Advanced-Treated Recycle Water: How it Can Help with Nutrient Reduction

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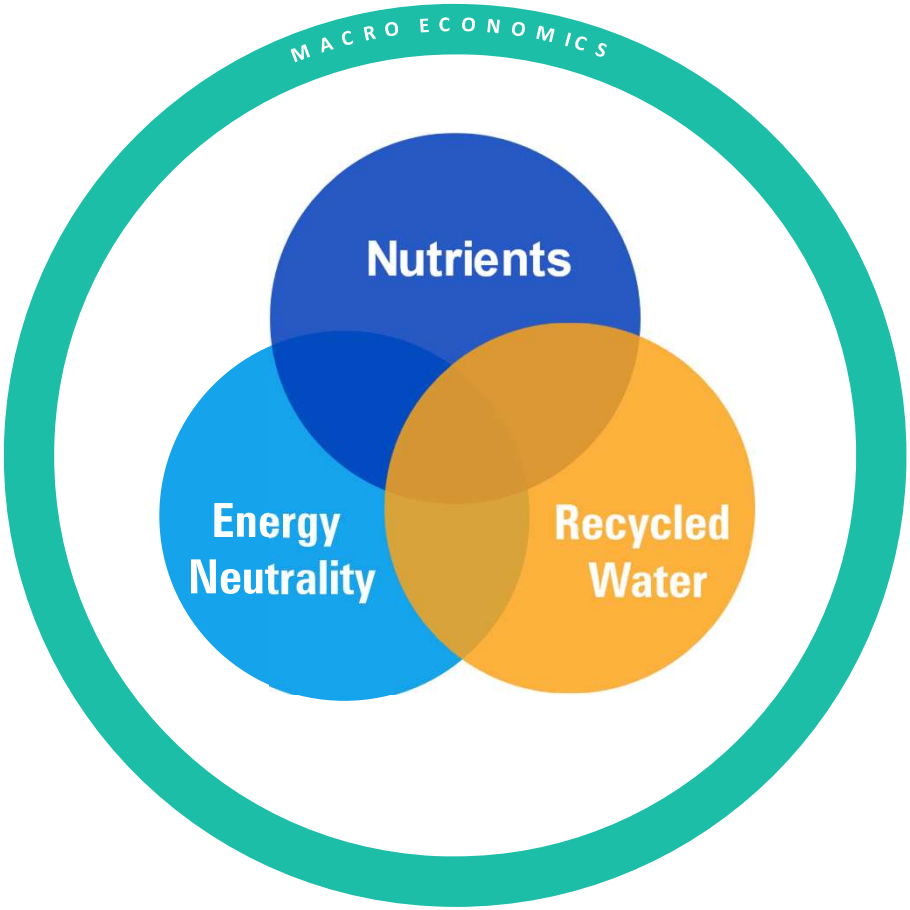
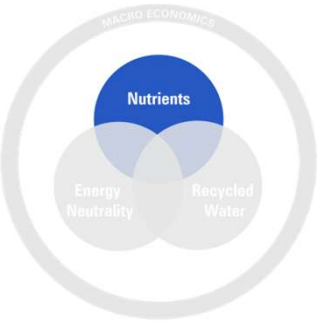
Our Multifaceted Challenge

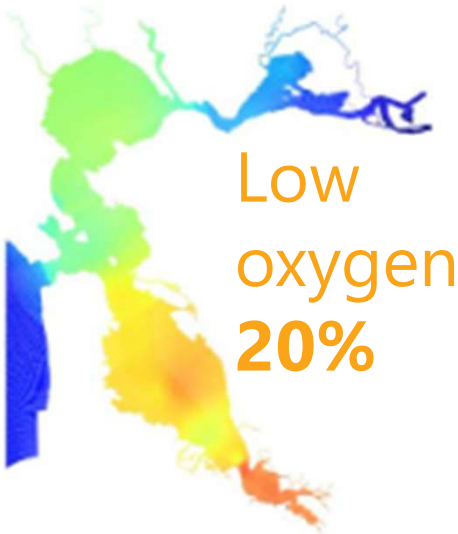




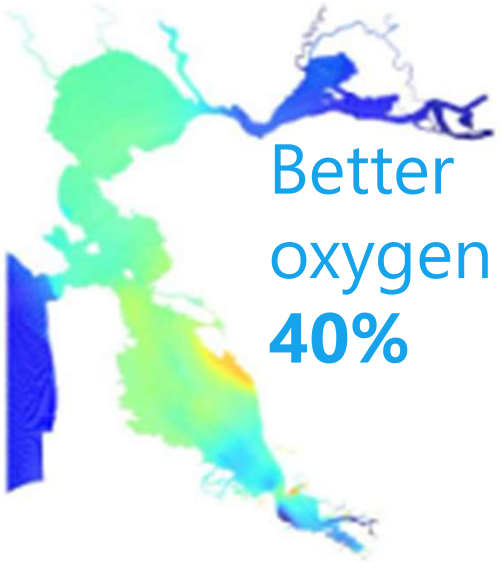
01 Nutrients

Nutrient removal solutions must build in flexibility

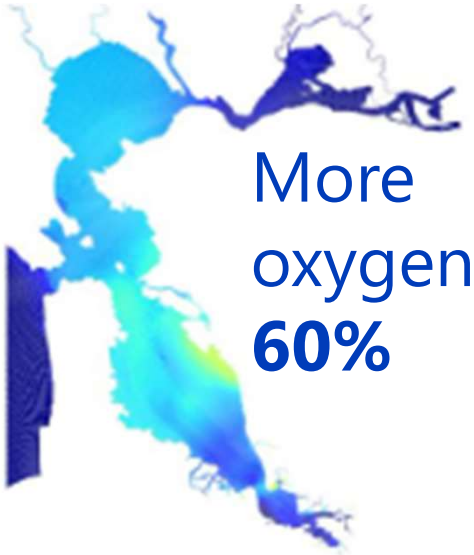
Reduced nitrogen loads equates to more oxygen left in SF Bay



