COMPARING POLYMERIC AND CERAMIC MEMBRANES IN A CHALLENGING SECONDARY EFFLUENT APPLICATION

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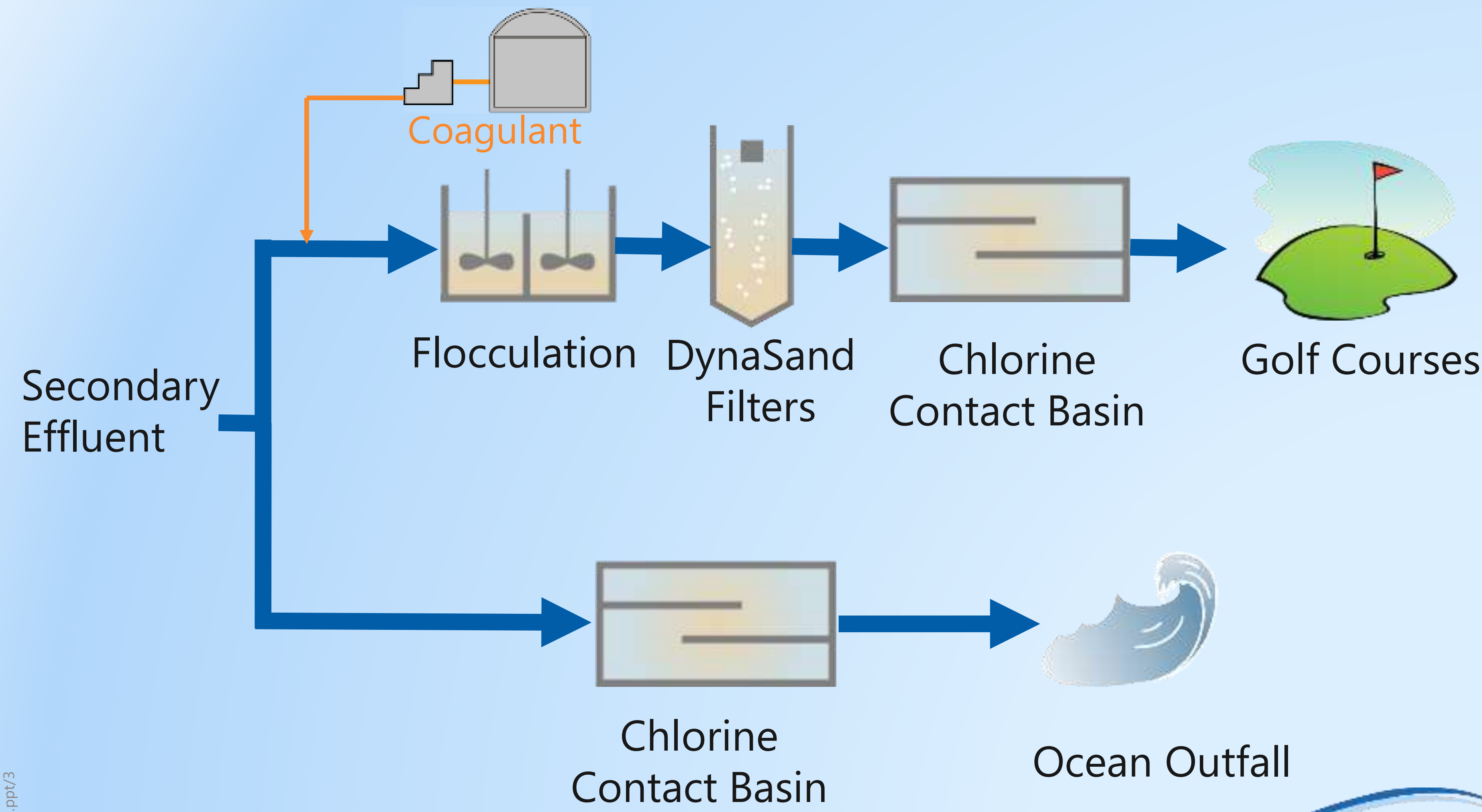
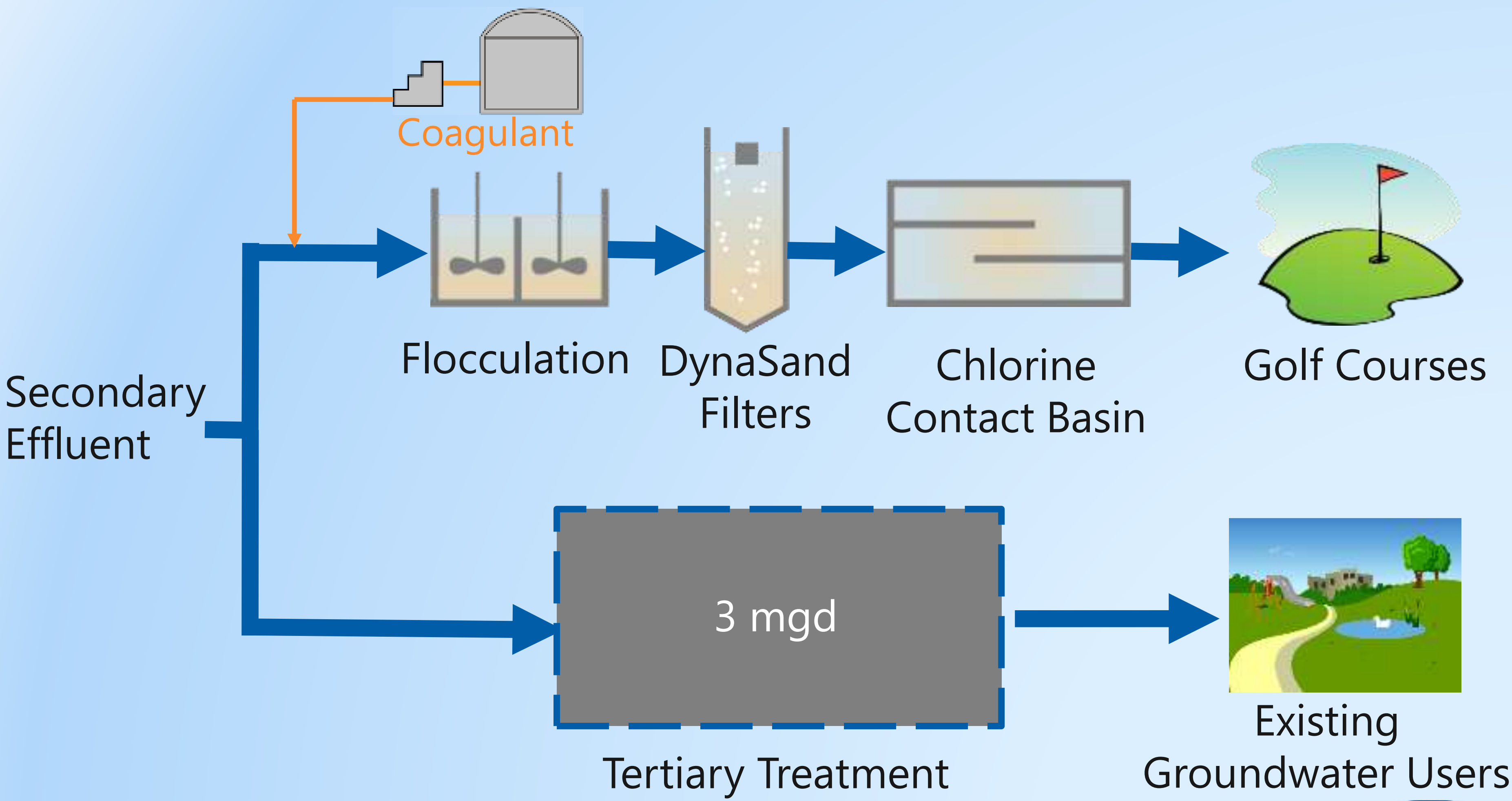
Background


