Manganese Sequestration in Potable Water – A Quantitative Evaluation

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Outline

- Information on Manganese, Polyphosphates, and Sequestration
- Water Quality
- Sequestrants
- Test Method
- Results
- Conclusions

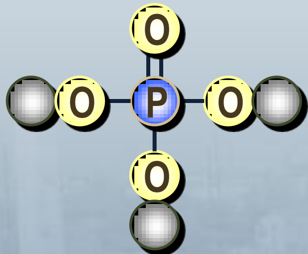
Manganese Information

- No Primary MCL
- Secondary MCL – 0.050 mg/L
  - Aesthetics - color and staining
- Typical Treatment Target
  - 0.010 to 0.020 mg/L

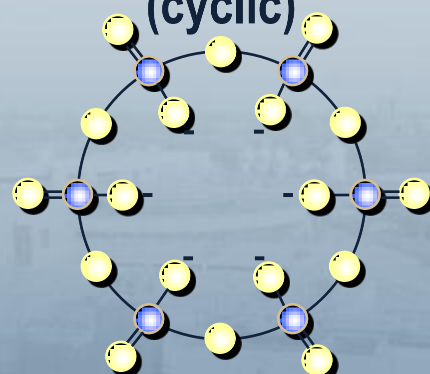
The Family of Phosphates

- Most polyphosphate sequestrants are really a soup consisting of all these compounds

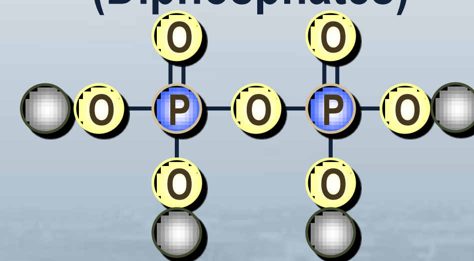
Orthophosphates
(Monophosphates)



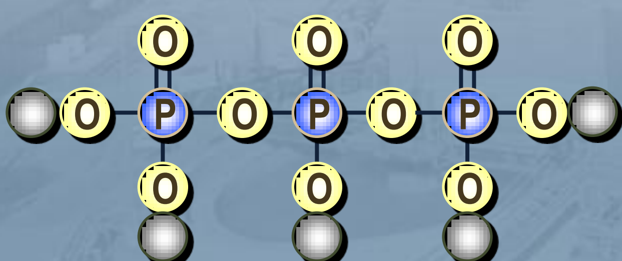
Metaphosphates
(cyclic)



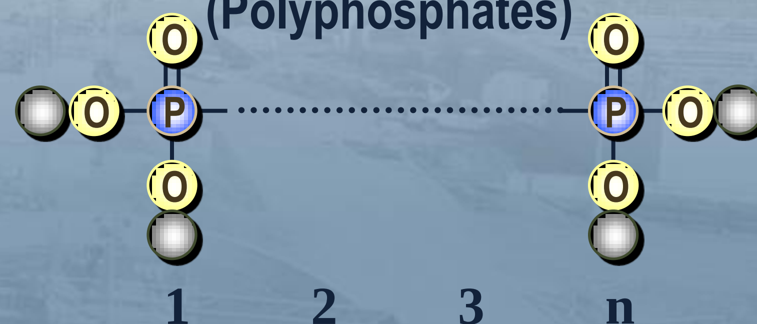
Pyrophosphates
(Diphosphates)



Tripolyphosphates

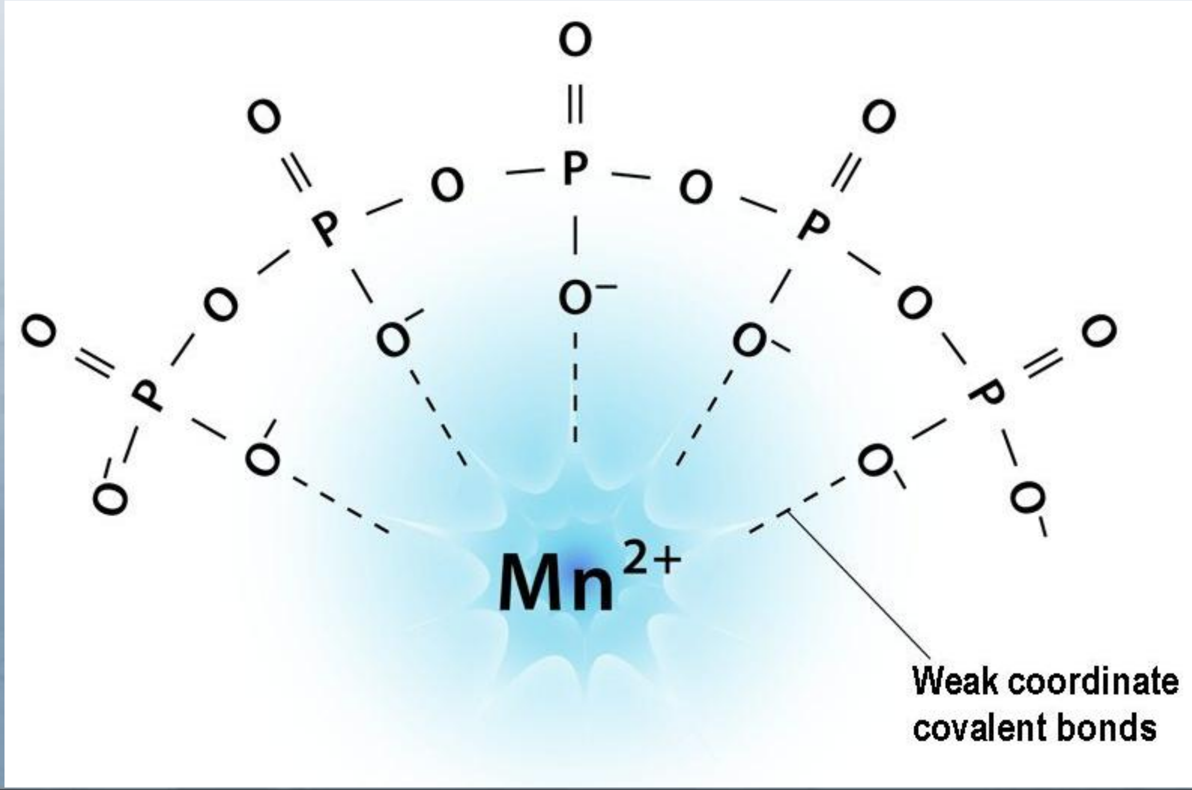


Condensed phosphates
(Polyphosphates)



