Occurrence and Distribution of Ground Water Arsenic in Public Water Supply Wells in Ohio

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Acknowledgments

Data:

OEPA District Ambient Network Field Personnel

OEPA District Drinking Water Field Personnel

GIS Support:

Brian Gara and Dick McClish of the DDAGW GIS Unit

Arsenic in Ohio's PWS

- Arsenic Rule driven by health concerns

  Reduction of MCL to 10 ug/L from 50 ug/L

  Understanding As provenance can help optimize reduction strategies

- State-wide As appears widespread

  Analysis suggests that redox controls are more important than lithologic or stratigraphic controls

  Regional patterns do not support anthropogenic source

Data Sources

- Ambient Monitoring Network

  214 Wells, Untreated Water

  Single modern MDL = 2.0 ug/L

  Good (electronic) locational, geologic control

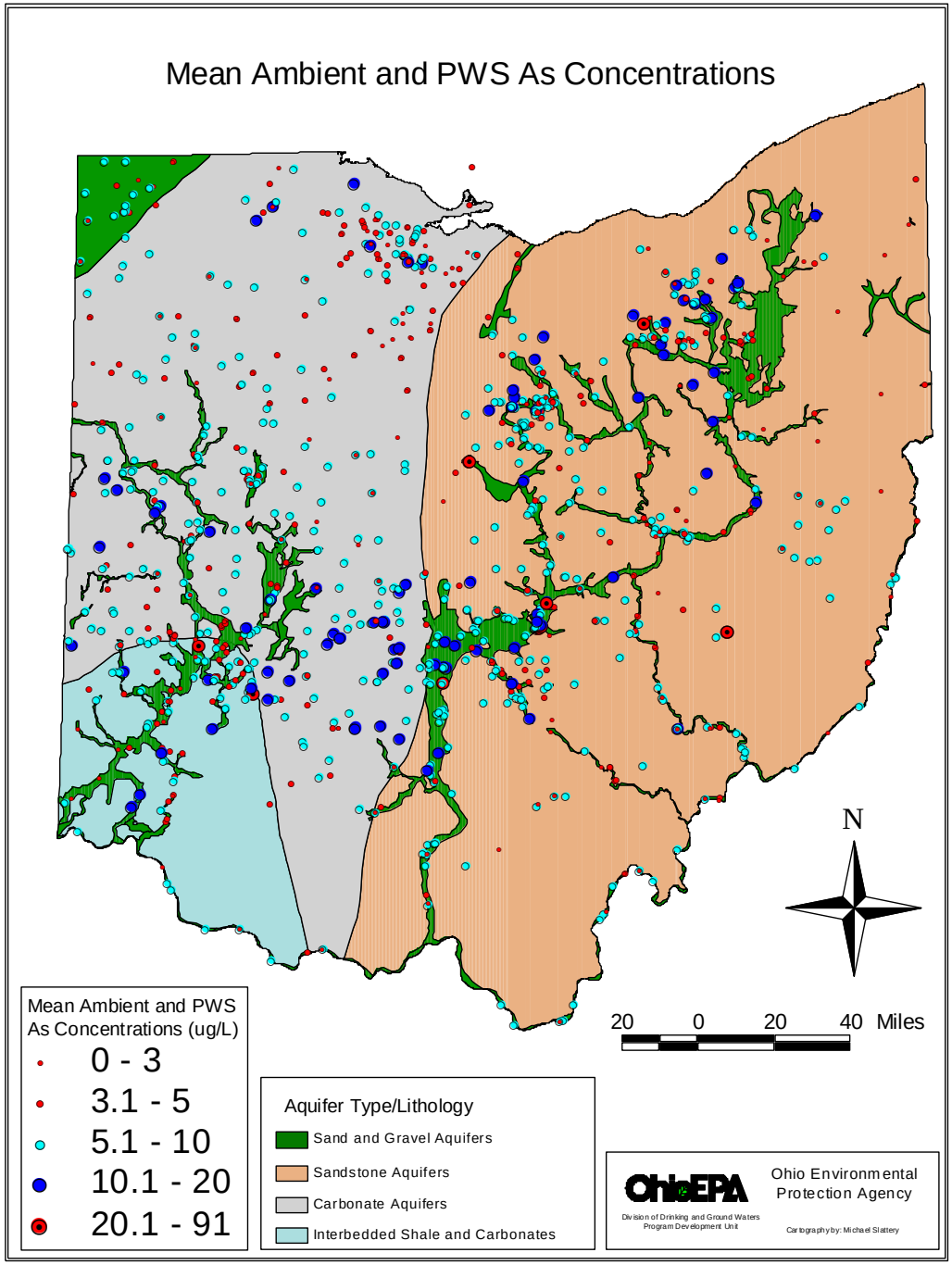
- Public Water Supply Database

  2922 PWSs, Treated Water

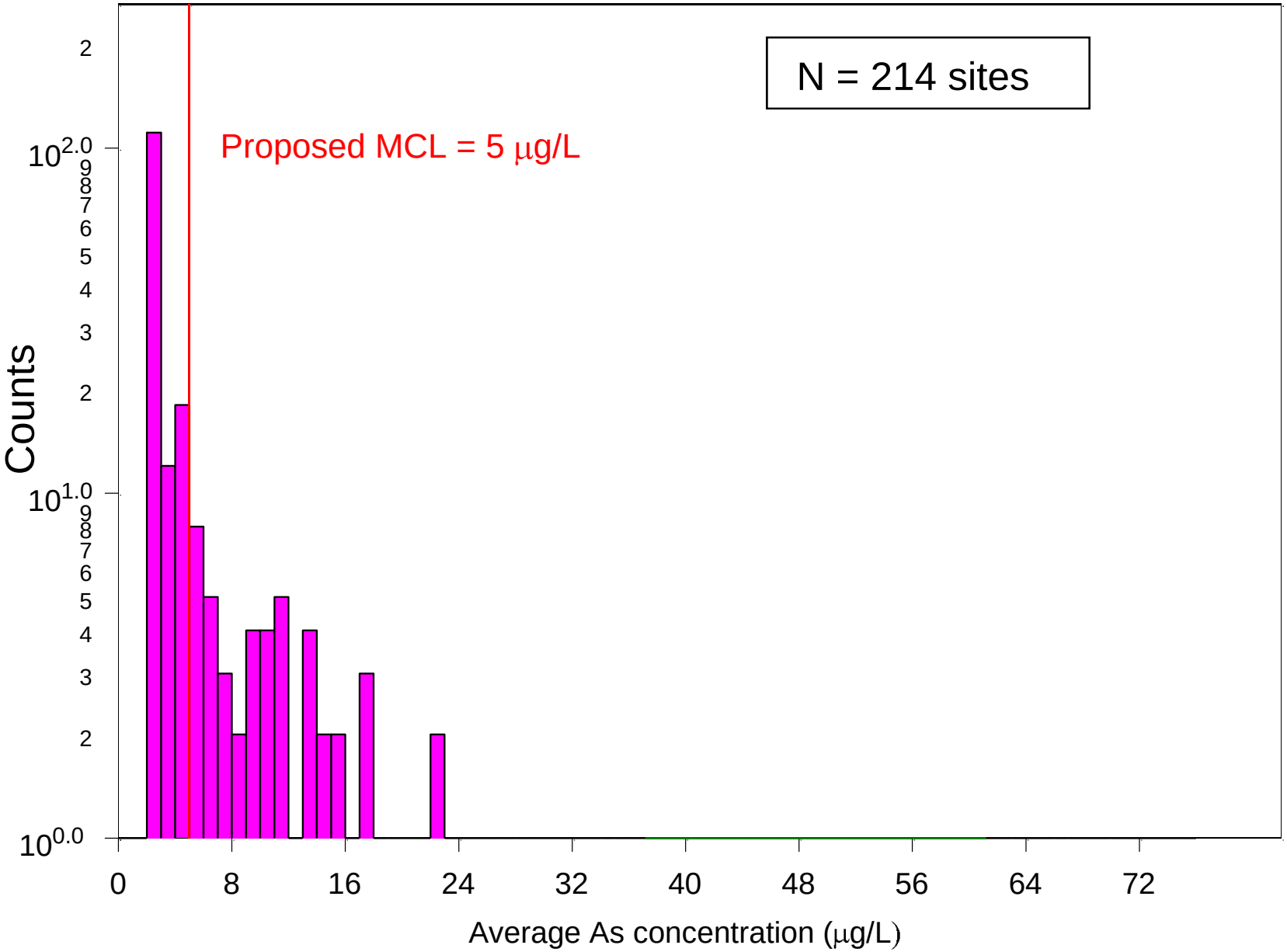
  Multiple MDLs = 2, 3, 5, 10 and 20 ug/L

