

# Using Tritium-Helium Groundwater Age to Assess Contamination Vulnerability



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The Groundwater Ambient Monitoring and Assessment program is sponsored by the State Water Resources Control Board and carried out in a collaboration between the U.S. Geological Survey and Lawrence Livermore National Laboratory

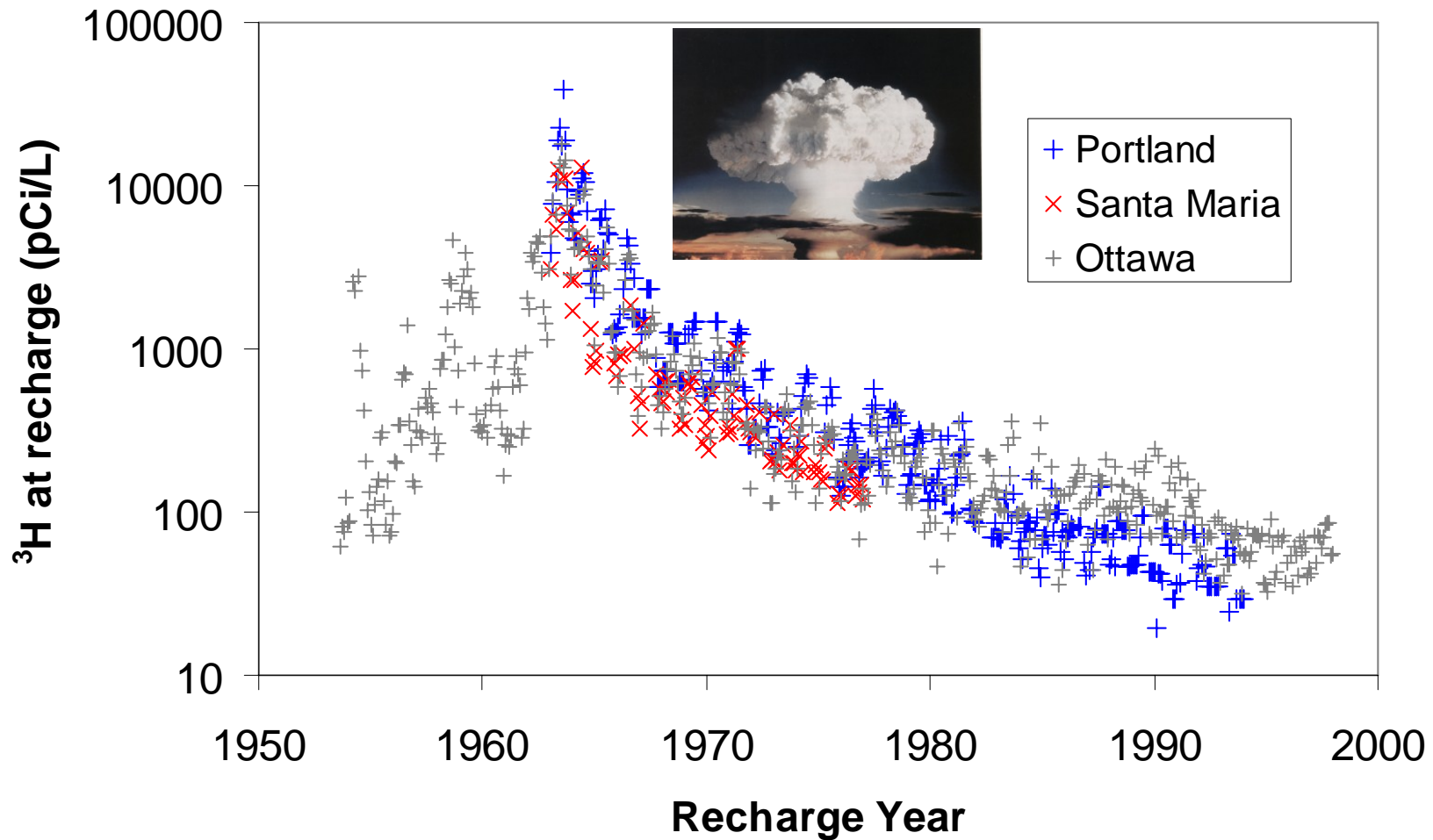
# The Question

- How will water quality in deep aquifers used for public water supply be affected by vertical transport?

# The Tools

- Groundwater Age (Tritium-Helium method)
- Oxygen isotopes (recharge water source)
- Ultra low level VOC analysis (part per trillion detection limits)

Atmospheric nuclear testing introduced a large amount of tritium into the atmosphere in the early 1960's

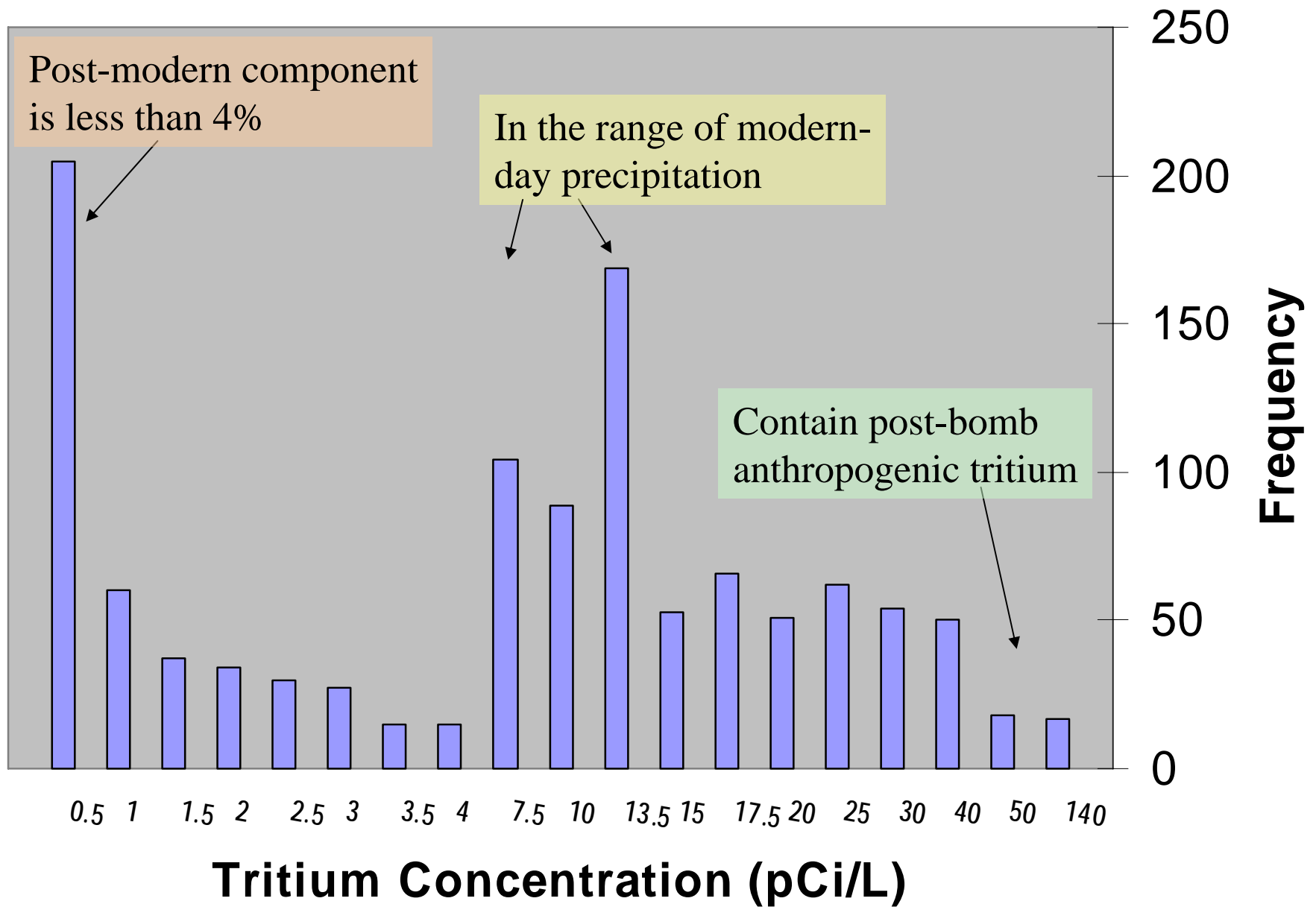


Water recharged before 1950 does not contain tritium now

# Assessing Groundwater Vulnerability

Water Age	VOCs detected?	Vulnerability
Post-modern	Yes	Vulnerable – sources present
Post-modern	No	Vulnerable – no sources
Pre-modern	No	Low vulnerability
Pre-modern	Yes	Short-circuit

