Comparing the Sustainability and Effectiveness of RO- and Non-RO Based Potable Reuse Schemes

Jim Lozier, P.E.
CH2M

Arizona Water Reuse 2016 Symposium

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Presentation Overview

- Introduction
- Types of Potable Reuse
- RO and Non-RO Advanced Treatment Schemes
- Treatment Cost Comparison
- Greenhouse Gas Emissions Comparison
- Pathogen and Trace Organic Removal
- Conclusions

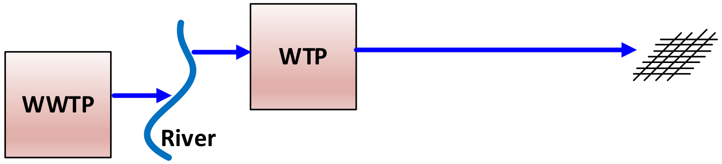
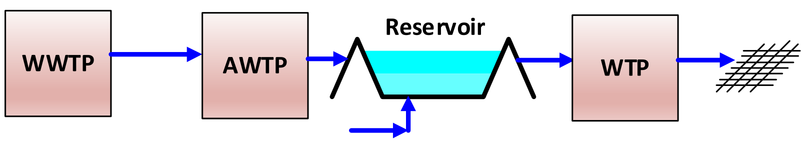
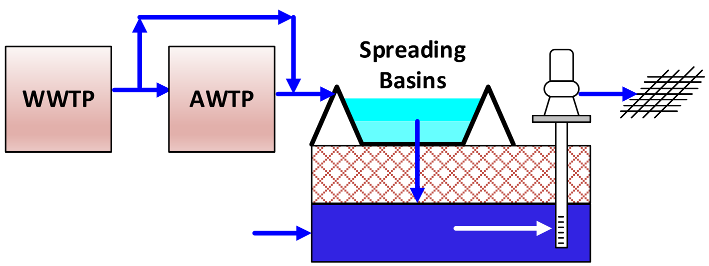
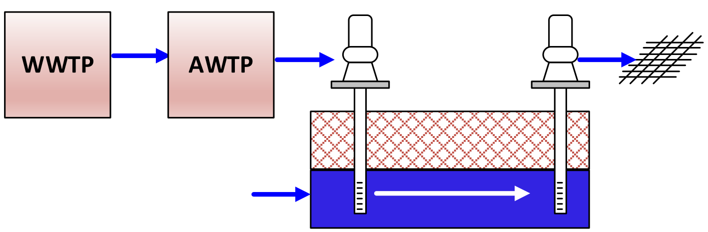
Introduction

- Increased interest in and implementation of potable reuse in U.S. as a means to meet water supply challenges
- Trend has been to use MF/RO/UV-AOP as default advanced treatment scheme driven by the broad contaminant removal capability of RO, particularly for bulk organics (TOC)
- RO produces a high salinity waste stream (concentrate) that can be challenging to dispose of
- Are other advanced treatment schemes capable to satisfying the pathogen, bulk and trace organic removals required for potable reuse but in a more cost-effective and sustainable manner

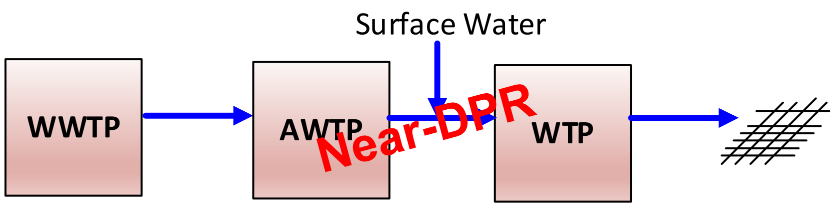
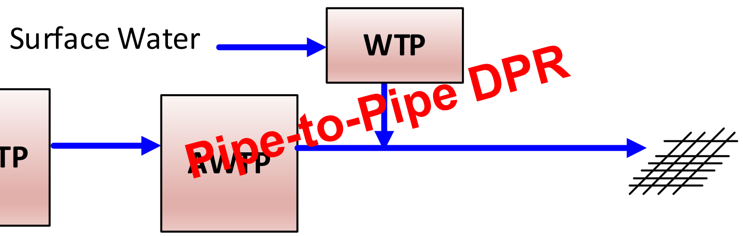
Approach

- Compare and contrast two distinctly different advanced treatment schemes employed at full-scale facilities designed to produce a high-quality water from secondary effluent -- suitable for indirect, and possibly, direct, potable reuse
- Illustrate how each scheme is tailored to meet treated water requirements based on influent and regulatory requirements
- Assess the ability of each scheme to meet pathogen removal requirements and provide a high level of trace organic compound (TrOC) removal
- Compare the cost and carbon footprint of each scheme

Indirect Potable Reuse

Indirect Potable Reuse Approaches	Examples
De Facto 	Common throughout the world (e.g., Mississippi River, Colorado River, etc…)
Surface Water Augmentation 	Upper Occoquan Service Authority (Northern Virginia); Gwinnett County (Georgia); Singapore NEWater
GW Recharge via Spreading Basins 	Montebello Forebay (Los Angeles, CA); El Paso (Texas); Chino Basin (Chico, CA)
GW Recharge via Direct Injection 	GWRS (Orange County, CA); West Basin (CA); Los Alamitos (Long Beach, CA); Scottsdale Water Campus (AZ)

Direct Potable Reuse

<table>
<tr><th>Direct Potable Reuse Approaches</th><th>Examples</th></tr>
<tr><td>
</td><td>Big Spring, TX</td></tr>
<tr><td>
</td><td>Windhoek, Namibia</td></tr>
</table>

