Simultaneous Compliance for Hard Waters: Softening Isn't Only About Hardness Removal

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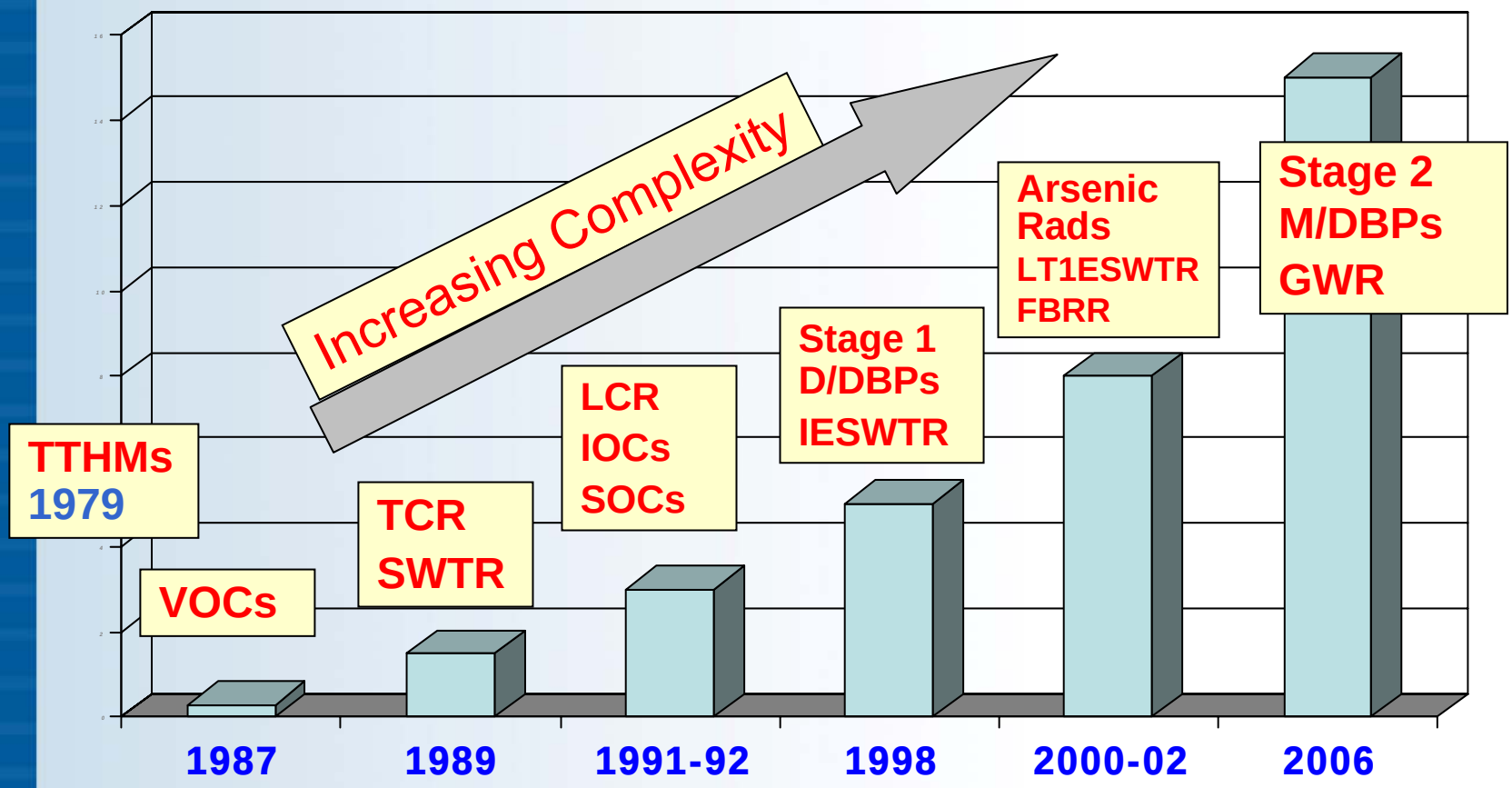
Simultaneous Compliance Complexity has Increased Significantly in 20 Years



Many "secondary water quality impacts" are also related to SDWA regulatory compliance

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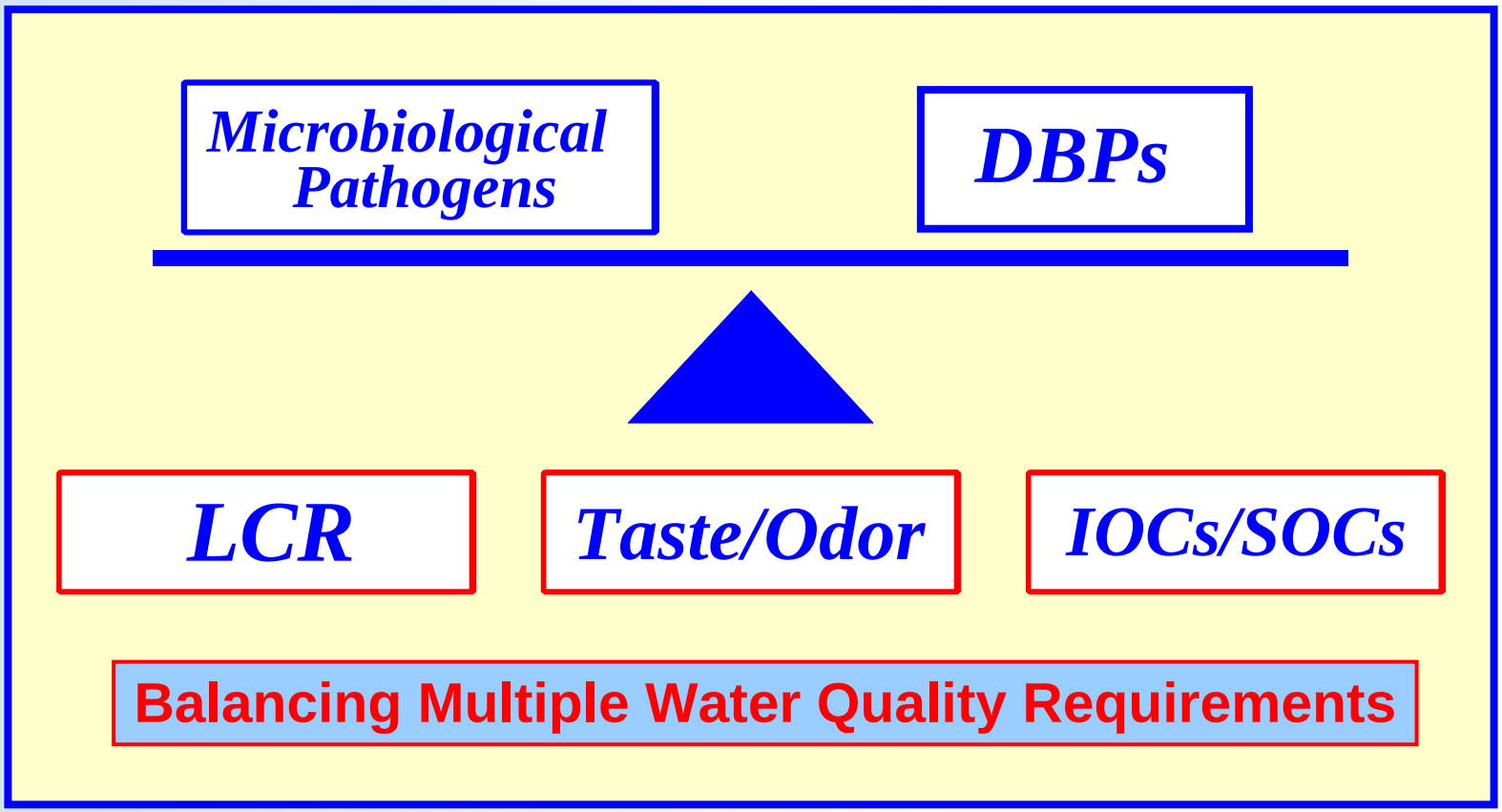
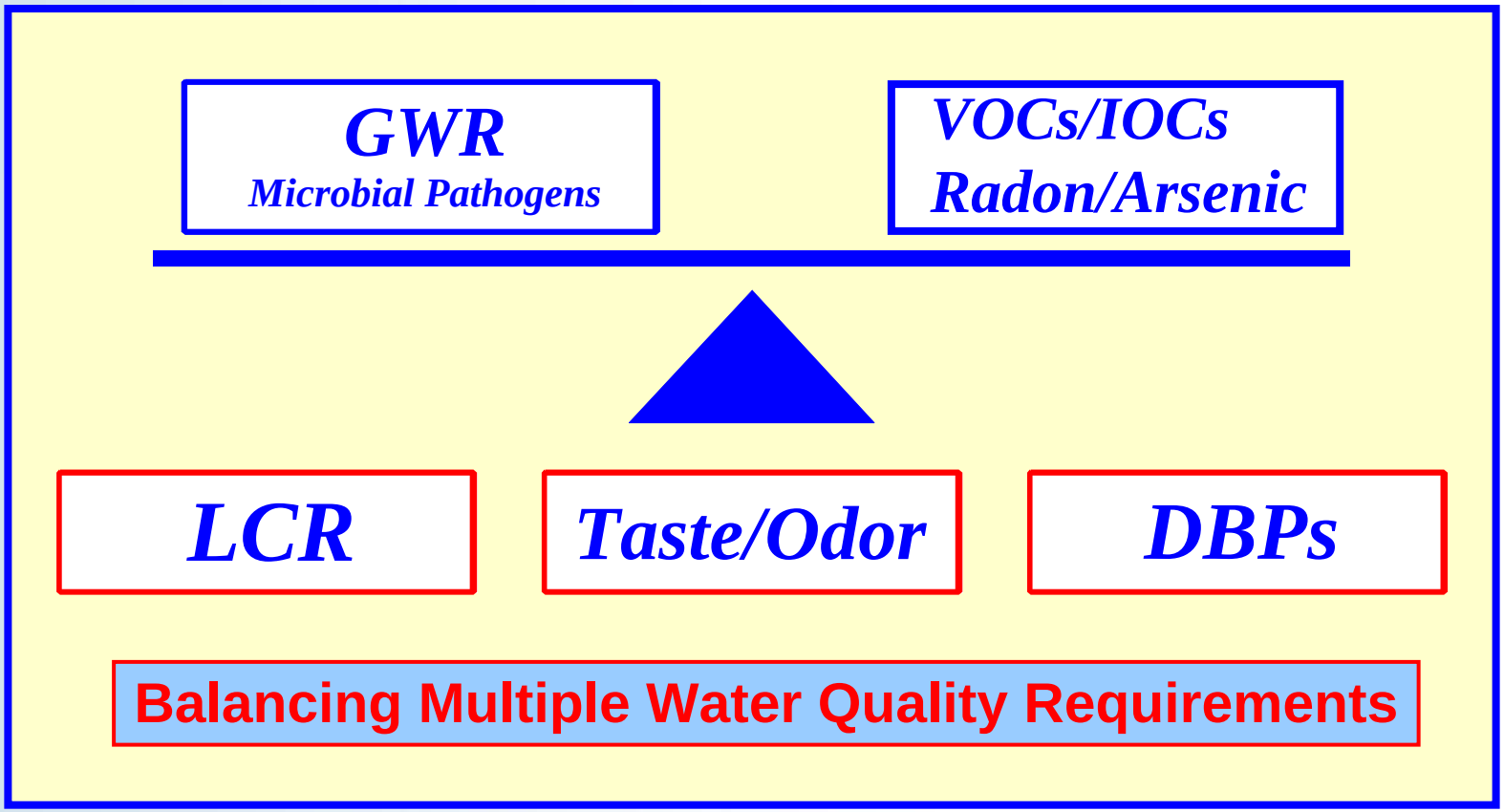
PWS are Increasingly Required to Balance Competing Regulatory Water Quality Requirements



