UV-Oxidation: Accomplishing Multiple Objectives in Potable Reuse

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Trojan Technologies
Arizona WateReuse Conference 2016

GLOBAL WATER SCARCITY

- World population has doubled in last 50 yr
- Drought is common, severe
- Groundwater being depleted at unprecedented rate
- Regulation developing to control groundwater and to facilitate reuse
- 9 states have issued potable reuse guidance (OK, NC, CA…)

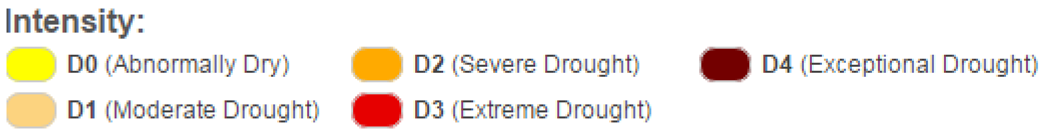
WATER STRESS IN THE UNITED STATES

California

- Southern cities (e.g. Los Angeles and San Diego) receive the bulk of their water from the Colorado river and from the northern part of the state
  - Extreme costs associated with transportation
  - 20% of energy used in state is used to move water

As of July 26, 2005

Source: U.S. Drought Monitor (University of Nebraska, Lincoln), 2015



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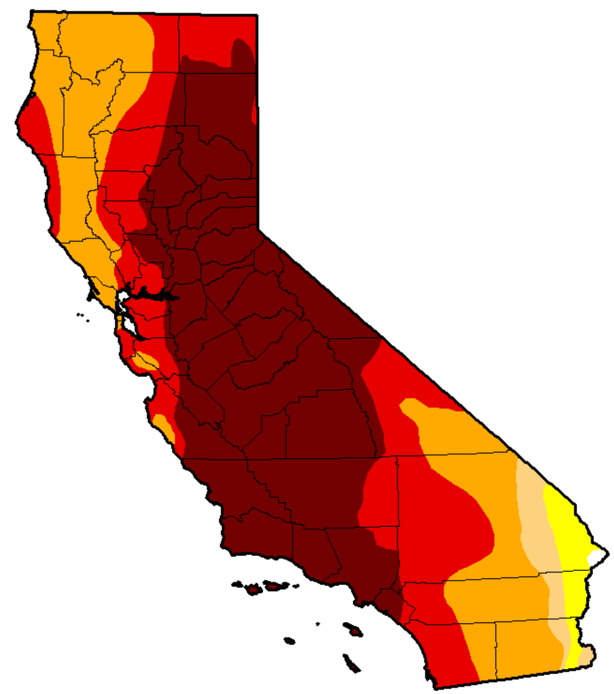
As of August 6, 2015



Source: U.S. Drought Monitor (University of Nebraska, Lincoln), 2015

Intensity:

- **D0** (Abnormally Dry)
- **D1** (Moderate Drought)
- **D2** (Severe Drought)
- **D3** (Extreme Drought)
- **D4** (Exceptional Drought)

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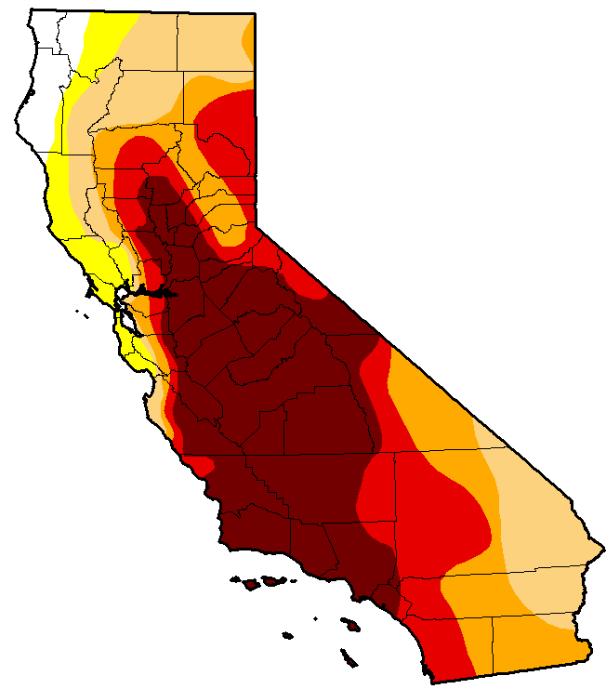
- **Drought has eased but mainly in Northern California**

As of March 29, 2016



Source: U.S. Drought Monitor (University of Nebraska, Lincoln), 2016

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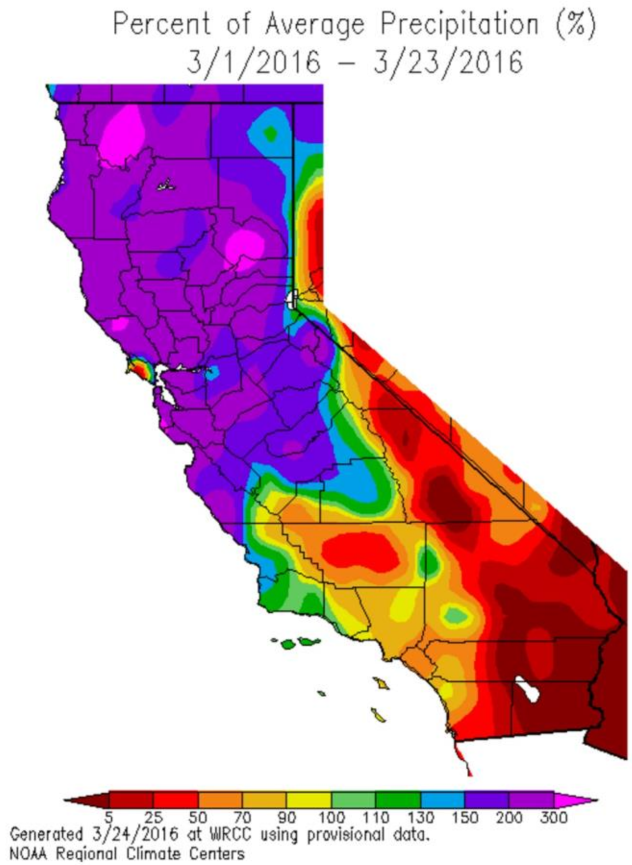

