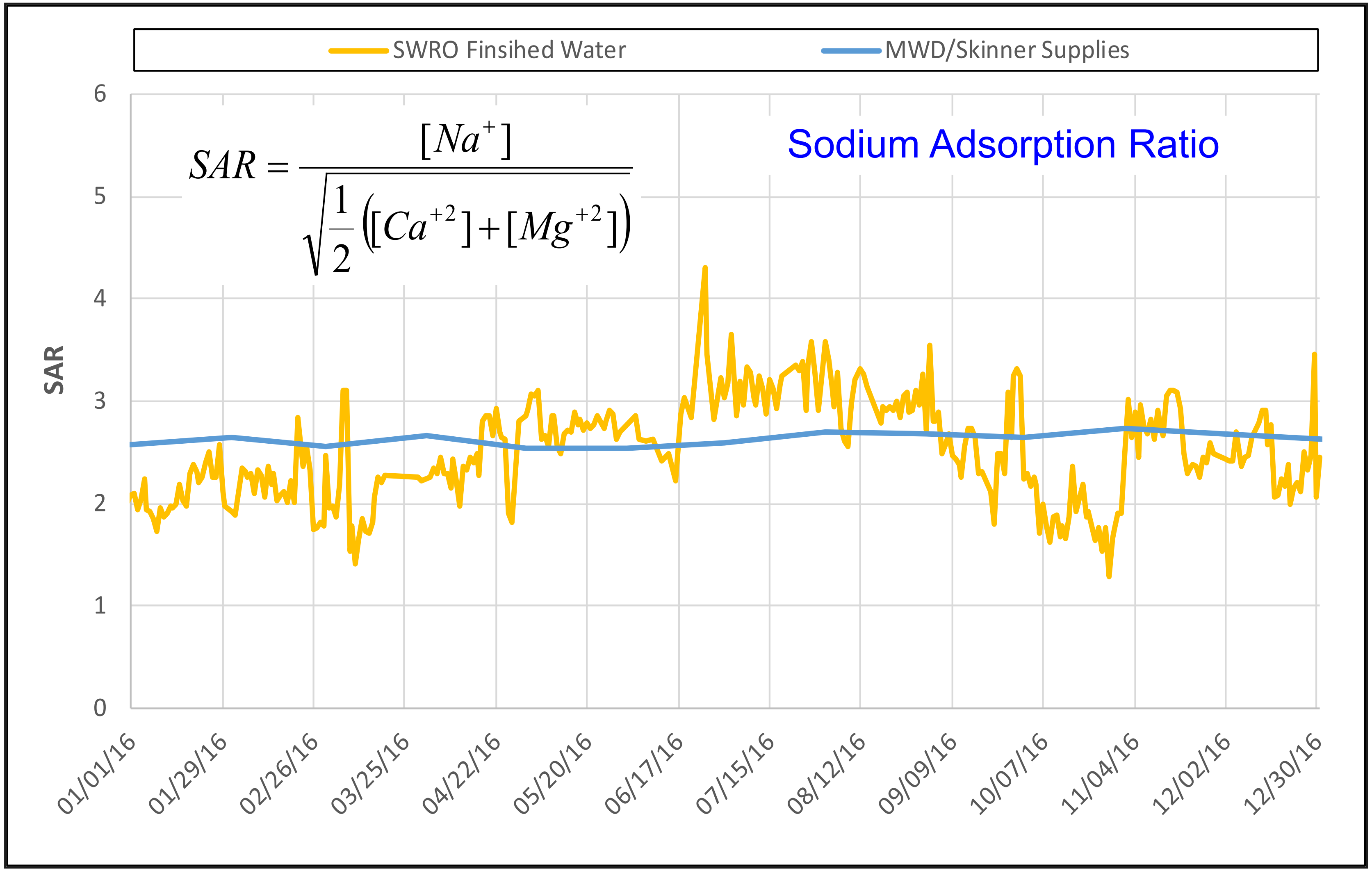
Key Points:

- The divalent magnesium ion is more efficiently rejected by SWRO membranes; thus, fluctuation of permeate levels with seasonal temperature is not observed.
- Magnesium levels are >10x higher in imported supplies vs. SWRO water.

→ SWRO supplies reduced magnesium in treated water blends in 2016.