Operational Potable Reuse Plants

Project	Location	Type of Potable Reuse	Year in Operation	Capacity	Current Advanced Treatment Process
Montebello Forebay, CA	Coastal	GW recharge via spreading basins	1962	44 mgd	GMF + Cl_2 + SAT (spreading basins)
Windhoek, Namibia	Inland	Direct potable reuse	1968	5.5 mgd	O_3 + Coag + DAF + GMF + O_3/H_2O_2 + BAC + GAC + UF + Cl_2
UOSA	Inland	Surface water augmentation	1978	54 mgd	Lime + GMF + GAC + Cl_2
Hueco Bolson, El Paso, TX	Inland	GW recharge via direct injection and spreading basins	1985	10 mgd	Lime + GMF + Ozone + GAC + Cl_2
Clayton County, GA	Inland	Surface water augmentation	1985	18 mgd	Cl_2 + UV disinfection + SAT (wetlands)
West Basin, El Segundo, CA	Coastal	GW recharge via direct injection	1993	12.5 mgd	MF + RO + UVAOP
Scottsdale, AZ	Inland	GW recharge via direct injection	1999	20 mgd	MF + RO + Cl2
Gwinnett County, GA	Inland	Surface water augmentation	2000	60 mgd	Coag/floc/sed + UF + Ozone + GAC + Ozone
NEWater, Singapore	Coastal	Surface water augmentation	2000	146 mgd (5 plants)	MF + RO + UV disinfection
Los Alamitos, CA	Coastal	GW recharge via direct injection	2006	3.0 mgd	MF + RO + UV disinfection
Chino GW Recharge, CA	Inland	GW recharge via spreading basins	2007	18 mgd	GMF + Cl_2 + SAT (spreading basins)
GWRS, Orange County, CA	Coastal	GW recharge via direct injection and spreading basins	2008	100 mgd	MF + RO + UVAOP + SAT (spreading basins for a portion of the flow)
Queensland, Australia	Coastal	Surface water augmentation	2009	66 mgd	MF + RO + UVAOP
Arapahoe County, CO	Inland	GW recharge via spreading	2009	9 mgd	SAT (via RBF) + RO + UVAOP
Loudoun County, VA	Inland	Surface water augmentation	2009	11 mgd	MBR + GAC + UV
Aurora, CO	Inland	Surface water augmentation	2010	50 mgd	SAT (via RBF) + Soft + UVAOP + GMF +GAC
Big Spring ,TX	Inland	Direct potable	2013	1.8 mgd	MF + RO + UVAOP

ARR = Aquifer Recharge and Recovery; BAC = Biological Activated Carbon filtration; Cl_2 = Chlorine Disinfection; Coag = Coagulation; DAF = Dissolved Air Flotation; GAC = Granular Activated Carbon; GMF = granular media filtration; GW = groundwater; H_2O_2 = Hydrogen Peroxide; MF = Microfiltration; O_3 = Ozone; RBF = riverbank filtration; RO = Reverse Osmosis; SAT = Soil Aquifer Treatment; UF = Ultrafiltration; UV = Ultraviolet; UVAOP = UV Advanced Oxidation

Why Not MF/RO/UV-AOP for AZ

- The scheme is:
  - High CAPEX and OPEX
  - Has high power consumption and carbon footprint
  - Produces a waste stream that is challenging and costly to dispose (concentrate)

AWT Plant Locations

Oxnard, CA

Gwinnett County, GA

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Indirect Potable Reuse Schemes

Facility	IPR Method	Treatment
Gwinnett County F. Wayne Hill Water Resources Center	Reservoir augmentation	Chemical clarification[1], screening, UF, O_3, BAC, O_3
Oxnard Advanced Water Purification Facility	Groundwater recharge	Micro-screening, chloramination[2], MF, RO, UV/AOP
[1] Ferric addition, rapid mix, flocculation, high-rate plate settling [3] Chlorine addition		

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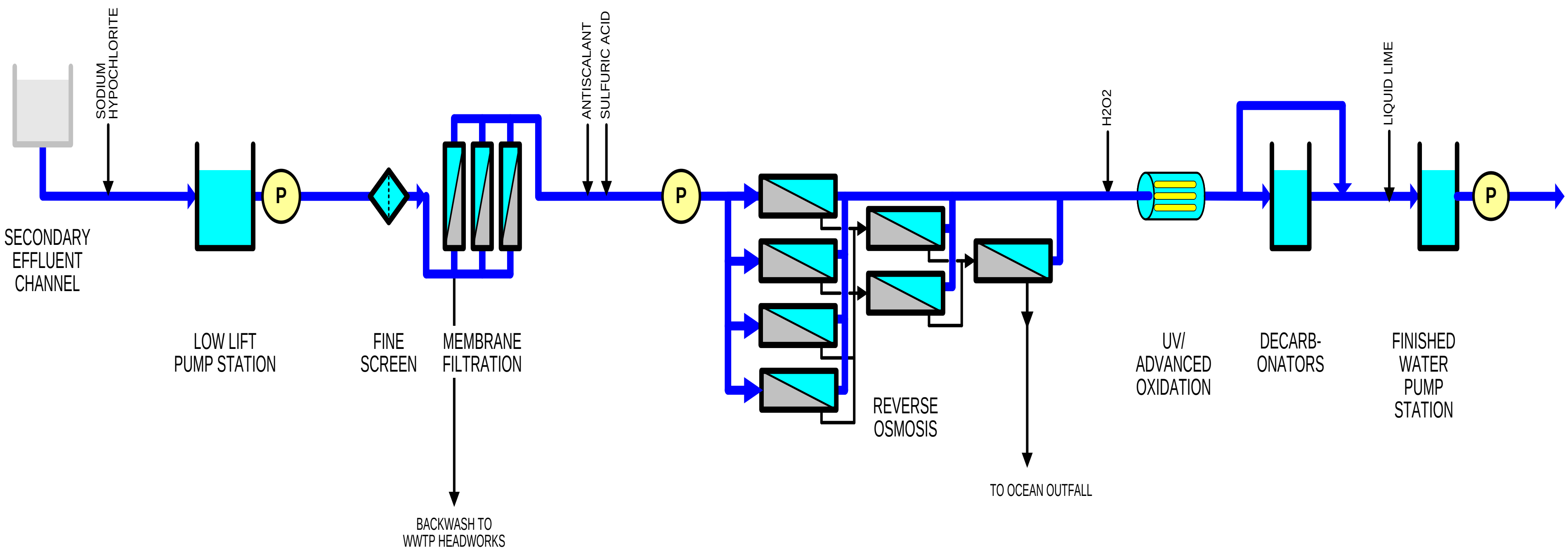
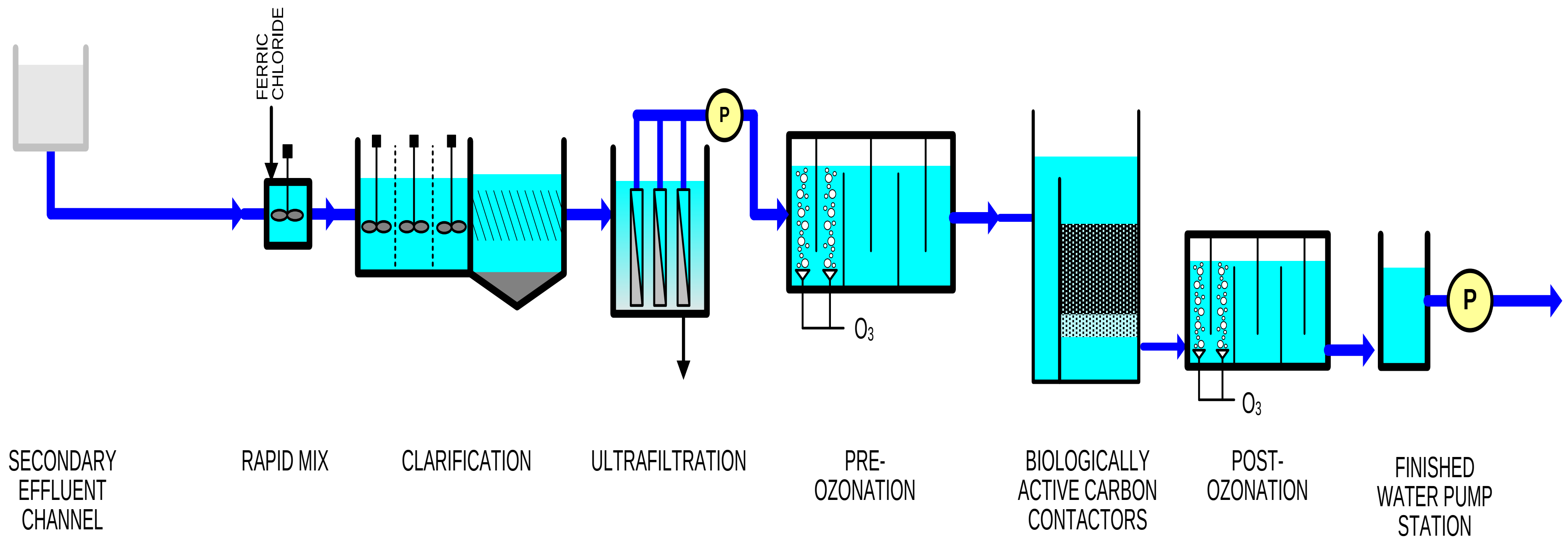
Oxnard AWPF Process Schematic (6.25 mgd Phase 1)



