

# Changing Views of Manganese and the Regulatory Horizon

PNWS-AWWA  
Boise, ID  
May 6, 2016



Melinda Friedman, PE  
Stephen Booth, Ph.D.

Confluence Engineering Group, LLC  
206.527.6832  
[www.confluence-engineering.com](http://www.confluence-engineering.com)



# Presentation Overview

## ■ Background - **Melinda**

- Overview
- Traditional View of Mn Issues

## ■ Emerging Issues - **Melinda**

- Mn Health Effects
- Mn-Supported Accumulation of Trace Contaminants

## ■ Utility Guidance - **Stephen**

- System Risk Assessment
- Mitigation and Control



# Traditional View of Mn Issues – All Apparently Incorrect....

## ■ Aesthetic problems only if $>$ than secondary MCL (SMCL)

- ❑ SMCL based on aesthetic threshold of 0.05 mg/L
- ❑ Staining/spotting of laundry, fixtures, etc.
- ❑ *But...New research suggests goal of  $\leq 0.02$  mg/L more appropriate*

## ■ Not a health-based or regulatory concern at low levels

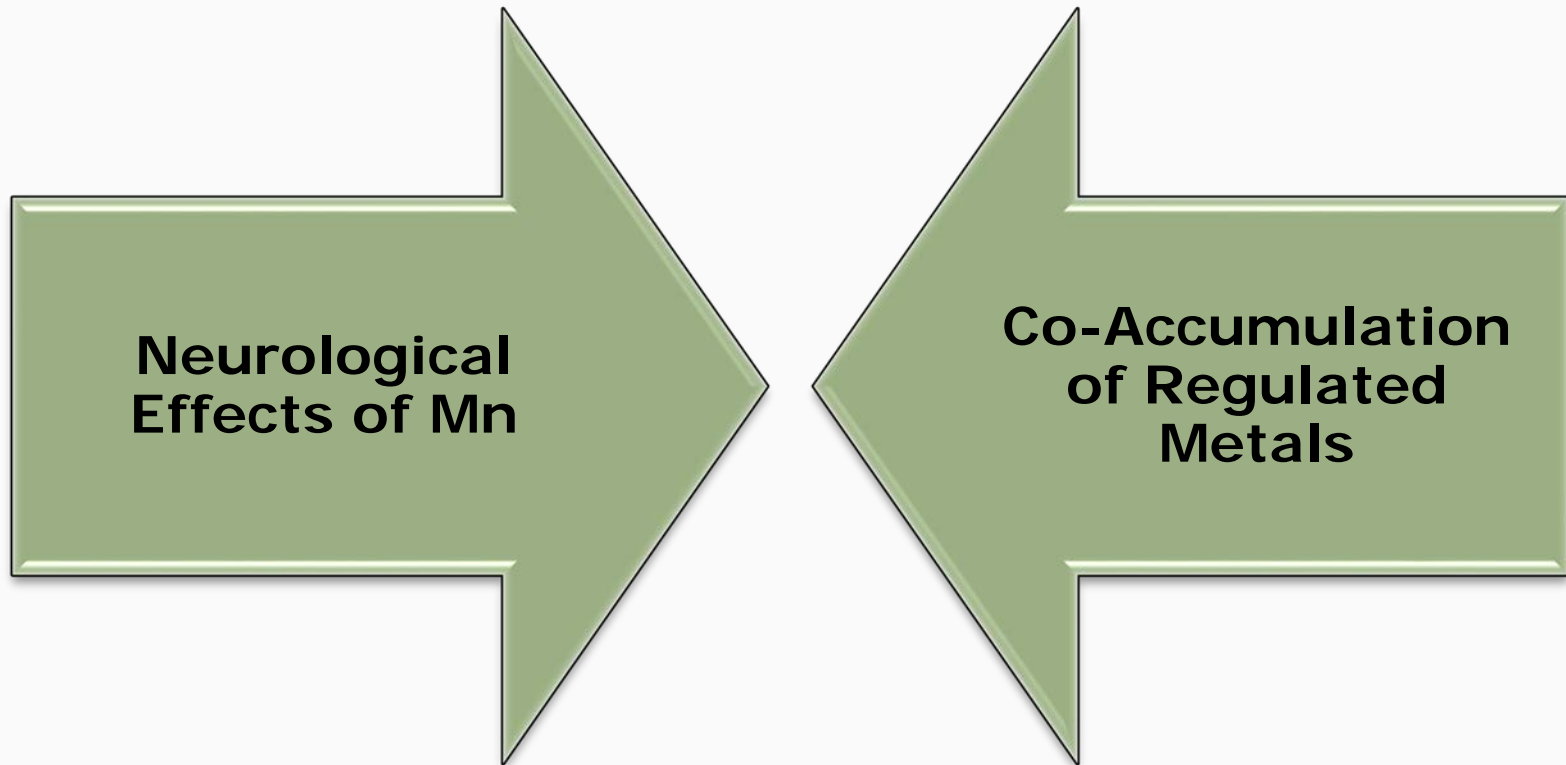
- ❑ Essential element in humans and animals
- ❑ Unregulated – no federal primary standard
- ❑ Health Advisory Value (HAV)
- ❑ SMCL of 0.05 mg/L  $\ll$  levels of health concern
- ❑ *But...new research suggests lower threshold health impact*

## ■ Considered “Self-Limiting”

- ❑ Yuck factor
- ❑ *But...soluble releases may not be visible*



# Two Main Areas of Health Concern



# Current Mn Regulatory Environment

Agency	Type	Level (mg/L)
USEPA	Maximum Contaminant Level (MCL)	None
	Secondary Maximum Contaminant Level (SMCL)	0.050
	Lifetime Health Advisory Value (HAV) - chronic	0.3
	1 & 10 Day Health Advisory HAV - acute	1.0
	Infants and Children HAV - acute	0.3