  Poor (electronic) locational, geologic control

Mean Ambient and PWS As Concentrations

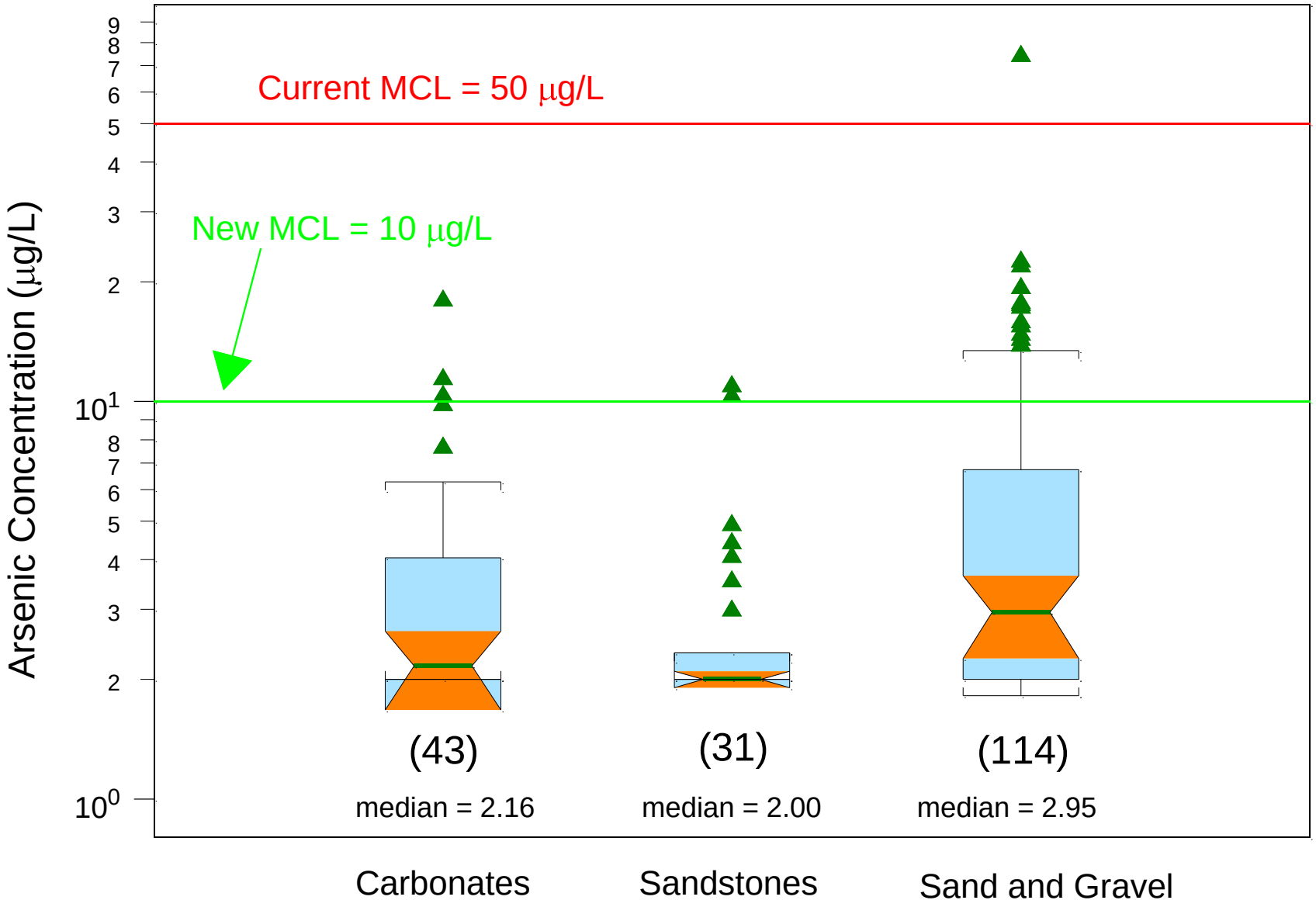


Histogram of Mean Ambient Arsenic Concentrations



Mean As Concentration by Lithology

Ambient Monitoring Network



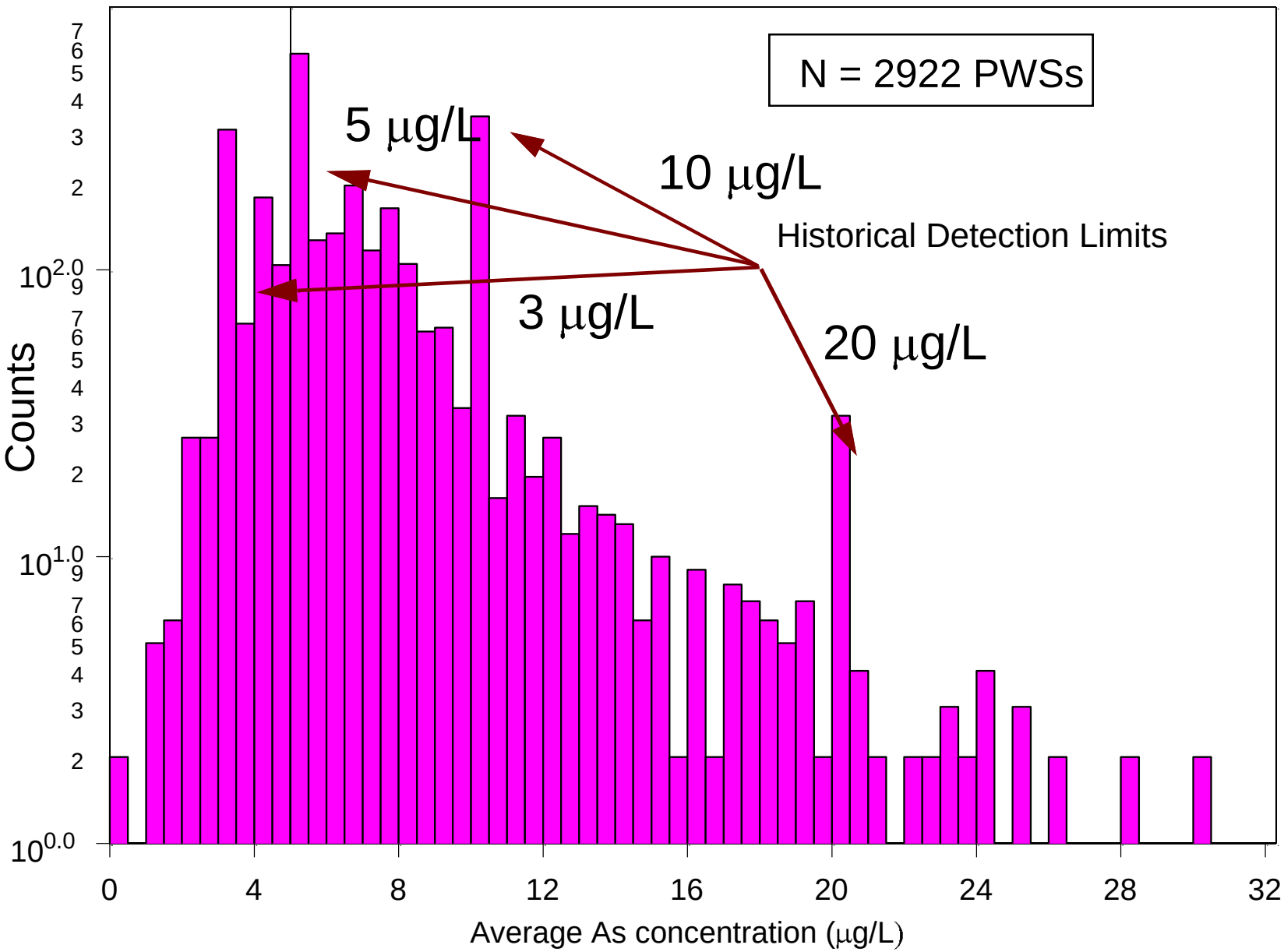
Arsenic and Natural Vulnerability

Arsenic (g/L) in Ambient Monitoring Network Wells

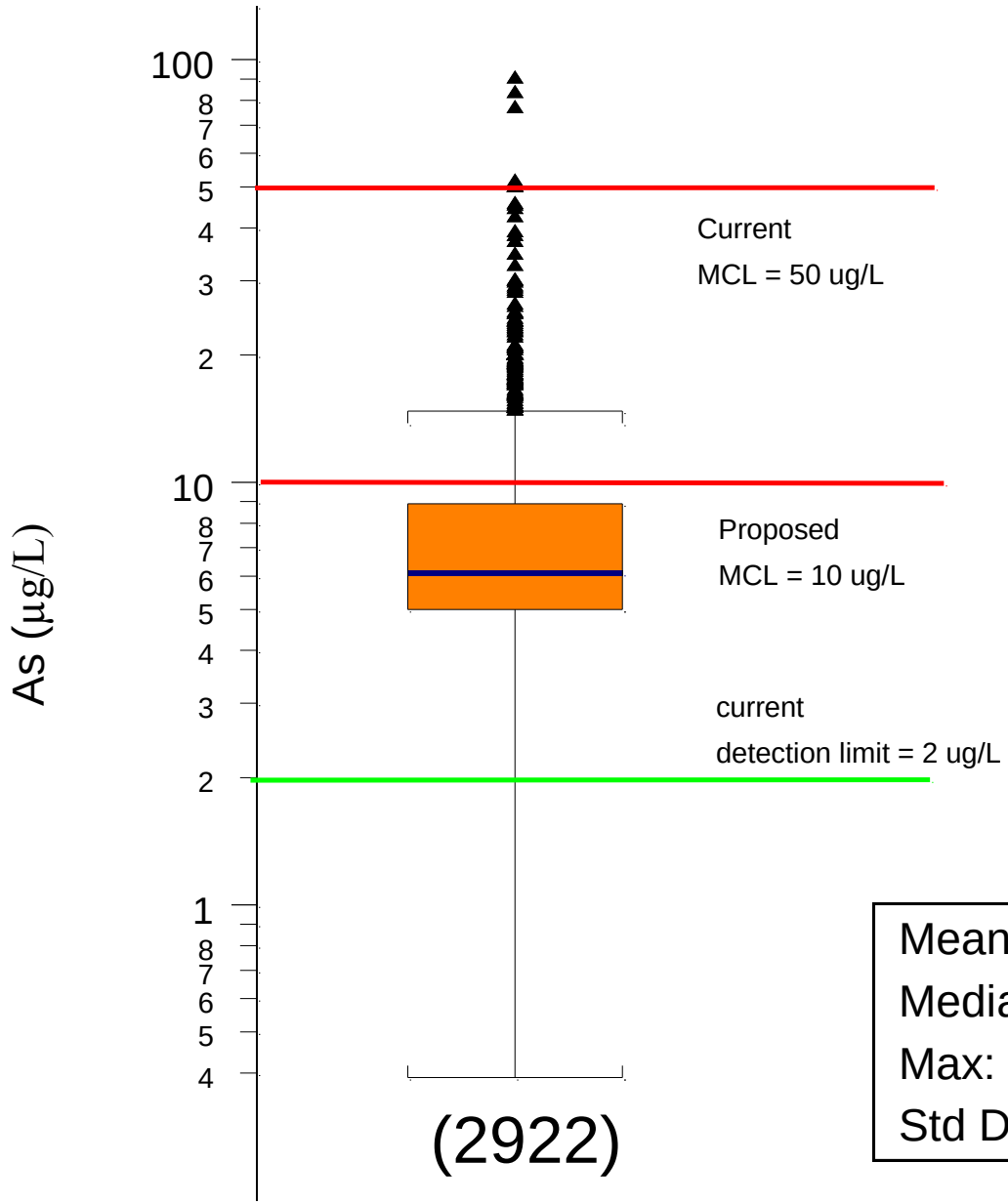
SYSTEM	$\bar{X}$	% Censor	Aitch $\bar{X}$s
Sand and Gravel/Buried Valley	5.8	51	5.3
Mississippian/Pennsylvanian Sandstones	2.5	77	1.6
Silurian/Devonian Carbonates	3.8	64	2.9

