Seawater Desalination Program Update
Long Beach Water Department

Metropolitan's Special Committee on Desalination and Recycling

August 25, 2009

Research Partners

Government

- US Bureau of Reclamation
- CA Dept. of Water Resources
- LA Department of Water and Power
- Southern Nevada Water Authority
- Tampa Bay Water Authority

Industry

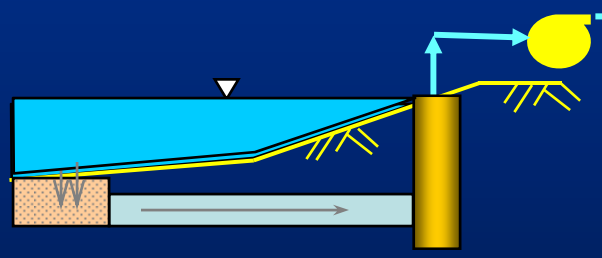
- DuPont
- AwwaRF

Academia

- UCLA
- University of New Hampshire
- Clemson University
- University of Illinois
- Montana State University
- University of Central Florida
- Virginia Tech
- University of Nevada, Reno
- University of Iowa

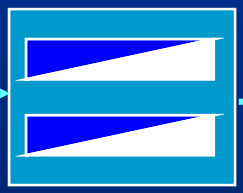
Long Beach's Research Initiatives

Intake and Pretreatment



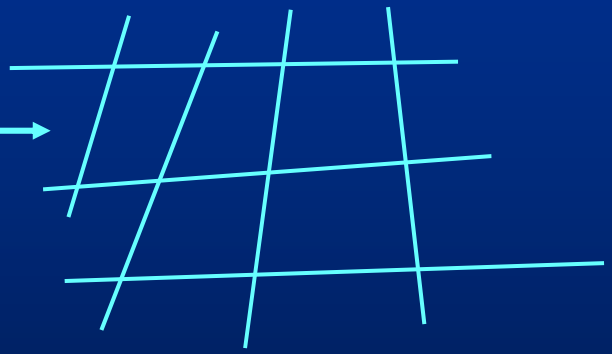
- Under Ocean Floor Intake and Discharge

NF^2 or RO



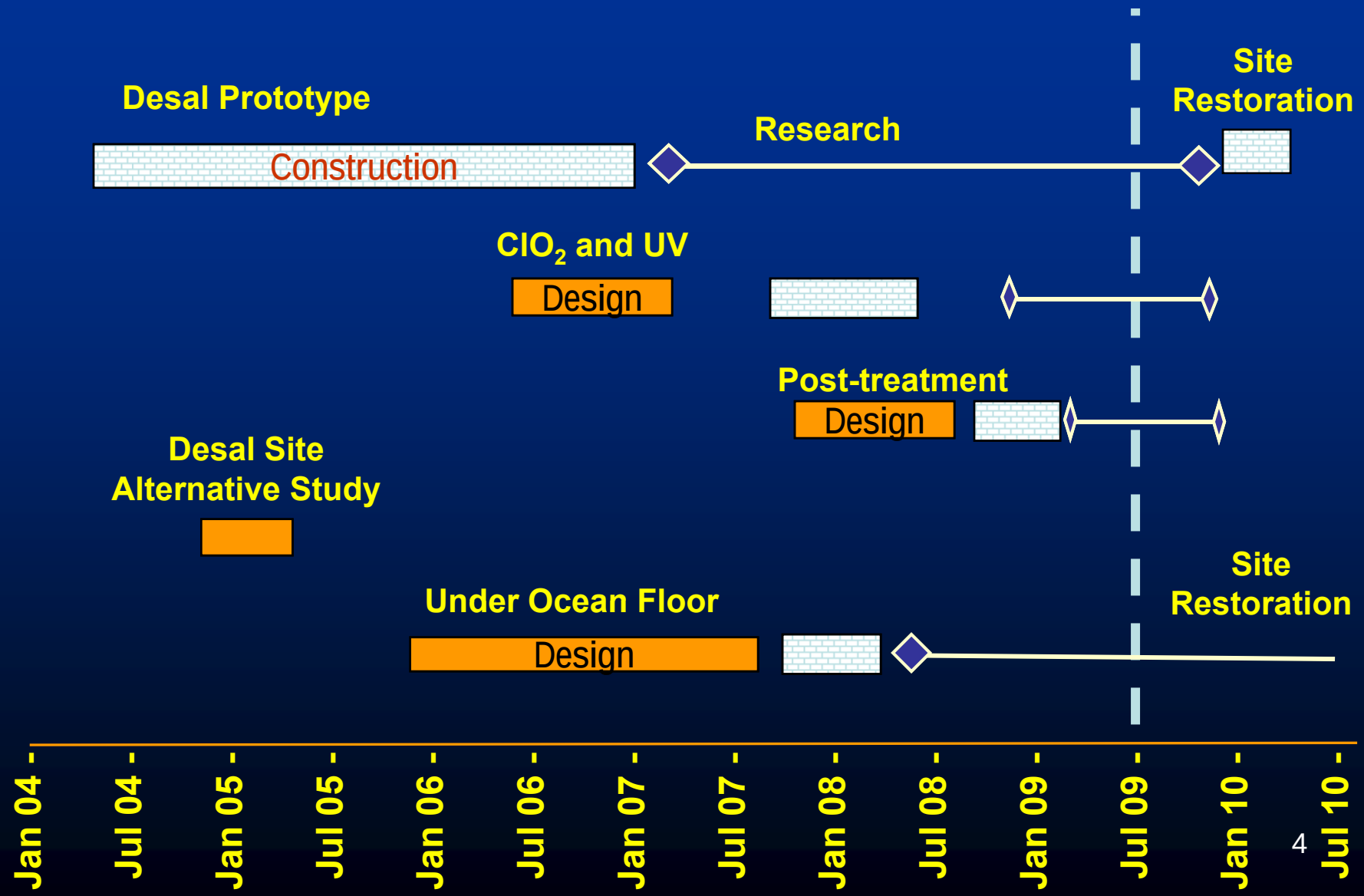
- Prototype Tests
- ClO_2 / UV

Post treatment / Distribution



- Posttreatment

Desalination Research Schedule



Research Presentations

2005 Presentations

- Harrison, Childress, Le Gouellec, and Cheng, "Bench-Scale Testing of Seawater Desalination Using Nanofiltration," AWWA 2005 Membrane Technology Conference and Workshop, Phoenix, AZ, March 6 - 9, 2005.
- Le Gouellec, Cheng, Harrison, and Cornwell, "Theoretical Modeling of a Novel Membrane-Based Seawater Desalination System," AWWA 2005 Membrane Technology Conference and Workshop, Phoenix, AZ, March 6 - 9, 2005.
- Le Gouellec, Harrison, and Cheng., "Modeling the Performance of Desalination by Dual-Staged Nanofiltration," AWWA 2005 Membrane Technology Conference and Workshop, Phoenix, AZ, March 6 - 9, 2005.
- Trejo, Leung, and Rohe. "Prototype Testing Facility for Two-Pass Nanofiltration Membrane Seawater Desalination Process," AWWA 2005 Membrane Technology Conference and Workshop, Phoenix, AZ, March 6 - 9, 2005.
- Tseng, Cheng, Vuong, and Wattier. "Developing and Experimental Protocol for Evaluating Low-Pressure Membranes for Seawater Desalination," AWWA 2005 Membrane Technology Conference and Workshop, Phoenix, AZ, March 6 - 9, 2005.
- Tseng, Grebel, Cheng, Vuong, and Wattier. "Emerging Water Quality Concerns Associated with Integrating Desalinated Seawater into Existing Distribution Systems," AWWA Annual Conference and Exposition, San Francisco, CA, June 14, 2005.
- Cheng, Tseng, Le Gouellec, Childress, and Cornwell. "A Novel Approach to Seawater Desalination Using Dual-Staged Nanofiltration Process," AWWA Annual Conference and Exposition, San Francisco, CA, June 14, 2005.
- Wattier. "Long Beach Seawater Desalination," Urban Water Institute, Seawater Desalination and Power Conference, June 23, 2005.
- Tseng, Grebel, Cheng, Vuong, and Wattier. "Emerging Water Quality Concerns Associated with Integrating Desalinated Seawater into Existing Distribution Systems," AWWA CA/NV Fall Conference, Reno, NV, October 12, 2005.
- Cheng and Wattier. "Update on Long Beach Water Department's Desalination Program," International Desalination Association, Monterey, CA, October 28, 2005.

2006 Presentations

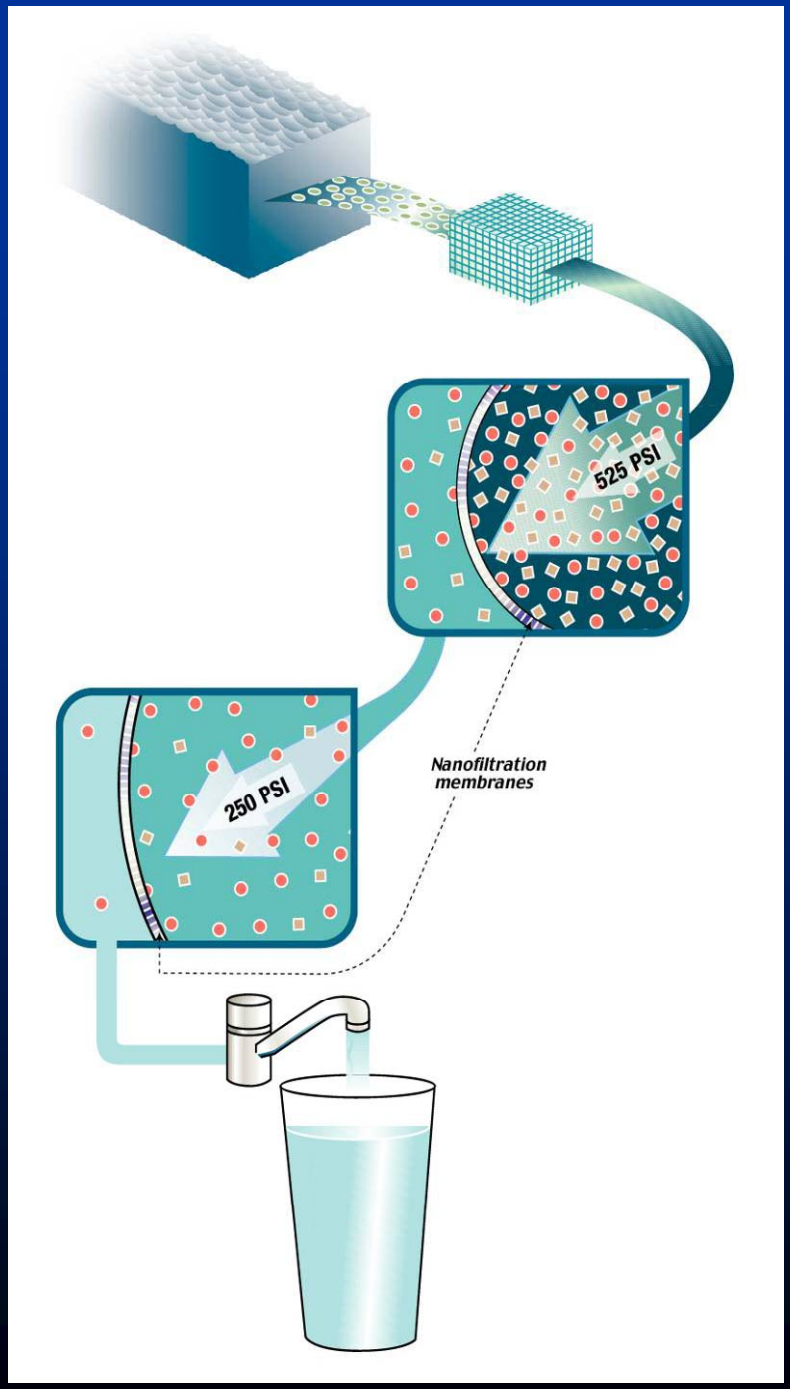
- Cheng and Wattier. "Update on Long Beach Water Department's Desalination Program Using Nanofiltration Membranes," American Chemical Society 40th Annual Regional Meeting, January 24, 2006.
- Wattier. "Long Beach Water Department Nano Nano Filters," Urban Water Institute, Seawater Desalination and Power Conference, January 30, 2006.
- Cheng, Tseng, and Wattier. "Permitting Issues Associated with a Seawater Desalination Prototype Testing Facility," AWWA CA/NV Spring Conference, Burlingame, CA, April 27, 2006.
- Tseng, Cheng, and Wattier. "Permitting Issues Associated with a Seawater Desalination Prototype Testing Facility," AWWA Desalination Symposium, Honolulu, HI, May 8, 2006.
- Tseng, Cheng, and Wattier. "LBWD's Testing of Dual-Pass NF and SWRO for Seawater Desalination," AWWA Desalination Symposium, Honolulu, HI, May 9, 2006.
- Cheng. "Permitting Issues Associated with a Seawater Desalination Prototype Testing Facility," AWWA Annual Conference and Exposition, San Antonio, TX, June 11 - 15, 2006.
- Wattier. "The Long Beach Seawater Desalination Research and Development Program," American Membrane Technology Association Anaheim, CA, August 1, 2006.
- Tseng, Cheng, and Wattier. "Full-Scale Water Quality Performance Comparison of SWRO to Dual-Pass Nanofiltration for Seawater Desalination," AWWA CA/NV Fall Conference, Long Beach, CA, October 4, 2006.
- Tseng, Cheng, and Wattier, "Full-Scale Water Quality Comparison of Single-Pass Reverse Osmosis to Dual-Pass Nanofiltration for Seawater Desalination," AWWA Water Quality Technology Conference, Denver, CO, November 5 - 9, 2006.

2007 – 08 Presentations

- Cheng and Wattier. "Long Beach Water Department's Perspectives on Seawater Desalination." AWWA Membrane Technology Conference, Tampa, FL, March 12, 2007.
- Tseng, Cheng, and Wattier. "Comparison of SWRO to Dual-Pass Nanofiltration for Seawater Desalination," AWWA Membrane Technology Conference, Tampa, FL, March 12, 2007.
- Tseng, Cheng, and Wattier. "WQ Monitoring During Full-Scale Seawater Desalination Operations," AWWA Water Quality Technology Conference, Charlotte, NC, November 6, 2007.
- Cheng and Wattier, "Researching Innovative Solutions for Seawater Desalination at the Long Beach Water Department." Multi-States Salinity Conference, National Salinity Summit, Las Vegas, NV, January 18, 2008
- Tseng, Cheng, Andrews-Tate, and Hulsey. "Bench-Scale Testing for Controlling Desalinated Water Quality." AWWA CA/NV Spring Conference, Hollywood, CA, April 23, 2008.
- Tseng, Cheng, and Wattier. "Update on Prototype-Scale Performance Comparison of SWRO and Dual-Pass Nanofiltration for Seawater Desalination," AWWA Annual Conference and Exposition, Atlanta, GA, June 12, 2008.
- Tseng, Cheng, and Wattier. "Pilot and Demonstration Testing of Subsurface Filtration for Seawater Desalination," AWWA CA-NV Fall Conference, Reno, NV, October 22, 2008.
- Tseng, Cheng, Andrews-Tate, and Wattier. "Bench-Scale Testing for Controlling Desalinated Water Quality," AWWA Water Quality Technology Conference, Cincinnati, OH, November 17, 2008.
- Allen, Tseng, Cheng, and Wattier. "Pilot and Demonstration-Scale Research Evaluation of Under-Ocean Floor Seawater Intake and Discharge," AWWA Water Quality Technology Conference, Cincinnati, OH, November 17, 2008.