# Emerging Mn Issue #1: Recent Health Effects Research

## ■ Concern with infants and children

- ❑ Higher absorption and retention rates
- ❑ More susceptible to neurotoxic effects
  - Increase in hyperactivity (Bouchard et al. 2007)
  - Decreased intellectual performance (Bouchard et al. 2011)
  - Decrease in memory and motor function (Oulhote et al. 2014)
- ❑ Statistically significantly correlated with heart birth defects (Sanders et al, 2014)

## ■ Concern with elderly

- ❑ Can cause disease similar in nature to Parkinson's

## ■ Health effects observed at fairly low levels

- ❑ Various studies showed impacts over range of 0.03 – 0.2 mg/L



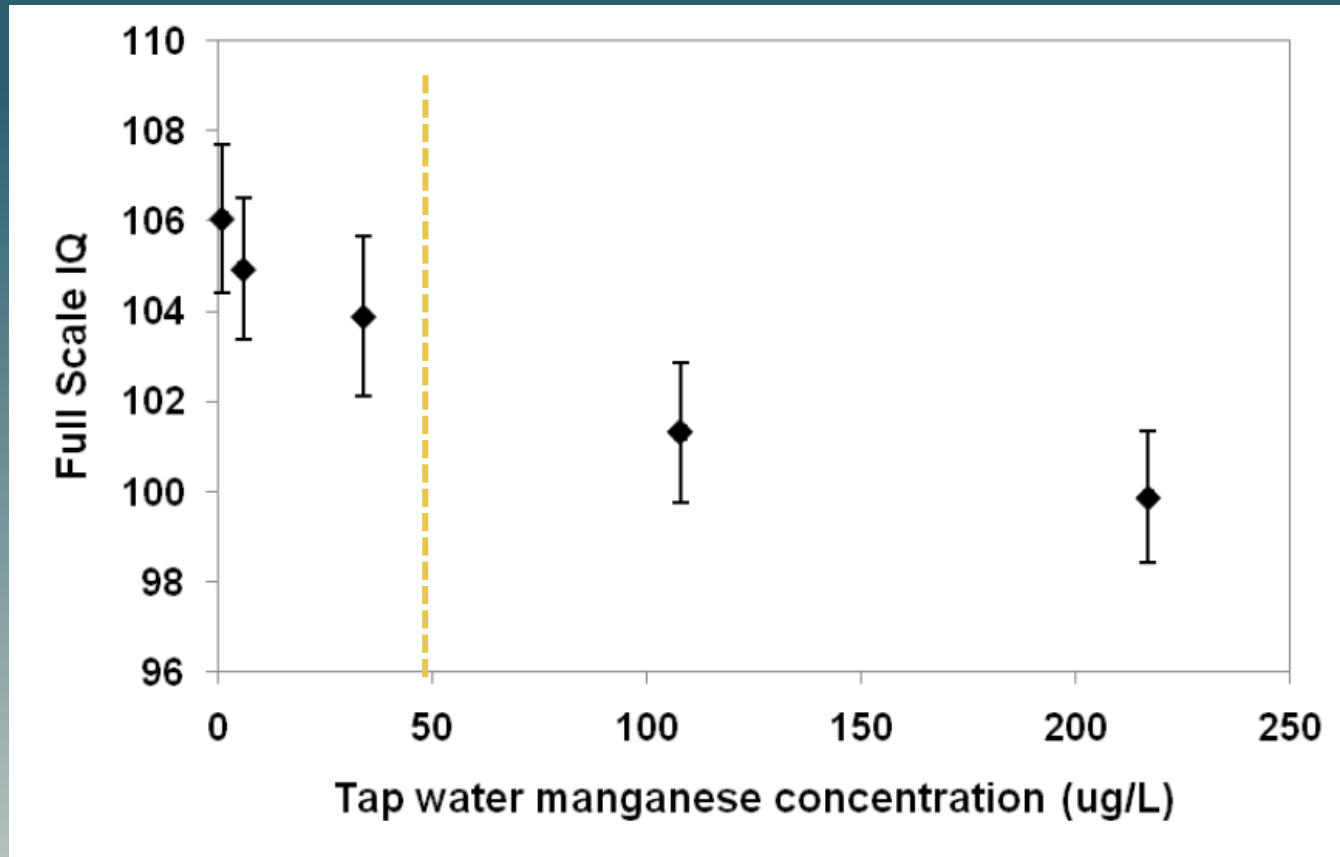
# Some Recent North American Studies

- **Intellectual Impairment in School-Age Children Exposed to Manganese from Drinking Water (Bouchard et al, 2011)**
- **Neurobehavioral Function in School-Aged Children Exposed to Manganese in Drinking Water (Oulhote et al, 2014)**
- **Association Between Arsenic, Cadmium, Manganese and Lead in Private Wells and Birth Defects Prevalence in North Carolina: A Semi-Ecological Study (Sanders et al, 2014)**
- **Associations of Early Childhood Manganese and Lead Co-exposure on Neurodevelopment (Henn et al, 2011)**



# Mn in Drinking Water: Cognitive Effects in Children

(Source: Bouchard et al, 2011)



- 10-fold increase in Mn associated with reduction of 2.4 IQ points
- Median Mn concentration = 34 ug/L (1-2,700 ug/L)
- 362 children in southern Quebec between 6 and 13 years of age



# Newer Understanding of Exposure Routes (Source: Bouchard et al, 2011)

- Mn neurotoxicity well documented from airborne exposure
- Water different than food
  - Mn is an essential nutrient in food
    - Recommended dietary allowance of 1.5-1.9 mg/d for children 6-13
  - Mn in hair increased with water intake but not food intake
    - Median water intake 1.6 ug/kg/month
    - Median food intake 2335 ug/kg/month
  - Metabolized differently when ingested in food vs. water
    - Diluted by intake of fiber, tannins, oxalic acids, etc.