Temperature Influence: SAR

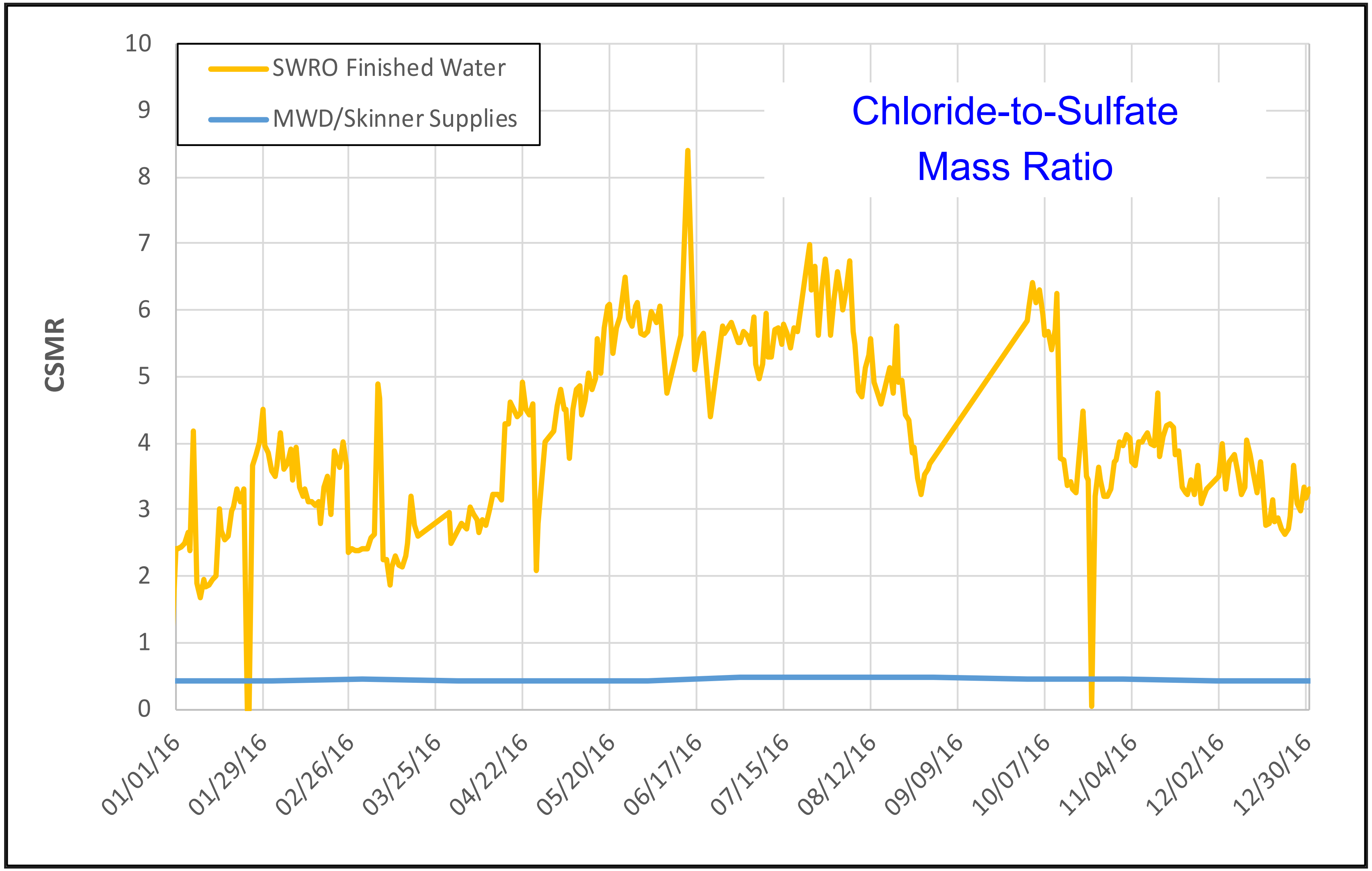


$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{1}{2}\left([Ca^{+2}]+[Mg^{+2}]\right)}}$$

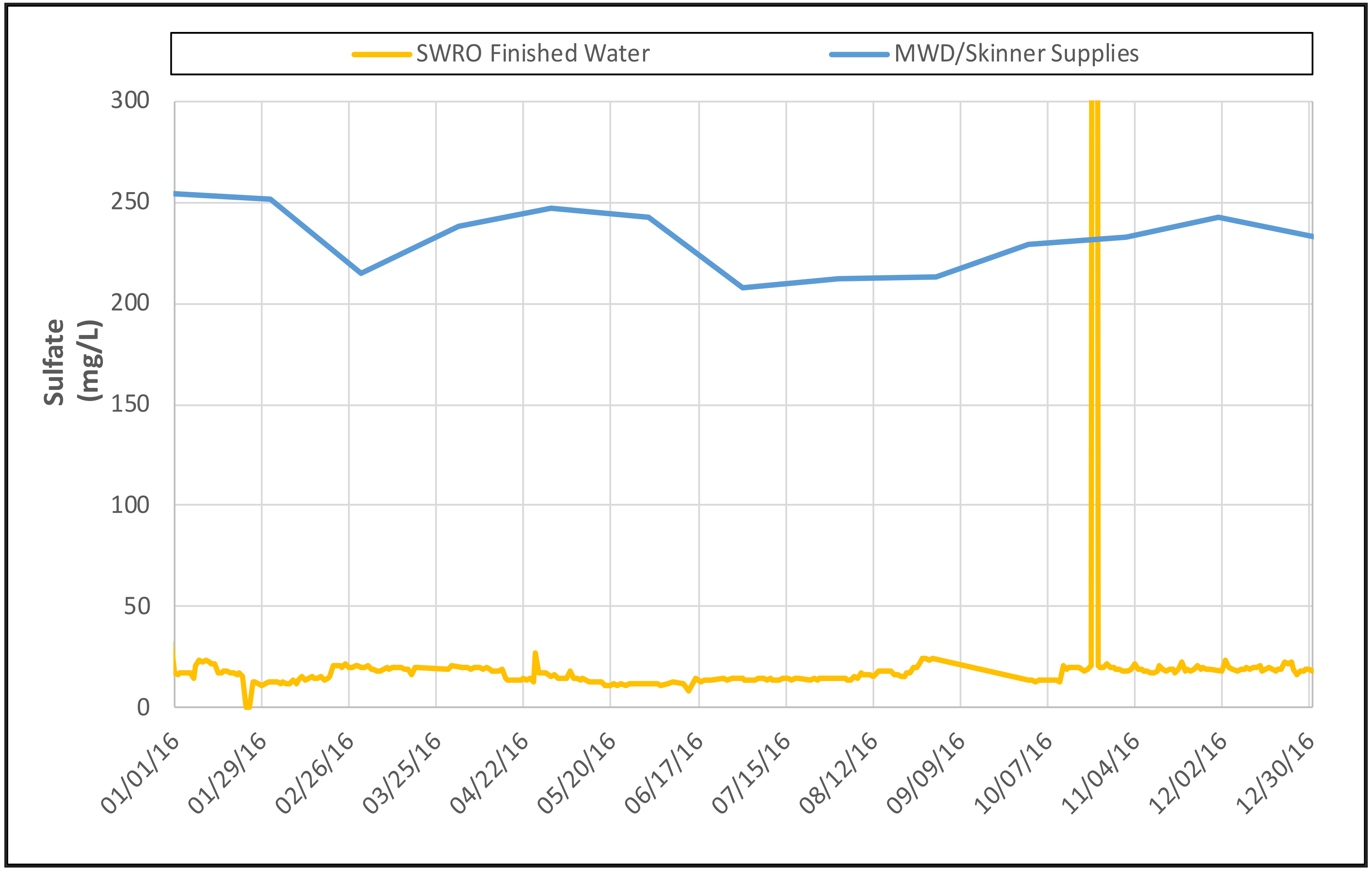
Key Points:

