



Distribution of Naturally-Occurring Perchlorate in Groundwater in California and the Southwest US

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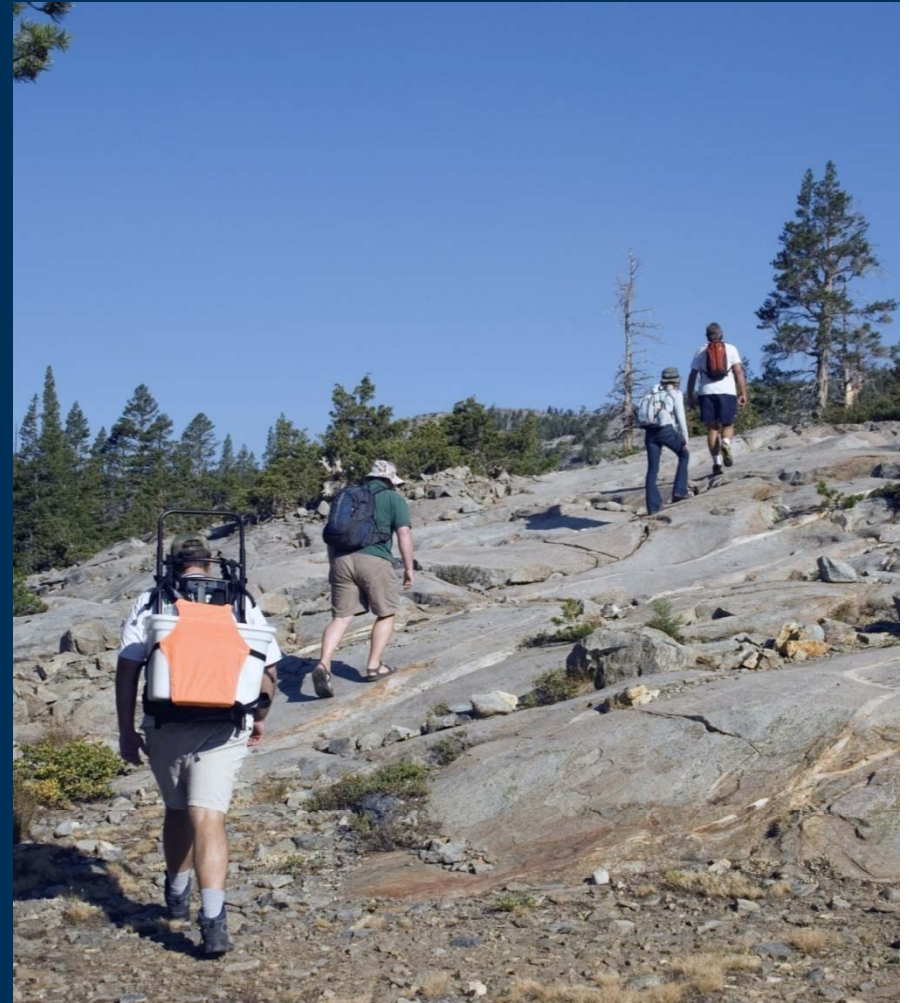
Groundwater Ambient Monitoring and Assessment
(GAMA) Program

U.S. Department of the Interior
U.S. Geological Survey



Acknowledgements

- ~ 1500 well owners and water purveyors allowed USGS to sample their wells
- 30 members of USGS GAMA team in 2004-2009
- Funding from California state bonds, administered by California State Water Resources Control Board



Outline

- Background on perchlorate
- California Groundwater Ambient Monitoring and Assessment (GAMA) Program
- Data analysis and modeling
- Distribution of naturally-occurring perchlorate in California and Southwest US



Perchlorate Basics

■ Chemistry:

- Highly soluble anion, ClO_4^-
- Redox behavior similar to nitrate

■ Health effects:

- Impairs iodine uptake and thyroid hormone production
- Most critical for fetuses, infants, young children - thyroid hormones affect growth and neurological development

■ Regulation:

- USEPA interim drinking water health advisory level 15 $\mu\text{g/L}$
- California MCL 6 $\mu\text{g/L}$ (Oct 2007)
- Other states ... 1 to 50 $\mu\text{g/L}$

Perchlorate Sources

■ Natural

- Atmospheric origin
- Found in Chilean Atacama Desert nitrate deposits, some evaporites, and salts accumulated in unsaturated zones in arid/semi-arid areas

■ Anthropogenic

- Aerospace/military/industrial (solid rocket fuel, explosives, safety flares, fireworks, matches, etc)
- Agricultural (fertilizer derived from Chilean nitrate deposits)
- Disinfection byproduct (aging of hypochlorite solutions)

