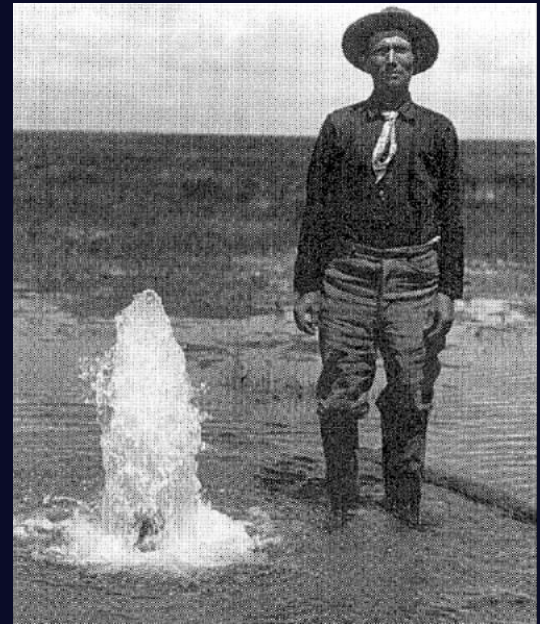


Introduction to the Science of Groundwater

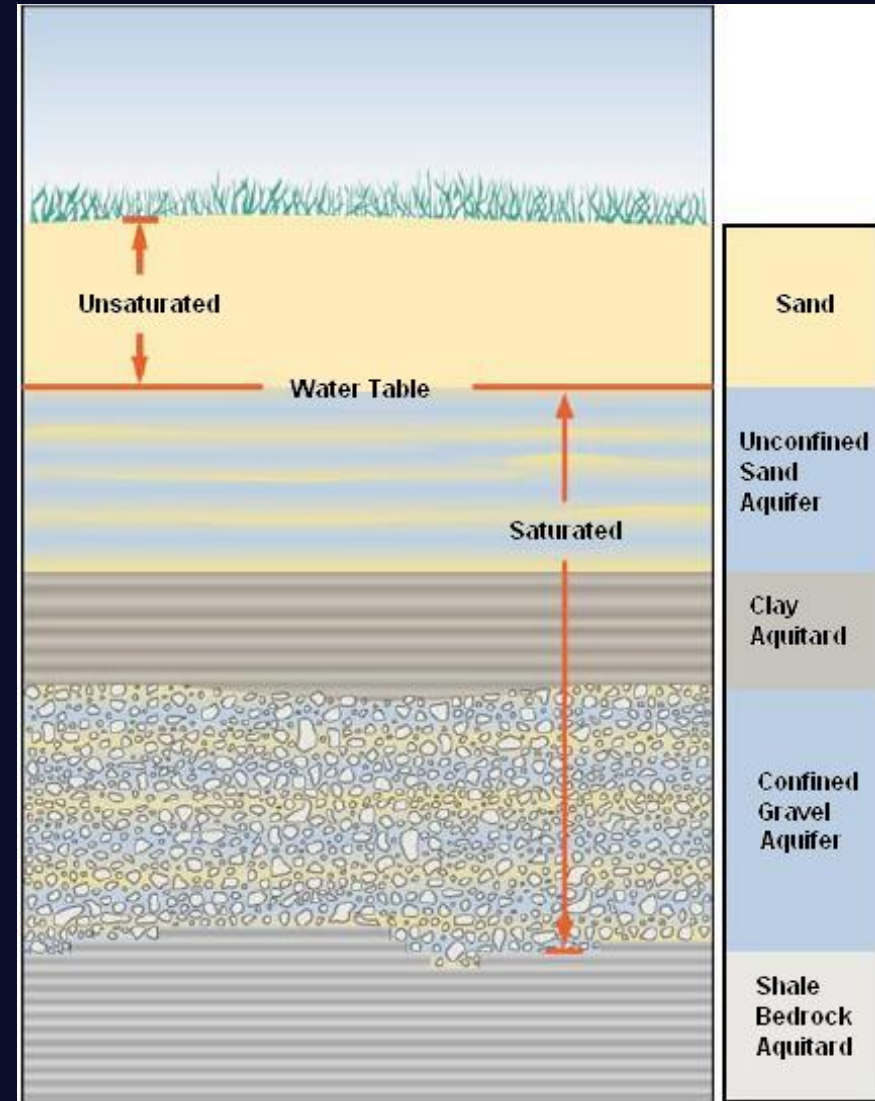
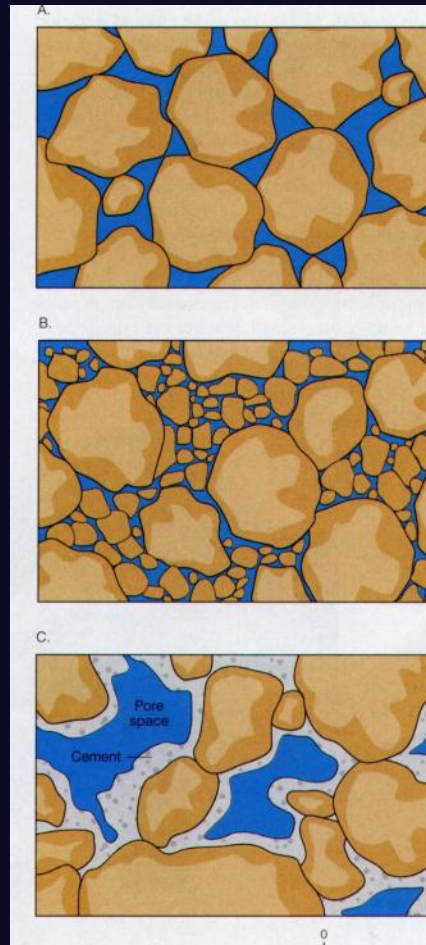
Steve Phillips

U.S. Geological Survey
California Water Science Center



What is groundwater?