Source: NOAA Regional Climate Centers

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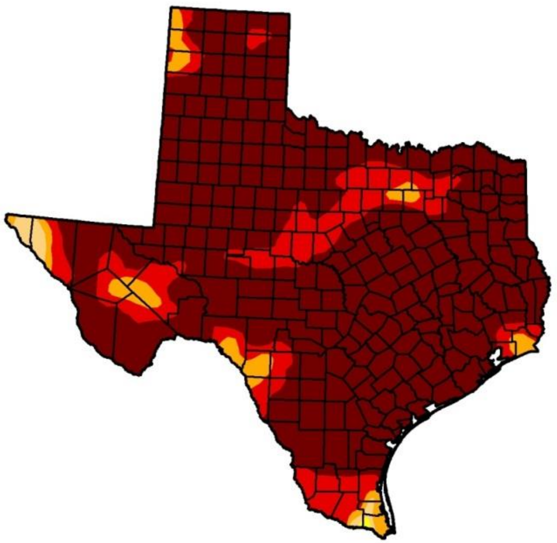
WATER STRESS IN THE UNITED STATES

Report from Texas

- Extreme drought conditions caused strain on drinking water sources
- Temporary DPR in Wichita Falls
- Numerous cities began to think about potable reuse

As of February 28, 2012



Source: U.S. Drought Monitor (University of Nebraska, Lincoln), 2012

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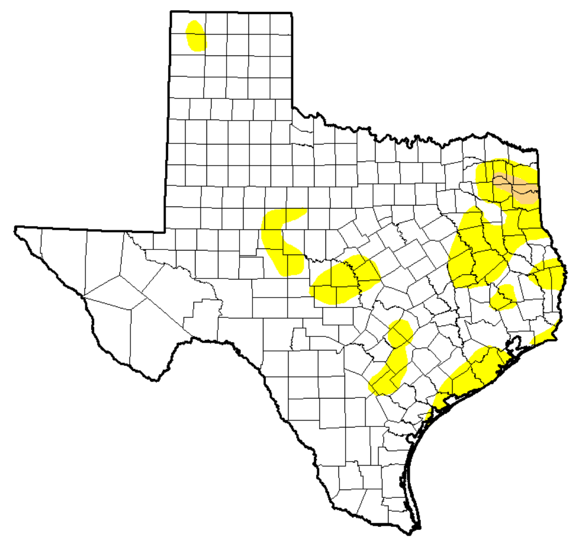
WICHITA FALLS TEMPORARY DPR USED UV

WATER STRESS IN THE UNITED STATES

Report from Texas

- Rain has come!
- Projects are slowing down
- Leaders in reuse urging cities to plan for the next drought

As of July 28, 2015



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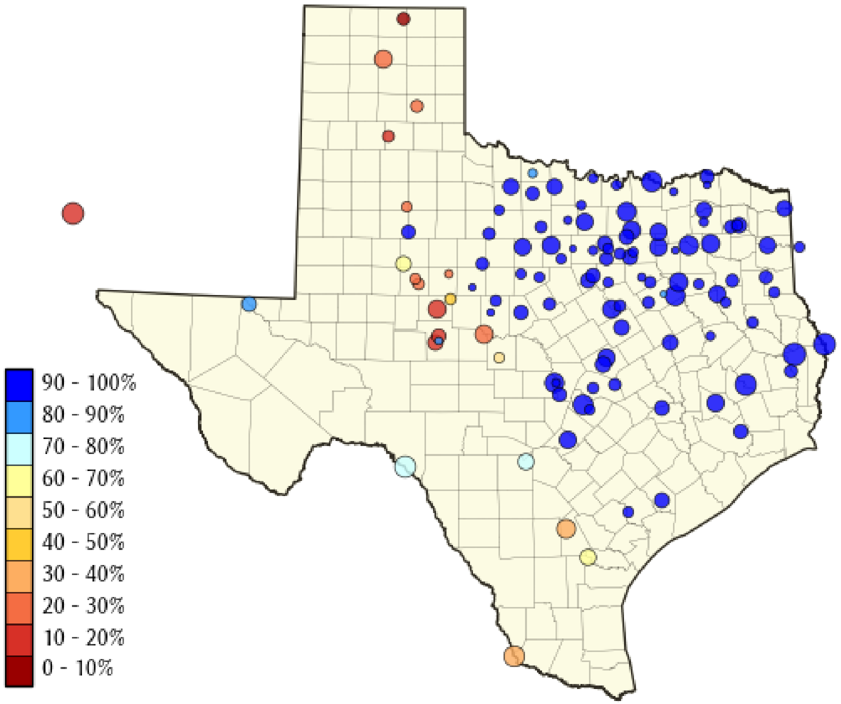
WATER STRESS IN THE UNITED STATES

Texas

- Reservoirs are full…in the east
- Western reservoirs are not full

As of July 19, 2016



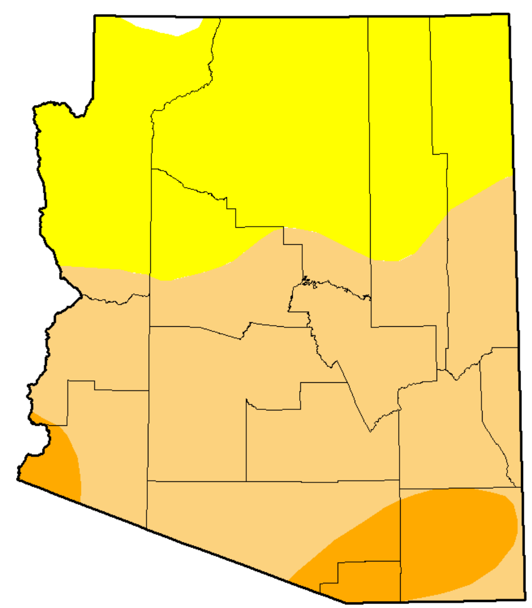
Source: http://waterdatafortexas.org/reservoirs/statewide 2016

WATER STRESS IN THE UNITED STATES

<u>Arizona</u>

- "Abnormally dry" to "severe drought"

As of July 12, 2016



Source: U.S. Drought Monitor (University of Nebraska, Lincoln), 2012

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WATER STRESS: WHAT ARE THE OPTIONS?

