

# A Utility Perspective on the Total Coliform Rule

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# A Little History.....

- **1800's Germ Theory**
- **1884** *Escherichia coli* identified as the cause of some diseases
- **1893** First “drinking water bacteriological standard” enacted

# The FIRST Standard (1893)

Under the Interstate Quarantine Act, the U.S. Public Health Service (USPHS) enacted a regulation prohibiting use of a **common drinking cup** by passengers on commercial transportation carriers traveling between states

# A Little More History.....

- **1925** “Standards for Drinking Water and Culinary Water Supplied by Common Carriers in Interstate Commerce”
- **1942** **USPHS Standards for Public Water Supplies**
- **1946** **USPHS Standard expanded to all public water systems**
- **1974** **Interim MCL for coliform bacteria**

As of the 1970's, Total Coliform was already imbedded in our regulatory structure

- **Total coliform considered the best available indicator**
- **Representative sampling throughout distribution**
- **Population-based sampling**
- **Monthly regulatory review**
- **Check sampling after positive samples**
- **Numerical and percent positive limits**
- **Lab certification**
- **More than one test method was available**
- **100 mL standardized sample volume**

# Total Coliform Rule of 1989

- Only the presence/absence of coliform bacteria is now reported.
- Coliforms are the best available indicator
- “Repeat” sampling after positive samples laid out in greater detail.
- Positive coliform samples must be tested for fecal coliforms (or *E. coli* once new methods for *E. coli* were developed).

# 1989 TCR and Components

- Indicator framework
- Routine monitoring and sample siting plans
- Repeat monitoring – routine/repeat samples
- Analytical methods specified
- MCLG's established
- Non-acute (monthly) AND acute Maximum Contaminant Level (MCL) established
- Variance provision added in 1991
- Public Notification required
- State involvement specified with positive samples and MCL violations

# Total Coliform Rule Objectives

- Evaluate the effectiveness of treatment
- Determine the integrity of the distribution system, and
- Signal the possible presence of fecal contamination

(U.S. Environmental Protection Agency 1987)

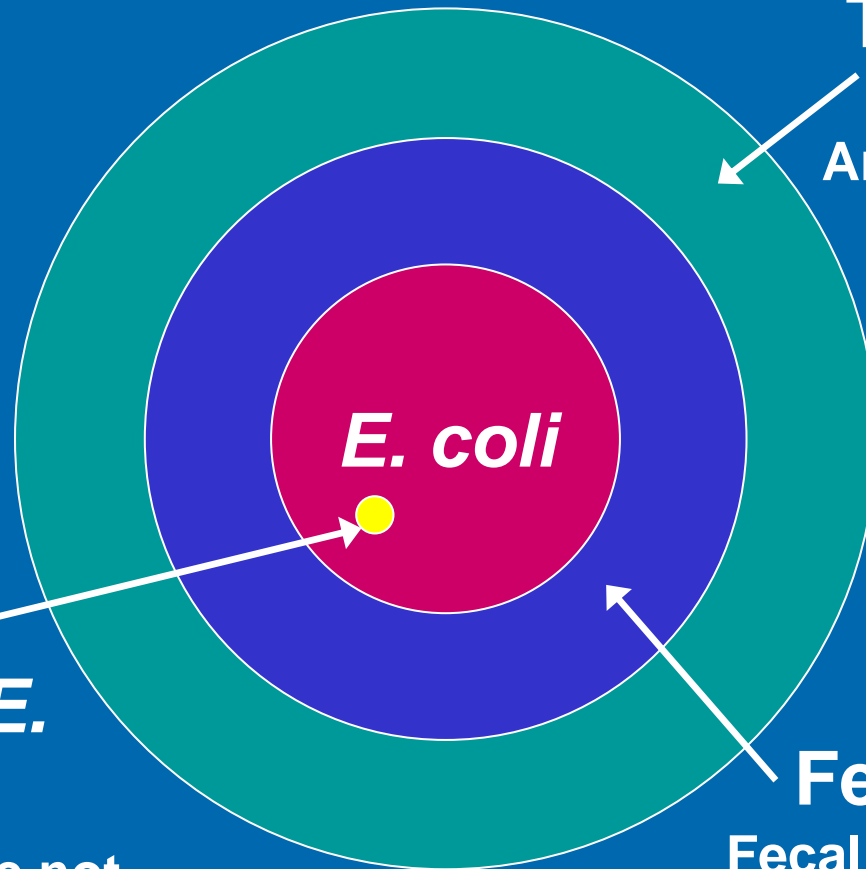
# TCR Applicability (1989)

- Requirements apply to all public water systems
  - 54,000 community water systems
  - 20,000 nontransient noncommunity water systems
  - 90,000 transient noncommunity water systems
- Only rule that applies to transient PWSs in a comprehensive manner
  - Monitoring at least annually (monthly for many)
  - Sanitary survey requirement
  - Fosters connection between system and State

# What is a Coliform?

Indicator Organisms indicate potential presence of disease-causing organisms

There are hundreds of pathogens and many cannot be detected or are expensive to measure



**Total Coliform**  
Ubiquitous in Ambient Environment

**Pathogenic *E. coli***

Some of which are not detectable by Total Coliform detection methods

**Fecal Coliform**  
Fecal Coliform or *E. coli* = Fecal Contamination

# Why use an indicator?

## **Coliforms:**

- **an indicator of fecal pollution**
- **may foreshadow the possibility of waterborne disease outbreaks**
- **provide a conservative estimate of the risk of more serious contamination**
- **Relative ease of analyses**

# Improved Understanding of Indicators Since 1989

- Fecal coliform is now referred to as “thermal tolerant coliform” rather than by analytical methods
- *E. coli* is now defined as its microbiological characteristics rather than by analytical methods
- Measurement of *E. coli* is now lower cost and practically available

New methods for coliforms came about with the TCR and its shift away from enumeration and towards presence/absence reporting

**Coliforms produce beta-galactosidase, which produces a yellow color in the media when coliforms are present**

New bacteriological methods for *E. coli* provided direct testing for *E. coli* under the TCR

***E. coli* produces another enzyme, beta-D-glucuronidase, which breaks down 4-methylumbelliferyl-beta-D-glucuronide (MUG) and fluoresces under UV light.**

# Fecal Coliforms

- Coliform bacteria which ferment lactose at 44.5 degrees C
- Elevated temperature test was added in the late 1940s to target *Escherichia coli*; later it was discovered that some strains of *Klebsiella* also ferment lactose at 44.5 C
- Now known as “thermotolerant”

# Multiple methods for identifying Total Coliform

- **Membrane filter with m-Endo medium**
- **Membrane filter with MI agar**
- **Multiple tube fermentation**
- **Presence/absence test using P-A medium or Readycult®**
- **MMO-MUG or Colilert®**
- **Colisure®**
- **E\*Colite®**
- **Etc! Etc! Etc!**

# The questions

- Characterize the percent positive samples for Total Coliform and E coli
- Do the data collected address the rule objectives adequately?
- How do result of total coliform results correlate with water quality parameters (e.g. chlorine residual)
- Are there patterns in the percent positive samples by system size, type or source

