



# San Francisco's Chloramine Conversion Experience

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National Museum of the American Indian  
New York City, NY

# Acknowledgements

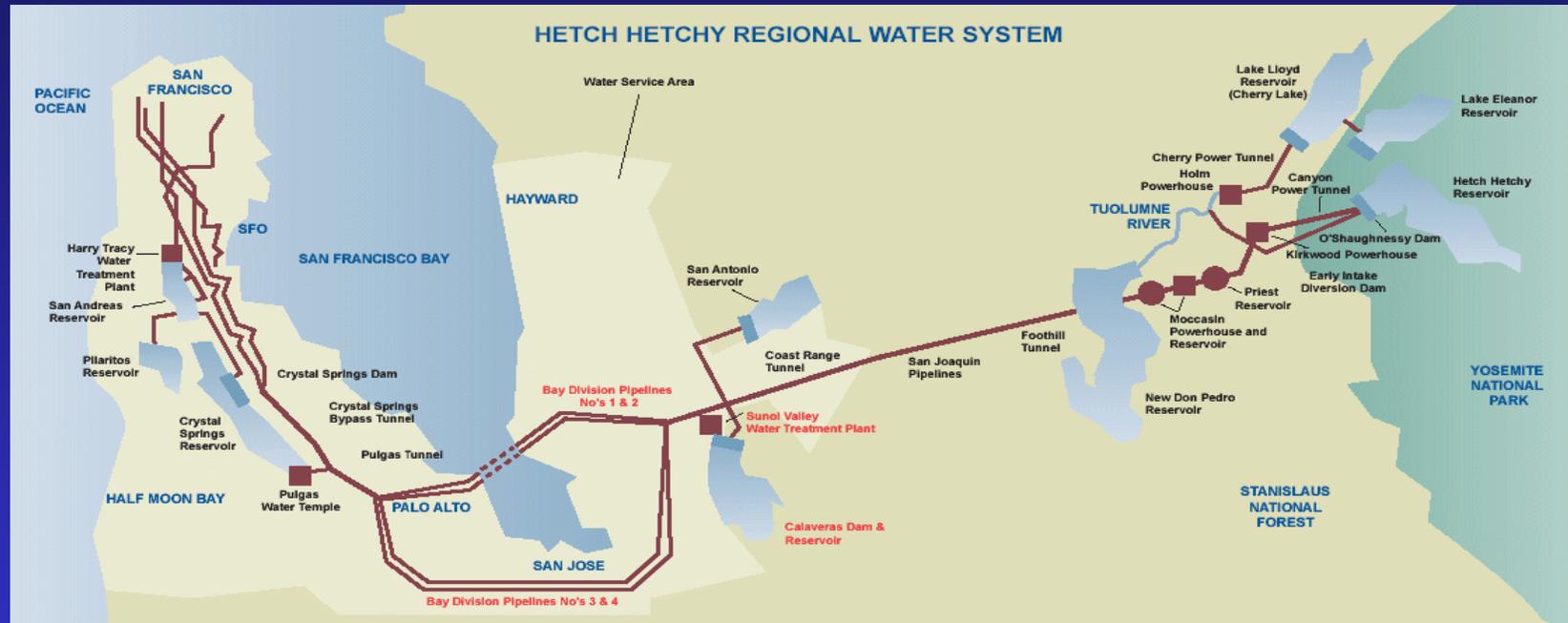
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- **Brendan Flannery, CDC**
- **June Weintraub, SFDPH**
- **Andrzej Wilczak, SFPUC**

# Presentation Outline

- **San Francisco Water System Overview**
- **Chloramine**
- **Conversion Decision**
- **Implementation**
- **Water Quality Results**
- **Post-Conversion Activities**
- **Conclusions**

# **SAN FRANCISCO WATER SYSTEM OVERVIEW**

# Regional Water System



- 2.5 million population served
- 1/3 retail, 2/3 wholesale (28 suburban customers)
- 265 mgd (85% unfiltered, 15% filtered)

# Retail Distribution System

- 80 MGD average demand
- 400 MG storage
  - 9 reservoirs (1 to 175 MG)
  - 7 tanks
- Water age in storage: few days to several weeks
- 1200 miles of mains (900 miles < 12", unlined cast-iron)
- Auxiliary Water Supply System (AWSS)



**CHLORAMINE**

# Chloramine (NH<sub>2</sub>Cl)



- One of two choices to maintain required residual disinfectant (other is Cl<sub>2</sub>)
- Used for over 90 years - since 1914 in Denver
- Currently used 29% of community water systems\*
- Projected use at 55% of surface water systems Post-D/DBP2 (13.5% Pre-D/DBP1 baseline)\*

\* = JAWWA, October 2005 "Have utilities switched to chloramines?" Seidel et. al.

# Chloramine: Benefits

- Lower TTHM and HAA5 formation – better D/DBPR compliance
- More persistent disinfectant – better TCR compliance
- Improved taste and odor
- Improved biofilm control

# Chloramine: Concerns

- Weaker disinfectant/oxidant
- Nitrification
- Implementation complexity
- Potential taste and odor (i.e., dichloramine)
- Degradation of old natural rubber plumbing parts
- More difficult to completely remove (i.e.,  $\text{NH}_3$ ), if required before environmental discharge

# Chloramine: Emerging Issues

- Emerging DBPs: nitrosoamines (i.e., NDMA) and iodoacids – both unique to source water precursors and treatment practices
- Lead and copper corrosion: possible under certain utility-specific conditions
- Customer health complaints: skin and respiratory

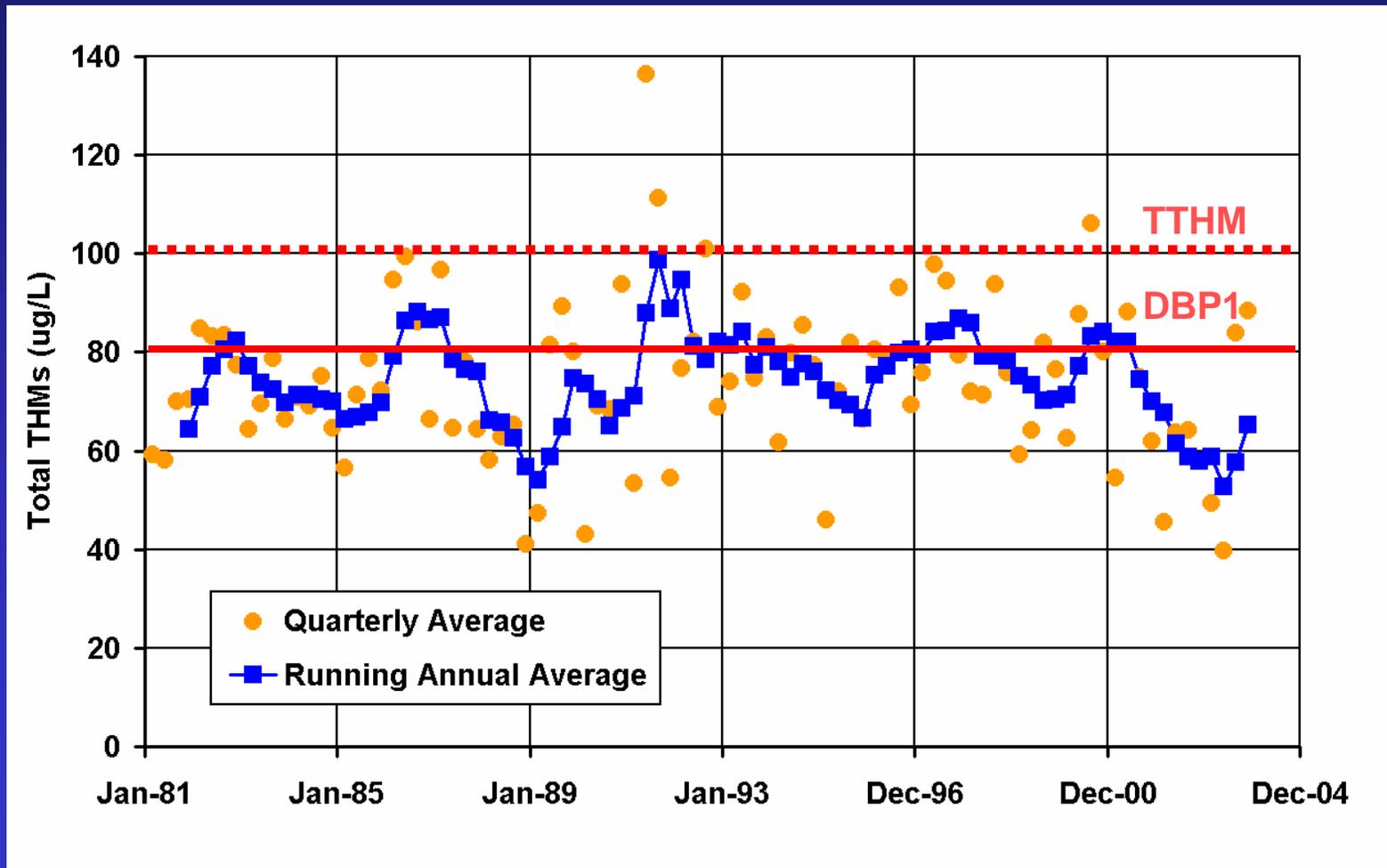
# CONVERSION DECISION

# Conversion Driver

<b>ACTION</b>	<b>YEAR</b>
TTHM Regulation	1979
SDWA Amendments 1986	1986
Water Quality Planning Study	1987 – 1995
M/DBP Reg Neg and ICR	1992 – 1998
Hetch Hetchy Water Treatment Project	1993 – 2004
SDWA Amendment 1996	1996
D/DBP Rule Stage 1 Promulgated	1998

- **Reliable compliance with existing/proposed regulations**

# Historical TTHM Levels



# Chloramine Selected

- **Reliable compliance with new DBP regulations: lower average and peak DBP values**
- **More persistent disinfectant – better TCR compliance**
- **Improved taste and odor**

