GAMA Program

Groundwater Ambient Monitoring and Assessment

John Borkovich, PG
GAMA Program
State Water Resources Control Board

Water Boards

Ground Rules

1) Use common conversational courtesy
2) All ideas and points of view have value
3) Avoid editorials
4) Honor time
5) Order of comments - PAC members speak first
6) Decision making by consensus

Goals of Today's Meeting

- Reconvene PAC
- Review Status of the GAMA Program; emphasis on Priority Basin Project
- Discuss proposed change in workscope
- Initiate Discussion on Future Issues Facing GAMA

Water Boards

Presentation Overview

- GAMA Background and Status
- Groundwater Information in GeoTracker GAMA

Water Boards

GAMA is:

Groundwater
Ambient
Monitoring and
Assessment

Water Boards

GAMA Background

- Legislature's concern about groundwater quality
- Budget Act of 2000
- Water Code Section 10780
  - Groundwater Quality Monitoring Act of 2001 - (AB 599, Liu)
    - PAC and ITF created as a result
  - Groundwater Quality Monitoring – (2008. AB 2222, Caballero)

Water Boards

PAC Representatives

AB 599 specified that we convene an advisory committee "PAC":

- Two from federal agencies
- Two from public water systems
- Two from environmental organizations
- Two from business community
- One from a local agency
- Two from agriculture
- Two from groundwater management entities

Note: SWRCB staff did not appoint. We invited representative groups to appoint PAC membership.

GAMA Program Functions

- Collect new and existing data
- Coordinate with other groundwater efforts
- Assess groundwater quality
- Serve information to the public

Water Boards

California Relies Heavily on Groundwater

- 35% of water for irrigation and public use is from groundwater
- 43% of Californians are served by groundwater
- Many communities rely 100% on groundwater
- Contaminated groundwater results in treatment costs, well closures, and new well construction which increases costs for consumers

Water Boards

Groundwater Quality Monitoring Importance

- Groundwater data and information critical for resource management
- Groundwater Information needs to be more centralized, integrated to be more easily monitored, evaluated, assessed

Water Boards

GAMA Program: Current Projects

Special Studies

Priority Basins

Domestic Wells

GeoTracker GAMA

Sampling conducted in *Voluntary Cooperation* with Participants

Water Boards

USGS science for a changing world

GAMA Domestic Well Project

- Tests for chemicals commonly found
- Provides Water quality info to well owners
- Coordinate with local environmental agencies
- Cost for testing incurred by State Water Board
- Water Quality data online

Water Boards

Status: Domestic Well Project

- 1,146 Wells sampled from 2003-11
- Key Results – *Yuba, El Dorado, Tehama, Tulare, San Diego, Monterey Counties:*
  - Total Coliform: 26% wells tested positive
    - Fecal 3.2%
  - Nitrate: 10% wells tested above MCL
    - Nitrate: 41% Tulare wells above MCL
  - Radionuclides (gross alpha): 33% San Diego >MCL
  - Perchlorate: 6% above MCL
  - VOCs: <1% above MCL

Water Boards

State Board Staff Technical Lead

Status: Priority Basins Project

- First statewide sampling cycle nearly complete
- 2,200 wells sampled
- Dozens of Reports, Fact Sheets published

USGS Technical Lead with LLNL support

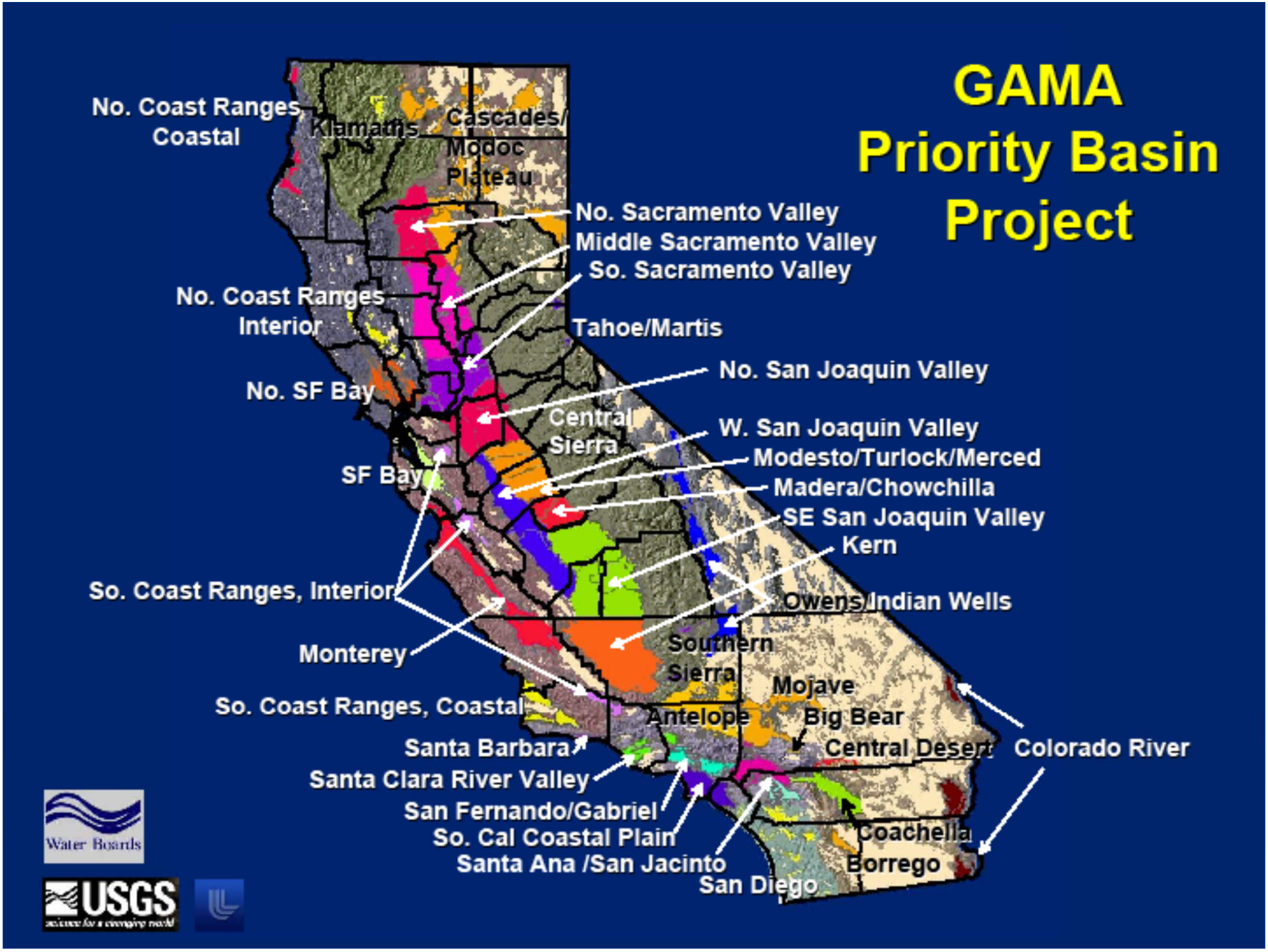
Water Boards

USGS science for a changing world

GAMA Priority Basins Project

- Status: >1,200 participants: 208 dists.,159 cities, 80 schools
- Major Findings:
  - "Naturally" occurring compounds most prevalent
  - Low level pharmaceuticals and wastewater chemicals indicate connection between surface and groundwater
  - Pesticides – mostly detected only at v. low levels

Water Boards


GAMA
Priority Basin
Project
No. Coast Ranges
Coastal
Klamaths
Cascades/
Modoc
Plateau
No. Sacramento Valley
Middle Sacramento Valley
So. Sacramento Valley
No. Coast Ranges
Interior
Tahoe/Martis
No. San Joaquin Valley
No. SF Bay
Central
Sierra
W. San Joaquin Valley
Modesto/Turlock/Merced
SF Bay
Madera/Chowchilla
SE San Joaquin Valley
Kern
So. Coast Ranges, Interior
Owens/Indian Wells
Southern
Sierra
Monterey
Mojave
So. Coast Ranges, Coastal
Antelope
Big Bear
Central Desert
Colorado River
Santa Barbara
Santa Clara River Valley
San Fernando/Gabriel
So. Cal Coastal Plain
Coachella
Santa Ana /San Jacinto
Borrego
San Diego
Water Boards
USGS

Priority Basin – Future Funding

- Priority Basins funding (Prop 50 bonds) ceases in 2015
- AB 2222 report (*1st one*) recommends extending GAMA to 2024
  - Funding for other GAMA Projects still intact
- New Funding Source Not Yet Identified
- Reconvene PAC later this year, to discuss potential options

Water Boards

GAMA Special Studies

- LLNL Lead
- Focus on areas of groundwater concern *(occurrence, source)*
  - Wastewater, Septics
  - Dairies
  - Nitrate
  - Recycled Water
- Tools used
  - Age dating (H3/He)
  - Isotopes (N, O, H, B)

Water Boards

Important Points/Findings:

- Most land uses can impact groundwater quality
  - Shallow groundwater more vulnerable to contaminants
  - Deeper water typically better quality, but has several contaminants-usually in trace amounts
- Monitoring groundwater quality is critical to track impacts over time

Water Boards

GeoTracker GAMA:
Groundwater Information System

- Fulfills AB599 intent: Central data system
- Shares data from CDPH, USGS, LLNL, DWR, DPR, State and Regional Water Boards
- Water quality, *PLUS* water levels, contaminant sources, groundwater publications

Water Boards

GeoTracker GAMA:
Groundwater Information System (cont.)

- Internet accessible; public and tiered access
- Can search for >225 chemical constituents
- Adds new Data as it is available

System is capable of expanding more

Water Boards

State Water Resources Control Board - Windows Internet Explorer provided by Internet Explorer 7 for SWRCB

http://www.waterboards.ca.gov/water_issues/programs/gama/geotracker_gama.shtml

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State Water Resources Control Board

Page Tools

Programs | Available Documents | Hot Topics |

- Cal/EPA
- State and Regional Water Boards' Map
- Laws/Regulations
- Plans/Policies
- Programs
- Decisions Pending and Opportunities for Public Participation

Water Quality

Performance Report

Website Feedback

GAMA RESOURCES

- GAMA Home
- Priority Basin Project
- Domestic Well Project
- Special Studies Project
- California Aquifer Susceptibility Project
- Groundwater Reports
- Chemicals of Concern (COC) Information Sheets
- Related Laws and Regulations
- Sources of Groundwater

Home » Water Issues » Programs » Gama

GAMA – Groundwater Ambient Monitoring & Assessment Program

GeoTracker GAMA Groundwater Data Sources

GeoTracker GAMA provides user-friendly internet access to groundwater data. Data are searchable by chemical, with results displayed on an interactive map (shown below).

» Start GeoTracker GAMA

Access system through GAMA Homepage

GeoTracker GAMA includes data for over 150,000 locations. GeoTracker GAMA integrates, standardizes, and provides tools to analyze several datasets, including data from:

- State and Regional Water Boards (SWRCB/RWQCB)
- California Department of Public Health (CDPH)
- Department of Pesticide Regulation (DPR)
- Department of Water Resources (DWR)
- United States Geological Survey (USGS)
- Lawrence Livermore National Laboratory (LLNL)

Shared datasets listed here

Sources of GeoTracker GAMA Data are depicted in the figure below. Move your mouse cursor over a well (A, B, C) for more information on these data sources.

Done

Trusted sites

100%


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GeoTracker
State Water Resourc...
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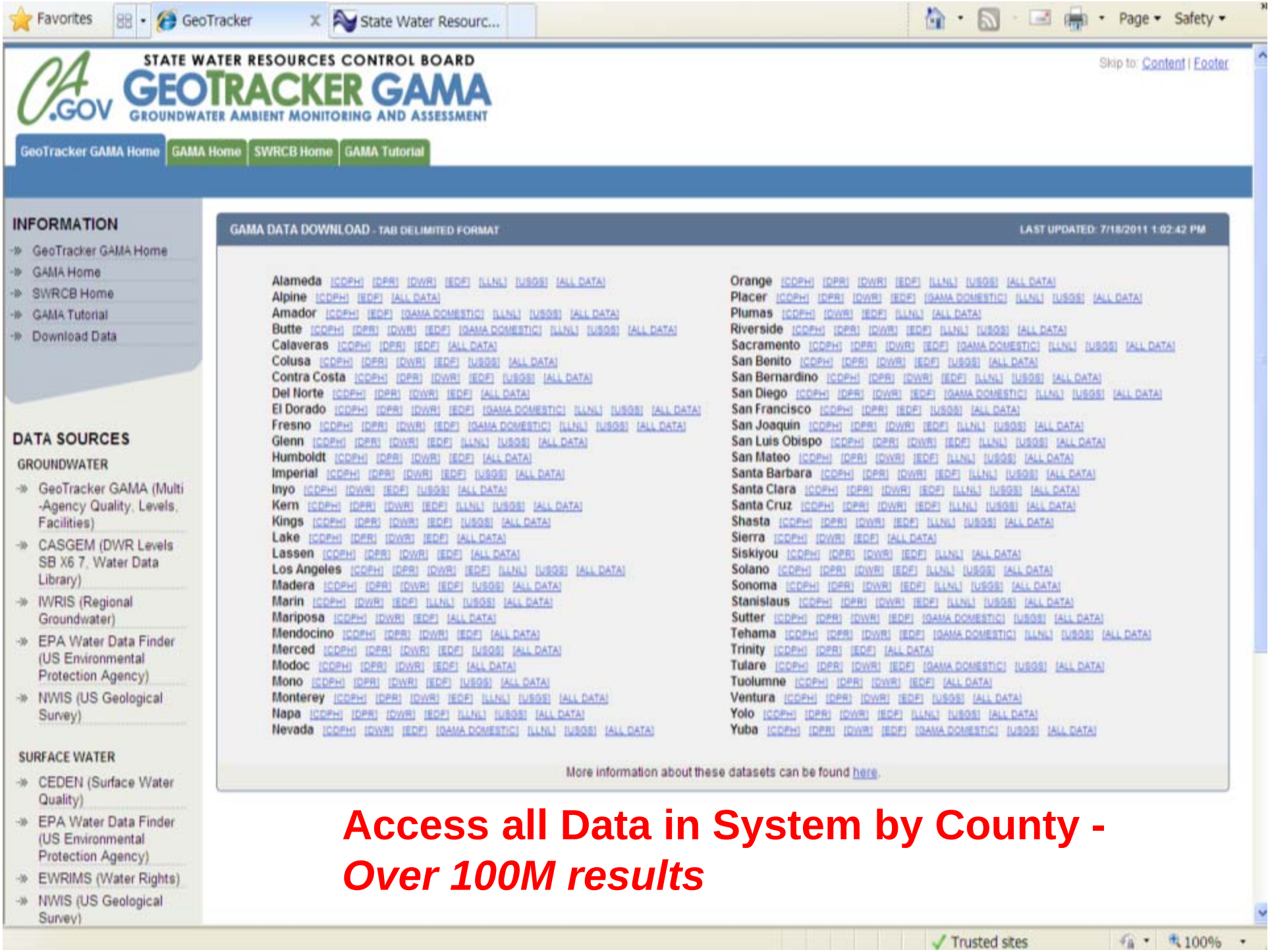
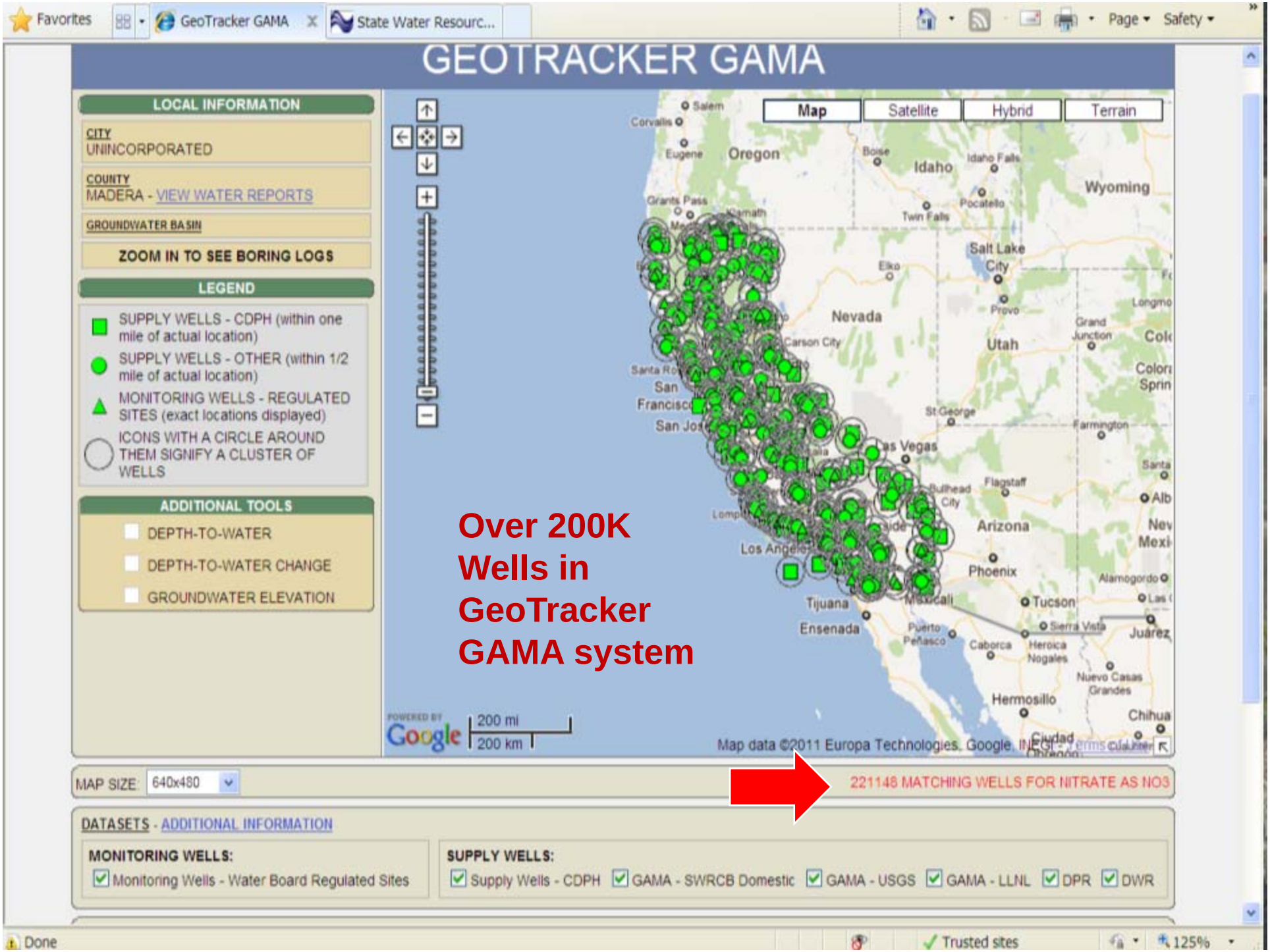
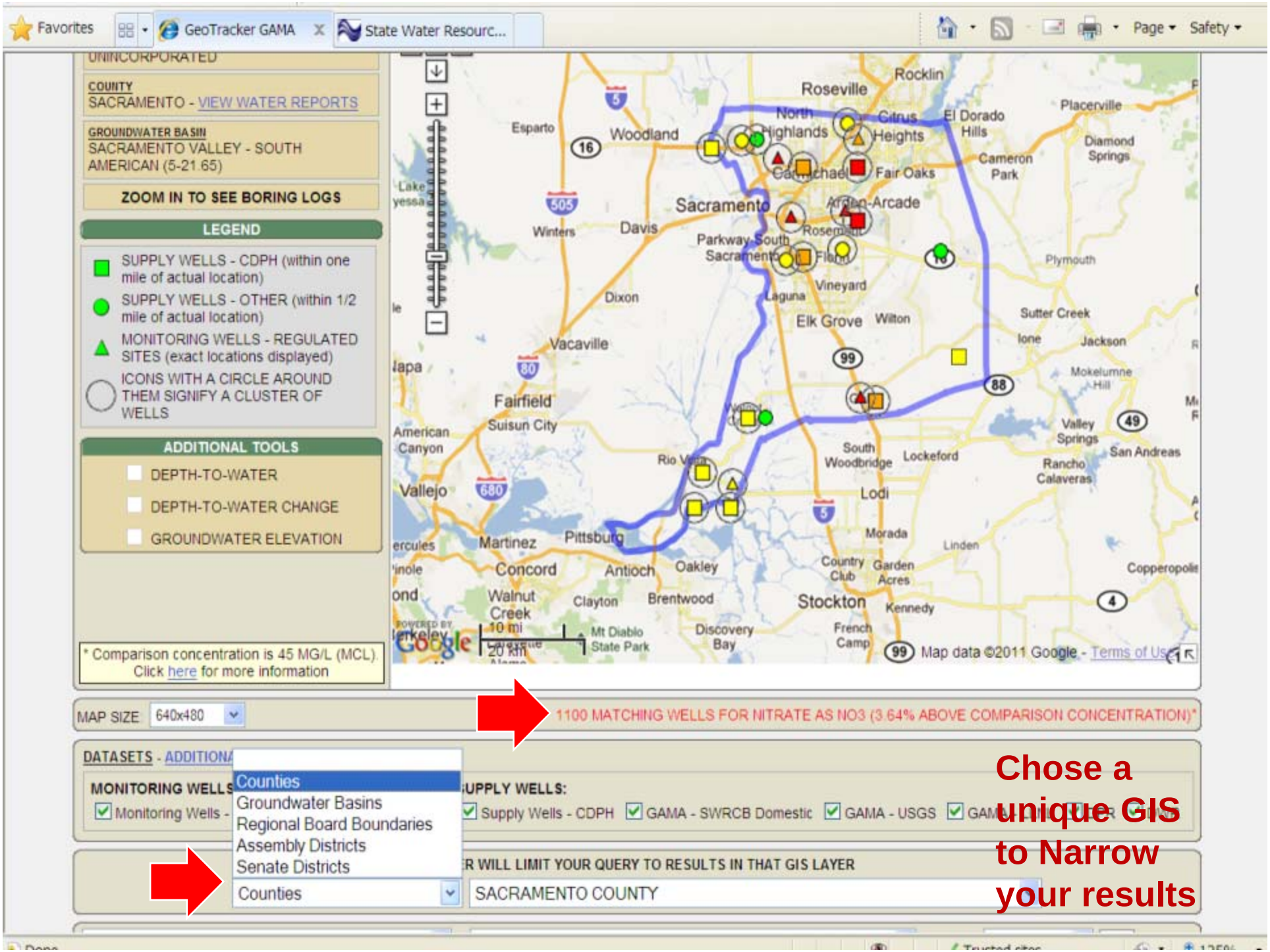
Safety
STATE WATER RESOURCES CONTROL BOARD
CA.GOV
GEOTRACKER GAMA
GROUNDWATER AMBIENT MONITORING AND ASSESSMENT
Skip to: Content | Footer
GeoTracker GAMA Home
GAMA Home
SWRCB Home
GAMA Tutorial
INFORMATION
GeoTracker GAMA Home
GAMA Home
SWRCB Home
GAMA Tutorial
Download Data
Access all Data in System by County
DATA SOURCES
GROUNDWATER
GeoTracker GAMA (Multi -Agency Quality, Levels, Facilities)
CASGEM (DWR Levels SB X6 7, Water Data Library)
IWRIS (Regional Groundwater)
EPA Water Data Finder (US Environmental Protection Agency)
NWIS (US Geological Survey)
SURFACE WATER
Welcome to GeoTracker GAMA
GeoTracker GAMA (Groundwater Ambient Monitoring and Assessment) is an online database using Google Maps that:
Makes searchable a number of groundwater quality databases
Provides links to other groundwater quality data
Provides links to other information about groundwater basics and groundwater protection
Brings together and standardizes datasets from California state agencies including: Public Health, Water Resources, and Pesticide Regulation as well as from the US Geological Survey, Lawrence Livermore National Laboratory, and the Water Boards.
MAP WATER QUALITY INFORMATION
Enter an address to display water quality information on a map.
e.g., "10 market st, san francisco, ca" - INFO
Enter an Address or City
Search
Enter your address, zip to start query