# Data Available

- Data from: utilities, states and EPA SDWIS
- Detailed data provided by 11 utilities
  - ➔ 242,631 observations
- Summarized data from 3 utilities
  - ➔ 62,588 observations
- Observations summarized by states
  - ➔ 6,822,343 observations
- Data included in these summaries
  - ➔ 7,127,562 observations

# Data Limitations

- Little ancillary data with total coliform data
- Organization of data is not consistent
- Total coliform events for utilities are RARE events - 1,584 observations (0.52%)
- *E.coli* positive even more RARE – 58 observations (0.02%)
- Very difficult to get broad representation of small utilities
- Data are most definitely do not meet the definition of statistically random samples; however, the biases are hard to define

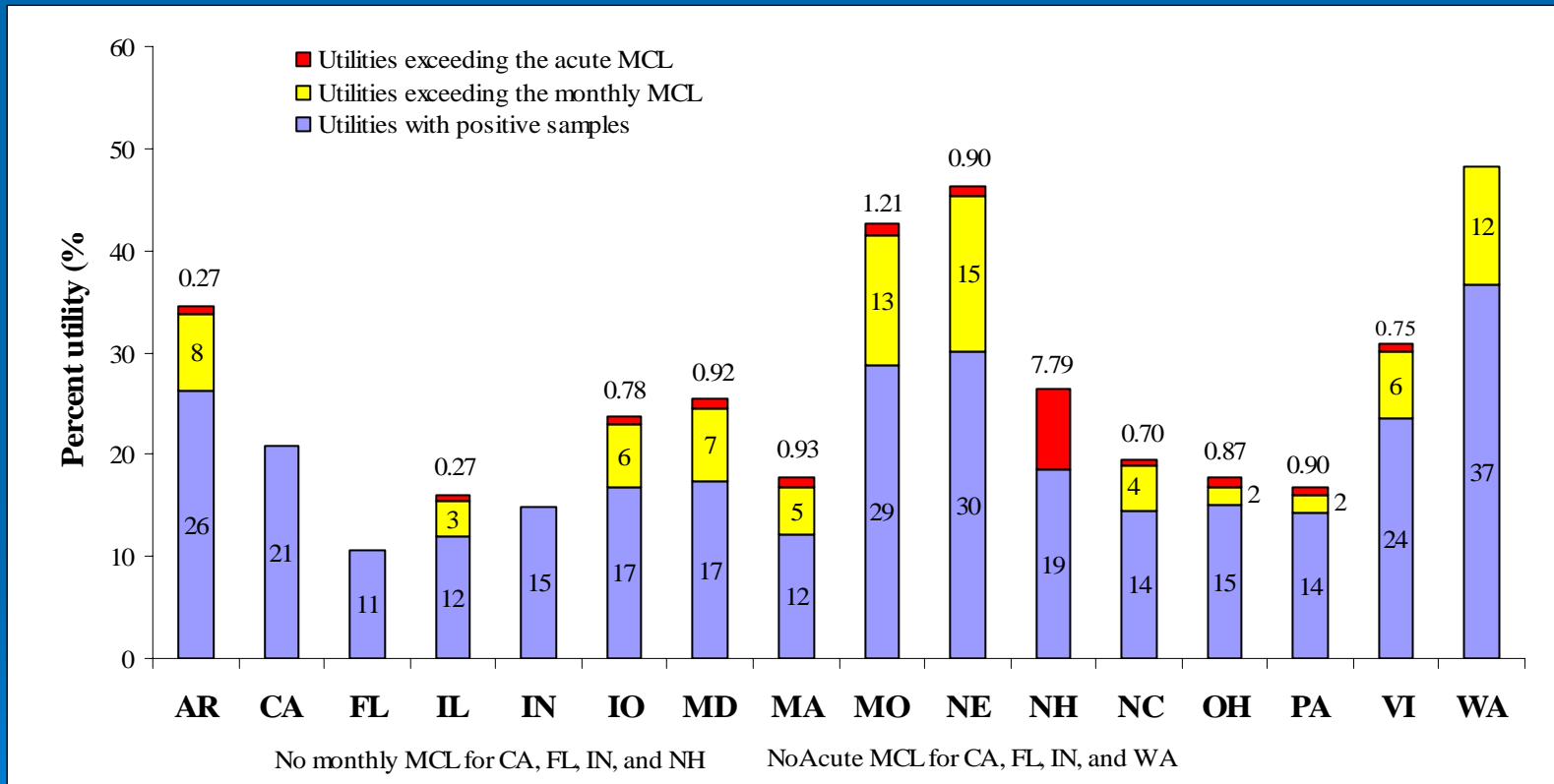
# Utility Results

Name	Number of Years of Data Collection	Number of Total Coliform Samples Collected	Percent of Positive Total Coliform Samples (%)	Percent of Positive <i>E. coli</i> Samples (%)	Maximum Monthly Percent Positive Total Coliform Samples (%)
	8	22411	0.78	0.013	6.18
	8	12882	2.39	0.070	12.18
	2	17003	0.26	0.035	na
	5	28599	0.15	0.007	na
	6	28264	0.22	0.039	na
	9	24351	0.12	0.004	1.25
	10	43034	0.39	0.000	1.92
	10	36513	0.49	0.000	4.20
	12	5725	0.03	0.000	na
	10	1718	1.05	0.058	na
	10	13774	0.59	0.000	4.54
	3	3112	0.48	0.064	3.85
	8	25247	0.37	0.008	na
	10	42553	0.86	0.049	na
	11	235171	0.99	0.009	60.00

# State Results

State	Years of Data	Number of Total coliform samples Collected	Percent samples Positive for Total Coliform
Missouri	6	467896	0.05
Illinois	6	680738	0.40
Pennsylvania	6	878849	0.53
Ohio	6	692051	0.66
Florida	2	537495	0.74
Arizona	5	328298	1.76
Iowa	6	303110	1.96
New Hampshire	6	74993	2.18
Washington	6	671118	2.69
Nebraska	6	157165	3.42
Indiana	6	437006	3.64
North Carolina	6	436338	4.07
Virginia	6	227474	4.41
Maryland	6	311925	4.70

# Summary of State Violations



# Results so far.....

- Percent samples with positive total coliforms for utilities ranged from 0.12% to 2.39% (all months pooled)
- The monthly percent positive Total Coliform sample ranged from 0% - 12.2%
- Only ten monthly MCL violations were observed for over 1330 months (combining all utilities)
- Overall positive total coliform for all state data is 1.8%
- Percent positive for *E. coli* samples pooled over all months is very low
  - highest observed at 0.0007 (0.07%)