Type(s) of VOCs detected, and age analysis including mixing, give additional time-of-travel information.



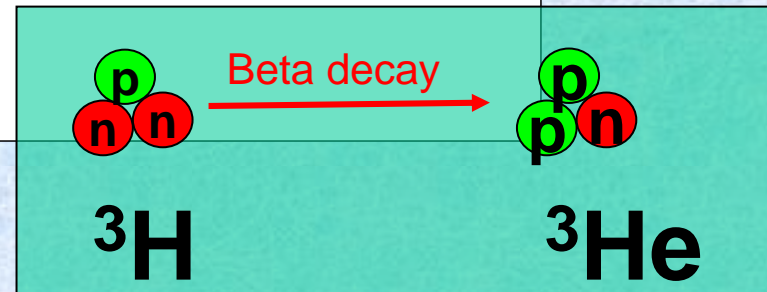
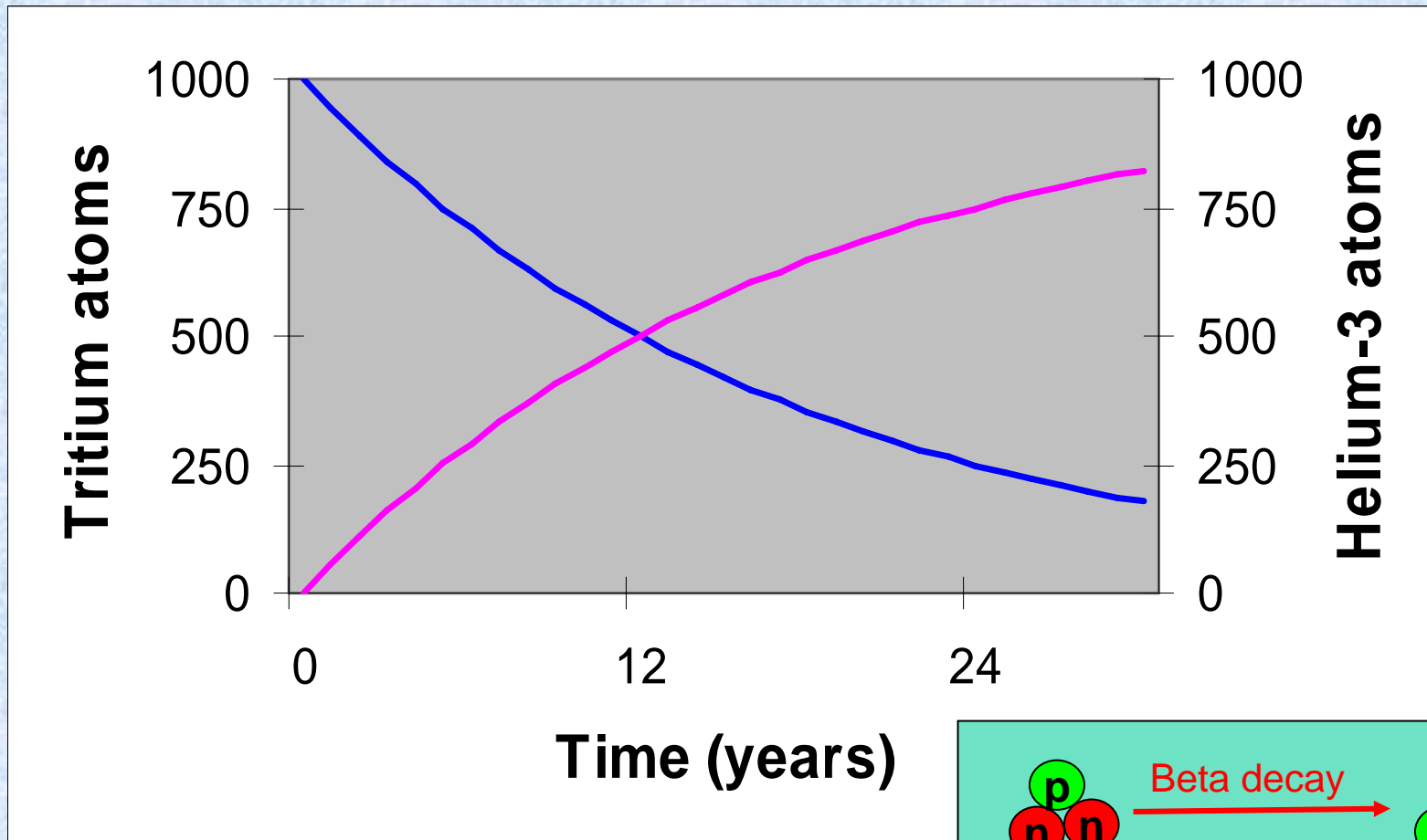
*Tritium-dead samples provide an archive of pre-modern water quality*

# Tritium alone can be misleading

Location	Measured Tritium (pCi/L)	Calculated GW Age (yrs)
Bakersfield 1	11.1	15
Bakersfield 2	11.3	34
San Jose 1	12.4	11
San Jose 2	12.5	42
Chico	11.0	32
Half Moon Bay	11.1	3.5

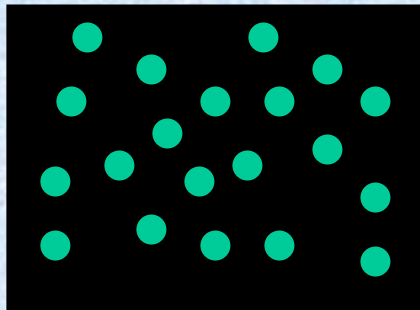
271 samples (25%) fall in the ambiguous range of 9 to 15 pCi/L tritium

For every tritium decay,  
an atom of  $^3\text{He}$  is produced

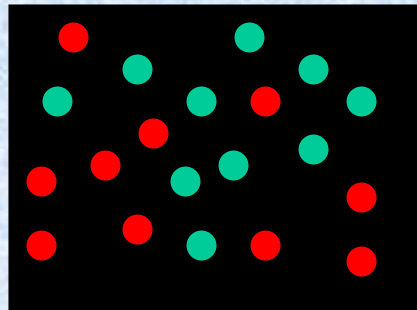




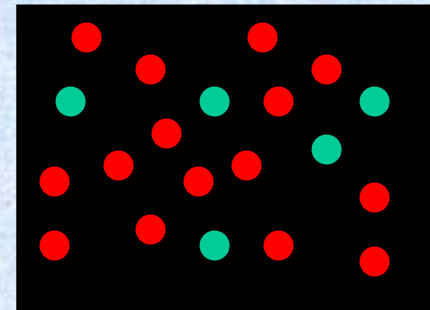
The  $^3\text{He}$  from  $^3\text{H}$  decay starts to accumulate once the water has become groundwater



