Data Mining 235 Chlorinated Solvent Sites to Evaluate Remediation Performance and Costs

15 February 2015

Texas Association of Environmental Professionals

GSI ENVIRONMENTAL

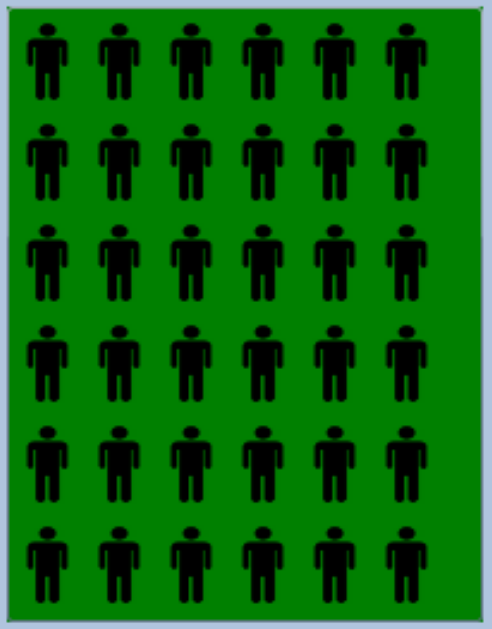
ESTCP

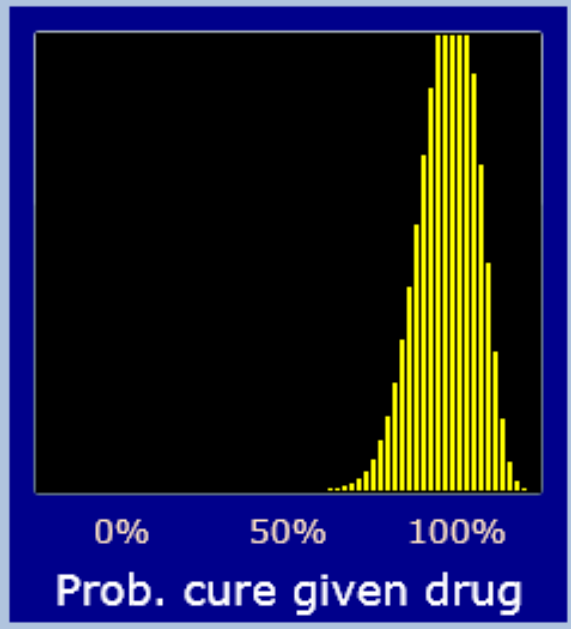
Travis M. McGuire, P.E.

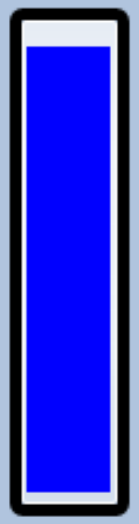
PERFORMANCE DATA IN MEDICINE

Cured

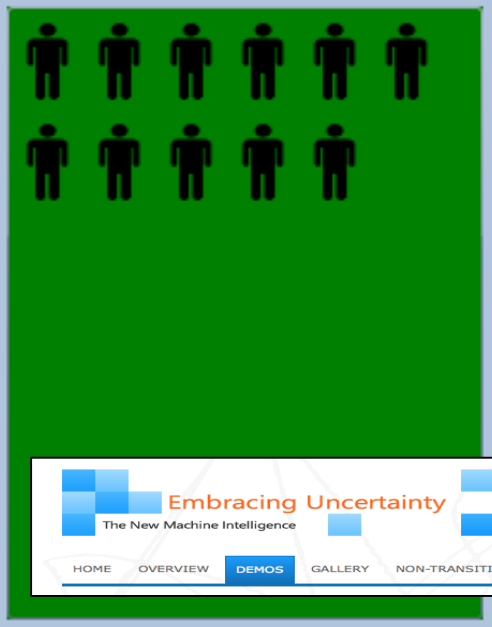
Not Cured

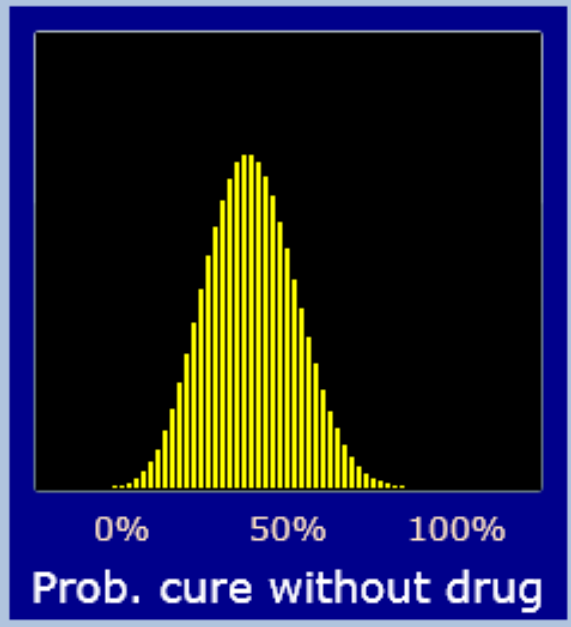






Probability that drug is effective



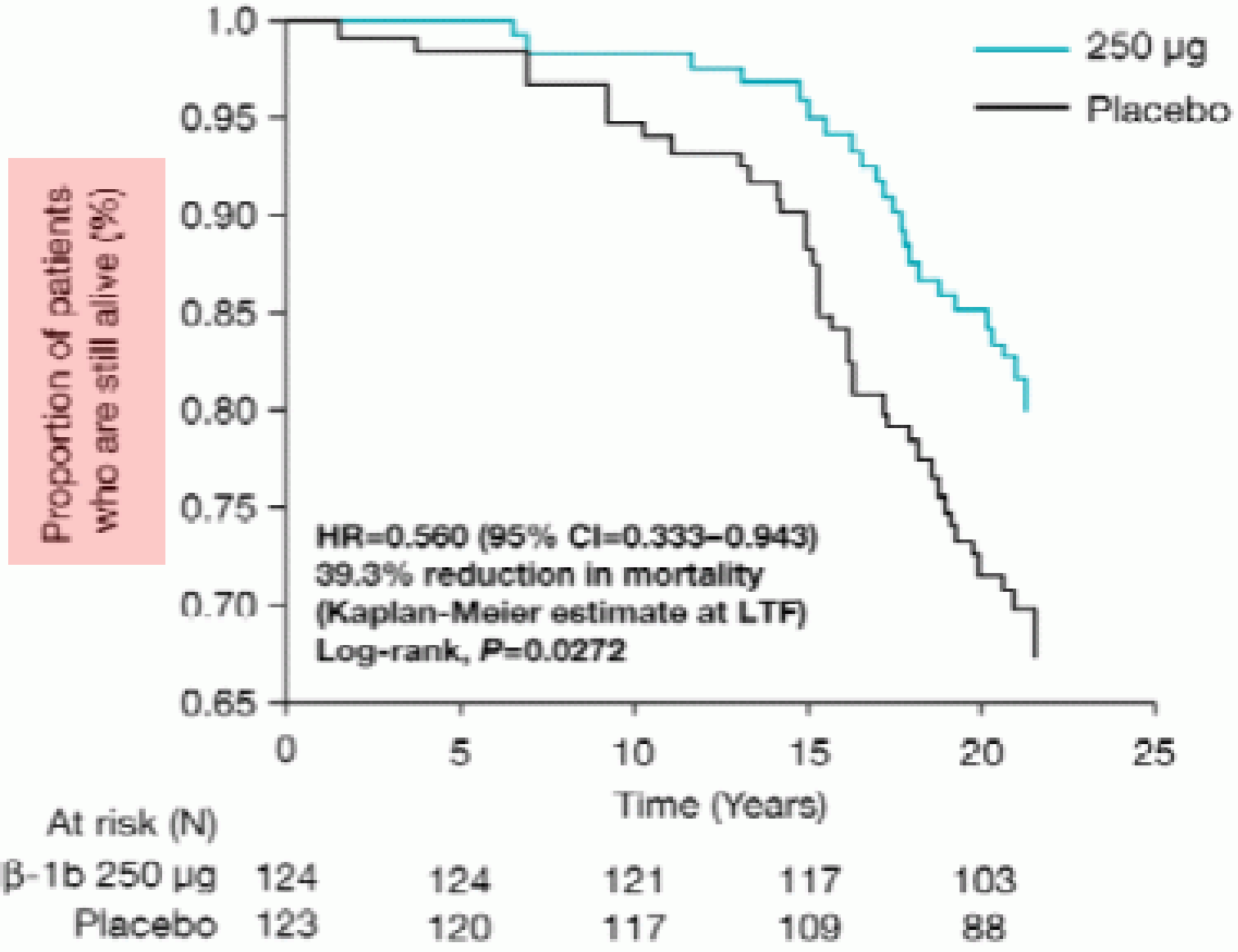


Placebo

Reset

http://embracinguncertainty.info/clinicaltrial.htm

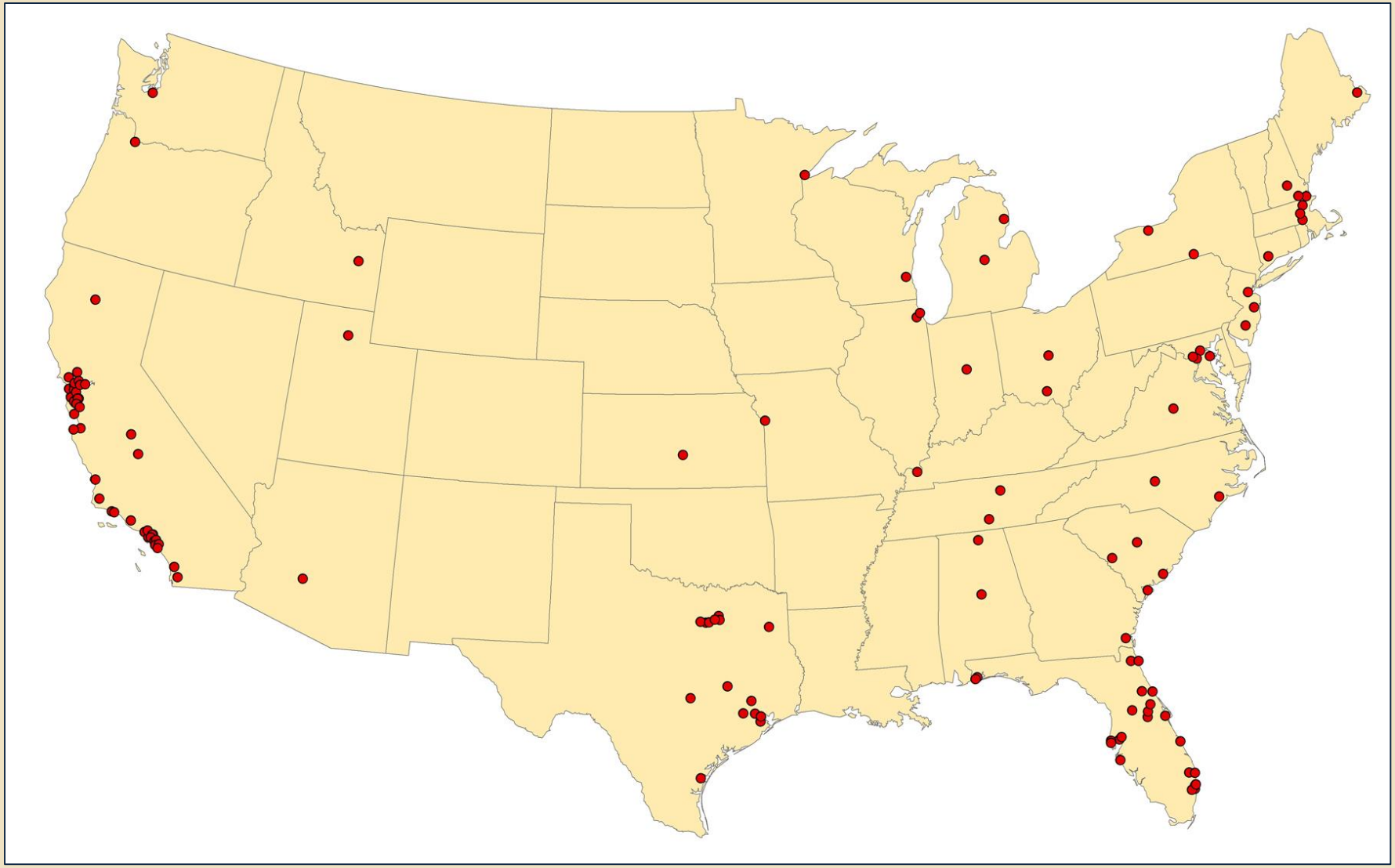
“Proportion of patients who are still alive (%)”



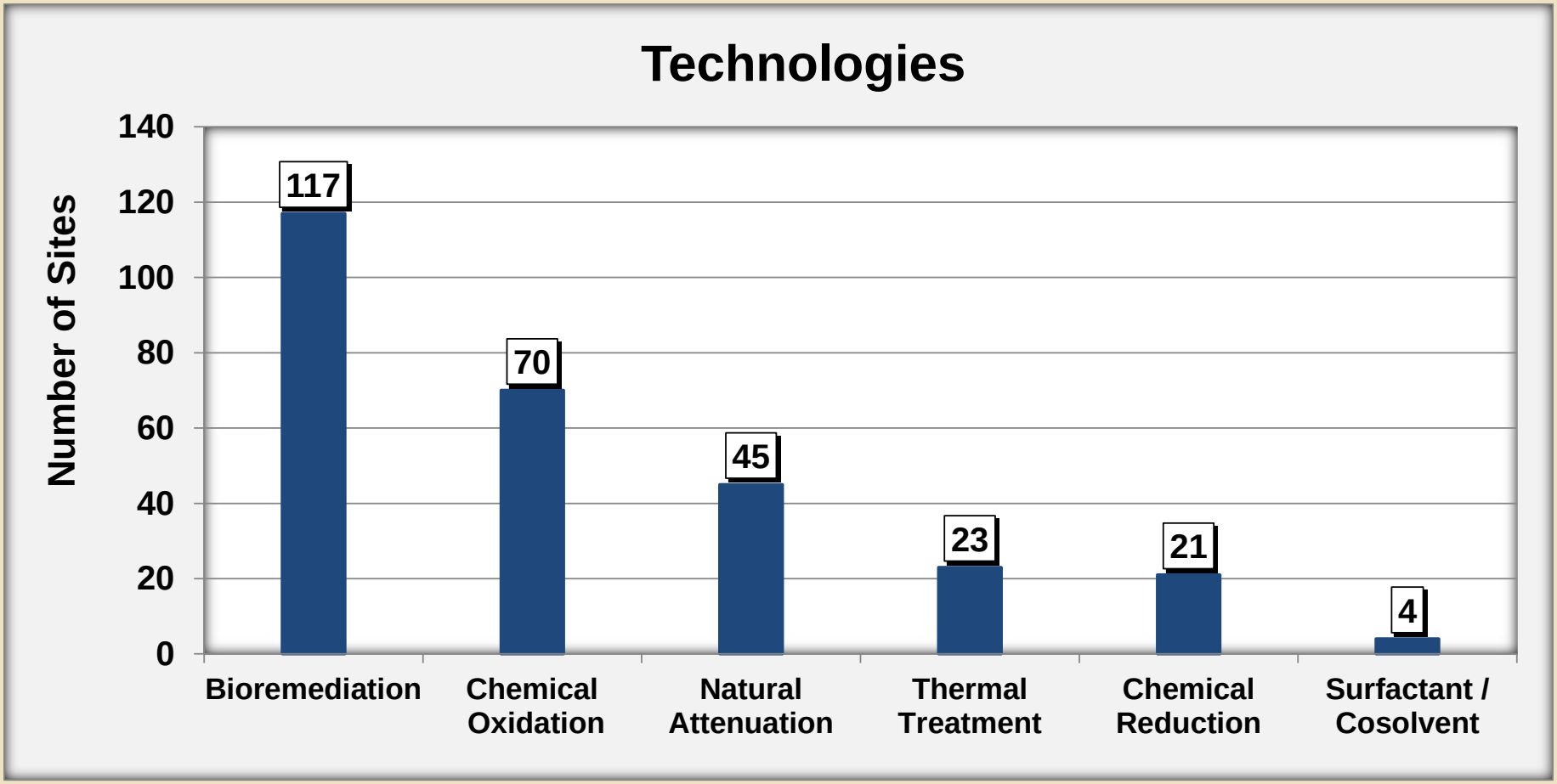
BIG DATA AND PERFORMANCE – *GROUNDWATER STYLE*

- **Database by the Numbers**
  - ⇨ **280 Chlorinated Solvent Groundwater Sites**
    - ⇨ **235 In-Situ Remediation Sites**
    - ⇨ **45 Untreated (MNA) Sites**
  - ⇨ **796 Wells**
  - ⇨ **11,965 Sampling Events**
  - ⇨ **48,594 Chlorinated Compound Concentrations**
  - ⇨ **~ $120,000,000 at $10,000 per event**

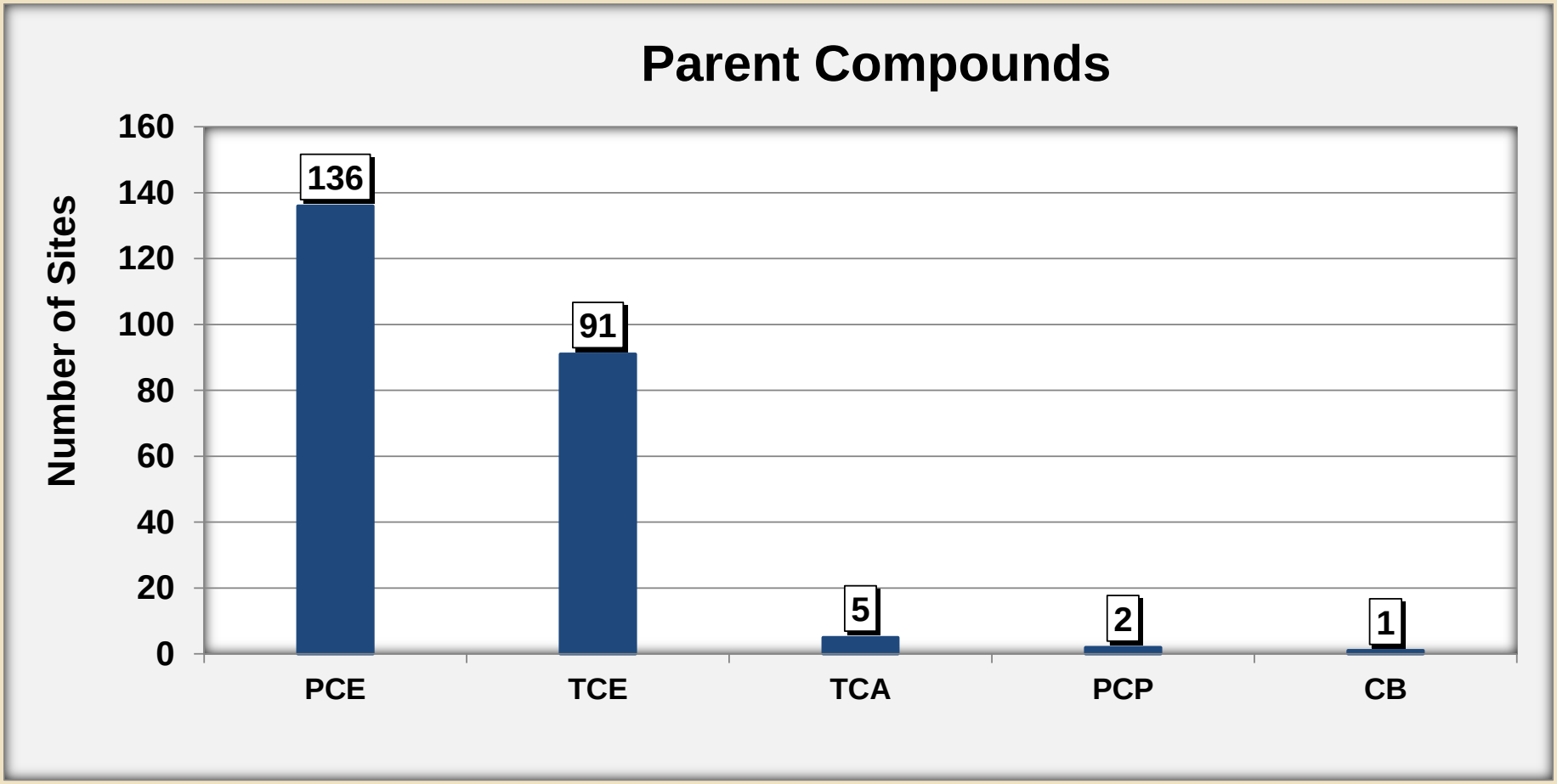
SITE LOCATIONS



TECHNOLOGY DISTRIBUTION



PARENT COMPOUND DISTRIBUTION



DATA MINING PROCESS

- Data mining Project example

- 4.5 Stars on Yelp!