# Repeat Sampling

**Is there an increased probability we will find Total Coliform in repeat samples?**

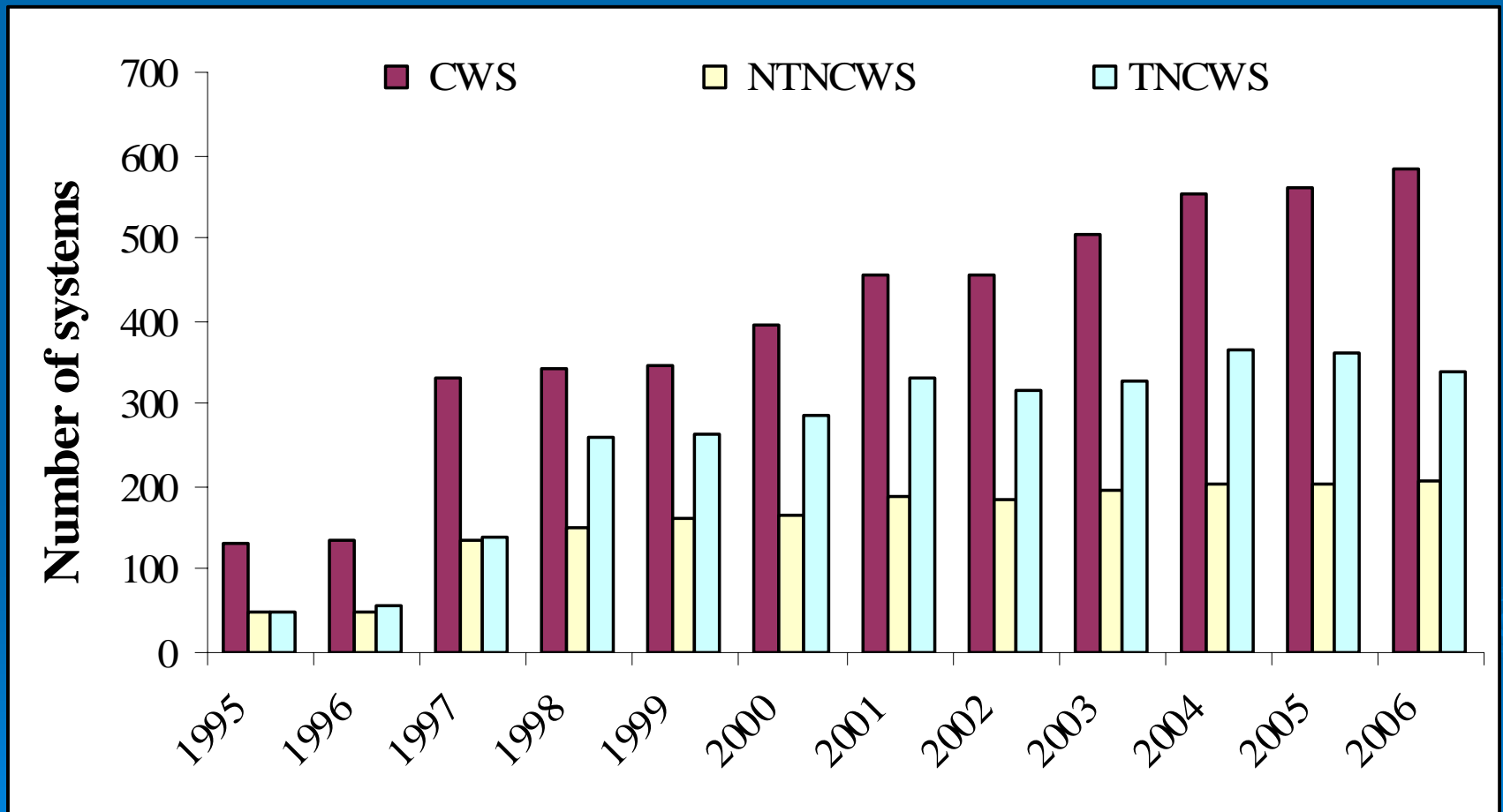
Sample Type	Count	TC+	% Positive
Routine	11,520	269	2.34
Repeat	1362	39	2.86
Total	12882	308	2.39

**Indistinguishable - therefore repeat samples do not have an increased probability of positive results**

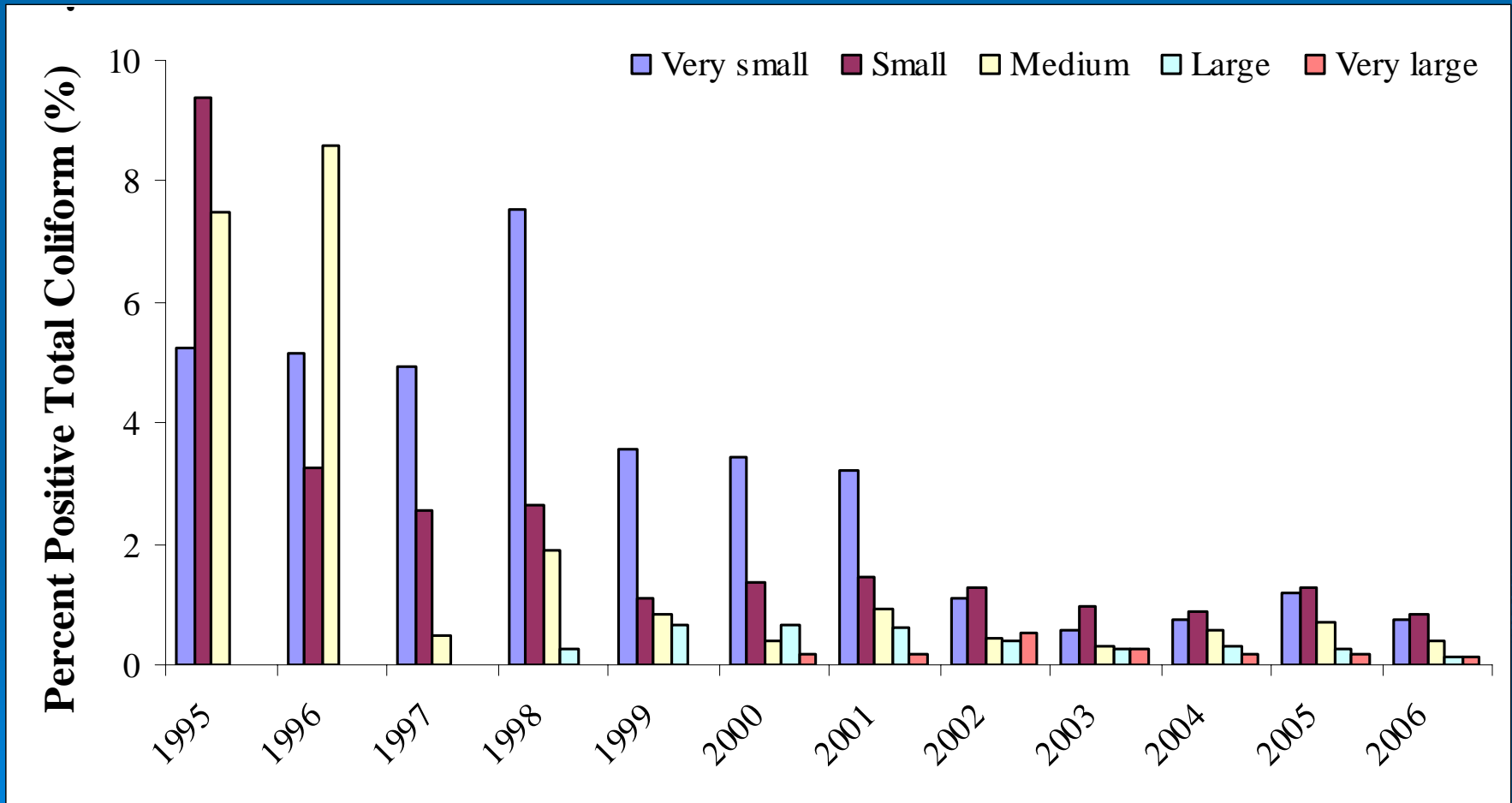
# Patterns in Detailed Utility Data

- **No difference in average values for chlorine residual for total coliform positive versus total coliform negative**
- **No other correlations evident (data is limited)**
- **Few apparent relationships with location in distribution system**
- **Possible spatial pattern at one utility difficult to reach any conclusions**