- SWRO water SAR levels vary seasonally due to sodium fluctuations.
- The magnitude of seasonal variation in SWRO water SAR levels is significant: **~ 1.4 - 4.3 mg/L (3x)**
- SWRO and imported water SAR levels are very similar, on average: **2.52 vs. 2.63 (resp.)**

Temperature Influence: CSMR



Temperature Influence: Sulfate

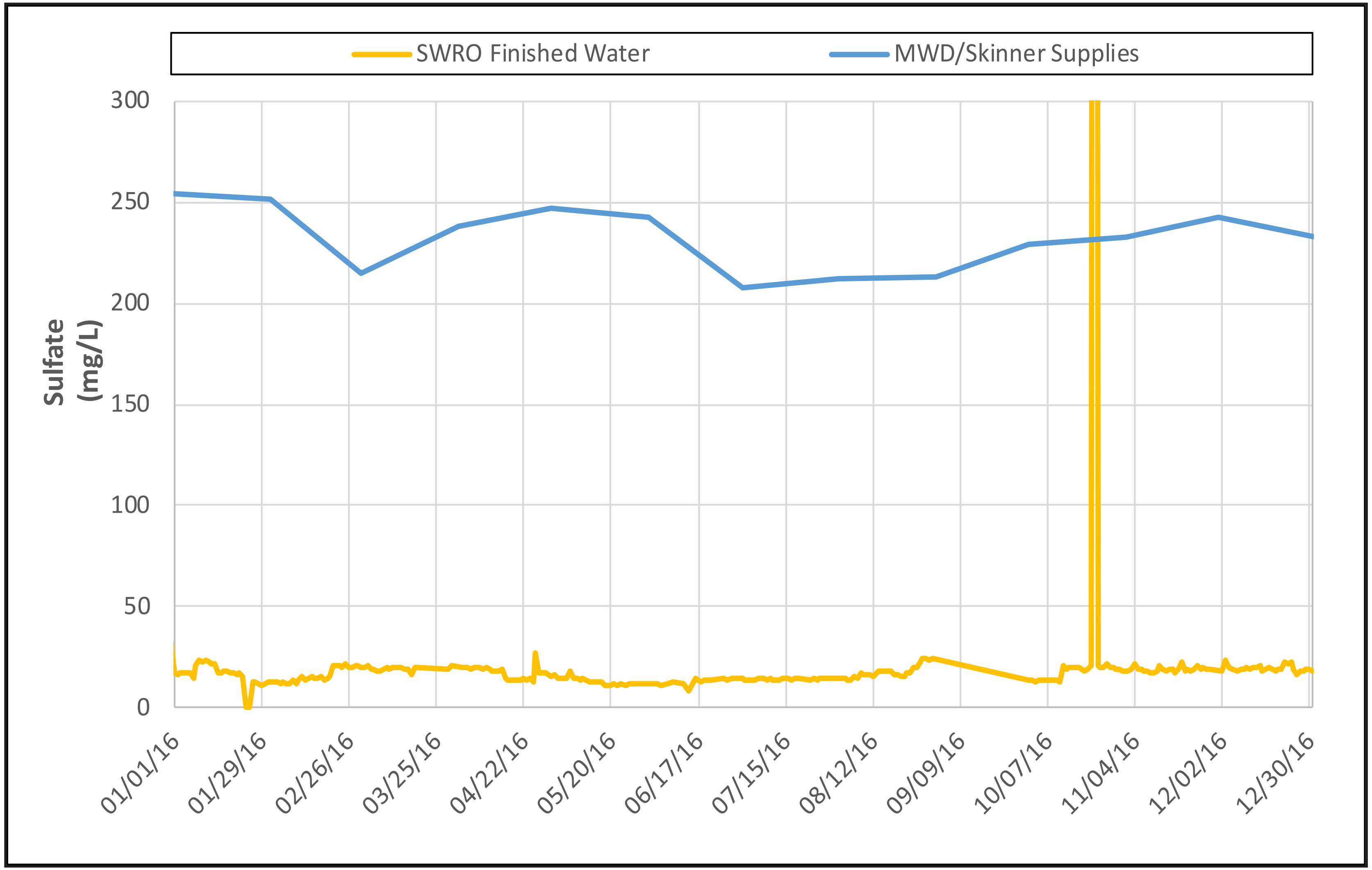