580
Richmond
Mill Valley
Berkeley
Oakland
San Francisco
Daly City
101
82
San Mateo
1

Daly City has an existing recycled water facility to reduce demands for groundwater



Daly City is considering expanding the recycled water treatment facility



Potential Customers

Facility Type	Number of Facilities
Cemeteries	11
Schools	6
Other	5
Total	22

Site Challenges

Limited Footprint

Challenging Feed Water Quality

Membranes were selected as the filtration process

- Media filtration was not selected due to large footprint
  - Large surface area
  - Flocculation tanks
- Membrane filtration was selected
  - Smaller footprint
  - Flexible footprint
  - Better filtered water quality

Daly City has especially challenging secondary effluent water quality

Parameter	Secondary Effluent		
	Typical[1]	West Basin[2]	Daly City[3]
Total Organic Carbon (mg/L)	10		
Total Suspended Solids (mg/L)	5 – 10		
Ammonia as N (mg/L)	0.1 – 1		
Turbidity (NTU)	2 – 6		
Total Iron (mg/L)	-		

1. Metcalf & Eddy – Effluent quality after secondary treatment with biological nutrient removal
2. Based on 2007 data from WBMWD's Master Plan and data presented at 2017 AMTA conference
3. Average values based on grab samples collected during pilot testing March 1, 2016 through March 17, 2017

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Parameter	Secondary Effluent		
	Typical[1]	West Basin[2]	Daly City[3]
Total Organic Carbon (mg/L)	10	12	
Total Suspended Solids (mg/L)	5 – 10	10 – 25	
Ammonia as N (mg/L)	0.1 – 1	48	
Turbidity (NTU)	2 – 6	7 – 10	
Total Iron (mg/L)	-	0.3 – 1.5	

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Daly City has especially challenging secondary effluent water quality

Parameter	Secondary Effluent		
	Typical[1]	West Basin[2]	Daly City[3]
Total Organic Carbon (mg/L)	10	12	21
Total Suspended Solids (mg/L)	5 – 10	10 – 25	8.4
Ammonia as N (mg/L)	0.1 – 1	48	53
Turbidity (NTU)	2 – 6	7 – 10	6.5
Total Iron (mg/L)	-	0.3 – 1.5	0.95

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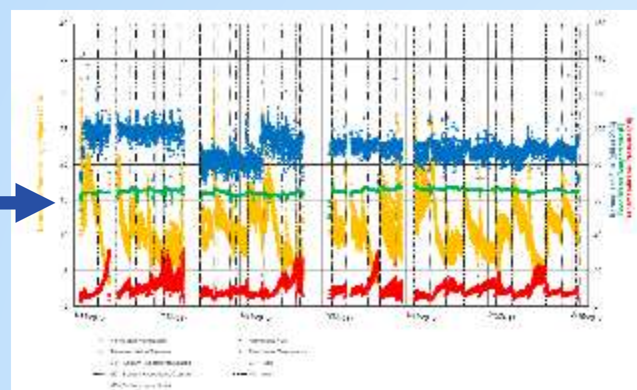
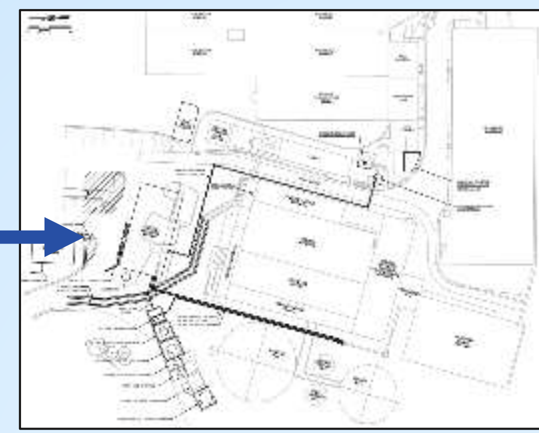
Limited space at the WWTP determined the required loading rate

"Typical" Sequence				
Pilot Testing	→	Loading Rate (15 – 20 gfd)	→	Building Size





Limited space at the WWTP determined the required loading rate

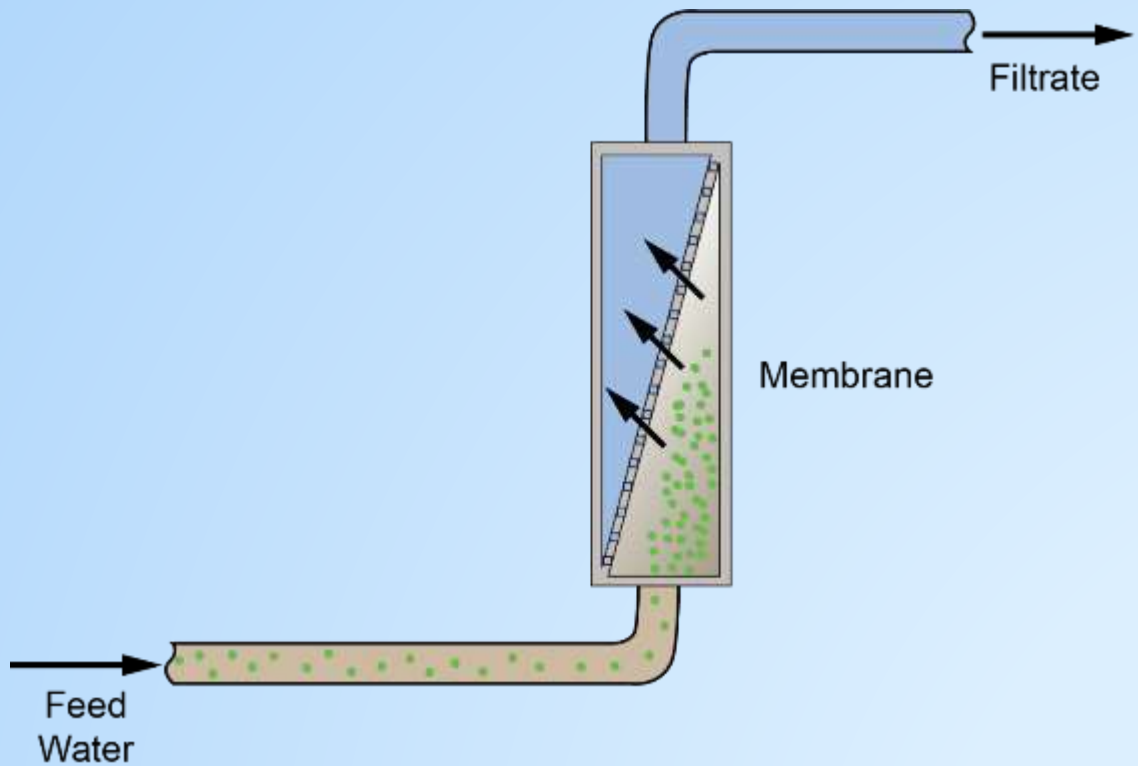
Daly City Sequence				
Building Size (80′ x 40′)	→	Loading Rate (31 gfd)	→	Pilot Testing

