# Distribution System – Nitrification Causes and Controls

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# Nitrification Starts with Chloramination

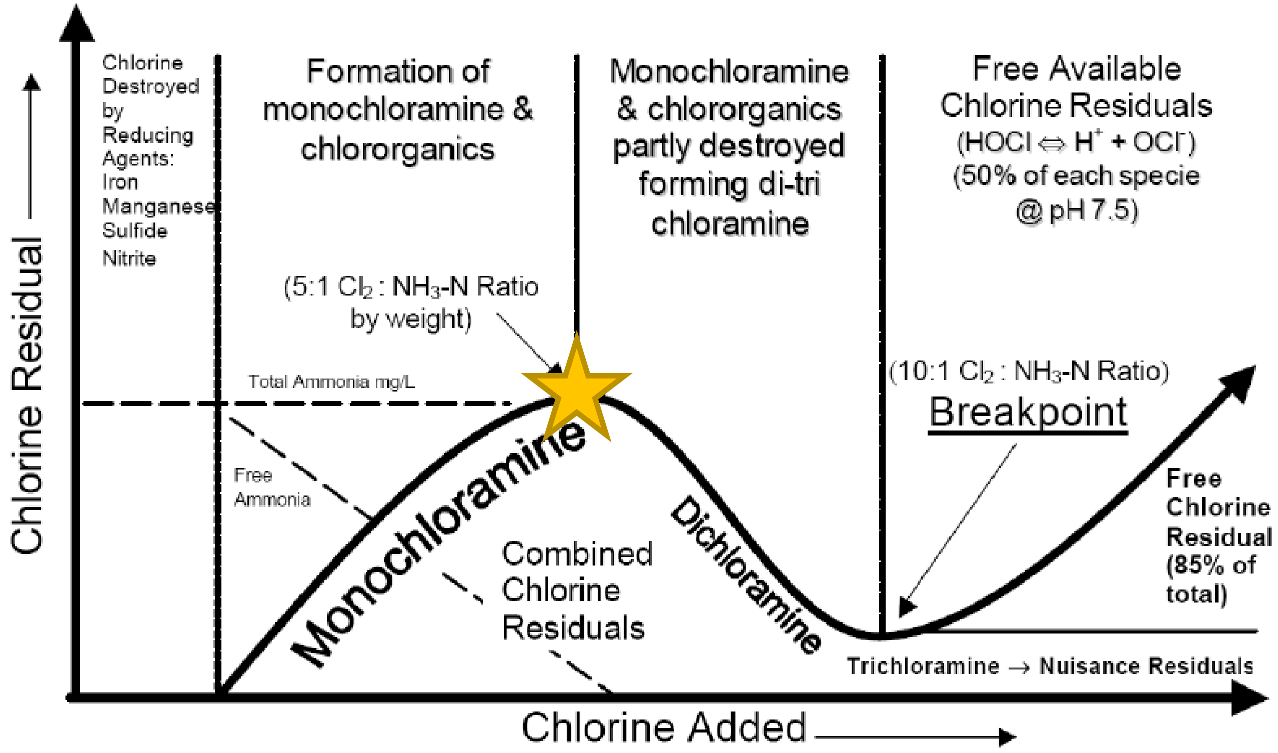
- Monochloramines are formed by:

$$HOCl \text{ (hypochlorite)} + NH_3 \text{ (ammonia)} \rightarrow NH_2Cl \text{ (monochloramine)} + H_2O \text{ (water)}$$