Ground Water Systems also Required to Balance Competing Water Quality Requirements

… just balancing different pins



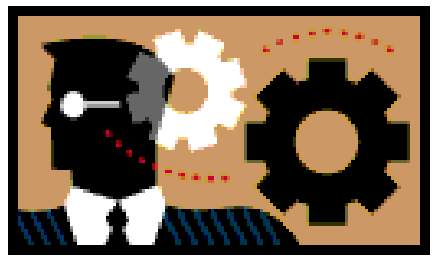
PWS Remain Under Pressure to Meet Secondary Water Quality Goals

- Hardness
- Taste & odor
- Scale stability
- “Dirty” water
- Fe/Mn
- Other Secondary MCLs

Utilities and Primacy Agencies Need to Anticipate Softening Interactions/Challenges

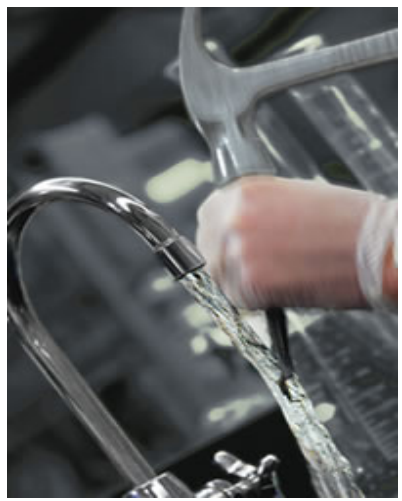
- Direct SDWA-driven Rule conflicts
- Treatment process interactions/impacts
  - Coagulation/Softening
  - Primary/Secondary Disinfection
  - Filtration performance
  - Carbonate stability
  - Residuals

- Distribution system impacts
  - Microbial/regrowth
  - Chemistry/Corrosion/Pipe-scale
  - Secondary/Aesthetics/Operations



Review: What is Hardness?

- Hardness caused by divalent metal ions
  - [Ca+2] & [Mg+2]
- Two types of hardness
  - Carbonate and Non-carbonate hardness
- Carbonate Hardness = Ca and Mg with either bicarbonate (HCO_3^{-1}) or carbonate (CO_3^{-2}) ion
  - Ca $(HCO_3)_2$ -- $CaCO_3$
  - Mg $(HCO_3)_2$ -- $MgCO_3$
- Carbonate Hardness ≈ Alkalinity



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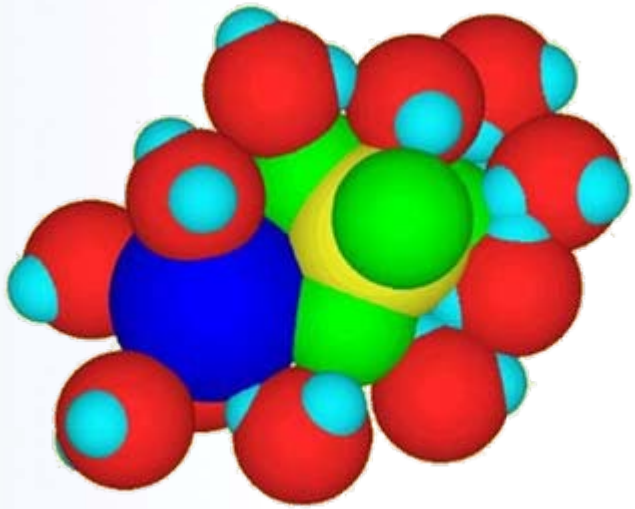
What is Hardness?

- Non-Carbonate Hardness Ca^{+2} and Mg^{+2} ions combined with anions other than HCO_3 or CO_3
  - $CaCl_2$
  - $CaSO_4$
  - $MgCl_2$
  - $MgSO_4$



Hydrated Calcium Sulfate Ion Pair

What is Hardness?

- Total Hardness is:
  - [Ca] + [Mg]
  - Carbonate Hardness plus Non-Carbonate Hardness
  - Total Hardness expressed in mg/l $CaCO_3$ units

MW=40
Ca (as Ca)
mg/l Ca

→

MW=100
Ca (as $CaCO_3$)
mg/l $CaCO_3$

mg/l $CaCO_3$= (100/40) x mg/l Ca

MW=24
Mg (as Mg)
mg/l Mg

→

MW=100
Mg (as $CaCO_3$)
mg/l $CaCO_3$

mg/l CaCO3= (100/24) x mg/l Mg

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Problems Caused by Hard Water

- Water Hardness Classifications

HARDNESS LEVEL, AS $CaCO_3$		HARDNESS CLASSIFICATION
Gpg	mg/l	
<4.4	<75	Low
4.5 to 8.8	76 to 150	Moderate
8.9 to 14.7	151 to 250	Hard
>14.8	>250	Very Hard

Note: 1.0 gpg = 17.1 mg/l

- Typically not a health issue
- Distribution system O&M costs
- Aesthetics and customer cost issues
  - Clogged appliances / pipes
  - Increased water heating costs
  - Decreased suds action of soaps / detergents
  - Increased residue on bathtubs / shower tiles

Softening Technologies

- Precipitative Softening
  - Straight lime
  - Lime-Soda Softening
  - Excess lime softening
- Membrane Softening (nanofiltration)
  - Removes all particulates
  - Removes larger dissolved inorganic & organic compounds
- Ion Exchange
  - Seldom used only for hardness removal
  - Effective for As, Fe/Mn, rads, perchlorate