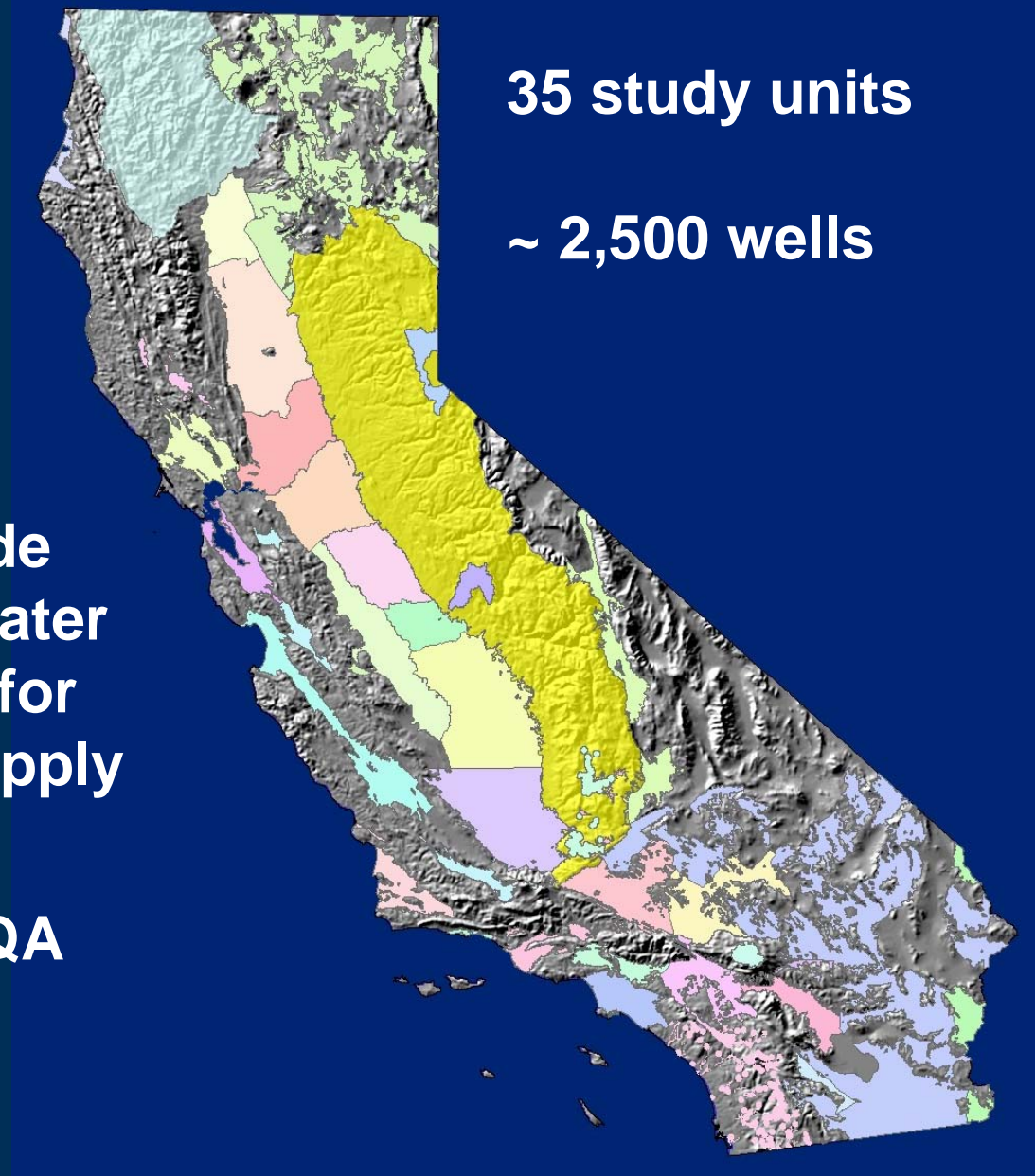
What is the natural background distribution of perchlorate in groundwater?