Low oxygen **20%**



Better oxygen **40%**

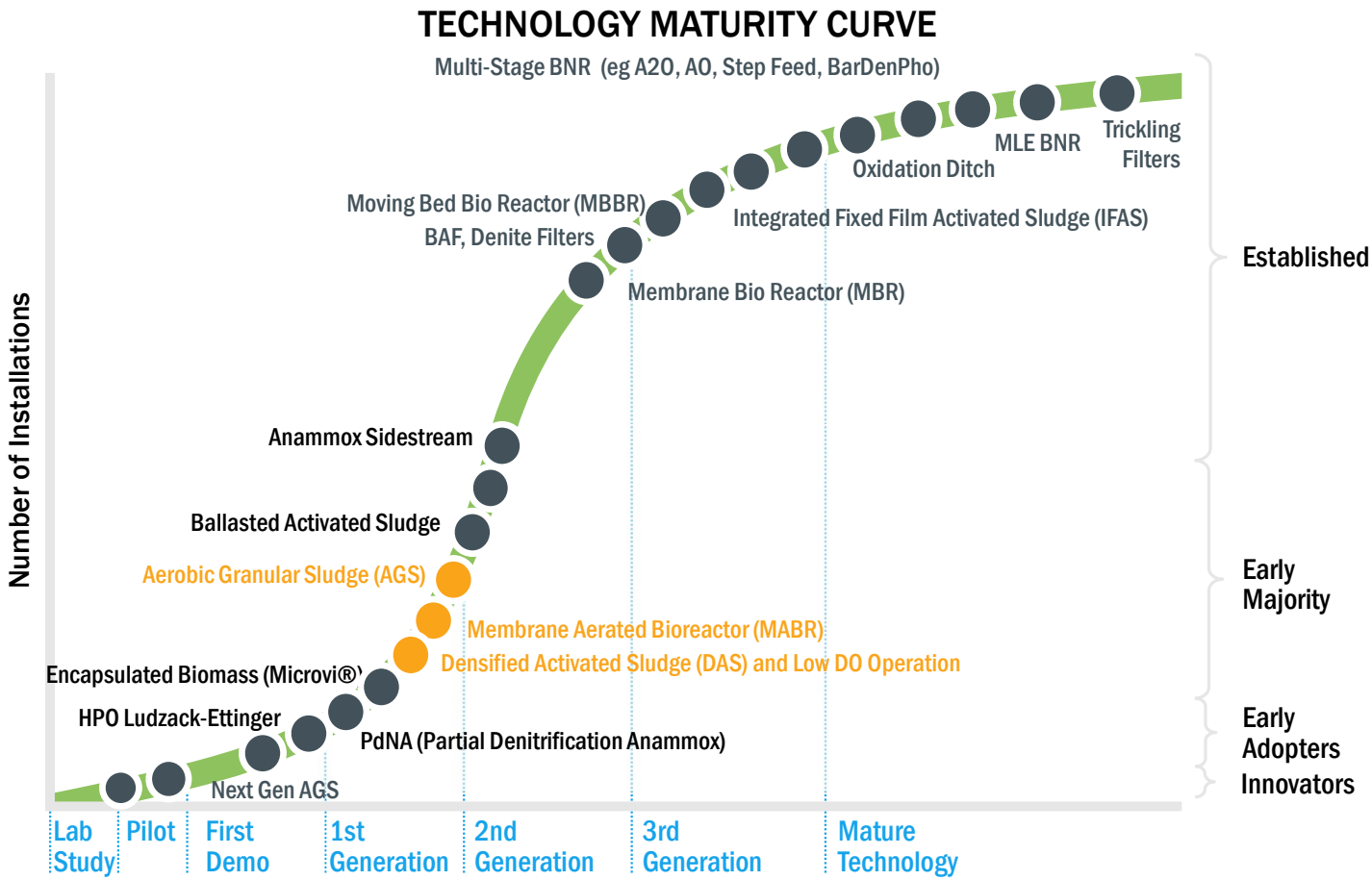


More oxygen **60%**

Permit requirements for compliance schedules

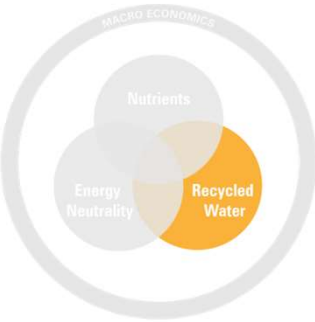
Interim Limits	Based on current treatment performance from **May through September** (95th percentile). Apply to each treatment plant individually.
Interim Requirements	Document efforts to minimize nutrient discharges to the Bay and progress on achieving compliance with final limits.
Final Limits	Include final limits **(May through September)** that will demonstrate attainment with the narrative biostimulatory substances objective.