Softening – Basic WQ Impacts

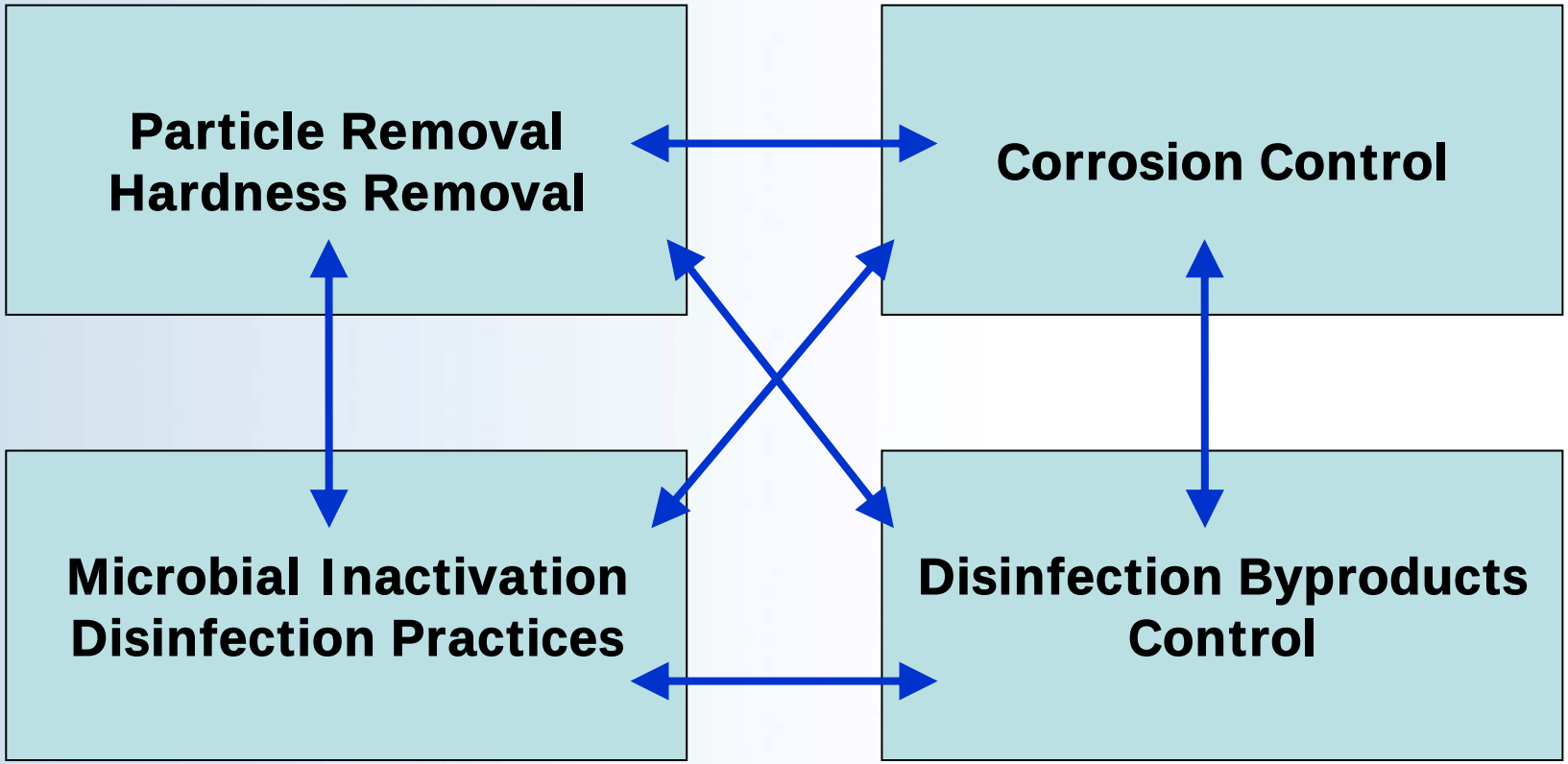
All softened waters not equal!

- Lime or Membrane Softening
  - Removes/lowers alkalinity
  - Removes/lowers dissolved solids
- Ion Exchange Softening
  - Exchanges Na^{+} for Ca^{++} and Mg^{++}
  - Does not remove/lower alkalinity
  - Does not remove/lower dissolved solids

Simultaneous Compliance Challenges and Treatment Process Interactions are Likewise Unequal

Simultaneous Compliance Interactions

(Technology; Challenges; Conflicts)



Softening Practices Have a Profound Impact on Simultaneous Compliance Challenges

Precipitative Softening

- Removes bacteria, protozoa
- Removes TOC/DBP precursors (with coagulant), Arsenic
- Removes SOCs
  - particulate-adsorbed
  - some dissolved
- CCT re-optimization
- Cl/SO_4 Ratio shifts
- Can limit disinfection options
- May increase scaling potential
- Stabile water if enough alkalinity
- Required recarbonation or sequestering agent for stabilization
- High residuals production

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Softening Practices Have a Profound Impact on Simultaneous Compliance Challenges

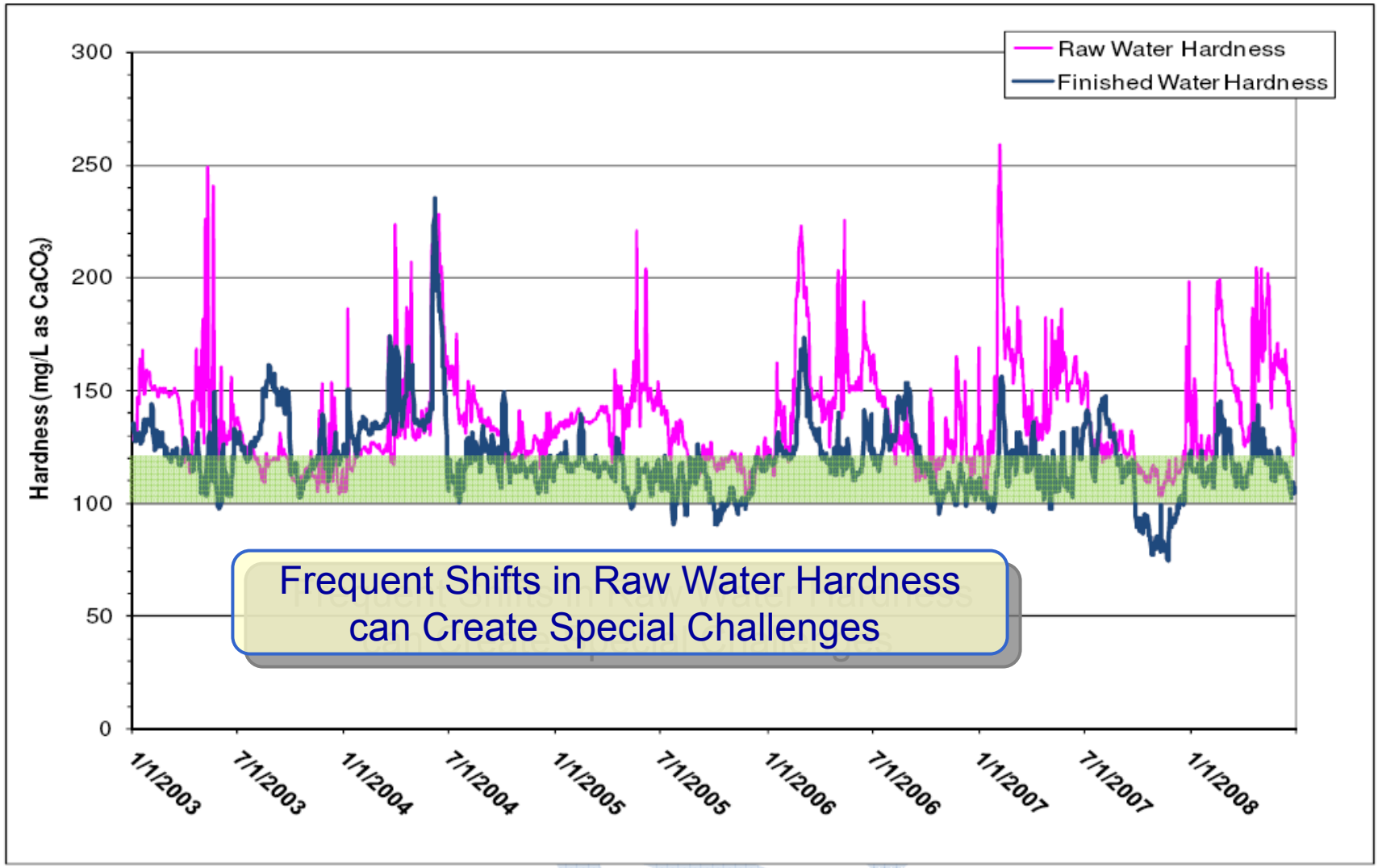
Membrane Softening/Nanofiltration

- Rejects bacteria, viruses, protozoa
- Removes DBP precursors, As, NOM
- Removes many IOCs
- NF/RO membranes fouled by organics/minerals
- Increases corrosivity
- High TDS residuals stream

Other Possible Softening Conflicts/Challenges

- Multiple Sources/Source Blending
  - temperature Shifts
  - CCT chemistry shifts (pH, ORP, alkalinity, PO4)
- Coagulation/Softening Impacts From Raw Water Quality Shifts
- Finished Water Aesthetics; Regrowth Potential, Scale Stability
- Fe/Mn/Sulfides