0 years



12 years



24 years

$$\text{Age (years)} = 18 \times \ln(1 + ^3\text{He} / ^3\text{H})$$

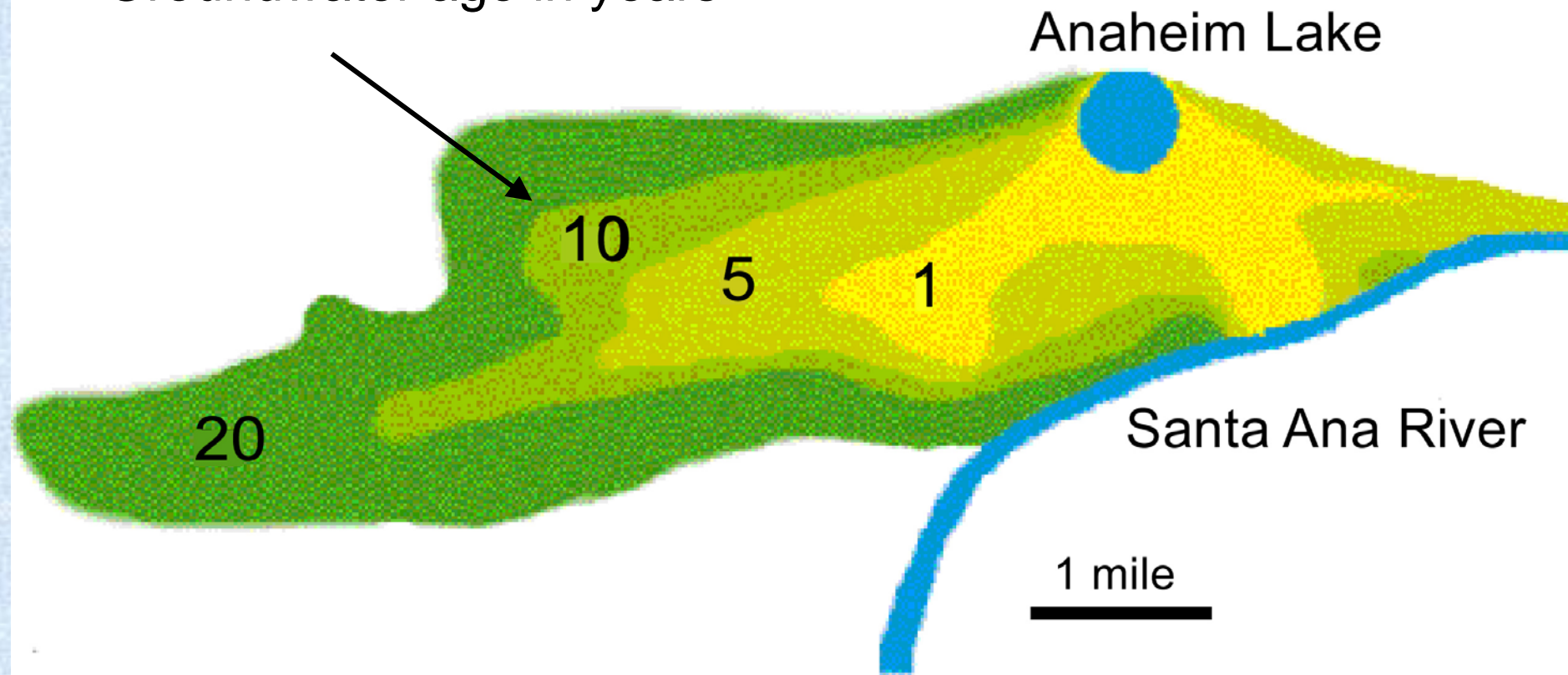


Dissolved noble gas concentrations and  $^3\text{He}/^4\text{He}$  are measured by noble gas mass spectrometry



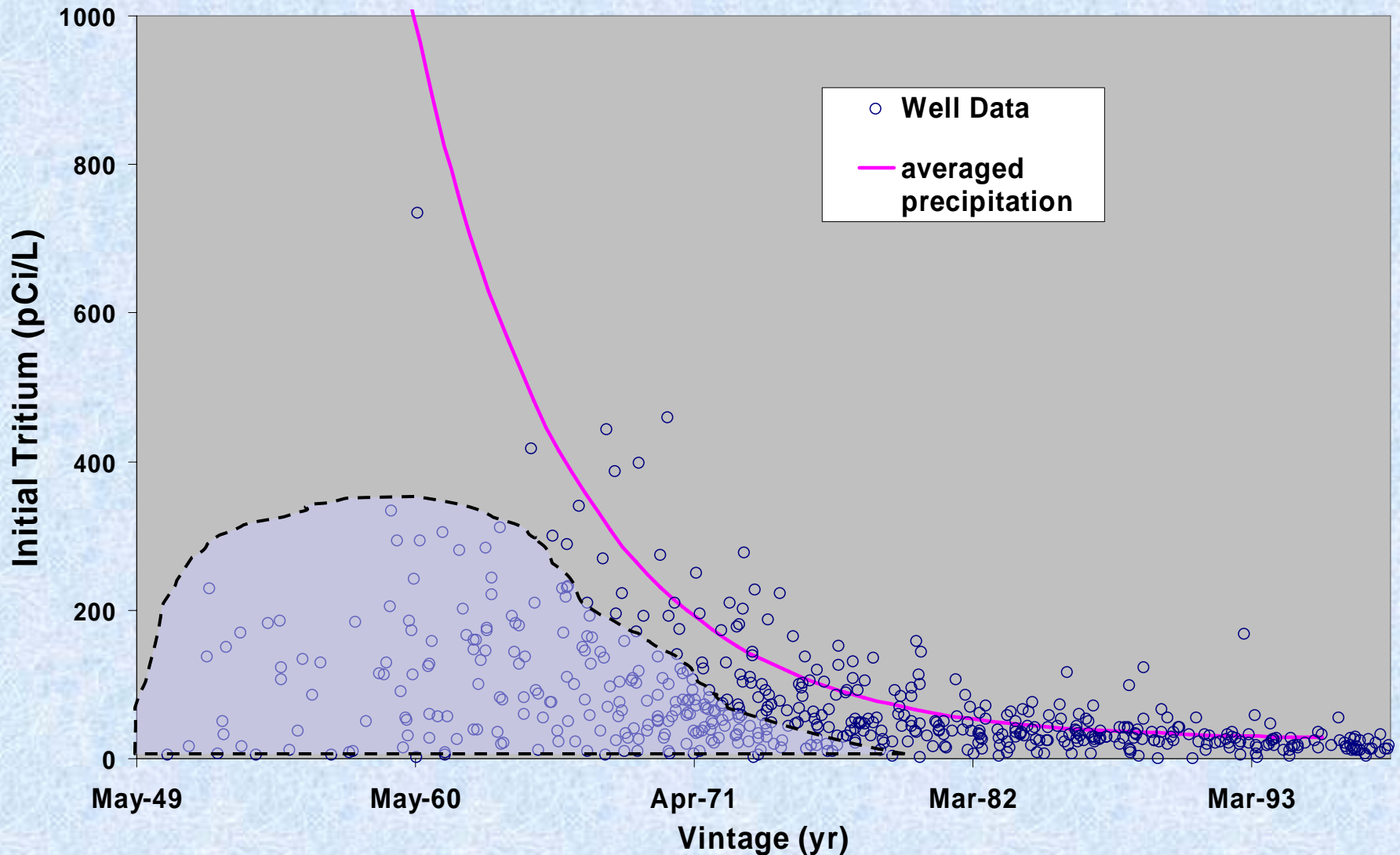
# Results from 150 $^3\text{H}$ - $^3\text{He}$ age measurements in Orange Co. CA