Conducted pilot testing to determine how to design robust and reliable system

- Pilot Study 1
  - Tested four polymeric hollow fiber membrane modules (800 ft^2 class)
- Pilot Study 2
  - Tested one ceramic membrane module
- Each module operated for a minimum of two months

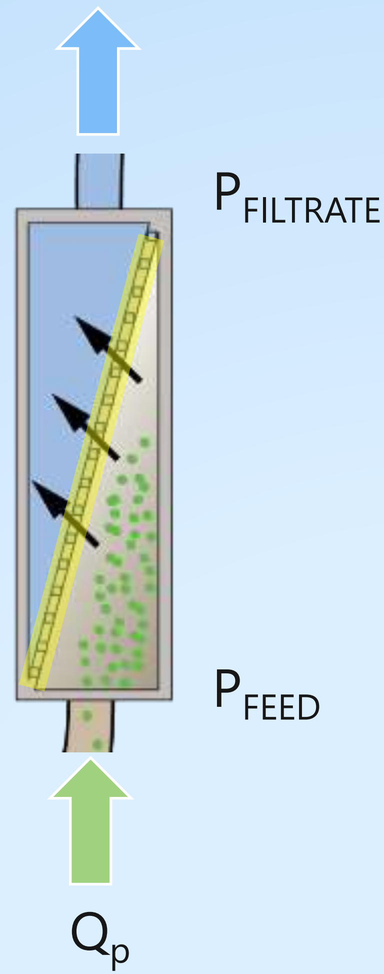
Pilot Study 1

Hydraulic Loading Rate is THE Critical Design Element



Flow Through a Membrane is Defined as a Hydraulic Loading Rate - ***Flux***

- Flux is the flow divided by the active membrane surface area (ASMA)
  - $J = Q_P/AMSA$ [gal/ft^2-day or L/m^2-hr]
- Flow through a membrane is proportional to pressure
  - $Q_P \propto$ Transmembrane Pressure (TMP)
- Membrane flux is impacted by resistance (R) to flow and the viscosity of water (μ_w)
  - $J = TMP/ ((R_M + R_F) * \mu_w)$



Over the Course of Operation, Membranes Will Become *Foiled*

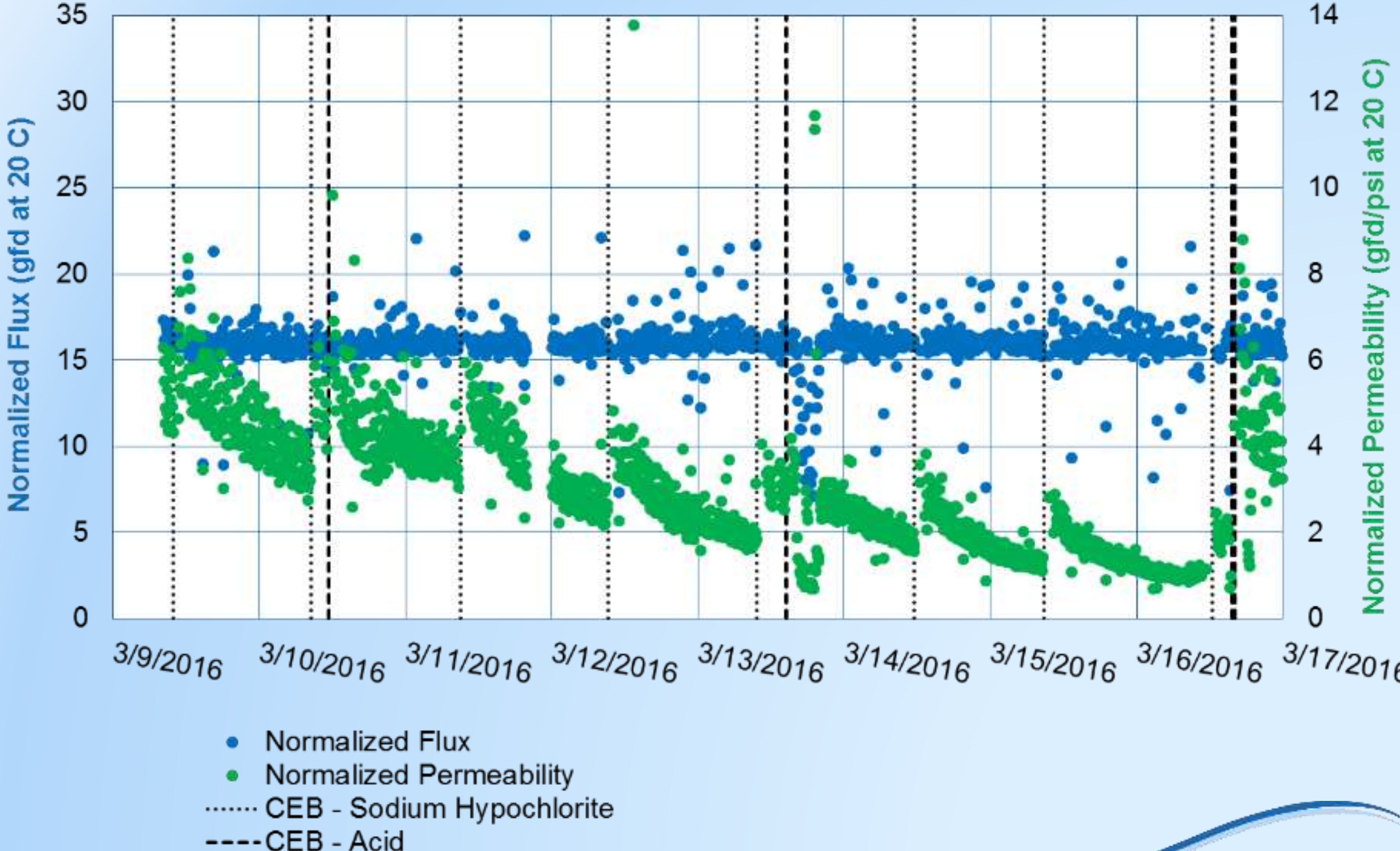
- Fouling is an increased resistance to flow
- Caused by:
  - Particle penetration
  - Sorption of natural organic matter (NOM, TOC)
  - Precipitation (Iron, Manganese, Calcium, Silica)
  - Particle accumulation

