Potable Reuse for Inland Applications: Pilot Testing Results from a New Potable Reuse Treatment Scheme (WRRF-13-09)

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CITY OF TUCSON FOUNDED 1775

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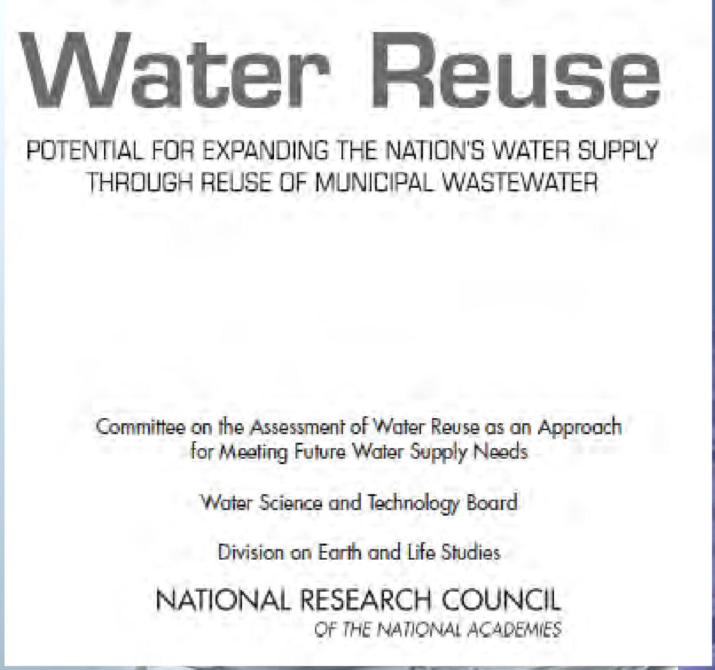
Agenda

- Potable Reuse Background – Drivers and Applications
- Tucson’s Water Supply and Potable Reuse Plans
- Pilot Facilities and Initial Results
- Conclusions