# Number of Systems by Type



# Percent Positive Samples



# Rule Discussions

- Concerns over data limitations
- Are the data that we have useful?
- Are the data that we have so far adequate to understand the effectiveness of the existing rule
- Is TC still a meaningful indicator?
- Sample frequency, volume, location?

# Impact of Sample Volume



# Pinellas County Large Volume Study 2004

Site	Percent Positive Total Coliform samples 100 ml	Percent Positive Total Coliform samples 2 Liter
Keller Trans Well (raw water)	100%	100%
Keller1 Effluent (finished water)	1%	2%
Keller1 Influent (raw water)	4%	35%
Keller 2 Effluent (finished water)	0%	1%
Keller 2 Influent (raw water)	8%	40%
TBW Influent (finished water)	0%	3%
Tank Effluent (primary disinfection)	0%	15%

# Effects of Larger Sample Volume

- What would we learn about the occurrence of total coliform if larger sample volumes were collected?
- 13,160 data points collected at 9 locations over 14 month period
  - Joint Pinellas County Utilities and Tampa Bay Water effort
- Study set up to simulate larger sample volumes from the data

# Increased Volume Experiment



# TBW / PCU Total Coliform Monitoring Program

- **9 Coliform samples taken per day at nine locations**
  - 1 100 ml sample
  - 8 250 ml samples (2 liters)
- **Analyzed by Colilert (24 hour media)**
- **Sampling started in October 2005**
- **4 days per week**
- **Completed Sampling December 2006**
- **Also collected concurrent data on Temperature, Turbidity, pH and Total Chlorine Residual**

# TBW / PCU Summary Results

Total Coliform Samples	Taken	Positive for		Percent +	
		TC	EC	TC	EC
100 ml	1464	5	1	0.34%	0.07%
250 ml	11696	21	0	0.18%	0.00%
2.1 Liter	1464	22	1	1.50%	0.07%

- Two (2) sampling events had 1X100 ml positive and 1X250ml positive samples
- Two (2) Sampling events had 2X250 ml positive samples

# TBW / PCU Observations

- **Very low incidence of positive samples (26 total)**
- **Only 1 positive E-coli sample out of 13,160 samples**
- **Multiple positive results in only 18% of the positive events**
  - **Heterogeneous**
- **No correlations between positives and any other data**
- **250 ml samples provide no more information than 100ml samples**
- **2.1 liter samples express a higher rate of positives than both 100 and 250 ml samples for total coliform**
- **Over 80% of positive samples were from a localized area**
  - **End of 64, Keller 1 and Keller 2**
- **Detectable patterns emerge after THOUSANDS of samples**

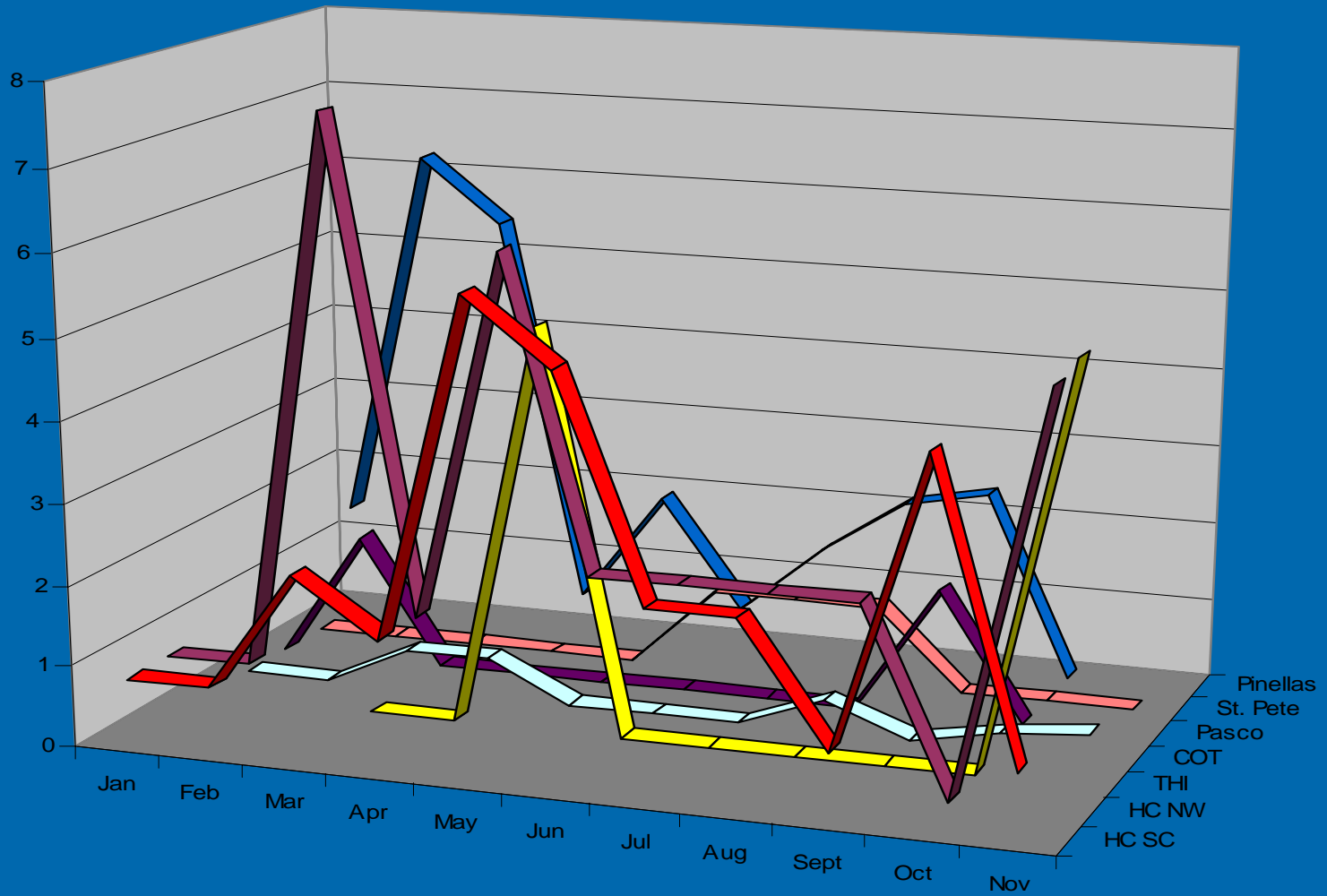
# Implications for TCR

- **Sample volume could matter**
- **Timing of sampling does not matter**
- **Location is important**
- **Difficult to measure if mitigation has any effect (what changes are meaningful? 1%? 5%?)**
- **Need many samples to detect even 5% changes**
- **No surrogates apparent from these data**

