INDUSTRIAL WATER REUSE NEW TECHNOLOGIES AND LESSONS LEARNED

IWC Workshop W-07

WELCOME

Industrial Water Reuse

Arizona (Arid Southwest)

- Copper
- Cattle
- Cotton
- Citrus
- Climate

Water, Water, Water, Water, Water …

Central Arizona Project

Central Arizona Project **(CAP)** [1973 – 1993]

- AZ, CA, CO, NV, NM, UT, WY share water allocations
- Delivers water from Colorado River to Southern AZ.
- **336 miles & 14 pump stations** from Lake Havasu to Tucson
- **Delivers water** to farmers, Native American nations, & **50 cities and communities**, including Phoenix & Tucson
- Water lifted 3000 feet from beginning to end
- CAP provides largest supply of water for the state
- Service area includes **5 million people**.
- Water delivery consumes ~ 4% of all energy used in Arizona.

Workshop Description 2021

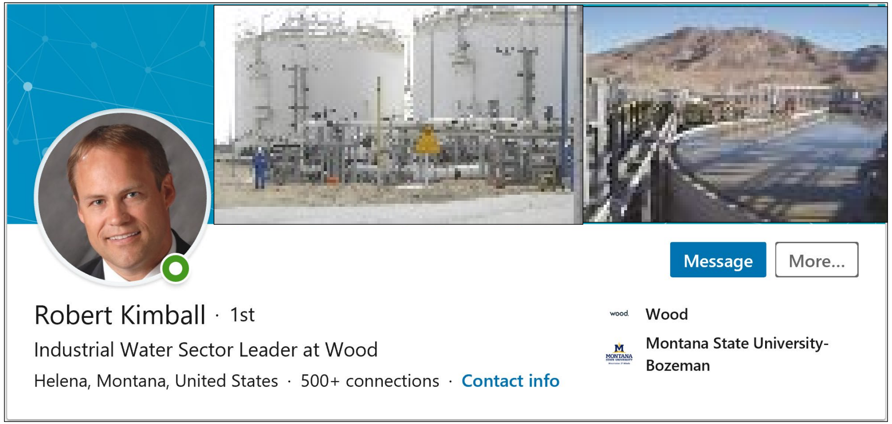
Primary objective is knowledge transfer -- Identify drivers of water conservation, water reuse, water recycle

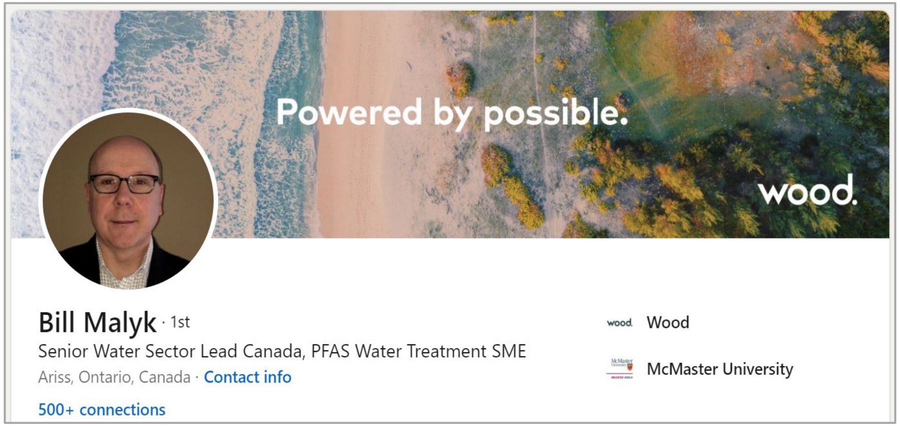
- Technical Design Factors
  - What drives the preparation of technical solutions
  - Chemistry
  - Water Reuse Destination
- Technology Choices
  - Navigating changing water treatment technology landscape
  - Technologies and their design constraints
  - “Fit for Purpose” water reuse strategies
  - Optimizing cost and reliability
  - Lessons learned and avoiding pitfalls

Participants will leave the workshop with:

- Broad understanding of the industrial water reuse landscape
- Why certain technologies are useful and how they work
- How the capabilities of water reuse systems have grown in recent years.

Speakers

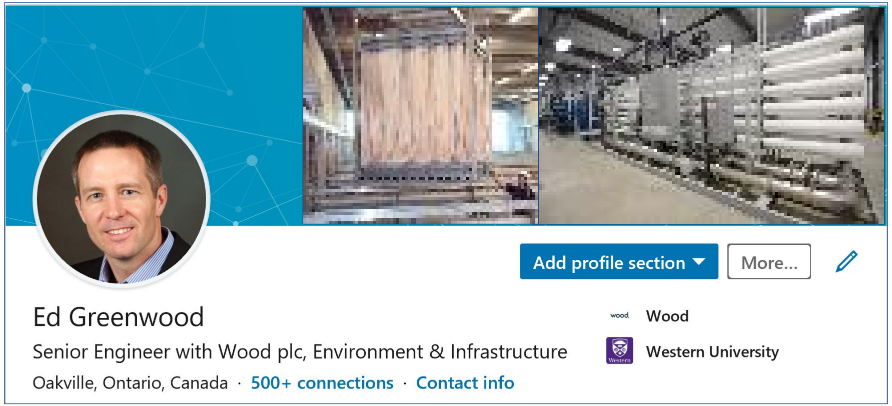




Jerry C. Bish

Water/Wastewater Service Line Leader at Wood

Phoenix, Arizona



Workshop Goals

1) Water quality drives design
2) Options to get from point A to point B
3) Unbiased comparison of popular flowsheets
4) Review currently used and emerging technologies
5) Case studies
6) Lessons learned – avoiding pitfalls

Workshop Agenda

Introduction/Background	Jerry Bish / Bill Malyk
Basis of Design	Bob Kimball
Module: Filtration	Ed Greenwood
Module: Desalination	Bob Kimball / Ed Greenwood
Module: Oxidation/Disinfection	Bill Malyk
Module: Byproduct Disposal	Jerry Bish
Case Studies	Various
Review and Wrap-up	

BACKGROUND

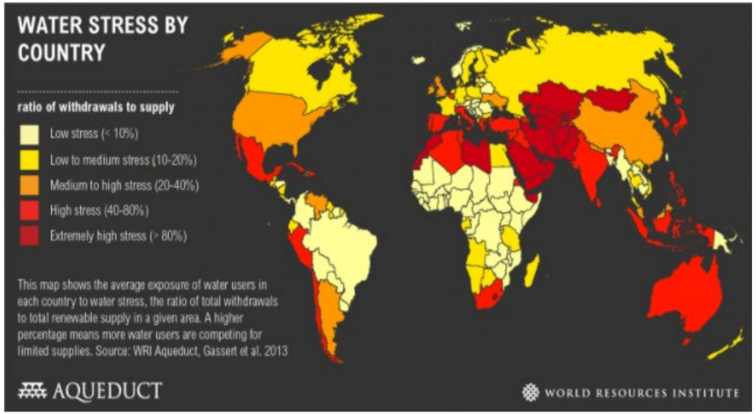
WHY?

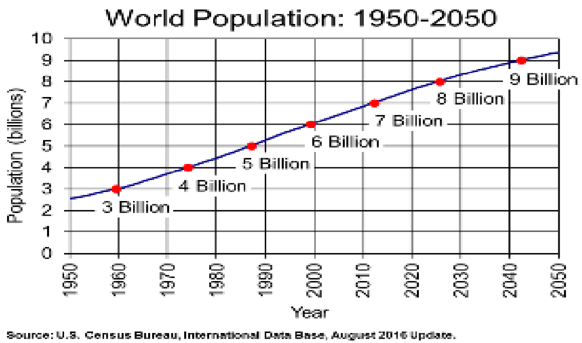
Drivers, benefits, and drawbacks of water reuse

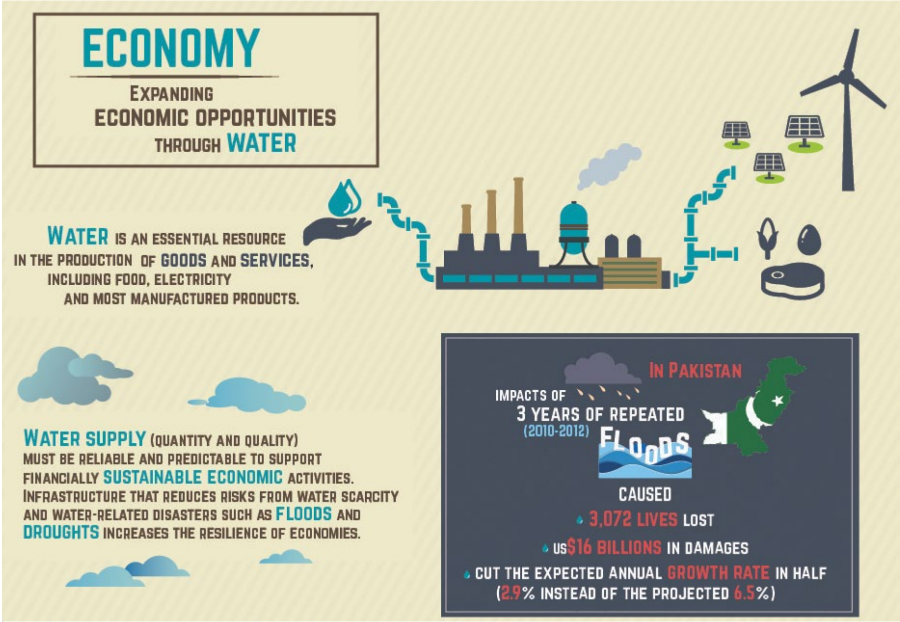
HOW?

Strategies for Water Reuse in Industry

Water Scarcity and Economy







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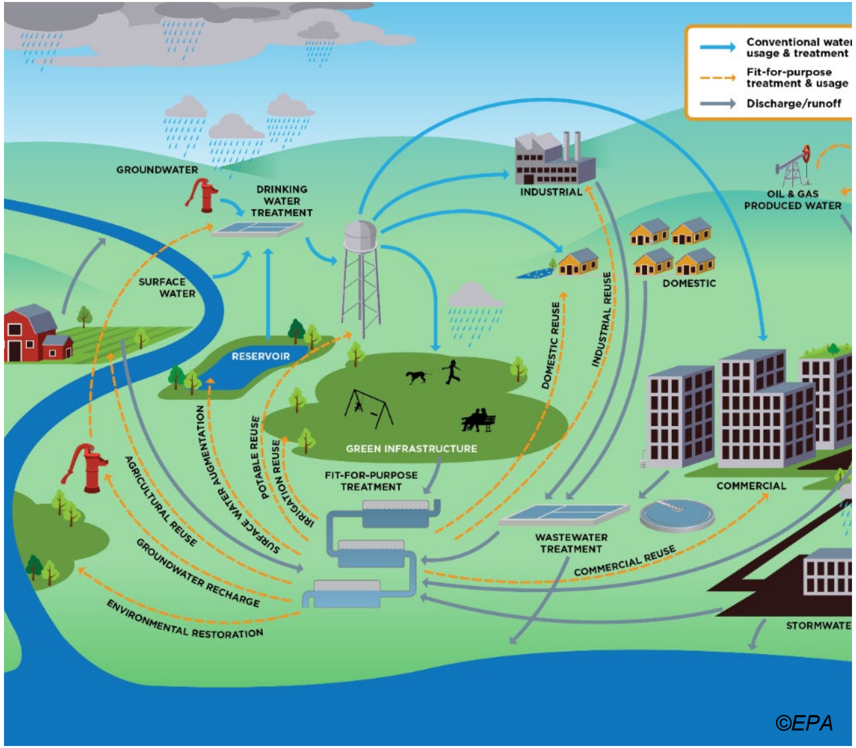
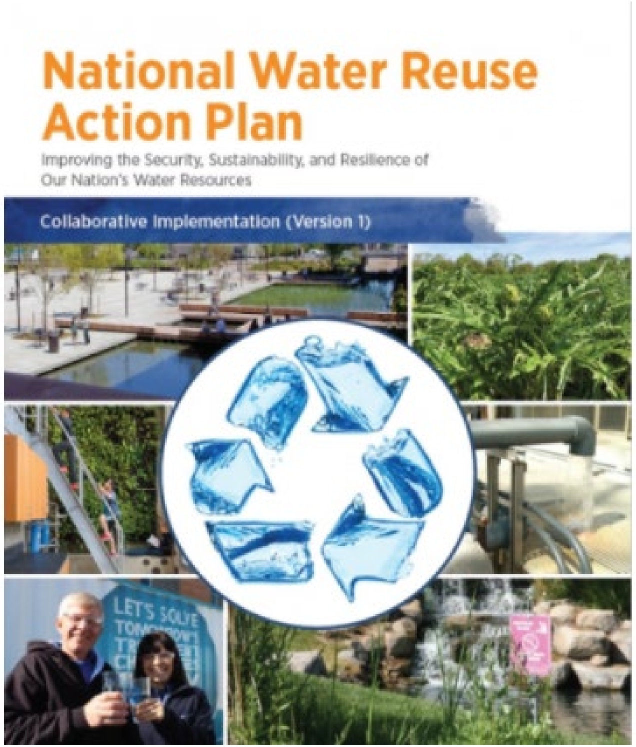
Water reuse is a government, industrial, academic, and personal opportunity



1. Water supply limits is a growing concern
2. Water supply is limited in places where water demand is growing (Middle East, South Europe, Some areas of US)
3. Many US States have a Water Rights System, where Senior Water rights Holders can force Junior Water rights Holders to give up supply in a shortage-Fairness is an issue
4. Most World Municipalities and Water Authorities have a Drought Contingency Plan (DCP)
5. Discharge Permits are restricted
6. Infrastructure Restrictions: municipal WWTP may not accept industrial wastewater
7. Water and sustainability goals are a key social perception for industries

US: National Water Reuse Action Plan.



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- The **National Water Reuse Action Plan (WRAP)** is a coordinated and collaborative effort across the water user community to advance consideration of water reuse to ensure the security, sustainability, and resilience of our nation's water resources.
- This Action Plan (Version 1) identifies action leaders, partners, implementation milestones, and target completion dates for **37 actions across 11 strategic** themes. These actions represent initial momentum and serve as a catalyst for additional partnerships and subsequent actions to strengthen and diversify the Nation's water resources

Europe: Minimum requirements for water reuse – Regulation 2020/741

©European Comission

- New Regulation to enter into force in **June 2023**.
- Harmonised minimum water quality requirements for the **safe reuse of treated urban wastewaters in agricultural irrigation**;
- Harmonised minimum monitoring requirements, notably the frequency of monitoring for each quality parameter, and validation monitoring requirements;
- Risk management provisions to assess and address potential additional health risks and possible environmental risks;
- Permitting requirements;
- Provisions on transparency, whereby key information about any water reuse project is made available to the public.

Kingdom Saudi Arabia: Vision 2030

Saudi Vision 2030

Moving toward optimal water use

The Kingdom of Saudi Arabia is taking proactive steps to achieve reductions in water consumption by promoting desalination, water reuse, and conservation. Patrick Dube of Water Environment Federation reports on the nation's water strategy that aims to solve water scarcity challenges.

- The Kingdom of Saudi Arabia has begun to take significant steps as part of its national plan – Saudi Vision 2030 – that is designed to solve its impending water crisis by promoting the optimal use of water resources.
- Saudi Vision 2030 is a nationwide plan designed to decrease the Kingdom's dependence on oil, diversify its economy, and develop public service sectors. To achieve this goal, the government outlined three pillars believed to be critical to the Saudi Vision: a vibrant society, a thriving economy, and an ambitious nation

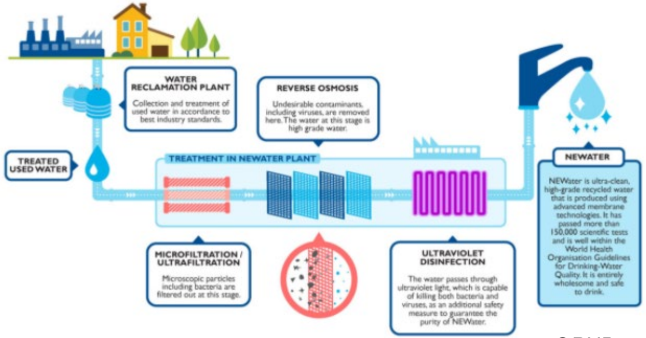
Singapore: Reusing water since 1966

Industrial Water Reuse

- Lower grade reclaimed water serving as alternative water source for non potable uses in industries

NEWater

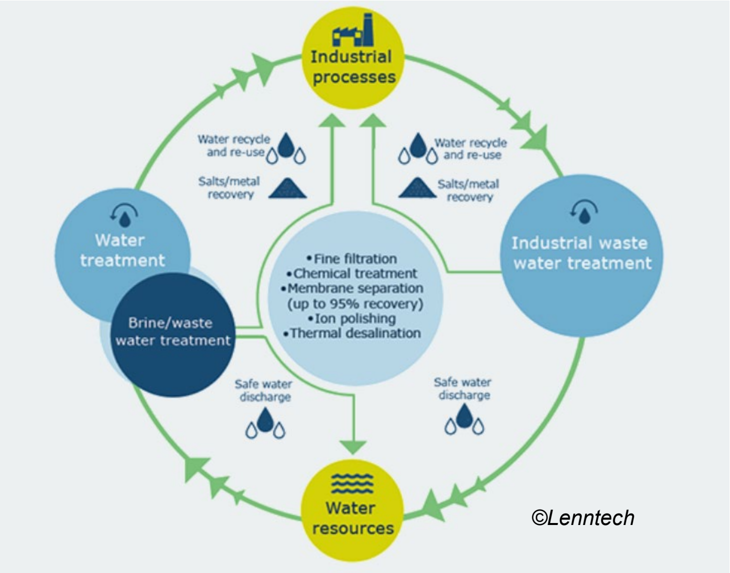
- High-grade reclaimed water, known as NEWater was introduced.
- NEWater is recycled from treated sewage (‘used water’) and produced using a rigorous 3-step purification process involving ultrafiltration/microfiltration, reverse osmosis (RO) and ultraviolet (UV) disinfection.
- Compared to desalination, NEWater is more energy-efficient and cost-efficient to produce because of the lower salt content in treated used water, as opposed to seawater.



©PUB

The drivers of reuse, conservation, recycle projects

- Water supply is costly or poor quality
- Water supply is restricted (water rights, droughts, subsidence or groundwater issues)
- There are government, stockholder, or stakeholder pressures to achieve sustainability by reducing water usage
- Effluents for potential reuse are available and have low barriers to be recycled
- Industry is receiving political pressure



Opportunities seen from the client side

- Unit by Unit conservation
- Make water do more than one pass through your process
- Reuse treated sewage effluent
- Reuse wastewater effluent with inorganic contaminants (Cooling Water, Boiler Blowdown, DEMIN Reject/Backwash)
- Reuse wastewater effluent with organic contaminant
- Drill wells and use brackish or non potable water (with treatment)
- Reuse stormwater

General Strategies of Water Use Reduction and Reuse

Benchmarking- Define Water Supply and Current Use

- Water balance where the supply to discharge balance is closed to within 10-15%
- Water "Audit" to examine large single water users. Identify "wasting" to conserve water

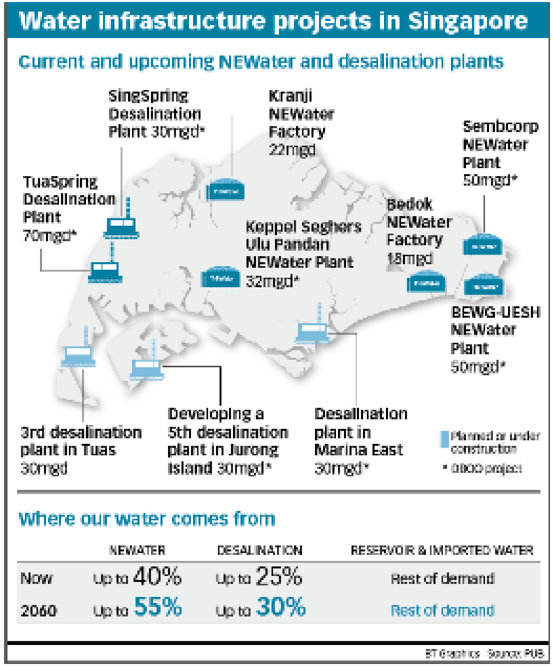
Water Sources- Surface Water vs. Groundwater

- Fresh groundwater is reserved for emergency withdrawal
- Brackish or Saline groundwater may be available
- Sewage effluent may be available (and be high quality water)

Water Use Reduction

- Use the water balance to identify major water users
- Optimize operation

Is Reuse Practical? Desalination and Reuse, including Direct Reuse, is happening now!



Timeline

- 1970s - DPR first proposed
- 1974 - "toilet to tap" piloted
- 1998 – NEWater study completed
- 2001 – 1st NEWater plant completed

Singapore's 'toilet to tap' concept

Singapore is one of Asia's most powerful economies, but it lacks a reliable water supply. Wastewater reuse plants could change that by soon recycling enough sewage to meet 50 percent of the nation's water needs.

Practical Industrial Water Reuse Applications

Food Industry may have the most practical applications

CDM GE Water 2010, GE is now Suez

Frito Lay has a 1 mgd activated sludge-filtration-reverse osmosis plant which has a 75% recovery (reuse) rate in Casa Grande, AZ. Reject is placed in evaporation ponds

Driver: No water rights available, stockholder pressure

Practical Industrial Water Reuse Applications

J.R. Simplot Potato Flake Manufacturing, Caldwell, ID

CDM GE Water 2014

J.R. Simplot has a 1.5 mgd activated sludge-filtration-reverse osmosis plant which has a 80% recovery (reuse) rate in Caldwell, ID. Reject is placed in evaporation ponds

Driver: No water rights available, stockholder pressure

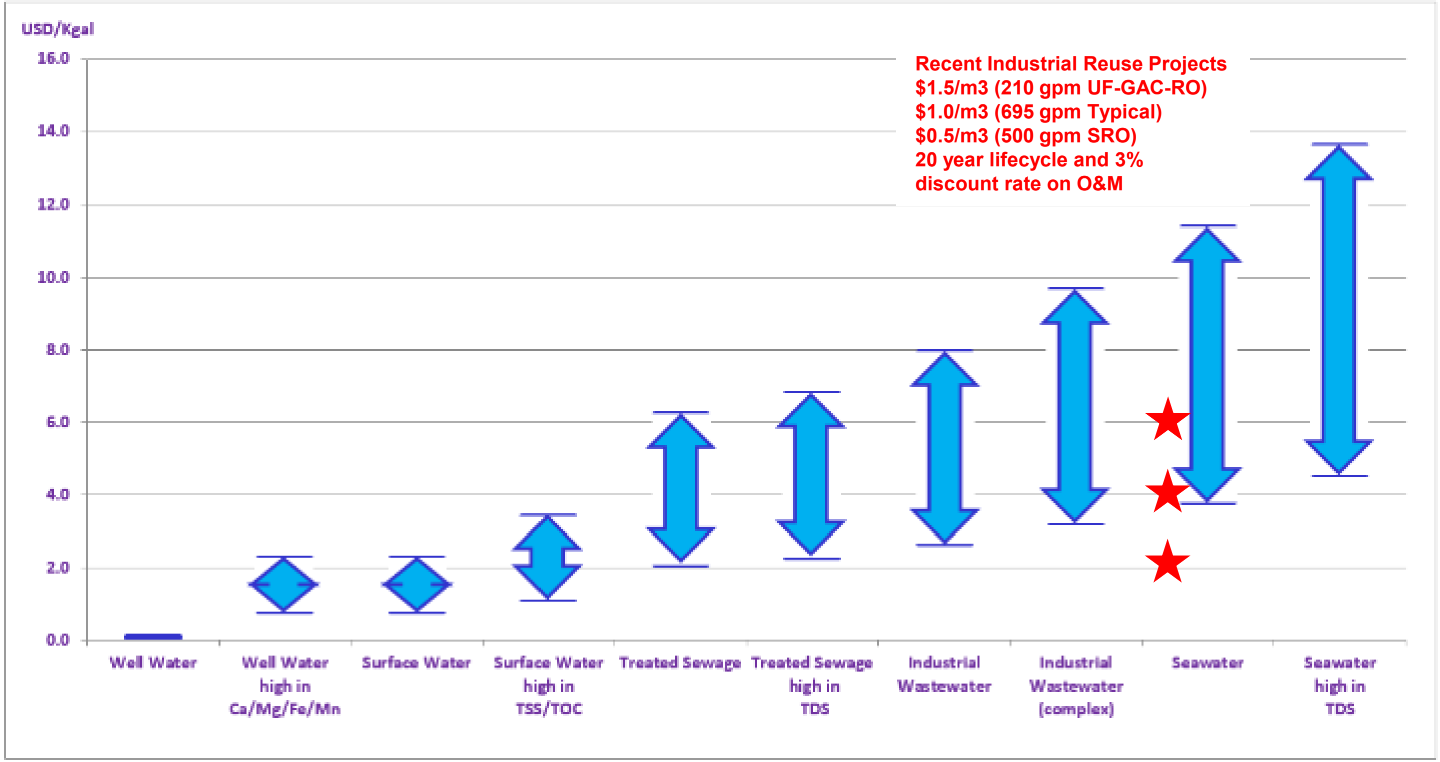
Water Reuse-EPC Secondary RO at NM Refinery

- Two (2) 500 gpm RO units which take Reject from a primary RO unit and extract more clean water for refinery use
- Feed 10,000 ppm TDS, 75%-92% recovery, useable for 575 psi steam
- Driver: Expensive poor quality, public water

This application features pretreatment, 2 x 500 gpm SROs, Decarbonation, Acid and Chemical injection

What you must contend with?

- The Relative Costs of Water Treatment are still high but costs are trending down in each category



New technologies

CLOSED CIRCUIT RO →INCREASING RECOVERY

NON THERMAL ZLD→ ABX NEW TECHNOLOGY

IMPROVED ZLD SYSTEMS→ IMPROVING EFFICIENCY


KEEP
CALM
AND
REUSE
WATER

INDUSTRIAL WATER REUSE NEW TECHNOLOGIES AND LESSONS LEARNED

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Basis of Design

INTERNATIONAL WATER CONFERENCE

wood.

BASIS OF DESIGN

Step by Step – From Concept to Design

1) Recommend starting with a Water Audit for the Facility
   - Understand the current and future water sources and water needs
   - Sample and Analyze all the sources of water and wastewater

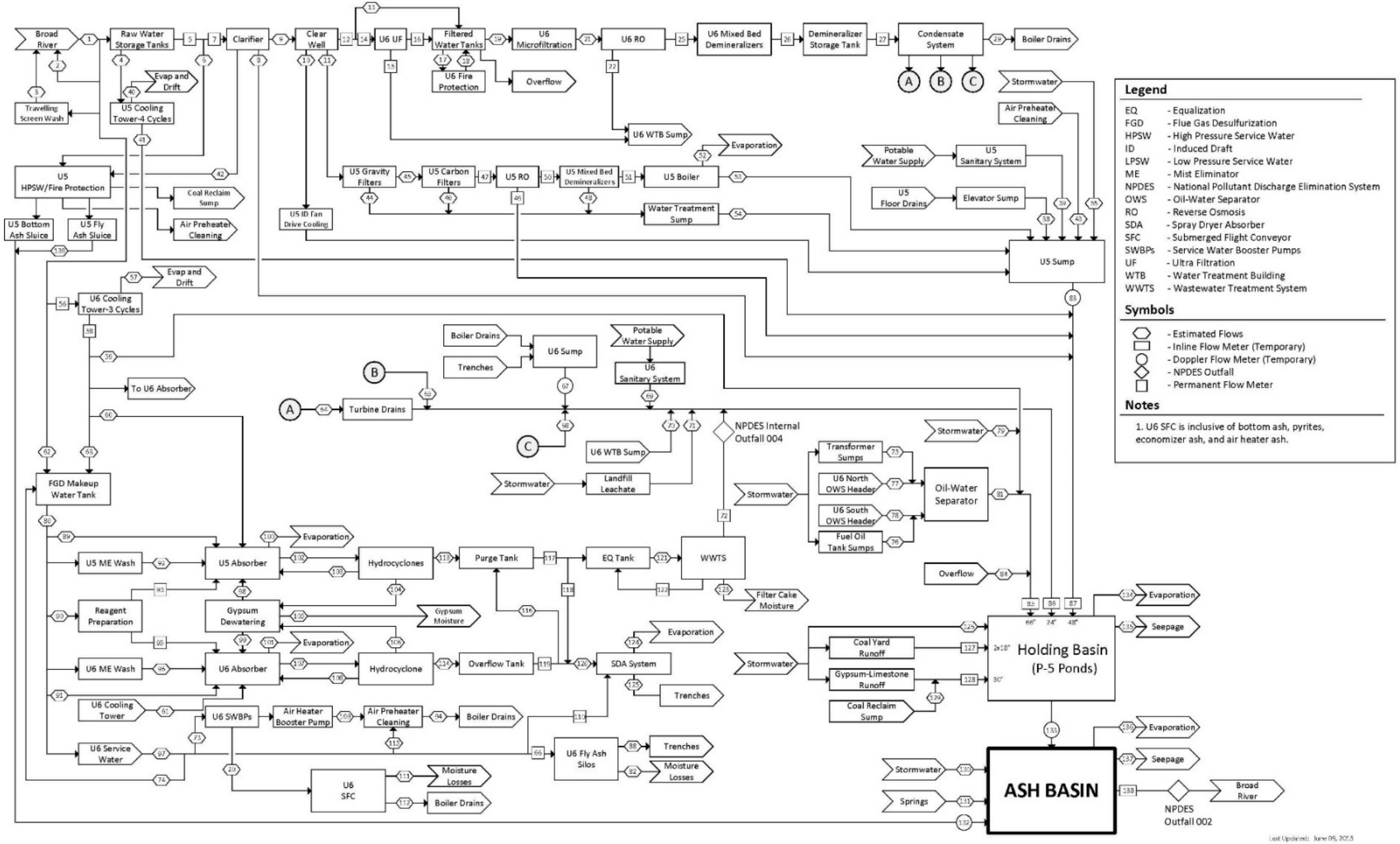
Fresh Water Sources

- Potable (City Water)
- Well water
- River water
- Seawater
- Other

Wastewater Sources

- Various industrial processes
- Plant drains (wash water)
- Blowdown from cooling towers
- Blowdown from boilers
- Sewage
- Other

C Steam Station PFD



Step by Step – From Concept to Design

2) Quantify the flows and water quality requirements for each need

- Cooling Towers
- Boilers
- Process Water
- Washwater
- Irrigation Water

3) Identify the major contaminates in each water source and wastewater stream

- Oil and Grease (Emulsified and Free)
- Suspended Solids (Settleable and Colloidal)
- Organics (Biologically Degradable and Recalcitrant)
- Salts (high and low solubility)
- Heavy Metals
- Toxins
- APIs, ECCs, etc.

Water Analysis – Feed Water Chem

Suspended Solids		
TSS (Total Suspended Solids)	mg/L	43
Turbidity	NTU	108
SDI (Silt Density Index)	-	5
Organics/Biological		
TOC (Total Organic Carbon)	mg/L	50
COD (Chemical Oxygen Demand)	mg/L	825
BOD (Biochemical Oxygen Demand)	mg/L	333
Total Coliforms	mg/L	333
Dissolved Salts (Anions)		
Cl (Chloride)	mg/L	19813
SO4 (Sulphate)	mg/L	2889
NO2 (Nitrite)	mg/L	2
NO3 (Nitrate)	mg/L	82.0
F (Fluoride)	mg/L	1
PO4 (Phosphate)	mg/L	23.9
SiO2 (Silica)	mg/L	24
Dissolved Salts (Cations)		
Na (Sodium)	mg/L	0.66
Ca (Calcium)	mg/L	87
Mg (Magnesium)	mg/L	0.13
K (Potassium)	mg/L	1.4
Fe (Iron)	mg/L	0.23
Mn (Manganese)	mg/L	0.15
Ba (Barium)	mg/L	<LOQ
St (Strontium)	mg/L	5.1
Z (Zinc)	mg/L	<LOQ
Other		
TDS (Total Dissolved Solids)	mg/L	42866
Conductivity @ 25 C	uS/cm	49200
pH	-	8.5
Total Alkalinity (as CaCO3)	mg/L	2434
Total Hardness (as CaCO3)	mg/L	3786

Filtration	Media (Sand, Multi, Carbon, Greensand, Biological) Cloth (Disc. Bag, Belt, Cartridge) Membrane (Microfilter, Ultrafilter)
Oxidation/Disinfection	Chemical (Chlorine, Peroxide, Ozone) Ultraviolet Light Advanced Oxidation (Hydroxyl Radical)
Desalination	Membrane (NF, RO) Ion Exchange (Cation, Anion, Mixed) Electrodionization (EDI) Electrodialysis Reversal (EDR) Evaporators & Crystallizers (Falling Film, MEE, BC) Multistage Flash Distillation (MSF)

Step by Step – From Concept to Design

4) Consider the opportunities for reuse. For example …
- Treated wastewater can be reused in Cooling Towers or Boilers as make-up
- Treated Process Wastewater can often be used in place of fresh water sources
- Irrigation needs (agriculture/industrial/municipal)
- All of the above … “Designer Water”

5) Consider the obstacles for reuse
- Cost (capital/operating)
- Space (footprint)
- Existing plant infrastructure restraints (locations of sources and needs, access to underground drains)
- Unknowns (treatability study, bench top tests, technology pilot)
- Disposal of byproducts (**i.e. RO Concentrate**)

Result: Basis of Design

for Treatment and Reuse

- Design Flows (peak, average)
- Feed Water Quality (max, min, average)
- Treatment Requirements (e.g., cooling tower makeup, boiler feed makeup, fresh water offset, etc.)
  - Site Specific Limitations
  - Footprint
  - Power
  - Cost
  - Residuals disposal
  - Etc.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CALM
AND
REUSE
WATER

INDUSTRIAL WATER REUSE NEW TECHNOLOGIES AND LESSONS LEARNED

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Filtration

3. FILTRATION

Filtration Agenda

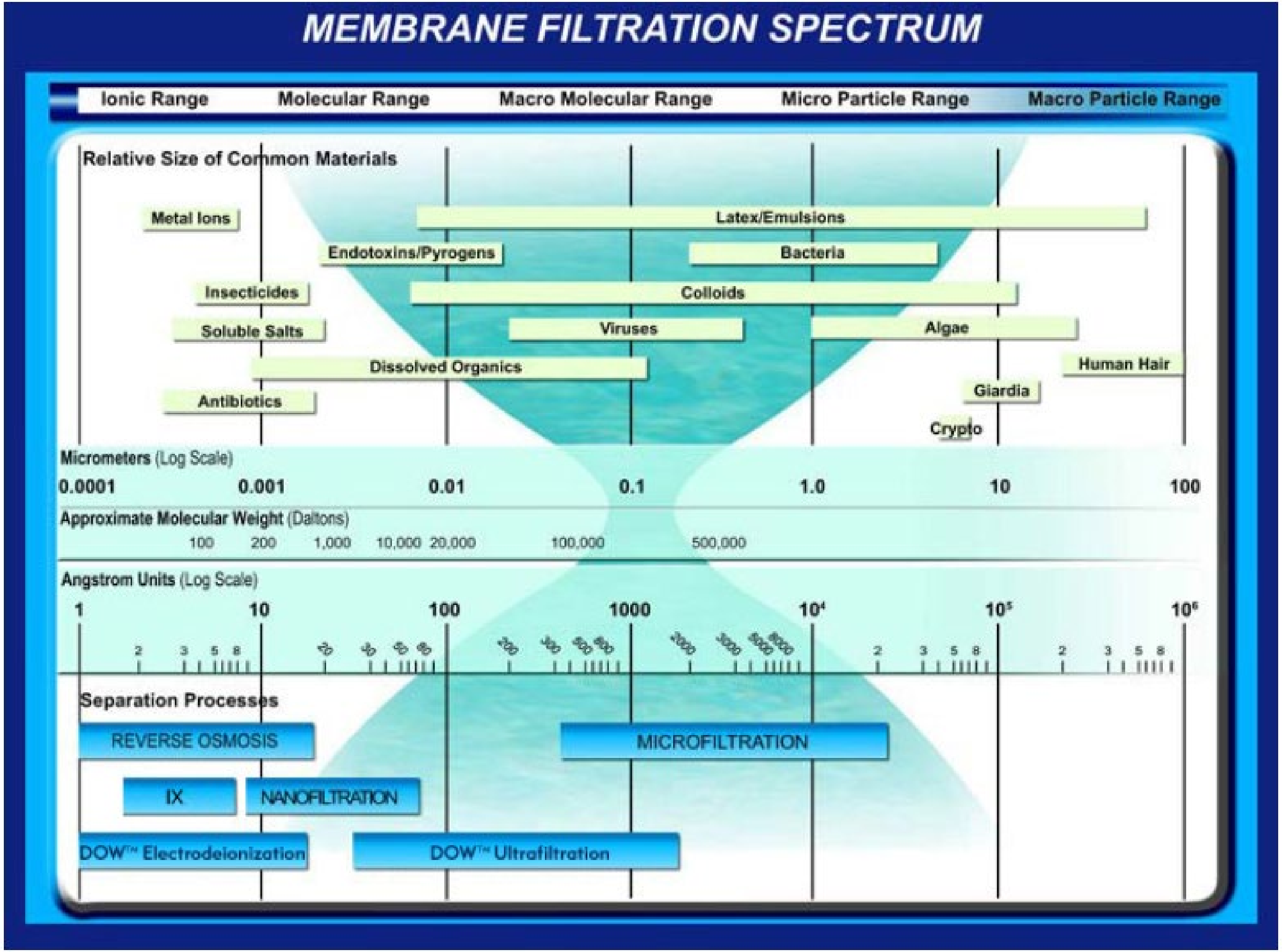
- Common Terms
- Goals of Filtration
- Filtration Spectrum
- Types of Filters
- Types of Media
- Types of Membranes
- Membrane Pore Size
- Membrane Materials
- Membrane Fouling
- Membrane Cleaning
- Water Reuse Upsets
- Comparing Filters (the numbers don't lie)
- Landmark Projects
- New Technologies (Game Changers)

Common Terms / Definitions

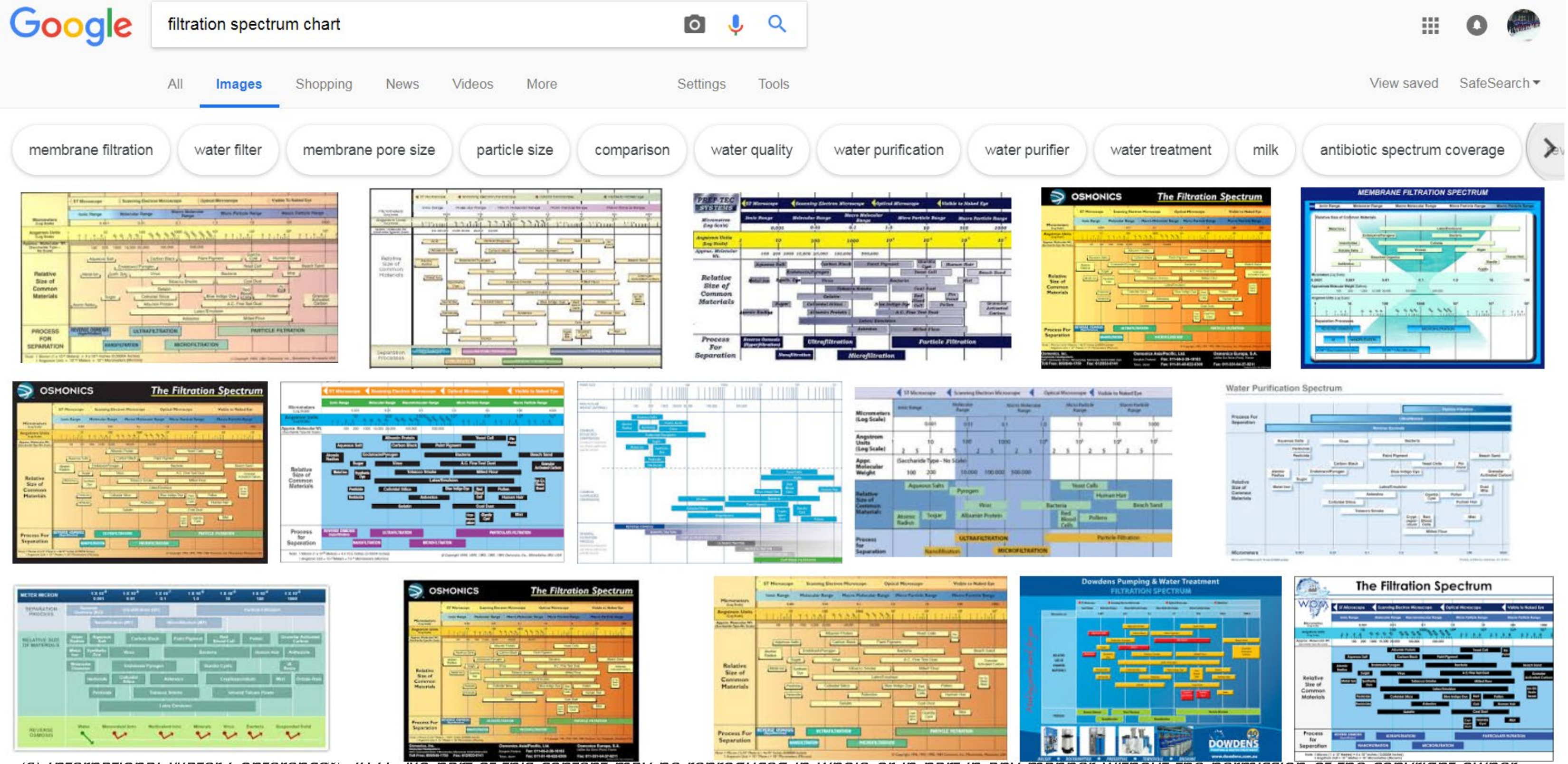
- TSS – Total Suspended Solids (mg/L or ppm)
- Turbidity (NTU)
- SDI - Silt Density Index
- Flow (gpd or gpm)
- Flux (gfd or gpd/ft2 or gpm/ft2)
- Solids Loading (gpd.ppm/ft2 or lbs/min/ft2)
- TMP - Trans Membrane Pressure (psid)
- Permeability (gfd/psi) … clean water, startup, operating

Filtration Goals

- Filtrate Water Quality
- Resistance to Plugging / Fouling
- Efficiency (space, power, chemicals, etc.)
- Automation vs. Simplicity
- Reliability during upsets
- Balance Cost vs. Reliability

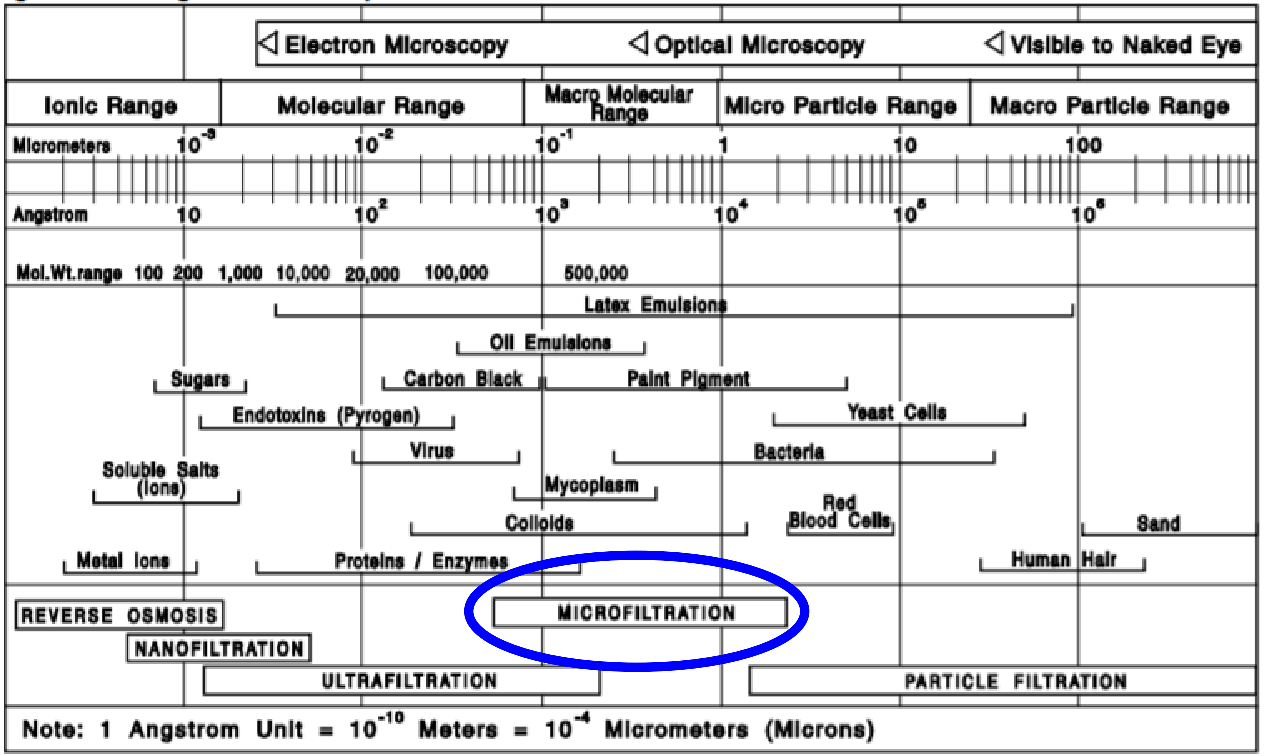

MEMBRANE FILTRATION SPECTRUM
Ionic Range
Molecular Range
Macro Molecular Range
Micro Particle Range
Macro Particle Range
Relative Size of Common Materials
Metal Ions
Latex/Emulsions
Endotoxins/Pyrogens
Bacteria
Insecticides
Colloids
Soluble Salts
Viruses
Algae
Dissolved Organics
Human Hair
Giardia
Antibiotics
Crypto
Micrometers (Log Scale)
0.0001
0.001
0.01
0.1
1.0
10
100
Approximate Molecular Weight (Daltons)
100
200
1,000
10,000
20,000
100,000
500,000
Angstrom Units (Log Scale)
1
10
100
1000
10^4
10^5
10^6
Separation Processes
REVERSE OSMOSIS
MICROFILTRATION
IX
NANOFILTRATION
DOW™ Electrodeionization
DOW™ Ultrafiltration

Filtration Spectrum



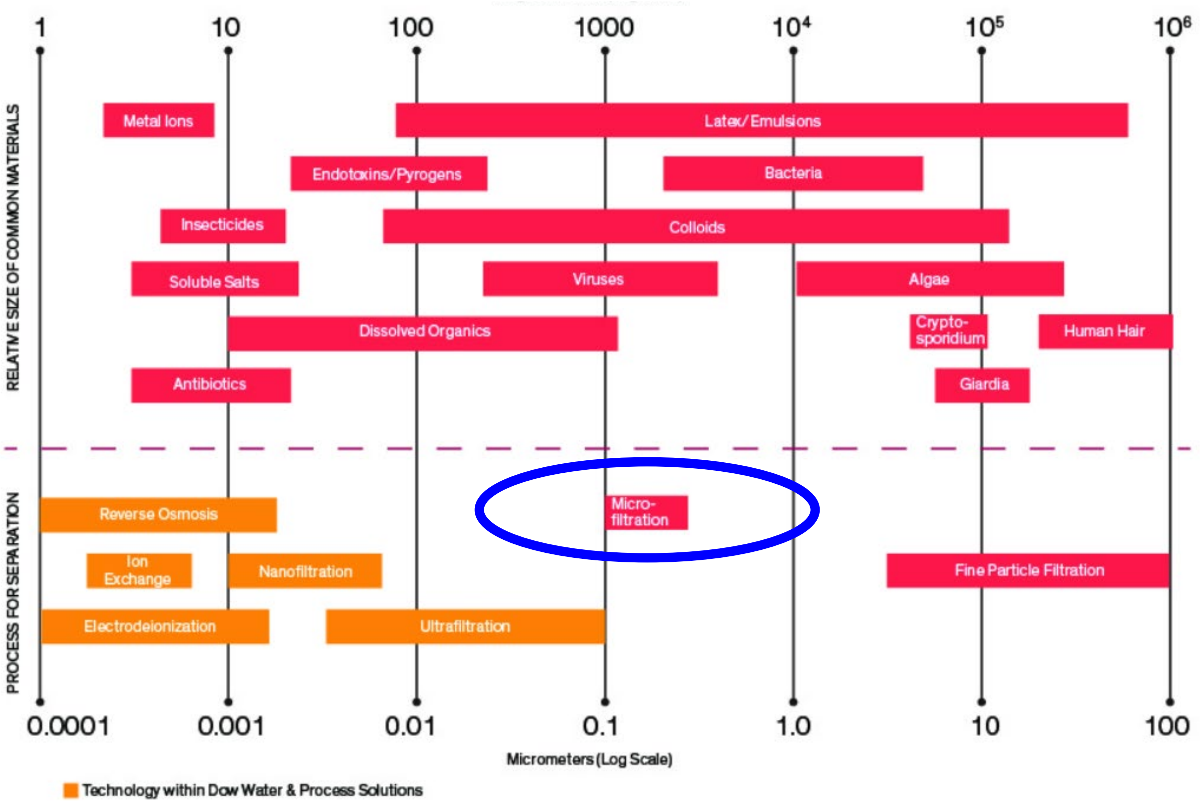
Filtration Spectrum

Figure 1.3 Ranges of filtration processes



http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_095b/0901b8038095b91d.pdf?filepath=liquidseps/pdfs/noreg/609-00071.pdf

Filtration Spectrum



Filtration Spectrum

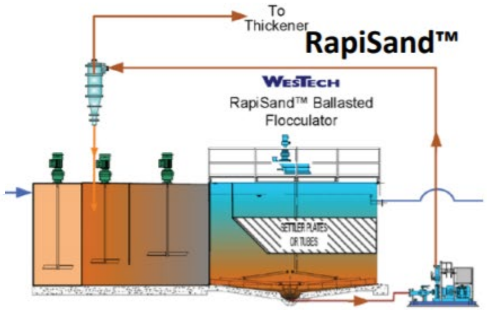
Recommendation:

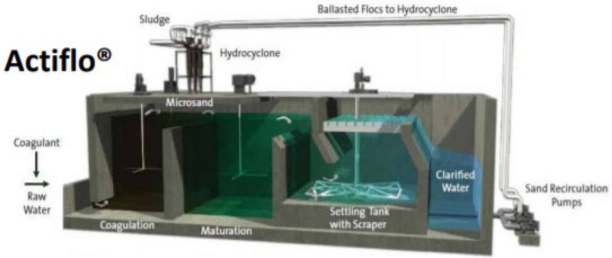
- Ensure you are getting support from unbiased sources
- Gather the data – get a particle size distribution test done on each of the streams to be treated.

http://www.schuettgutportal.com/13code/pagemain.php?lang=UK&req_file=newsitem&id=7662&lmid=2265

Ballasted Settling

- Veolia/Kruger: Actiflo®
- Degremont: DensaDeg®
- Evoqua: CoMag™
- WesTech: RapiSand™





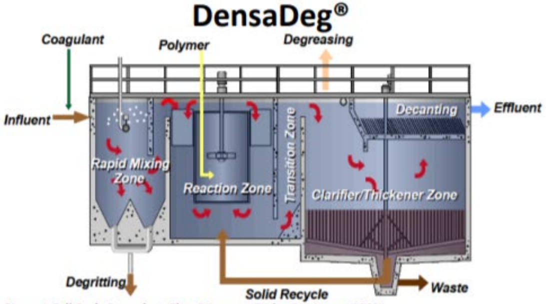
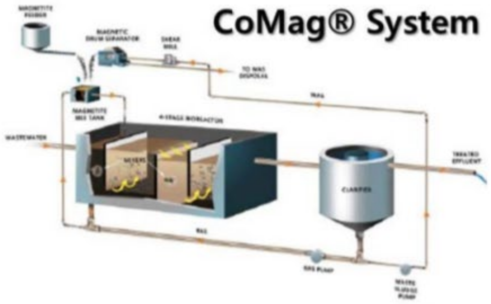


Figure 1.Full-Scale Densadeg® Flow Diagram. (Ondeo Degremont 2002)

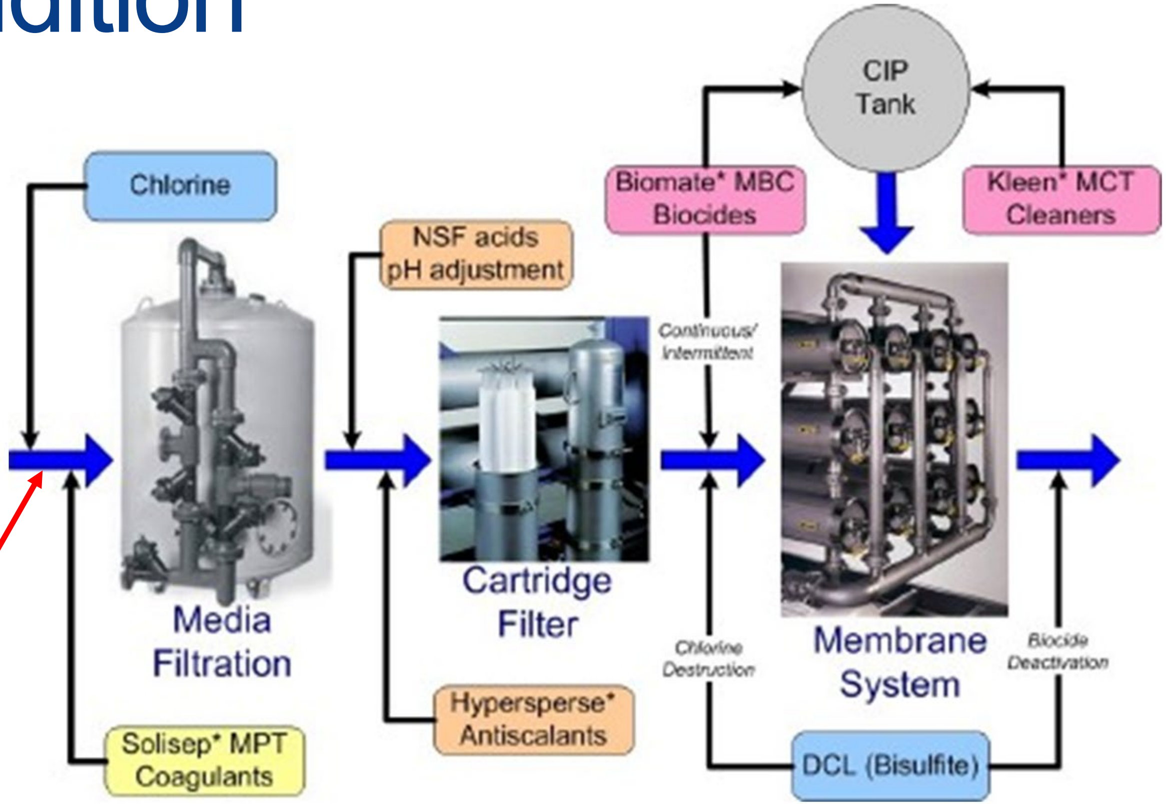


Chemical Addition

Typical Flowsheet Based on MMF-RO:

- Chlorine
- Coagulant
- Acid
- Antiscalant
- Sodium Bisulfite
- Biocide

pH Adjust



Source: GE Water & Process Technologies RO Best Practices

A "Few" General Types of Filters

- Simple "Disposable" Filters (Cartridge, Bag, Cloth)
- Media Filters (Sand, Multi-Media, Glass Bead)
- Media Filters (Selective: Carbon, Greensand, Bio, etc.)
- Membrane Filters (Config: hollow fiber, tubular, flat sheet)
- Membrane Filters (Mode: immersed, pressure, crossflow)
- Membrane Filters (Mat'l: Polymeric, Ceramic, SS)
- Membrane Filters (Pore size: MF, UF, NF)

Disposable Filters "Dead-End"

Bag Filters

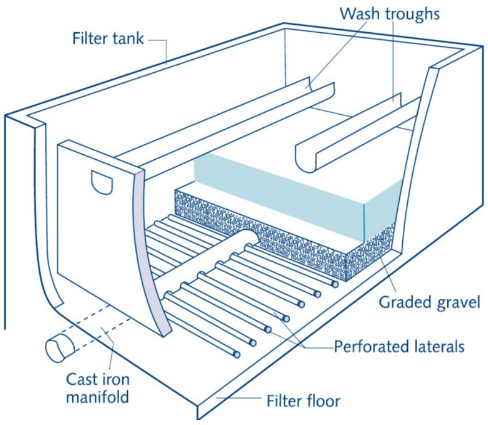
https://www.rosedaleproducts.com/model-p-219.html

Cartridge Filters

https://www.johnbrooks.ca/manufacturers/3m/

Media Filtration

Gravity



Ref: http://napier-reid.com/products/gravity-filtration-systems/

Pressure

Ref: https://www.culligan.com/CulliganCom/media/products/Hi_Flo_50_Water_Filter_Brochure.