Pilot study evaluated flux maintenance tools to reduce and reverse fouling

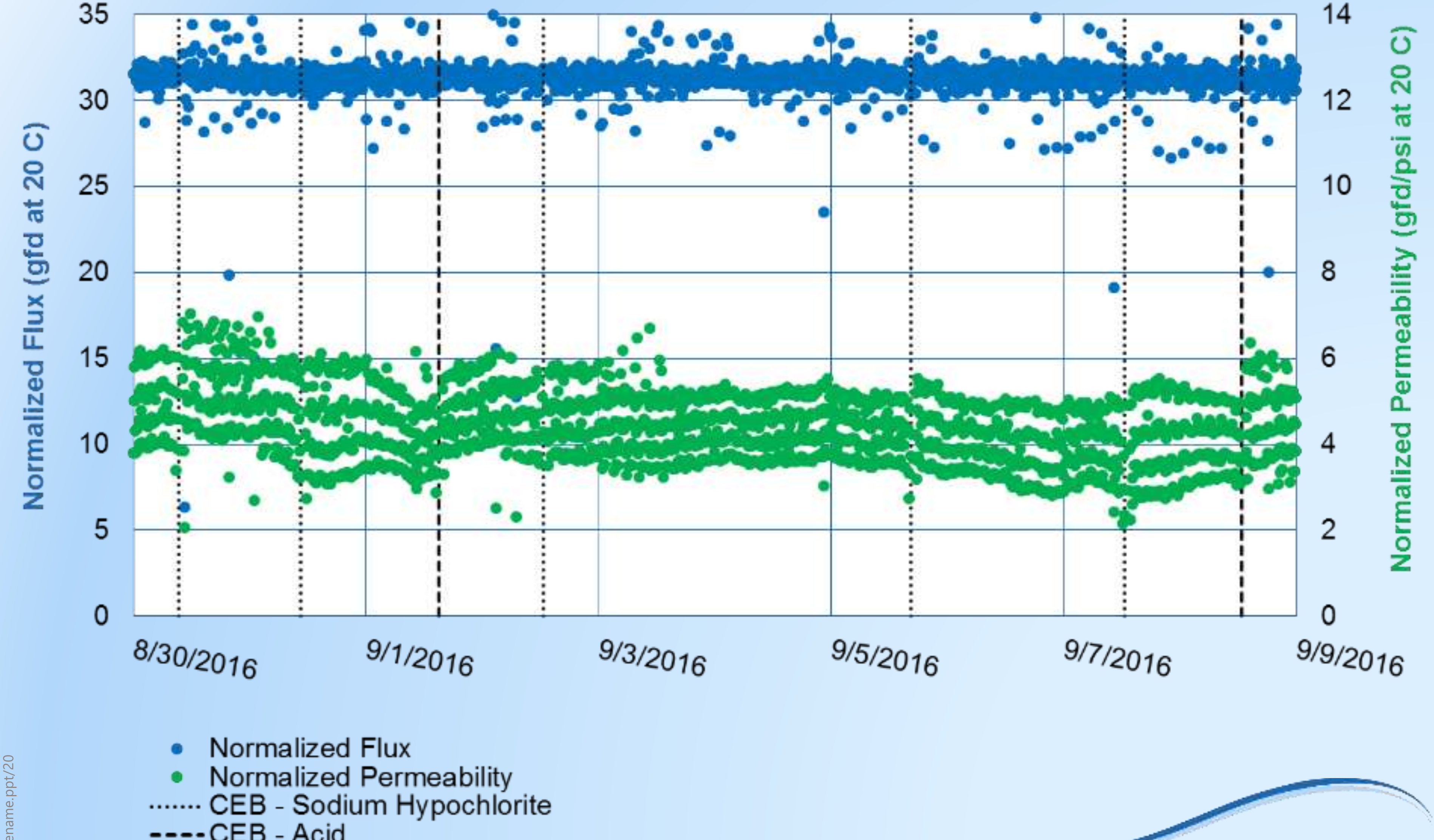
Tools:

- Hydraulic backwash
- Chemical clean
- Pretreatment

Initial Polymeric Membrane Performance – 15 gfd

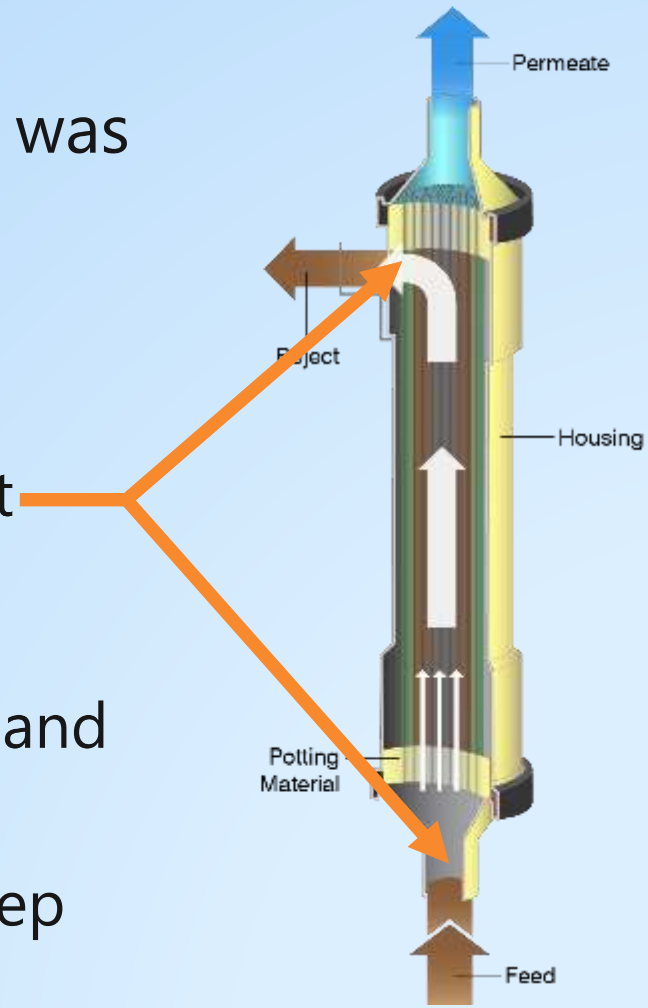


Final Polymeric Membrane Performance – 31 gfd

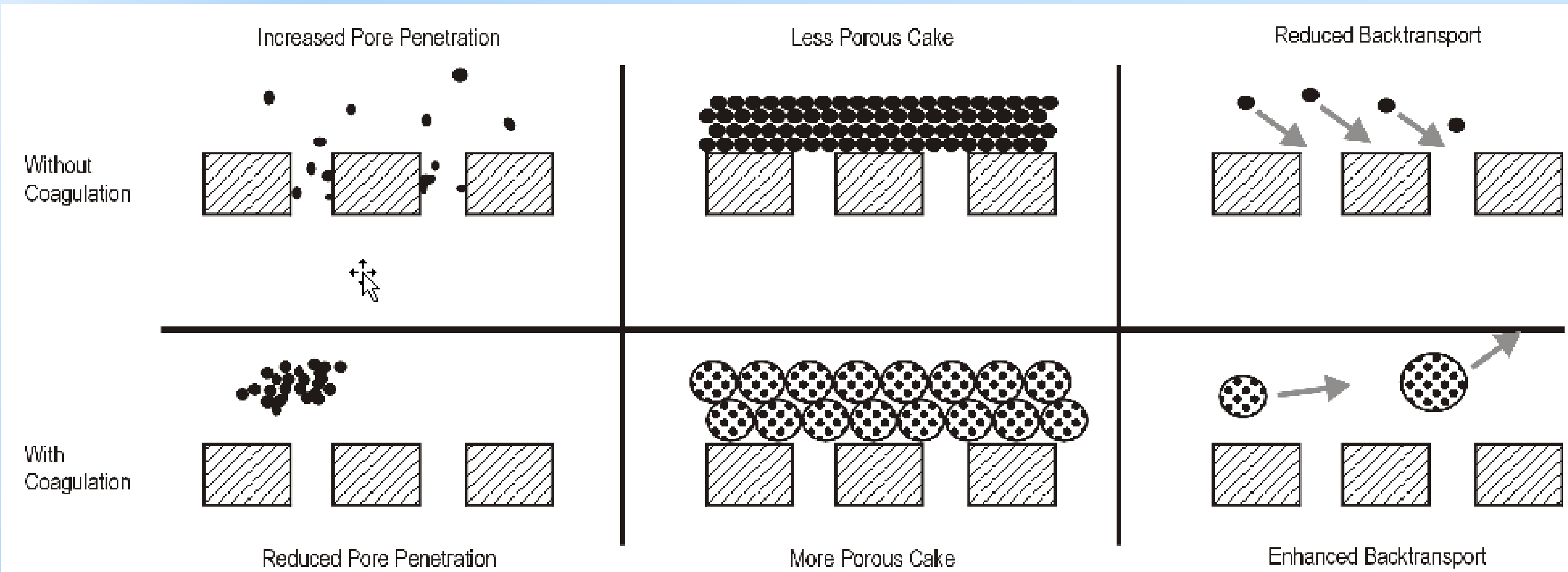


Improved robustness of backwash system

- Standard backwash procedure was inefficient
  - Rapid decline in membrane permeability
  - Clogging in feed & drain port
- Improved operation by:
  - Increasing air scrub flow rate and backwash flow rate
  - Added backwash out drain step
  - Added gravity drain step

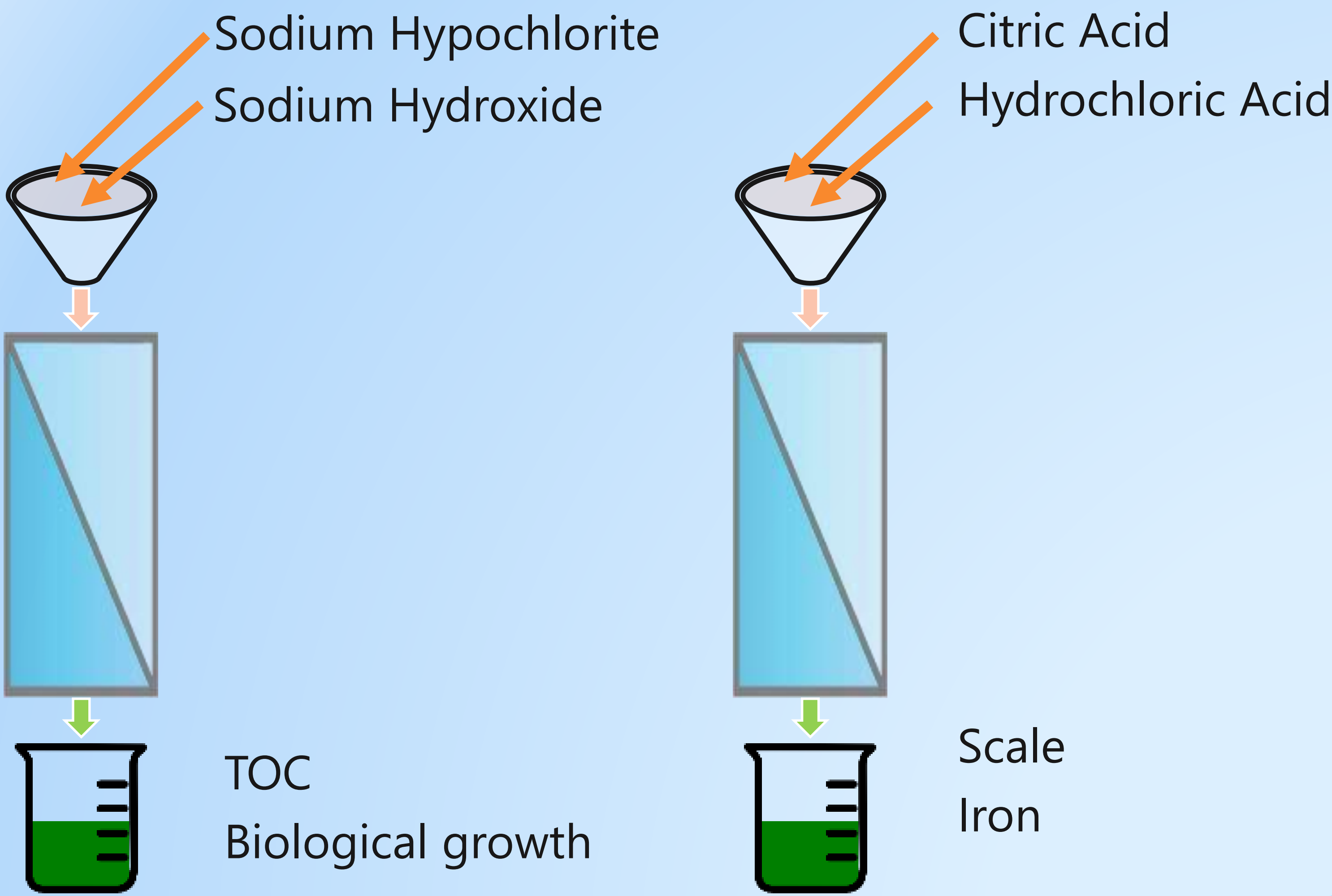


Pretreatment improved backwash efficiency and decreased cleans



From *Water Treatment Membrane Processes* 1996

Optimized chemical cleaning strategy to maintain stable operation



Polymeric Membrane Operating Conditions

Parameter		Baseline	
Water Quality		High Quality Wastewater	HPO Plant High TOC, TSS, and Turbidity
Capacity	mgd	3	
Flux Rate	gfd	31	
Pretreatment Sodium Hypochlorite Dose	mg/L	3.5	
Pretreatment Coagulant (ACH) Dose	mg/L	0	
MC Frequency	No/Rack/Week	3	
MC Chemical Doses	mg/L	NaOCl – 250 NaOH - 0	
CIP Interval	days	30	
Feed Pressure	psi	28	