- Reduce Growth
- Conserve
- Develop New Water Sources
- Water Transfer
- Desalination
  - Seawater
  - Brackish Water
- Non-potable Reuse to Offset DW
- Remediate impaired sources
- Indirect or Direct Potable Reuse (IPR/DPR)

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DIRECT POTABLE REUSE – LET'S ADVANCE THE DEBATE

- Provides reliable new source of water
- Has a "buyer" year round (i.e. not dependent on agricultural growing season)
- "Yuck" factor decreases with increasing drought
- Aquifer recharge makes sense in some areas but not in all
- Avoids the cost and challenge of purple pipe distribution
- Environmental benefits (e.g. Reduction in wastewater discharge; Improves beaches/fishing for tourism)

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POTABLE REUSE REGULATORY FRAMEWORK

- **California** requires an oxidation step post-RO
  - Demonstrated by removing a basket of contaminants or 0.5-log 1,4-dioxane
  - 12/10/10 – Log Reduction of Virus/Giardia/Crypto
  - Max 6-log inactivation per step
- **Texas**
  - 8/6/4 – Log Reduction of Virus/Giardia/Crypto
  - Disinfection according to USEPA

Projects in both states have used UV to meet these objectives…

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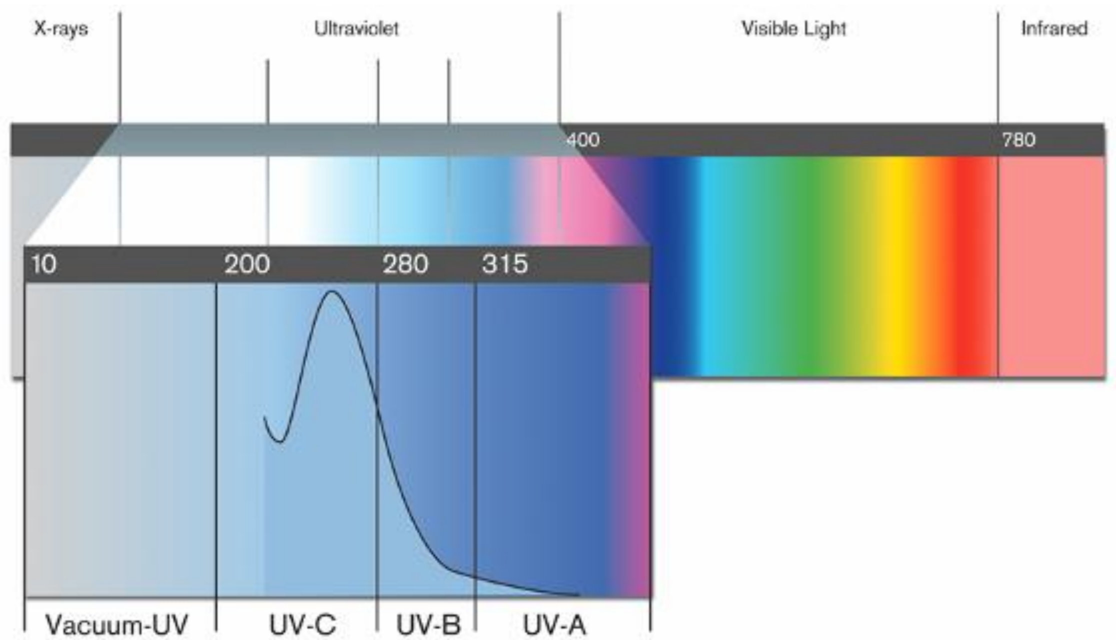
ENVIRONMENTAL CONTAMINANT TREATMENT

Using UV and an oxidant (hydrogen peroxide or chlorine) to destroy trace organic contaminants in water by:

UV-Photolysis

UV-Oxidation



UV-OXIDATION – TRENDS

- Orange County Water District GWRS and many other Full Advanced Treatment (FAT) Plants in successful operation

ORANGE COUNTY – INDIRECT POTABLE REUSE (IPR)

WEST BASIN MUNICIPAL WATER DISTRICT, CA

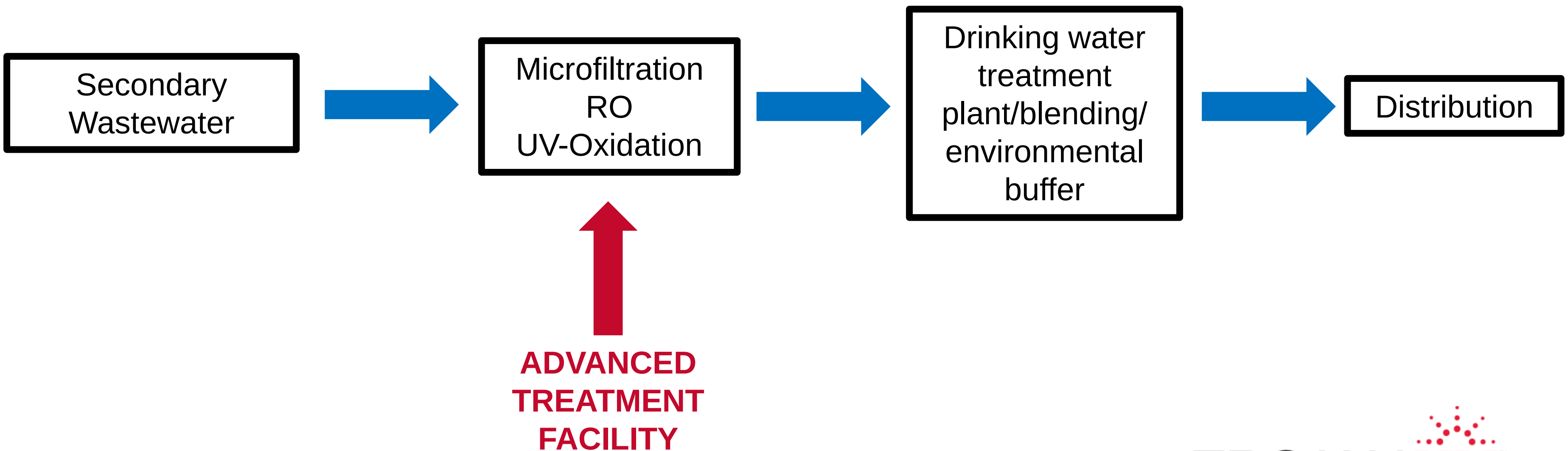
OXNARD CALIFORNIA’S GROUNDWATER RECOVERY ENHANCEMENT AND TREATMENT (GREAT) PROGRAM

LEO J. VANDER LANS ADVANCED WATER TREATMENT FACILITY

MAKING POTABLE WATER FROM “WASTEWATER”

- Water collected from wastewater treatment plants is “advanced” treated to higher standard allowing this water to be treated again back into drinkable water

- Full Advanced Treatment (“FAT”) includes three different treatment technologies:
    1. Microfiltration
    2. Reverse osmosis
    3. UV-oxidation



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UV-OXIDATION – TRENDS

- Orange County Water District GWRS and many other Full Advanced Treatment (FAT) Plants in operation
- UV-peroxide proven effective, but when residual chlorine needed…
- UV-chlorine being implemented
    - Demo- and full-scale demonstrations
    - Full scale systems being built
    - But it doesn’t work everywhere (ammonia present?)
- Sites using UV today for disinfection and contaminant treatment…how?