Emerging technologies have considerable benefits



Benefits
Compact
Cost
O&M

Risk
Performance
Unknowns

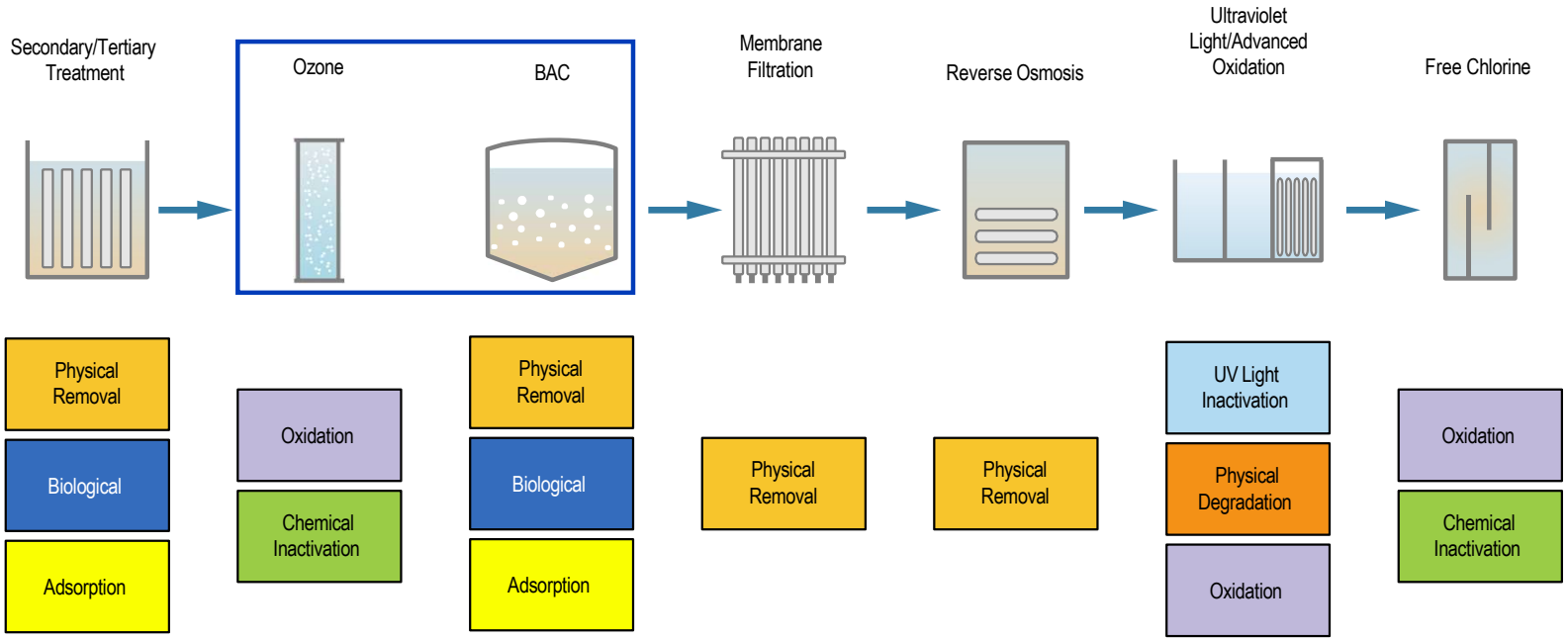


02

Recycled Water

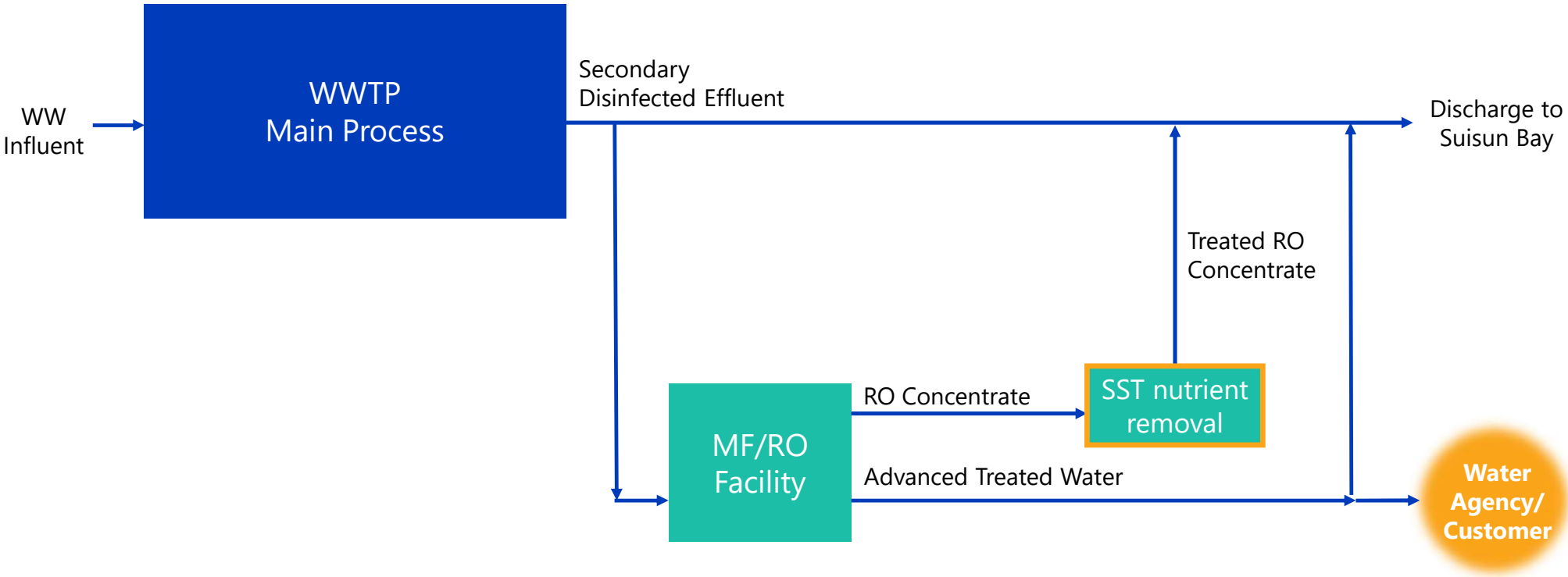
Direct potable reuse regulations – treatment process

Multi-barrier treatment train showing diverse treatment mechanisms



Source: May 2017 City of San Diego Pure Water Program Title 22 Engineering Report

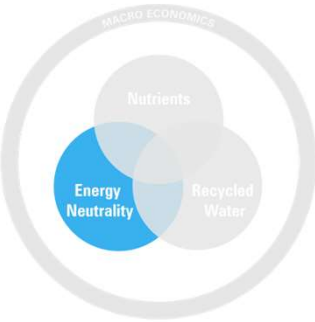
MF/RO Facility is a multi-benefit approach to nutrient removal



Sidestream treatment of highly concentrated reject streams

Piloting of MABR technology with **Anammox** has been successful for high ammonia and TDS streams

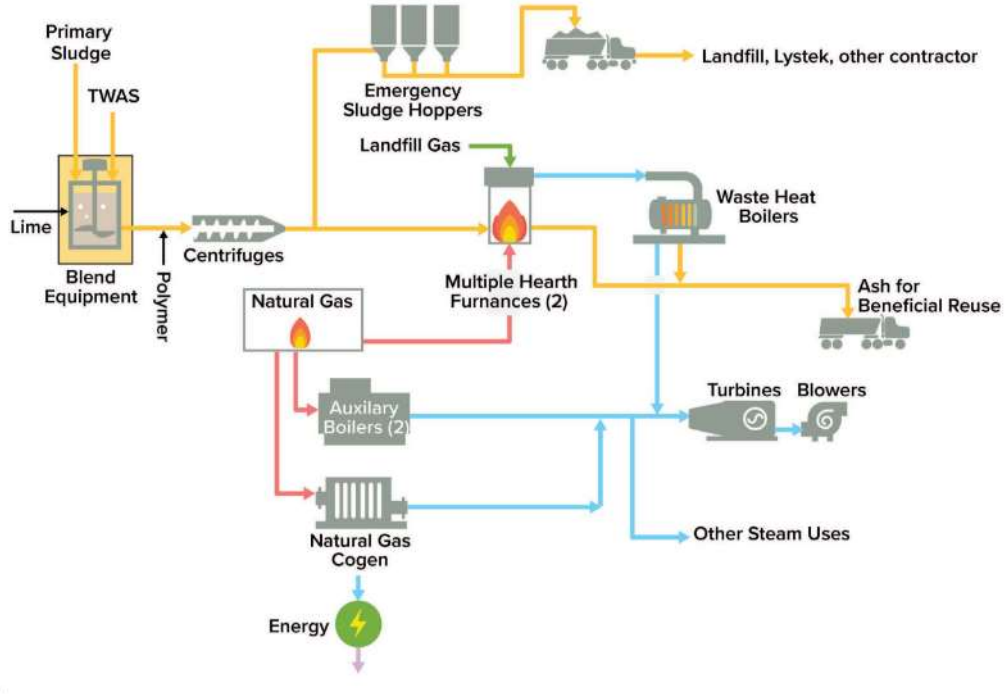
Biottta treating combination of high-TDS well water and raw wastewater for perchlorate removal. ***Conceptually very similar matrix to RO concentrate!***