Access all Data in System by County -

Over 100M results


GEOTRACKER GAMA
LOCAL INFORMATION
CITY
UNINCORPORATED
COUNTY
MADERA - VIEW WATER REPORTS
GROUNDWATER BASIN
ZOOM IN TO SEE BORING LOGS
LEGEND
SUPPLY WELLS - CDPH (within one mile of actual location)
SUPPLY WELLS - OTHER (within 1/2 mile of actual location)
MONITORING WELLS - REGULATED SITES (exact locations displayed)
ICONS WITH A CIRCLE AROUND THEM SIGNIFY A CLUSTER OF WELLS
ADDITIONAL TOOLS
DEPTH-TO-WATER
DEPTH-TO-WATER CHANGE
GROUNDWATER ELEVATION
Map
Satellite
Hybrid
Terrain
Over 200K Wells in GeoTracker GAMA system
200 mi
200 km
Map data ©2011 Europa Technologies, Google, INEGI
MAP SIZE: 640x480
221148 MATCHING WELLS FOR NITRATE AS NO3
DATASETS - ADDITIONAL INFORMATION
MONITORING WELLS:
Monitoring Wells - Water Board Regulated Sites
SUPPLY WELLS:
Supply Wells - CDPH
GAMA - SWRCB Domestic
GAMA - USGS
GAMA - LLNL
DPR
DWR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SACRAMENTO VALLEY - SOUTH AMERICAN (5-21.65)
ZOOM IN TO SEE BORING LOGS
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MONITORING WELLS - REGULATED SITES (exact locations displayed)
ICONS WITH A CIRCLE AROUND THEM SIGNIFY A CLUSTER OF WELLS
ADDITIONAL TOOLS
DEPTH-TO-WATER
DEPTH-TO-WATER CHANGE
GROUNDWATER ELEVATION
* Comparison concentration is 45 MG/L (MCL). Click here for more information
Roseville
Rocklin
Placerville
Esparto
Woodland
North Highlands
Citrus Heights
El Dorado Hills
Cameron Park
Diamond Springs
Fair Oaks
Sacramento
Arden-Arcade
Winters
Davis
Parkway-South Sacramento
Plymouth
Vineyard
Dixon
Laguna
Elk Grove
Wilton
Sutter Creek
Ione
Jackson
Vacaville
Mokelumne Hill
Fairfield
Suisun City
American Canyon
Valley Springs
San Andreas
Rancho Calaveras
South Woodbridge
Lockeford
Vallejo
Lodi
Martinez
Pittsburg
Concord
Antioch
Oakley
Morada
Linden
Country Club
Garden Acres
Copperopolis
Walnut Creek
Clayton
Brentwood
Stockton
Kennedy
Mt Diablo State Park
Discovery Bay
French Camp
Map data ©2011 Google - Terms of Use
MAP SIZE 640x480
1100 MATCHING WELLS FOR NITRATE AS NO3 (3.64% ABOVE COMPARISON CONCENTRATION)*
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Monitoring Wells -
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Supply Wells - CDPH
GAMA - SWRCB Domestic
GAMA - USGS
Counties
Groundwater Basins
Regional Board Boundaries
Assembly Districts
Senate Districts
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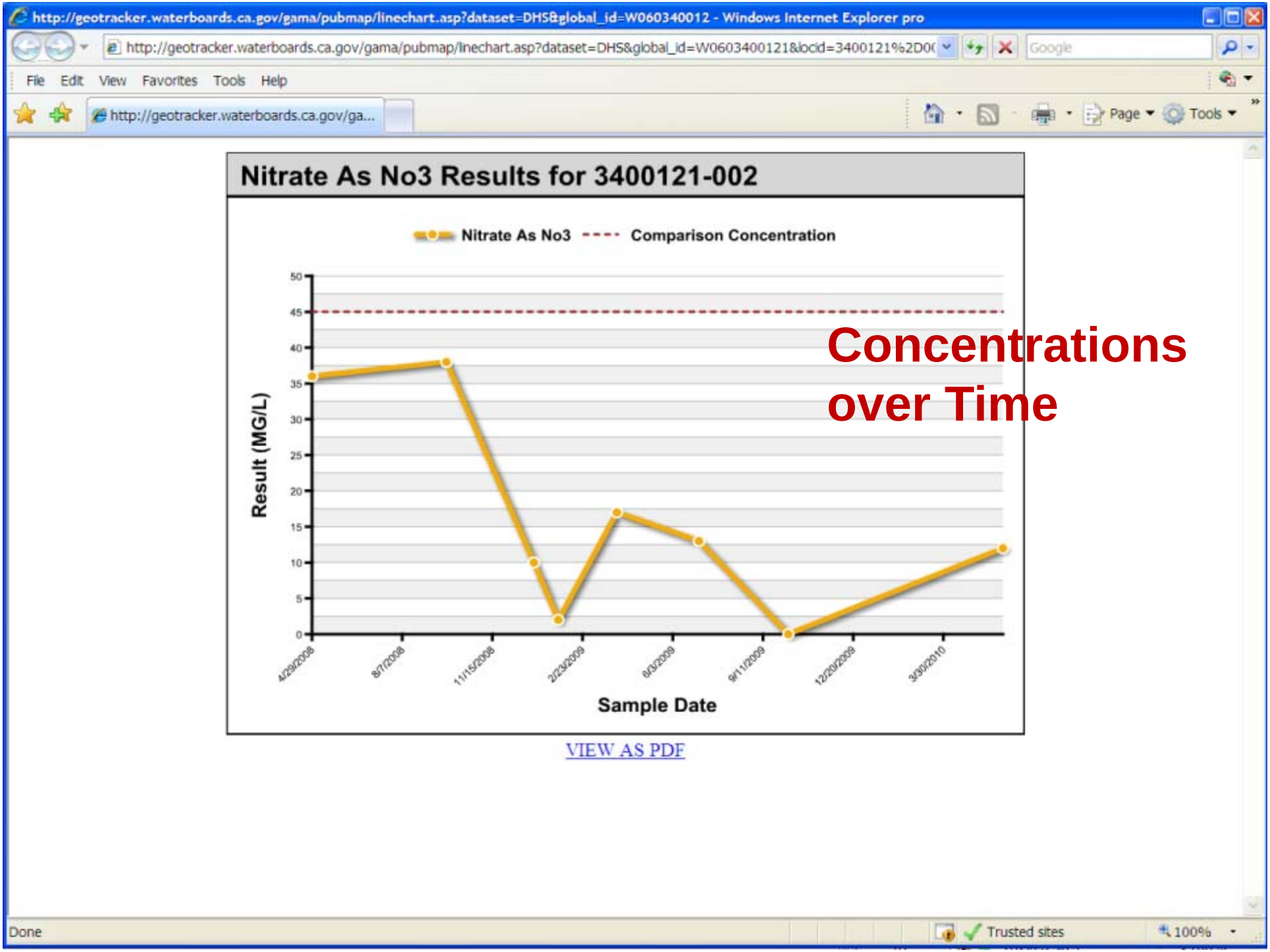
Counties
SACRAMENTO COUNTY
Chose a unique GIS to Narrow your results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Page Tools
Nitrate As No3 Results for 3400121-002
Nitrate As No3
Comparison Concentration
Result (MG/L)
50
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8/7/2008
11/15/2008
2/23/2009
6/3/2009
9/11/2009
12/20/2009
3/30/2010
Sample Date
VIEW AS PDF
Concentrations over Time
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Other Groundwater Information

Water Boards


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Page
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GEOTRACKER GAMA HOME | GAMA HOME | SWRCB HOME | HOTSPOT LEGEND | TRANSLATION TABLE | CONTACT US | HELP
GEOTRACKER GAMA
LOCAL INFORMATION
CITY
LOS ANGELES
COUNTY
LOS ANGELES - VIEW WATER REPORTS
GROUNDWATER BASIN
SAN FERNANDO VALLEY (4-12)
VIEW 494 WELL BORING LOGS
LEGEND
SUPPLY WELLS - CDPH (within one mile of actual location)
SUPPLY WELLS - OTHER (within 1/2 mile of actual location)
MONITORING WELLS - REGULATED SITES (exact locations displayed)
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ADDITIONAL TOOLS
DEPTH-TO-WATER
DEPTH-TO-WATER CHANGE
GROUNDWATER ELEVATION
Allows access to Pertinent Tech reports and Well Logs
Map
Satellite
Hybrid
Terrain
Glendale
Somerset
Eagle Rock
South Arroyo
Griffith Park
York Blvd
Highland Park
Garvanza
South Pasadena
San Marin
Glassell Park
Mt Washington
Elephant Hill
Huntington Dr
Alhambra
Little Armenia
Fountain Ave
Ernest E. Debs Regional Park
Silver Lake
Montecito Heights
W Main
Wilshire Center
Rampart Village
Lincoln Heights
W Valley Blvd
Ascot Hills Park
Monterey Park
Chinatown
Los Angeles
City Terrace
Mid City
Downtown
Hazard
Santa Monica Fwy
Jefferson
Boyle Heights
East Los Angeles
Pomona Fwy
Santa Ana Fwy
2 mi
2 km
Map data ©2011 Google - Terms of Use
MAP SIZE: 640x480
136 MATCHING WELLS FOR NITRATE AS NO3
DATASETS - ADDITIONAL INFORMATION
MONITORING WELLS:
Monitoring Wells - Water Board Regulated Sites
SUPPLY WELLS:
Supply Wells - CDPH
GAMA - SWRCB Domestic
GAMA - USGS
GAMA - LLNL
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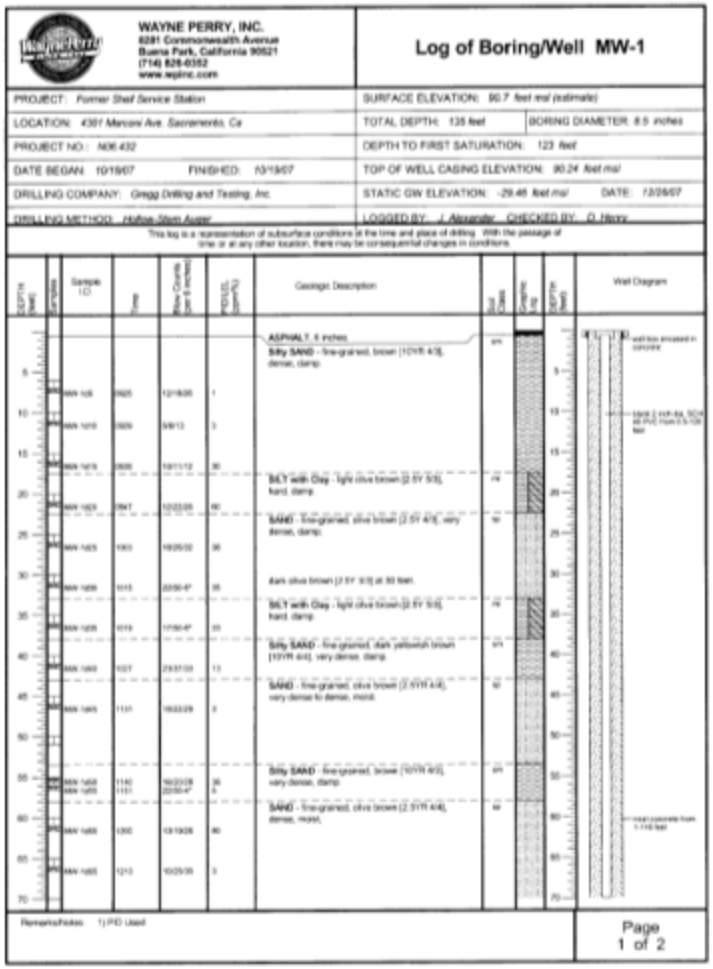


WAYNE PERRY, INC.
8281 Commonwealth Avenue
Buena Park, California 90621
(714) 828-0352
www.wpinc.com

Log of Boring/Well MW-1

PROJECT: Former Shell Service Station	SURFACE ELEVATION: 90.7 feet msl (estimate)
LOCATION: 4301 Marconi Ave. Sacramento, Ca	TOTAL DEPTH: 135 feet / BORING DIAMETER: 8.5 inches
PROJECT NO.: N06.432	DEPTH TO FIRST SATURATION: 123 feet
DATE BEGAN: 10/19/07 FINISHED: 10/19/07	TOP OF WELL CASING ELEVATION: 90.24 feet msl
DRILLING COMPANY: Gregg Drilling and Testing, Inc.	STATIC GW ELEVATION: -29.46 feet msl / DATE: 12/26/07
DRILLING METHOD: Hollow Stem Auger	LOGGED BY: J. Alexander CHECKED BY: D. Henry

This log is a representation of subsurface conditions at the time and place of drilling. With the passage of time or at any other location, there may be consequential changes in conditions.