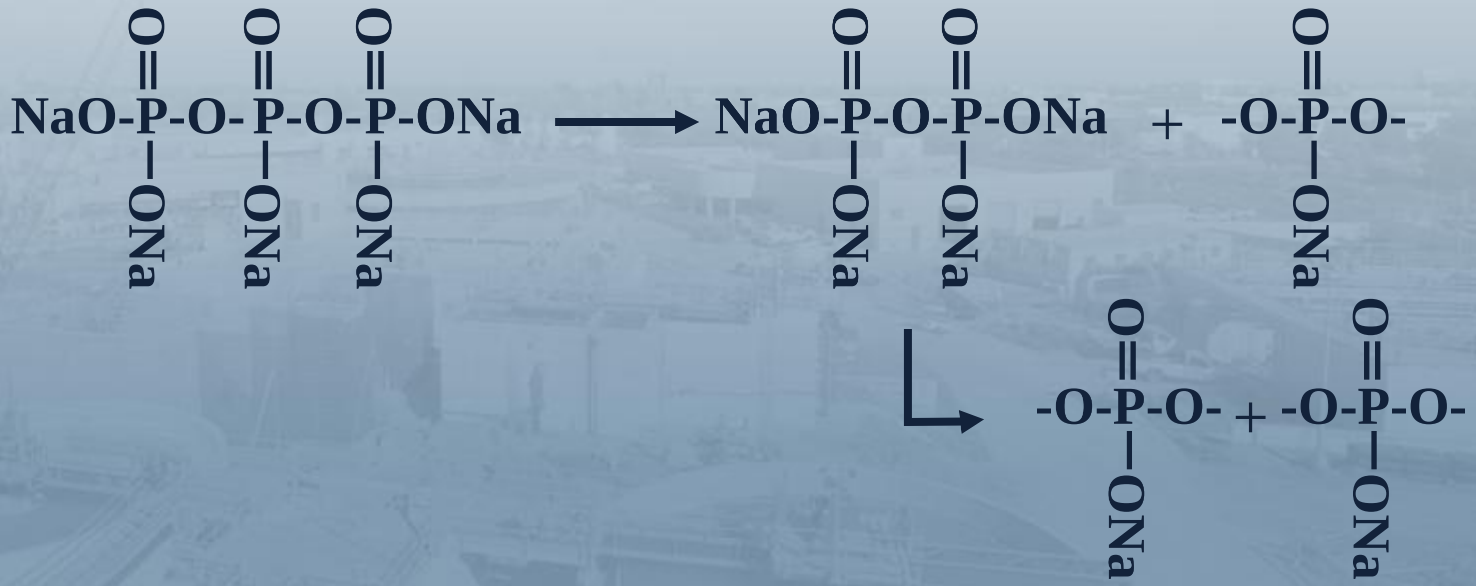
Theoretical Poly-P / Manganese Complex

- Parameters Affecting Complex Stability
  - pH
  - Temperature
  - Poly-P chain length



The Problem with Poly-P: Hydrolysis

- Slow reaction with water to yield orthophosphate – loss of complexation capability
- Rate of hydrolysis is related to temperature and pH
- Time release – Controllable kinetics based on polymer length
- Longer chain polyphosphates retain sequestration efficiency longer

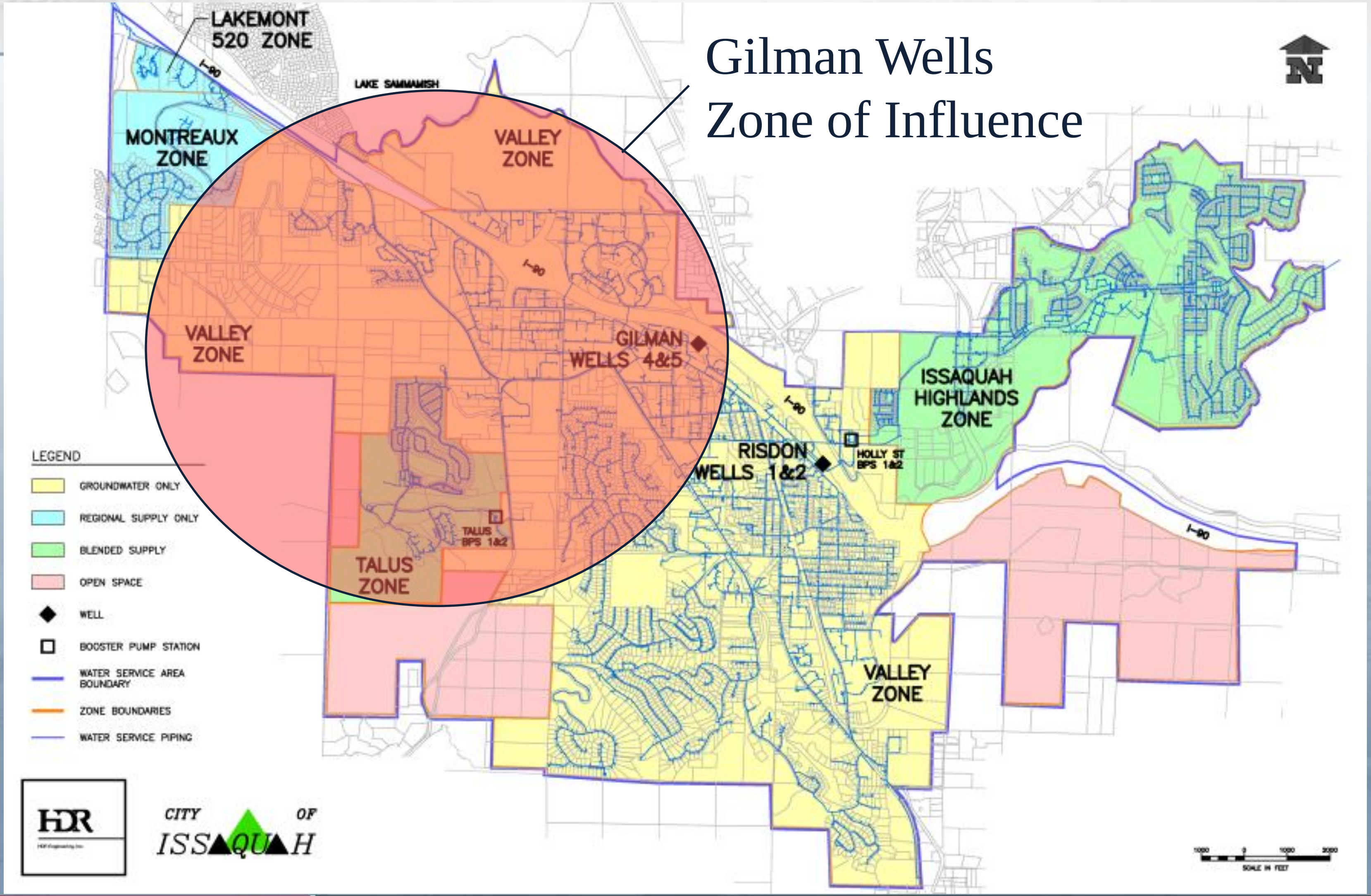


Parameters Affecting Sequestrant Efficiency

- pH
- Temperature
- Poly-P chain length
- Sequestered water age
- Chlorine concentration
- Mn concentration
- Completing ion concentration (i.e., TDS, hardness)