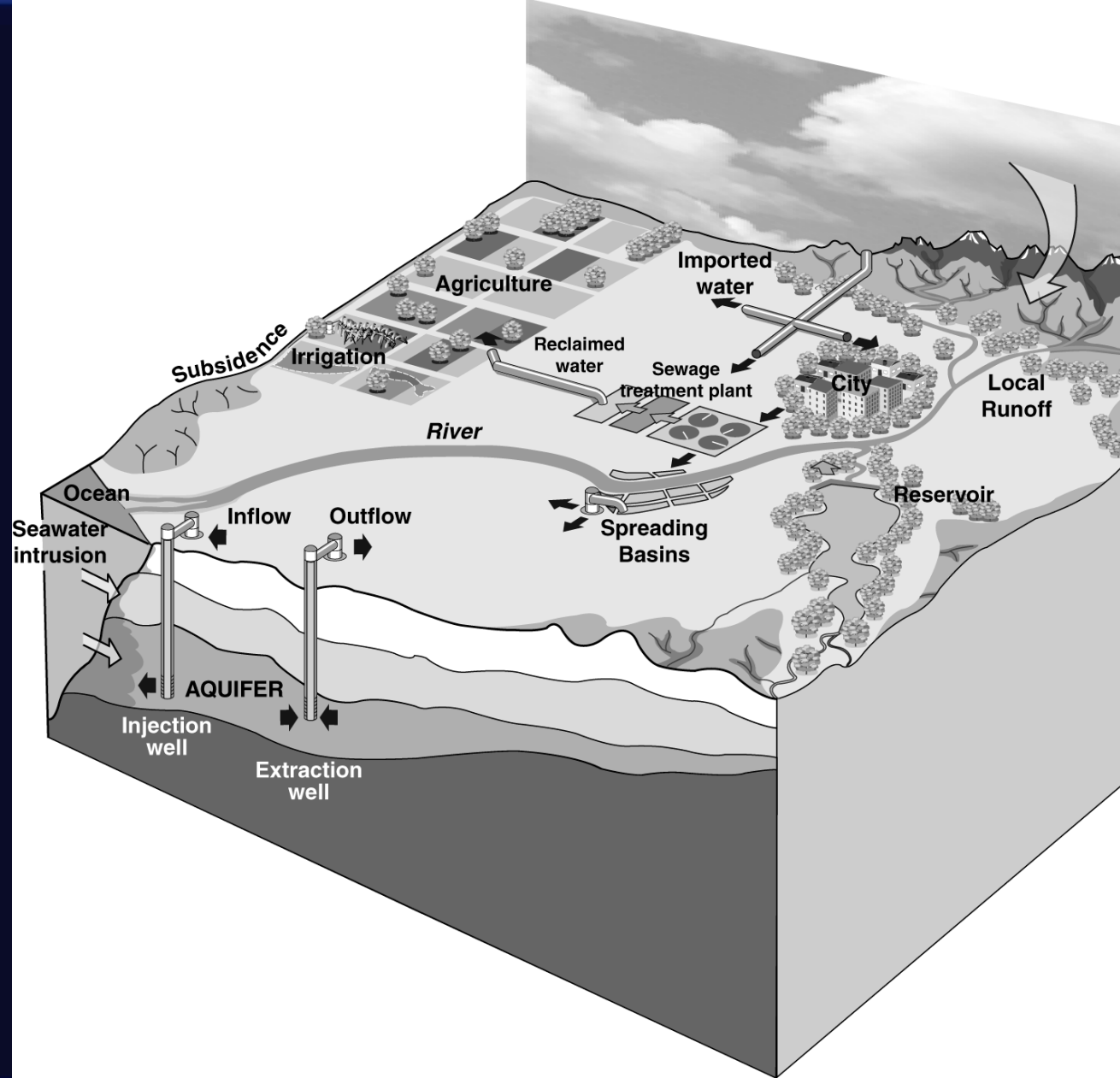
Groundwater occurs in small pore spaces within rock and alluvium (unconsolidated sediment)



Where does groundwater come from? (recharge)

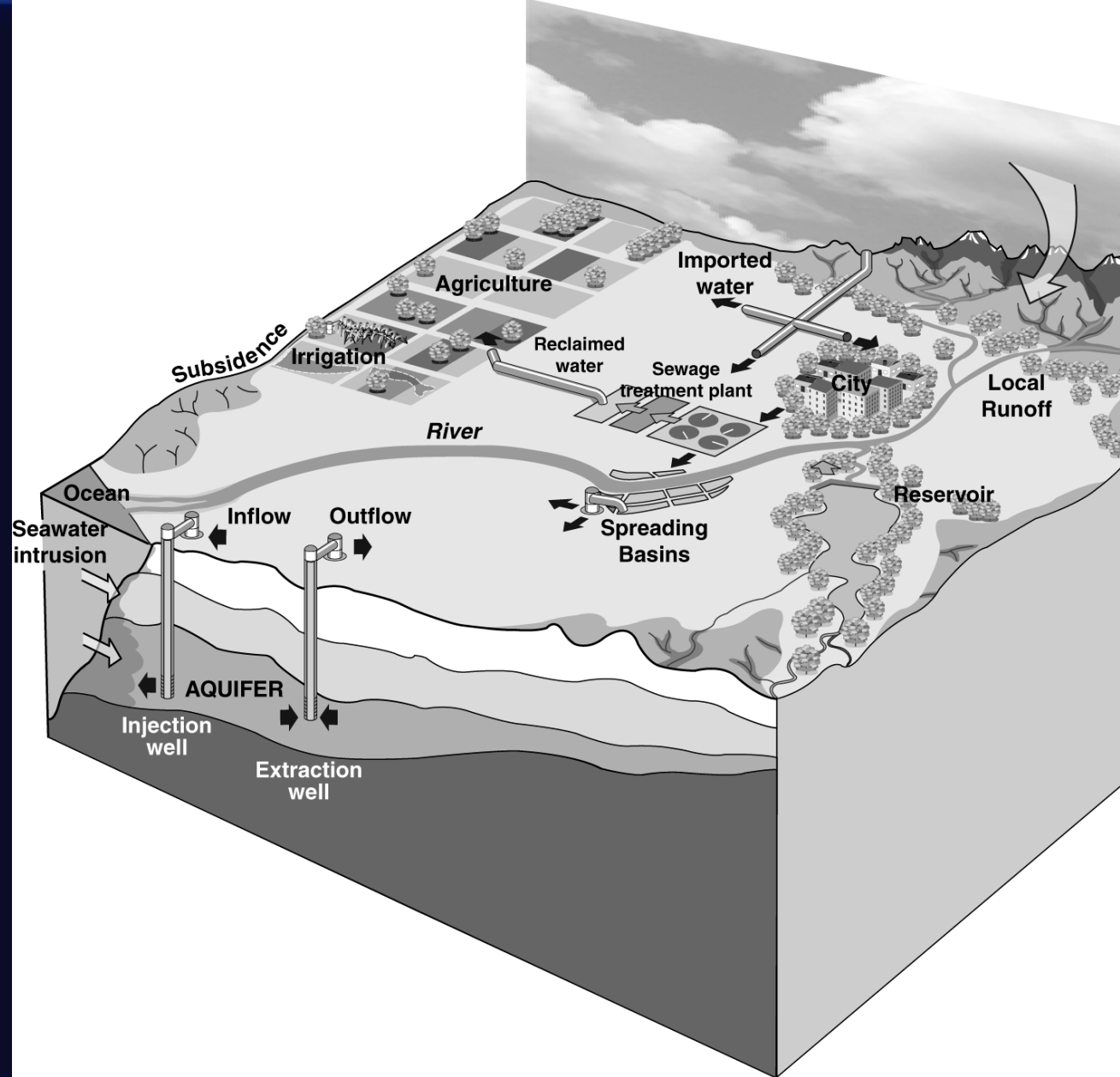
Many possible sources, including

- Precipitation
- Streams/lakes
- Irrigation
- Managed aquifer recharge
- Subsurface flow