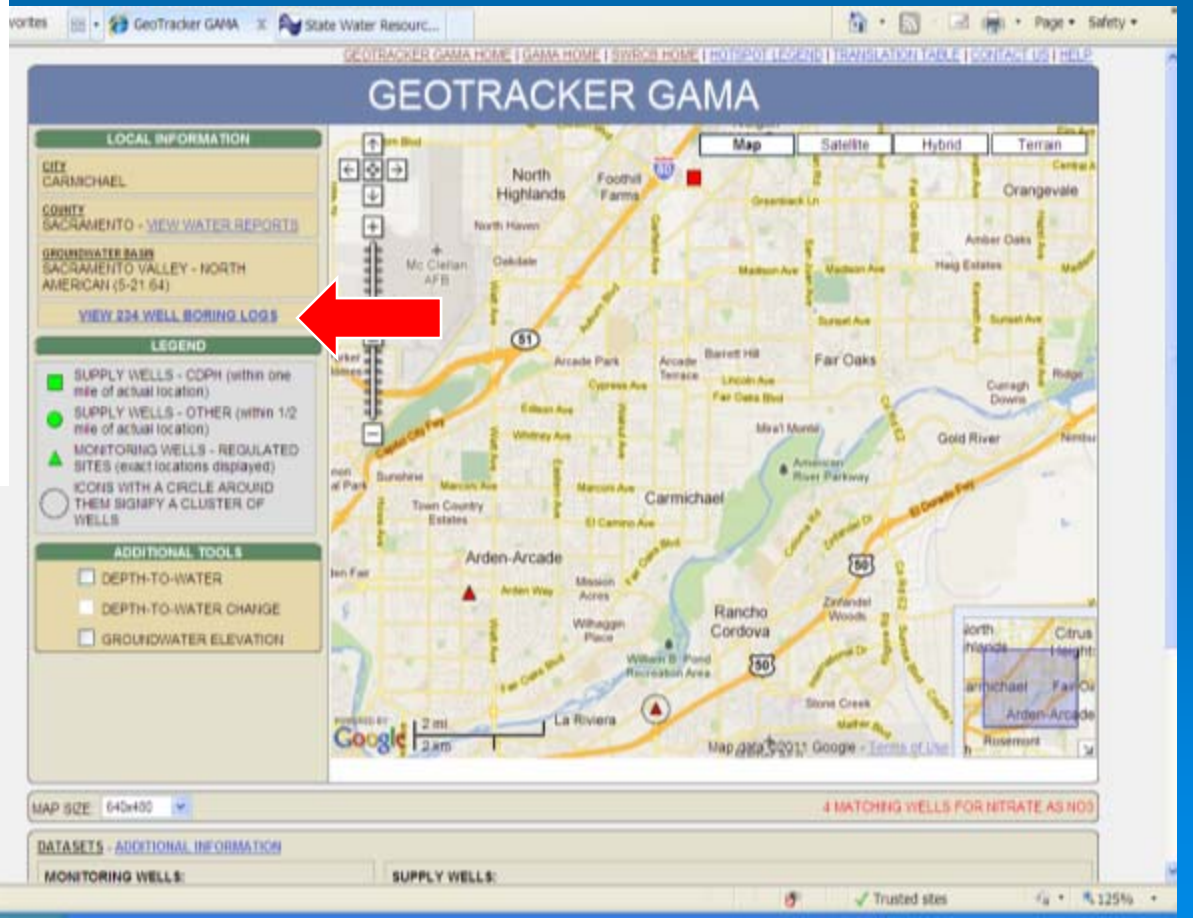
Depth (feet) | Graphics | Sample ID | Time | Blow Counts (per 6 inches) | PID/FID (ppm/%) | Geologic Description | Soil Class | Graphic Log | Depth (feet) | Well Diagram

ASPHALT - 4 inches
Silty SAND - fine-grained, brown (10YR 4/3), dense, damp
SILT with Clay - light olive brown (2.5Y 5/3), hard, damp
SAND - fine-grained, olive brown (2.5Y 4/3), very dense, damp
dark olive brown (2.5Y 3/3) at 30 feet.
SILT with Clay - light olive brown (2.5Y 5/3), hard, damp
Silty SAND - fine-grained, dark yellowish brown (10YR 4/4), very dense, damp
SAND - fine-grained, olive brown (2.5YR 4/4), very dense to dense, moist
Silty SAND - fine-grained, brown (10YR 4/3), very dense, damp
SAND - fine-grained, olive brown (2.5YR 4/4), dense, moist

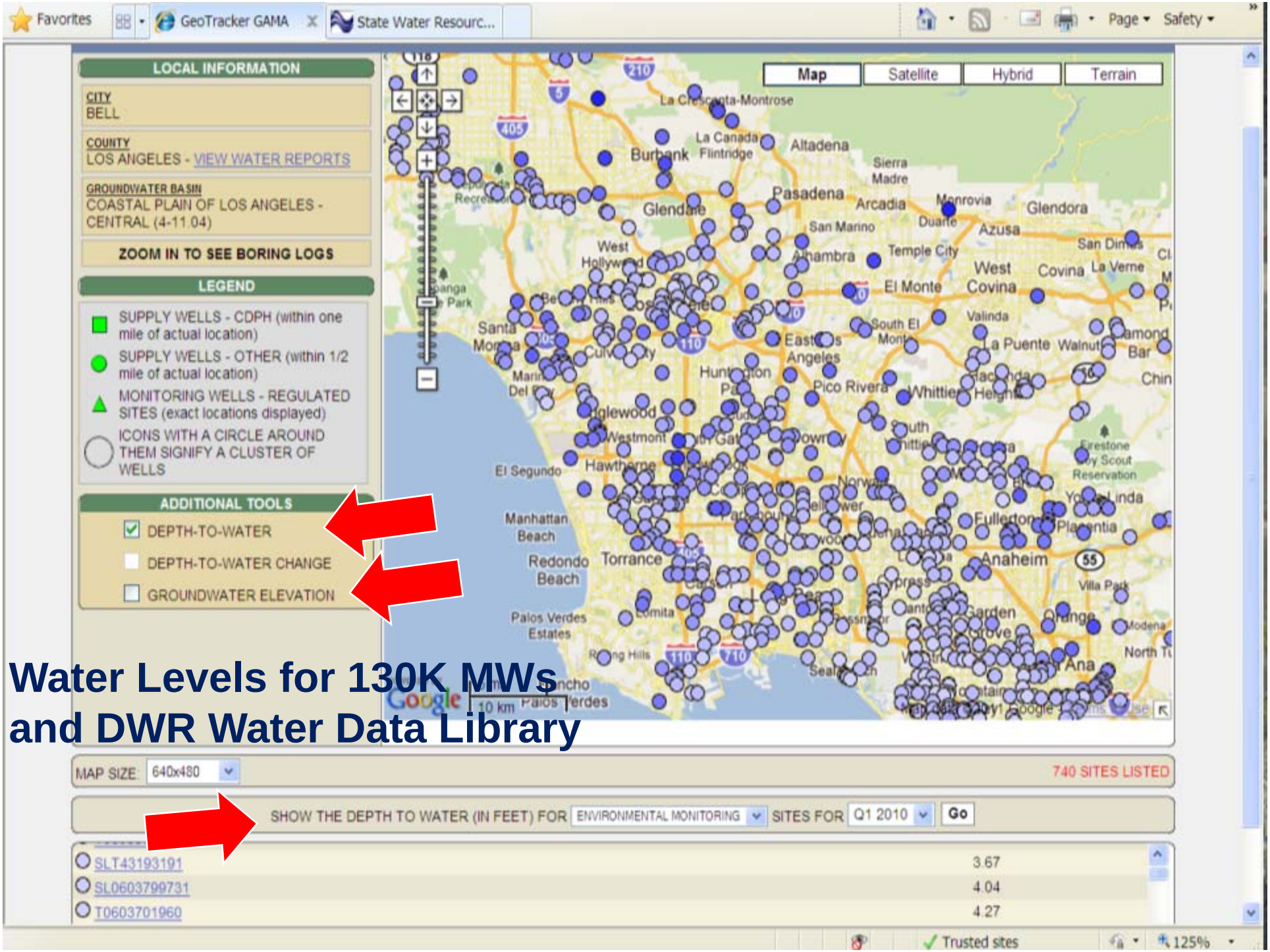
Remarks/Notes: 1) PID Used

Page 1 of 2

Shows Well Logs for over 130 K Monitoring Wells



Water Boards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Page
Safety
LOCAL INFORMATION
CITY
BELL
COUNTY
LOS ANGELES - VIEW WATER REPORTS
GROUNDWATER BASIN
COASTAL PLAIN OF LOS ANGELES - CENTRAL (4-11.04)
ZOOM IN TO SEE BORING LOGS
LEGEND
SUPPLY WELLS - CDPH (within one mile of actual location)
SUPPLY WELLS - OTHER (within 1/2 mile of actual location)
MONITORING WELLS - REGULATED SITES (exact locations displayed)
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ADDITIONAL TOOLS
DEPTH-TO-WATER
DEPTH-TO-WATER CHANGE
GROUNDWATER ELEVATION
Map
Satellite
Hybrid
Terrain
Water Levels for 130K MWs and DWR Water Data Library
MAP SIZE 640x480
740 SITES LISTED
SHOW THE DEPTH TO WATER (IN FEET) FOR ENVIRONMENTAL MONITORING SITES FOR Q1 2010 Go
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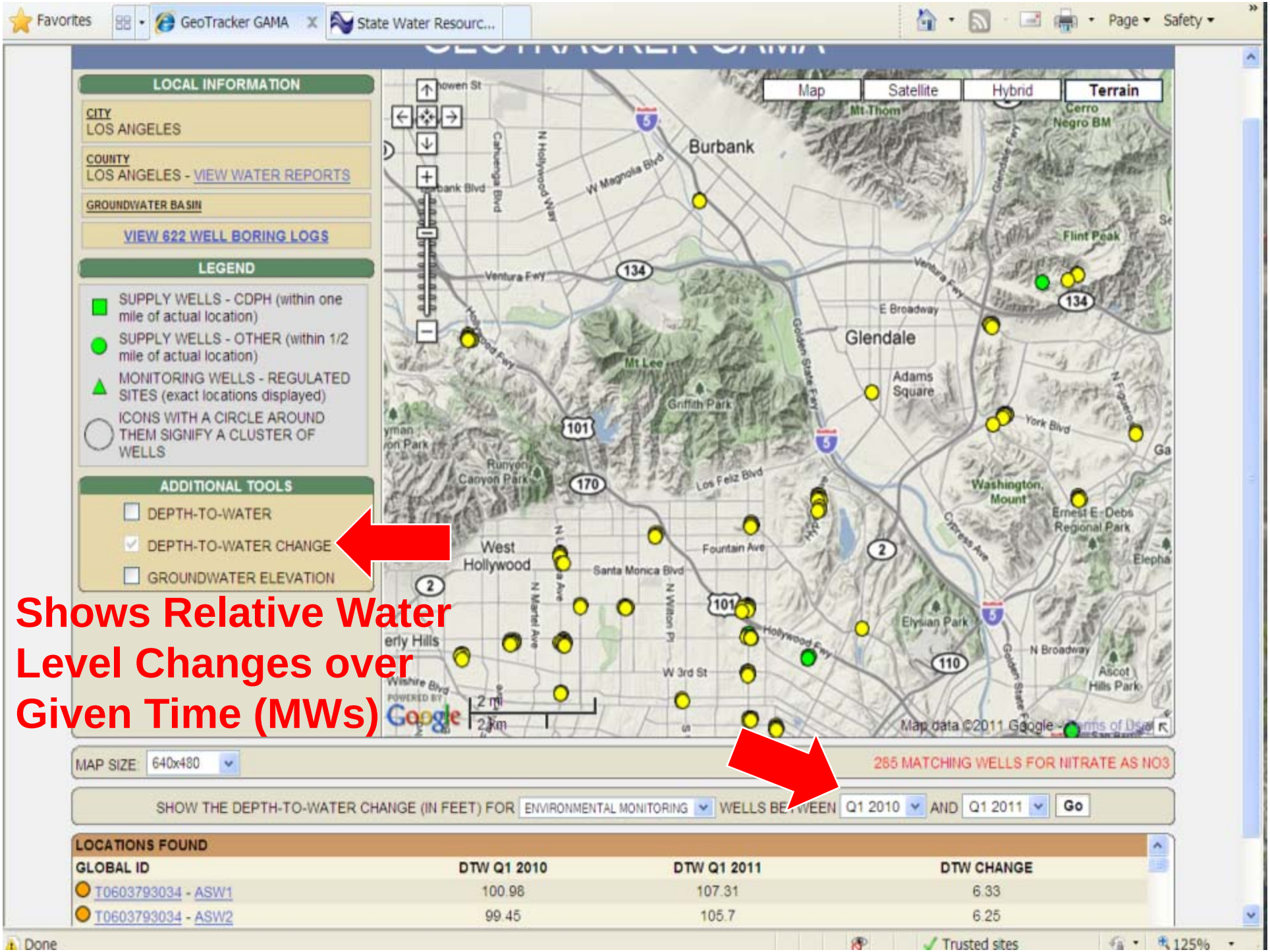
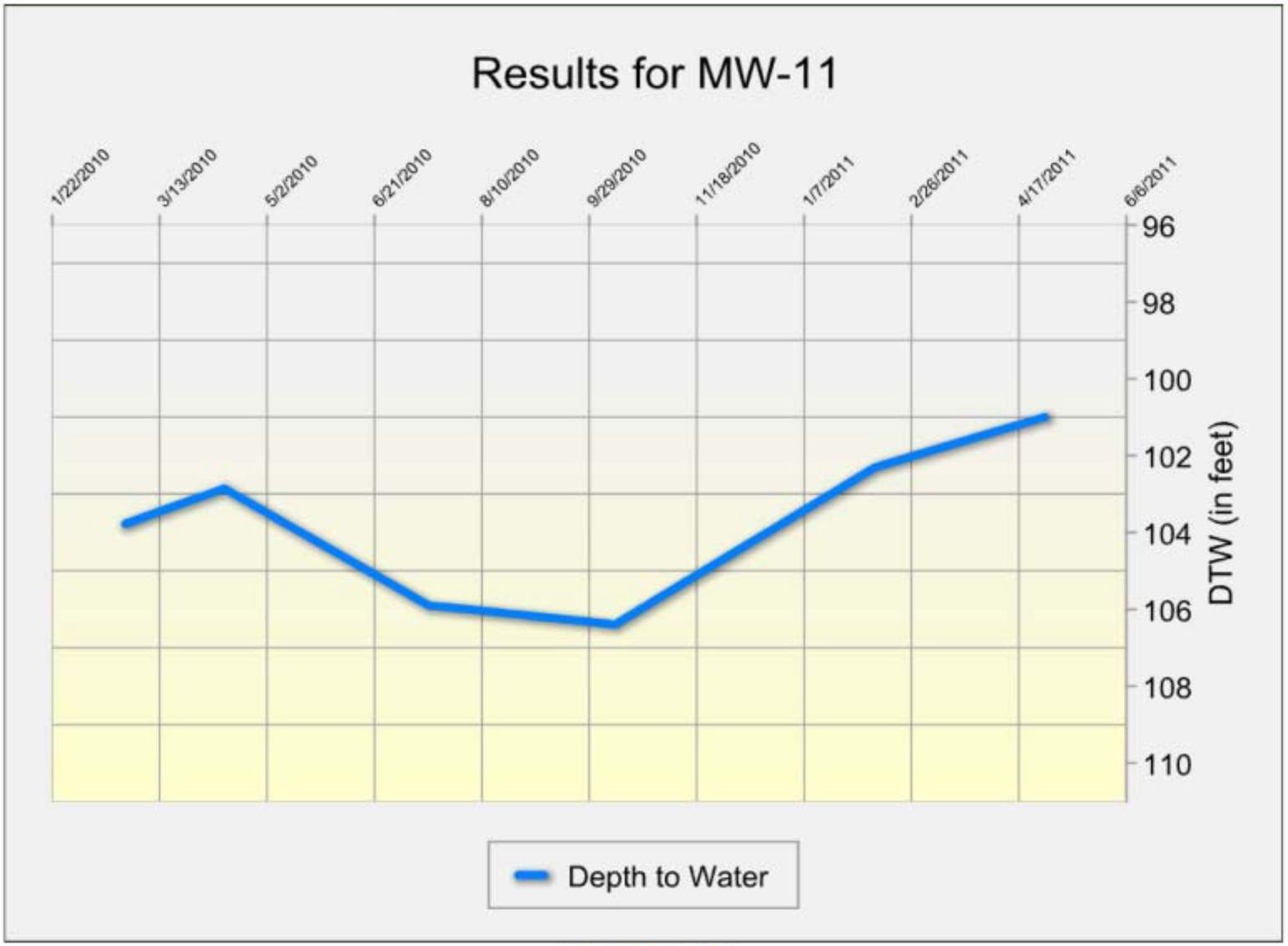
SL0603799731 4.04
T0603701960 4.27
Trusted sites
125%



Shows Relative Water Level Changes over Given Time (MWs)

http://geotracker.waterboards.ca.gov/linechartxy.asp?global_id=T0606700068&locid=MW-11&SHOWDTW= - Windows Internet Explorer pro



VIEW PDF VERSION

Click on a Well and get its Hydrograph (water level history)

Thanks

John Borkovich

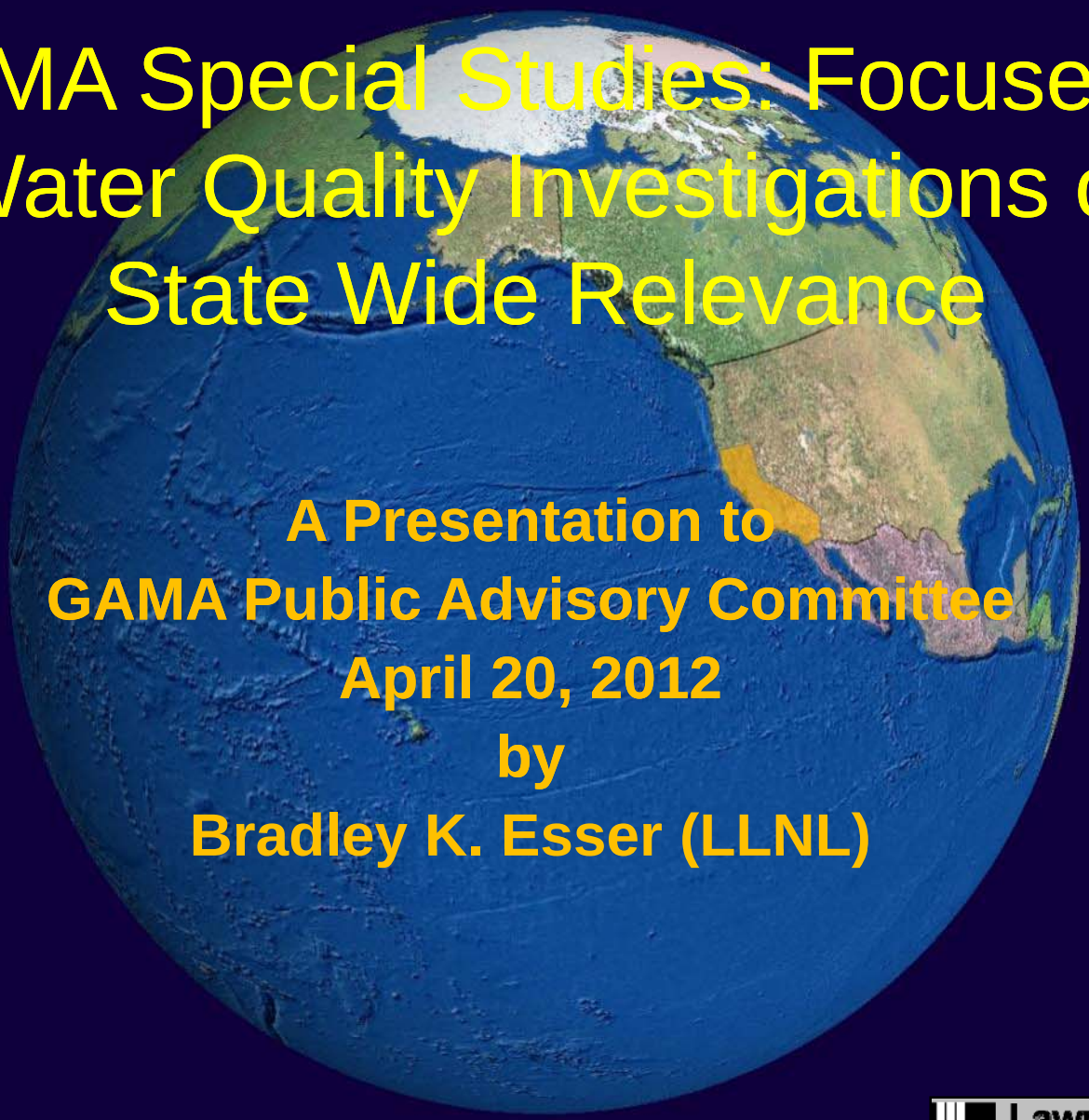
GAMA Program Manager

jborkovich@waterboards.ca.gov

http://geotracker.waterboards.ca.gov/gama

California Water Boards
State Water Resources Control Boards
Regional Water Quality Control Boards