Reporting Limit, Total Unfiltered Arsenic = 2.0 (g/L)

Histogram of Mean PWS Arsenic Concentrations, 1980-1999

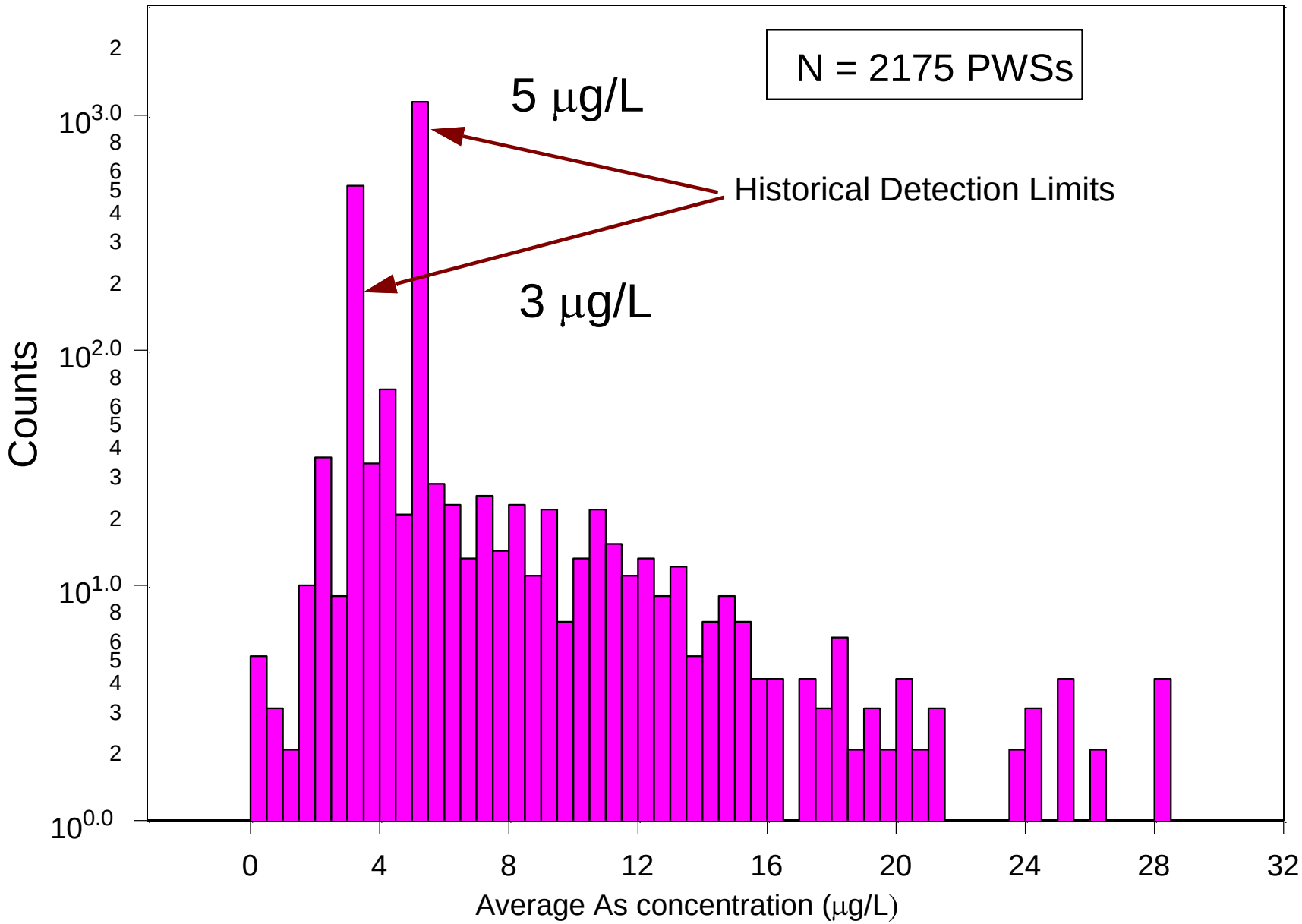


Mean PWS As concentrations, 1980-1999

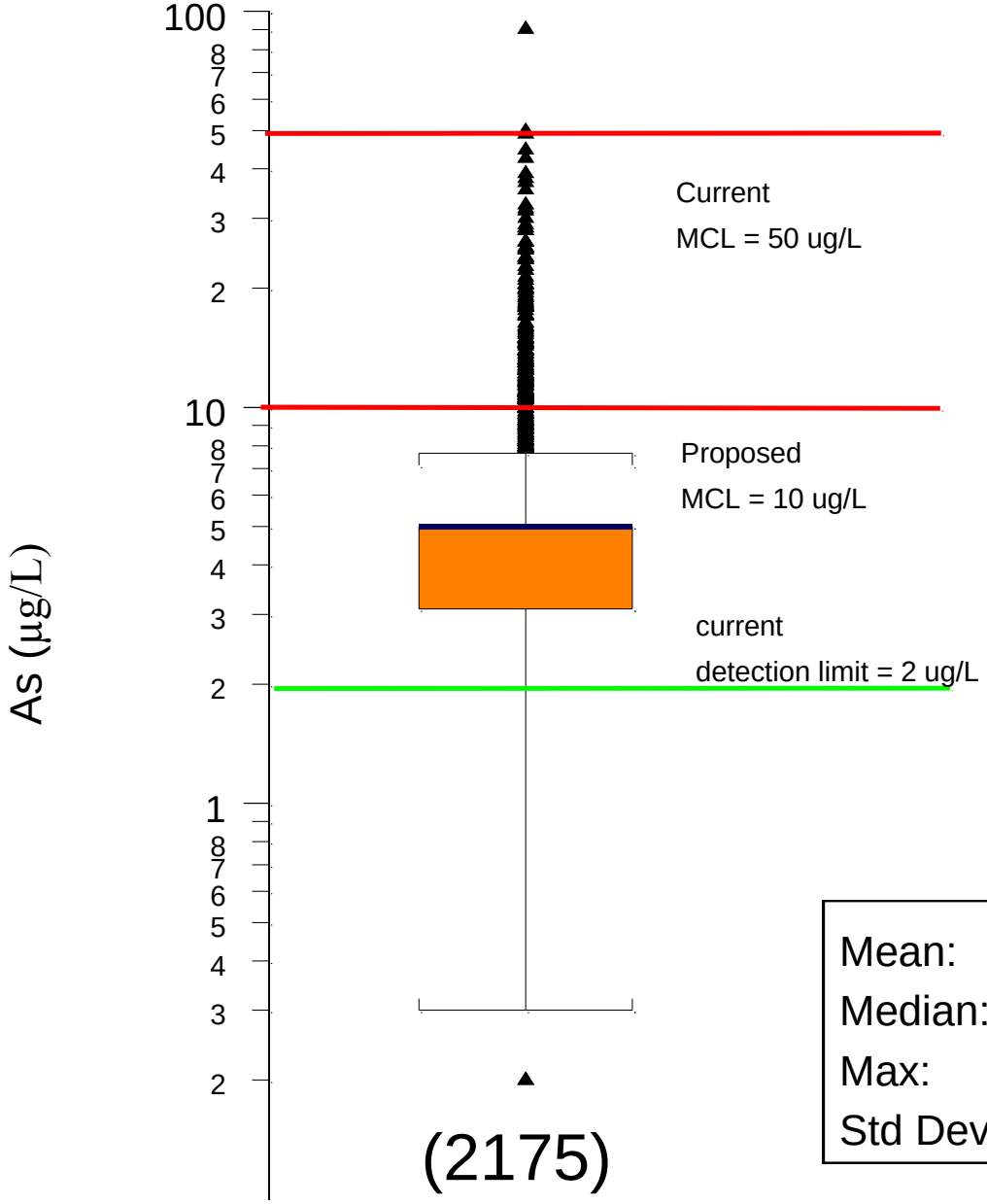


Mean:	7.23
Median:	6.09
Max:	90.11
Std Dev.:	5.1

Histogram of Mean PWS Arsenic Concentrations, 1996-1999



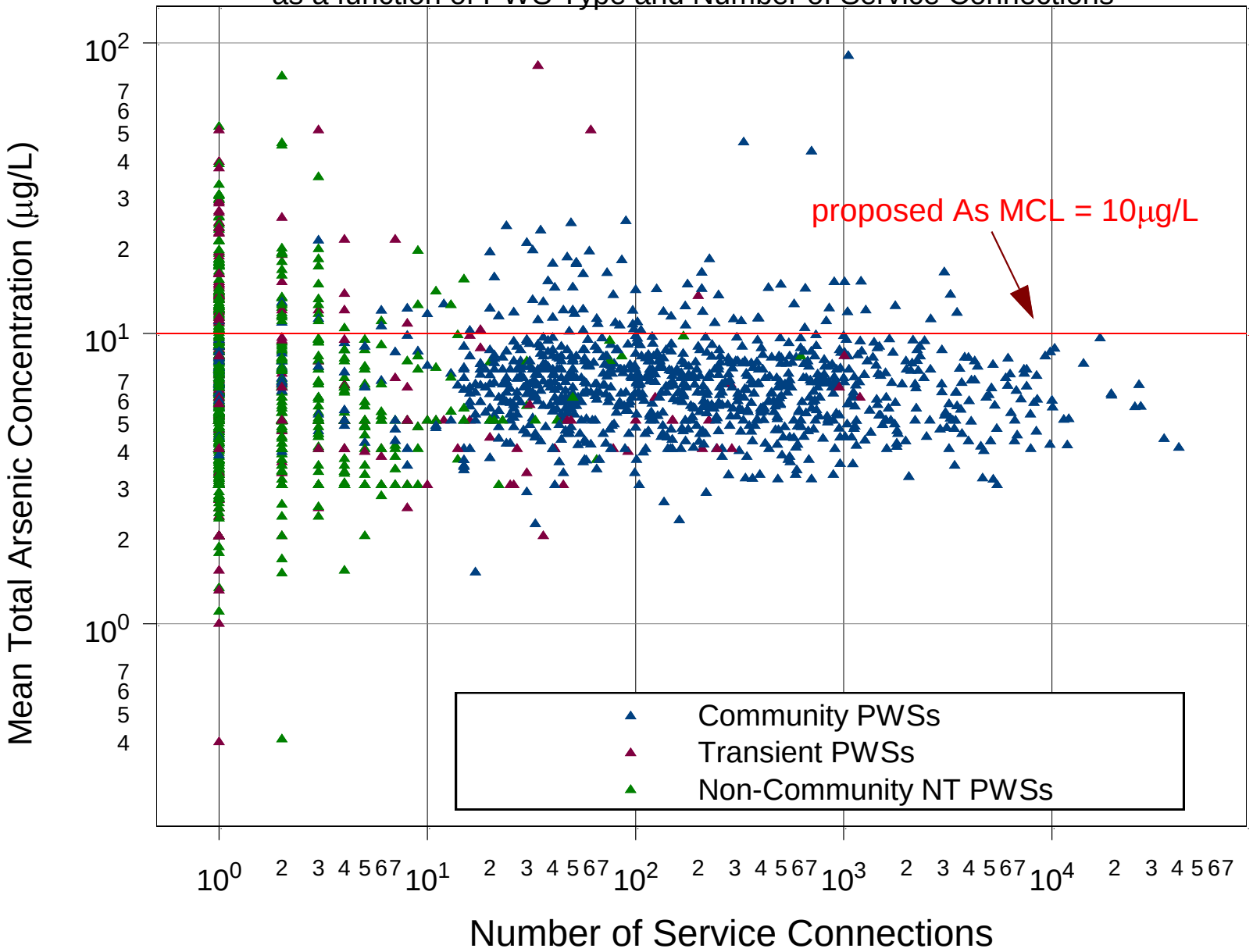