DISINFECTION

CASE STUDY #1: BIG SPRINGS, TX (COLORADO RIVER MUNICIPAL WATER DISTRICT)

- In 2004, the reservoirs used to supply drinking water were at 10% of capacity
  - At lowest, reservoirs were <2%
  - <u>Today</u> two of the three sources of raw water are ~10% capacity

ELECTED TO BUILD PERMANENT DPR – WHY?

- Local aquifers don't recharge well
- Other surface water too far away
- Non-potable reuse (NPR) inconsistent
- NPR required extensive distribution and RO anyway due to high TDS
- DPR consists of blending highly treated water into source supply to WTP

BIG SPRINGS PLANT DESIGN DETAILS AND CA PRECEDENT

- MF/RO/UV for Full Advanced Treatment
- Precedent aided in Public Acceptance
- UV-oxidation serves multiple purposes
  - Treatment of NDMA and 1,4-Dioxane
  - Treatment of pharmaceuticals and endocrine-disrupting chemicals not removed by MF or RO
  - **Additional disinfection barrier of 4-log virus credit**

Raw Water Production Facility Design Parameters	
Design Flow:	1.8 MGD
Target Contaminants:	NDMA 1,4-Dioxane
Design NDMA Reduction:	1.2 - Log
Design 1,4-Dioxane:	0.5 - Log
Oxidant:	H_2O_2
Disinfection Method:	UV Light

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UV DOSE

- Design Requirement for UV are stated in terms of “Dose”
- UV Dose is equivalent to CT for chlorine
- CT = Residual concentration (mg/L) x Contact Time (minutes)

- UV Dose = UV Intensity (mW/cm^2) x Exposure Time (seconds)

LOG INACTIVATION CREDITS AND UV DOSE – SET BY EPA

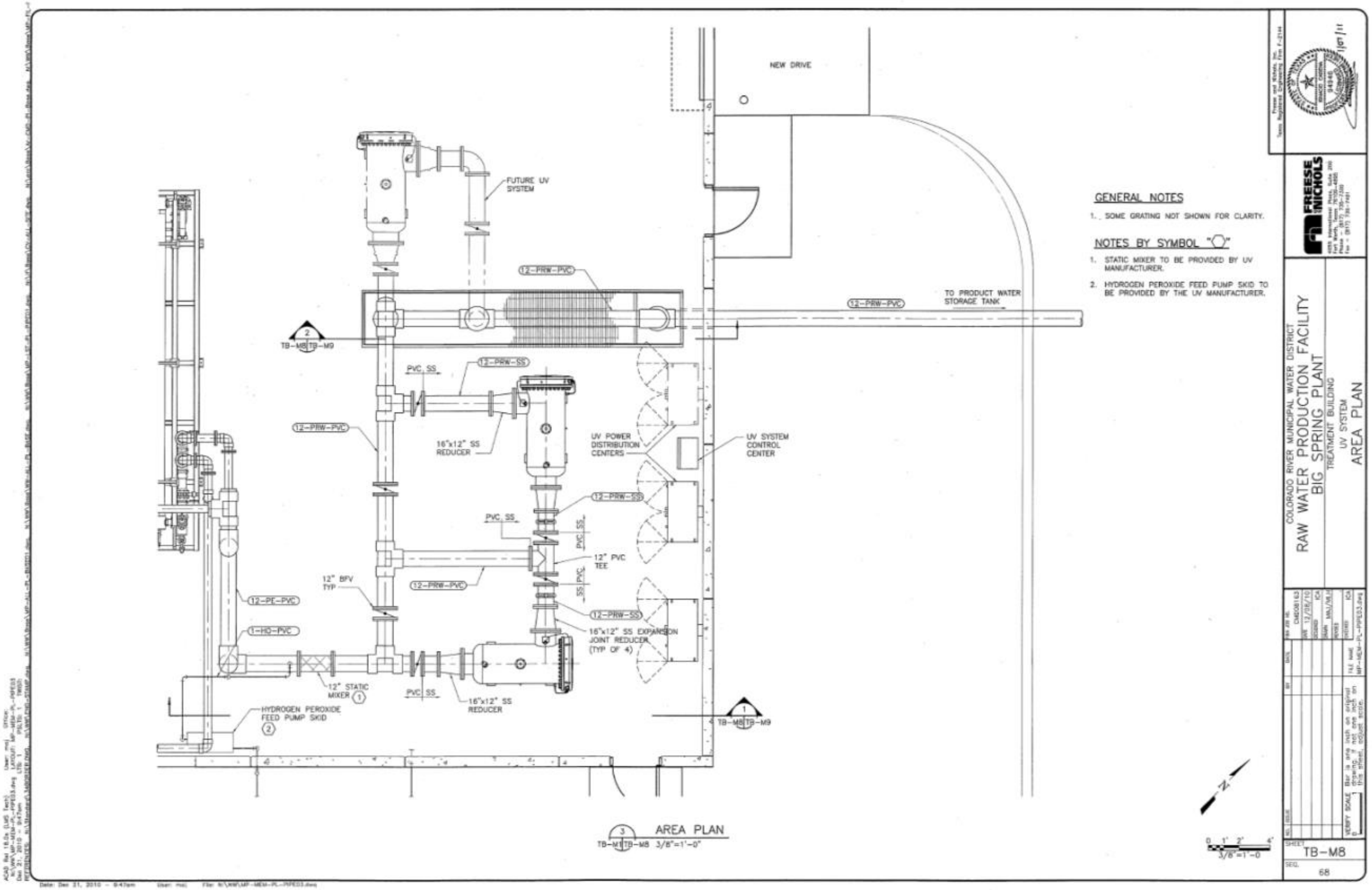
Table 1.4. UV Dose Requirements – millijoules per centimeter squared (mJ/cm^2) [1]

Target Pathogens	Log Inactivation							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

[1] 40 CFR 141.720(d)(1)