Bay City, MI
Straight Lime Softening Example



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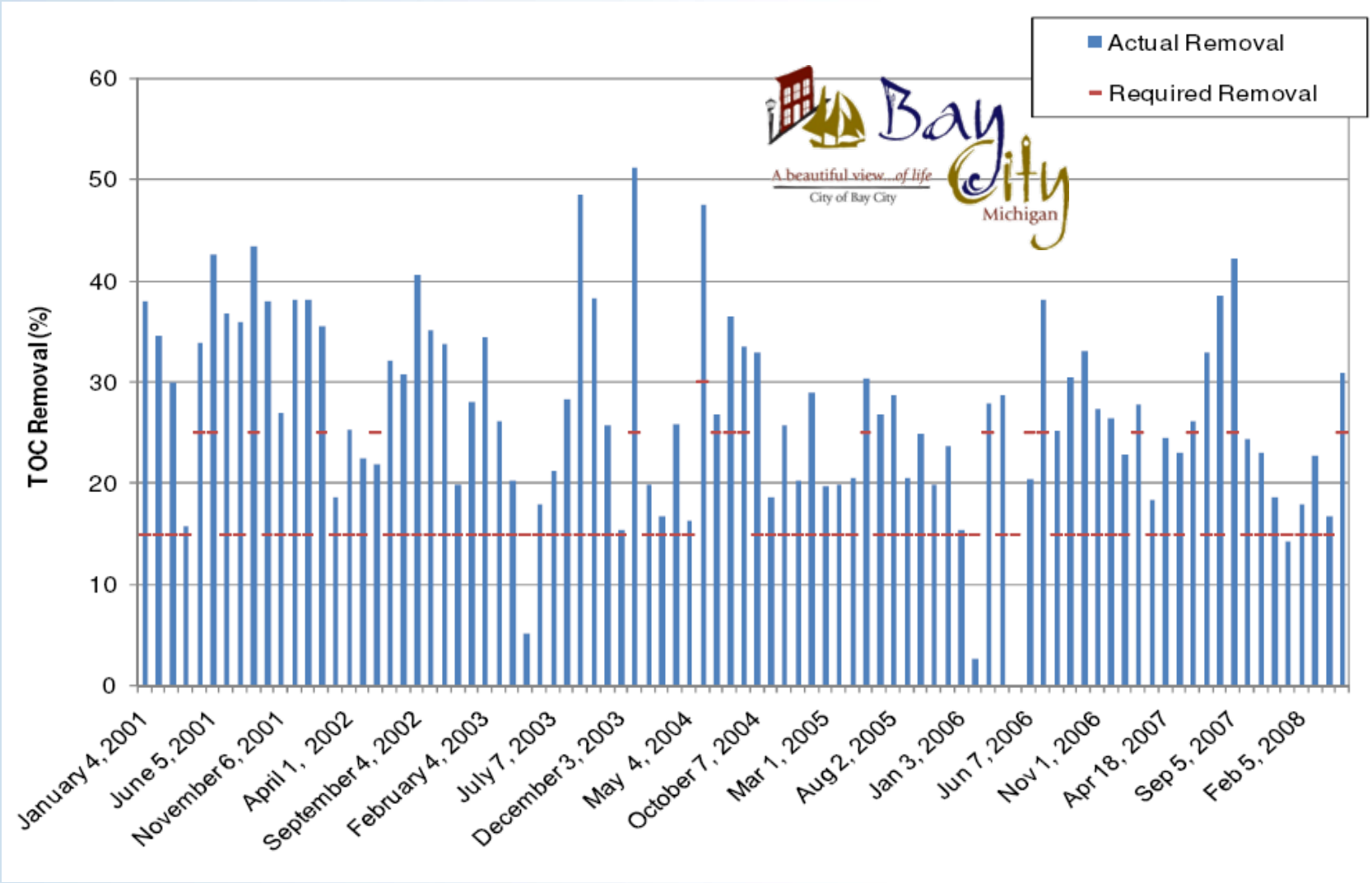
Bay City, Michigan
TOC Removal by Straight Lime Softening



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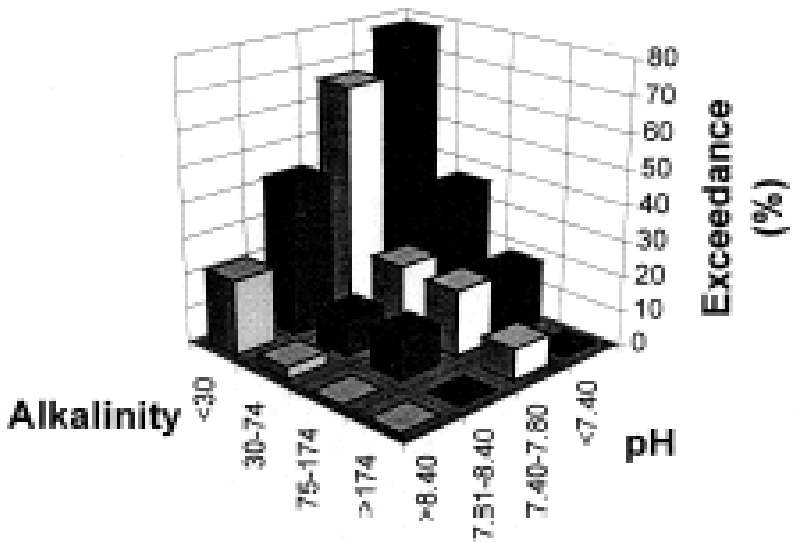
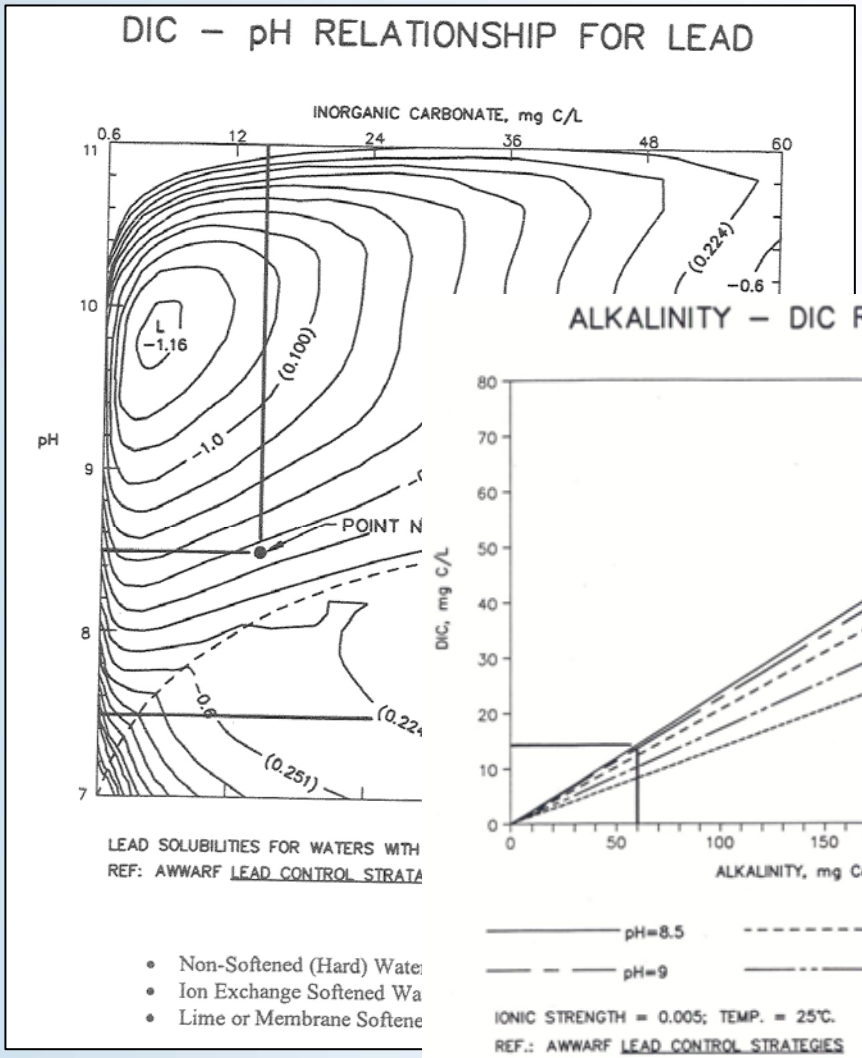
LCR Corrosion Control Treatment

- Carbonate Passivation
- Carbonate Precipitation
- Passivation using a corrosion inhibitor chemical (PO_4)



LCR Corrosion Control Treatment



LIKE THIS!

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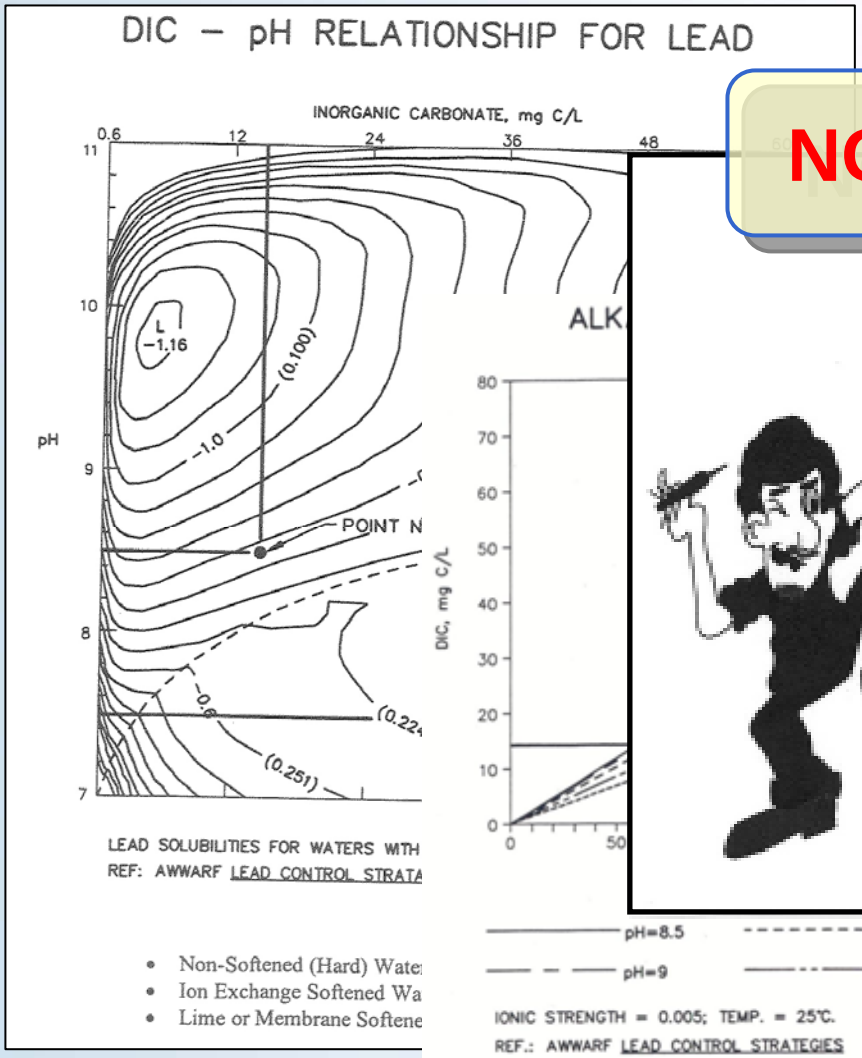
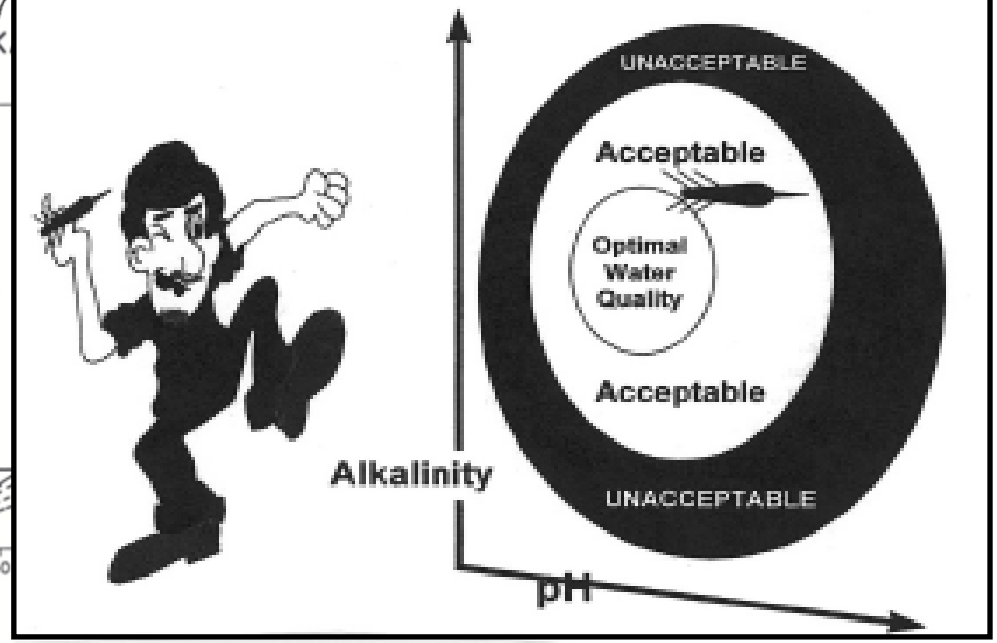
LCR Corrosion Control Treatment