City of Issaquah, Washington State

City of Issaquah Water Distribution System



Water Quality

Parameter	Gilman 5	Gilman 4&5	Risdon 1&2
Manganese, Total (mg/L)	**0.090**	**0.078**	ND
Iron, Total (mg/L)	ND	0.034	ND
Calcium (mg/L)	34	32	16
pH	8.4	7.8	8.0
Alkalinity (mg/L as $CaCO_3$)	103	102	67

ND: Non-Detect

Sequestrant Information

Seq.	Strength (% PO_4)	S.G. (mg/L)	Recommended Dose (mg/L as PO_4)	NSF 60 Certified
A	35%	1.73	1.00	Yes
B	29%	1.32	1.45	Yes
C	35%	1.40	0.35	Yes
D	33%	1.40	0.50	Yes
E	25%	1.51	1.00	Yes
F	23%	1.29	1.00	Not Found

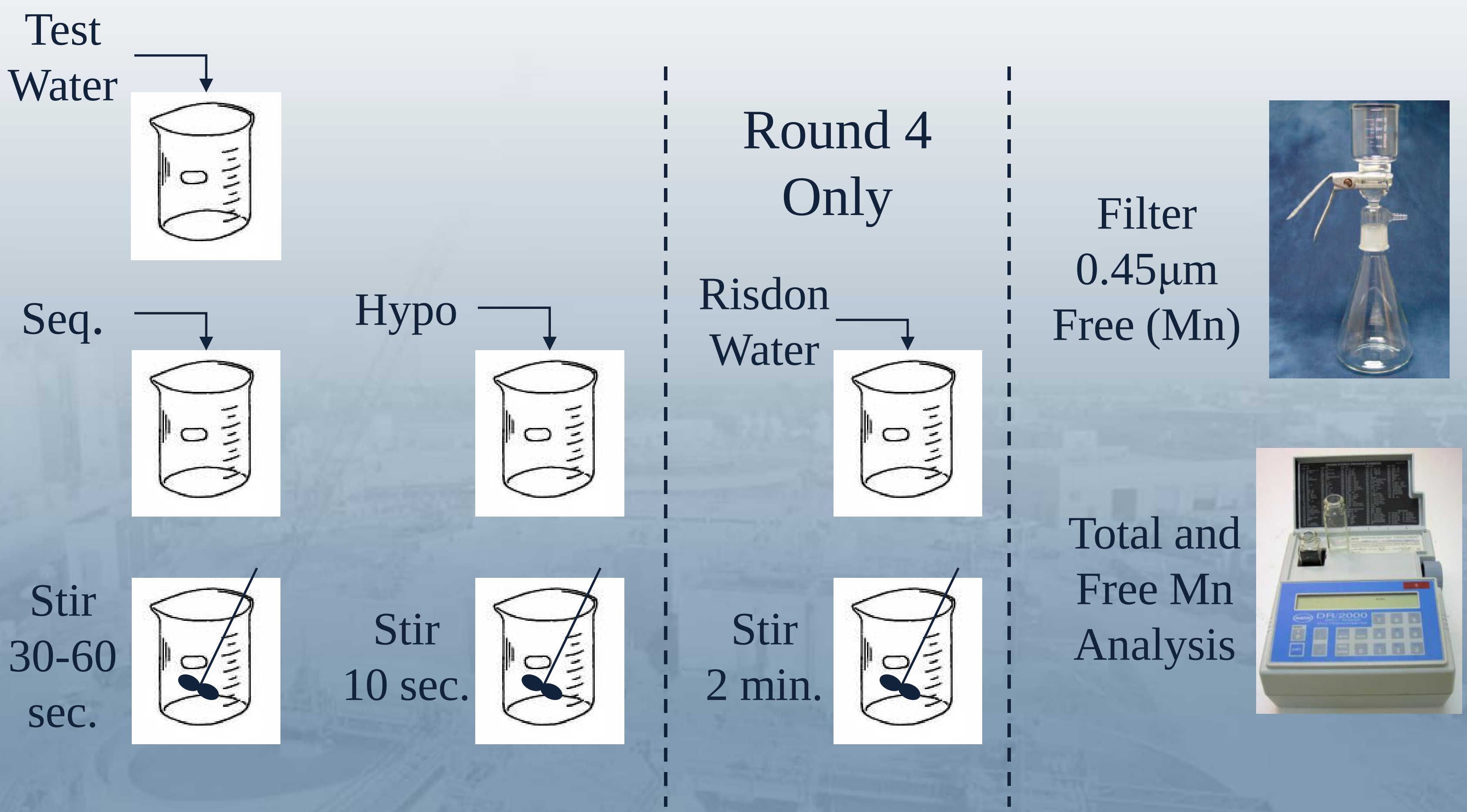
Test Matrix

Round	Water	# of Seq.	Seq. Dose (mg/L)
1	Well 5	6	1X
2	Gilman (Well 5+4)	6	3X
3	Gilman (Well 5+4)	2	1X, 2X, 3X, & 5X
4	Gilman:Risdon 100:0, 90:10, 50:50, & 10:90	1	5X

Test Procedure - General

- Chlorine burn out of amber glass bottles
  - Soaked for ≥24 hours with 3 to 3.5 mg/L chlorine
  - Rinsed 3 times with DI water
- Each test included a control
  - Test water with no sequestrant
- Chlorine doses target
  - 0.5 mg/L Cl_2 Residual after 48 hours
- Constant Temperature
  - 60 ± 5°F