Remedial Action Plan Modification

Herman Jackson Cleaners

1981 San Marco Boulevard
Jacksonville, Florida

February 21, 2011

FDEP Facility Identification 169502441
FDEP Task Assignment D14L
LFR Project 004-06004-19

Prepared for
Florida Department of Environmental Protection
Bob Martinez Center
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Prepared by
LFR Inc.
3382 Capital Circle N.E.
Tallahassee, Florida 32308-1568

LFR

DATA MINING PROCESS

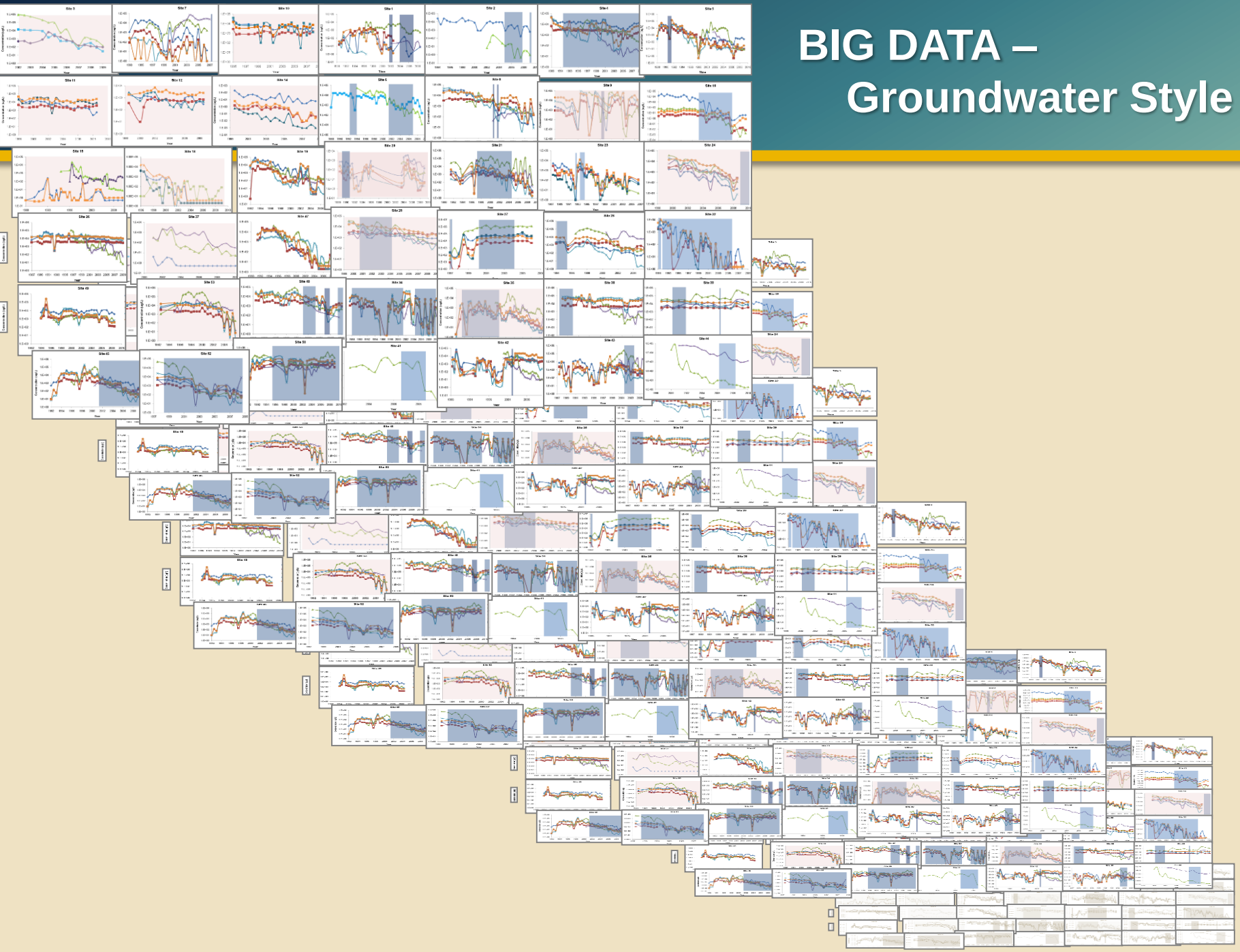
- **Data mining Project example**

The remediation system was originally started on August 25, 2004. The remediation system includes the following components:

- Ten 2-inch-diameter injection wells ranging in depth from 12 to 38 feet bgs. The injection-well piping is routed from each injection well and stubbed up on the northern side of the equipment building. A trailer-mounted injection system was mobilized to the Site to inject ethyl lactate into the subsurface through the injection wells.

The last ethyl-lactate injection event was completed in August 2007, and the SVE system was shut down on November 7, 2007, as documented in the data submittal deliverable submitted to FDEP on December 19, 2007.

BIG DATA – Groundwater Style



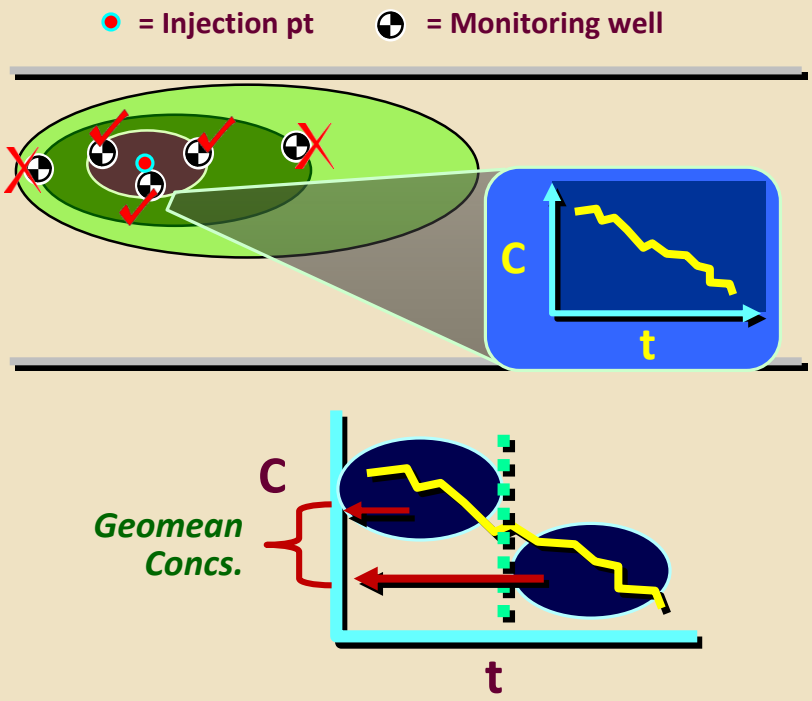
DATA REDUCTION

PERFORMANCE CALCULATIONS:

A) Compile conc. vs. time data for wells within <u>treatment</u> zone

B) Calculate geometric mean and maximum concentrations of <u>before</u> and <u>after</u> treatment periods

C) For geomean, calculate <u>median</u> before and after treatment concentrations of multiple wells as final performance metric for the site

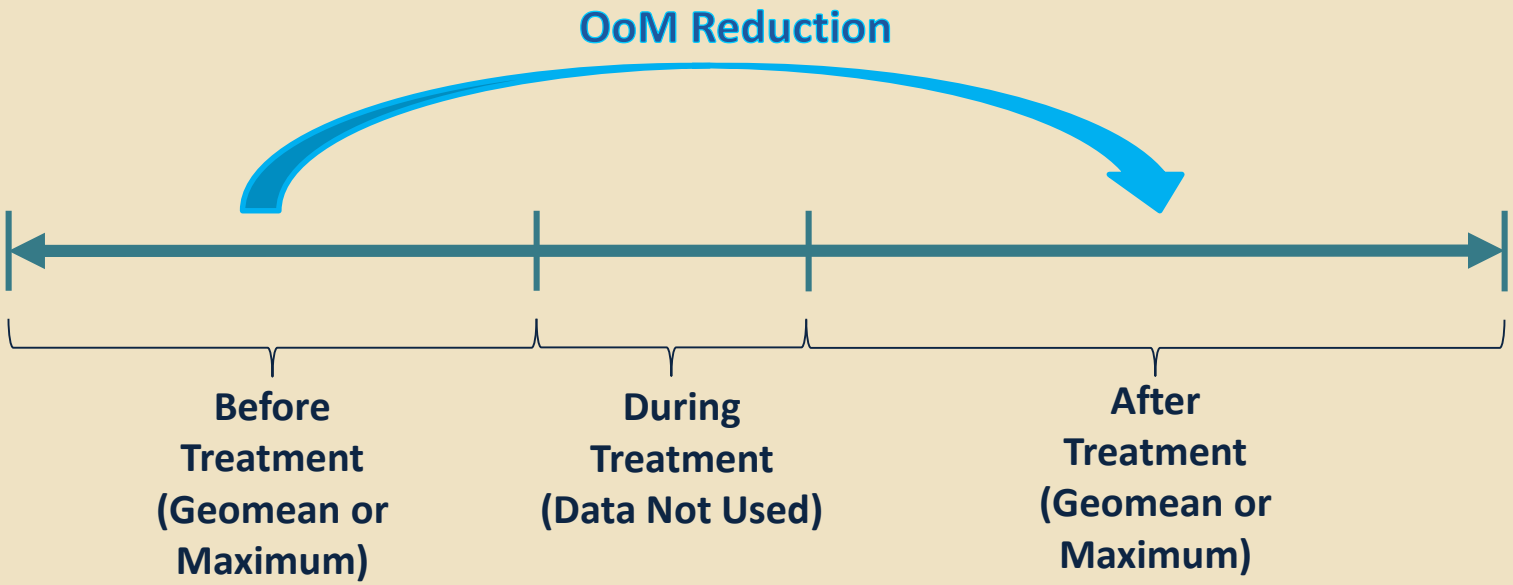


	Geomean	Median
Well #1	50	7.5
Well #2	10	
Well #3	5	
Well #4	0.05	

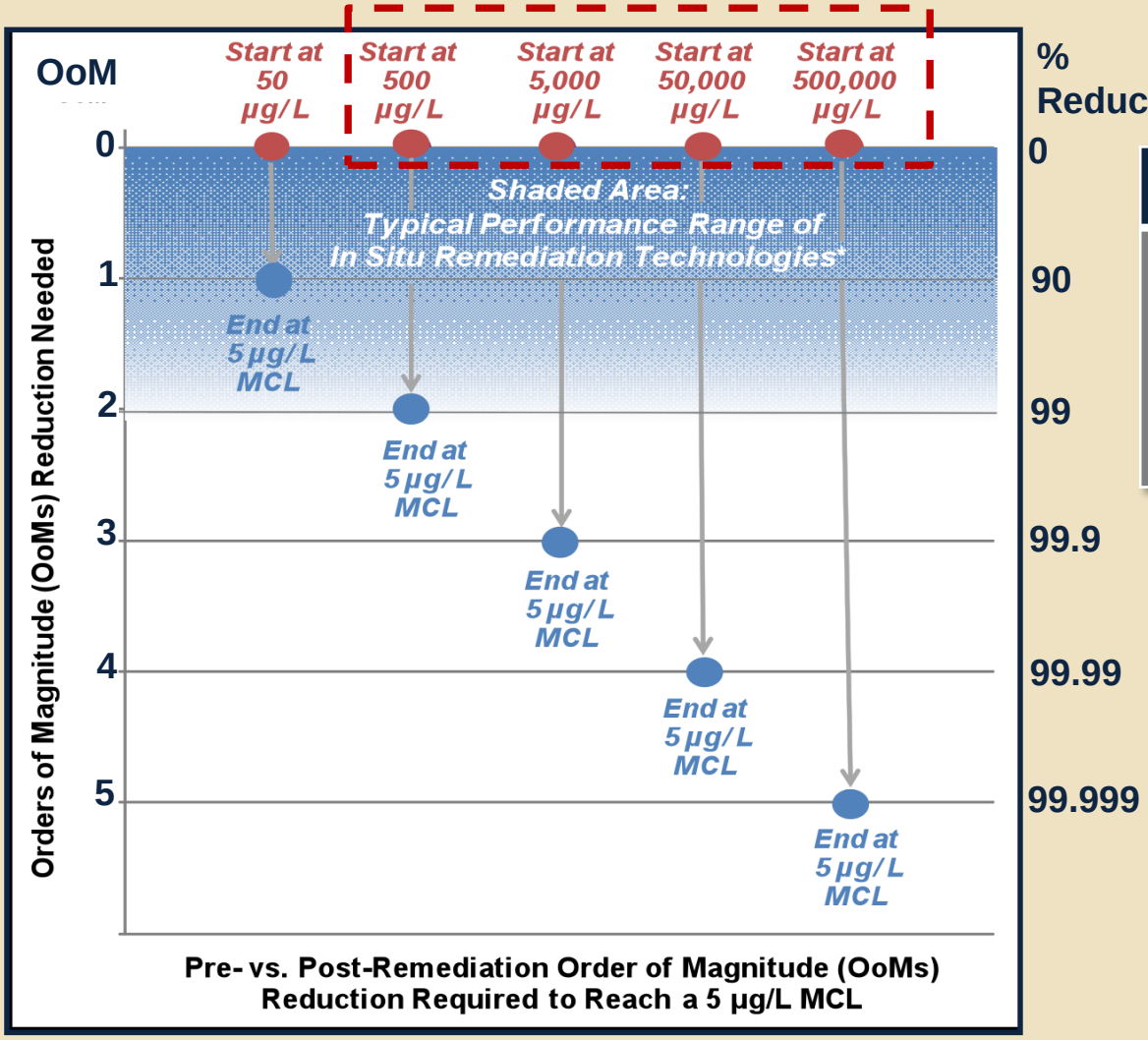
DATA REDUCTION

- **Order of Magnitude (OoM) Concentration Reduction**

$$OoM\ Reduction = -\log\left(\frac{C_{Post}}{C_{Pre}}\right)$$



WHY *OoMs*?



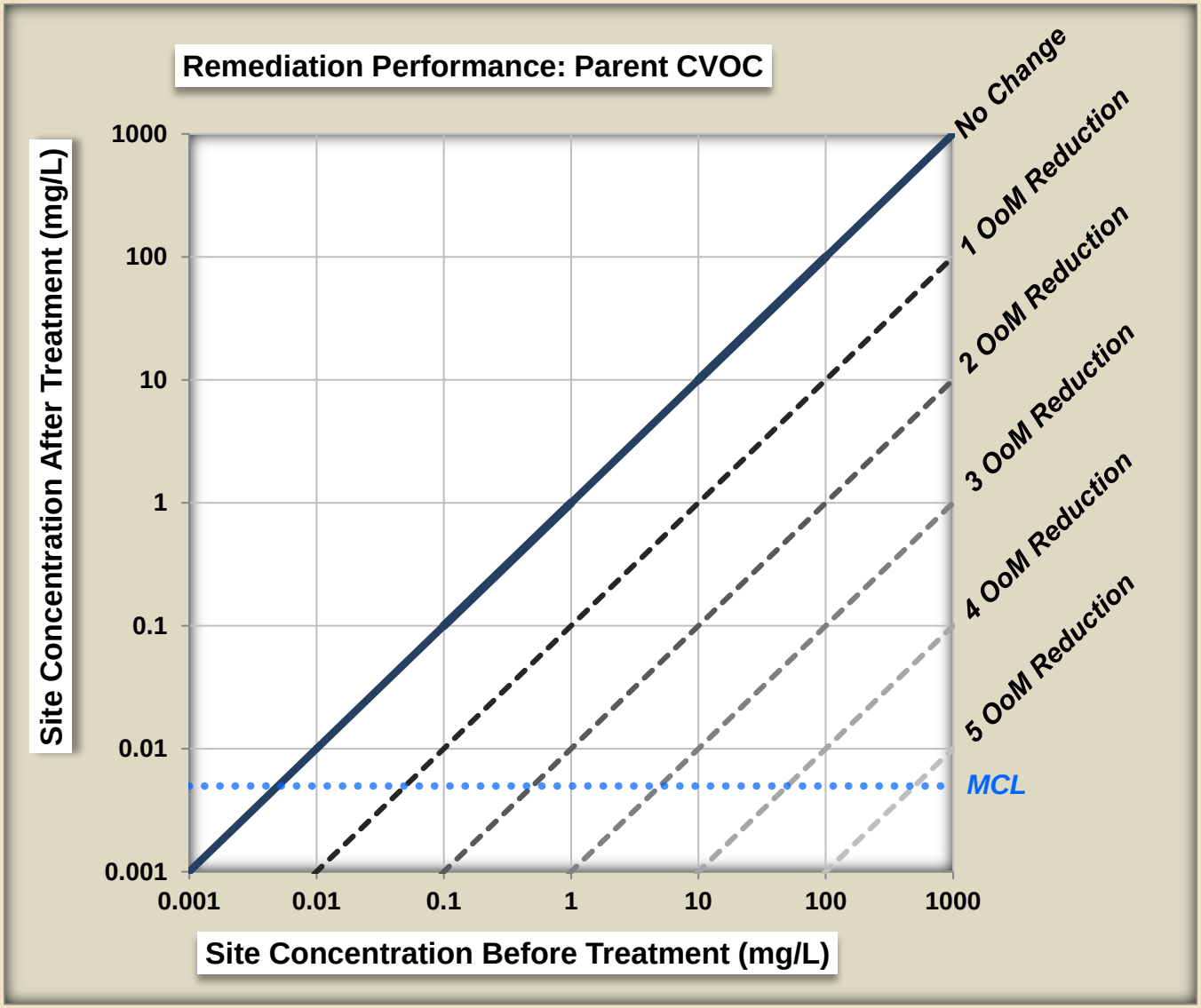
KEY POINT:

Most CVOC sources zones need 2 to 5 OoM reduction to reach MCLs

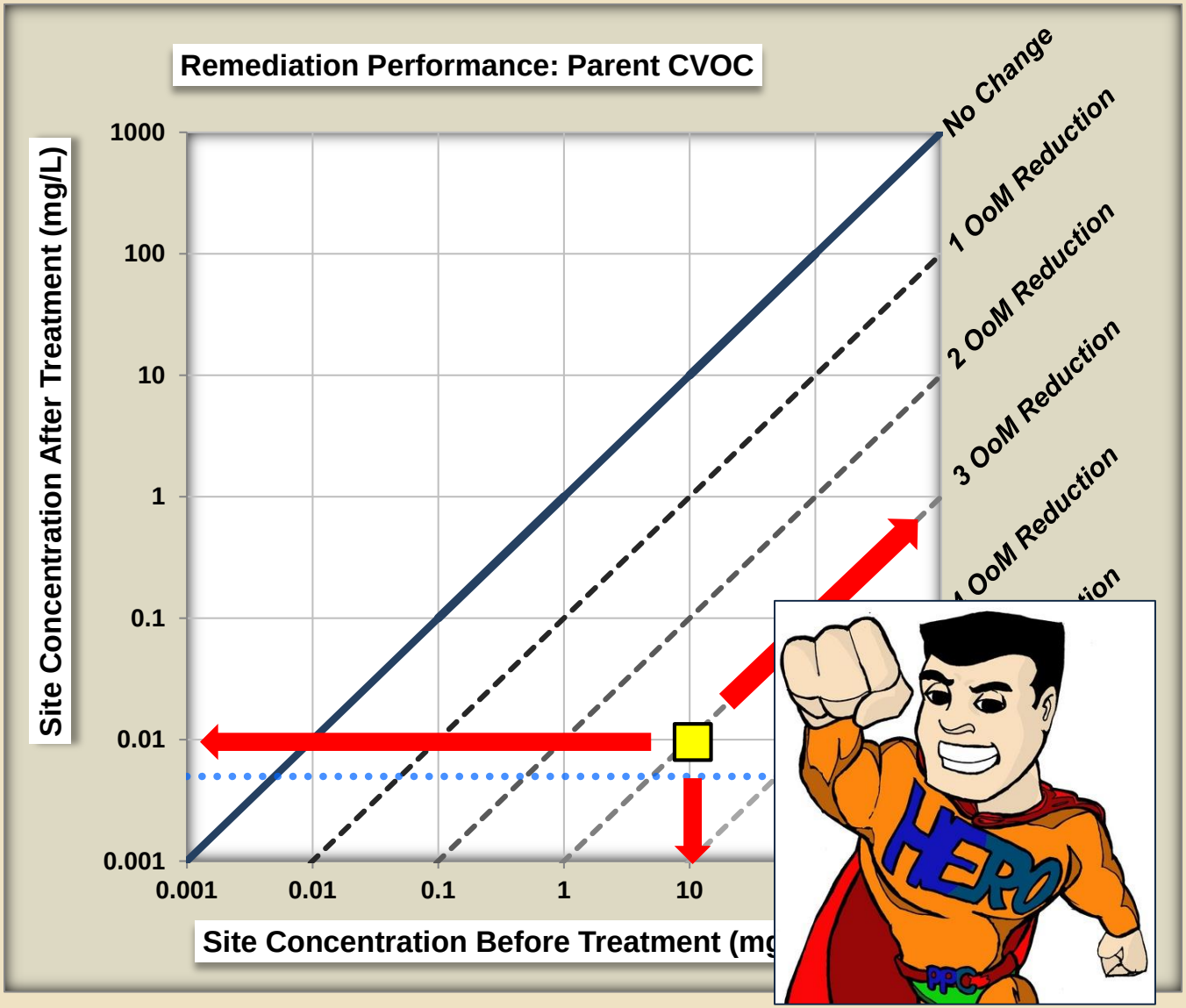
ITRC, 2012. Integrated DNAPL Site Strategy Guidance

PERFORMANCE RESULTS

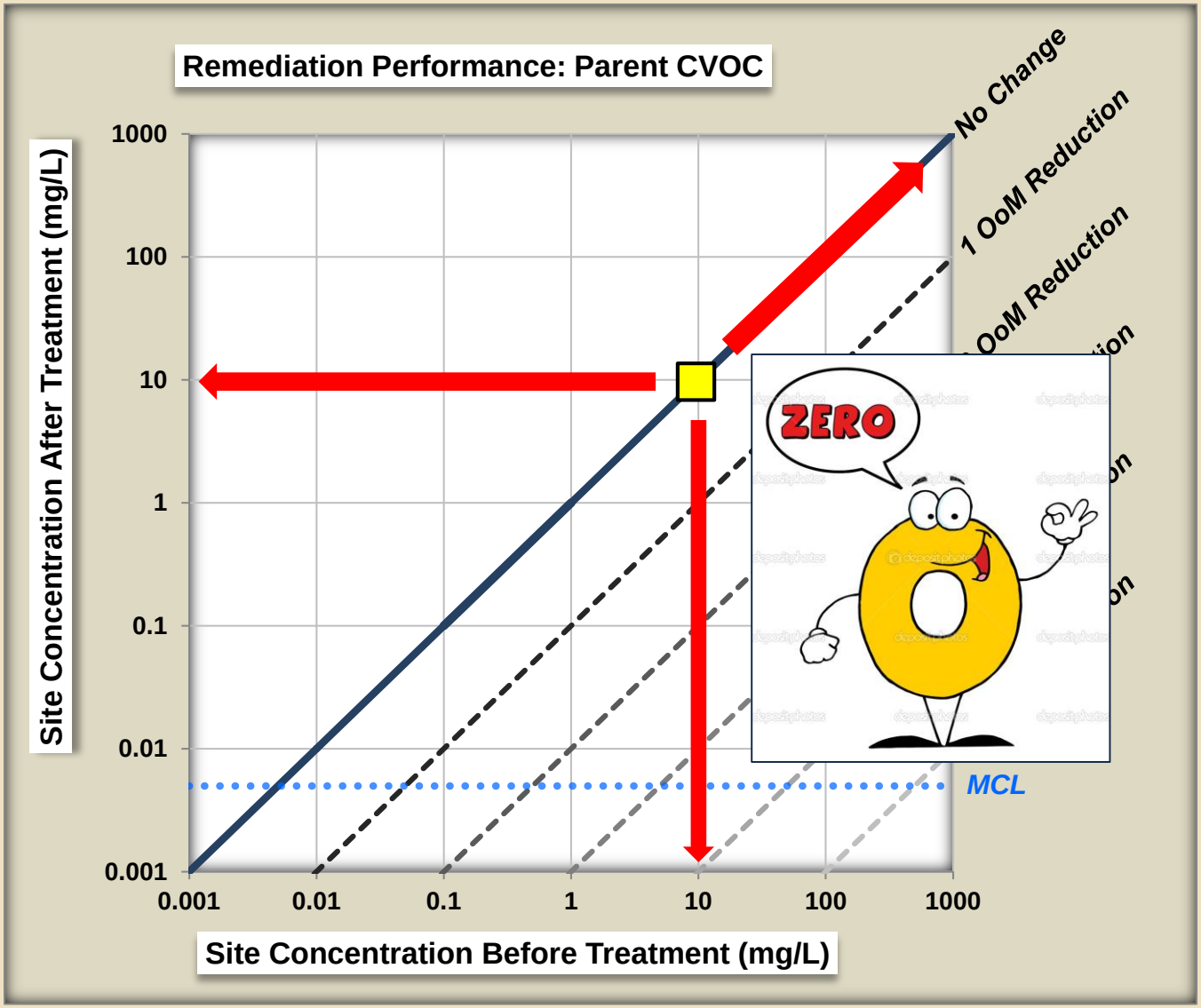
PERFORMANCE RESULTS



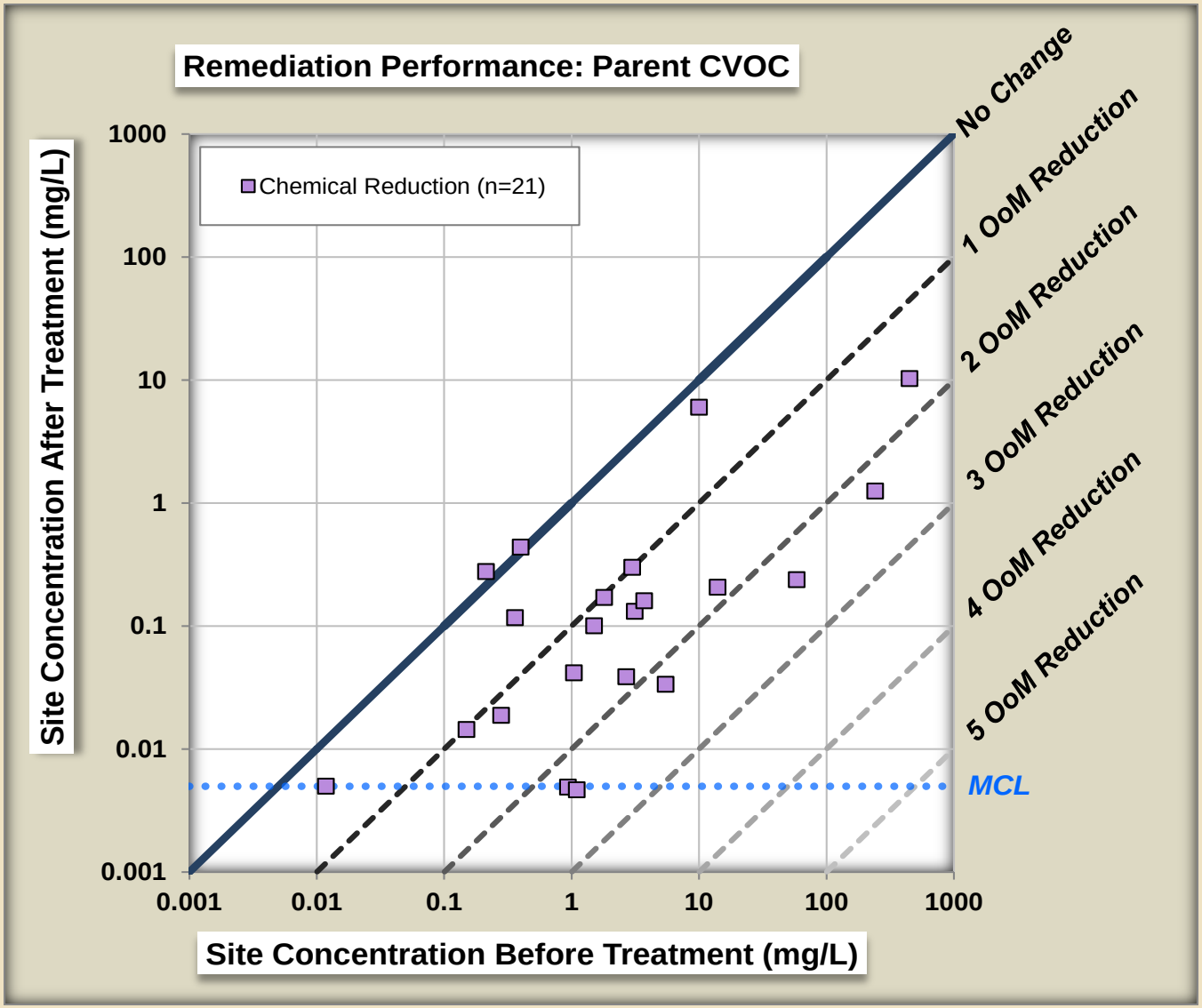
PERFORMANCE RESULTS



PERFORMANCE RESULTS



PERFORMANCE – Geomean Conc. by Site



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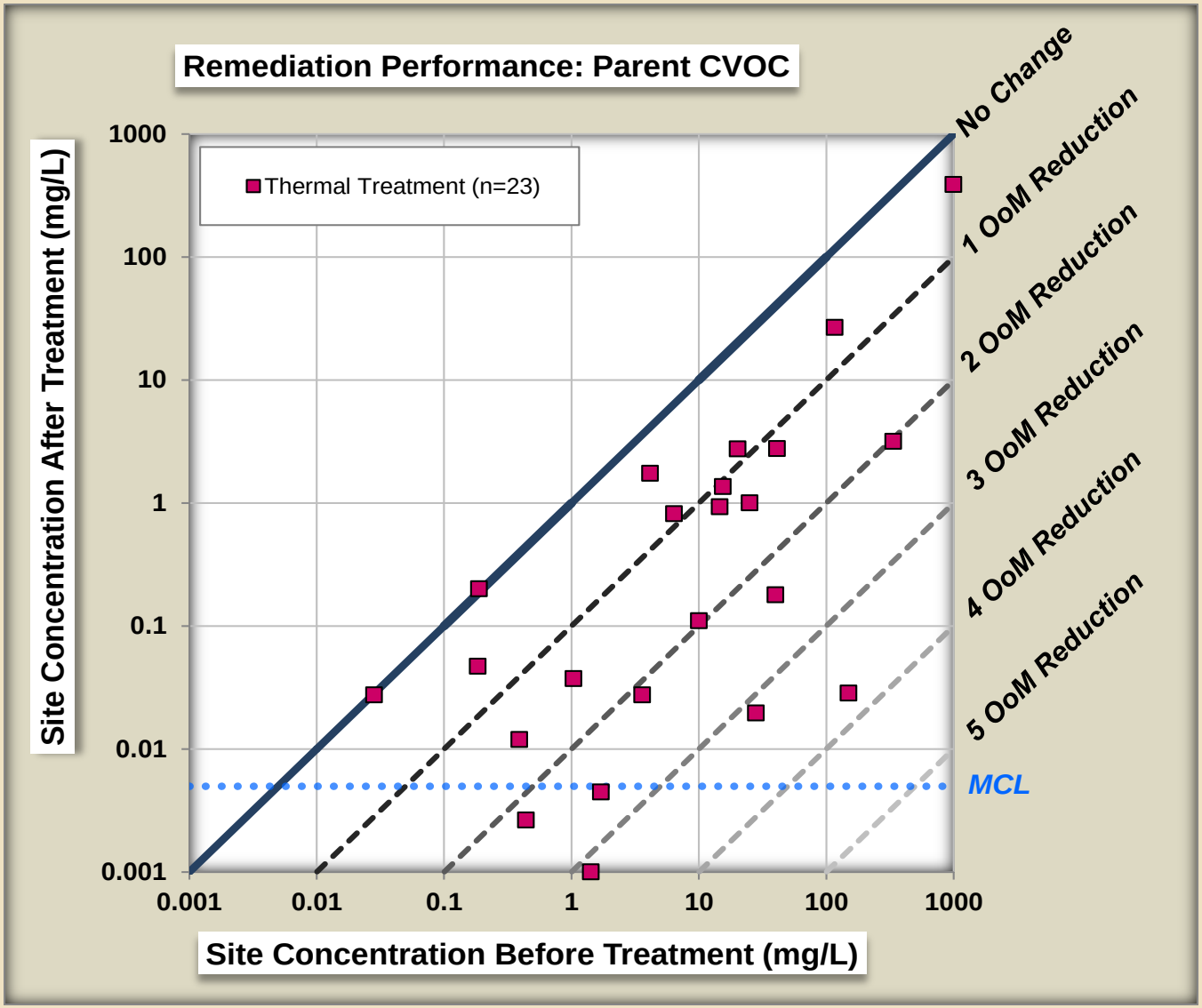