- Optimum $Cl_2$ to $NH_3$-N ratio = 4.5:1 to 5.0:1

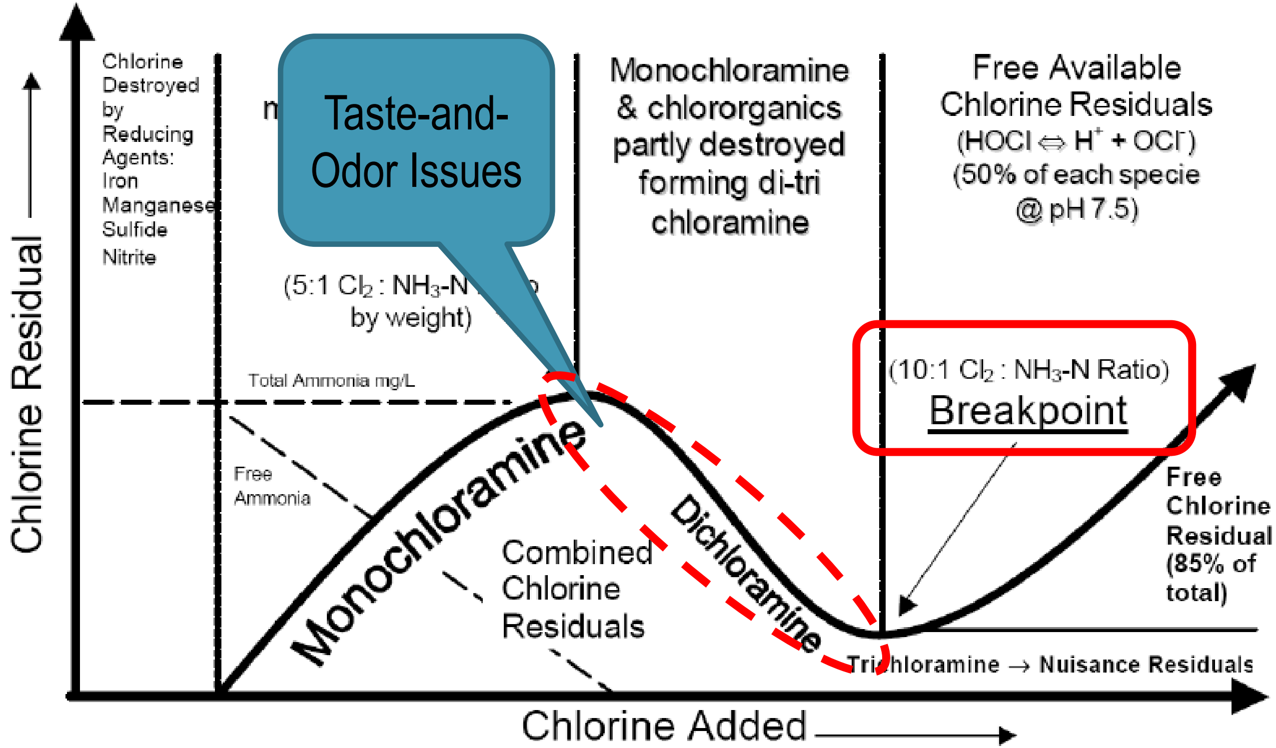
- More chlorine needed to minimize free ammonia