**IMPLEMENTATION**

# Implementation Timeline

<b>ACTION</b>	<b>YEAR</b>
<b>Hetch Hetchy Water Treatment Project</b>	<b>1993 – 2004</b>
<b>CER</b>	<b>1997 - 1999</b>
<b>PEIR</b>	<b>1999 - 2000</b>
<b>Final Design</b>	<b>2000 - 2001</b>
<b>Construction</b>	<b>2001 - 2003</b>
<b>Facility Start-up</b>	<b>February 2004</b>

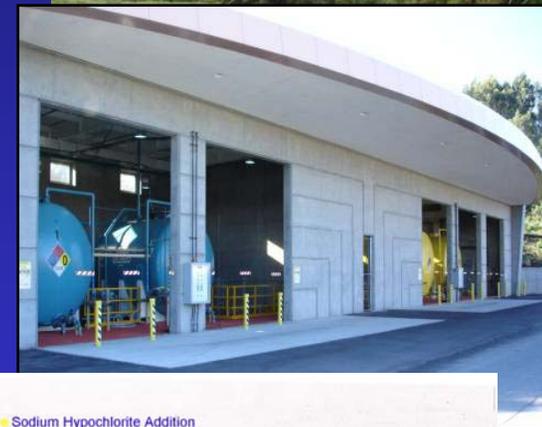
# Implementation Activities

- New treatment facilities
- Distribution system improvements
- Training
  - SFPUC
  - BAWSCA
  - other stakeholders
- Public outreach
- Start-up

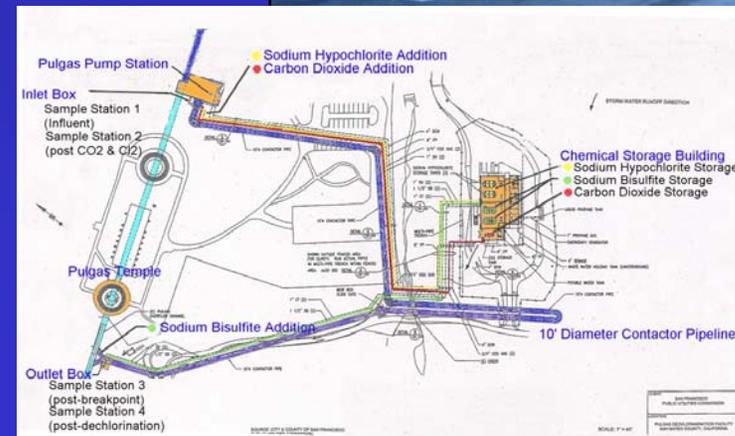


# New treatment facilities

- Sunol and HTWTP Chloramination Facilities (\$22M)

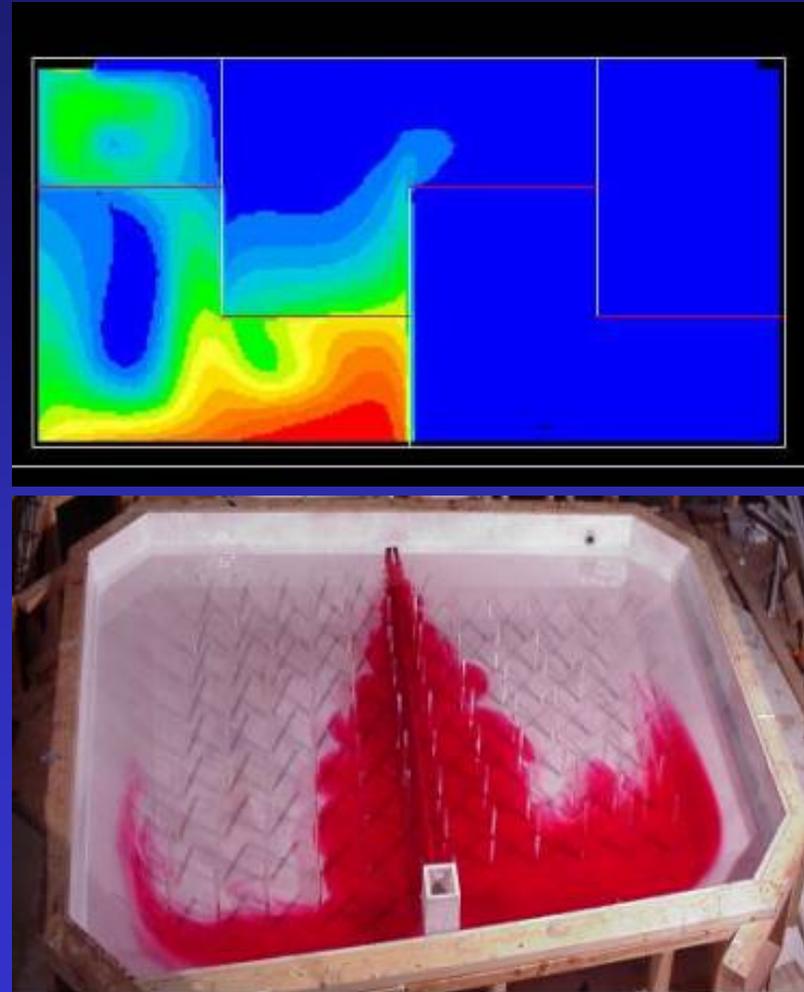


- Pulgas Dechloramination Facility (\$24M)



# Distribution System Improvements

- Unidirectional flushing
- Reservoir cleaning
- Reservoir mixing studies
- Inlet/outlet modifications and new internal mixers
- Additional reservoir monitoring locations



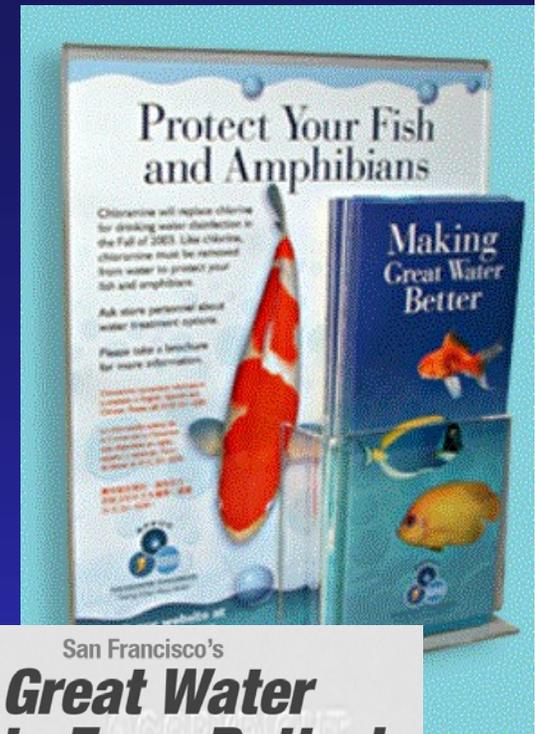
# Training

- Quarterly Technical Workshops (1998 to 2003)
  - BAWSCA, CaDHS
  - SFDPH, SFPUC
- Staff development
  - Internal training
  - O&M Plans
- Consultants plus other experts (utilities and regulatory agency)



# Public Outreach

- Extensive outreach (>\$1M) from 2001 – 2004, peaked before start up
- General public (multilingual)
  - print material
  - web site
  - phone hotline
  - media (briefings and paid ads)
- Sensitive users (dialysis centers, aquariums, high tech businesses...)
  - mailing
  - outreach to interest groups
- BAWSCA agencies lead own effort but generally used SFPUC material



San Francisco's  
**Great Water Gets Even Better!**  
Starting February 2004

We are switching from chlorine to chloramine to help ensure that our drinking water always meets the highest water quality standards.

Fish and amphibian owners and people and businesses with special water needs can contact us for more information at [better.sfwater.org](http://better.sfwater.org) or (415) 351-4200.

 Providing drinking water to over 2.4 million people in San Francisco, the Peninsula, South Bay and East Bay.  
SAN FRANCISCO PUBLIC UTILITIES COMMISSION