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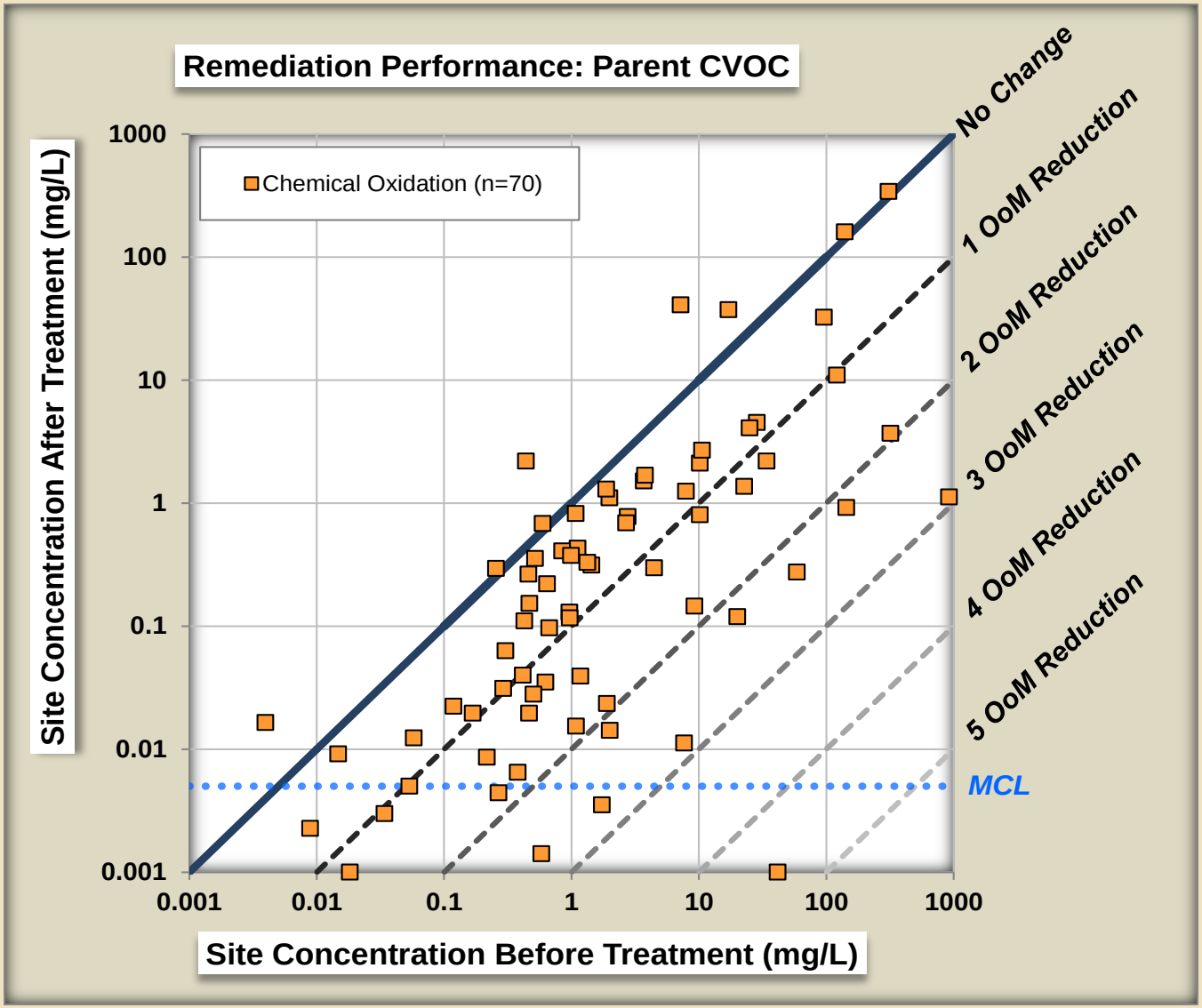
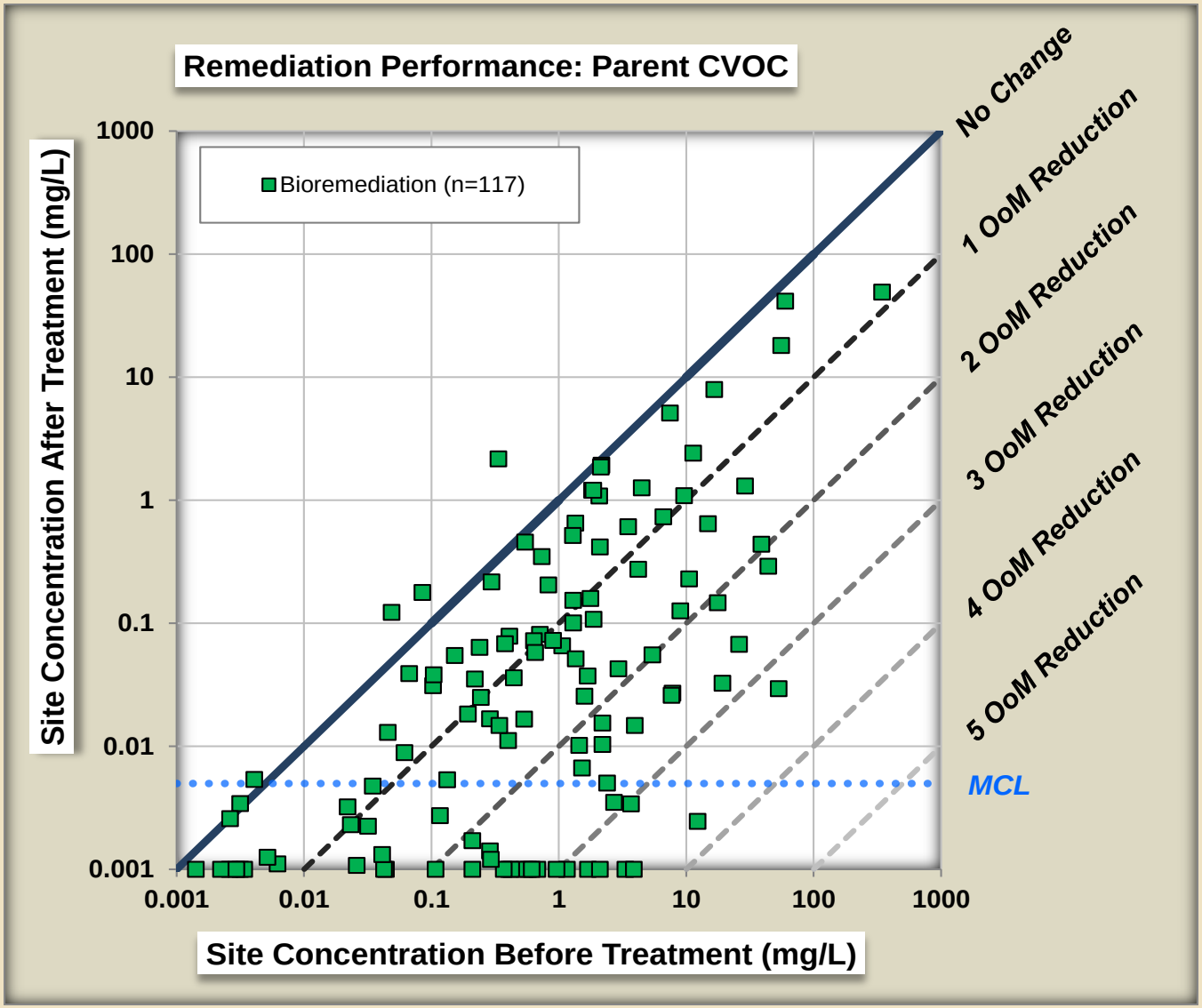
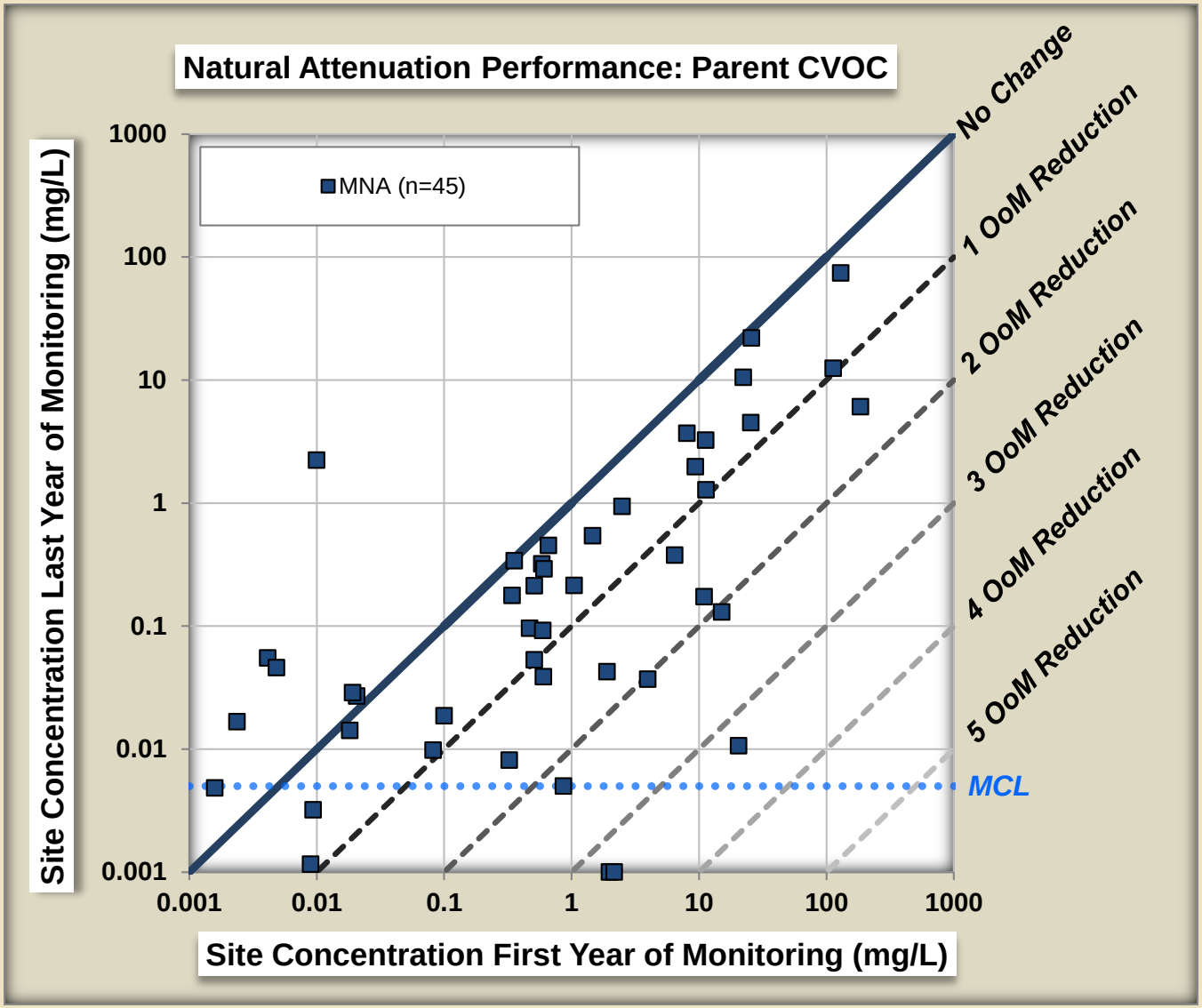


PERFORMANCE – Geomean Conc. by Site



PERFORMANCE – Geomean Conc. by Site



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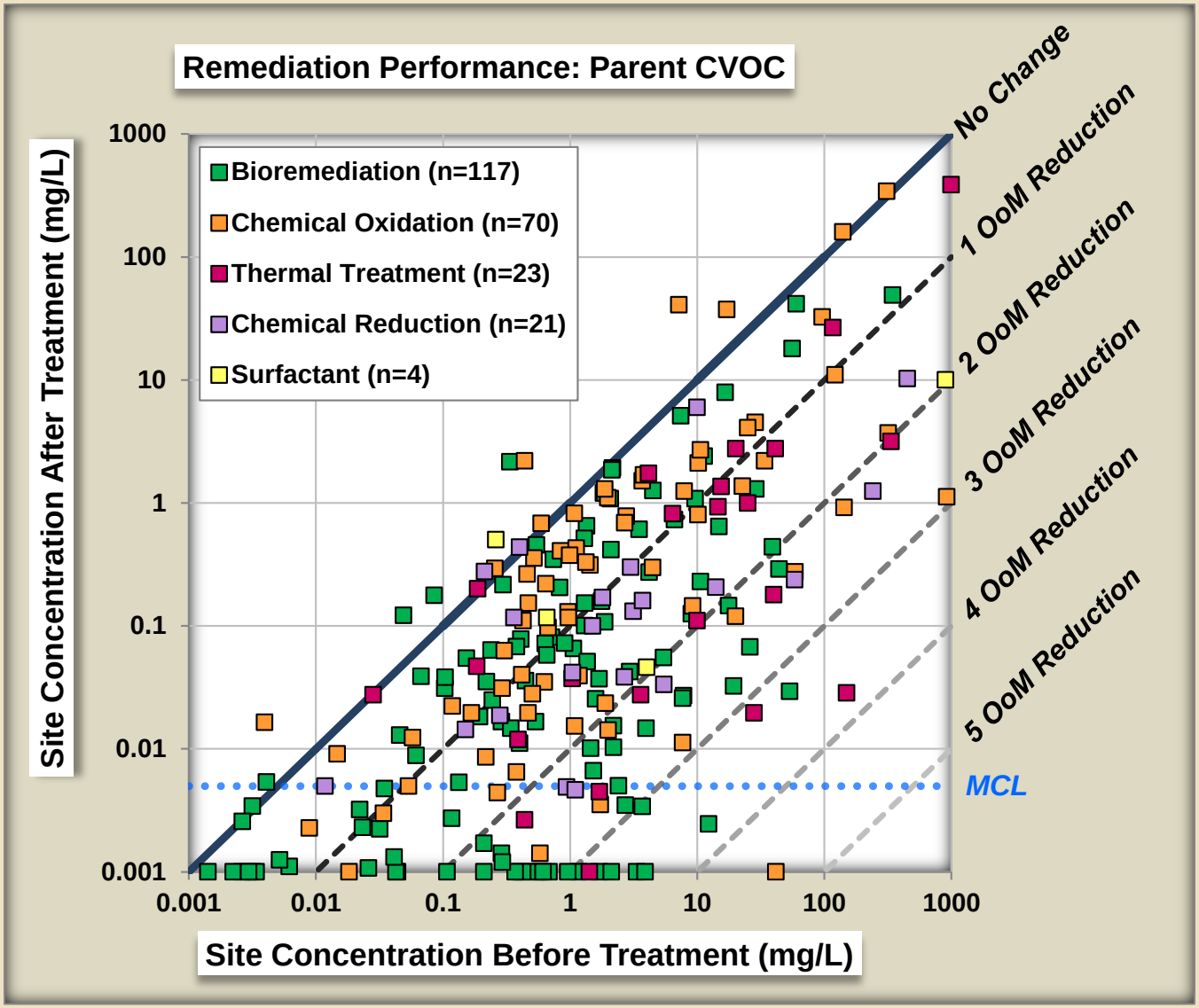
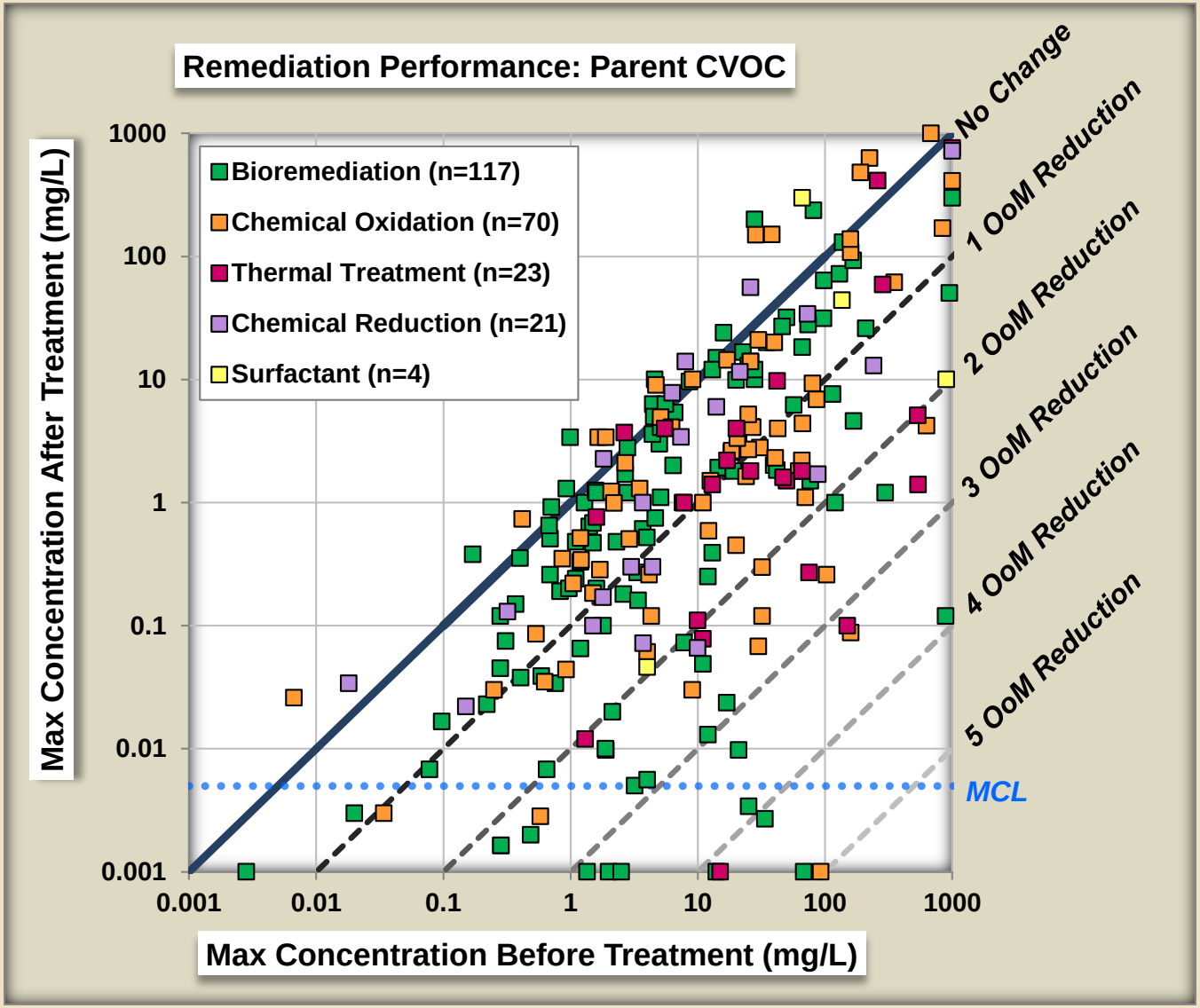


PERFORMANCE – Max Conc. by Site



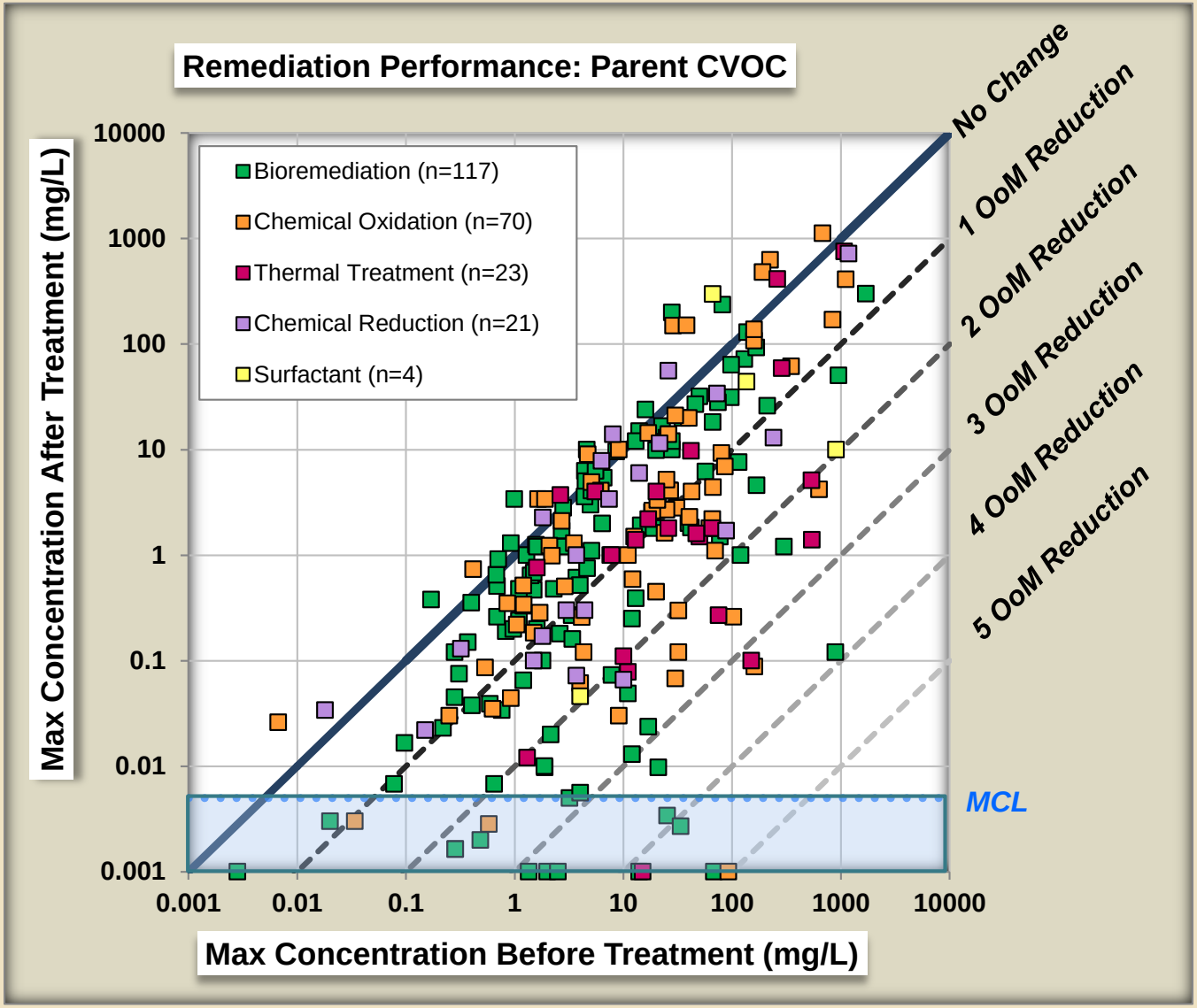
PERFORMANCE – Max Conc. by Well

PERFORMANCE – A Closer Look

Max. Concs. (Regulatory Drivers)

