



Hydrologic and Geochemical Characterization of the Santa Rosa Plain Watershed

Tracy Nishikawa

Prepared in cooperation with the Sonoma County Water Agency

Hydrologic and Geochemical Characterization of the Santa Rosa Plain Watershed, Sonoma County, California



Scientific Investigations Report 2013–5118

Study Objectives

- **Develop an updated assessment of the hydrology and geochemistry of the SRP.**
- **Develop a coupled watershed/groundwater-flow model for SRPW.**
- **Evaluate the hydrologic impacts of alternative groundwater management strategies on the basin.**

Study Scope

- **Regional hydrogeology**
- **Surface-water hydrology**
- **Groundwater hydrology**
 - **Aquifer characteristics**
 - **Recharge/discharge**
 - **Levels and movement**
- **Geochemistry**
 - **Quality**
 - **Source**
 - **Age**

USGS Personnel

- **Database/GIS**
 - Andy Morita
 - Donna Knifong
- **Data Collection/ Interpretation**
 - Loren Metzger
 - Chris Farrar
- **Geologic Modeling**
 - Victoria Langenheim
 - Robert McLaughlin
 - Robert Jachens
- **Water Quality**
 - Peter Martin
 - Jill Densmore
 - Loren Metzger
 - Roy Schroeder
- **Lithologic Modeling**
 - Don Sweetkind
 - Emily Taylor
- **Surface Water**
 - Joe Hevesi
- **Groundwater**
 - Peter Martin
 - Don Sweetkind