# Increased Volume

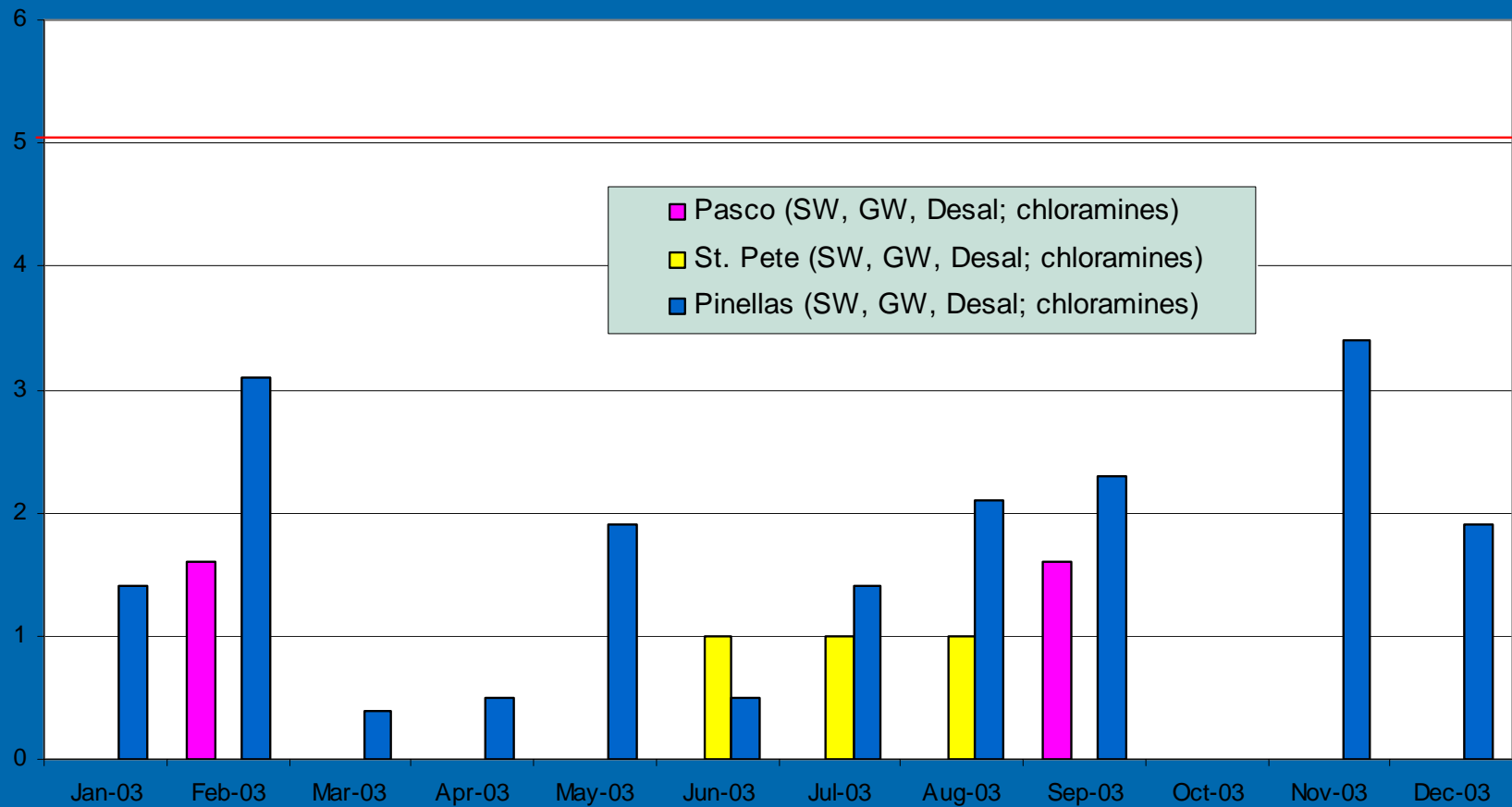
- Possible roles in sampling options
- Roles in repeat sampling?
- Efficacy of the indicator
- Other