NOT LIKE THIS!



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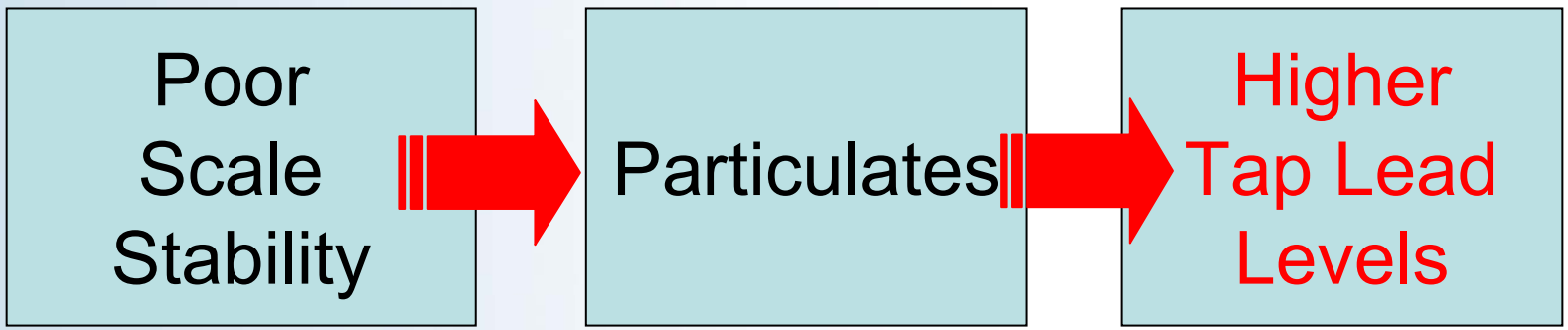
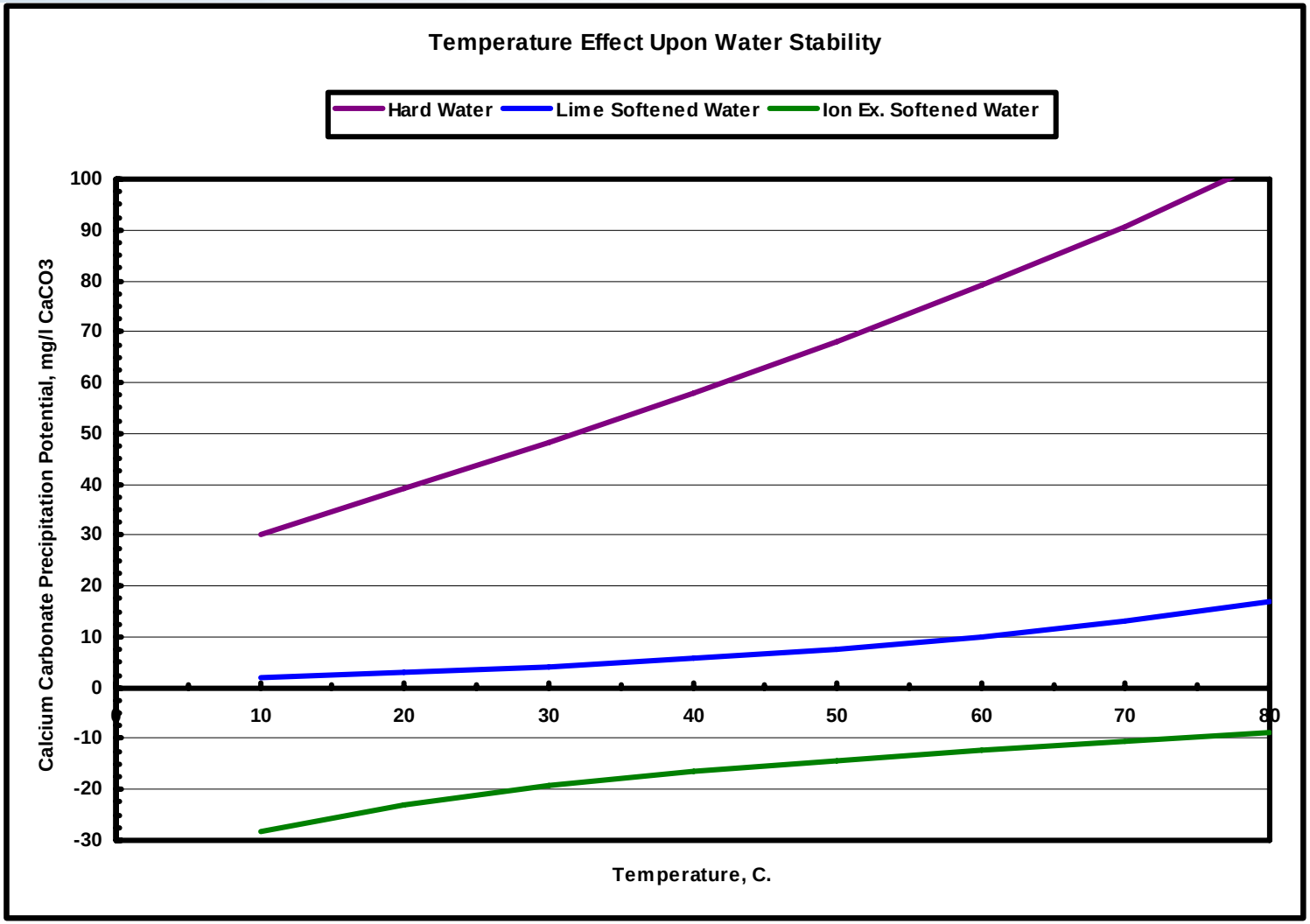
Managing CCT is Frequently about Consistency

- pH, alkalinity, orthophosphate, ORP, NOM, TDS, nitrifying bacteria, etc. etc.
- Solubility (Pb, Cu, Ca, Cd,)
- Scale "Stability"
  - Deposition, permeability and scale hardness