# More on Exposure (Bouchard et al, 2011)

## ■ Persistence of effects unknown

- ❑ Shown to be persistent in mice
- ❑ Accumulated in the basal ganglia, white matter, and cortical structure with signs of neuronal degeneration in non-human primates

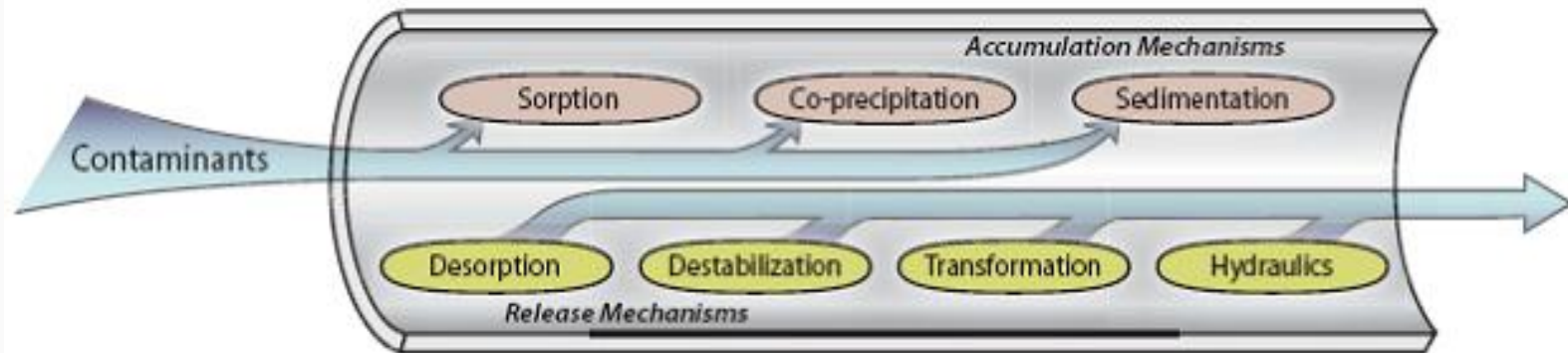
## ■ Currently no consensus on optimal biomarker

- ❑ Even at very high water concentrations, no relation to blood manganese levels in children
- ❑ Manganese content in hair reflects metal uptake averaged over the duration of the follicle formation



## Emerging Mn Issue #2: Accumulation of Metals within the Distribution System

- Can't install treatment and assume your problems are solved....
- Legacy manganese within the distribution system an on-going problem
  - Non-conservative behavior:  $in \neq out$
  - DS isn't just a conduit – it's a reactor



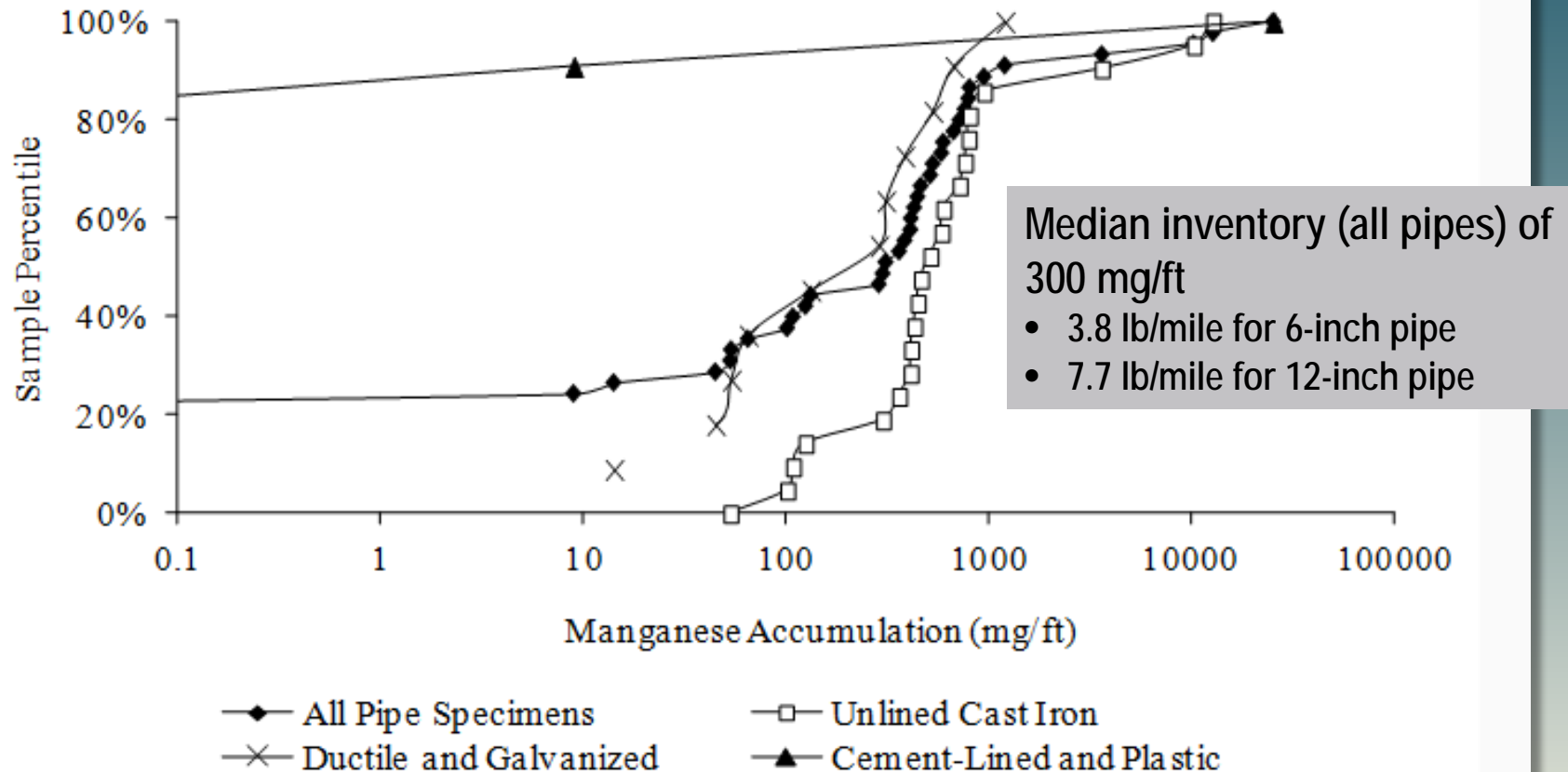
# Miles and Miles of Adsorptive Capacity...