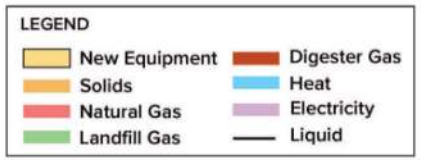


03

Energy Neutrality

Central San's existing solids process





Green house gas emissions

SCOPE 1, 2 & 3 EMISSIONS

Scope 1: Direct Emissions

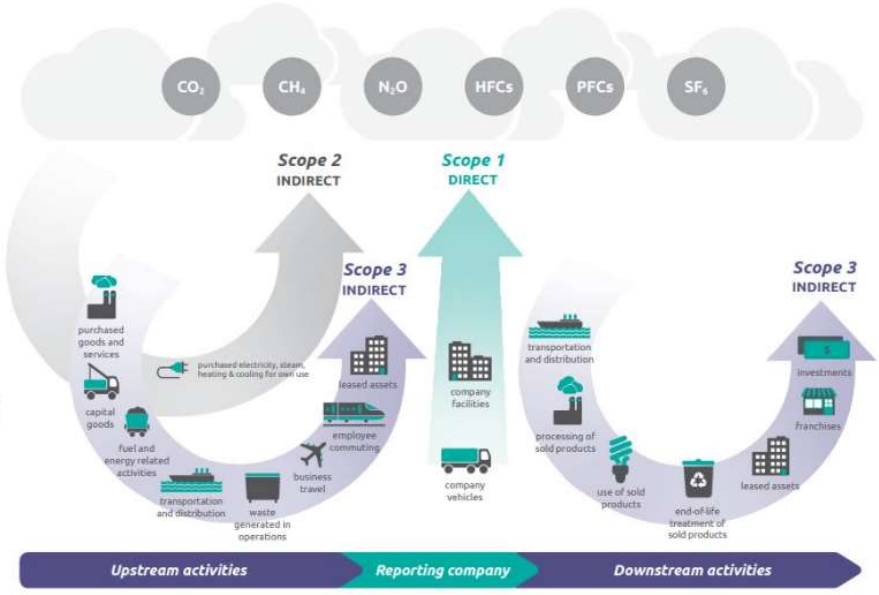
- Facility emissions (MHFs, Cogen, Boilers…)
- Central San vehicles emissions

Scope 2: Indirect Emissions

- Purchased electricity (treatment plant, pumping stations…)

Scope 3: Indirect Emissions

- 15 categories associated with upstream & downstream activities

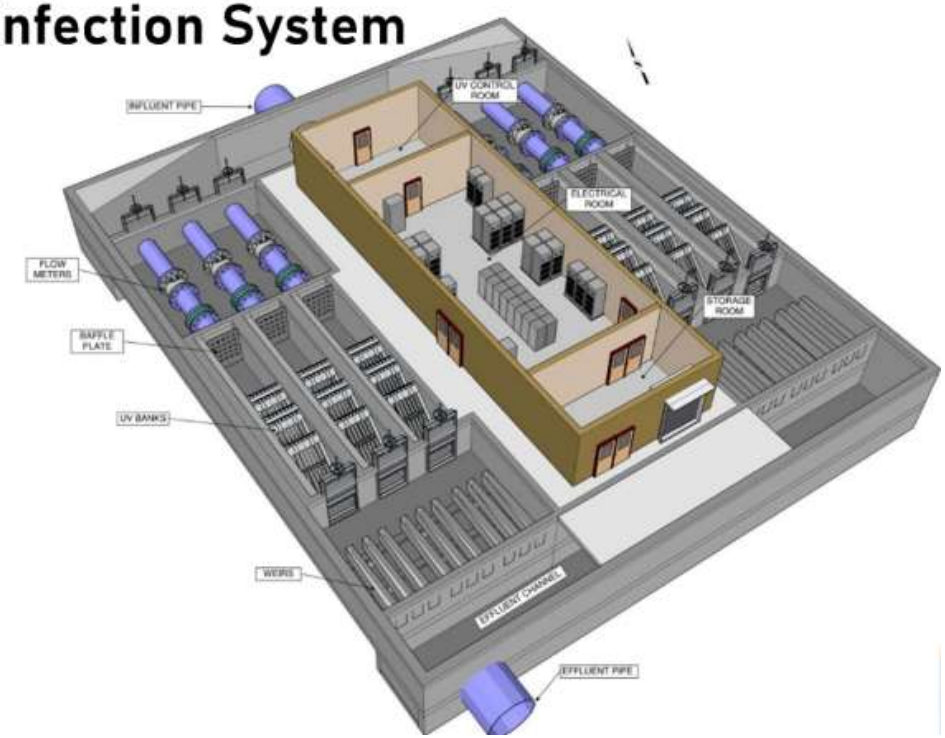


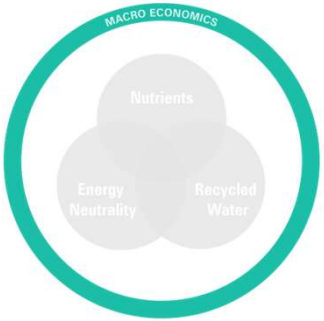
Source: https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard_041613_2.pdf

Several optimization projects in progress

Final Design of New UV Disinfection System

- Metered flow and self-cleaning UV lamp system
- Better power control and electrical savings of 50-60% (~250 kw)
- Increase wet weather capacity by an additional 40 MGD to 140 MGD