Polymeric Membrane Operating Conditions

Parameter		Baseline	Pilot
Water Quality		High Quality Wastewater	HPO Plant High TOC, TSS, and Turbidity
Capacity	mgd	3	3
Flux Rate	gfd	31	31
Pretreatment Sodium Hypochlorite Dose	mg/L	3.5	3.5
Pretreatment Coagulant (ACH) Dose	mg/L	0	5
MC Frequency	No/Rack/Week	3	3
MC Chemical Doses	mg/L	NaOCl – 250 NaOH - 0	NaOCl – 1500 NaOH - 550
CIP Interval	days	30	14
Feed Pressure	psi	28	31

Polymeric Membrane Annual Cost

Item	Baseline	Final
Water Quality	High Quality Wastewater	HPO Plant High TOC, TSS, and Turbidity
Pretreatment Chemicals	$17,000	$118,000
Cleaning Chemicals	$11,000	$185,000
Membrane System Energy	$59,000	$65,000
Total	**$87,000**	**$368,000**

Successful operation with challenging feed water quality increased O&M costs.

Pilot Study 2

Major Difference Between Polymeric and Ceramic Modules

Polymeric

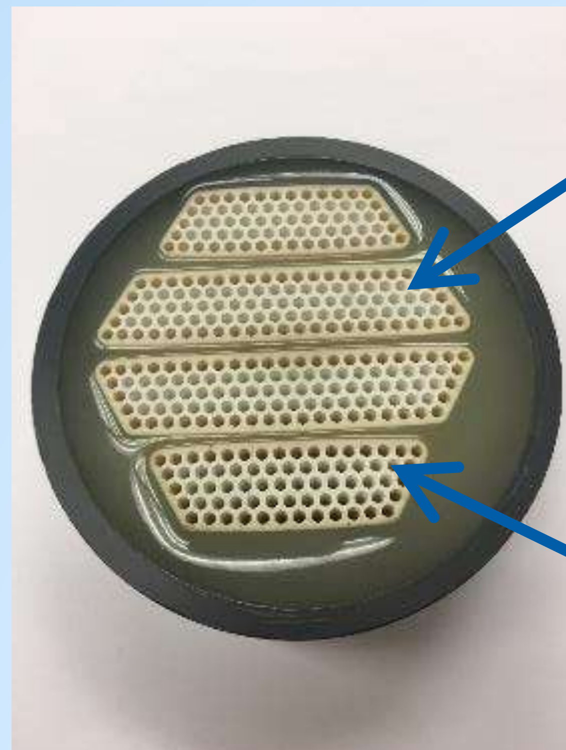
Bundle of fibers

More surface area

Ceramic

One "piece"