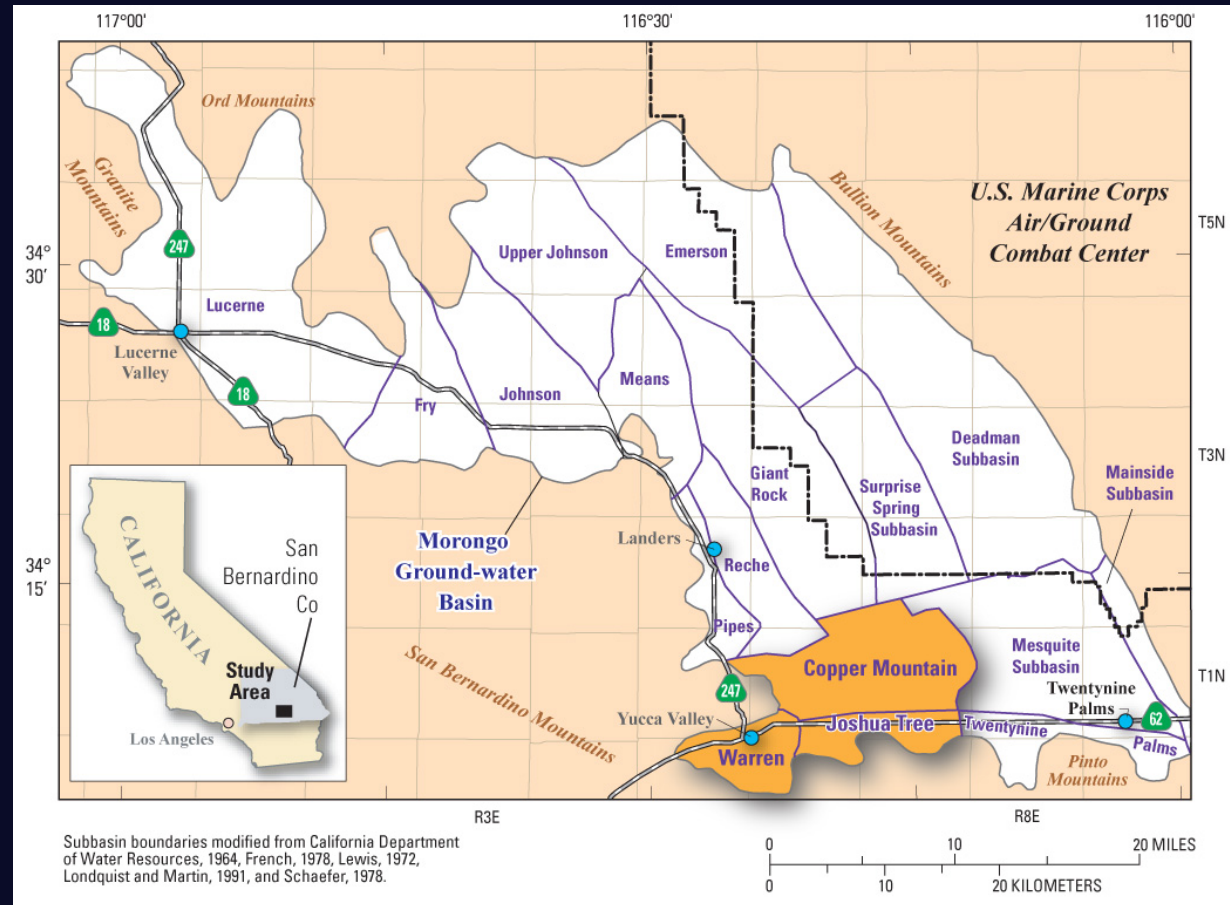
Where does groundwater go? (discharge)

- Streams, lakes, wetlands, the ocean
- Evapotranspiration
- Springs, seeps
- Wells
- Drains
- Subsurface flow
- Etc.



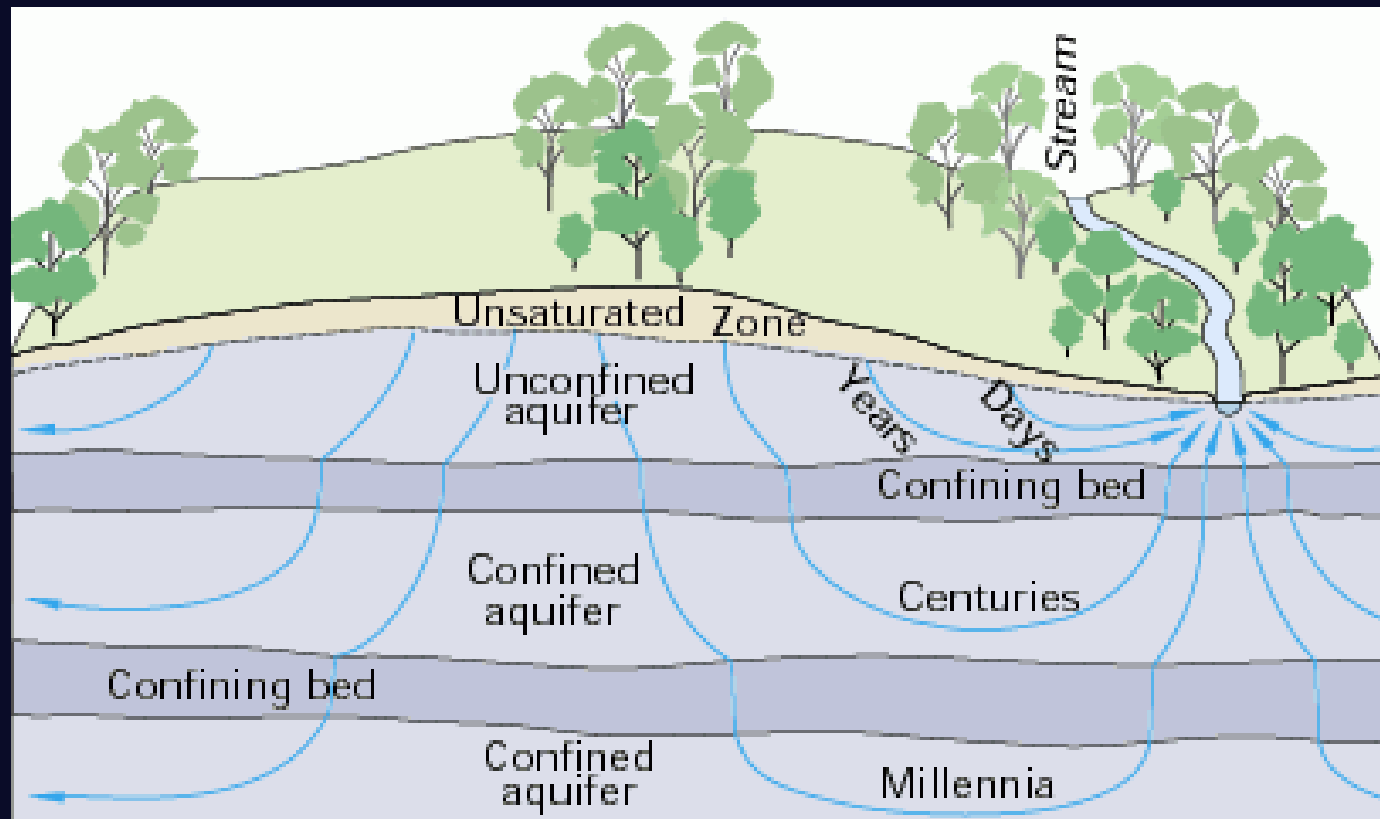
Groundwater basins & subbasins

- **Basins:** An alluvial aquifer or stacked series of aquifers with reasonably defined lateral boundaries and having a defined bottom
- **Subbasins:** A subdivision of a groundwater basin created by dividing the basin using geologic or hydrologic conditions or institutional boundaries



Groundwater flow & age

Groundwater flows down-gradient, from water-level highs to water-level lows.



Groundwater Use

estimated 2010 california **WATER USE**

California has been the state with largest water use in the US since the USGS began compiling water-use data in 1950.

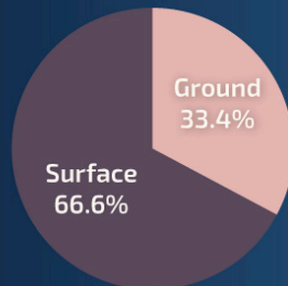
38 Billion
gallons per day

(total withdrawals of all water types in California)

TOTAL DAILY WATER
withdrawals for California is enough to drain
SHASTA LAKE
(California's largest reservoir) about once
every 40 days

water withdrawal by **SOURCE** type

Groundwater vs Surface Water



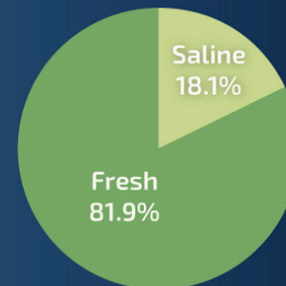
Surface Water



Groundwater



Fresh Water vs Saline Water



water withdrawal by **CATEGORY**

Groundwater Use

There is substantial uncertainty in estimates of groundwater pumping for irrigation in CA.