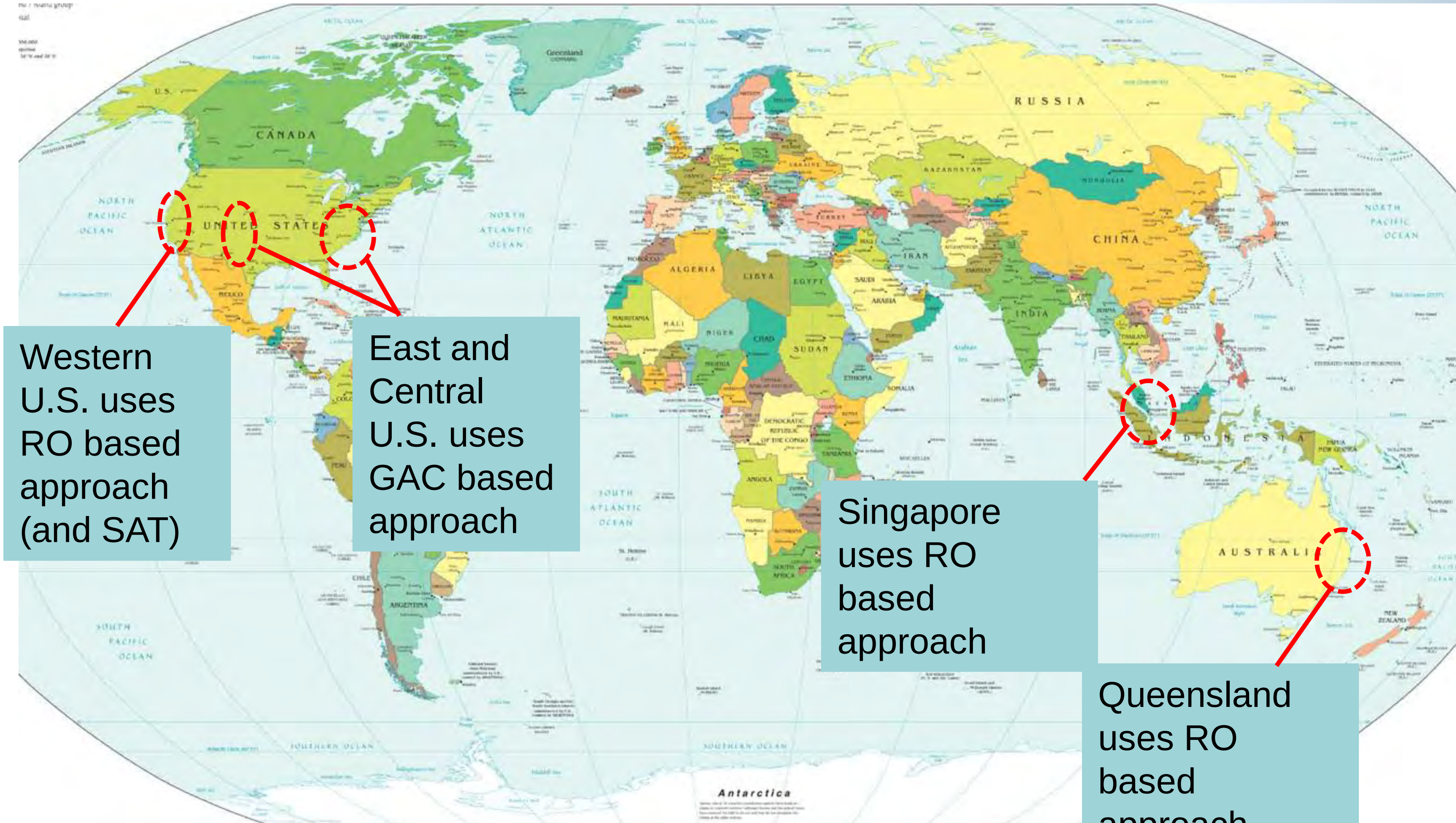
Current Drivers towards Potable Reuse

- Drivers for water reuse: population growth, climate change and drought, easy supplies have already been tapped
- Why is there a trend in some areas to move away from non-potable reuse and towards potable reuse?
  – Winter demands for non-potable reuse are often low, resulting in low reuse during winter months
  – Non-potable demands often are geographically separated by large distances which results in very high pumping and piping costs
    - *"When large nonpotable reuse customers are located far from the water reclamation plant, the total costs of nonpotable projects can be significantly greater than potable reuse projects, which do not require separate distribution lines." (*2012 National Research Council (NRC) Report on Water Reuse)
- Some locations are looking towards direct potable reuse
  - California discharges 3.5 MAF/year of treated wastewater to the ocean and DPR is likely the only option that will allow reuse



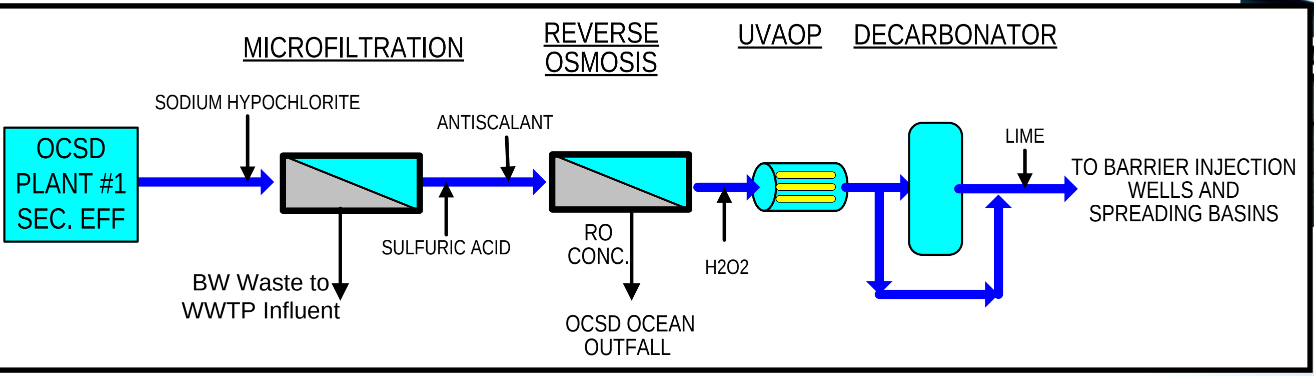
Potable Reuse Plants

RO-Based (West U.S. and International) vs. GAC-Based (East and Central U.S)



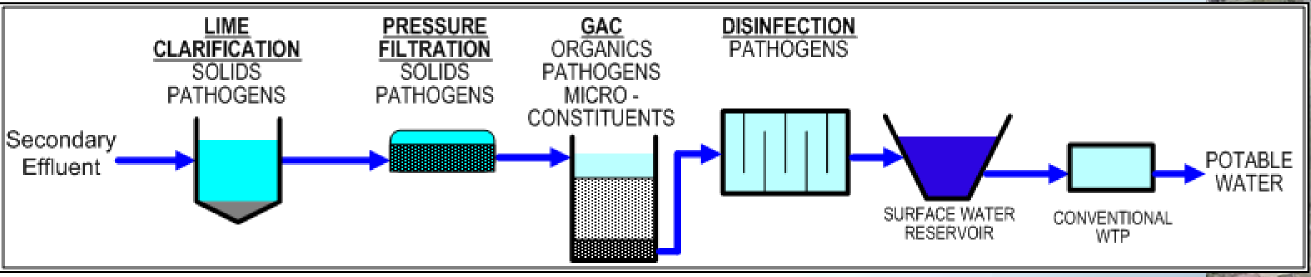
Potable Reuse: Full-Scale Examples

GWRS– RO Based Treatment (70 mgd)