- Differentiate between perchlorate from natural and anthropogenic sources
 - Direct measures – water quality parameters
 - Indirect measures – land use, climate, etc.
- Need large dataset with lots of variability in potential source terms ... California GAMA



GAMA Priority Basin Project 2004 - 2010

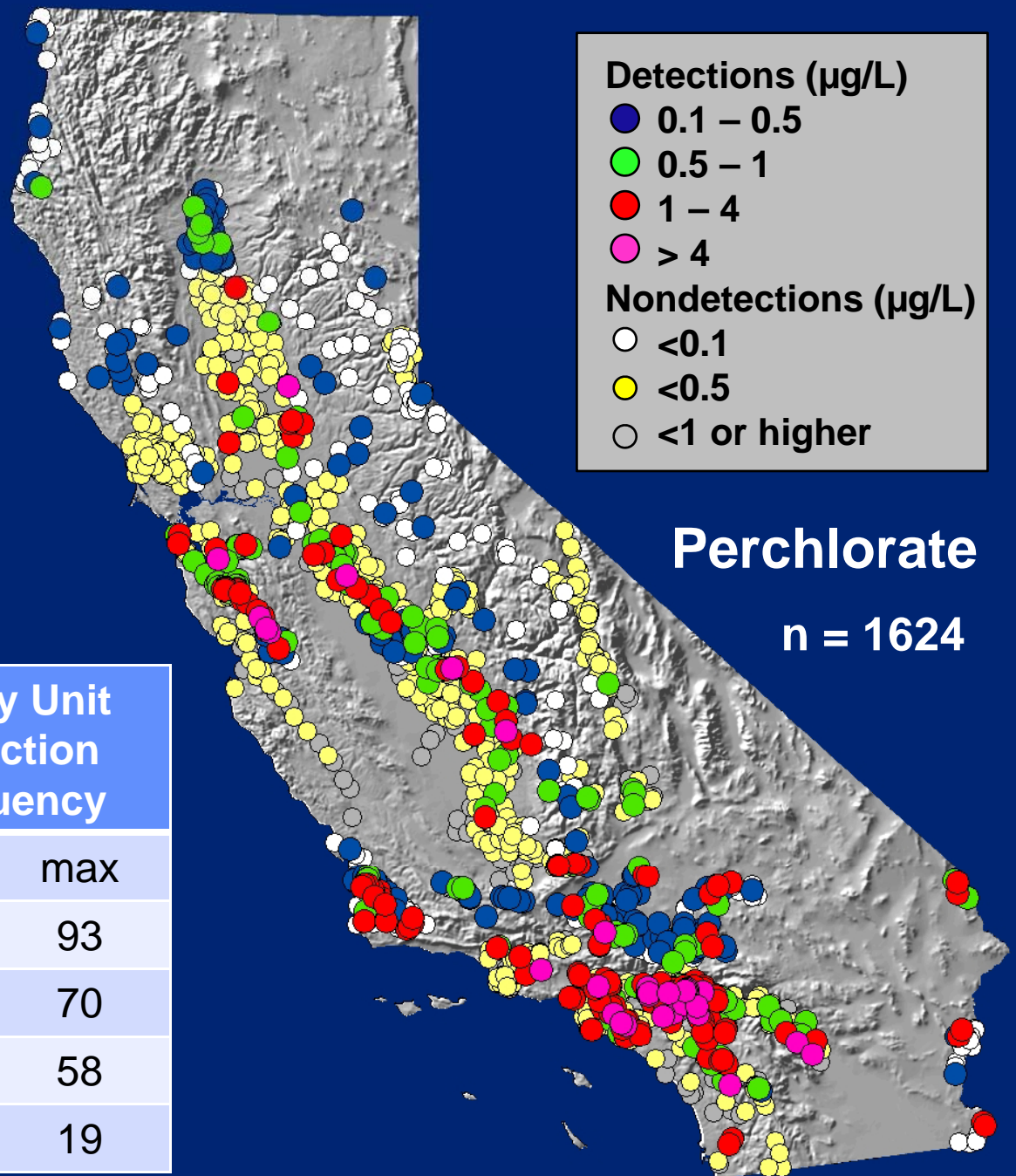
- Comprehensive statewide assessment of groundwater quality in aquifers used for public drinking water supply
- Design* based on NAWQA