Groundwater age in years

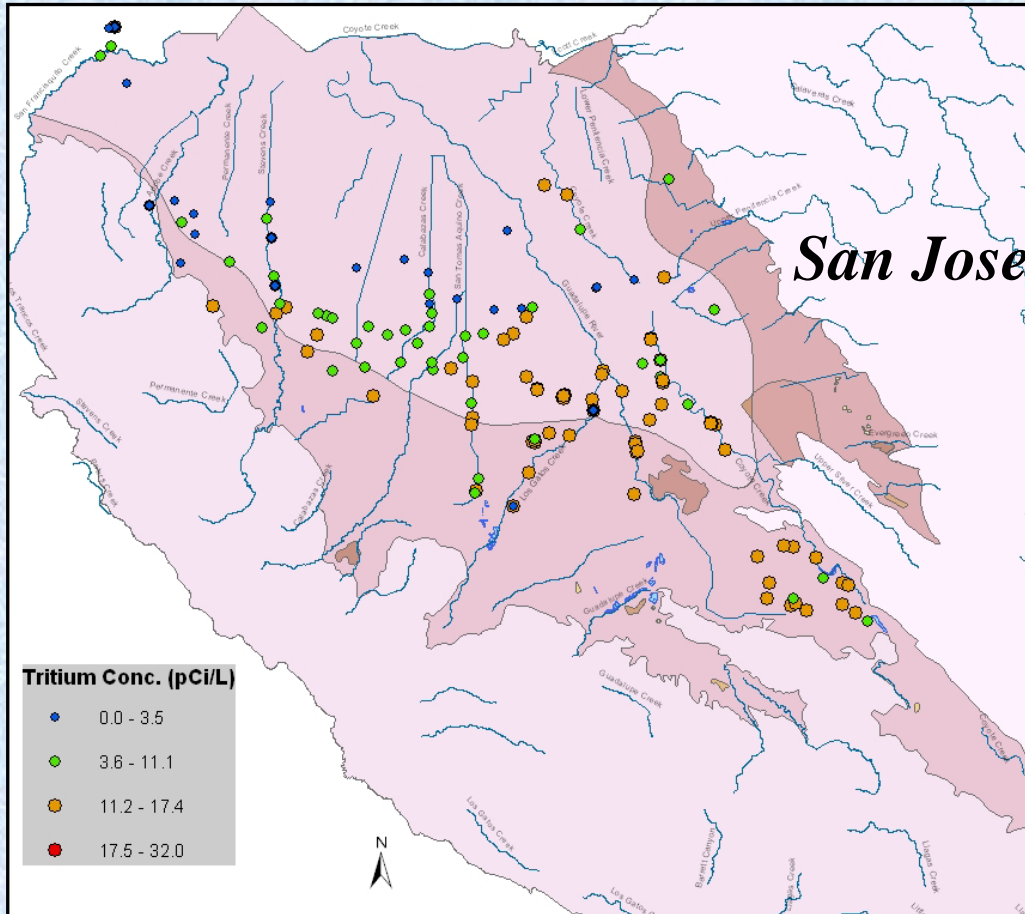




Many tritiated samples contain a large fraction of pre-modern water



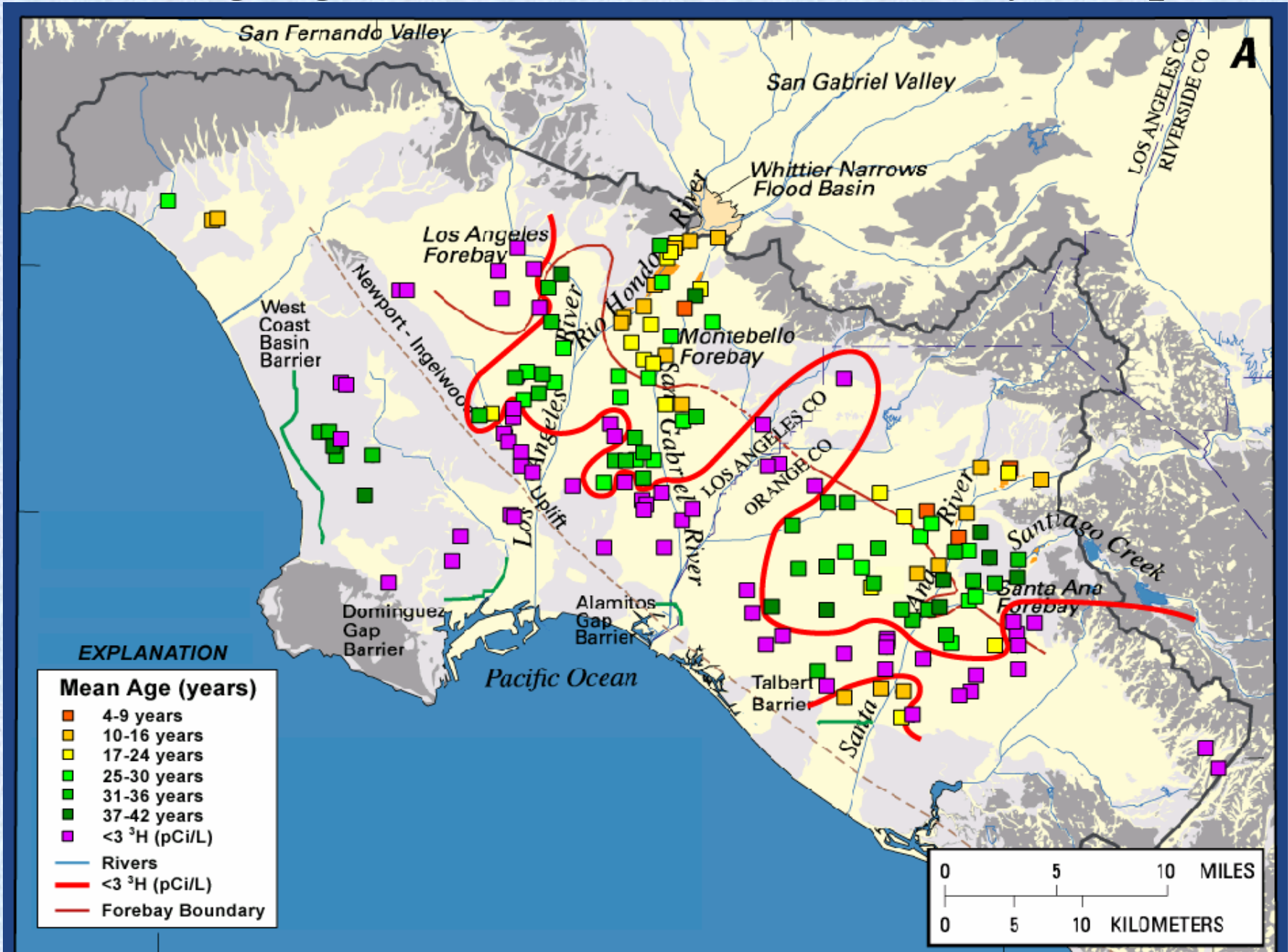
# Relative ages are most informative



- Relative ages and mixing fractions in a basin allow delineation of flow field and identification of vulnerable areas
- Absolute ages at individual wells can be difficult to interpret