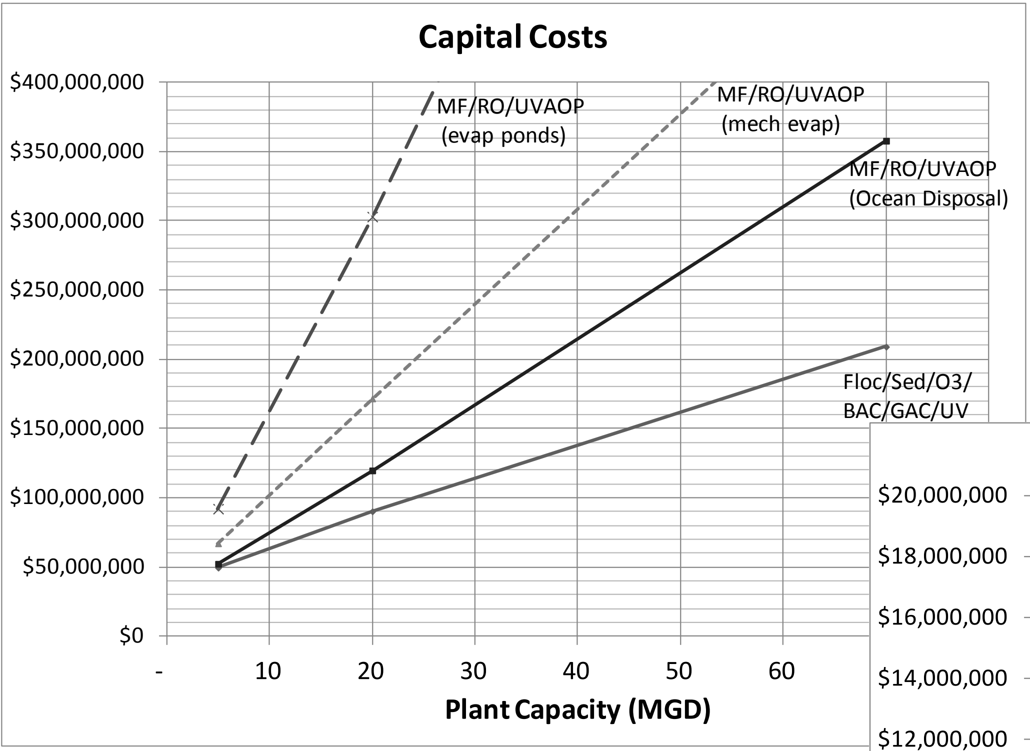
Courtesy of Jim Kutzie, OCWD

UOSA (VA) – GAC Based Treatment (54 mgd)

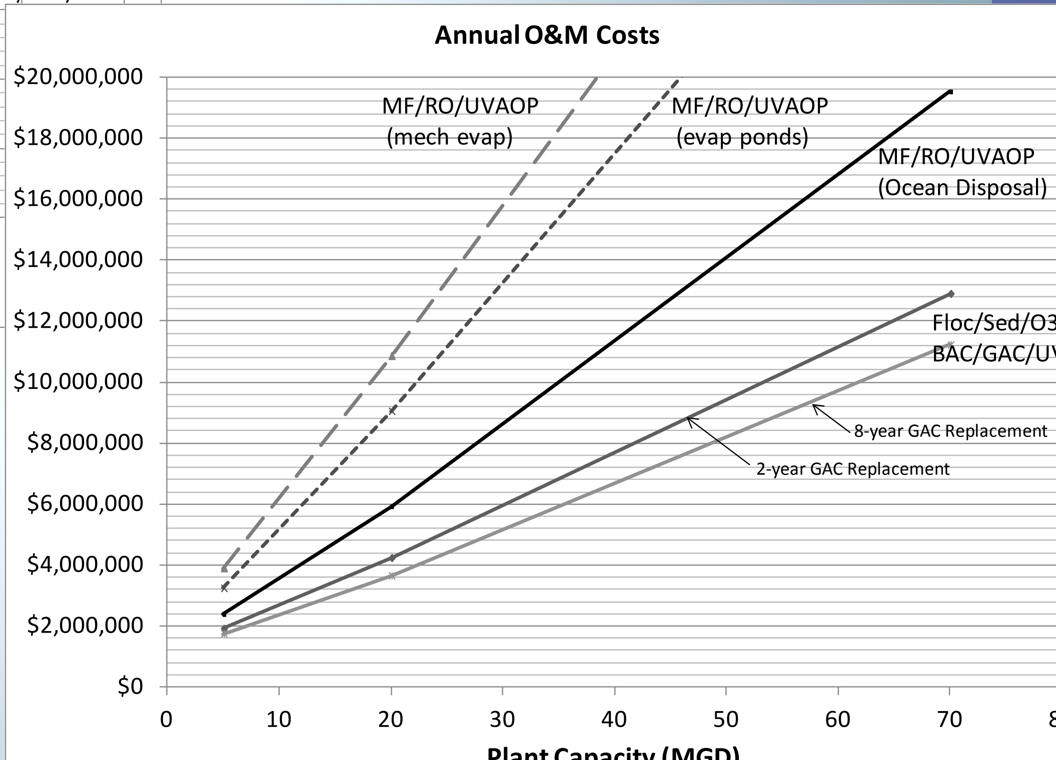


- Multiple barriers provided by each treatment train for removal of bulk organic matter, trace organics, and pathogens
- **Disposal of RO concentrate required for Train #1; very expensive for inland locations**