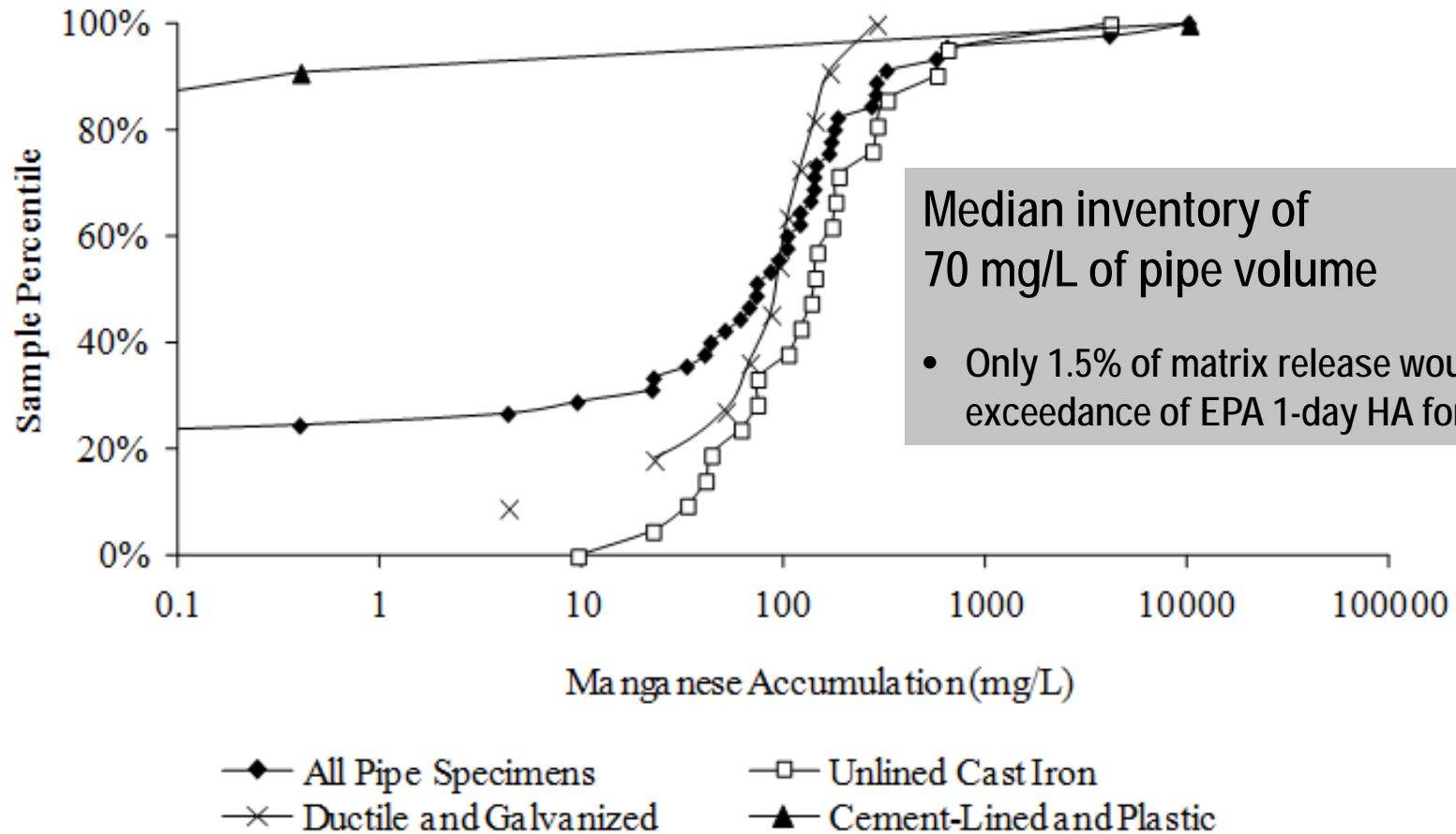
- We use iron to adsorb, coagulate, co-precipitate many contaminants at the treatment plant
- We use manganese oxide filter media to remove iron, manganese, arsenic at the treatment plant
  - $\text{MnO}_2$  media used for  $\text{Mn}^{2+}$
  - HMO solids for  $\text{Ra}^{2+}$
  - Natural analogs: scavenging of Pb, Cd, Cu, Tl, etc.
    - Trace metal cations