2009 Presentations

- Tseng, Cheng, Tanuwidjaja, and Wattier, “Evaluation of UV and ClO2 in Seawater Desalination Pretreatment for Biogrowth Control and Pathogen Inactivation.” AWWA Membrane Technology Conference, Memphis, TN, March 15 - 18, 2009.
- Allen, Tseng, Cheng , and Wattier,. “Update for the Pilot and Demonstration-Scale Research Evaluation of Under-Ocean Floor Seawater Intake and Discharge,” AWWA Membrane Technology Conference, Memphis, TN, March 15 - 18, 2009.
- Cheng, Andrews-Tate,Tseng, and Wattier, “Issues with Distribution of Desalinated Seawaters:Are Corrosion Indicators Sufficient?” AWWA Membrane Technology Conference, Memphis, TN, March 15 - 18, 2009.
- Tseng, Cheng, and Wattier, “Comprehensive Update on Seawater Desalination Testing at the LBWD Seawater Prototype Facility,” AWWA Annual Conference and Exposition, San Diego, CA, June 16, 2009.
- Allen, Tseng, Cheng, and Wattier,. “Update for the Pilot and Demonstration-Scale Research Evaluation of Under-Ocean Floor Seawater Intake and Discharge,” AWWA Annual Conference and Exposition, San Diego, CA, June 16, 2009.
- Cheng, Tseng, and Wattier, “Prototype Evaluation of NF2 and RO for Seawater Desalination: Water Quality and Energy Comparisons.” AWWA Annual Conference and Exposition, San Diego, CA, June 16, 2009.

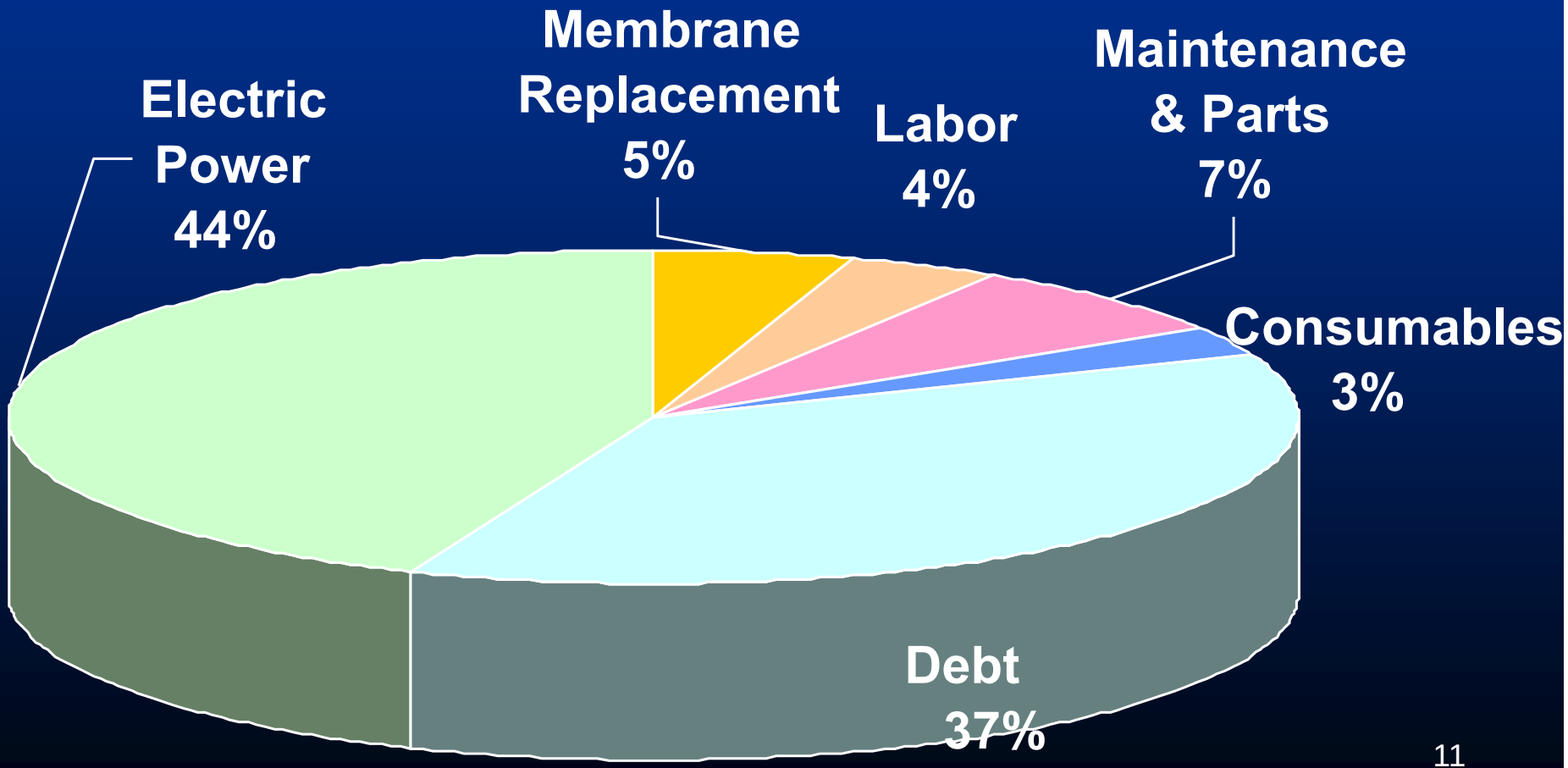


"The Long Beach Method" *Two Pass Nanofiltration*

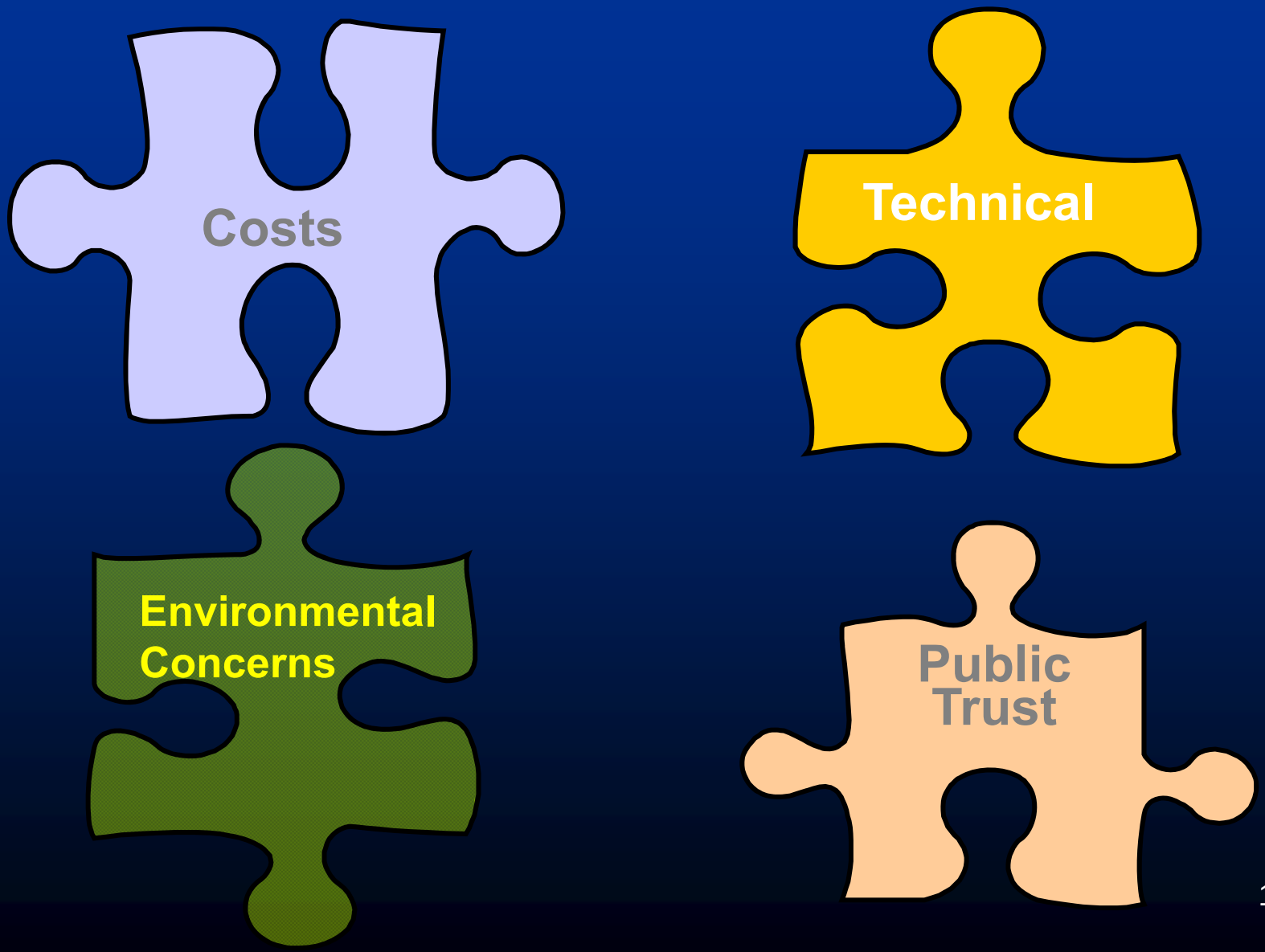
- **Energy Savings**
  - **Lower pressure requirements, lower energy consumption**
- **Quality Protection**
  - **Twice the protection of single-pass technology**

Cost – Major Driver is Energy

Federal Roadmap Estimate: Power + Debt = 81%



Program Considerations



Other Issues

- Technical
  - **Water quality (boron, bromide, etc.)**
  - **Blending issues (compatible w/existing water)**
- Environmental
  - **Impingement/entrainment**
  - **Discharge**
- Public Trust
  - **Sound investment**
  - **Transparency**
- Permitting

Permits for Construction and Operation

Issues	Permitting Agency
Endangered Species	▪ Fish and Wildlife Service ▪ National Marine Fisheries Service ▪ California Dept. of Fish and Game
Coastal Land Use	▪ State Lands Commission ▪ California Coastal Commission ▪ Local Planning and Building
Waterway Use	▪ Mineral Management Service ▪ Army Corp of Engineers ▪ Coast Guard
Regulation	▪ Environmental Protection Agency ▪ Air Quality Management District ▪ Regional Water Quality Control Board ▪ California Department of Public Health

Permitting Experience

- Test NF^2 and SWRO side-by-side
  - **300,000 gpd Prototype facility**
- Strategy
  - **Temporary facility**
  - **Obtain permit waivers and exemptions**
  - **Avoid waterway issues**
  - **No distribution of treated water**
  - **Limited discharge**

Regional Water Quality Control Board

- Clean Water Act (NPDES)
  - brine discharge
- California Ocean Plan
  - prohibits brine discharges into Areas of Special Biological Significance
- California Water Quality Control Plan
  - limits temperature of brine discharges
- Section 401
  - certifies brine discharges under Federal permits in State Waters

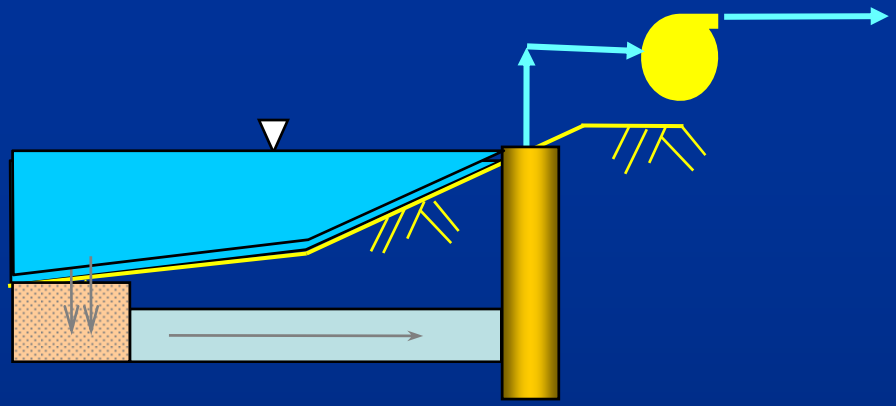
Discharge Issues

- Added chemicals
  - Continuous (scale inhibitor, acid, chlorine, sodium bisulfite)
  - Periodic (membrane-cleaning solutions, hauled off-site for disposal)
- Permeate and brine
  - contain low or trace levels of other chemicals
- No discharge waiver granted
  - attempted by performing mass balance and demonstrating limited impacts

Discharge Issues (cont'd)

- Metals discharge limits are very low
  - Copper discharge = 3.2 µg/L
  - Background = 2.8 µg/L
- Difficult to analyze metals in seawater
  - Analytical interferences from high salt concentrations result in errors (high bias)
- Ultimately issued a discharge permit
  - contained provisions for routine monitoring and reporting