Capital and O&M Costs for RO-Based and GAC-Based Potable Reuse



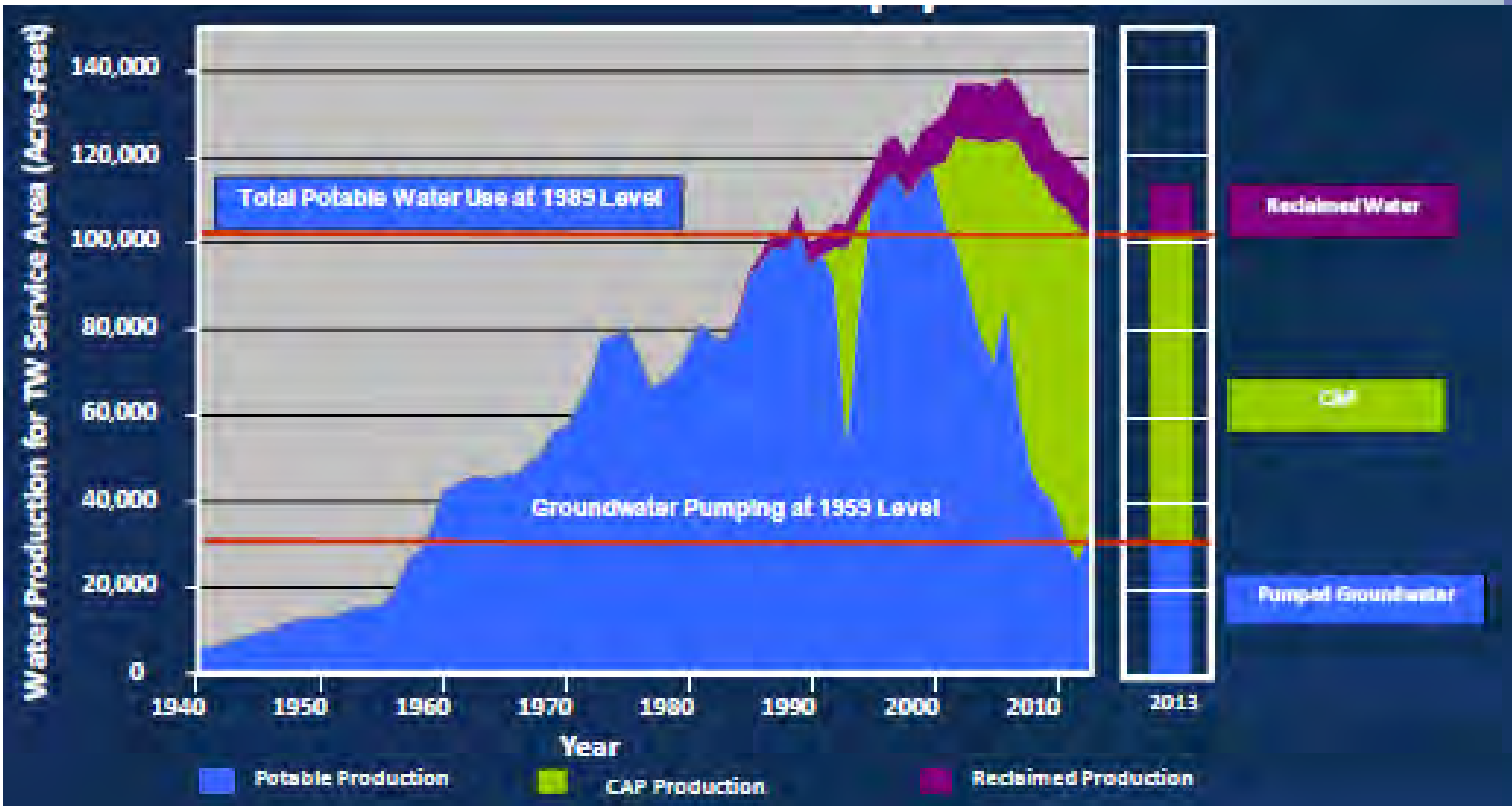
- GAC-based treatment is less expensive
- RO concentrate handling costs can be extremely expensive, especially at in-land locations
- RO (or NF) may be required when TDS removal is needed