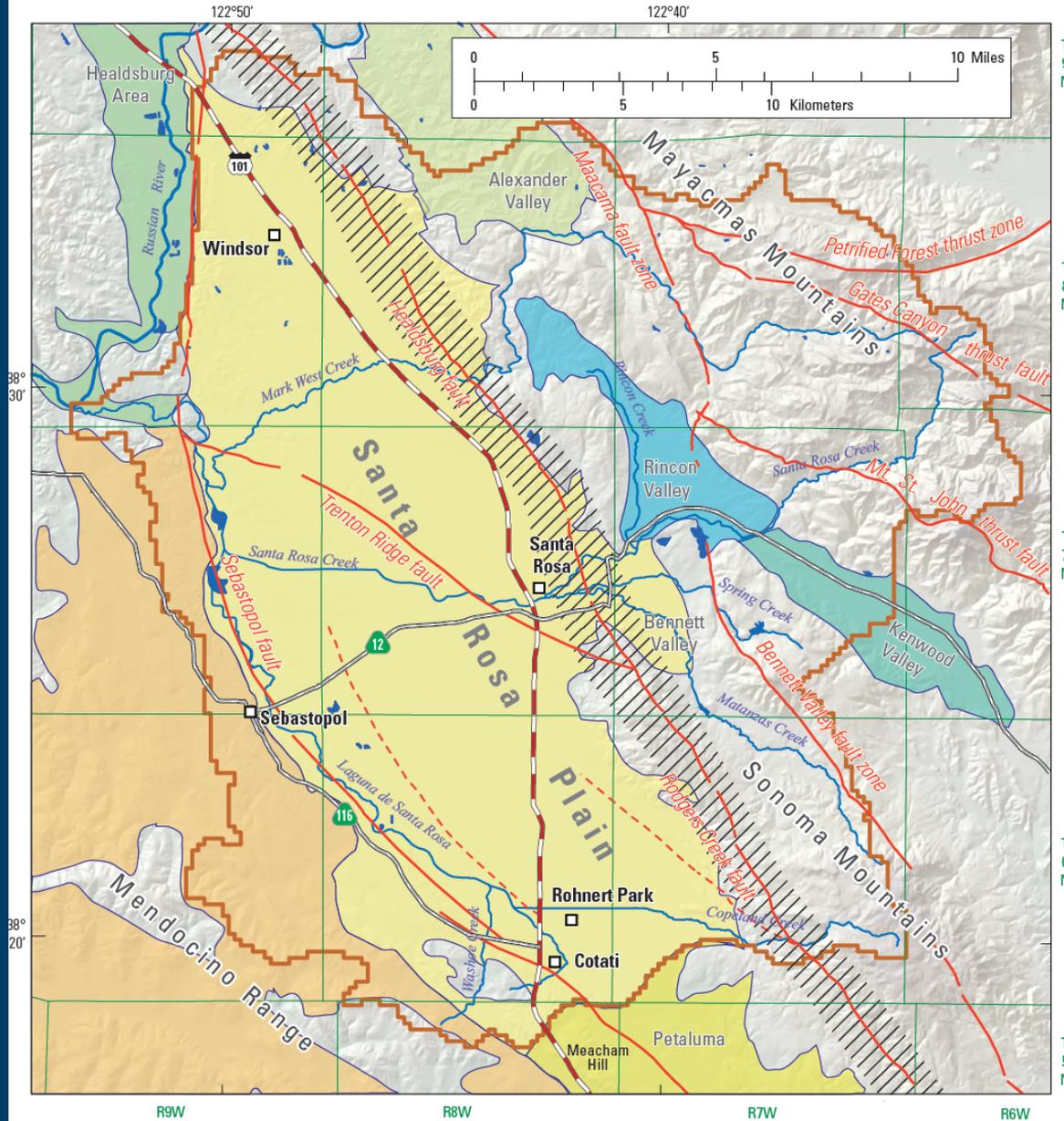
Cooperative Study

- USGS/CA Water Science Center
- Stakeholders
 - **Sonoma County Water Agency**
 - City of Santa Rosa
 - City of Sebastopol
 - City of Rohnert Park
 - City of Cotati
 - Town of Windsor
 - Cal-Am Water
 - Sonoma County

Report Outline

- **Chapter A: Introduction**
- **Chapter B: Hydrology and Hydrogeology**
- **Chapter C: Water Quality**
- **Chapter D: Conceptual Model**

Chapter A: Introduction



EXPLANATION

Groundwater basin or subbasins

- Wilson Grove Formation Highlands
- Santa Rosa Plain
- Rincon Valley
- Healdsburg Area
- Alexander Valley
- Kenwood Valley
- Petaluma