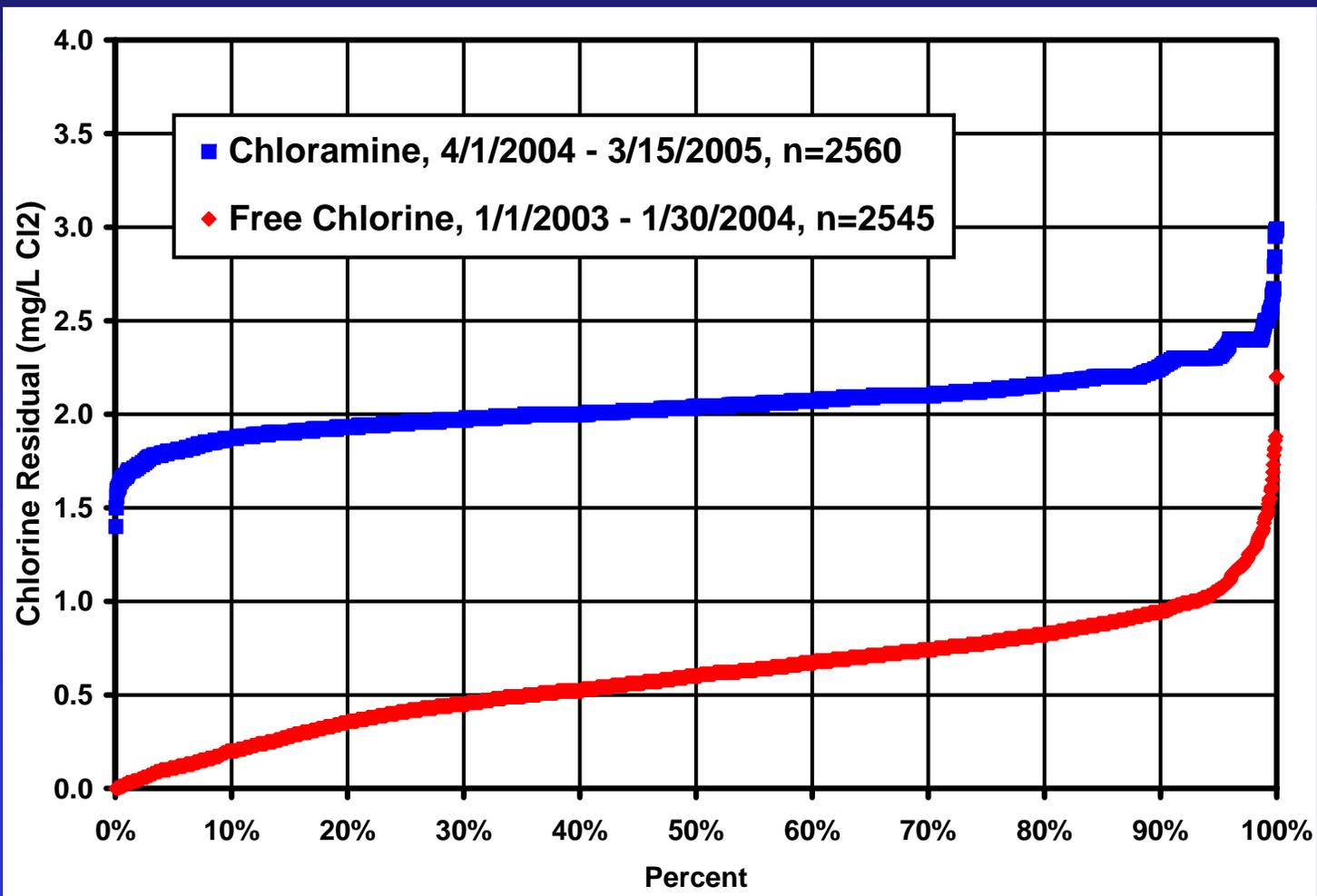
# Start up

- **Regulatory approval gained (i.e., dialysis) on 1/6/04**
- **Treatment facilities started operation on 2/2/04**
- **Increase in customer informational inquiries, primarily due to significant media campaign**
- **Relatively few complaints - some red/dirty water complaints due to extensive conversion flushing and fish kills**
- **No reported business disruption. Dialysis center GAC usage increased.**
- **One month to fully chloraminate system**