Achieved MCLs

8 % of sites

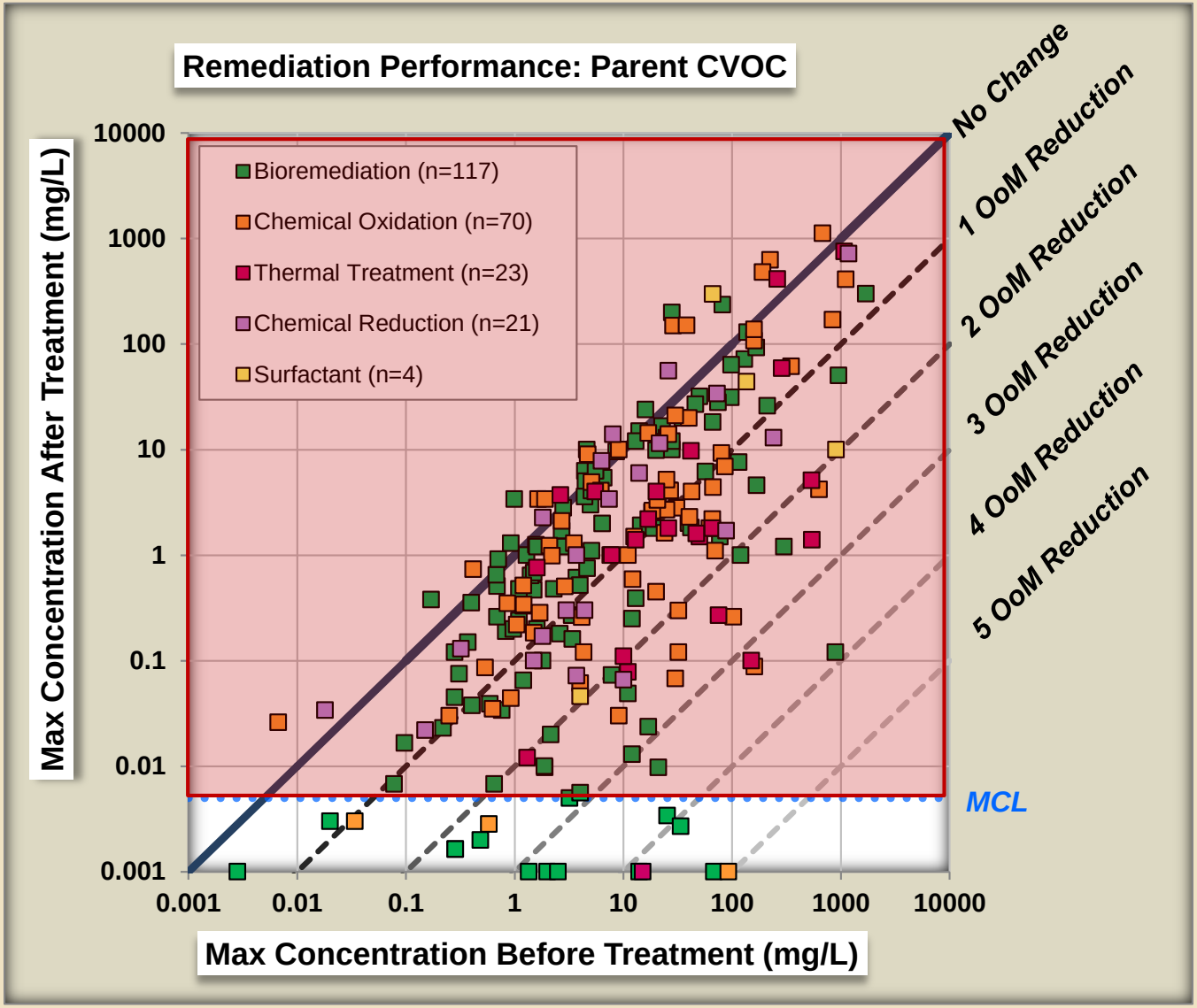


PERFORMANCE – A Closer Look

Max. Concs. (Regulatory Drivers)

Failed to Achieve MCLs

92 % of sites

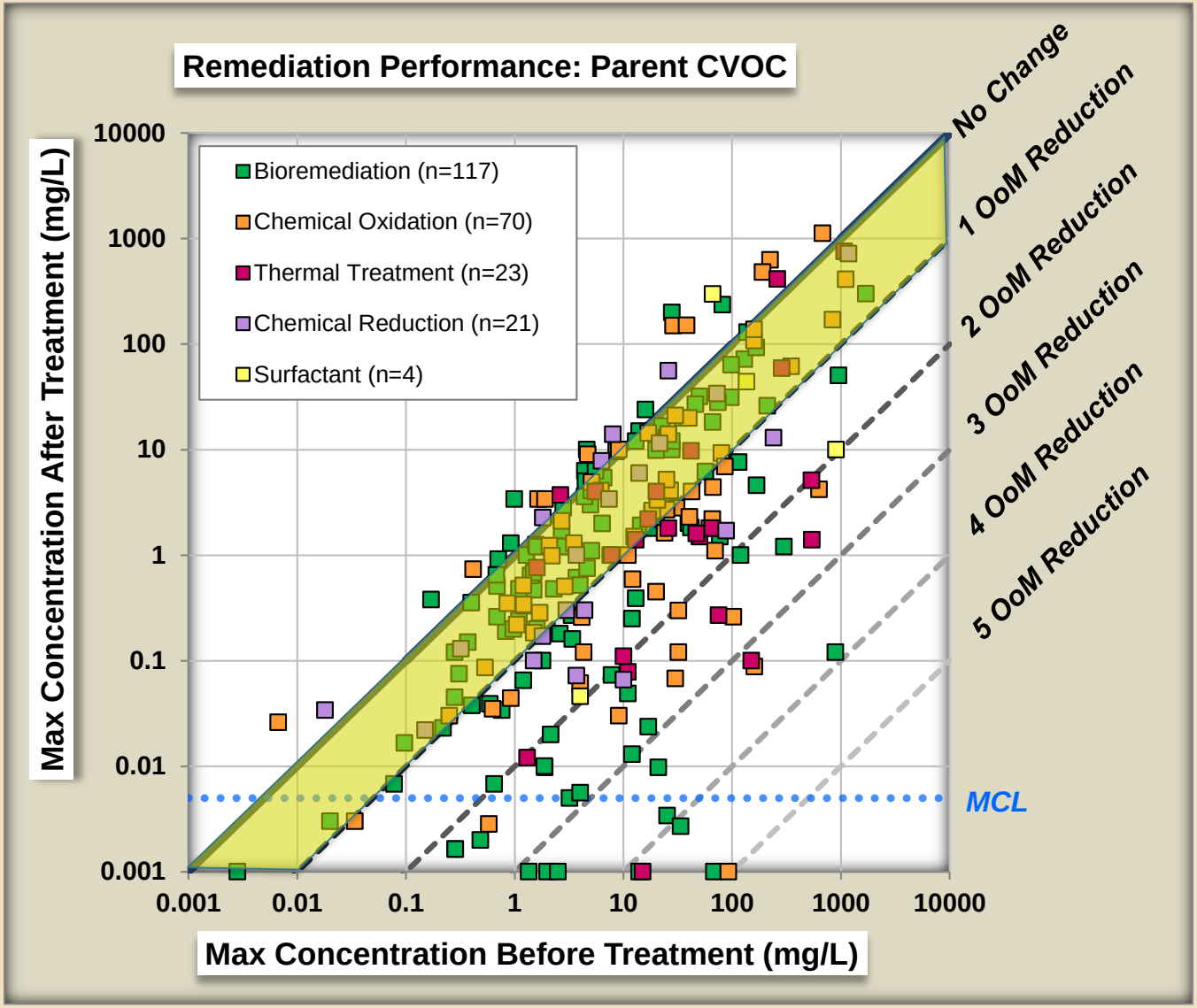


PERFORMANCE – A Closer Look

Max. Concs. (Regulatory Drivers)

Achieved 0 to 1 OoM Reduction

47 % of sites

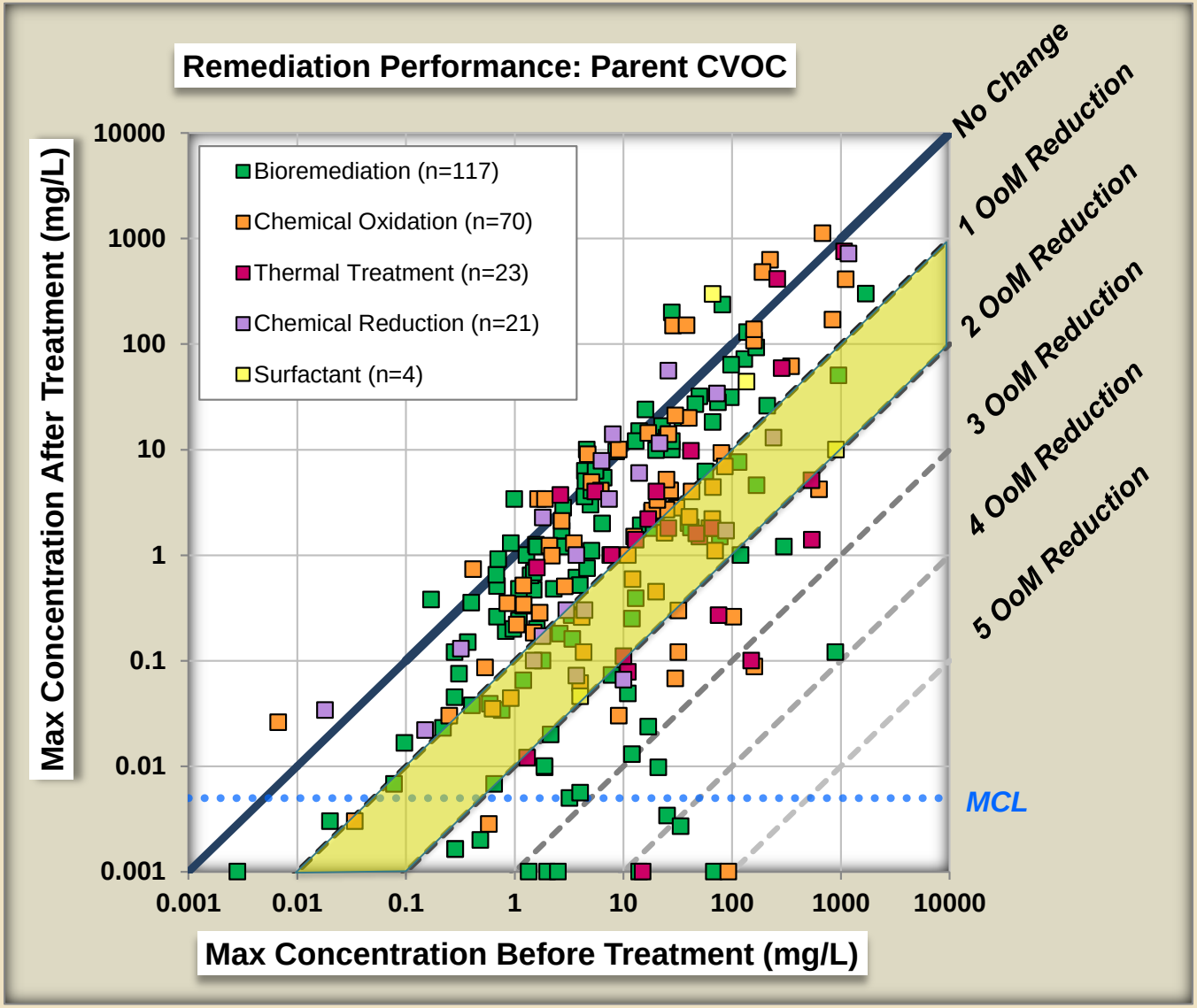


PERFORMANCE – A Closer Look

Max. Concs. (Regulatory Drivers)

Achieved 1 to 2 OoM Reduction

22 % of sites

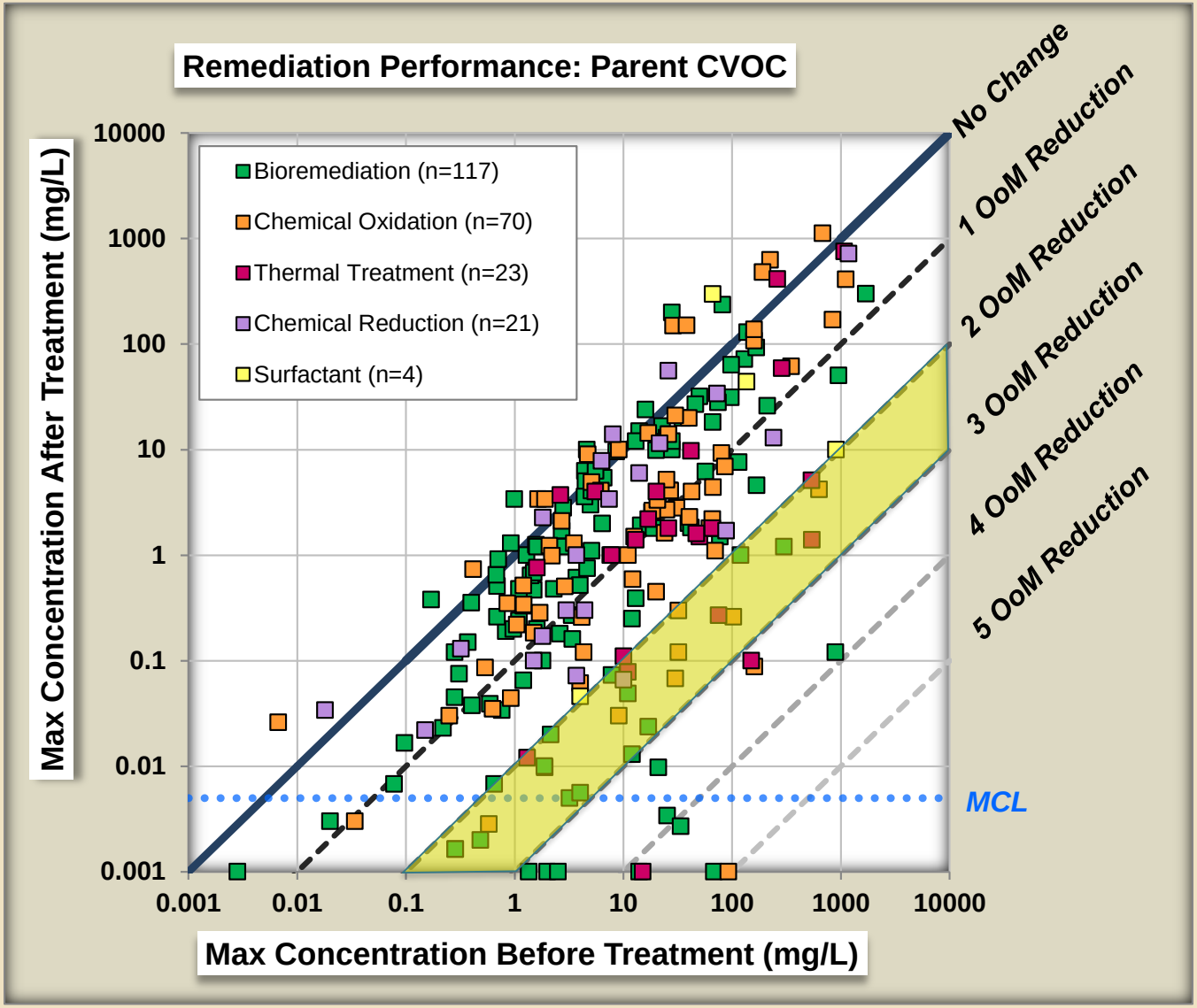


PERFORMANCE – A Closer Look

Max. Concs. (Regulatory Drivers)