Mean PWS As concentrations, 1996-1999



Mean:	5.59
Median:	5.00
Max:	90.34
Std Dev.:	4.56

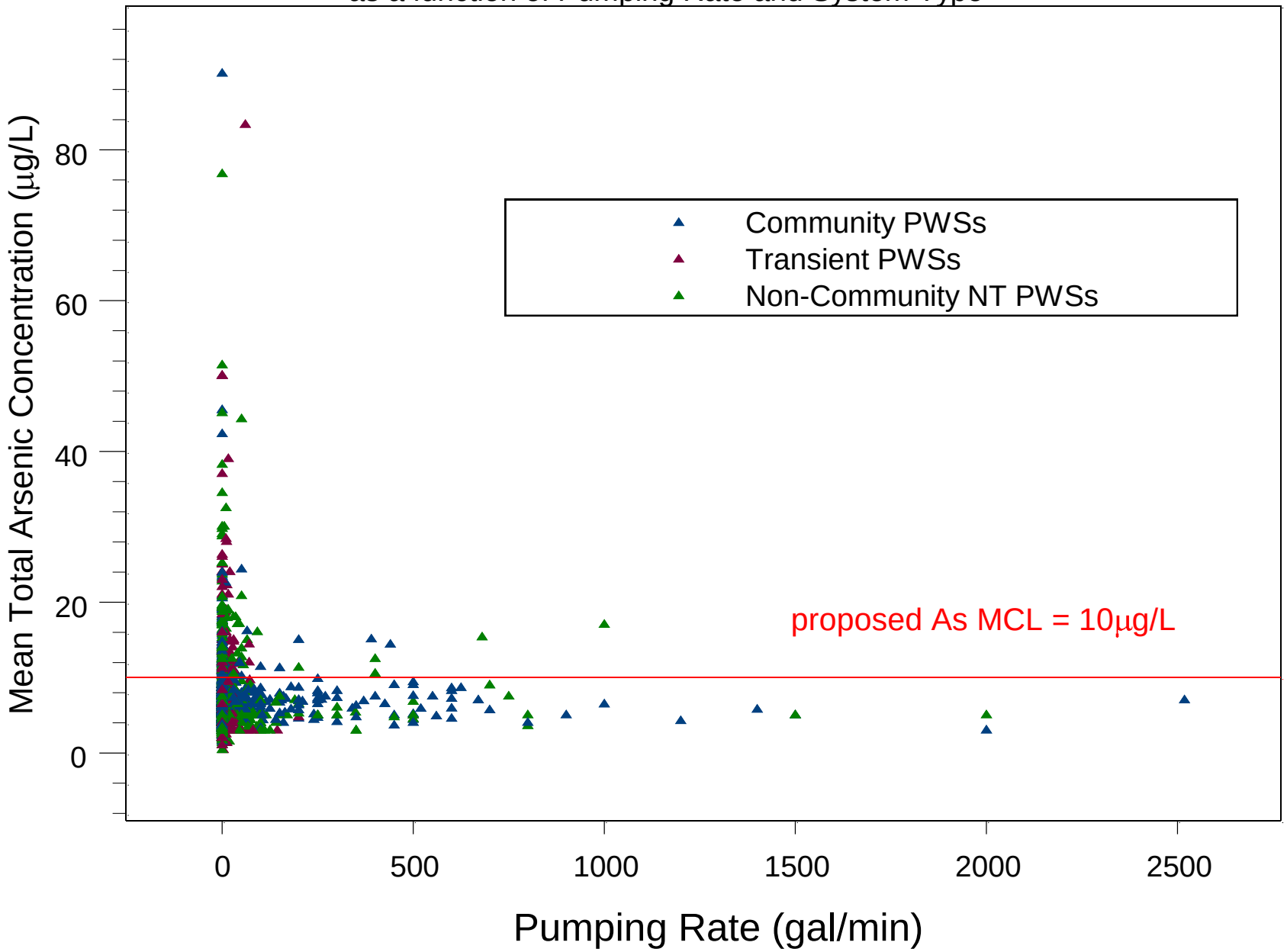
Mean Arsenic in Ohio PWSs

as a function of PWS Type and Number of Service Connections



Mean Arsenic Concentrations in Ohio PWSs

as a function of Pumping Rate and System Type



Arsenic Mobilization

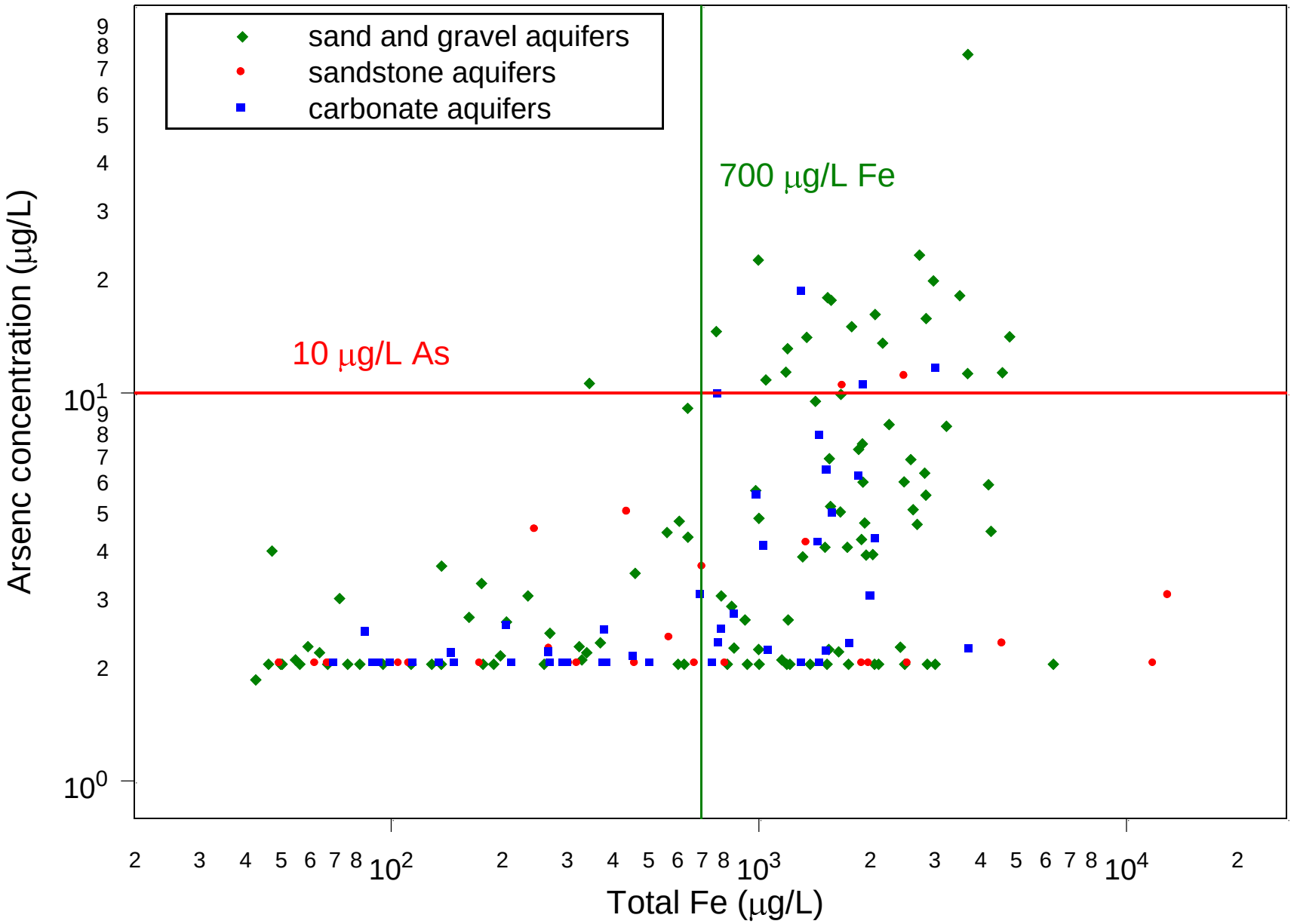
As derives from dissolution of Fe oxyhydroxides