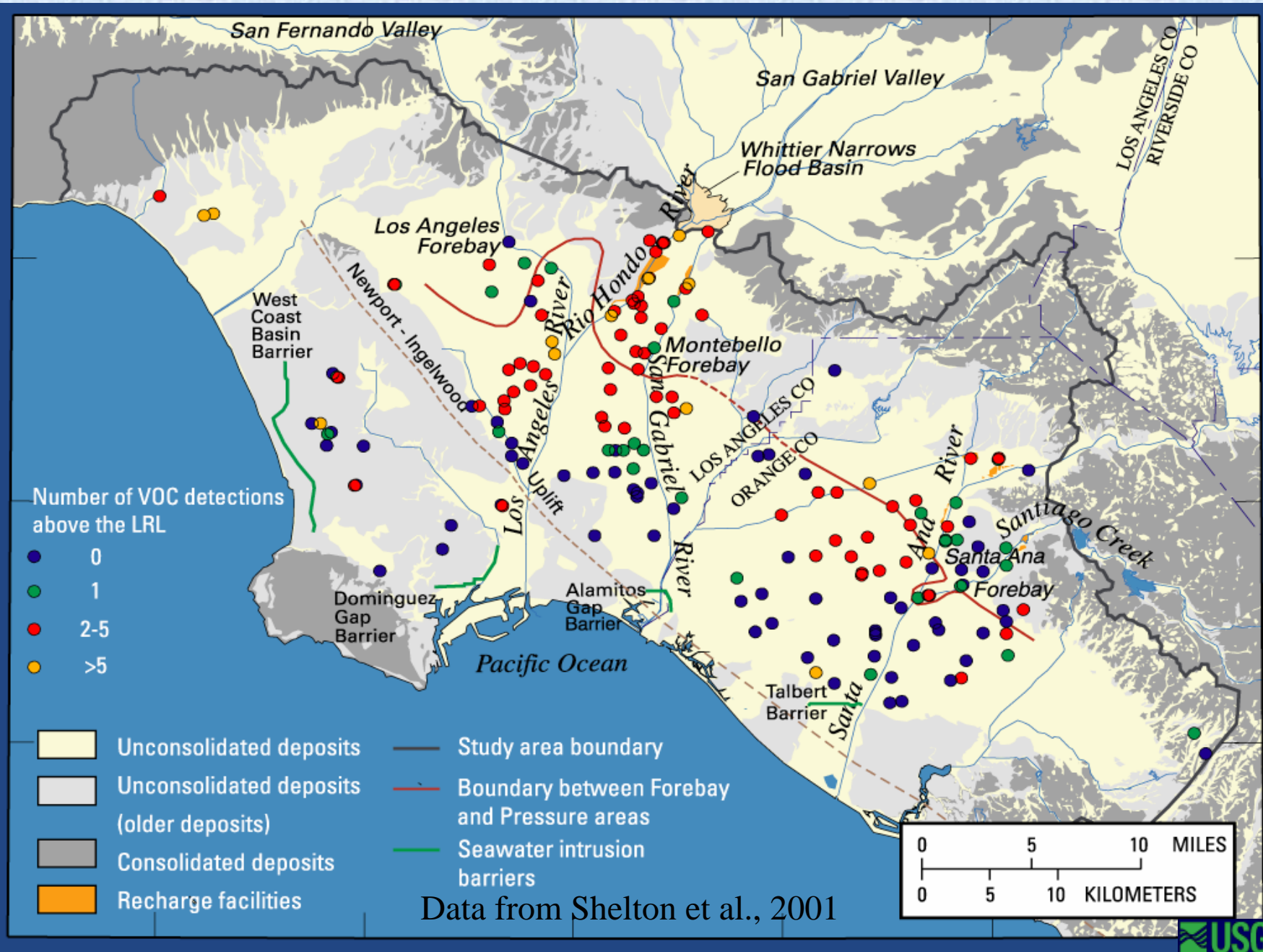
*The GAMA program has provided the means to go from low density to basin-wide coverage*