*Belitz et al., 2003

GAMA Perchlorate 2004-2009

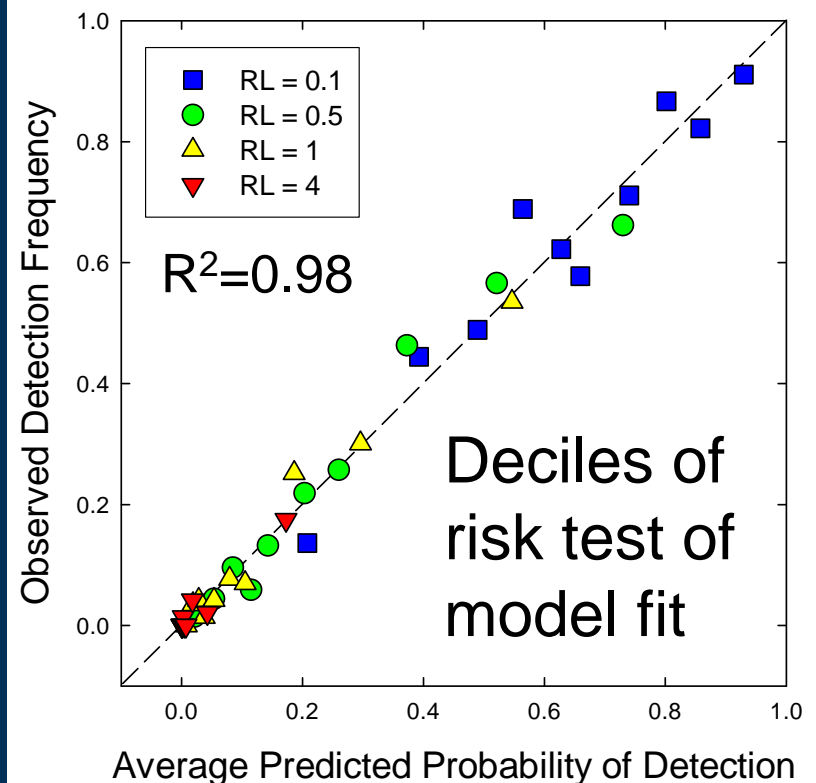
Report limit ($\mu\text{g/L}$)	Statewide detection frequency	Study Unit detection frequency	
		min	max
0.1	63	12	93
0.5	25	0	70
1	14	0	58
4	3	0	19



Logistic Regression Model

- Probability of perchlorate detection (above a specified reporting level, RL)