# Mn Inventory as a Function of Pipe Type – Accumulation Considerations



# Mn Inventory as a Function of Pipe Type – Release Considerations

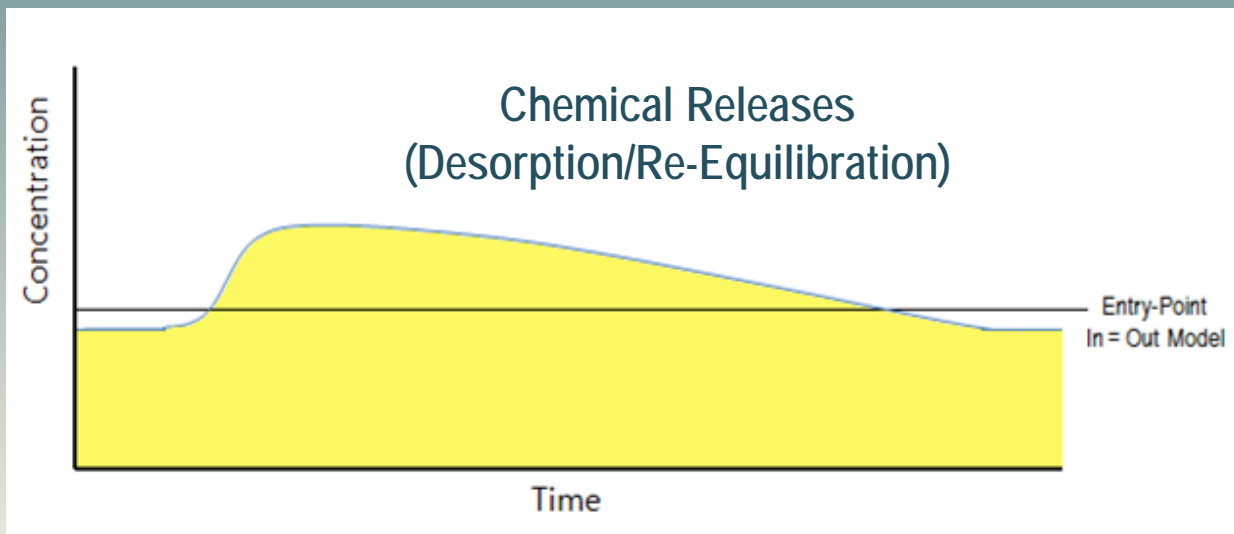
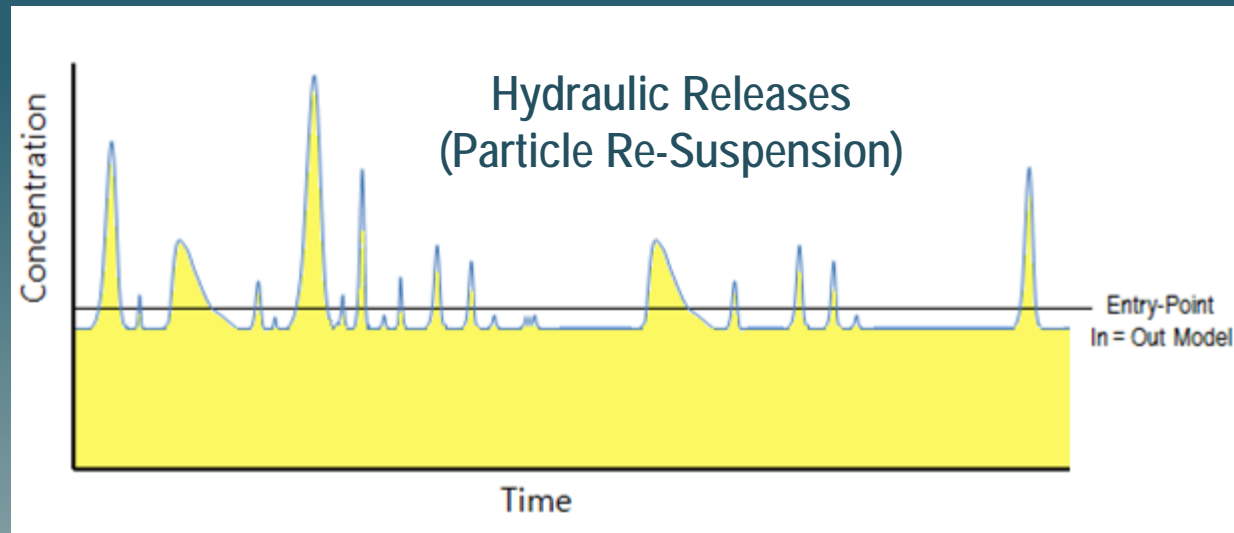


# Reasons for Concern – RELEASE!!

- **If it all accumulated and stayed put, then DS could be considered extension of treatment plant!**
- **Accumulated contaminants and microorganisms can be released**
  - ❑ Can result in elevated metals concentrations (>MCLs) at the tap
  - ❑ Can result in coliform occurrence
  - ❑ Exert disinfectant demand
  - ❑ Cause taste and odor problems
  - ❑ Mitigation strategies can cause additional problems