# Break Point Chlorination Curve



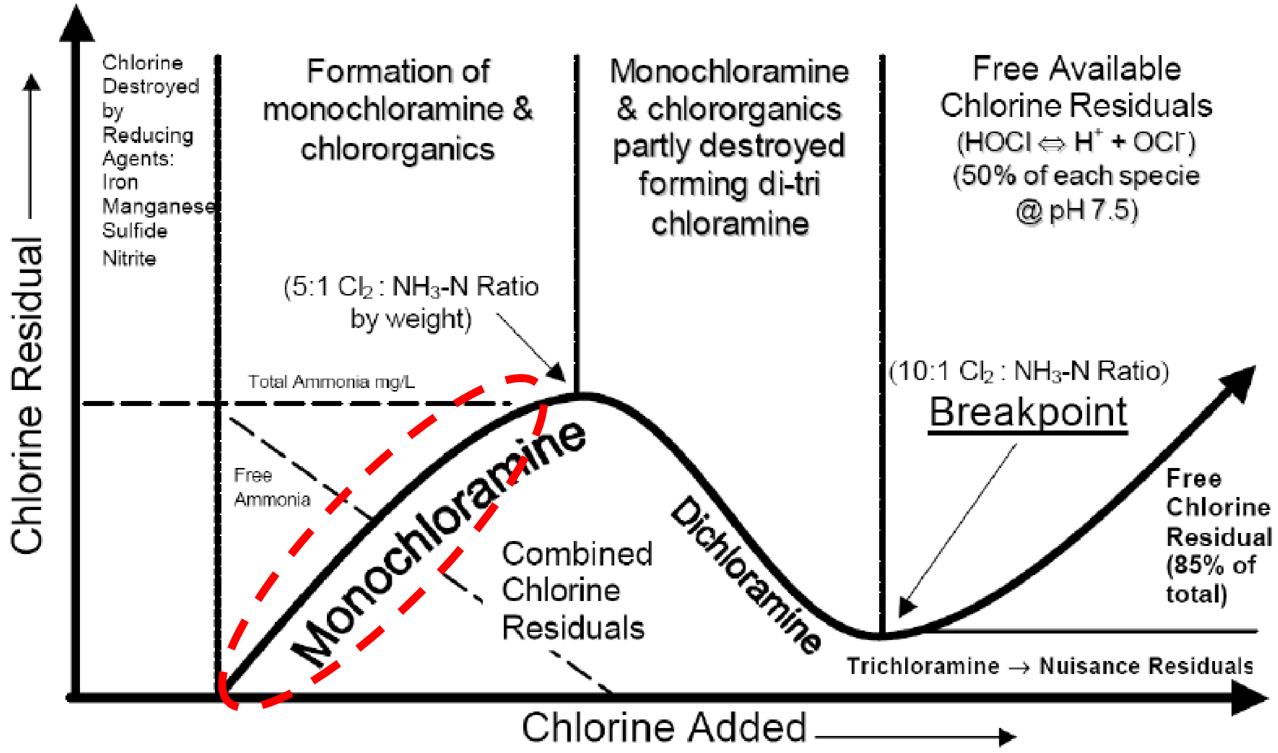

Source: Saskatchewan Water

# More Chlorine than 5.0:1 $Cl_2:NH_3$-N




Source: Saskatchewan Water

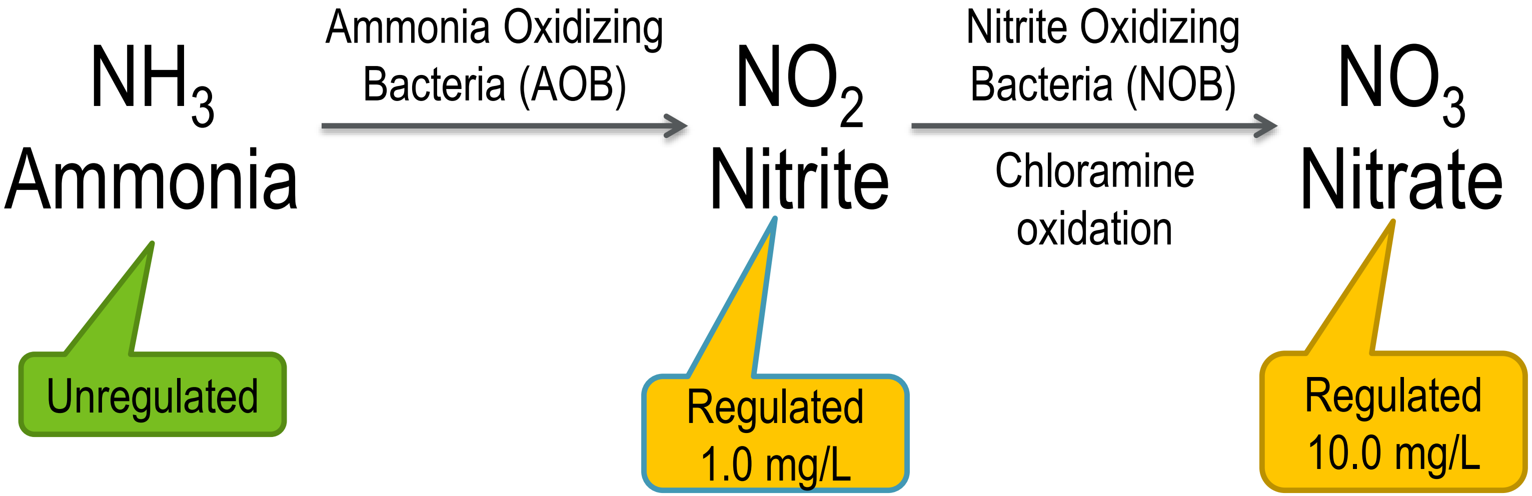
# How Does Nitrification Start?
# Have Chlorine Less than 4.5:1 $Cl_2:NH_3$-N




Source: Saskatchewan Water

# Free Ammonia + Bacteria = Nitrification

- Nitrification is the oxidation of free ammonia to nitrite by bacteria.
- Nitrite conversion to nitrate to bacteria and chloramines.