- RLs: 0.1, 0.5, 1, and 4 µg/L
- Independent variables
 - Natural sources
 - Anthropogenic sources

$$\text{Pr} = \frac{e^{(b_0 + b_{AI}AI + b_{AS}AS)}}{1 + e^{(b_0 + b_{AI}AI + b_{AS}AS)}}$$



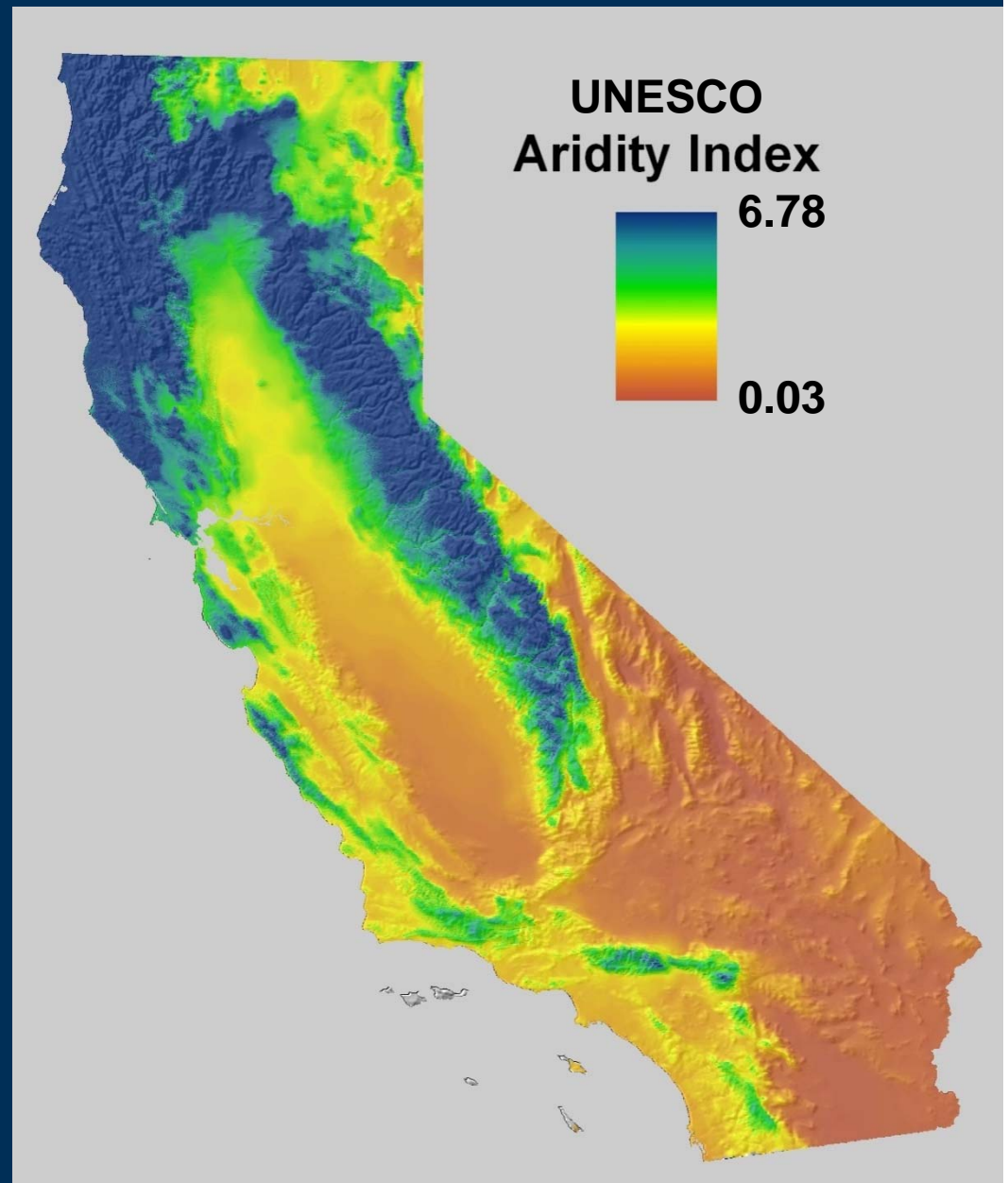
Proxy for Natural Source is Aridity Index