Advanced Treatment at FWHWRC, Gwinnett County



Representative AWT Feed Water Quality

mg/L	Gwinnett County	Oxnard
BOD	--	16
COD	25	--
TOC	6	16.6
TSS	9	6.4
Turbidity, NTU	2.0	4.0
TDS	300	1,750
NH3-N	0.2	23.3
NO3-N	6.5	2.6
Total N	8.0	25.9
Total P	0.2	1.24

AWT Treated Water Quality Requirements

mg/L or as shown	Gwinnett County		Oxnard
	Req'd	Actual	Req'd
COD	18	10	NR
TOC	NR	3.5	0.5[a]
TSS	3	<1	NR
Turbidity, NTU	0.5	<0.1	0.2
TDS	NR		500
NH3-N	0.4		NR
Total N	<10		<10 (5)
Total P	0.08		NR

NR = Not regulated
[a] Assumes 100% treated water injection

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AWT Treated Water Quality Requirements

mg/L or as shown	Gwinnett County	Oxnard
	Req'd	Req'd
NDMA, ng/L	NR	1.2 LR[b]
1,-4 dioxane, ng/L	NR	0.5 LR[b]

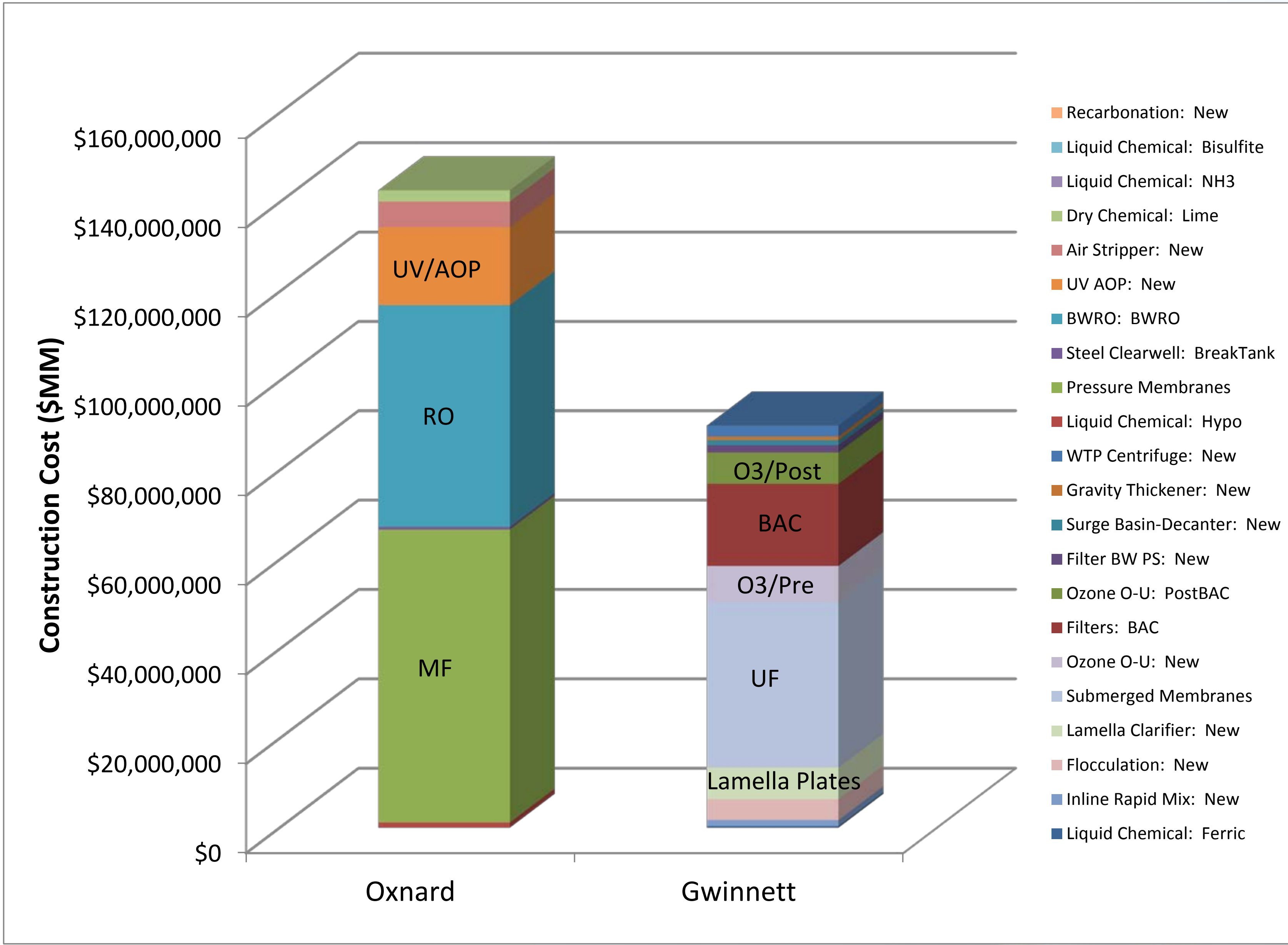
NR = Not regulated

[b] Log reduction by H_2O_2/UV

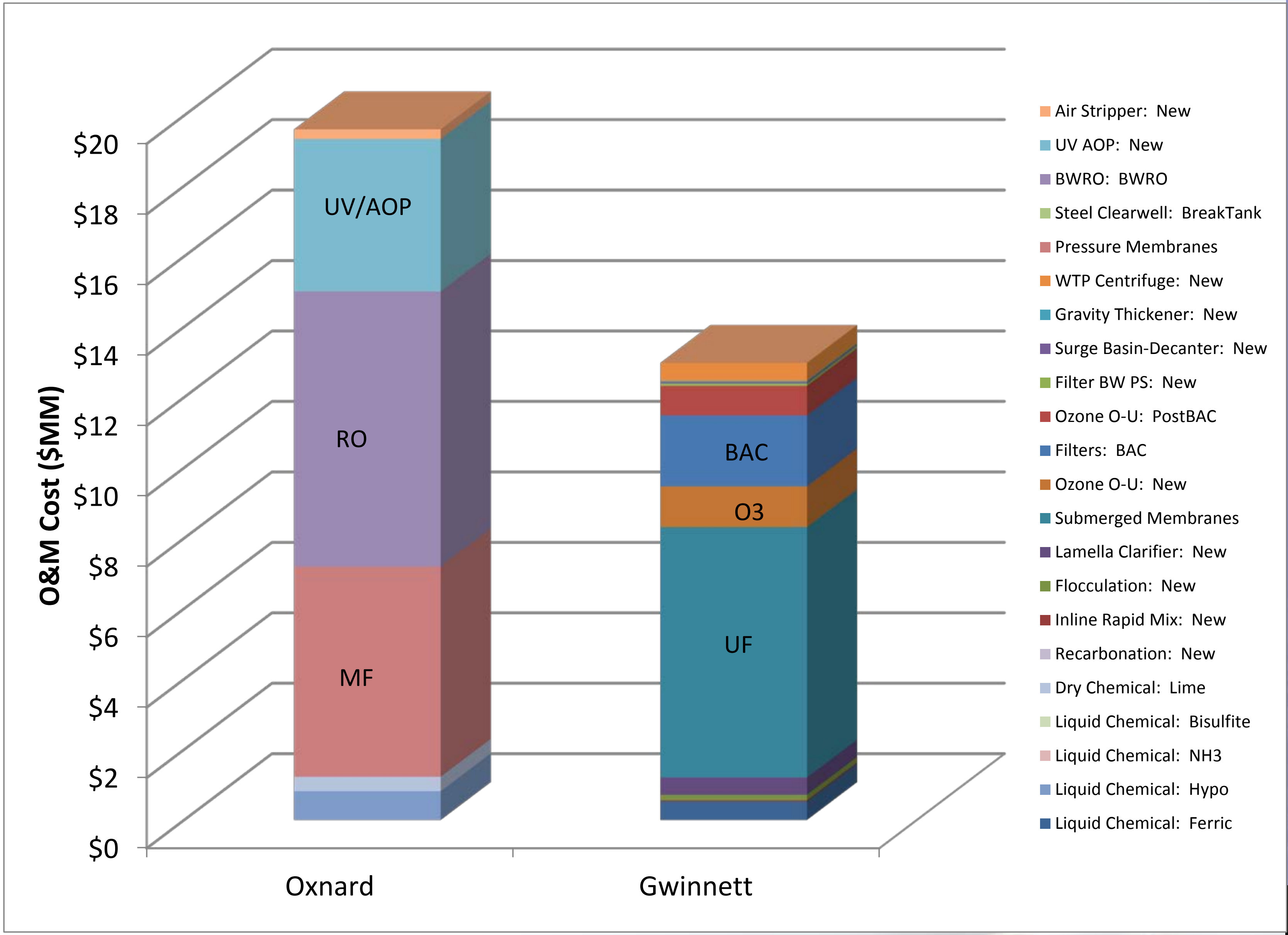
Construction and O&M Cost Estimates – AWT Schemes at 25 mgd capacity

- Developed using CH2MHILL's proprietary cost estimating program (CPES)
    - Parametric-based, uses detailed quantity take-offs and extensive database of constructed facility costs
- Both AWTPs sized at 25 mgd using design criteria from full-scale plant
- All unit processes and operations included except finished water pumping
- O&M costs include power, chemicals, residuals but excludes labor
- No costs included for RO concentrate disposal from Oxnard AWTP; concentrate discharged to river or ocean