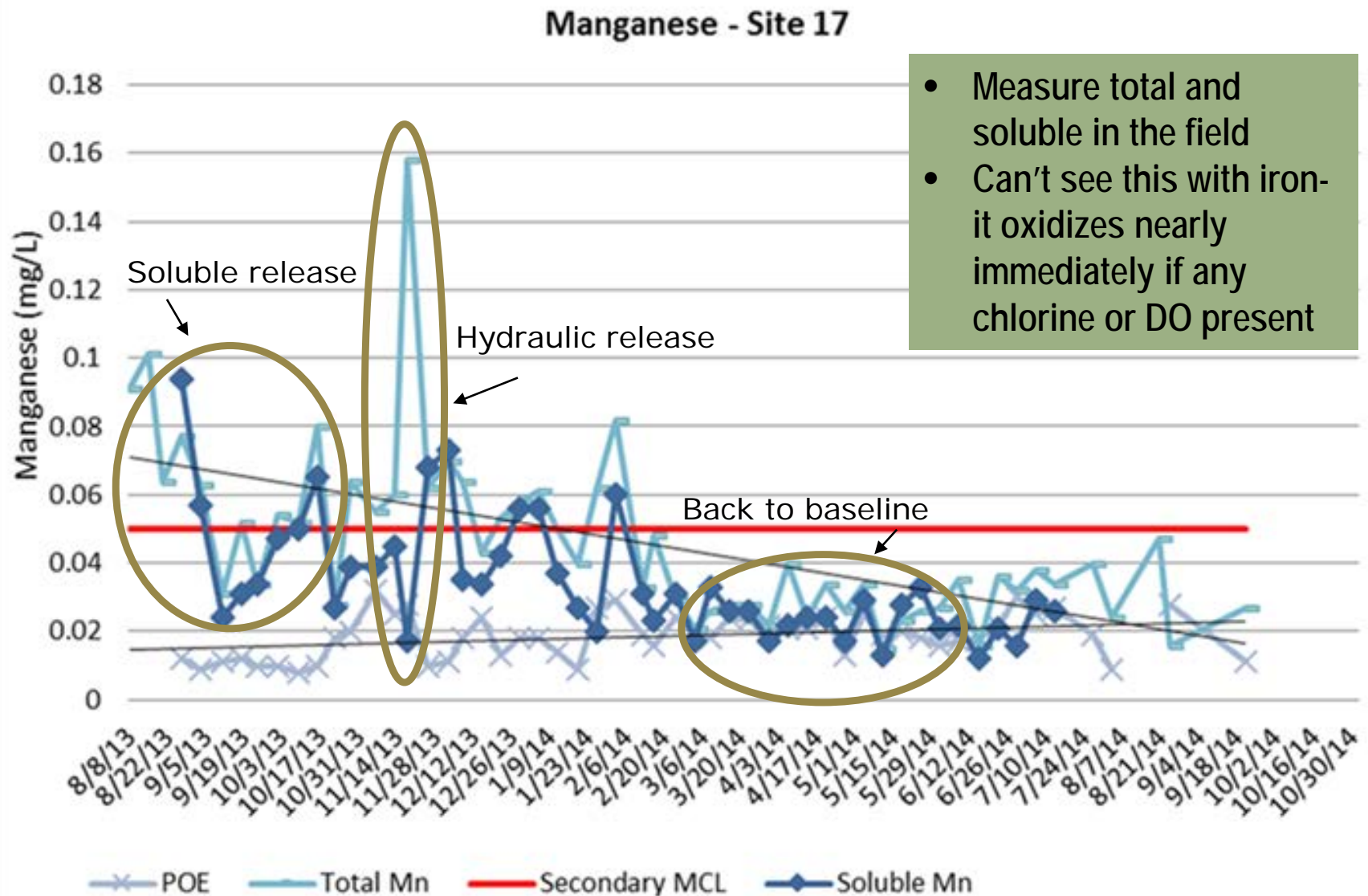


# Conceptual Contaminant Release Profiles





# Using Mn to track and understand releases

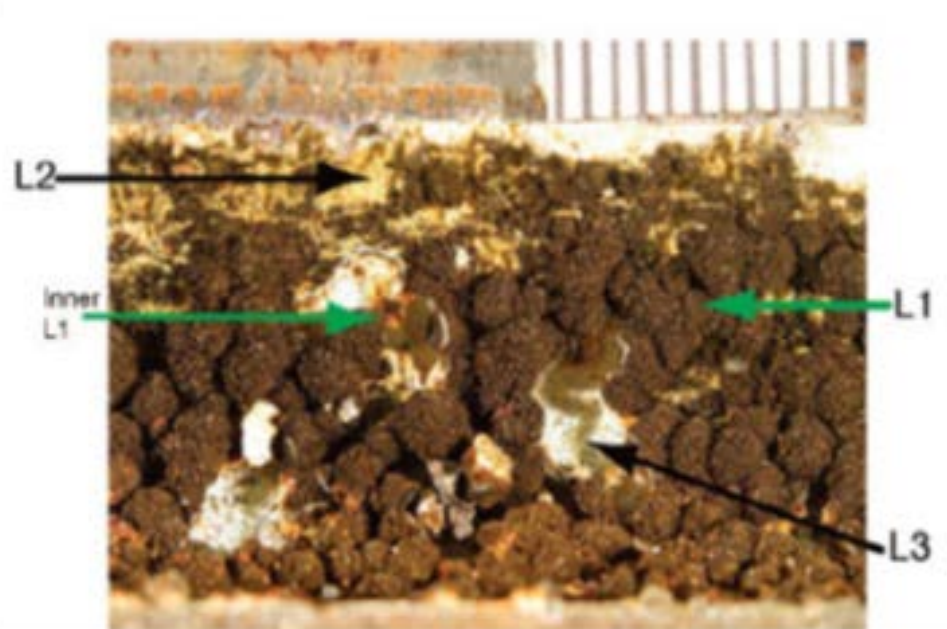


Science News –January 23, 2008

## Pipe scales release hazardous metals into drinking water

**Mobilization of mineral deposits within the distribution system can contaminate treated water before it reaches the tap.**