$$AI = \frac{\text{Precipitation}^*}{\text{Potential ET}^{**}}$$

<0.05	Hyper-arid
0.05-0.2	Arid
0.2-0.5	Semi-arid
0.5-0.65	Dry subhumid
0.65-1	Humid
>1	Wet

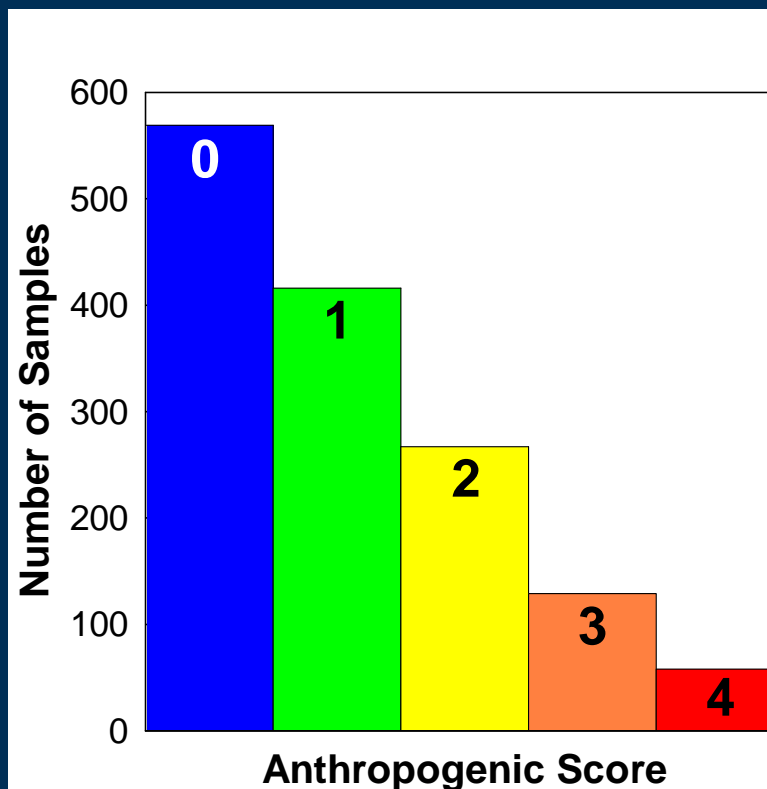
*PRISM, 2006

**Flint and Flint, 2007

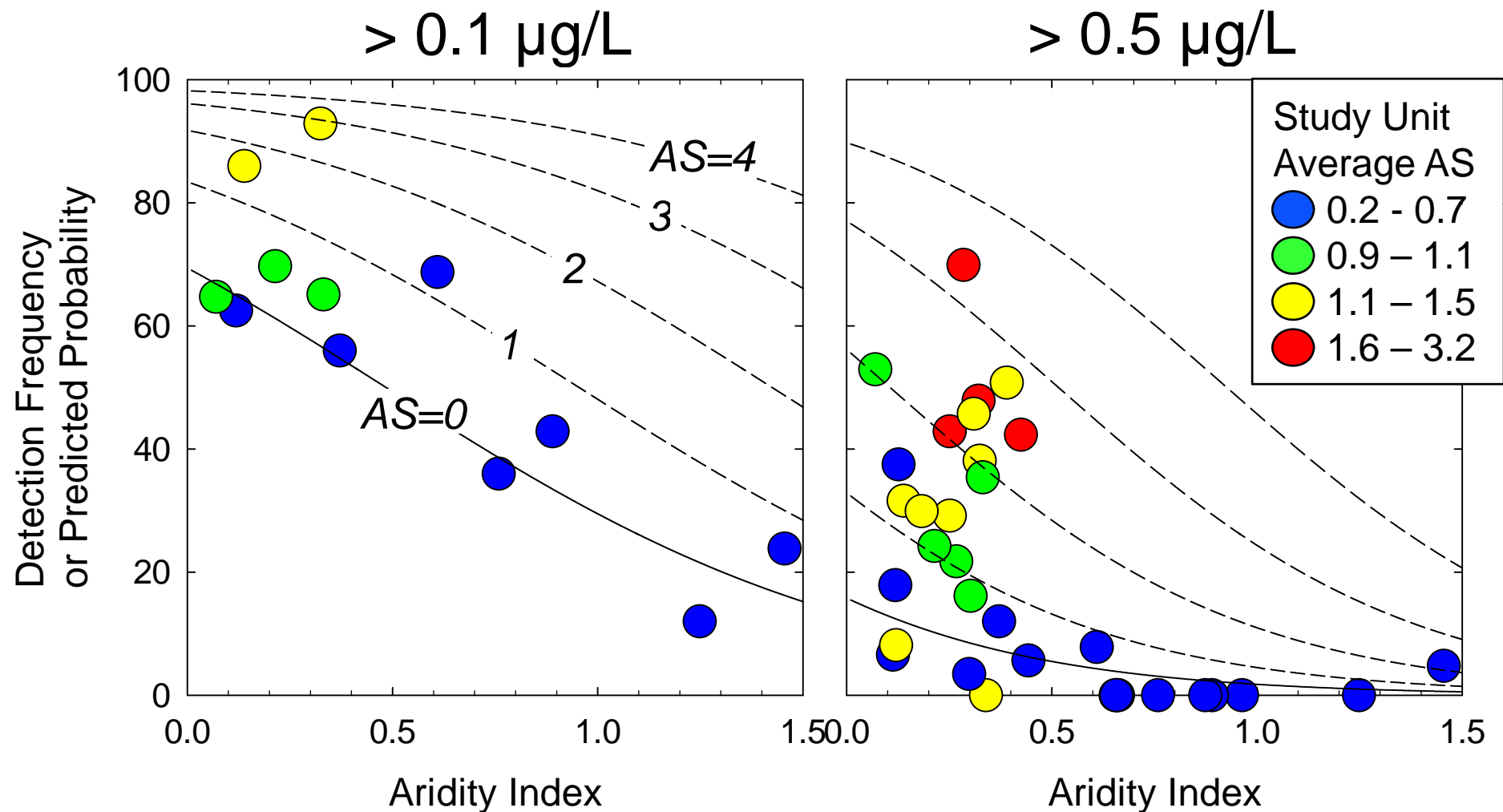


Anthropogenic Sources Represented by a 4-Component 'Anthropogenic Score'