BIG SPRING PLANT

BIG SPRING PLANT LAYOUT



Courtesy of David Sloane, Freese and Nichols

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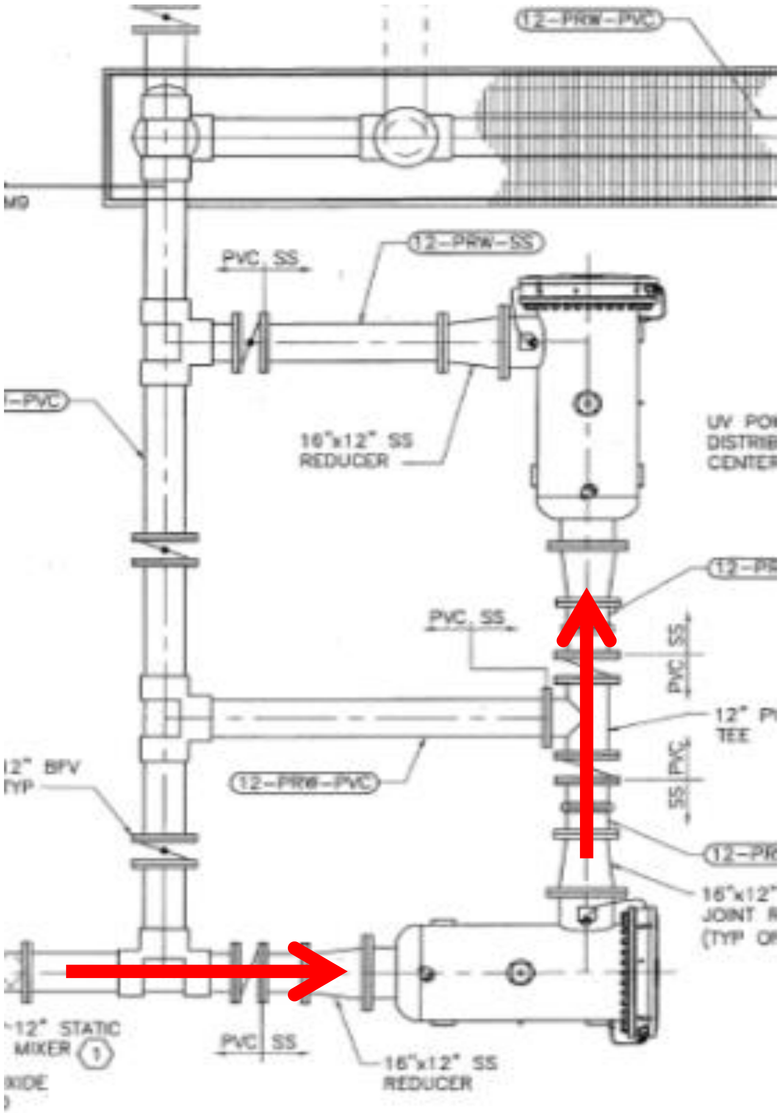
BIG SPRING PLANT LAYOUT LEADS TO VALIDATED UV DOSE



- Each reactor delivers a validated dose of 100 mJ/cm^2 for 2-log virus
- Added together, they accomplish 4-log virus
- Parallel operating critical control points: EEO and UV dose

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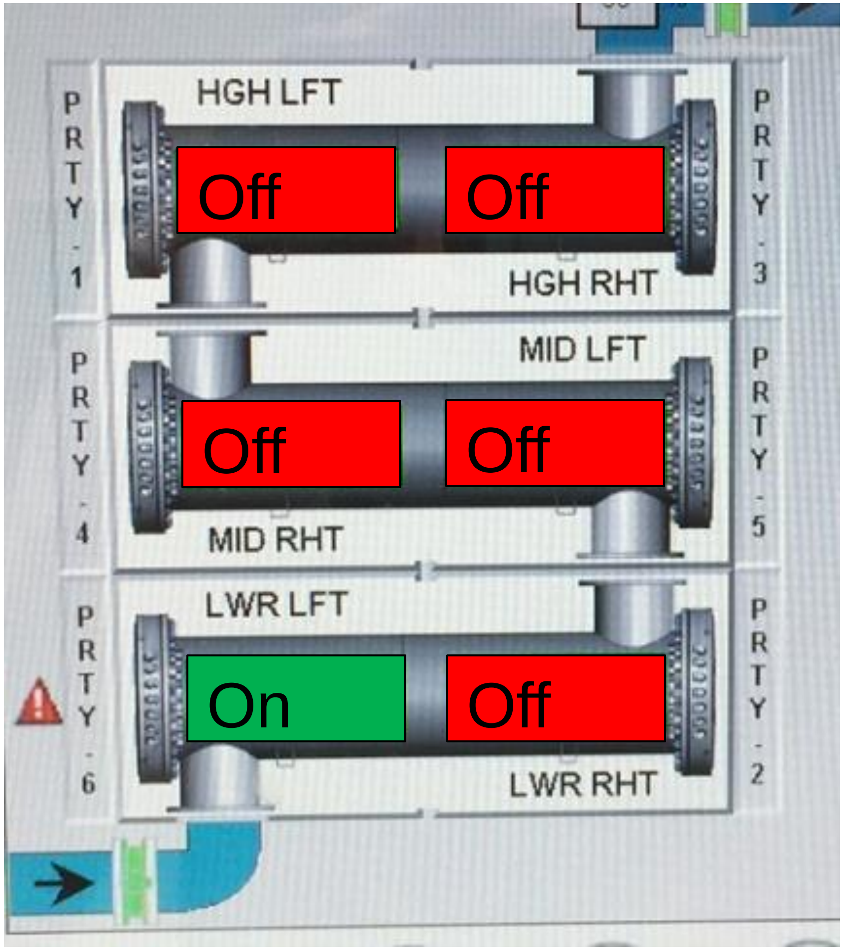
CASE STUDY #2 – ORANGE COUNTY DISINFECTION

- To meet 6-log microbial inactivation (max allowed for a single step)
- Testing demonstrated >5-log virus (MS2) reduction in one reactor zone
- Operating minimum of 4 reactors zones of 6 delivers 6-log



Validation Condition

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CASE STUDY #2 – ORANGE COUNTY DISINFECTION