Figures taken from WRRF-10-01. Figures are WateReuse Research Foundation's Intellectual Property

Tucson's Potable Reuse Project

- Tucson is exploring potable reuse to diversify their water supply portfolio
- Tucson's is Transitioning to More Renewable Water Supplies

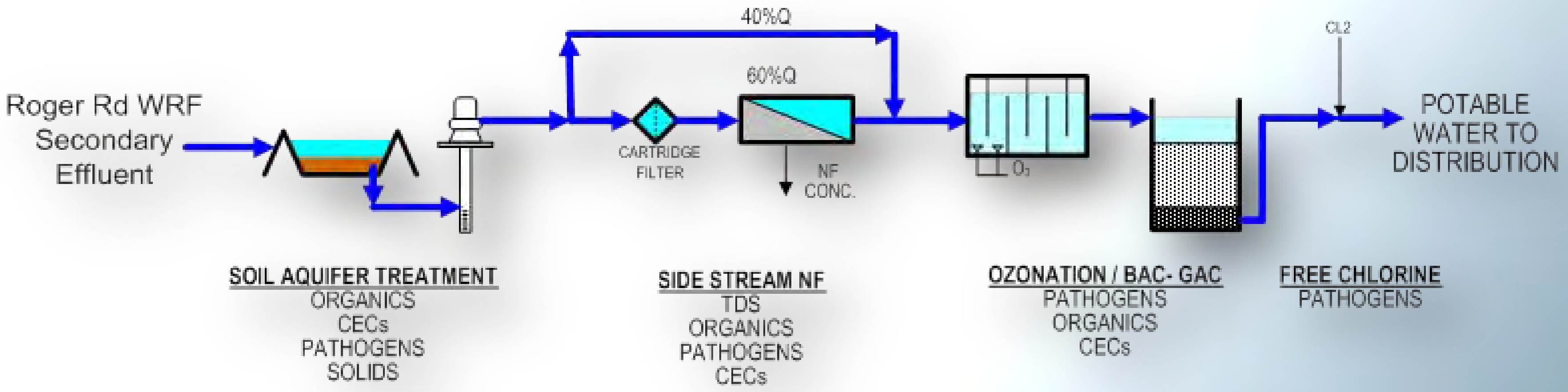


Tucson's Potable Reuse Project (cont'd)

- Independent Expert Advisory Panel recognizes the importance of a potable reuse project to the City of Tucson
- What treatment is needed? MF-RO-UVAOP has been shown to be effective, but Tucson Water wants to explore alternative treatment methods, while:
  - Providing multiple barriers for organics and pathogens
  - Removing salt
  - Reducing energy consumption
  - Mitigating concentrate disposal

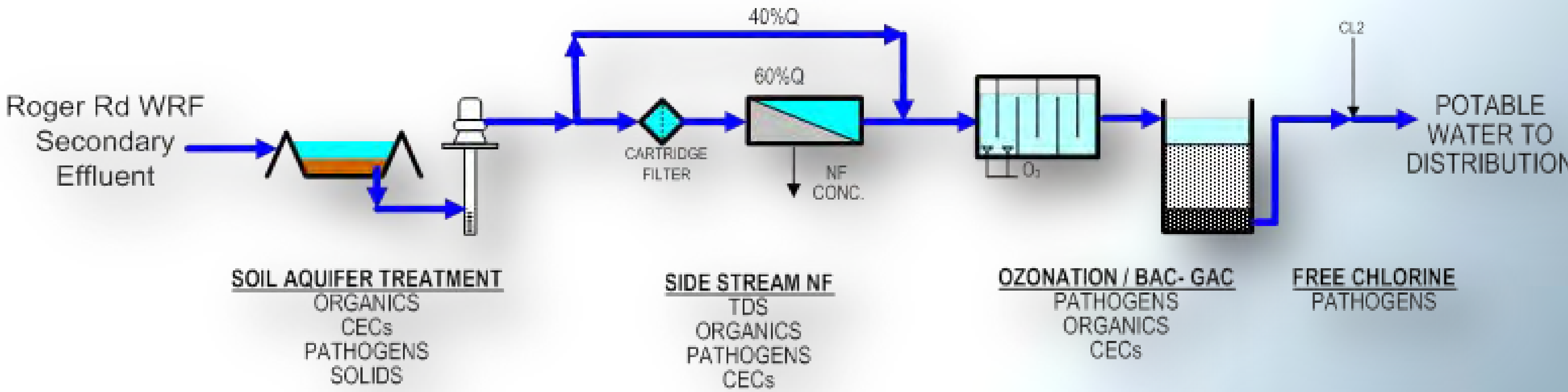
"It is the unanimous conclusion of the Panel that the efforts described in the *Recycled Water Master Plan* will be a **landmark development** in the acceptance and implementation of IPR and will contribute to the **City of Tucson's renewable water resources portfolio.** The proposed new recycled water programs identified in the *Recycled Water Master Plan* will supplement existing sources and provide a greater degree of independence, thus improving the **reliability and sustainability** of existing water supplies."