Scaling Potential: Temperature Effect upon Carbonate Stability



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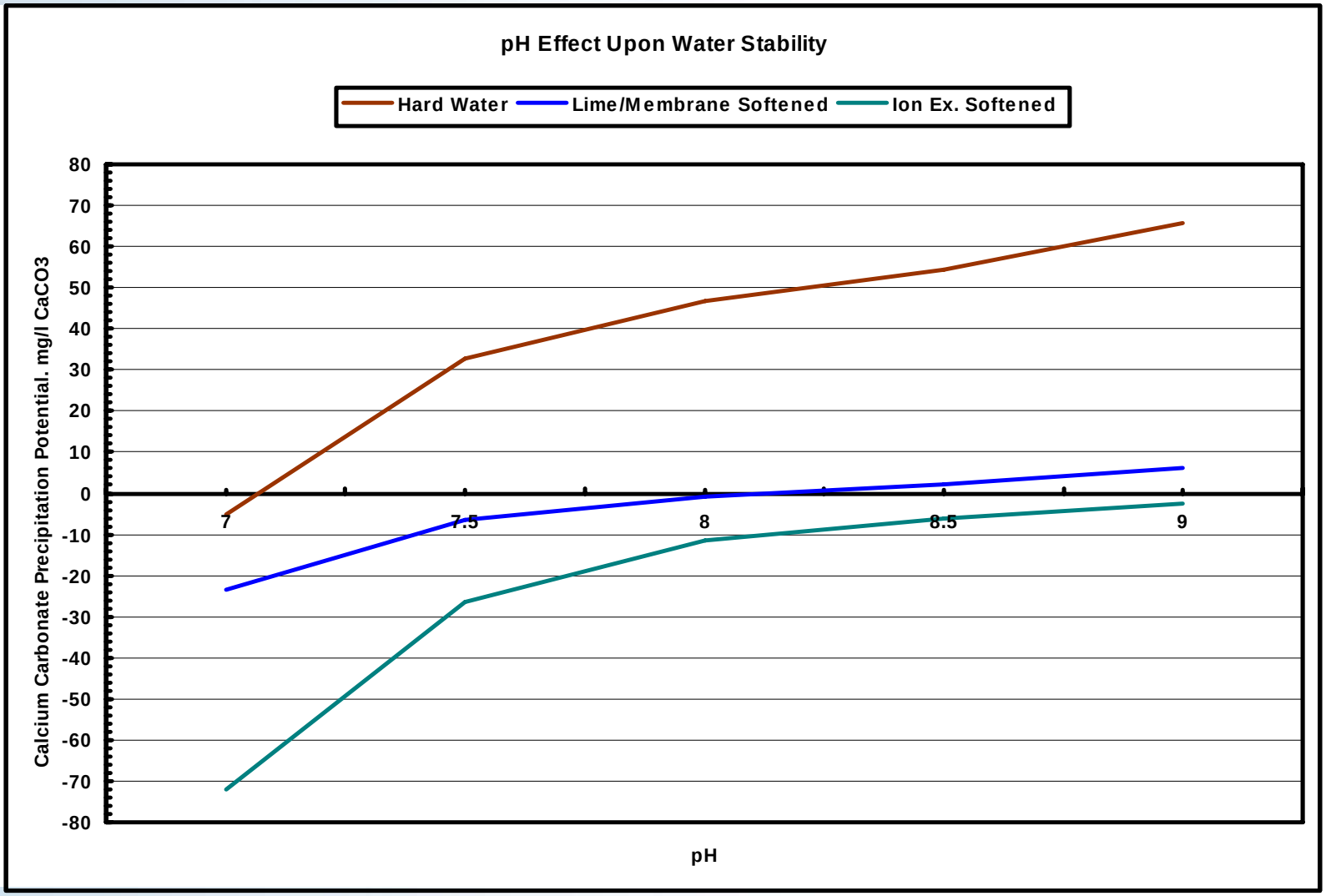
Scaling Potential:
pH Effect on Carbonate Stability



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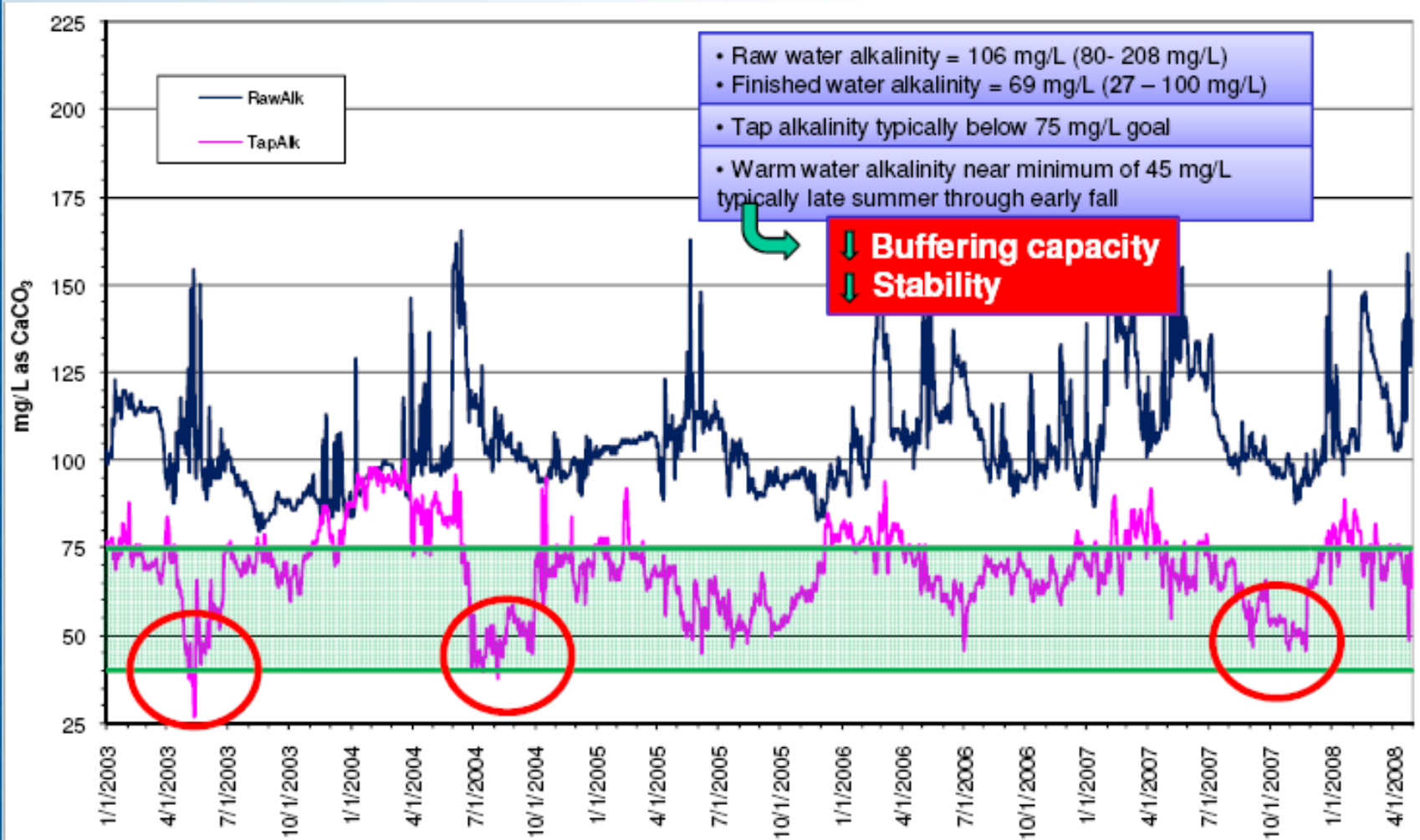
LCR CCT Re-Optimization Possible Conflicts/Challenges

- Maintaining consistent target pH/alkalinity under reduced buffering
- Scale stability/release
- Shift in Cl:SO4 ratio
- Secondary disinfection efficacy
- Bio-regrowth potential
- Red water / “dirty water” / aesthetics

Bay City Carbonate Stability



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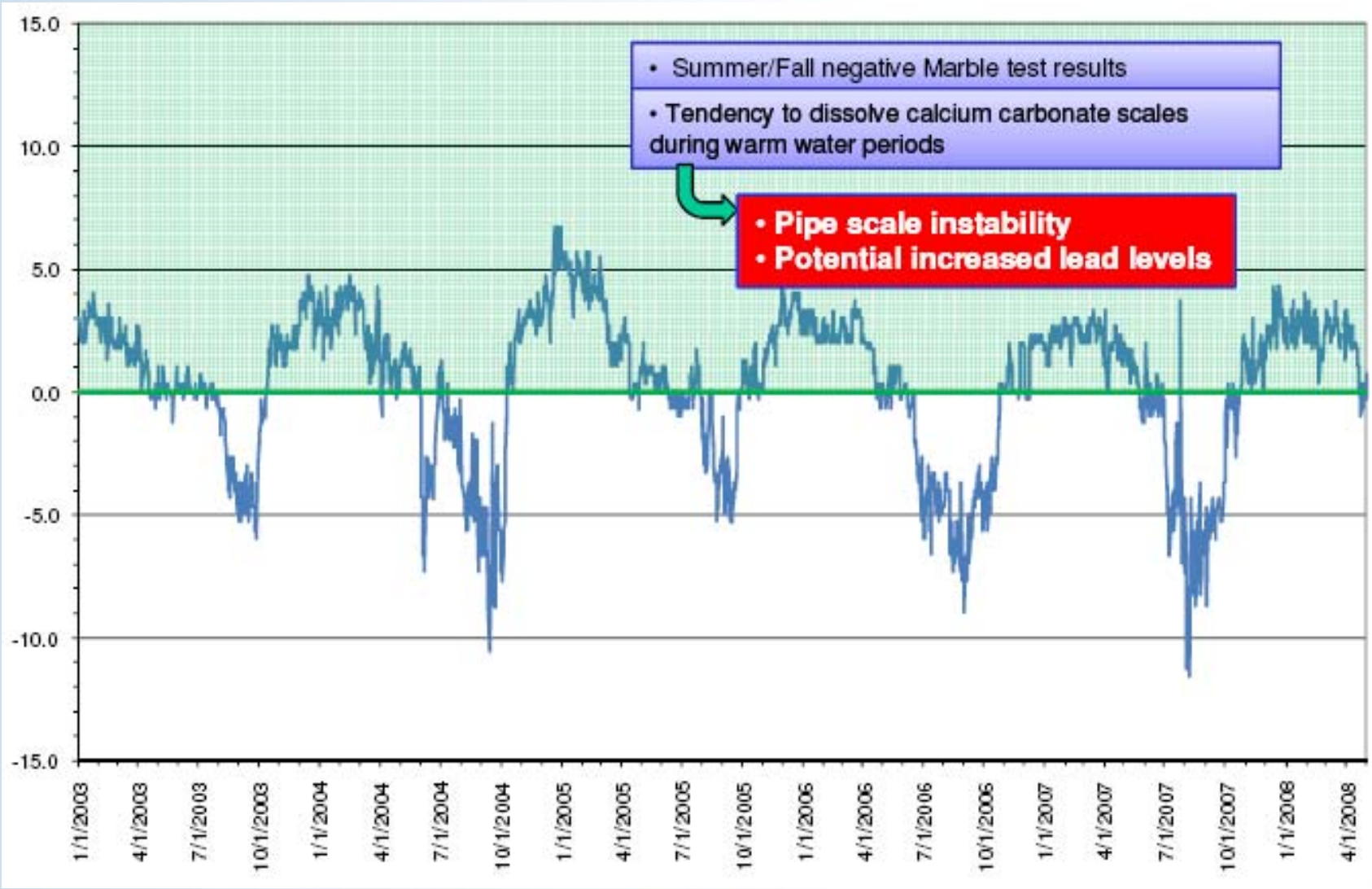
Corrosivity: Marble Test Results