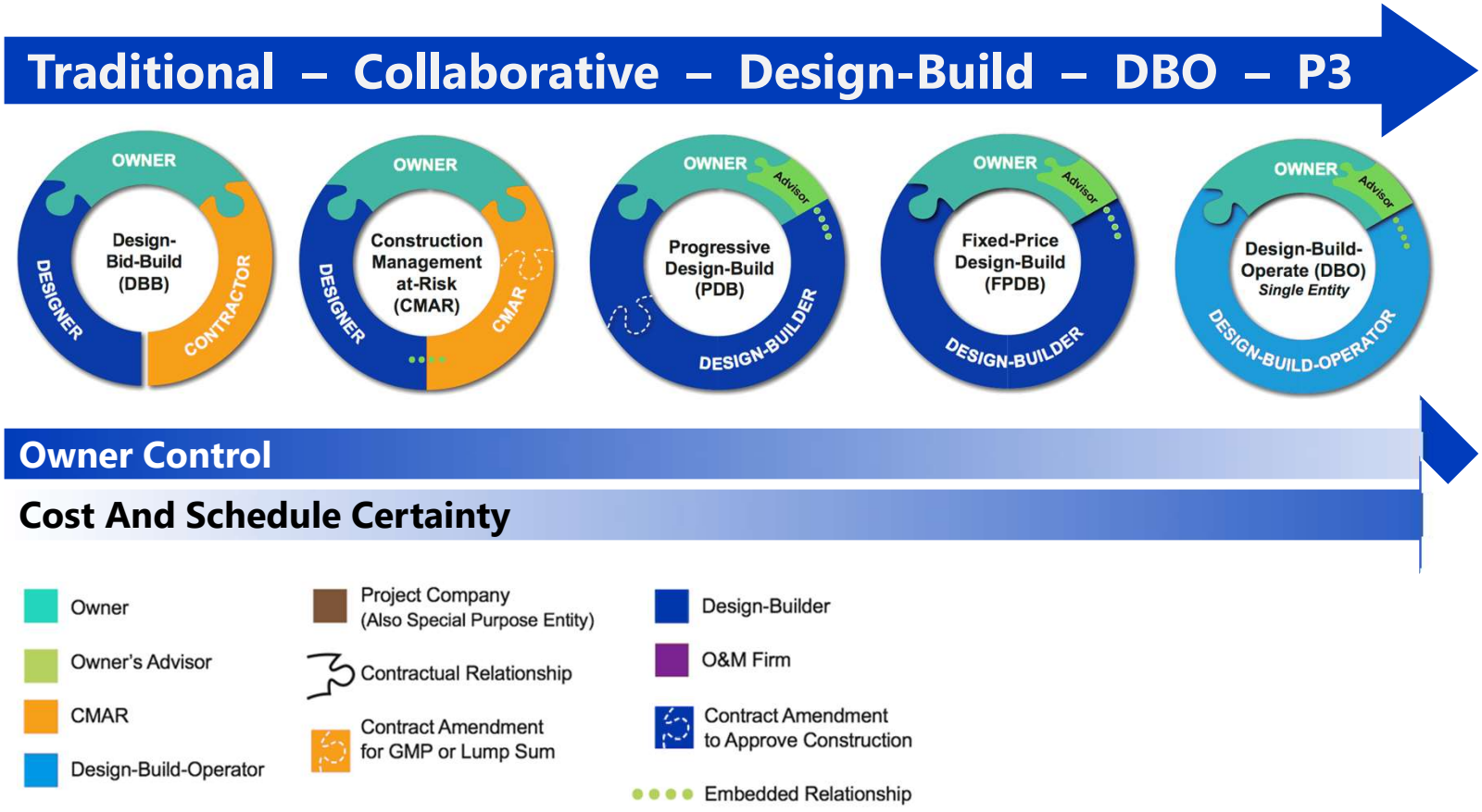




04 Macro Economics

Inflation the silent killer!

Spectrum of collaborative project delivery options



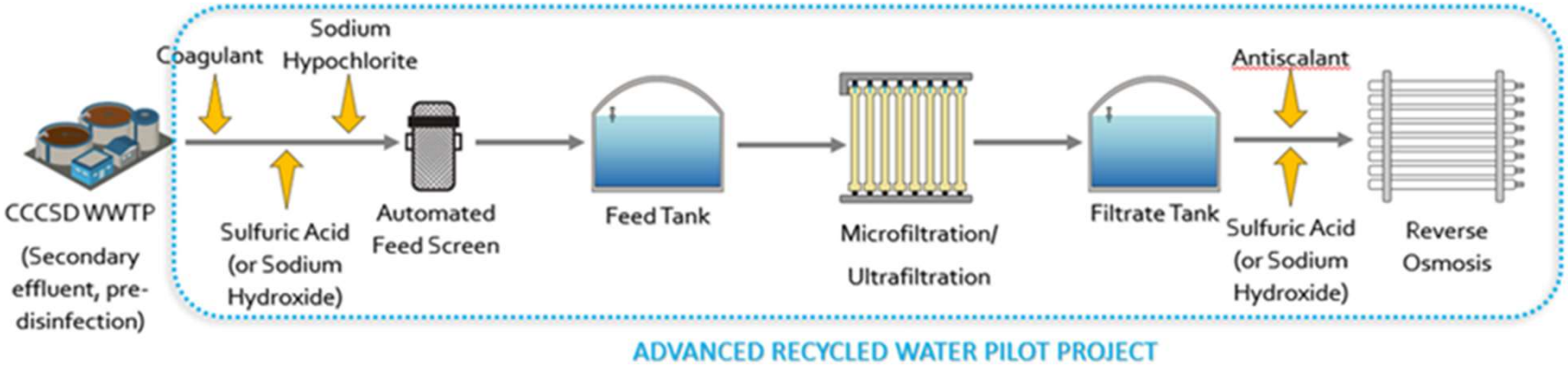
05

Membrane Performance for Refinery Reuse of Non-Nitrified Wastewater

Secondary process operated with low SRT

- Conventional activated sludge, no nitrification
- Save aeration power costs and still meet BOD and TSS limits
- SRT less than 2 days, more free bacteria and less floc
  - » More challenging to settle, “light and fluffy”
  - » Smaller colloidal particles in effluent
  - » Variability in effluent turbidity
- Membrane manufacturers usually want nitrified WW

Pilot system process flow

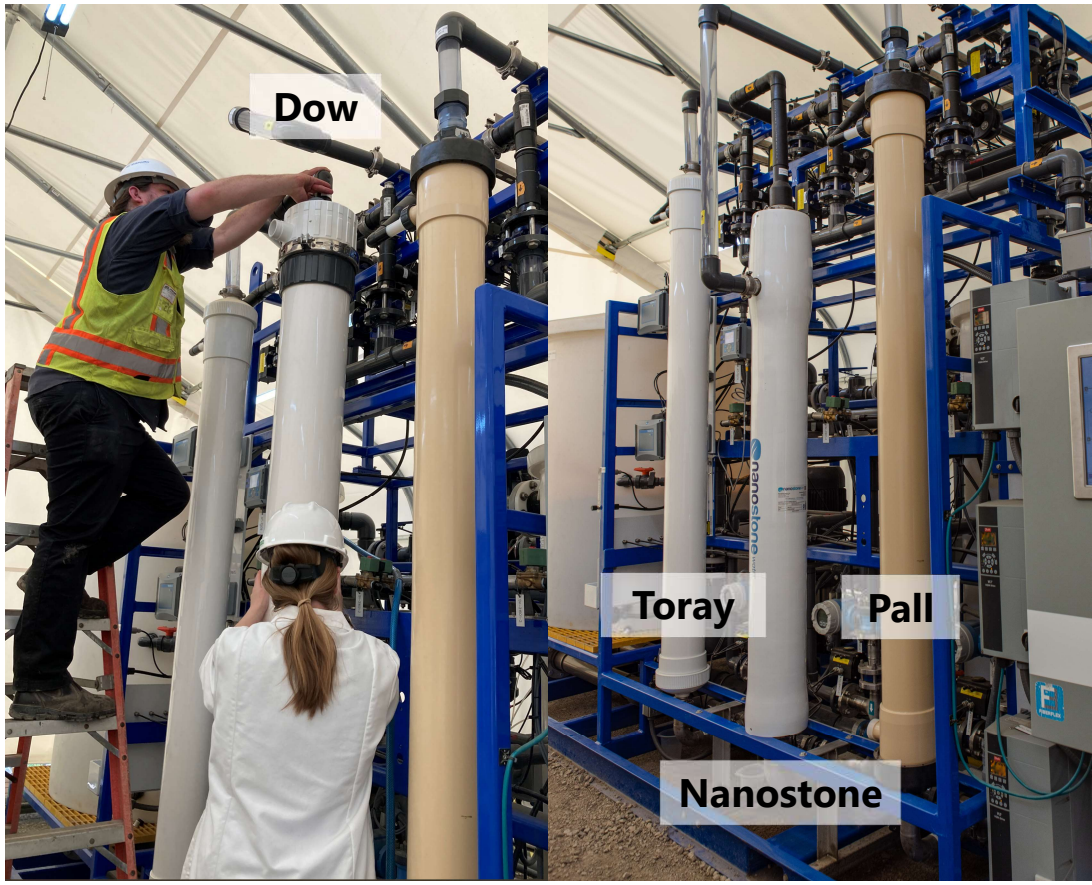


Coagulants Tested

- Ferric Chloride
- Aluminum Chlorohydrate (ACH)

Evaluated multiple membrane manufacturers with different characteristics

	Membrane	Operation Mode	Type
Nano-stone	Ultra-filtration	Inside-Out	Ceramic
Toray	Ultra-filtration	Outside-In	Polymeric
Dow	Ultra-filtration	Outside-In	Polymeric
Pall	Micro-filtration	Outside-In	Polymeric