Ref: http://www.bluewaterbio.com/filterclear/

Media Filtration

Gravity

Advantages:

- Can be inexpensive
- Can be very simple (manual valves)
- Can have very low maintenance (reduced cleaning)

Pressure

Advantages:

- Can be very space efficient
- Can be very automated
- Can require more maintenance (more regular cleaning)

Media Filters

Media Filters	Typical Flux (gpm/ft2)
Gravity Filter (Athracite and Sand)	2-3
Upflow Filter (Sand)	3-4
Anthacite Filter	5-9
Sand Filter	5-9
Multi Media Filter (Antracite, Sand and Garnet)	5-9

Media Filters (special media)	Typical Flux (gpm/ft2)
Greensand Filter (Fe & Mn removal)	1-5
Activated Carbon Filter (Cl removal)	1-2
Activated Carbon Filter (TOC removal)	1-1.5
Organoclay Filter (O&G removal)	3-4

https://www.suezwaterhandbook.com/degremont-R-technologies/desalination/filtration/vertical-pressure-filter-FV2B-Filter

Comparing Media and Membranes

Media

- Simple and cost effective
- Limits are well understood
- Media is cheap (no risk of membrane damage if feed water is off spec or if the system is poorly designed)
- No future membrane replacement costs
- Potential for breakthrough so Cartridge Filters are used to protect RO
- Reliable in many reuse applications … SDI typically 3 to 5

Membranes

- Can be cost effective in some applications (depends on the limits)
- Proven results with very high TSS levels (higher then media)
- Small footprint
- Automated cleaning
- Guaranteed Treated Water Quality (No Breakthough)
- SDI < 3 (100% of the time)

Conventional Technologies

Recommendation:

- Understand the limits of the media (conventional technology)
- Always question the limits of new or "advanced" technologies

Pretreatment Equipment Selection is based on water source and turbidity.

Pretreatment Equipment Selection Based on Water Source and Turbidity		
Water Source	**Critical water parameter**	**Suggested Treatment Equipment**
River	NTU > 25*	Clarifier* + MMF or MF
	NTU 10-25	MMF or MF with Coagulant
	NTU <10	MMF or MF (Coagulant may be needed)
Surface water Lake	Hard water and TOC	Lime softener + Clarifier MMF
	NTU >25*	Clarifier* + MMF or MF
	NTU<25	MMF or MF
Well Water	Iron and manganese	Chlorination + MMF
		Greensand Filter
	NTU < 10	UF/ MMF or MF
Brackish Water	NTU >10	MMF
	NTU <10	UF/MF or MMF
Sea or Ocean	NTU >50	Clarifier* + MMF
	NTU < 50	MF – Check with MF supplier
	NTU <25	MF

TOC= Organics, MF= Micro filtration, UF= Ultrafiltration, MMF= Multimedia Filters

*Total suspended solids greater than 100 mg/L require clarification.

MF/UF Membranes

PALL
Pall Corporation

MEMCOR®
an evoqua brand

suez
ZeeWeed* 500D module

For Earth, For Life
Kubota

PENTAIR X-FLOW

KOCH MEMBRANE SYSTEMS
PURON®

Comparing Membrane Systems

	Calculation			Measures
Flowrate	Volume / Time	gal / min	gpm	The capacity of the filtration system
Fluxrate	Flow / Filtration Area	gal / min . ft2	gfd	How efficient the filtration system is (footprint or capital cost)
Permeability	Flow / Filt Area . Diff Press	gal / min . ft2 . psi	gfd / psi	How efficient the filtration system is (performance or operating cost)
Contaminate Conc.	Mass / Volume	mg / Liter	ppm	How challenging the feed water is to treat
Solids Loading	Flow x Conc.	gal . mg / min . L	lbs / hr	How challenging the goals are
Solids Flux	Flow x Conc. / Filtration Area	gal . mg / min . L . ft2	lbs / hr . ft2	How aggressive the design is

Comparing Membrane Systems

Flowrate

Fluxrate

Permeabili

Contaminate

ASK FOR SUPPLIERS FOR

- REFERENCE PROJECTS
- DESIGN DATA and OPERATING DATA
- OPERATOR CONTACT DETAILS

al cost)

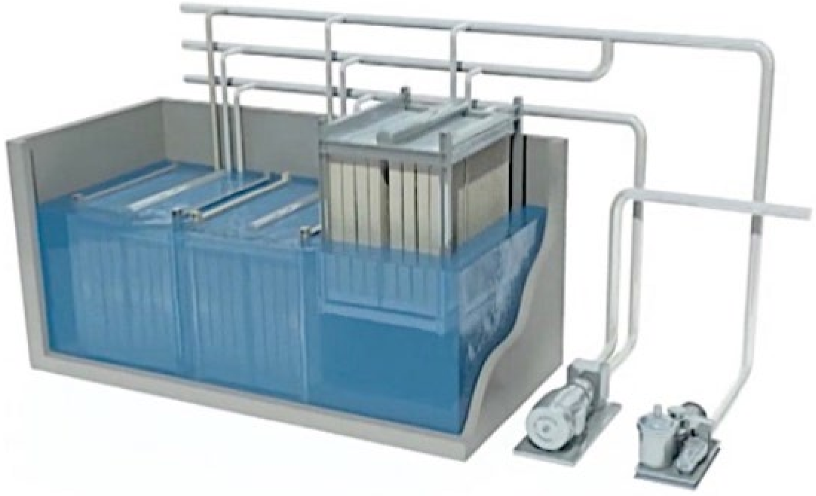
perating cost)

	Volume	Liter		
Solids Loading	Flow x Conc.	gal . mg / min . L	lbs / hr	How challenging the goals are
Solids Flux	Flow x Conc. / Filtration Area	gal . mg / min . L . ft2	lbs / hr . ft2	How aggressive the design is

Membranes – Configuration

Configuration:

- Flat Sheet
- Tubular
- Hollow Fiber
- Multitube
- Spiral Wound



https://www.ediweekly.com/regina-refinery-will-reuse-water-ge-wastewater-technology/ge-wastewater-zeewwater-membrane-recycle-refinery-regina-saskatechewan-membrane-filtration-holding-ponds-ediweekly/

Types of Membranes

Suction/Immersed

Pressure

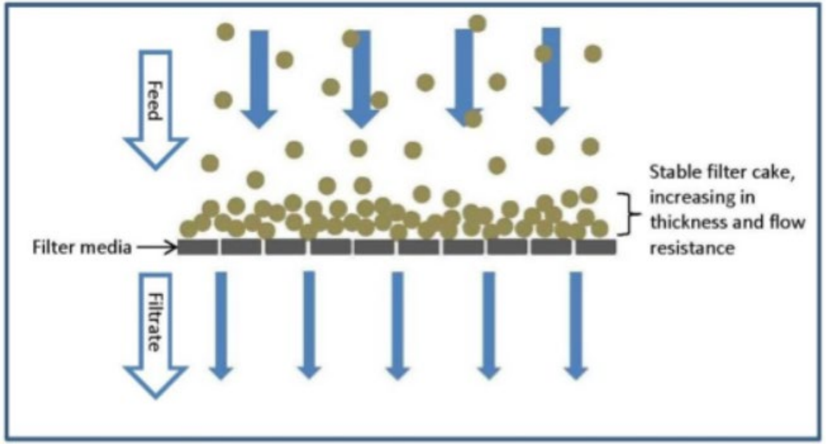
MEMCOR® SUBMERGED MEMBRANE SYSTEM

MEMCOR® PRESSURISED MEMBRANE SYSTEM

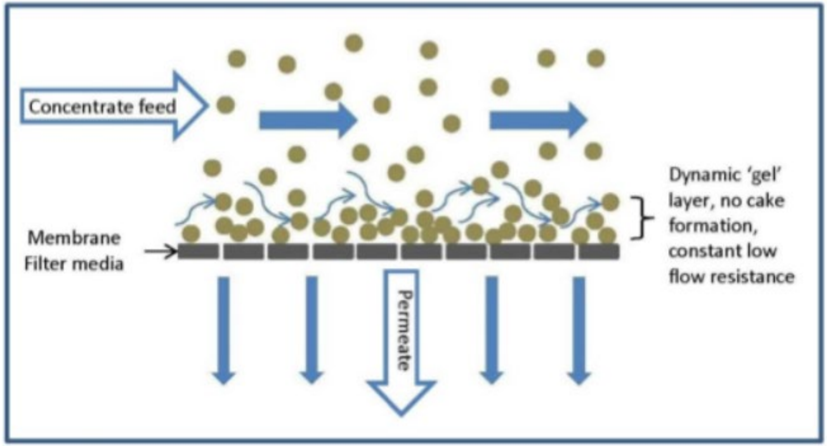
https://www.evoqua.com/en/about/Australia/Documents/MC-TERTIARYREUSE-AU-BR-A4-FINAL-LR.pdf

Types of Membranes

Dead End



Crossflow



http://www.porexfiltration.com/learning-center/technology/what-is-cross-flow-filtration/

Types of Membranes

Dead-End Adv/Disadv

- Simple and inexpensive - both CapEx and OpEx (relative to crossflow)
- Often designed to produces a "cake" on the membrane surface with additional filtration benefits
- Can produce surprisingly high quality treated water but cake can be unstable and treated water quality can vary
- Can require frequent cleaning

Crossflow Adv/Disadv

- Robust resistance to fouling – often used for very challenging applications
- Smaller footprint / higher operating flows and pressures (recirculation to get crossflow)
- Advanced controls with adjustable setpoints
- Reliable treated water quality (no breakthrough)

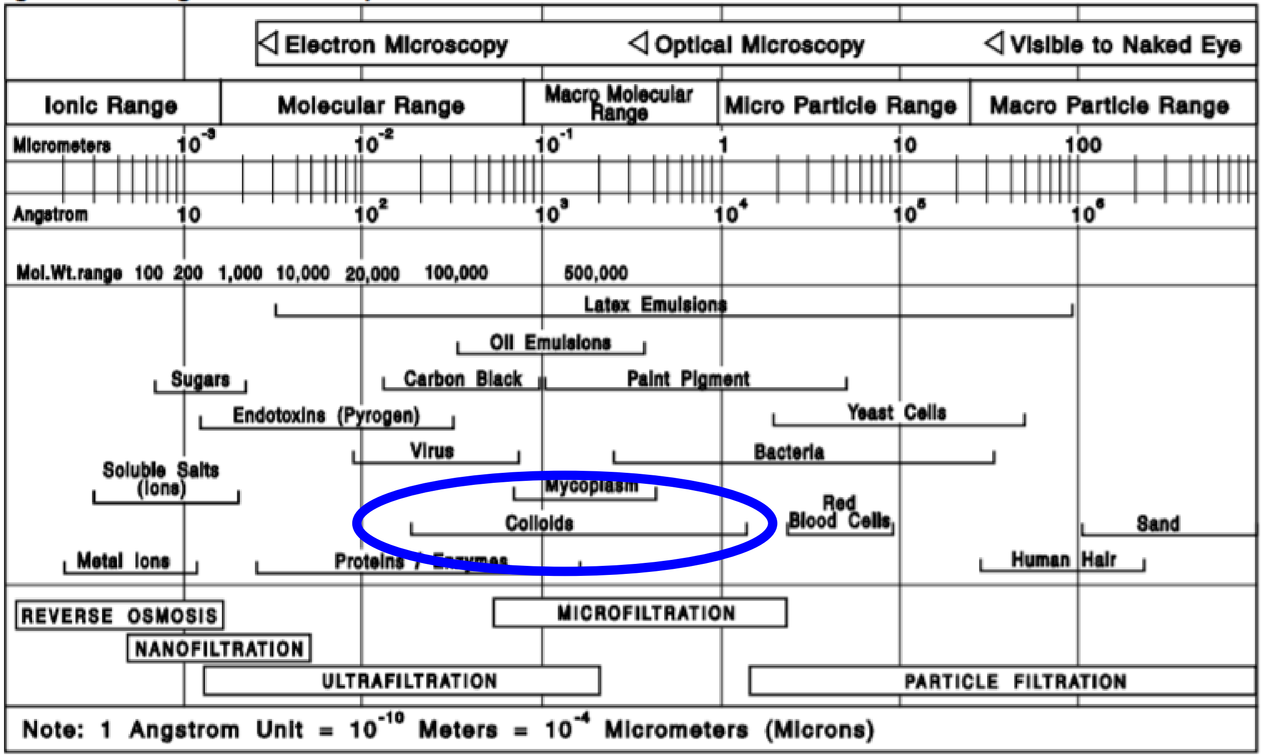
Membranes – Pore Size

Nominal Pore Size:

- Microfilter (0.1 - 1.0 µm)
- Ultrafilter (0.01 - 0.1 µm)
- Nanofilter (0.001 - 0.01 µm)

Filtration Spectrum

Figure 1.3 Ranges of filtration processes



http://msdssearch.dow.com/PublishedLiteratureDOWCOM/dh_095b/0901b8038095b91d.pdf?filepath=liquidseps/pdfs/noreg/609-00071.pdf

Membranes – Materials

Materials of Construction:

- Polymeric (PVDF, PES, PE, PP, PTFE, PAN, PET etc.)
- Stainless Steel
- Ceramic

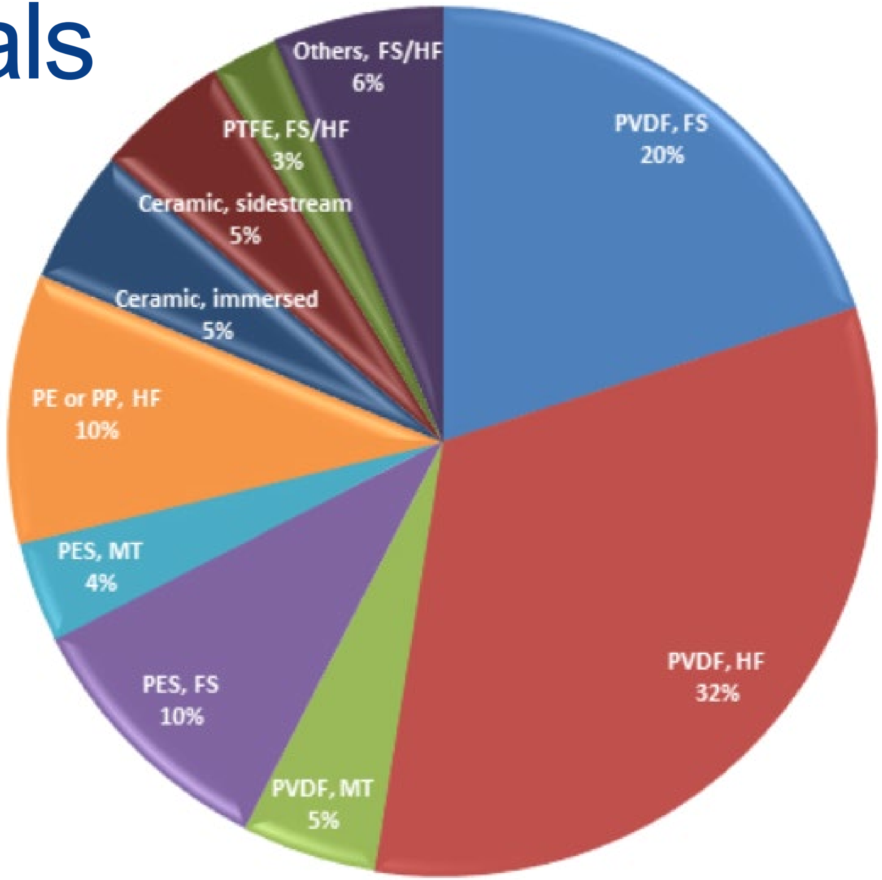
Relevant properties

- Permeability
- Resistant to fouling
- Flexible (do they break)
- Resistant to strong oxidizers (i.e. chlorine)
- Resistant to high temp (> 104 deg F)
- Resistant to high and low pH (2 to 11)

Membrane Materials

What is everyone buying?

- PVDF is king in wastewater!
- PVDF 57% market share
- PES 14%
- Ceramic 10%
- PE or PP 10%
- PTFE 3%
- Other 6%



https://www.thembrsite.com/#

Membrane Fouling

- Fouling occurs when deposits accumulate on the membrane surface.
- Fouling results in a drop in performance increased hydraulic resistance (increase in pressure or drop in flow).
- Fouling may be considered
  - colloidal (particulate)
  - inorganic (scaling)
  - organic (adsorption)
  - biofouling
- In most cases all these types of fouling occur simultaneously

Membrane Cleaning

- If you can prevent or reduce fouling using pretreatment (i.e. coagulation or oxidation) than always do so
- If you can prevent or reduce fouling with controls (i.e. high turbidity alarm or high TMP alarm) then always do so
- Cleaning should be done regularly … both before and during the fouling event … never wait until the membranes are fouled
- Cleaning is usually automated (mechanical or chemical)
- Air scouring, backpulsing are common mechanical cleaning methods used (when membrane configuration allows)
- Chemical cleaning is done with hypochlorite and low pH acids (when the membrane materials allow)

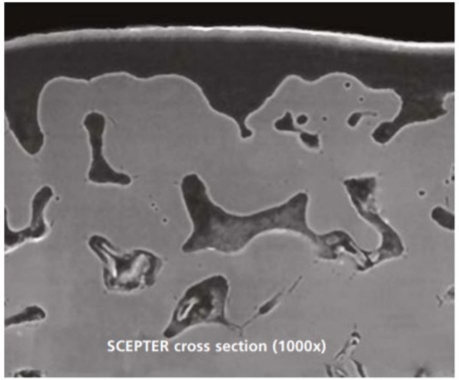
Unique Technologies

Scepter® Tubular MF and UF Modules

Info@gravertech.com +1-302-731-1700

Graver Technologies

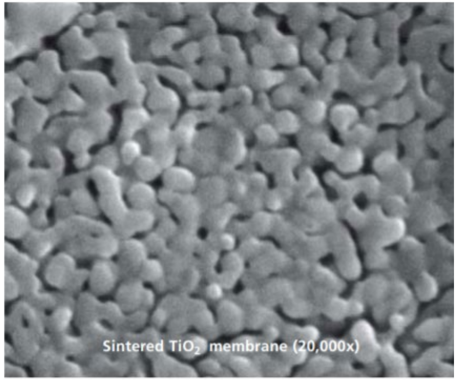
All-welded, no-gasket construction enhances cleanability, durability and compatibility.

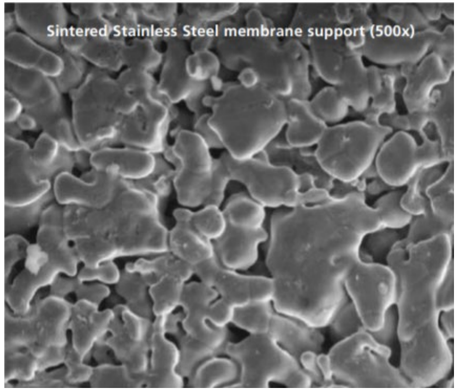


Titanium Oxide membrane enhances performance.

Using a patented process, a titanium dioxide (TiO_2) coating is permanently sintered to the inside surface of the stainless support tube. This creates a smooth, foulant-resistant membrane with a nominal pore size of about 0.1 or 0.02 microns.

Innovative "form-in-place" membrane coatings, dynamically applied to the inside surface of the tubes, can further extend the flexibility of the SCEPTER system.

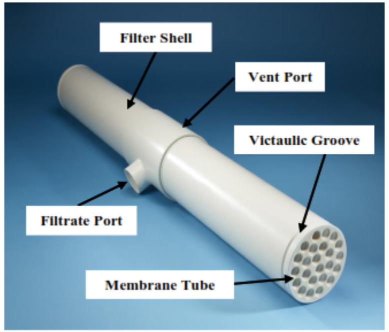




Technologies

DURAFLOW®

Model DF – 824T
24-Tube Compact Tubular Membrane Module



18 Modules per Train x 16 Trains
System Installation (1 of 16 Trains Shown)

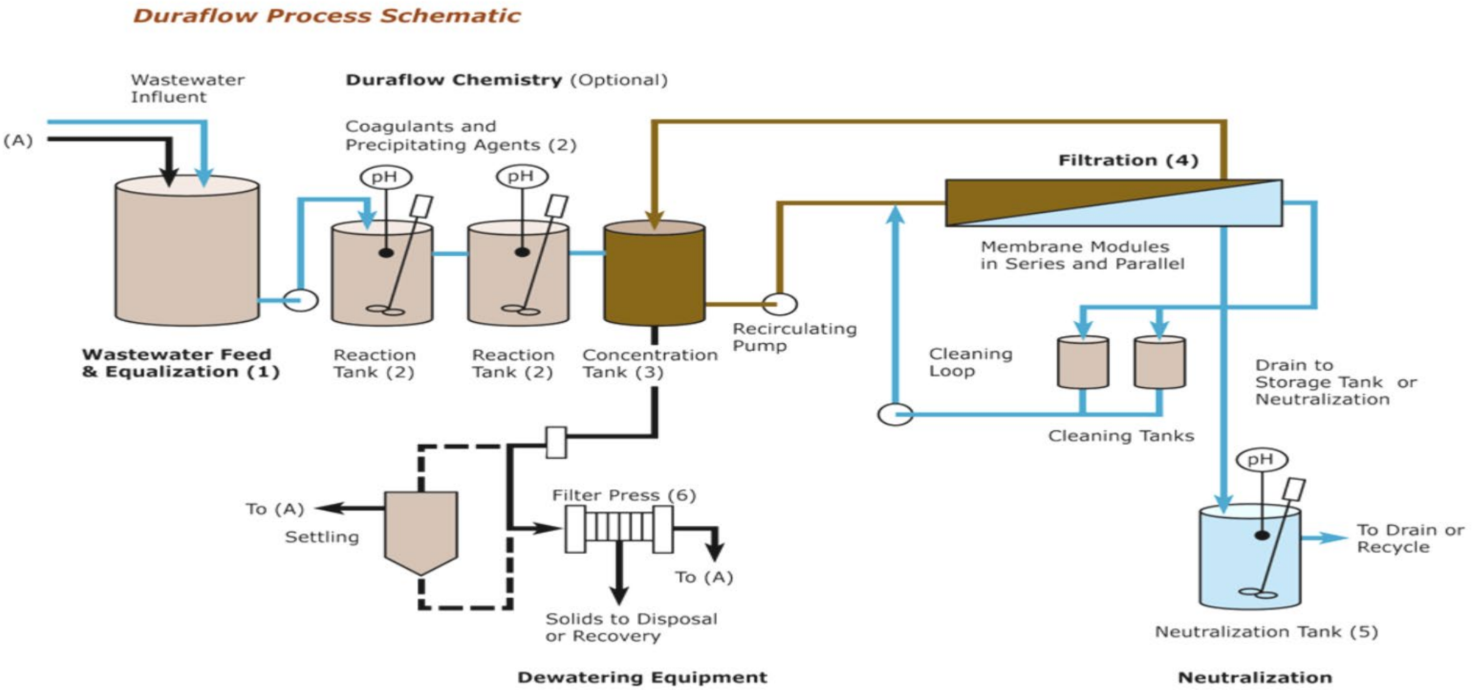
Membrane Module Specifications

Filter Module	
Number of Filter Tubes	24
Tube Diameter Size	1" (2.54 cm)
Module Diameter Size	8" (20.3 cm)
Module Length	72" (1.82 m)
Shell Material	SCH 40 PVC
Filtrate Port	3" IPS Female Socket
Vent Port	1" FNPT
Weight (Dry)	75 lb (34 kg)

Membrane	
Membrane Material	Polyvinylidene Fluoride (PVDF)
Substrate Material	High Density Polyethylene (HDPE)
Surface Area	36 ft^2 (3.36 m^2)
Pore Size (Nominal)	0.1 micron
Operating Pressure (Max)	60 psi or 4.2 kg/cm^2
Operating Temperature (Max)	110°F or 43°C
Operating TSS Concentration	>3% weight

Technologies

DF Membrane Filtration (DFMF) System Operation



New Technologies

New Technologies

CERA DUR

i2M
a MANN+HUMMEL company

Technical Specifications

FILTER SPECIFICATIONS	
Structure	Hollow fiber
Material	Ceramic
Pore size (D90)	30, 80, 100, 130 nm
Potting	Epoxy
Housing Material	Stainless steel
RECOMMENDED OPERATING PARAMETERS	
Flow type	In-out
Filtration	Cross-flow
Flux rate (operational)	50-500 LMH (30-300 GFD)
Clean water permeability	400-2,500 LMH at 1 bar 235-1,500 GFD at 1 bar
Cross flow velocity (CFV) +	1-3 m/s (3.3-10 ft/s)
Operating TMP +	Max 2.0 bar (30 psi)
Operating temperature	Max 80 °C (175 °F)
Operating pressure *	Max 3.0 bar (43 psi)
Back wash pressure *	Max 3.5 bar (50 psi)
pH conditions	2-12 at 40 °C (105 °F) 2-10 at 80 °C (175 °F)

Notes:
+ Operational parameters are limited to Industrial wastewater treatment.
* Max. pressure is only used during cleaning conditions for short intervals.

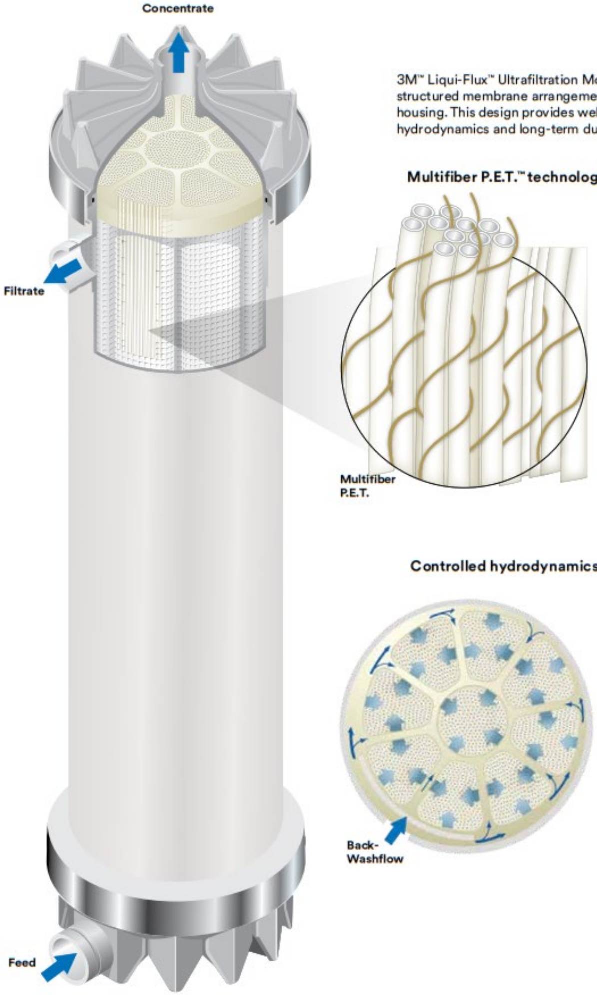
For more information, please contact us at:

www.i-2-m.com
1053 East Whitaker Mill Road, Suite 155
Raleigh, NC 27604, USA

Greg Wood
Head of Sales & Marketing
Mobile : +1-919-939-7219
info@i-2-m.com

New Technologies

3M | Liqui-Flux™ Filtration Modules



3M™ Liqui-Flux™ Ultrafiltration Modules consist of a structured membrane arrangement inside a 12-inch housing. This design provides well-defined liquid flow hydrodynamics and long-term durability.

Multifiber P.E.T.™ technology: sophisticated membrane support

Hollow fiber membranes are stabilized by 3M's multifiber P.E.T. technology, where P.E.T. yarn is twisted around and potted with the hollow fibers.

This provides excellent mechanical support to the membrane and ensures long-term stability.

Controlled hydrodynamics: even flow distribution promotes efficient backwash

The special module design is optimized for favorable hydro-dynamic conditions during the backwash procedure.

- The introduction of backwash water through a narrowing annular channel ensures a uniform pressure distribution. This leads to excellent physical cleaning performance.
- No O-ring seal is required to separate the feed from the filtrate side, reducing the potential for microbiological cross-contamination.

New Technologies

3M | Liqui-Flux™ Filtration Modules

88 gfd x 1033 ft2 = 90904 gpd (63 gpm)

Typical Properties

Applications	
Intended Use	Ultrafiltration

Membrane Characteristics	
Membrane Type	Hollow fiber, inside - out
Membrane Material	Polyethersulfone
Outer/Inner Diameter	1.2 mm/0.8 mm
Burst Pressure	≥1200 kPa (174 psi)
Membrane Configuration	Multifiber P.E.T. Technology

Housing Characteristics	
Housing Material	PVC
Potting Material	Polyurethane
Sealing End Caps	EPDM
Connectors	Variable, see back side
Weight, Dry	56 kg (124 lbs)
Weight Filled with Liquid	153 kg (338 lbs)
Effective Membrane Surface Area	96 m² (1033 ft²)
Maximum Working Pressure	600 kPa (87 psi) @ 20°C (68°F)
Maximum Working Temperature	40°C (104°F) @ 400 kPa (58 psi)

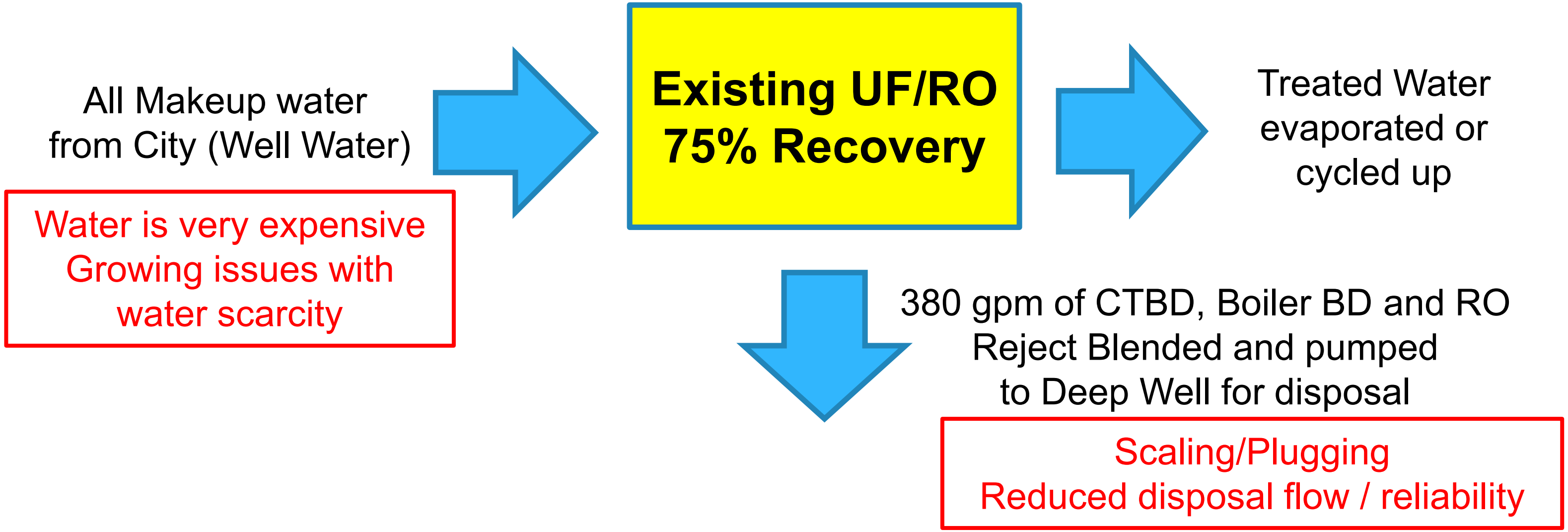
Regulatory Compliance	
Germany	KTW
USA	ANSI / NSF61

Typical Application/Operating Data	
Operating Mode	Dead-End / Cross-Flow
Typical Flux Range, Filtration	50 - 150 l/m²*h (29 - 88 gal/ft²*day)
Typical Flux, Backwash	250 l/m²*h (147 gal/ft²*day) (-10%/+20%)
Filtrate Flow Rate Range	5 - 15 m³/h (22 - 64 gpm)
Typical Transmembrane Pressure, Filtration	10 - 70 kPa (1.5 - 10 psi)
Typical Transmembrane Pressure, Backwash	50 - 200 kPa (7 - 30 psi)
Maximum Transmembrane Pressure	250 kPa (36 psi)
Typical Cleaning Chemicals	NaOH, HCl, NaOCl
pH-range During Cleaning	1 - 13
Maximum Instantaneous Free Chlorine Concentration	200 ppm @ pH ≥9.5
Maximum Free Chlorine Exposure	200000 ppm h @ pH ≥9.5

Practical Reuse Examples for Industry

1) Power Plant in California

Cooling tower blowdown wastewater treated using physical/chemical treatment followed by filtration, and desalination technologies



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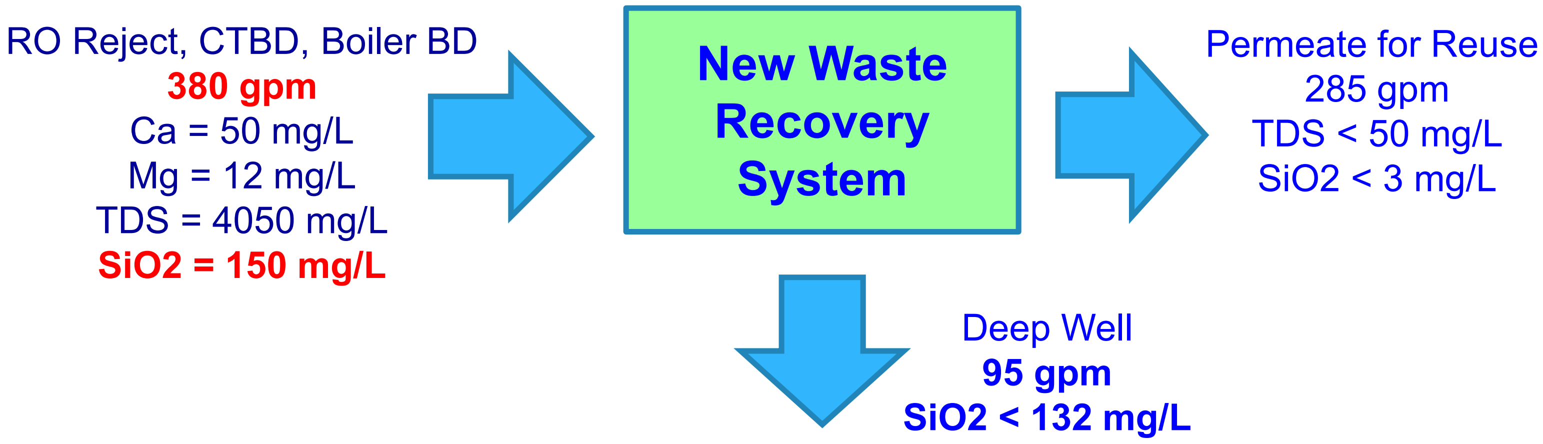

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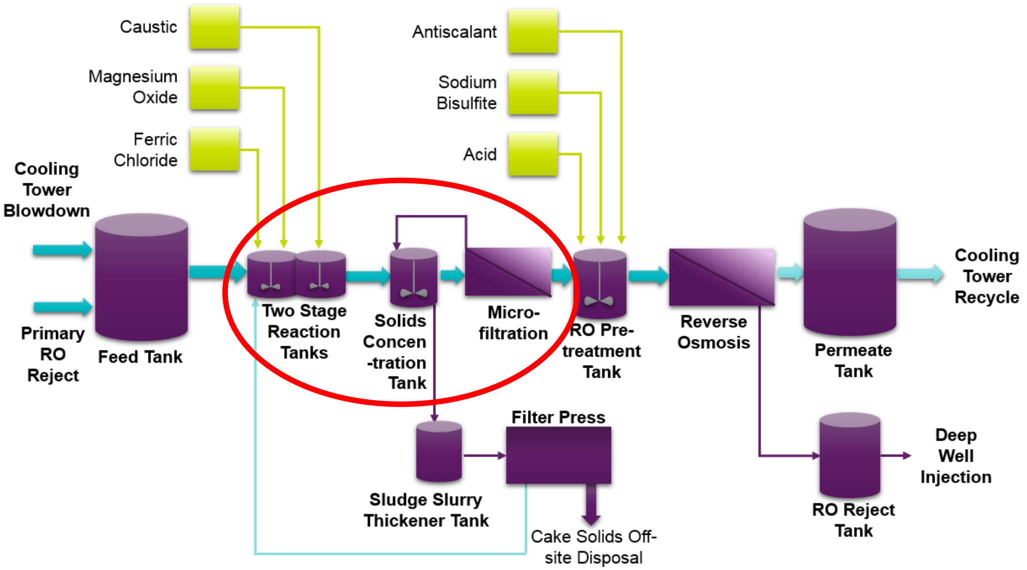

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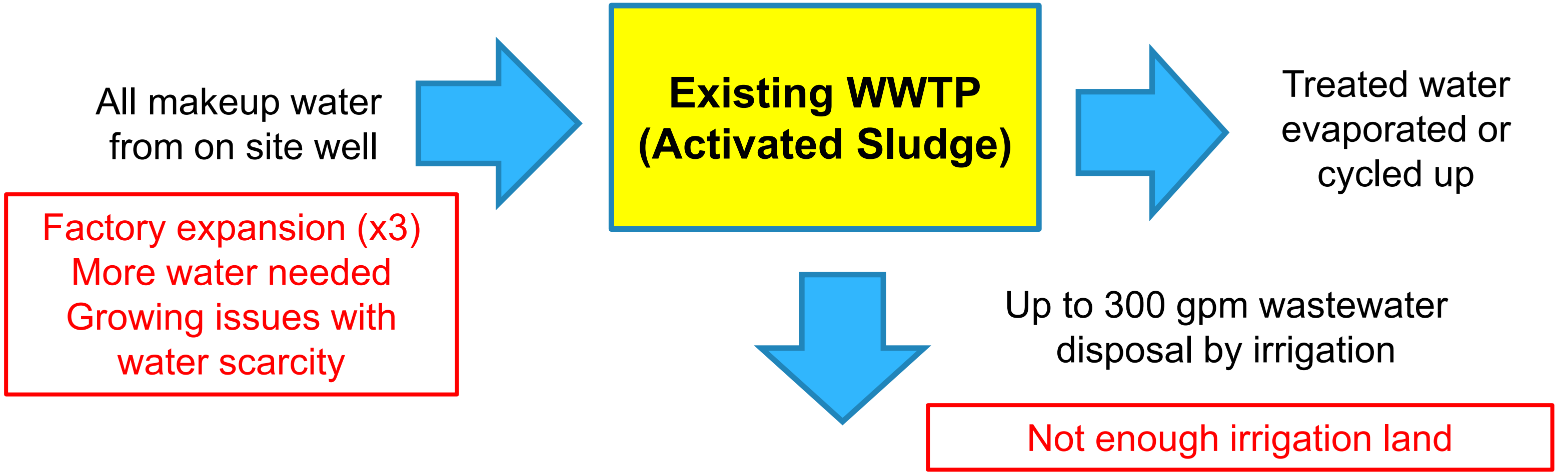
2) Potato Processing Plant in India – Installed 2013

Wastewater with COD ~ 8000 mg/L treated using Activated Sludge, Tertiary UF, GAC, RO and MEE to produce process water for reuse to meet potable water standards



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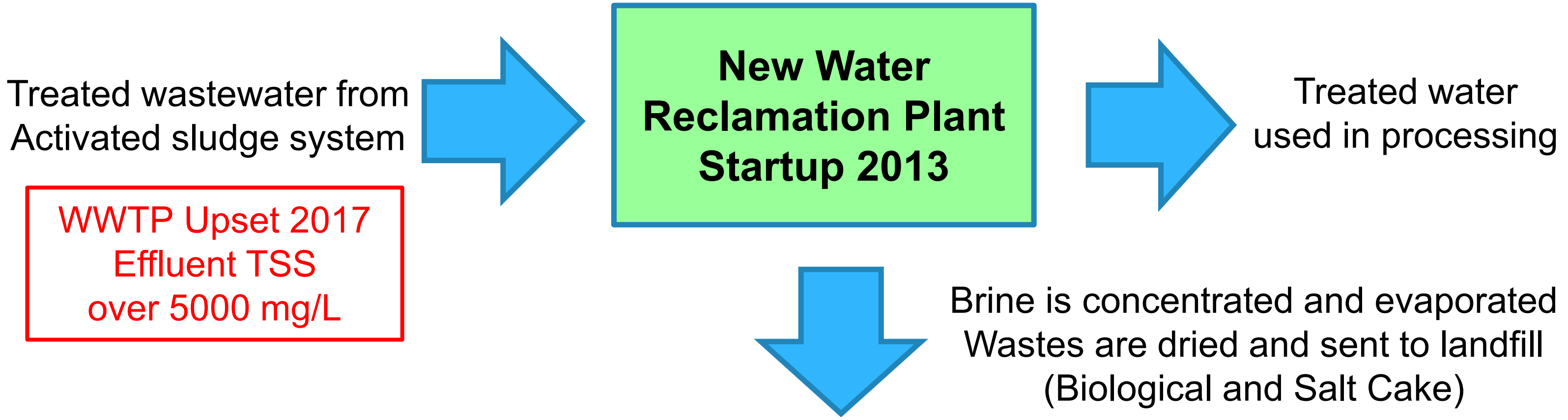

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Practical Reuse Examples for Industry

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KEEP
CALM
AND
REUSE
WATER

INDUSTRIAL WATER REUSE NEW TECHNOLOGIES AND LESSONS LEARNED

IWC Workshop W-07

Desalination

INTERNATIONAL WATER CONFERENCE

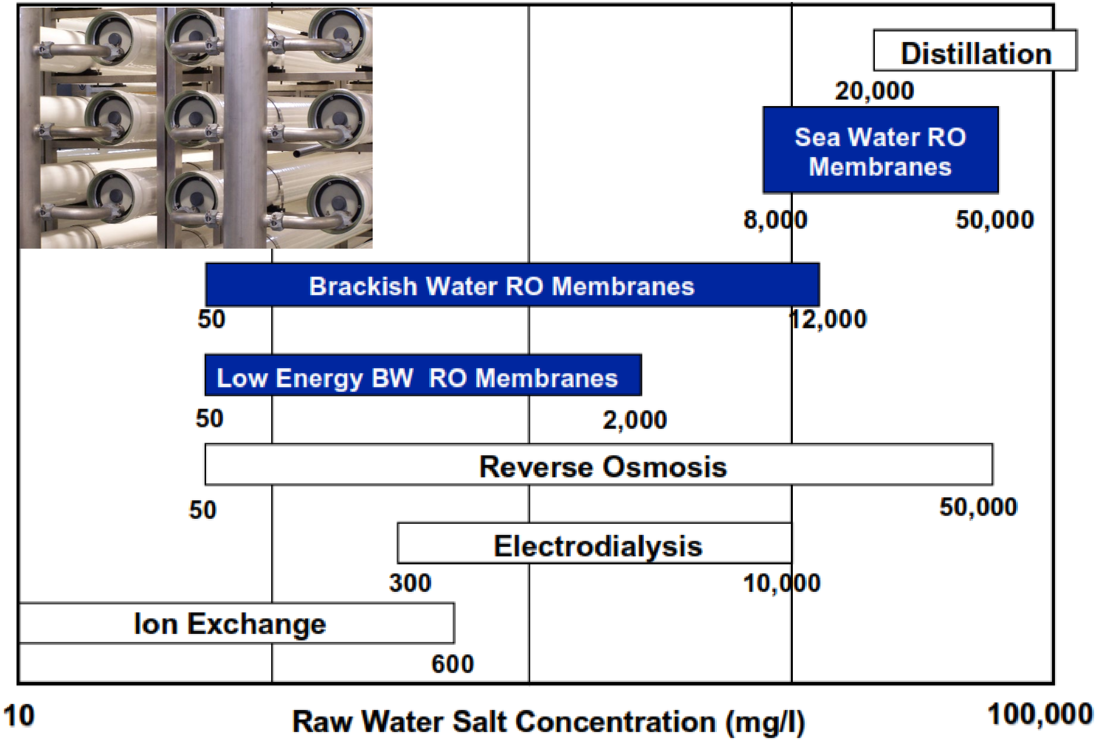
wood.

4. DESALINATION

Desalination Definition

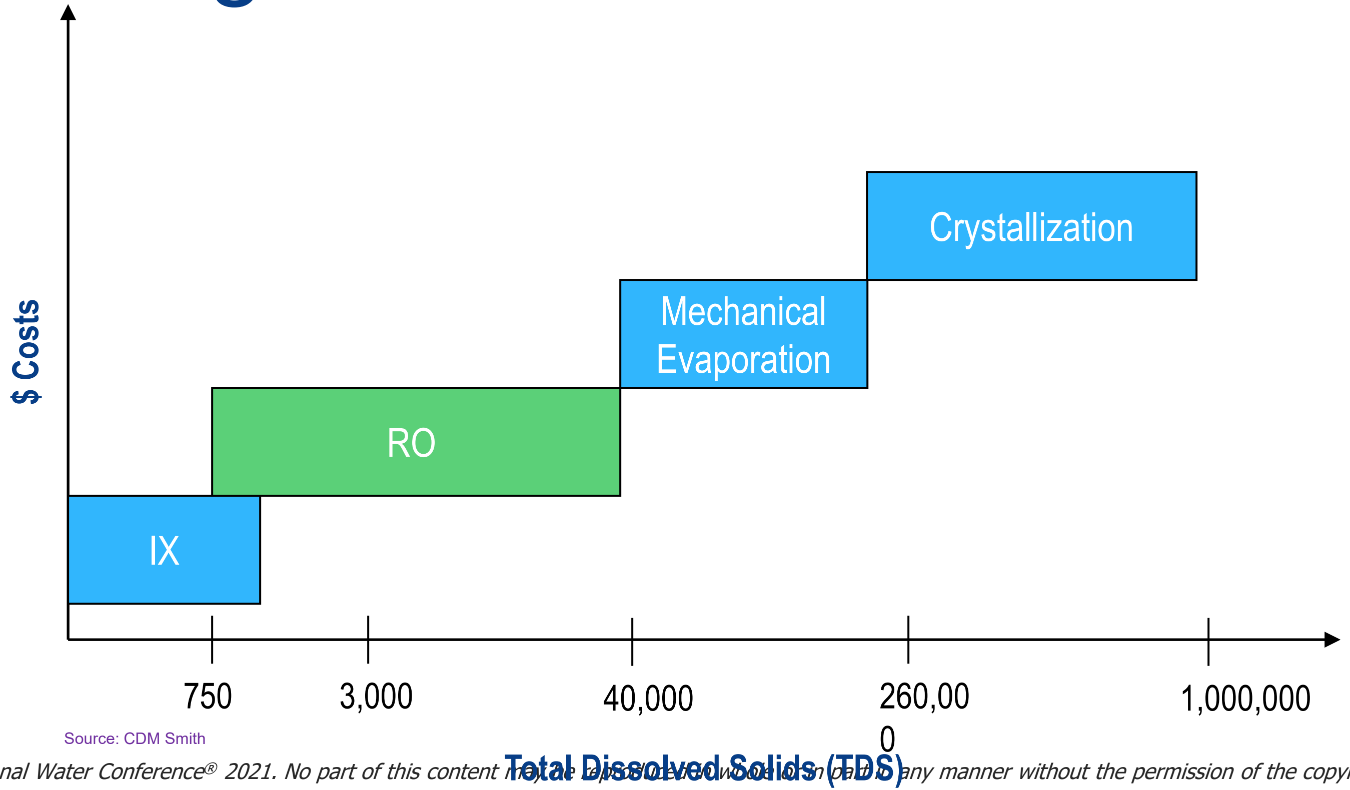
Desalination refers to any of several processes that remove excess salt and other minerals from water in order to obtain fresh water for reuse

Desalination Options



Source: Dow Filmtech Tech Manual

Range of Applicability for TDS Removal Technologies vs. Cost



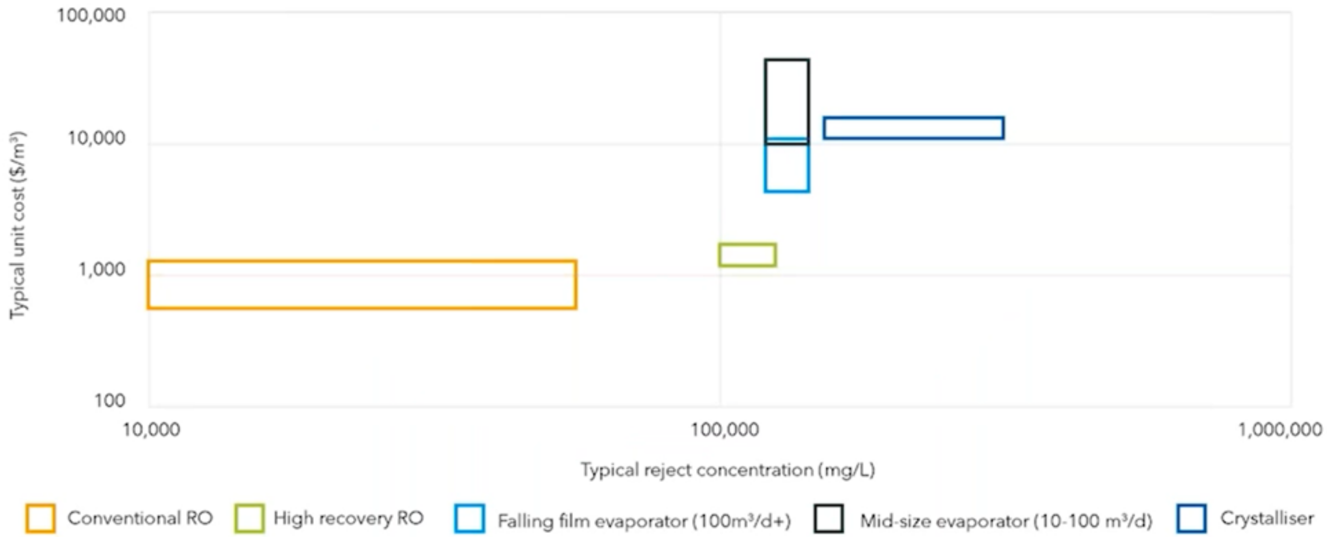
Source: CDM Smith

QWi | DESALDATA

Assessing the cost of brine concentration

As the concentration of a solution increases, the energy required to separate the remaining free water rises exponentially. This means that the final step to ZLD (crystallisation) can represent the majority of a ZLD system's total energy consumption.

Conventional brine concentration technologies rely on thermal processes, but new reverse osmosis (RO) configurations are able to produce brine rejects of up to 175,000mg/l. Membrane processes do not require a phase change, which reduces both costs and operational complexity.



Typical Treatment Objectives When Using RO on Wastewater

Primary Objectives:

- TDS Removal
- Minimize cost of brine disposal
- Meet stringent discharge criteria
- Cost-effective

Additional Objectives Vary by Application:

- Trace constituents removal (e.g., nitrogen, silica, iron, etc.)

Water Chemistry Considerations

Precipitation Potentials

Salt	Saturation Concentration (mg/L)
Calcium Carbonate ($CaCO_3$)	8
Calcium Fluoride (CaF_2)	29
Calcium Sulfate ($CaSO_4$)	680
Magnesium Sulfate ($MgSO_4$)	309
Strontium Sulfate ($SrSO_4$)	146
Barium Sulfate ($BaSO_4$)	3
Silica (SiO_2)	120
Sodium Carbonate (Na_2CO_2)	174,000
Sodium Chloride (NaCl)	312,000
Sodium Sulfate (Na_2SO_4)	266,500

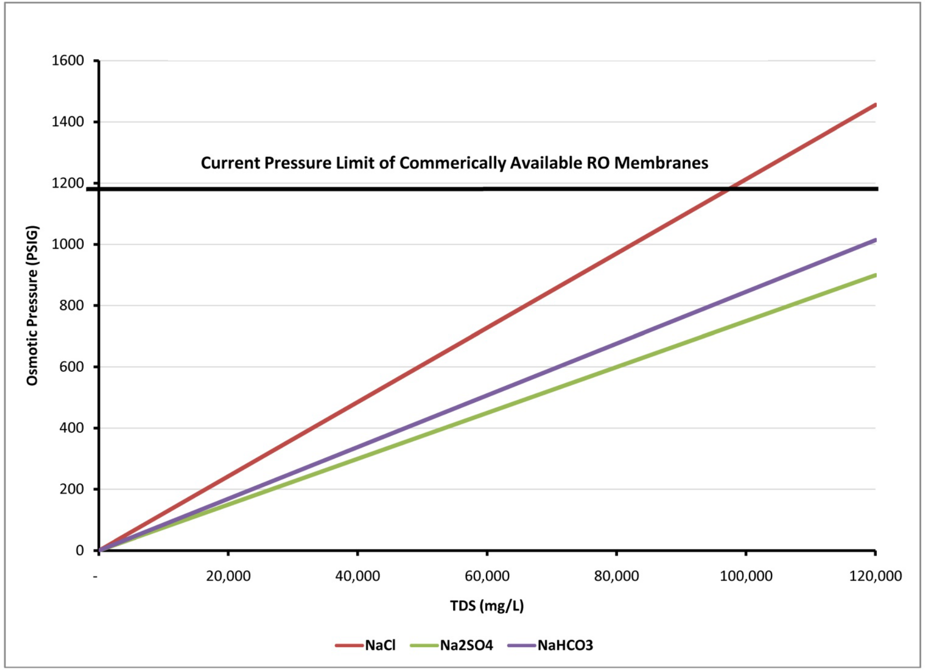
Consideration of Concentration Factor

(CF) = 1/ (1 – Recovery)

Recovery:	CF:
50%	2
75%	4
85%	6.67
90%	10
95%	20
98%	50

- The Potential for Precipitation from Divalent Compounds Increases Quickly!

Maximizing Water Recovery



- Goal: Recovery limited by only osmotic pressure
- Remove limiting polyvalent ions that form precipitates
- Allow operation with soluble sodium salts

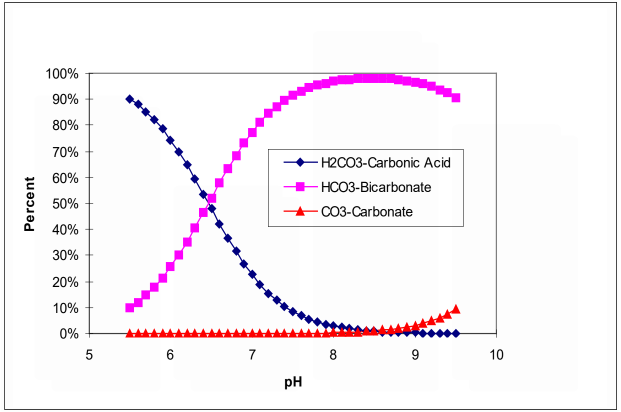
This is not the result you want when you operate a membrane system!

How Does a System Designer Avoid This?