GAMA Special Studies: Focused Water Quality Investigations of State Wide Relevance



A Presentation to
GAMA Public Advisory Committee
April 20, 2012
by
Bradley K. Esser (LLNL)

Water Boards

Lawrence Livermore National Laboratory

Groundwater Ambient Monitoring & Assessment (GAMA): A State Water Board Program

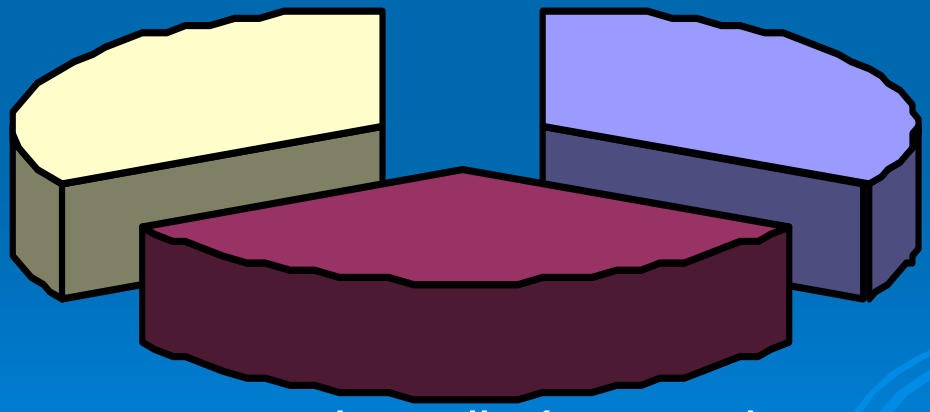
Initial Program

California Aquifer Susceptibility Program (2001-2003)

Current Programs

Priority Basins (USGS)

Special Studies (LLNL)



Domestic Wells (SWRCB)

Lawrence Livermore National Laboratory

Water Boards

USGS science for a changing world

What is a GAMA Special Study?

- **A focused water-quality investigation**
  - Local scale and limited duration
  - Specific water quality issue
- **Of state-wide relevance**
  - Common or emerging water quality issue affecting groundwater used for drinking water
- **Using innovative & scientifically credible methods**
  - Scientifically credible case studies using cutting-edge science
  - Publications in peer-reviewed literature
- **With outreach to the professional community & public**
  - Work with local agencies, well owners & stakeholders
  - Involve & train students

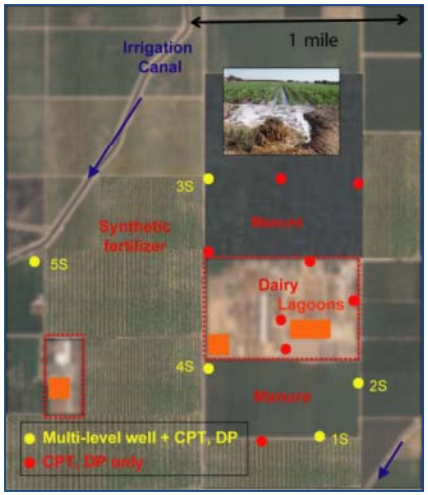
Goal: Science-Informed Policy

A Focused Water Quality Investigation

A single well

Is high nitrate in a city well from orchards or a farm supply yard?

Is high nitrate in a community well affected by agricultural nitrate?



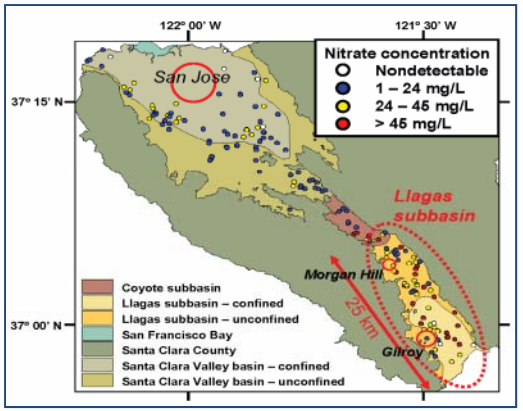
Small dairy farm

Transport & fate of dairy-derived nitrate to underlying aquifer

A managed aquifer recharge operation

How can we trace recharged water without SF6?

Is high arsenic caused by recent recharge operation?



Groundwater basins

Sources of nitrate and impact of nutrient management plans.

Impact of climate change on alpine headwater basins.

Of State-Wide Relevance

- **Nitrate in groundwater – sources, fate and transport**
  - Nitrate impacts from point & non-point sources
    - Basins with nitrate management plans or PSW exceedences (e.g. Llagas & Salinas)
    - Central Valley dairies & Tulare County domestic wells
    - Municipal wells (e.g. Ripon)
  - Development & demonstration of source attribution for nitrate
    - Isotopic composition and co-contaminants

- **Wastewater impacts on groundwater**
  - Development of new tracers of wastewater in groundwater
    - Pharmaceuticals (carbamazepine); artificial sweeteners; and boron isotopes
  - Impact of septic discharge and recycled municipal wastewater

- **Groundwater recharge and transport**
  - Development of new age tracers for groundwater recharge
    - Introduced tracers (to replace SF6) and natural tracers
  - Water quality changes during groundwater recharge
  - Impact of climate change on recharge in headwater basins
  - Identification of recharge area and surface/groundwater interaction

Using Innovative Approaches

Groundwater Age Dating

- Delineate groundwater recharge, flow & contaminant transport
- Proxy for aquifer susceptibility
- Tool for assessment of management practices

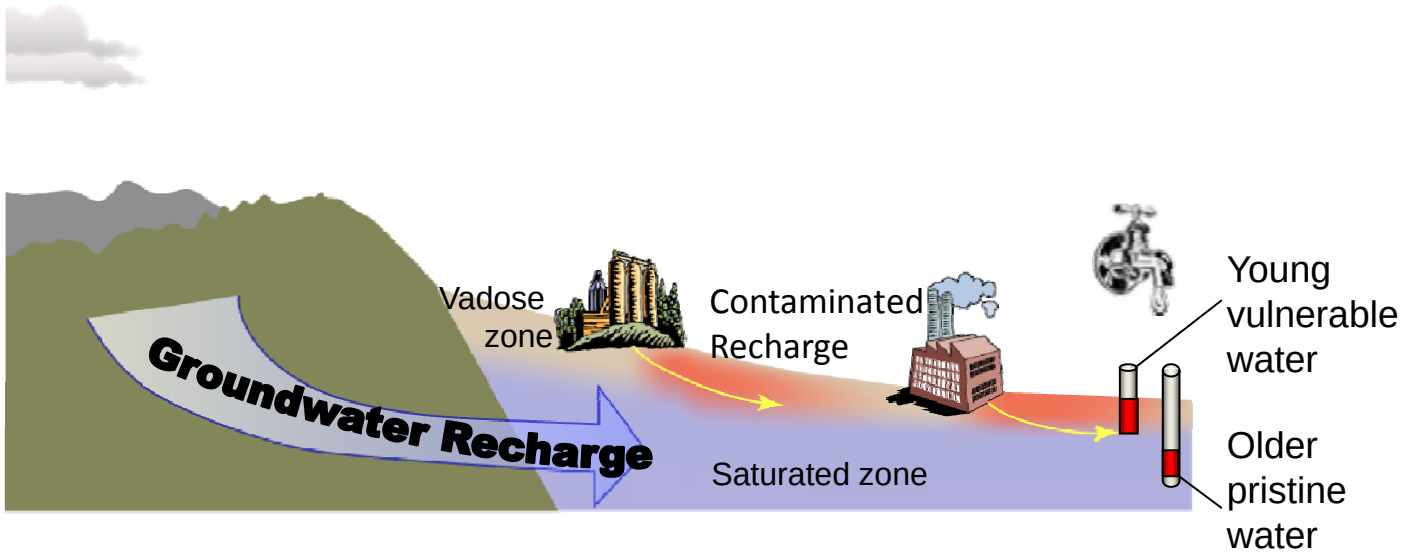
Isotope & Dissolved Gas Geochemistry

- Water source (stable isotopes of water)
- Water “tagging” (introduced gas tracers)
- Contaminant source (isotopic composition)
- Contaminant degradation (e.g. denitrification)

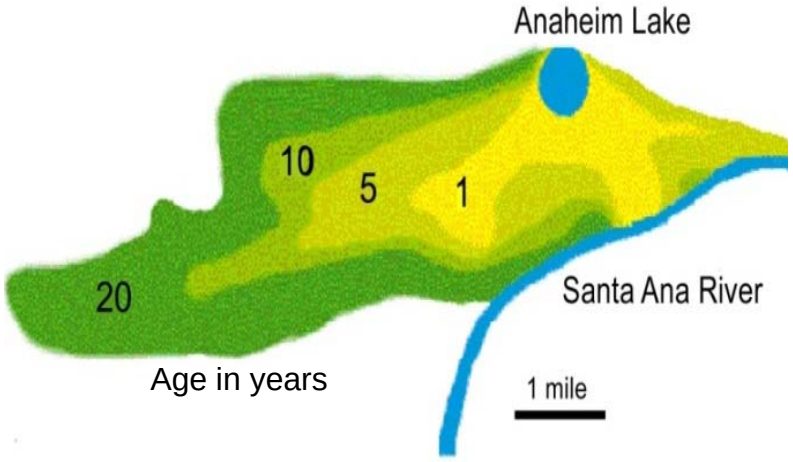
Industrial VOCs & Emerging Contaminants

- Proxy for aquifer susceptibility
- Contaminant source tracers
- Emerging contaminant transport & degradation in subsurface

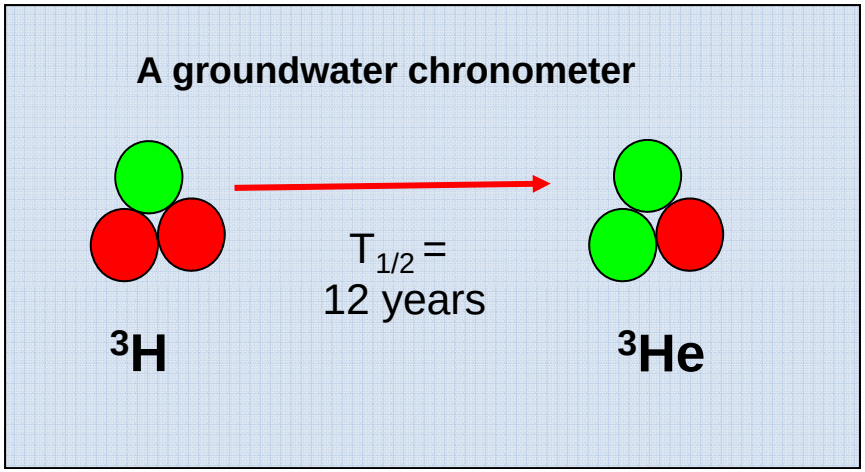
Groundwater age tracers act as proxies for groundwater susceptibility & track groundwater flow



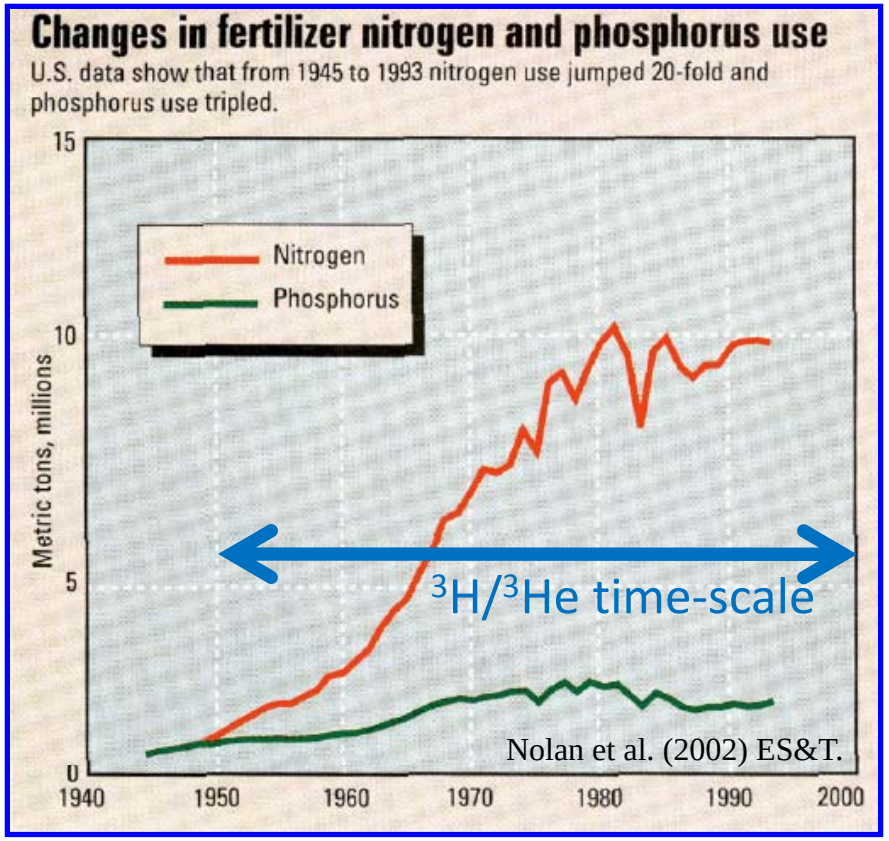
- **Groundwater age by Tritium/Helium ($^3H/^3He$)**
  - To determine mean age
- **Low Level VOCs**
  - To detect recent recharge
- **Stable isotopic composition of water**
  - To distinguish sources of water



The tritium/helium ($^3H/^3H$) method measures groundwater age on an appropriate time-scale for water resource studies



- *The method is useful over the last 50 years with an uncertainty of 1-2 years.*
- *Tritium has both natural and anthropogenic sources in the atmosphere.*



Most public-drinking water wells in California produce water with measurable tritium.

Tritium-Helium ($^3H/^3He$) age dating and noble gas geochemistry is a signature LLNL capability

Noble Gas Mass Spectrometry

The detection level for ^3He is one zeptomole (600 atoms). LLNL routinely measures 10^5 atoms of ^3He.

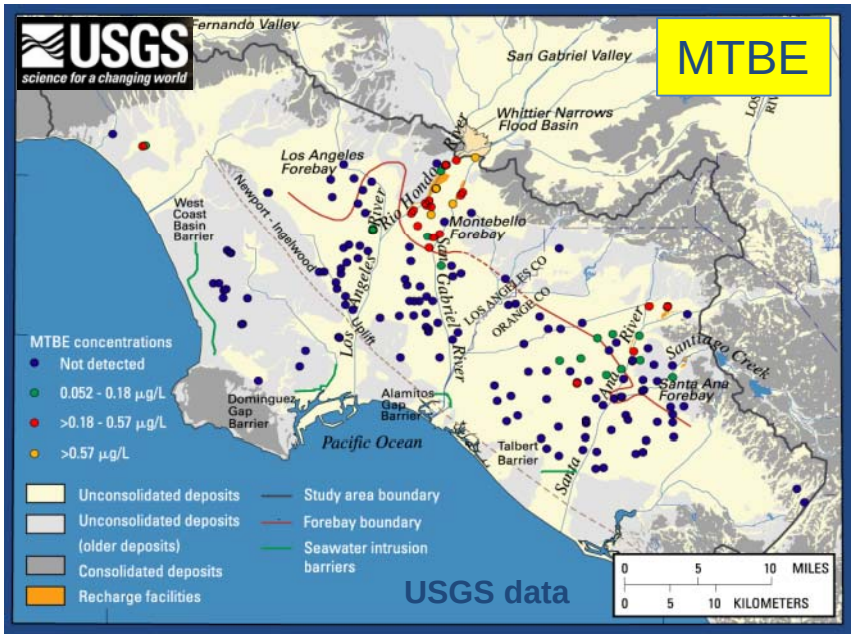
LLNL is one of two high-throughput noble gas mass spectrometry labs in the country

- 500-1,000 samples per year
- ^3He accumulation for ^3H determination

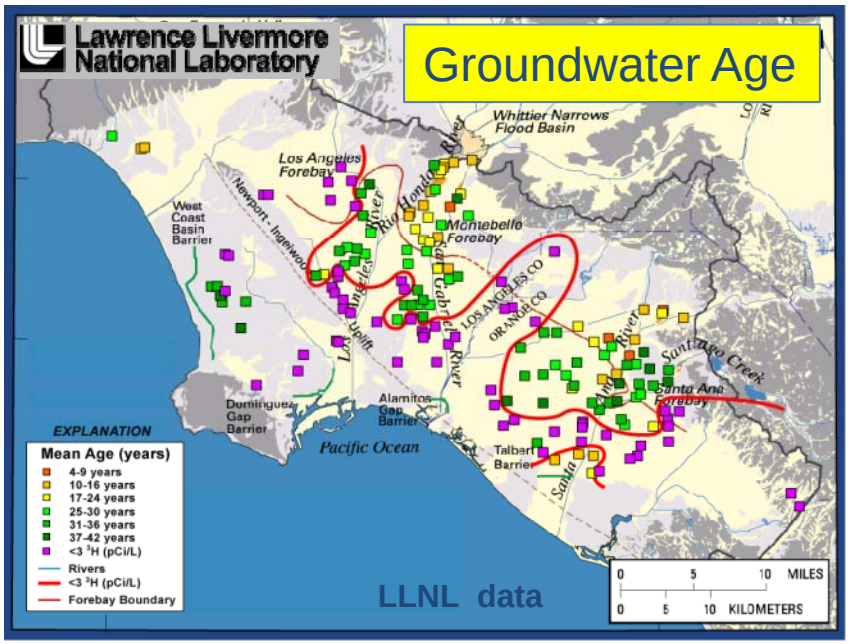
Over the past 15 years, LLNL has made age-dating accessible to water resource managers

GAMA validated using groundwater age as a proxy for susceptibility assessment in the California Aquifer Susceptibility Project

In the Los Angeles Basin, old groundwaters are devoid of contamination, despite the ubiquity of leaking underground fuel tanks and their proximity to production wells



Shelton, J.L., Burow, K.R., Belitz, K., Dubrovsky, N.M., Land, M., Gronberg, J., 2001. Low-Level Volatile Organic Compounds in Active Public Supply Wells as Ground-Water Tracers in the Los Angeles Physiographic Basin, California, 2000. USGS Water-Resources Investigations Report 01-4188, p. 29.