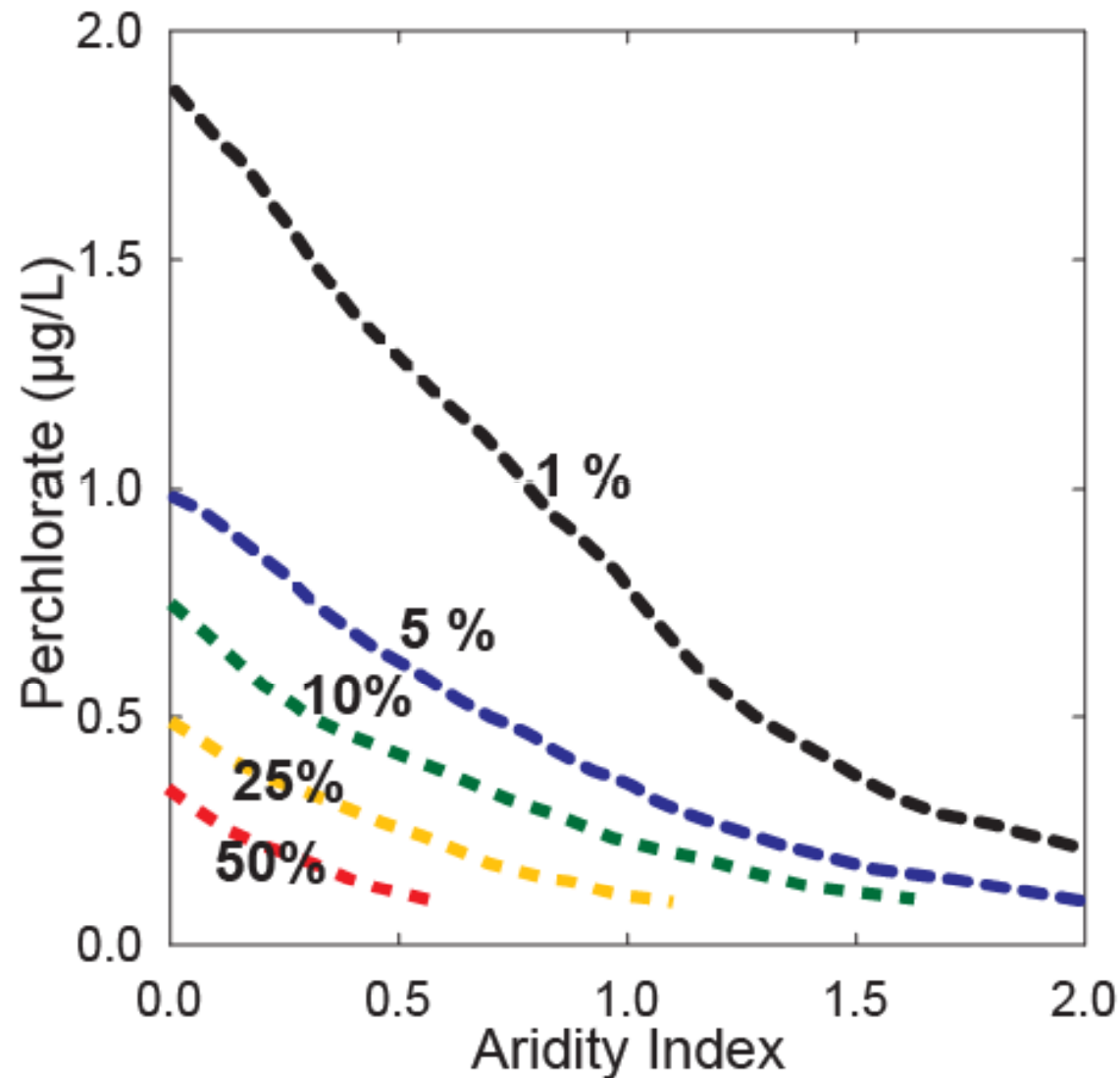
- Nitrate-N greater than 3 mg/L
- Pesticides or fumigants present
- Solvents or fuel components present
- Close to known contamination sites
 - 1 site within 10 km or
2 within 25 km
 - Special case of Colorado
River water
- Other variables tested
 - Land use (urban, agricultural)
 - Chloroform