Pretreatment/ Discharge



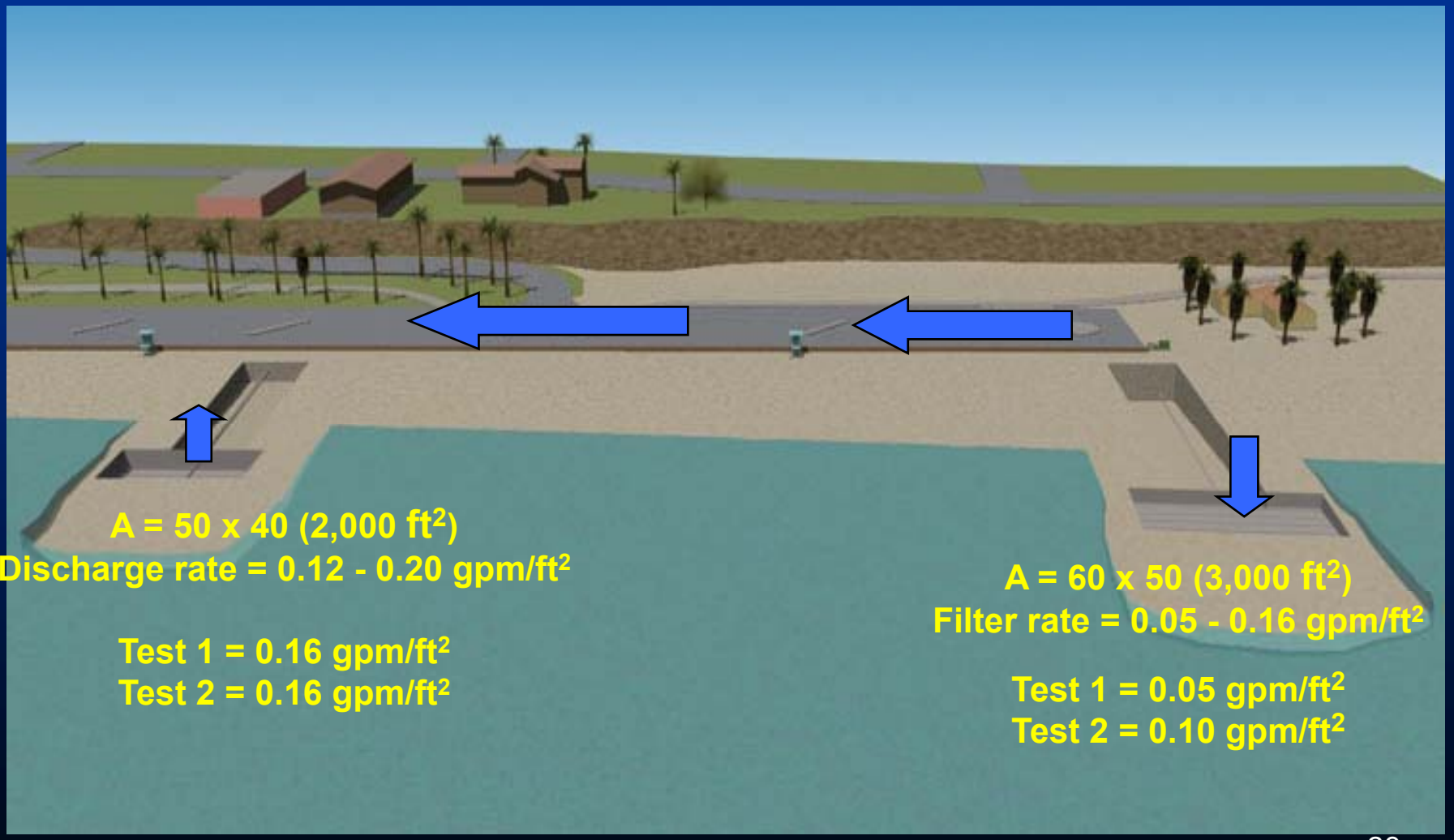
Under Ocean Floor Intake and Discharge

- $5 Million
- USBR, CaDWR

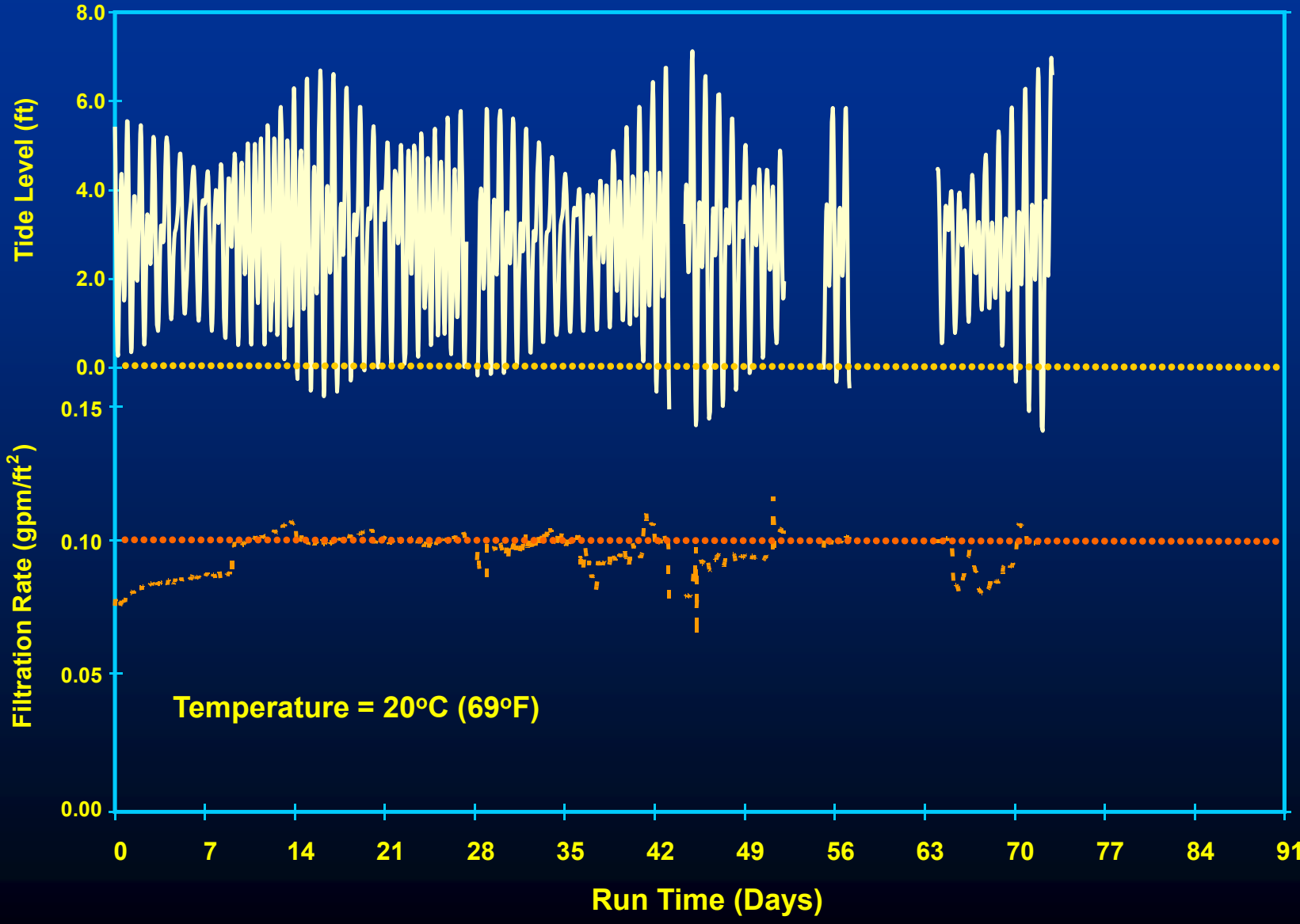
Addresses

- **Cost**
- **Technical**
- **Environmental Concerns**
- **Permitting**

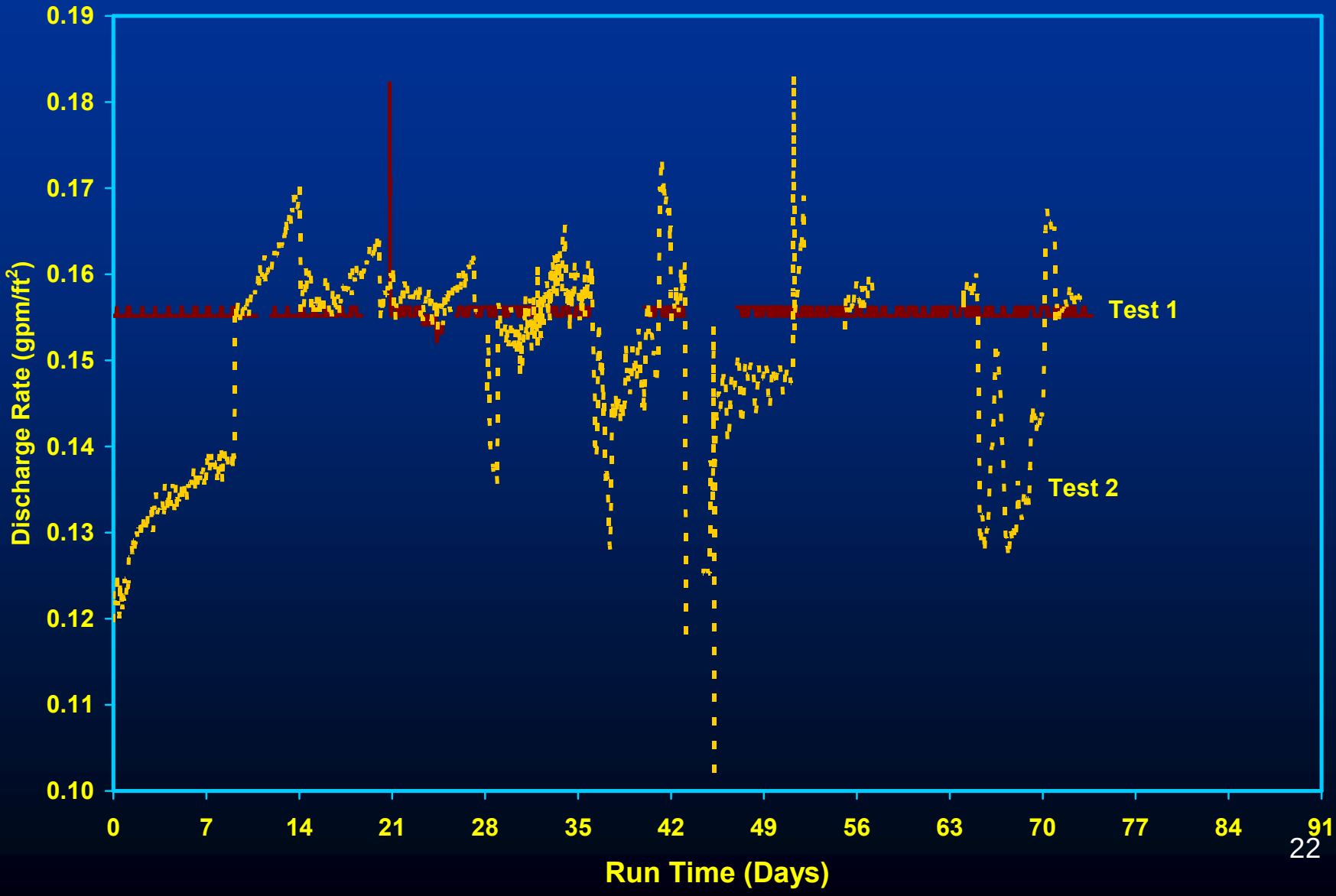
Underocean Floor Test Site



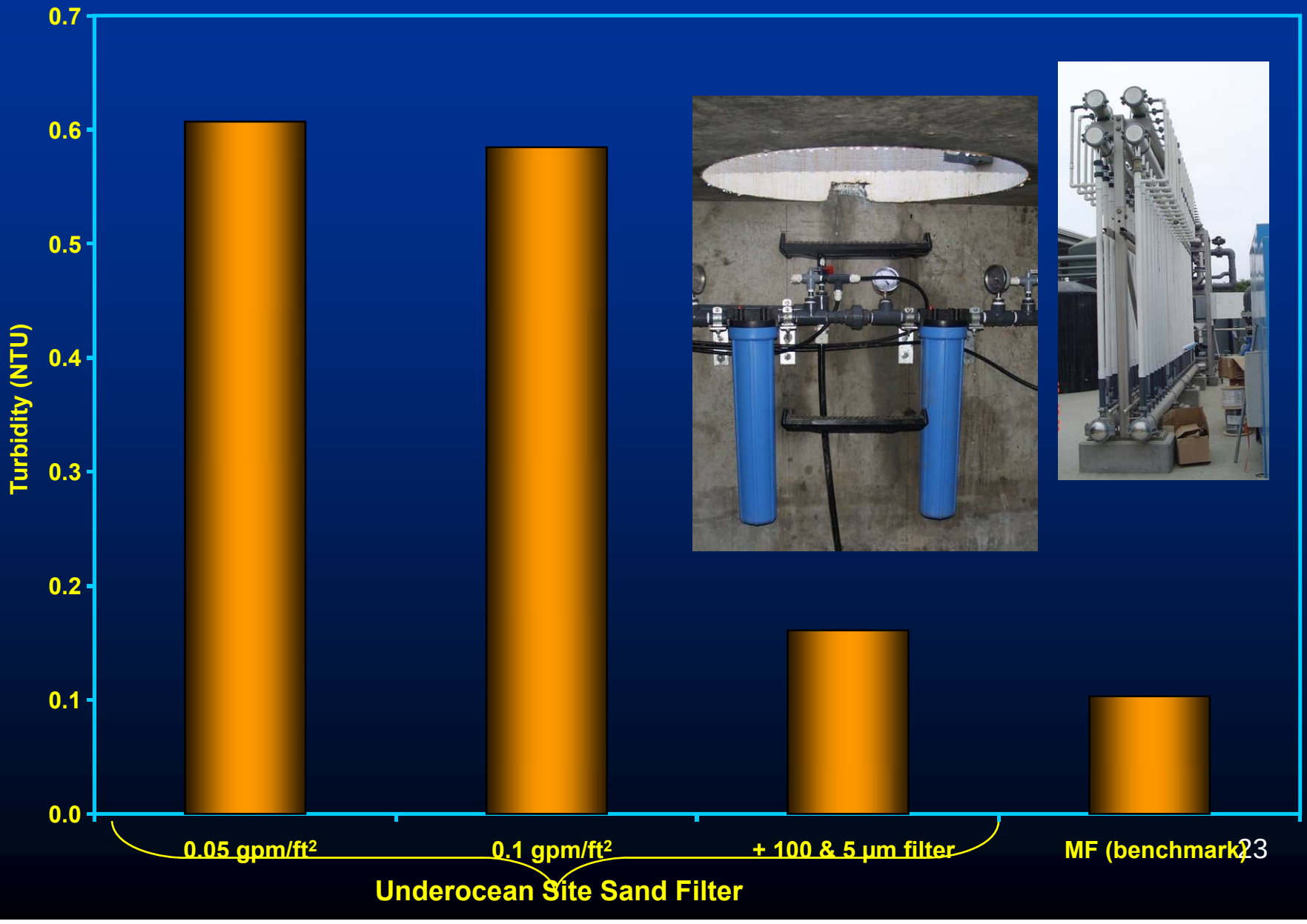
Filter Rate = 0.10 gpm/ft^2



Discharge Performance



Water Quality by Process

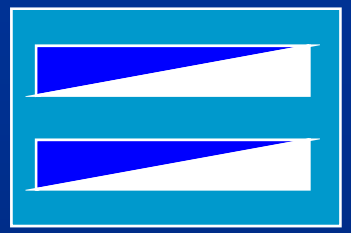


Underocean Floor Summary

- Initial results positive
  - 0.05 – 0.10 gpm/ft^2 rate little to no impacts by tides
  - No impacts on discharge
- Additional treatment may be required
  - 5 µm cartridge filter provides comparable water quality levels as microfiltratio process

Desalting Process

NF^2 or RO



Projects

- Pilot
  - $500k
  - AwwaRF, U. NV (Reno)
- Prototype
  - $8 M
  - USBR, LADWP
- UV/ClO_2
  - $2 M
  - USBR, CaDWR
  - UCLA, DuPont