THERMOELECTRIC POWER GENERATION

accounts for **95%** of all **SALINE** water withdrawals in California



Aquaculture
2.6%, 973 Mgal/day

74% of all **FRESH** water withdrawals in California were for **IRRIGATION**



Self-supply Domestic
0.5%, 172 Mgal/day
69 gal/day per Capita

Livestock
0.5%, 188 Mgal/day

Mining
0.7%, 272 Mgal/day

Industrial
1.0%, 400 Mgal/day

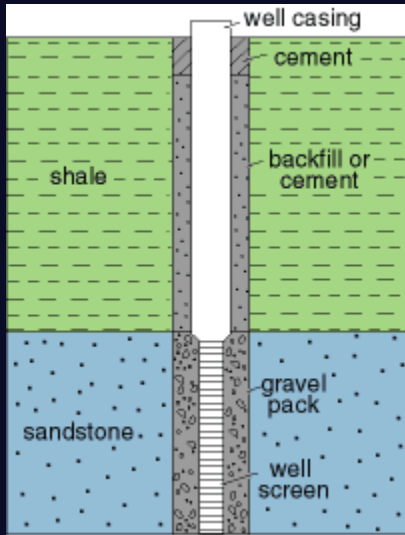


Ways to measure groundwater



Monitoring wells

Measuring depth to water



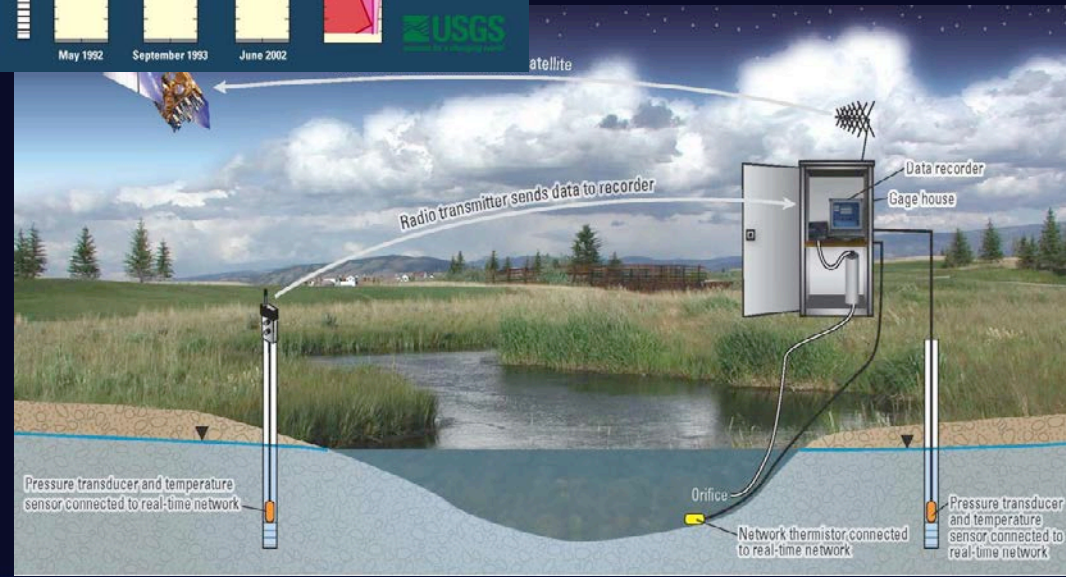
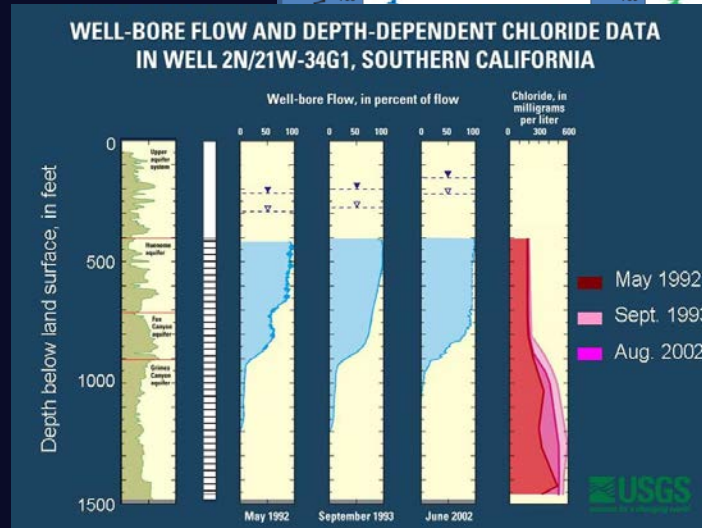
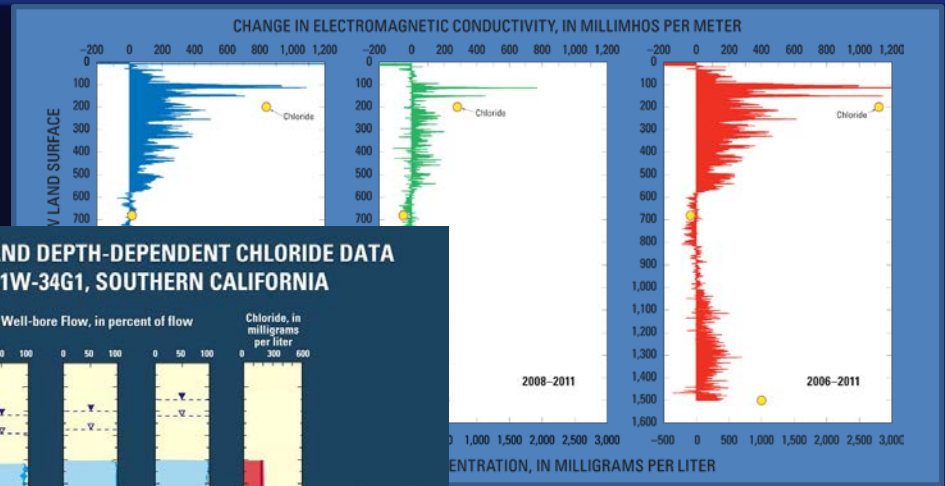
Supply well





More ways to measure groundwater & aquifer system characteristics

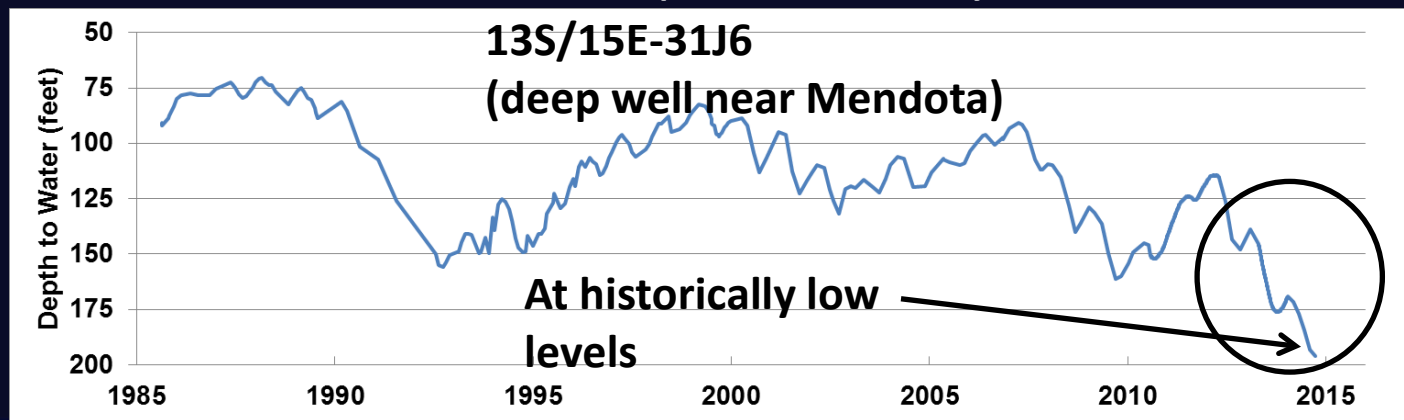
- Borehole & surface geophysics
- Aquifer tests
- Instrumentation of the saturated and unsaturated zones
- Remote sensing
- Well logs
- Etc.