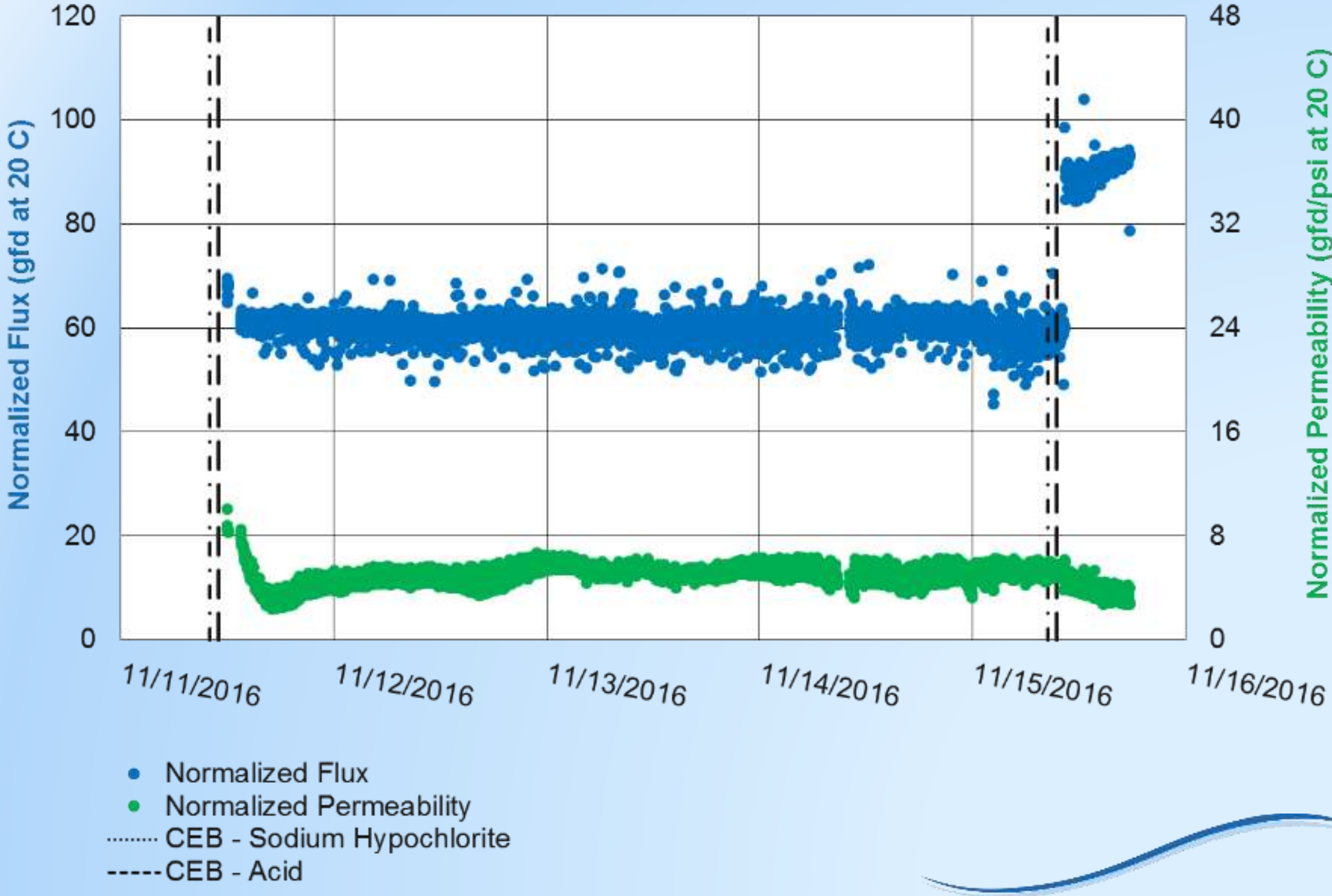
Higher loading rate



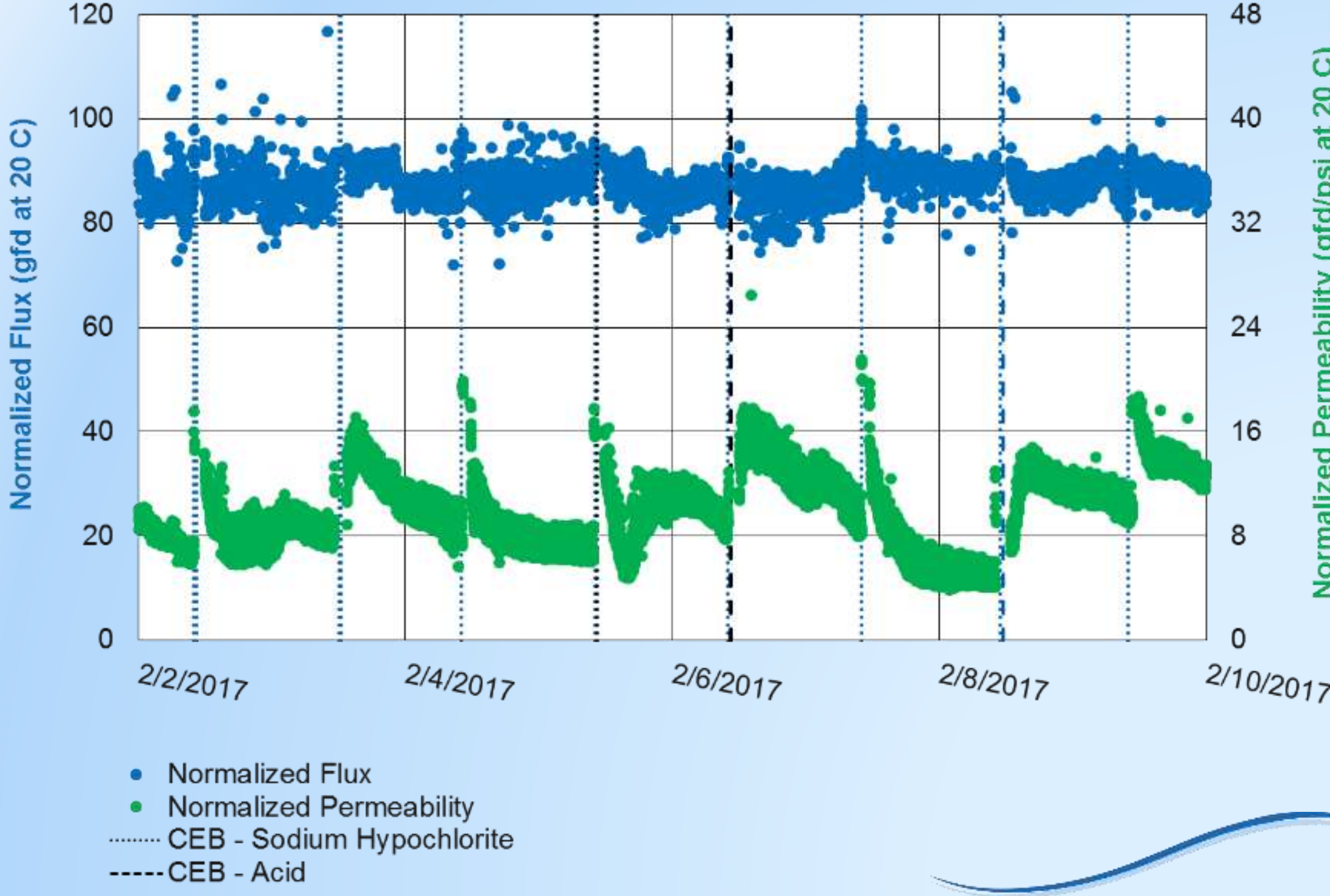
Major Operational Differences Between Ceramic and Polymeric Modules

- Easier to clean
  - Increased backwash flowrate (2x)
- Increased operating flux
- Tighter control on pore size
- Lower chlorine tolerance
  - Increased frequency of high-pH MC

Initial Ceramic Membrane Performance – 60 gfd



Final Ceramic Membrane Performance – 85 gfd



Comparing Polymeric and Ceramic Performance

Parameter		Polymeric Membranes	Ceramic Membranes
Pretreatment NaOCl Dose	gfd	3.5	6.5
Pretreatment Coagulant (ACH) Dose	mg/L	5	34-64
Flux	gfd	31	70/91
Backwash Flow	gpm	35	40
High pH MC Frequency	No/Rack/Week	3/5	7
Low pH MC Frequency	No/Rack/Week	1/3	3.5
MC Chemical Doses	mg/L	NaOCl – 1,150 NaOH – 540	NaOCl – 600 NaOH – 1200

Comparison of Annual O&M Cost for 3 mgd Facility

	Polymeric Membranes	Ceramic Membranes
Power	$198,000	$210,000
Maintenance	$160,000	$160,000
Chemicals	$256,000	$600,000
Membrane Replacement	$549,000	$287,000
Total	**$1,163,000**	**$1,257,000**

Preliminary Design

Used site specific tools to design a robust and reliable plant in limited footprint

Design incorporated measures to mitigate the operational risks observed during the pilot tests

	Observed Pilot Risks	Mitigation Measures
1	Iron Fouling	Coagulant pretreatment and citric acid maintenance cleans

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4	Excessive chemical required to achieve cleaning effectiveness	Use of potable water for cleaning solutions
5	Fouling Events	Robust cleaning system (4 MCs/rack/week & 2 CIPs/rack/month)