Test Procedure

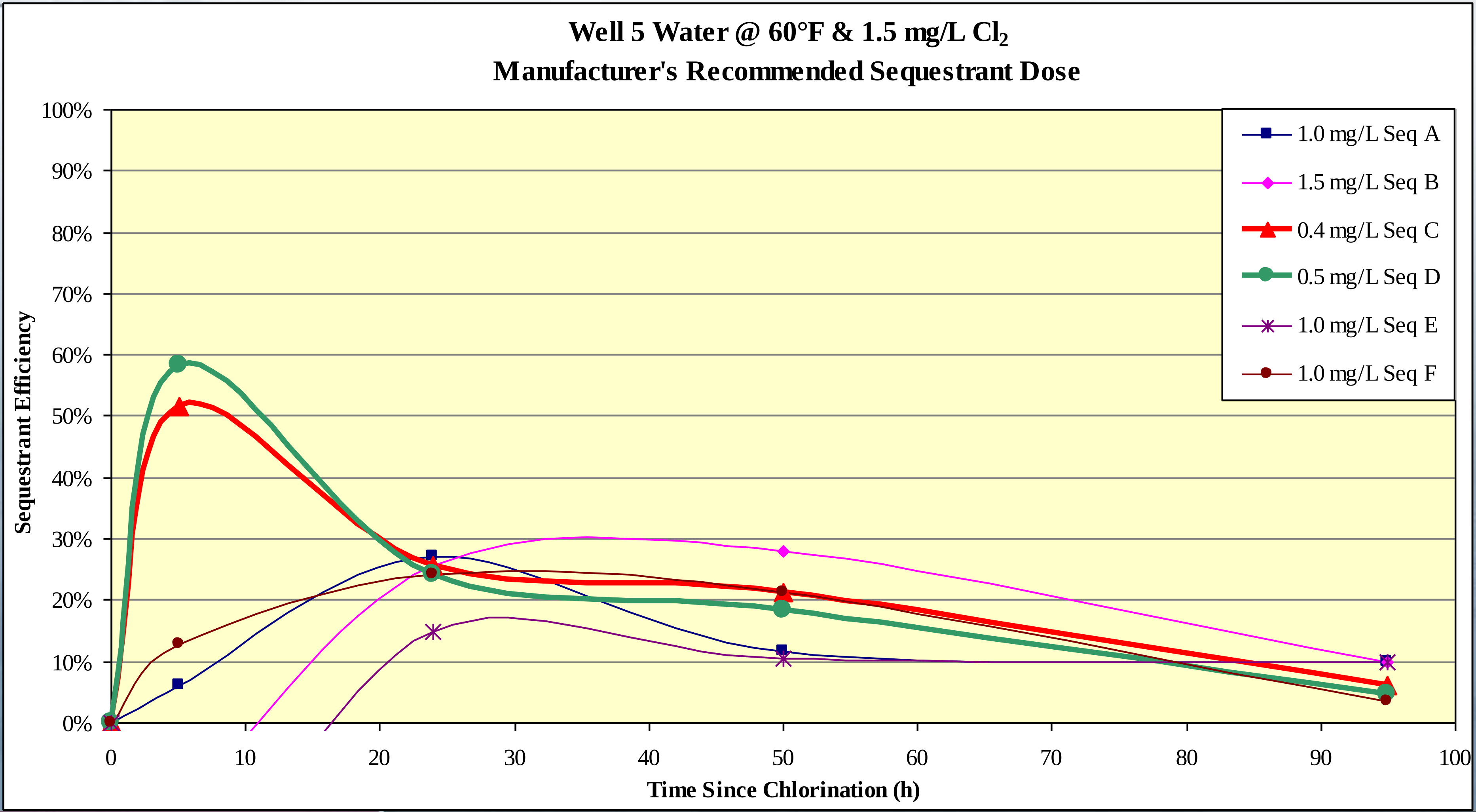


Calculations

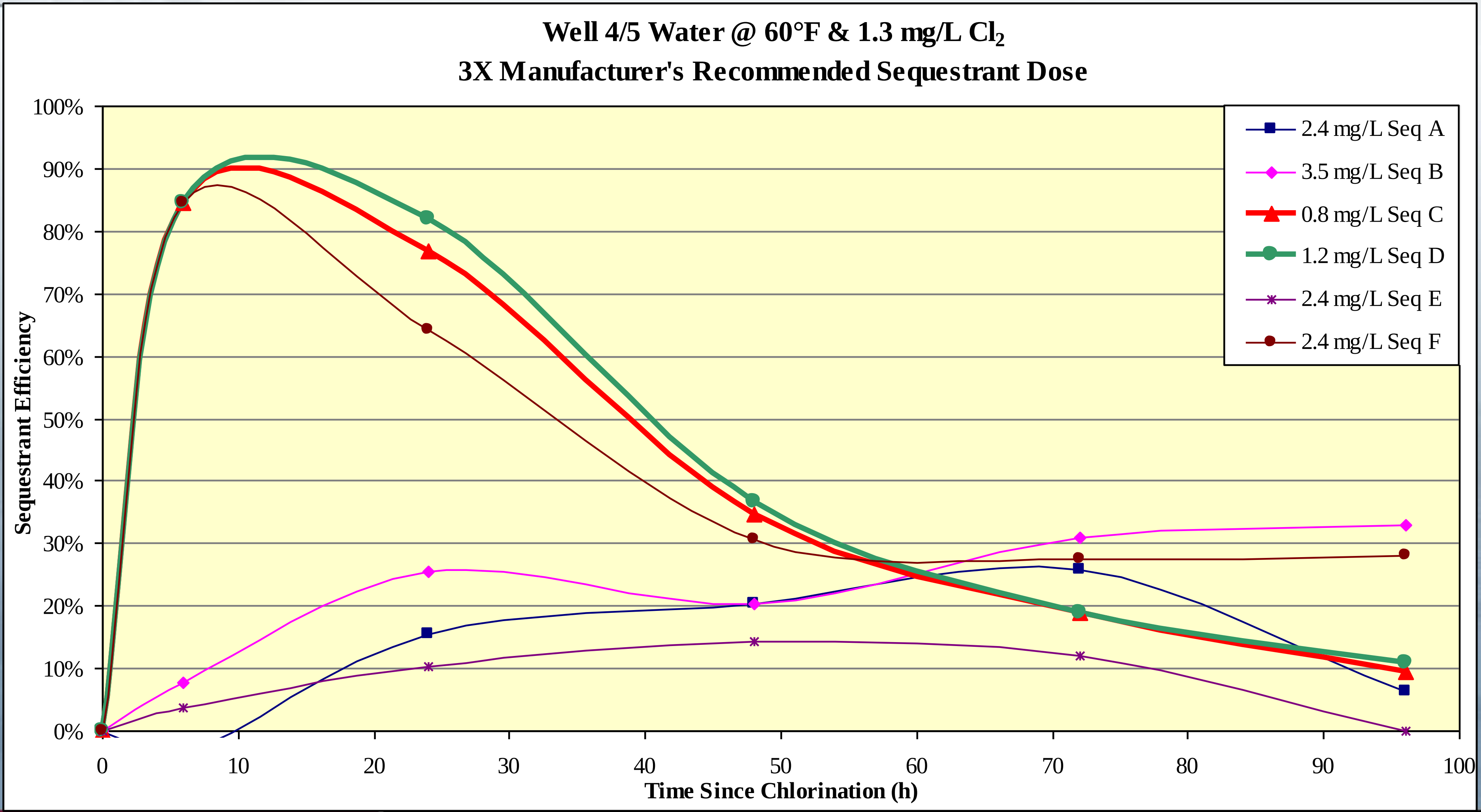
- Soluble Mn
  - Mn that passes through 0.45 µm filter
- Precipitated Mn @ time t
  - Soluble Mn @ time 0 – Soluble Mn @ time t
- Sequestrant Efficiency
  - Percent reduction in Mn precipitation due to sequestrant