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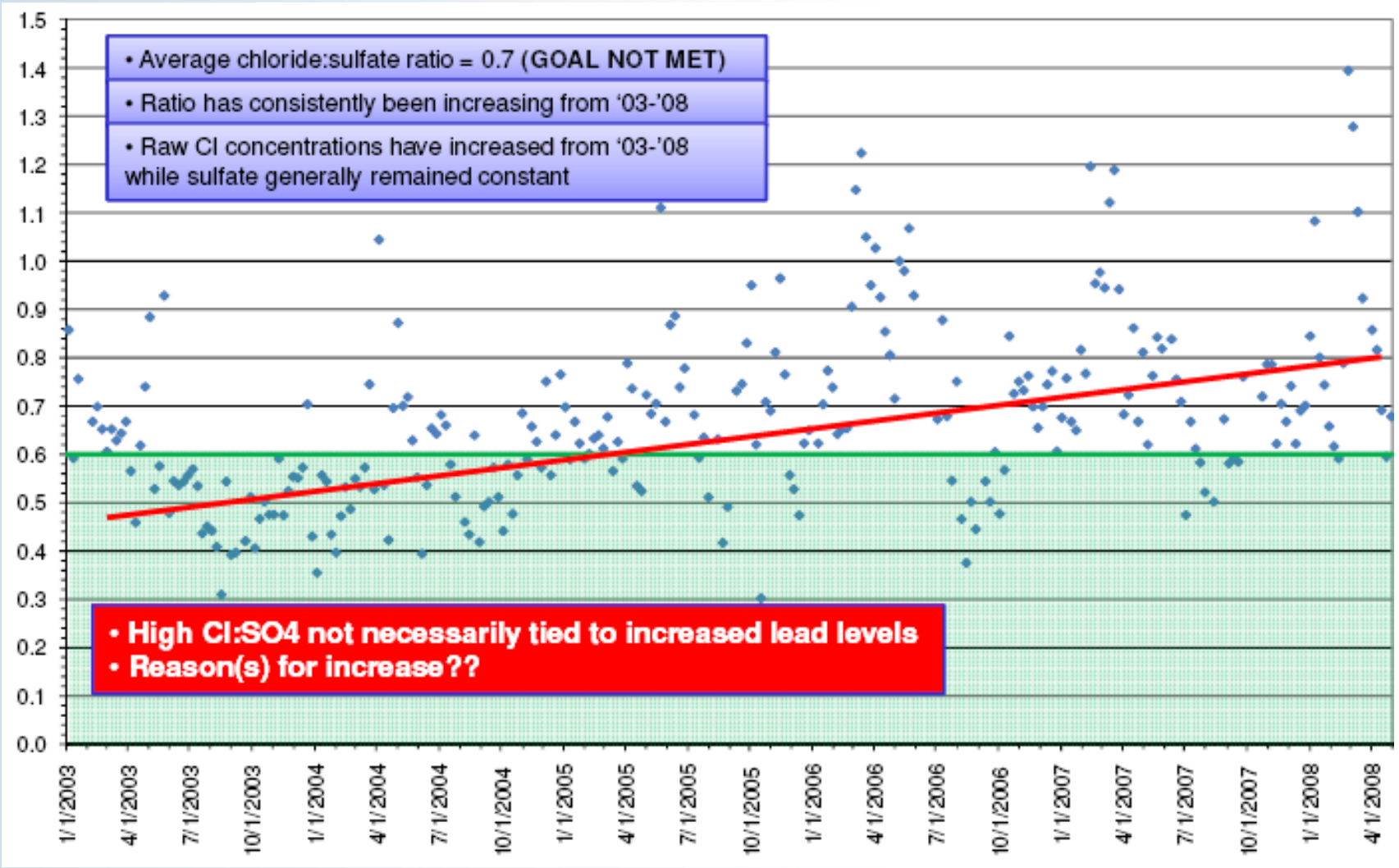
Corrosivity: Chloride/Sulfate Ratio



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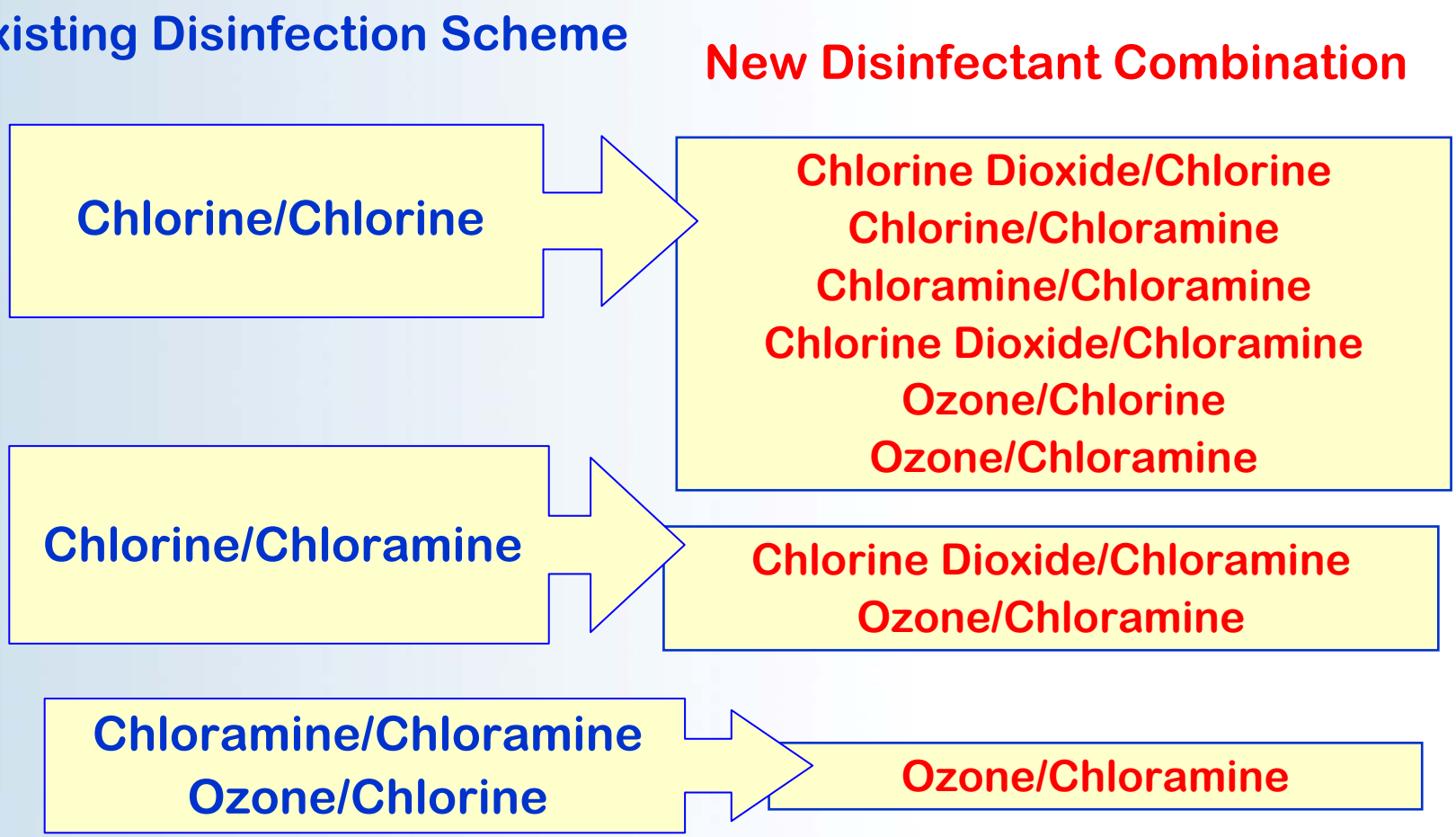
New Disinfectant Combinations each Have Unique Potential for Simultaneous Compliance Challenges



Disinfection scenario listed as “primary/secondary” disinfectant chemicals.