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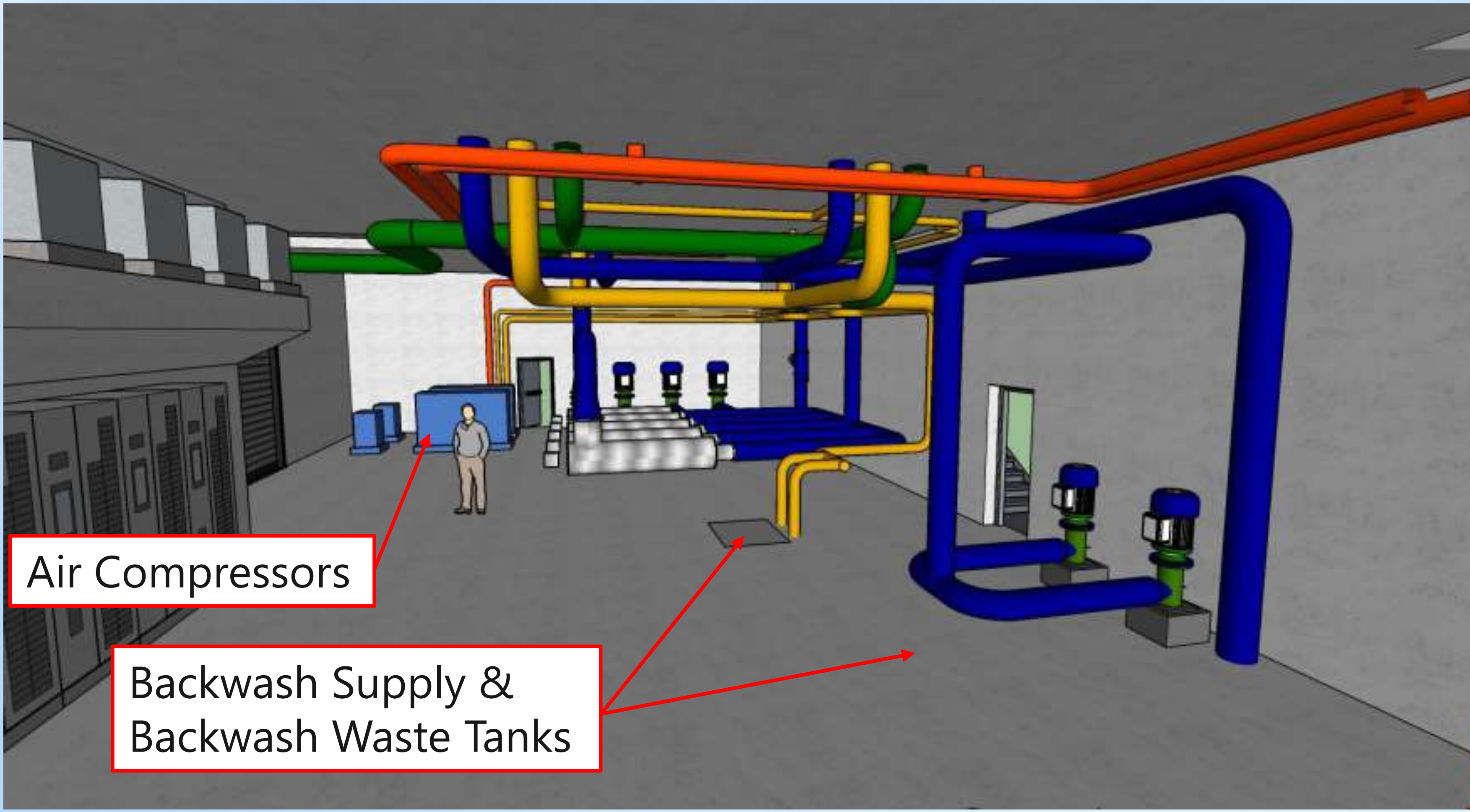

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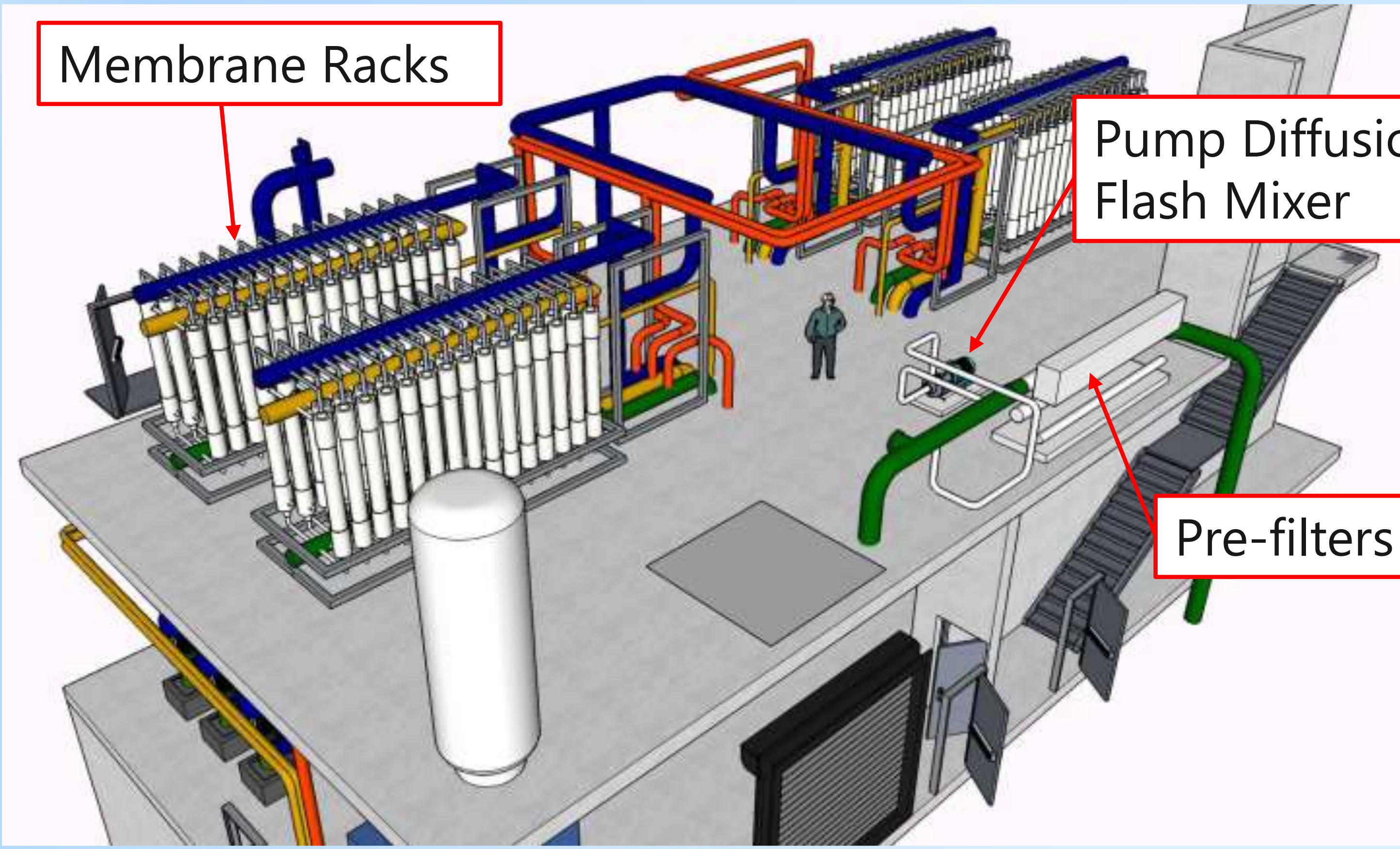

Questions?