Addresses

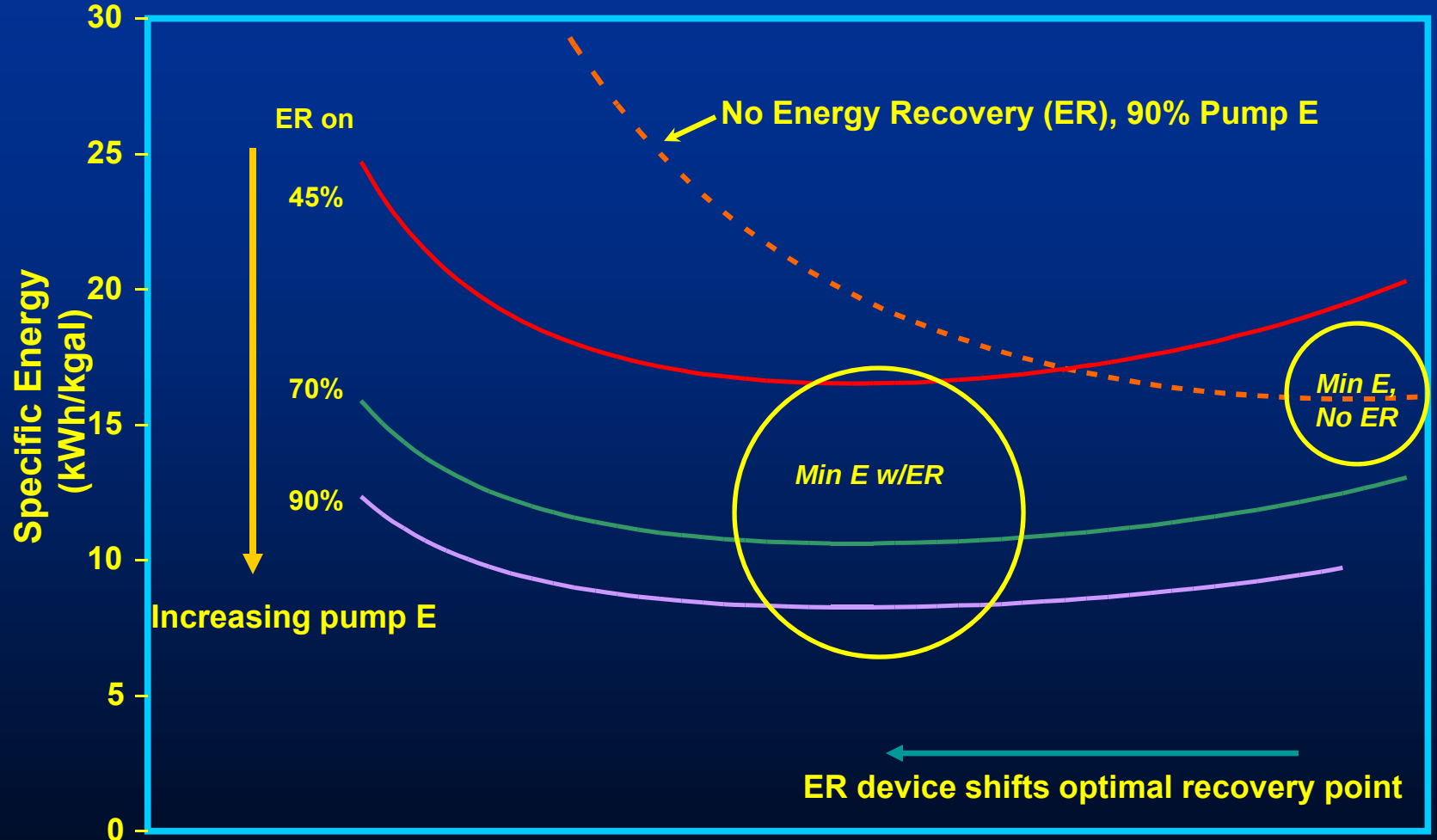
- Cost
- Technical
- Public Trust
- Permitting

Goal of Comparison

- Compare NF2 and SWRO (one-, two-pass) side-by-side under following guidelines:
  - Efficiency
    - f(recovery, energy usage)
  - Reliability
    - Minimize down time
  - Water quality
    - TDS: < 500 mg/L
    - Boron: 0.5 – 0.8 mg/L
    - Bromide: < 0.4 mg/L
- Optimize NF2 operations

Energy and Recovery

Calculated values, 35,000 mg/L seawater



Water Quality - Boron

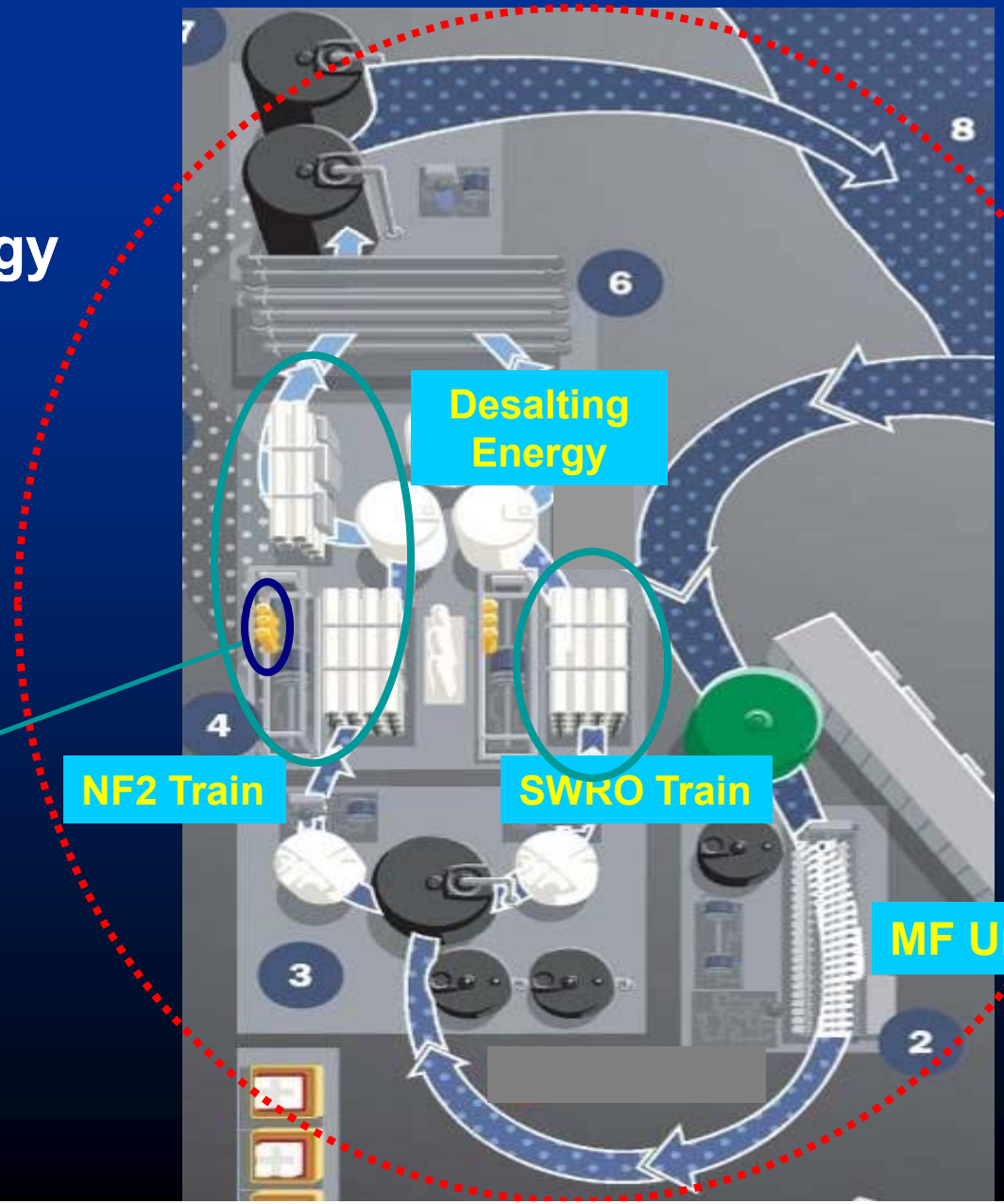
- Significant issue in various desalination reports (e.g. NAS)
- Varying limits
  - 1 mg/L – California Action Level
  - 0.5 mg/L - WHO standards
  - 0.3 mg/L - Israeli target
- Customer perception issue

Water Quality - Bromide

- Not regulated
  - typical < 0.1 mg/L (unimpacted surface or ground waters)
- Higher concentrations can cause disinfectant residual stability issues
  - may cause TCR violations
- Tampa Bay Water experienced with desalinated seawater

Prototype Facility

- Compares water quality and energy from NF2 and SWRO



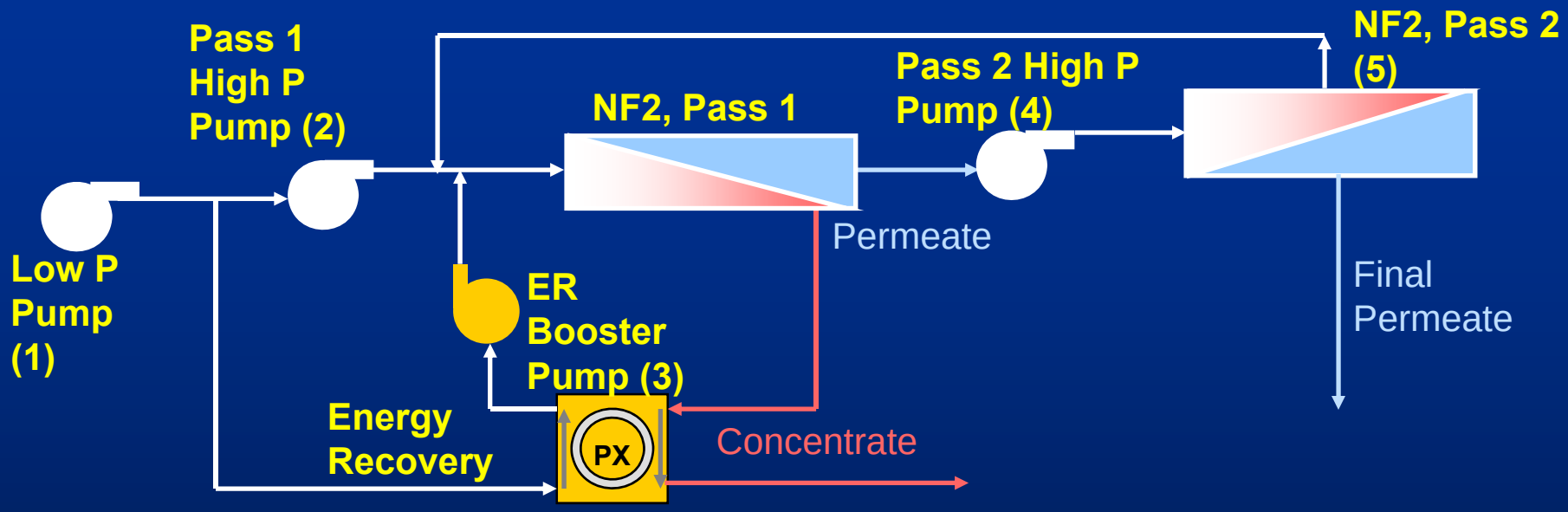
Prototype Facility

- 300,000 gpd facility, 8-in vessels

Research Methodology

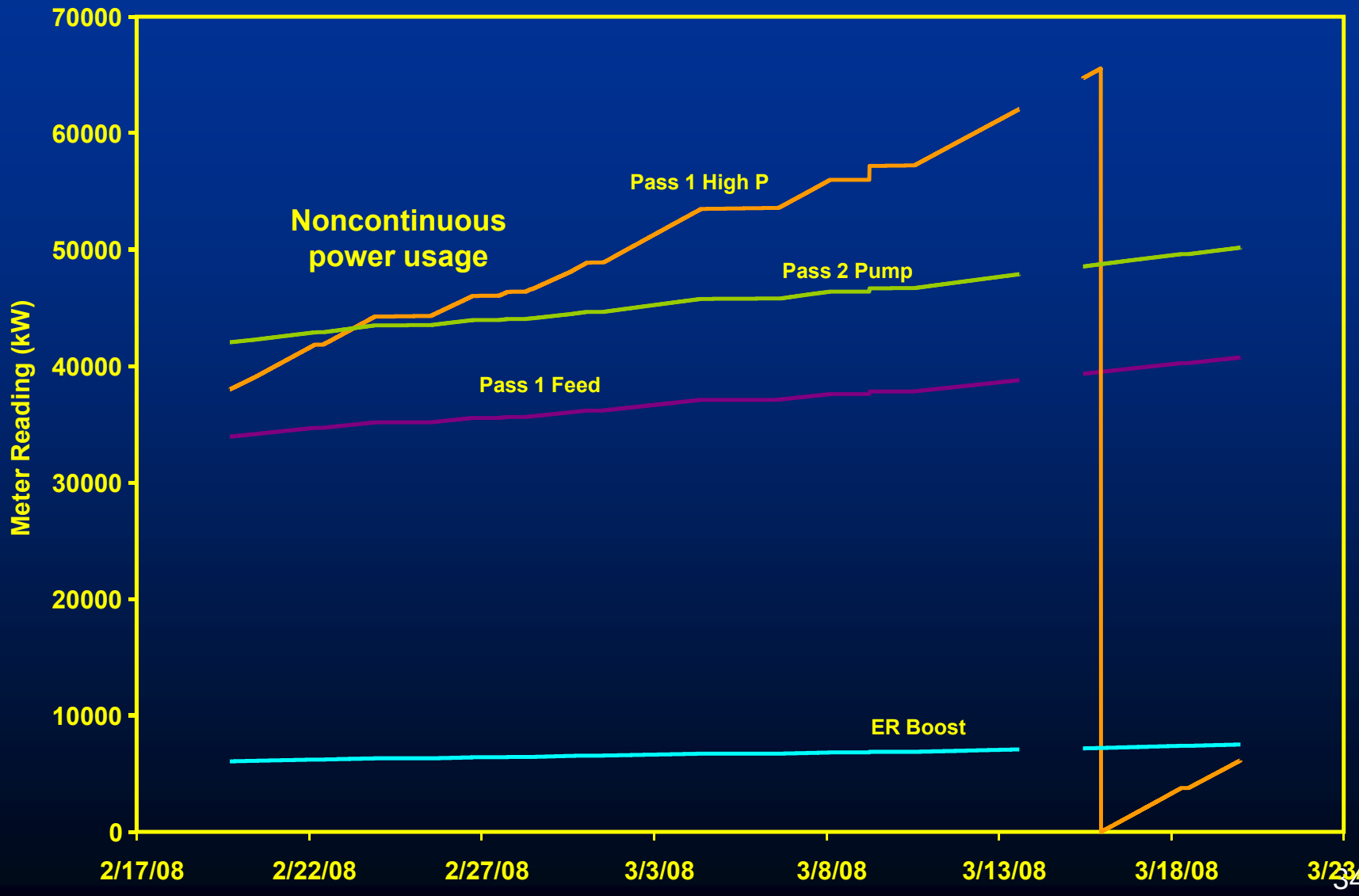
- **Phase I**
  - short tests to determine trends
  - Limited water quality data (conductivity)
  - May ’06 – Dec ‘07
- **Phase II**
  - 2+ weeks of selected conditions from Phase I
  - detailed WQ analyses
  - Jan ’08 – Oct ‘08
- **Operate with ER device**
  - Energy results from power monitors and calculations

Energy – NF2 System



	Process	Design Flow (gpm)	P (psi)	Efficiency	Actual Flow (gpm)
1	Pass 1 low P pump	200+	70	60%	200+
2	Pass 1 high P pump	200+	< 600	75%	<140
3	ER Boost Pump	200+	20	60%	200+
4	Pass 2 pump	100	<300	75%	100
5	Pass 2 conc return	< 50	<300	60%+	< 50