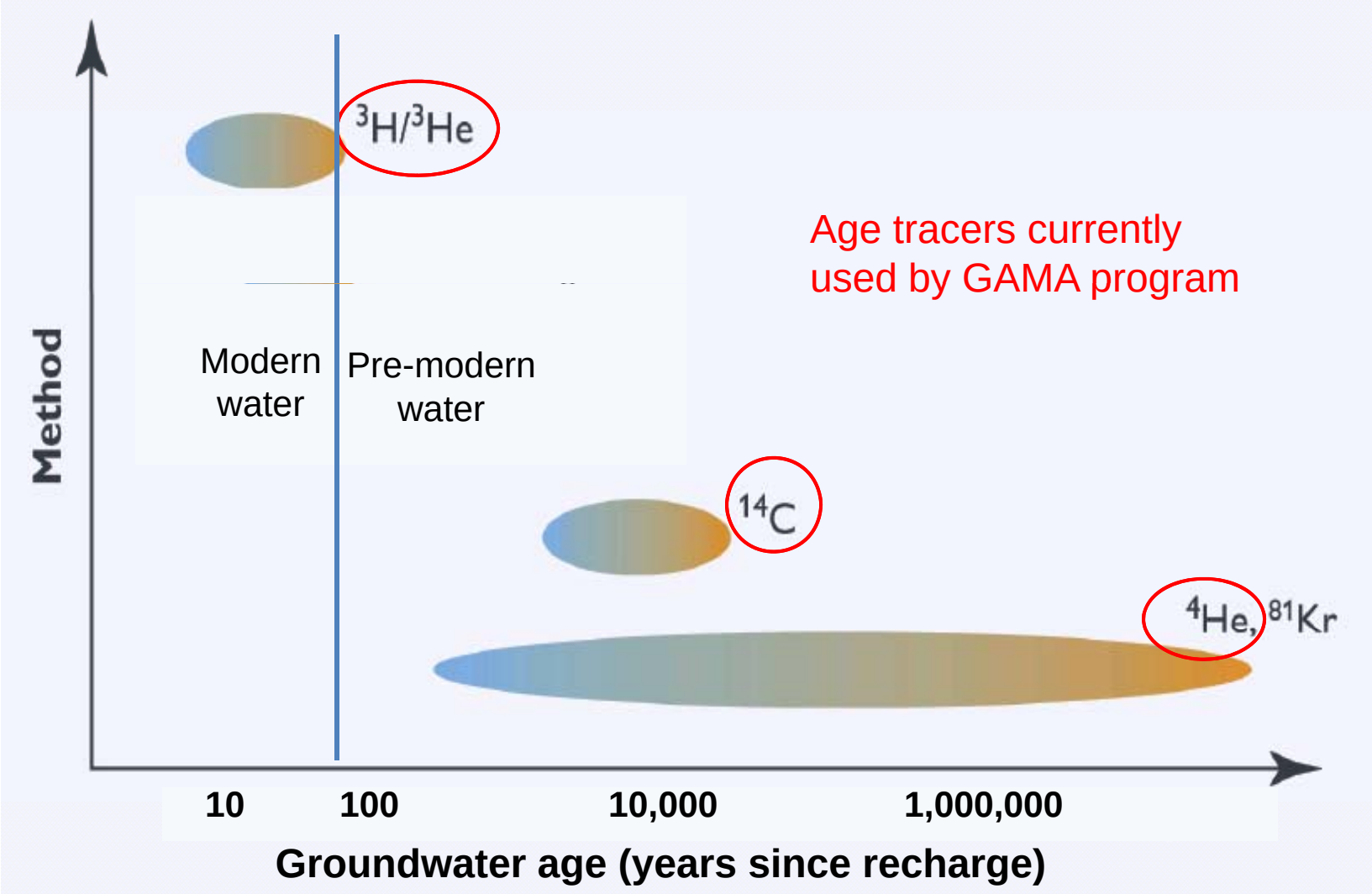


Hudson, G.B., Moran, J.E., Eaton, G.F., 2002. Interpretation of Tritium-3Helium Groundwater Ages and Associated Dissolved Noble Gas Results from Public Water Supply Wells in the Los Angeles Physiographic Basin. LLNL, UCRL-AR-151447

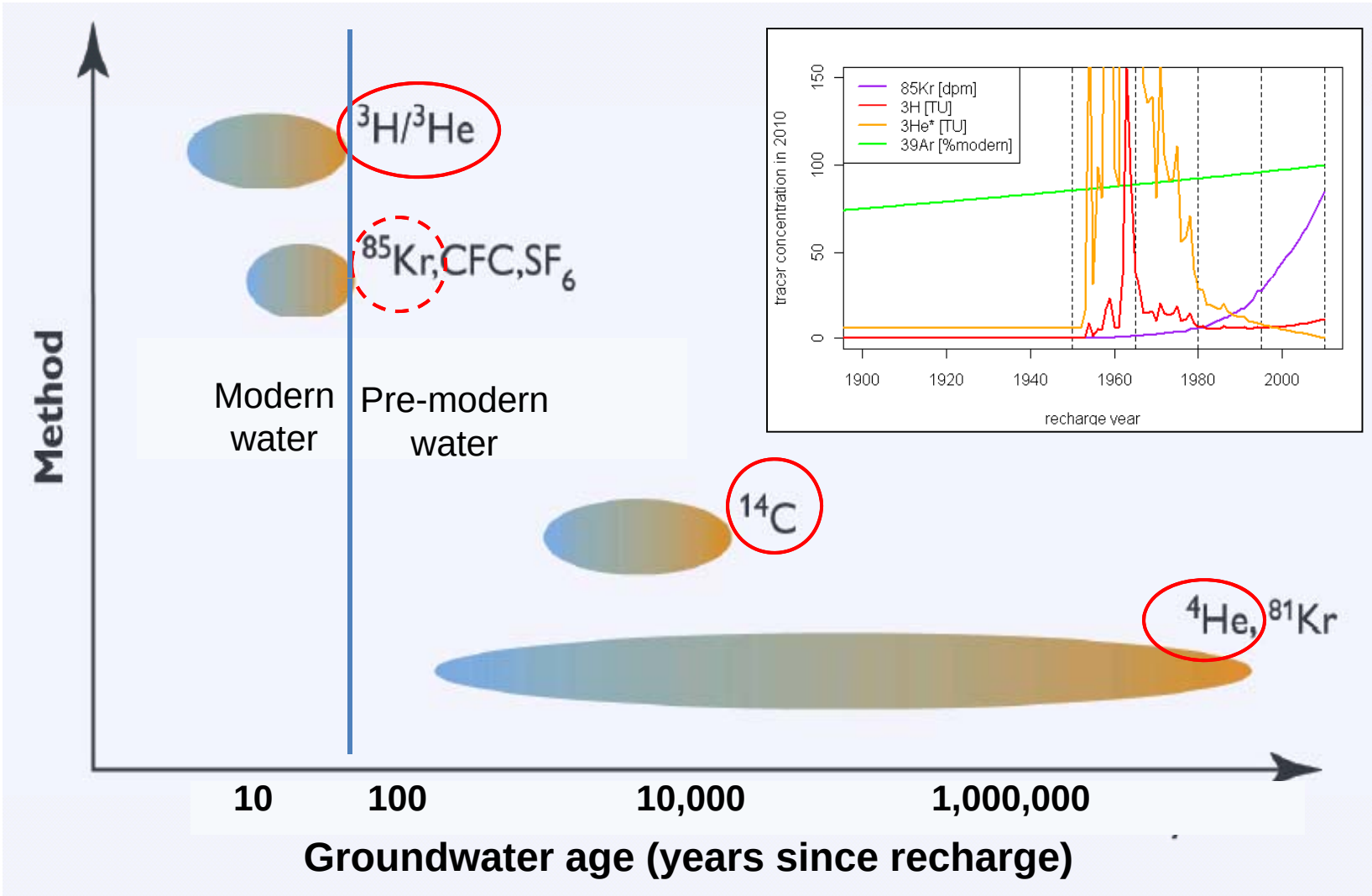
Significant findings of the California Aquifer Susceptibility project

- Coastal aquifers are well-protected from surface contamination
- Central Valley aquifers are not well-protected from surface contamination

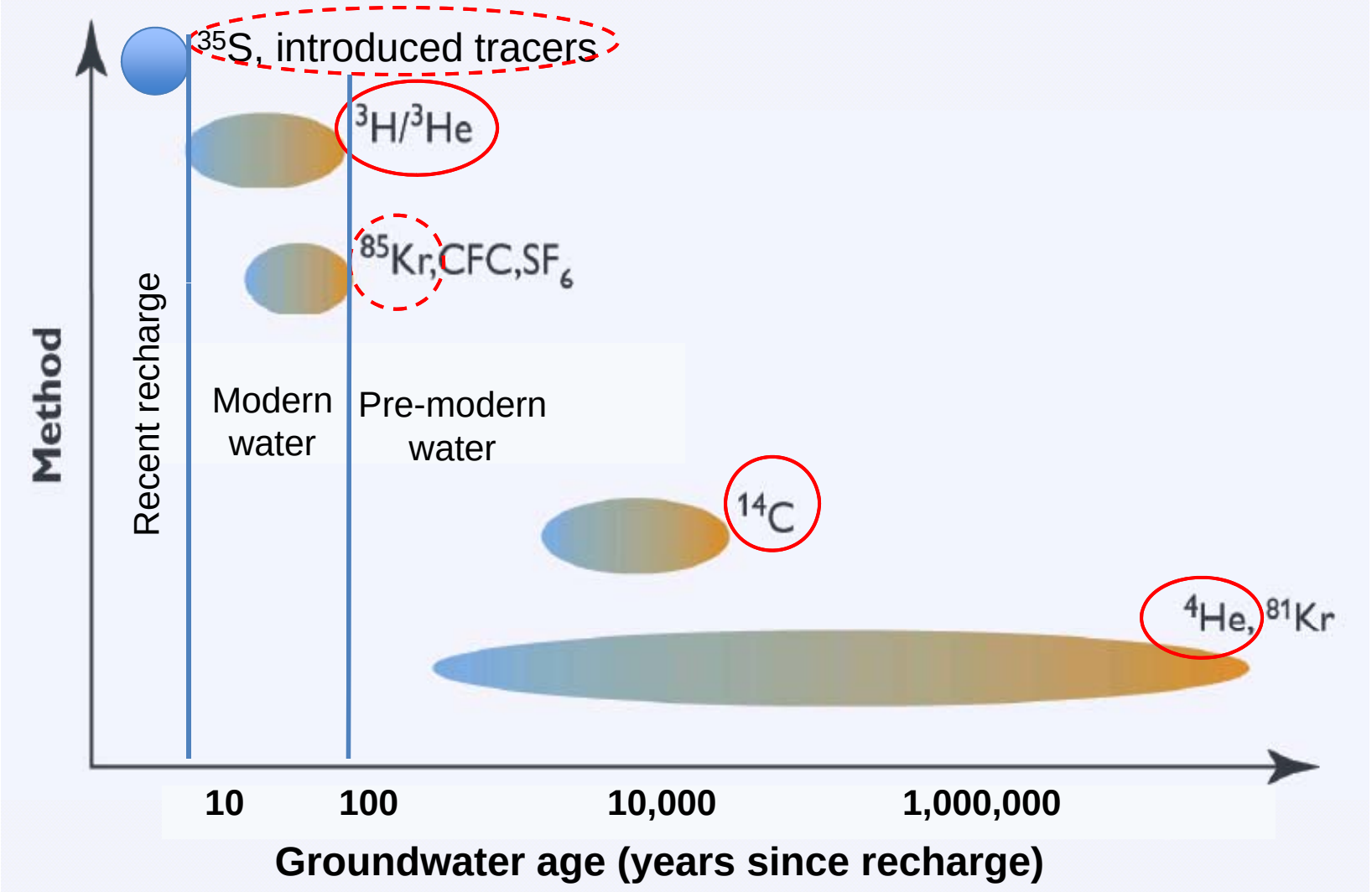
The GAMA program currently uses multiple age tracers: Tritium/helium-3; radiocarbon; and radiogenic helium



GAMA Special Studies is also developing krypton-85 to complement tritium/helium-3



…and sulfur-35 and introduced noble gases to trace recent recharge (< 2 year old water)



Characterizing managed aquifer recharge requires tracing groundwater transport on short time scales

Treated wastewater used for groundwater recharge requires a subsurface residence time of months to years.

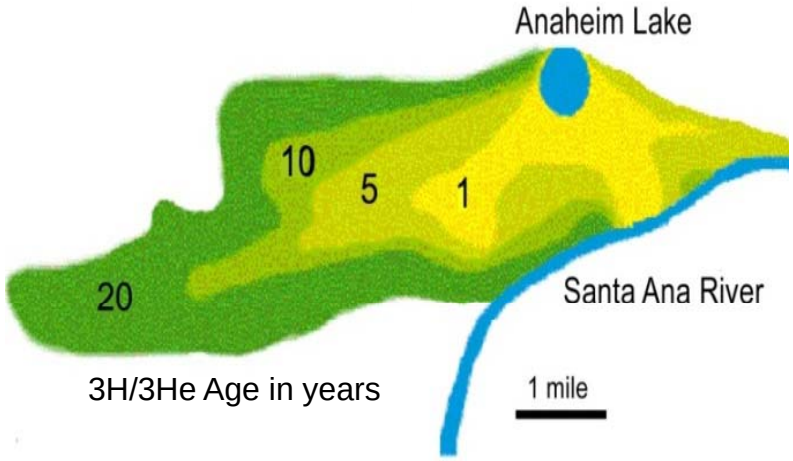
Method	General accuracy	General level of effort	Safety factor	Retention time (months)
Formula (Darcy's)	Poor	Some info on aquifer	4.0	24
3-D model	Fair	Lots of info on aquifer	2.0	12
Intrinsic tracer	Better	Sample existing tracers	1.5	9
Added tracer	Desired	Track added tracer	1.0	6

California Department of Public Health, 2008. Draft Groundwater Recharge Reuse Regulations (Title 22, California Code of Regulations; Division 4,. Environmental Health; Chapter 3. Recycling Criteria).

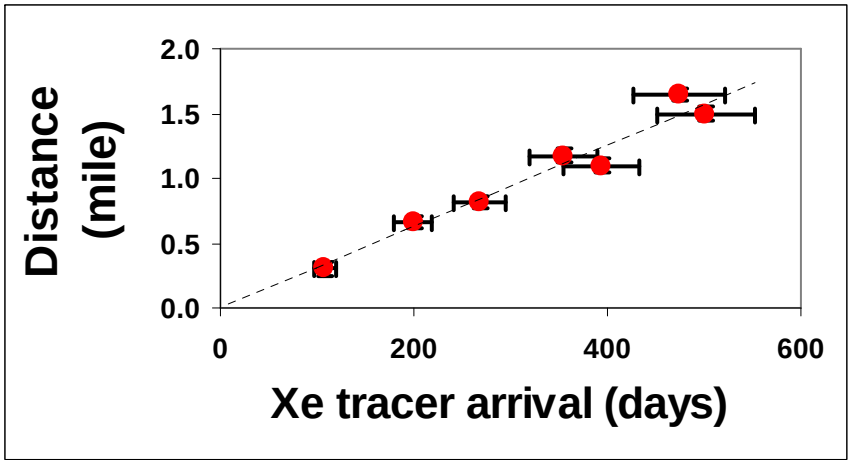
GAMA Special Studies is developing new age tracers for managed aquifer recharge:

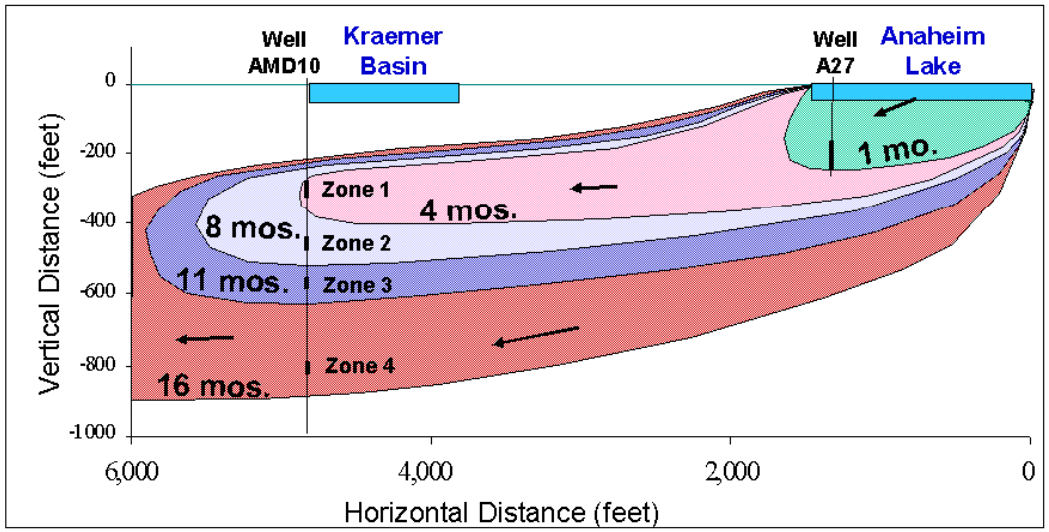
- **Introduced:** Noble gas tracers to replace SF6
- **Natural:** Sulfur-35 (for water less than two years old)

Introduced noble gas isotopic tracers can be used for short time scales (OCWD and LLNL)