Proposed Treatment Scheme



- **Soil Aquifer Treatment (SAT):**
  - Provides excellent removal of organics, pathogens, and nitrogen compounds
  - Use short-term SAT (2 weeks) to lower implementation costs and make application more universally applicable
- **Nanofiltration:**
  - Excellent removal of pathogens, organics, and divalent ions (moderate removal of monovalent ions)
  - Operates at lower pressure than RO - meet specific TDS goals at lower power requirements
  - Concentrate handling is less expensive and may allow beneficial use
- **Ozone and BAC Filtration / GAC Adsorption:**
  - Excellent oxidation of trace organics and inactivation of pathogens
  - BAC filtration / GAC Adsorption will remove transformed organics by both biological and adsorptive mechanisms.

Proposed Treatment Scheme



- **Soil Aquifer Treatment (SAT)**
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- **Nano**
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- **Ozon**
  - Excellent oxidation of trace organics and inactivation of pathogens
  - BAC filtration / GAC Adsorption will remove transformed organics by both biological and adsorptive mechanisms.

✓Provides multiple barriers for organics and pathogens
✓Removes salt
✓Reduces energy consumption
✓Mitigates concentrate disposal

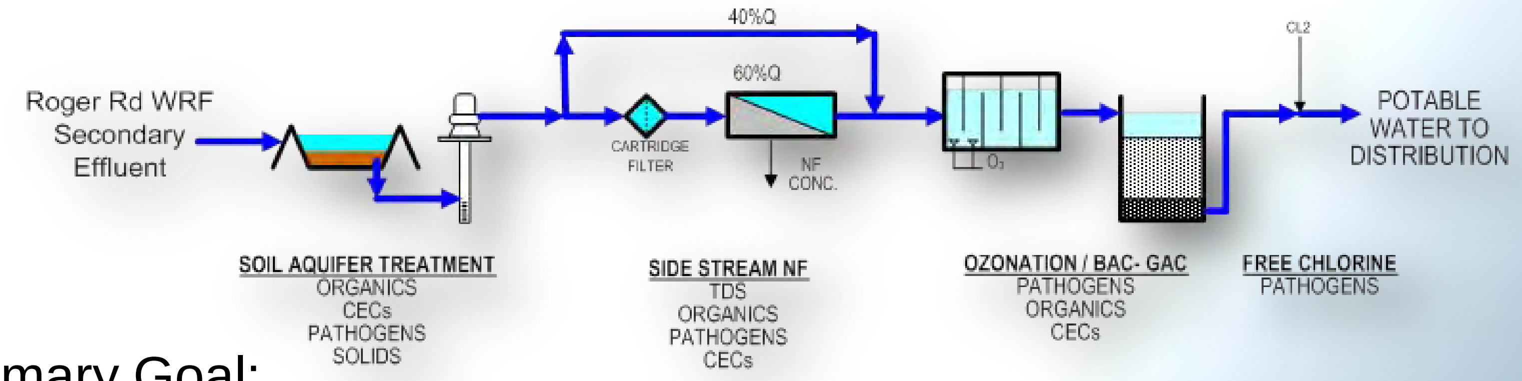
Other Water Quality Concerns

- NDMA
  - Significant formation can occur with ozone addition to secondary effluent
  - SAT and NF will remove precursors and BAC will remove NDMa formed
- Bromate
  - Bromide concentrations in secondary effluent are high (0.2 – 0.3 mg/L), could lead to elevated bromate with ozone addition
  - Add ozone at sub-residual doses if possible
- TDS
  - Secondary effluent 650 – 800 mg/L
  - Goal is < 500 mg/L; side-stream NF treatment

Water Quality Concerns (cont'd)

- Summary
  - Bulk organics, CECs: multiple barriers from SAT, NF, ozone, BAC/GAC filtration/adsorption
  - Pathogens: Multiple barriers from SAT, NF, ozone, BAC/GAC filtration, and chlorine disinfection (UV could be added if necessary)
  - TDS: partial NF treatment
  - Bromate: ammonia addition if needed
  - NDMA: Removal by BAC; lower O3 dose to sub-residual dose if necessary