- Arsenopyrite is a possible As source from near-surface oxidized environments to FeO_x
- Fe oxides exist as dispersed phases
- Arsenic is strongly sorbed onto Mn, Fe oxide coatings
- Microbially mediated reduction of Fe oxides, oxidation of C releases adsorbed As through reaction sequence similar to natural attenuation

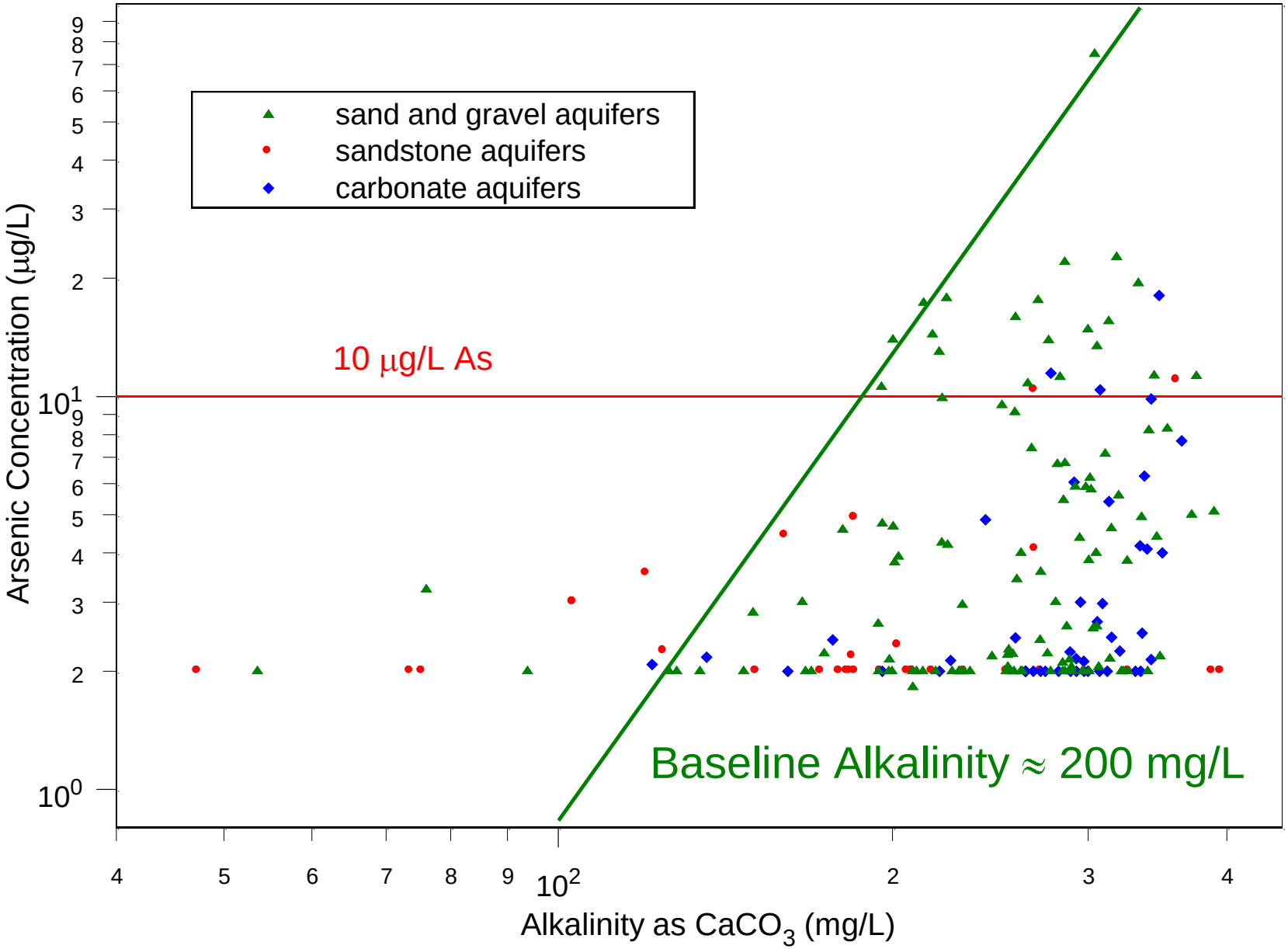
Evidence for Fe oxide source

- Arsenic appears ubiquitous in all aquifer types
- Increase in As with depth (reducing conditions)
- Lack of elevated As in known oxidized conditions
- Pyrites common locally, not regionally, in carbonates
- Increase in alkalinity supports reductive scheme
- In-phase changes of Fe and As suggests co-variation

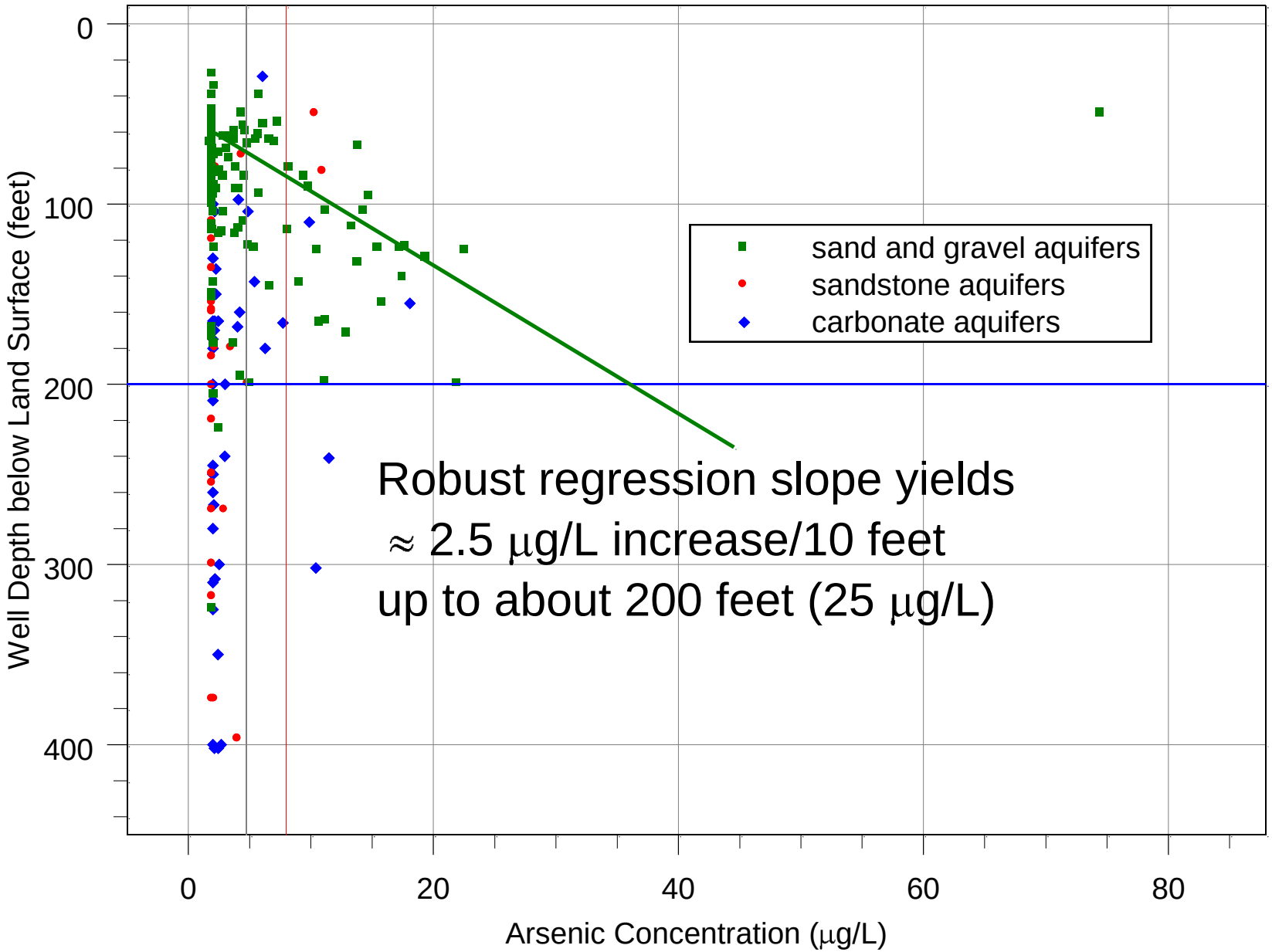
Mean Arsenic - Total Fe Relations in Ambient Wells