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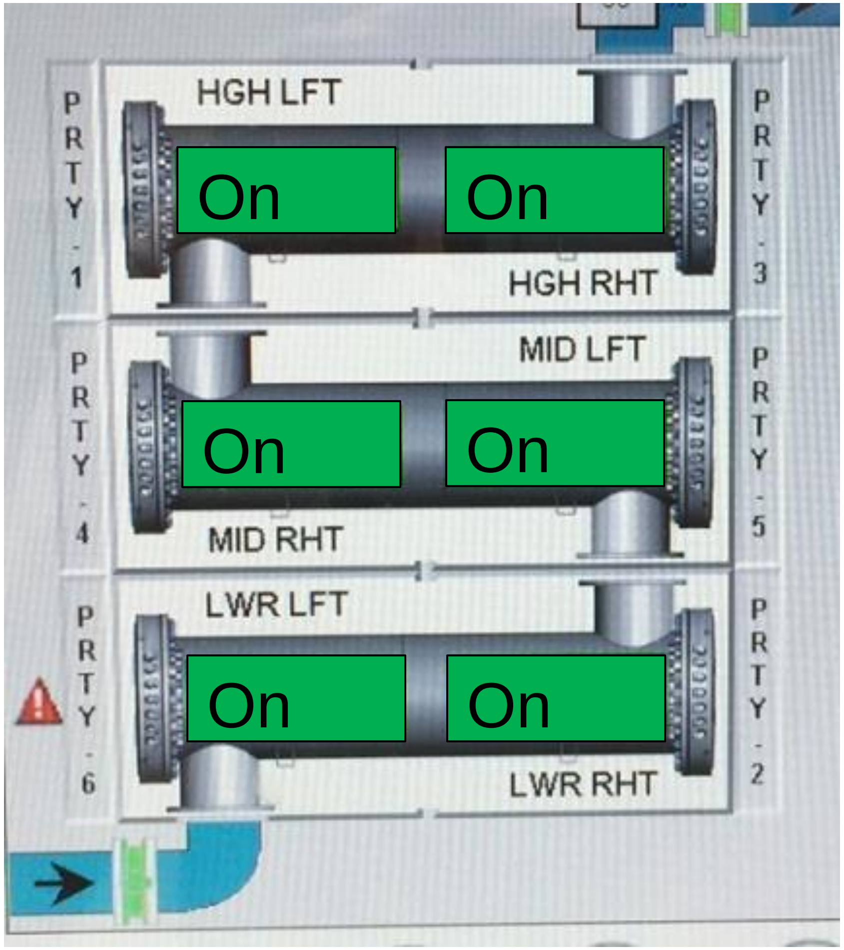
- Testing demonstrated >5-log MS2 reduction in one reactor zone
- Operating minimum of 4 reactors zones of 6 delivers 6-log
- Critical control point: Minimum EEO, which is a dynamically-calculated as a function of UVT/flow rate
- NWRI dose of >100 mJ/cm^2



Operating Condition

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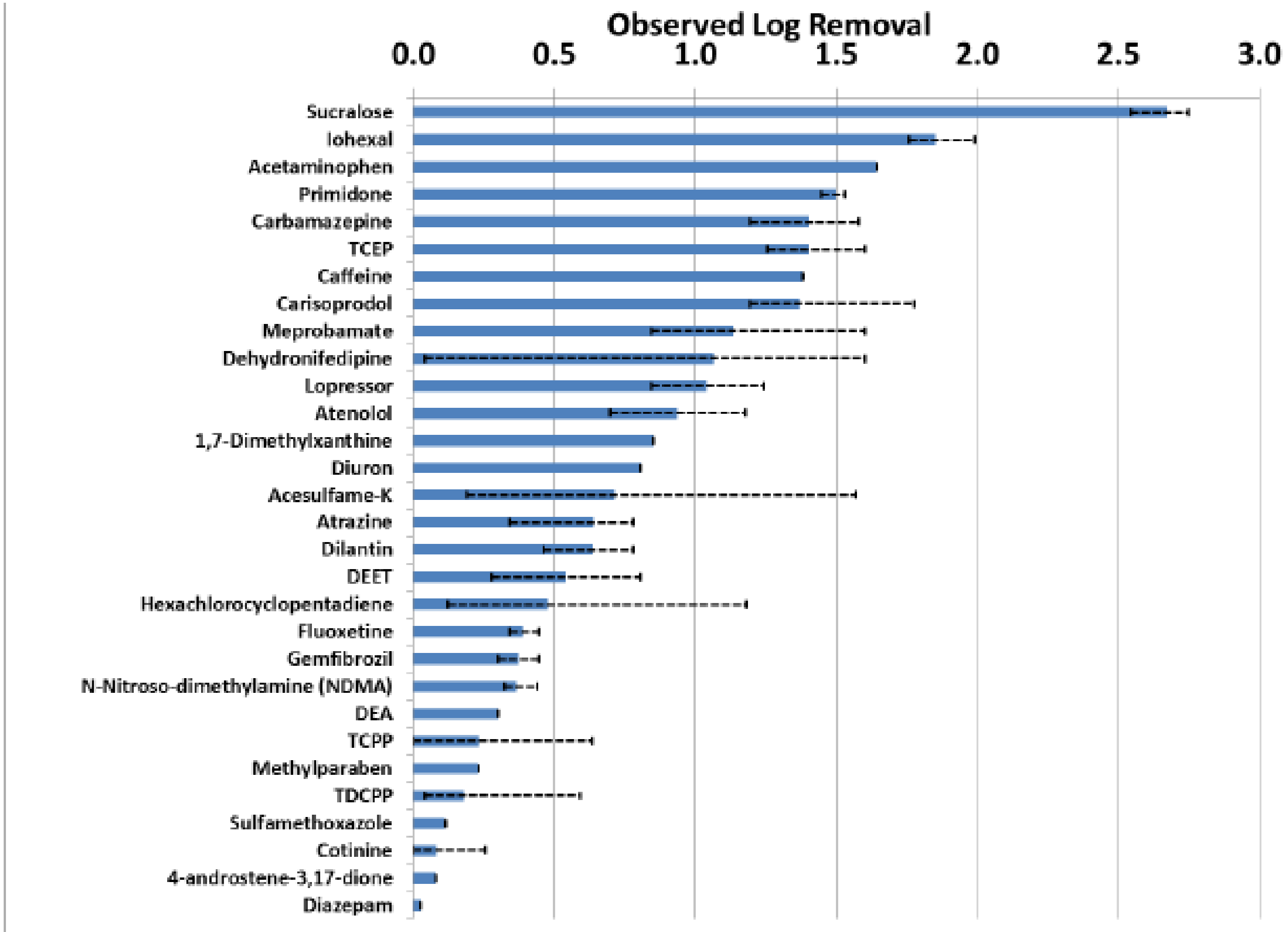
CONTAMINANT TREATMENT

CASE STUDY #3: CLEARWATER FLORIDA POTABLE REUSE

- FAT (UF/RO/UV) for contaminant treatment and disinfection
- Recharge to Floridan Aquifer
- 3 MGD
- Clearwater pilot tested FAT for one year
- The treatment train consistently purified water to all drinking water standards and State treatment standards