Power Monitor Information



Match Power Data

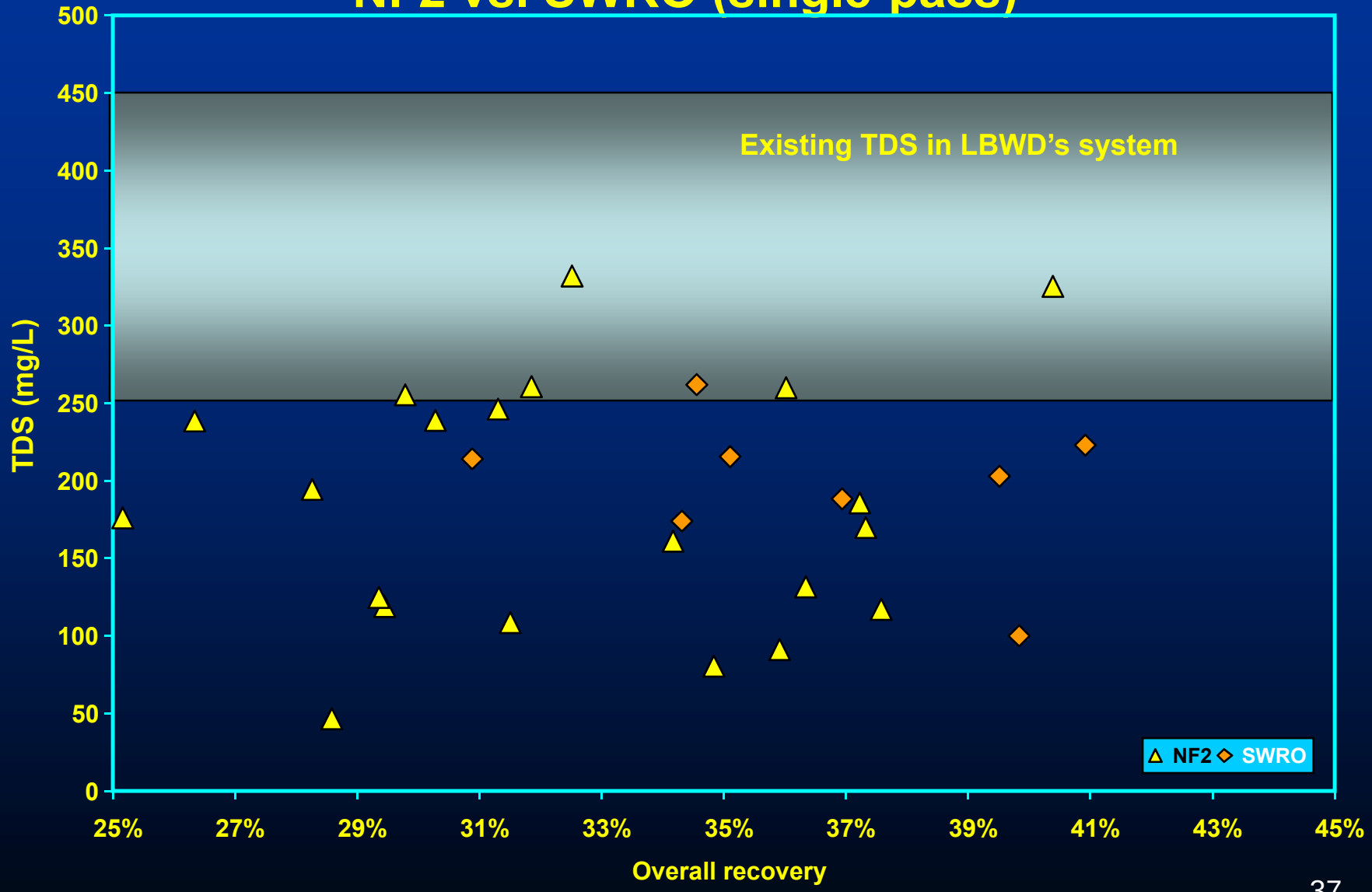
- Specific power (kWh/kgal) = kWh used/1,000 gal of permeate produced
- (1) Power monitor data
  - **kW from graphs (take out nonoperational periods)**
- (2) Hp equation
  - **Hp = (Q * H)/(3960 * E_{tot})**
    - **$E_{tot} = E_{pump} * E_{motor}$**
    - **pump ~ 75%, motor ~ 90%, E_{tot} = 67.5%**
  - **Energy (kWh) = Hp * 0.746 *hr**
- Use results from (1) and (2) to calculate E_{tot}
  - **Actual E of high P pump, ER on = 45%, ER off = 60%**

Data Presentation

- Actual energy
  - **No compensation for T**
  - **Steady state operational conditions**
- Adjusted energy
  - **Normalized to T = 25^{o}C**
  - **E used are representative of large plants**
    - **Low P pump = 75%**
    - **High P pump = 72%**
    - **PX = 94%**

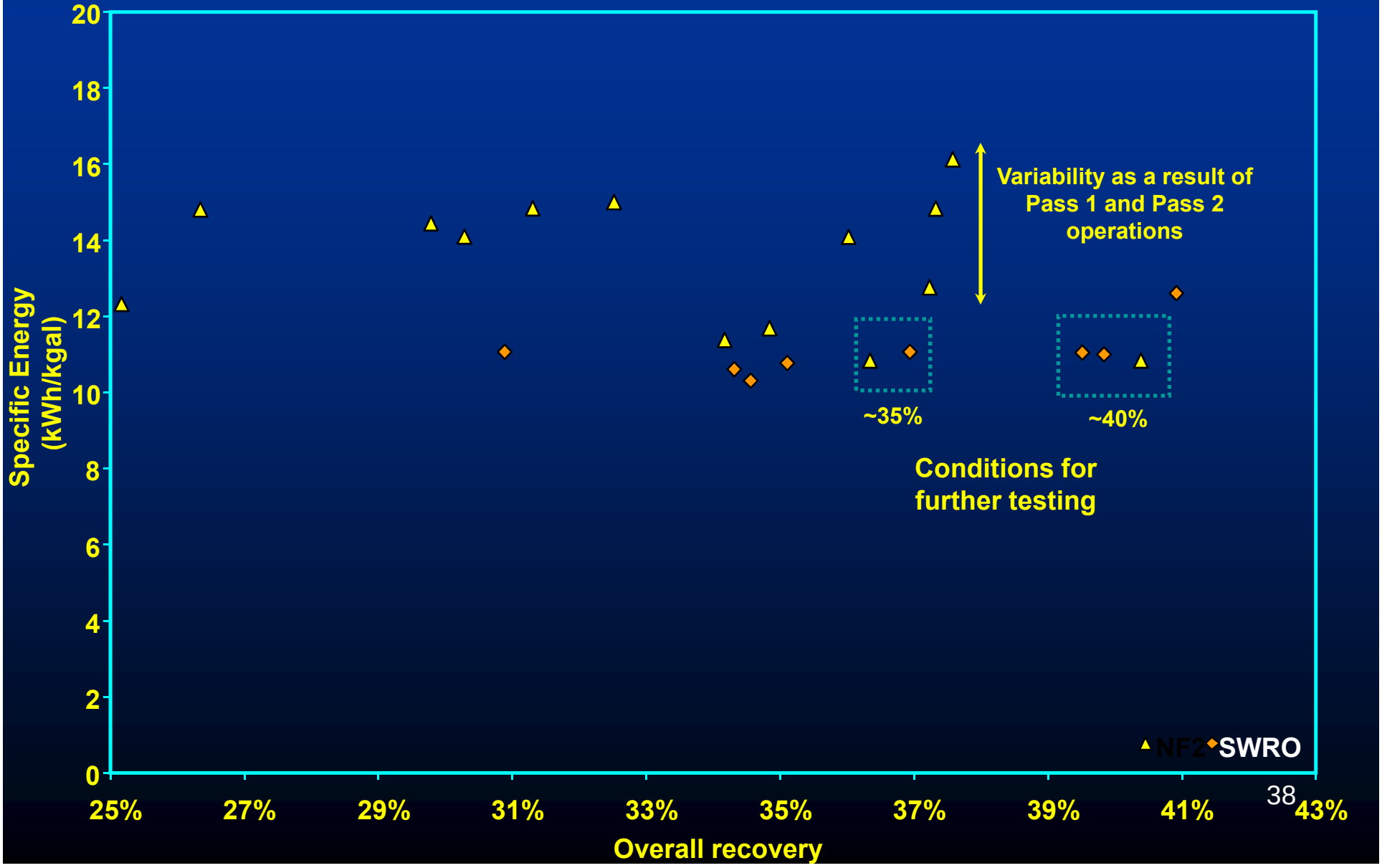
Permeate TDS, Phase I

NF2 vs. SWRO (single-pass)



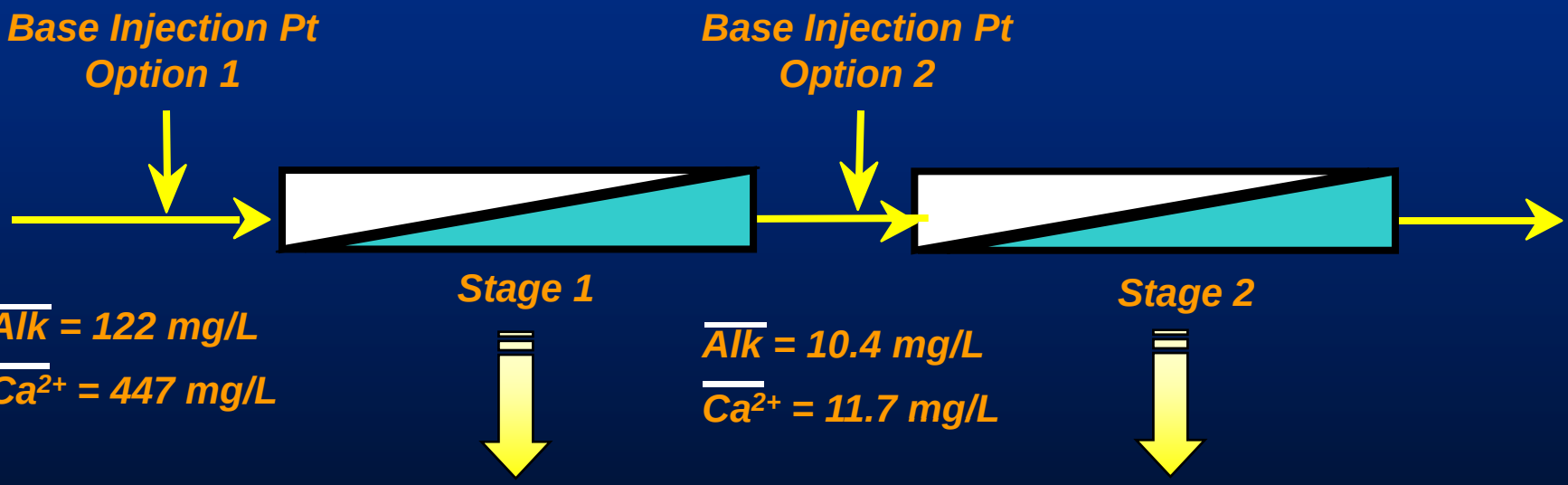
NF2 vs. SWRO, Single Pass, Phase I

Adjusted Energy, Realistic E, 25°C



Boron Treatment

- Single-pass SWRO achieves 43% - 78% rejection
- Baseline NF^2 process achieves ~ 50% rejection
- Enhance boron rejection through base addition



$\overline{Alk}$ = 122 mg/L

$\overline{Ca^{2+}}$ = 447 mg/L

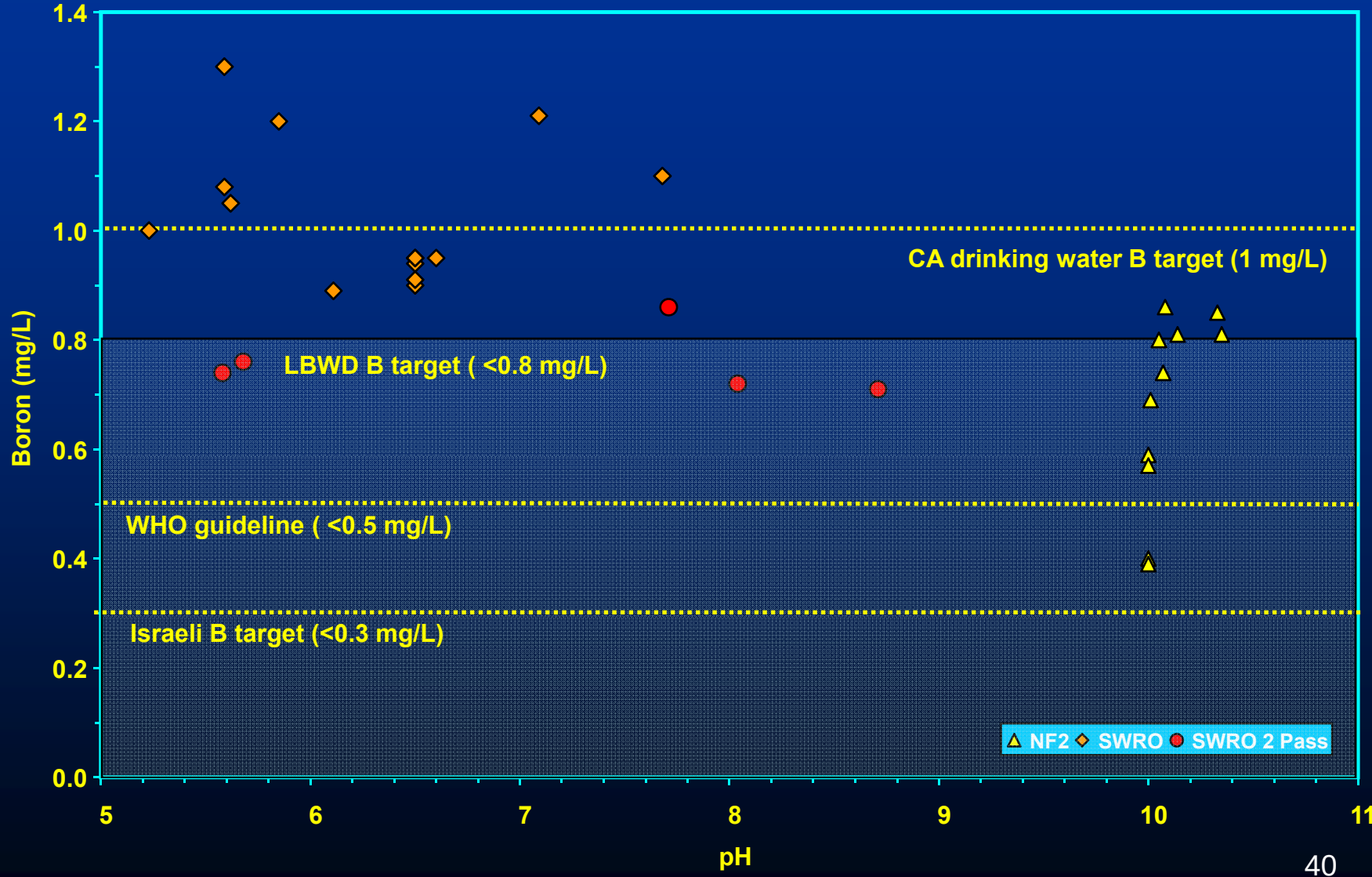
- More base required to change pH
- HIGH potential for fouling