Achieved 2 to 3 OoM Reduction

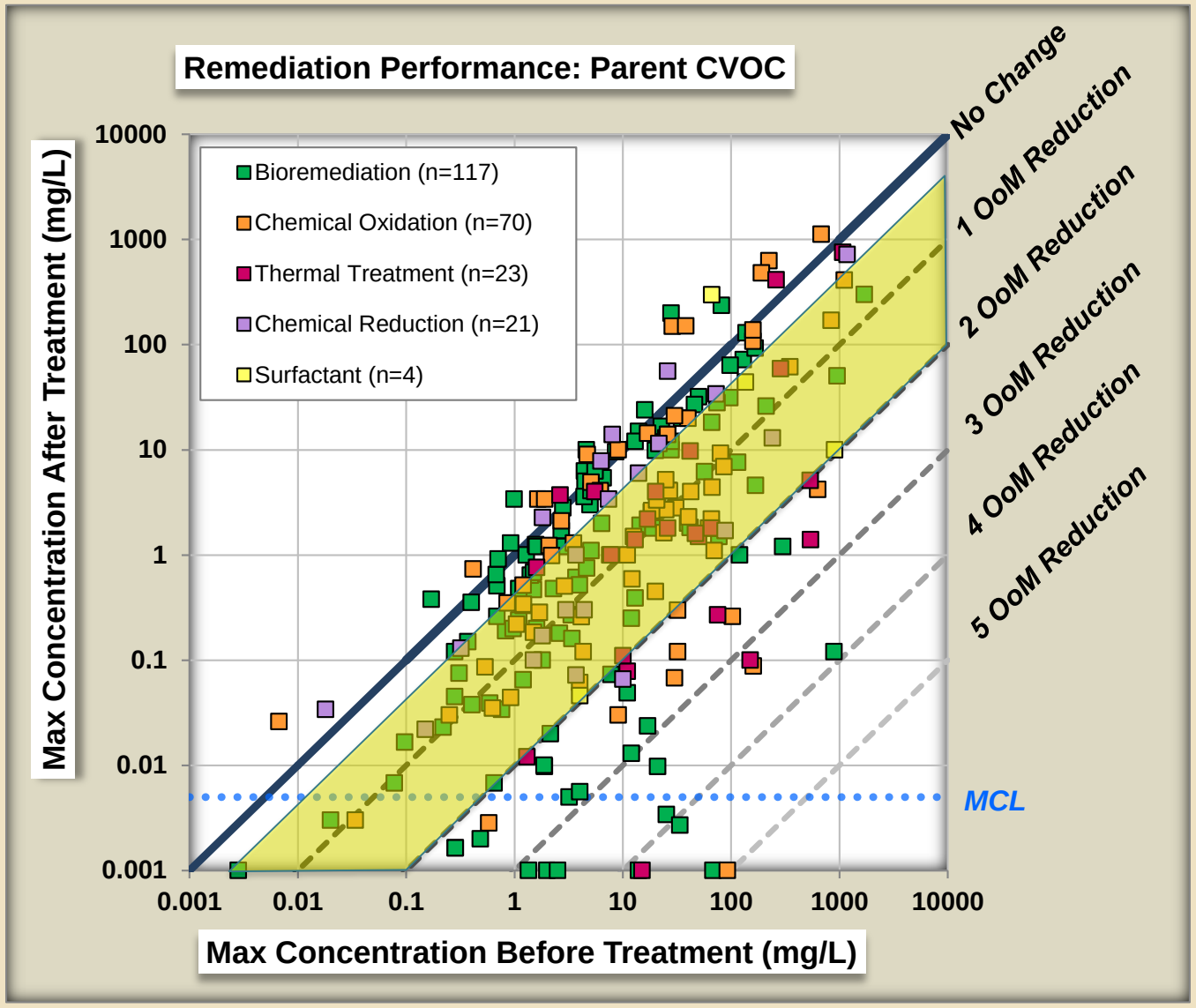
11 % of sites



PERFORMANCE – Rule of Thumb

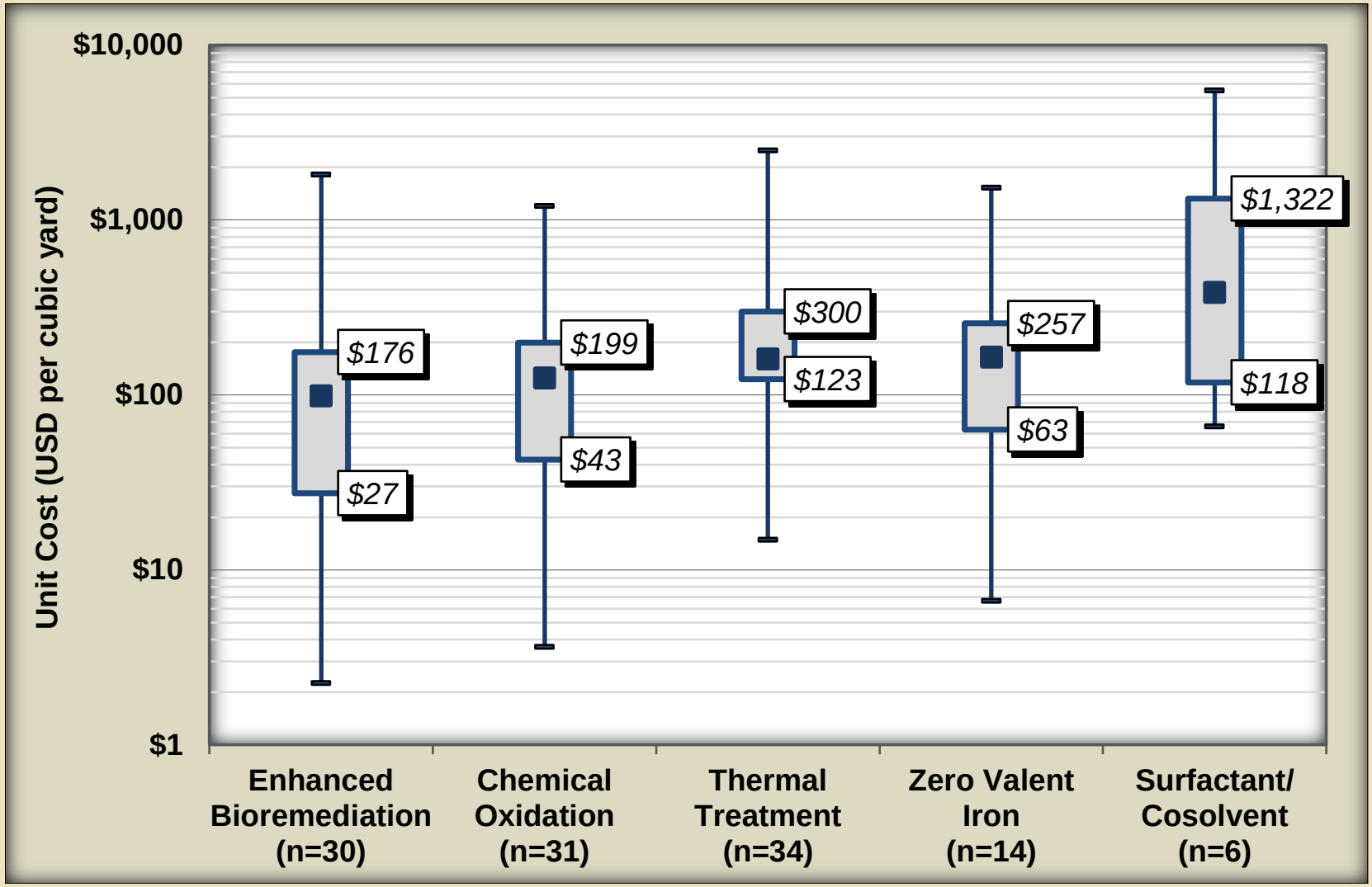
Max. Concs. (Regulatory Drivers)

Middle 50% of Sites Achieved ~ 0.5 to 2 OoM Reduction

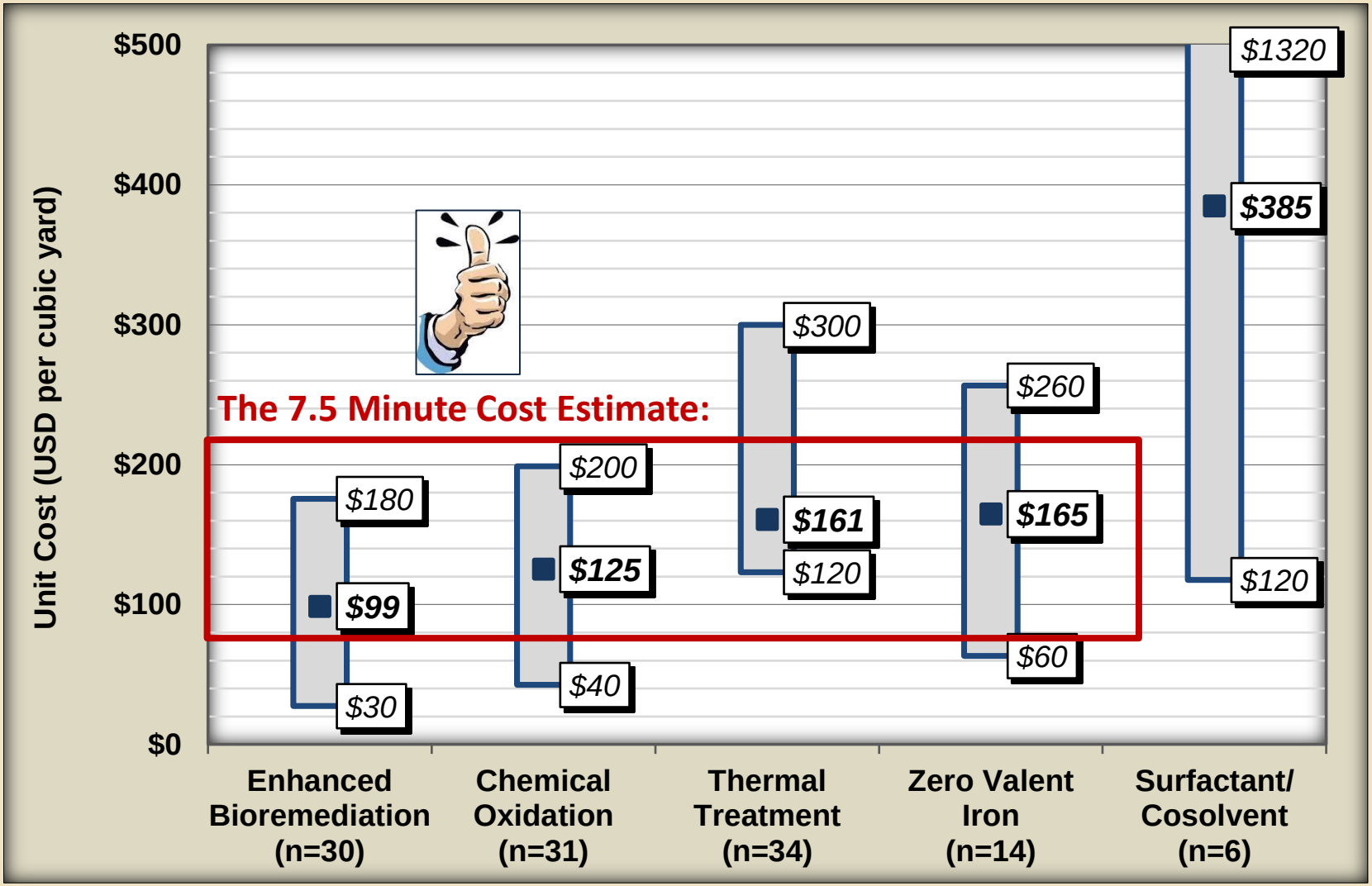


AT WHAT COST?

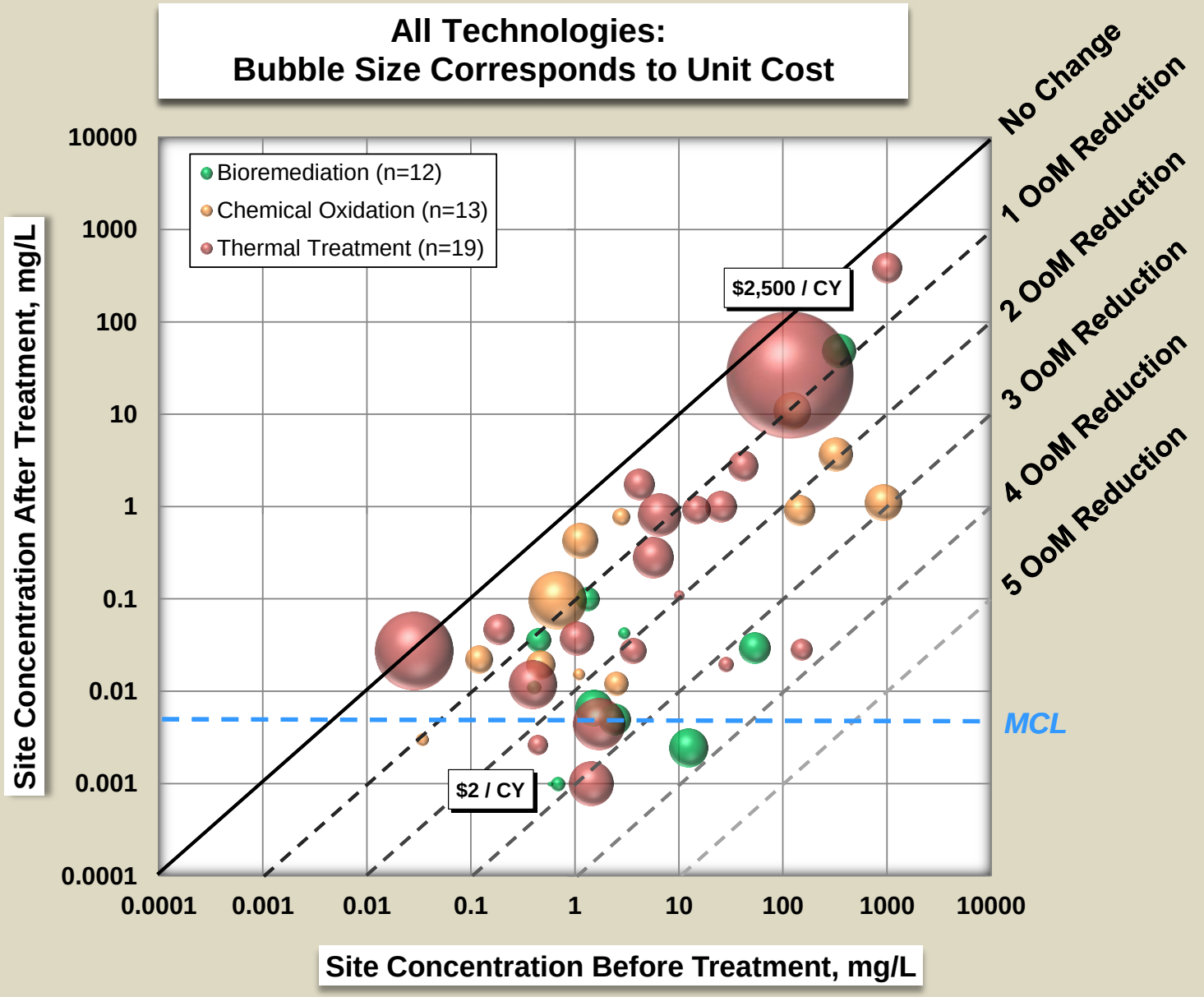
AT WHAT COST?


$10,000
$1,000
$100
$10
$1
Unit Cost (USD per cubic yard)
$176
$27
$199
$43
$300
$123
$257
$63
$1,322
$118
Enhanced Bioremediation (n=30)
Chemical Oxidation (n=31)
Thermal Treatment (n=34)
Zero Valent Iron (n=14)
Surfactant/ Cosolvent (n=6)

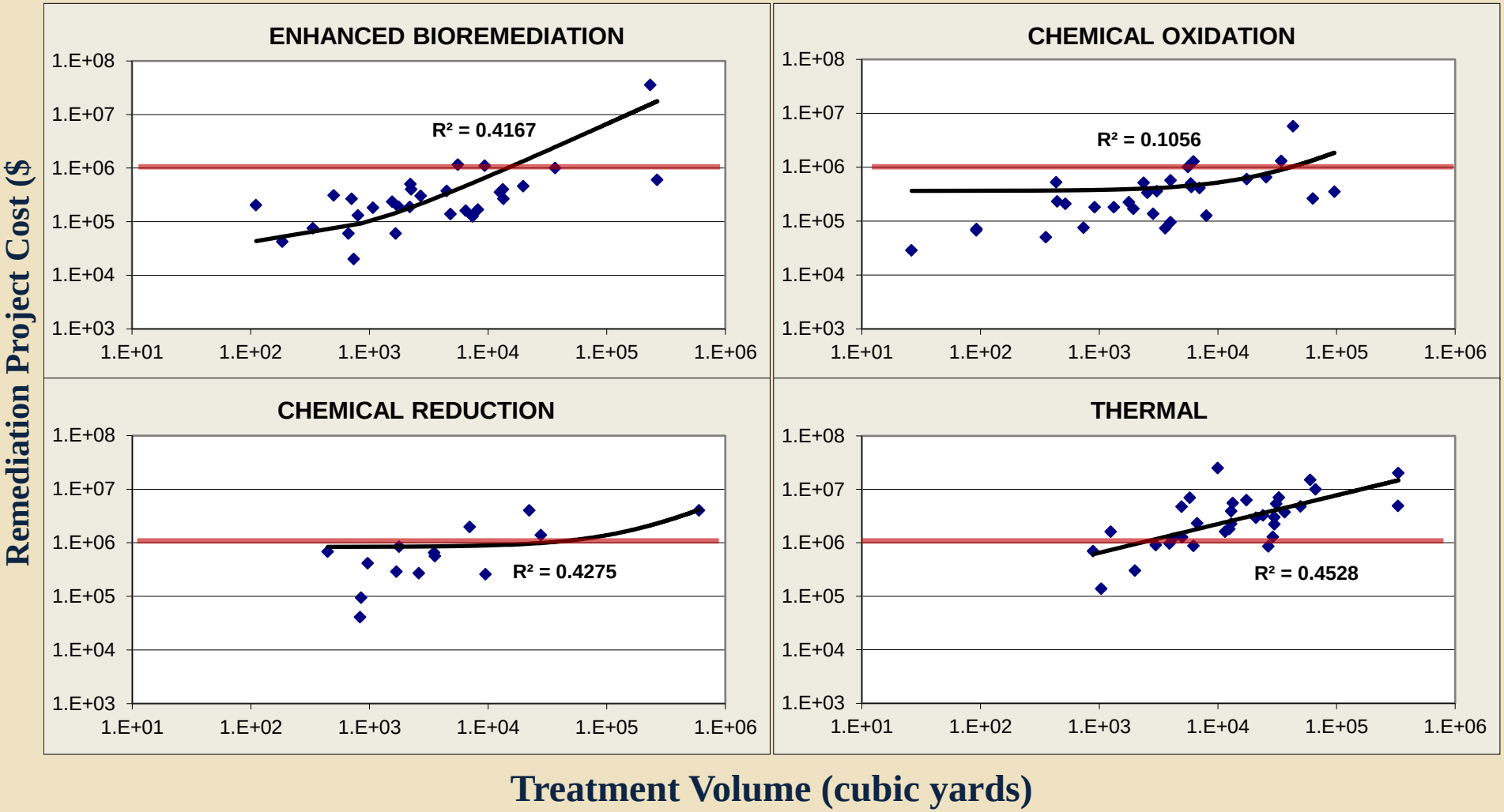
AT WHAT COST?


Unit Cost (USD per cubic yard)
$500
$400
$300
$200
$100
$0
The 7.5 Minute Cost Estimate:
$180
$99
$30
$200
$125
$40
$300
$161
$120
$260
$165
$60
$1320
$385
$120
Enhanced Bioremediation (n=30)
Chemical Oxidation (n=31)
Thermal Treatment (n=34)
Zero Valent Iron (n=14)
Surfactant/ Cosolvent (n=6)

AT WHAT COST?


All Technologies:
Bubble Size Corresponds to Unit Cost
Bioremediation (n=12)
Chemical Oxidation (n=13)
Thermal Treatment (n=19)
$2,500 / CY
$2 / CY
No Change
1 OoM Reduction
2 OoM Reduction
3 OoM Reduction
4 OoM Reduction
5 OoM Reduction
MCL
Site Concentration After Treatment, mg/L
Site Concentration Before Treatment, mg/L
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.0001
0.001
0.01
0.1
1
10
100
1000
10000

AT WHAT COST?