3H/3He Age in years

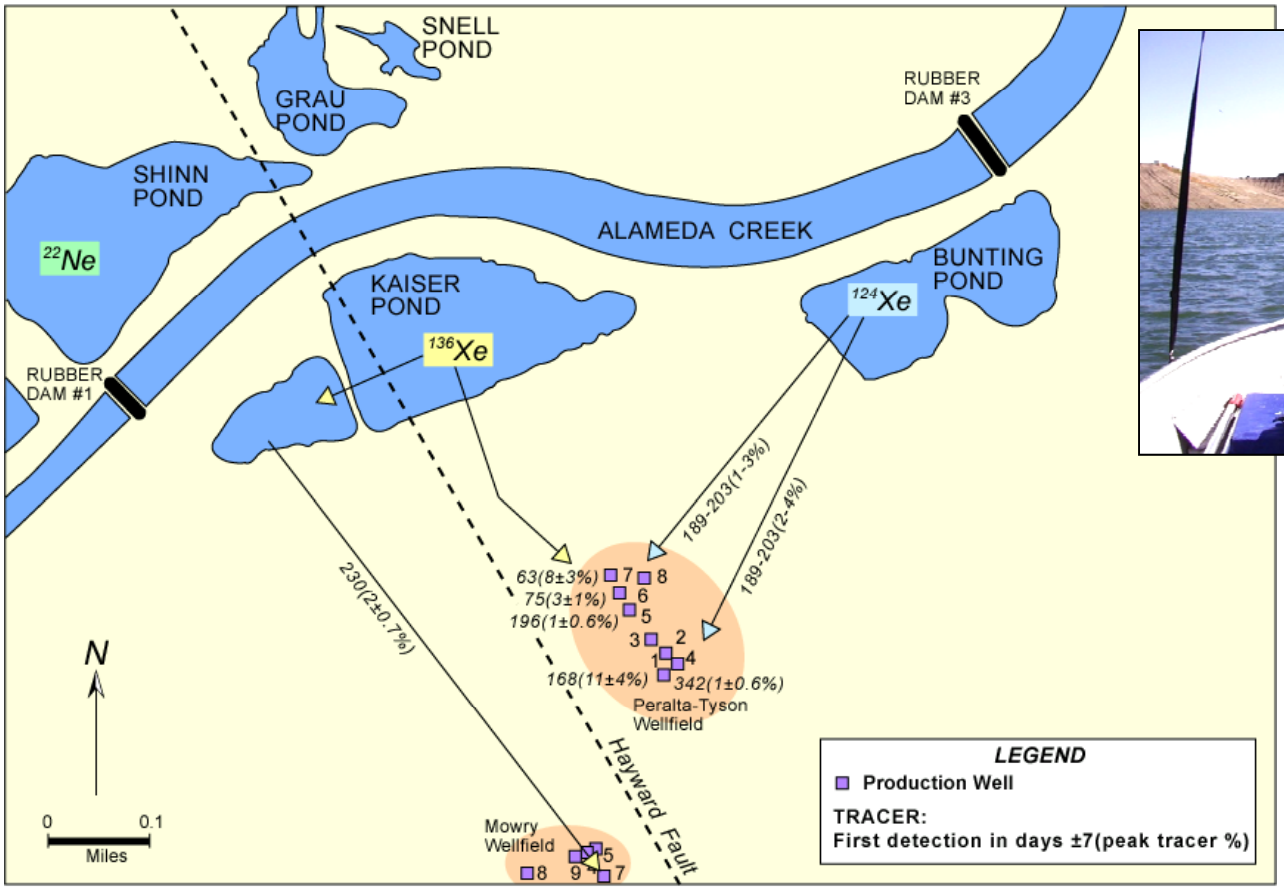




Clark, J.F., Hudson, G.B., Davisson, M.L., Woodside, G., Herndon, R., 2004. Geochemical imaging of flow near an artificial recharge facility, Orange County, California. Ground Water 42, 167-174.

Maxwell, R.M., Welty, C., Tompson, A.F.B., 2004. Streamline-based simulation of virus transport resulting from long term artificial recharge in a heterogeneous aquifer (vol 26, pg 1075, 2003). Advances in Water Resources 27, 857-857.

Introduced noble gas tracers can be used to constrain recharge and flow in complex settings (AWWARF)



This approach works, and is an alternative to SF6

The challenge is making it cost-effective and widely accessible

Moran, J.E., Halliwell, M.S., 2003. Characterizing Groundwater Recharge: A Comprehensive Isotopic Approach. American Water Works Association Research Foundation Report 90941, p. 199.

GAMA Special Studies developed an inexpensive benchtop instrument with high throughput for noble gas analysis: NG-MIMS

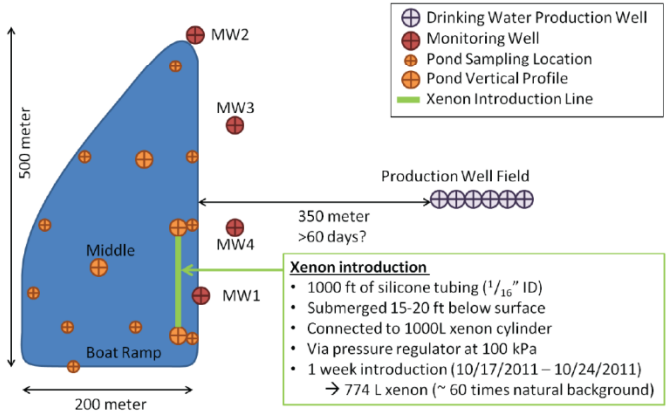


Figure I.6. Map of the tracer study site.

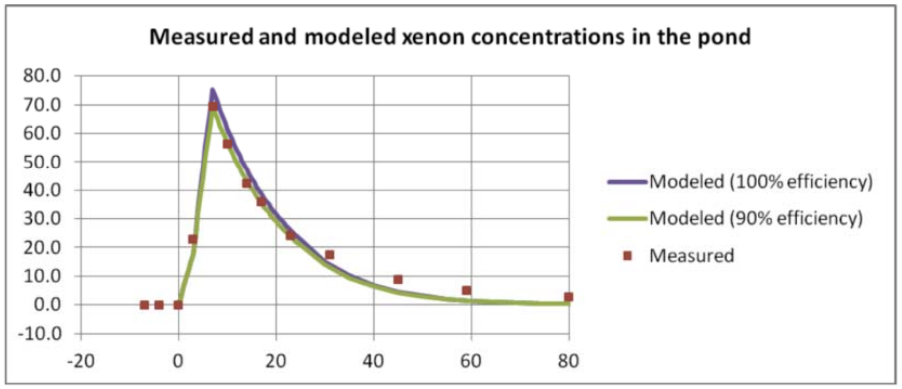


Figure I.11: Measured and modeled concentrations of xenon in the pond.

A current GAMA Special Study

Noble gas membrane inlet mass spectrometry (NG-MIMS)

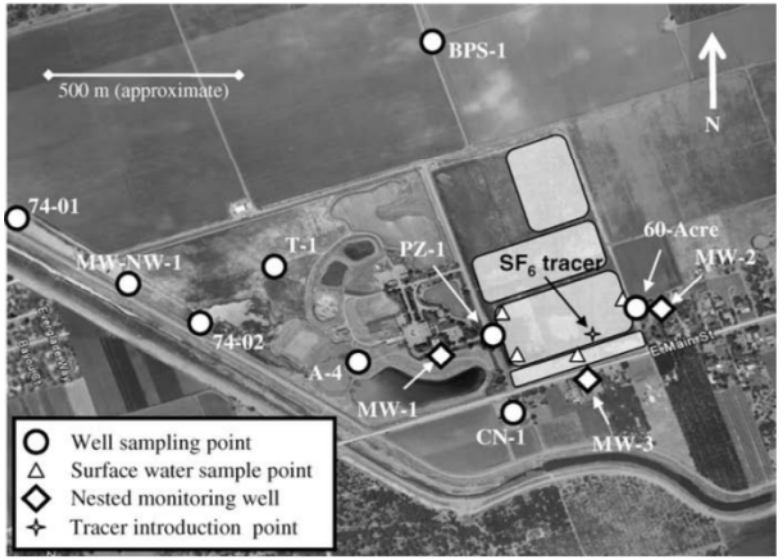
Aquifer Storage and Recovery Projects are vital for California's water supply

Investigated a groundwater banking project in California's Central Valley:

- Introduced SF_6 tracer
- Tritium/helium-3 age dating
- Geochemical modeling

Key Findings:

- **Identification of suitable areas**
- **Travel times** for banked water
- **Water quality changes in** banked high-quality water
- **Transport of emerging contaminants** associated with groundwater recharge

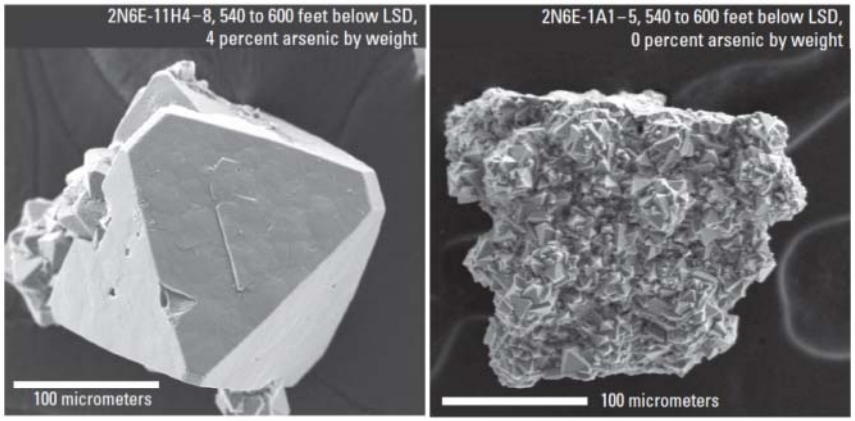


A key finding was that the highest groundwater arsenic concentrations occurred in the most recently recharged water.

Water quality can be affected by groundwater banking under specific recharge conditions

Arsenic release is controlled by local geology and the composition of the recharge water

- Arsenic is rapidly released from naturally occurring iron oxides in the aquifer to recharge waters, which have higher pH than ambient water



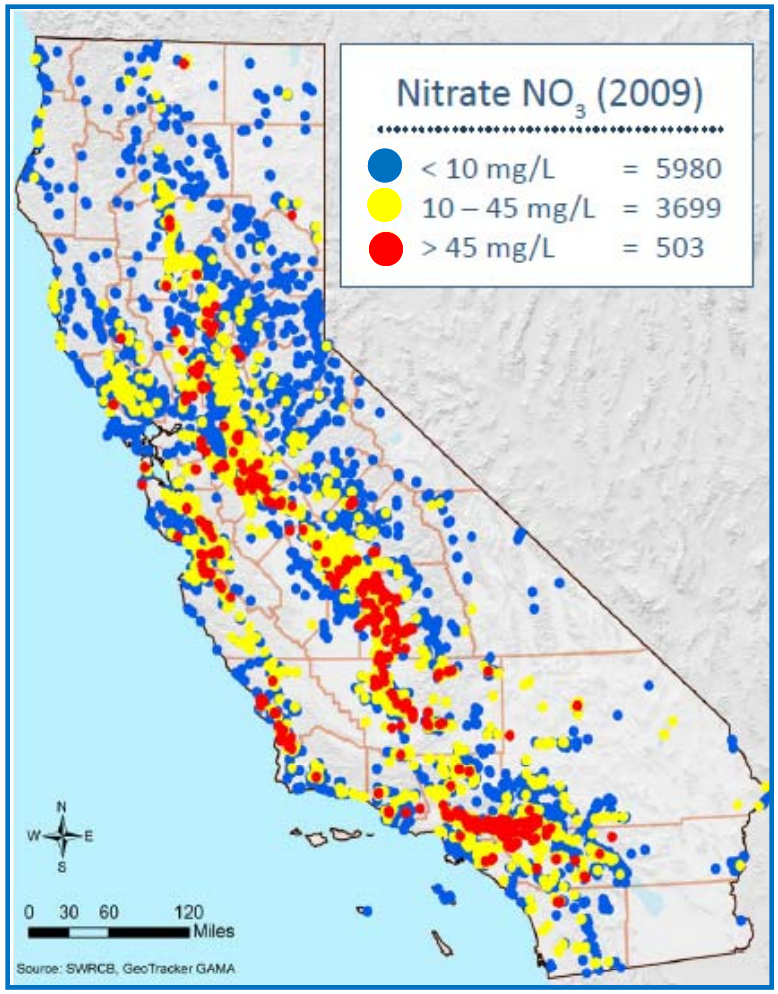
Izbicki et al. 2008. USGS OFR-2008-1272.

Specific recommendations can be made on recharge management

- Low-oxygen conditions during recharge will result in dissolution of ferric oxides, and release of much higher concentrations of arsenic.
- High oxygen demand in recharging water should be avoided.
- The current operation is sustainable with monitoring

McNab WW, Singleton MJ, Moran JE, and Esser BK, 2009. Ion exchange and trace element surface complexation reactions associated with applied recharge of low-TDS water in the San Joaquin Valley, California. *Applied Geochemistry* ***24, 129-137.***

Nitrate contamination is a water-quality issue of state-wide relevance

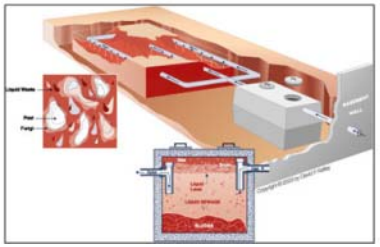


Animal Manure

Fertilized Agriculture

http://www.scinetcc/cgi-bin/picpost/posts/346.shtml

Septic Systems



Organic Soil N

Sources of nitrate are often co-located and non-point source.

Nitrate-contaminated groundwater: Distinguishing sources

Shallow groundwater is contaminated by nitrate

- Deeper groundwater is primary source of drinking water

What is the source & age of the contamination?

- High-density septic systems?
- Legacy or current agricultural practices?

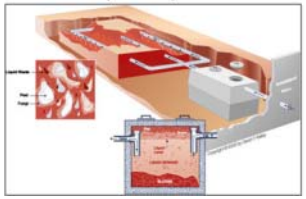
An isotopic approach: Distinguishing synthetic fertilizers, manure, and wastewater

The dual-isotope approach can distinguish synthetic fertilizers from organic N sources, but cannot distinguish manure from septic sources

Animal Manure

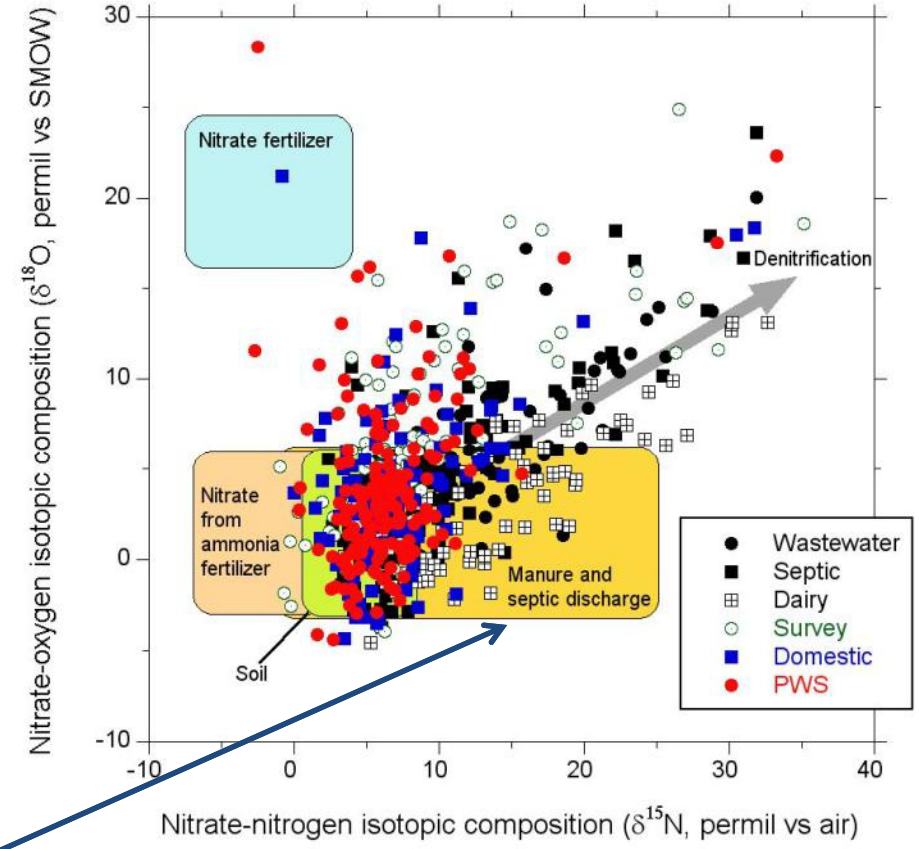
Fertilized Agriculture

Septic Systems



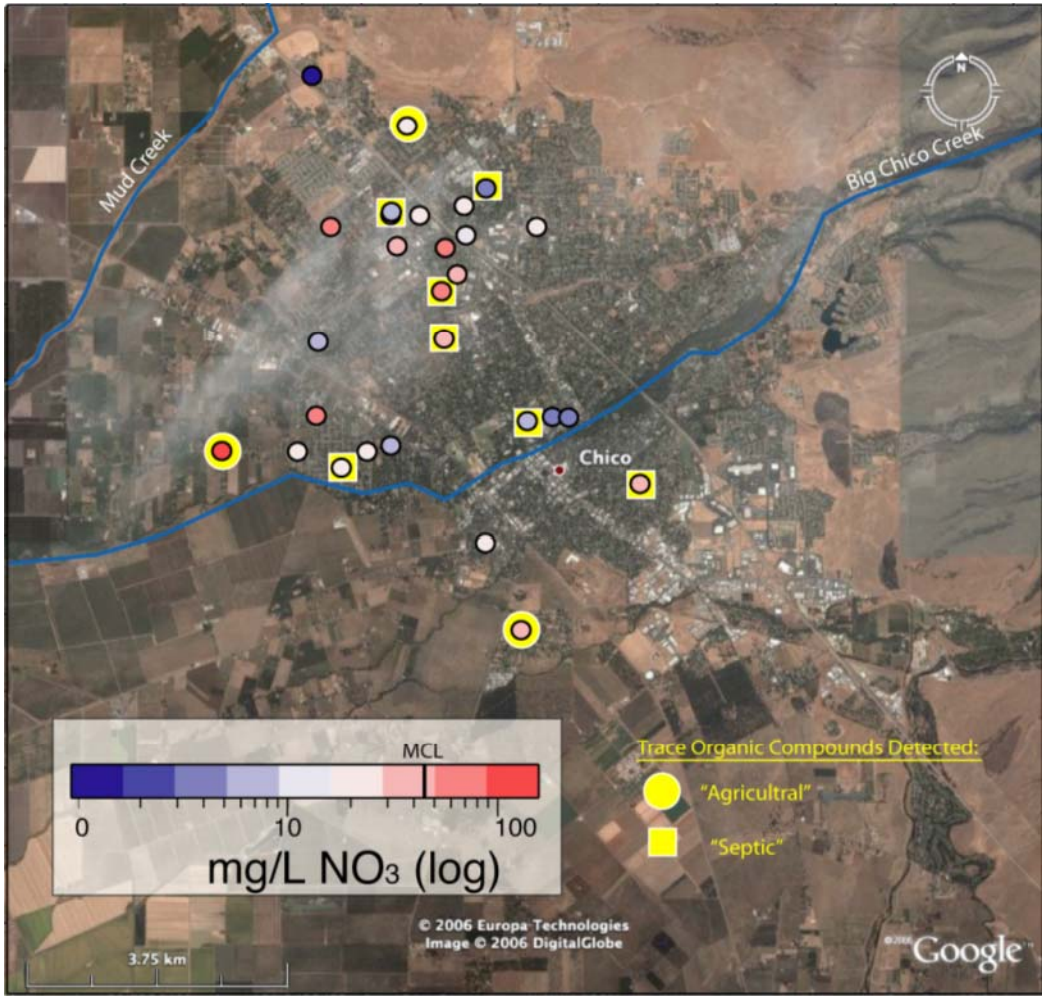
Organic Soil N

Nitrogen & oxygen isotopic composition of nitrate in GAMA Special Study groundwaters



Nitrate from Chico falls mostly in the "manure and septic discharge" field. GAMA Special Studies is exploring the use of boron isotopic composition to distinguish manure from septic sources of nitrate.