Pilot Testing Project Goals



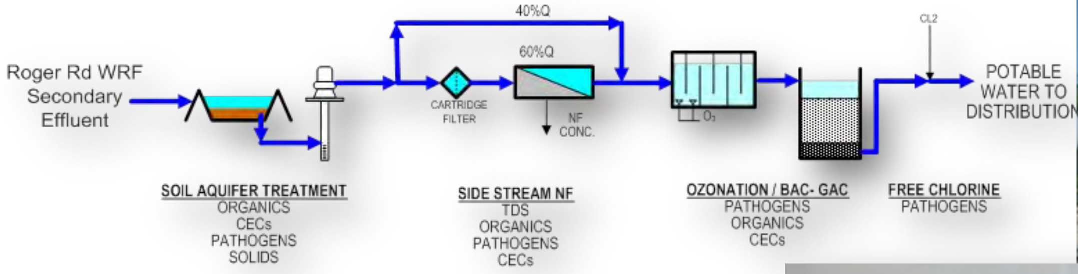
- Primary Goal:
  - Test the viability of the proposed treatment scheme for Tucson Water’s future Potable Reuse Project through water quality testing and treatment process performance monitoring
- Secondary Goals:
  - Test the viability of short-term SAT as a pretreatment approach to NF, which would allow substitution of NF for RO at locations where possible.
  - Evaluate GAC regeneration requirements by comparison of 3-month old BAC to virgin GAC
  - Test ozone for oxidation of CECs
  - Test the biostability of the water post SAT and determine the need for a biocide (e.g., monochloramine) upstream of NF
  - Test the viability of using NF concentrate for crop irrigation through characterization of concentrate stream for constituents critical to crop growth and health

Pilot Facilities

- Soil Aquifer Treatment (SAT)
  - Tucson Water operates 11 recharge basins
  - Monitoring Well 069B used in pilot because of short travel time (2 weeks) and close proximity to recharge basins

Tucson's Sweetwater Recharge Basins

Pilot Facilities (cont’d)



- Phase I:
  - 3 months
  - Extensive water quality sampling

- Phase II – 3 months:
  - 3 months
  - Compare virgin GAC performance to 3-month old BAC/GAC

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Water Quality Testing

Parameter	Lab	Sample Location and Frequency									
		Sweetwater Recharge Basin Feed (Agua Nueva Effluent)	Shallow Monitoring Well 69B Effluent	NF Feed (after CF)	Blend Water (NF Permeate + NF Bypass)	NF Concentrate	Ozone Effluent	BAC1 Eff (Phase I and II)	BAC2 Eff (Phase I and II)	BAC3 Eff (Phase II only)	BAC4 Eff (Phase II only)
Sample Designation		**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
pH	Field		Daily	Daily	Daily	Daily					
Temperature	Field		Daily	Daily	Daily		Daily				
Conductivity	Field		Daily	Daily	Daily	Daily					
Total Chlorine	Field			Daily	Daily						
Free Chlorine	Field			Daily							
SDI	Field			3x/week							
Turbidity	TW		Weekly								
TSS	TW		Weekly								
Alkalinity	TW	Biweekly	Weekly		Weekly	Weekly					
TDS	TW	Biweekly	Weekly	Weekly	Weekly	Biweekly					
TOC	TW	Biweekly	Weekly		Weekly		Weekly	Weekly	Weekly	Weekly	Weekly
UVT-254	TW		Weekly		Weekly		Weekly	Weekly	Weekly	Weekly	Weekly
Total Nitrogen	TW	Biweekly	Biweekly		Biweekly	Biweekly					
Total Phosphorus	TW	Biweekly	Biweekly		Biweekly	Biweekly					
Bromide	TW		Biweekly								
Calcium	TW		Biweekly		Biweekly	Biweekly					
Magnesium	TW		Biweekly		Biweekly	Biweekly					
Sodium	TW		Biweekly		Biweekly	Biweekly					
Sulfate	TW		Biweekly		Biweekly	Biweekly					
Chloride	TW		Biweekly		Biweekly	Biweekly					
Boron	TW		Biweekly	Biweekly	Biweekly	Biweekly					
Silica	TW		Biweekly								
Barium	TW		Biweekly								
Strontium	TW		Biweekly								
Bromate	Contract Lab		Monthly		Monthly		Biweekly	Biweekly	Biweekly	Biweekly	Biweekly
CECs	UA	Monthly	Biweekly		Biweekly		Biweekly	Biweekly	Biweekly	Biweekly	Biweekly
EEM	UA	Monthly	Biweekly		Biweekly		Biweekly	Biweekly	Biweekly	Biweekly	Biweekly
Nitrosamines	UA	Monthly	Biweekly					Biweekly	Biweekly	Biweekly	Biweekly
Total Coliform	TW		Monthly		Monthly			Monthly	Monthly		
E. Coli	TW		Monthly		Monthly			Monthly	Monthly		
Enteric Virus	Contract Lab		Monthly*				Monthly*				
Crypto / Giardia	Contract Lab		Monthly*				Monthly*				

Initial Water Quality Results

- Soil Aquifer Treatment (SAT)
  - Travel time measured at approximately 2 weeks
  - Soil aquifer treatment lowered the TOC in the secondary effluent to less than 1 mg/L (>80% reduction)
  - Significant reduction in chemicals of emerging concern (CECs)