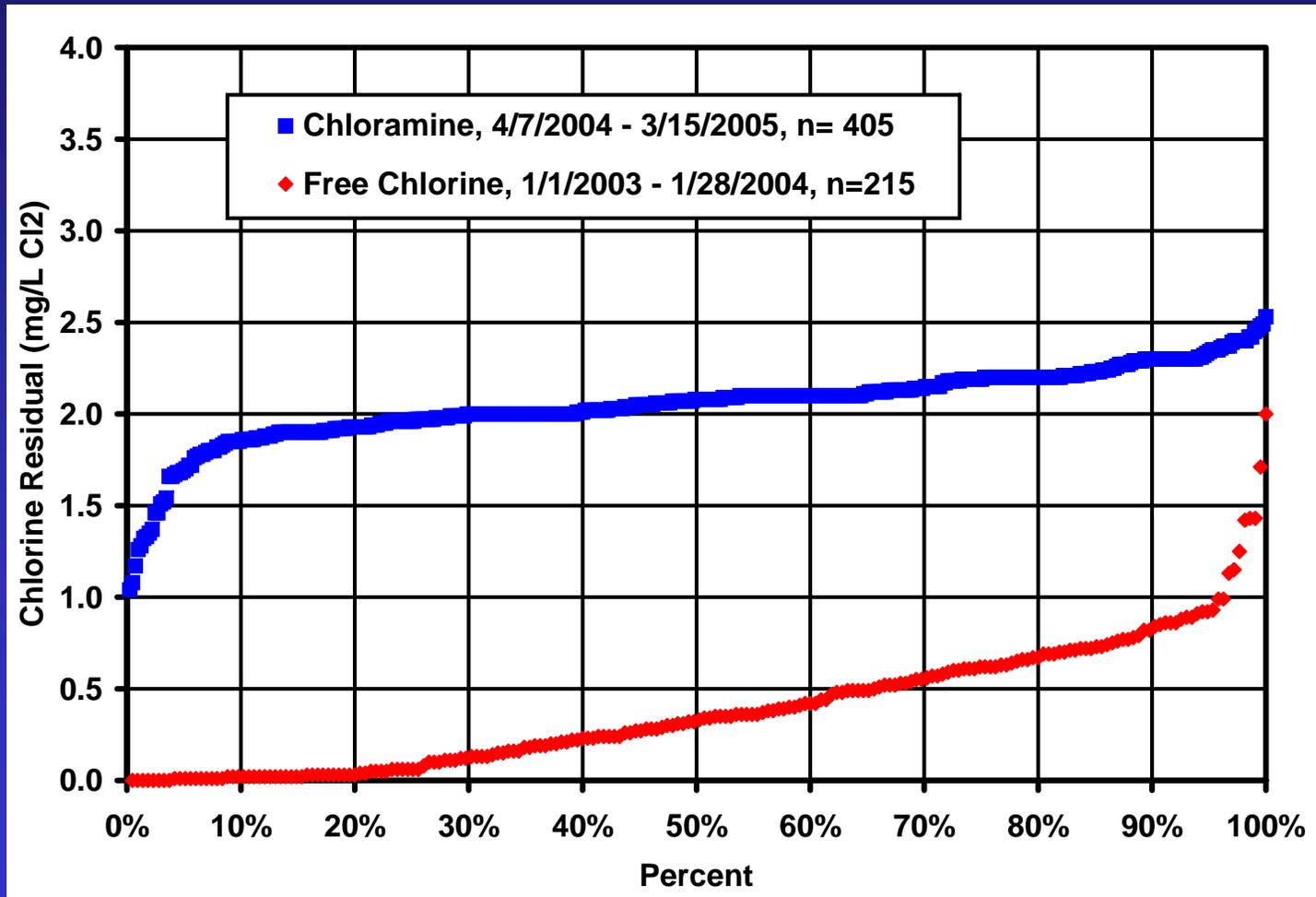
# **WATER QUALITY RESULTS**

# **WQ Results: Disinfectant Levels**

# Disinfectant at TCR Taps



# Disinfectant in Reservoirs

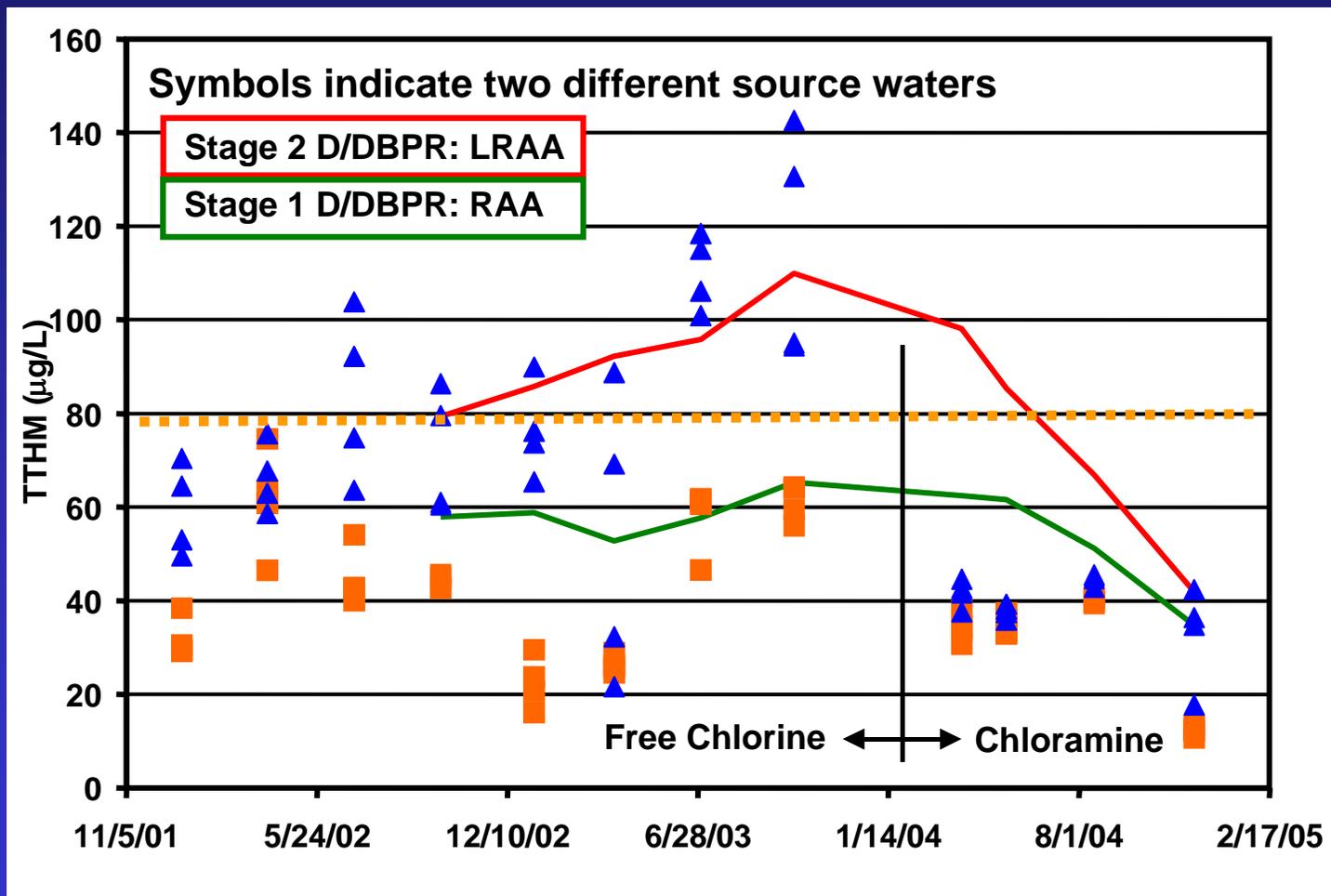


# Effect on Disinfectant Residual

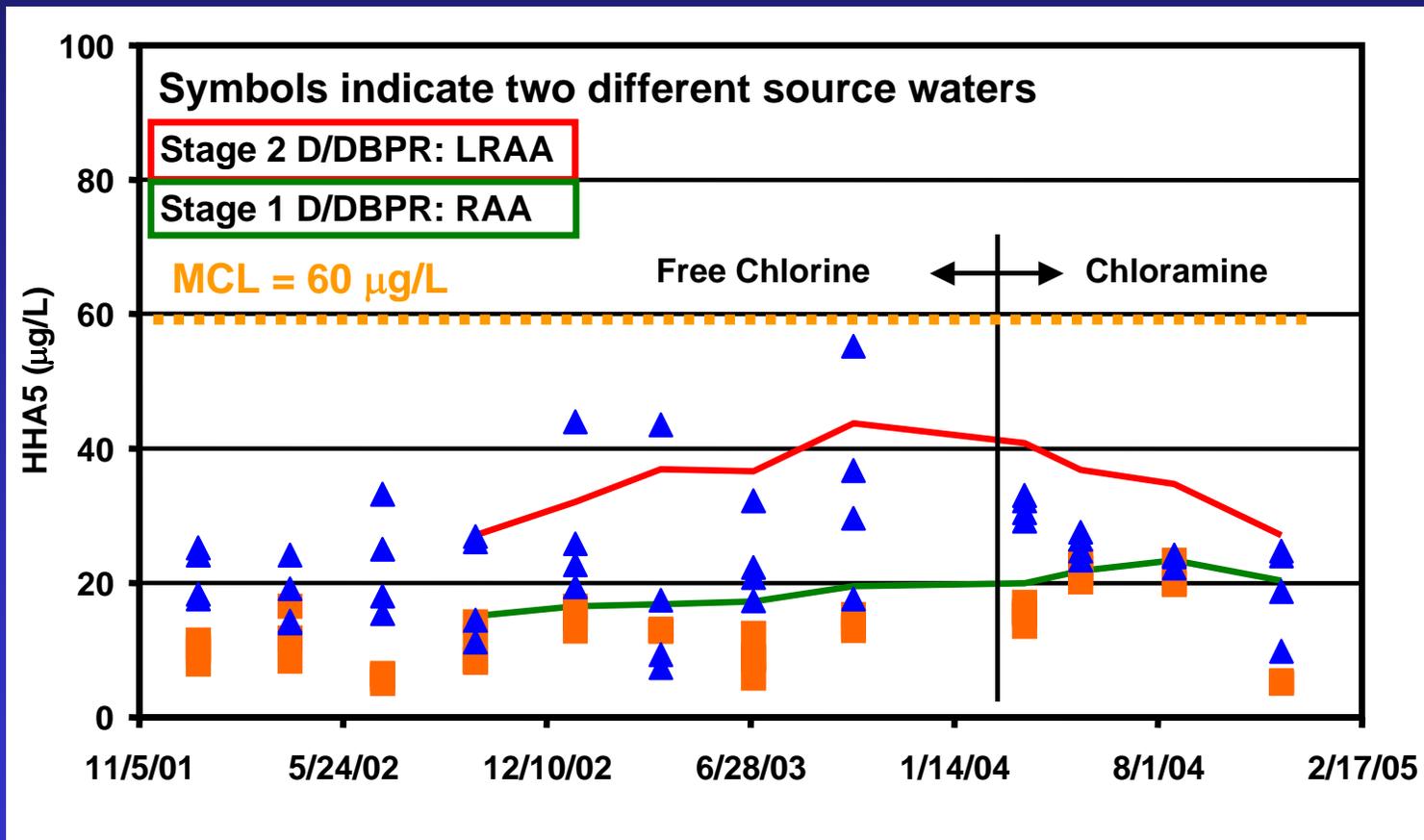
	Free Chlorine	Chloramine
Persistence	Reacts rapidly; no residual in dead zones	Measurable throughout system
Reservoir Levels—median	0.3 mg/L	2.1 mg/L
Disinfectant Booster Stations (maintain residual & TCR compliance)	13	0

# **WQ Result: Disinfection By-products (DBPs)**

# Total Trihalomethane (TTHM)



# Haloacetic Acids (HAA<sub>5</sub>)



# N-nitroso-dimethylamine (NDMA)

Sample Date	1999	Oct-00	Apr-04	Aug-04	Nov-04	Mar-05	
Sample Site Name	Free Chlorine			Chloramine			
	Hetch Hetchy Source						
Raw Water - Tesla	ND	ND	-	ND	ND	ND	ND
Free Chlorinated - Alameda East	ND	ND	-	ND	ND	ND	ND
	Sunol Source						
Raw Water - Sunol WTP	ND	ND	-	ND	ND	ND	ND
Free Chlorinated - Sunol WTP	3.3	ND	ND	ND	ND	ND	ND
Distribution System	ND	ND	ND	ND	ND	ND	2
	Harry Tracy Source						
Raw Water - HT WTP	ND	ND	-	ND	ND	ND	ND
Plant Effluent - HT WTP	1.8	ND	ND	4	ND	ND	ND
Distribution system	1.3	ND	ND	ND	ND	2.1	2.9

California NDMA Notification Level = 10 ng/L

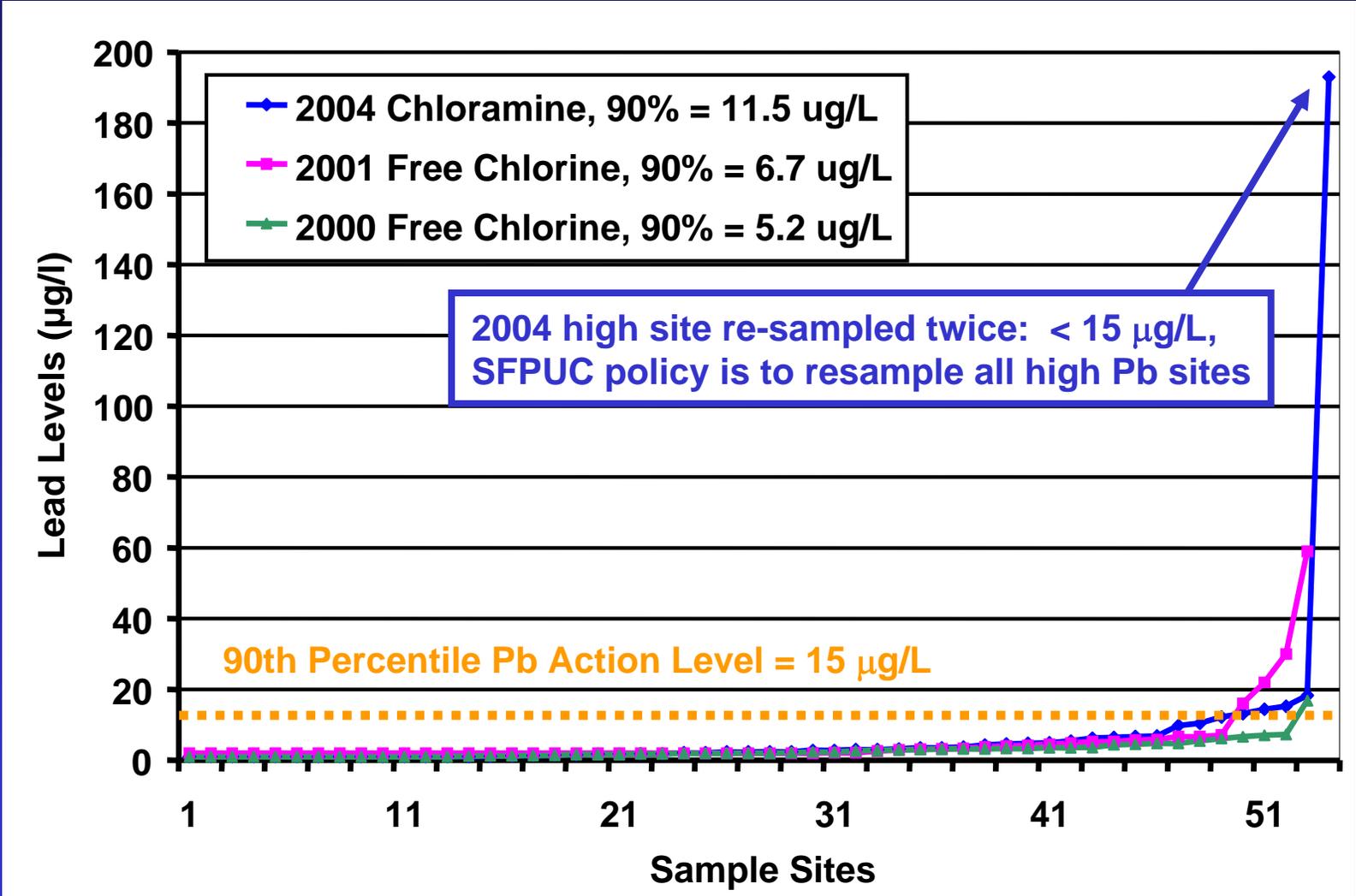
Detection Level = 1 ng/L (1999 and 2000), 2 ng/L (2004 and 2005)