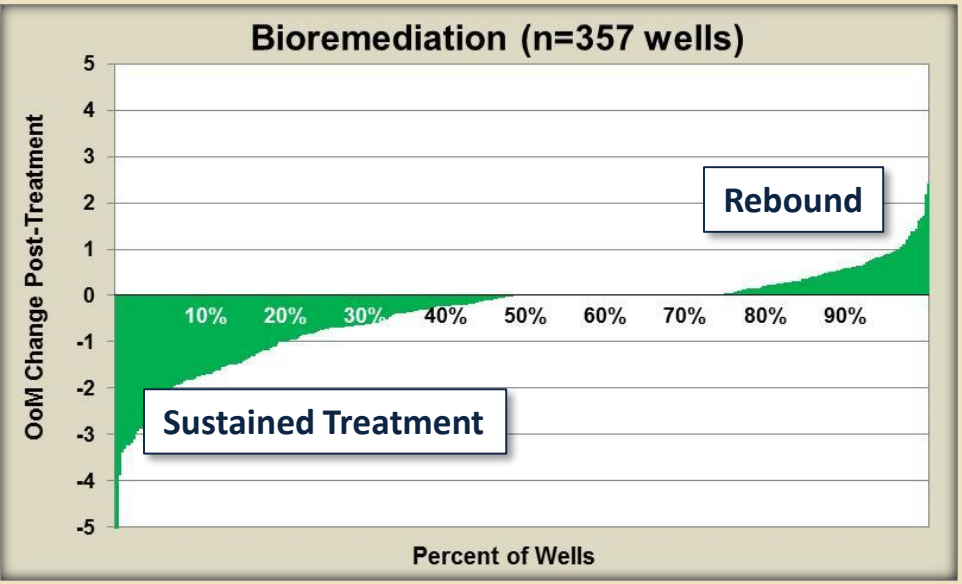

ENHANCED BIOREMEDIATION
R² = 0.4167
CHEMICAL OXIDATION
R² = 0.1056
CHEMICAL REDUCTION
R² = 0.4275
THERMAL
R² = 0.4528
1.E+08
1.E+07
1.E+06
1.E+05
1.E+04
1.E+03
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
1.E+06
Remediation Project Cost ($
Treatment Volume (cubic yards)

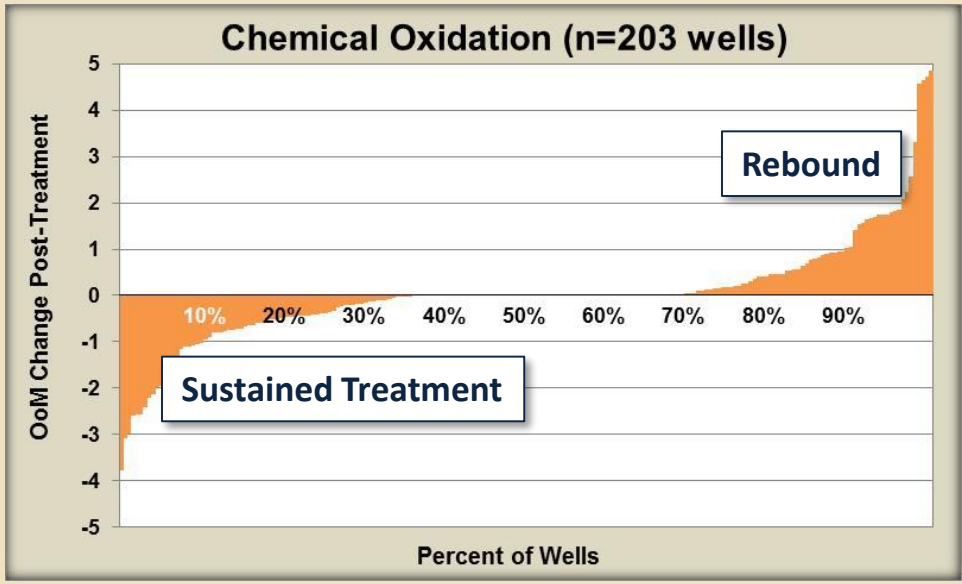
OTHER IMPLICATIONS

1. Sustained Treatment vs. Rebound
2. Transitions Assessments
3. Mass Discharge
4. Aquifer Management

OTHER IMPLICATIONS

Sustained Treatment vs. Rebound for 2 Most Common Technologies





Evidence of Sustained Treatment at about two-thirds of Bioremediation sites with 3 to 12 years post-treatment data (n=34)

McGuire et al., 2016. Groundwater Monitoring & Remediation, 36(2), pp 32-44.

OTHER IMPLICATIONS

- **Consider "Transition Assessment" when further active remediation not much benefit; instead focus on risk and containment**
- **Performance data can be used to support transition from active to passive remedy**
- **Incorporate performance data into 5-Year Reviews at Superfund sites**

National Research Council, 2012

OTHER IMPLICATIONS

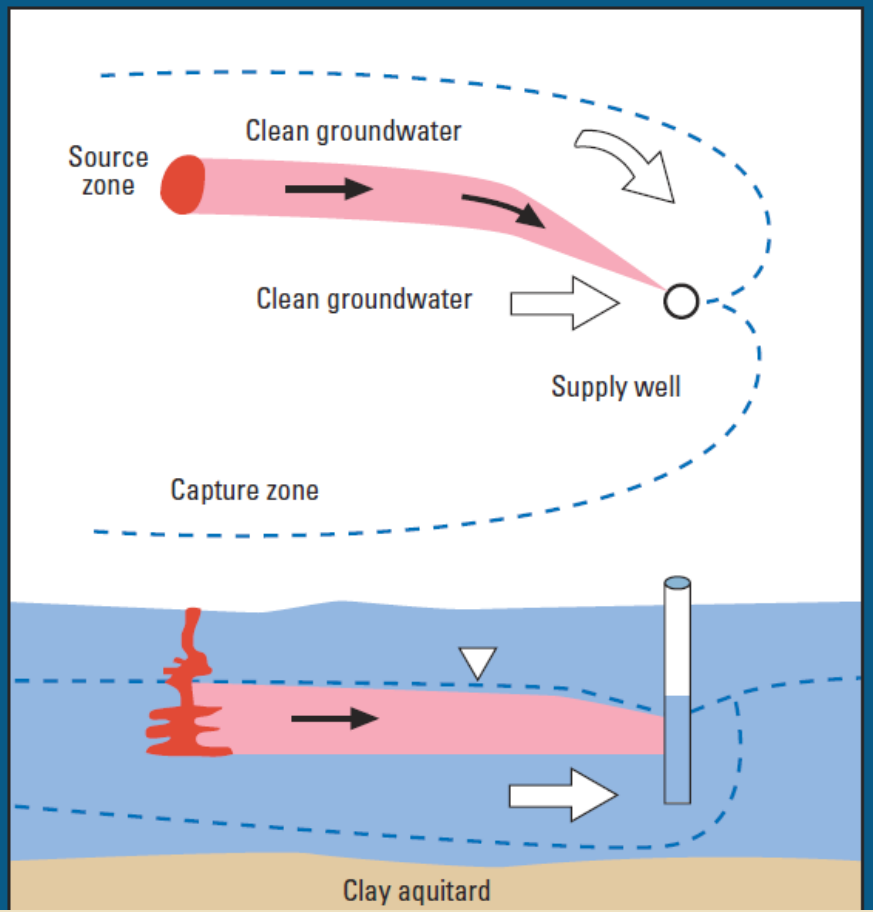
- **More emphasis on Mass Discharge**
  - What is the risk to water supply well?
  - What will the mass discharge be after a remediation project that achieves 1 to 2 OoM reduction?

Einarson and Mackay, 2001. ES&T, 35(3), 66A-73A

FIGURE 1

Plume capture by a supply well

A dissolved plume of contaminants can be hydraulically captured by a downgradient supply well. The contaminant release shown is migrating within a uniform sand aquifer (no fill) overlying a clay aquitard. Clean water on all sides of the plume is also extracted, diluting the concentration of dissolved contaminants in the water pumped from the well.



OTHER IMPLICATIONS

EXAMPLE. Before Treatment:

- 60 ft wide x 10 ft thick source
- Seepage velocity = 1 ft/d
- PCE = 2.5 mg/L

⇨ **Mass discharge ≈ 11 g/d**

- Supply well Q ≈ 260 gpm

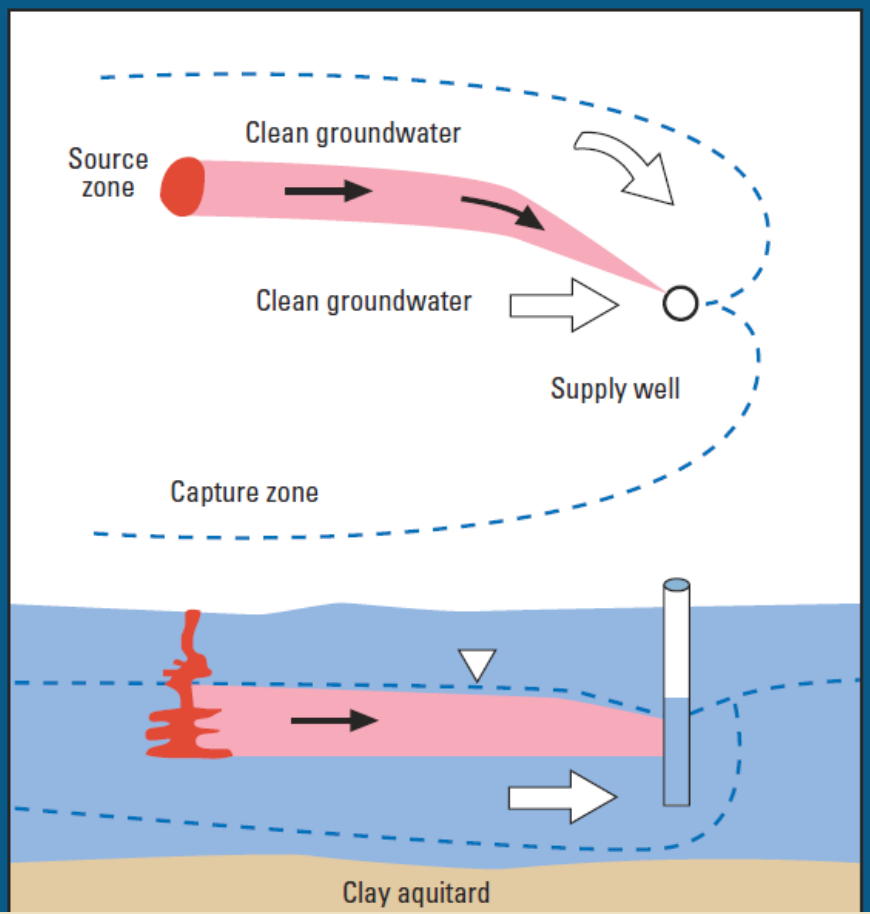
⇨ **Supply well TCE ≈ 8 µg/L**

Exceeds MCL of 5 µg/L

FIGURE 1

Plume capture by a supply well

A dissolved plume of contaminants can be hydraulically captured by a downgradient supply well. The contaminant release shown is migrating within a uniform sand aquifer (no fill) overlying a clay aquitard. Clean water on all sides of the plume is also extracted, diluting the concentration of dissolved contaminants in the water pumped from the well.



OTHER IMPLICATIONS

EXAMPLE. After Treatment that Achieves 1 OoM Reduction in Source:

- PCE = 0.25 mg/L

⇨ **Mass discharge ≈ 1 g/d**

- Supply well Q = 260 gpm

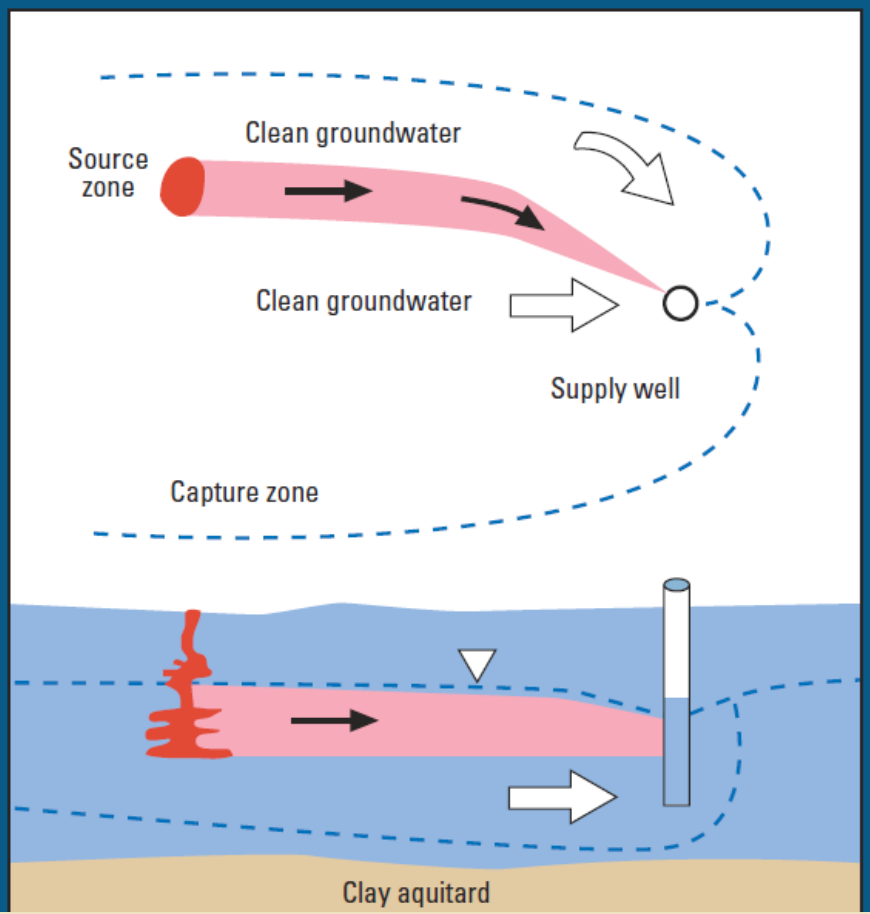
⇨ **Supply well TCE ≈ 0.8 µg/L**

Below the MCL of 5 µg/L

FIGURE 1

Plume capture by a supply well

A dissolved plume of contaminants can be hydraulically captured by a downgradient supply well. The contaminant release shown is migrating within a uniform sand aquifer (no fill) overlying a clay aquitard. Clean water on all sides of the plume is also extracted, diluting the concentration of dissolved contaminants in the water pumped from the well.



OTHER IMPLICATIONS

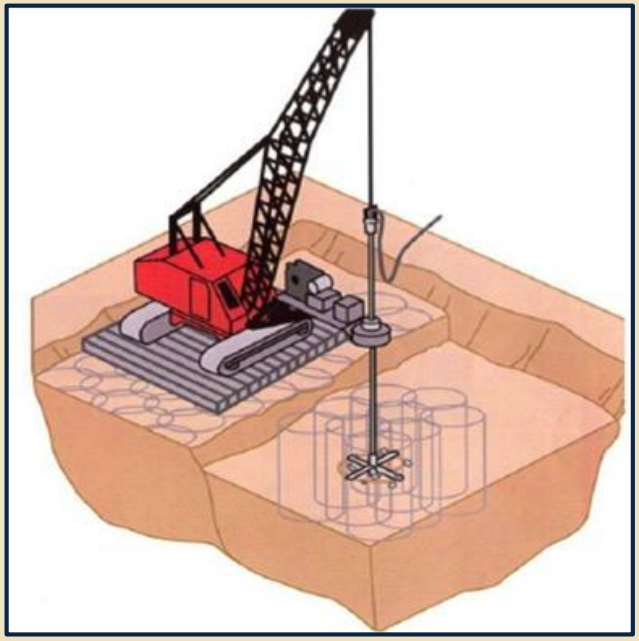
- **More emphasis on Aquifer Management**

  Isolate the source (a Containment Comeback?)

  - ⇨ Stop new groundwater contamination
  - ⇨ Less influence from heterogeneity
  - ⇨ More contact time inside source zone
  - ⇨ Natural attenuation of downgradient plume

OTHER IMPLICATIONS

Deep Soil Mixing / ZVI Clay



Source: Colorado State University

OTHER IMPLICATIONS

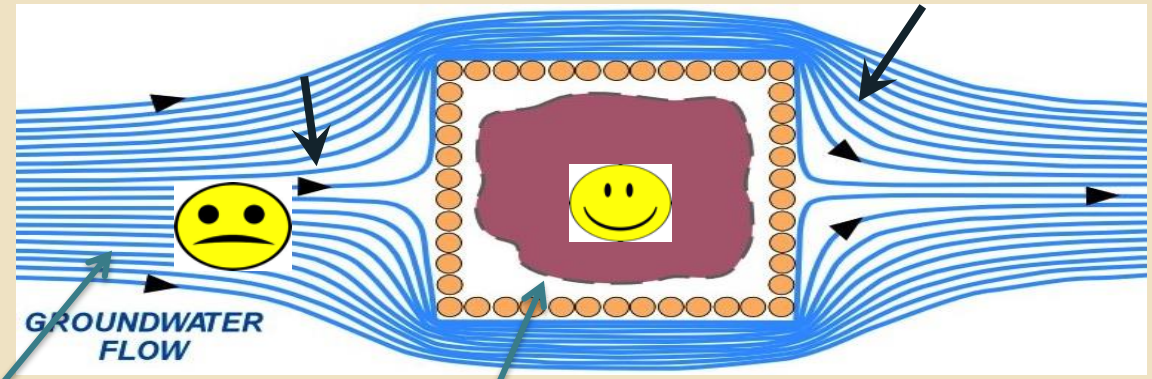
"FLUX CLOG"

Competing Electron Acceptors:

Dissolved Oxygen (O_2)

Nitrate (NO_3)

Sulfate (SO_4)



GSI ENVIRONMENTAL

ESTCP Project 201328

ESTCP

WRAP UP

Conclusions:

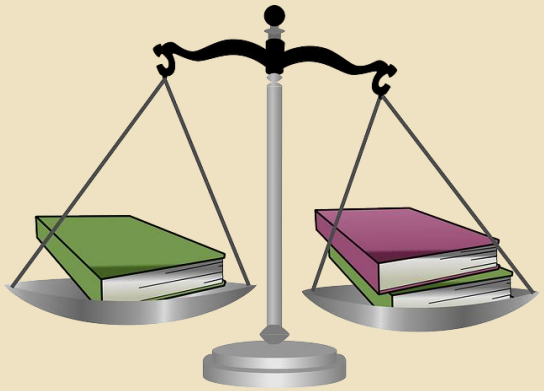
- MCLs achieved at less than 1 in 10 sites
- Typical performance was about 0.5 to 2 OoM reduction in groundwater concentrations
- Costs generally $100 to $200 per cubic yard
- Bioremediation appears effective for long-term, sustained treatment at most sites

Future:

- Quantifying sustained treatment benefits
- Continued emphasis on mass discharge
- More evaluation of matrix diffusion
- A Containment Comeback?