$\overline{Alk}$ = 10.4 mg/L

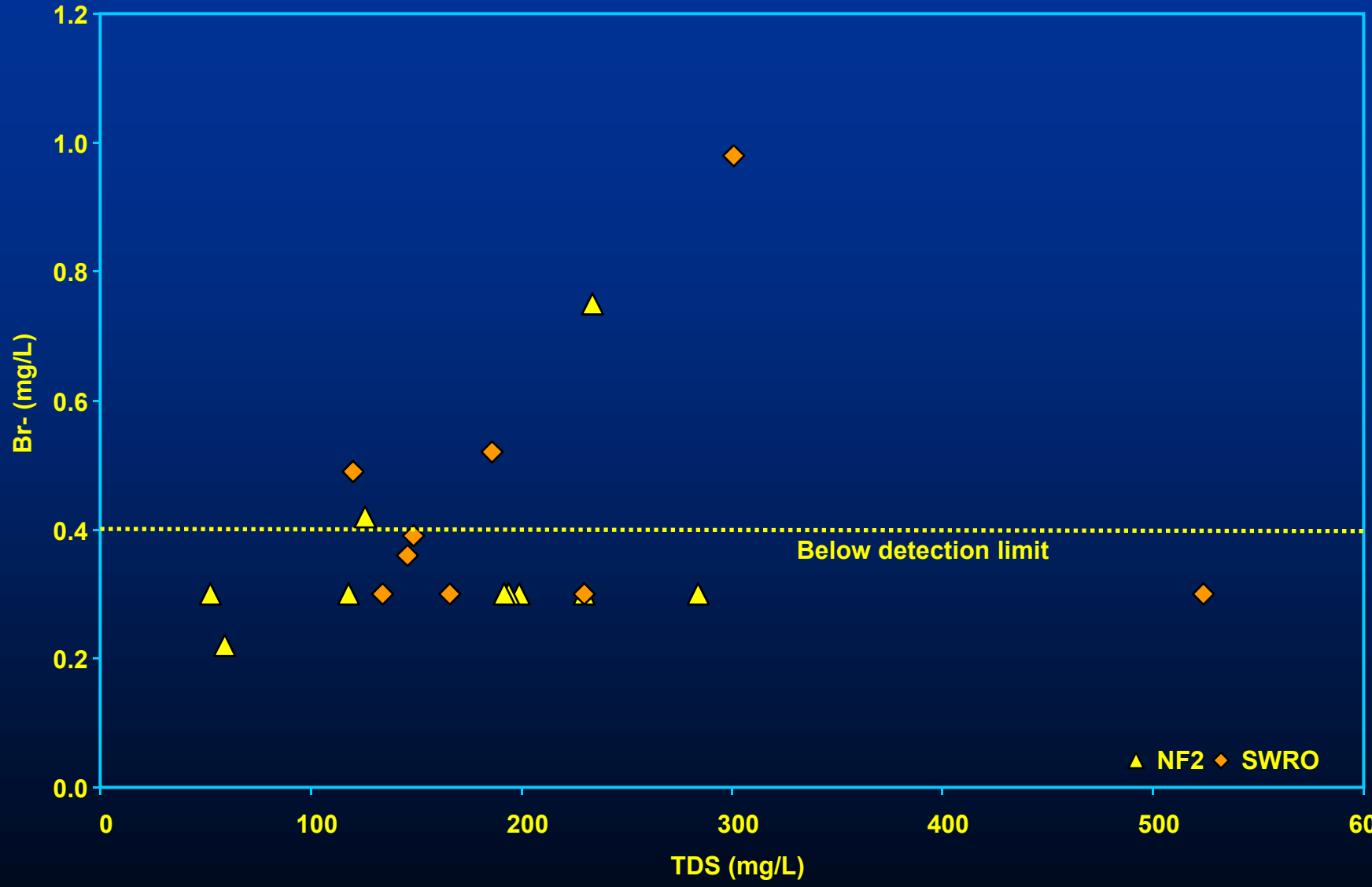
$\overline{Ca^{2+}}$ = 11.7 mg/L

- Less base to change pH
- 97% rejection of Ca^{2+}. Decreased potential for fouling

Permeate Boron

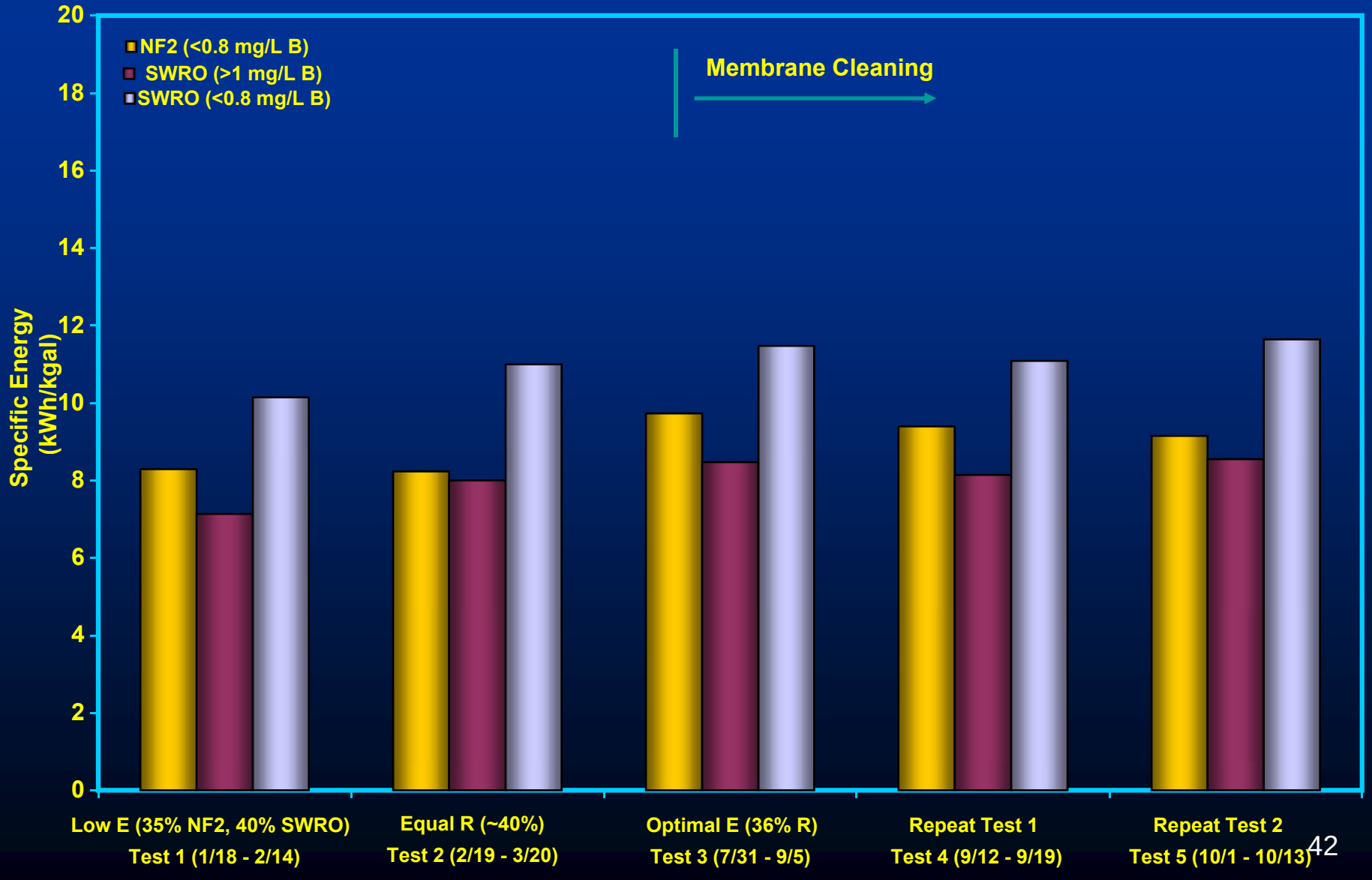


Permeate Bromide

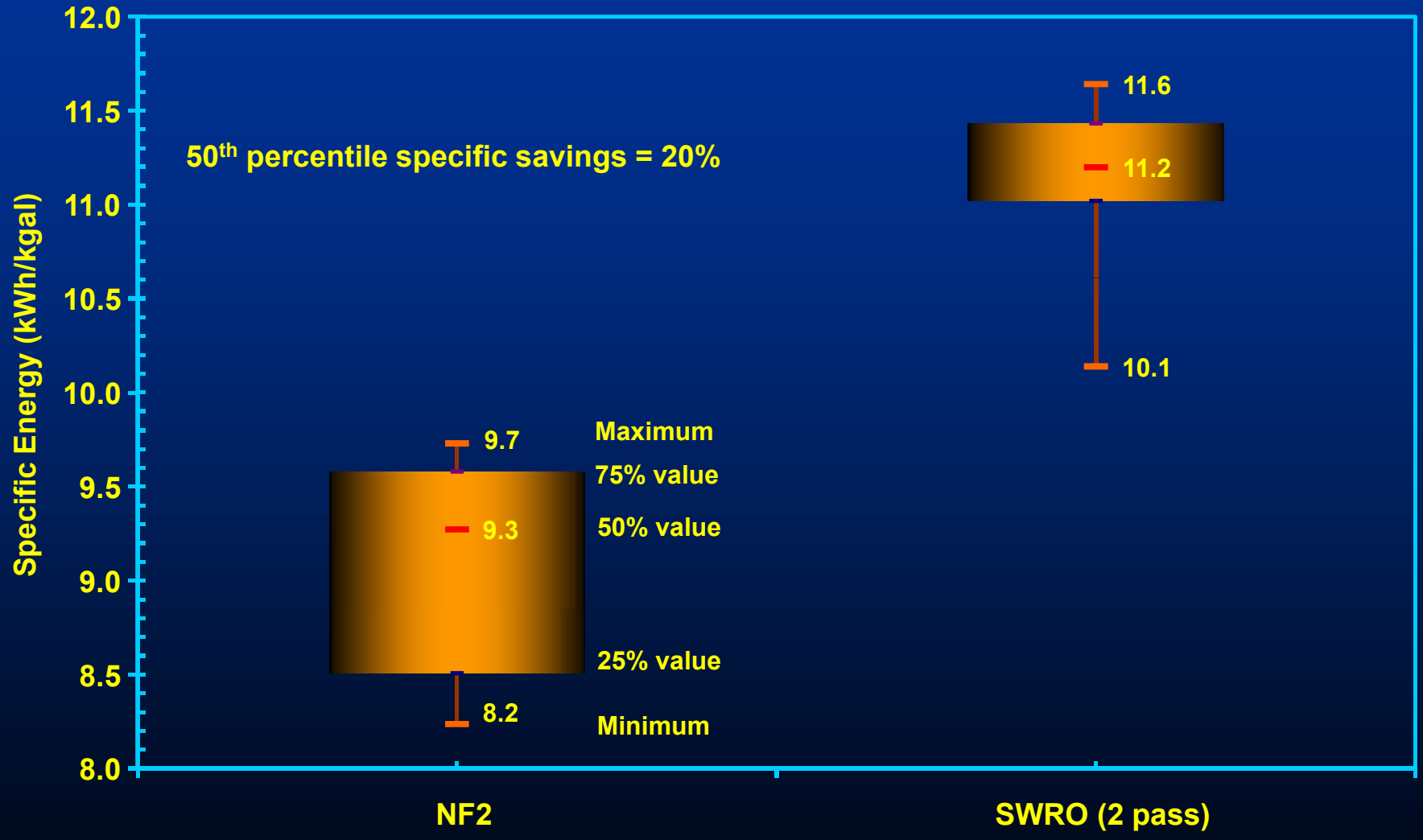


Adjusted Energy, Phase II

Realistic E, 25°C



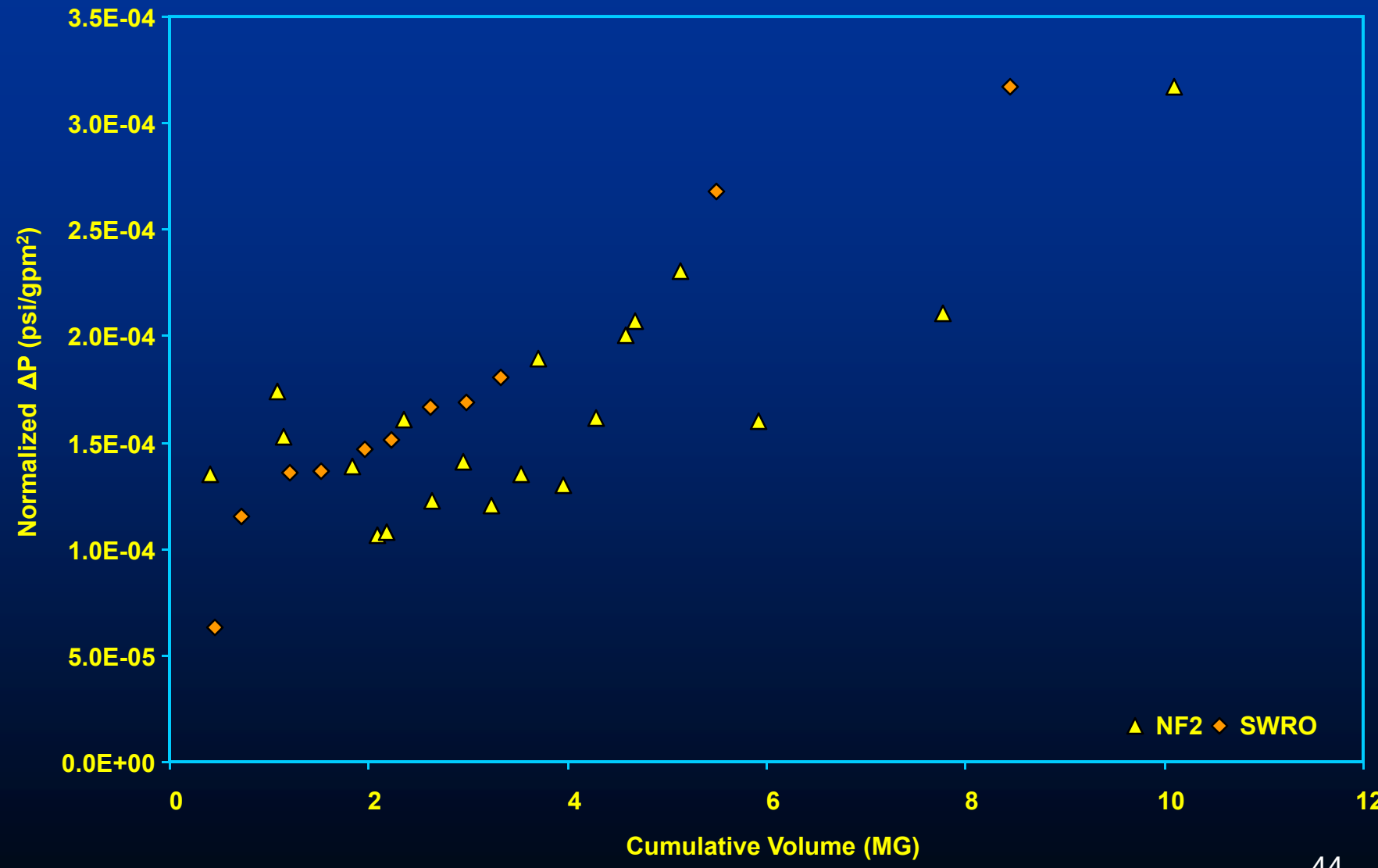
Specific Energy Summary
Effluent B <0.8 mg/L