# Effect on DBPs

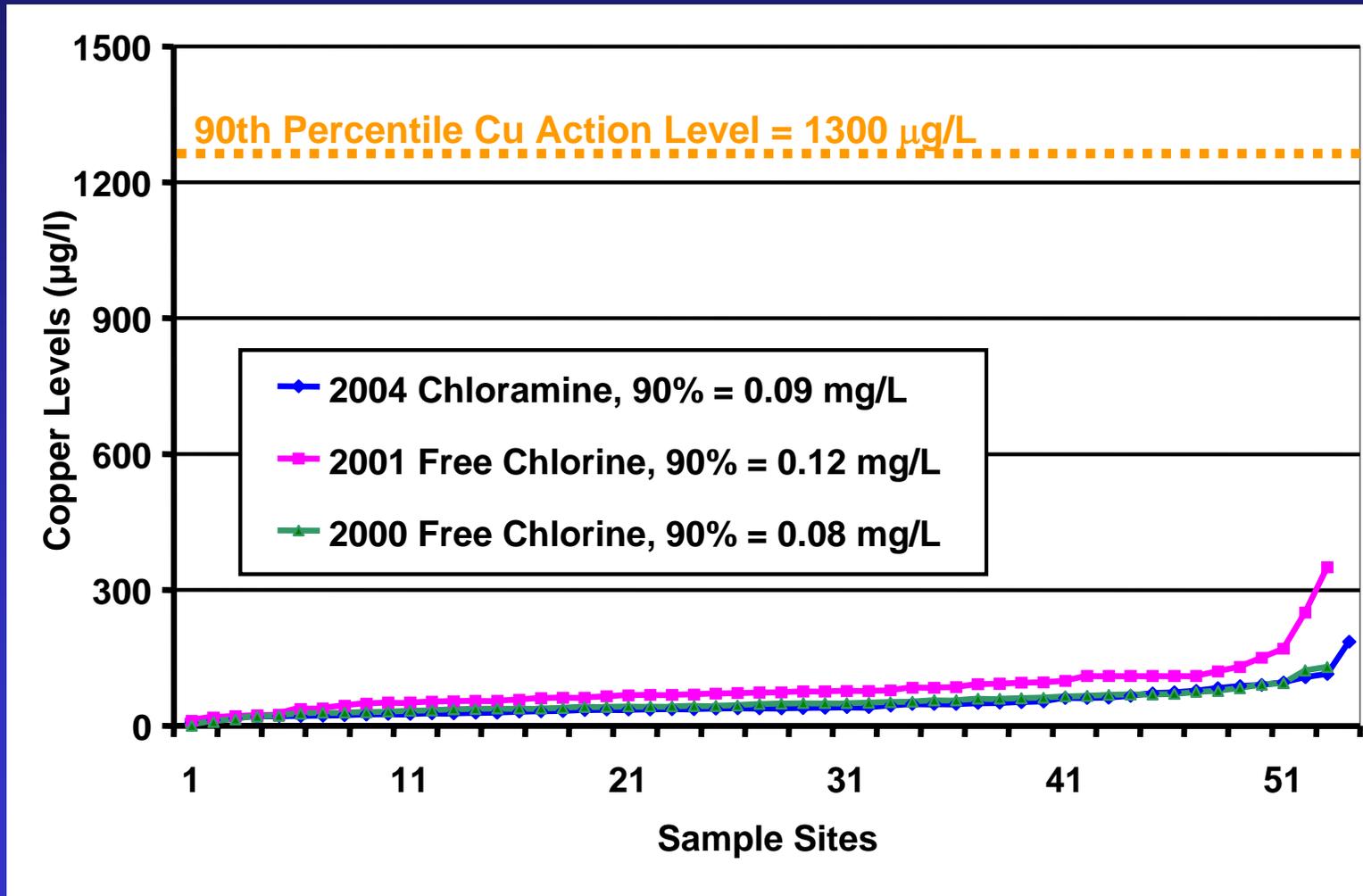
- **Primary objective of chloramination accomplished: regulated DBPs average and peak levels significantly lowered**
- **TTHM and HAA5 results below Stage 1 and Stage 2 D/DBPR MCLs**
- **NDMA non-detected for most samples: maximum NDMA for one sample 4 ng/L**

# **WQ Results: Lead and Copper**

# Lead (Pb)



# Copper (Cu)

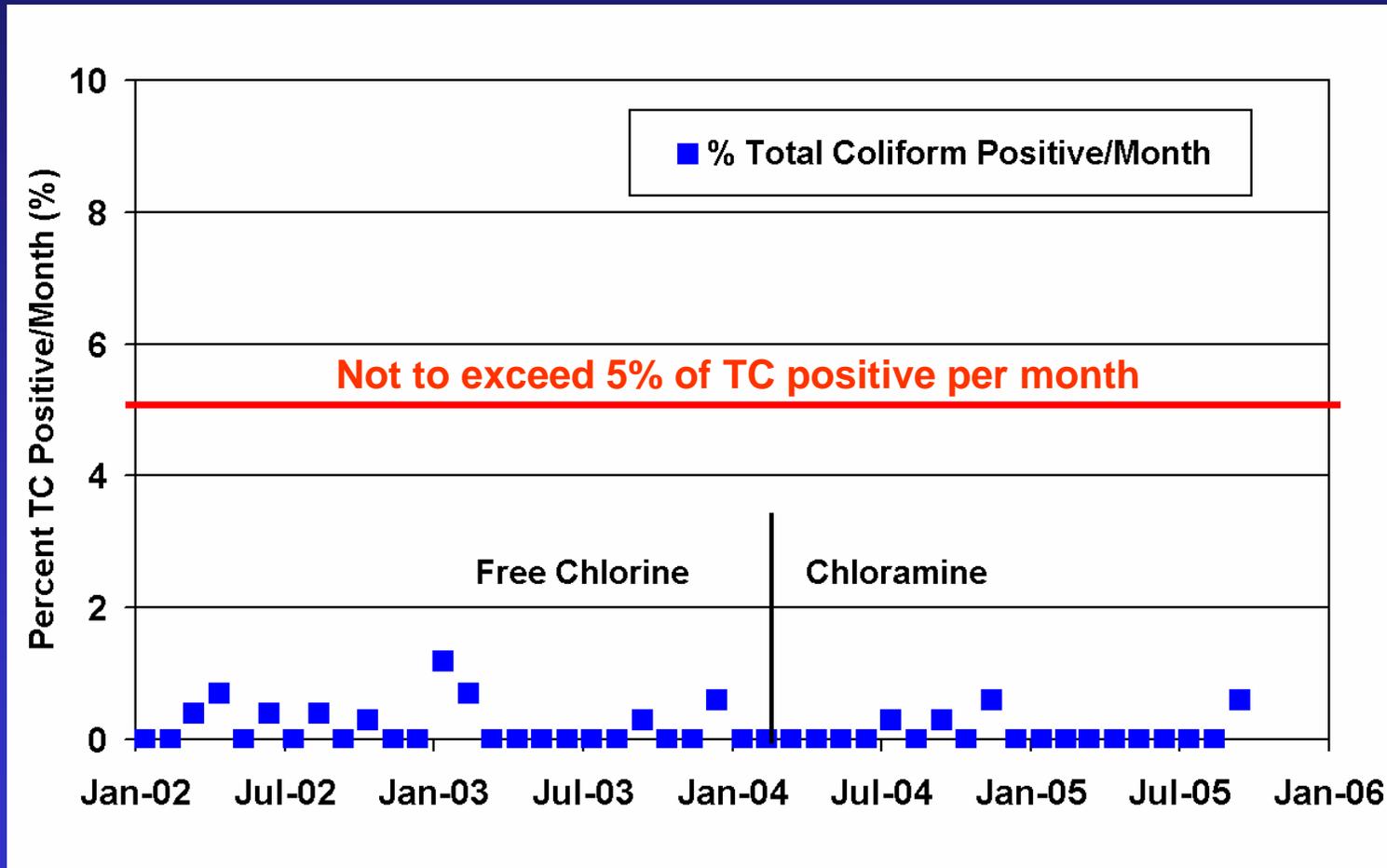


# Effect on Lead and Copper

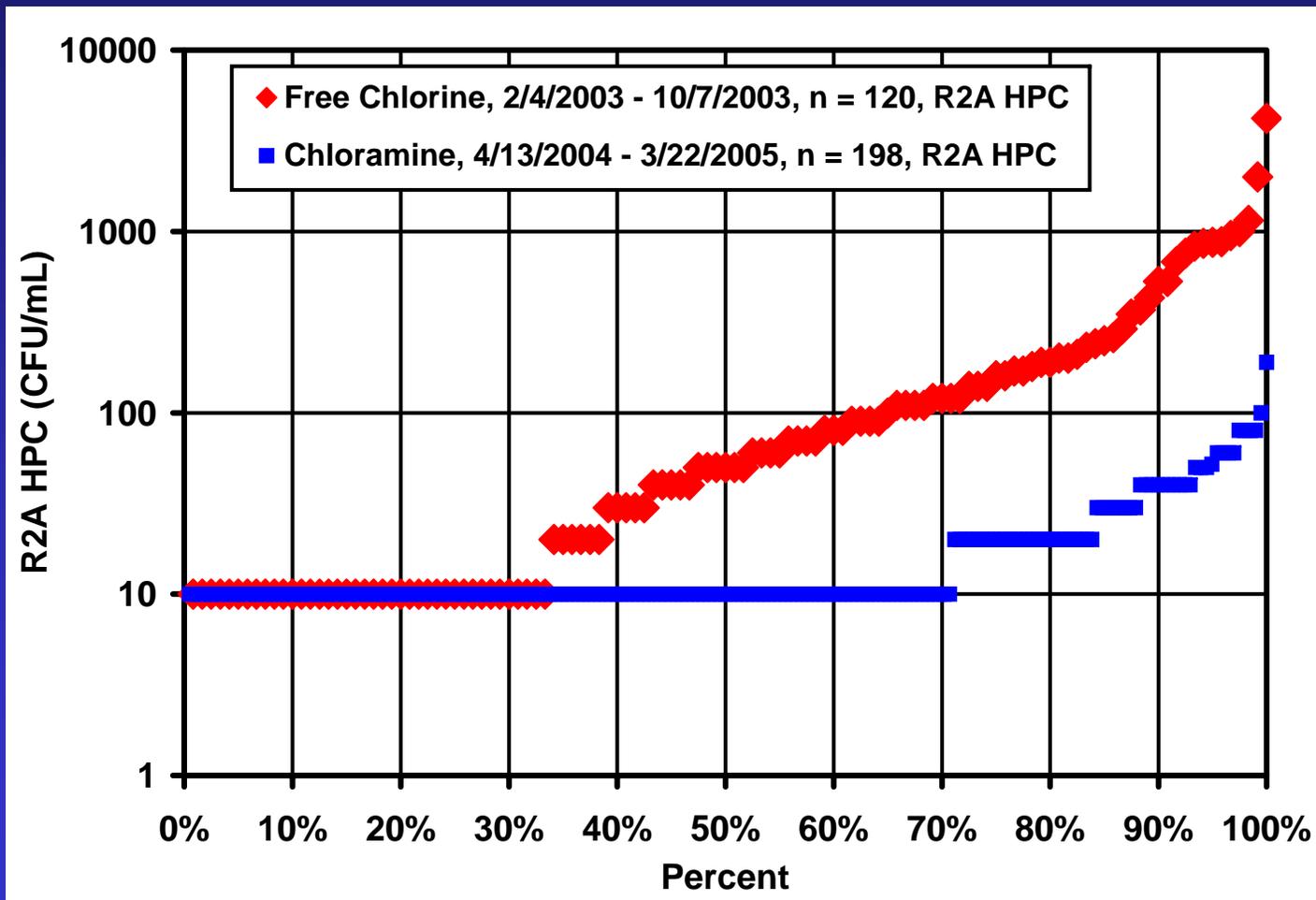
- Lead and copper concentrations: below action levels and comparable for chloramine and free chlorine
- No significant impact was anticipated in part due to Lead Minimization Program (corrosion optimization, lead service lines removed in 80s, lead-free meter replacement, lead-free faucet program...)
- High pH > 9.0 (lime and caustic adjustments) is the current system-wide corrosion control strategy
- SFPUC continues to evaluate corrosion control and will further optimize, if necessary