Santa Rosa Plain watershed boundary

Rodgers Creek fault zone

Fault

Inferred fault

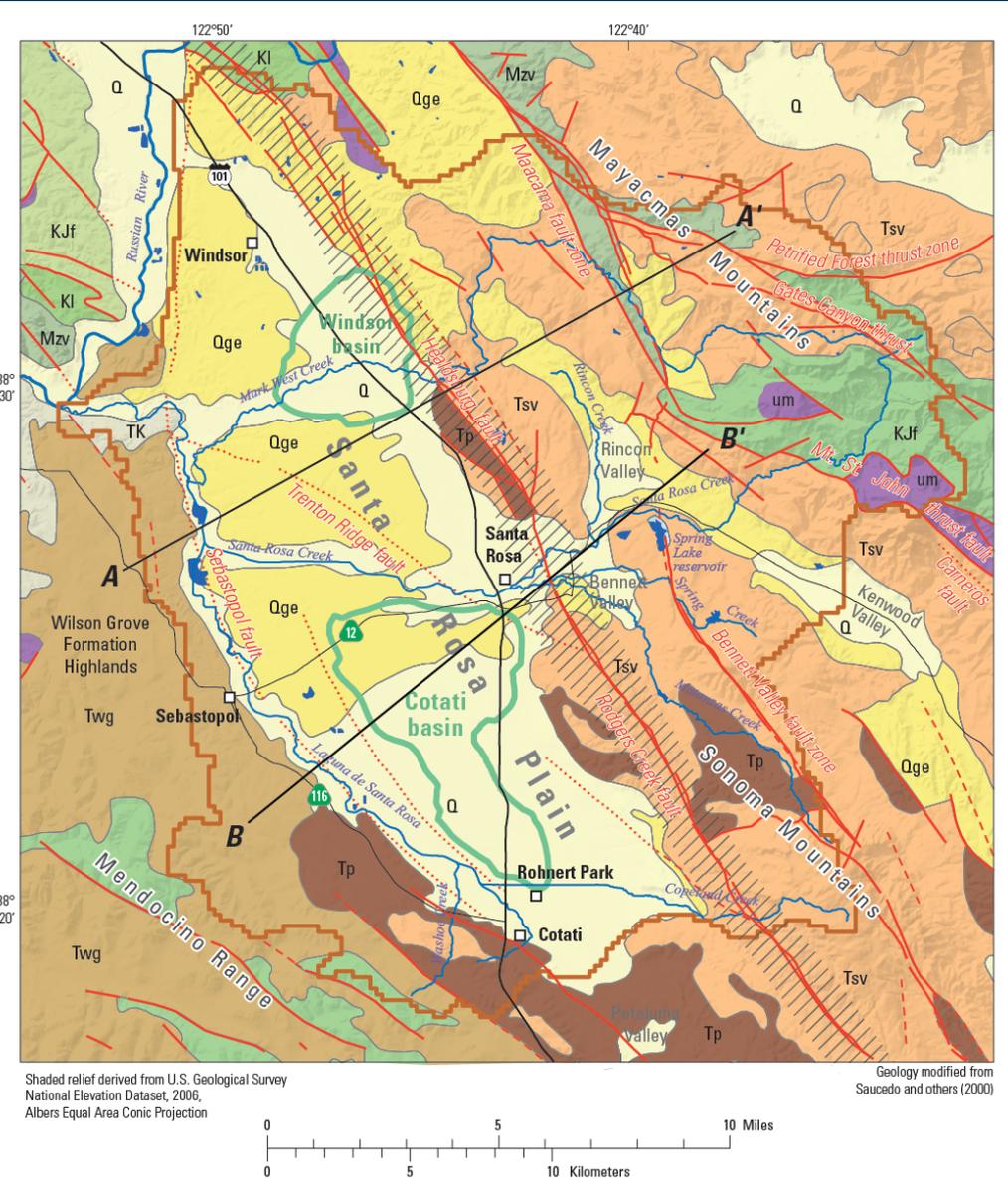


Previous Work

- **USGS-Cardwell (1958): Santa Rosa Valley**
- **CA DWR**
 - Ford (1975)
 - Herbst and others (1982)
 - Kadir and McGuire (1987)
- **USGS-Kulongoski (2010): Water quality**