Compound	Post SAT (ng/L)
Caffeine	<6.8
Trimethoprim	<2
PFBA	<17
Primidone	13
Meprobamate	4.6
Sulfamethoxazole	4.1
Diphenhydramine	<1.6
Hydracortisone	<2.4
Ditiazem	<1.4
Simazine	<1.7
Dexamethasone	<6.6
Carbamezapine	51
PFHxA	<5.7
Fluoxetine	<1.5
TCEP	25
Atrazine	<1.7
DEET	<2.9
Propylparaben	<2.7
Bisphenol A	<14
Testosterone	<3.4
Clofibric Acid	<2.3
Naproxen	<2.3
Norgestrel	<2.4
PFOA	<1.5
Benzophenone	8.1
Ibuprofen	<20
Gemfibrozil	<2.1
Triclocarban	<1.7
Triclosan	<2
PFOS	24
Iopamidol	1470
Iohexol	< 57
Iopromide	< 22
Acesulfame	303
Sucralose	7670
Atenolol	14

Initial Water Quality Results

- Ozone
  - Bromide concentration in secondary effluent is relatively high (0.1 – 0.35 mg/L)
  - Bromate formation low (<10 µg/L) at ozone doses less than 1:1 O3/DOC (sub-residual dose)
  - NDMA formation low; ammonia addition or pH reduction further reduced NDMA formation

Sample	Bromate (µg/L)	NDMA (ng/L)
Feed	<0.4	< 1.0
Ozone at 0.5 mg/L	2.0	2.1
Ozone at 0.75 mg/L	2.3	2.6
Ozone at 1.0 mg/L	6.4	2.4
Ozone 1.0 mg/L; pH=6.5	3.4	1.8
Ozone 1.0 mg/L, NH3=0.5 mg/L	2.5	< 1.0

Initial Water Quality Results

- Ozone (cont'd)
  – CECs: Good reduction in some compounds, but little reduction in recalcitrant compounds
  – BAC/GAC will provide additional removal of recalcitrant compounds
- Significantly more pilot data to be collected through summer / fall 2014

Compound	Post SAT (ng/L)	Post O3 at 1 mg/L (ng/L)
Caffeine	<6.8	<14
Trimethoprim	<2	<2.4
PFBA	<17	<21
Primidone	13	<20
Meprobamate	4.6	4.2
Sulfamethoxazole	4.1	<3.3
Diphenhydramine	<1.6	<1.9
Hydracortisone	<2.4	<2.6
Ditiazem	<1.4	<1.7
Simazine	<1.7	<1.6
Dexamethasone	<6.6	<5.1
Carbamezapine	51	<4.9
PFHxA	<5.7	<6.1
Fluoxetine	<1.5	<2
TCEP	25	34
Atrazine	<1.7	<1.6
DEET	<2.9	<3.4
Propylparaben	<2.7	<3.4
Bisphenol A	<14	<13
Testosterone	<3.4	<2.9
Clofibric Acid	<2.3	<2.6
Naproxen	<2.3	<2.6
Norgestrel	<2.4	<2.6
PFOA	<1.5	<1.7
Benzophenone	8.1	6.6
Ibuprofen	<20	<24
Gemfibrozil	<2.1	<2.4
Triclocarban	<1.7	<2.3
Triclosan	<2	<2.6
PFOS	24	26
Iopamidol	1470	1230
Iohexol	< 57	< 58
Iopromide	< 22	< 22
Acesulfame	303	102
Sucralose	7670	6890
Atenolol	14	14

Conclusions

- Full-scale potable reuse plants have historically used RO- and GAC-based treatment trains, although recent trend in the industry is leaning more towards RO.
- Alternative treatment for potable reuse should be considered for inland utilities due to difficulty and cost of RO concentrate disposal
- SAT-NF(side-stream)-Ozone-BAC/GAC being considered by Tucson for potable reuse
- Short term soil aquifer treatment provides excellent removal of bulk organics, including CECs
  - Excellent pathogen removal is also expected (data pending)
- Ozone added at sub-residual doses provides oxidation of organics without significant bromate and NDMA formation
- Additional data will be collected on NF and BAC/GAC performance over next 6 months

Acknowledgements

Team Member	Role
Justin Mattingly, WRRF	WRRF Project Manager
Larry Schimmoller, CH2M HILL	Principal Investigator
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Ryan Rhoades, CH2M HILL	Project Management, Progress Reporting
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Bruce Prior, TW	Hydrogeologist
Dan Candelaria, CH2M HILL	Pilot Construction and Operation Support
Tarun Anumol, UA	Lead Ozone and BAC/GAC Operations; WQ Testing
Andrea Corral, UA	NF Pilot Operations, Membrane Autopsy

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Questions

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