Application of Antiscalants

Levels of Super-saturation with Antiscalants	
Index	Typical
LSI	<1.8
CaF_2 (% Sat)	10,000
$CaSO_4$ (% Sat)	230
$SrSO_4$ (% Sat)	800
$BaSO_4$ (% Sat)	6,000
SiO_2 (% Sat)	150

pH Adjustment



Pretreatment to remove specific ions:

- Precipitation and Clarification
- Advanced Filtration
- Ion exchange

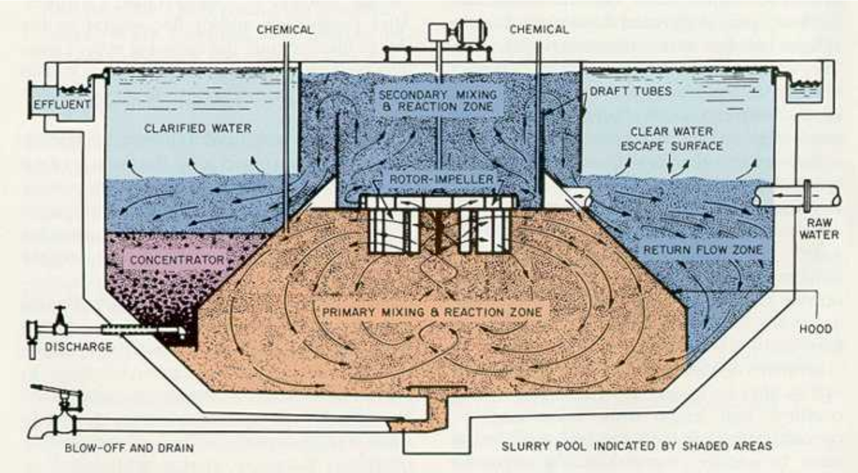
Precipitation and Clarification

Lime Softening

- Calcium
- Magnesium
- Silica
- Sparingly Soluble Salts
  - Barium, Strontium, Iron, Manganese, heavy metals

Solids Contact Clarifier

- Removal of TSS to < 20 mg/L
- Sludge thickening to 3-10%



Source: gewater.com

Advanced Filtration

Greensand Filtration

- Iron, manganese and TSS removal
- Requires chlorine or potassium permanganate
- Slow filtration rates ($\leq$4 gpm/ft_2) recommended to achieve low SDI values (<3)

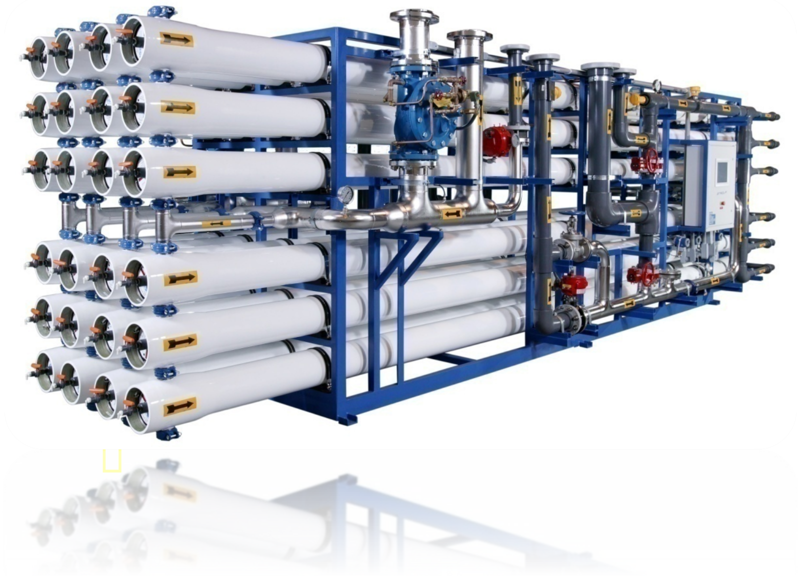
Membrane Filtration

- Filtration to 0.01 microns
- Polymeric and ceramic filters available
- Produces lowest SDI value (<2)

Ion Exchange

- Removes polyvalent cations to very low levels
- Two Types of Resins
    - Strong Acid Resin (Na+) (sodium zeolite)
    - Weak Acid Resin (H+)
- WAC best for high TDS brine stream applications
- Consideration of regeneration chemicals
- Produces a brine waste requiring disposal

Nanofiltration (NF)



- NF is a “loose” reverse osmosis (RO) membrane
- Much lower operating pressure than RO
- Used primarily as a softening membrane (removes divalent ions)
- Skid mounted system design
- Commercially available from several manufacturers

Development of Integrated Solutions

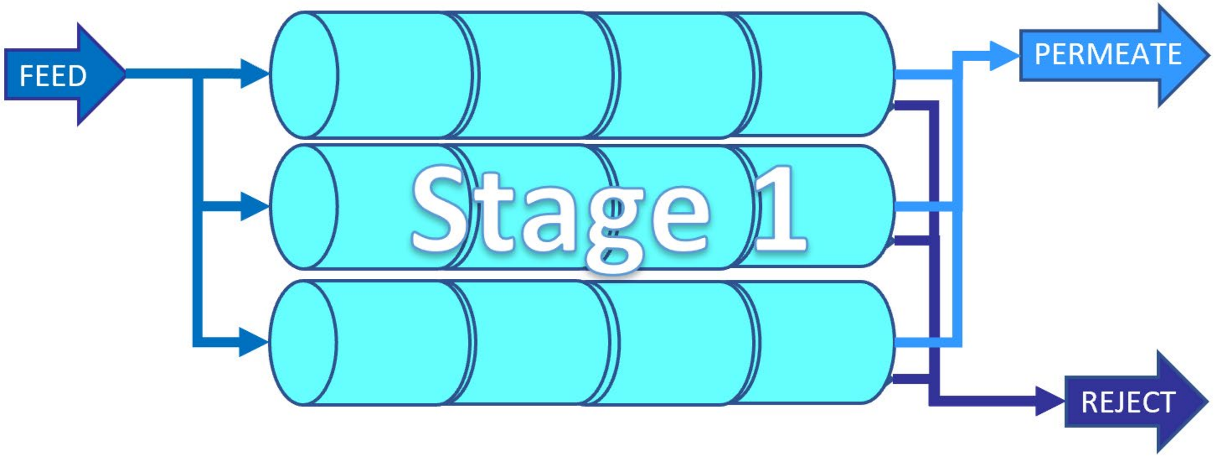
- What are Integrated Solutions
  - Site specific water treatment systems that are constructed by incorporating a variety of treatment technologies
- Benefits of Integrated Solutions for Reuse
  - Combining technologies often results in multiple benefits that can not be achieved as stand-alone technologies:
    - Lower energy consumption
    - Higher Water Recovery
    - Lower waste production
    - Increases potential to produce saleable byproducts
  - Lower Cost
    - O&M costs
    - Capital costs (more suppliers, smaller systems, etc.)

Advancements in RO Technology

- Osmosis was first observed in 1748
- In 1950 Univ California first started making reverse osmosis membranes
- The first commercial systems started to appear in the 1970's
- Early 1990's many lessons learned - RO systems became "standardized" with universal process design guidelines
- By the late 1990's all the major OEMs had pre-engineered standards to be more cost effective

Basic RO (single stage)

- Simple – Single Stage – all the housings receive the same flow and pressure.
- Often only 4 membrane elements per housing – smaller and less expensive.
- Low recovery (50% to 75%)
- Typically not optimized for flow, or pressure so membrane life is shorter (i.e. 2-3 years)

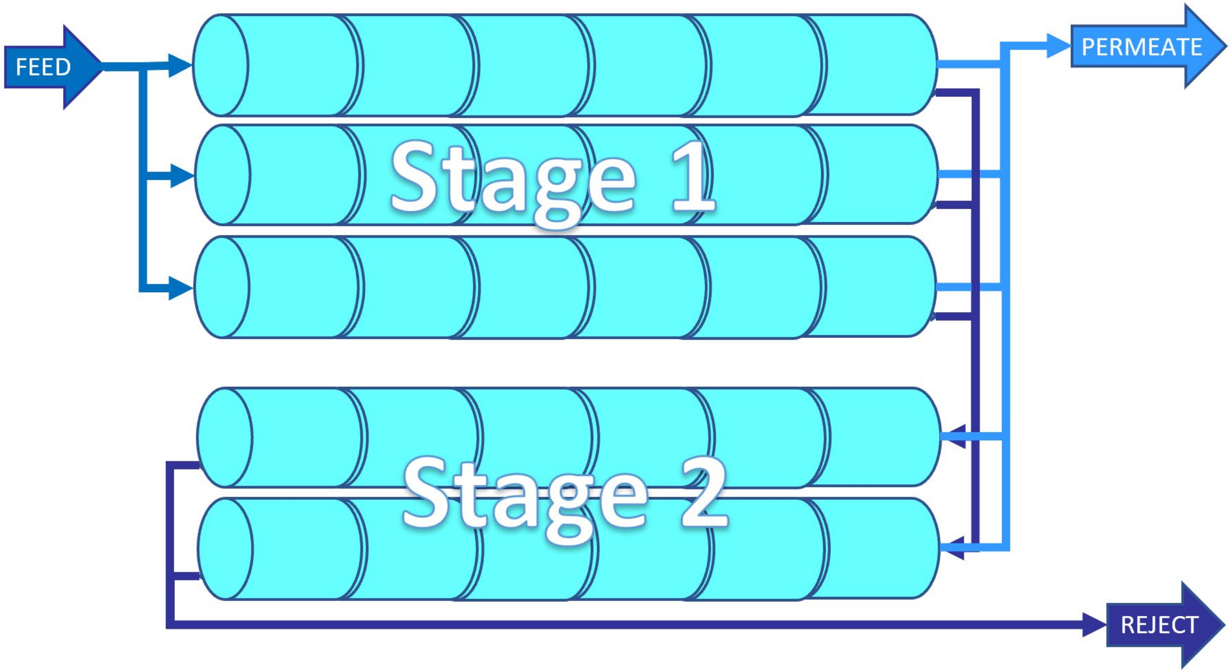


Advancements in RO Technology

- In the 1990's the goal was to be cost effective … more competitive vs. ion exchange
- To "change the game" RO membranes needed to become more efficient
  - smaller and less expensive (higher fluxrate)
  - lower power (lower diff press)
  - more reliable (> 3 year membrane life)
  - easier to operate (predictable performance with automated controls)
- Early 2000's everyone was replacing their Mixed Beds with the "Conventional RO"
  - well designed by engineers with >10 years of practical experience
  - process design guidelines were well understood
  - competitive priced vs. ion exchange

Conventional RO (2 stages)

- Basic design – two stages
- “Pre-engineered Standard”
- Typically 4 or 6 membrane elements per housing
- The housings in the first stage receive higher pressure and produce more permeate (higher recovery)
- Housings in the second stage receive lower pressure and produce less permeate (lower recovery)
- Low recovery (typically 75%)
- Typically not well optimized for flow, or pressure so membrane life is shorter (i.e. 3-4 years)

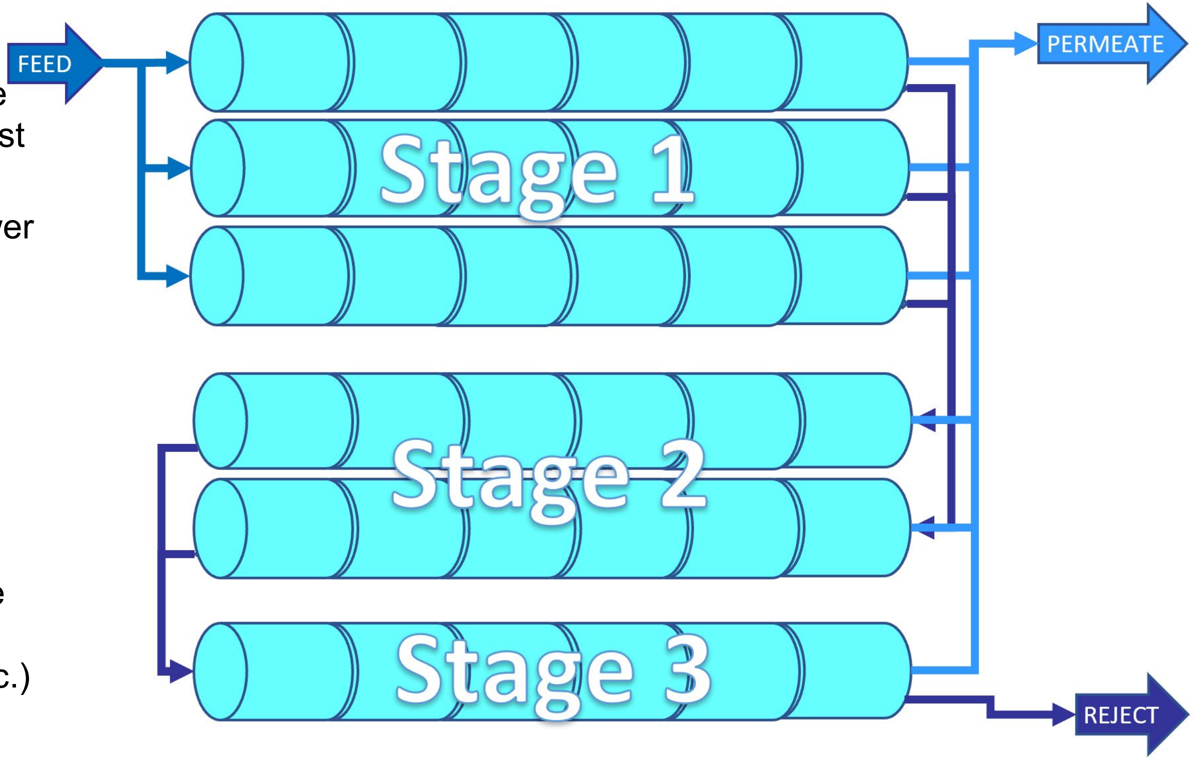


Continued Advancements in RO Technology

- Then someone said - RO for wastewater reuse
- Wastewater is not well water - not as “friendly” to membranes - what happens when you try to filter O&G?
- Guess what happened when a really good salesman sold an Industrial Client a Conventional RO system for a wastewater reuse application?
- In the late 2000’s the term “Conventional RO” was used to describe a basic two stage RO design.
- They really don’t work that well on wastewater
- A Conventional RO follows the manufacturer’s guidelines for flowrates, pressure, differential pressure, temp, fluxrate, etc. in a well water or surface water application with mildly brackish water
- If you need a RO to treat well water don’t reinvent the wheel
- However, if you need something else you need to take a step back
- Next generation of RO systems

Advanced RO For Reuse (3 stages)

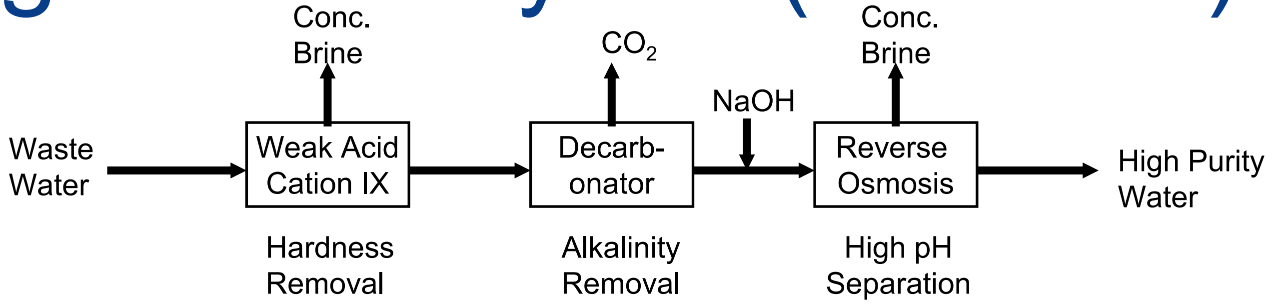
- Three stages
- "Custom Design" but can be pre-engineered.
- The housings in the first stage receive highest pressure and produce the most permeate (higher recovery)
- Housings in the last stage receive lower pressure and produce least permeate (lower recovery)
- Typically 6 membrane elements per housing
- High recovery (typically >80%)
- Optimized for flow and pressure so membrane life is longer (>4 years)
- Many options available (i.e. interstage pumps, interstage CIP, flux balancing valves, automated permeate flush, etc.)



1. High Efficiency RO (HERO™)

- Specialized version of reverse osmosis (RO)
- Multiple Patents by Deb Mukhopadhyay
- Developed in the Microelectronics industry for the production of high purity water
- Multiple licensees (Aquatech, GE Power and Water, etc.)

1. High Efficiency RO (HERO™)



Key Steps

WAC

Removes Ions That Form Scale

- Calcium
- Magnesium
- Barium
- Strontium
- Iron
- Manganese
- Aluminum

Decarbonation

Removes buffering effect from carbon dioxide to lower caustic demands in next step

RO

High pH Operation

Eliminates Fouling From:

- Bio-growth
- Silica
- Particulates
- Oil and grease

1. High Efficiency RO (HERO™)

Benefits versus Conventional RO

- More Immune to Fouling from Silica, bacterial growth and some organics
- Higher Recoveries (90% vs. 75%)
- Higher Potential Operating Flux (claim 20 gfd vs 15 gfd)
- Higher Rejection for some constituents (e.g. anions)
- Less reliance on scale inhibitor

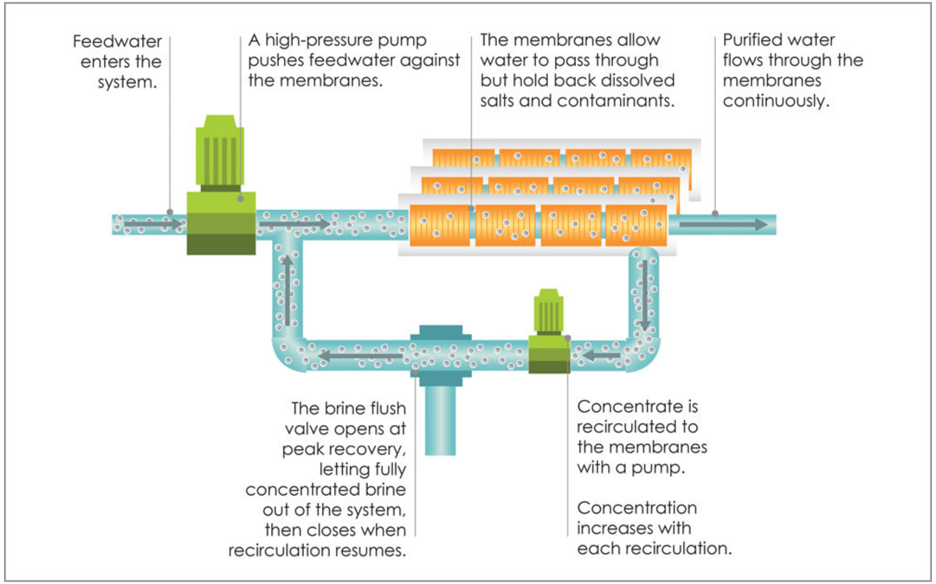
Continued Advancements in RO Technology

- Today we are seeing all kinds of advancements in RO technology – it is really quite exciting.
- These next generation of RO systems are opening people's eyes on what can be done. The old process guidelines are being completely broken and yet the systems still work.
- The big driver for most of the next generation RO systems is a need for a higher recovery. With water scarcity every drop counts. Not only every drop of permeate but also every drop of concentrate.

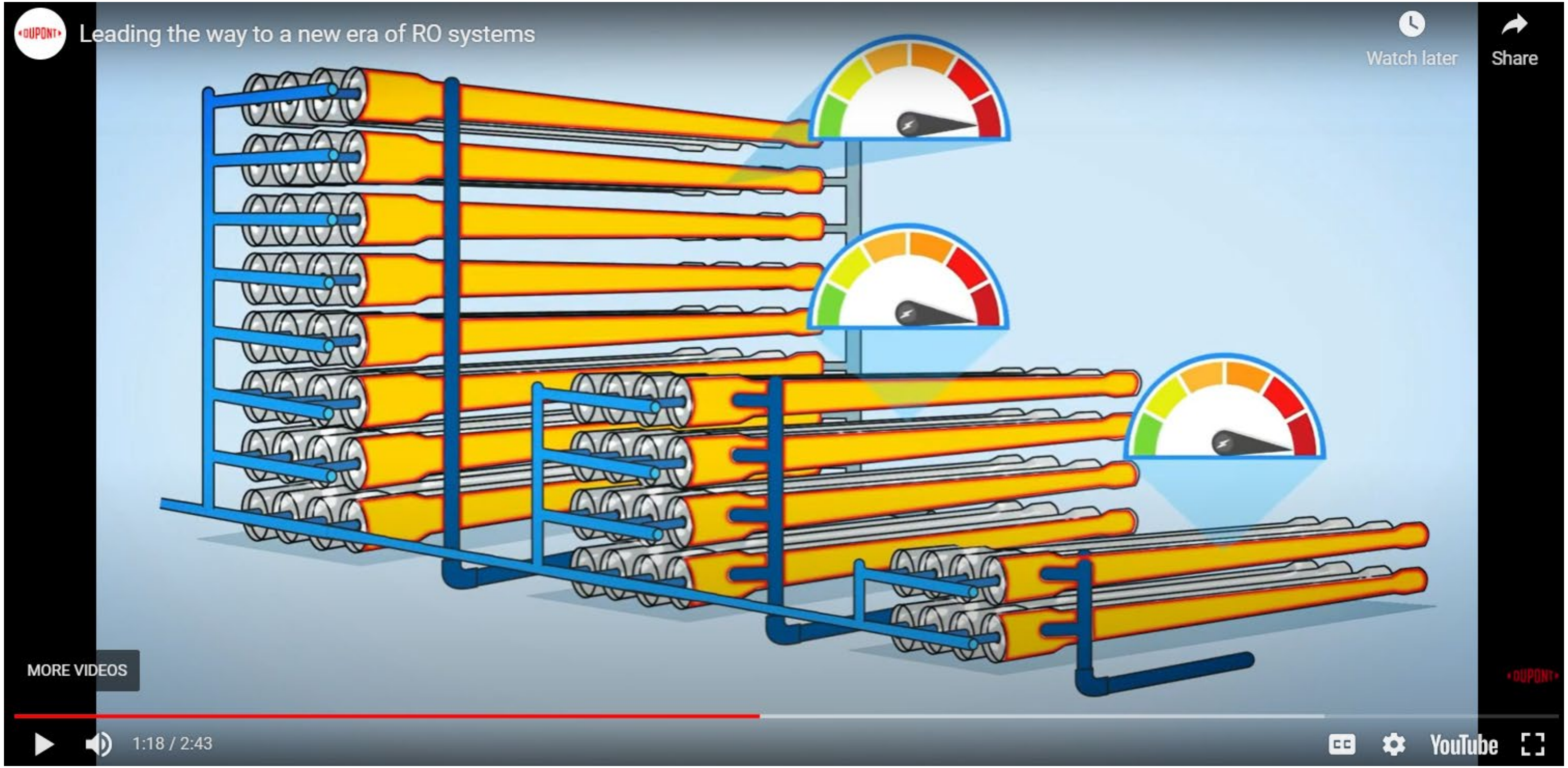
2. Desalitech – Closed Circuit RO

Advantages of a CCRO:

- A single stage – simple design
- A single stage – all membranes see similar conditions
- Flexible – Cross flow is independent from permeate or feed flow
- Permeate flow = feed flow



Why CCRO?



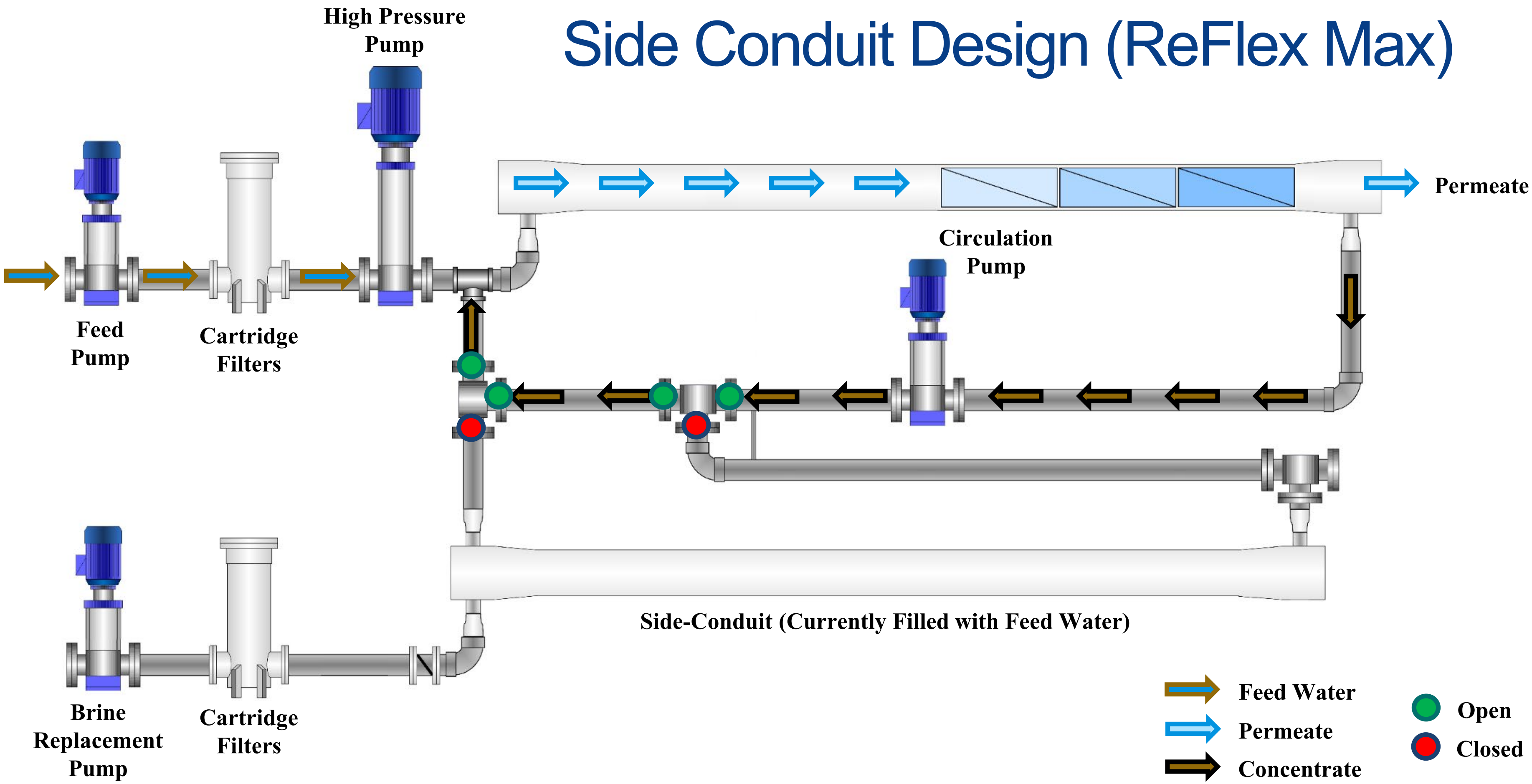
Leading the way to a new era of RO systems
Watch later
Share
MORE VIDEOS
1:18 / 2:43
YouTube

2. Desalitech – Closed Circuit RO

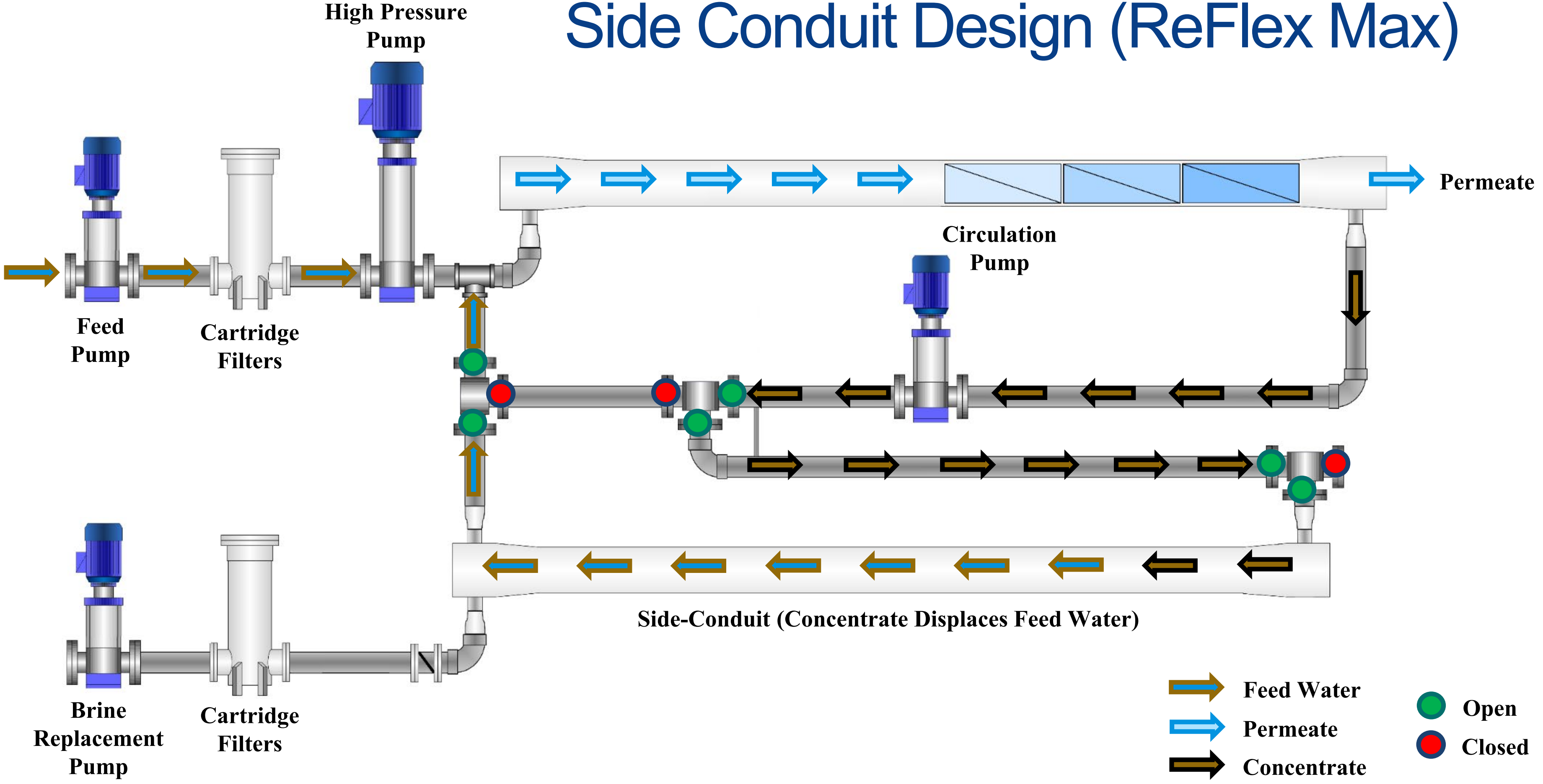
Advantages of a CCRO (continued):

- Permeate flow = feed flow
- Cycle time determines recovery
- Recovery – limited only by osmotic pressure or salt saturation
- As the cycle time increases brine becomes more concentrated – then quick blowdown
- Controls – a bit complex but flexible
- Varying conditions create varying water chemistry – dilute then concentrated

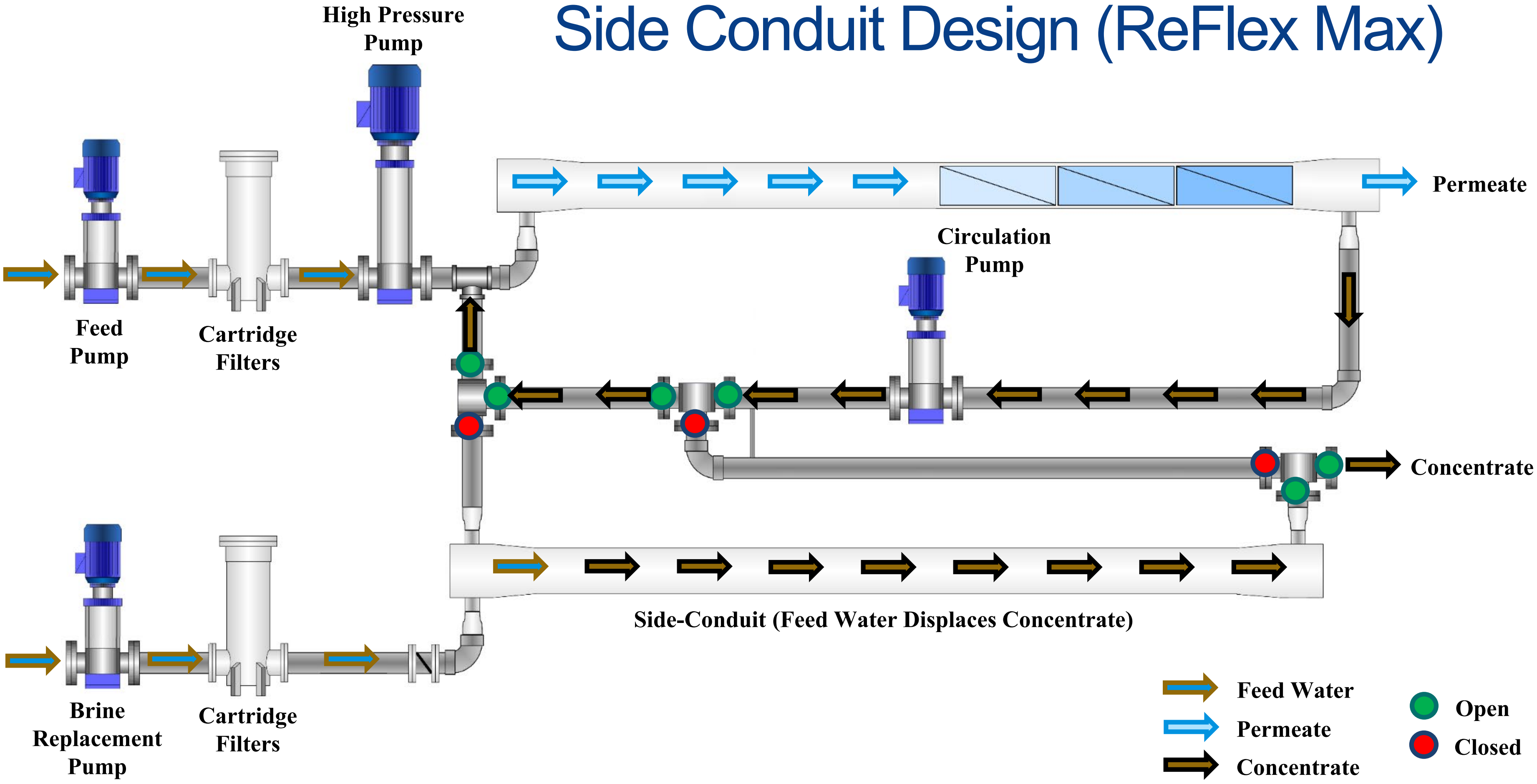
Side Conduit Design (ReFlex Max)



Side Conduit Design (ReFlex Max)



Side Conduit Design (ReFlex Max)



2. Desalitech – Closed Circuit RO

There are two advantages in running the RO in a concentration cycle (with changing water chemistry):

1. When the cycle ends the concentrated brine is removed and replaced with relatively dilute feed water again. Salt crystals that do precipitate do not have time to grow and scale the membranes (unlike conventional RO).
2. As the salinity gets higher the osmotic pressure on each membrane increases. Bacteria don’t like rapid changes in salinity. The cell walls of the Bacteria are similar to the RO membranes. They allow water to pass through them and Bacteria quickly dehydrate. This means “biofouling” is typically not an issue for a CCRO (unlike conventional RO).

2. Desalitech – Closed Circuit RO

- Two types of CCRO systems:
  - ReFlex RO system purges the concentrate to atmosphere
  - ReFlex Max system isolates the concentrate in a side-conduit before purging to waste without breaking pressure.
- The side-conduit operates at shorter sequence times (as low as 90 seconds) compared to a ReFlex product which requires a minimum sequence time of six (6) minutes.
- The volume of the side-conduit equals that of the membrane array and is filled with fresh feed in each cycle
- Once the system reaches the desired recovery, the pressurized CCRO concentrate is purged from the membrane array into the side conduit, which displaces the fresh feed to the front of the membrane array
- Using the side-conduit, pressure is never broken during the flush step, greatly reducing the energy required for desalination
- the ReFlex Max CCRO can operate at recovery rates ranging from 35% to 98% by operating with sequence times as low as 90 seconds

3. IDE Technologies – MAXH$_2$O

3. IDE Technologies – MAXH_2O

- Patented RO process based on a Closed Circuit RO with Salt Precipitation
- Physically – a more complex RO than conventional RO systems
- Controls – quite complex.
- Potential to achieve greater than the maximum recovery due to the salt precipitation step
- Greater potential for issues associated with waters that have variable feed chemistries
- Expect higher recoveries than a "well-designed high recovery RO system"
- Expect similar energy consumption as a "well-designed high recovery RO system"
- Fewer vendors of technology increases risk and may result in increased capital costs
- In my mind there are several advantages of a CCRO, however, IDE's CCRO is not the same as Desalitech's CCRO:
  - A single stage is a simple design
  - Recovery is independent from flow
  - Variability of water chemistry … could be an issue for salt precipitation
  - All membranes see the same conditions
- Advantage of salt precipitation within the loop:
  - Hardness removal within a closed loop means overall higher recovery when hardness is the limiting factor.

3. IDE Technologies – $MAXH_2O$

Reasons to choose the MAXH2O DESALTER

- High recovery rates – limited only by osmotic pressure and not by supersaturation of sparingly soluble salts
- Able to achieve different total recovery levels in the same system – the brine recirculation can be stopped at any recovery, at any RO brine level
- High flexibility – operates with variable feed water qualities, concentrations, flows and recoveries
- Membrane elements are exposed to variable salt concentration or variable osmotic pressure during the operation, reducing the biofouling potential
- At the beginning of every cycle, the last elements are exposed to under-saturated water conditions, which reduce the tendency for scaling and improve the ability to dissolve scale
- Semi-batch RO system with an integrated salt precipitation cycle for continuous desaturation of RO brine
- Low investment and operational costs

Advantages of the Pellet Reactor (Salt Precipitation Unit)

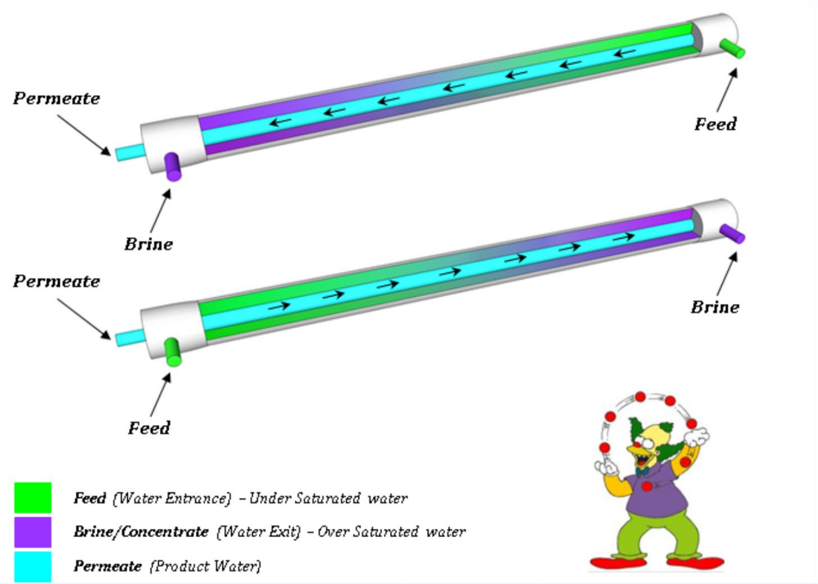
- Short residence time
- Small footprint
- Lower chemical consumption
- Minimal sludge handling (high solid content percentage)

Is $MAXH_2O$ DESALTER technology suitable for your needs?

The $MAXH_2O$ DESALTER is applicable for RO brine and industrial effluents with high scaling tendency and low to moderate salinity (0.1 – 7.0 %w)

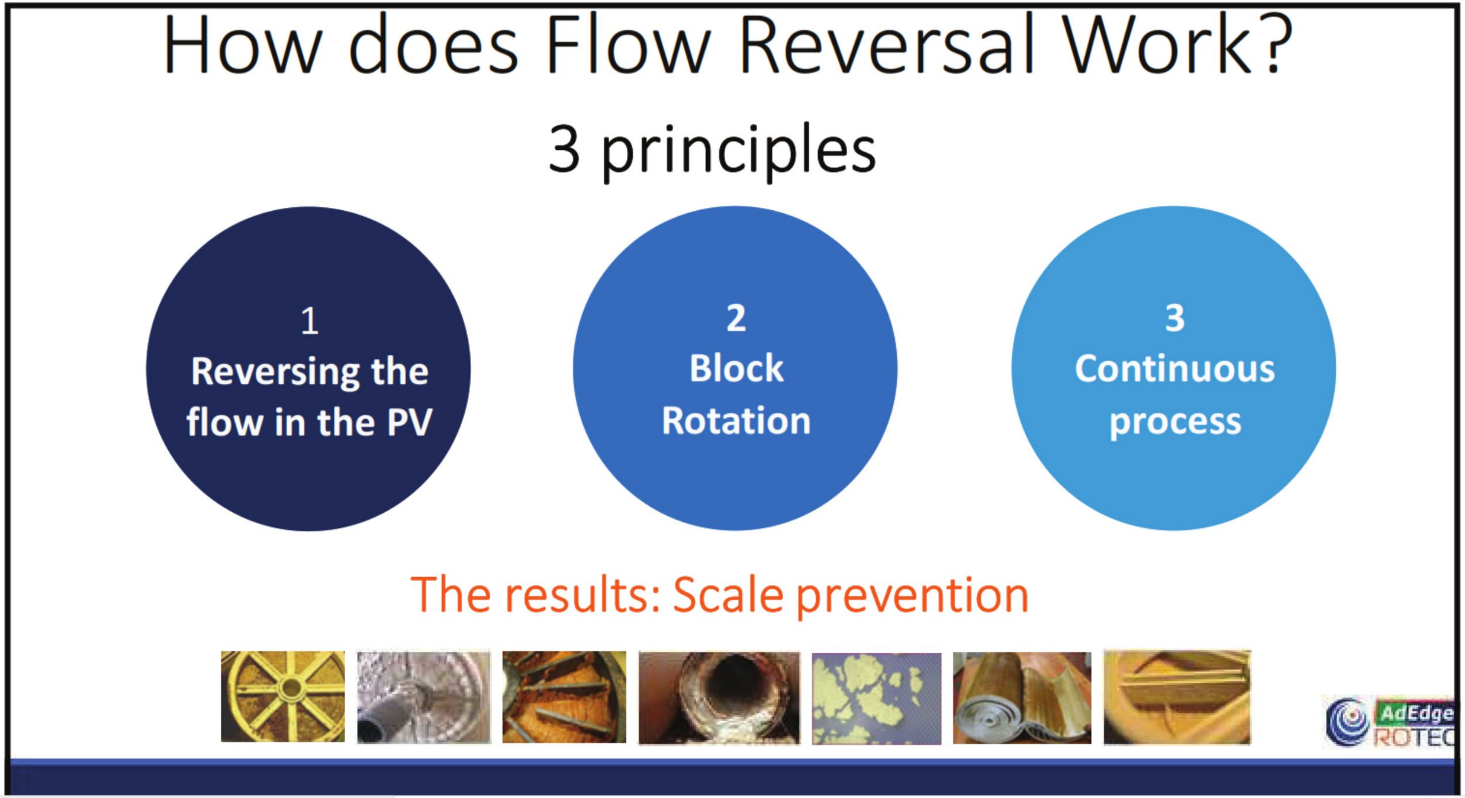
The Latest in Brine Management

4. Rotec – Flow Reversal RO

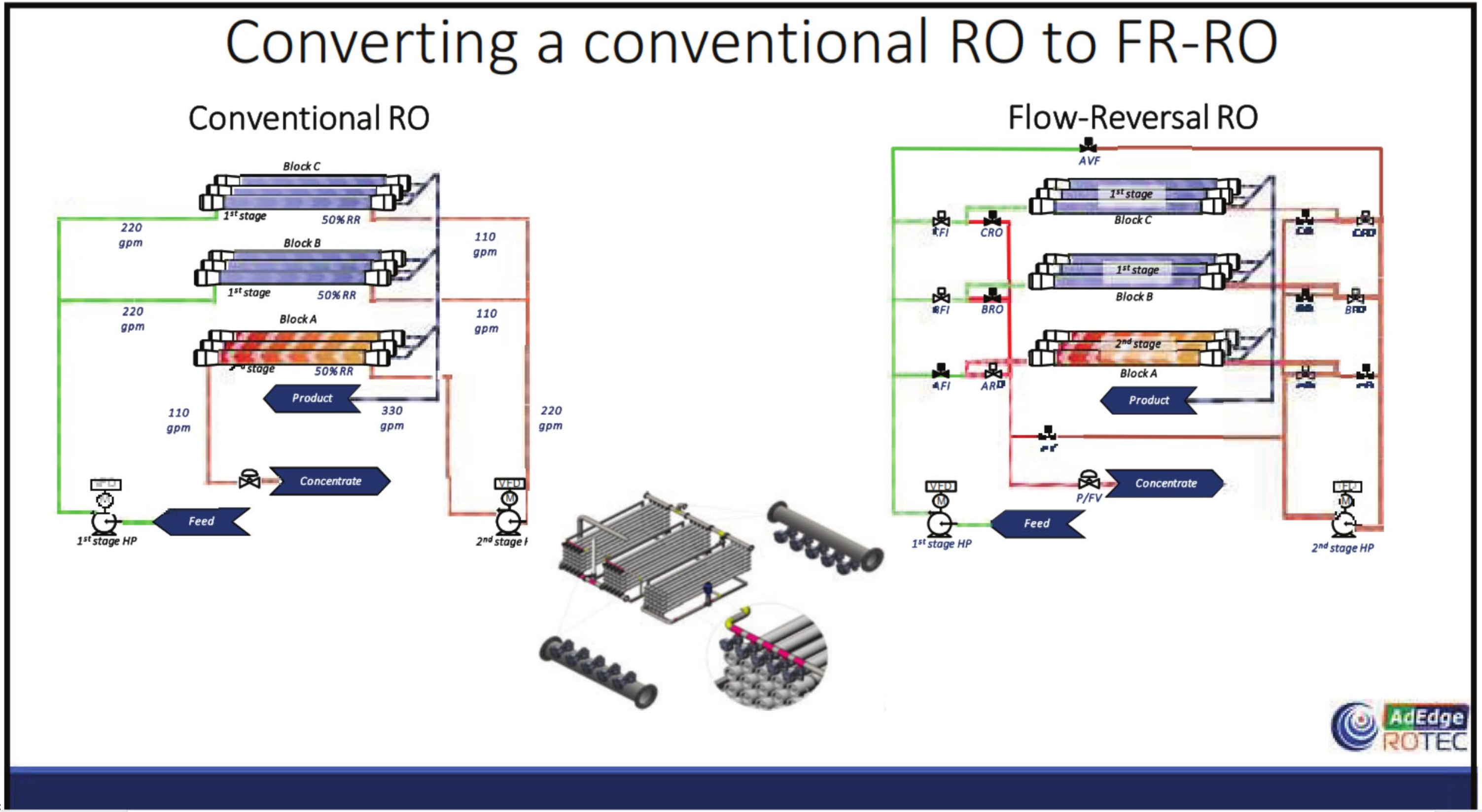


Figure– Flow reversal principle – switches the connection of feed and concentrate before supersaturated solutions can precipitate from the concentrate onto the membrane Timing is determined by knowledge of feed composition and operating conditions. Scaling is prevented by the "juggler principle" – change the condition to under-saturation before the supersaturated solution can precipitate.

4. Rotec – Flow Reversal RO



4. Rotec – Flow Reversal RO



5. Saltworks

Maximize RO Recovery

Shrink Your Brine Volume

Manage Scale Risk

Optimized Total System Design

Xtreme RO (X-RO) enabled by BrineRefine

Extreme Reverse Osmosis Brine Concentrator

- Next generation RO: available in 1200, 1800 psi models
- Reduce brine volumes to new levels
- Leverage BrineRefine: automated chemical softening to remove scaling ions upstream
- Reduce costs through total system integration

Minimize Brine Volume
Reach peak brine concentration approaching osmotic pressure limit, made possible by removing scaling ions with BrineRefine.

Intelligent Automation, System View
Integrated controls for total system performance and monitoring.

Delivery Models
Saltworks can deliver complete RO-optimized packages or work with engineering companies and RO vendors to deliver a partnered project.

Process Flexibility
Reacts and adjusts to changing chemistry and capacity requirements.

Integration
Saltworks integrates with any RO system, tying upstream chemistry adjustments with downstream brine management through optimized processing and controls.

Total Support Operations
Complete packaged delivery and installation options: remote monitoring, 24/7/365 expert assistance, and predictive maintenance.

Operating Specifications

	X-RO 1200	X-RO 1800
Max Pressure	1200 psi ~ 82 bar	1800 psi ~ 124 bar
Osmotic Pressure Brine Concentration Limit (mg/L NaCl)	80,000	130,000
Typical Flux at Peak (LMH)	10	2
Typical Energy at Peak (kWh/m^3 permeate)	6	8
X-RO (25 vessels)*	2,500 m^3/day ~ 458 gpm	500 m^3/day ~91 gpm

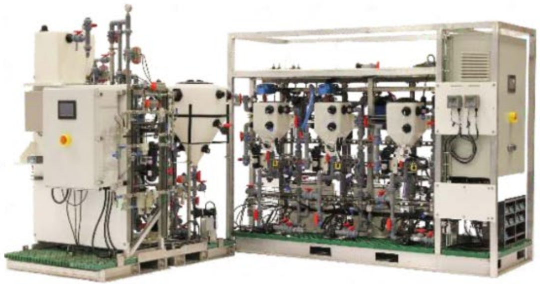
**Peak capacity stated without de-rates*

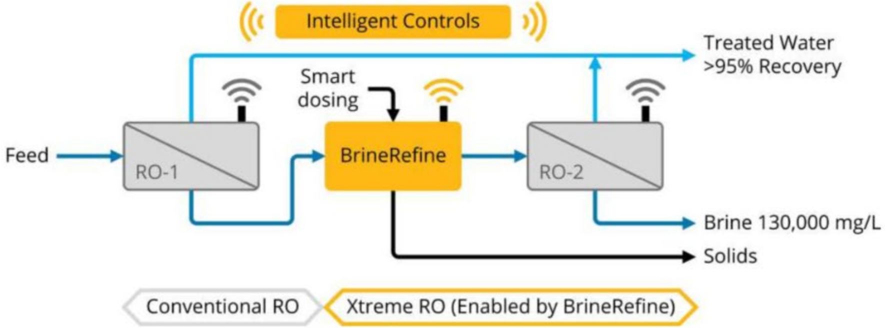
5. Saltworks

BrineRefine

Precise & Automated: Packaged Chemical Softening Technology

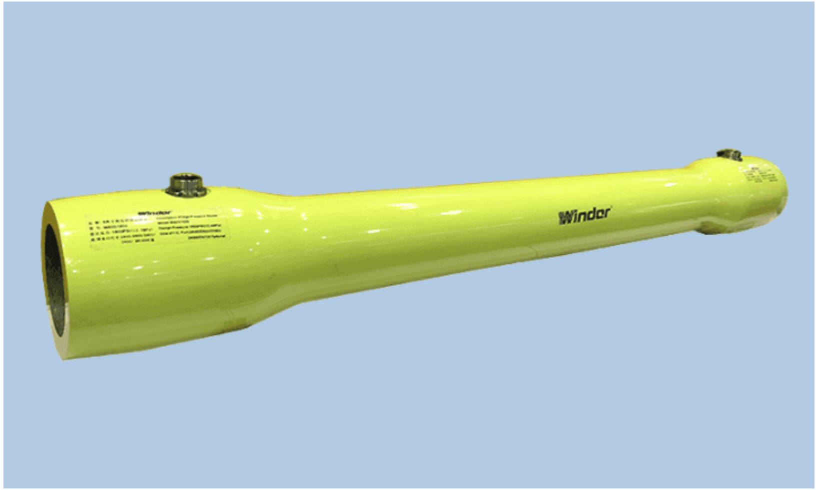
- Removes scaling ions to increase downstream recovery
- No coagulants or flocculants that foul reverse osmosis membranes
- No large clarifiers
- Compact, modular & expandable
- Single package with precision dosing & intelligent controls
- Total treatment optimization: communicates up & downstream
- Smart solids management





5. Saltworks High Pressure RO

8" FRP RO MEMBRANE HOUSING – WORKING PRESSURE: 1800 PSI



Winder® **1800 PSI 8" FRP membrane housing** is designed for high and super high pressure reverse osmosis membrane filtration element. We adopt imported fiberglass and epoxy as material for continuous use.

Winder® series FRP membrane housing are applicable to multiple standard membrane element, E.g. Filmtec, Hydranautics, Osmonics, Koch, Toray, CSM, Vontron and BDX, etc. And non-standard products could be tailor-made to meet the satisfaction of your special projects.

5. Saltworks High Pressure RO

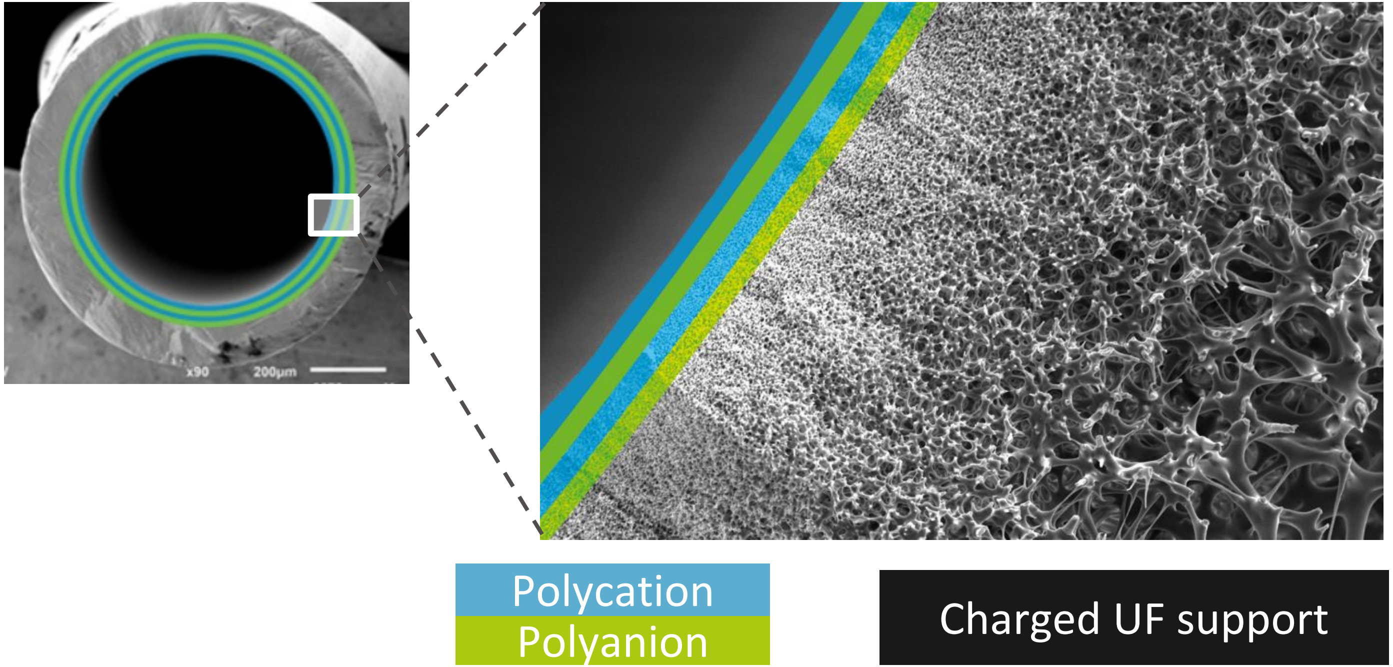
FEATURE

- Composite construction is anti-wearable.
- No rusting,anti-oxidation & aging.
- Working pressure is 1800 PSI.
- Multi-porting option.
- Well heat-insulting property.
- Unique quick locking system.
- Mirror inner wall and brightly surface.
- Test every membrane housing, not sampling.