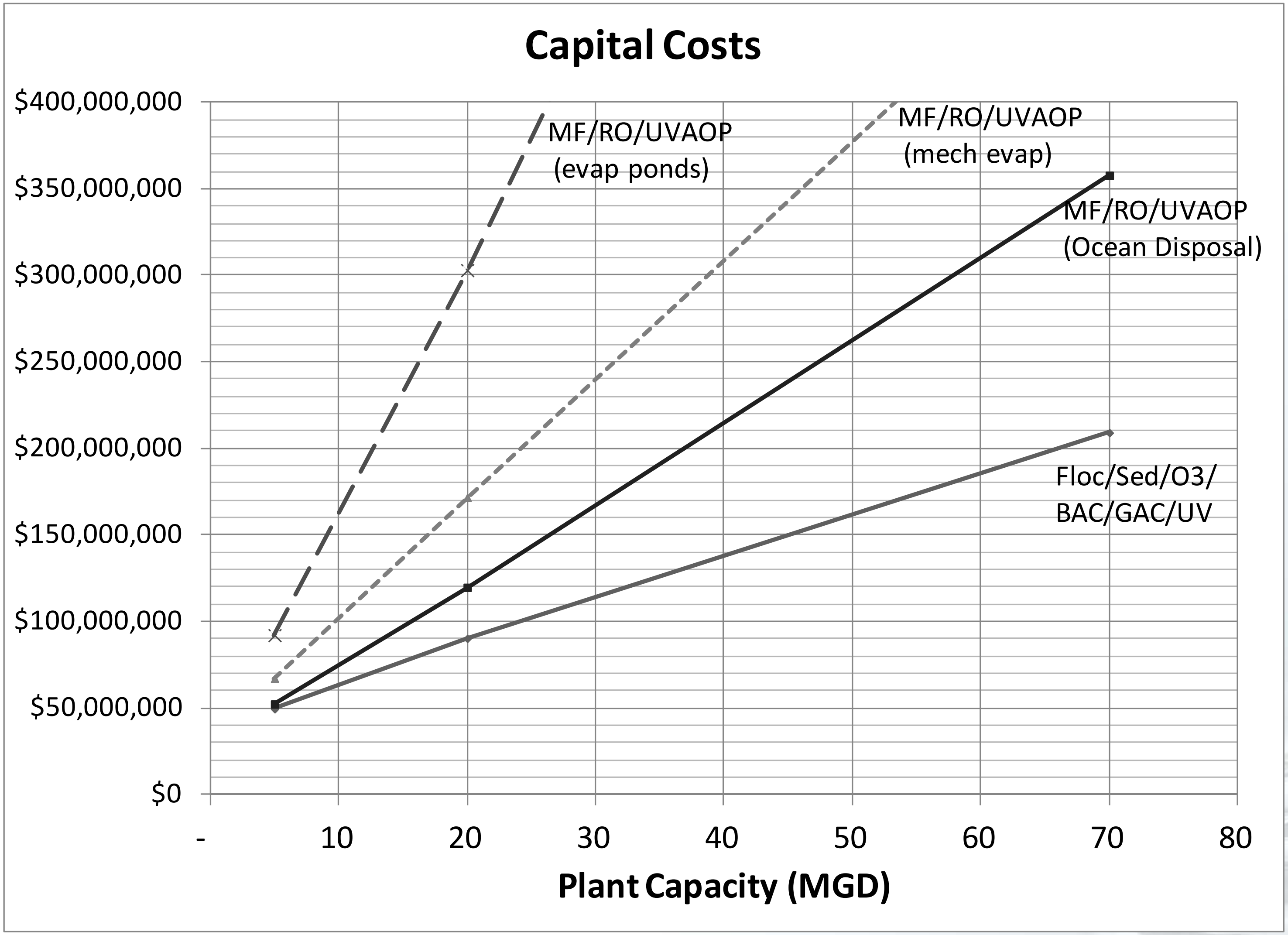
Estimated Construction Costs (25 mgd)



Estimated Annual O&M Costs (25 mgd)



Cost Impact of Zero Liquid Discharge of RO Concentrate



From *WRRF-10-01*, Fit for Purpose Water: The Cost of Overtreating Reclaimed Water

Greenhouse Gas Emissions Estimates

- Similar to Water Research Foundation Project 4156: *Greenhouse Gas Emission Inventory and Management Strategy Guidelines for Water Utilities*
- Evaluation is predictive based on specific design criteria and GHG production data
- Carbon dioxide, methane, nitrous oxide in carbon dioxide equivalents (CO2e)
- Accurate development and understanding of the facility and associated physical footprint, energy and chemical use, and residuals production is critical
  - CPES use provides foundation for estimates

GHG Production Bases

Component	Emission Value	Emission Unit
GAC Media [1]	368	Lbs CO_2e/ton GAC
Electricity		
Gwinnett County (Southeast USA) [2]	1,294	Lbs CO_2e/MWh
Oxnard (California) [2]	879	Lbs CO_2e/MWh
Fuel Use [3]	21.96	Lbs CO_2e/gal

[1] Liu, P. and Wagner, N. *Thermal Regeneration of Activated Carbon.* Environmental Progress. May 1985.
[2] USEPA. *Indirect Emissions from Purchaces/Sales of Electricity and Stream*. June 2008.
[3] *California Climate Action Registry General Reporting Protocol, Version 2.2.* California Climate Action Registry. 2007 (based on diesel fuel)