~~Temperature Influence~~: Sulfate

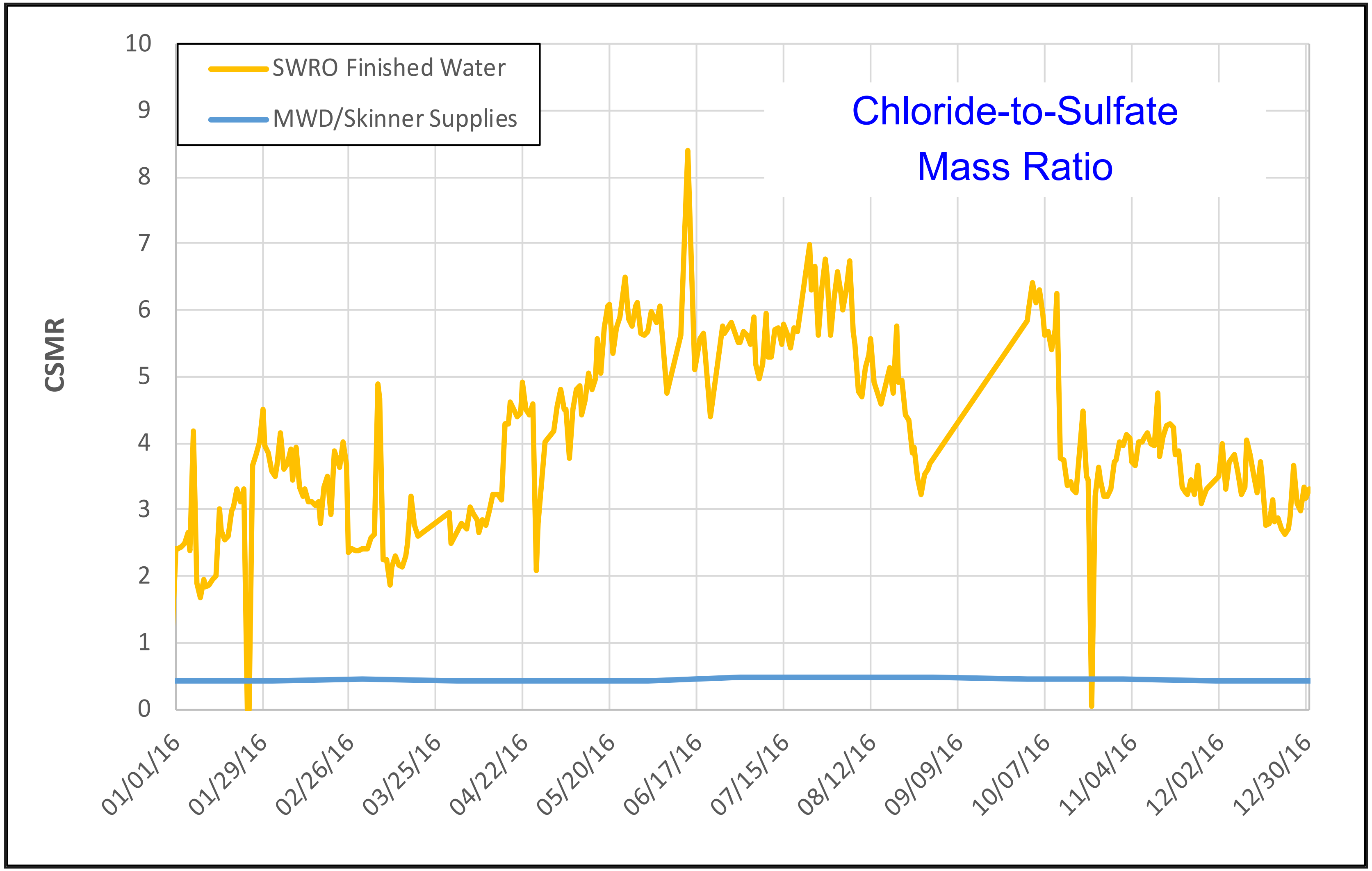
Key Points:

- The divalent sulfate ion is more efficiently rejected by SWRO membranes; thus, fluctuation of permeate levels with seasonal temperature is not observed.
- Sulfate levels are about 10x higher in imported supplies vs. SWRO water.

→ SWRO supplies reduced sulfate in treated water blends in 2016.