# 2003 Regional TCR Compliance

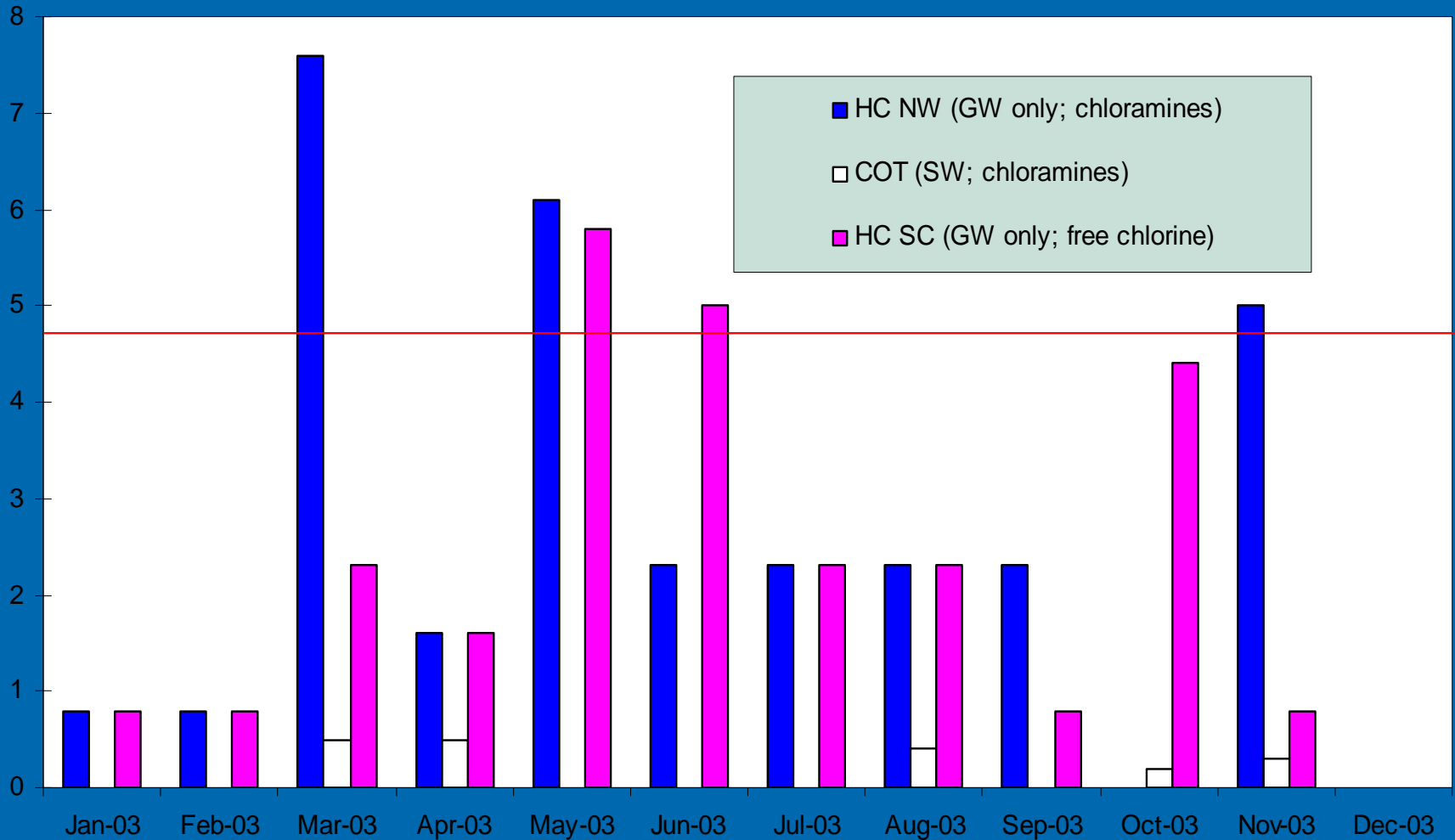


# 2003 TCR Compliance

## Systems Receiving New Water Supplies



# 2003 TCR for Systems NOT Receiving New Supplies



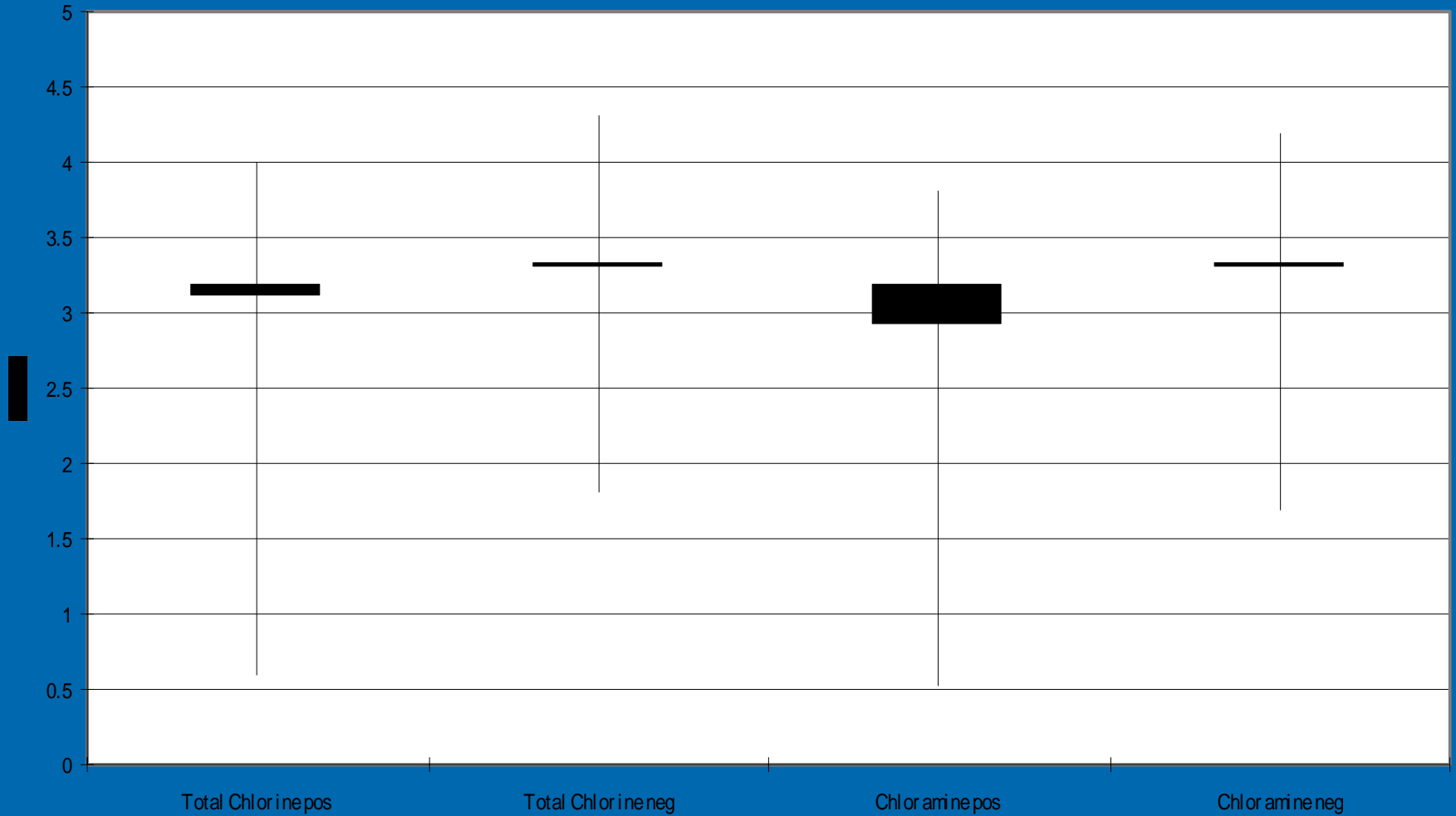
# Hillsborough County

- Northwest TCR compliance
  - 1.1% mean
  - 7.6% max
- South Central TCR compliance
  - 1.0% mean
  - 5.8% max
- Extensive evaluation of analytical methods and sample taps resolved much of the issue