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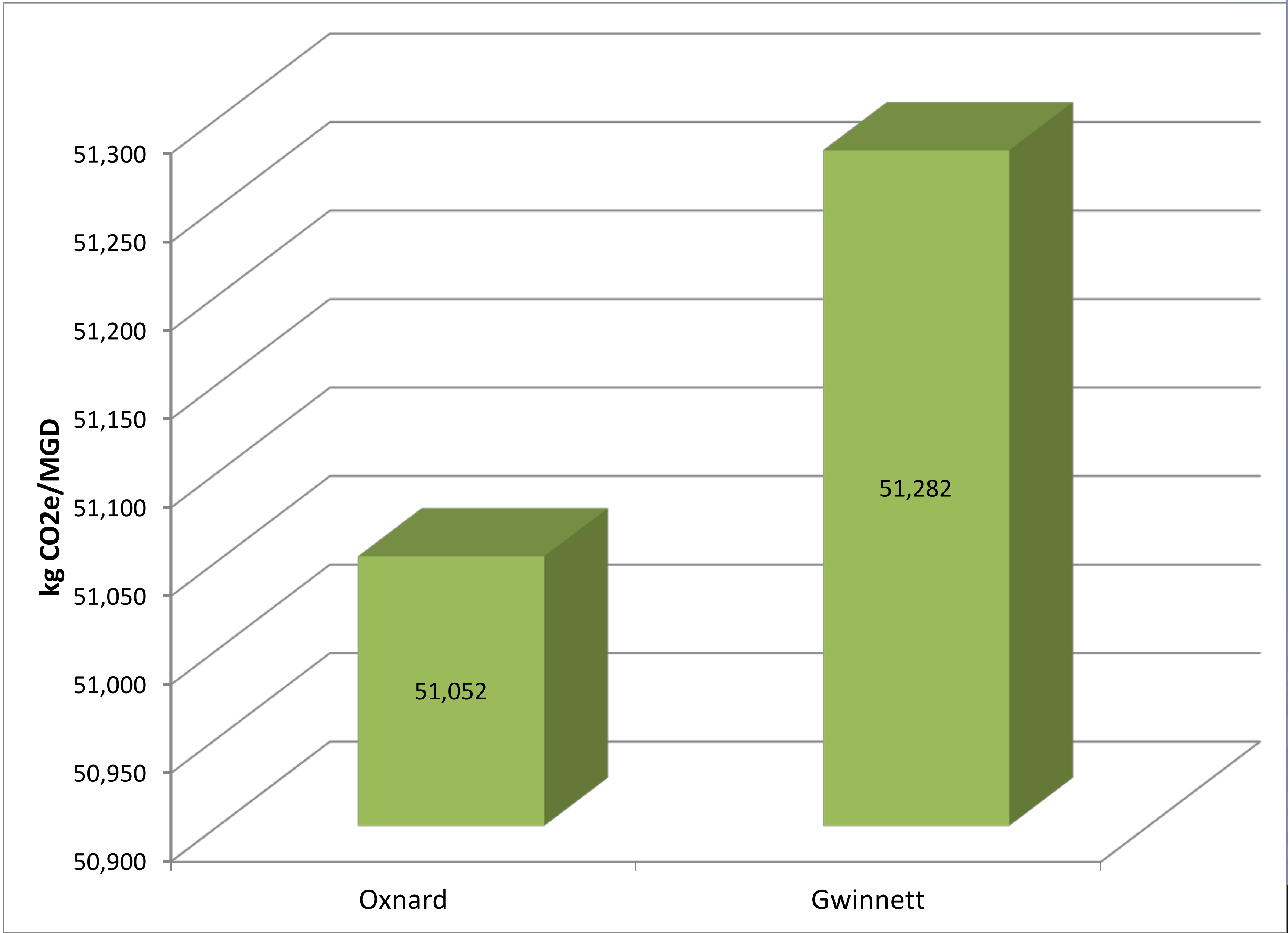
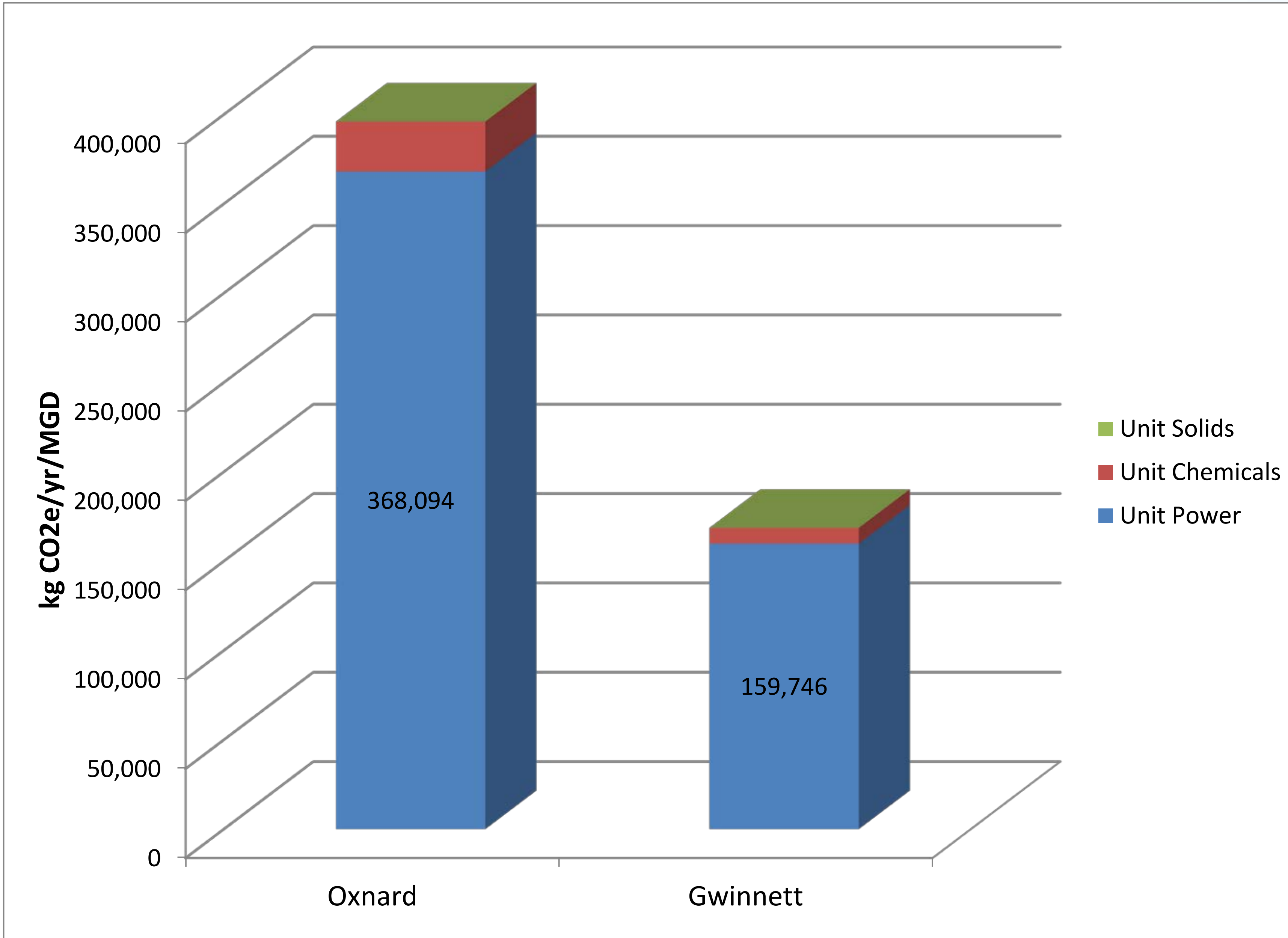
Construction-Related CO_2 Emissions