Model No.	W80S1800
Material	Fiberglass and epoxy.
Element length	40" x (1–7)
Connection type	side port
Design Pressure	1800 PSI (12.4 MPa)
Operating temperature	-10 °C–49 °C
Feed/permeate port	DN40, DN50, DN65, DN80, DN100 optional
Surface treatment:	Polyurethane coated
Color: .	White (standard), blue, yellow, green or customized
Certificate:	ASME, ISO9001, ISO14001, ISO18001

6. NXFiltration

Unique Hollow Fiber Membrane … layer-by-layer coating



6. NXFiltration

- Hollow Fiber configuration
- MF, UF and NF membranes
- Outside-In flow path
- PES fiber chemistry
- Chlorine tolerant and back washable
- Minimal pretreatment requirements

Coagulation + Clarification + Sand Filtration + UF + sw RO or NF = Hollow Fiber dNF

6. NXFiltration

Filtration objective:	Microfiltration MF500	Microfiltration MF100	Ultrafiltration UF075	Ultrafiltration UF010	Nanofiltration dNF80	Nanofiltration dNF40
Suspended solids and micro plastics	✓	✓	✓	✓	✓	✓
Bacteria		✓	✓	✓	✓	✓
Viruses			✓	✓	✓	✓
Protein and colloidal sillica				✓	✓	✓
Micropollutants, color and nano plastics					✓	✓
Selective salt, softening and pharmaceuticals						✓
Cut off	500nm	100nm	75kDa	10kDa	800Da	400Da
Typical Flux (lmh)	25-100	25-100	50-100	50-100	20-50	20-40
$MgSO_4$ rejection (%)	n/a	n/a	n/a	n/a	80	90

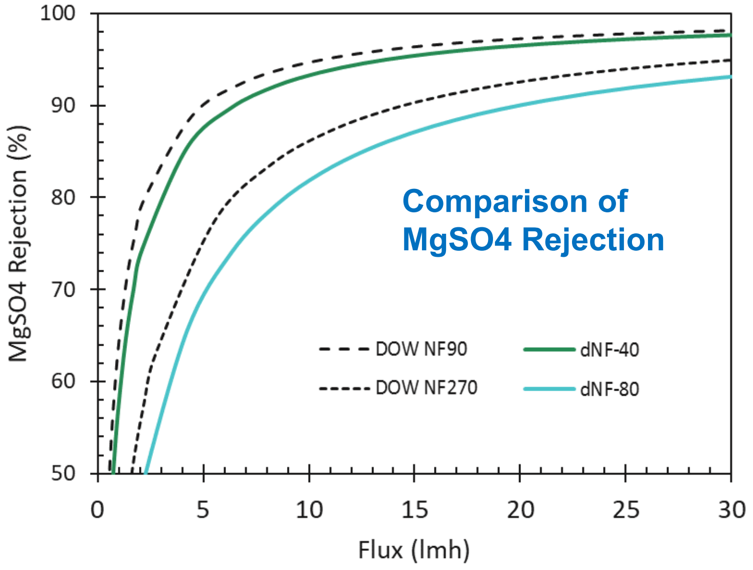
4-inch module

8-inch module

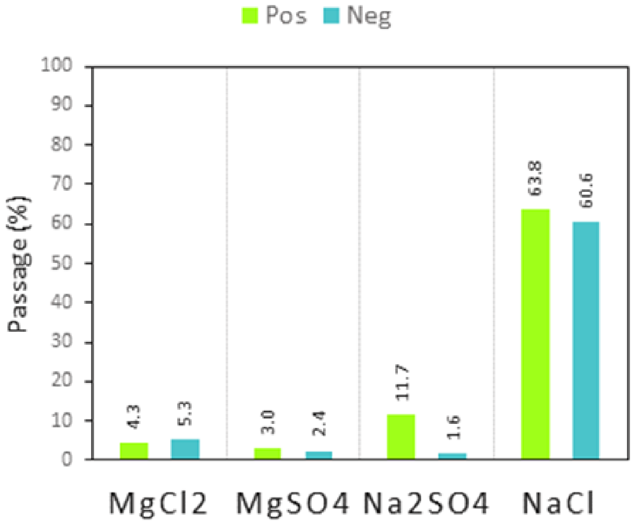
NXFiltration your membrane partner

6. NXFiltration

dNF vs Spiral Wound NF



dNF40 – Salt Passage



6. NXFiltration

Industrial Wastewater

Client: Industrial multinational, Hungary operations

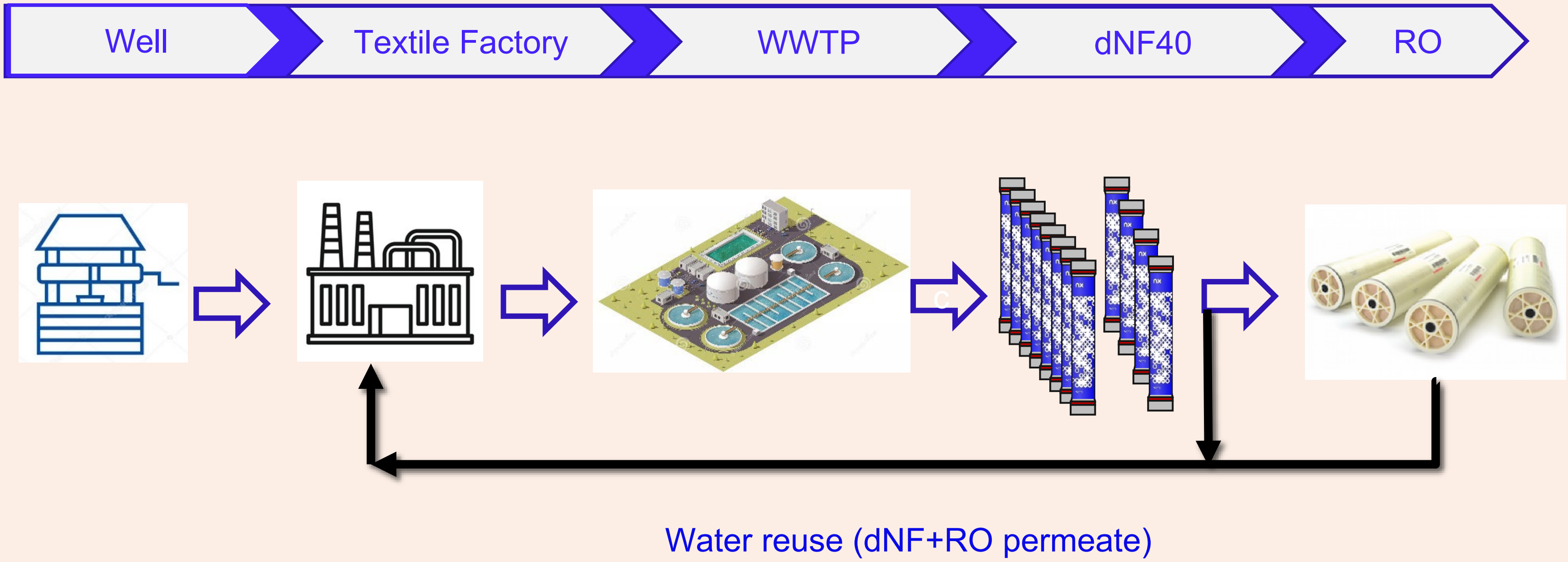
Capacity: 10 m^3/h (44 gpm) with WMC200 dNF40 modules

Start-up: 2018

Process: Treatment of wastewater from airplane parts cleaning operation as pretreatment for reverse osmosis. Feed is 1000-3000 ppm COD.

Results: Recovery dNF >90%; doubling of the RO flux and expanded life time of the reverse osmosis elements, COD removal of the dNF is 80-90%.

Water reuse from textile wastewater – Turkey (220 gpm)
The process



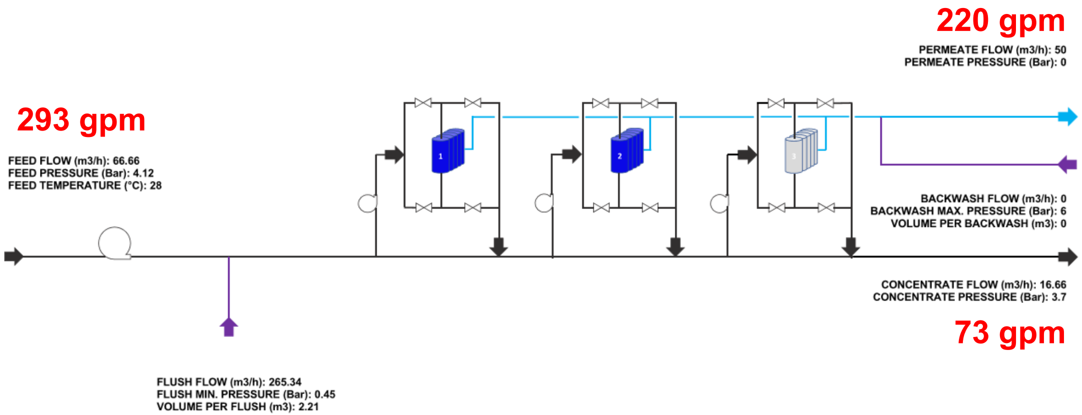
Water reuse from textile wastewater – Turkey (220 gpm)
Final design: 2-stage feed & bleed

nx filtration

Institutenweg 35
7521 PH Enschede
The Netherlands

+31 (0)850 479 900
info@nxfiltration.com
www.nxfiltration.com

PROCESS - PROPOSAL



Parameters	Unit	Value
Design recovery	%	75
Filtration availability	%	96.8
Net permeate / Feed efficiency	%	72.5
Specific energy consumption	kWh/m³ permeate	0.35

Parameters	Unit	Value
Flux	LMH	20
Recovery	%	75
Cross-flow velocity	m/s	0.5

Parameters	Type	Unit	Value
Filtration cycle		Minutes	120
Hydraulic cleaning	Forward Flush + Air Scour	Seconds	30

Cleaning type	Chemicals	Concentration	Cleaning cycles	Frequency
		ppm	minutes	
High pH (pH=10.5)	NaOH	-	30	every 84 hours
	NaOCl	150		
Low pH (pH=2)	Citric acid	0.5%	30	When necessary

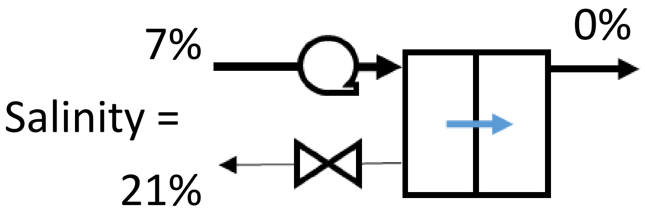
8. Gradiant – CounterFlow RO

SWRO plant
Jeddah, Saudi Arabia
15,000 m³/d Permeate

Brine Desalination at Existing SWRO Plant

- Increasing demand but unable to increase intake
- Demo system running since December 2019
- 40-50% additional recovery from SWRO reject
- Full scale installation: 5,000 m3/day new permeate
- 7 kWh/m3, < $0.90/m3 total cost
- No additional intake or pretreatment

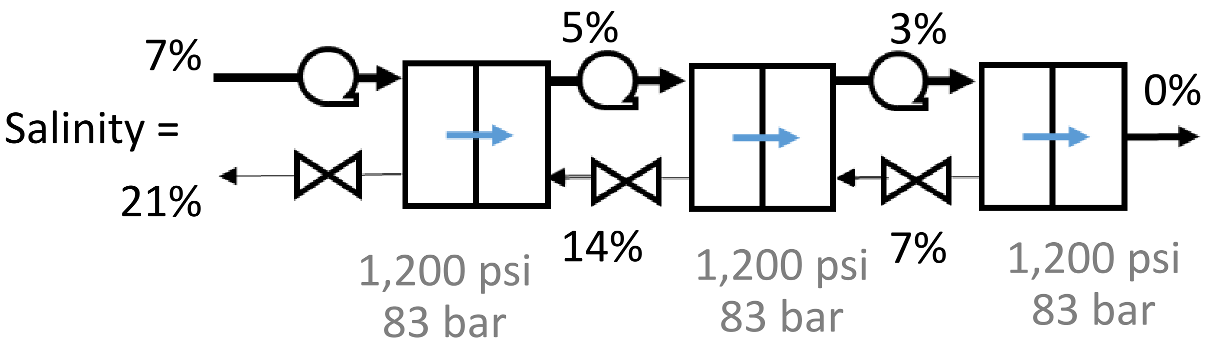
8. Gradiant – CounterFlow RO

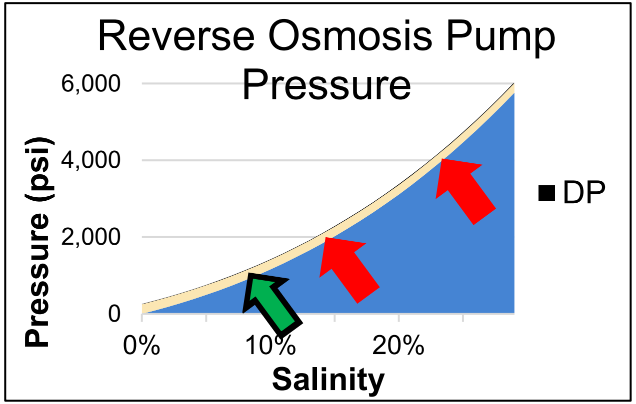


4,000 psi
276 bar

Unfortunately Membranes / Housings rated for 4000 psi don’t exist.

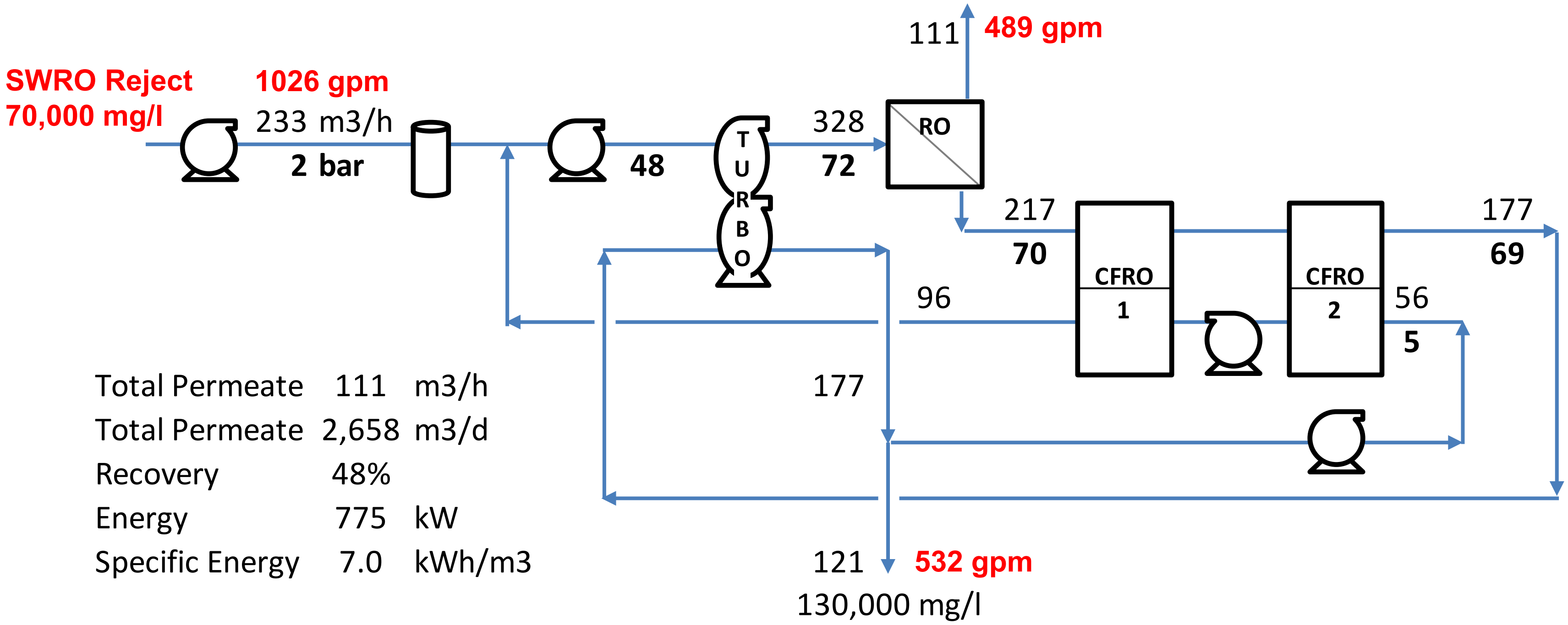
8. Gradiant – CounterFlow RO





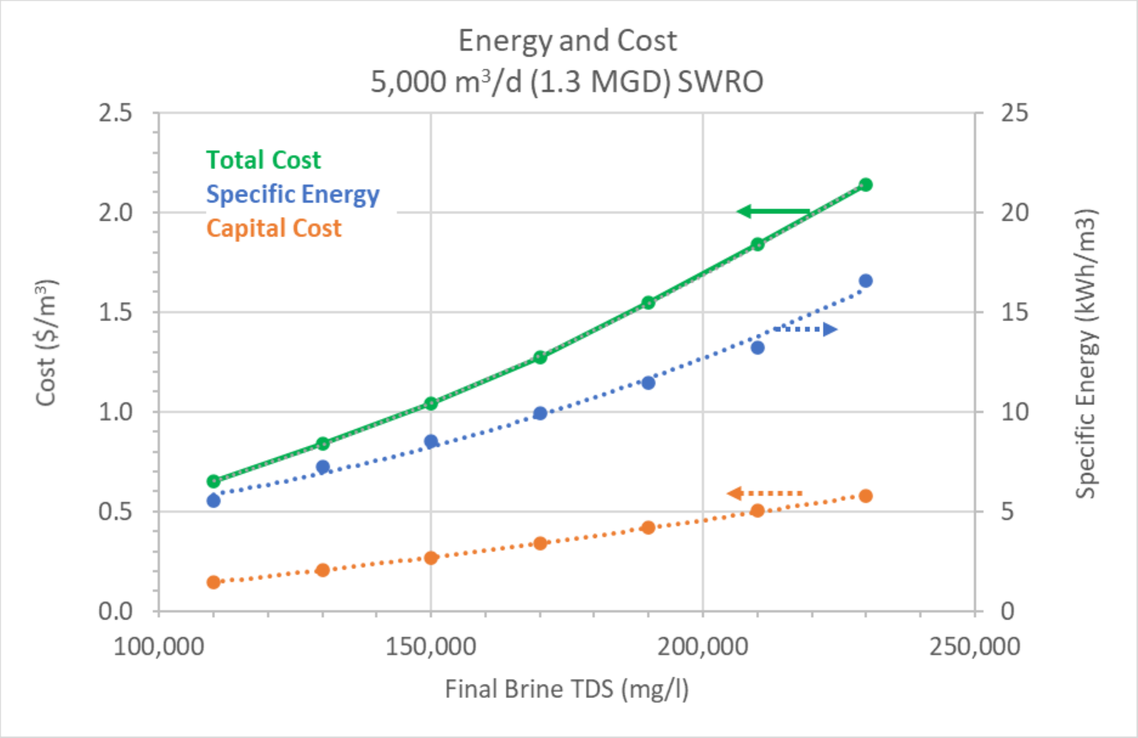
- Saline solution on permeate side reduces osmotic barrier
- Up to 260,000 mg/l brine concentrate
- Drinking water quality permeate
- Pressure low enough for use of commercially available components

8. Gradiant – CounterFlow RO



Total Permeate	111	m3/h
Total Permeate	2,658	m3/d
Recovery	48%	
Energy	775	kW
Specific Energy	7.0	kWh/m3

8. Gradiant – CounterFlow RO



<u>Full-Scale SAWACO</u>

- 5,000 m^3/d **917 gpm**
- 130,000 mg/l brine
- 7 kWh/m^3
- Iodine mitigation with SBS
- Same counterflow RO design as pilot
- <$0.90/$m^3$ ($3.40/kgal)
- Cost comparable to existing SWRO

8. Gradiant – CounterFlow RO

CounterFlow Reverse Osmosis
CFRO

- Membrane Brine Desalination and Concentration
- Off-the-shelf Components
- Bolt-on Implementation
- Saline Sweep: Pressure <1,000 psi
- Cost Effective vs Thermal & UHPRO
- Lower Cost than Greenfield SWRO due to no intake or pretreatment

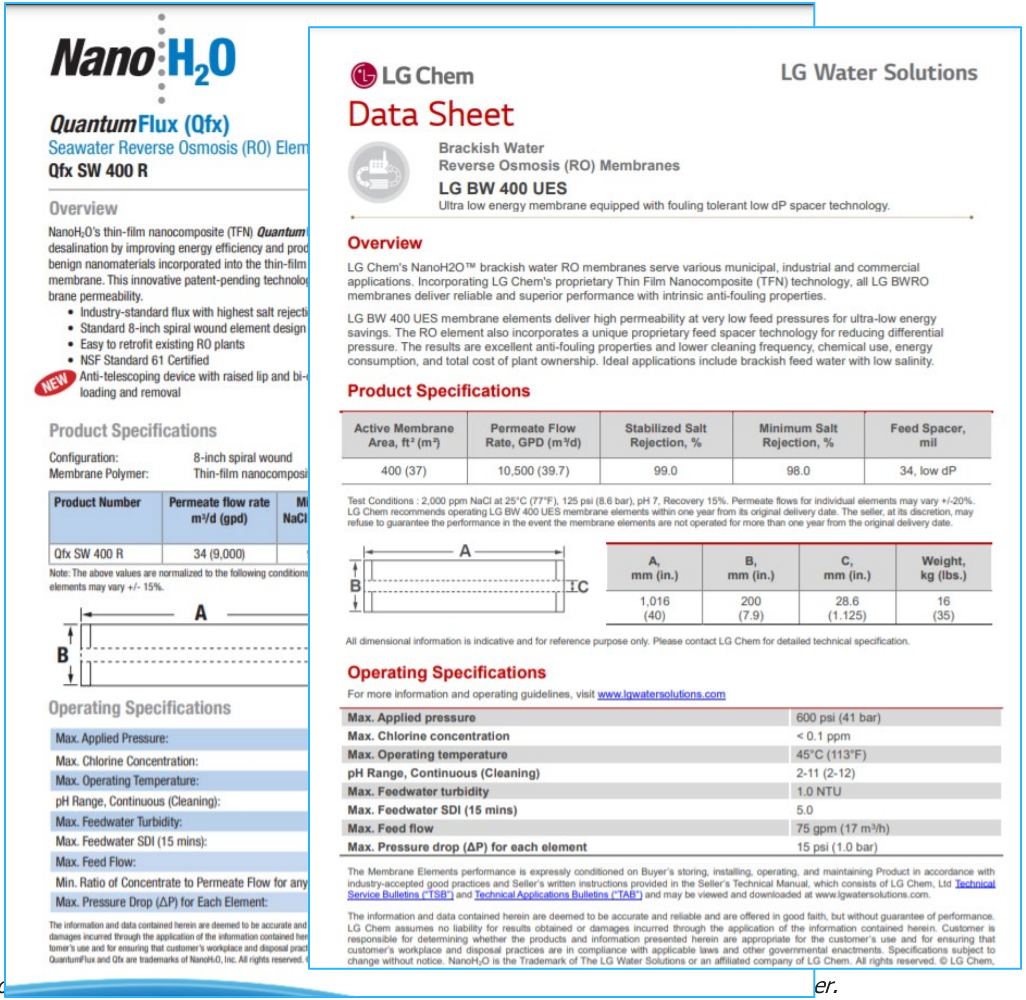
LG Nano H20

Low Energy SWRO Membranes

- Retrofit – potential for significant OPEX savings
- New Build – potential for significant CAPEX savings

→Need to download the LG software, run the RO projections and get a quote.

→ https://www.lgwatersolutions.com/en/tools/software


NanoH$_2$O

QuantumFlux (Qfx)

Seawater Reverse Osmosis (RO) Elem

Qfx SW 400 R

Overview

NanoH$_2$O's thin-film nanocomposite (TFN) Quantum desalination by improving energy efficiency and prod benign nanomaterials incorporated into the thin-film membrane. This innovative patent-pending technolog brane permeability.

- Industry-standard flux with highest salt rejecti
- Standard 8-inch spiral wound element design
- Easy to retrofit existing RO plants
- NSF Standard 61 Certified
- NEW Anti-telescoping device with raised lip and bi- loading and removal

Product Specifications

Configuration: 8-inch spiral wound

Membrane Polymer: Thin-film nanocomposi

Product Number	Permeate flow rate m³/d (gpd)	Mi NaCl
Qfx SW 400 R	34 (9,000)	

Note: The above values are normalized to the following conditions elements may vary +/- 15%.

Operating Specifications

Max. Applied Pressure:

Max. Chlorine Concentration:

Max. Operating Temperature:

pH Range, Continuous (Cleaning):

Max. Feedwater Turbidity:

Max. Feedwater SDI (15 mins):

Max. Feed Flow:

Min. Ratio of Concentrate to Permeate Flow for any

Max. Pressure Drop (ΔP) for Each Element:

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LG Chem — LG Water Solutions

Data Sheet

Brackish Water Reverse Osmosis (RO) Membranes

LG BW 400 UES

Ultra low energy membrane equipped with fouling tolerant low dP spacer technology.

Overview

LG Chem's NanoH2O™ brackish water RO membranes serve various municipal, industrial and commercial applications. Incorporating LG Chem's proprietary Thin Film Nanocomposite (TFN) technology, all LG BWRO membranes deliver reliable and superior performance with intrinsic anti-fouling properties.

LG BW 400 UES membrane elements deliver high permeability at very low feed pressures for ultra-low energy savings. The RO element also incorporates a unique proprietary feed spacer technology for reducing differential pressure. The results are excellent anti-fouling properties and lower cleaning frequency, chemical use, energy consumption, and total cost of plant ownership. Ideal applications include brackish feed water with low salinity.

Product Specifications

Active Membrane Area, ft² (m²)	Permeate Flow Rate, GPD (m³/d)	Stabilized Salt Rejection, %	Minimum Salt Rejection, %	Feed Spacer, mil
400 (37)	10,500 (39.7)	99.0	98.0	34, low dP

Test Conditions : 2,000 ppm NaCl at 25°C (77°F), 125 psi (8.6 bar), pH 7, Recovery 15%. Permeate flows for individual elements may vary +/-20%. LG Chem recommends operating LG BW 400 UES membrane elements within one year from its original delivery date. The seller, at its discretion, may refuse to guarantee the performance in the event the membrane elements are not operated for more than one year from the original delivery date.

A, mm (in.)	B, mm (in.)	C, mm (in.)	Weight, kg (lbs.)
1,016 (40)	200 (7.9)	28.6 (1.125)	16 (35)

All dimensional information is indicative and for reference purpose only. Please contact LG Chem for detailed technical specification.

Operating Specifications

For more information and operating guidelines, visit www.lgwatersolutions.com

Max. Applied pressure	600 psi (41 bar)
Max. Chlorine concentration	< 0.1 ppm
Max. Operating temperature	45°C (113°F)
pH Range, Continuous (Cleaning)	2-11 (2-12)
Max. Feedwater turbidity	1.0 NTU
Max. Feedwater SDI (15 mins)	5.0
Max. Feed flow	75 gpm (17 m³/h)
Max. Pressure drop (ΔP) for each element	15 psi (1.0 bar)

The Membrane Elements performance is expressly conditioned on Buyer's storing, installing, operating, and maintaining Product in accordance with industry-accepted good practices and Seller's written instructions provided in the Seller's Technical Manual, which consists of LG Chem, Ltd Technical Service Bulletins ("TSB") and Technical Applications Bulletins ("TAB") and may be viewed and downloaded at www.lgwatersolutions.com.

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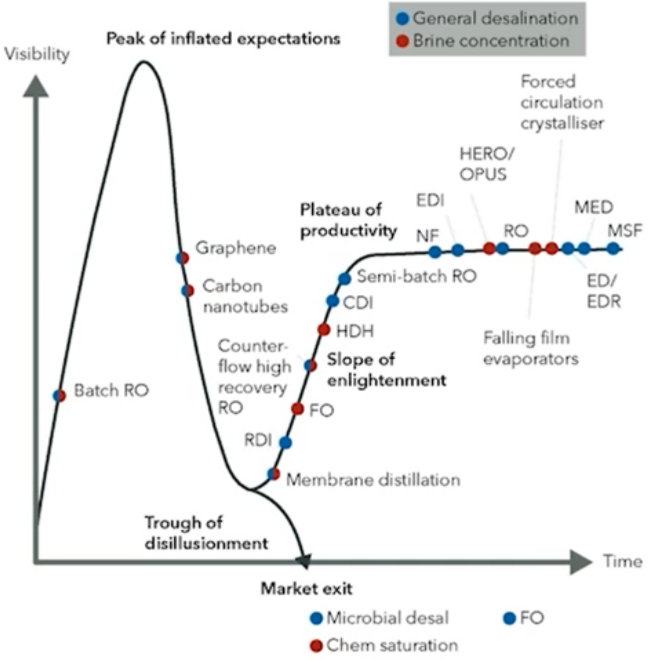
Overview

- This schematic of a technology's journey towards commercialisation charts the initial excitement that surrounds a new technology, followed by disillusionment as practical difficulties set in, before a final move towards commercialisation and mainstream acceptance.
- Brine management is currently a key driver of adoption. Almost all of the technologies making the slow ascent to mainstream use are primarily used in brine concentration, with the notable exception of semi-batch reverse osmosis.
- The time needed to create reliable and affordable manufacturing methods for materials such as graphene and carbon nanotubes, means that these are among the slowest technologies to mature. However, 'operational R&D' such as semi-batch or counter-flow reverse osmosis system configurations are likely to take off much more quickly.

Commercialisation of new technologies in desalination & brine concentration




KEEP
CALM
AND
REUSE
WATER

INDUSTRIAL WATER REUSE NEW TECHNOLOGIES AND LESSONS LEARNED

IWC Workshop W-07

Oxidation and Disinfection

INTERNATIONAL WATER CONFERENCE

wood.

OXIDATION / DISINFECTION

Section 5: Disinfection/Oxidation

- Disinfection and Oxidation in Water Reuse
  - Why Disinfection?
  - How to choose the right technology?
- Main technologies
  - Chlorination
  - UV
  - Ozone
  - Advanced Oxidation: Combined ozone, H_2O_2, UV/H_2O_2… etc

Disinfection: Why do we need it?

- Why?
  - Protect human health
  - Discharge to surface waters
  - Ecological Impact
  - Prevent spreading of diseases

- Factors affecting Disinfection
  - Contact Time
  - pH
  - Concentration or Intensity of the disinfectant
  - Concentration of the organisms
  - Concentration of interfering substances

How to choose the right technology?

- Ability to penetrate and destroy infectious agents
- Safe and easy handling
- Absence of toxic residuals and mutagenic or carcinogenic compounds
- Affordable CAPEX and O&M cost

DISINFECTION				
	Chlorine	**Ozone**	**UV**	**Elect.**
Depot effect	A few days	A few minutes	None	Many hours
Operating resources	HCl and NaClO2	Air/O2, energy	Energy	NaCl
Disinf. Strength	Strong	Strongest	Medium	Medium
pH value	None	Low	None	6.5-7.5

		Chlorine	O3	UV	Elect.
Oxidation	Metals (Fe, Mn, Ar)	+	+++	-	+
	Organic impurities	+	+++	-	-
	Odour	++	+++	-	-
Decomp.	Chlorine	-	-	+++	-
	Trihalomethanes	-	+++	-	-
	Chloramines	-	+++	+++	-

Chlorination (1): How it works?

- Chlorination is the most common used technology for disinfection
- Supplied as:
  - Chlorine gas - liquid chlorine
  - Hypochlorite as sodium hypochlorite, calcium hypochlorite]
  - Chlorine Dioxide (Cl_2O)→ through Sodium Chlorate or Sodium Chlorite
- Chlorine gas, hypochlorite salts and Chlorine Dioxide are added to water, hydrolysis and ionization take place to form→ HOCl and OCl-
  - $Cl_2 + H_2O = HOCl + HCl$
  - $HOCl = OCl^- + H^+$
  - $NaOCl + H_2O = OCl^- + OH^-$
  - $2NaClO_3 + H_2SO_4 + SO_2 = 2ClO_2 + 2NaHSO_4$
  - $2NaClO_3 + CH_3OH + H_2SO_4 = 2ClO_2 + HCHO + Na_2SO_4 + 2H_2O$
  - $NaClO_3 + NaCl + H_2SO_4 = ClO_2 + 1/2Cl_2 + NaSO_4 + H_2O$
  - $Cl_2 + H_2O = HOCl + HCl$
  - $HOCl + Hcl + 2NaClO = 2ClO + 2NaCl + H_2O$

  FREE AVAILABLE CHLORINE.
- Kills bacteria, pathogens, removes odor

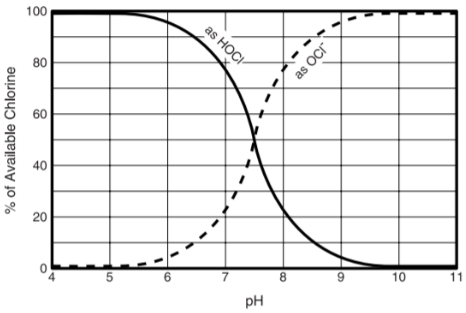
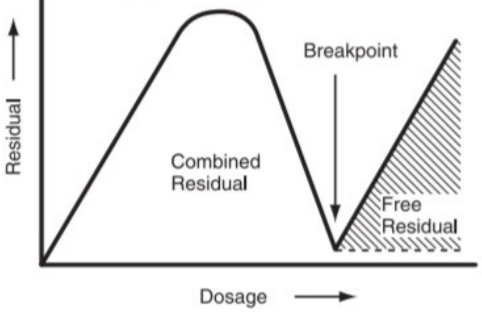


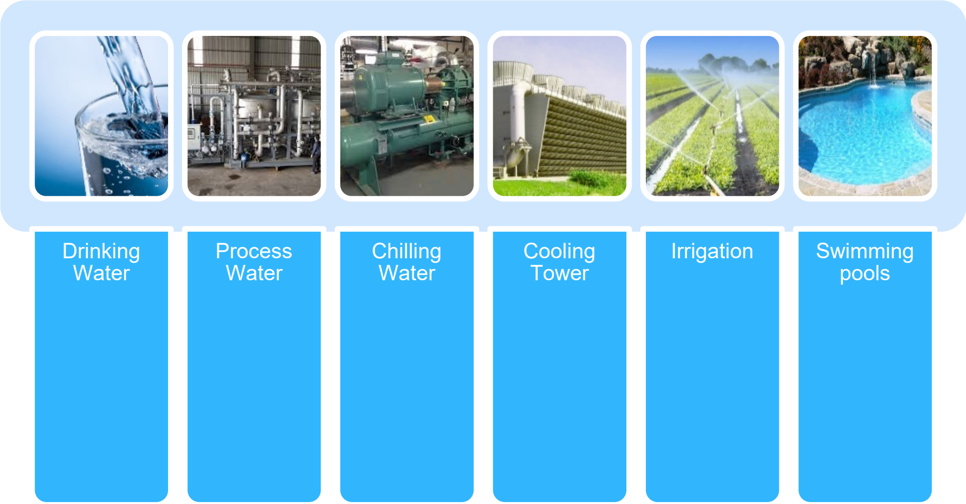
Fig. 2: Breakpoint Curve



Chlorination (2): Advantages and disadvantages

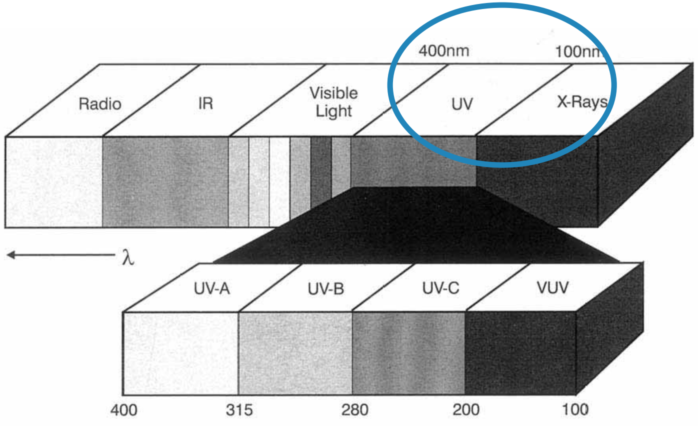
- ADVANTAGES
  - Well stablished technology
  - Cost effective
  - Chlorine residual can prolong disinfection
  - Flexible in operation
  - Odors control
- DISADVANTAGES
  - Can be toxic to aquatic life
  - Highly corrosive (storage and handling…)
  - Creation of THM
  - Increase TDS
  - Some parasitic species have shown resistance to low doses

- MAIN APPLICATION



UV (1): How it works?

- UV transfers electromagnetic energy from a mercury arc lam to an organism genetic material (DNA and RNA).
- UV penetrates the cell wall, it destroys/retards ability to reproduce
- UV spectrum divided into 3 parts
  - UV-A (315 –400 nm)
  - UV-B (280 –315 nm)
  - UV-C (200 –280 nm) (UV output 254nm)
- Effectiveness depends on: Intensity of UV, time, microorganism, reactor configuration, colloidal and particulate constituents.
- Cryptosporidium and Giardia removal (drinking water)



UV (2): Types: LP and MP

- Low-Pressure Lamps
  - Wavelength of 253.7 nm
  - Lengths of 0.75 and 1.5 meters with diameter of 1.5 –2.0 cm.
- Medium-Pressure Lamps
  - 15-20 times germicidal UV intensity of low-pressure lamps
  - Disinfect faster
  - Greater penetration capacity
  - Operate at higher temperatures; higher energy consumption

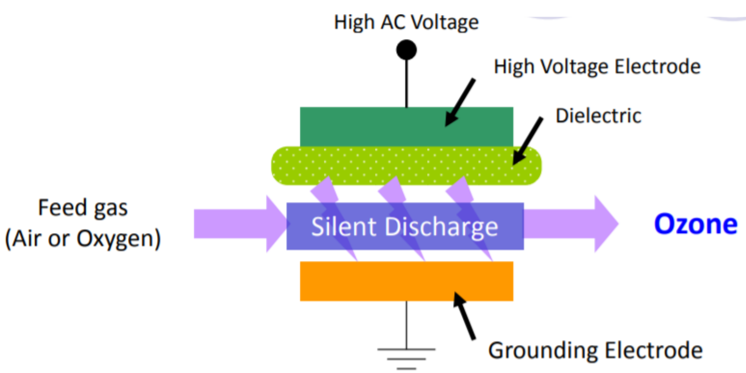
UV (3): Advantages and Disadvantages

- ADVANTAGES
  - Effective and inactivate most virus, spores and cysts
  - Physical process (so not need for handle transport chemicals)
  - No residual effect f
  - User friendly
  - Short contact time
  - Small footprint
- DISADVANTAGES
  - Low dose can be inefficient
  - Some organism can repair and become life again
  - Turbidity and TSS can limit effectiveness
  - Need to control fouling→ preventive maintenance

UV offers the benefits of not producing by-products and replaces a complicated three step chemical disinfection process with a single physical UV process.

Ozone (1): How it works?

- Strong Oxidizer
- Effective disinfectant for microorganisms and virus
- Limited secondary byproducts
- Electric power required
- Ozone is formed by recombination
  of ionized Oxygen atoms
  generated by applying high AC power
  and un-ionized molecular oxygen



Ozone (2): Applications, advantages, disadvantages

APPLICATIONS

- Industrial Water Reuse
- Best Solution for industries: Can combine Biological Treatment with Tertiary treatment

ADVANTAGES

- Effective against pathogenic organisms (bacterial and viruses), organic chemicials, some color, taste and odor
- Oxidises reduced inorganic metals & sulfides

DISADVANTAGES

- Not effective against large cysts and some other large organisms
- Potential to form harmful bromates
- Ozone gas is toxic people are sensitive to odors.

Advanced Oxidation-AOPs (1)

- AOP are oxidative water treatment used to treat toxic effluents.
- AOP are well established technologies (UV/Peroxide has been in use for >30 yrs)
- AOP are successful in transforming toxic organic compounds into biodegradable substances.
- AOP are generally affordable to install but with high operating costs (due to chemicals and energy).
- To limit costs, AOP can be installed as pre-treatment.
- Recently AOP are used to remove micro-pollutants in the STW and as disinfection of clean/potable water.
- AOP involves 2 stage oxidization:
  - 1st stage: Formation of strong oxidants (hydroxyl radicals **·OH**)
  - 2nd Stage: Reaction of these oxidants with organic contaminants

Oxidant	Potential (V)
Fluor	3.06
Hydroxyl	2.80
Ozone	2.07
Permanganate ion	1.77
H2O2	1.67
ClO2	1.50
Cl2	1.36

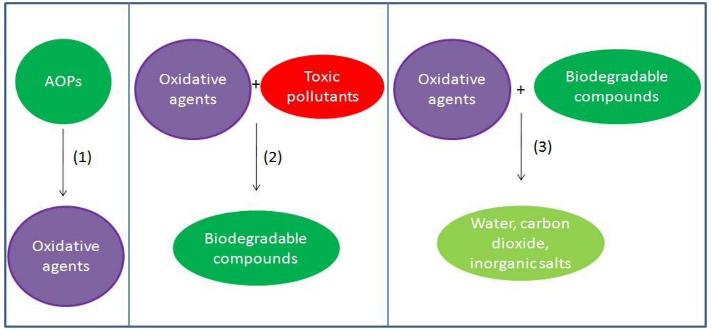
AOPs (2): 1st stage: How **·OH** is formed?

AOP	Oxidant agent/Catalyst	Reaction
Fenton	H_2O_2/Fe^{2+}	$H_2O_2 + Fe^{2+} \rightarrow Fe^{3+} + OH^- + \cdot OH$
Sonolysis / Cavitation	Ultrasound	$O_3 + H_2O \rightarrow O_2 + 2\cdot OH$
UV Peroxide	H_2O_2/UV	$H_2O_2 \rightarrow \cdot OH$
Photocatalysis (Photo Fenton)	H_2O_2/Fe^{2+}	$H_2O_2 + Fe^{2+} \rightarrow Fe^{3+} + OH^- + \cdot OH$
(Peroxyozone) H_2O_2/O_3	H_2O_2/O_3	$H_2O_2 + H_2O \rightarrow HO_2^- + \cdot OH + H_3O^+$ $O_3 + HO_2^- \rightarrow \cdot OH + O_2^- + O_2$
UV Ozone	O_3/UV	$O_3 + H_2O \rightarrow O_2 + H_2O_2$ $O_3 + H_2O_2 \rightarrow 2\cdot OH + O_2$
E-beam	Electron accelerator	$H_2O \rightarrow 2.7\cdot OH + 0.6H^+ + 2.6\ eq^-$ $+ 0.45H_2 + 0.7H_2O_2 + H_3O$
Photocatalytic oxidation with TiO_2	$TiO_2 + UV \rightarrow e^- + h^+$ *(irradiation of the photocatalytic surface leads to an excited electron (e^-) and electron gap (h^+))* Ti(IV) + $H_2O \rightleftharpoons$ Ti(IV)-H_2O *(water adsorbs onto the catalyst surface)* Ti(IV)-H_2O + $h^+ \rightleftharpoons$ Ti(IV)-·OH + H^+ *the highly reactive electron gap will react with water*	

AOPs (3): 2nd Stage: What ·OH does?

1) **·OH** breaks double chains or aromatic bonds (pollutants), transforming toxic pollutants into biodegradable compounds.

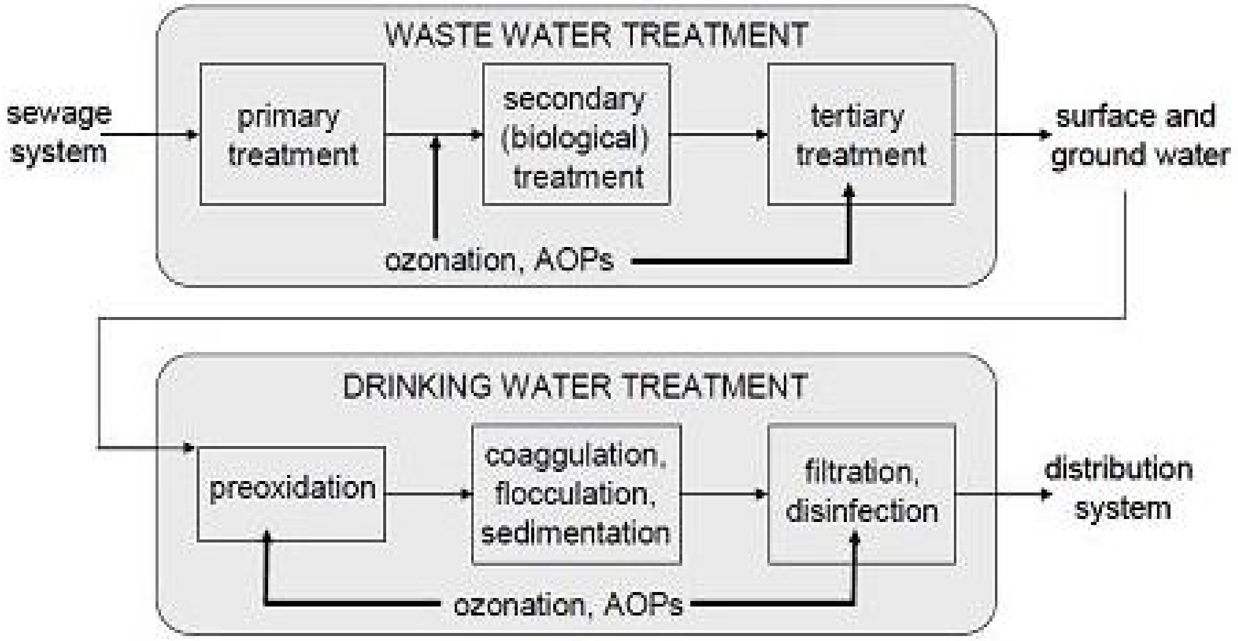
2) Oxidative agents continue reacting generating water, carbon dioxide and inorganic salts.



AOPs (4): Main Applications

Main applications are:

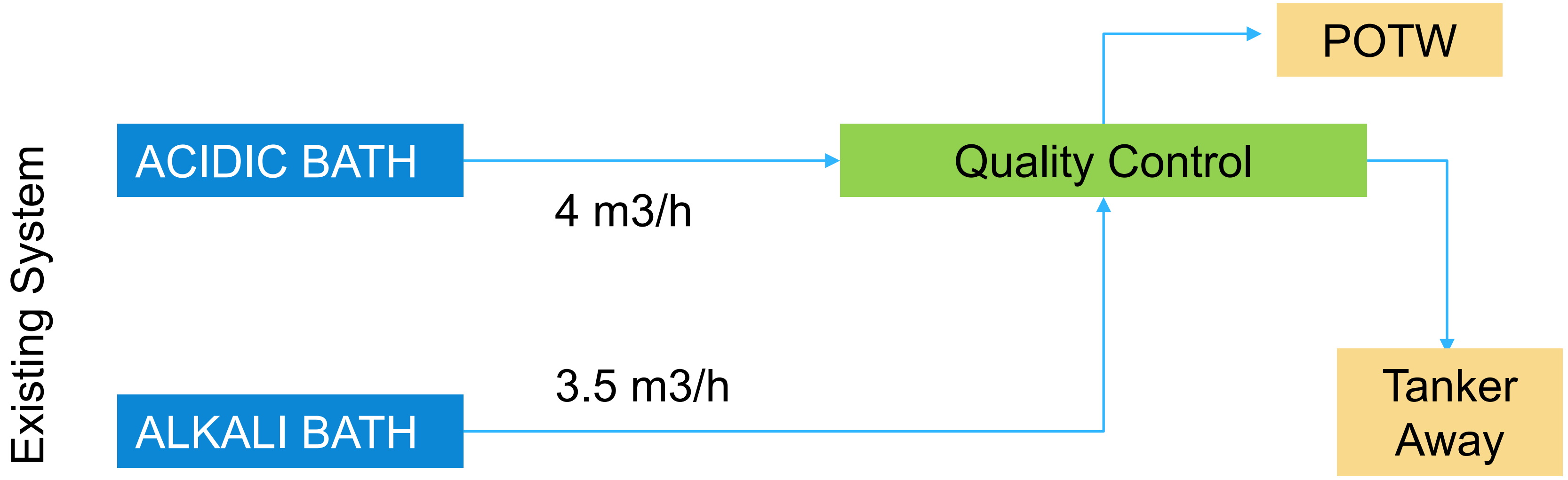
- Recalcitrant or toxic effluent from Industry
- Effluent organic matter in biological treated secondary effluent
- Water Reuse/Drinking Water



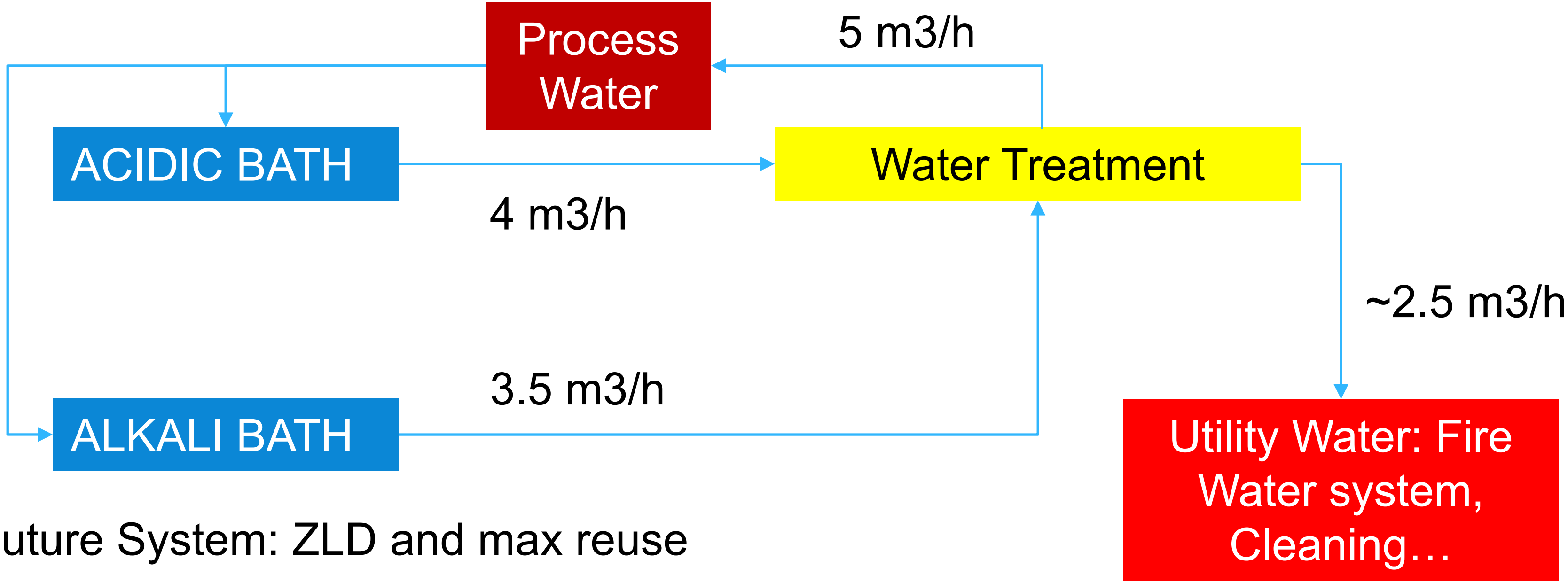
AOP (5): Advantages and Disadvantages

Advantages	Disadvantages
Destroys toxic organic compounds without pollution transfer to another phase	Relatively high operation costs due to chemicals and/or energy input.
Very efficient to treat almost all organic pollutants and remove some toxic metals	Some are emerging technologies (still a lot of research is required).
Works also for water disinfection	Production of by-products, interfering compounds and bromate formation (for drinking water)
	Safety is a key issue.