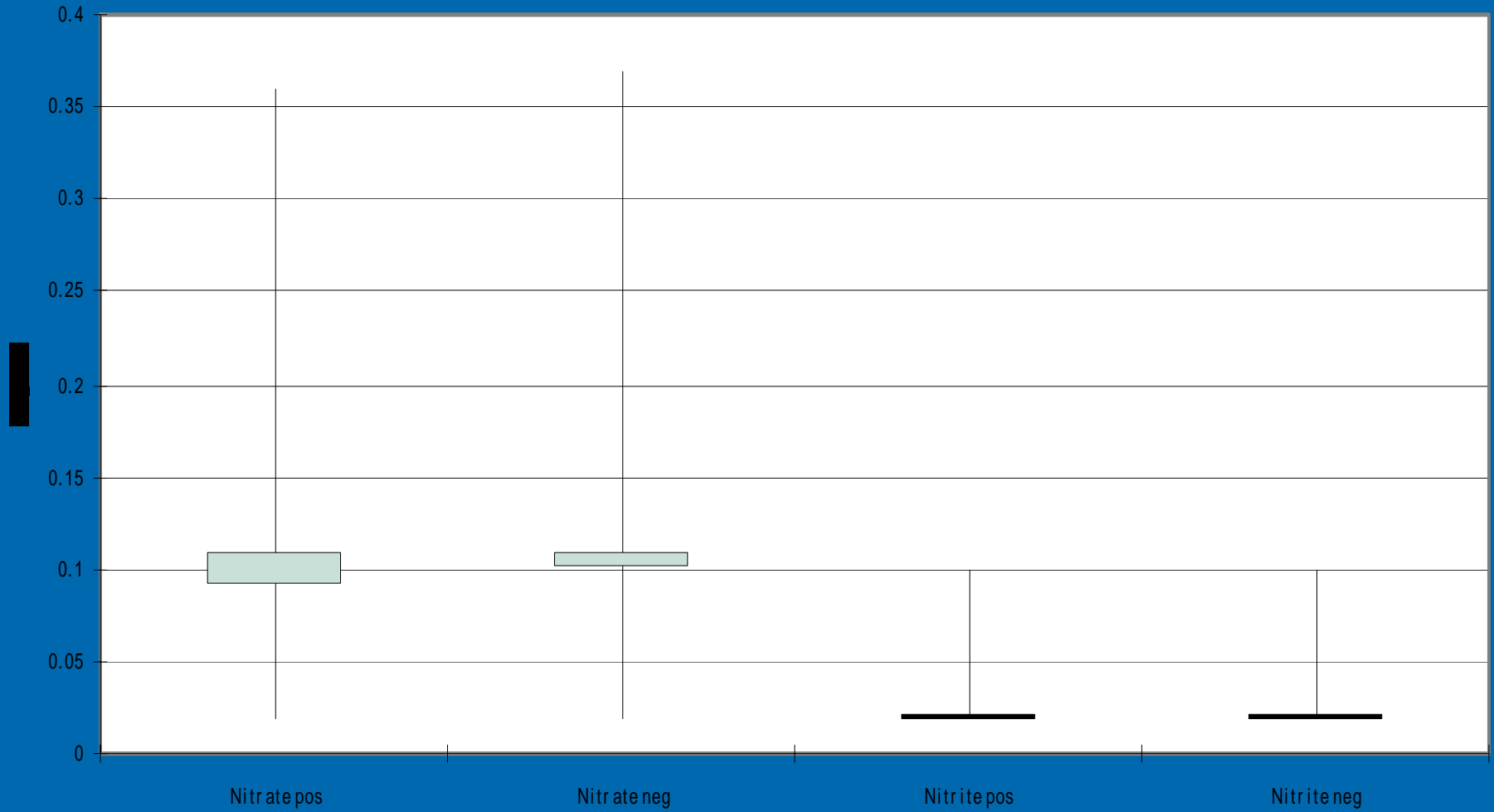
# Pinellas County

- Total Coliform Rule compliance
  - Mean 0.9%
  - max 4.4%
- More than 70% TCP's in 2003 located in NW section of County
- Nitrification reported
- Flushes in response to customer complaints, system maintenance, and unidirectional

# Disinfectant Residuals



# Nitrate/Nitrite (N=448)





# Hydrogen Sulfide Removal Process and Total Coliform

- Forced Draft Aeration commonly used in FL to remove hydrogen sulfide
- Increased turbidity following implementation (>8 NTU's)
- Turbidity is NOT inorganic precipitation; it is biological; FDA samples all TC positive
- Cleaning frequencies and procedures reviewed (survey and site visits)
- Initiated aggressive weekly cleaning