# **WQ Results: Microbial Indicators**

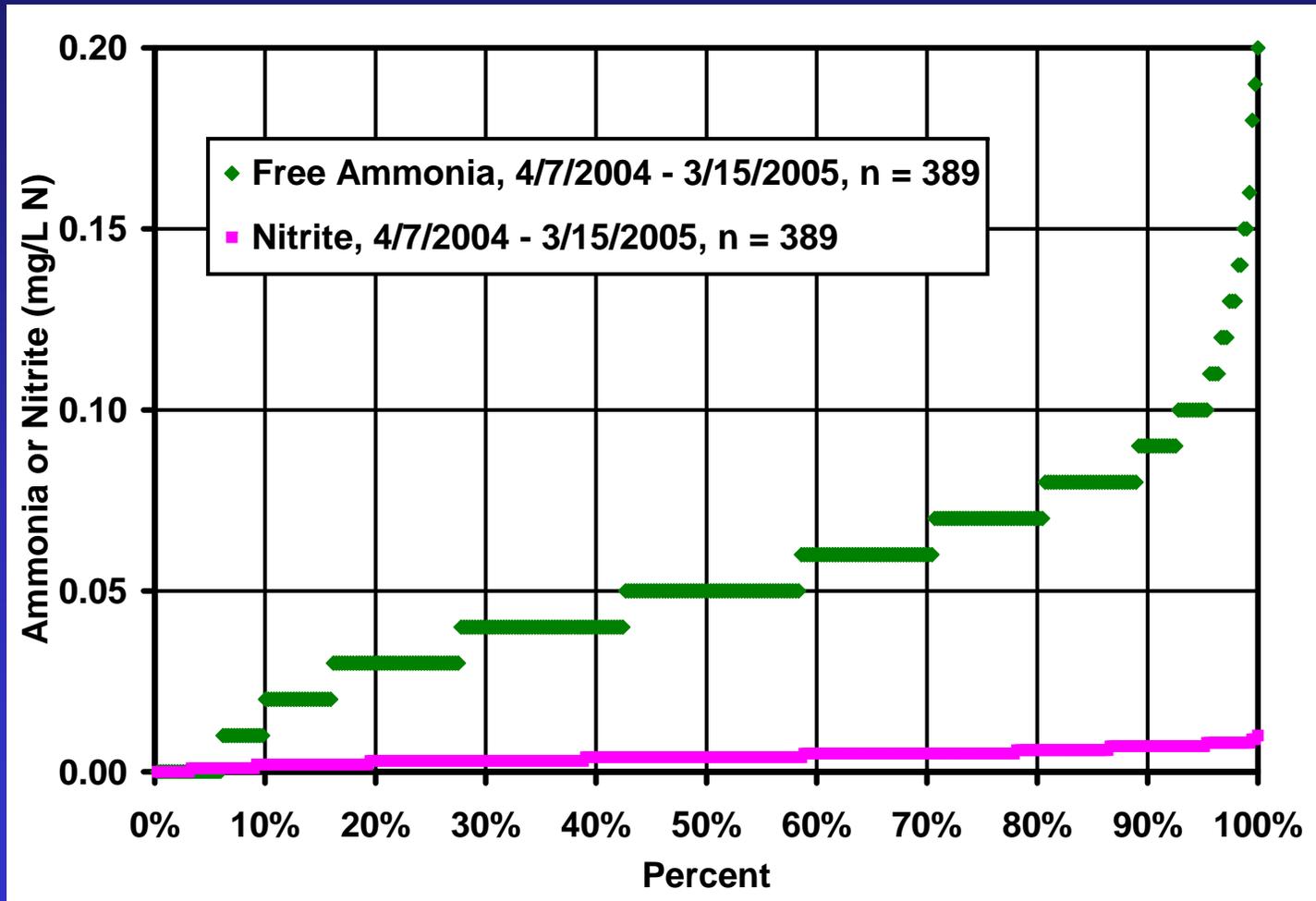
# Coliform Bacteria at TCR Taps



# HPC R2A at TCR Taps



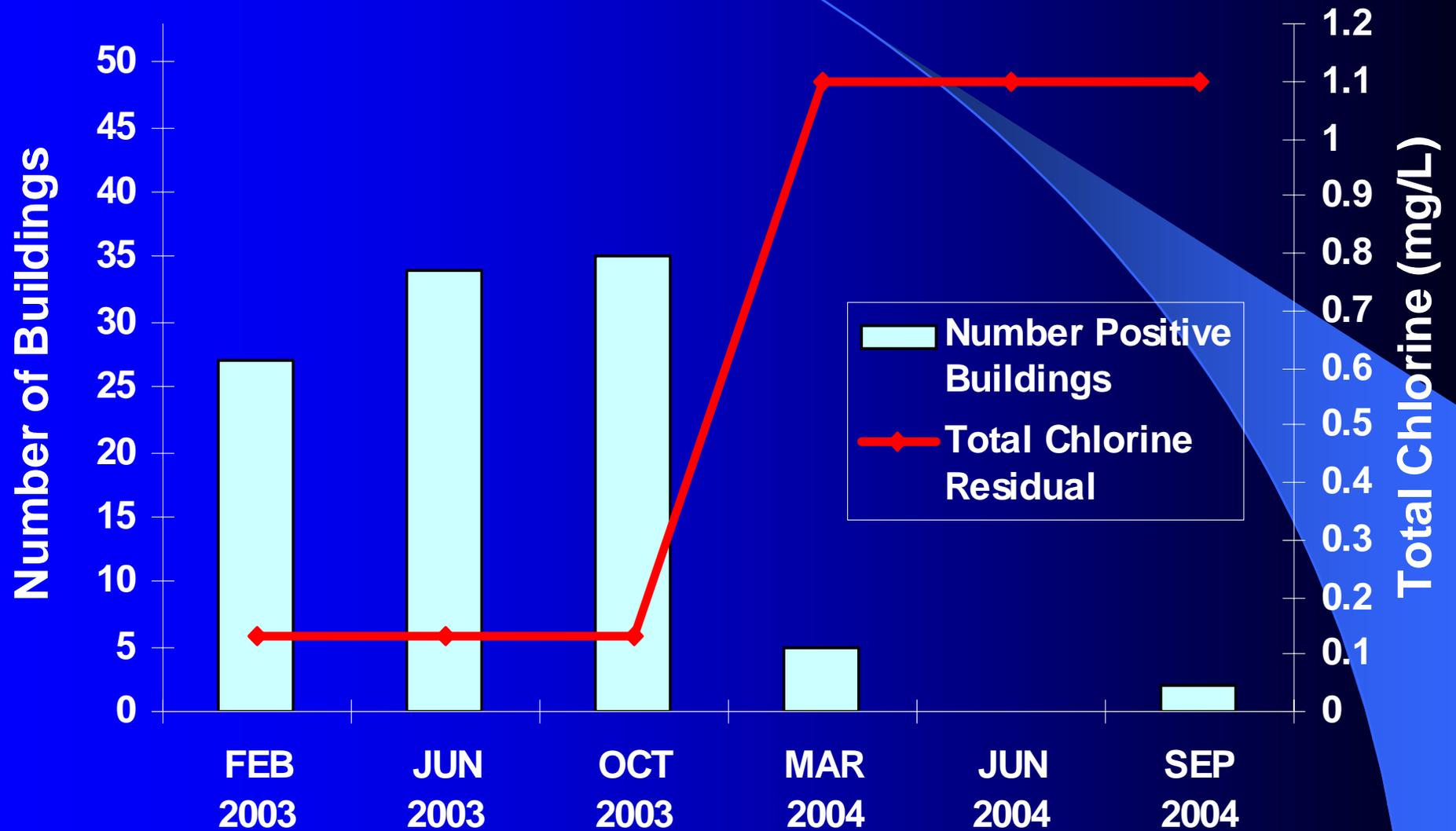
# Free-NH<sub>3</sub> & NO<sub>2</sub> in Reservoirs



# *Legionella* Study

- *Legionella* tends to colonize large buildings with extensive hot water systems
- Prospective study by SFPUC, Centers for Disease Control (CDC) in Atlanta, SF Dept. of Public Health, California Dept. of Health Services, and California Emerging Infections Program
- 53 buildings in San Francisco sampled 3x on free chlorine and 3x on chloramine
- **Significant reduction in *Legionella* observed with chloramine**

# Legionella Colonization



# Effect on Microbial Indicators

- Excellent compliance for *Total Coliforms* for both chloramine and free chlorine
- Better control of biofilm – HPCs and *Legionella* - with chloramine
- No significant evidence of nitrifying bacteria
- Significant investment by SFPUC to reduce water age - storage reservoir mixing and flushing - important