EXERCISE: Metal Plating Facility



EXERCISE: Metal Plating Facility



Future System: ZLD and max reuse

EXERCICE: WATER ANALYSIS

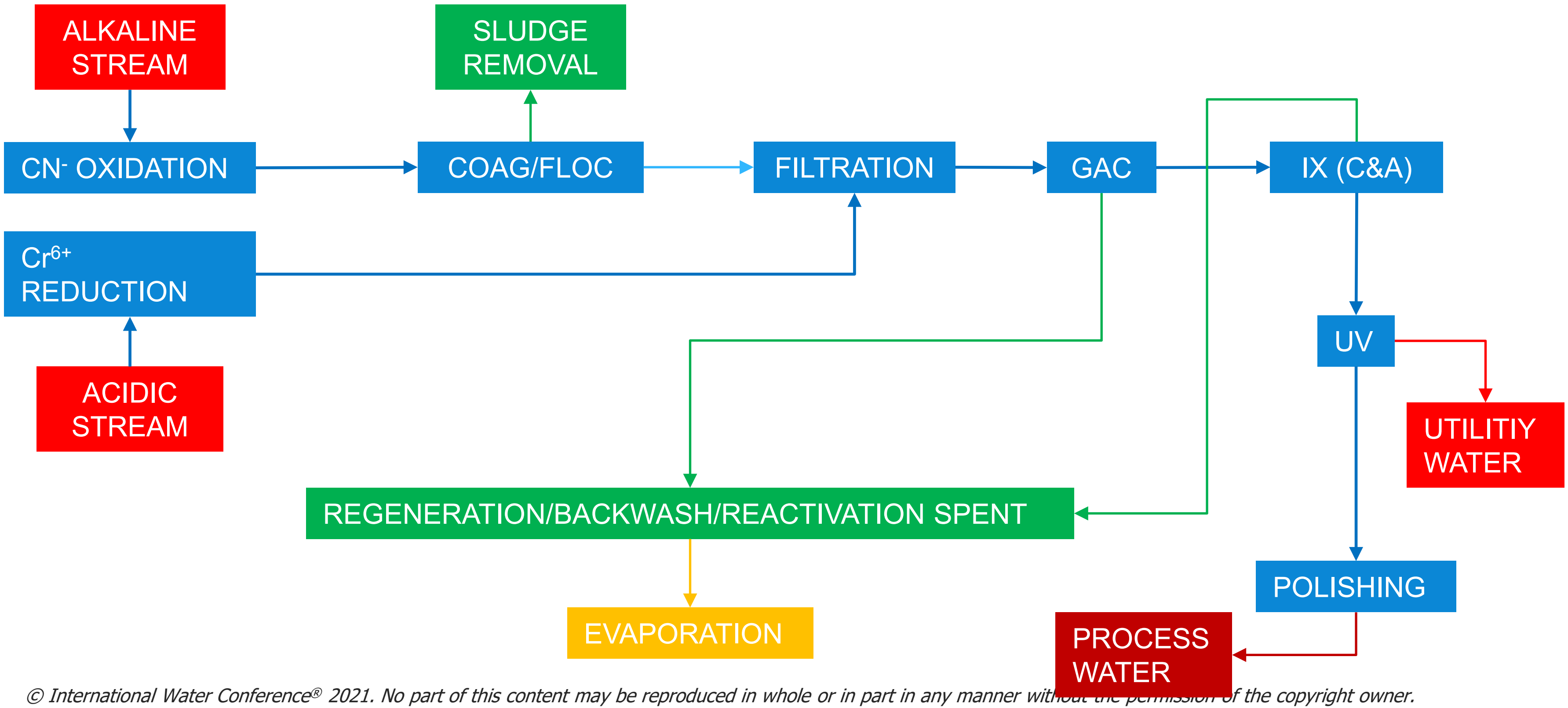
Water Chemistry

	Cyanide	Cadmium	Chromium	Copper	Mercury	Nickel	Zinc	Tin	Lead	Arsenic	Silver	Gold	pH	Conductivity (us/cm)	BOD
Alkali Bath	800	0.11	0	100	0.002	5	20	1	2	5	2	1	8-9	500	200
Acidic Bath	0	1.5	200	122	0.002	3628	290	0	0	0	0	0	2-5	1000	200

Requirements for Water Reuse

	Cyanide	Cadmium	Chromium	Copper	Mercury	Nickel	Zinc	pH	Conductivity (us/cm)	BOD
Utilities	0.5	0.001	0.01	0.1	0.0001	0.5	0.5	7-8	100	<3
Process Water	0.5	0.001	0.001	0.01	0.0001	0.05	0.05	7-8	30	<3

EXERCISE: PROPOSED SOLUTION

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Byproduct Disposal

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BYPRODUCT DISPOSAL / REUSE

- Industrial Waters & Complexity
- Recycle/Reuse + IW -- Challenging Byproducts
- Treatment & Disposal & Fate of Byproducts

Industrial Waters - Complexity

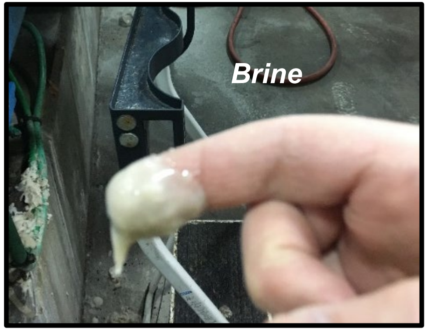
Complex Industrial Water Examples

- Coal Mine AMD
- Food & Beverage Processing Water
- Chemical & Fertilizer Scrubbing Water
- Landfill leachate
- Mining & Mineral Process Circuit Water
- Oil & Gas Exploration Produced Water
- Refinery Effluent
- Power FGD Scrubber Blowdown Ash Pond
- General Industrial Cooling Tower Blowdown

Constituents (Byproducts)

- TSS (solids & sludge)
- TDS (salts & brines)
- Metals & Nutrients (sludge)
- Oils & Grease & Hydrocarbons (oils)

Byproducts


Brine


Mixing Brine & Flyash


Beneficial Mineral
Byproduct

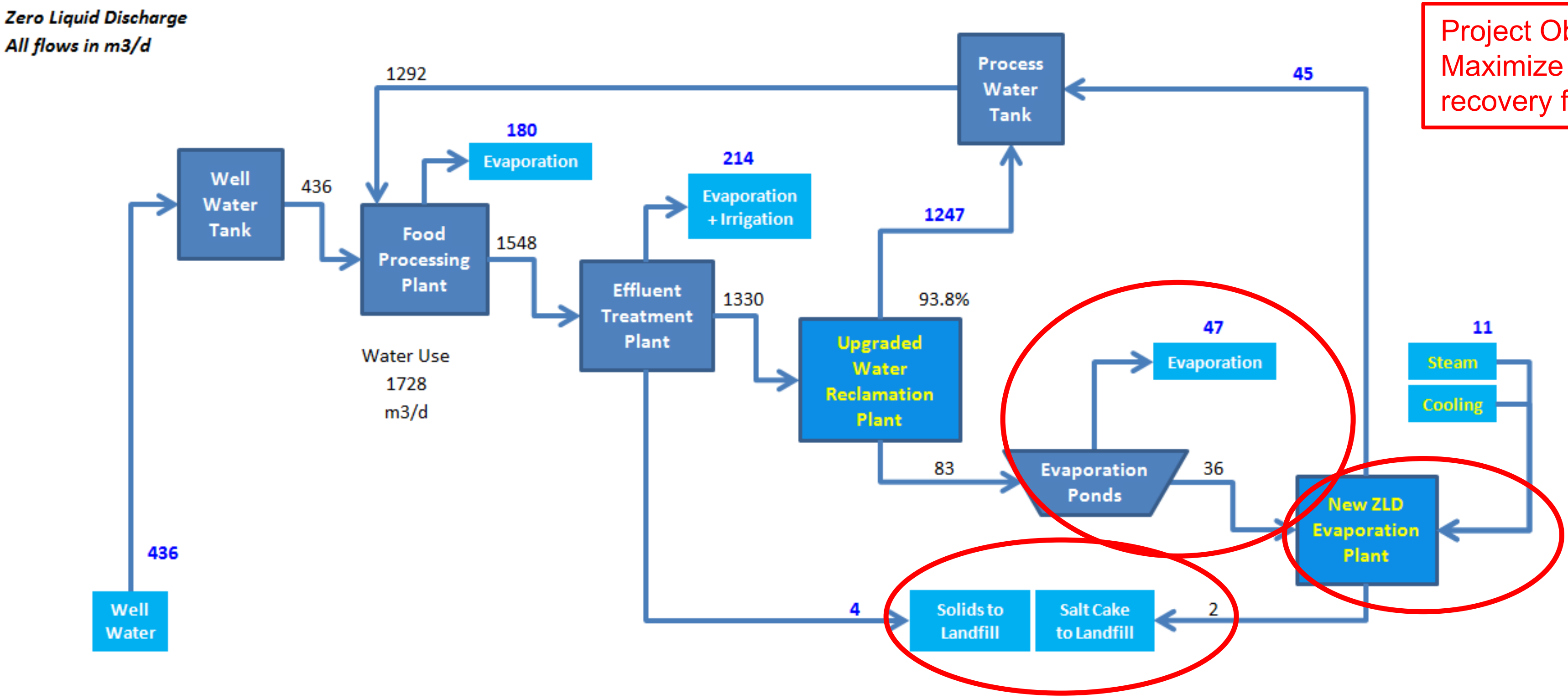

Fat Solids


Sludge

Recycle Reuse + Industrial Water

- Goal is to recover/reuse more water
- But, as recovery increases
  - **Concentration effects increase**
    - Cycle up solids, nutrients, salts, metals, organics
  - **Generate water -- difficult to treat/recover/clean for reuse**
    - May need to evaporate (costly)
  - **Generate byproducts/residuals challenging to treat/handle/dispose**
    - Impure sludges, salts, oils

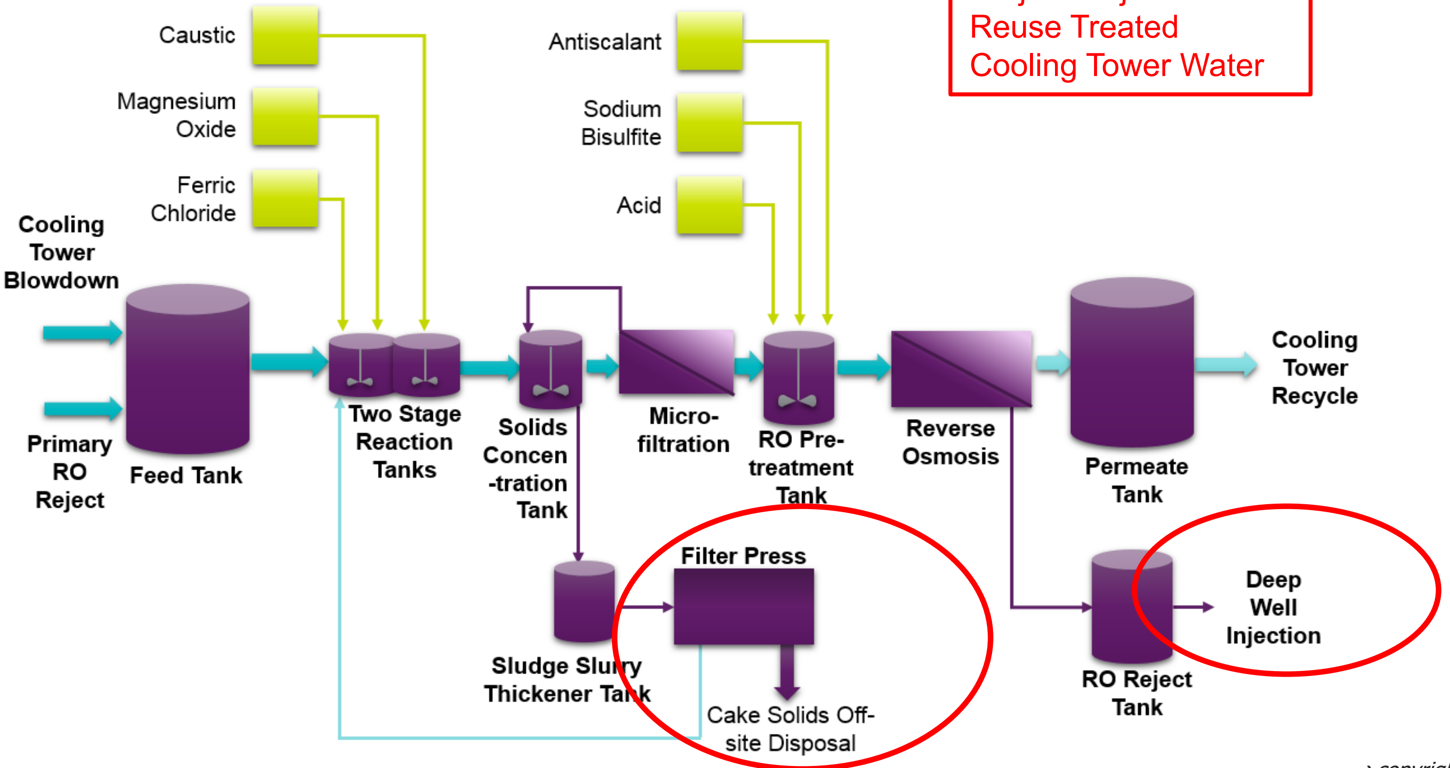
Example 1 – Food Processing Plant



Project Objective: Maximize water recovery for reuse

Example 2 - Refinery

Project Objective:
Reuse Treated
Cooling Tower Water



Byproduct Treatment, Disposal & Fate

- Concentration & Evaporation
- Drying/ Dewatering/Handling
- Sequester (Landfill, Deepwell Injection)
- Beneficial Use

Concentration & Evaporation Technologies

- Reverse Osmosis
- Brine Concentrators (BC)
- Crystallizers
- Spray Dryers
- Evaporation Ponds

Concentration & Evaporation

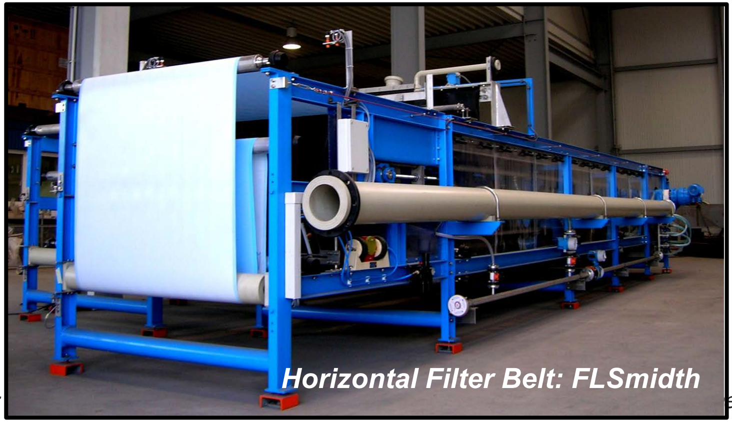
	Reverse Osmosis	Brine Concentrator	Crystallizer	Spray Dryer	Evaporation Ponds
+	1/10 energy as evaporators	Proven technology	Goes to Dryness	Goes to Dryness	Static Process
+	High water recoveries possible	High water recoveries possible (MVR)	Can treat water with high levels of TDS (up to 0.1%)	Rugged technology ….slurries with up to 20% solids as well as and mixed salts	Cost Effective
+	Lower capital cost and O&M cost vs. evaporators	Can configure to recovery a distillate or evaporate (atmospheric)	Ideal for crystallization of pure salts…..resale	Mechanically Simple	Possible benefit to birds
−	TDS Limited (up to 40,000 mg/L)	High energy consumption	May end up with unwanted low volume distillate	May not be economical without waste heat (I.e. use large amounts of natural gas)	Large footprint
−	May need pre-treatment (e.g. Multimedia filtration, phys-chem)	Does not go to dryness, produces a concentrated brine solution	High capital cost	Throughput	Climate dependent
−	Fouling & scaling potential	Process issues (e.g. foaming) – BC need solids pretreatment	Process & Technology is complex	Potential air emissions depending on configuration	Potential bird hazard

Dewatering Equipment

- Sludges & Slurries
- Impacts $ on many levels
- Equipment
  - Centrifuges
  - Horizontal Filter Belts
  - P&F Filter Presses
  - Variations/types of above


Centrifuge: Andritz


Plate & Frame Press: Evoqua


Horizontal Filter Belt: FLSmidth

Dewatering Equipment Comparisons

	Horizontal Filter Belt	Plate & Frame Filter Press	Centrifuge
Footprint	Large	Medium	Small
Labor	Low	Medium to High	Medium
Capital	Medium to High	High	Medium to High
O&M	Low	Medium to High	High (power & maintenance)
Level of Dryness	Dry	Moist to Wet	Moist to Wet
Technology	Vacuum or Gravity	Pressure	Spinning/Rotation
Batch or Continuous	Continuous	Batch	Continuous
Why Select	- When multi-stage washing of the particles is required - Ideal for discreet particle slurries, byproducts streams such as minerals, ores, chemicals (beneficial use)	- Rugged and wide application range - Sludges to Slurries	- Process large volumes (especially) with minimal solids - Ideal for separating oils, greasy fats

Landfill

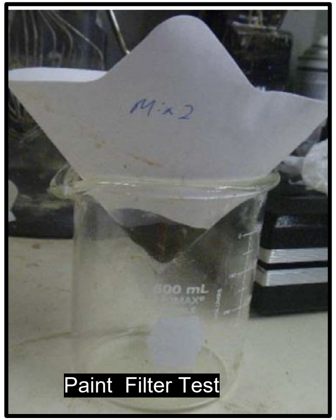
- Costs
  - Full characterization analysis to determine if waste is hazardous / non-hazardous
    - At minimum required 1x
    - Organics, wet-chem, TCLP (metals & semi-vols) parameters
  - Approximate *(Ballpark)* Landfill Costs
    - Hazardous $450/ton vs. Special $55/ton vs. Basic $11/ton
  - Waste Hauler Example Costs
    - Roll-Off rental ($275 per month…20-yard dumpster, 1/month)
    - Mobilization/Demobilization ($275),
    - Transportation ($1000/load)
    - Fuel/Insurance Surcharge (10%)
  - Need for condition or solidification of waste solids
    - Lime to raise pH (Lime ~ $120/ton)
    - Solids fixation

Roll offs


Filter Press Cake

Landfill (continued)

- Example criteria for landfilling Sludge & Filter Cakes
  - Cake Dryness
    - 25% minimum (typically)
  - Paint Test
    - Detects presence of free water in sludge/solids
  - TCLP
    - Measure of leachability



Paint Filter Test


TCLP


Hazardous Landfill

Conditioning & Fixation

- Conditioning
  - Lime Addition
    - Helps fixate metals
    - Neutralizes acidic properties
    - Increases dry matter
    - Helps destroy bacteria in sludges from bio process
- Fixation
  - Mix Portland cement, ash, binders to fixate for acceptable landfill properties
    - Brines and Salts Slurries
    - Maybe important process to couple with concentration & evaporation

Photo: Seneca Resources

Deep Well Injection (Development)

- DWI facilitated through Underground Injection Control (UIC) Program
- Regulated through EPA or primacy granted States
- Six class types of DWI
  - (I) Industrial and Municipal, (II) Oil & Gas related, (III) Solution Mining, (IV)Shallow Hazardous & Radioactive, (V) Non-Hazardous Fluids/Drinking Water, (VI) CO2 Sequestration
- Class I most regulated, can be used for RCRA hazardous wastes
  - Composition determines RCRA
    - e.g. Organic wastes/solvents (flammable, explosivity) and Inorganic (ppm levels of arsenic)
- Takes Time and $
  - Application, Review (6 mos. minimum) followed by 30-day public comment periods
  - Millions $ to develop & drill
  - Thousands $ for monitoring & annual O&M
- https://www.epa.gov/sites/production/files/2015-07/documents/study_uic-class1_study_risks_class1.pdf

Deep Well Injection Considerations

- Issues
  - Damage to formation
  - Plugging & Scale
    - Fines
    - $CaCO_3$, $CaSO_4$, $BaSO_4$, $SrSO_4$
    - Si, CaF_2, PO_4, Fe compounds
  - Corrosion
- Good Industry Practices
  - Filtration -Free of Fines
  - Anti-corrosion additives
  - pH control additives
  - Additives to limit migration
  - Anti-scalant additives
  - Chemical or mechanical degas for O_2, CO_2, H_2S

Deep Well Injection Example

- Shale Gas Industry Produced Water
  - Pay trucking and disposal costs to DWI at 3rd party facility
    - Trucking
      - ~ Hauling cost is $1 / bbl. / hour transport
        - ~$100 / hr. based on a haul of 100 barrels or 4,500 gallons.
    - Disposal Charge
      - ~$1 to $5 / bbl. (Class II) depending on part of country

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Note: bbl = 45 gallons

Beneficial Recycle / Reuse

- Byproducts may have beneficial use
  - Salts & Brines and Minerals
    - Chemicals & Additives
      - e.g. Sodium Sulfate $130/ton, Calcium Chloride (dry) $250/ton
      - Gypsum (calcium sulfate) for wallboard, plaster mixtures, and construction amendments
      - **BUT there are purity, demand, cost justification barriers**
        - Water treatment systems are not necessarily designed to deliver the needed purity
    - De-icing applications
      - Cleanliness concerns, legal restrictions, logistical impediments
  - Sludge Metals & Nutrients
      - Example: Metals customer is sending filter cake (dewater clarified sludge enriched with metals…Ni, Cr, Ti) to another facility where it is beneficially used/sold due to its high metal content. Customer generates 60 tons of cake /month
  - Oils
    - Oil recycling / waste handling company (e.g. Clean Harbors, Heritage)


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Wrap-up

Workshop Goals

1) Water quality drives design
2) Options to get from point A to point B
3) Unbiased comparison of popular flowsheets
4) Review currently used and emerging technologies
5) Balancing cost and reliability
6) Lessons learned – avoiding pitfalls

Round Table

1) What are your experiences with water reuse?
2) What do you think is the biggest challenge for water reuse?
3) What do you think future plants will look like?

Thank You!

- Attendees
- Facilitators/Speakers
- IWC
- All Our Clients


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INDUSTRIAL WATER REUSE
A ROADMAP FOR THE FUTURE

IWC Workshop W7

Case Study – **Not a Site Wood has worked on**

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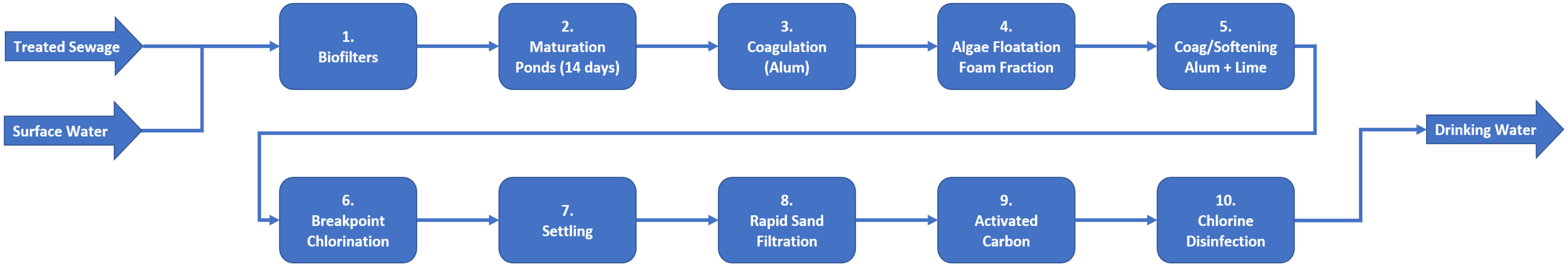
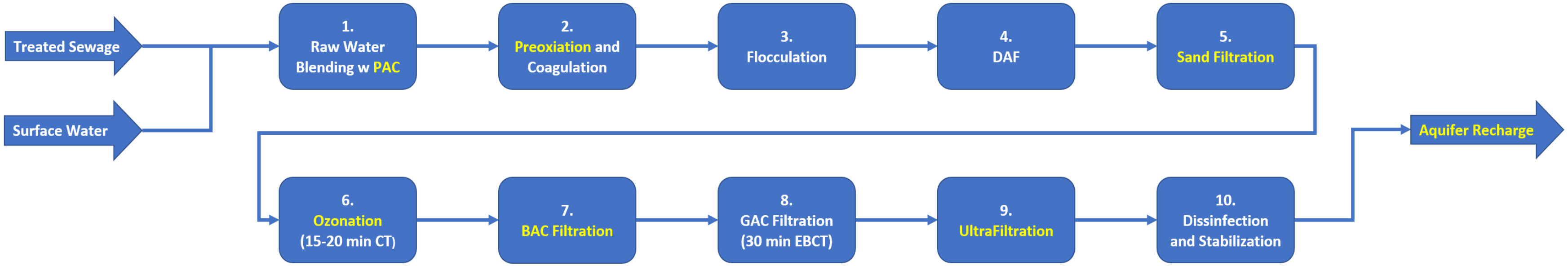
1. City of Windhoek, Namibia

- Direct Potable Reuse since 1968!

Old Goreangab Reclamation Plant (OGRP): 1968 to 1971



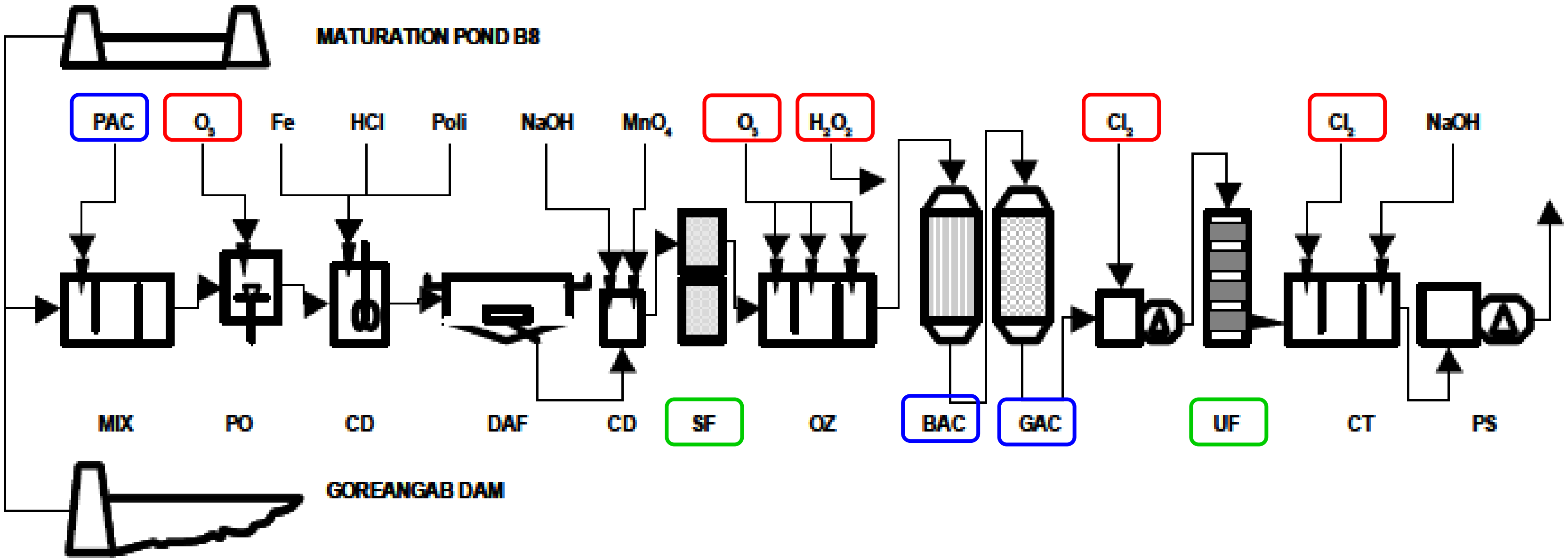
New Goreangab Reclamation Plant (NGRP): 2002 to Current (WINGOC)



Source: J. Menge (City of Windhoek), 2006

Process Design (Current)

Project Objective:
Resolve Water Scarcity



Source: J. Menge (City of Windhoek), 2006

Lessons Learned

1. Rigorous and continuous quality monitoring (COD, DOC)
2. Blending of reclaimed water with conventional treated water – 35%. Switched from DPR to Aquifer Recharge
3. Critical Processes require multiple barriers (back-ups)
   - Adsorption of residual organics (PAC, BAC, GAC)
   - Oxidation / disinfection of recalcitrant organics and pathogens (O_3, O_3, H_2O_2, Cl_2, Cl_2)
   - Filtration for reduction of Turbidity (SF, UF)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Case Study

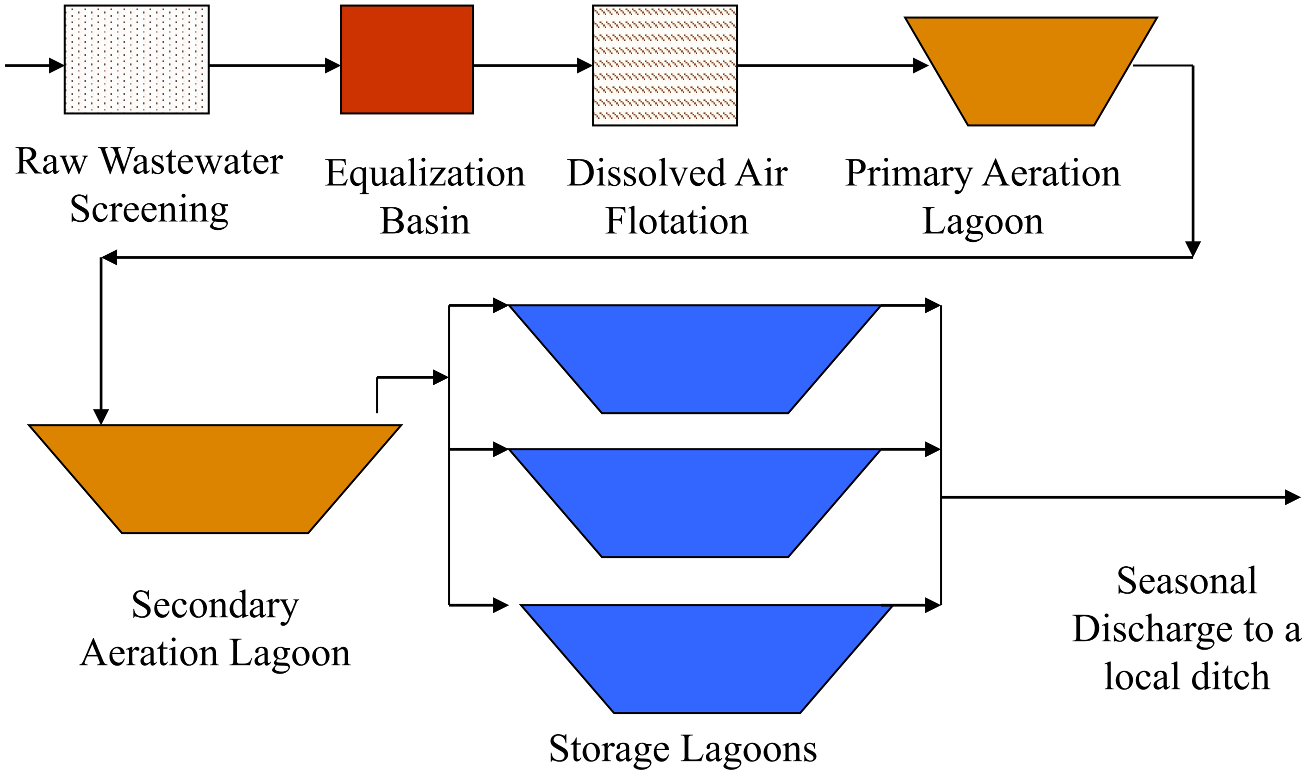
Discussion Outline

- Background
- Existing Treatment Facility
- Drivers for Water Recycling
- Regulatory Requirements (CFIA)
- Further Steps

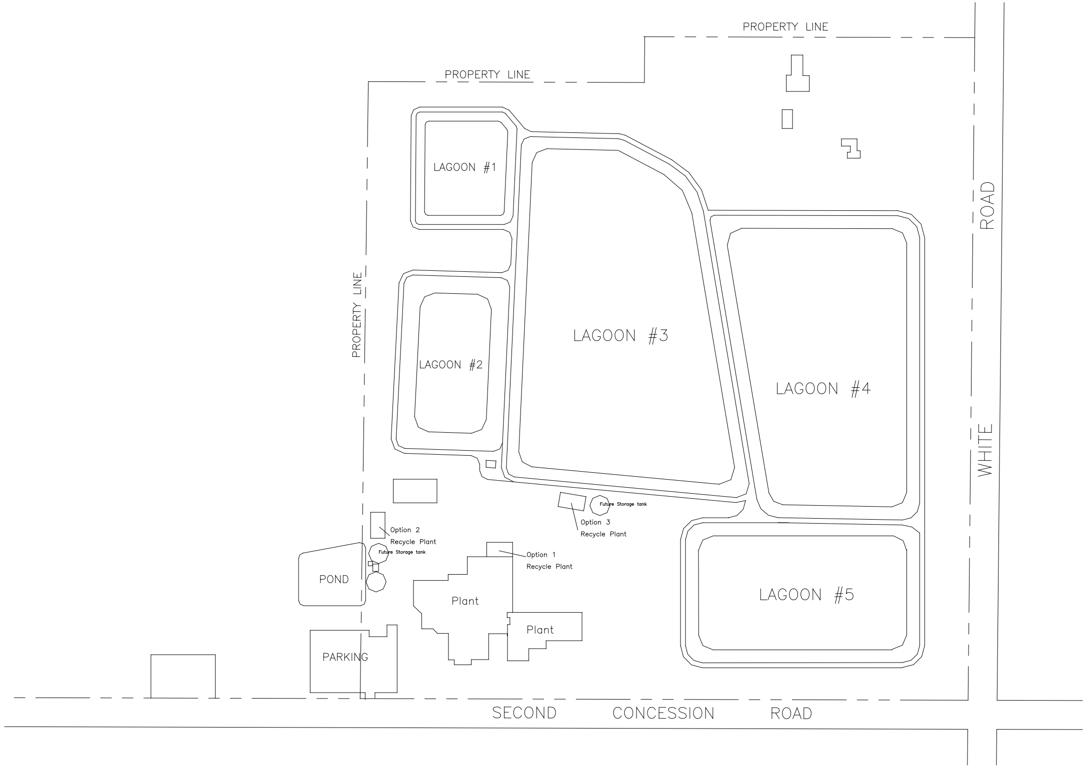
BACKGROUND

- Federally Inspected Poultry Processing Facility
  - 300,000 birds per week kill capacity with 1 kill shift operation
  - 300,000 gallons per day water use
  - Water is supplied by the Town of Port Colborne via a 2 mile long pipeline
  - Water costs were high and increasing

Wastewater Treatment System



Treatment System Layout



Discharge Requirements

Parameter	Allowable Effluent Concentrations
5-day carbonaceous Biological Oxygen Demand (cBOD5)	25 mg/L
Total Suspended Solids (TSS)	25 mg/L
Ammonia (NH3-N)	10 mg/L
Total Phosphorous (TP)	1 mg/L

Drivers for Water Recycling

- Why Consider Water Recycling?
  - Limitation on Volume of Water Discharged from their Treatment System
  - Facility Looking at Future Production Increase
  - Increase in Wastewater Flow Results in More Stringent Discharge Parameters

  - This Would Result in a Requirement for Advanced Wastewater Treatment
  - Is Recycle More Cost Effective Than Treatment Upgrades?

System Considerations

- Concept to Reuse up to 50% of Water Discharged
- Water to be Used in Front End of Facility Only
- System Must be Capable of Meeting All Water Quality Requirements According to CFIA
- Must Use Lagoon Water from Storage Lagoons

Regulatory Requirements

- Water Criteria Would be Based on Meeting Health Canada Water Quality Requirements
  - Bacteriological Testing
  - Chemical Parameter Testing
  - Pesticide Testing
- No Specific CFIA Operational/Physical System Requirements
  - No membrane system requirements (positive barrier)

CFIA Water Quality Requirements

Bacteriological	Objective = 0 Total Coliform Total Plate Count < 500/mL
Chemical	Metal Concentration Limits Pesticide Limits
Physical Characteristics	Clear without offensive taste or odor

USDA Regulatory Requirements

- USDA Addresses Water Recycling and Has Policies in Place for Reuse of Treated Wastewater in Potable Areas
  - Treatment facility may not treat any human waste
  - Reuse water lines identified and separate from potable water lines
  - Dual back flow prevention valves
  - Water must meet EPA “Safe for Intended Use” Criteria

USDA Regulatory Requirements

- Similar to CFIA water must meet EPA “Safe for Intended Use” Criteria
  - Microbial Requirements
    - Total Plate Count < 500/mL
    - Free of Total Coliform
    - Free of E. coli
  - Chemical Requirements
  - Physical Requirements
    - Low Turbidity (< 1 NTU)

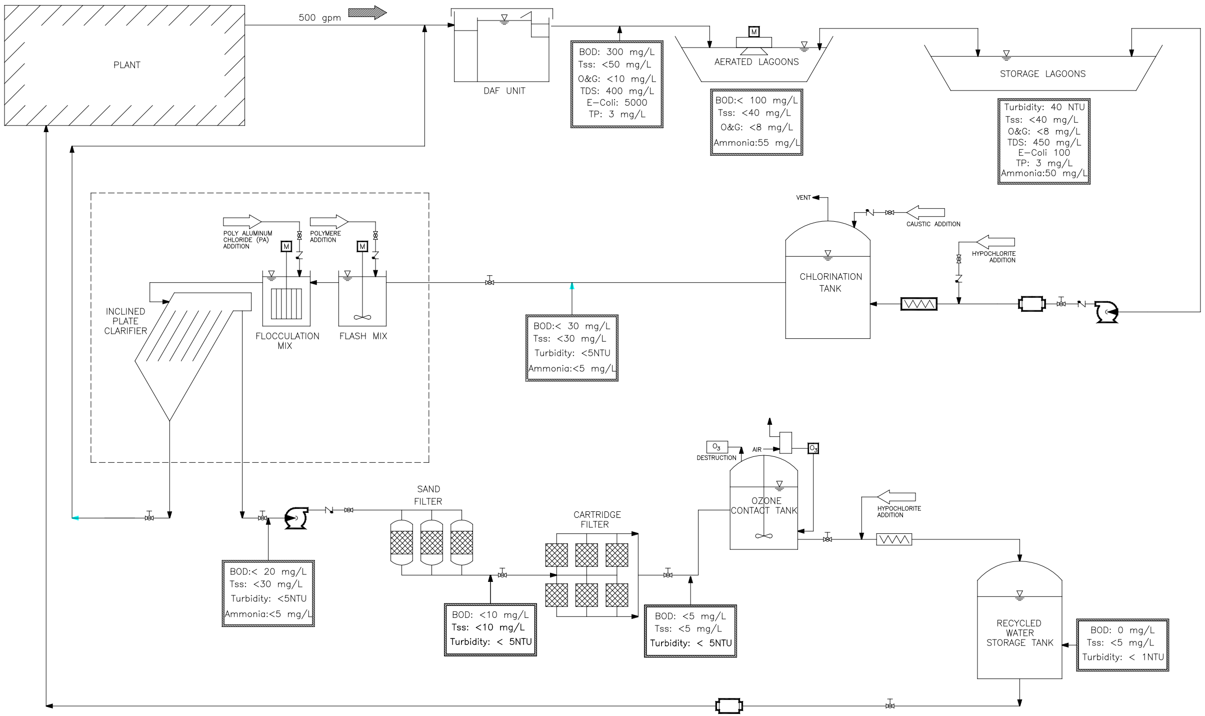
Existing Water Quality

Lagoon #3 Comparison with the Canadian Drinking Water Quality Guidelines				
Parameters	**Sample**	**Units**	**Canadian Drinking Water Guidelines**	**Units**
Standard Metals				
Boron	12	mg/L	5	mg/L
pH	8.77			
Volatile Organics				
14 Compounds	All Samples Meet Health Canada Guidelines			
Turbidity	41	NTU	1	NTU
Total Dissolved Solids	580	mg/L	<500	mg/L
Pesticides List 1& 2 O Reg 170/03				
34 Compounds	All Samples Meet Health Canada Guidelines			
Colour Apparent	180	C.U.	<15	C.U.
Nitrate-N	<0.3	Mg/L	45	mg/L

System Preliminary Design

- Treatment System Developed for 300 gpm of Recycled Water Based on Work with Zentox
- Treatment System Concept:
  - Suspended Solids Removal
  - Sand Filtration
  - Fine Filtration
  - Ozonation
  - Chlorination

System Preliminary Design



Overall Recycled Water Costs

- Current Municipal Water Costs
  - $0.30 to $1.10/m^3
- Recycle Water Operational Costs
  - $0.31 to $0.80/m^3
- Recycled Water Costs with Capital Investment
  - $0.81 to $1.60/m^3

Next Steps...

WHY?

- Uncertain regulatory environment & approval
- Concerns about public perception
- Early adopter uncertainty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INDUSTRIAL WATER REUSE NEW TECHNOLOGIES AND LESSONS LEARNED

IWC Workshop W-07

Case Study

Beneficial Water Reuse

Palo Verde Nuclear Power Plant

- Most nuclear power generating facilities use river or seawater to cool reactors, Palo Verde uses treated effluent water from 91st Avenue Wastewater Treatment Plant (WWTP)
- Only nuclear power generation facility in the world that is not located on a major body of water
- Make up for evaporation rate of cooling towers
  - Winter: 40,000 gpm [58 mgd or 2.6 m^3/s]
  - Summer: 60,000 gpm [86 mgd or 3.8 m^3/s]
  - 26 billion gallons (~100,000,000 m^3) treated water evaporated / yr.
- Operational since 1988

Palo Verde Nuclear Power Plant Statistics

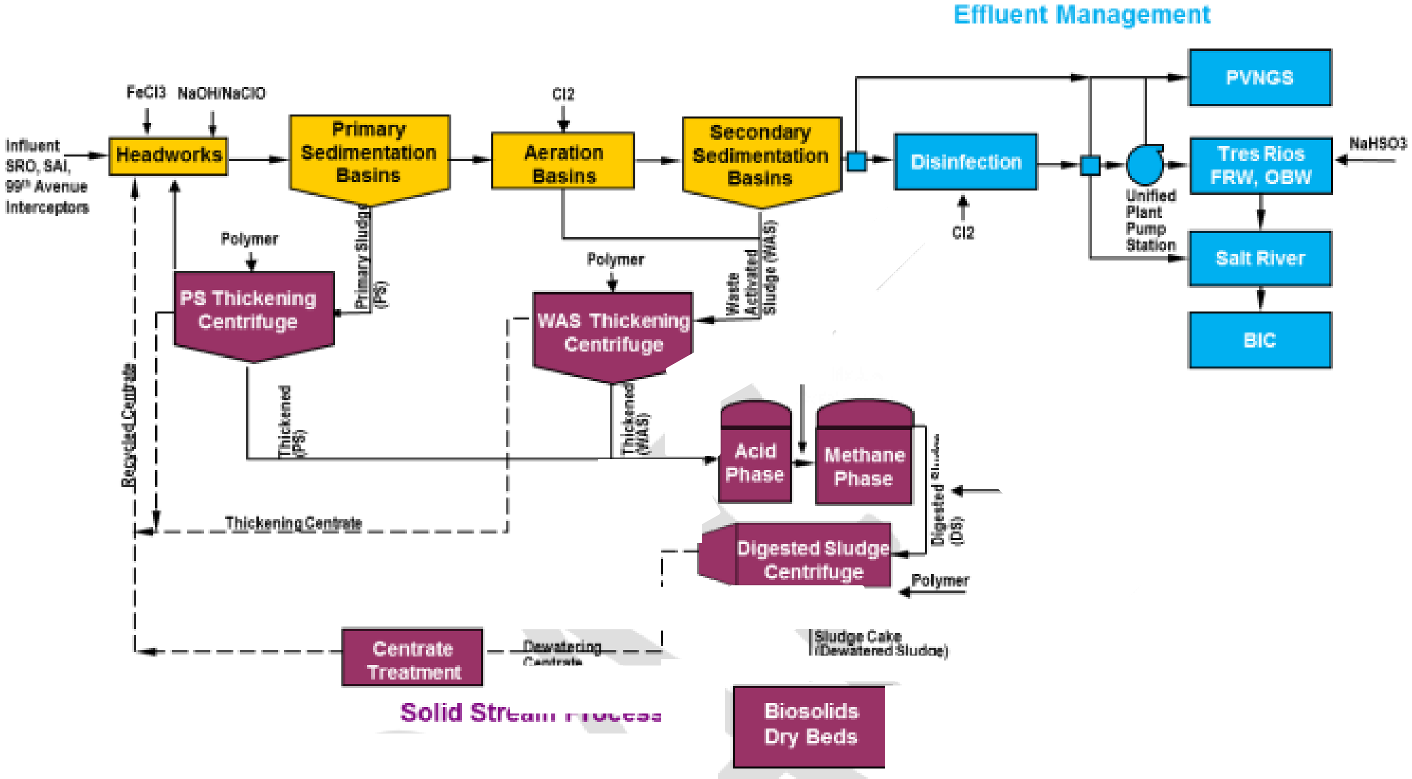
- Nation's largest nuclear power plant
- Located 45 miles (72 km) due west of downtown Phoenix, Arizona
- Provides 70 percent of state's clean energy. *No carbon emissions. No air pollutants.*
- **Emissions Offsets:**
  - **484 million tons of carbon dioxide *(equivalent to 84 million cars for one year)***
  - **253,000 tons of sulfur dioxide**
  - **618,000 tons of nitrogen oxide**
- Year after year, recognized for safety and reliability by Institute of Nuclear Power Operations and Federal Nuclear Regulatory Commission (NRC)
- Each nuclear reactor (total 2) produces 1.45 Giga Watts of electric power

Palo Verde Nuclear Generation Site

Municipal Wastewater Treatment

- **91st Avenue WWTP** jointly owned by Sub-Regional Operating Group (SROG) Cities of Glendale, Mesa, Phoenix, Scottsdale and Tempe. Operated by City of Phoenix
- WWTP serves a population ~ 2.5 million
- Processes an average of about 140 MGD. Major portion of treated effluent is conveyed to the Palo Verde Nuclear Generating Station for reuse.
- Includes: **screening, grit removal, primary sedimentation (with enhanced sedimentation), activated sludge biological treatment (MLE), secondary clarification, chlorine disinfection, centrifuge thickening of sludge, anaerobic sludge digestion, centrifuge dewatering of digested sludge, and sludge drying beds**

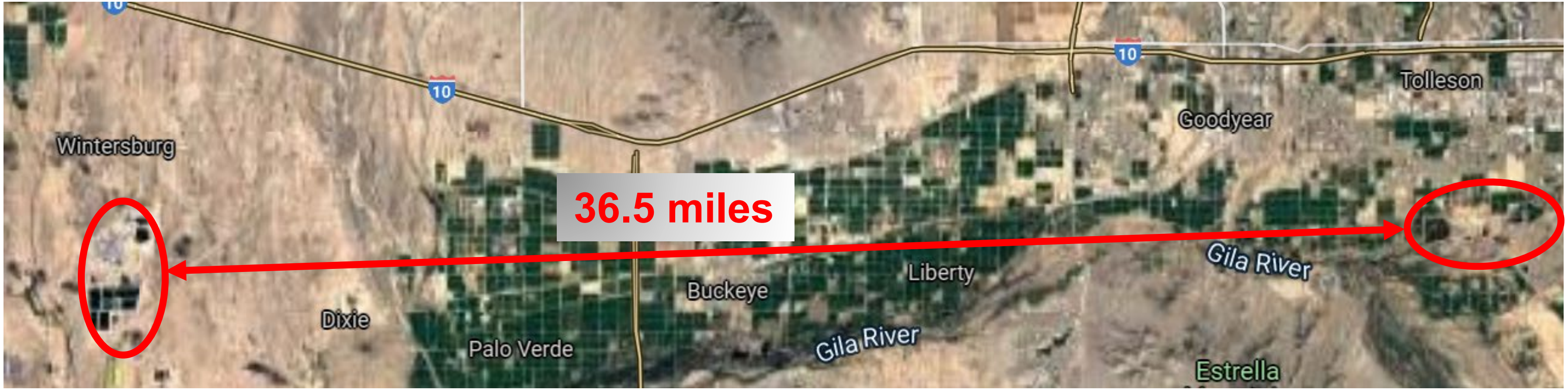
SROG Wastewater Treatment

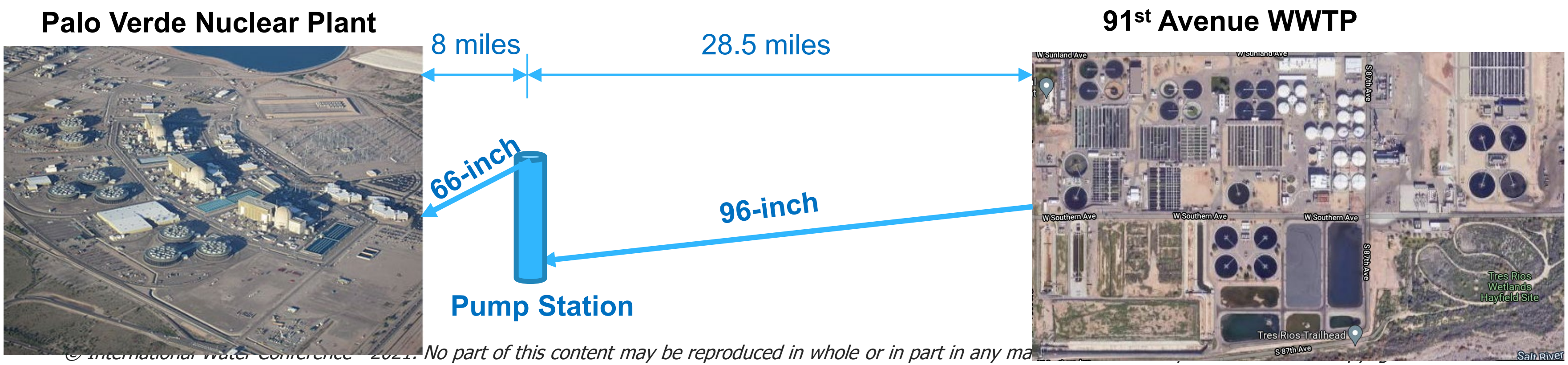


Other Environmental Benefits

- ~70 MGD of effluent discharges to constructed 700-acre “Tres Rios” Wetlands
- WWTP converts biogas, byproduct of anaerobic digestion, into renewable energy
  - Benefits regional economy (product sale)
  - Reduces greenhouse gas emissions.
    - **Emissions offset equivalent of 44,671 metric tons of CO_2 per year -- equal to 70,500 cars taken off the road annually**
- **Nuclear Power Station Water Reuse:**
  - Contracted for 24 billion gallons/year (2.2 billion gallons/year from Tolleson)
  - Effluent flows 100 feet downhill for 28.5 miles
    - 6 miles of 114-inch and 22.5 miles of 96-inch diameter pipe to Hassayampa Pumping Station
    - Pump station lifts flow 125 feet
    - 8 miles (66-inch diameter pipe) to Palo Verde Nuclear Plant

Conveyance Pipeline System

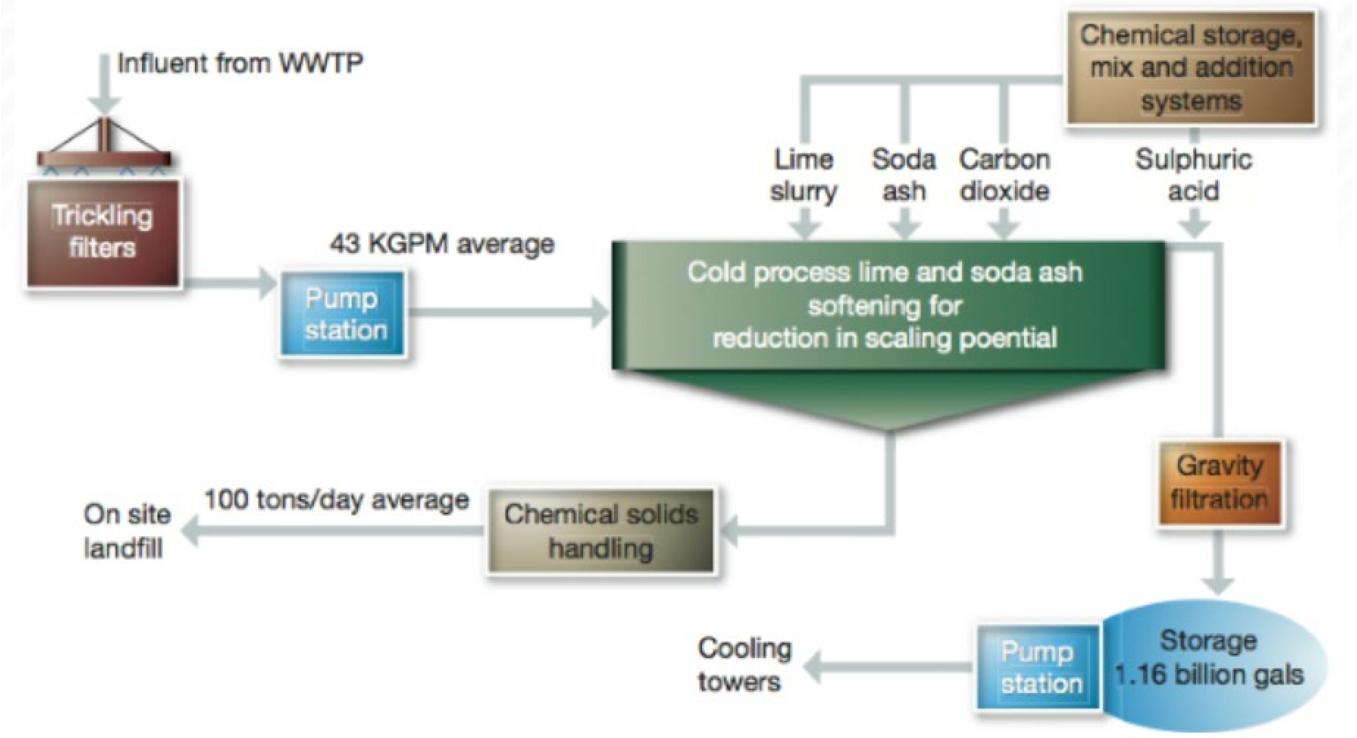




Palo Verde Water Treatment

- Three forced-air cooling towers evaporates between 13,500 to 18,500 gpm / unit.
- **Three-Stage Water Treatment Process:**
  - **First Stage:** Biological Treatment (reduction of ammonia): trickling filters (biological growth on plastic media)
  - **Second Stage -** Lime Soda Softening: Slaked lime is added to first set of solids contact clarifiers -- pH elevated to 11.2 -- scales settle and removed as a heavy sludge. In second set of solids contact clarifiers -- pH lowered to 10.2 by adding CO_2 and with addition of soda ash -- precipitates calcium to reduce hardness
  - **Third Stage -** Dual Media Filtration: Flow adjusts pH to 9.2 before distribution to 24 filters (anthracite coal over sand)
- Effluent quality is controlled on calculated solubility of constituents. Solubility indices were established from extensive testing to determine scale potential. Solubility index for calcium carbonate, fluoride, phosphate and sulfate are derived from real-time data.

Palo Verde Treatment



Water Storage and Evaporation Ponds

- **Water Reservoirs** (one billion gallons):
  - Reservoir 1: 788 million gallons, 85-acre (34.4 ha)
  - Reservoir 2: 372 million gallons, 50-acre (20.2 ha)
  - 60 mm-thick inner and outer HDPE liners
- **Evaporation Ponds:**
  - three rectangular evaporation ponds
  - 650 acres (263 ha)
  - Zero liquid discharge

Water Reservoirs

Evaporation Ponds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IWC Workshop W-07

Case Study

A UNIQUE HIGH RECOVERY SECONDARY RO TO RESOLVE REFINERY SOURCE WATER AND BRINE DISPOSAL ISSUES

IWC 17-18

Authors: Ed Greenwood, John Christiansen, Scott Denton, Dan Kwcienski, Bob Kimball

wood.

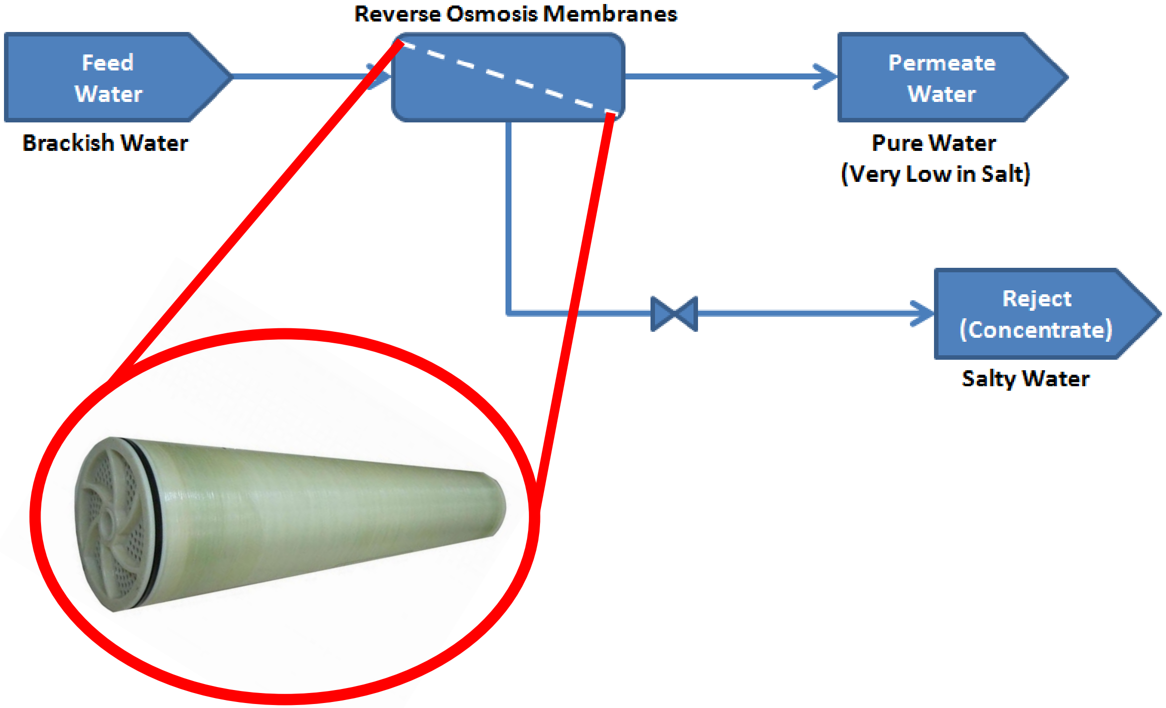
ABSTRACT

Wood Environment and Infrastrucuter designed and constructed a unique high recovery Secondary RO system at a Refinery in New Mexico to resolve source water and wastewater disposal limitations. The new system is directly coupled to the Primary RO System and operates beyond the solubility limits for Silica and Calcium Sulfate by using a unique high recovery three stage array with both permeate and concentrate recycle loops to optimize performance.