Groundwater trends in CA

In general, long-term (not during drought):

- **Desert basins** – *declining*
 - Minimal natural recharge & alternative supplies
- **Coastal basins** – *steady to declining*
 - More natural recharge in north; more active management in south & central
- **Central Valley** – *steady* north, *declining* south
 - More natural recharge & SW supplies in north
 - Declines severe in southernmost part of valley



A common question

How much groundwater is there in my basin?

The answer doesn't really matter, because there are many issues associated with groundwater depletion.

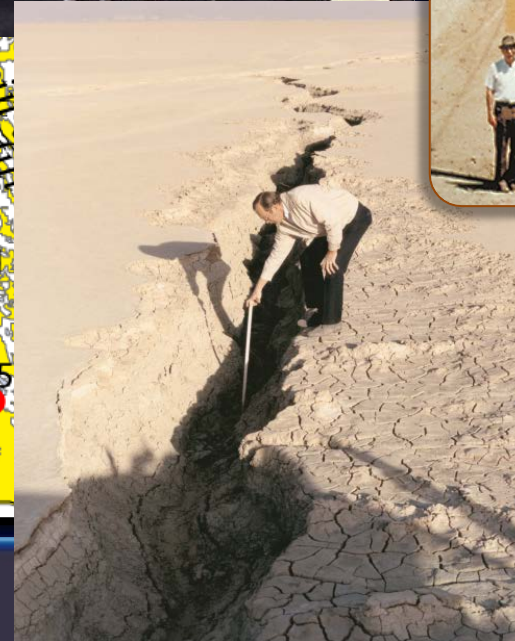
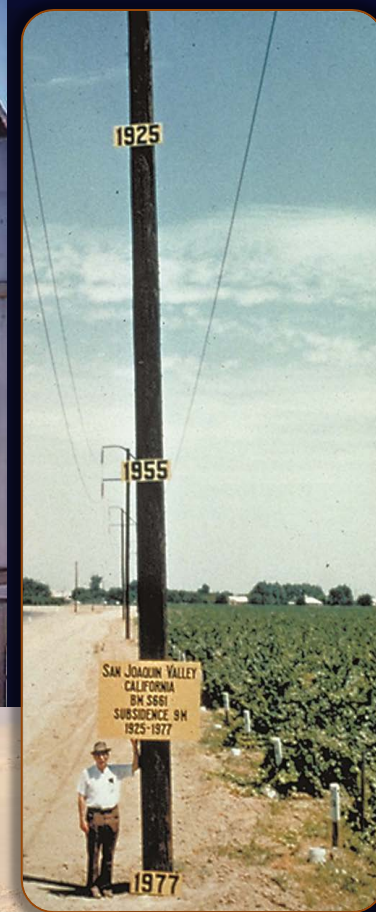
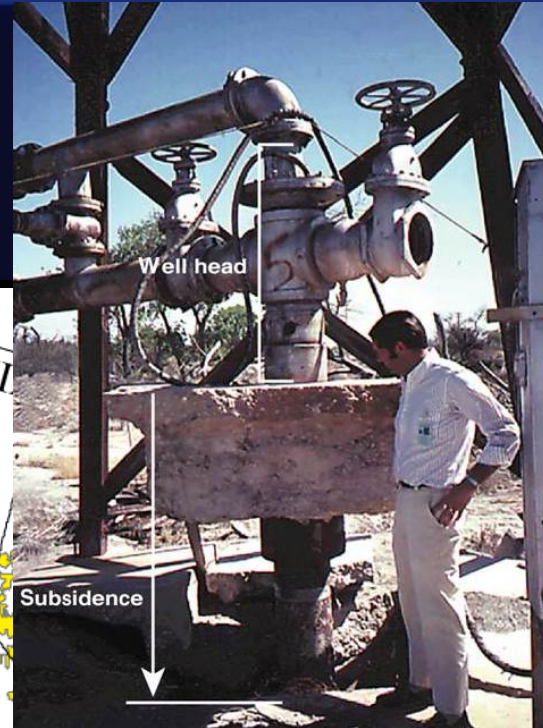
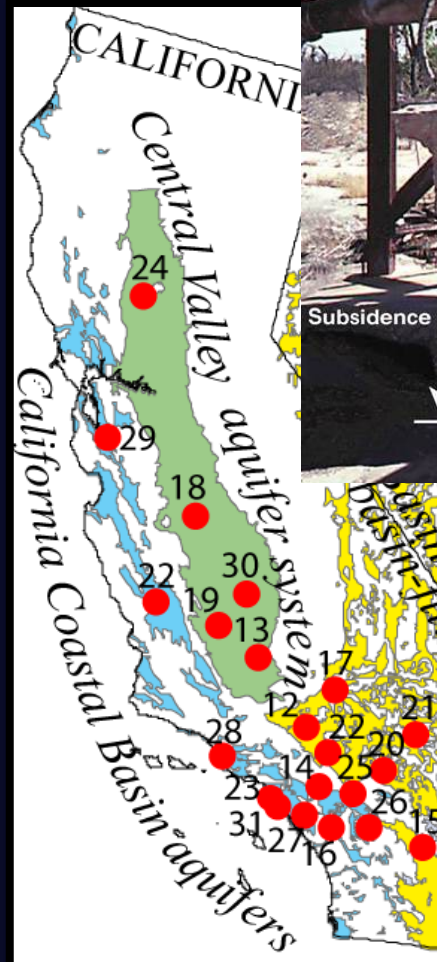
Issues associated with groundwater depletion

- Land subsidence
- Seawater intrusion
- Degradation of groundwater quality
 - e.g., reliance on older, more mineralized waters
- Depletion of surface water
 - e.g., drying of wetlands, reduced streamflow
- Increased cost of withdrawal
- Loss of (often) most productive aquifer zones

Land subsidence from groundwater withdrawal

Compaction of fine-grained materials in the aquifer system can occur when water levels exceed previous lows.