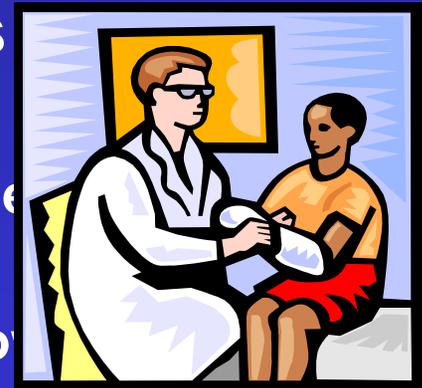
# POST-CONVERSION ACTIVITIES

# Post-Conversion Activities

- **Process Optimization**
  - monitoring instruments
  - treatment/chemical
  - dose reduction
- **Health**
- **Environmental**
- **New regulations/issues**

# Health

- **Some skin and respiratory complaints**
- **SFDPH investigated - questionnaire administered to 17 people with skin complaints did not reveal consistency among the symptoms**
- **SFDPH Director letter supporting chloramination**
- **California Conference of Local Health Officers (CCLHO) supports chloramination**
- **CCLHO letter to local health officers 2005:**
  - **Chloramine protects public health from waterborne organisms**
  - **Chloraminated drinking water is not known to have adverse health effects**
  - **Chloramine lowers regulated disinfection byproducts**



# Health (cont.)

- CCLHO recommends:

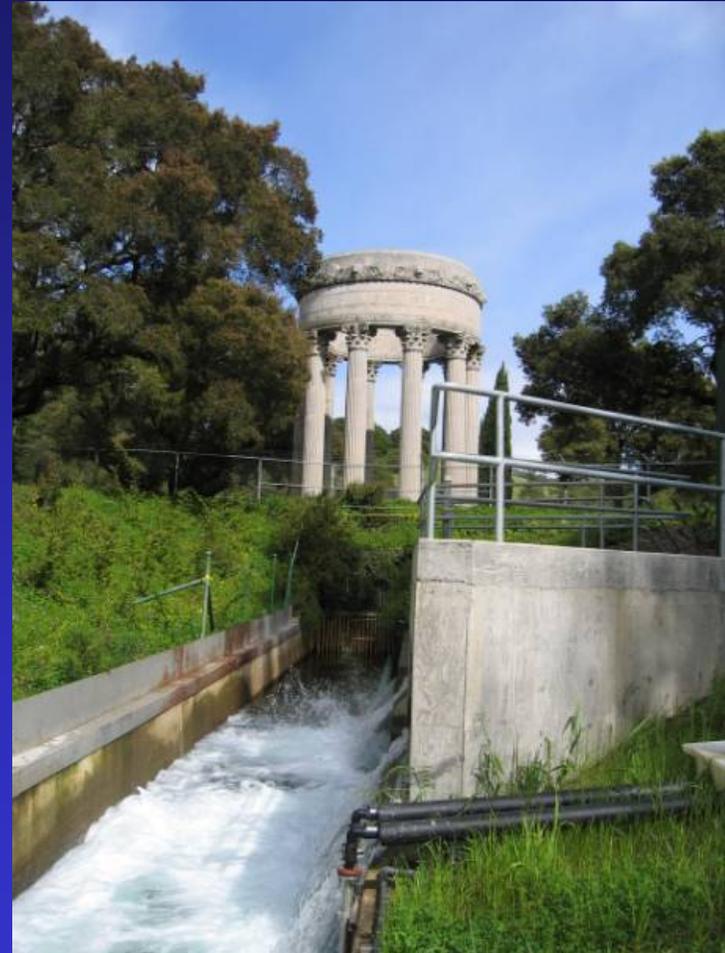
- Continue water quality monitoring (e.g., NDMA, Pb)
- Department of Public Health track water quality complaints
- Continually review current knowledge, experiences of other municipalities, current or emerging health research (e.g., PFAS, AWWA)



# Environmental

## Pulgas Dechlorination Facility

- Must request new NPDES permit
- Must address lingering compliance issues (0.2% of discharge with residual using on-line measure)
- Rapid rate changes 0 to 250 mgd in 15 minutes
- Significant staff and capital expenditures needed to fix



# New regulations/issues

## LT2ESWTR

- HH Advanced Disinfection (ClO<sub>2</sub>, O<sub>3</sub>, or UV)

## D/DBP2

- IDSE
- 'Operational Evaluation' of peaks

## WQPS Update

- Regulations beyond M/DBP<sub>2</sub>, emerging contaminants, and existing contaminants with new science



# CONCLUSIONS

- **Expected water quality improvements – especially DBP and disinfectant residual - were met**
- **Critical to success were: significant and early stakeholder involvement, distribution system improvements (mixing, cleaning and UDF), and intensive public outreach**
- **Must stay current with emerging water quality issues (DBPs, Pb, health claims...) and be prepared to address them**
- **Treatment optimization will continue**

**QUESTIONS?**



# Why Disinfect?

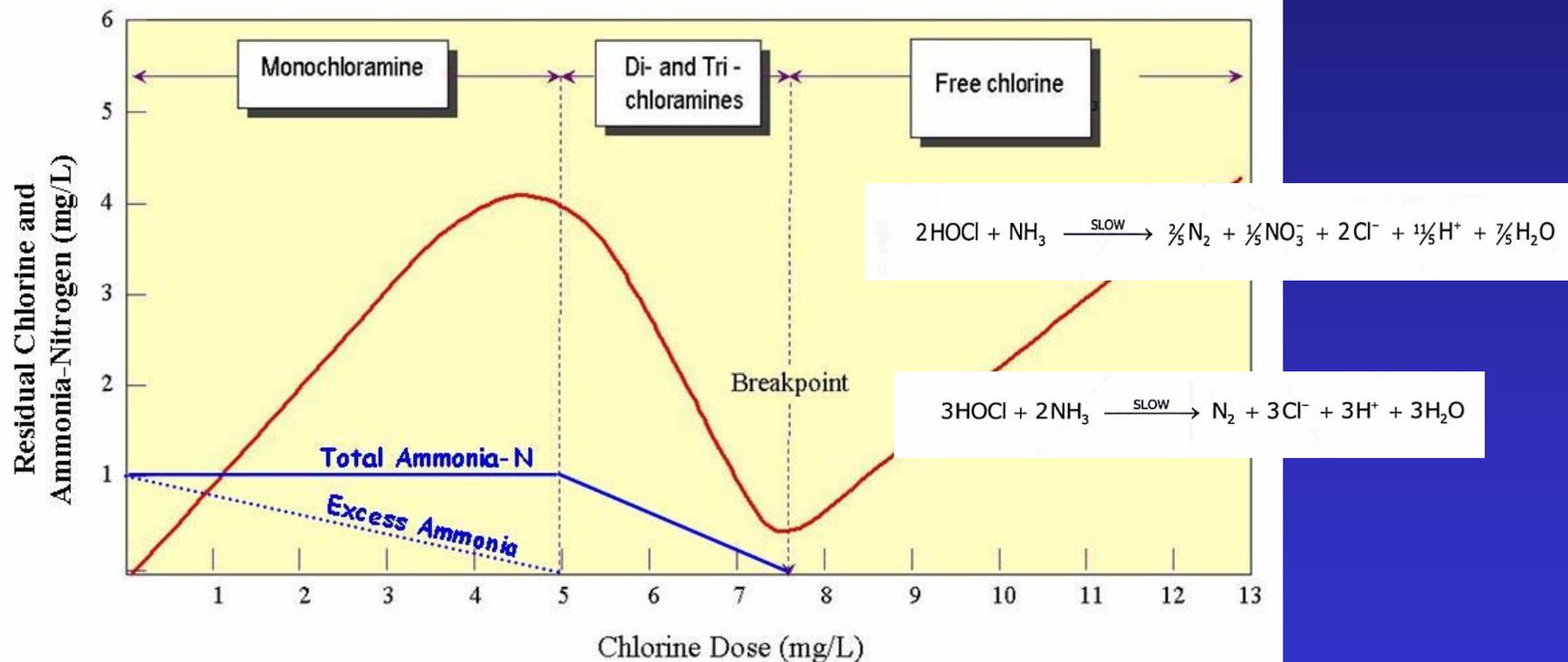
- Kill disease causing organisms (pathogens)
- Secondary functions - Control taste and odor
- Regulatory requirement

*“Chlorine disinfection is probably the most significant public health advance of the past 1,000 years..” LIFE magazine*





# Breakpoint chlorination converts ammonia to nitrogen gas + nitrate



# Keys to Chloramine Optimization

- **Perform Instrument QA/QC**
  - On-line analyzer validation and maintenance
- **Check chemical feed equipment**
  - Daily pump catch
  - Chemical flow meter
- **Verify chemical strengths**
  - Check Certificate of Analysis
  - Use chemical flow meters for process control
- **Reduce ammonia decay**
  - More frequent ammonia deliveries
  - Keep tanks well mixed