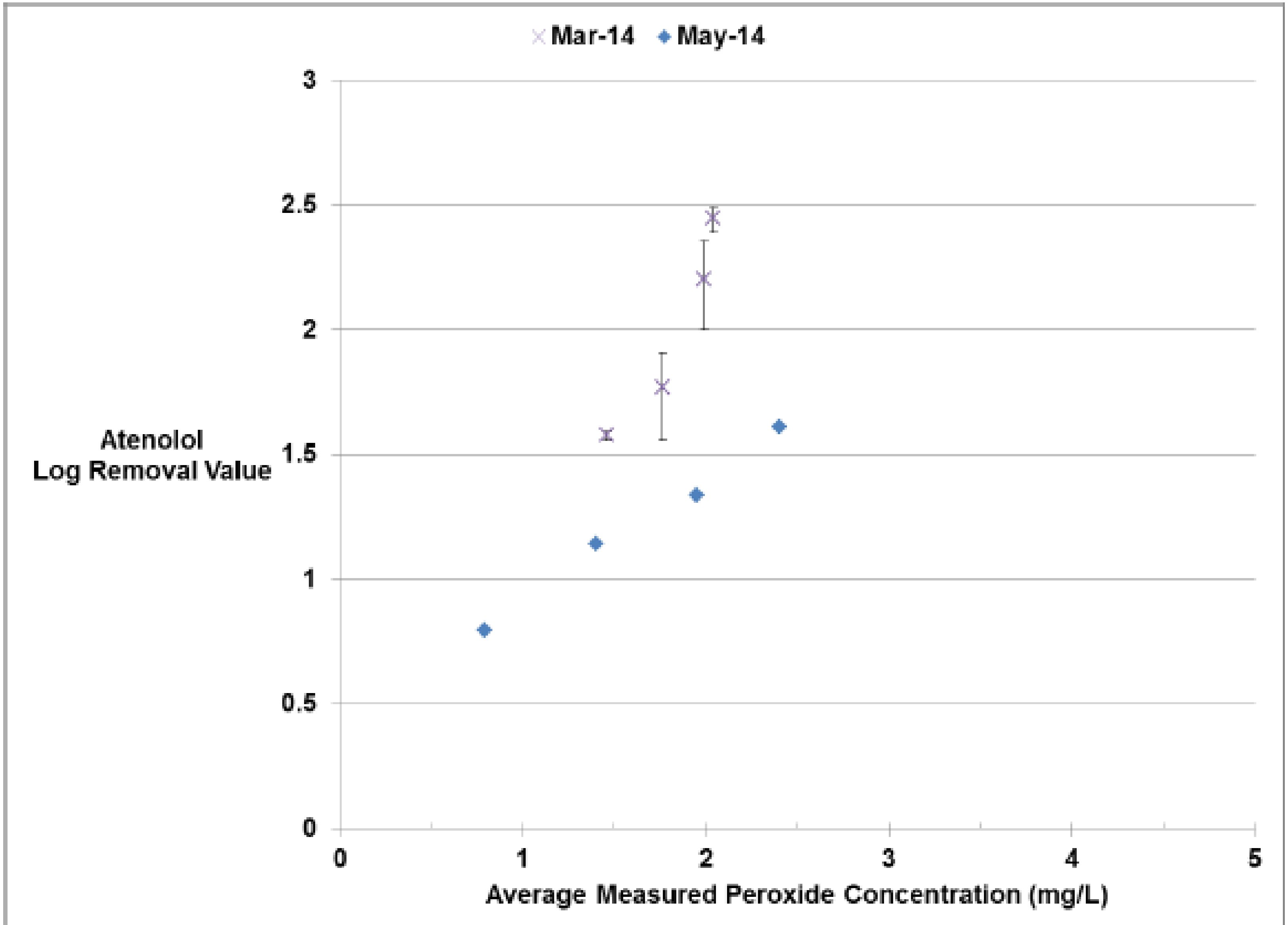
OBSERVED LOG REMOVAL – CLEARWATER PILOT



Bars show average, min, and max LRV of five sampling events

Courtesy David MacNevin, Tetra Tech

FOLLOW-UP TESTING ON ATENOLOL



Courtesy David MacNevin, Tetra Tech

UV-CHLORINE: A BETTER ALTERNATIVE?

Understanding UV-chlorine requires understanding:

- Free & combined chlorine speciation as a function of pH & retention time following hypo injection
- Breakpoint reactions: HOCl + NH_2Cl, etc.
- Degradation of chlorine as it passes through the UV system
- pH effects
- Photochemistry of chlorine species (HOCl, OCl^-, NH_2Cl, $NHCl_2$, …)
- Reactivity of radical species (Cl• and •OH) toward water micropollutants and chlorine species