Temperature Influence: CSMR

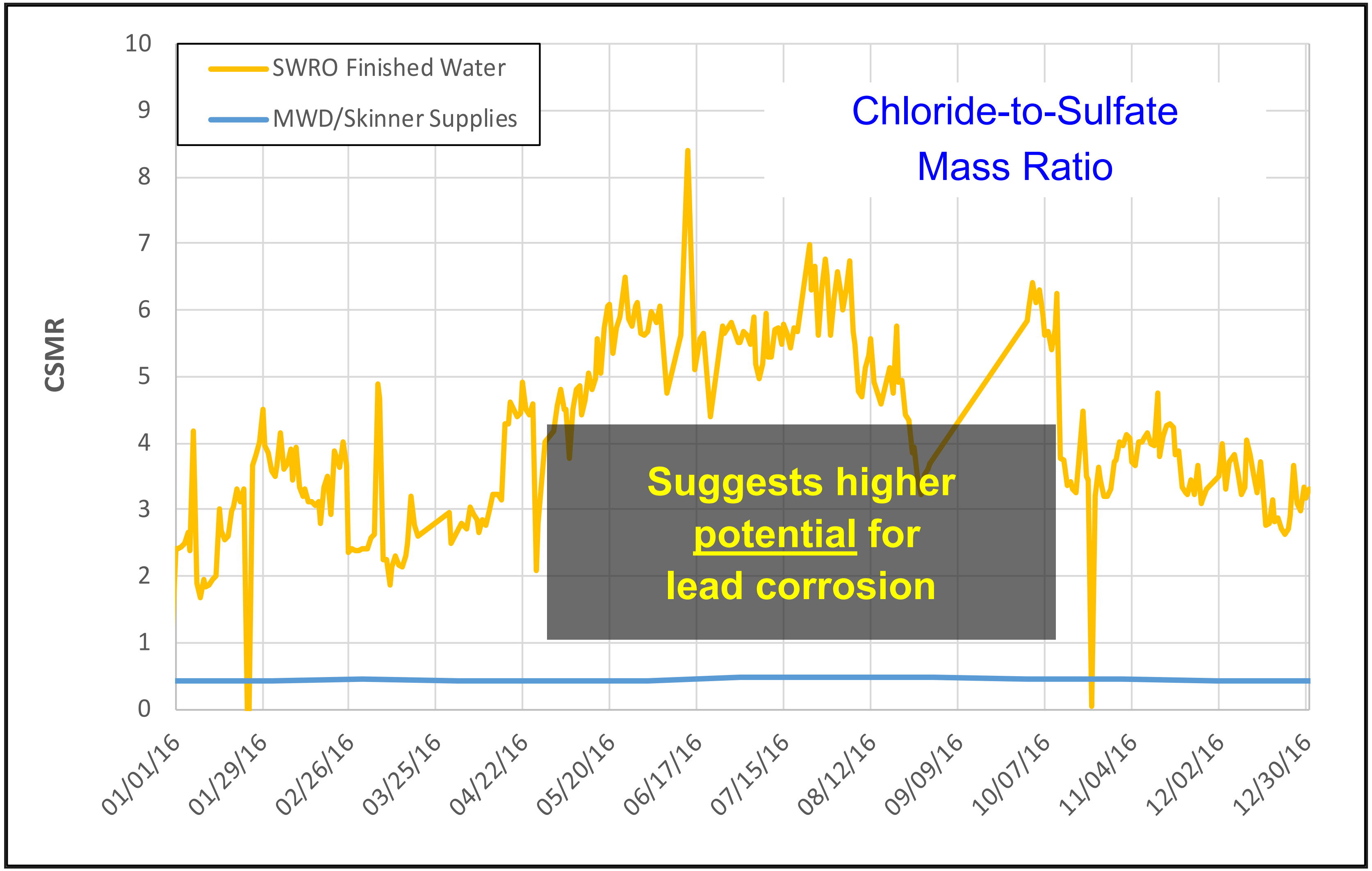


Key Points:

- The CSMR in SWRO water varies with temperature due to the similar phenomenon observed for chloride.
- SWRO water CSMR values are significantly higher than benchmark values reported in the literature.
- The magnitude of seasonal variation in SWRO water CSMR levels is significant: **~ 2 - 7 (3.5x)**

→ **SWRO supplies significantly increased CSMR in treated water blends in 2016.**

Temperature Influence: CSMR



Key Points:

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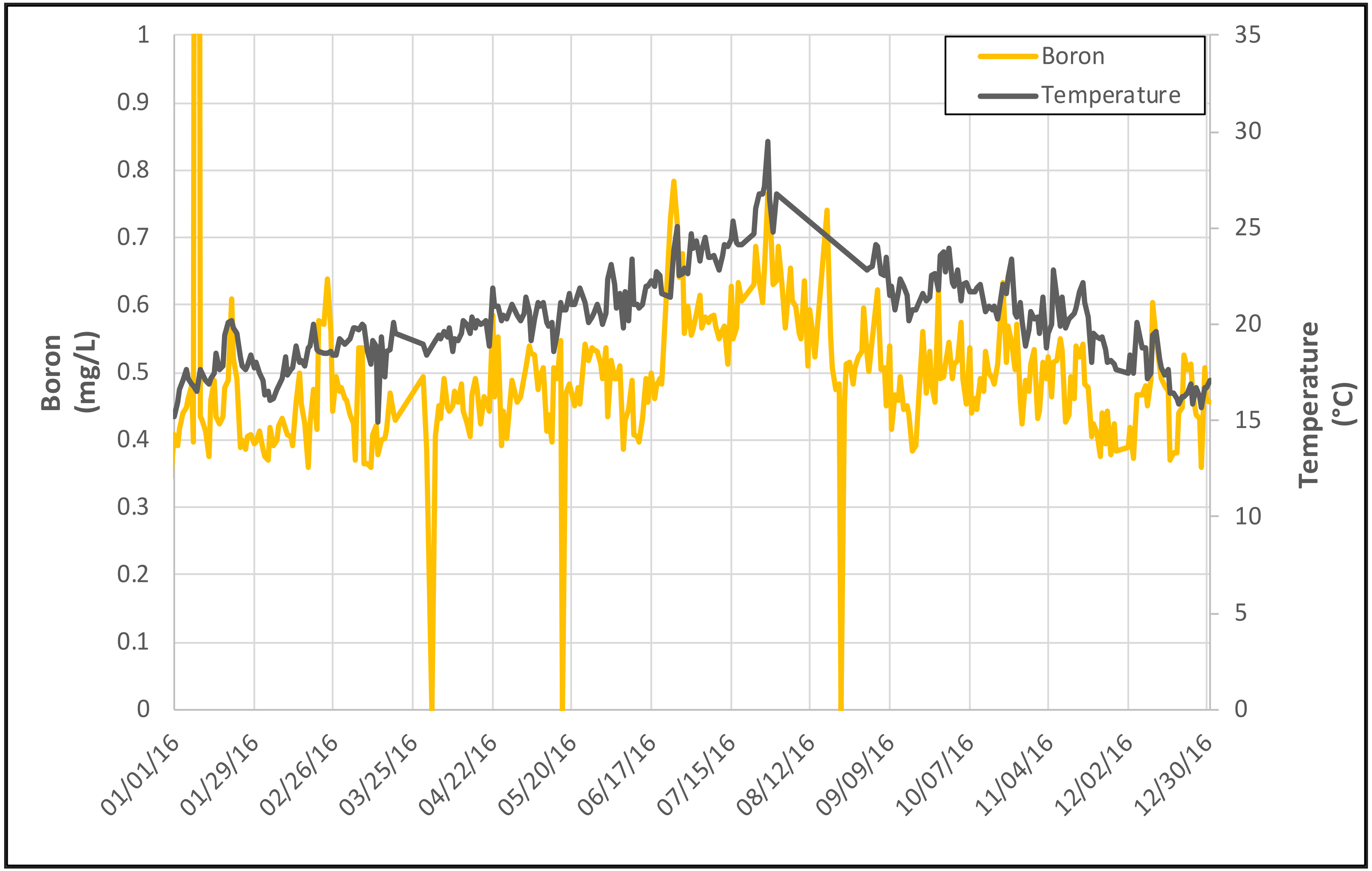
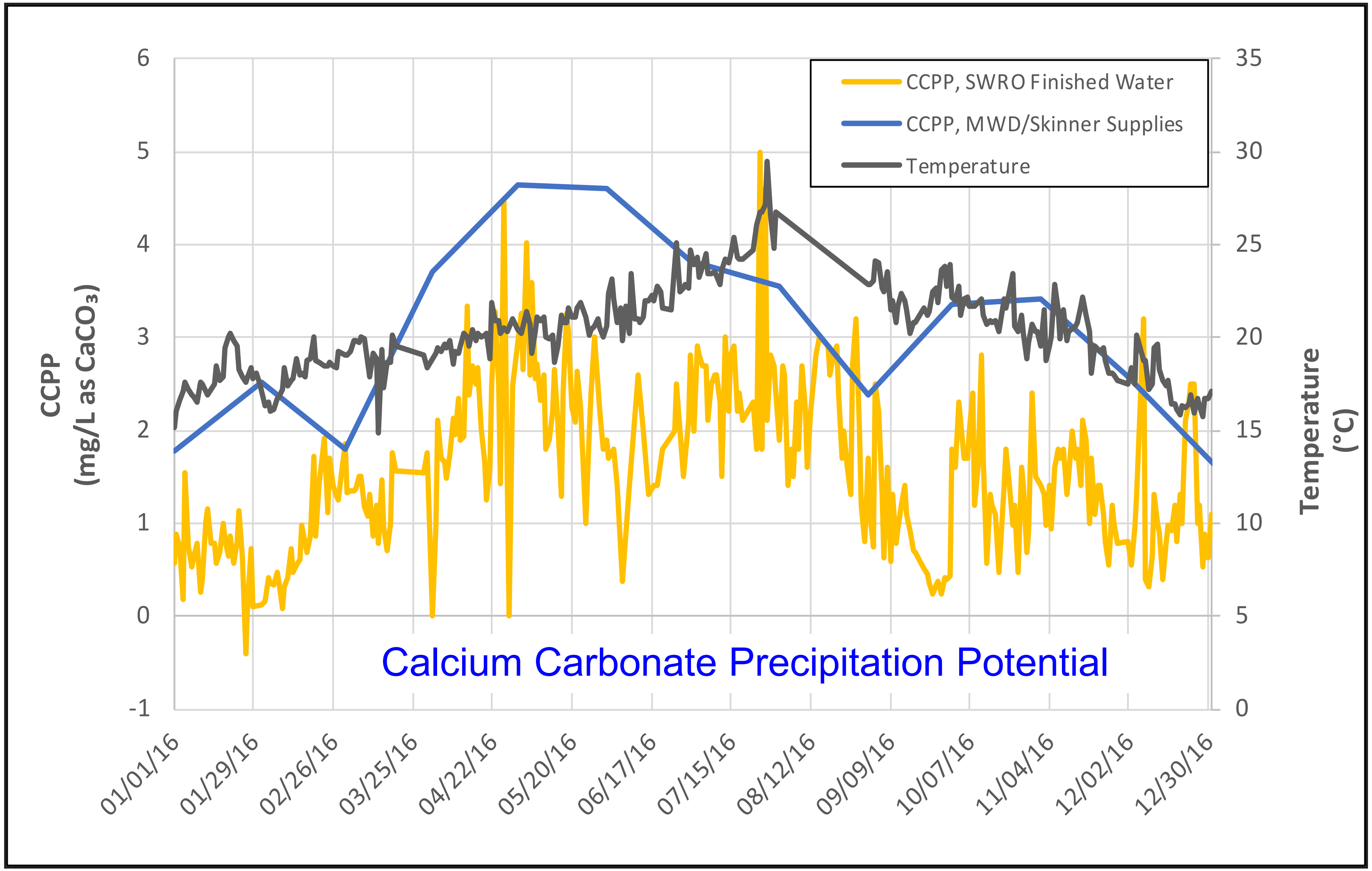
Temperature Influence: Boron



Key Points:

- SWRO water boron levels exhibit seasonal variation with temperature due to fluctuations in RO rejection
- The magnitude of seasonal variation in SWRO water boron levels is significant: **~ 0.4 - 0.8 mg/L (2x)**
- Recent historic imported water boron levels: ≈ 0.11 - 0.16 mg/L.