$$\frac{\text{Prec. Mn Control} - \text{Prec. Mn Test}}{\text{Prec. Mn Control}} * 100\%$$

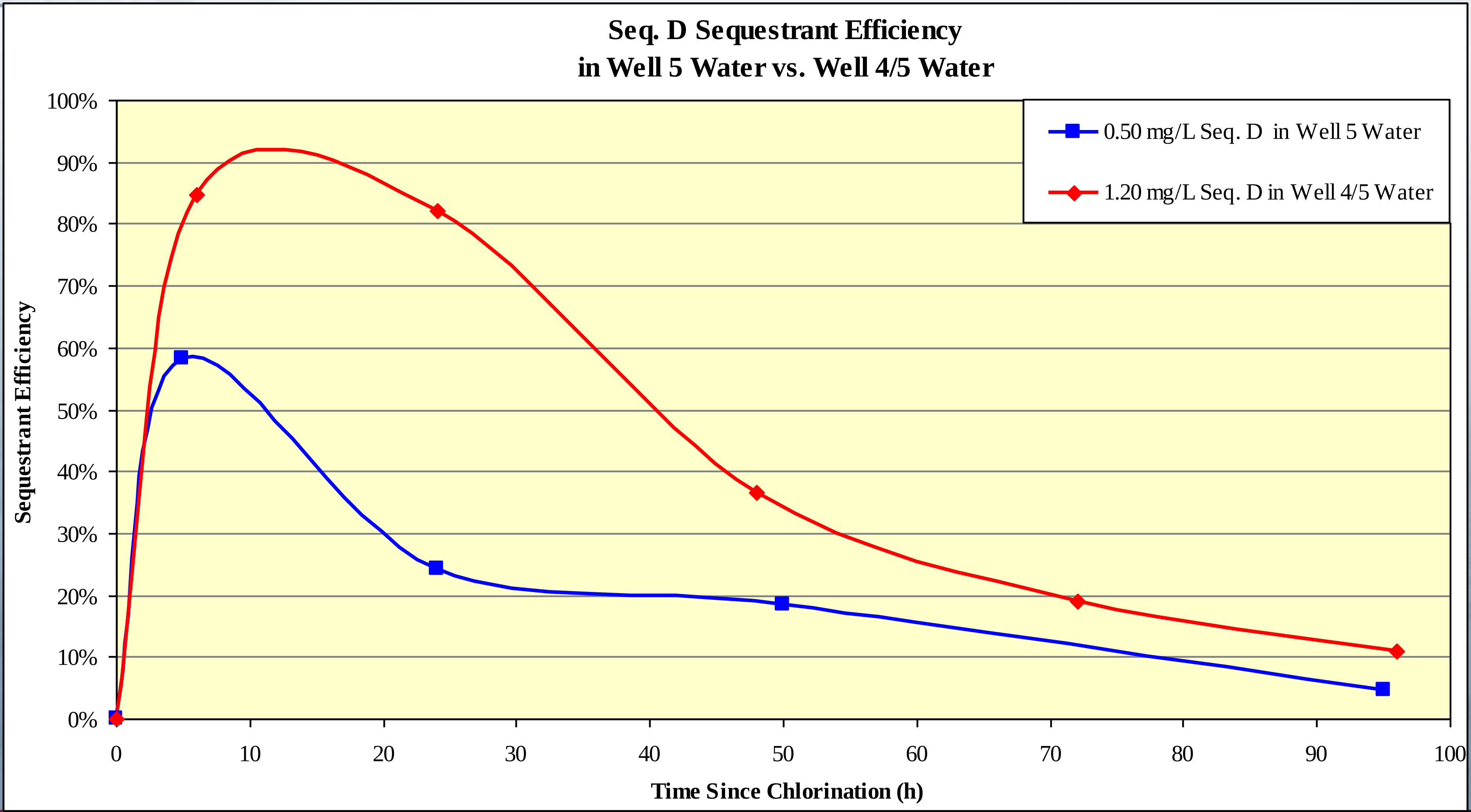
Round 1 – Sequestrant Efficiency



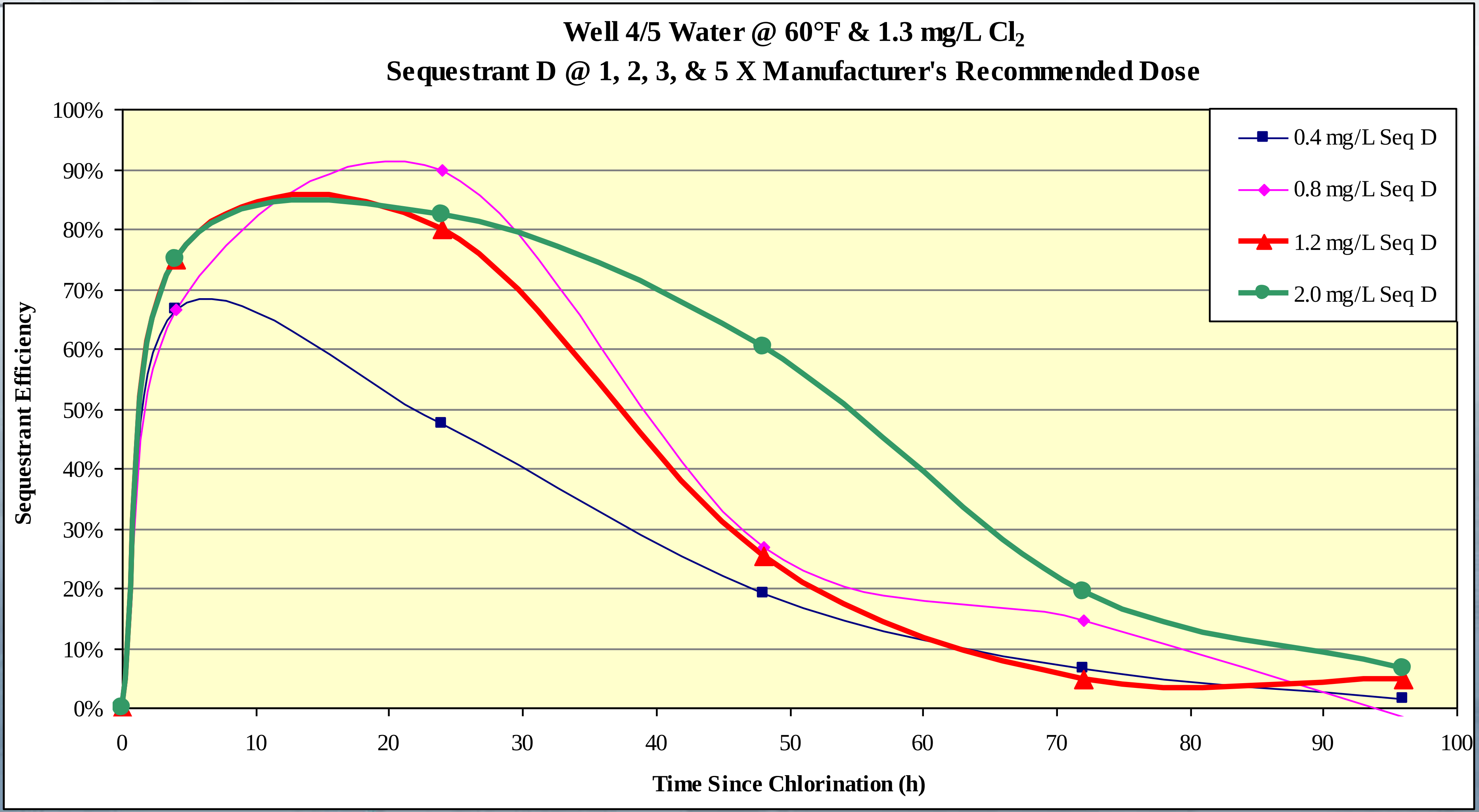
Round 2 – Sequestrant Efficiency



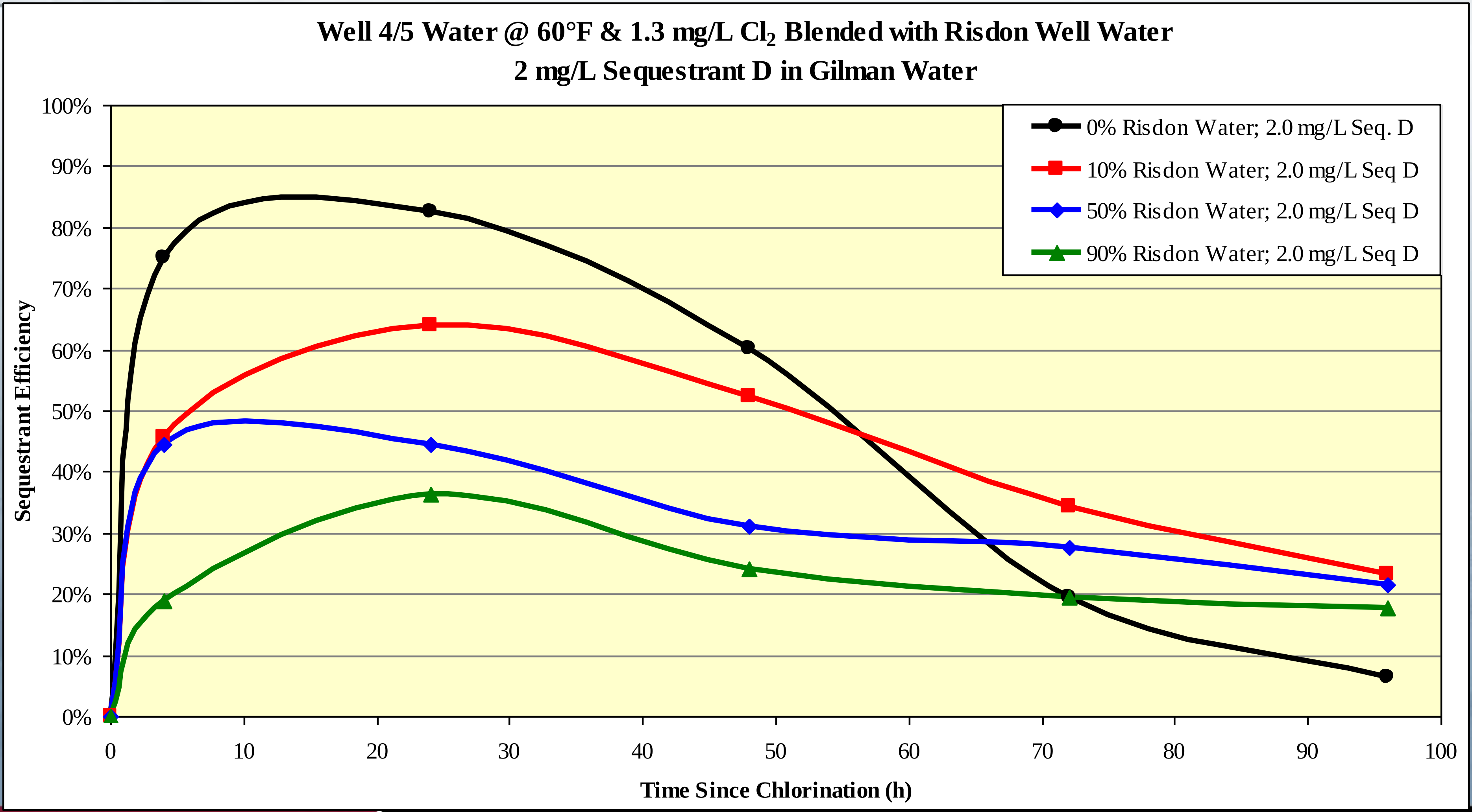
Comparison of Round 1 and 2 – Seq. D



Round 3, Seq. D – Sequestrant Efficiency



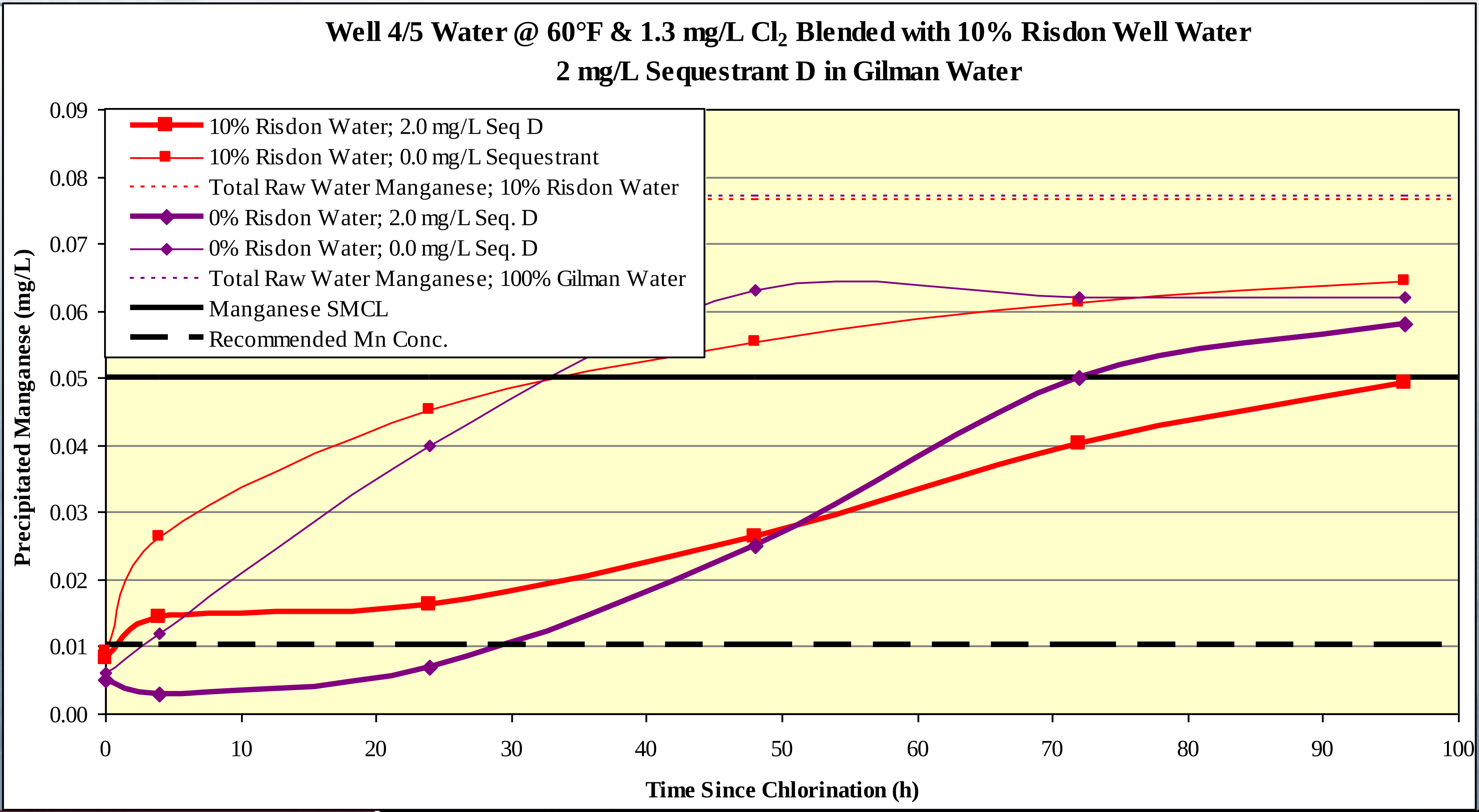
Round 4 – Gilman/Risdon Blended Water



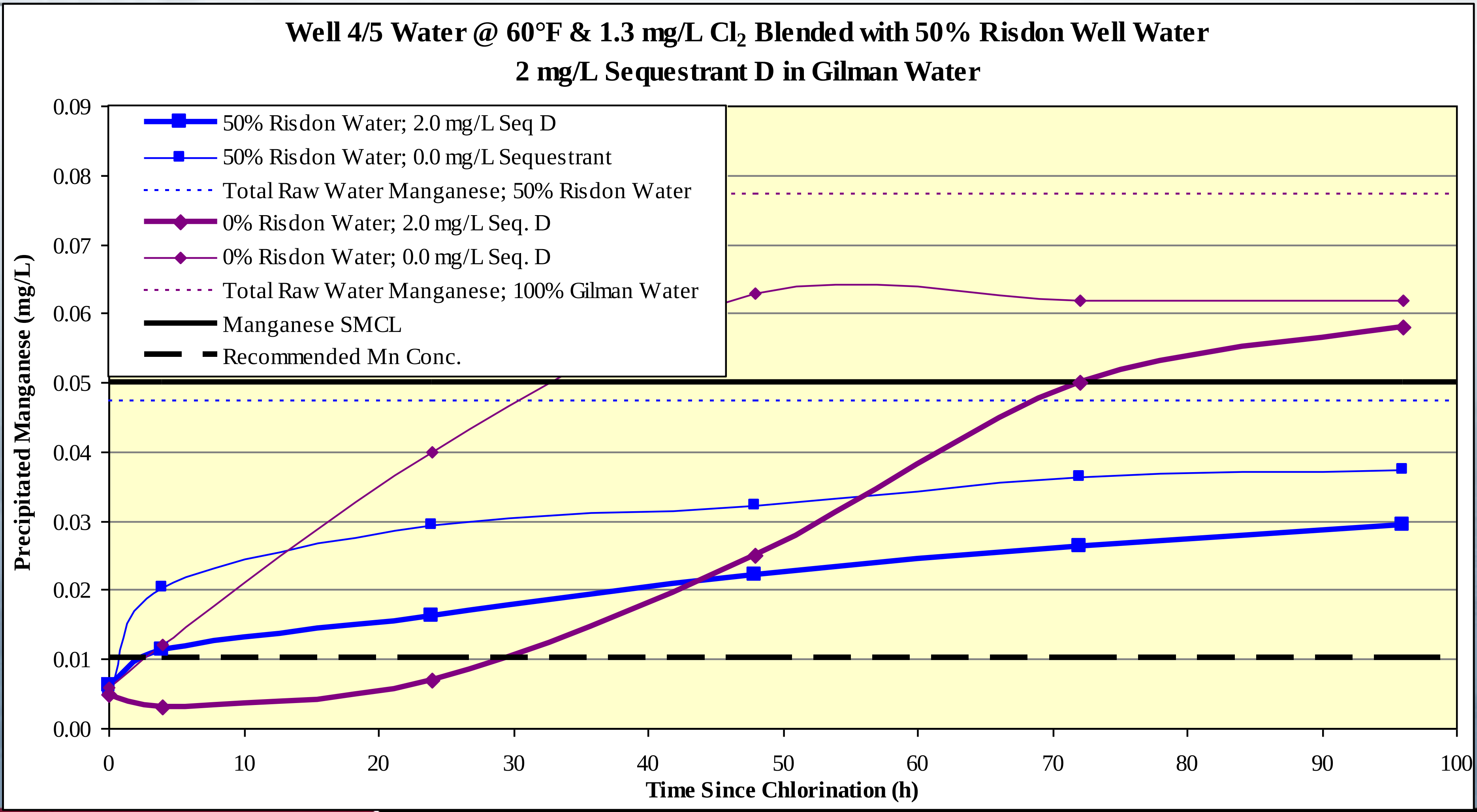