Annual O&M-Related CO_2 Emissions



Pathogen Log Removals – DPR (1)

Oxnard AWPF	Crypto	Giardia	Virus
MF	4	4	0.5
RO	1.5 - 3	1.5 - 3	1.5 - 3
UV-AOP	6	6	6
Total	**11.5 - 13**	**11.5 - 13**	**8-9.5***
DPR Req'mt	10	10	12

<table>
<tr><th>FWH WRC AWT</th><th>Crypto</th><th>Giardia</th><th>1</th></tr>
<tr><td>Coag-Sed</td><td>--</td><td>--</td><td rowspan="2">2</td></tr>
<tr><td>UF</td><td>4</td><td>4</td></tr>
<tr><td>Pre-O3</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>BAC</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Post-O3</td><td>1.5</td><td>3</td><td>6</td></tr>
<tr><td>Total</td><td>5.5</td><td>7</td><td>8</td></tr>
<tr><td>DPR Req'mt</td><td>10</td><td>10</td><td>12</td></tr>
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(1) No downstream WTP   *Add'l 6 log virus through aquifer storage

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FWH WRC AWT	Crypto	Giardia	Virus
Coag-Sed	--	--	2
UF	4	4	
Pre-O3	0	0	0
BAC	0	0	0
Post-O3	1.5	3	6
UV-AOP	6	6	6
Total	**11.5**	**13**	**12**
DPR Req'mt	10	10	12

(1) No downstream WTP *Add'l 6-log removal through aquifer storage

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Pathogen Log Removals – DPR (2)

Oxnard AWPF	Crypto	Giardia	Virus
MF	4	4	0.5
RO	1.5 - 3	1.5 - 3	1.5 - 3
UV-AOP	6	6	6
Total	**11.5 - 13**	**11.5 - 13**	**8-9.5**
N-DPR	8	7	8

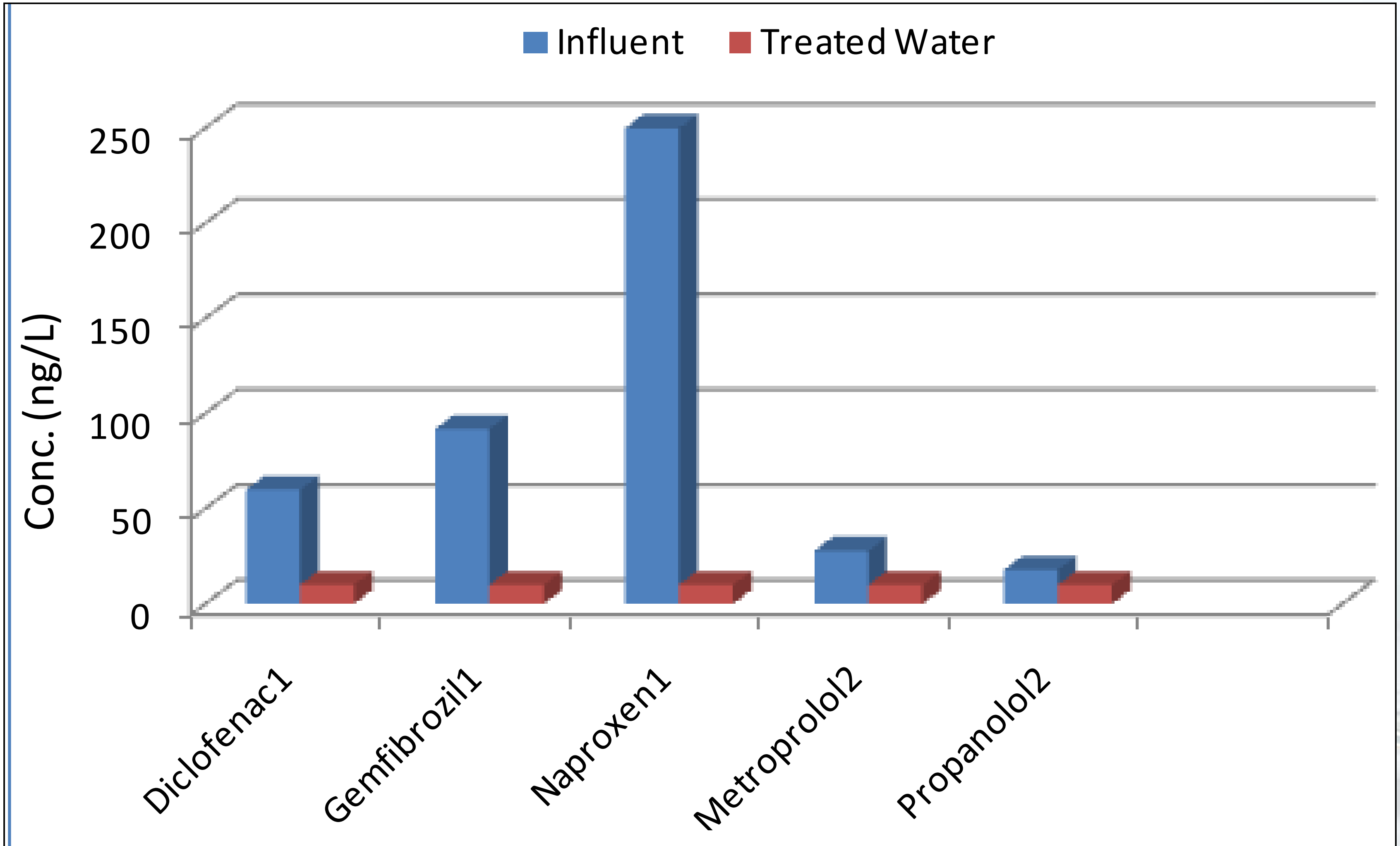
FWH WRC AWT	Crypto	Giardia	Virus
Coag-Sed	--	--	2
UF	4	4	
Pre-O3	0	0	0
BAC	0	0	0
Post-O3	1.5	3	6
UV	4	4	2
Total	**9.5**	**11**	**10**
N-DPR	8	7	8