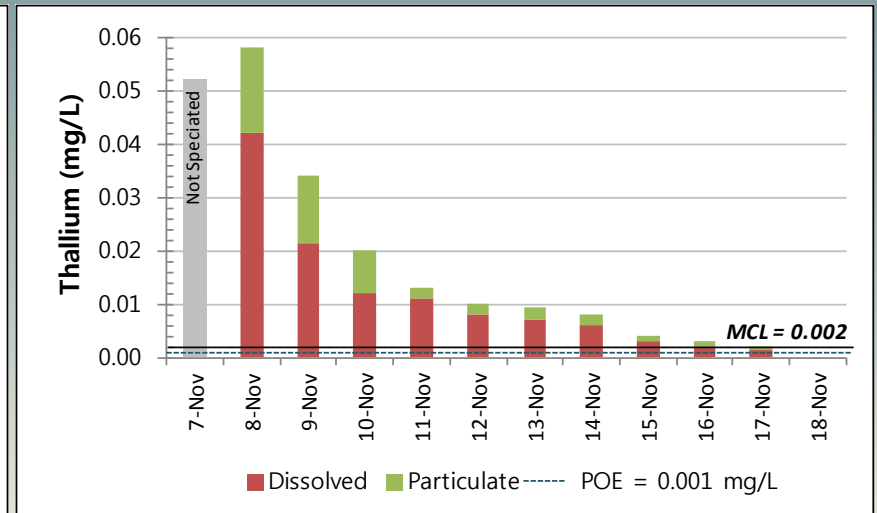
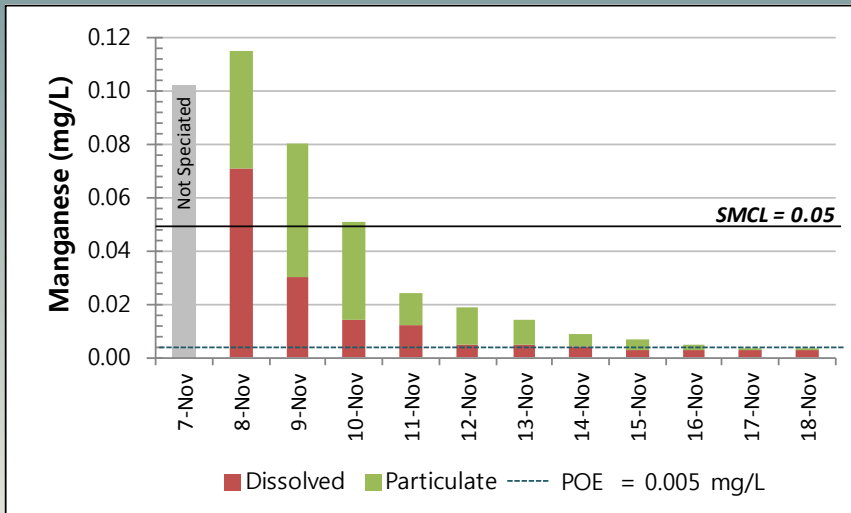
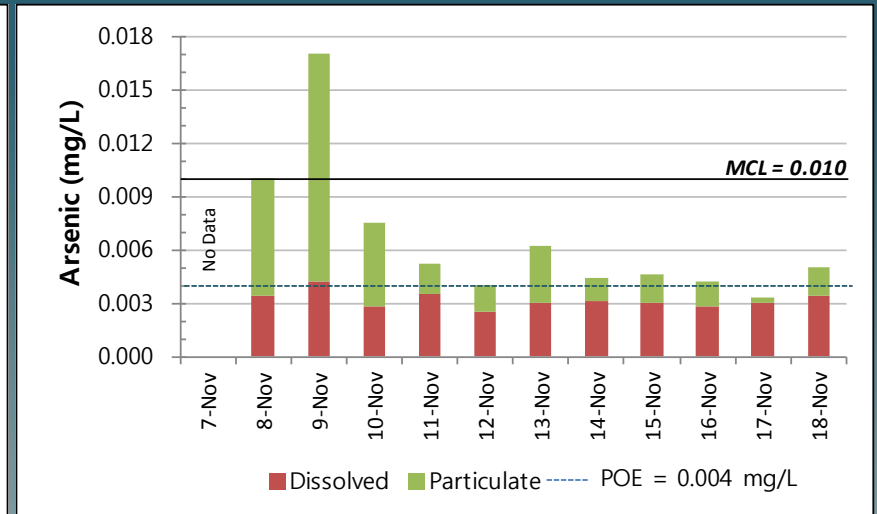
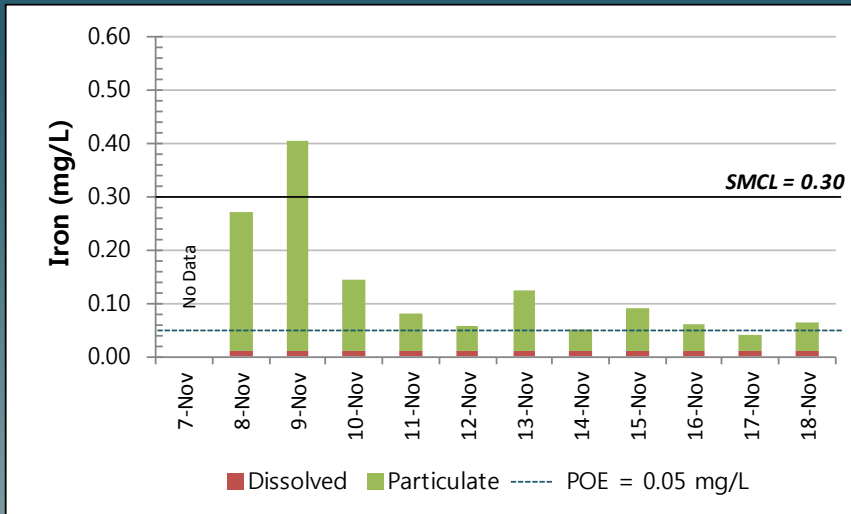
Mineral deposits inside drinking-water pipes can contain high levels of hazardous metals, including arsenic, cadmium, and mercury, and the metals can contaminate tap water when they are disturbed, according to new research published in *ES&T* (DOI: [10.1021/es0702488y](https://doi.org/10.1021/es0702488y)). But current water-quality regulations miss such disturbances, because they call for monitoring at the treatment plant before the water enters the distribution system pipes.



Michael Scheck et al.

Pipe scales concentrate many different metals.