Diluting Mn Requires New Graph

- Sequestrant Efficiency
  = % reduction in Mn precipitation due to sequestrant.
- Blending
  - Reduces original Mn
  - Reduces Mn precipitation.
- For blending tests, look at total Mn precipitation, not Sequestrant Efficiency

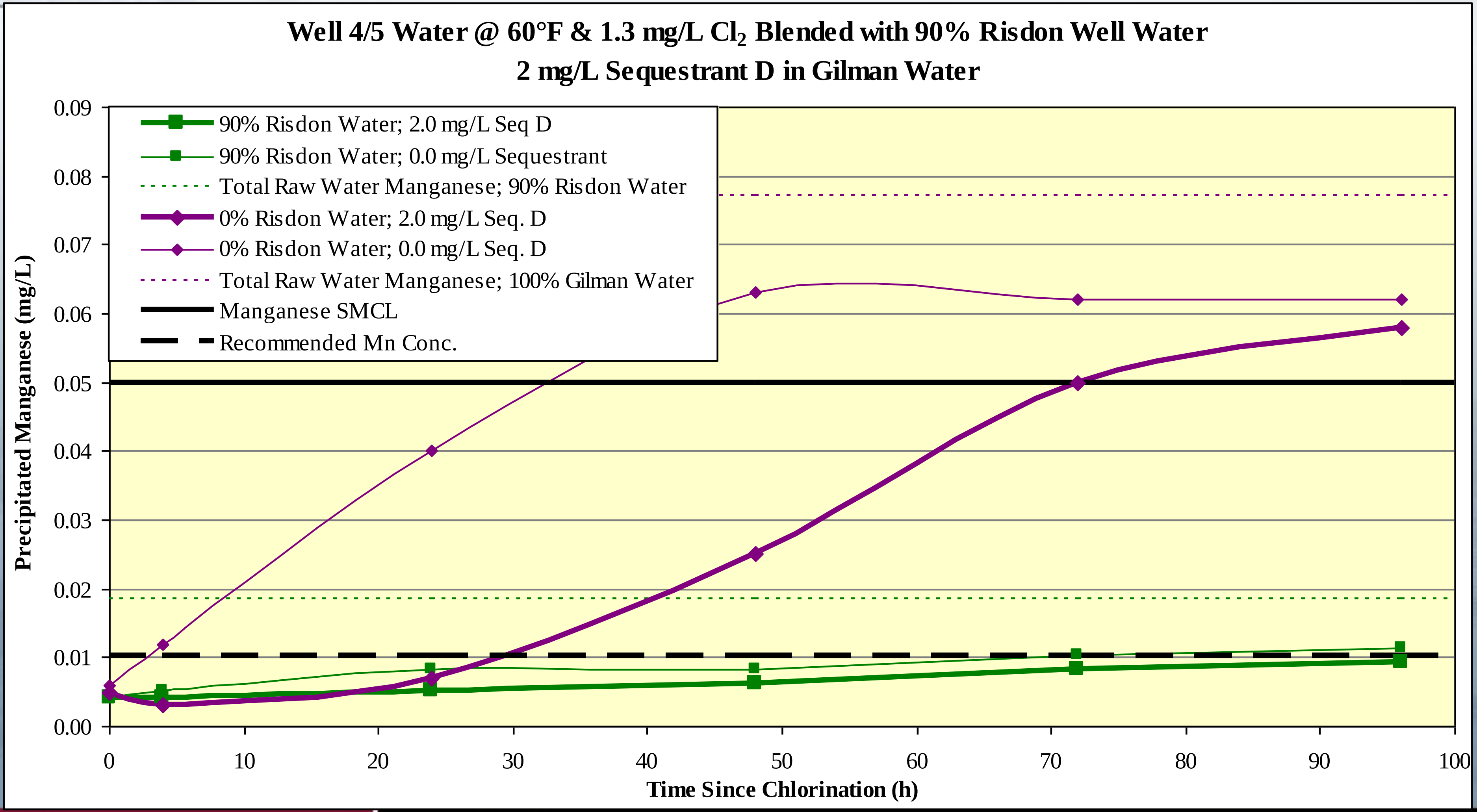
Round 4 – 90:10 Gilman to Risdon Water



Round 4 – 50:50 Gilman to Risdon Water



Round 4 – 10:90 Gilman to Risdon Water



Conclusions

- Demonstrated 2.0 mg/L Sequestrant D reduced manganese precipitation by:
  - 82% for 24 hours
  - 60% for 48 hours
  - 20% for 72 hours
- Sequestrants can reduce or delay manganese precipitation in chlorinated water, but not significantly longer than 72 hours
- Blending high Mn water with low Mn water reduces manganese precipitation more than the sequestrant

Conclusions

- Sequestrants do not completely eliminate Mn precipitation
- Sequestration reduces Mn precipitation problem by
  - Slowing Mn precipitation
  - Allowing Mn to precipitate over wider region
- This results in
  - Smaller settled precipitate layer in pipes
  - Less Mn stirred up in hydraulic disturbances

Conclusions

- City of Issaquah
  - Instituted sequestration at 3X recommended dose
  - Plans to increase directional high-volume flushing
  - Plans to increase dead-end flushing
  - Plans to increase water reservoir cleaning
  - Visually inspects flush water for Mn precipitates
  - Anticipates 1 FTE for flushing
- Results
  - Online since July 2008
  - No complaints

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