# Monitoring

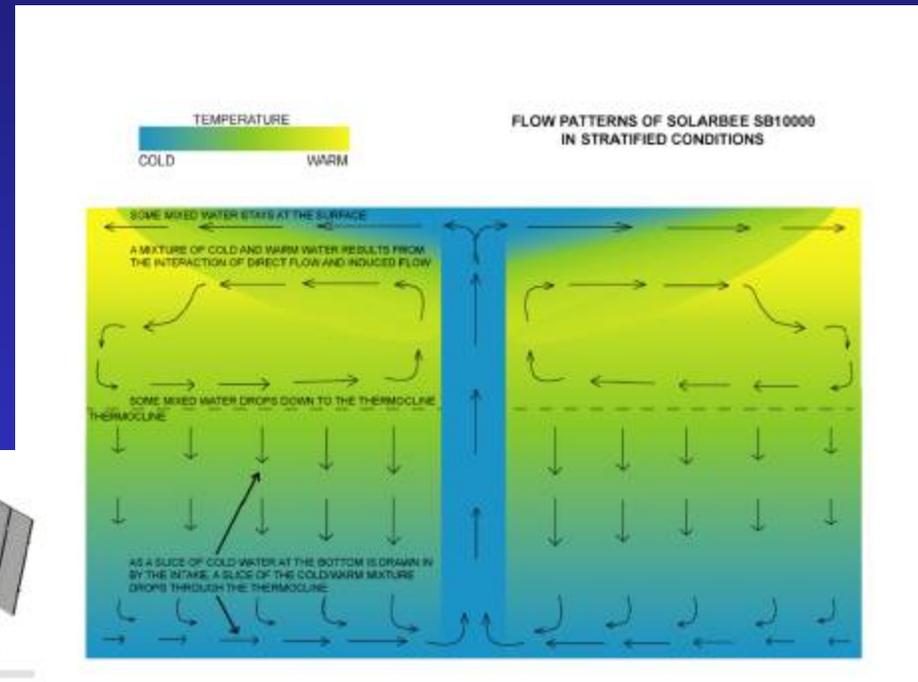
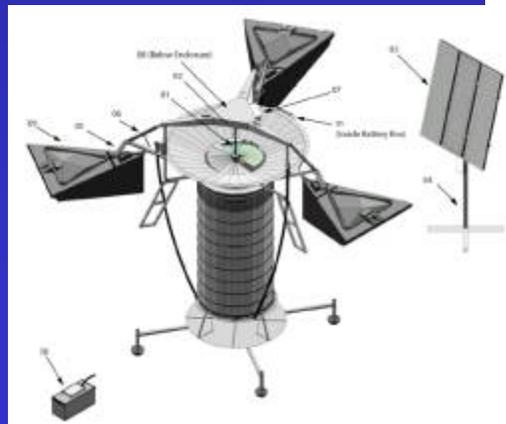
- **Monitoring reservoirs is critical for detecting nitrification in the SFPUC City system.**
- **Reservoir monitoring should continue for total chlorine, free ammonia, nitrite, HPC-R2A, pH and temperature.**
- **Dedicated sampling facilities are helpful for detecting nitrification and evaluating the effectiveness of nitrification responses.**

# **Nitrification Prevention for Facilities with High Water Age**

- **Evaluate reservoir drawdown restrictions**
- **Provide mixing and circulation improvements by deep-cycling reservoirs, reconfiguring inlet/outlets, or employing mechanical mixers**
- **Conduct reservoir in-situ cleaning**
- **Create a Nitrification Response Plan**
- **Routine nitrification monitoring**

# SolarBee<sup>®</sup> Mechanical Mixer

- Utilizes solar energy to turn low rpm propeller shaft.
- Draws water from bottom and distributes across surface in a laminar fashion and entrains bulk water to promote circulation.



# Nitrification Alert and Action Levels

**Table ES-2: Alert and Action Levels**

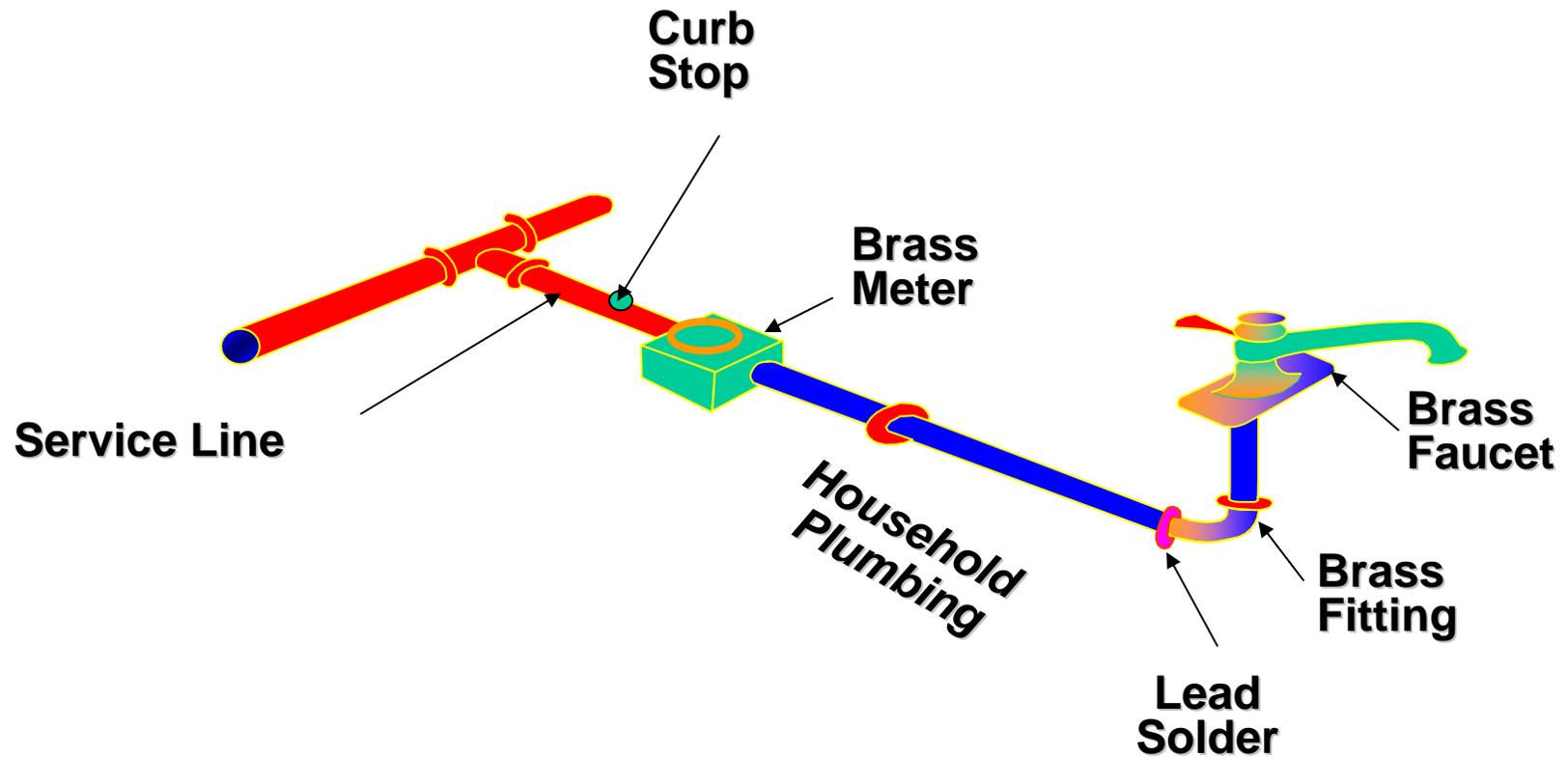
Parameter	Target at Reservoir Inlets	Target at TCR Sampling Stations	Action Level 1 (Alert Level)	Action Level 2 (Operational Responses Required)	Action Level 3 (Regulatory Violation Possible)
Total Chlorine (mg/L)	>1.7	>.1.5	1.0 - 1.5 <sup>1</sup>	< 1.0	< 0.2
Nitrite-N (mg/L)	<0.01	< 0.01	> 0.02	> 0.03	> 0.05
HPC-R2A (CFU/ml)	<100	< 100	> 100	> 200	> 500
Free ammonia-N (mg/L)	< 0.1	< 0.15	>0.15	> 0.2	NA <sup>2</sup>

1. Use 1.0 for TCR Sampling Stations representative of low flow in the pipes.
2. Assumes free ammonia-N has been converted to nitrite-N
3. Table is based on Nitrification Response Plan, SFPUC - CS&A, August 2003.

# Three Levels of Action

- **Action Level 1 (Alert)** - Increase water quality monitoring, prepare for situation escalation, increase communication, and identify responses.
- **Action Level 2 (Operational Response)** - Evaluate operational responses, document water quality changes, response measures include Deep cycle reservoirs, reduce storage volume to decrease water age, and conduct flushing.
- **Action Level 3 (Regulatory Violation Possible)** - Determine whether regulatory violation potential, refer to Water Quality Notifications and Communications Plan, SFPUC. If potential regulatory violation, response measures include breakpoint chlorinate tank or reservoir, completely drain and refill, breakpoint chlorinate a pressure zone, switch water supplies

# Typical Tap Water Lead Sources



# Lead Reduction Measures

- In 1980s, removed 7000+ lead service lines
- In 1983, discontinued use of lead joints in water main
- In 1992, began LCR monitoring
- In 1994
  - Submitted report “Treatment Recommendation for Corrosion Control” to EPA
  - Initiated “Lead Test for a Fee” Program

# Lead Reduction Measures (Cont'd)

- **In 1997, conducted pilot test in Moccasin:**
  - Installed unleaded kitchen faucets
  - Followed by unleaded lavatory faucets and unleaded drinking fountains
- **In 1998, began free lead-in-water tests for Women, Infants & Children (WIC) program participants**
- **In 2000**
  - Provided lead-free faucets to childcare centers and schools
  - Adopted policy to replace brass meters with lead-free meters

# **Lead Reduction Measures (more...)**

- **In 2001, started providing lead-free faucets to City residents at substantially discounted price**
- **Since 2002, removed all known large compound meters except two (buried deep under a skyscraper in downtown)**
- **In 2003, started field testing lead-free curb stops**
- **In 2004, built redundant corrosion control facilities (part of chloramine project)**

# Ongoing Measures

- Corrosion control treatment optimization
- Lead-free faucets distribution
- Replacement of leaded meters
- Free lead tests for WIC clients
- Lead test for City residents at discounted price
- Public education (Annual Water Quality Reports, lead brochures, website information on lead hazards, etc.)
- New AwwaRF research projects

# Advanced Disinfection Project Schedule

## ■ Key Milestones

	<u>Start – Complete By</u>
Planning	7/01/02A – 06/31/06
Environmental Review	04/03/06 – 07/18/07
Design	08/01/06 – 08/06/08
Bid & Award	08/07/08 – 01/08/09
Construction	01/09/09 – 04/07/10
Close Out	04/08/10 – 09/29/10