## Other Factors for Nitrification

- Long water ages
- Poor reservoir turnover
- Dead end mains

→ Factors that causes chlorine residual to go away

- Tuberculated pipe
- In-pipe sediment deposits
- Reservoir deposits
- Biofilm formation

→ Factors that allows bacteria to grow

# Other Factors for Nitrification

- Water pH
  - Optimum pH is 7.2 – 8.5
  - A good pH for lead and copper corrosion control
  - Nitrification has been found between pH 6.5 and 10

- Water temperature
  - Often occurs when at 15 degC or higher
  - Biological activity likes warmer temperatures
  - Nitrification can still occur at lower temperatures

# Why is Nitrification Bad?

- Increased nitrite concentrations
  - Usually by 0.05 to 0.5 mg/L as N
  - Potentially by more than 1 mg/L as N
- Increased nitrate concentrations
  - Usually slight increase
  - Potentially by more than 1 mg/L as N
- Lower to no chloramine residuals
  - Chloramine oxidizes nitrite
  - Consumed in oxidizing bacteria

*Nitrosomonas europaea*

# More Bad News

- Significant increase in heterotrophic bacterial populations

- Potential for Total Coliform Rule violations

- Increase in organic nitrogen concentrations – acts as a nutrient

# And Even More Bad News

- Consumption of dissolved oxygen, often by 2 mg/L or more
  - Potentially reducing conditions (no oxygen, no chloramines)
  - Red water, taste-and-odor complaints, metals release

- A slight pH decrease
  - Bacteria consumes oxygen and releases carbon dioxide
  - Carbon dioxide in water is an acid (carbonic acid)
  - May be difficult to detect due to variable distribution system operations
  - Could affect lead and copper compliance

# How Do You Know Nitrification is Occurring?

- Robust distribution system monitoring program

- Normally monthly sampling, weekly when nitrification potential is high

- Samples taken at:
    - Raw water supply
    - Distribution system Point of Entry
    - Reservoirs with long water ages
    - Dead-end mains
    - Routine coliform monitoring stations

# What to Sample

Minimum Recommended

- Heterotrophic plate count
- Free ammonia
- Total ammonia
- Nitrite
- Nitrate
- Chlorine dose
- Chloramine residual

Nice to Haves

- Temperature
- Dissolved oxygen
- Alkalinity
- pH
- Total organic carbon
- Dissolved organic carbon
- Assimilable organic carbon
- Ammonia oxidizing bacteria counts

# What Happens If You Find Nitrification

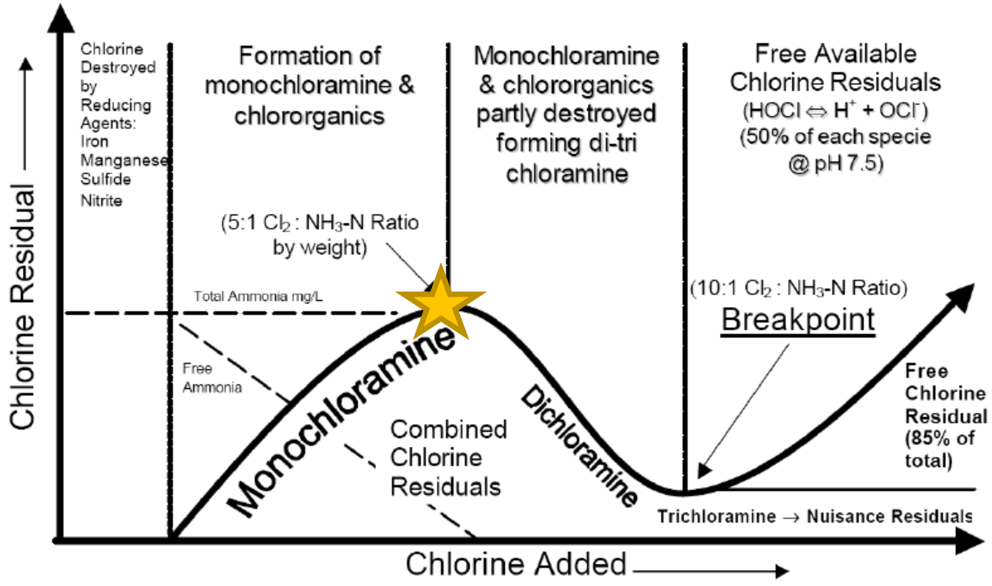
- Temporary solutions
  - Operational fixes