Temperature Influence: CCPP

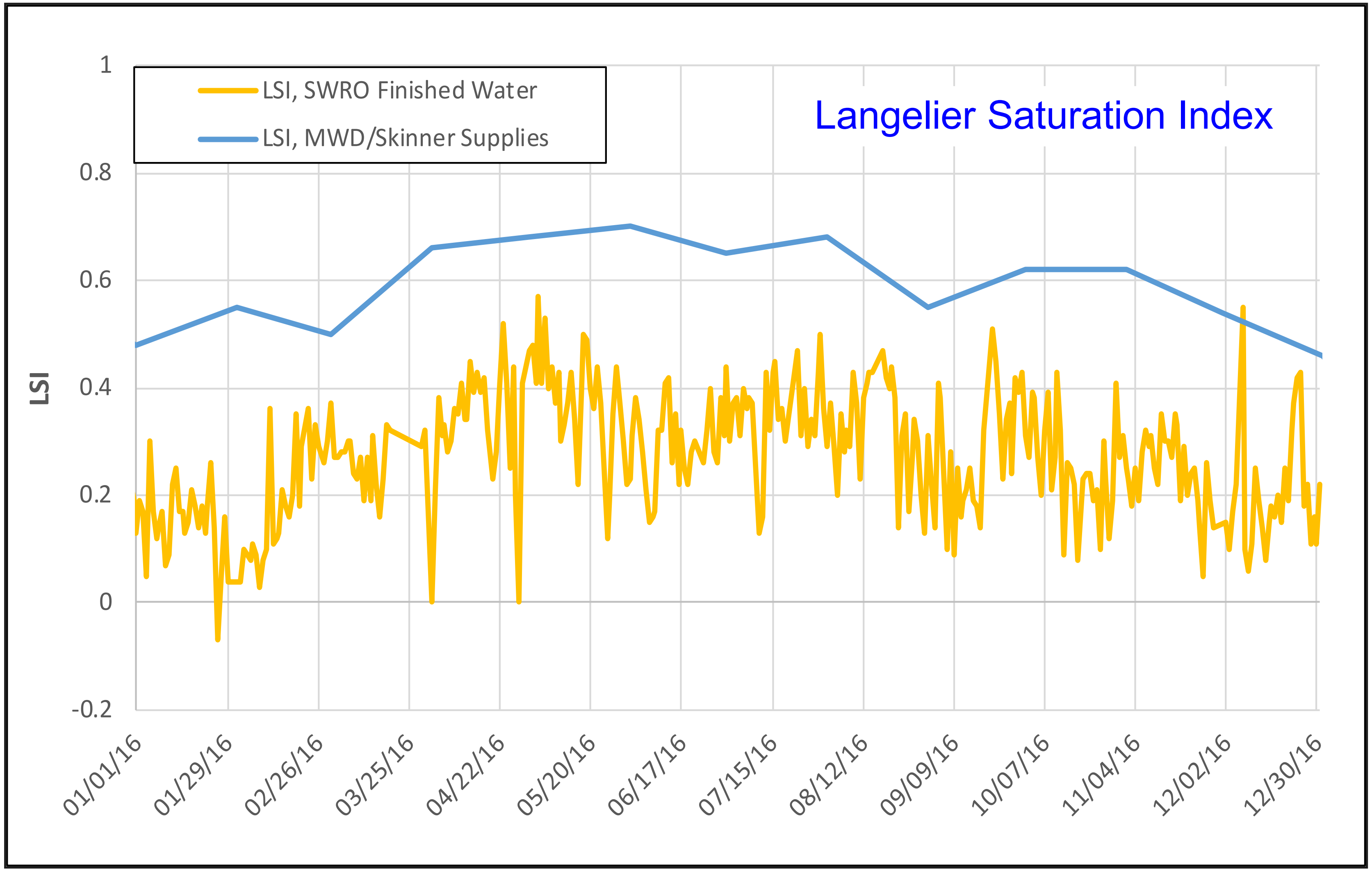


Key Points:

- SWRO water has lower CCPP than imported water supplies over 2016.
- CCPP exhibits seasonal variation with temperature, which is a variable in the calculation (and not due to the influence of fluctuations in RO rejection).

→ **SWRO supplies reduced CCPP in treated water blends in 2016.**

Temperature Influence: LSI



Key Points:

- SWRO water has lower LSI than imported water supplies over 2016.
- LSI exhibits seasonal variation with temperature, which is a variable in the calculation (and not due to the influence of fluctuations in RO rejection).

→ SWRO supplies reduced LSI in treated water blends in 2016.

Same key points as for CCPP

Assessing the Impact of Temperature

Influence of Temperature on NF/RO Systems

Increasing feed water temperature…

System Component	Phenomenon	Result(s)	Net Impact on Permeate Concentrations
Dissolved Solids	Higher diffusion coefficient	• Increased salt passage	Higher
Membrane Product	Increased membrane permeability	• Increased salt passage • Increased water throughput	Mixed
Water	Decreased viscosity	• Increased water throughput	Lower

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Automatic reduced-pressure compensation for constant flow systems

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Automatic reduced-pressure compensation for constant flow systems

Prevailing influence

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Simplistic assessment of complex phenomena…

Automatic reduced-pressure compensation for constant flow systems

Prevailing influence

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…but useful for illustration purposes.