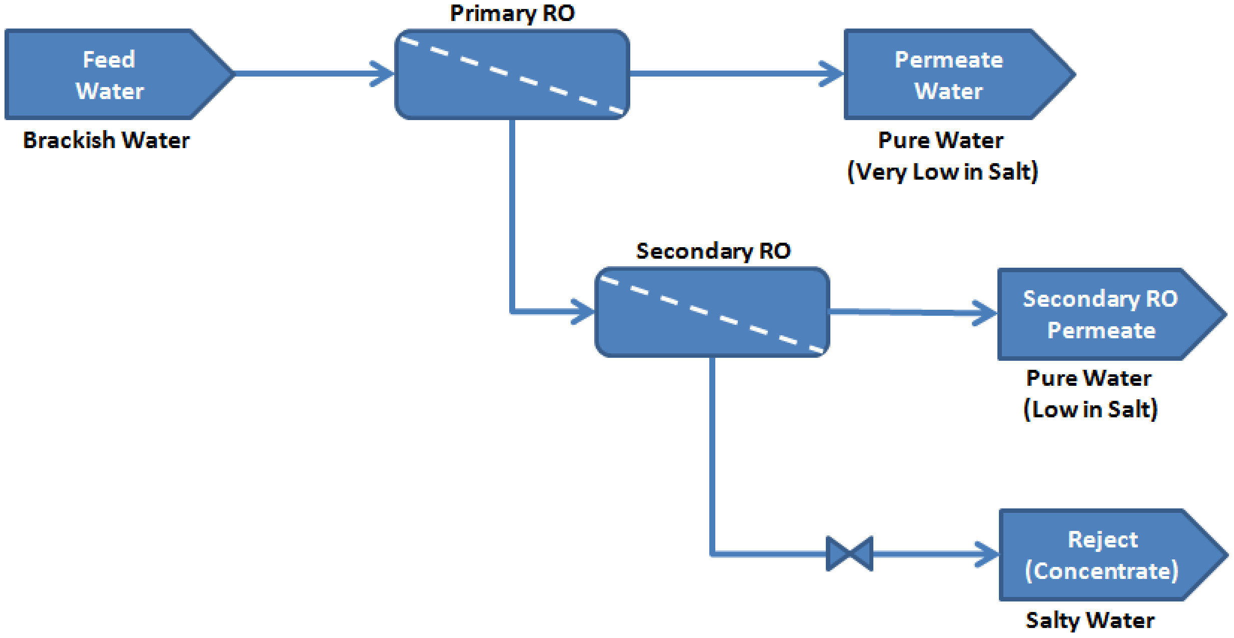
Agenda

1. RO Basics
2. Our Client
3. Our Challenge
4. Our Solution
5. The Results
6. Discussion

RO Basics

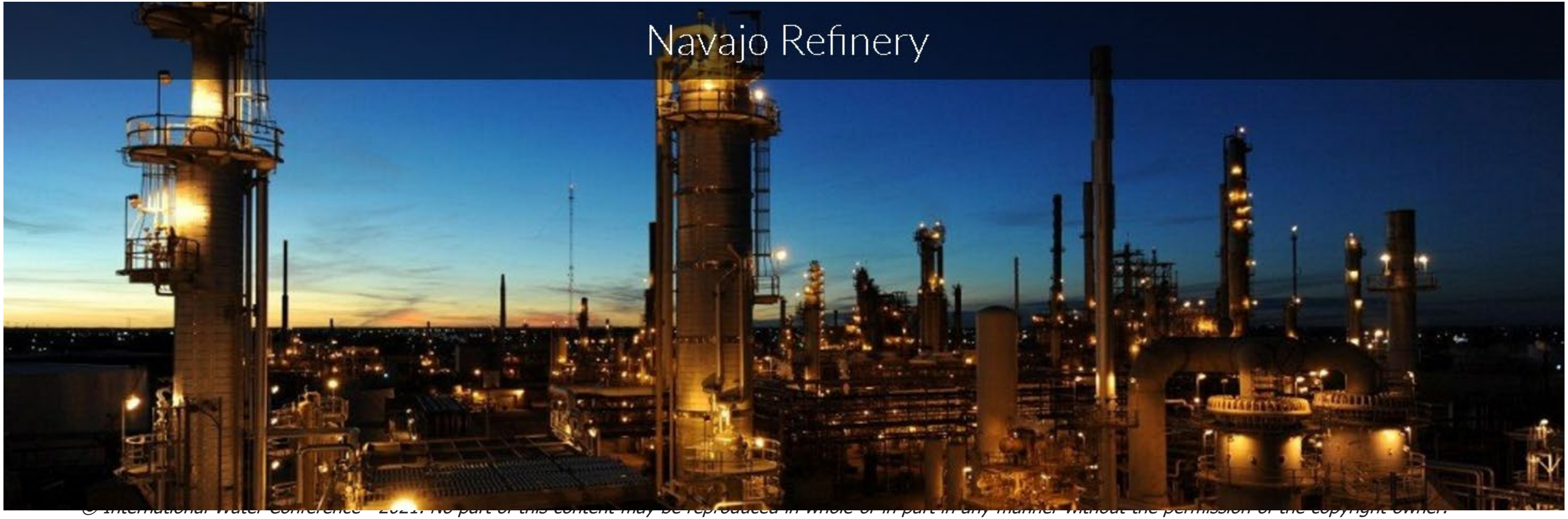

Reverse Osmosis Membranes
Feed Water
Brackish Water
Permeate Water
Pure Water
(Very Low in Salt)
Reject (Concentrate)
Salty Water

RO Basics


Primary RO
Feed Water
Brackish Water
Permeate Water
Pure Water (Very Low in Salt)
Secondary RO
Secondary RO Permeate
Pure Water (Low in Salt)
Reject (Concentrate)
Salty Water

Our Client

- Navajo Refining Co. (NRC) is a 100,000 bbl/d complex
- Artesia is a city of 12,000 located in South Eastern New Mexico



Our Challenge

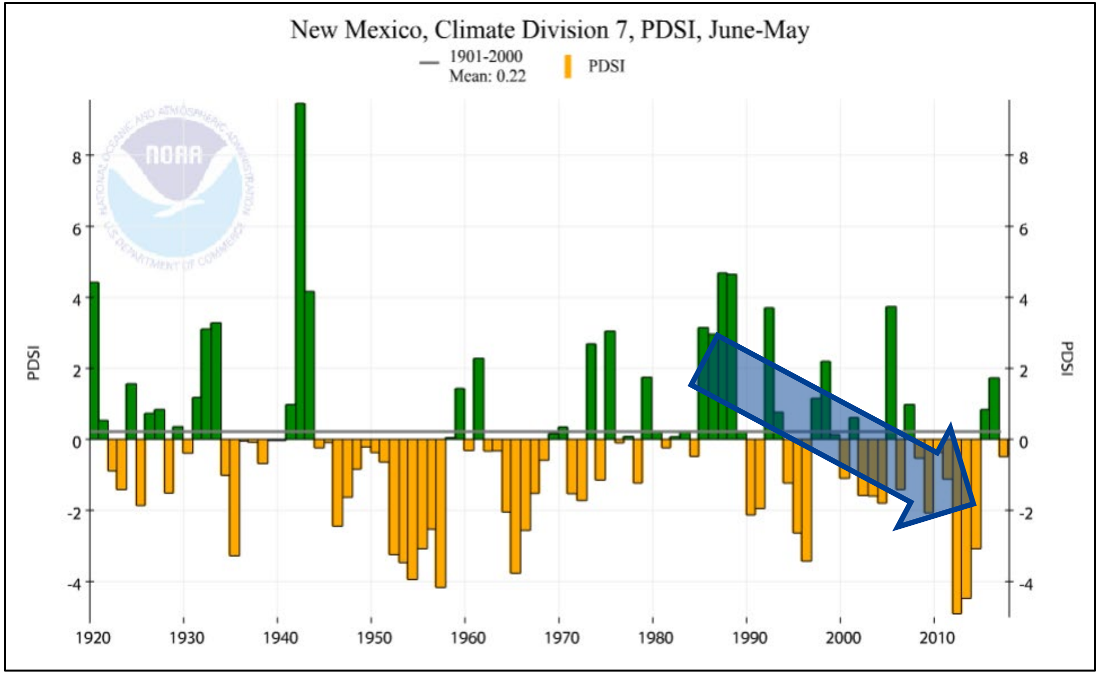


Figure 1: Palmer Drought Severity Index for South Eastern New Mexico

Our Challenge

2.6 mgd of Groundwater

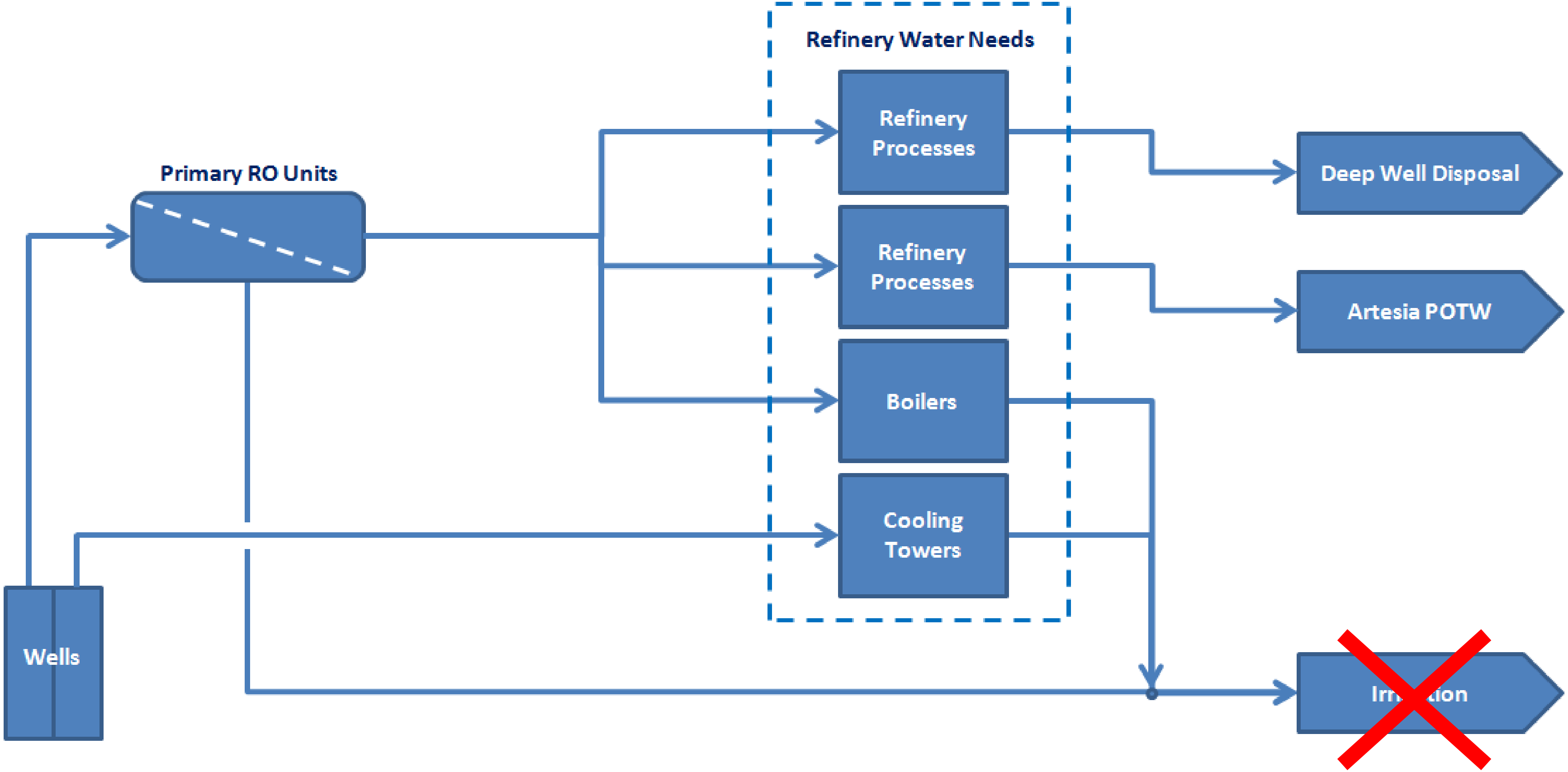
Up to 1400 mg/L of TDS (Salt)

Wastewater disposal issues

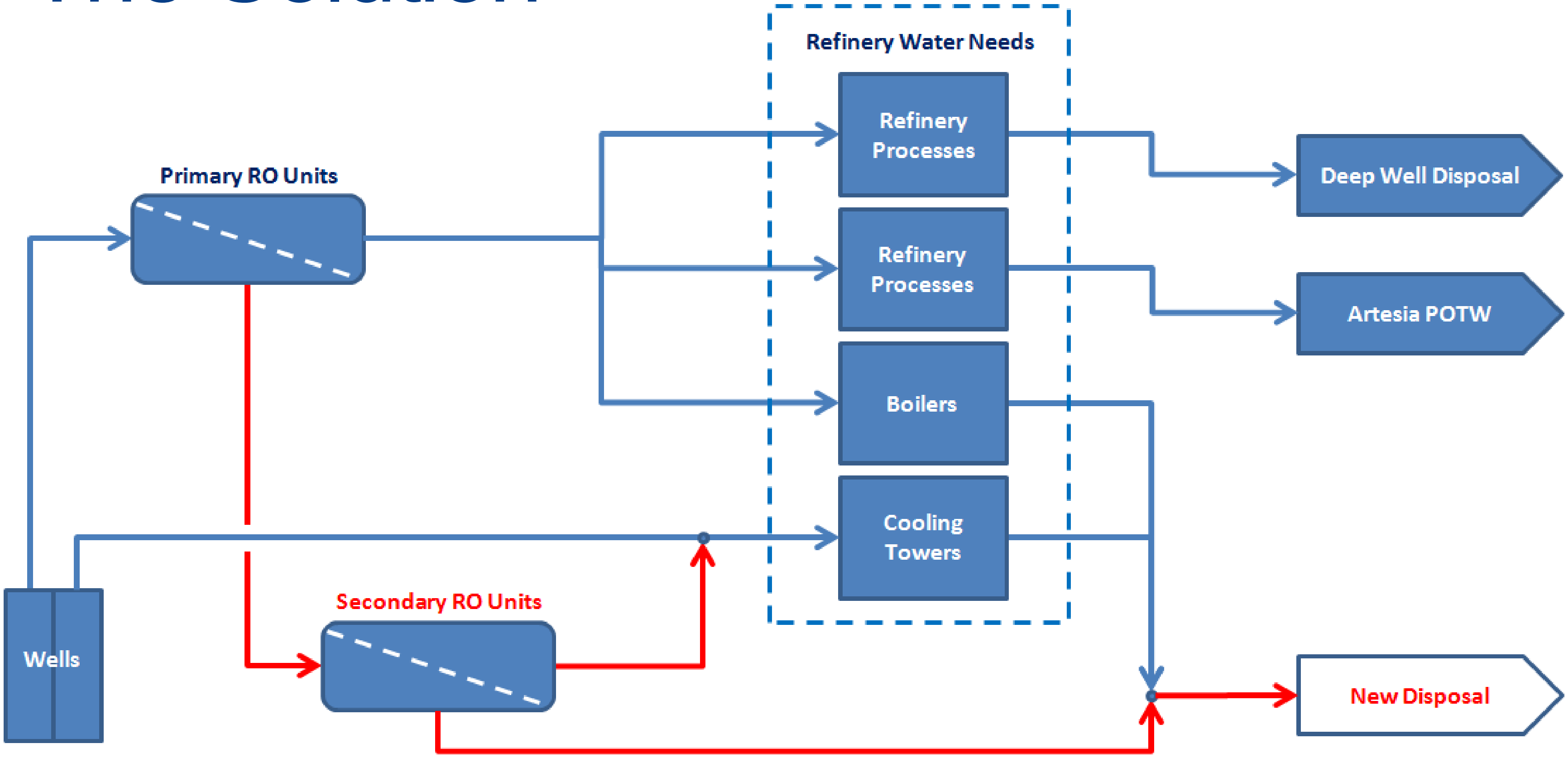
Wastewater Disposal is Complex

- Salty wastewater (RO Reject) is currently irrigated onsite
- Oily wastewater is treated by Refinery's WWTP then discharged to the City
- Other wastewaters pumped into deep wells

Water Balance



The Solution



The Solution

1. Expand the Primary RO

- More process water
- More salty wastewater to dispose

2. New Secondary RO system

- Squeeze more water from the waste
- Minimize disposal needs

3. Disposal of Secondary RO Reject

- Option 1 – New Deep Well
- Option 2 – New Softener System
- Option 3 – Evaporation Ponds

Squeeze out
as much pure water
as possible

Maximize flexibility and
reliability

Resolve the
wastewater
disposal issues

Our Challenge

- Recovery of the Primary RO limited to between 60% – 75%
- Fluxrates were ok, however, feed flows were low and stages were unbalanced with respect to concentration polarization
- Pretreatment of the Feed was limited (pH Control)
- O&M issues with corrosion of the permeate piping
- Post treatment of the Permeate was limited (FDD)

Overall the performance was acceptable
… because the RO Reject was irrigated

Our Challenge

Primary RO Reject (Secondary RO Feed)			
Flow	gpm	500	
TDS	mg/L	4864	
Calcium	mg/L	692	High
Magnesium	mg/L	219	High
Sodium	mg/L	424	
Bicarbonate	mg/L	1027	High
Chloride	mg/L	454	
Sulfate	mg/L	1963	High
Silica	mg/L	43	High
pH		7.8	

Our Challenge

Understanding Scaling

- Calcium Carbonate
- Calcium Sulfate
- Silica

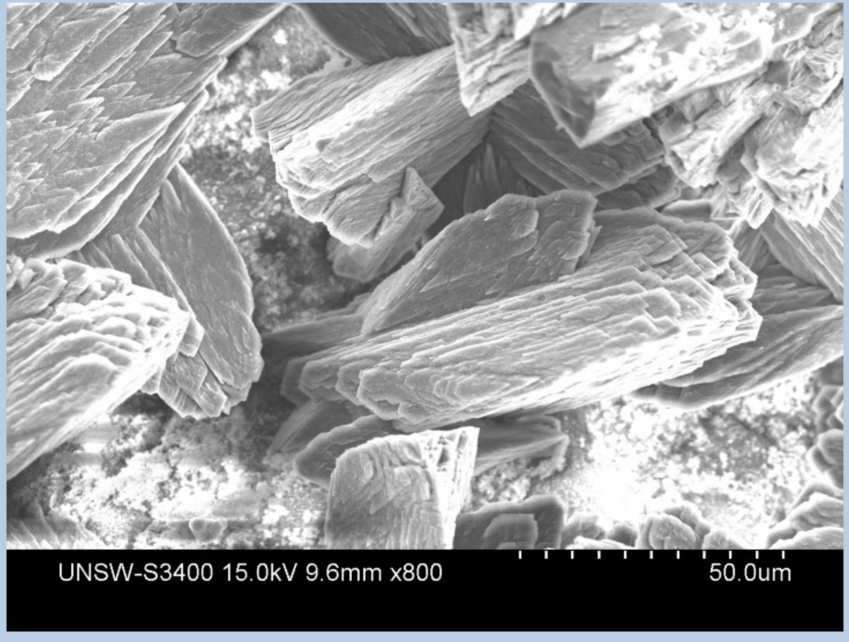
Calcium Carbonate Scaling

Effective methods of control:

- pH Adjustment
- Antiscalant addition

→ Adjust the pH until the Langlier Saturation Index (LSI) is negative. Shift equilibrium away from $CaCO_3$ precipitation

$Ca^{++} + HCO_3^- \leftrightarrow H^+ + CaCO_3$



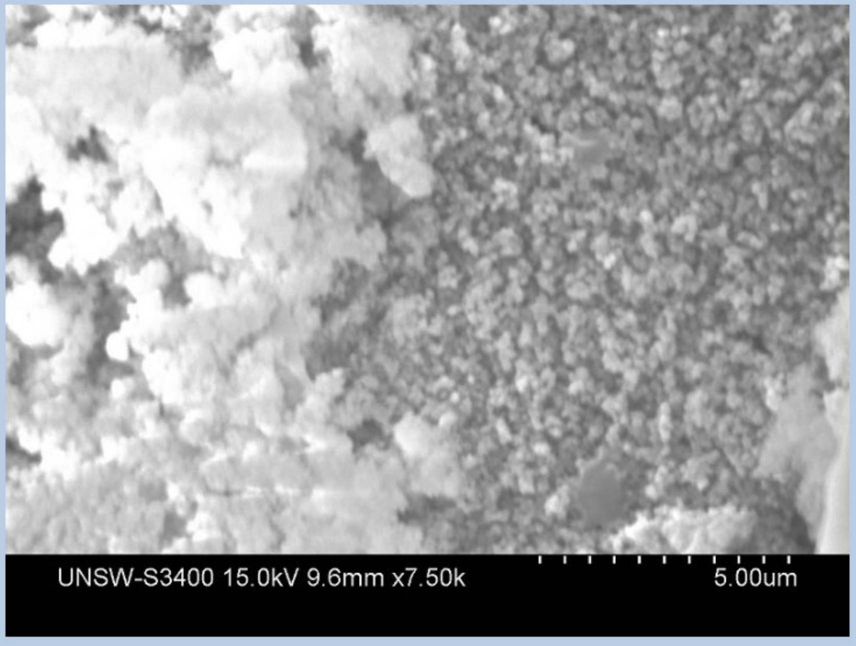
Rhomboidal calcium carbonate crystals with underlying silica fouling.

Silica Scaling

Silica is present in two forms:

- Non-reactive / Colloidal / Particulate
- Reactive / Soluble

→ Optimized Antiscalant selection and use



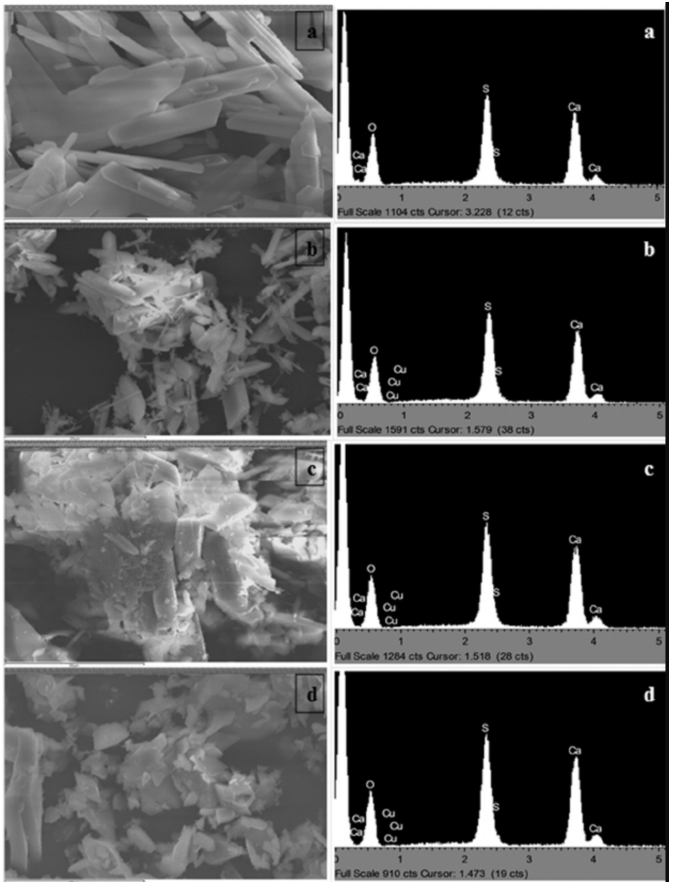
Silica fouling.

Calcium Sulfate Scaling

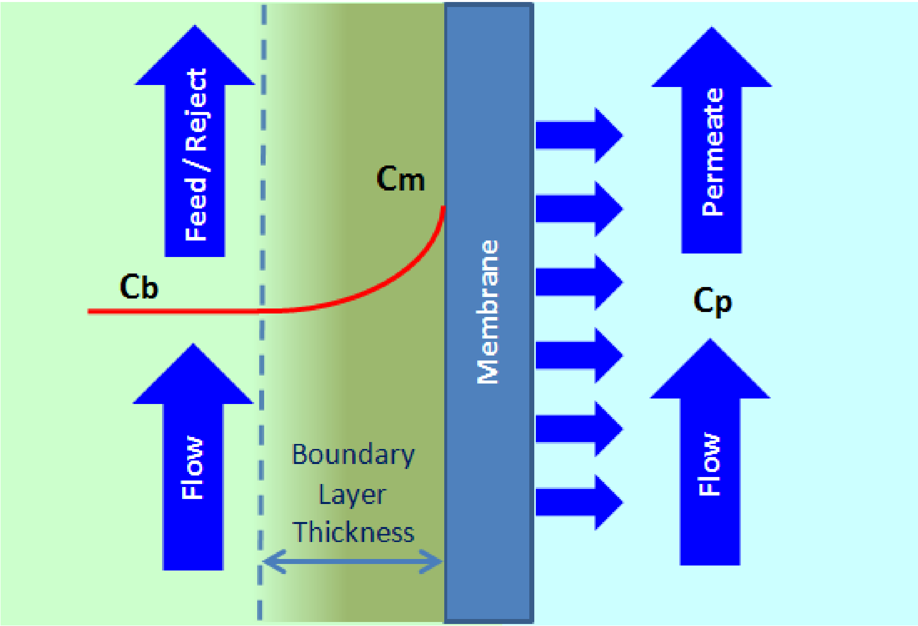
Background:

- Generally not pH dependent
- Antiscalants may have limited effectiveness
- Relatively slow rate of precipitation

→ Optimize design to minimize concentration polarization / maximize cross flow velocity



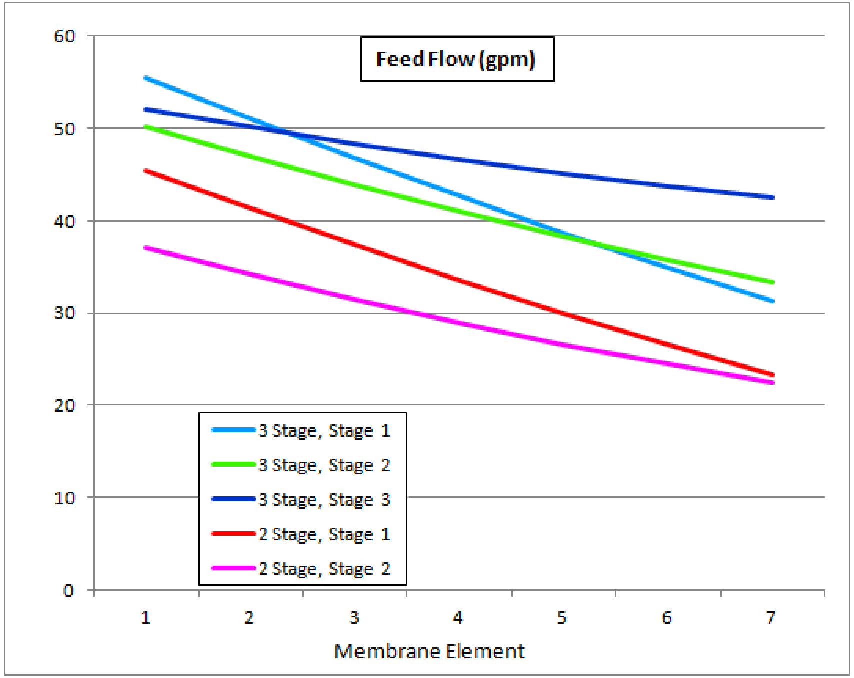
Concentration Polarization

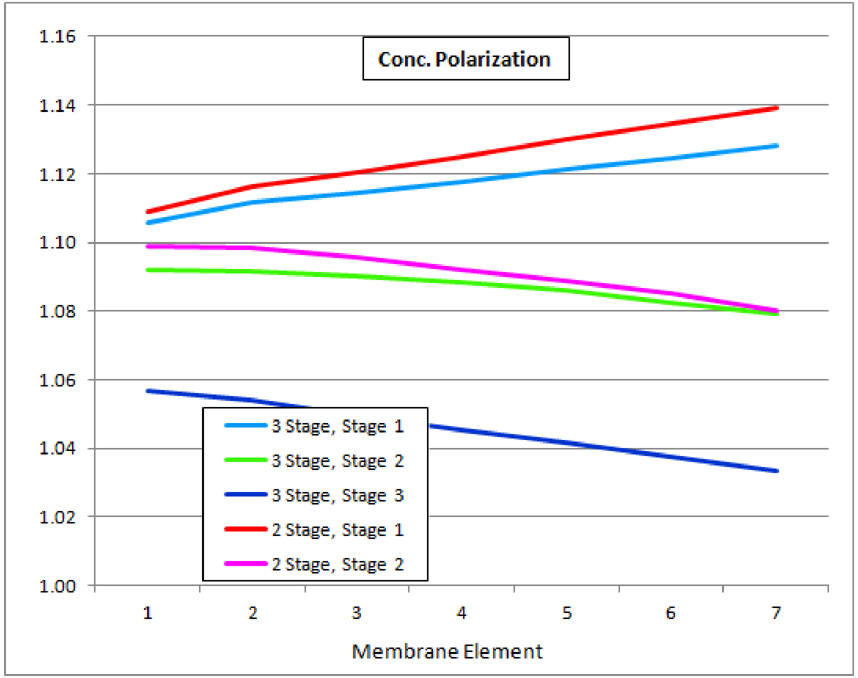


$$\text{Concentration Polarization} = \frac{Cm - Cp}{Cb - Cp}$$

Cb = Solute Conc. in Bulk Solution
Cm = Solute Conc. at Membrane Surface
Cp = Solute Conc. in Permeate

Concentration Polarization





Design Features

Pretreatment

- Automated feed pH control
- Optimized membrane antiscalant selection

Custom Design

- High quality low scaling membranes specifically selected for the SRO application
- A robust three stage SRO membrane system (total 5 stages)
- …

Design Features

Custom Design (Cont.)

- Permeate recycle for continuous operation and feed pressure balancing
- Concentrate recycle for closed circuit continuous operation and recovery optimization
- Interstage flux balancing valves for optimization of transmembrane pressures and crossflow velocities
- …

Design Features

Custom Design (Cont.)

- Enhanced instrumentation and control features for monitoring interstage performance
- Fully-automated permeate flush sequence
- Fully-automated Clean-In Place system with temperature control
- Performance analysis and monitoring tools

Startup Results

	SRO Reject	SRO Reject
Source File	SRO Design Basis	SRO Start-up Cardinal Labs
pH	7.5	7.5
Temp	25	25
TDS, mg/L	14123	7240
Ca, mg/L	2446	1120
K, mg/L	15	10
Mg, mg/L	744	408
Na, mg/L	596	455
Sr, mg/L		17.6
Cl, mg/L	1216	1050
CO_3, mg/L	0	0
HCO_3, mg/L	2697	646
F, mg/L	12	7
SO_4, mg/L	6558	4060
SiO_2, mg/L	170	115

Optimizing Reliability

- Robust Designs are difficult to procure if equipment buying decisions are based on low price – The best solution probably won't win a bid
- Equipment vendors shy away from performance guarantees
- Cost reduction is a necessary task on every project. If a design feature that adds reliability also adds cost it is often not implemented.

Understand all the risks … and the options.

If you don't the result could be an unreliable (or under designed) system.

Questions?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INDUSTRIAL WATER REUSE NEW TECHNOLOGIES AND LESSONS LEARNED

IWC Workshop W-07

Case Study

INTERNATIONAL WATER CONFERENCE

wood.

Resolving Wastewater Disposal Well Scaling Issues with a Unique Membrane Process

- WEFTEC Session 504
- September 28, 2016

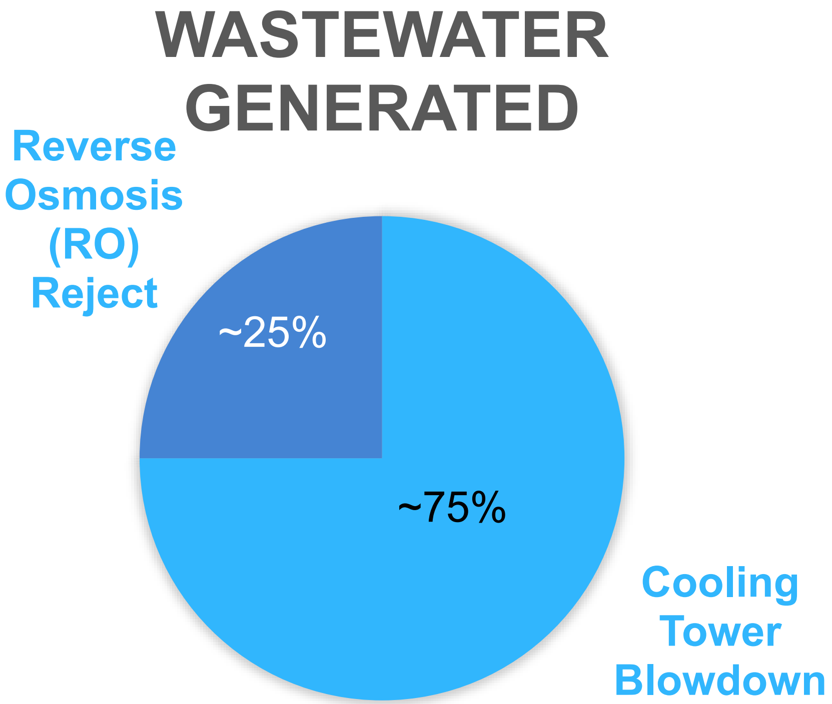
wood.

Agenda

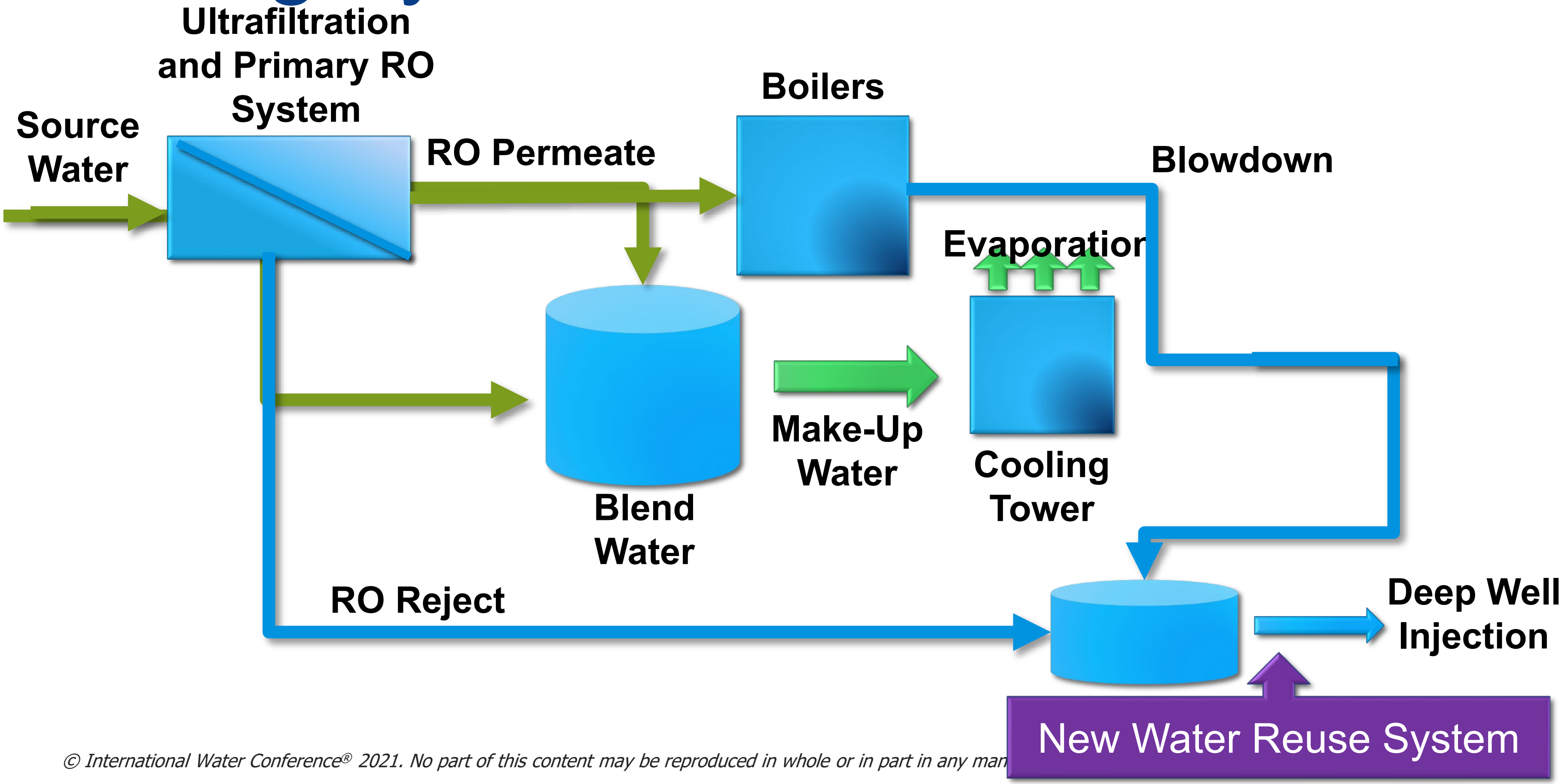
1) Background
2) Project Objectives
3) Project Team
4) Water Quality
5) System Selected
6) Performance
7) Summary

Site Background

- Semi arid region of US
- Source water is groundwater
- Non-hazardous deep well injection
- Approximately 493 Million Litres (400 acre-feet) wastewater generated per year



Existing System



Project Objectives

- Wastewater disposal limited
  - Scaling and capacity issues in deep well injection
  - High injection pressures reduced flow
- Source water supply limited

Objectives

- Reduce wastewater production
- Improve the sustainability of the injection wells
- Reuse water / Reduce water use
- Add operational flexibility as related to water use

Project Team

- Confidential Client
- Wood Environment and Infrastructure
  - Engineering
    - Engineer on Record: Civil, Structural, Process, Mechanical, Geotechnical, Electrical
  - Permitting
  - Construction Management
  - Commissioning
- Evoqua Water Technologies
  - Equipment Supply
- Local Contractor

Water Quality and Design

- Blended Wastewater = Existing RO Reject + Blowdown

Plant Effluent (Ave):

- Flow = 1,440 Lpm (380 gpm)
- Ca = 50 mg/L
- Mg = 12 mg/L
- TDS = 4,050 mg/L
- **SiO_2 = 150 mg/L**

75% Recovery

New Reuse System

Permeate to Cooling Towers:

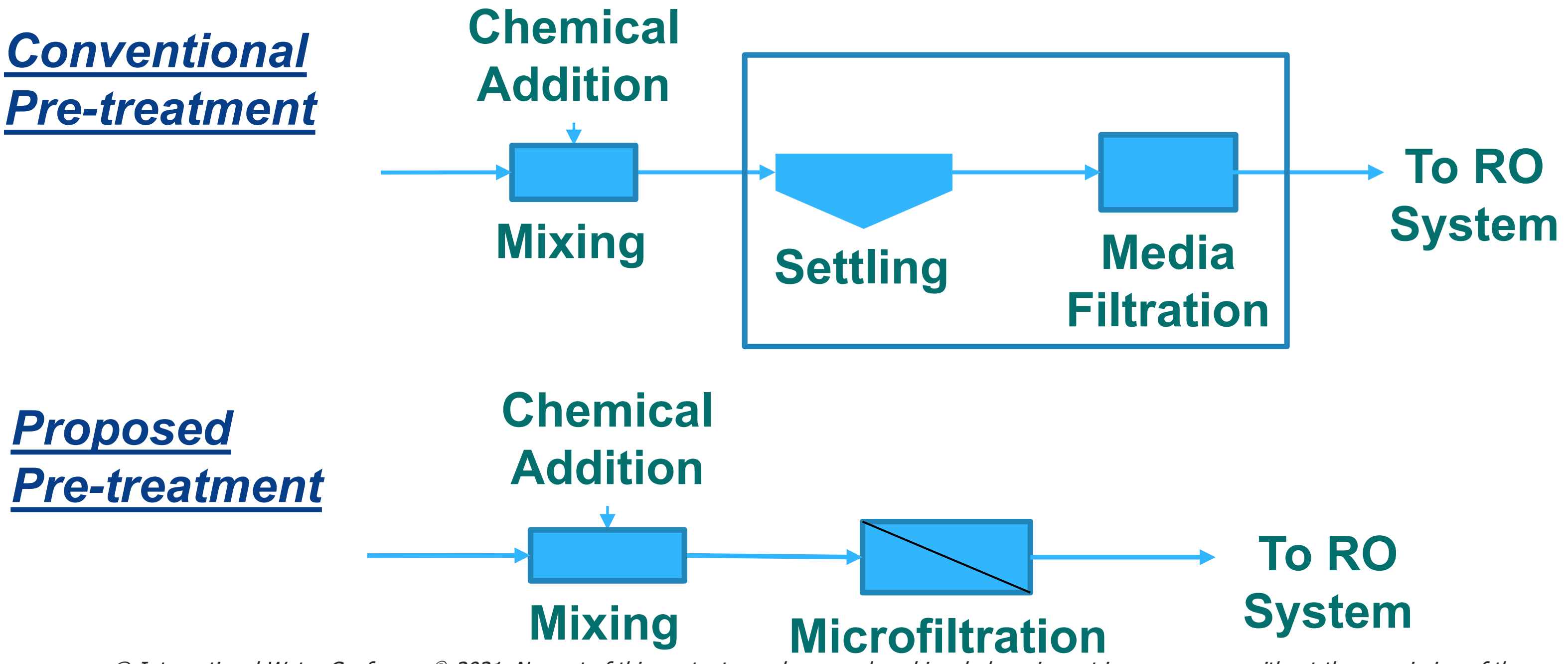
- Flow = 1,080 Lpm (285 gpm)
- SiO_2 = <3 mg/L

Reject to Deep Well:

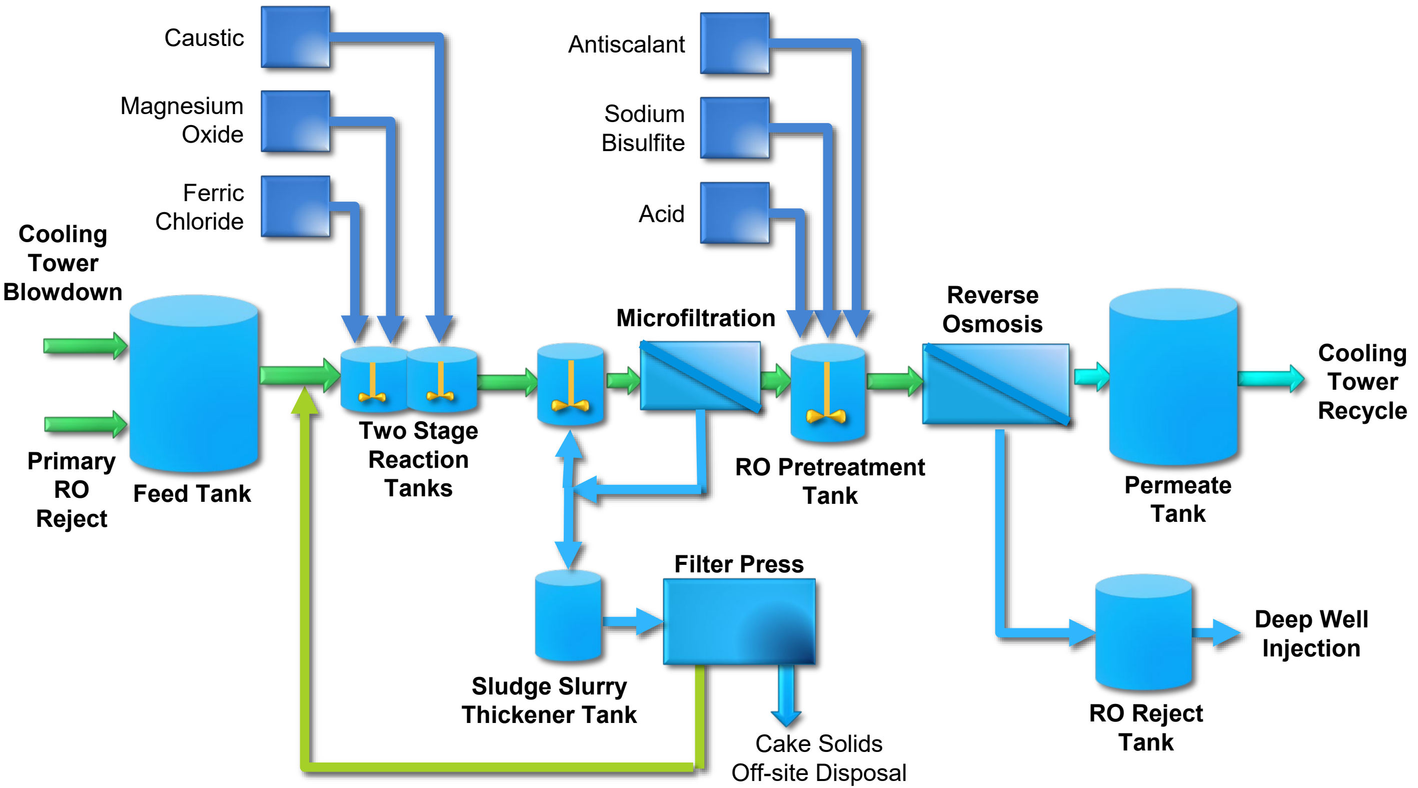
- Flow = 360 Lpm (95 gpm)
- SiO_2 = <132 mg/L

RO System

- Removal of silica required to reduce scaling in injection wells



Process Selected



Microfiltration

- Memtek cross-flow PVDF tubular membrane
- Pore size 0.1 to 0.3 microns
- Feed solids concentrations up to 5%
- Solids recycled to feed
- Turbulent flow minimizes particulate accumulation
- Regular back flushing with air
- Periodic chemical cleans

System Advantages

Compared to Conventional Clarifier/Media Filtration Pre-treatment

- Fewer treatment steps
- Lower TSS in feed to RO
- More consistent feed to RO
- Controlled process
- Modular
- Smaller footprint

Performance

- SiO_2 concentration <35 mg/L in RO feed
- 98% TDS rejection
- 75% RO Recovery of Power Plant Effluent (RO Reject and Boiler Blowdown)

Summary

Reduction in volume of wastewater by 75%

Improved injection well sustainability

Summary


Reduction in volume of groundwater needed for operations
Added operational flexibility

Thank You!

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INDUSTRIAL WATER REUSE
A ROADMAP FOR THE FUTURE

IWC Workshop W7

Case Study

A CASE STUDY OF INDUSTRIAL WATER REUSE AND ZLD: FOUR YEARS OF OPERATION AND LESSONS LEARNED

ED GREENWOOD, P.ENG., BCEE
BILL MALYK, P.ENG., BCEE

IWC 18-09

ABSTRACT

One food processor rose to the challenge of water scarcity with a unique high recovery water reclamation plant. To meet the needs of production the RO system was designed with a water recovery rate of 87%. A few years later the RO was upgraded to over 93%. Since then operators have dealt with a major wastewater treatment plant upset, issues with brine management and several other plant expansions and upgrades. Four years of operating data and lessons learned are presented in this paper.

AGENDA

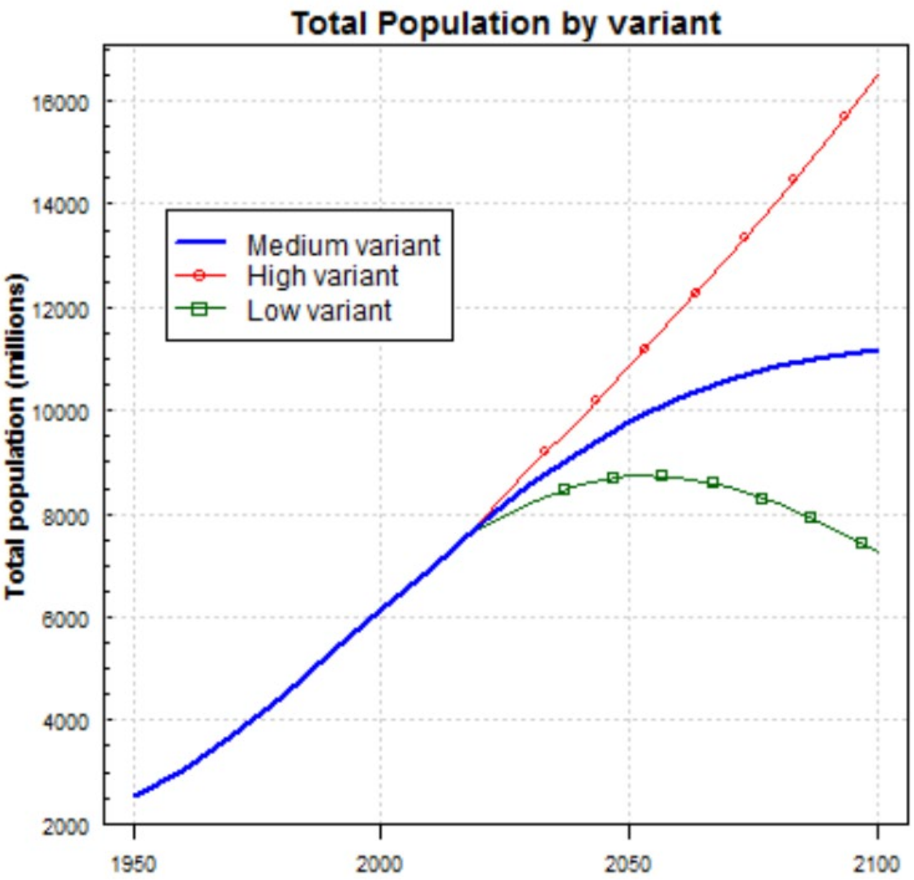
- Background
- Objectives
- Process Design
- Expansions/Upgrades
- Major Upset
- Results/Data
- Lessons Learned

BACKGROUND

BACKGROUND

Why Water Reuse:

- Growing Population

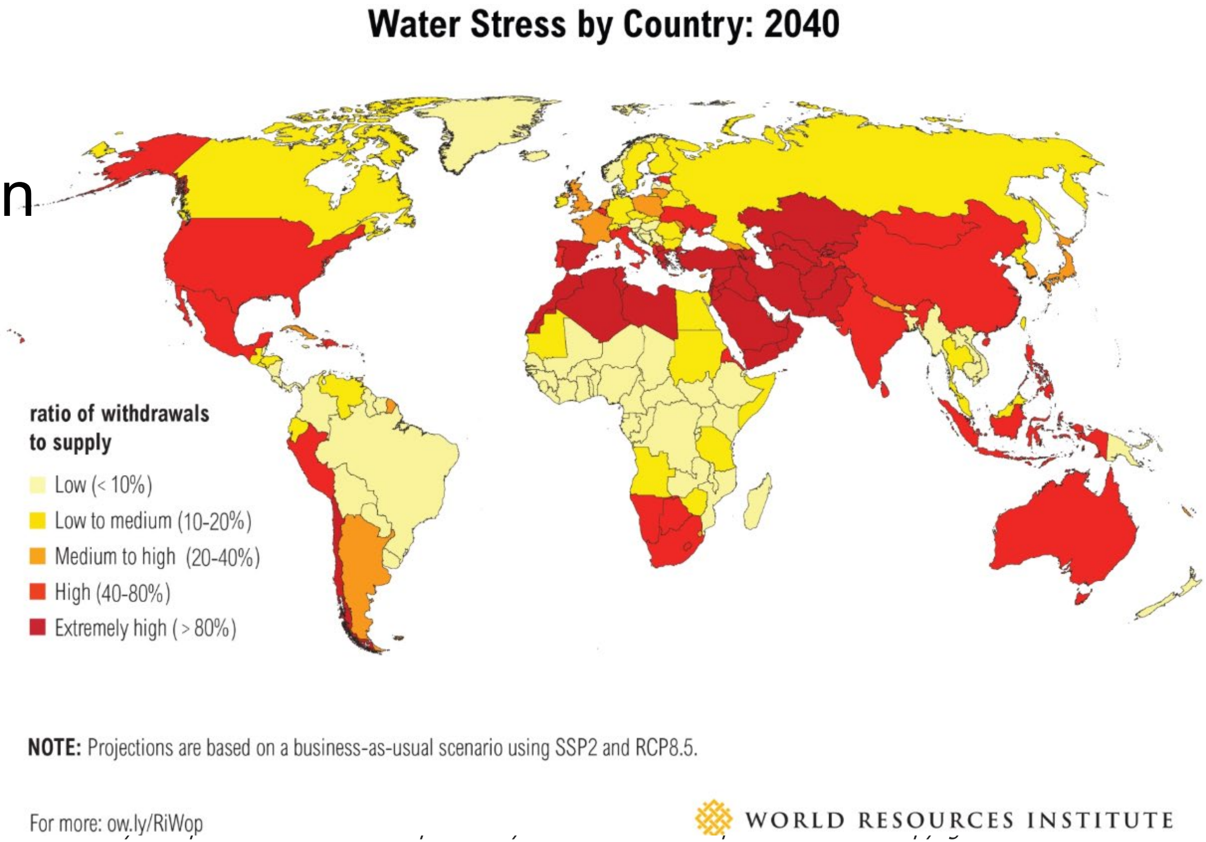


UN DESA https://esa.un.org/unpd/wpp/Graphs/DemographicProfiles/

BACKGROUND

Why Water Reuse:

- Growing Population
- Droughts



BACKGROUND

Why Water Reuse:

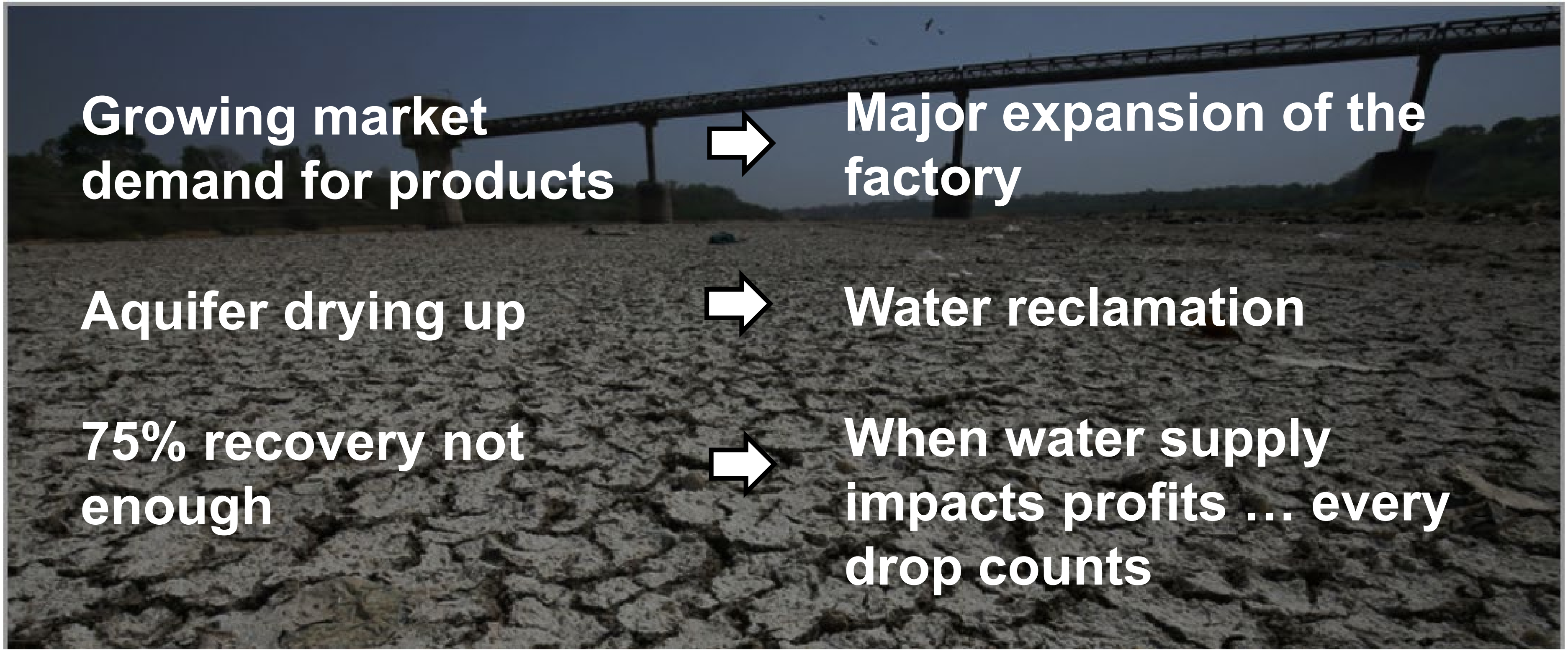
- Growing Population
- Droughts
- Floods