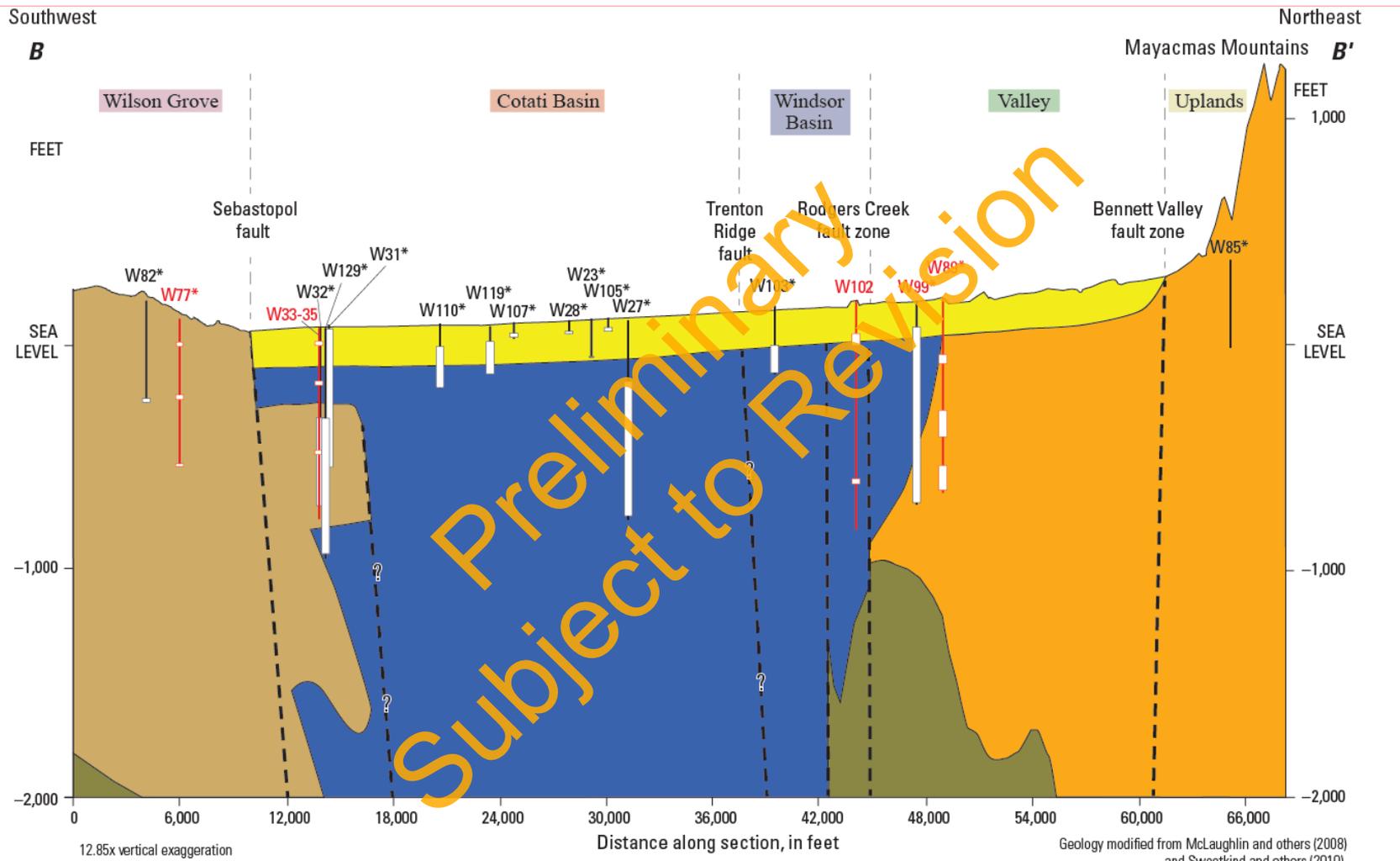
Chapter B: Hydrology and Hydrogeology

Stratigraphic Units and Faults



GEOLOGIC UNIT		EXPLANATION	
Cenozoic		Mesozoic	
<i>Sedimentary rocks</i>		<i>Sedimentary and metasedimentary rocks</i>	
Quaternary		Tertiary-Cretaceous	
Q	Recent alluvium, landslide, and sand dune deposits	TK	Coastal belt rocks
Plio-Pleistocene and Pliocene		Cretaceous	
Qge	Glen Ellen Formation	N	Lower Cretaceous marine
Pliocene and Miocene		KJf	Franciscan Complex
Twg	Wilson Grove Formation	Plutonic, metavolcanic, and mixed rocks	
Tp	Petaluma Formation	um	Ultramafic rocks
Volcanic rocks		Mzv	Volcanic and metavolcanic
Pliocene and Miocene			Water
Tsv	Sonoma Volcanics		

B-B' X-section

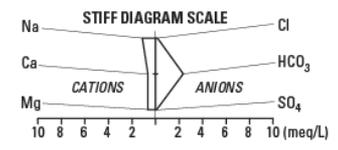


- Glen Ellen Formation
- Wilson Grove Formation
- Sonoma Volcanics
- Petaluma Formation
- Undifferentiated basement