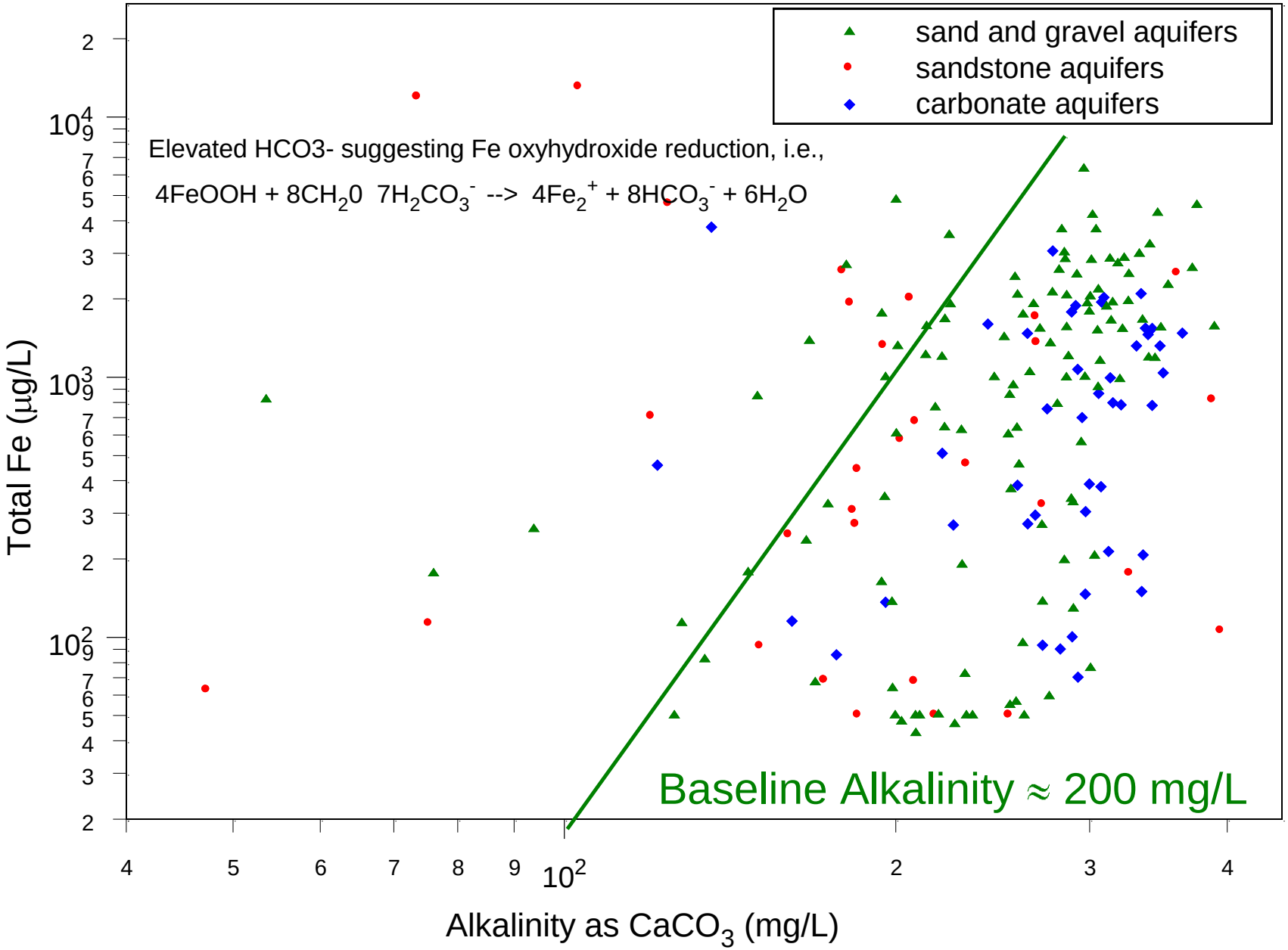
Mean Arsenic - Alkalinity Relations in Ambient Wells



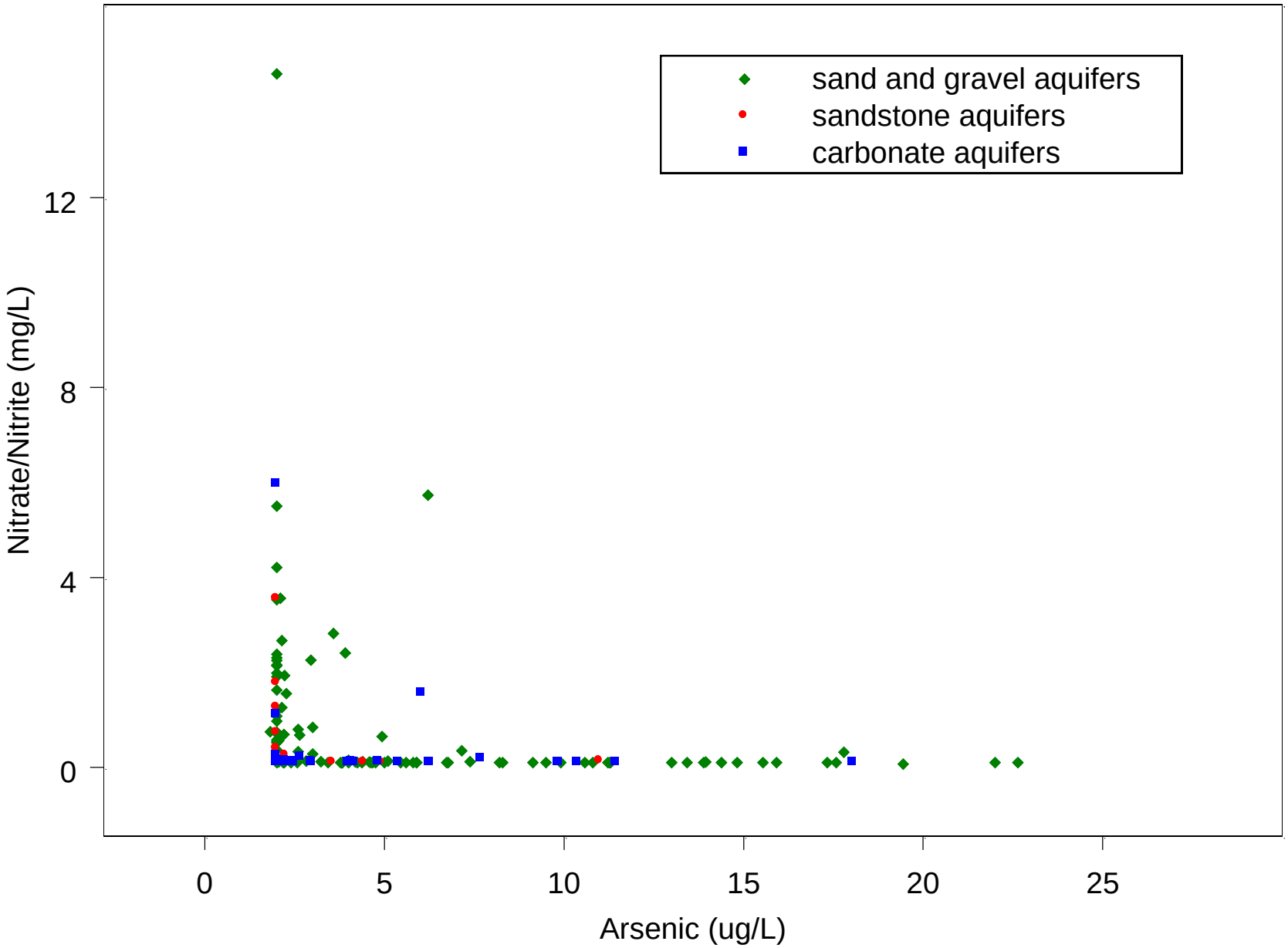
As - Depth Relations in Ambient Wells



Mean Iron - Alkalinity Relations in Ambient Wells



Mean Arsenic-Nitrate/Nitrate Relations in Ambient Wells



Temporal As Variation

- As appears to have two end-member modes with respect to N

  1. Positive co-variation between As and Fe, NO_X (N) excluded
  2. As and Fe non-detect, NO_X (N) detected

- Variability has recharge, pumping, and seasonal components

- Pattern appears to follow “natural attenuation” reduction sequence : $O_2 > NO_3 > Mn > Fe > SO_4$

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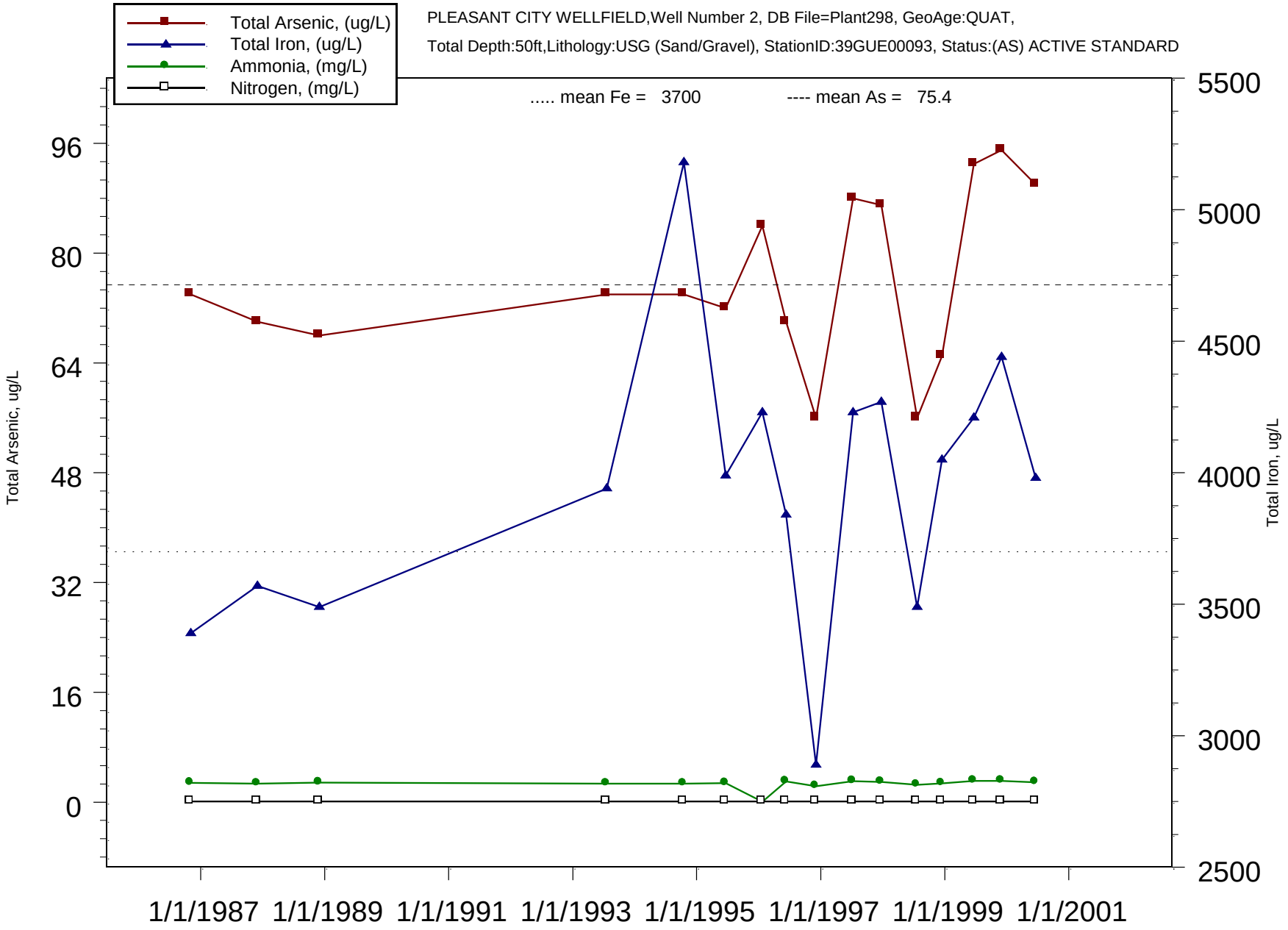
AMBIENT MONITORING NETWORK, OEPA