Data normalized to 25°C and realistic mechanical efficiencies

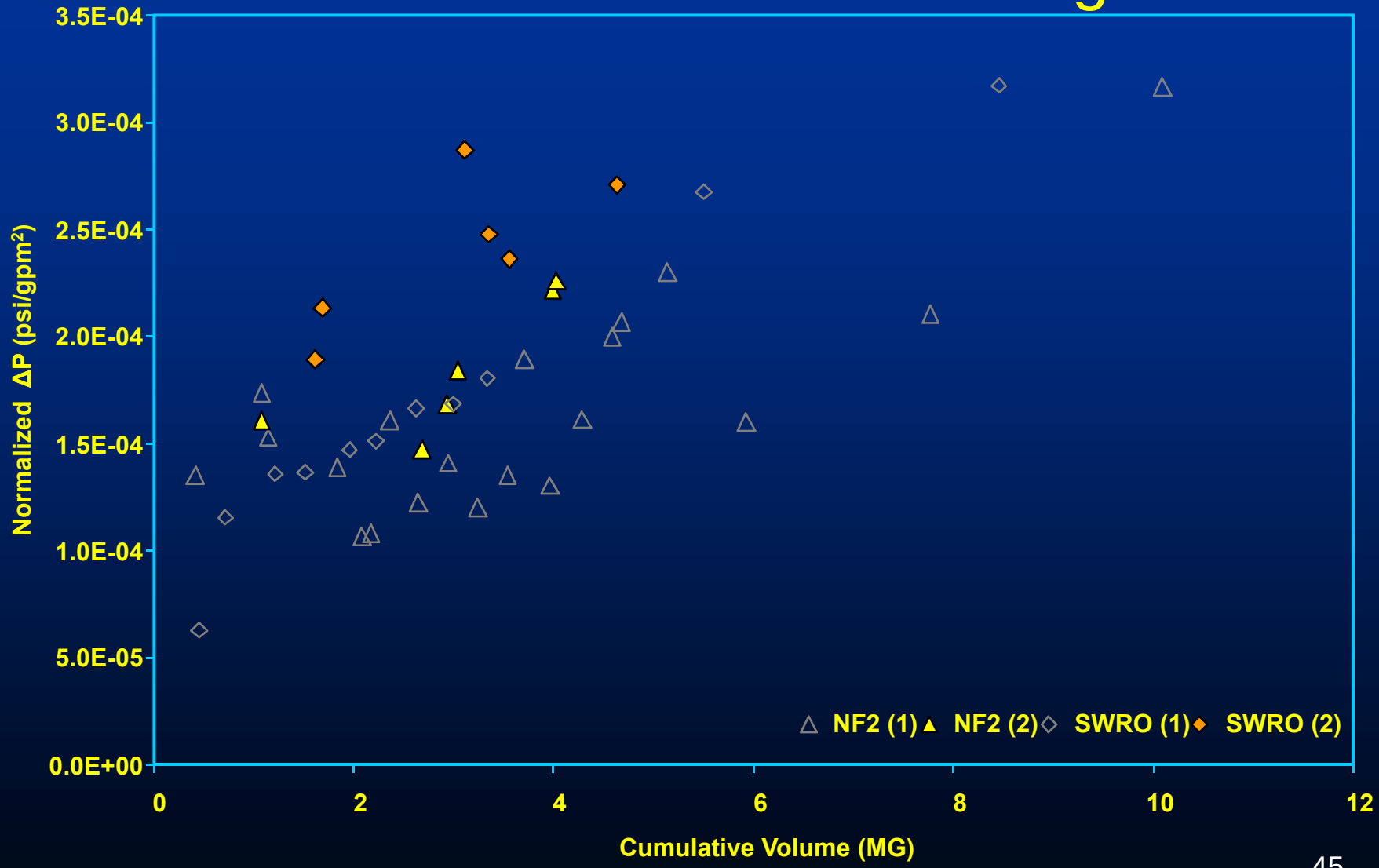
Normalized Δ P

Before Membrane Cleaning



Normalized Δ P

After Membrane Cleaning



Prototype Test Summary

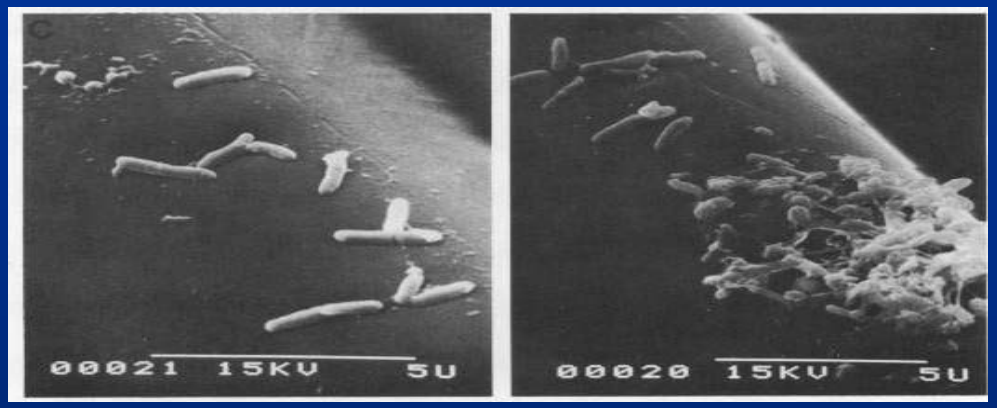
- **Water quality**
  - TDS, bromide goal met
  - Boron goal < 0.8 mg/L
    - NF2 meets target
    - Second pass SWRO is required
- **Energy comparison**
  - based on meeting all water quality targets, 25oC
  - NF2 = 8.2 – 9.7 kWh/kgal
  - SWRO = 10.0 – 11.6 kWh/kgal
  - Average specific energy savings = 20% (14 – 24%)

NF2 Optimization Matrix

Modeling results, 7 gfd, 45% recovery

Configuration	P (psi)	Cp (mg/L)	kWh/ kgal	Last elem Qf	Last elem P	Rank
ULP-ULP-NF-NF-NF	604	3284	14.6	13.3	538	1
ULP-NF-NF-NF-NF	589	3843	14.2	12.0	540	2
NF-NF-NF-ULP-ULP	613	2987	14.8	14.4	500	3
BW-BW-BW-NF-NF	668	2512	16.1	11.9	518	
BW-BW-NF-NF-NF	628	3200	15.2	13.5	523	
BW-NF-NF-NF-NF	597	3882	14.4	12.0	534	
NF-NF-NF-NF-NF	574	4366	13.9	13.0	540	
NF-NF-NF-NF-ULP	593	3699	14.3	13.2	536	
NF-NF-ULP-ULP-ULP	643	2336	15.5	12.6	566	
ULP-ULP-ULP-NF-NF	623	2857	15.0	13.5	535	

UV/ClO_2 Testing Goal

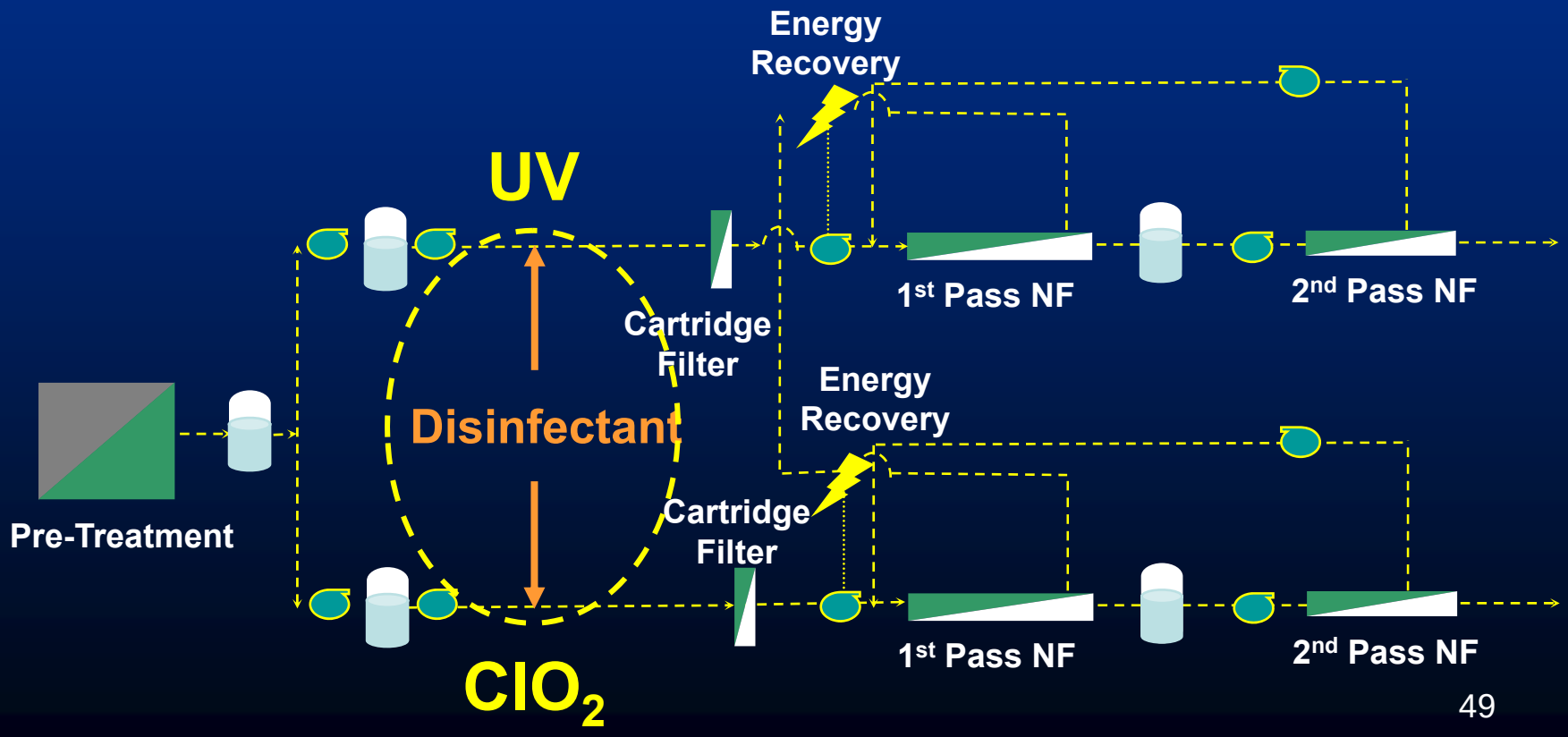


Membrane photomicrographs

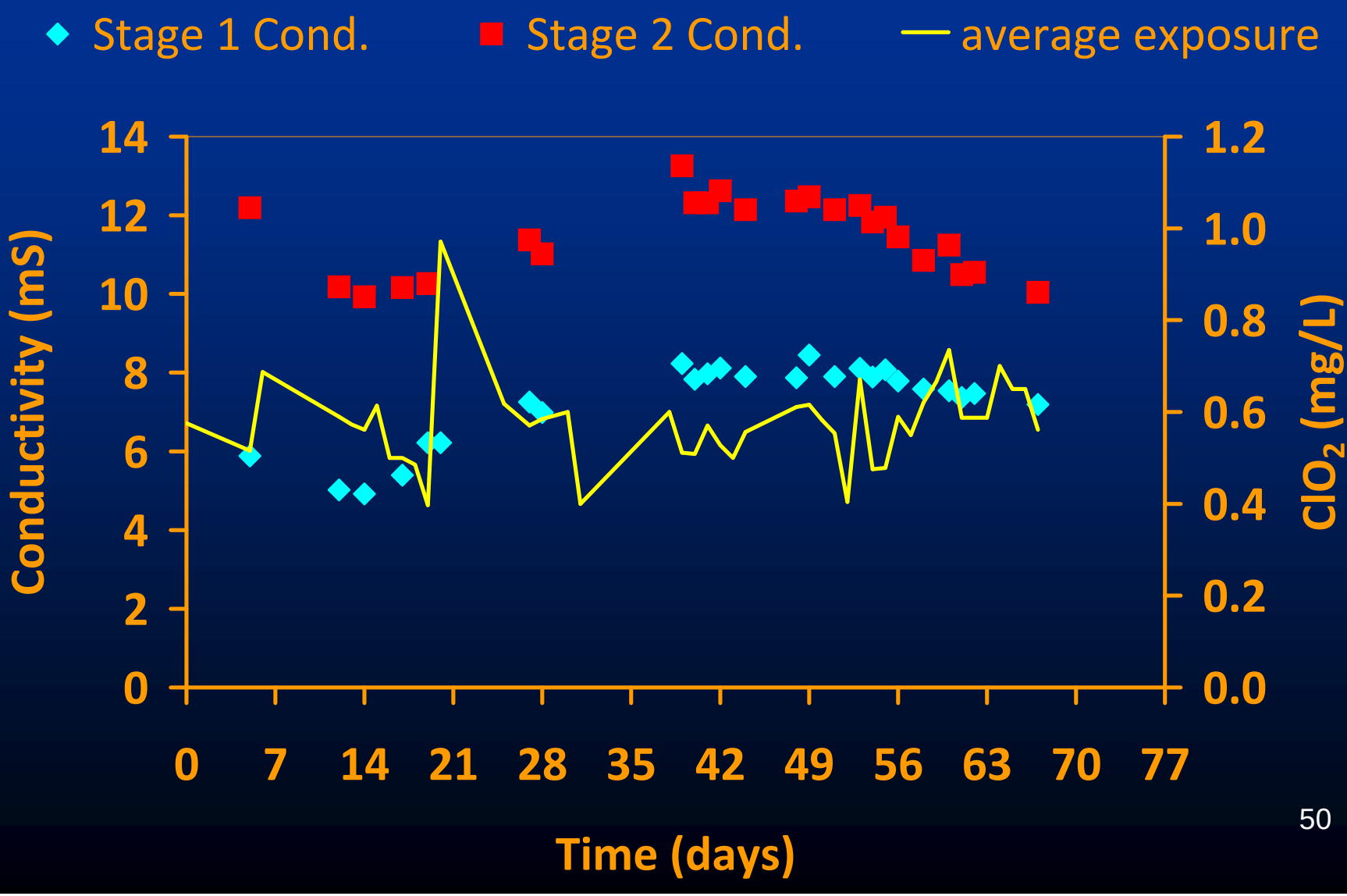
- Biological growth control desirable
  - (increases membrane life)
- Chlorine cannot be used
  - Destroys membranes
- Seek alternative disinfectants
  - Ultraviolet light (UV)
  - Chlorine dioxide (ClO_2)