Fault, sense of offset not shown

Reported Total dissolved solids (TDS) value

EXPLANATION

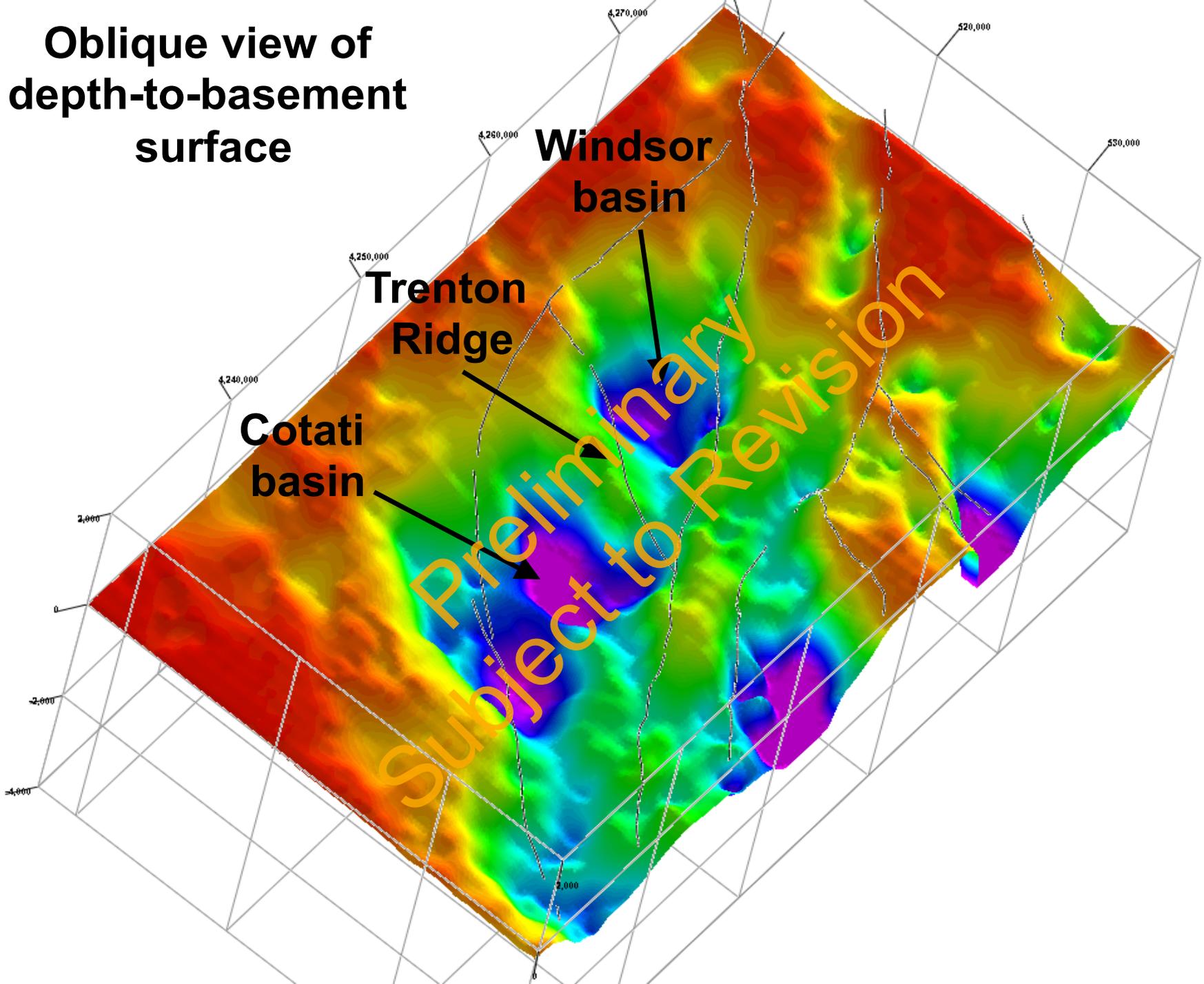


W82* Well map number (asterisk indicates well projected to section)