→ Impact on Industry

People queue to collect drinking water from a municipal tanker at a flooded residential colony in Ahmedabad, India, July 29, 2017. REUTERS/Amit Dave

https://www.reuters.com/article/us-india-floods-climatechange-idUSKBN1AG1PB

The Impact of Water Scarcity on Industry



Source https://www.csmonitor.com/World/Asia-South-Central/2018/0425/As-water-scarcity-worsens-Day-Zero-becomes-commonplace-in-India

OBJECTIVES

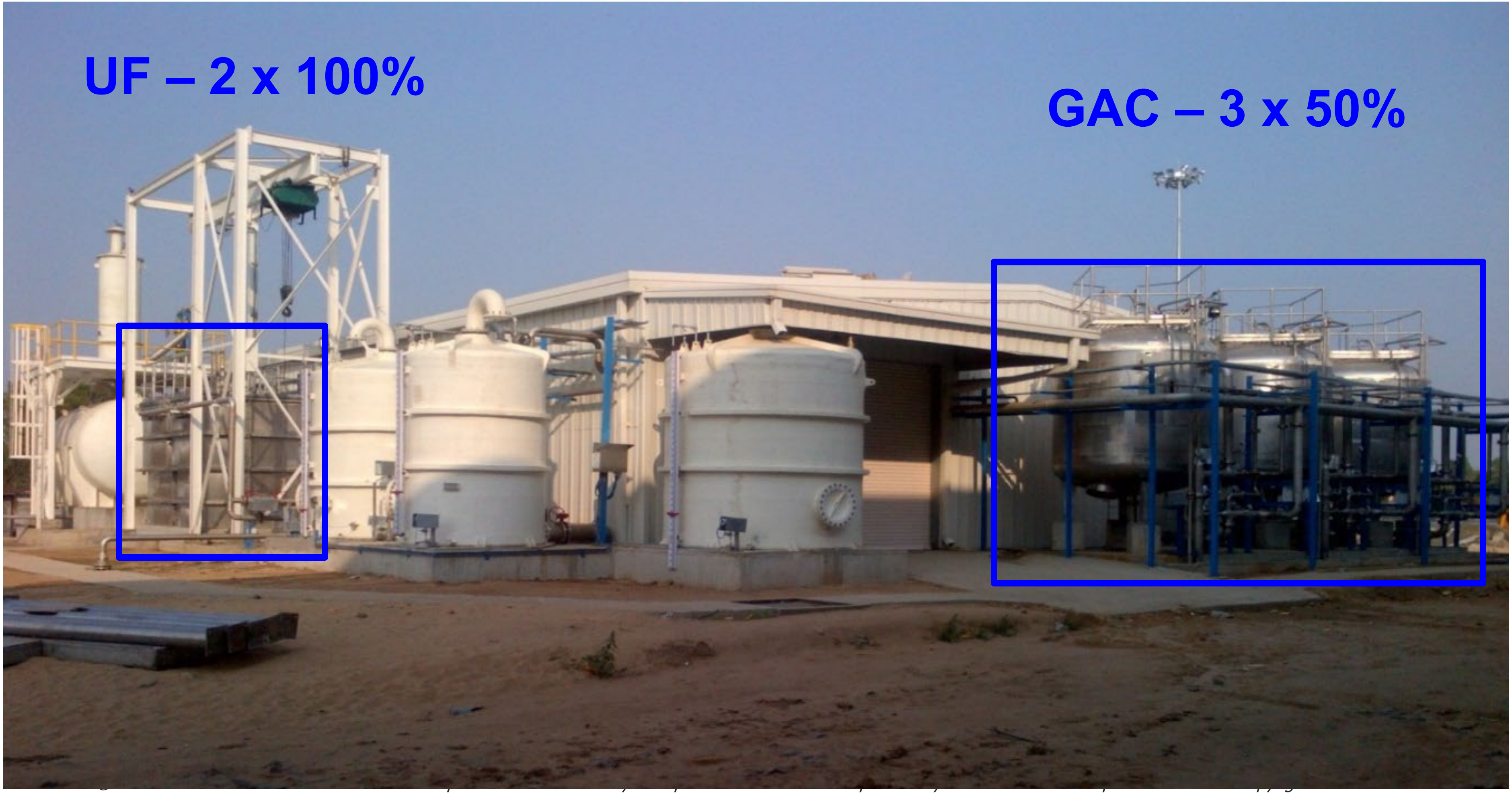
OBJECTIVES

• Highest water recovery	⇨	Push the limits of membranes (membrane scaling)
• Highest water quality	⇨	Exceed ISA potable water (100% of the time)
• Highest reliability	⇨	Conservative design with complete redundancy
• Cost effective	⇨	Design … Bid … Build

PROCESS DESIGN

PROCESS DESIGN

Ultrafiltration Membranes (Supported, Immersed, Hollow-Fiber)	Granular Activated Carbon	Reverse Osmosis Membranes (High Rejection & Low Fouling)

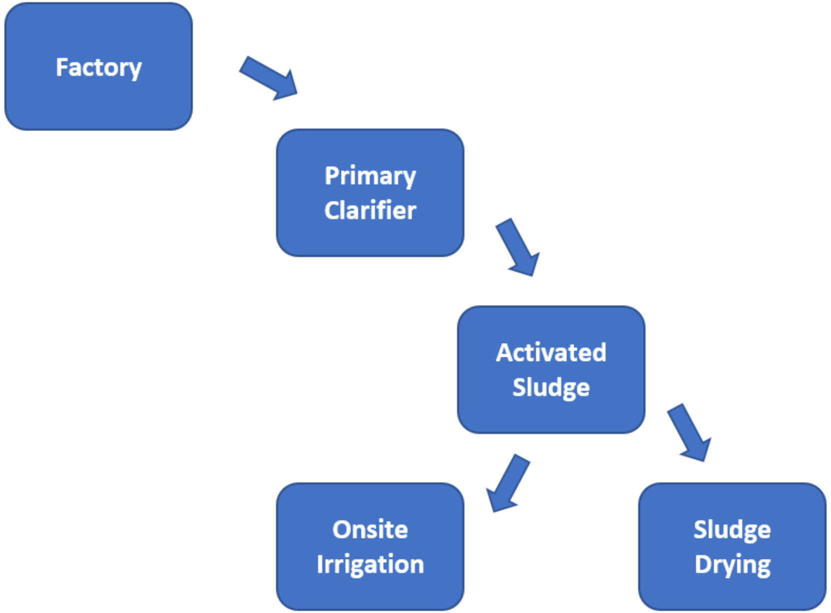

UF – 2 x 100%
GAC – 3 x 50%

RO – 4 x 33% operating at 87.5% recovery

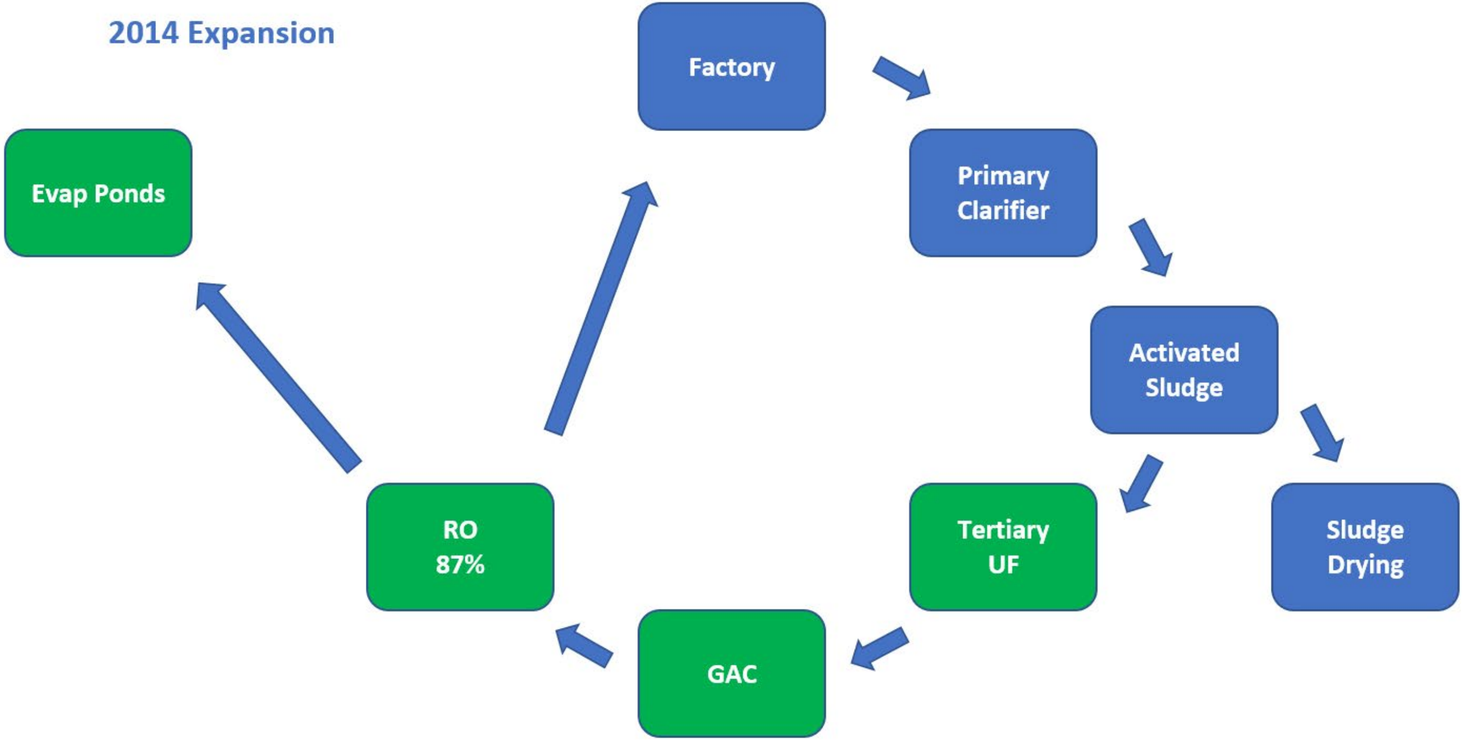
EXPANSIONS AND UPGRADES

EXPANSIONS AND UPGRADES

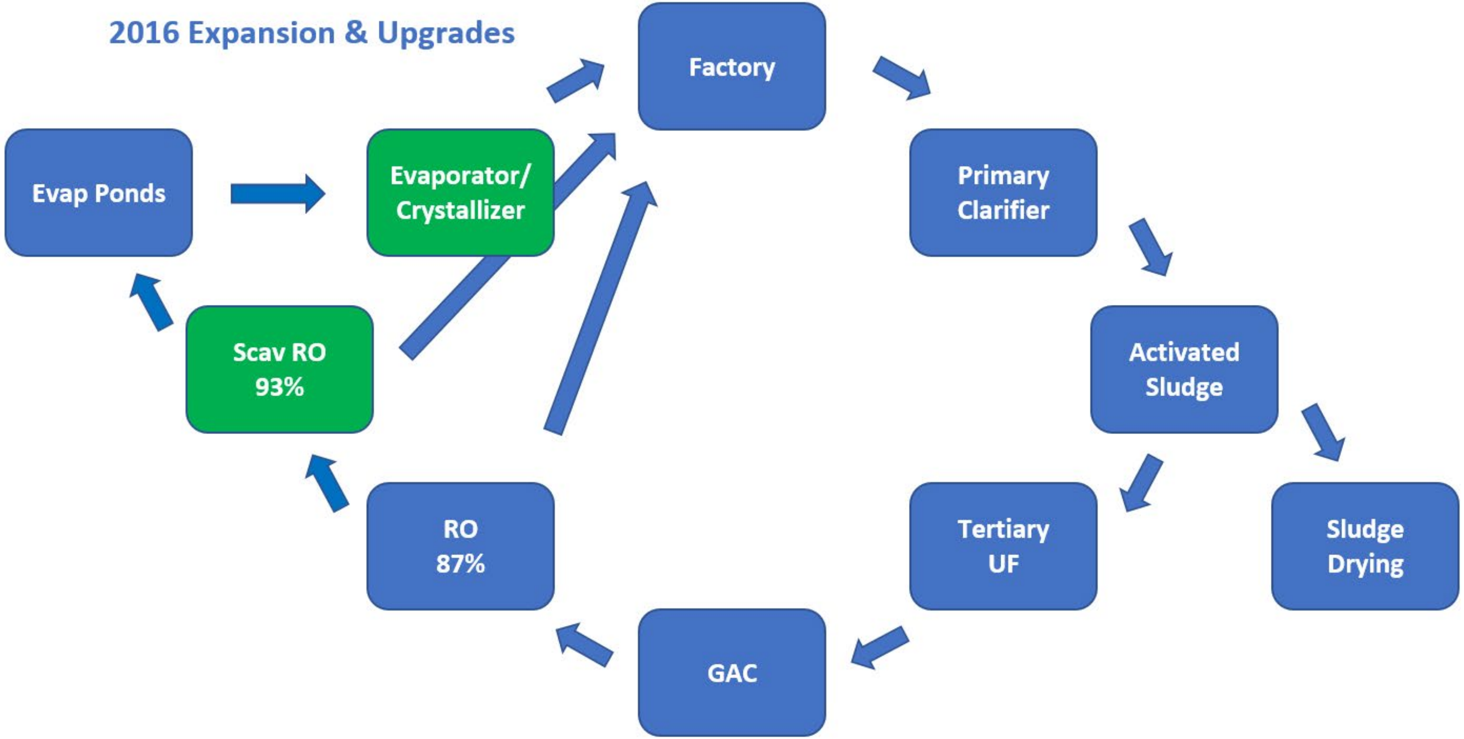
2013 and Earlier



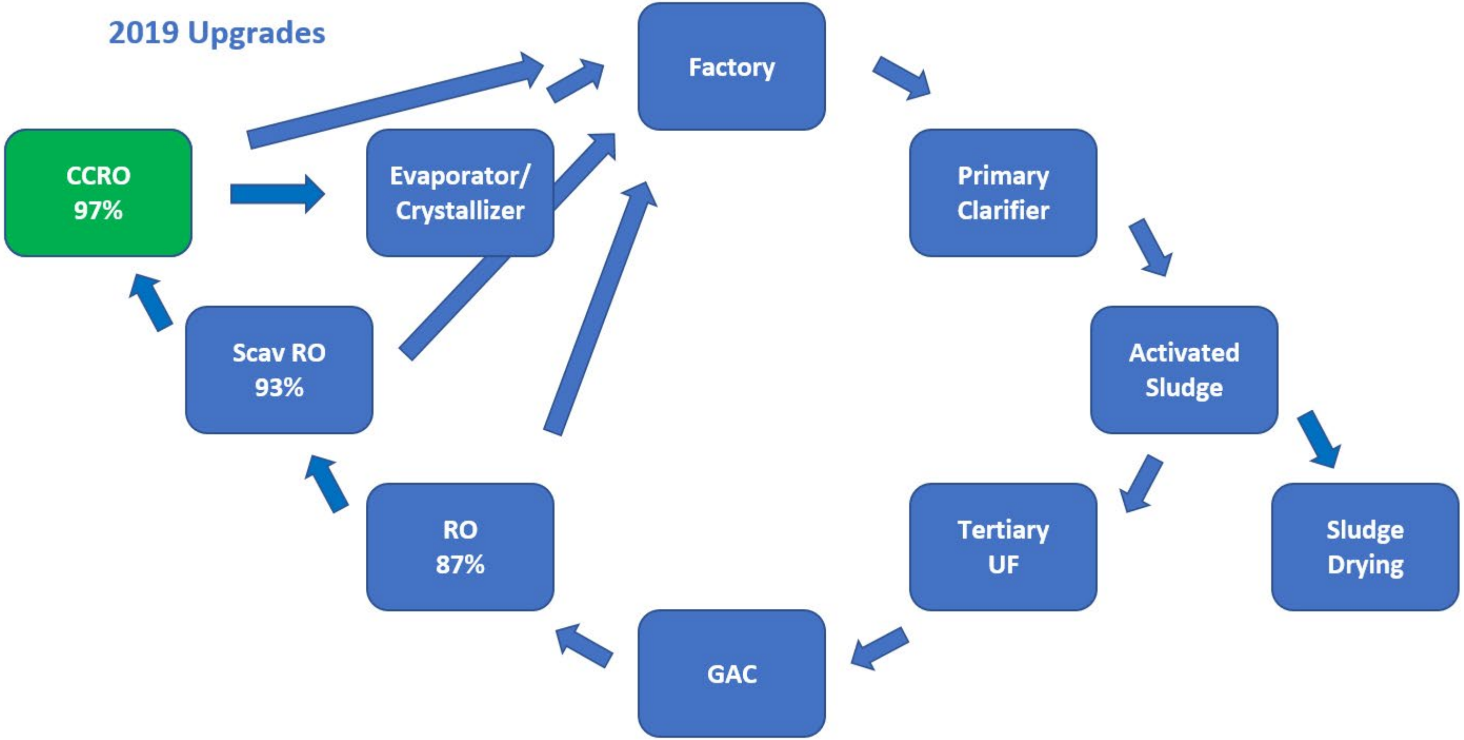
EXPANSIONS AND UPGRADES



EXPANSIONS AND UPGRADES



EXPANSIONS AND UPGRADES



EXPANSIONS AND UPGRADES

		System	Feed (m3/d)	Recovery (m3/d)	Product (m3/d)	Reject (m3/d)	Combined RO Recovery
Original	Prior to 2014	WWTP	600	-	-	400	-
		Irrigation	400	-	-	-	-
Expansion	2014-2015	WWTP	1800	83.3%	1500	-	-
		UF	**1500**	**90.0%**	**1350**	**150**	**-**
		RO	**1350**	**87.5%**	**1181**	**169**	**87.5%**
		Evap Ponds	**169**	**-**	**-**	**-**	**-**
Expansion and Upgrade	2015-2018	WWTP	1800	83.3%	1500	-	-
		UF	1500	90.0%	1350	150	-
		RO	1350	87.5%	1181	169	87.5%
		Scav RO	**169**	**50%**	**84**	**84**	**93.8%**
		Evap Ponds	42	-	-	-	-
		ZLD	**42**	**-**	**-**	**-**	**-**
Upgrade	2018 (In Design)	WWTP	1800	83.3%	1500	-	-
		UF	1500	90.0%	1350	150	-
		RO	1350	87.5%	1181	169	87.5%
		Scav RO	169	50.0%	84	84	93.8%
		CCRO	**84**	**60.0%**	**51**	**33**	**97.6%**
		ZLD	33	-	-	-	-

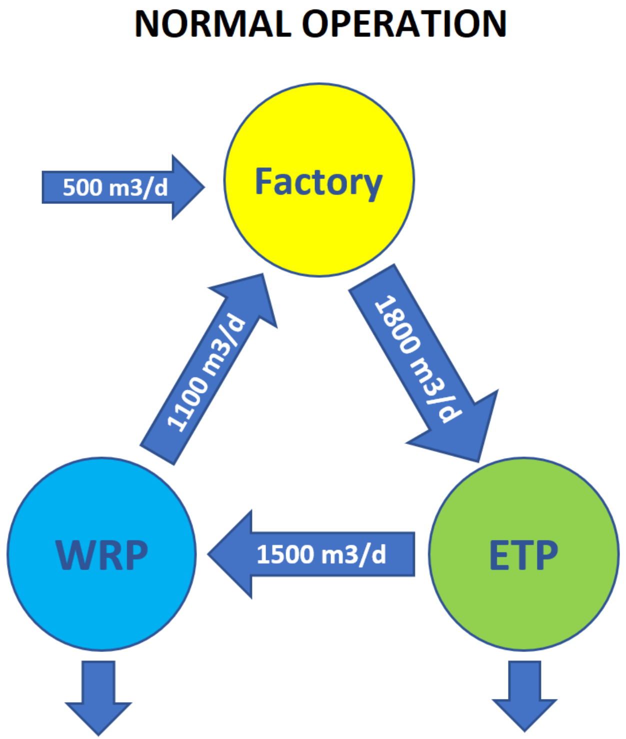
MAJOR UPSET

MAJOR UPSET

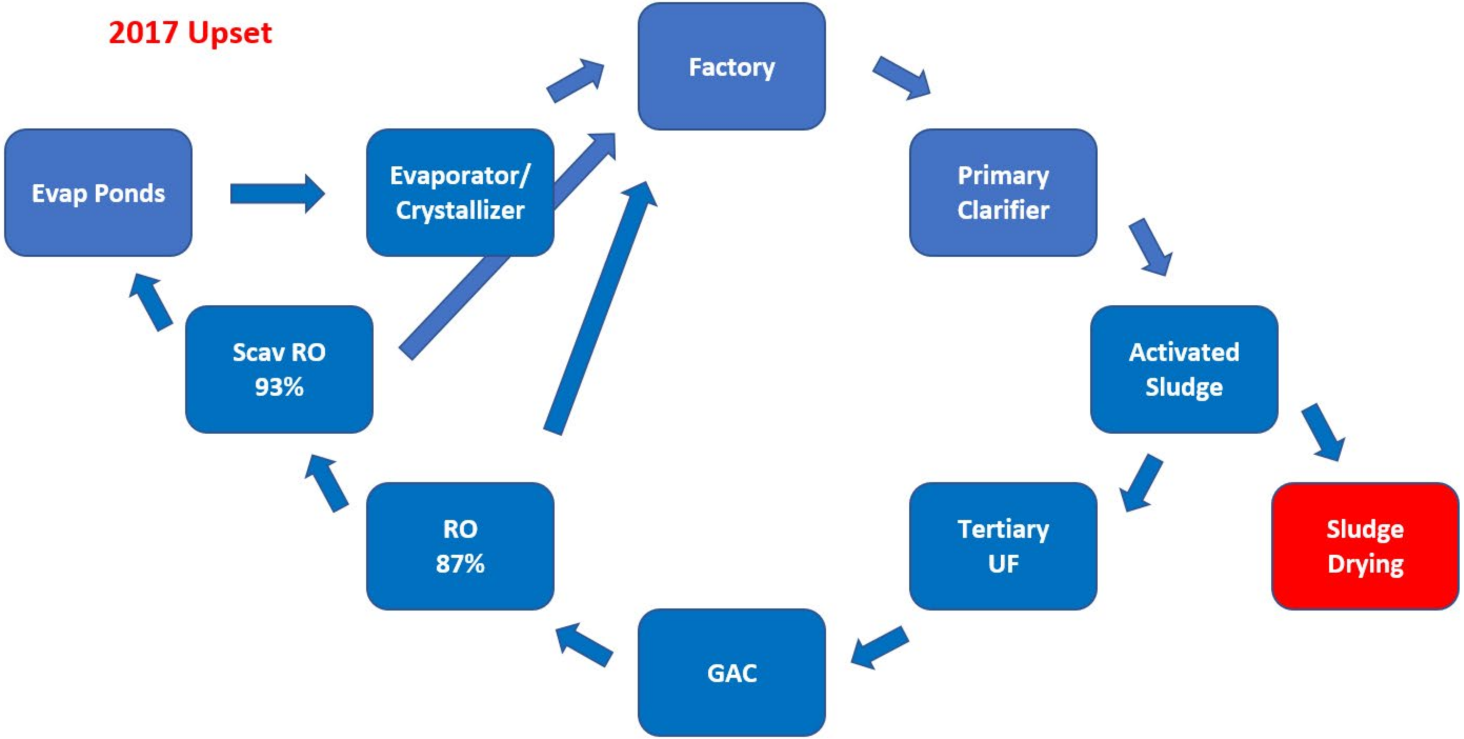
Biological Treatment Upset in late 2017:

- Rainiest monsoon season of the decade
- Reduced sludge wasting to Drying Beds
- MLSS too high
- F:M too low
- Filamentous growth

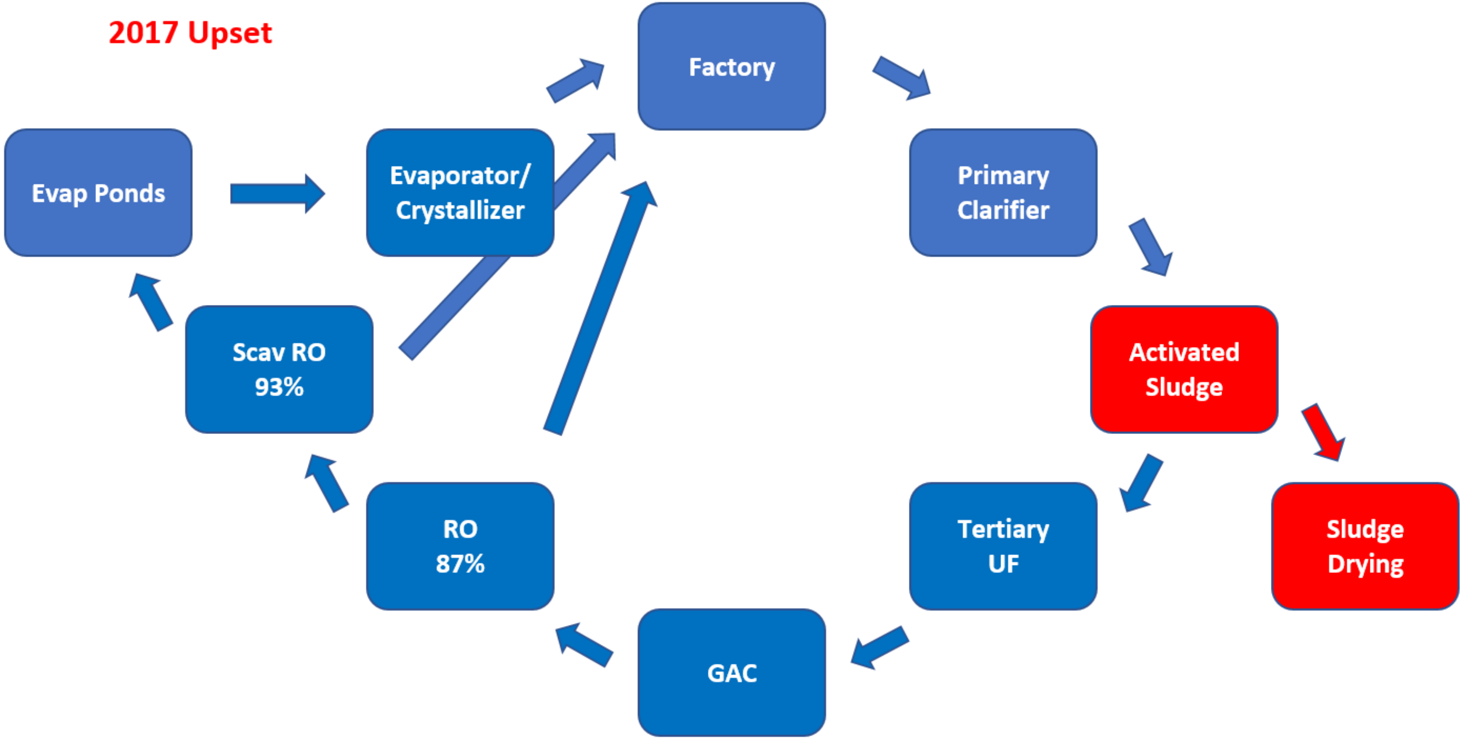
Lessons Learned



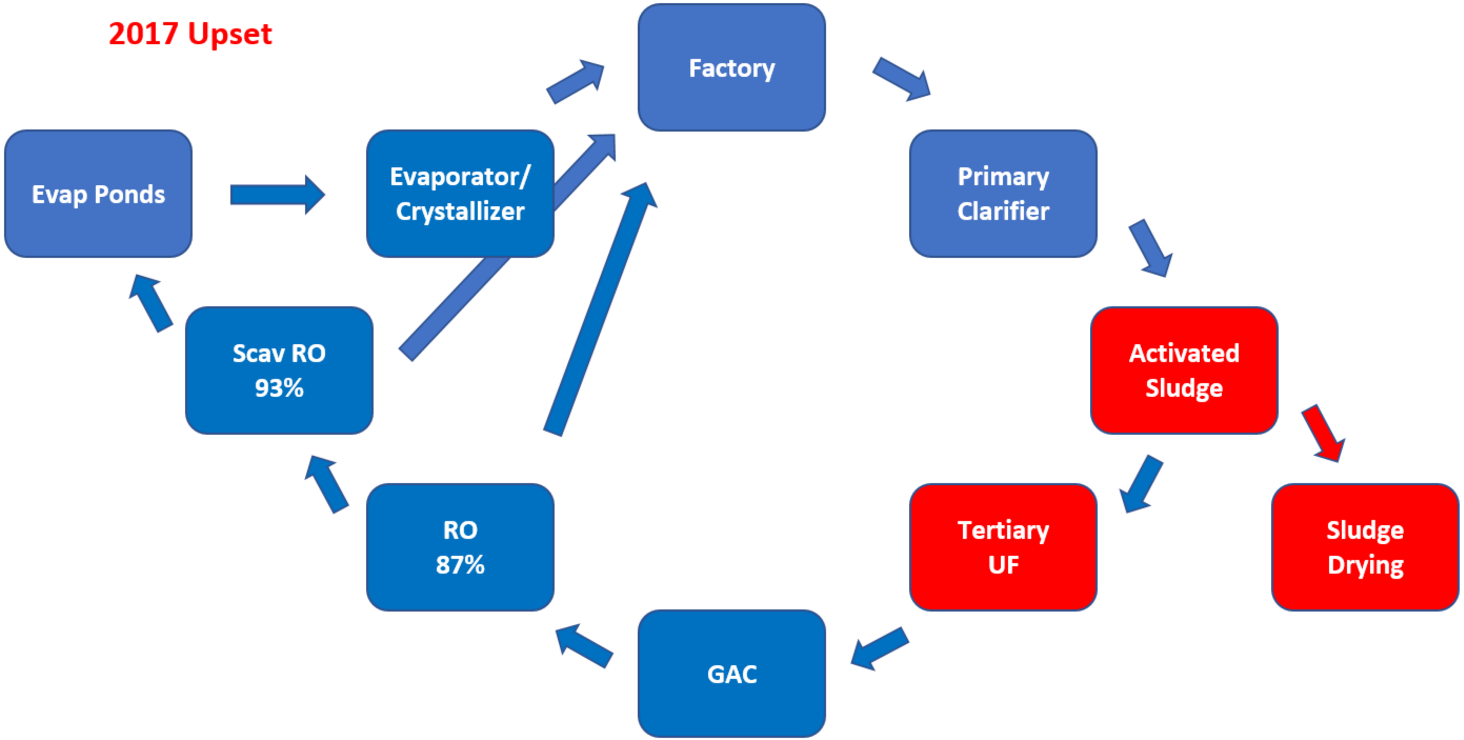
MAJOR UPSET


2017 Upset
Factory
Evap Ponds
Evaporator/
Crystallizer
Primary
Clarifier
Activated
Sludge
Scav RO
93%
RO
87%
Tertiary
UF
Sludge
Drying
GAC

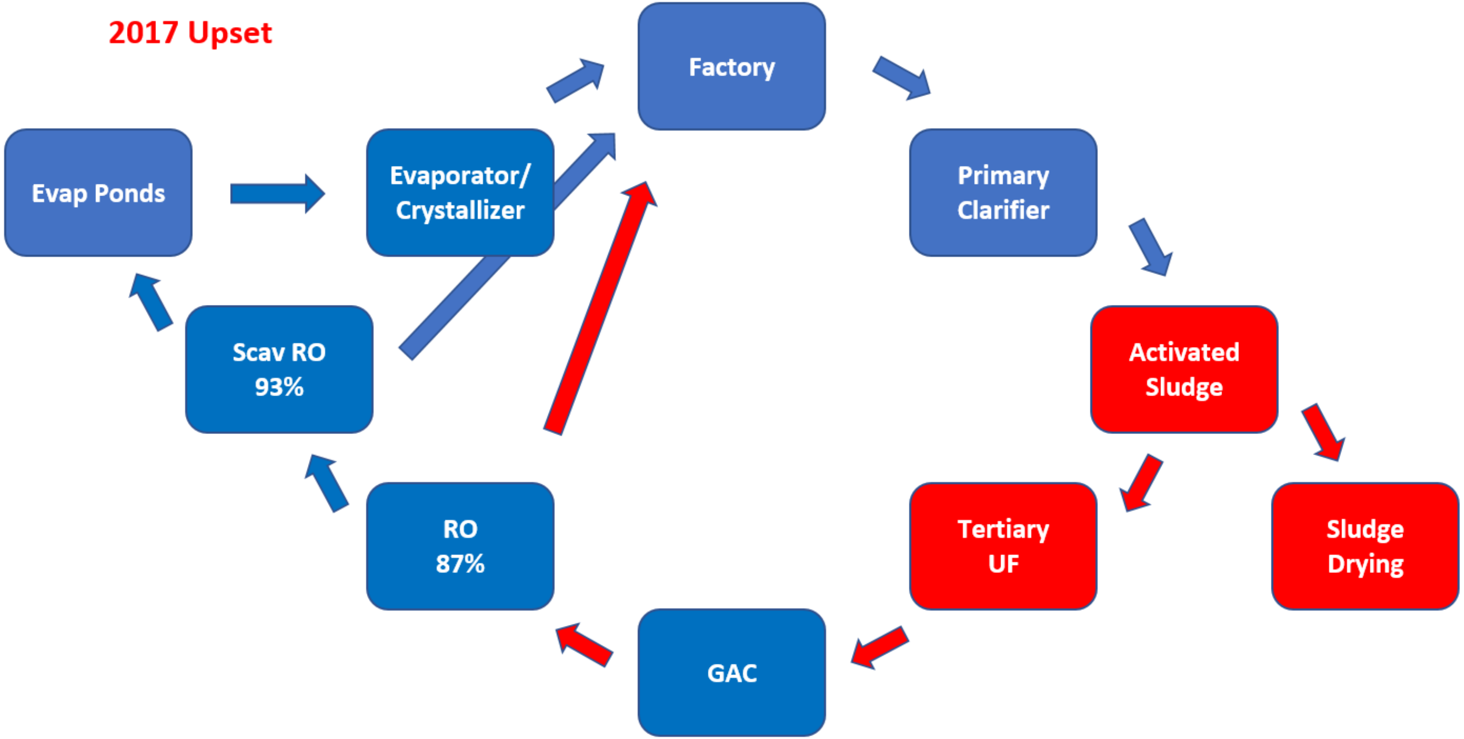
MAJOR UPSET


2017 Upset
Factory
Evap Ponds
Evaporator/
Crystallizer
Primary
Clarifier
Scav RO
93%
Activated
Sludge
RO
87%
Tertiary
UF
Sludge
Drying
GAC

MAJOR UPSET

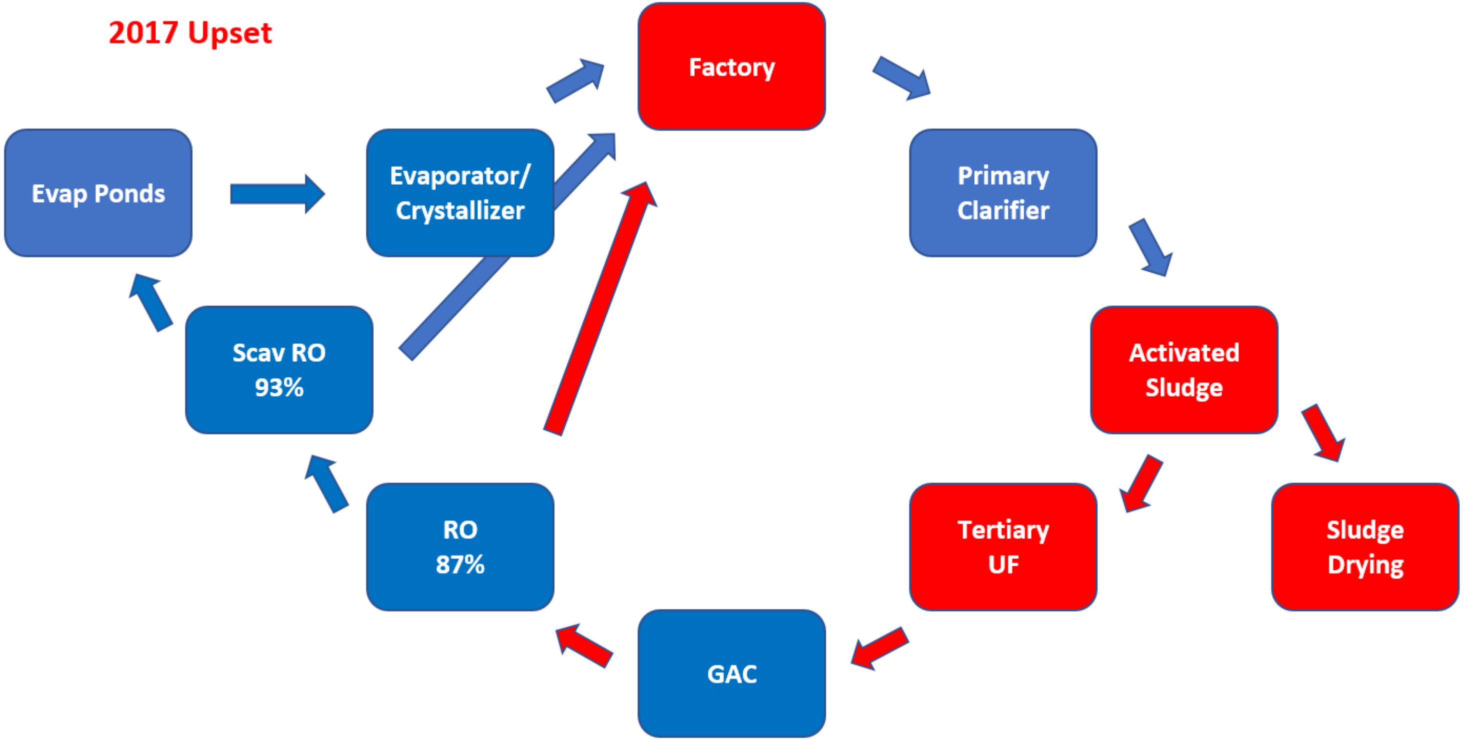

2017 Upset
Factory
Evap Ponds
Evaporator/ Crystallizer
Primary Clarifier
Activated Sludge
Scav RO 93%
RO 87%
Tertiary UF
Sludge Drying
GAC

MAJOR UPSET



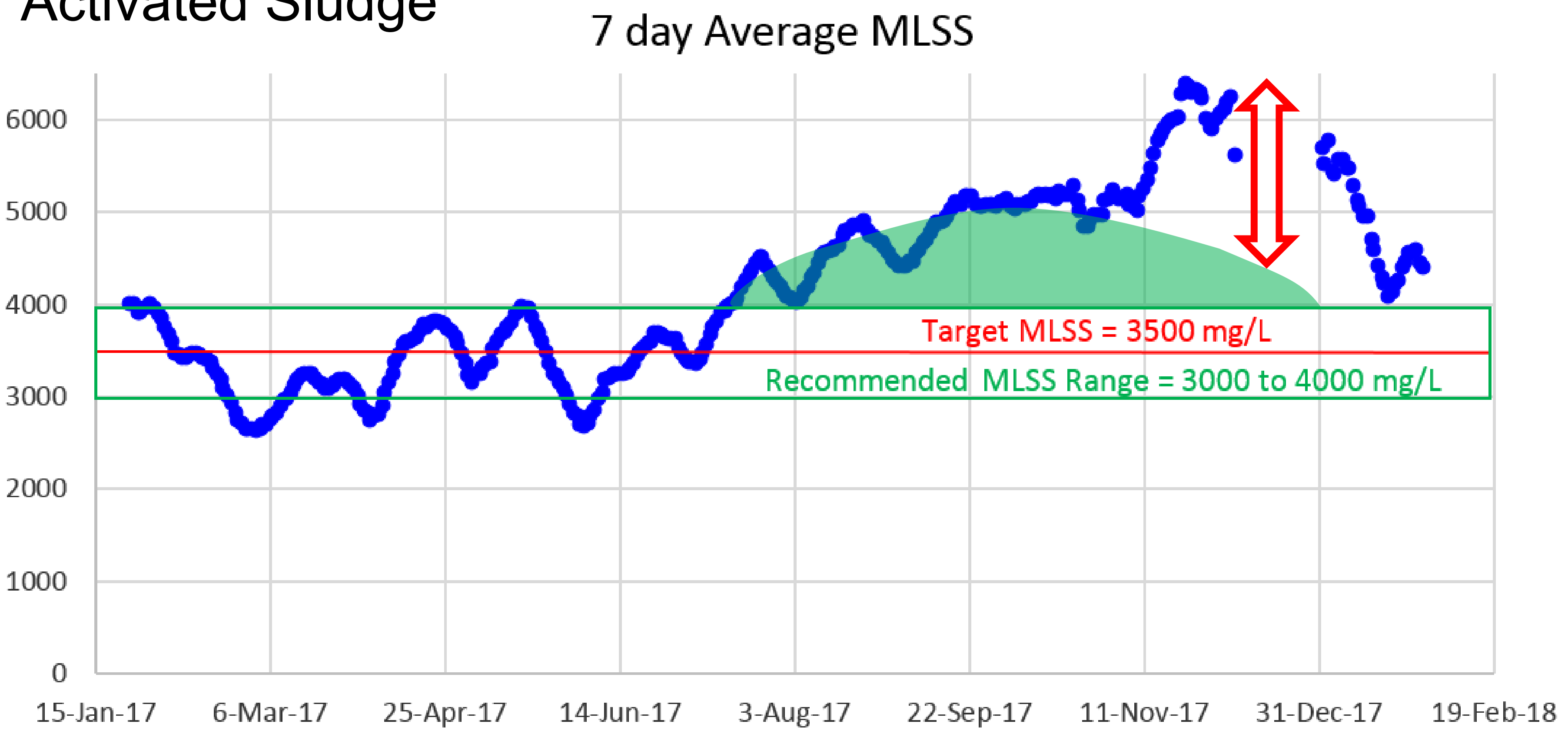
2017 Upset
Factory
Evap Ponds
Evaporator/ Crystallizer
Primary Clarifier
Scav RO 93%
Activated Sludge
RO 87%
Tertiary UF
Sludge Drying
GAC

MAJOR UPSET

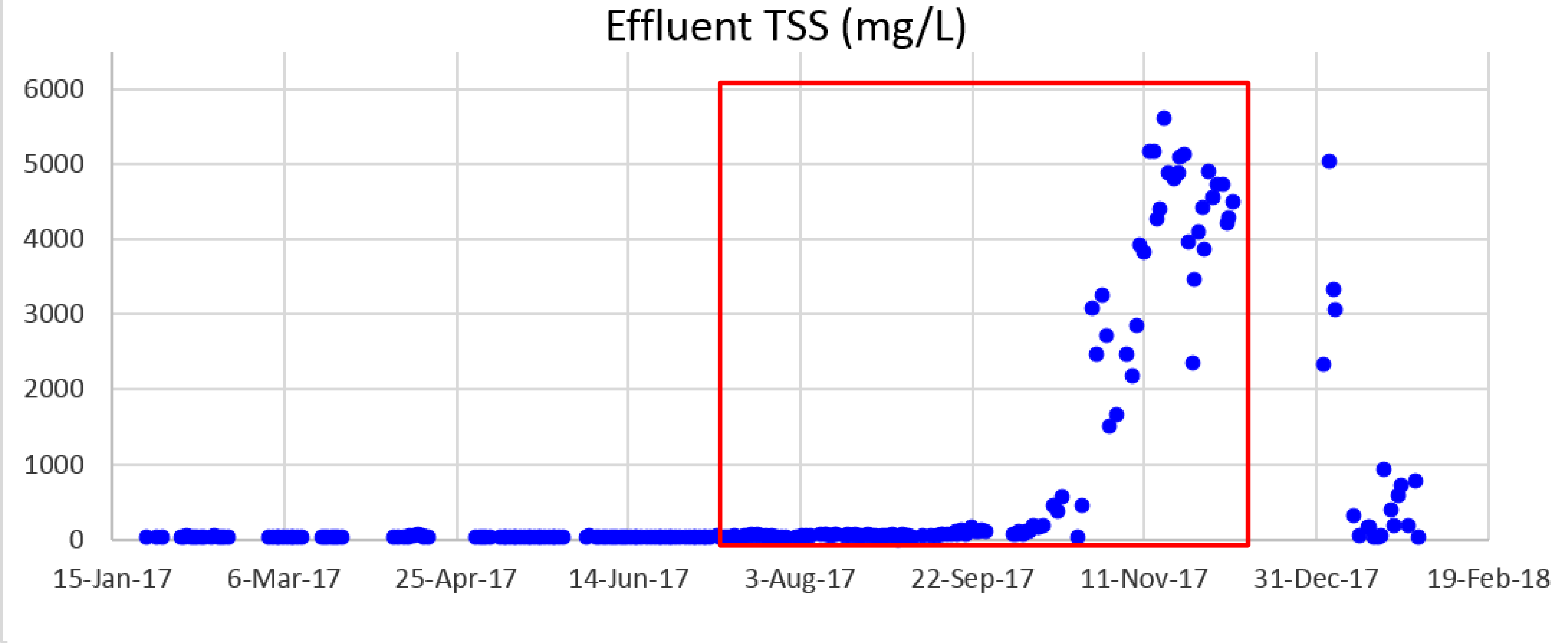

2017 Upset
Factory
Evap Ponds
Evaporator/
Crystallizer
Primary
Clarifier
Scav RO
93%
Activated
Sludge
RO
87%
Tertiary
UF
Sludge
Drying
GAC

RESULTS / DATA

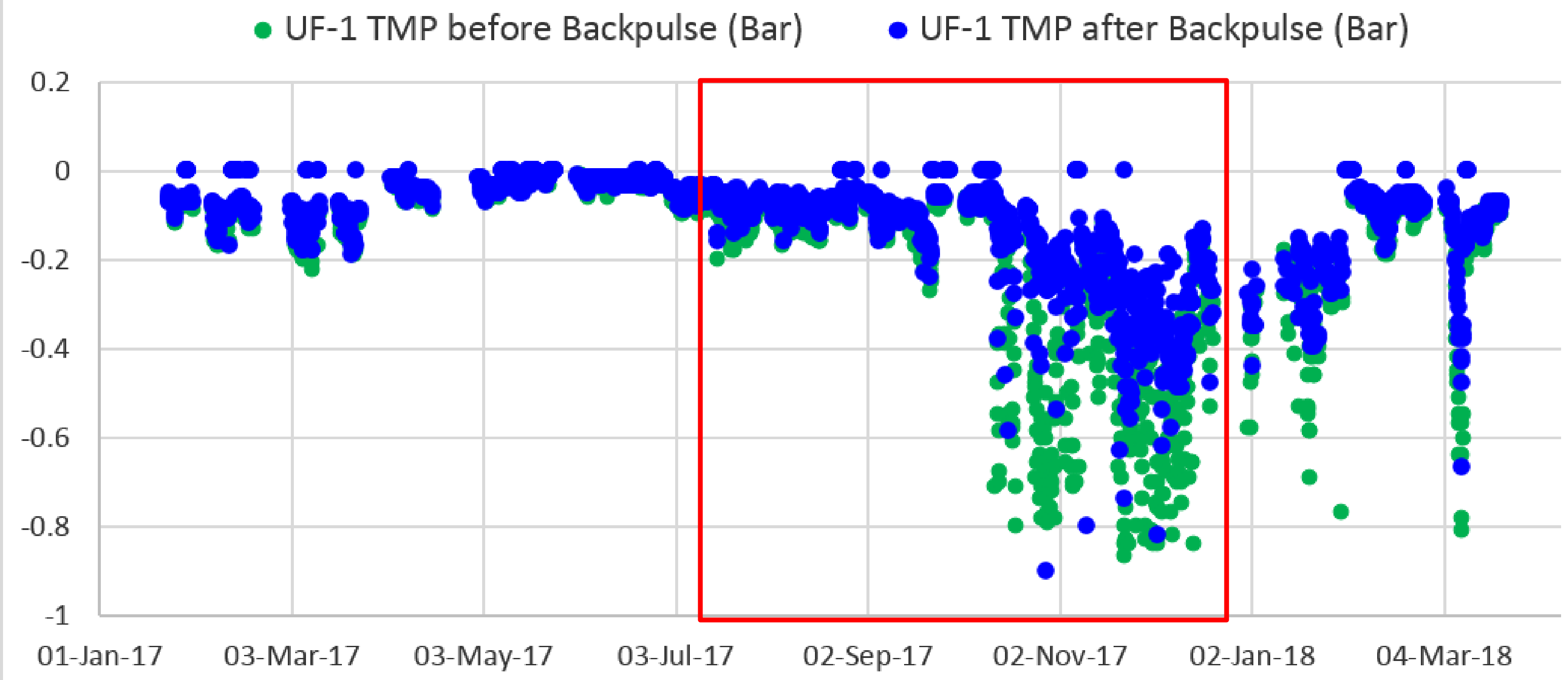
Activated Sludge



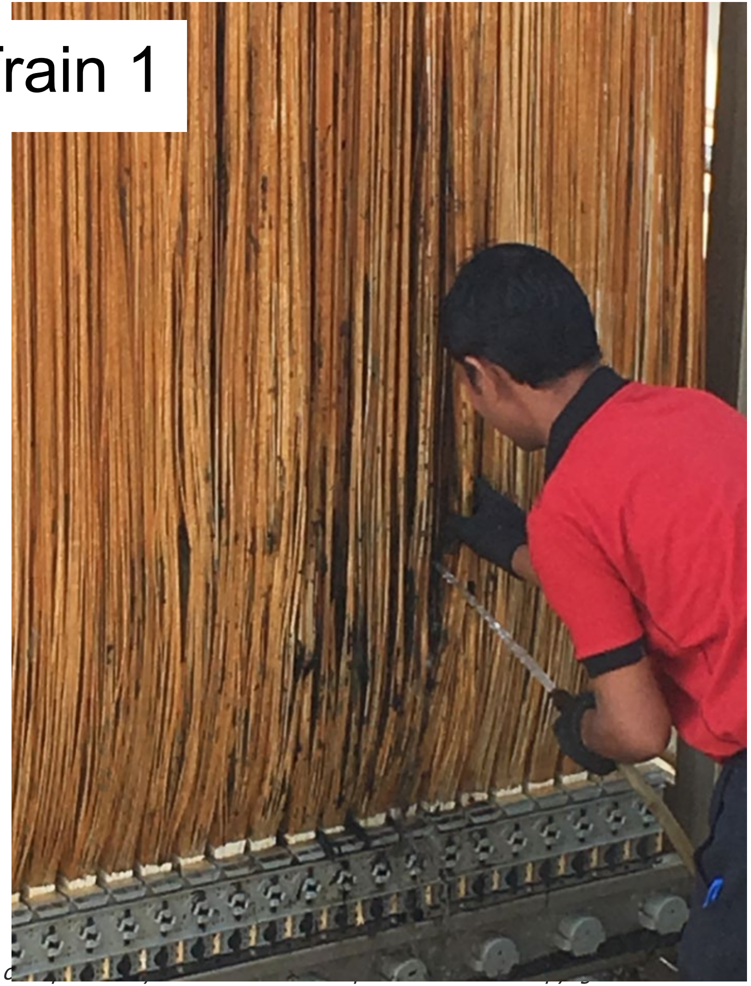
Secondary Clarifier



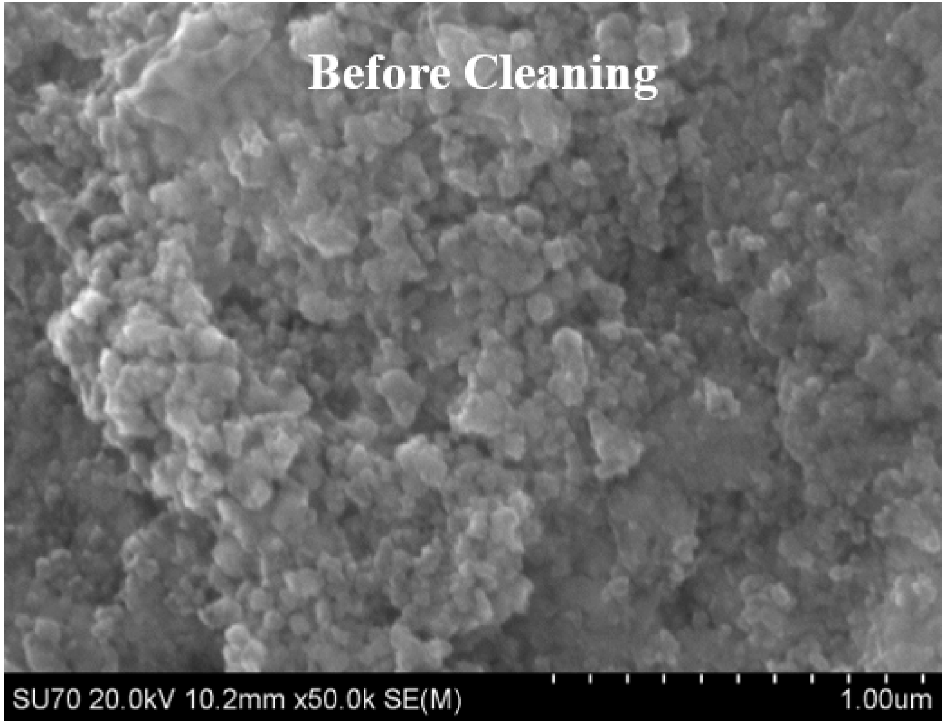
UF – Train 1

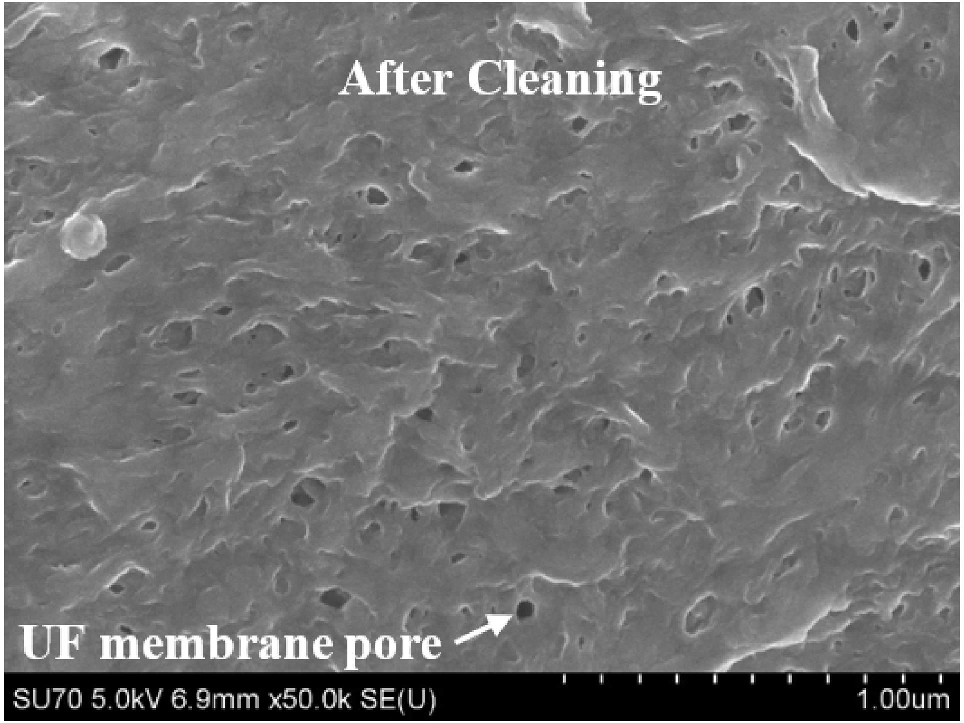

UF-1 TMP before Backpulse (Bar)
UF-1 TMP after Backpulse (Bar)
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
01-Jan-17
03-Mar-17
03-May-17
03-Jul-17
02-Sep-17
02-Nov-17
02-Jan-18
04-Mar-18