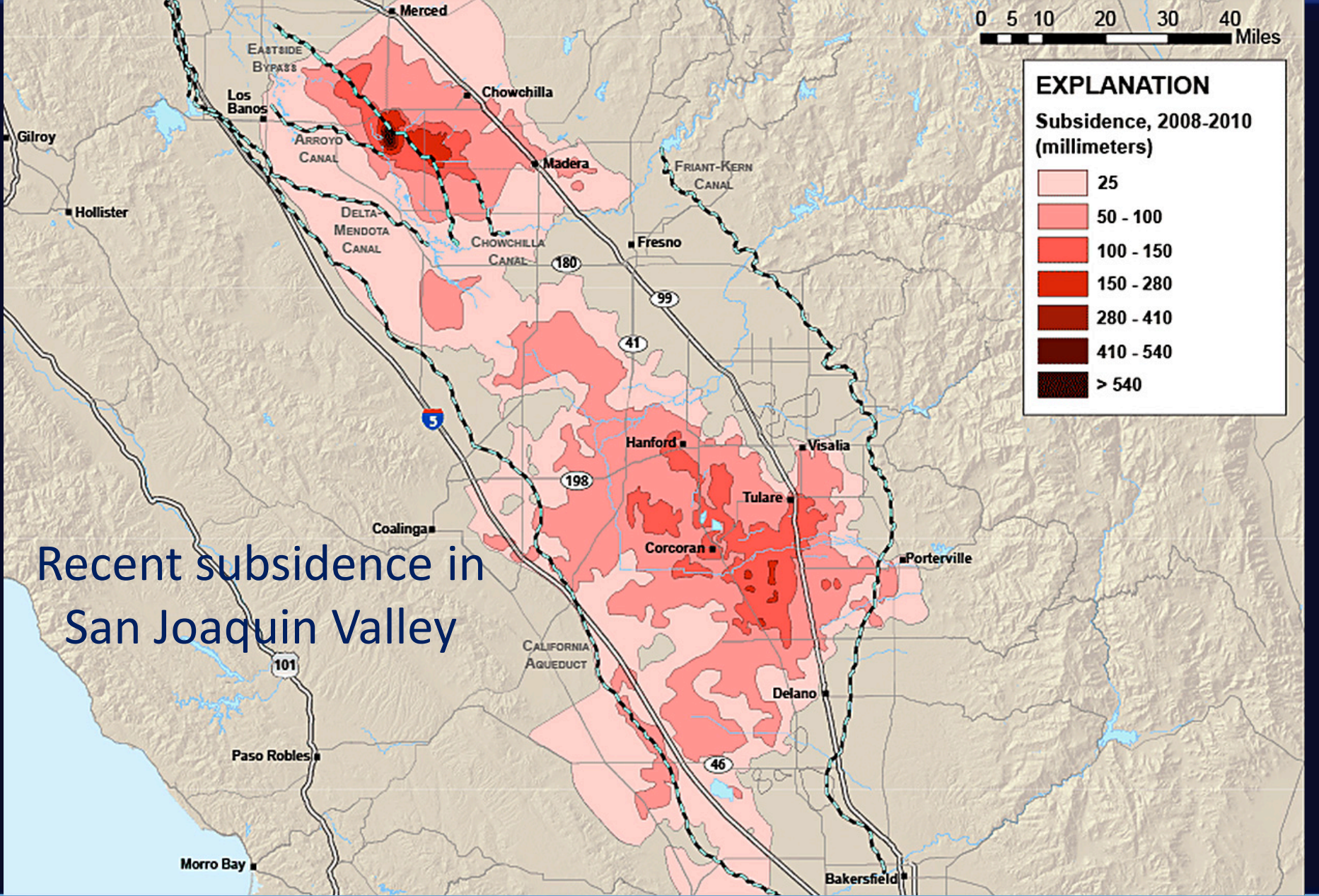
This causes deformation at land surface, and damages infrastructure.



0 5 10 20 30 40 Miles

EXPLANATION
Subsidence, 2008-2010
(millimeters)

Lightest Pink	25
Light Pink	50 - 100
Medium Pink	100 - 150
Red	150 - 280
Dark Red	280 - 410
Brownish Red	410 - 540
Black with Dotted Pattern	> 540