Preliminary refinery water quality objectives

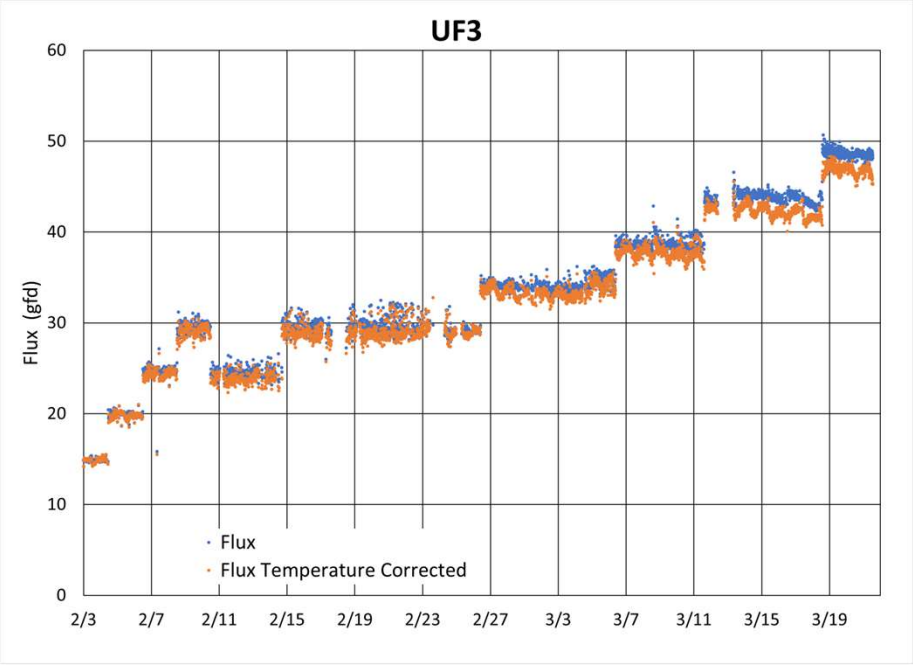
Boiler Feed

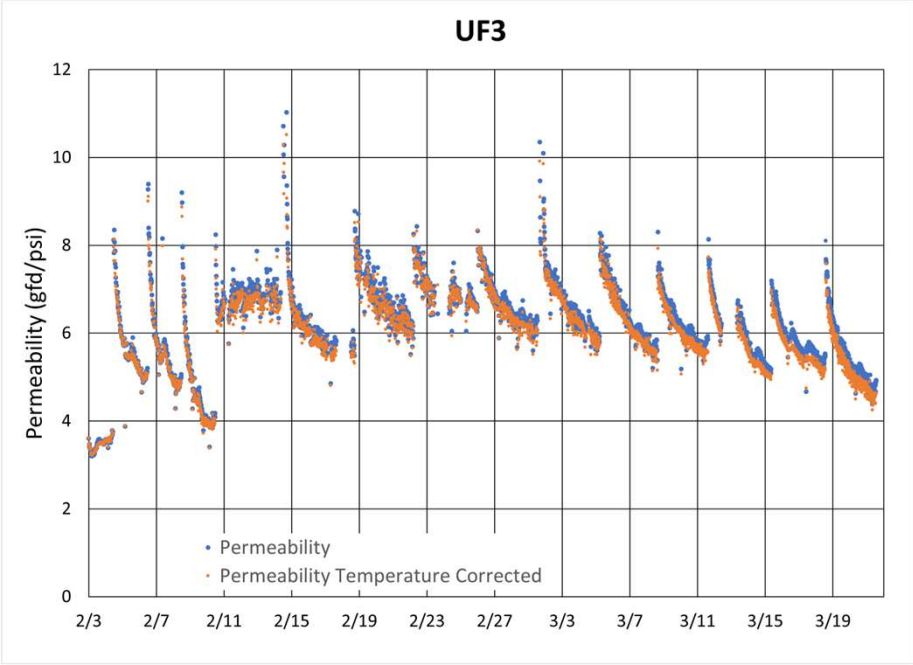
Cooling Tower Makeup

Parameter	Unit	Preliminary Refinery Specification	Central San Average Final Effluent Water Quality
Ammonia	**mg-N/L**	**<1.0**	**25**
Calcium Hardness	**mg/L as CaCO3**	**130**	**250**
Chromium (total)	mg/L	1.67	0.53
Copper (total)	µg/L	60	6.2
Lead (total)	µg/L	3.7	0.48
Nickel (total)	µg/L	43	4.1
Nitrate	mg-N/L	15	1.8
Silica	mg/L	25	13.1
TDS	**mg/L**	**280**	**528**

Flux step increases

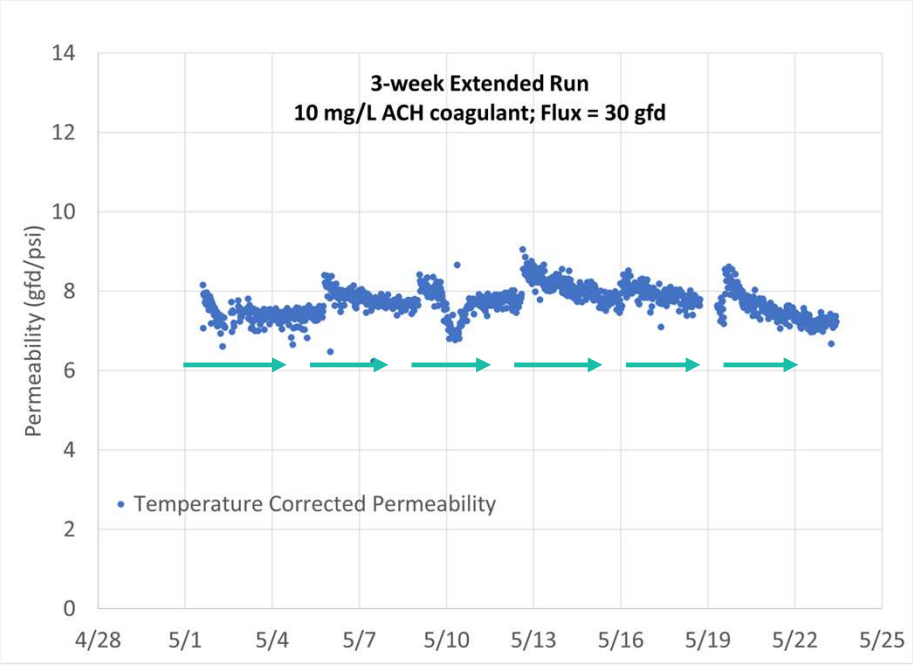
$$\text{Permeability (gfd/psi)} = \frac{\text{Flux (gfd)}}{\text{Transmembrane Pressure (psi)}}$$