Arsenic-Iron Relations

PLEASANT CITY WELLFIELD,Well Number 2, DB File=Plant298, GeoAge:QUAT,

Total Depth:50ft,Lithology:USG (Sand/Gravel), StationID:39GUE00093, Status:(AS) ACTIVE STANDARD



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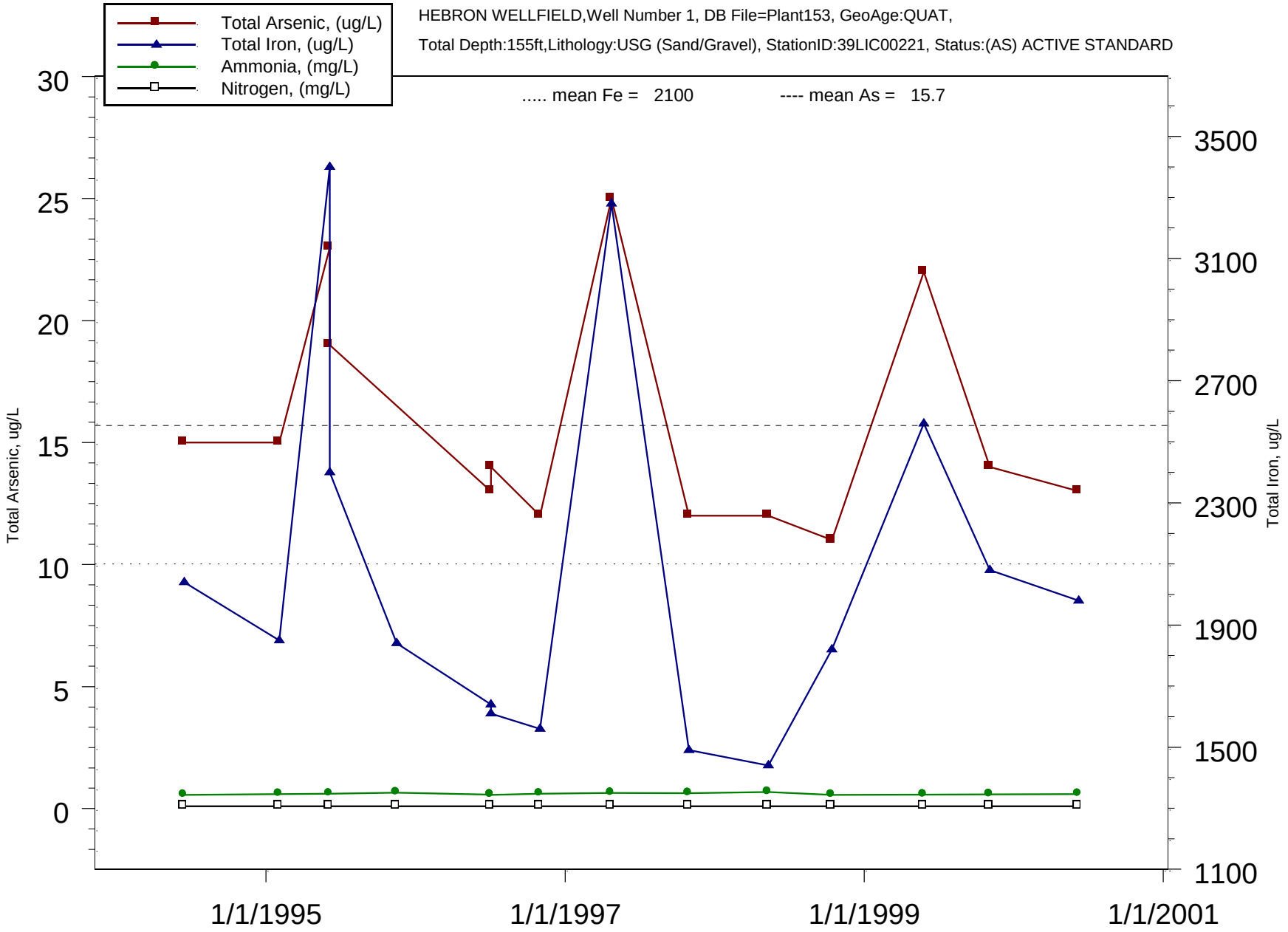
AMBIENT MONITORING NETWORK, OEPA

Arsenic-Iron Relations

HEBRON WELLFIELD,Well Number 1, DB File=Plant153, GeoAge:QUAT,

Total Depth:155ft,Lithology:USG (Sand/Gravel), StationID:39LIC00221, Status:(AS) ACTIVE STANDARD



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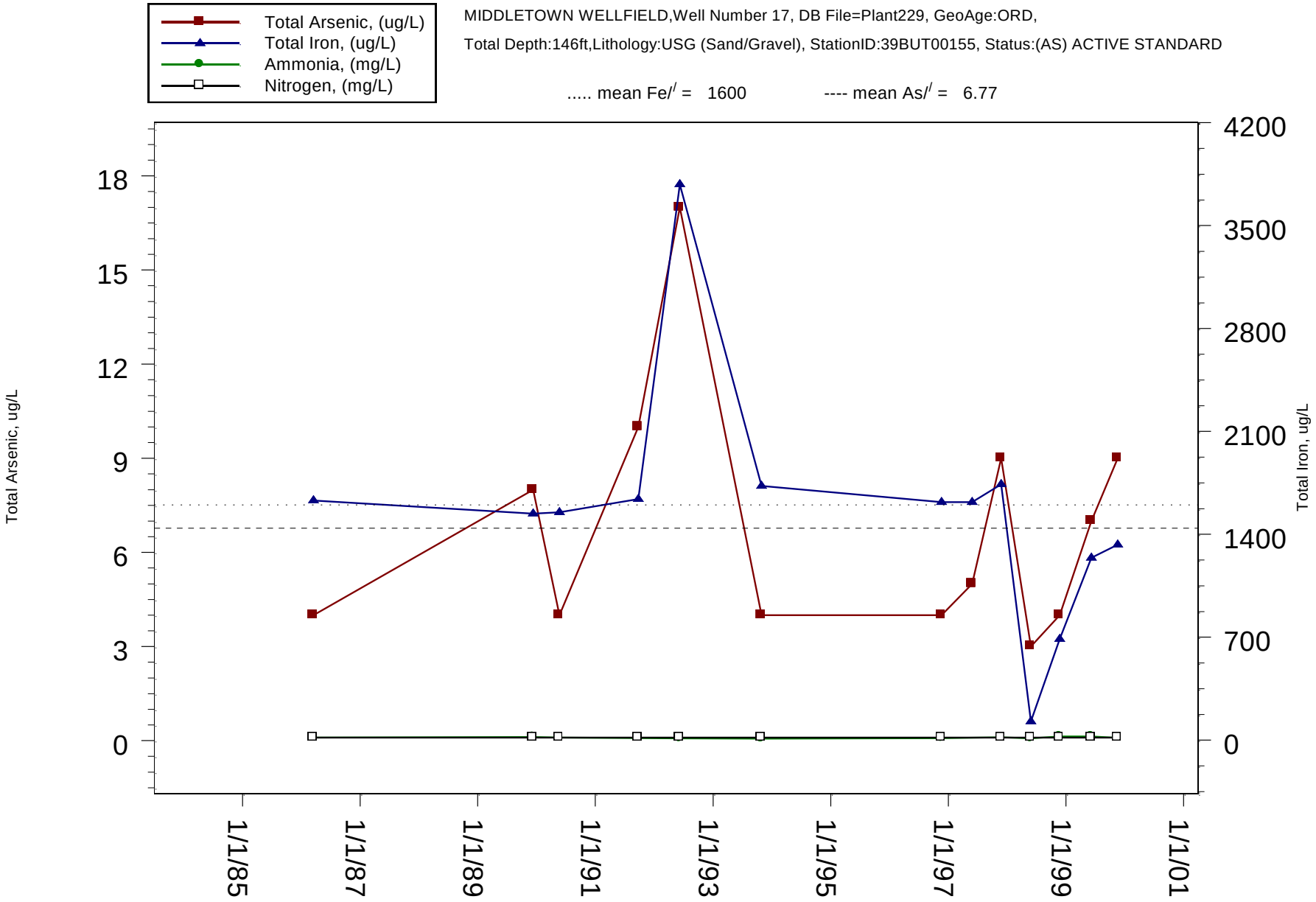
AMBIENT MONITORING NETWORK, OEPA