# Metals Releases and Correlations



# Linear Regressions for Paired Occurrence Data – Ice Pigging

## AST Site

### Common Matrix Elements

Fe Mn Ca TUE

Trace Contaminants	As	0.91	0.23	0.15	0.83*
	Pb	0.30	0.90	0.00*	0.24*
	Tl	0.01	0.86	0.09*	0.24*
	Cu	0.83	0.46	0.13	0.77*
	Zn	0.51	0.75	0.07	0.50*

\* indicates negative slope

## UPA Site

### Common Matrix Elements

Fe Mn Ca TUE

Trace Contaminants	As	0.28	0.05	0.01	0.00
	Pb	0.13	0.72	0.03*	0.14*
	Tl	0.03	0.84	0.07*	0.23*
	Cu	0.29	0.90	0.01*	0.32*
	Zn	0.04	0.59	0.20*	0.26*

\* indicates negative slope

# Limitations of Current SDWA Framework

Metals monitoring  
and MCLs apply to  
system entry-points  
(POEs) only

MCLs intended to  
protect against  
chronic health  
effects



# Future Regulatory Action?

Health Canada is developing a primary  
MCL (MAC) for Mn

USEPA – on CCL4 and Proposed UCMR4  
-30 contaminants  
-Final expected in late 2016  
-Monitoring 2018-2020 at Entry Point to DS

# Conclusions

- Mn presents previously unrecognized risks
- On USEPA's radar screen – could have very wide-reaching impacts since not just a source water issue...
- Do not tell customers that colored water is “just a nuisance” or “safe to drink”, unless you have proven that it is
- Must monitor to determine potential issues (Chemical/Hydraulic release)
- Treatment at the source very important to reduce loading, but won't rid your system of manganese – it is the gift that keeps on giving!



# Questions?

**Presented By:**

**Melinda Friedman, P.E.**

**Stephen Booth, P. Eng.**

**Confluence Engineering Group, LLC**

**[melinda@confluence-engineering.com](mailto:melinda@confluence-engineering.com)**

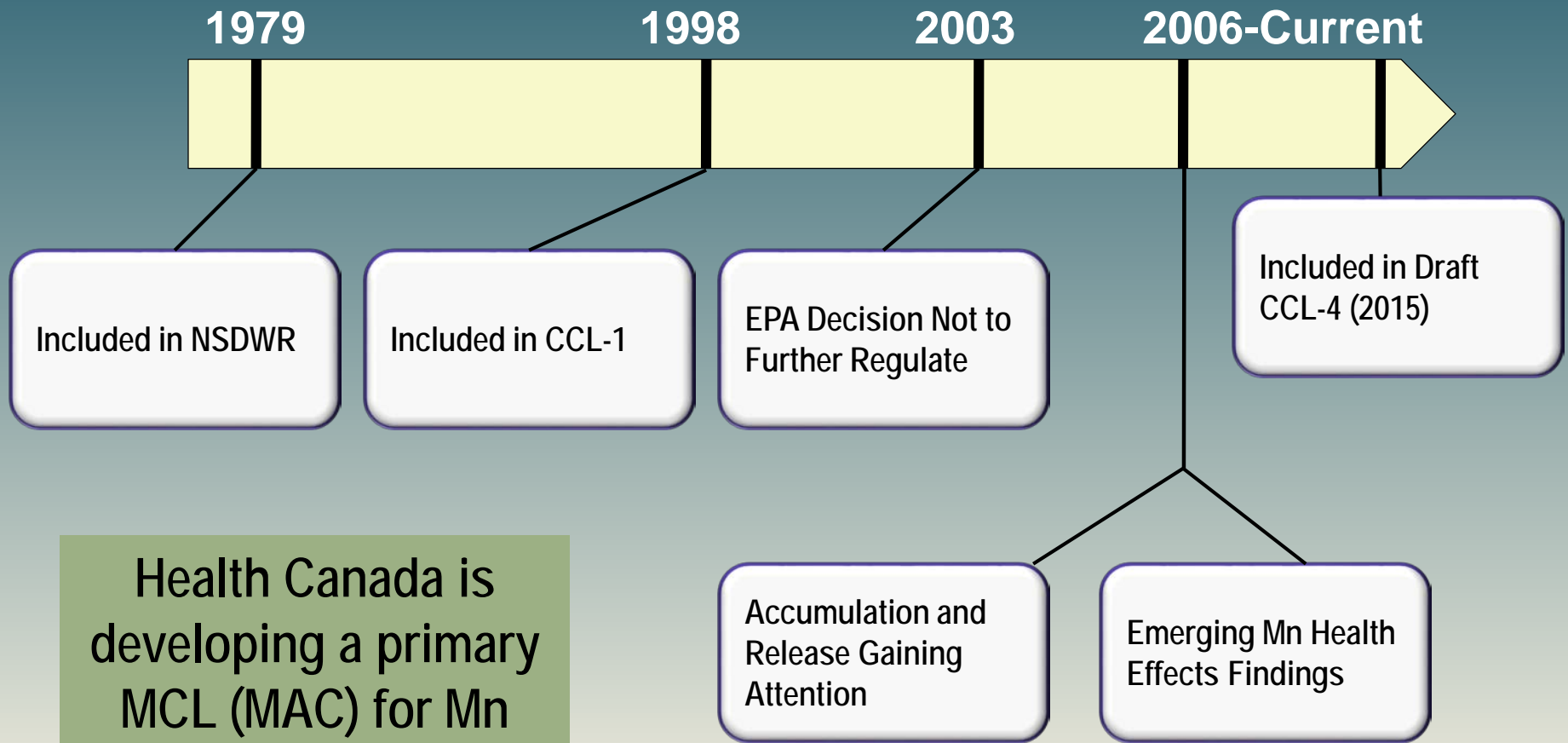
**206.527.6832**

**[www.confluence-engineering.com](http://www.confluence-engineering.com)**





# Manganese SDWA Regulatory History



# AWWA Comments to EPA on CCL4 – April 3, 2015

“AWWA supports the inclusion of manganese in the Draft (and Final) CCL4. As knowledge evolved for manganese in 2014 and early 2015, the CCL TAW decided to shift manganese from Group 4 to Group 2 so that robust national occurrence data could be collected through a future UCMR.”