- Long-term solutions
  - Distribution system improvements
  - Implement more treatment

# Operational Nitrification Control Measures

- Increasing $Cl_2$ to $NH_3$-N ratio back to 4.5:1 to 5.0:1

- Often an issue with multiple sources with different $NH_3$ concentrations or seasonally variable concentrations



# Operational Nitrification Control Measures

- Breakpoint chlorination (free chlorine burn) at select spots or throughout system

- Increasing chloramine residual from treatment plant or rechlorination stations
  - Increase both chlorine and ammonia

# Long-Term Nitrification Control Measures

- Treatment responses

- Greater disinfection to kill off more bacteria
  - Using something other than chlorine

- Removing organics (nutrients) with enhanced coagulation/filtration

- Improved ammonia monitoring and feed systems

# General Distribution System Best Practices

- Pipe flushing and pigging to remove sediment and tubercules
- Eliminating dead-end mains
- Reducing detention time in reservoirs and throughout the distribution system

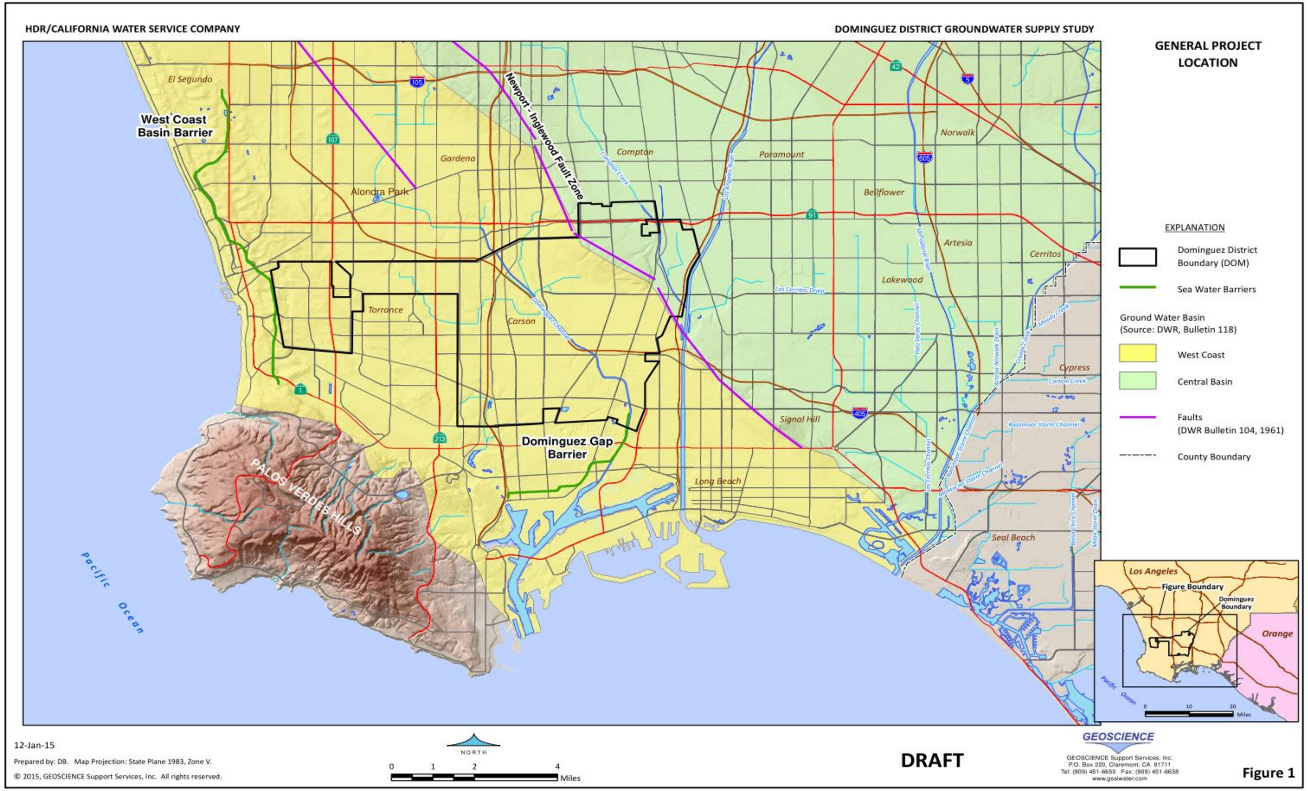
# Case Study – CalWater, Los Angeles

- Serves southern Los Angeles County
  - Los Angeles, Long Beach, Carson, Compton, Torrence

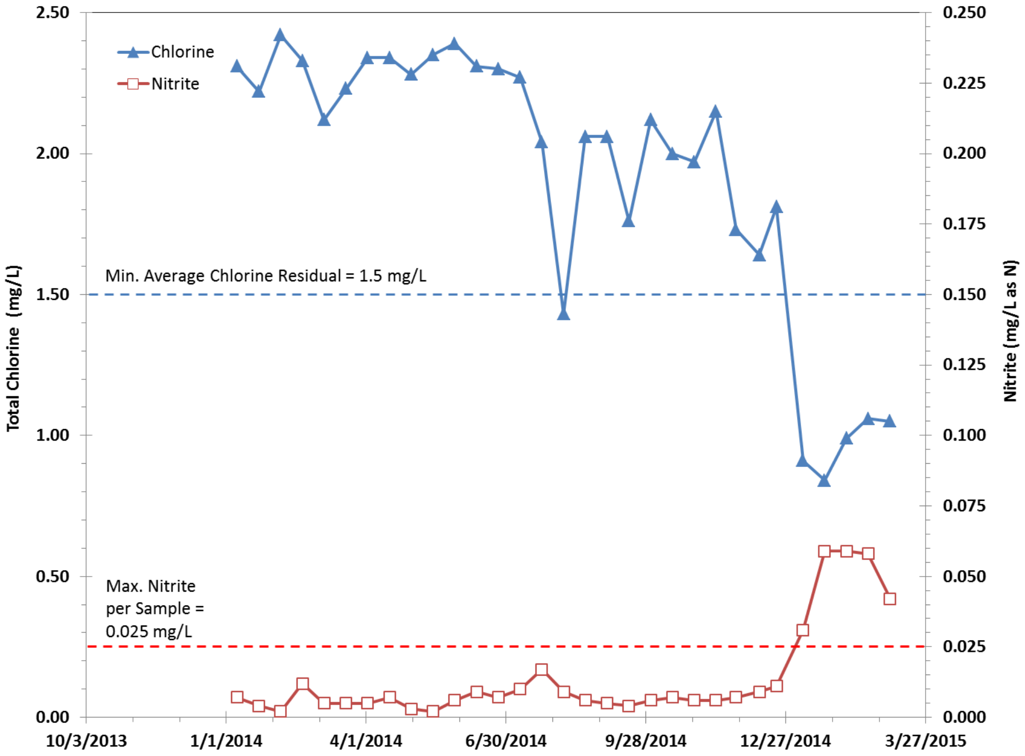
- Water supply
  - Metropolitan Water District of Southern California (Colorado River water)
  - Ten wells owned by District
  - One well owned by another District

- All supplies chloraminated for disinfection byproducts control.