Arsenic-Iron Relations

MIDDLETOWN WELLFIELD,Well Number 17, DB File=Plant229, GeoAge:ORD,

Total Depth:146ft,Lithology:USG (Sand/Gravel), StationID:39BUT00155, Status:(AS) ACTIVE STANDARD



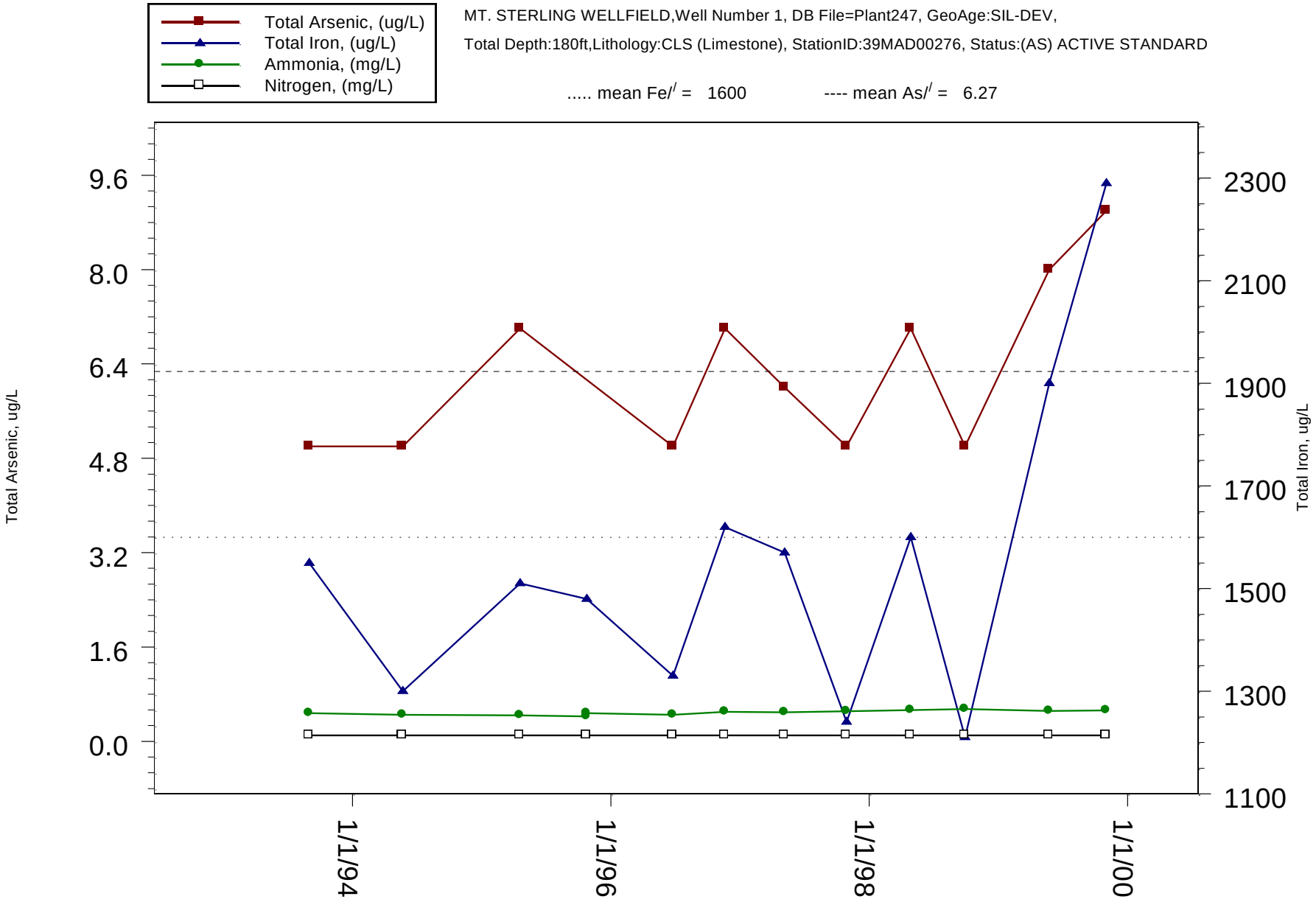
GS18 Feb. 2, 2000 12:54:54 PM

AMBIENT MONITORING NETWORK, OEPA

Arsenic-Iron Relations

MT. STERLING WELLFIELD,Well Number 1, DB File=Plant247, GeoAge:SIL-DEV,

Total Depth:180ft,Lithology:CLS (Limestone), StationID:39MAD00276, Status:(AS) ACTIVE STANDARD



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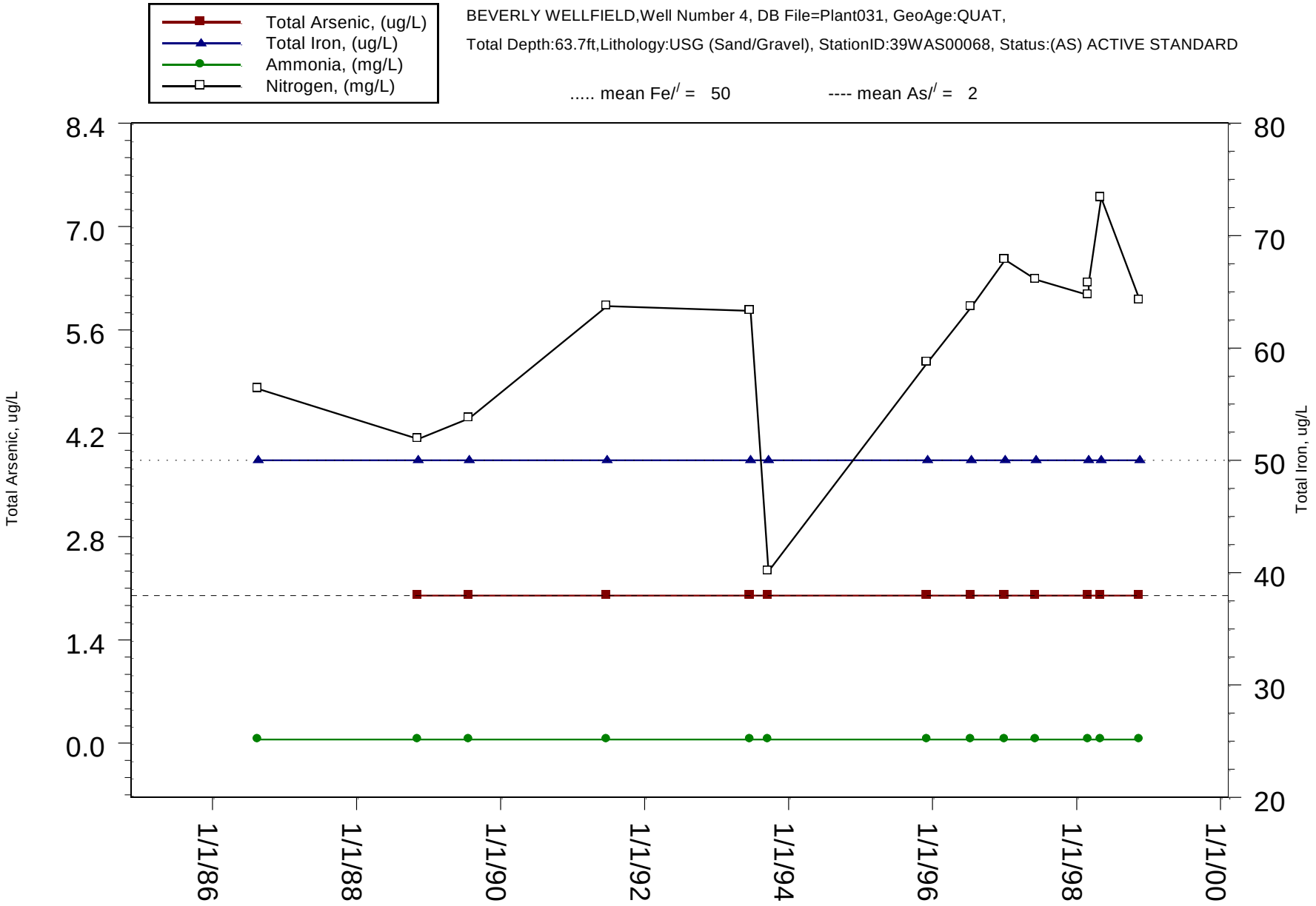
AMBIENT MONITORING NETWORK, OEPA

Arsenic-Iron Relations

BEVERLY WELLFIELD,Well Number 4, DB File=Plant031, GeoAge:QUAT,

Total Depth:63.7ft,Lithology:USG (Sand/Gravel), StationID:39WAS00068, Status:(AS) ACTIVE STANDARD



Arsenic Summary

- Arsenic derives from microbially mediated reduction of FeO_x, oxidation of sedimentary organic C
- Distribution of elevated As favors reduced carbonate and glacial sediment aquifer settings
- Pattern appears to follow “natural attenuation” sequence of $O_2 > NO_3 > Mn > Fe > SO_4$ reduction
- Time series correlations indicate two end-members with respect to nitrate/nitrite

Conclusions

- Arsenic derives from microbially mediated reduction of FeO_x, oxidation of sedimentary organic C

- Distribution of elevated As favors reduced carbonate and glacial sediment aquifer settings

- Pattern appears to follow “natural attenuation” sequence of $O_2 > NO_3 > Mn > Fe > SO_4$ reduction

Future Directions

- Increase data sources (ODNR, USGS, ODH etc)
- Aquire redox data (O2 concentrations, ORP, eH)
- Speciate As(III), As(V)
- Review / aquire whole rock As data
- Formalize reductive sequence model
- Short term sampling to evaluate As variation

Public Data Access

Website: http://www.epa.state.oh.us

Requests for ground water quality data:

gwq@epa.state.oh.us