UV/ClO_2 Testing

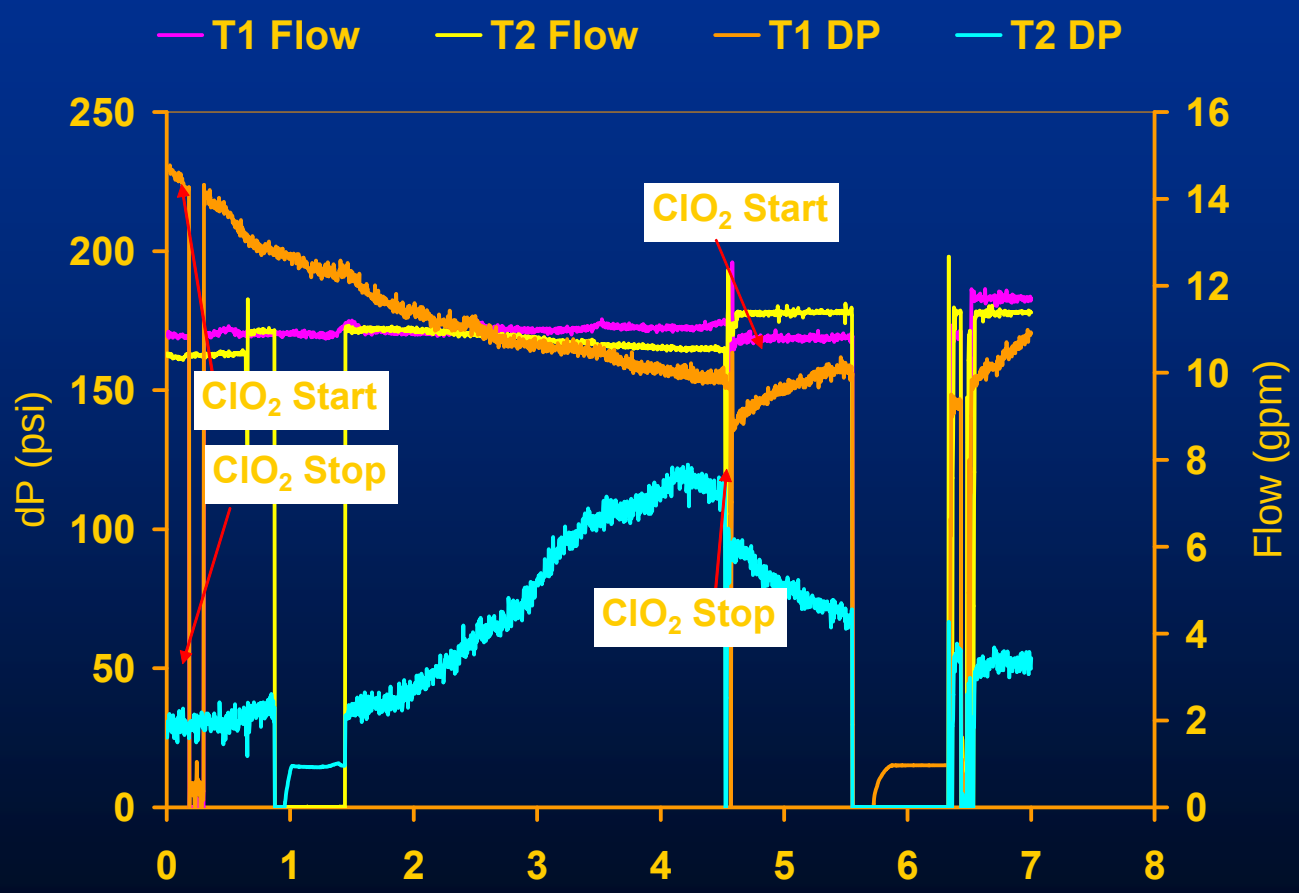
- Meet primary disinfection, minimize membrane fouling



No Membrane Degradation

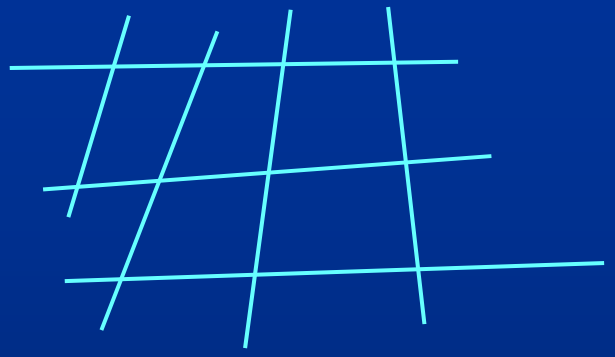


Controls Fouling on Cartridge Filters



Posttreatment

Distribution



Project

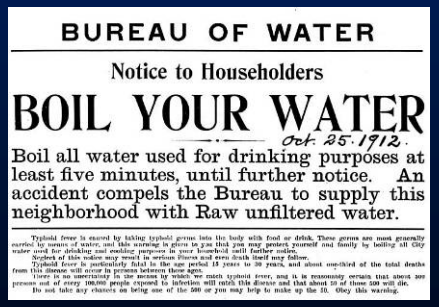
- Posttreatment of Desalinated Seawater
  - $2 M
  - USBR, CaDWR
- Bromamines
  - Water Research Foundation
  - $400 K
  - SNWA, Tampa Bay Water

Addresses

- Technical
- Public Trust
- Permitting

Posttreatment Research Goals

- Corrosion from low minerals content
  - **Leaching of minerals from pipes**
  - **How to control negative impacts**
- Higher bromide levels
  - **Increased bromide-containing disinfection byproducts (DBP)**
  - **Residual stability issues leading to drinking water violations**
- At what conditions can desalinated water be distributed into the system?



BUREAU OF WATER

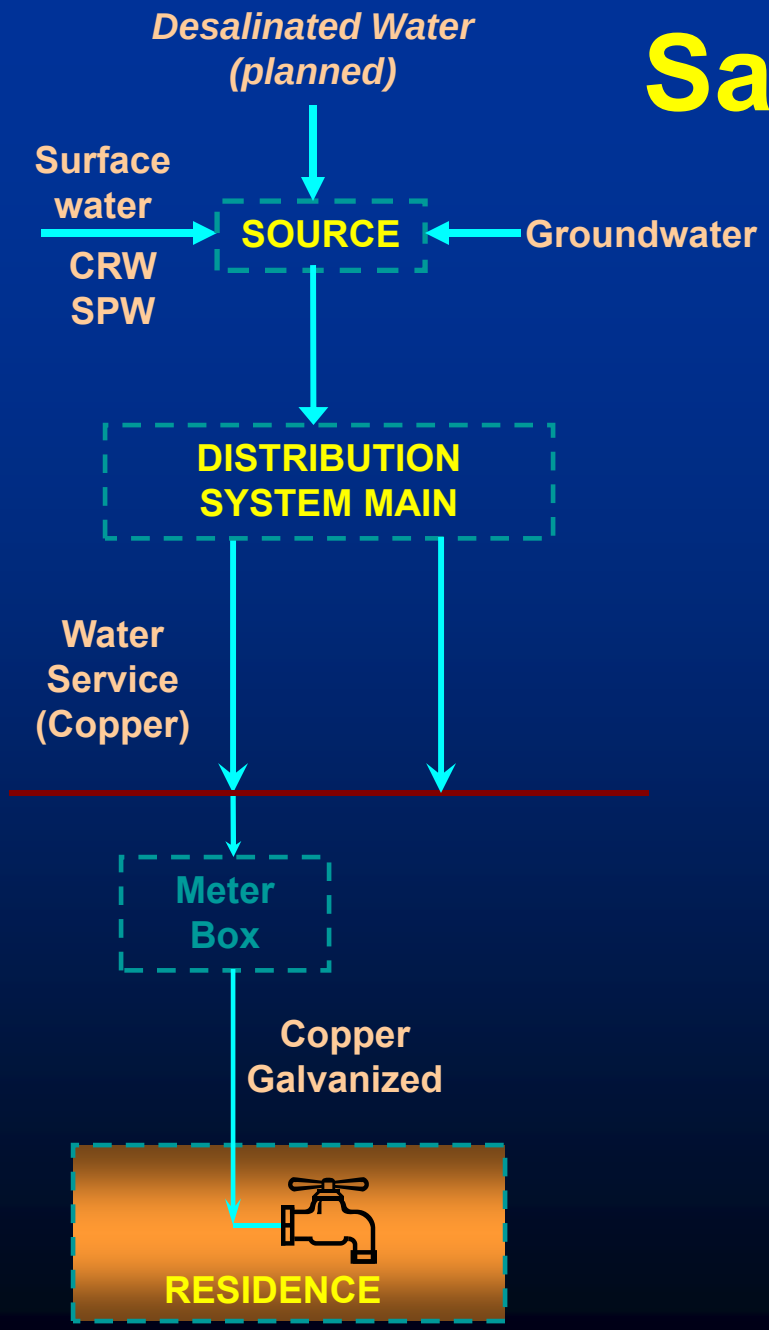
Notice to Householders

BOIL YOUR WATER

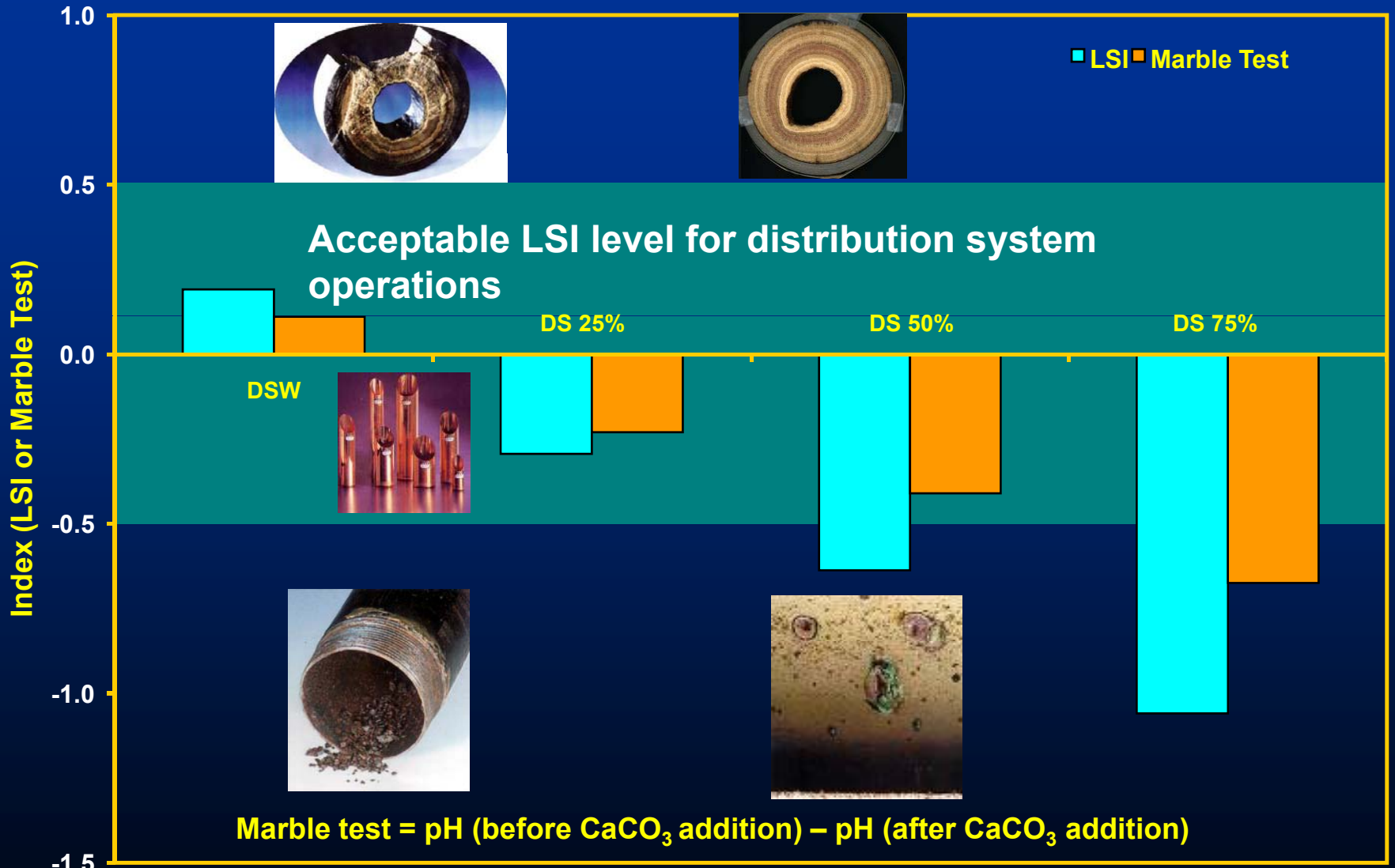
Oct. 25. 1912.

Boil all water used for drinking purposes at least five minutes, until further notice. An accident compels the Bureau to supply this neighborhood with Raw unfiltered water.

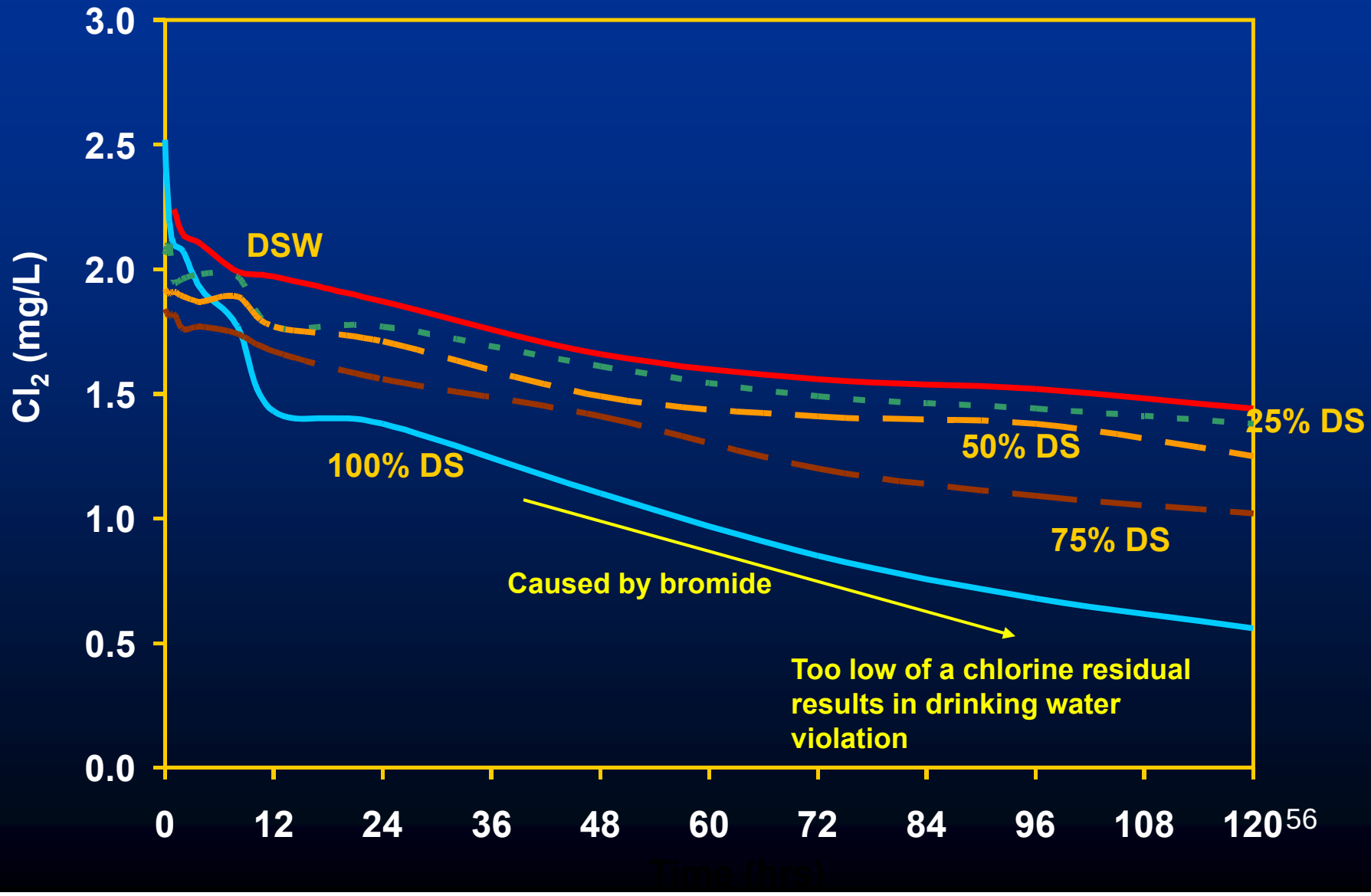
Sample System



Comparing Stability of Water Blends



Chlorine Residual Results



Findings to Date

- Underocean floor intake operational up to 0.10 gpm/ft^2
- Underocean floor discharge operational up to 0.16 gpm/ft^2
- NF2 shows ~ 20% energy savings from SWRO (equal water quality)
- No membrane degradation from ClO_2 so far
- Adding desalinated waters to chloraminated systems may be problematic
  - more research needed
  - continue to work with SNWA, Tampa Bay Water

Questions?

www.lbwater.org