Trace organics can be used to distinguish between septic & agricultural sources of nitrate



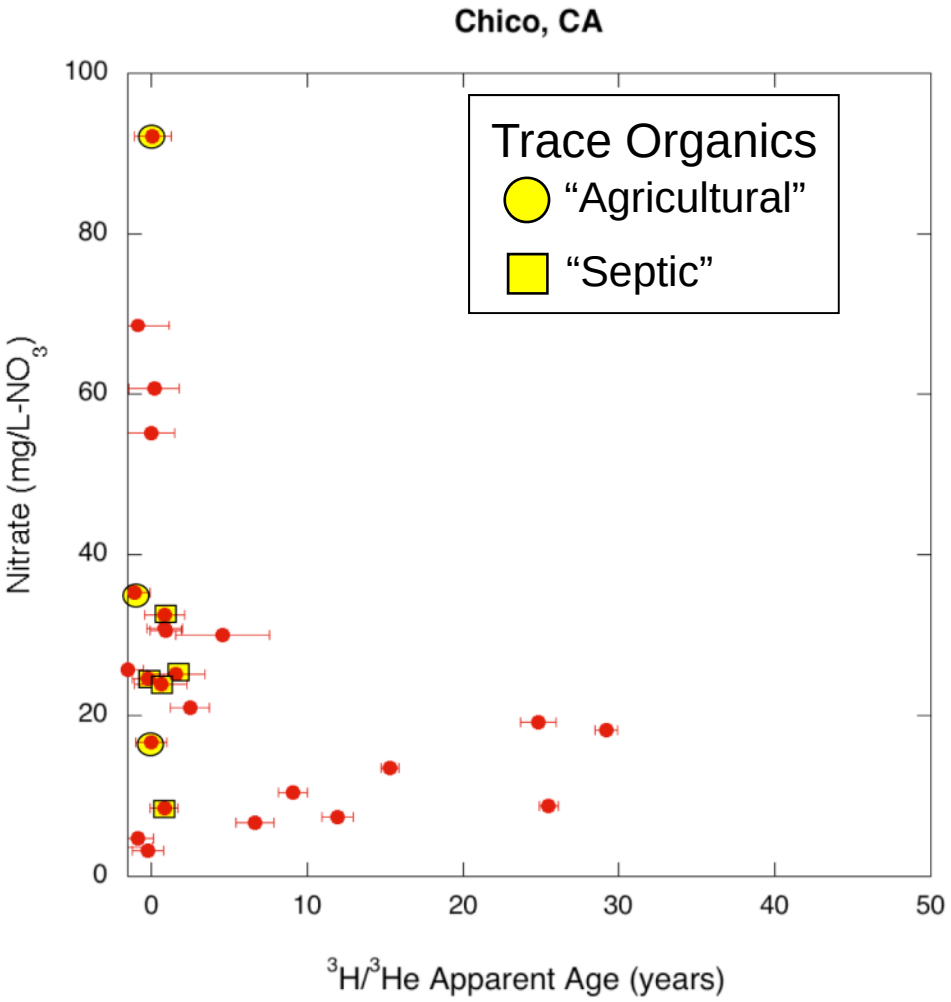
Trace Organics
- "Agricultural"
- "Septic"

"Agricultural "
- Herbicides (1)
- Herbicide degradates (2)

"Septic"
- DEET (1)
- Caffeine (2)
- Surfactants (1)
- Carbamazepine (4)

Current & future studies:
boron isotopes, artificial sweeteners

Tritium/helium-3 age dating can be used to distinguish between recent and past sources of nitrate



- **Nitrate contamination in Chico**
  - High-density septic system discharge is a source of nitrate within the city limits
  - Manure from agricultural operations is a source of nitrate on the periphery of the city
  - Nitrate contamination is ongoing and associated with current practices

We used a similar approach to distinguish nitrate sources in the Livermore-Amador Basin:

The International Association of GeoChemistry selected the paper – "Moore et al. (2006) *Sources of Groundwater Nitrate Revealed Using Residence Time and Isotope Methods*" -- as the year's most significant paper published in *Applied Geochemistry*, the IAGC's monthly scientific journal.

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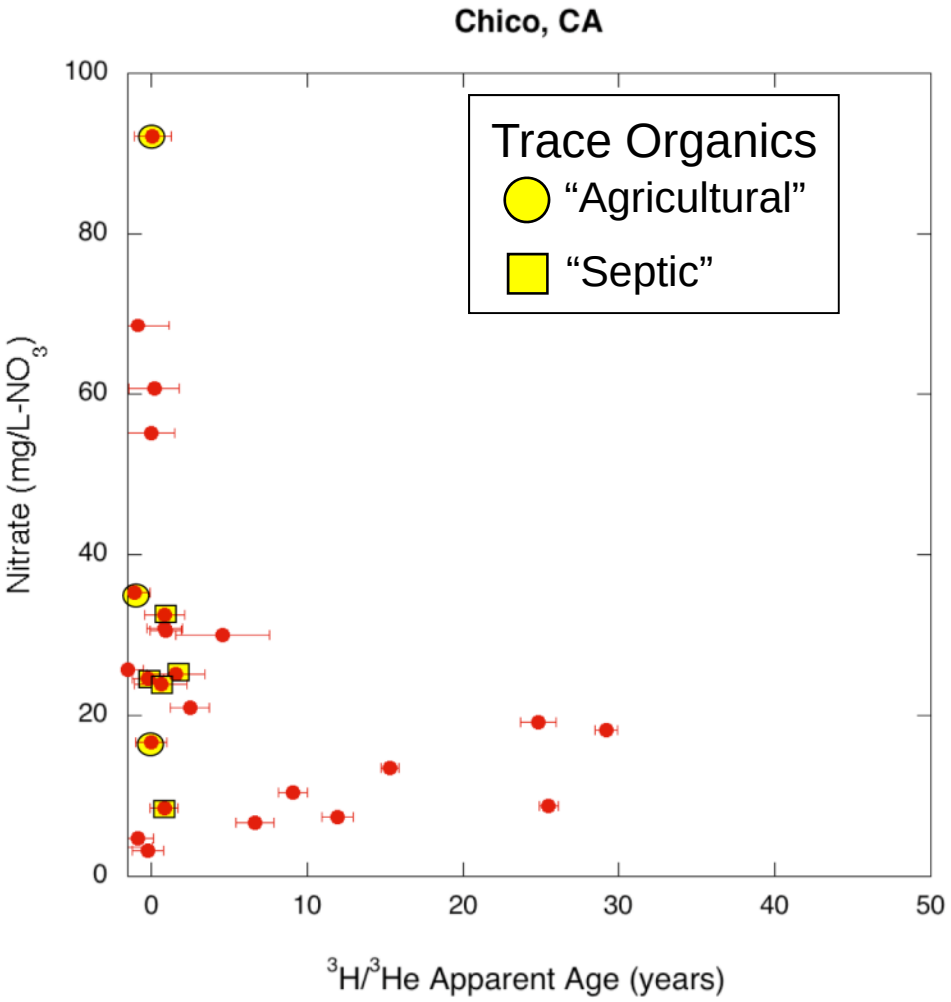

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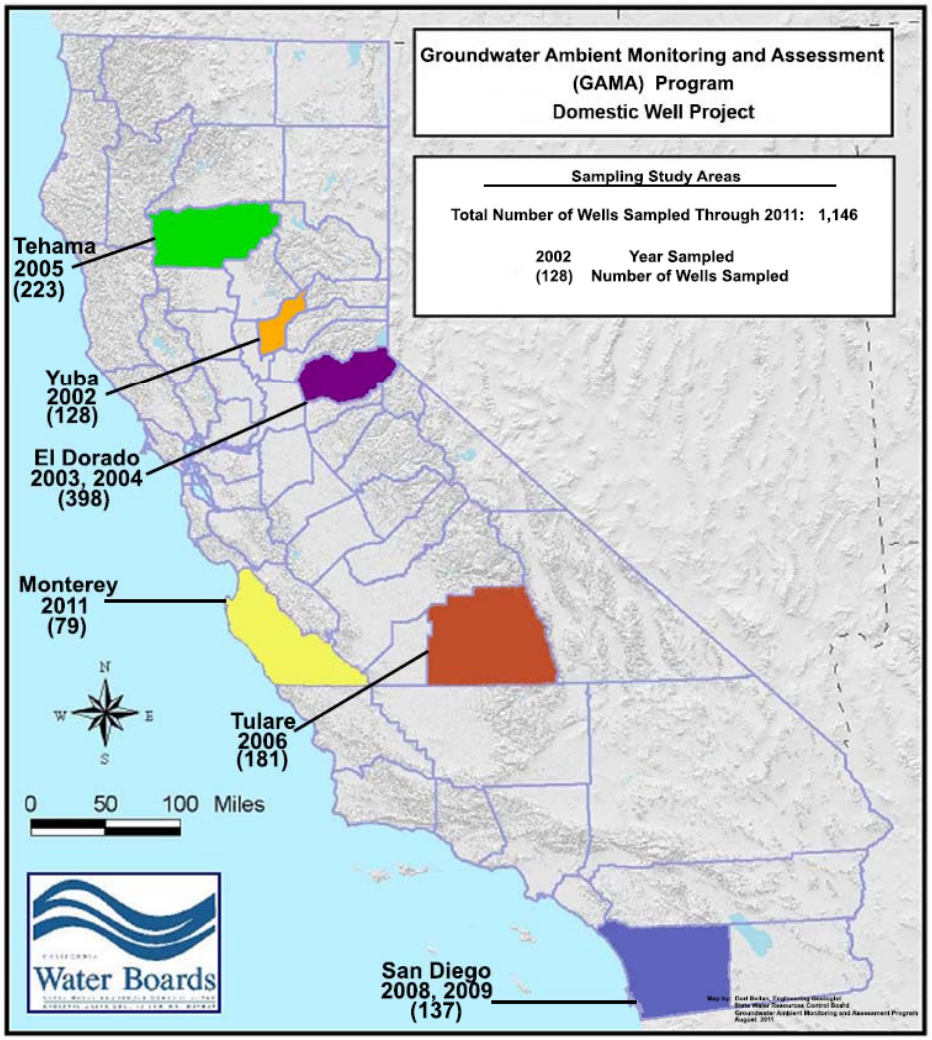
LLNL also provides support to the GAMA Domestic Well Project with isotopic analyses to constrain water & contaminant sources



- **LLNL analyses**
  - Isotopic composition of water
  - Isotopic composition of nitrate
  - Isotopic composition of boron
- **Tulare County**
  - >40% of wells exceed nitrate MCL
  - Isotopic data consistent with findings of SBX2 report (Harter et al, 2012):
    - Water isotopes indicate most domestic well water is from irrigation returns
    - Nitrate isotopes are consistent with a mixed source of synthetic and organic fertilizer
- **Boron isotopes**
  - Better distinction between synthetic fertilizer; manure; and septic discharge
  - Samples collected and processed for San Diego and Monterey Counties

Salinas Valley nitrate study

Basemap from Kulongoski et al., 2005

Study Questions:

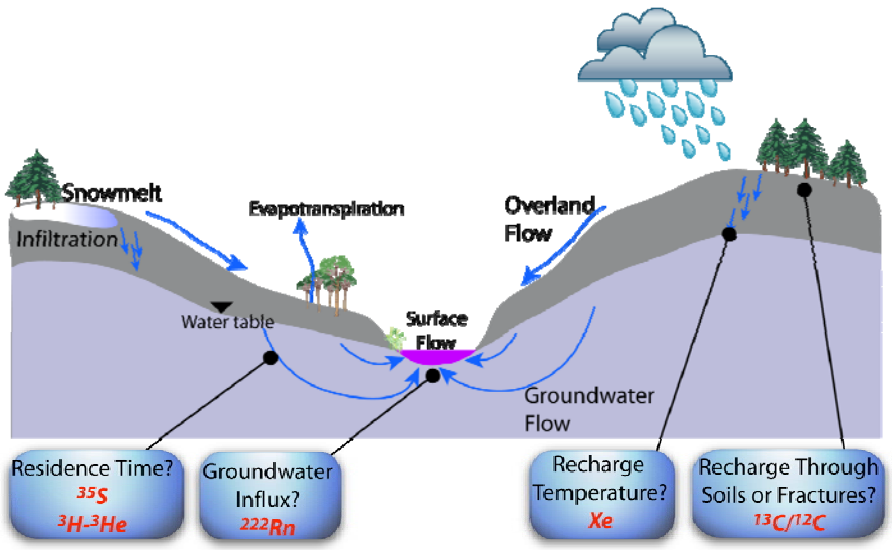
- What is the natural background nitrate concentration for the study area?
- What happens to nitrate in the Salinas River during recharge and transport?
- What is the source of nitrate in a contaminated drinking water wells?

Study Findings

- When rainwater and soil are the only source of N, groundwater nitrate is very low (< 4ppm)
- Groundwater from shallow & deep wells adjacent to the river has recharged relatively recently. Older water is found in the confined zone and in the Eastside subbasin
- Denitrification is taking place in the vadose zone and in groundwater near the Salinas River.
- The San Jerardo community well draws high-nitrate irrigation return water in the spring and summer

J. Moran et al. (2011) Nitrate Fate and Transport in the Salinas Valley: Presentation to Region 3 Board (San Luis Obispo; 09/01/2011).

Determining Water Resource Vulnerability to Climate Change (LLNL Climate Initiative)



Squaw Creek (Olympic Valley)

Singleton, M.J., Moran, J.E., 2010. Dissolved noble gas and isotopic tracers reveal vulnerability of groundwater in a small, high-elevation catchment to predicted climate changes. Water Resour. Res. 46, W00F06.

How will changes in climate impact runoff in alpine headwater basins?

- ***Groundwater discharge is a significant component in alpine stream runoff***
- *Alpine groundwaters spend between a few years to more than a decade below the surface, and **may buffer or reduce the impact on water resources from extreme wet or dry years.***
- *Recharge occurs over diffuse vegetated areas, rather than along exposed bedrock, which **may buffer the impact of the transition from snow to rainfall**.*

LLNL is providing age tracer constraints on development of the Martis Valley Groundwater Model and Management Plan

GAMA Special Study (LLNL and SWRCB)

- Consider climate change impacts to groundwater recharge & groundwater quality,
- Determine primary recharge locations & their vulnerability

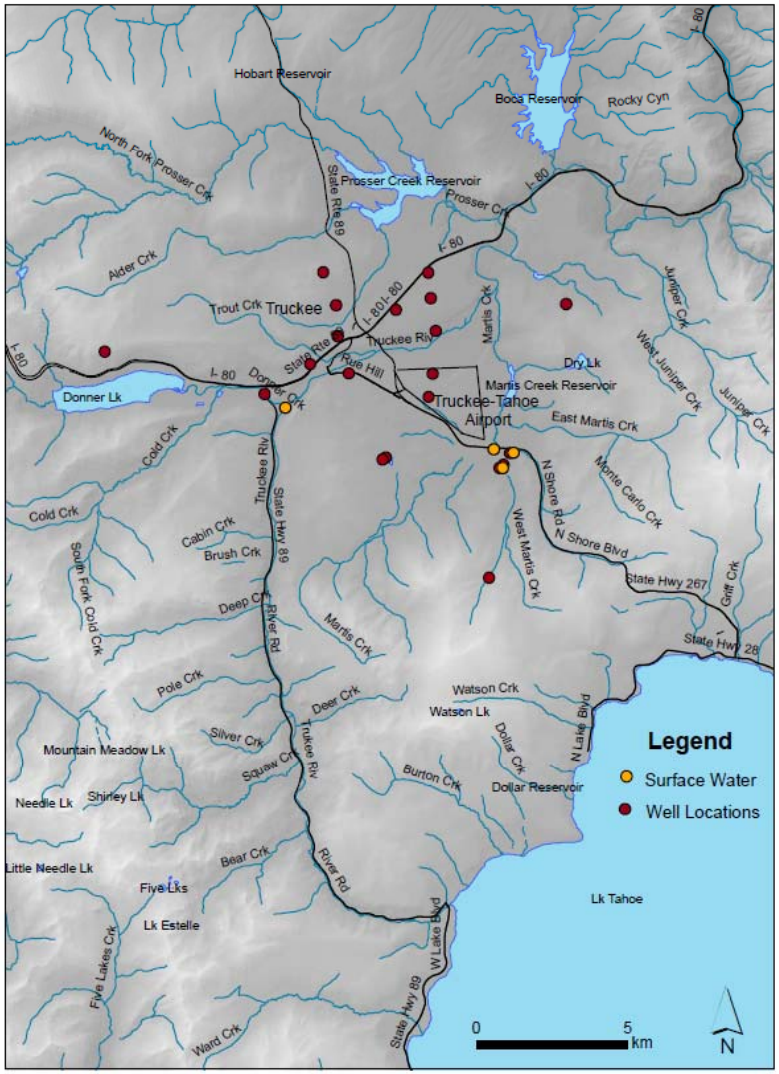
Martis Valley Groundwater Model
(Desert Research Institute and US Bureau of Reclamation)

- Estimate effects of large scale groundwater trends,
- Estimate the location of key recharge areas, and
- Estimate implications of potential climate change on Martis Valley's water resources.

Martis Valley Groundwater Management Plan

- The Placer County Water Agency (PCWA)
- Truckee Donner PUD (TDPUD):
- The Northstar Community Services District (NCSD)

Age tracer data will used in the development of a groundwater basin management plan.



Age tracer data

- **Tritium, helium isotopic, and noble gas concentration data**
  - Mean groundwater age: Tritium/helium-3
  - Fraction pre-modern: Initial tritium
  - Recharge temperature: Xenon
  - Excess air (recharge condition): Neon

- **Age Tracer Database:**
  - Compile and standardize reductiion of all project age tracer data
  - Upload archival tritium and noble gas data from the GAMA Special Studies and California Aquifer Susceptibility Projects to Geotracker
  - Develop a map and database of groundwater age for all groundwater samples collected by the GAMA project

What are the general findings?