Automatic reduced-pressure compensation for constant flow systems

Prevailing influence

Impact of Increasing Salt Passage

Permeate Concentration vs. % Rejection

Feed TDS (mg/L)	Permeate Concentration (mg/L) with Rejection at…		
	99.8%	99.5%	99.2%

Impact of Increasing Salt Passage

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Large % change (amplification factor), but small magnitude

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**Same % change,
but large magnitude**

Impact of Increasing Salt Passage

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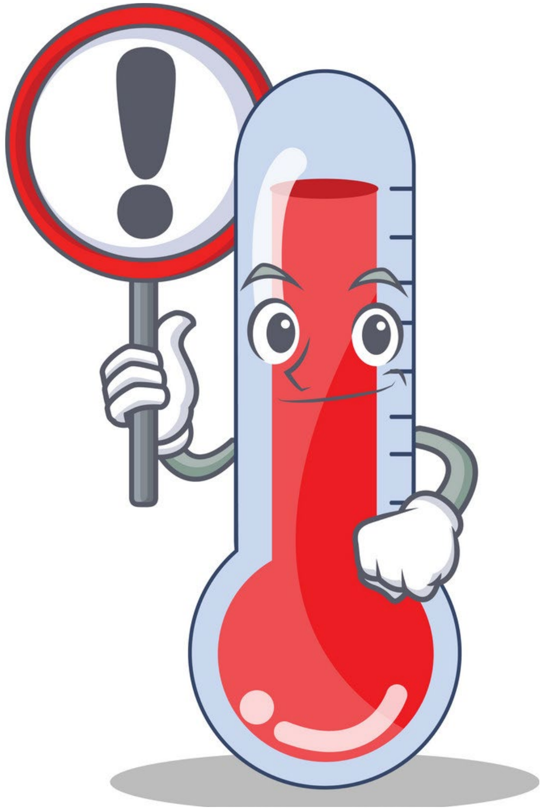
Desal-15-06 Observations

Parameter	Amplification
Boron	2x
Chloride	2.5x
CSMR	3.5x
Sodium	3x
SAR	3x
TDS	3x

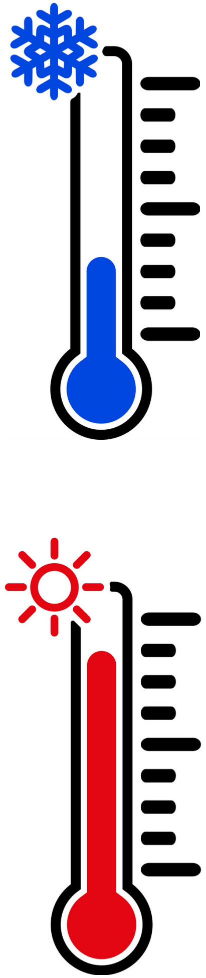
…for a temperature range of about **10 °C.**

Implications

Be attentive
to temperature!

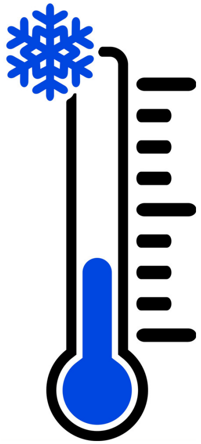


Temperature Considerations for RO Design



- Evaluate cold water temperature to size the system for sufficient throughput under limiting conditions.

Temperature Considerations for RO Design



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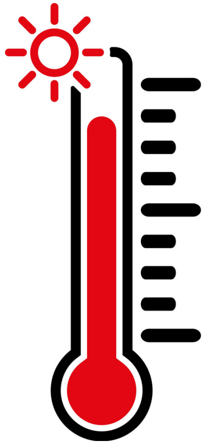

- Evaluate warm water temperature to ensure target permeate quality, particularly for conditions of:
  - ⇨ High feed water TDS (e.g., seawater)
  - ⇨ Stringent permeate concentration targets

Temperature Considerations for RO Design

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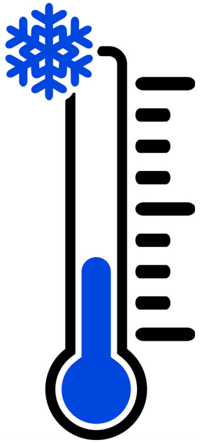
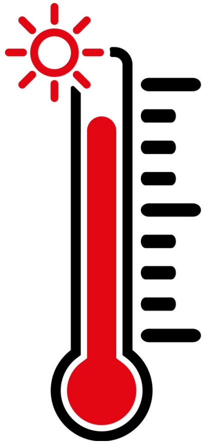
NF/RO system designers are typically very studious about this step…

Temperature Considerations for RO Design



- Evaluate cold water temperature to size the system for sufficient throughput under limiting conditions.

…but not always as careful to account for this consideration.



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  - ⇨ High feed water TDS (e.g., seawater)
  - ⇨ Stringent permeate concentration targets

Final Message…

Be diligent about details in
non-standard RO applications.

Brent Alspach
Arcadis
brent.alspach@arcadis.com
(760) 602-3828

Thank you for your attention!

Brent Alspach

Arcadis

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