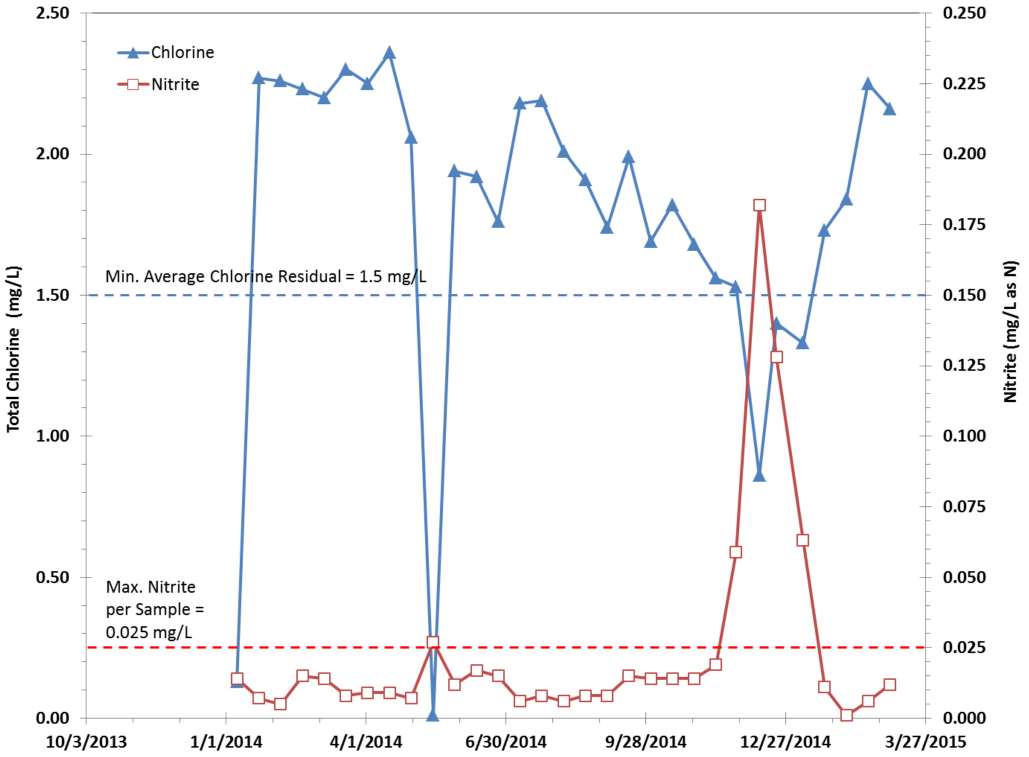
# Case Study – CalWater, Los Angeles



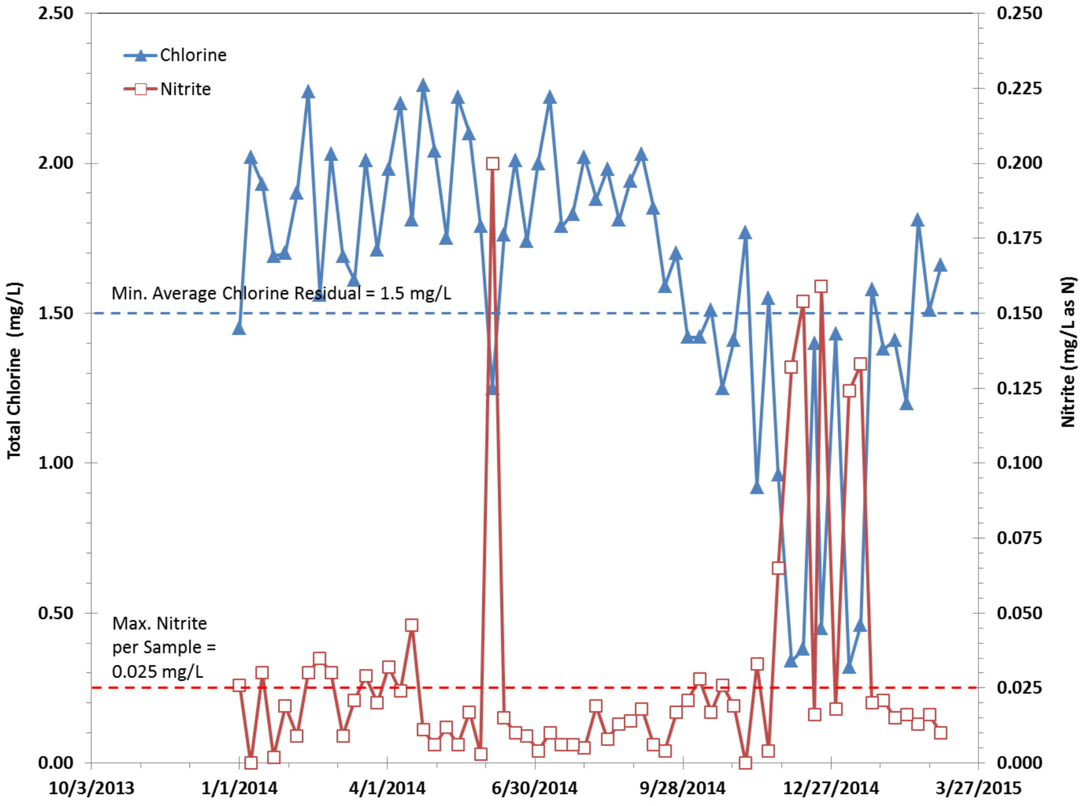
# TCR Site No. 4 – Slowly Increasing Water Ages