- **Groundwater age is a valuable tool**
  - as a predictor of groundwater susceptibility
  - as a constraint on groundwater flow (e.g. managed recharge)

- **Multi-disciplinary approaches provide valuable new information and approaches for water management**
  - Managed aquifer recharge can impact water quality
  - Contaminant attribution often requires multiple tracers

Two last points

- **Shallow groundwater is important & susceptible**

Affected water
Domestic wells
Managed recharge
Surface water

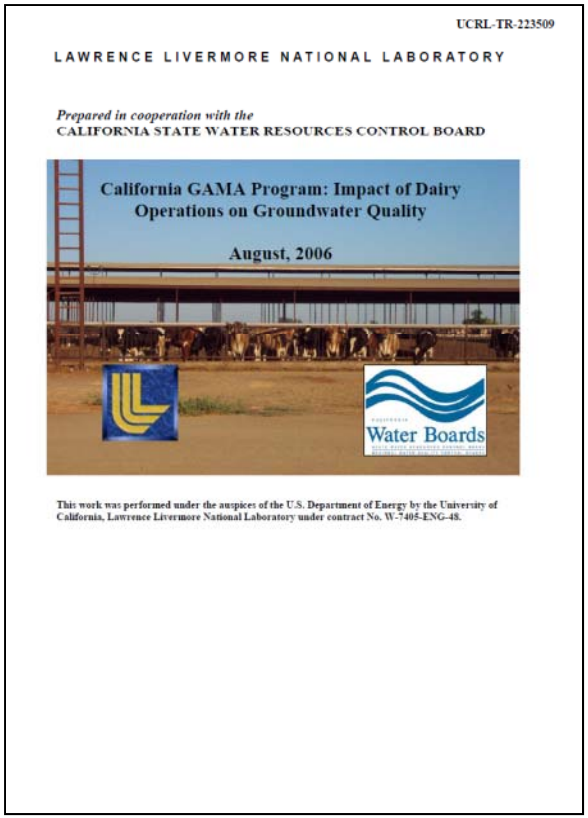
Challenges
Shallow groundwaters are susceptible to contamination and to climate change
The quality of shallow groundwater is poorly known
Monitoring shallow groundwater is important to track the impact of land use, management practice and climate change on water quality

- **Special Studies success requires collaboration**

Organization	Need
Water Board(s)	Funding; prioritization
LLNL	Unique capability & expertise; Internal funding (Water Initiative; Climate Initiative)
Districts	Access; expertise; in-kind staff contributions; projects
Research institutions	Expertise; capability students; projects

Technical Publications

Technical Reports



UCRL-TR-223509

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Prepared in cooperation with the
CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

California GAMA Program: Impact of Dairy Operations on Groundwater Quality

August, 2006

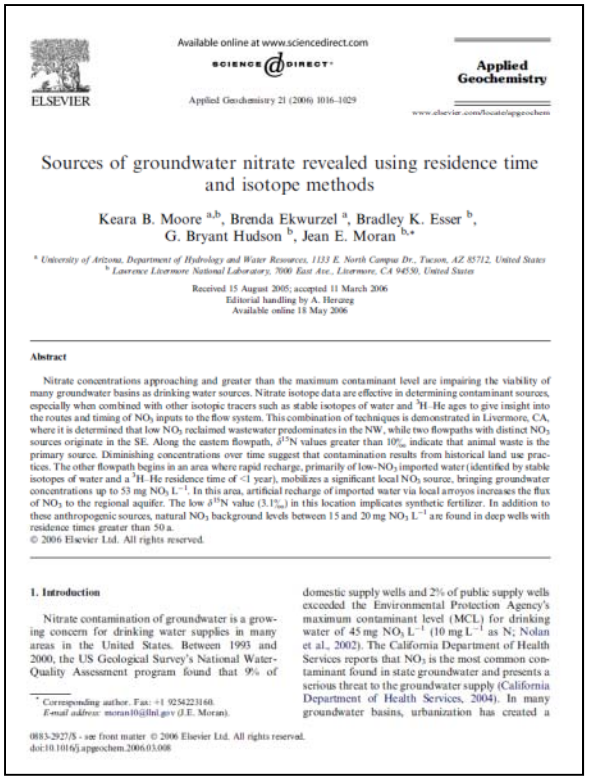
Water Boards

This work was performed under the auspices of the U.S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.

14 published (as of 04/2011)

www.swrcb.ca.gov/water_issues/programs/gama/gamadocs.shtml

Peer-reviewed Publications



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Sources of groundwater nitrate revealed using residence time and isotope methods

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Received 15 August 2005; accepted 11 March 2006
Editorial handling by A. Herczeg
Available online 18 May 2006

Abstract

Nitrate concentrations approaching and greater than the maximum contaminant level are impairing the viability of many groundwater basins as drinking water sources. Nitrate isotope data are effective in determining contaminant sources, especially when combined with other isotopic tracers such as stable isotopes of water and ^{3}H–He ages to give insight into the routes and timing of NO_3 inputs to the flow system. This combination of techniques is demonstrated in Livermore, CA, where it is determined that low NO_3 reclaimed wastewater predominates in the NW, while two flowpaths with distinct NO_3 sources originate in the SE. Along the eastern flowpath, $\delta^{15}N$ values greater than 10‰ indicate that animal waste is the primary source. Diminishing concentrations over time suggest that contamination results from historical land use practices. The other flowpath begins in an area where rapid recharge, primarily of low-NO_3 imported water (identified by stable isotopes of water and a ^{3}H–He residence time of <1 year), mobilizes a significant local NO_3 source, bringing groundwater concentrations up to 53 mg NO_3 L^{-1}. In this area, artificial recharge of imported water via local arroyos increases the flux of NO_3 to the regional aquifer. The low $\delta^{15}N$ value (3.1‰) in this location implicates synthetic fertilizer. In addition to these anthropogenic sources, natural NO_3 background levels between 15 and 20 mg NO_3 L^{-1} are found in deep wells with residence times greater than 50 a.

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1. Introduction

Nitrate contamination of groundwater is a growing concern for drinking water supplies in many areas in the United States. Between 1993 and 2000, the US Geological Survey's National Water-Quality Assessment program found that 9% of domestic supply wells and 2% of public supply wells exceeded the Environmental Protection Agency's maximum contaminant level (MCL) for drinking water of 45 mg NO_3 L^{-1} (10 mg L^{-1} as N; Nolan et al., 2002). The California Department of Health Services reports that NO_3 is the most common contaminant found in state groundwater and presents a serious threat to the groundwater supply (California Department of Health Services, 2004). In many groundwater basins, urbanization has created a

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0883-2927/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apgeochem.2006.03.008

9 published (as of 04/2011)

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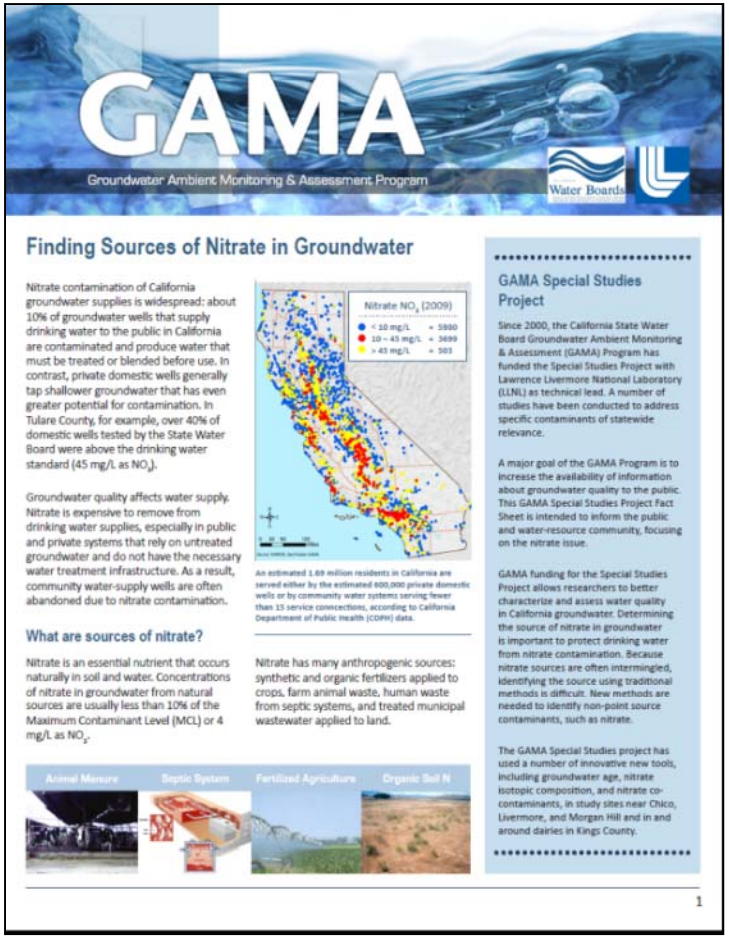

GAMA

Groundwater Ambient Monitoring & Assessment Program

Water Boards

Finding Sources of Nitrate in Groundwater

Nitrate contamination of California groundwater supplies is widespread: about 10% of groundwater wells that supply drinking water to the public in California are contaminated and produce water that must be treated or blended before use. In contrast, private domestic wells generally tap shallower groundwater that has even greater potential for contamination. In Tulare County, for example, over 40% of domestic wells tested by the State Water Board were above the drinking water standard (45 mg/L as NO_3).

Groundwater quality affects water supply. Nitrate is expensive to remove from drinking water supplies, especially in public and private systems that rely on untreated groundwater and do not have the necessary water treatment infrastructure. As a result, community water-supply wells are often abandoned due to nitrate contamination.

Nitrate NO_3 (2009)

< 10 mg/L = 5990
10 – 45 mg/L = 3699
> 45 mg/L = 503

An estimated 1.69 million residents in California are served either by the estimated 600,000 private domestic wells or by community water systems serving fewer than 15 service connections, according to California Department of Public Health (CDPH) data.

What are sources of nitrate?

Nitrate is an essential nutrient that occurs naturally in soil and water. Concentrations of nitrate in groundwater from natural sources are usually less than 10% of the Maximum Contaminant Level (MCL) or 4 mg/L as NO_3.

Nitrate has many anthropogenic sources: synthetic and organic fertilizers applied to crops, farm animal waste, human waste from septic systems, and treated municipal wastewater applied to land.

Animal Manure | Septic System | Fertilized Agriculture | Organic Soil N

GAMA Special Studies Project

Since 2000, the California State Water Board Groundwater Ambient Monitoring & Assessment (GAMA) Program has funded the Special Studies Project with Lawrence Livermore National Laboratory (LLNL) as technical lead. A number of studies have been conducted to address specific contaminants of statewide relevance.

A major goal of the GAMA Program is to increase the availability of information about groundwater quality to the public. This GAMA Special Studies Project Fact Sheet is intended to inform the public and water-resource community, focusing on the nitrate issue.

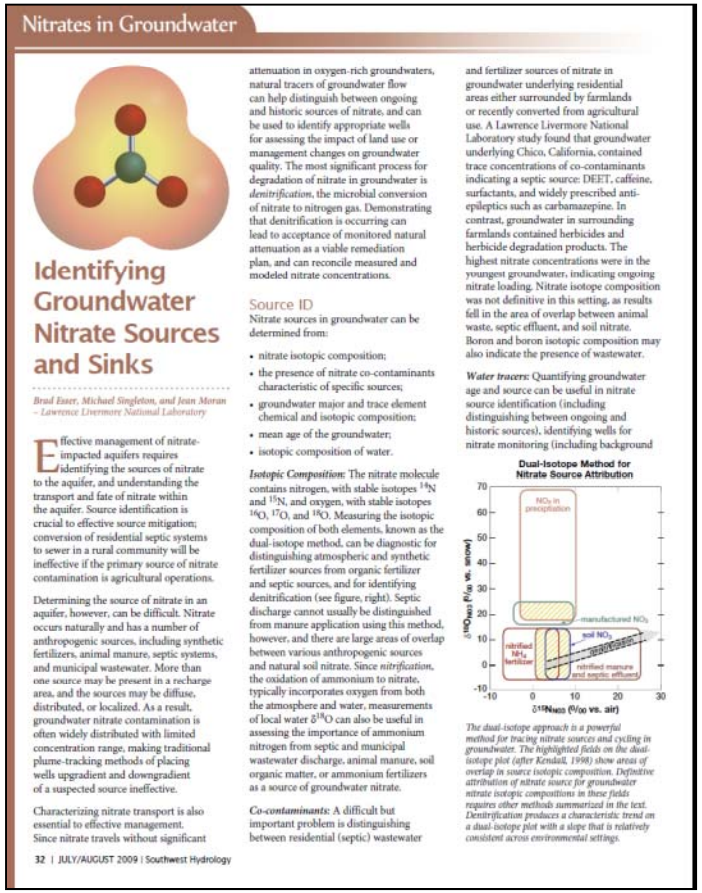
GAMA funding for the Special Studies Project allows researchers to better characterize and assess water quality in California groundwater. Determining the source of nitrate in groundwater is important to protect drinking water from nitrate contamination. Because nitrate sources are often intermingled, identifying the source using traditional methods is difficult. New methods are needed to identify non-point source contaminants, such as nitrate.

The GAMA Special Studies project has used a number of innovative new tools, including groundwater age, nitrate isotopic composition, and nitrate co-contaminants, in study sites near Chico, Livermore, and Morgan Hill and in and around dairies in Kings County.

1

1 published

Non-technical publications


Nitrates in Groundwater

Identifying Groundwater Nitrate Sources and Sinks

Brad Esser, Michael Singleton, and Jean Moran – Lawrence Livermore National Laboratory

Effective management of nitrate-impacted aquifers requires identifying the sources of nitrate to the aquifer, and understanding the transport and fate of nitrate within the aquifer. Source identification is crucial to effective source mitigation; conversion of residential septic systems to sewer in a rural community will be ineffective if the primary source of nitrate contamination is agricultural operations.

Determining the source of nitrate in an aquifer, however, can be difficult. Nitrate occurs naturally and has a number of anthropogenic sources, including synthetic fertilizers, animal manure, septic systems, and municipal wastewater. More than one source may be present in a recharge area, and the sources may be diffuse, distributed, or localized. As a result, groundwater nitrate contamination is often widely distributed with limited concentration range, making traditional plume-tracking methods of placing wells upgradient and downgradient of a suspected source ineffective.

Characterizing nitrate transport is also essential to effective management. Since nitrate travels without significant attenuation in oxygen-rich groundwaters, natural tracers of groundwater flow can help distinguish between ongoing and historic sources of nitrate, and can be used to identify appropriate wells for assessing the impact of land use or management changes on groundwater quality. The most significant process for degradation of nitrate in groundwater is *denitrification*, the microbial conversion of nitrate to nitrogen gas. Demonstrating that denitrification is occurring can lead to acceptance of monitored natural attenuation as a viable remediation plan, and can reconcile measured and modeled nitrate concentrations.

Source ID

Nitrate sources in groundwater can be determined from:

- nitrate isotopic composition;
- the presence of nitrate co-contaminants characteristic of specific sources;
- groundwater major and trace element chemical and isotopic composition;
- mean age of the groundwater;
- isotopic composition of water.

Isotopic Composition: The nitrate molecule contains nitrogen, with stable isotopes ^{14}N and ^{15}N, and oxygen, with stable isotopes ^{16}O, ^{17}O, and ^{18}O. Measuring the isotopic composition of both elements, known as the dual-isotope method, can be diagnostic for distinguishing atmospheric and synthetic fertilizer sources from organic fertilizer and septic sources, and for identifying denitrification (see figure, right). Septic discharge cannot usually be distinguished from manure application using this method, however, and there are large areas of overlap between various anthropogenic sources and natural soil nitrate. Since *nitrification*, the oxidation of ammonium to nitrate, typically incorporates oxygen from both the atmosphere and water, measurements of local water $\delta^{18}O$ can also be useful in assessing the importance of ammonium nitrogen from septic and municipal wastewater discharge, animal manure, soil organic matter, or ammonium fertilizers as a source of groundwater nitrate.

Co-contaminants: A difficult but important problem is distinguishing between residential (septic) wastewater and fertilizer sources of nitrate in groundwater underlying residential areas either surrounded by farmlands or recently converted from agricultural use. A Lawrence Livermore National Laboratory study found that groundwater underlying Chico, California, contained trace concentrations of co-contaminants indicating a septic source: DEET, caffeine, surfactants, and widely prescribed anti-epileptics such as carbamazepine. In contrast, groundwater in surrounding farmlands contained herbicides and herbicide degradation products. The highest nitrate concentrations were in the youngest groundwater, indicating ongoing nitrate loading. Nitrate isotope composition was not definitive in this setting, as results fell in the area of overlap between animal waste, septic effluent, and soil nitrate. Boron and boron isotopic composition may also indicate the presence of wastewater.

Water tracers: Quantifying groundwater age and source can be useful in nitrate source identification (including distinguishing between ongoing and historic sources), identifying wells for nitrate monitoring (including background

Dual-Isotope Method for Nitrate Source Attribution

The dual-isotope approach is a powerful method for tracing nitrate sources and cycling in groundwater. The highlighted fields on the dual-isotope plot (after Kendall, 1998) show areas of overlap in source isotopic composition. Definitive attribution of nitrate source for groundwater nitrate isotopic compositions in these fields requires other methods summarized in the text. Denitrification produces a characteristic trend on a dual-isotope plot with a slope that is relatively consistent across environmental settings.

32 | JULY/AUGUST 2009 | Southwest Hydrology

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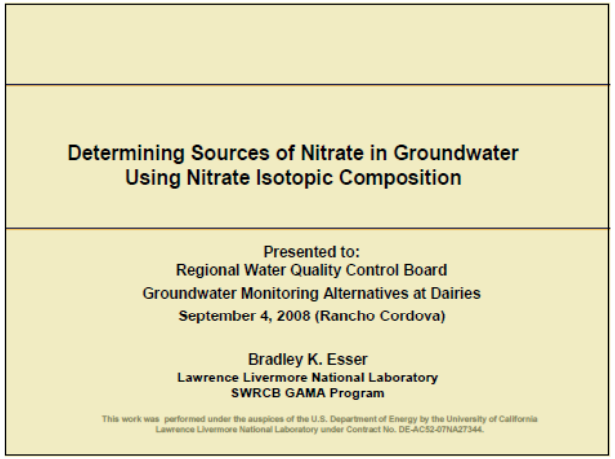

Determining Sources of Nitrate in Groundwater
Using Nitrate Isotopic Composition

Presented to:
Regional Water Quality Control Board
Groundwater Monitoring Alternatives at Dairies
September 4, 2008 (Rancho Cordova)

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SWRCB GAMA Program

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract No. DE-AC52-07NA27344.

Scientific conferences

Stakeholder & professional workshops & meetings

Acknowledgements

LLNL GAMA Project Team

Steve Carle, Brad Cey, Wayne Culham. Brad Esser, Darren Hillegonds, G. Bryant Hudson, Roald Leif, Walt McNab, Jean Moran, Michael Singleton, Mike Sharp, Sarah Roberts, Ate Visser

Agency Collaborations

SWRCB (State & Regional)
DWR
UC Cooperative Extension
Numerous Water Districts
Numerous Well Owners

LLNL Student Programs

LLNL Summer Intern Program
LLNL Postdoc Program

University collaborations

California State University, East Bay
University of California, Davis
University of California, Merced
University of Arizona
University of Texas, Austin

For more information

State Water Board GAMA Program Website:

http://www.waterboards.ca.gov/gama

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