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AQUEOUS CHLORINE SPECIATION AS A FUNCTION OF PH

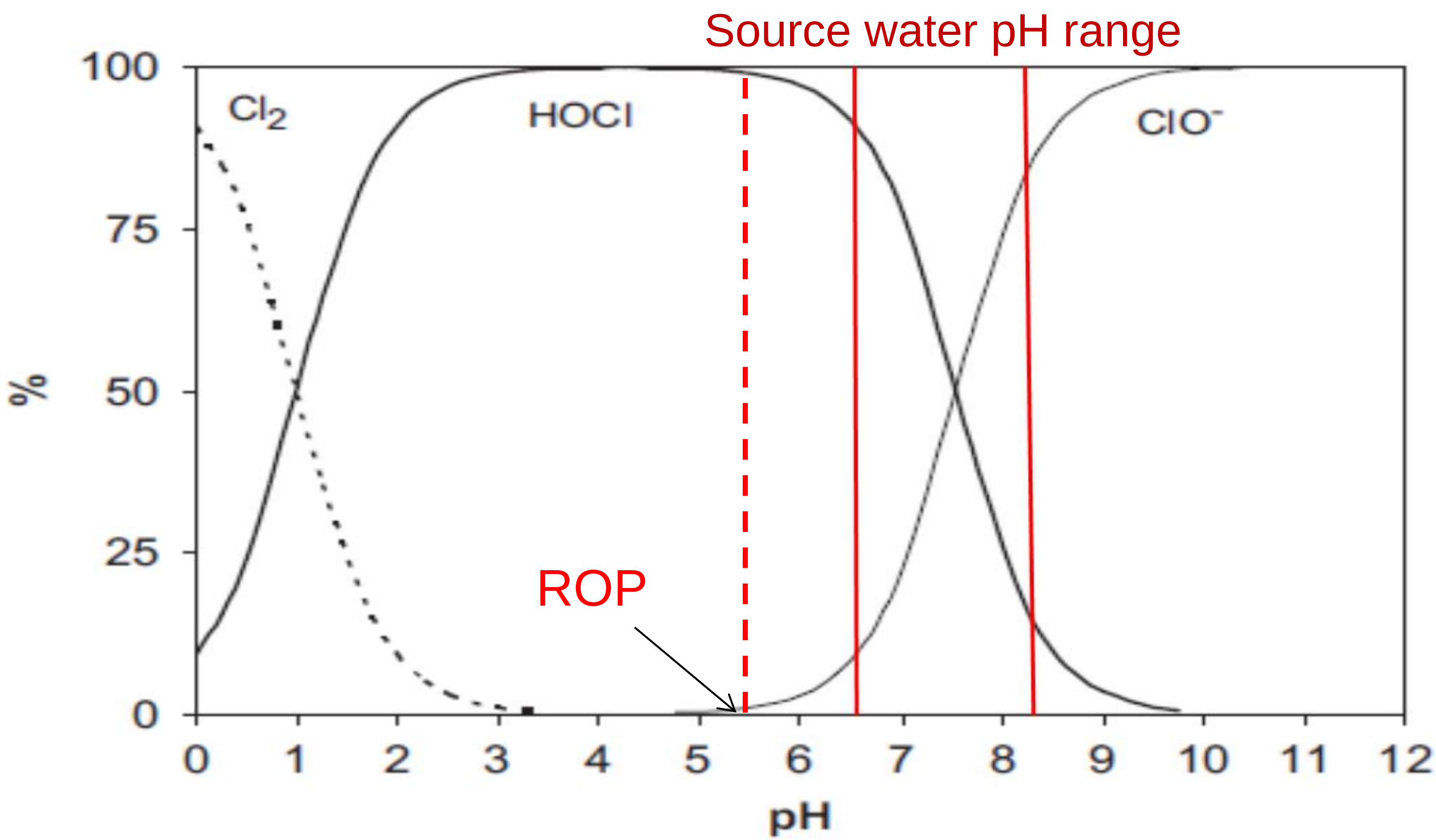

Fig. 1 – Relative distribution of main aqueous chlorine species as a function of pH at 25 °C and for a chloride concentration of 5×10^{-3} M (177.5 mg L^{-1}).

From Deborde and von Gunten, *Wat. Res.* 2008.

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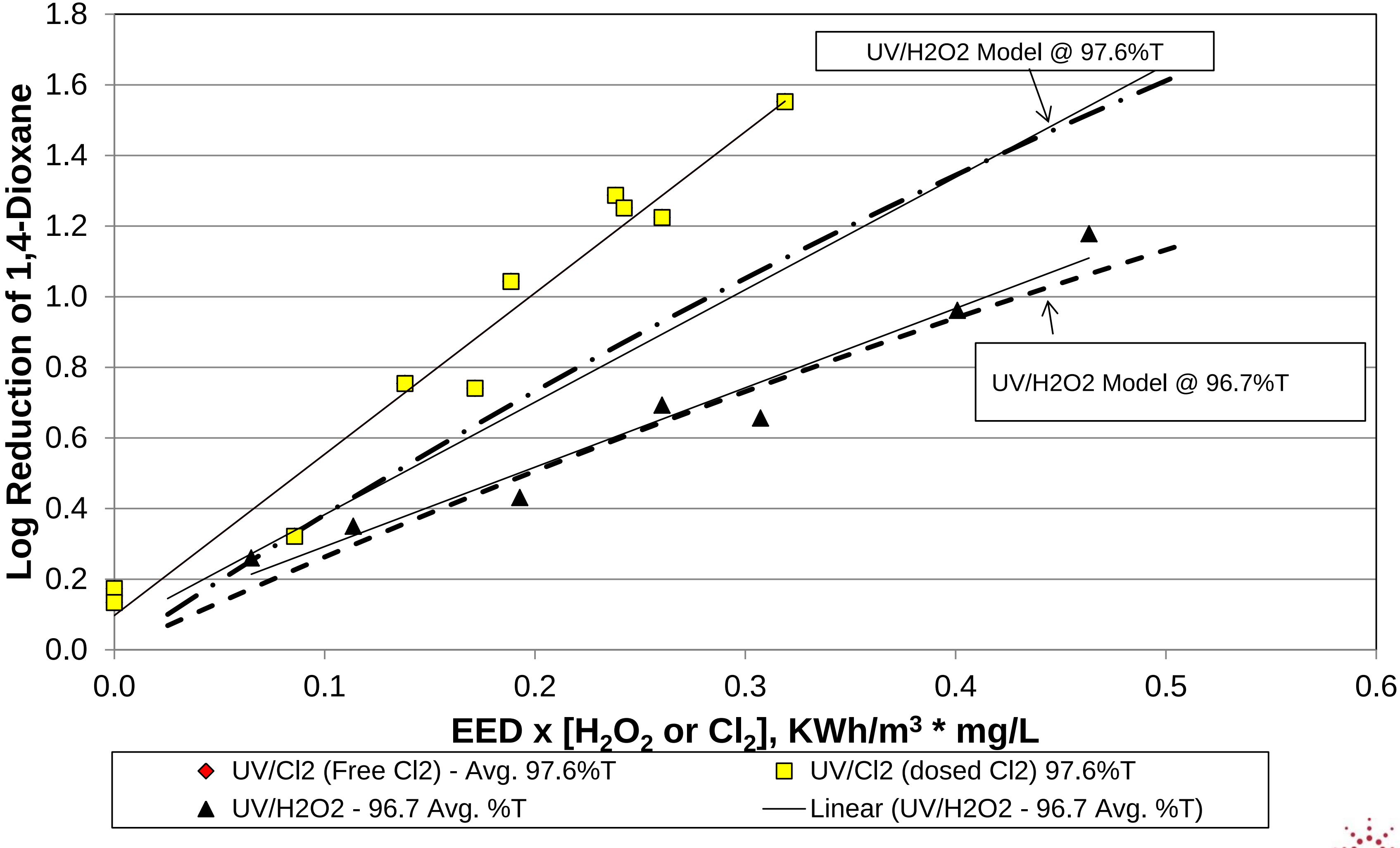
CASE STUDY #4 – FULL SCALE TESTING AT WRD LEO VANDER LANS UV/H_2O_2 & UV/CL_2 AOP



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ACKNOWLEDGEMENTS

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Thank You

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