UF – Train 1

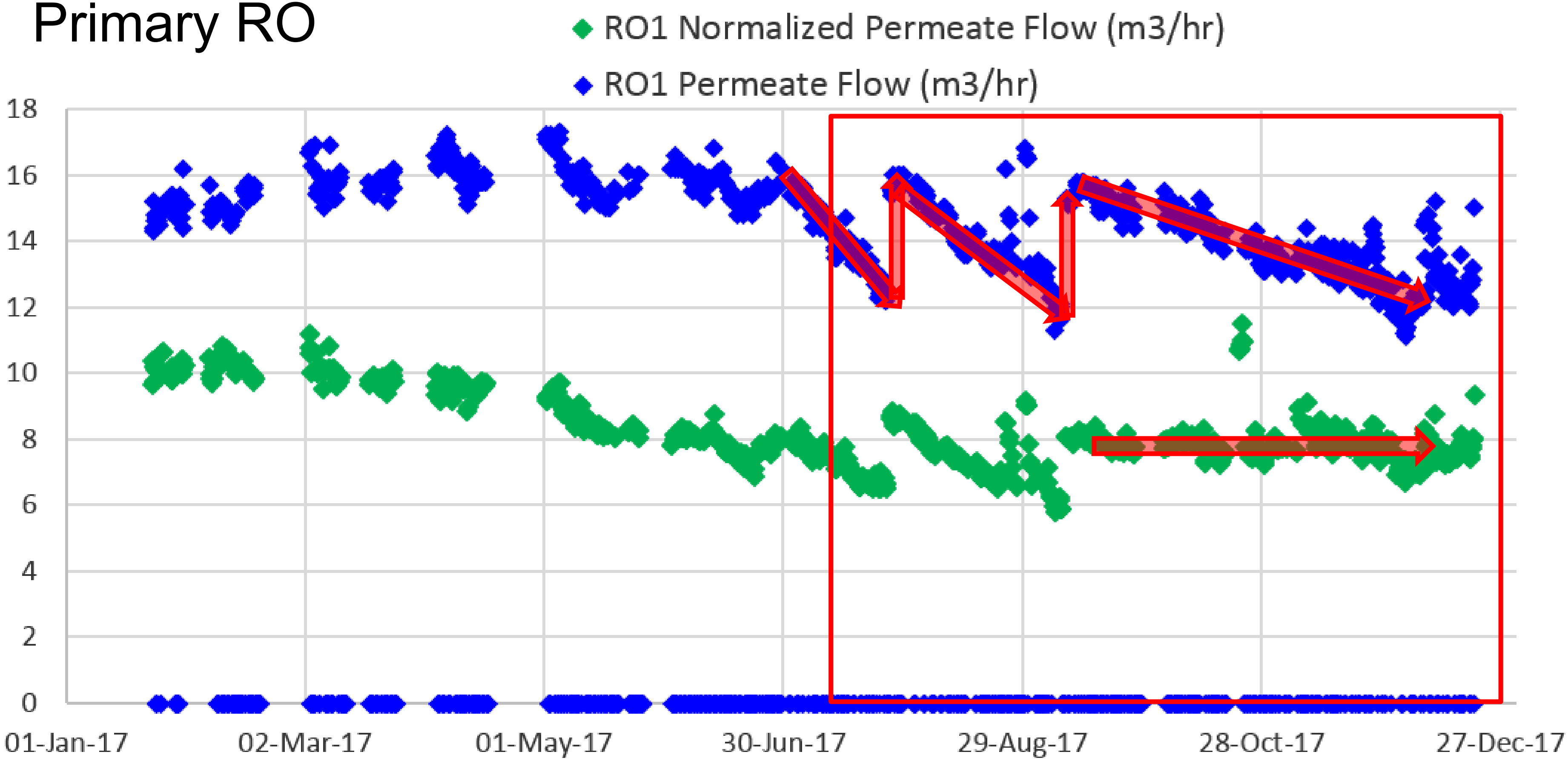


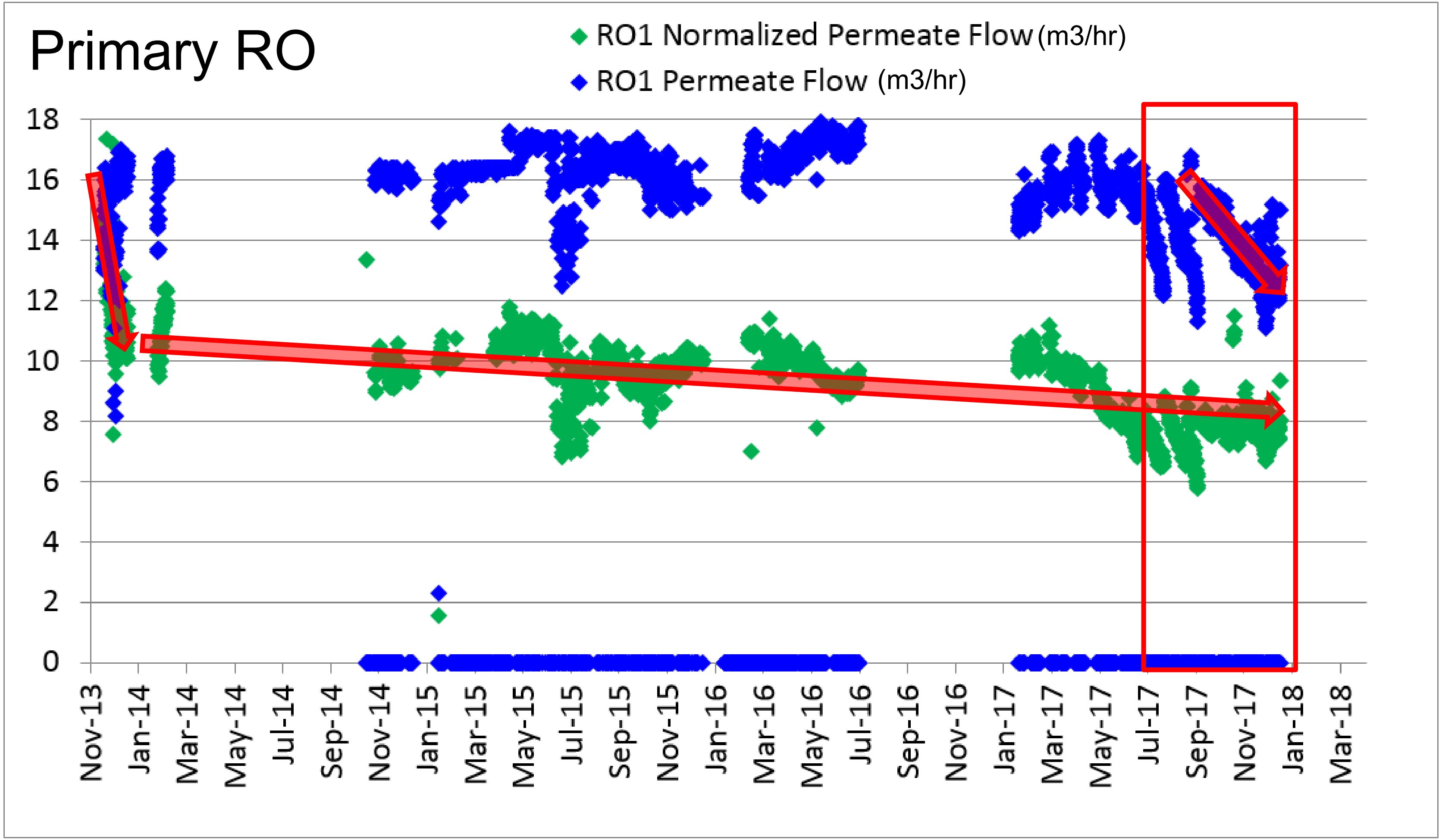
UF - Membrane Autopsy



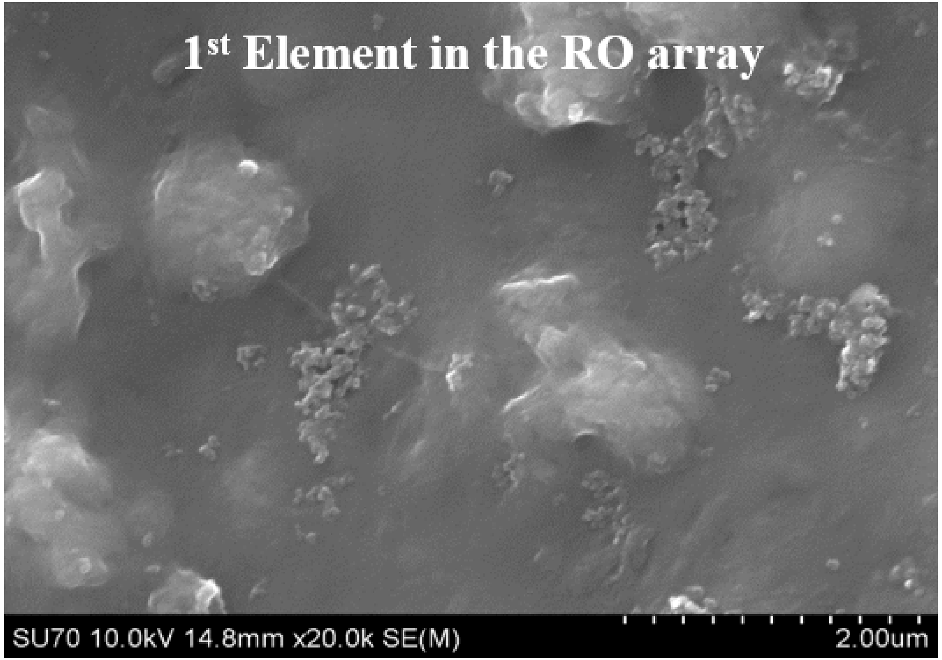


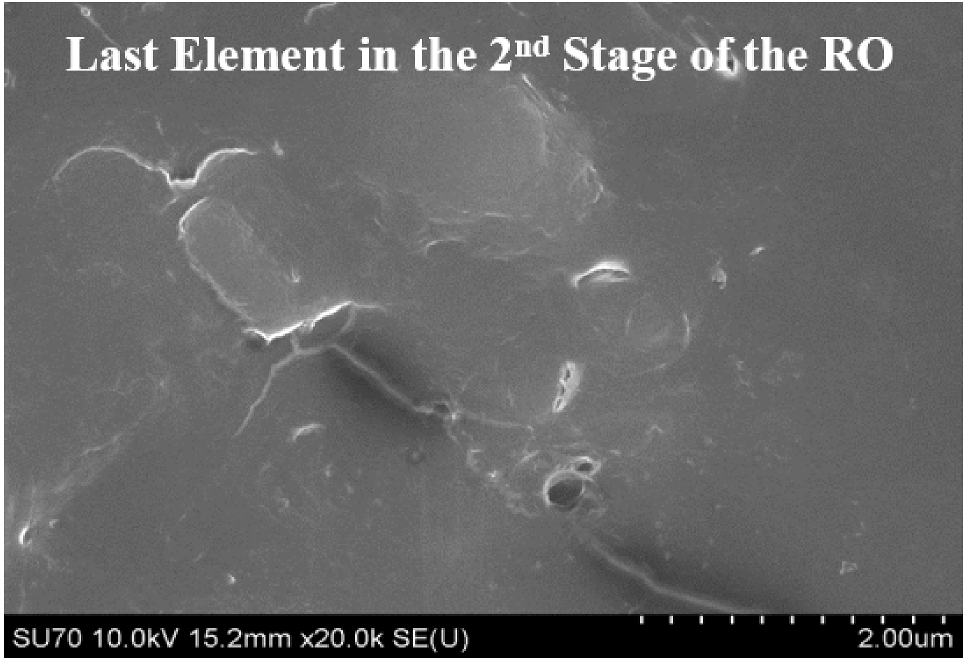
Primary RO

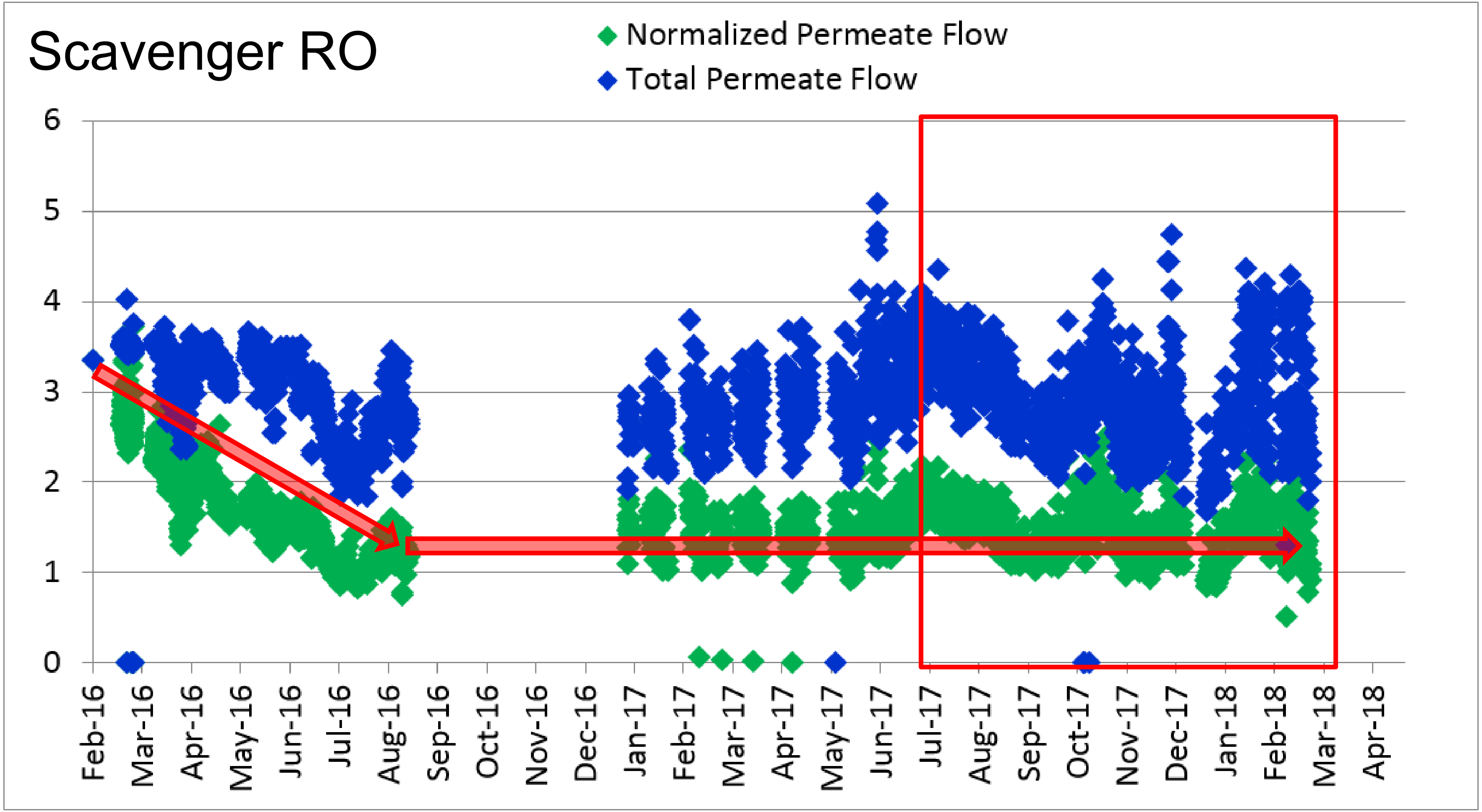

RO1 Normalized Permeate Flow (m3/hr)
RO1 Permeate Flow (m3/hr)
18
16
14
12
10
8
6
4
2
0
01-Jan-17
02-Mar-17
01-May-17
30-Jun-17
29-Aug-17
28-Oct-17
27-Dec-17


Primary RO
RO1 Normalized Permeate Flow (m3/hr)
RO1 Permeate Flow (m3/hr)
18
16
14
12
10
8
6
4
2
0
Nov-13
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Sep-16
Nov-16
Jan-17
Mar-17
May-17
Jul-17
Sep-17
Nov-17
Jan-18
Mar-18

Primary RO – Membrane Autopsy

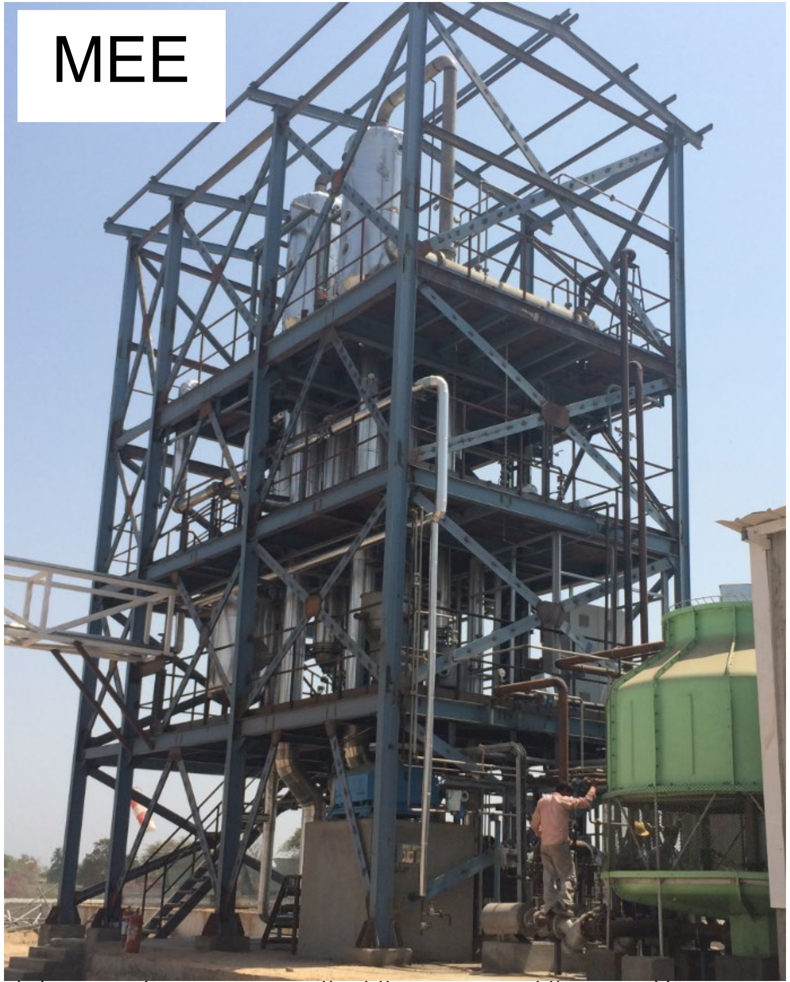






Scavenger RO
Normalized Permeate Flow
Total Permeate Flow
6
5
4
3
2
1
0
Feb-16
Mar-16
Apr-16
May-16
Jun-16
Jul-16
Aug-16
Sep-16
Oct-16
Nov-16
Dec-16
Jan-17
Feb-17
Mar-17
Apr-17
May-17
Jun-17
Jul-17
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18


Scavenger RO


MEE

LESSONS LEARNED

LESSONS LEARNED

- Regular sludge wasting is required
- Filamentous growth can cause an upset that increases UF solids loading and UF fouling rates
- Increasing the UF system back-pulsing frequency and duration, adopting continuous aeration, and frequent chemical cleaning are effective methods to keep an overloaded UF system in operation
- During a major upset the UF will become a bottleneck for water reuse and impact production
- UF performance can be recovered by chemical cleaning. Membrane replacement is not required

LESSONS LEARNED

- The operation of this water reuse RO over the last 4.5 years at 87.5% recovery is proof that reliable performance can be achieved at recovery rates greater than 75%
- High recovery wastewater RO systems can operate during a major upset without a reduction in recovery
- RO membrane autopsy results after 4 years of operation showed that organic biofilms are the predominate RO membrane foulant (87%)
- RO membrane permeability is estimated to be approximately half of what it was at startup in early 2014 (4.5 years)

LESSONS LEARNED

- The performance of this industrial wastewater treatment plant and membrane-based water reclamation plant demonstrate that even extreme variations in operating conditions can be accommodated without a membrane replacement. The key elements to achieving reliability are attentive operators and a conservative design

Thank You!

- Our Client's Operations Staff … Excellent Results … Very Attentive
- Project Design Team
- IWC Conference and Attendees


KEEP
CALM
AND
REUSE
WATER

INDUSTRIAL WATER REUSE
A ROADMAP FOR THE FUTURE

IWC Workshop W7

8. Case Studies

wood.

BMFOU Berkeley Pit and Discharge Pilot Project Polishing Facility

Butte, Montana 59701

Bob Kimball, P.E., BCEE
robert.kimball@woodpl.com

Mine Water Reuse

Basis of Design

- Source: Tailings Water
- Design Feed Flow:
  - 10 MGD
- Influent Water Quality
  - High pH (9.5 to 10.5), consists mostly of calcium sulfate, low metals concentrations, most dissolved metals already meet final CD limits
  - Future water quality estimated to remain similar but with possible increased aluminum concentrations (0.6 and 2.5 mg/L)
- Effluent Discharge Criteria
  - Consent Decree requirements for discharge into creek
  - Potential reuse for Green Hydrogen Production

Water Quality and Discharge Limits

Parameter	Units	Type	Existing YDTI Water Quality			Predicted Future YDTI Water Quality	Final Discharge Limit (30-day average)
			Min	Max	Average		
pH	s.u.	Field	8.4	10.6	9.6	10.5	6.5 to 9
Total Alkalinity, as $CaCO_3$	mg/L	Total	12	44	43	34	-
Major Anions							
Chloride	mg/L	Total	11.8	13.3	12.6	14.5	-
Sulfate	mg/L	Total	1,030	2,500	1,382	1,458	-
Major Cations							
Calcium	mg/L	Diss	389	715	500	573	-
Magnesium	mg/L	Diss	1.1	1.7	1.4	1	-
Potassium	mg/L	Diss	33	46	38	7	-
Sodium	mg/L	Diss	83	109	95	55	-
Other							
TSS	mg/L	Total	5	43	15	15	20
TDS	mg/L	Total	-	-	2,081	2,147	-
Total Hardness, as $CaCO_3$	mg/L	Total	959	1,260	1,090	1,436	-

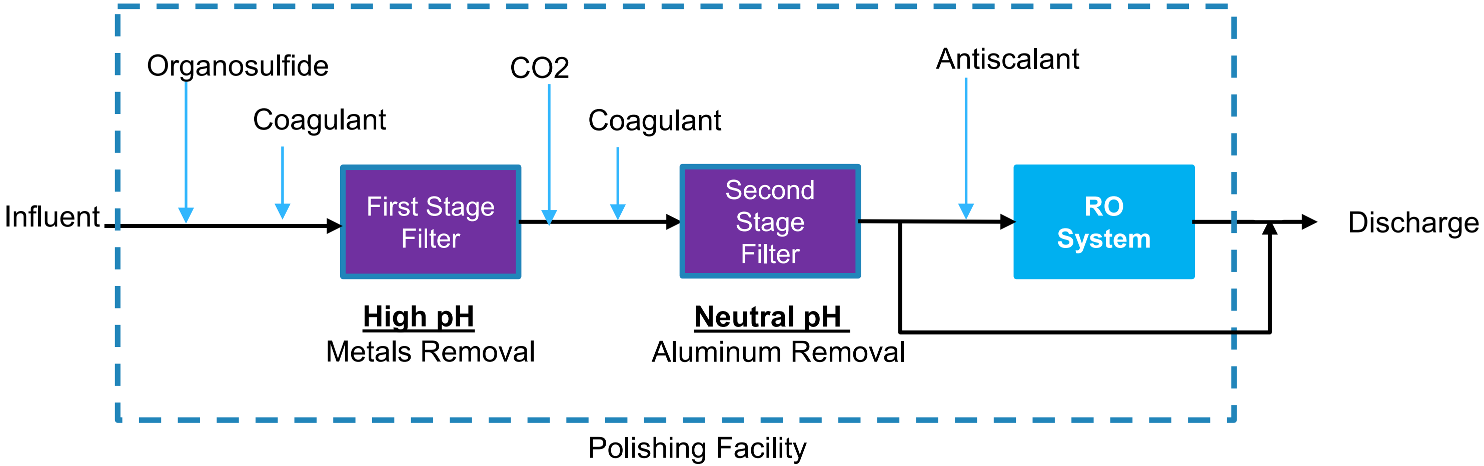
Water Quality and Discharge Limits

Parameter	Units	Type	Existing YDTI Water Quality			Predicted Future YDTI Water Quality	Final Discharge Limit (30-day average)
			Min	Max	Average		
Aluminum	µg/L	Total	64	2,300	410	600 – 2,500	-
	µg/L	Diss	10	69	31	600 – 2,500	-
Arsenic	µg/L	Total	3.76	29.0	6.90	Same	10
	µg/L	Diss	-	-	-	Same	-
Cadmium	µg/L	Total	0.028	3.6	0.32	Same	0.8
	µg/L	Diss	0.028	1.6	0.19	Same	-
Copper	µg/L	Total	4	340	32.5	Same	30.5
	µg/L	Diss	1.1	8.6	3.5	Same	-
Iron	µg/L	Total	18	4,200	722	Same	1,000
	µg/L	Diss	6.8	140	13.5	Same	-
Lead	µg/L	Total	0.3	13.1	1.83	Same	15
Zinc	µg/L	Total	0.82	310	30.2	Same	388
	µg/L	Diss	0.78	16	1.89	Same	-

Polishing Plant Project Overview

- Design/Build/Operate
- Completely gravity flow
- Simple, proven technologies
- Designed with flexibility to operate system in various configurations
- Target constituents include: aluminum, metals and dissolved salts, especially calcium and sulfate
- Majority of equipment was pre-fabricated for quick installation
- Completely automated with remote monitoring and operator call-out

Conceptual Design of the Polishing Facility



Multimedia Filters

- Design Flow: 10 MGD
- Design Filtration Rate: 5.1 gpm/ft^2
- Integrated, low volume backwash
- 6 Filter Vessels, 3 Cells/Vessel, 150 ft^2/cell
- Media:
  - 18” fine sand
  - 18” anthracite
- Effluent turbidity target:
  - Turbidity< 0.2 NTU
  - SDI <3-4
- Designed for single or two stage operation

Reverse Osmosis

- Design Capacity: 3 MGD permeate
- Recovery: 75%
- Design Flux: 12.2 to 12.8 gfd
- 2 Skids, 3 RO Systems:
  - Skid 1: 2 x 0.75 MGD
  - Skid 2: 1 x 1.5 MGD
- Membranes:
  - Hydranautics: ESNA1-LF2-LD-400
  - Low pressure, low fouling
  - 96% calcium rejection
- Operating Pressure: 100 to 150 psig

Carbon Dioxide System

- Supplier: Praxair
- 54 ton horizontal cylinder with vaporizer
- Three diffuser injection locations
- pH target 6.8 to 7.2 at discharge
- Typical dosage: 20 to 40 ppm

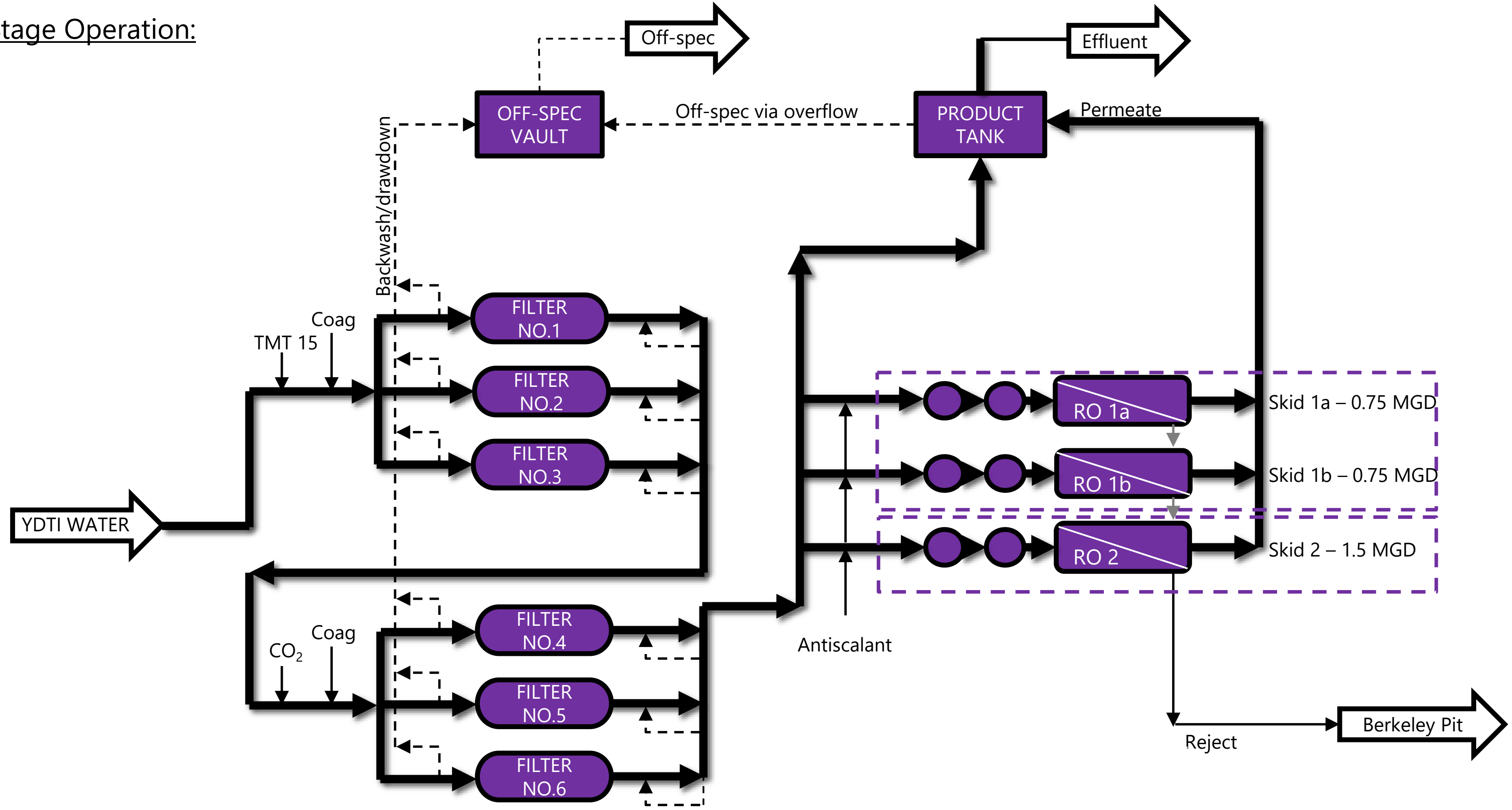
Chemical Feeds

- Coagulant
  - Cationic polymer
  - RoQuest 3000 (Avista)
  - Vichem 2001
  - Dosage 0.5 to 1.0 ppm
- TMT-15
  - Organosulfide
  - Precipitates heavy metals to low levels
  - Dosage < 3 mg/L
- Antiscalant
  - Vitec 7000 (Avista)
  - Nalco 9714
  - Dosage 2 to 3 mg/L

Product Tank

- 7,000 gallon FRB tank
- Blends Filtered Effluent and RO permeate
- 1 min retention time at max flow
- Simple design; internal weirs direct flow to discharge (lower weir) or off-spec/ waste vault (upper weir)
- Equipped with pH and conductivity instruments for online measurement and control

Two Stage Operation:



Summary

- Design/Build/ Operate Project
- Simple treatment process with flexible operating configurations
- Completed in less than 15 months
- H&S: >90,000 hours without an incident
- Discharge: Sept 30, 2019


KEEP
CALM
AND
REUSE
WATER

INDUSTRIAL WATER REUSE NEW TECHNOLOGIES AND LESSONS LEARNED

IWC Workshop W-07

Case Study

INTERNATIONAL WATER CONFERENCE

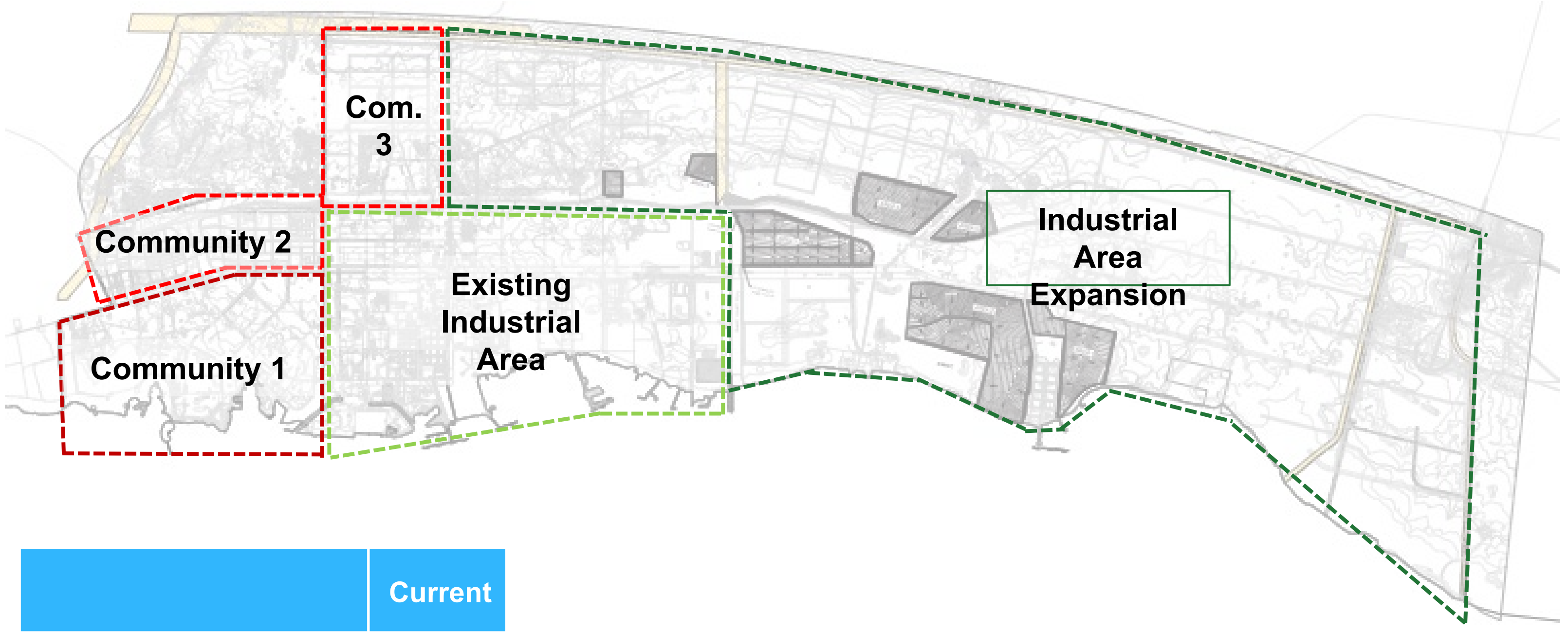
wood.

YANBU INDUSTRIAL CITY

Industrial Wastewater Reuse Strategy

Location: Suburb Yanbu Ak Bahr, Saudi Arabia *(Medina Region)*

Yanbu Industrial City Expansion – Current vs 2030



	Current		
Community	1		
Population	102,000		
Residential Area Gross (ha)	402		
Industrial Area (ha)	19,100	42,923	125

Ref: Yanbu Master Plan – Vol 1
Tables 1.1.1, 1.1.2, 1.3.2, 1.3.3

Industrial Wastewater Treatment Plant

SETE Saudia (SETE Energy Saudia for Industrial Projects Ltd.) Project

- Capacity: 48,000m^3/day (12.7 mgd)
- Influent wastewater generated by Oil & Gas / Petrochemical industries
- Technology: Conventional Extended Aeration followed by Physical Chemical Treatment
- Discharge utilized for local irrigation or discharge into Red Sea.

Treatment Processes

Systems and Technologies:

Biological treatment

- API Separator
- Primary Treatment with Primary Lamella Plates
- Biological Treatment: Extended Aeration by Fines Bubbles Diffusion for nitrification / mixing for anoxic de-nitrification conditions
- Dissolved Air Flotation Clarifiers
- Odor Control

Physical Chemical Treatment:

- Fenton Reaction Tanks

Tertiary Treatment:

- Multi-Media Filters,
- GAC Filters
- Chlorination System.

Fenton Reaction[1]

- H.J.H Fenton discovered in 1894 that several metals have special oxygen transfer properties which improve use of hydrogen peroxide.
- Actually, some metals have a strong catalytic power to generate highly reactive hydroxyl radicals (OH). *Since this discovery, iron catalyzed hydrogen peroxide has been called Fenton's reaction.*
- Fenton's reaction is used to treat a large variety of water pollution such as: phenols, formaldehyde, BTEX (benzene, toluene, ethylbenzene and xylene), pesticides, rubber chemicals...

Fenton Reaction$_2$

Used in wastewater for:

- Organic pollutant destruction
- Toxicity reduction
- Biodegradability improvement
- BOD/COD Removal
- Odor and color removal
- Destruction of resin in radioactive contaminated sludge

After addition of iron and hydrogen peroxide, chemicals react to generate hydroxyl radicals:

- **$Fe^{2+} + H_2O_2$ ----> Fe^{3+} + .OH + OH^-**
- **$Fe^{3+} + H_2O_2$ ----> Fe^{2+} + .OOH + H^+**

Typical range for the iron dose is 1 part of Fe per 5-25 parts of H_2O_2.

- *pH adjustment of 3 to 5 necessary to control effective reaction rates of iron / peroxide*

Clarifiers

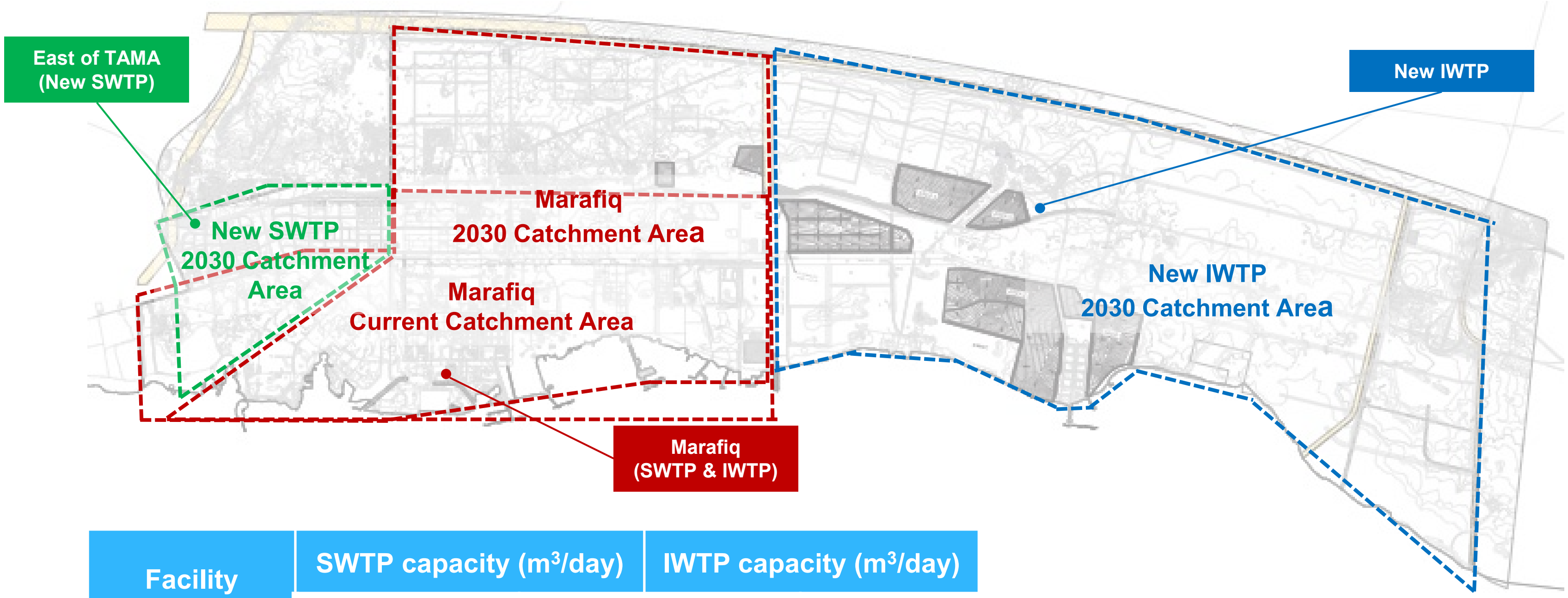
Fine Bubble Aeration

Multi-Media & GAC Filtration

Dissolved Air Flotation Thickeners

FUTURE VISION

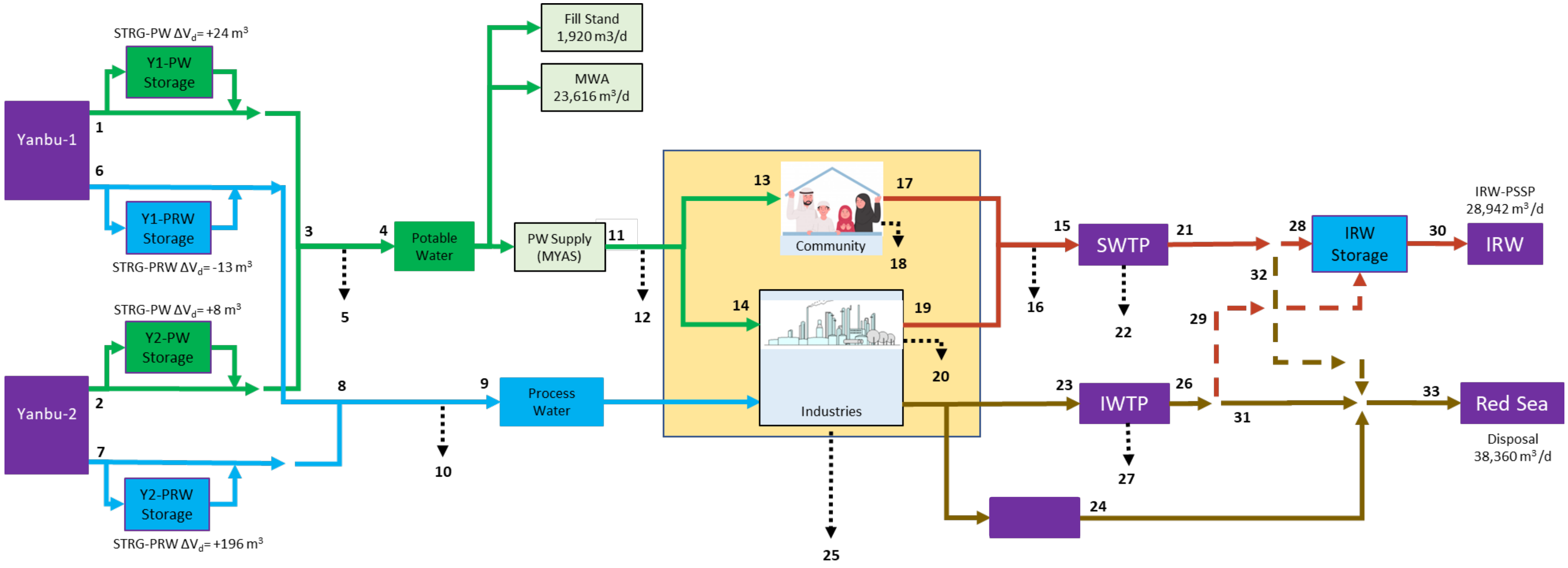
Water Treatment Facilities – Current vs 2030



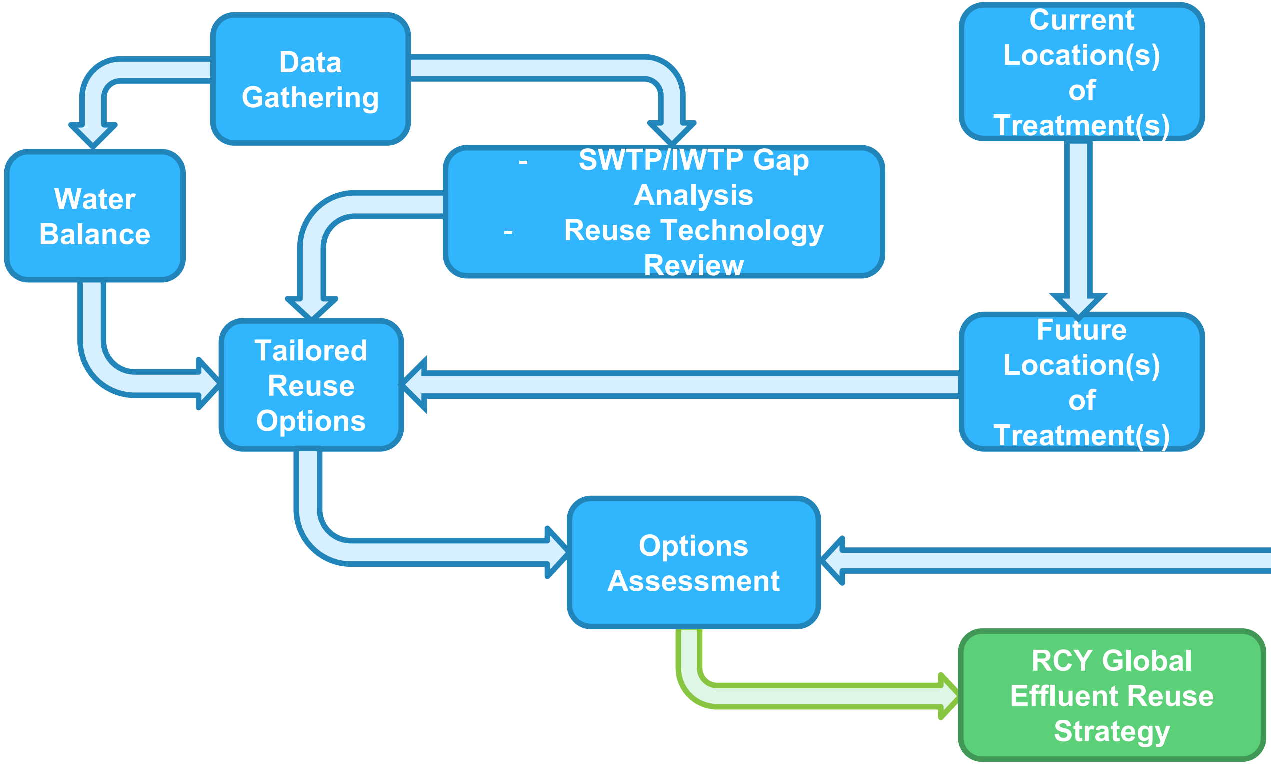
Facility	SWTP capacity (m^3/day)		IWTP capacity (m^3/day)	
	Current	2030	Current	2030
Marafiq	27,000 + 20,000	Same	48,000	Same

Ref: Parsons Technology Review
SWTP (doc 06) & IWTP (doc 09)

Water Balance – Gap Analysis



Brief Methodology



Reuse Technology Review

Natural Treatment
- Lagoons
- Constructed wetlands

Disinfection & AOPs
- Chlorination
- UV
- H_2O_2

Activated Carbon
- GAC
- PAC

(upward, downward, moving bed, etc.)

Desalination / TDS Removal
- Softening: Ion Exchanging, chemical
- Membrane: NF, UF, RO, ED, FO, DM
- Distillation: MSF, MVC, MED

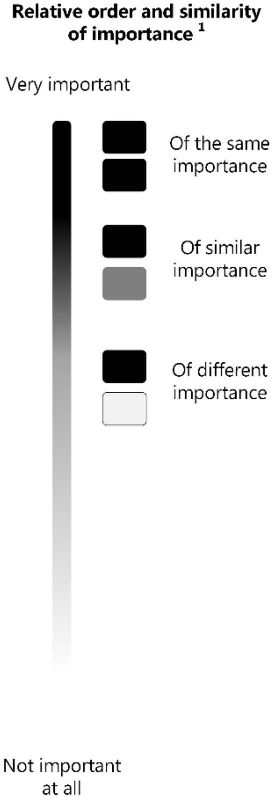
Brine Treatment
- Crystallisation: evaporative, cooling, Reaction, Drowning Out, Membrane-based
- Evaporation Ponds

Reuse Engineering Options Development

Onsite Reuse	Intra-Plot Reuse	Centralised Recycling & Reuse	Segregated Wastewater Reuse	Reuse as Desalinatio n Feedstock
Non-food Crop Agriculture	Non-agriculture Irrigation	Engineering Pond	Engineering Wetland	Constructio n

Reuse Options Scoring & Sensitivity Analysis

Technical	Financial	Environmental	Social	Political	Economic
Technology reliability	CAPEX	Red Sea impact -water quantity	Impact on business value chains	Local/ national policy	Increased industry productivity
Long term resiliance	Lifetime of assets	Red Sea impact -water quality	Impact on local plans/ customs	Stakeholder support and beneficiaries	Increased agricultural productivity
Volumetric contribution	OPEX	Groundwater impact -water quality	Impact on climate change adaptation	Attractivenes s for private sector investment	Net employment generation
Construction/ operation risks		Greenhouse gas emissions		Contribution to SDG's	
Development footprint		Groundwater impact -water quantity			



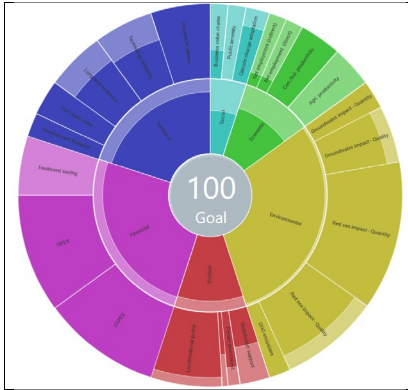
Reuse Options Scoring & Sensitivity Analysis

	Rank	Option	Total score	Financial	Technical	Social	Economic	Environmental	Political
High Priority	1	10.1	100						
	2	3.4	84						
	3	3.3	84						
	4	7.1	78						
	5	8.1	78						
	6	6.1	78						
Medium Priority	7	1.3	77						
	8	3.2	76						
	9	9.1	76						
	10	5.1	71						
	11	3.5	69						
	12	2.1	66						
Low Priority	13	3.1	62						
	14	1.2	57						
	15	2.7	53						
	16	2.4	49						
	17	1.1	45						
	18	2.6	35						
Eliminated options	19	2.3	32						
	20	4.1	29						
	21	2.5	25						
	22	2.2	15						
	23	4.3	6						
	24	4.2	0						

DecisionVue

Wood's DecisionVue platform is based on Multi Criteria Decision Analysis (MCDA) and Robust-Utility Analysis (RUA), a quantitative decision-making under uncertainty evaluation technique which compares options or strategies based on their performance and robustness across a range of possible futures.

Reuse Options Scoring & Sensitivity Analysis

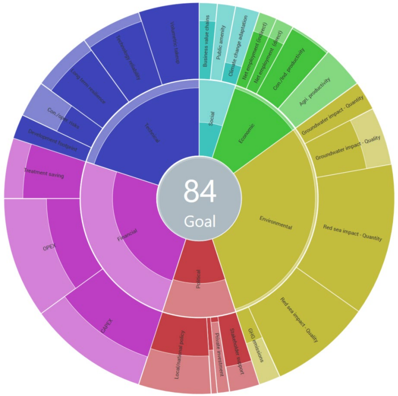


Option 10.1 Strategic Construction

Total Score: 100%

- Financial: 88%
- Technical: 82%
- Social: 57%
- Economic: 67%
- Environmental: 97%
- Political: 86%

Summary: This particular option scores highly for all criteria with the exception of *Social* and *Economic* criteria where it scores above average.

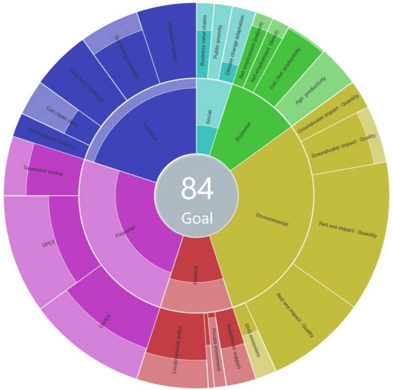


Option 3.4 Mixed recycling facility, ZLD with evaporation pond

Total Score: 84%

- Financial: 58%
- Technical: 89%
- Social: 44%
- Economic: 96%
- Environmental: 97%
- Political: 56%

Summary: This particular option scores highly for technical, economic and environmental criteria, but above average for financial, social and political criteria.



Option 3.3 Mixed recycling facility, ZLD with evapo-crystallisation

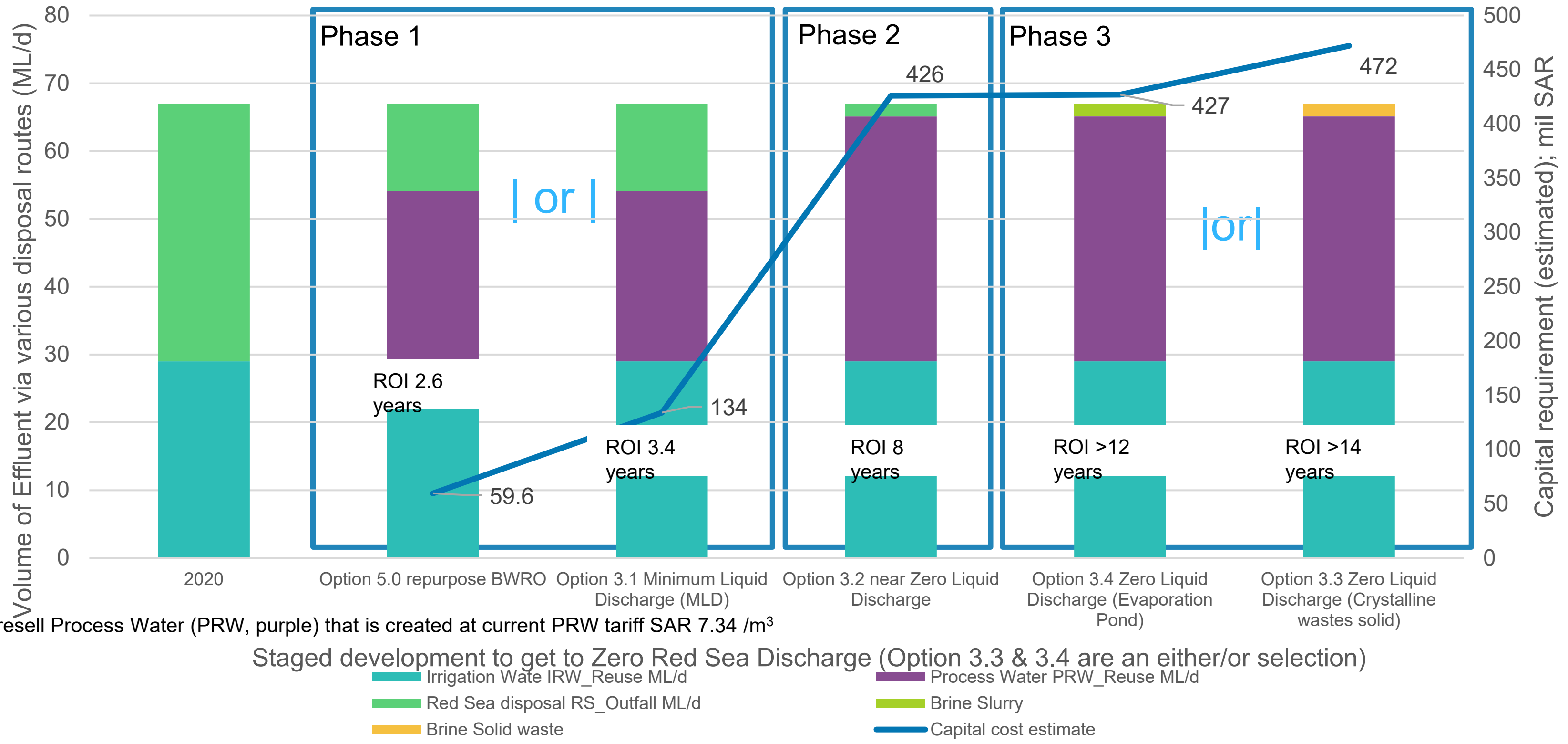
Total Score: 84%

- Financial: 52%
- Technical: 87%
- Social: 38%
- Economic: 100%
- Environmental: 100%
- Political: 60%

Summary: This particular option scores highly for technical, economic and environmental criteria, but above average for financial and political criteria.

Phased Investment

(for a fixed volume; 38,000 m³/d excess effluent currently being discharged to Red Sea)




KEEP
CALM
AND
REUSE
WATER