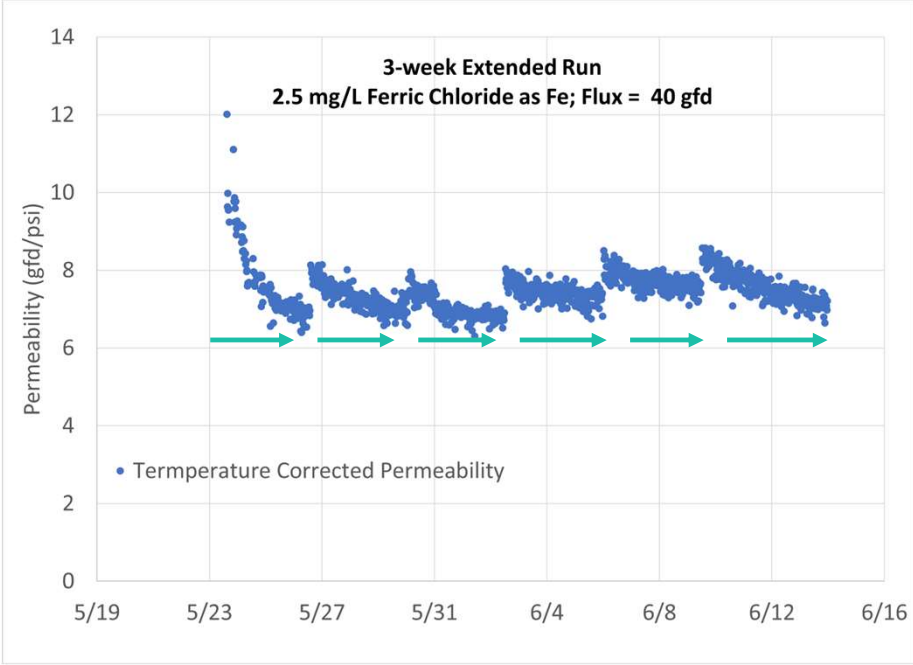




Three-week extended runs

$$\text{Permeability} = (\text{gfd/psi}) \quad \frac{\text{Flux (gfd)}}{\text{Transmembrane Pressure (psi)}}$$





Reverse osmosis operation

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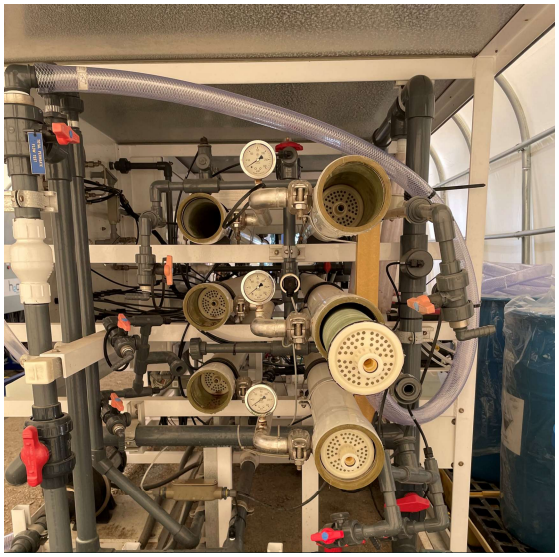
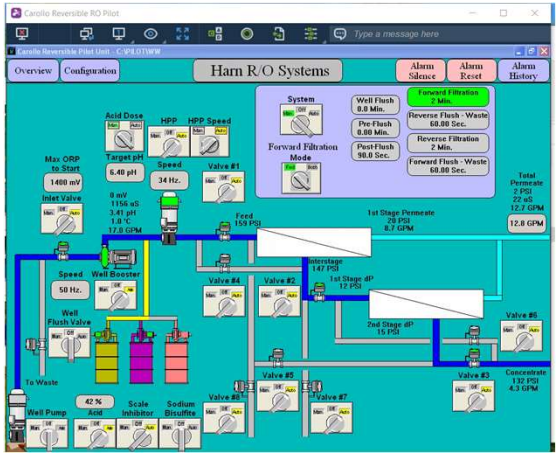
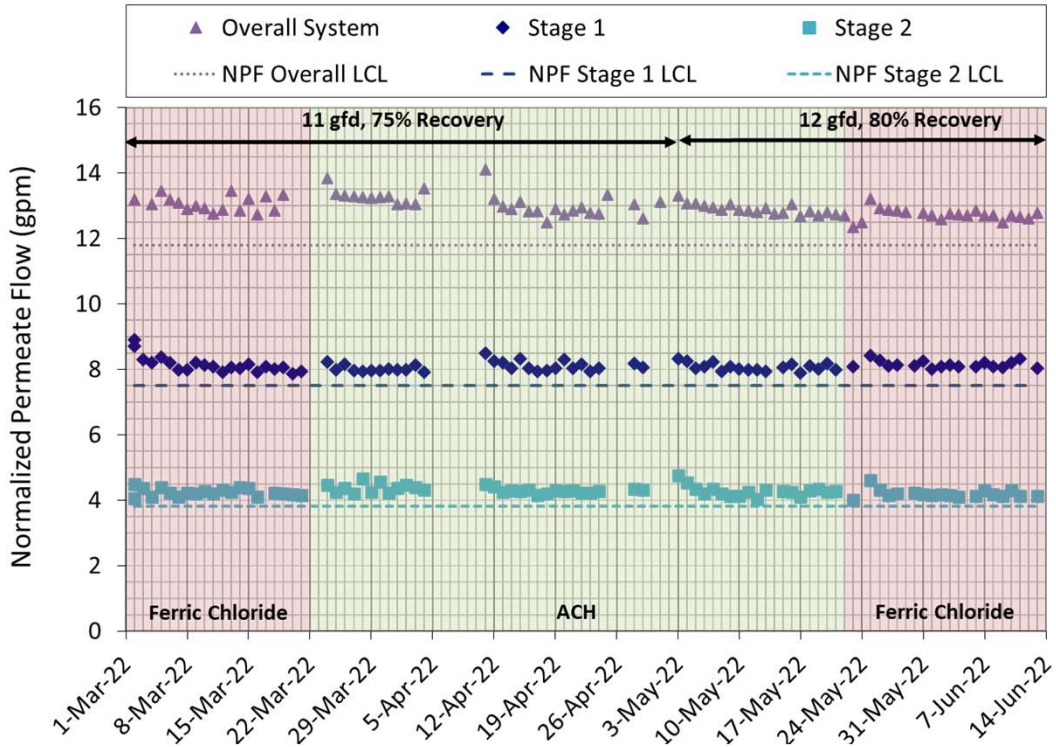




RO normalized permeate flow

- Permeate flow metric that adjusts for the temperature and osmotic pressure (as a result of TDS) encountered by each stage
- A sudden and exponential decrease in NPF is associated with biological fouling or scaling
- Cleaning trigger at 90% starting NPF
- Stable and consistent performance while operating on both coagulants



Can meet preliminary refinery water quality objectives

- Ammonia was reduced 95-97%
- Bench tested a few methods to reduce ammonia
- Breakpoint chlorination found to be simple and effective method