# Relative ages give bulk flow rate and identify 'fastpaths'



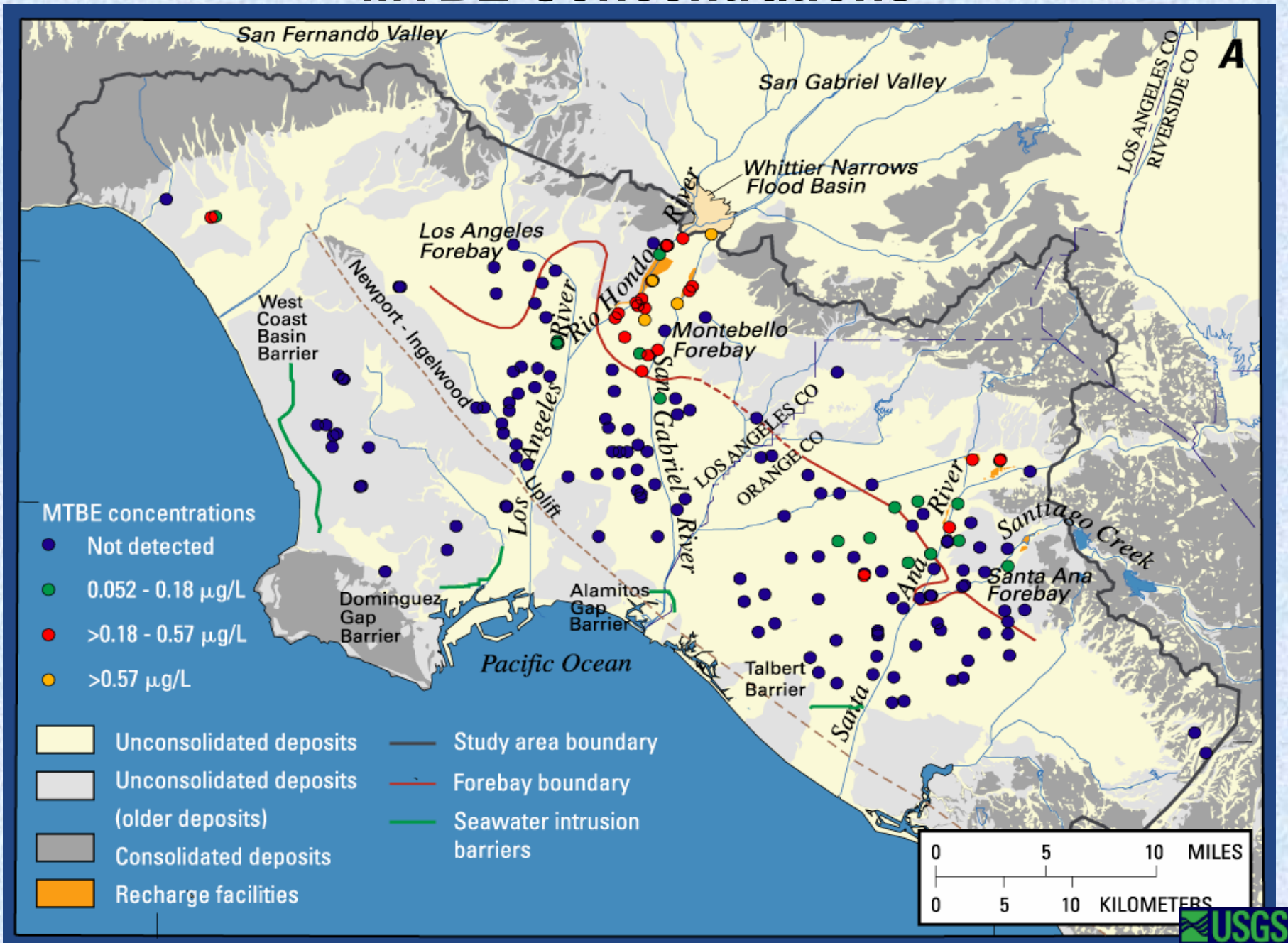


# VOC Detections





# MTBE Concentrations



# Groundwater Age is a Good Predictor of Contamination Vulnerability

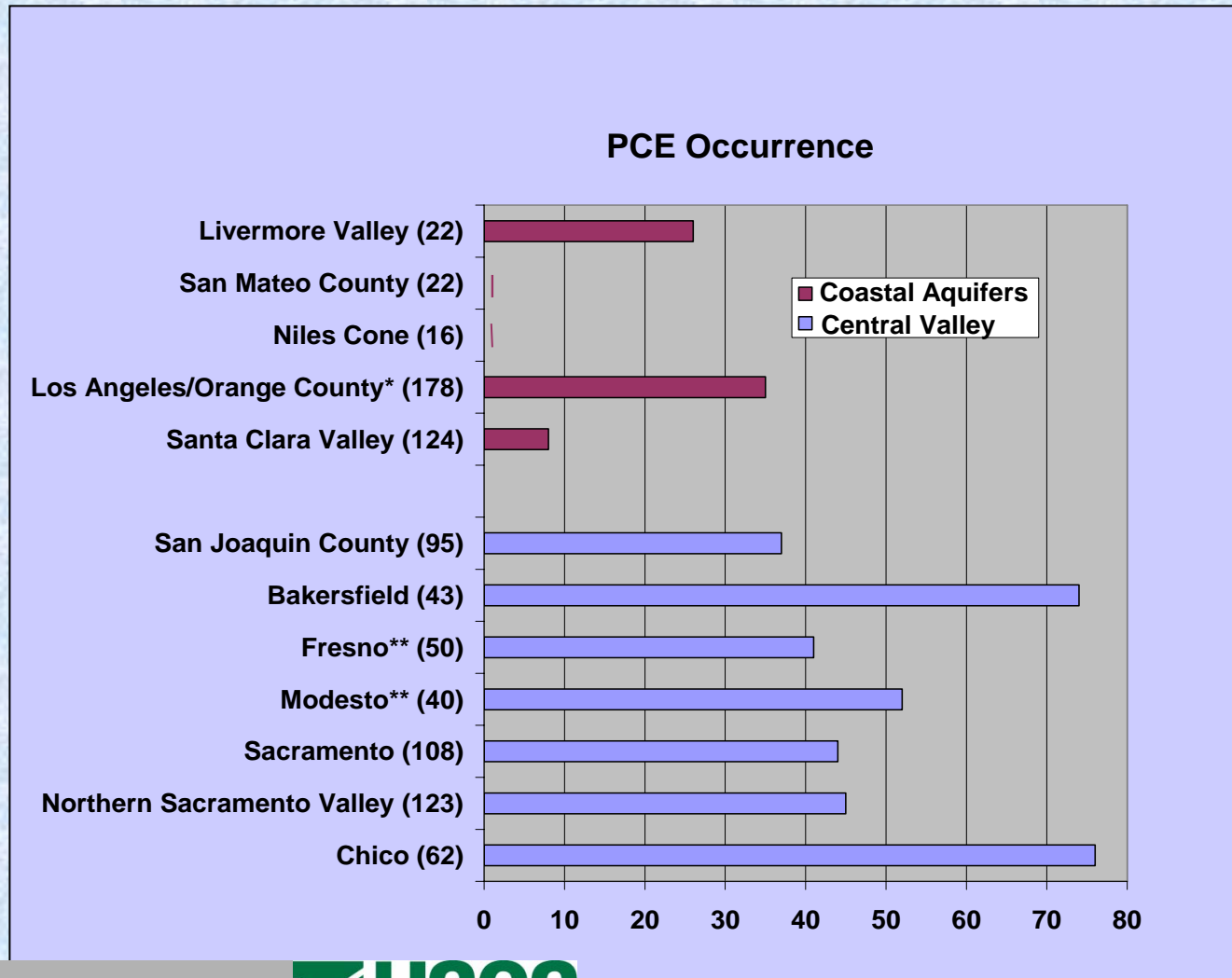
	< 11 years	> 50 years
No VOCs	18% (Burney, Ft. Jones, Santa Clara County)	57%
MtBE	67%	6% (Tulelake, Sacto, Chico)
PCE	24%	16% (Sacto, Stockton, Chico)
Any THM	68%	43%

# There is a large contrast in VOC occurrence in Coastal versus Central Valley Basin wells

	Coastal Basins <sup>1</sup> N=194	Central Valley Basins <sup>2</sup> N=338
No VOCs <sup>3</sup>	105 (54%)	48 (14%)
MtBE	29 (15%)	87 (25%)
PCE	18 (9%)	166 (49%)
CHCl <sub>3</sub>	68 (35%)	252 (74%)

- 1 Includes Santa Clara Valley, Basins of San Mateo County (San Mateo Plain, Westside Basin and Coastside Basin), Livermore-Amador Basin, and Niles Cone (Fremont, CA)
- 2 Includes Bakersfield, Chico and surrounding northern Sacramento Valley, Sacramento, and San Joaquin County urban areas (Stockton, Lodi, and Manteca); wells from areas outside of alluvial basins are not included on this table
- 3 Samples had <RL for all compounds listed in Table 1

# PCE is found in pre-modern water, especially in the Central Valley



\*Shelton et al., 2001

\*\*Wright et al., 2004



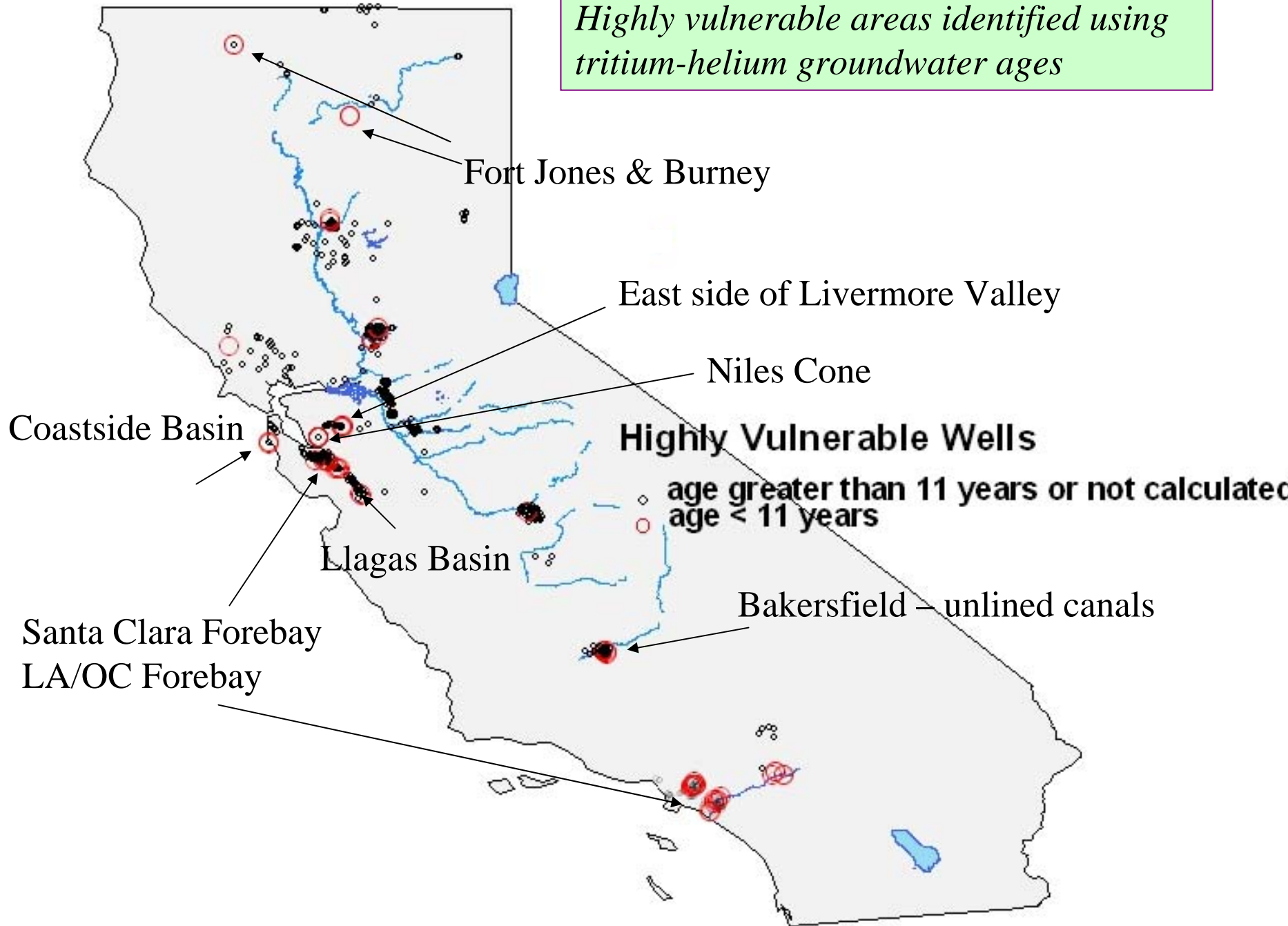
# Groundwater ages can be used by water managers