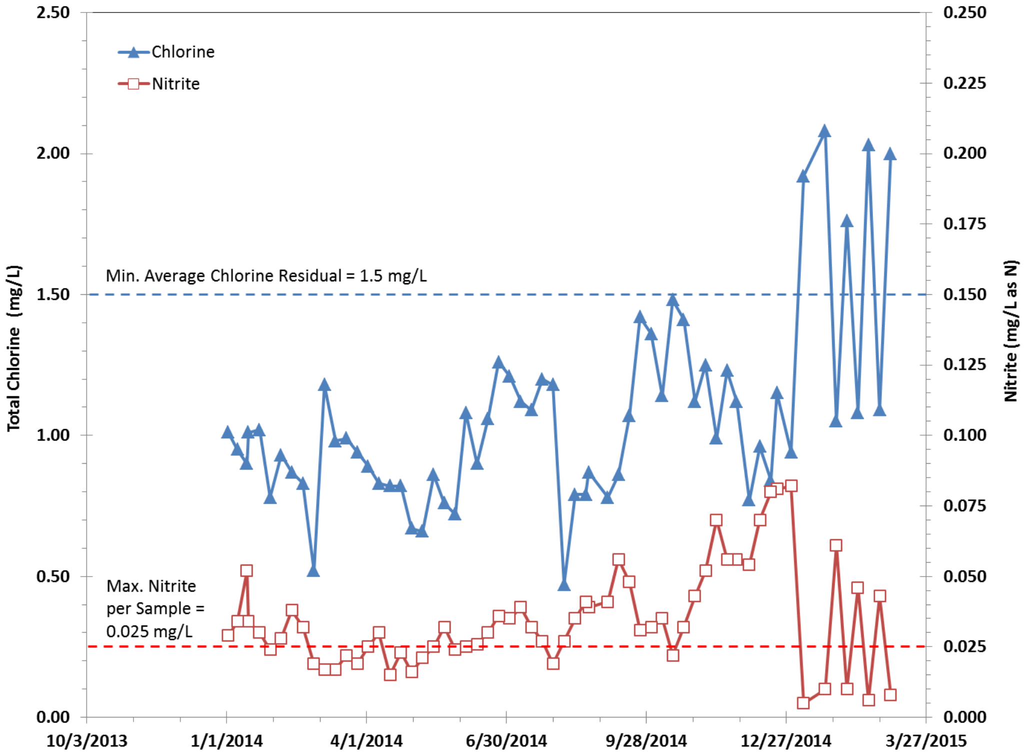
# TCR Site No. 1 – Free Chlorine Burn



# TCR Site No. 28 – Pump Control Issues



# TCR Site No. 5 – Alternating Supplies



## Study Recommendations

- Free chlorine burn by pressure zone – two weeks at a time
- Implement treatment at six wells
- Replace/upgrade chlorine feed systems
- Install on-line ammonia monitors
- Continue with routine sampling at 30 locations

# Summary

- Nitrification is very common for chloraminated systems
- Can lead to multiple negative effects in the distribution system
- Precision chemical feed control is important
- Robust raw water and distribution monitoring is also important
- There are several short-term fixes to address the issue
- Persistent issues need to be addressed with treatment
- Having an optimized distribution system operations goes a long way to control nitrification.

# Distribution System – Nitrification Causes and Controls

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