# Floor of FDA before cleaning



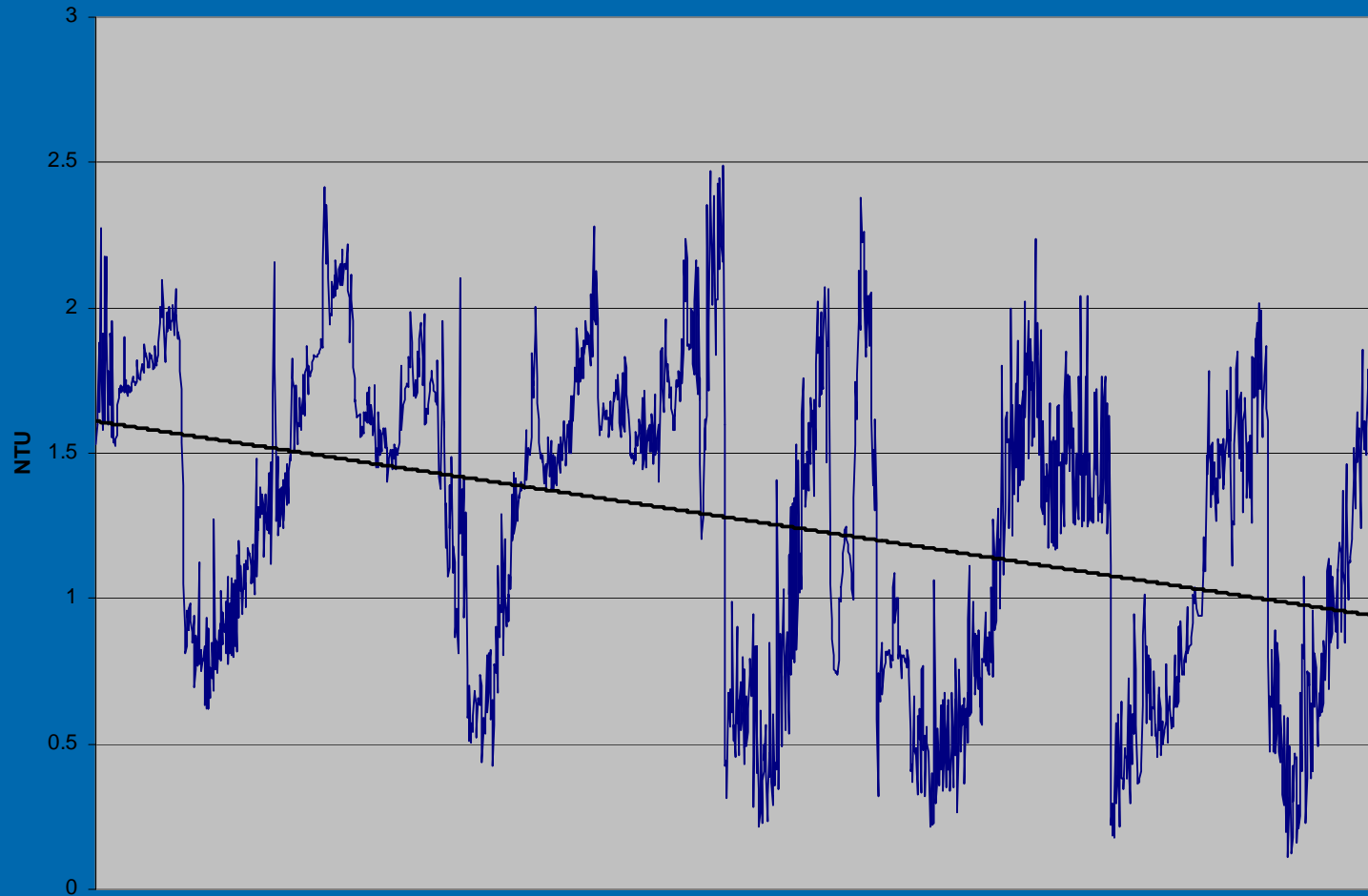
# Tower Bioflora



# Forced Draft Aerator Before Cleaning



# Turbidity and Cleaning Cycles

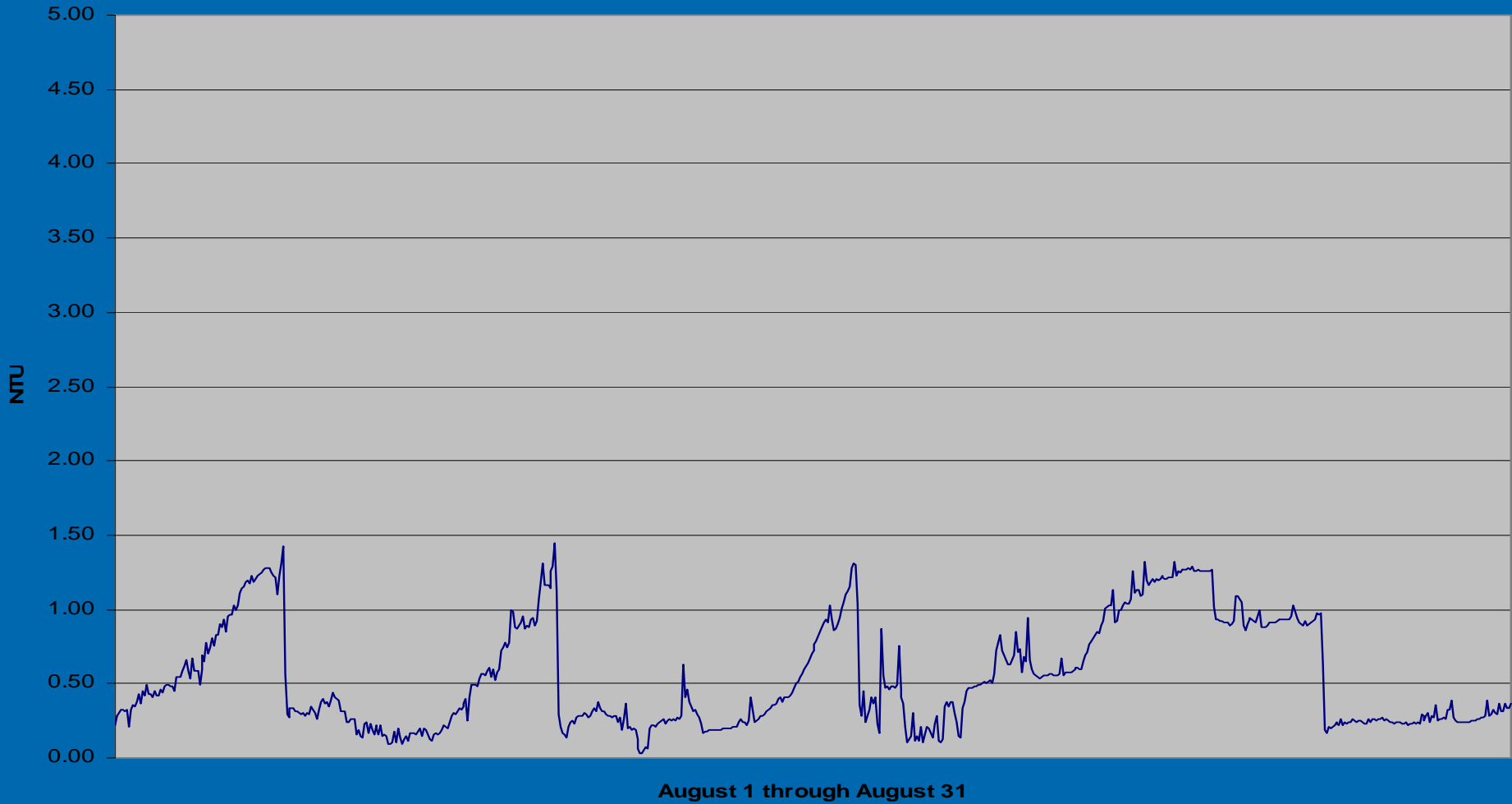


JAN 3 - MAR 10, 2004

# FDA after cleaning



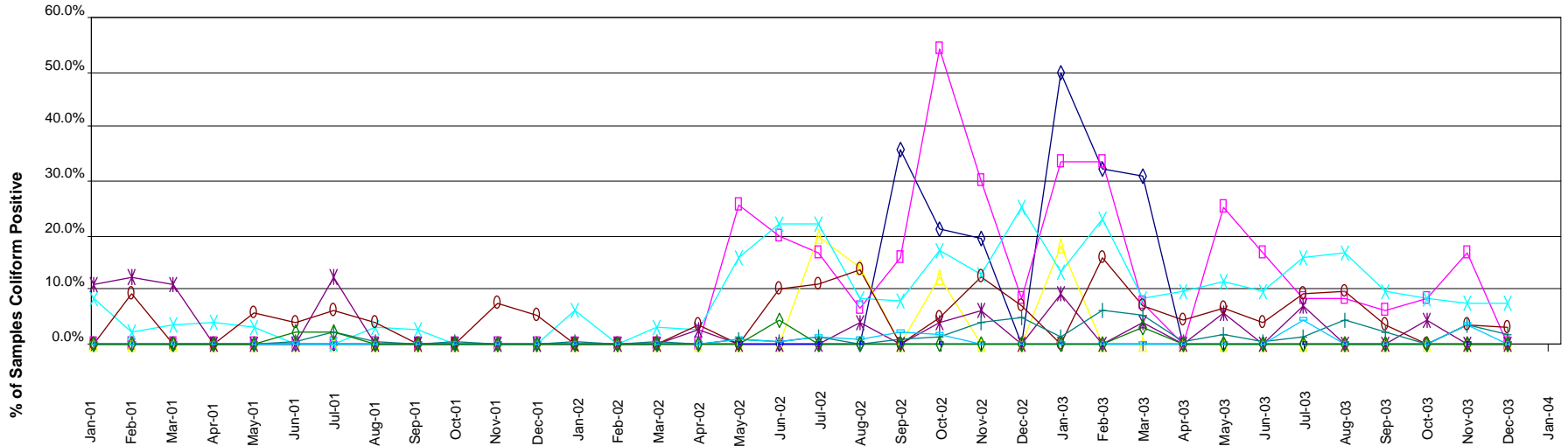
# August 2004 Turbidity Levels



# TBW / PCU Observations

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# Positive Bac-t Results



**New secondary disinfection (chloramines) in May 02**

**New water sources in Sept 02**

**Disinfection process modified in August 02**

**Unidirectional Flushing Program April 02 to May 03**

**The perfect storm?**

# Take Home Message.....

- Focus effort on identifying real problems (i.e., FDA turbidity)
- Invest in getting the right data to evaluate the “resolution”
- Keep an eye open for unintended consequences
- Try not to change everything all at once! 😊
- Not clear that routine TCR monitoring would have identified or helped resolve the FDA issue

# Thank You!