- Dictate the frequency and extent of monitoring
  - Wells with ages e.g., < 10 years should be monitored more frequently and for more compounds, including emerging contaminants
  - Expend fewer resources for testing wells that will likely remain ‘non-detect’ at DHS reporting levels
- Source area protection & remediation
  - ‘Radial distance’ method of delineating source area is more relevant for wells with young ages

Location	VOCs detected	Calculated GW Age (yrs)
Bakersfield 1	TCE, PCE, THMs	15
Bakersfield 2	THMs	34
San Jose 1	THMs	11
San Jose 2	none	42
Livermore 1	MtBE, TCE, THMs	18
Livermore 2	THMs	> 50

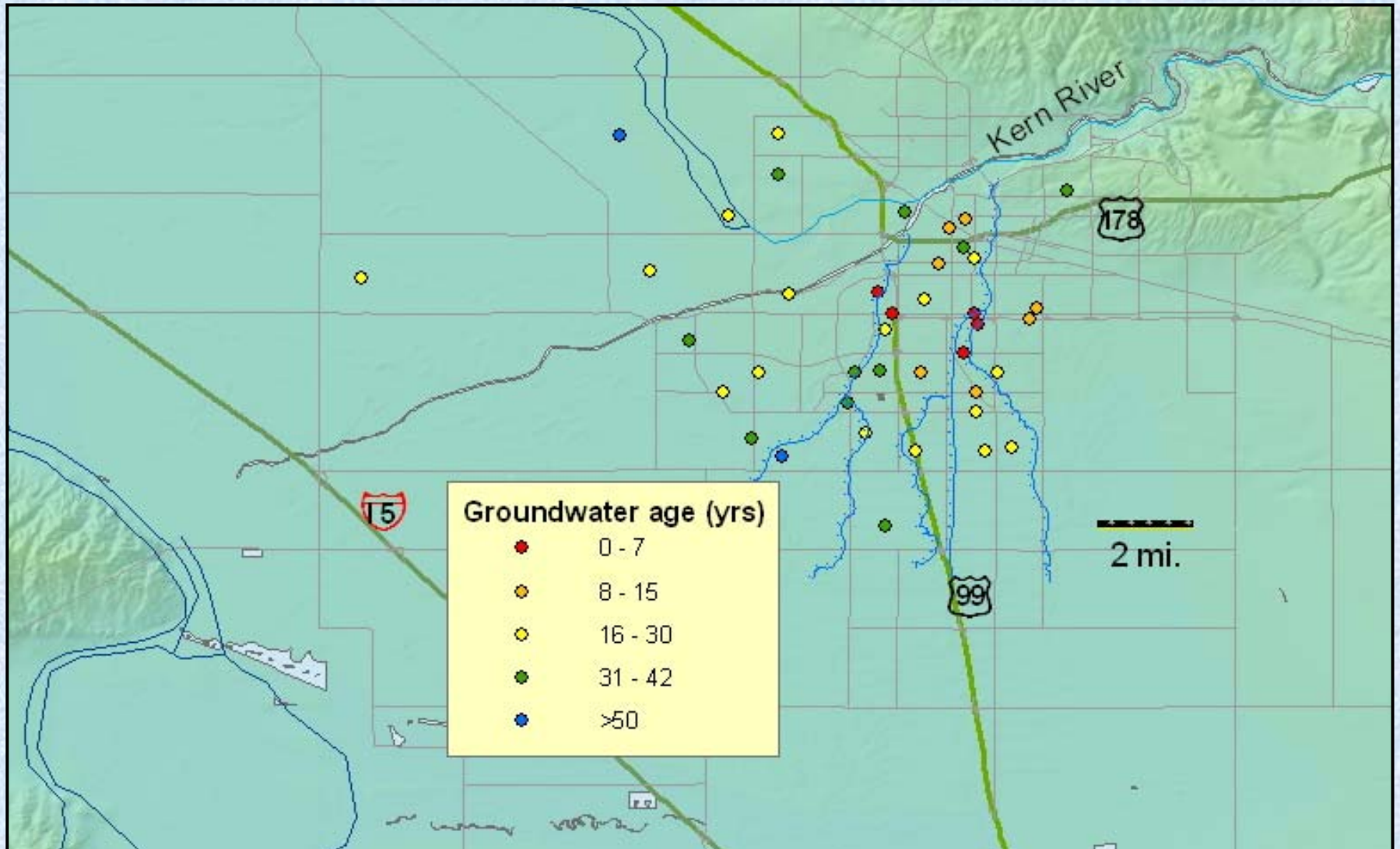
*Ages and relative contamination vulnerability can inform managers and regulators about which wells to “pay attention to”*