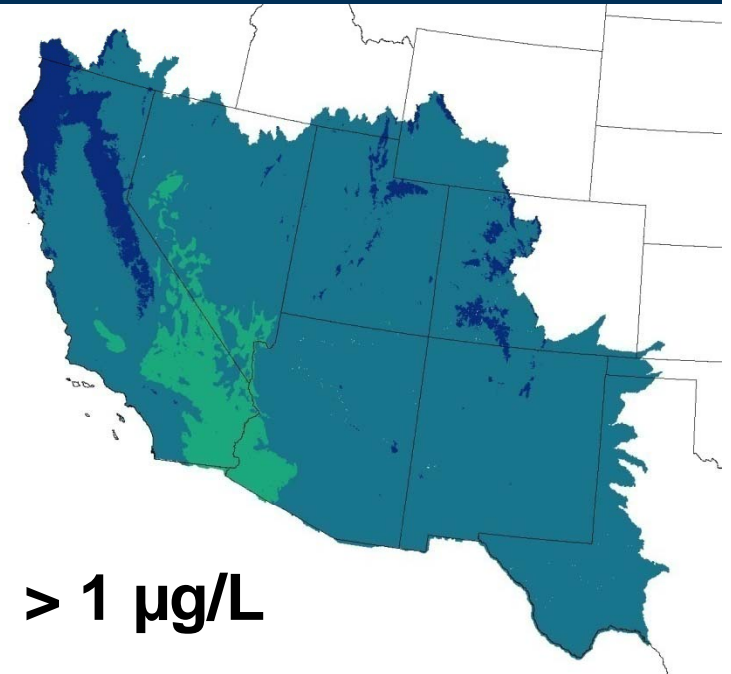
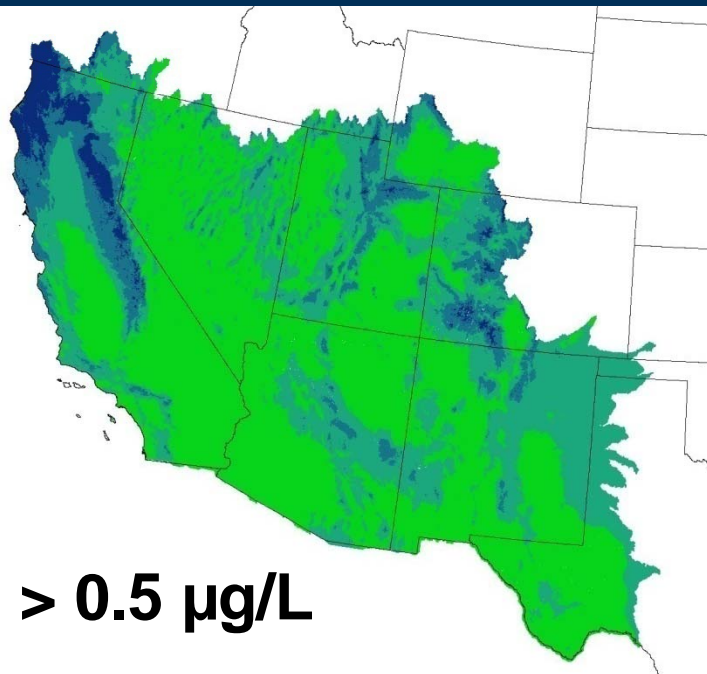
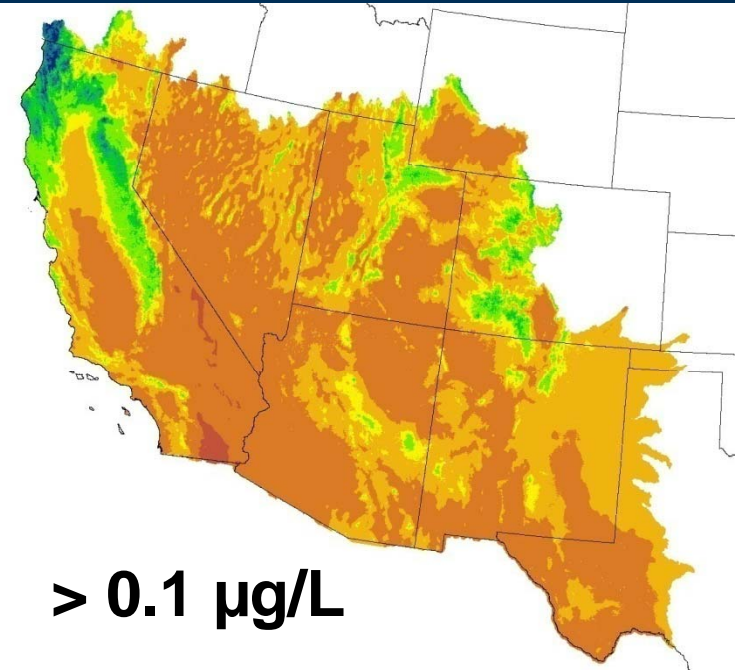
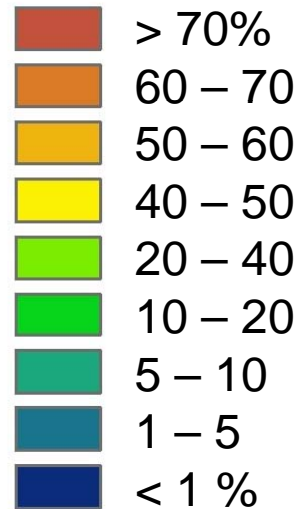
Study Unit Results



Probability that Detected Perchlorate is Naturally-Occurring



Probability of Detecting Naturally-Occurring Perchlorate



Summary

- **Logistic regression model yields probability of detecting naturally-occurring perchlorate as a function of climate**
 - Model uses direct measures – water quality – to infer presence of potential anthropogenic sources
 - Low concentrations ($<0.5 \mu\text{g/L}$) widespread
 - Probability decreases rapidly as concentration increases
- **Study unit scale anthropogenic sources/processes**
 - Relative importance of industrial and agricultural sources
 - Redistribution of natural perchlorate by anthropogenic process – irrigation