Parameter	Unit	Preliminary Refinery Specification	Maximum RO Permeate Concentration
Ammonia	**mg-N/L**	**<1.0**	**1.6**
Calcium Hardness	mg/L as CaCO3	130	<3.0
Chromium (total)	mg/L	1.67	<0.002
Copper (total)	µg/L	60	<2.0
Lead (total)	µg/L	3.7	<0.5
Nickel (total)	µg/L	43	<5.0
Nitrate	mg-N/L	15	<0.1
Silica	mg/L	25	<0.5
TDS	mg/L	280	17

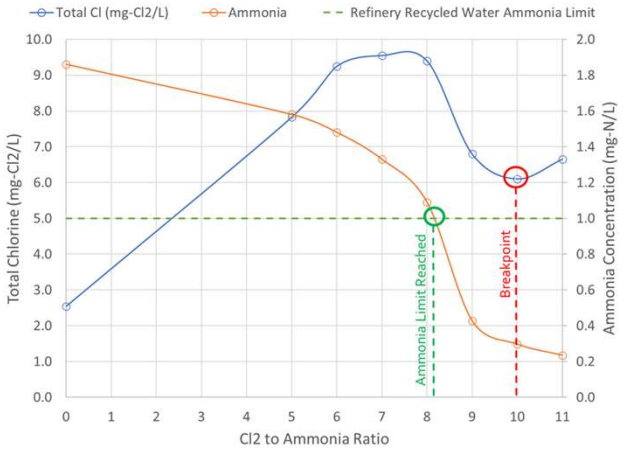
Ammonia rejection by RO

- Ammonia Removal Across RO was high 95 – 97%.
- Removal was not quite high enough to meet the refinery target(<1.0) consistently.
- The RO operated in a stable fashion in spite of the non-nitrified feed water.
- As anticipated, recovery increases marginally reduced rejection (c. 2%)

Date	NH_3 Concentration (mg/L as N)		RO NH_3 Removal (%)	RO Recovery (%)
	Combined RO Feed/ UF Filtrate	RO Permeate		
3/2/2022	37	1.1	97.0	75
3/9/2022	39	1.2	96.9	
3/16/2022	36	1.2	96.7	
3/21/2022	35	1.1	96.9	
3/30/2022	48	1.6	96.7	
4/13/2022	43	1.2	97.2	
4/20/2022	32	1.2	96.3	
5/25/2022	35	1.6	95.4	80
6/6/2022	33	1.4	95.8	

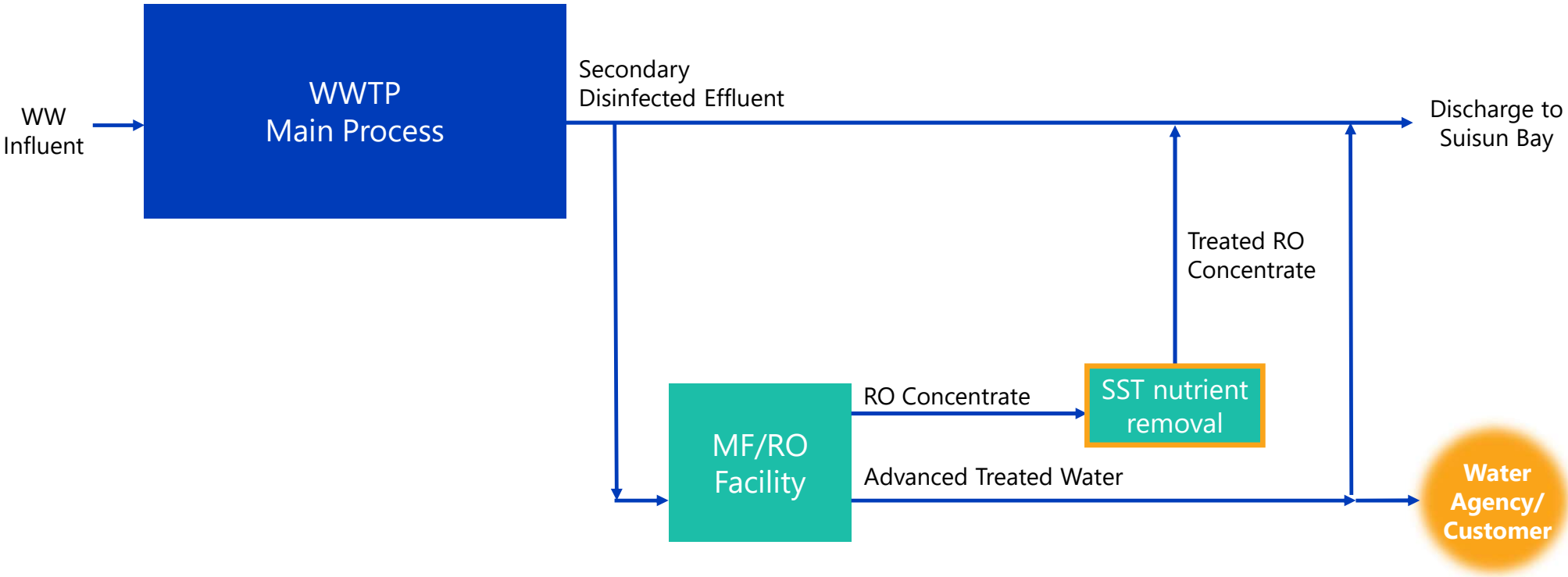
We can meet refinery and CA Title 22 non potable reuse objectives

- Refinery limits estimated from their NPDES permit
- Water quality specifications are preliminary, subject to later discussion and all can be met
- Finished water ammonia is an issue that can be solved by breakpoint chlorination



Parameter	Unit	Maximum RO Permeate Concentration[8]	Preliminary Refinery Recycled Water Quality Specification[1]	Title 22 Regulatory Compliance Limit
Alkalinity	mg/L as $CaCO_3$	not tested[7]	80	-
Ammonia	mg-N/L	1.6	< 1.0	-
Calcium Hardness	mg/L as $CaCO_3$	<3.0	130	-
Chloride	mg/L	1.8	170	-
Chromium (total)	mg/L	<0.002	1.17-1.67[2]	-
Copper (total)	µg/L	<2.0	37-60[3]	-
Lead (total)	µg/L	<0.5	3.7[4]	-
Nickel (total)	µg/L	<5.0	43[5]	-
Nitrate	mg-N/L	<0.1	15	-
Orthophosphate	mg-PO_4/L	<0.03 (<0.01 mg/L as P)	3 (0.97 mg/L as P)	-
Silica (as SiO_2)	mg/L	<0.5	25	-
Total Coliform	MPN/100 mL	not tested[7]	-	<2.2 <23 (one sample in 7 day period)
TDS	mg/L	17	280	-
TSS	mg/L	<10[6]	< 2.0	-
Turbidity	NTU	All UF systems complied prior to RO typically at 0.05 NTU	-	< 0.2 (95% of time in 24-hour period) < 0.5 (at all times)

MF/RO Facility is a multi-benefit approach to nutrient removal



Conclusions

- Advanced recycle water treatment trains can be designed in a way to remove nutrients
- Advanced treated water may not be the cheapest way to remove nitrogen; however, just implementing biological nitrogen removal seems like a missed opportunity
- Advanced treated water can be tacked on later in time but there will efficiency loses