*Highly vulnerable areas identified using  
tritium-helium groundwater ages*

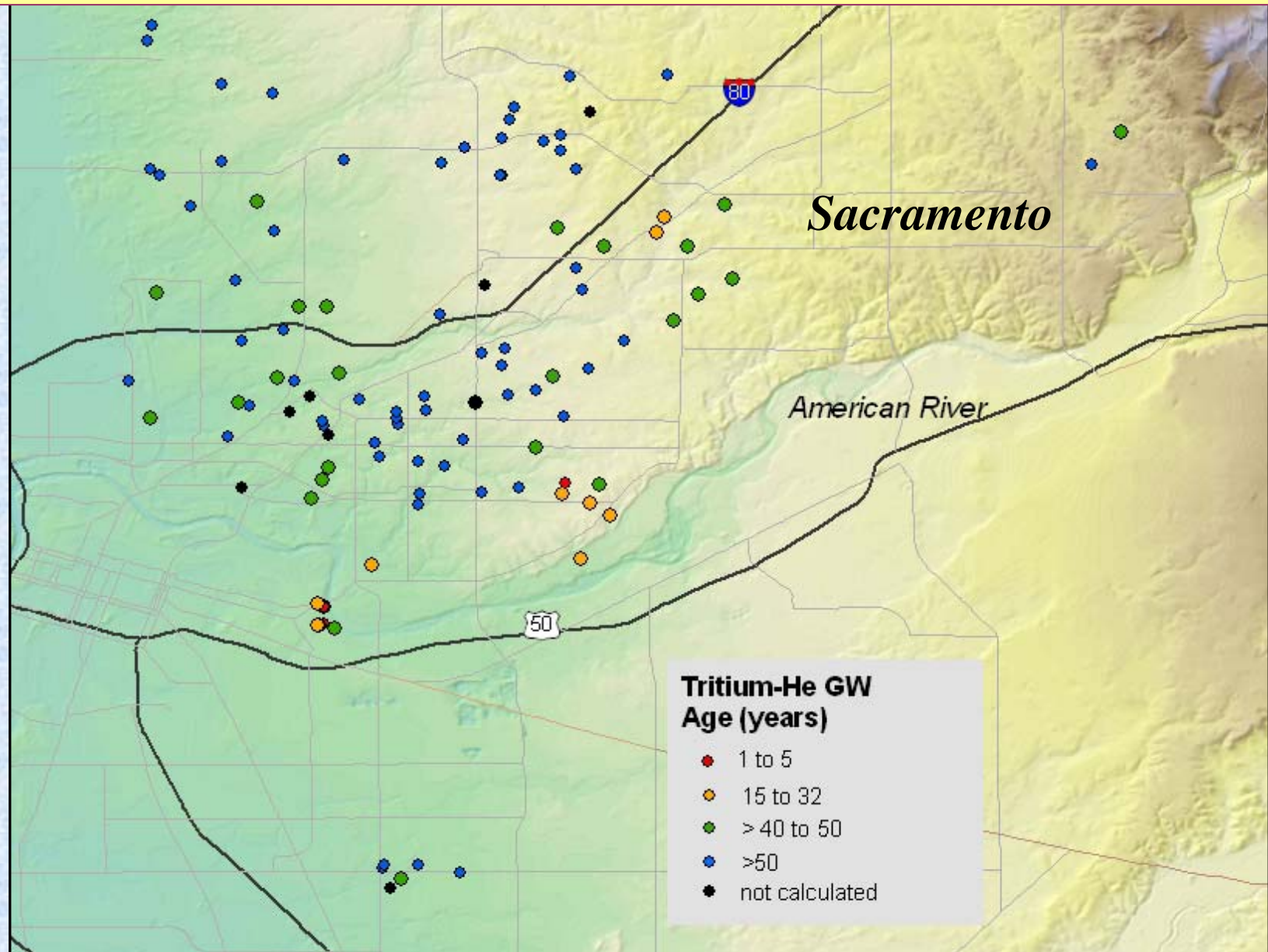




In Bakersfield, some production wells have mean ages of less than 2 years



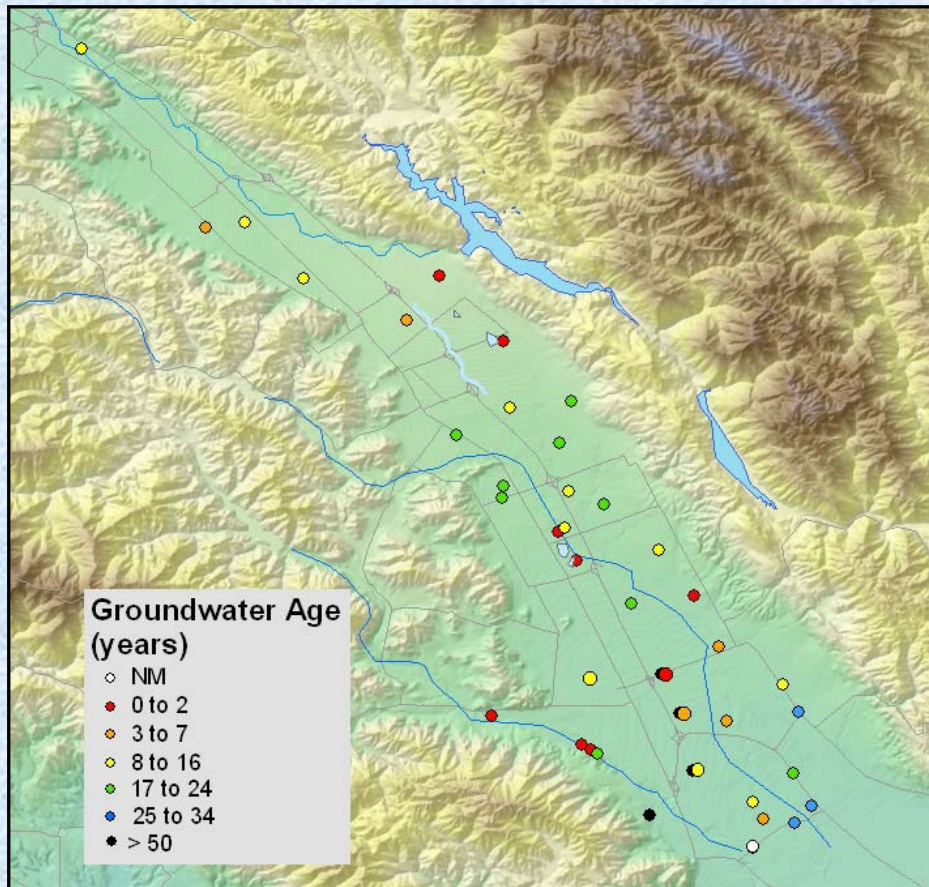
Very low tritium concentrations over a wide area bode poorly for water supply and opportunities for artificial recharge





# Using groundwater age to evaluate recharge scenarios

## Llagas Basin, Santa Clara County



### ➤ Protecting recharge areas

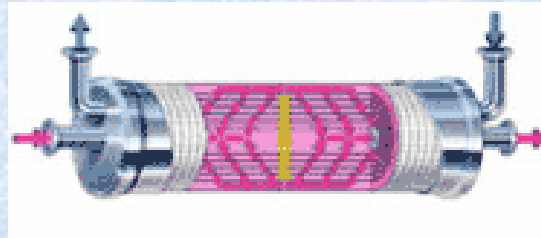
- Widely dispersed recharge areas in which young ages are observed over a wide area (Llagas, Livermore, Bakersfield)
- Distant recharge area in which deep-screened drinking water well has a recharge area different from shallow aquifer (Chico)

### Evaluating potential artificial recharge scenarios

- entraining contaminants from a multitude of point sources in recharge areas (Santa Clara, Los Angeles, Orange County)
- may take water a long time to reach deep aquifer (Sacramento, Chico)

# Looking to the future...

- Other dissolved gases have untapped potential in groundwater investigations
- $^{85}\text{Krypton}$ 
  - Simple source function, no subsurface sources
  - Covers same age range as tritium
- Depth-specific sampling
- Assessing BMPs and remediation schemes
- Examining water quality changes during groundwater banking and aquifer storage and recovery



# Contact Information

Groundwater Ambient Monitoring and  
Assessment (GAMA) Program

California State Water Resources Control  
Board

[www.swrcb.ca.gov/gama](http://www.swrcb.ca.gov/gama)

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# Sample set is mainly long-screened production wells

- Advantages

- You get a good, clean sample (both dissolved gases and low level VOCs)
- Characteristics are usually known
- It's the water people are drinking

- Disadvantages

- Vertical information is smeared
- 'Signal' is diluted
- Flow field is altered
- It's the water people are drinking



Fremont wells have narrow age distributions; some  
Livermore wells have older water components