WRAP UP

"Past performance may not be indicative of future results"



"Those who do not remember the past are doomed to repeat it"

FOR MORE INFORMATION

- Final Report available on ESTCP website
- Search “ESTCP data mining”

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BACKUP SLIDES

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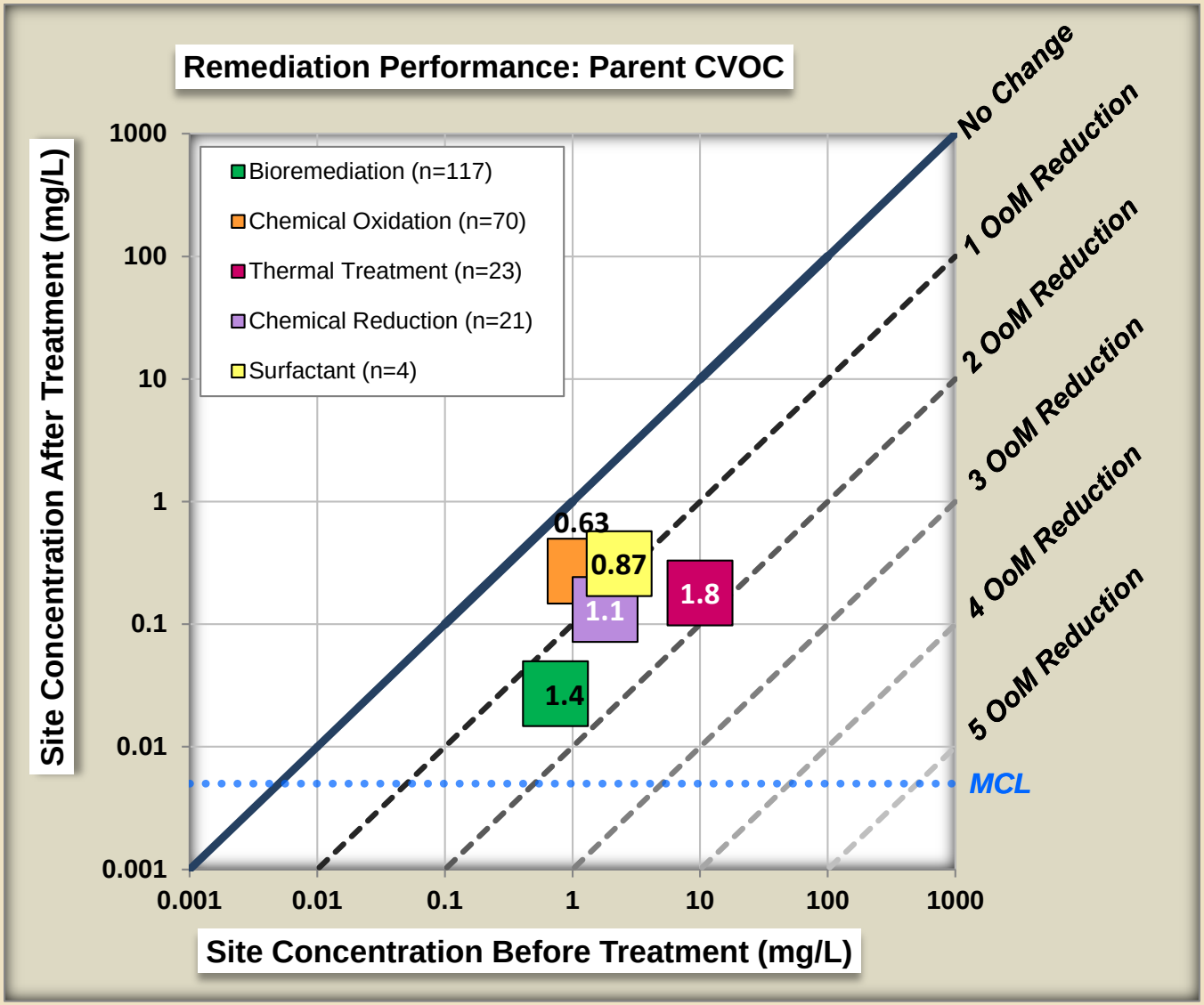

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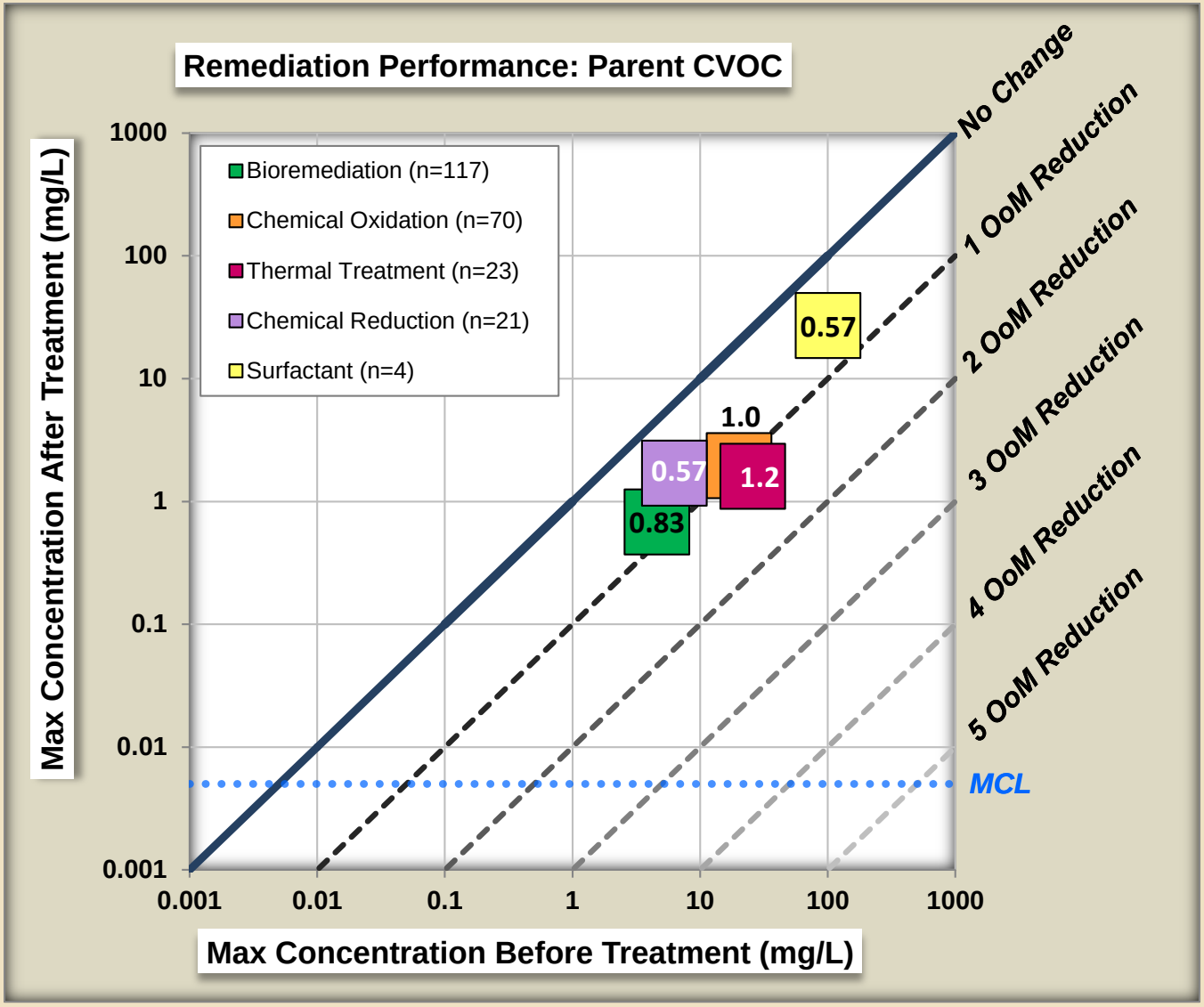

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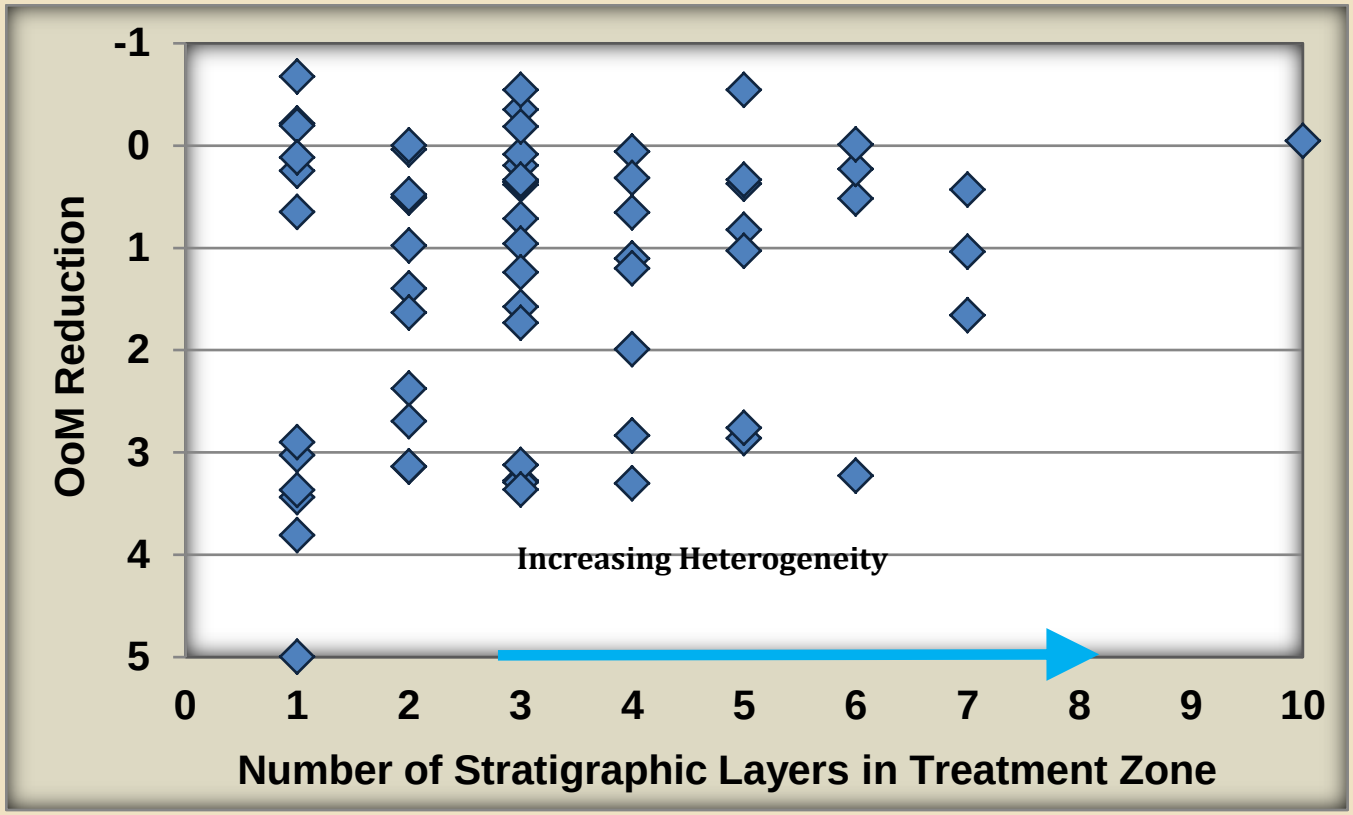

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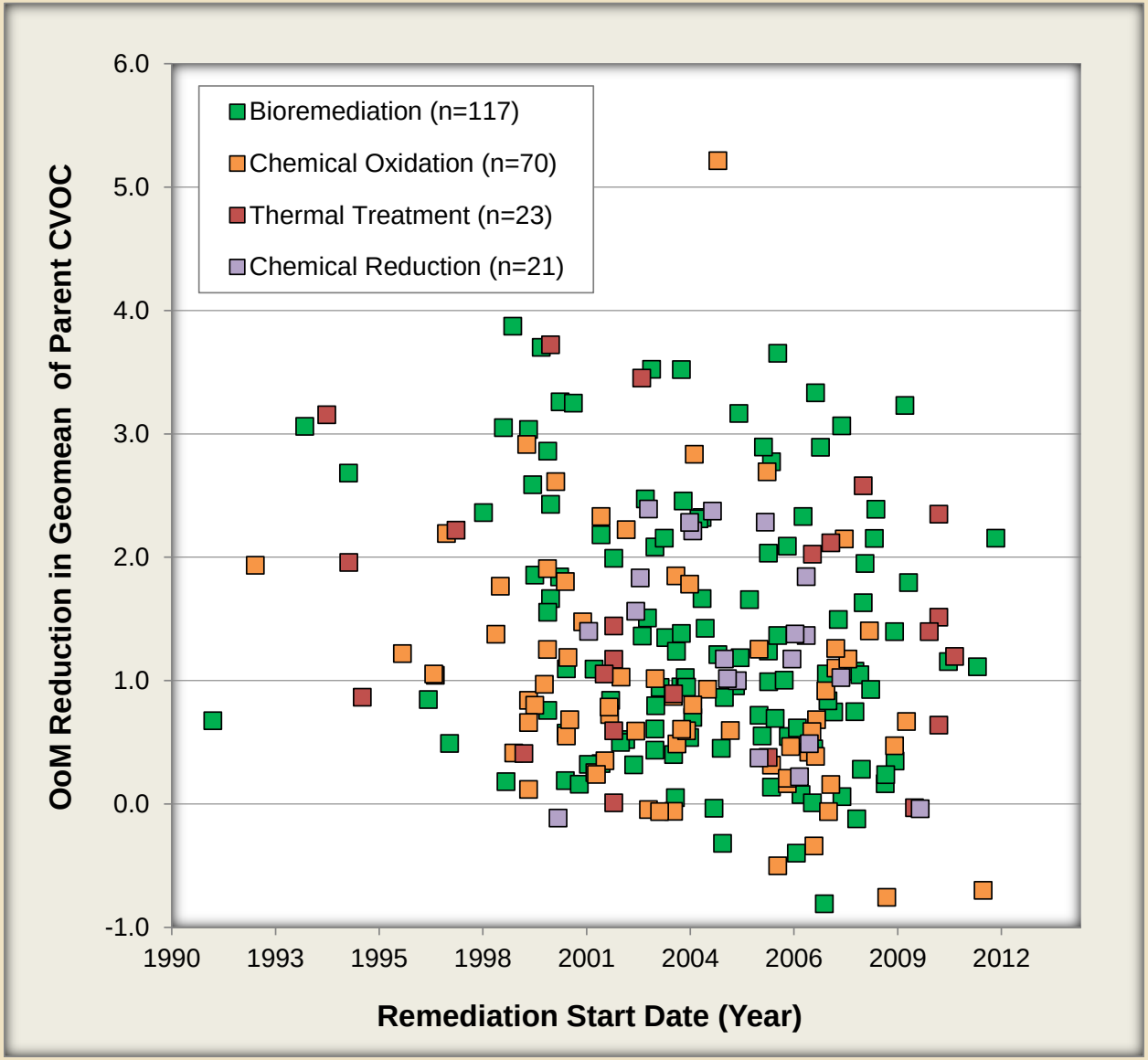

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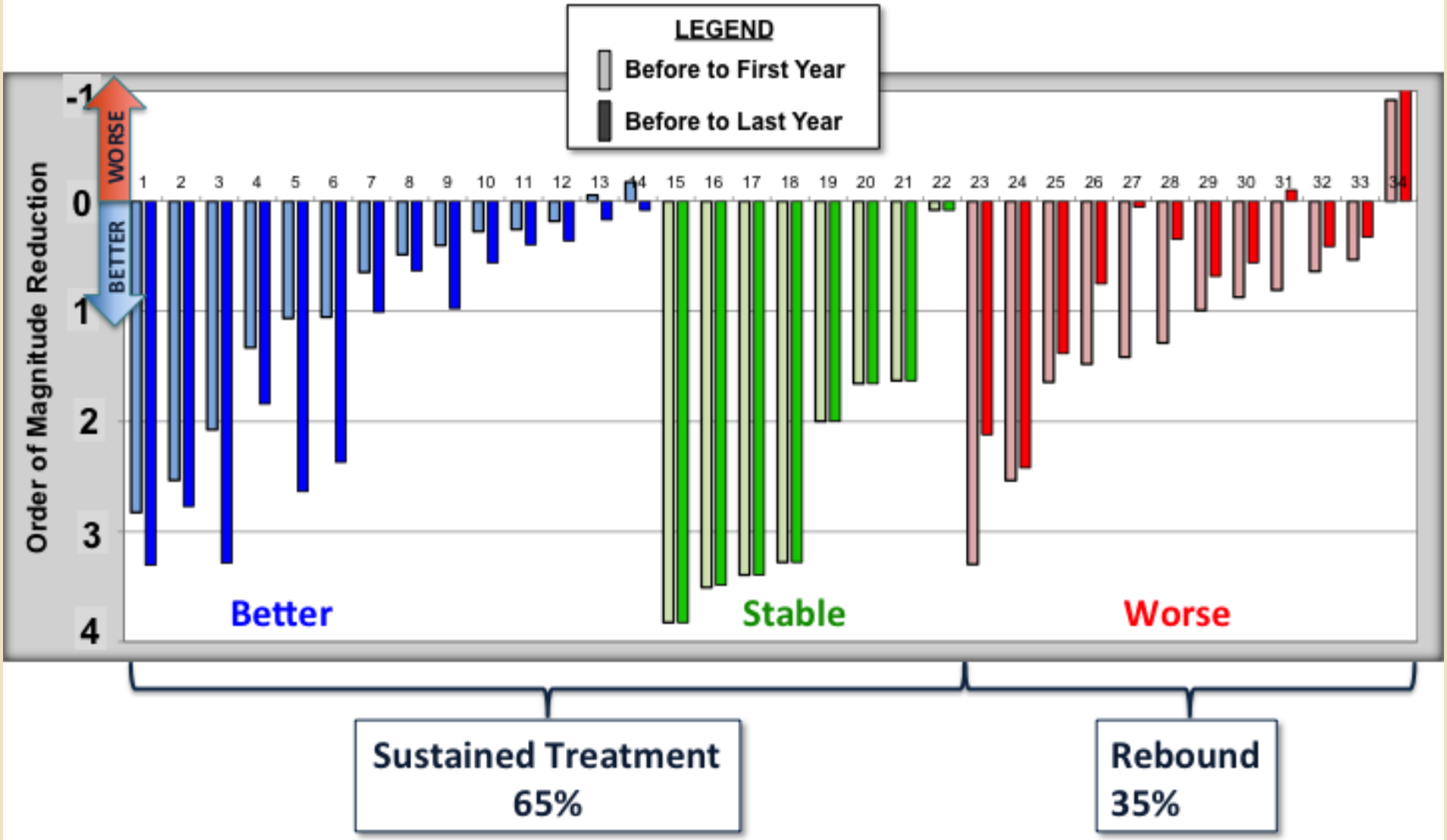

* Average time between first year and last year ≈ 4 years