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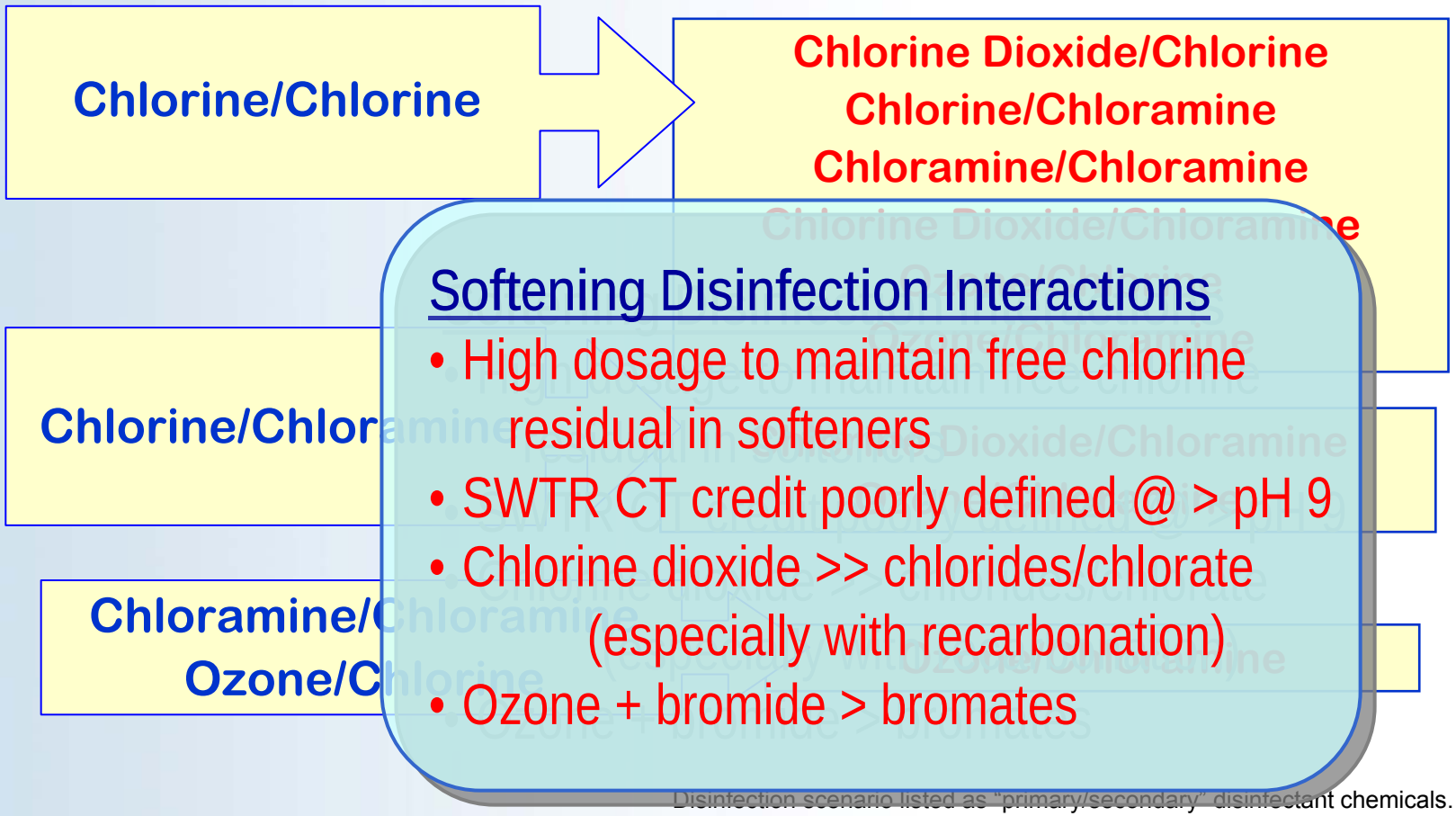
New Disinfectant Combinations each Have Unique Potential for Simultaneous Compliance Challenges



Disinfection scenario listed as "primary/secondary" disinfectant chemicals.

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Arsenic Removal by Lime Softening

As Solids in Residuals Stream!!

Species	pH < 10	pH >10.5
Arsenite (+3) Groundwater	0 – 10%	Up to 75%
Arsenate (+5) Surface Water Groundwater	0 – 10%	60 – 95%

Reference: *Arsenic Removal from Drinking Water by Coagulation/Filtration and Lime Softening Plants*. Fields, et al. USEPA, June 2000.

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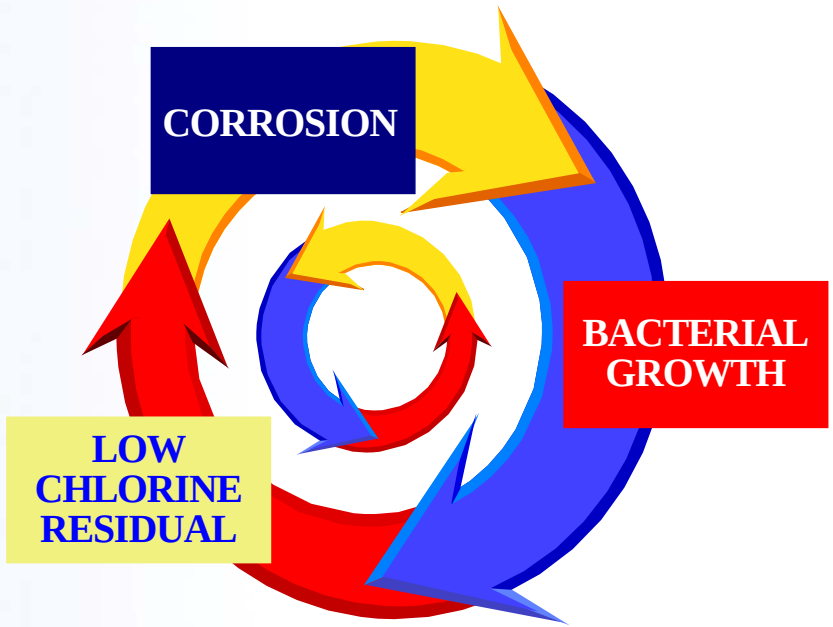
Negative Water Quality Impacts Can Result from a Diverse Array of Changes

- Source Water
  - New Source
  - Blending of sources
- Treatment
  - Unit process modifications/additions
  - Oxidants/disinfectants
  - Shifts in ORP, dose
  - O_3, chlorine dioxide, or UV
  - Enhanced/modified Softening
  - Modified CCT
- Distribution System
  - Conversion to chloramines
  - Switch from Cl_2 gas to NaOCl
  - Nitrification
  - Nitrification control



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Numerous and Subtle *Secondary Impacts* Increasingly Challenge Water System Operations

Hardness
Taste & Odor
Iron/manganese
"Dirty Water"
Degradation of Filter Performance

Scale Stability & Metals Release
Nutrients and Regrowth Problems
Residuals Issues (As, Rads)
Wastewater treatment conflicts

Blending of source/finished waters
Changes in flow, direction and pressure
Cross connection control
Cleaning and other maintenance activities

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Take Away

Softening ***indeed*** removes hardness, and there are many ways to practice "softening"

- Softening has potential to remove:
  - NOM, TOC, DBP precursors
  - Bacteria, protozoa
  - Viruses (NF)
  - Inorganics (Fe/Mn, Arsenic)
  - VOCs/SOCs

- Softening may also promote consistent WQ
  - CCT Effectiveness
  - Scale stability; avoid bio-regrowth

Take Away

Softening practices also have significant simultaneous compliance interactions

- May constrain primary disinfection options
  - Chlorine
  - ClO2, Ozone
- CCT Impacts
  - pH/Alkalinity/DIC shifts
  - Cl/SO4 Ratio shifts
- Recarbonation or sequestering agent for stabilization
  - Stabile water if pH/alkalinity right
  - If not, may increase scaling potential
- NF/RO membranes easily fouled by organics/minerals
- NF/RO will increases corrosivity
- High residuals production
- High TDS residuals stream

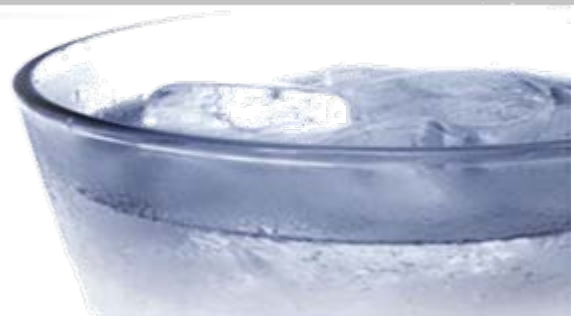
Take Away

- PWS need help to recognize and assess changes which impacts:
  - *source of supply*
  - *water quality performance*
  - *treatment process effectiveness*
  - *distribution system pH, disinfectant concentrations*
  - *corrosion control treatment*
- Utility compliance responses are sometimes constrained by “aesthetics/secondary” issues.
- Many technical resources are available.

Resources

- USEPA, March 2007. Simultaneous Compliance Guide for the Long Term 2 and Stage 2 DBP Rules. EPA 815-R-07-017
- Water Research Foundation, 2009. “Simultaneous Compliance Tool,” Report 3115 (coming soon)
- AWWA, 2005. “Managing Lead and Copper Rule Corrosion Control Practices to Avoid Unintended Consequences”
- USEPA, October 2008. Sanitary Survey Guidance Manual for Ground Water Systems
- USEPA, 1999. Microbial and Disinfection Byproduct Rules Simultaneous Compliance Manual. EPA 815-R-99-015
- WRF, 1998. “Balancing Multiple Water Quality Objectives”

USEPA Webinar Series
Best Practices for Drinking Water Compliance
Office of Ground Water and Drinking Water



2009 Webinar Series:

- Source/Treatment Changes
  - What Primacy Agencies Should Consider
- Simultaneous Compliance Planning Issues for Ground Water PWS
- Simultaneous Compliance Planning Issues for Surface Water PWS
- Water Quality Management in Distribution Systems
  - Simultaneous Compliance and Unintended Consequences

http://www.epa.gov/ogwdw/dwa/pdfs/flyer_simultaneouscompliance_webinar_2009-05-21.pdf

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Q&A

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