(2) ATW to downstream WTP

Trace Organic Compound (TrOC) Removal

- Oxnard AWT designed specifically to achieve high level of removal of two TrOCs (NDMA and 1,4-dioxane) per California recycled water regulations for subsurface injection.
- RO and UV-AOP combination provides excellent removal of all classes of TrOCs as demonstrated by full-scale potable reuse facilities
- Gwinnett County AWT isn't specifically designed to achieve TrOC removal, but O_3/BAC/O_3 provides good-to-excellent removal of most TrOCs, confirmed through research conducted on pharmaceutically-active compounds (PhACs)

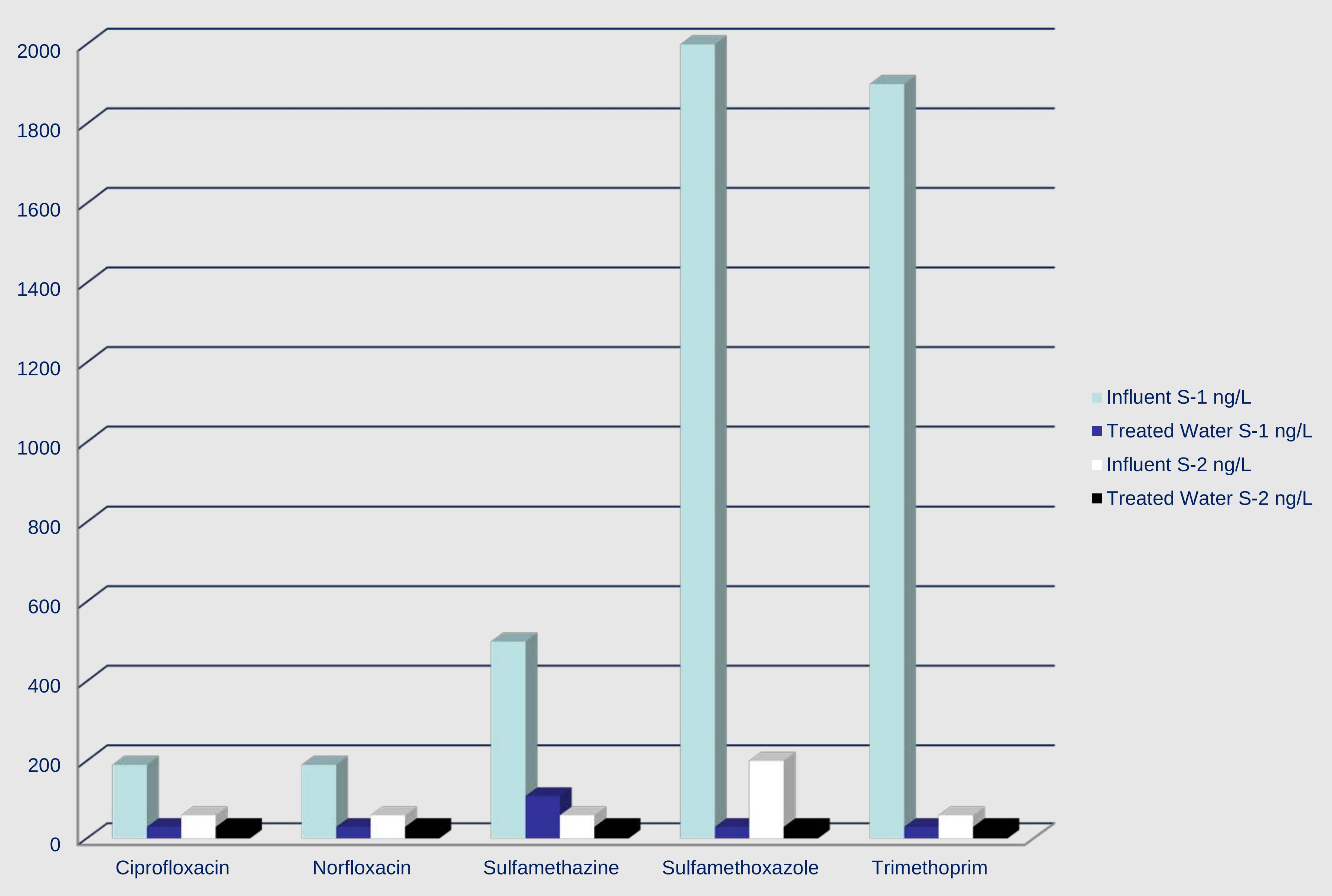
PhAC Removal - Gwinnett County



1 - acidics; 2 - beta blockers

Active Compounds, AwwaRF, 2005

Antibiotic Removal – Gwinnett County



Conclusions

- RO- and non RO-based treatment schemes are both capable of meeting or exceeding pathogen log removal requirements, whether for direct or near-direct potable reuse – a key requirement for any potable reuse facility
- Although RO provides better bulk organics (TOC) removal, both schemes are capable of providing a high level of TrOC removal
- The non RO-based treatment scheme has significant lower CAPEX, OPEX and life-cycle costs, even where a low-cost concentrate disposal option is available
- The non RO-based treatment scheme has significantly lower GHG emissions
- If some demineralization and improved TOC removal is required, the non-RO based scheme can be adapted by incorporating nanofiltration, and soil aquifer treatment (SAT) and/or GAC.

Acknowledgements

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  - Larry Schimmoller
  - Jason Curl
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  - Gwinnett County, GA
  - City of Oxnard, CA

Questions?

- jlozier@ch2m.com