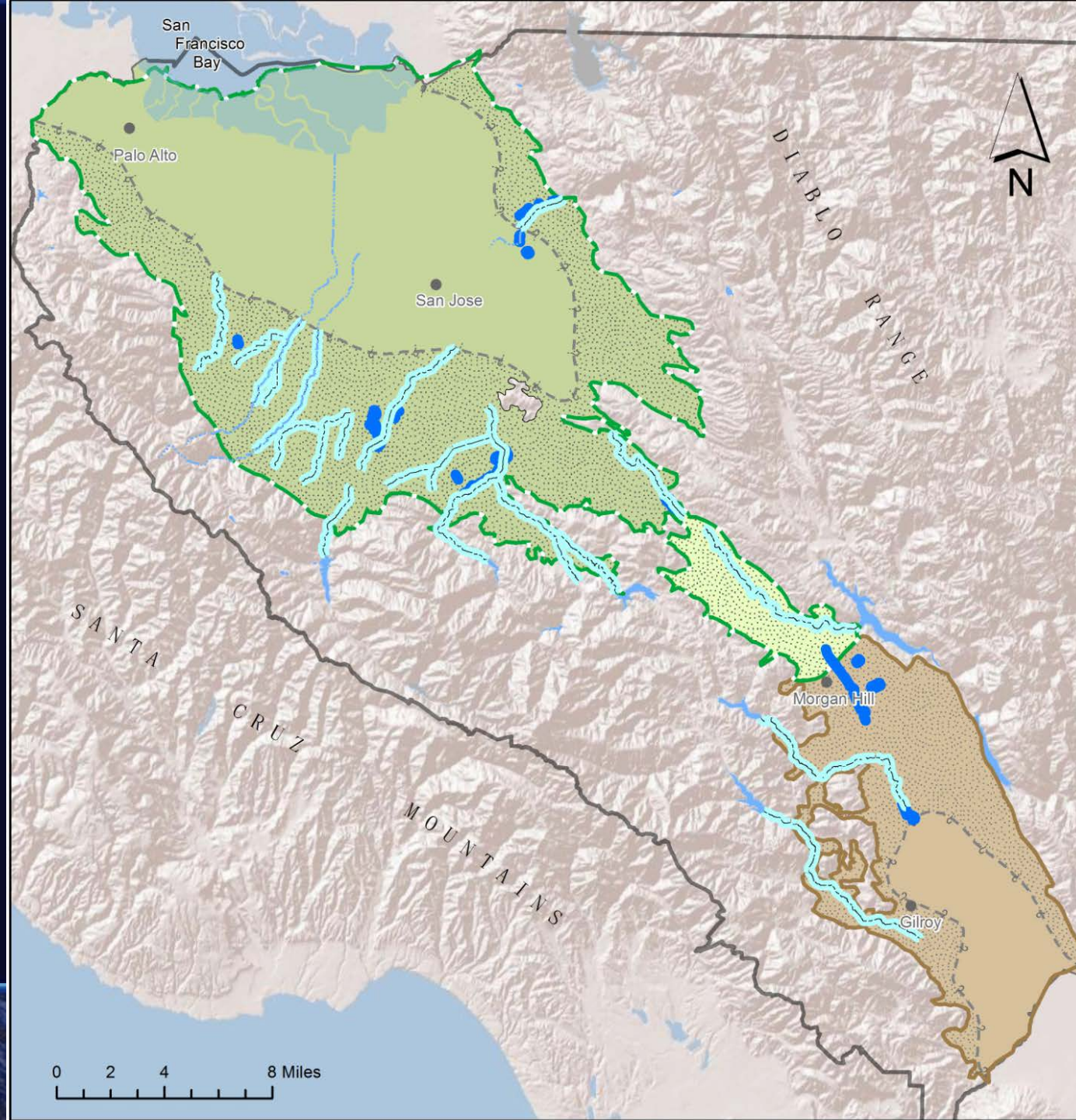


Recent subsidence in San Joaquin Valley

Managing land subsidence

Example: Santa Clara Valley WD

Successful subsidence abatement using managed aquifer recharge

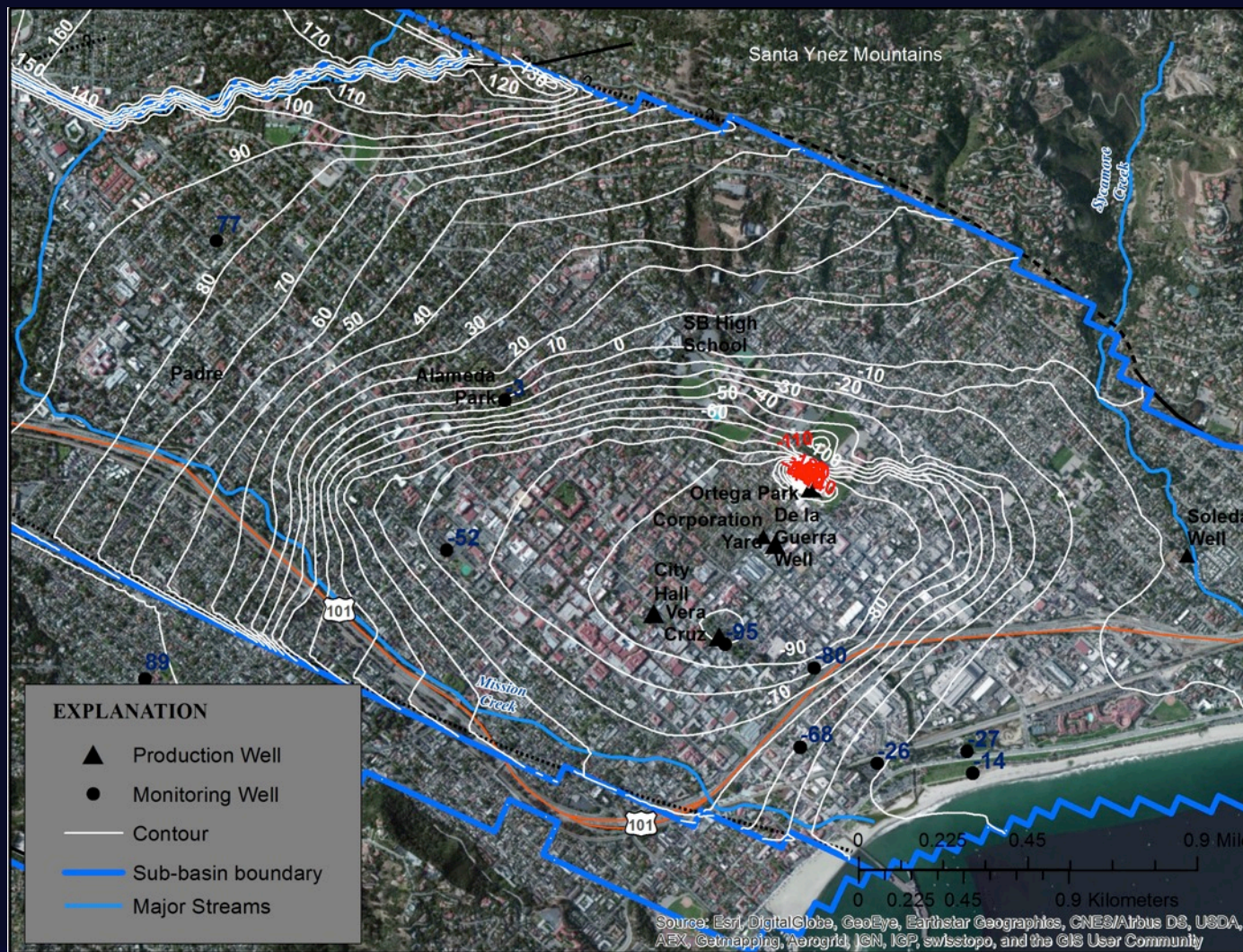


Seawater intrusion

Example: Santa Barbara

Water-levels below sea level at shoreline

This draws seawater toward the aquifer



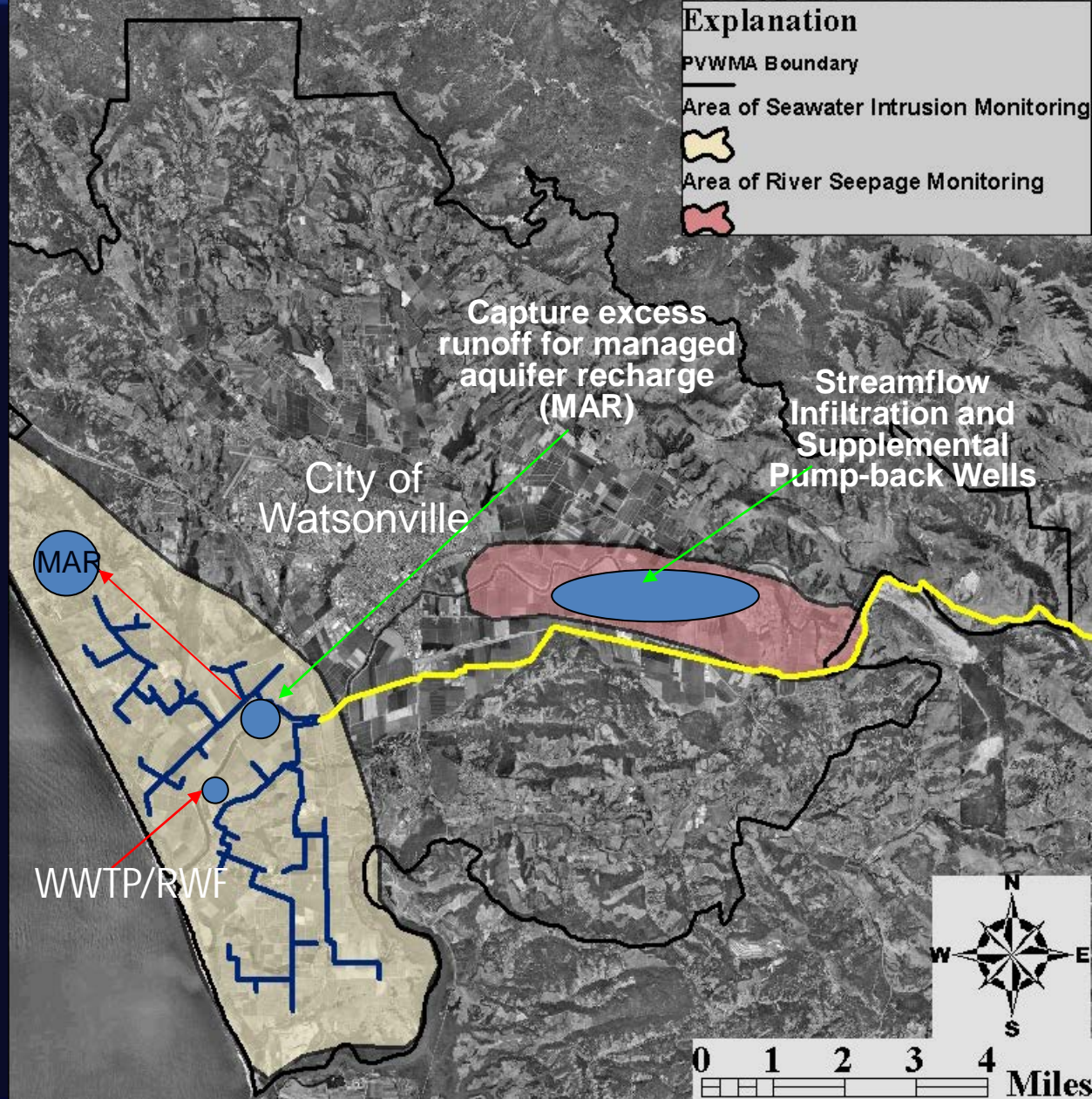
Managing seawater intrusion

Pajaro Valley WMA

Management actions:

- Coastal delivery system
- Managed aquifer recharge
- Wastewater treatment

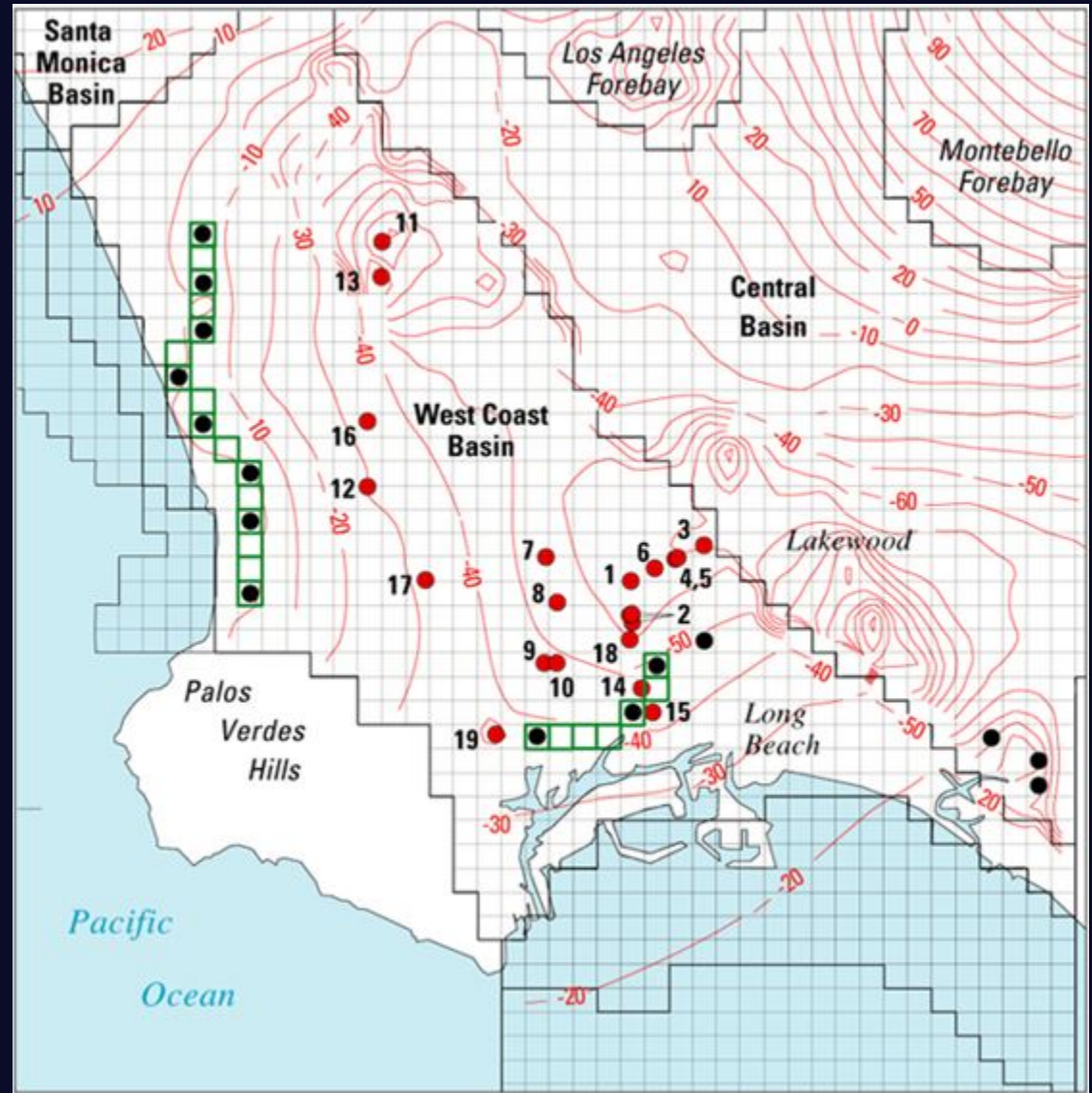
Modeling helped to evaluate effectiveness of actions, and to target other actions.



Managing seawater intrusion

Injection barriers in
Los Angeles and
Orange County have
been very effective

Modeling in LA basin
helped with injection
barrier/well design

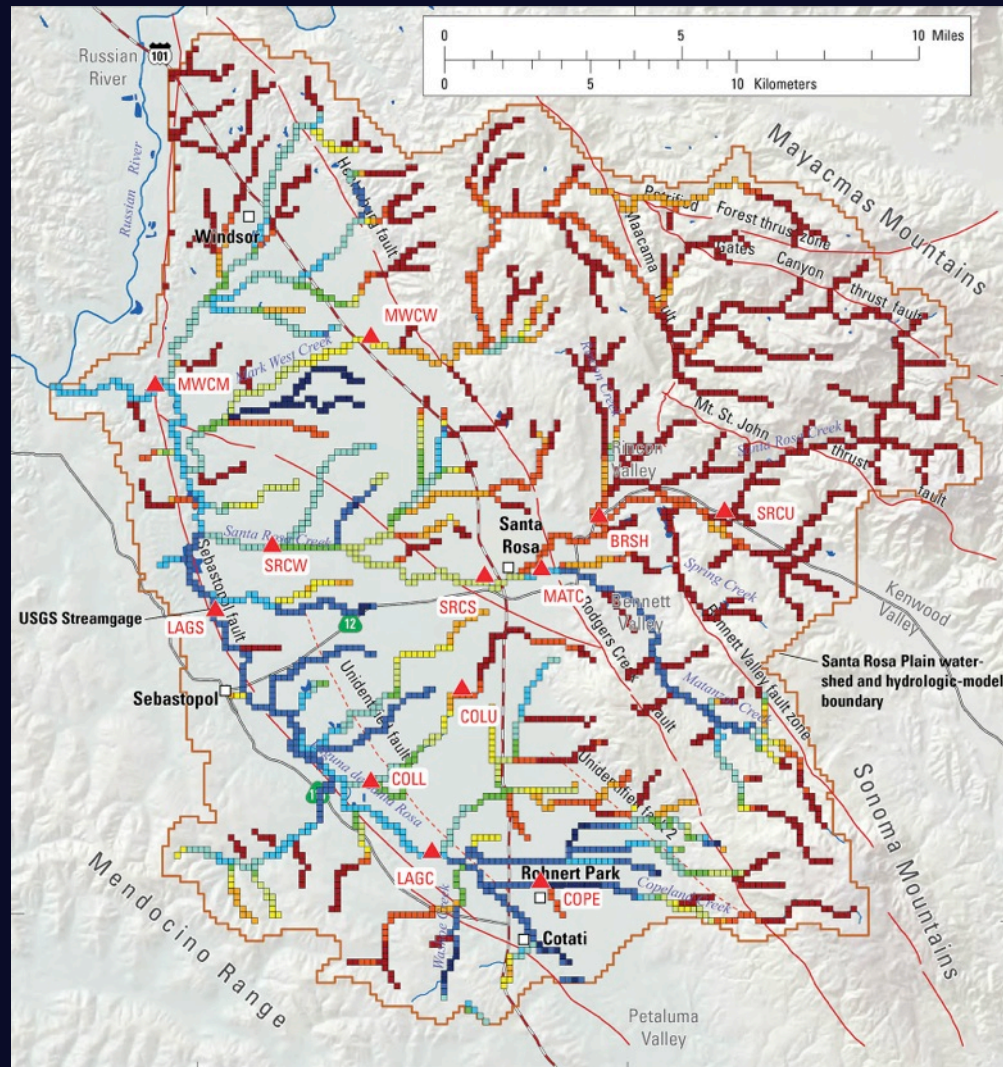


Streamflow depletion

Groundwater and surface water interact, 1-way or 2-way

Example: Santa Rosa Plain, Sonoma Co. WA

Modeling was used to estimate changes in streamflow with climate change, etc.



Thank you!
Questions?

Contact Steve Phillips for more information:
sphillip@usgs.gov 916-278-3002