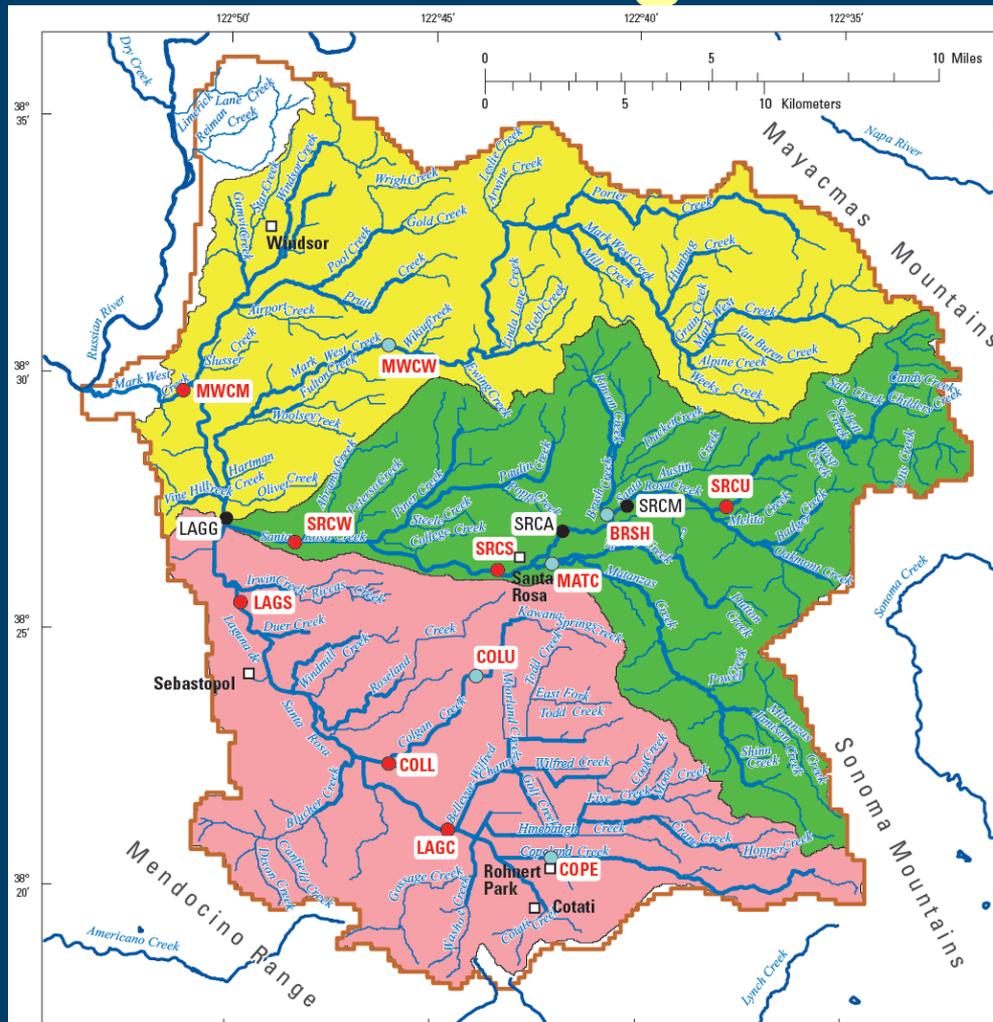
Well (black = production well, red = observation or discrete-depth sampled test well)

Well perforation (white box)

Oblique view of depth-to-basement surface



Surface Water and Gages



Surface-water subbasins

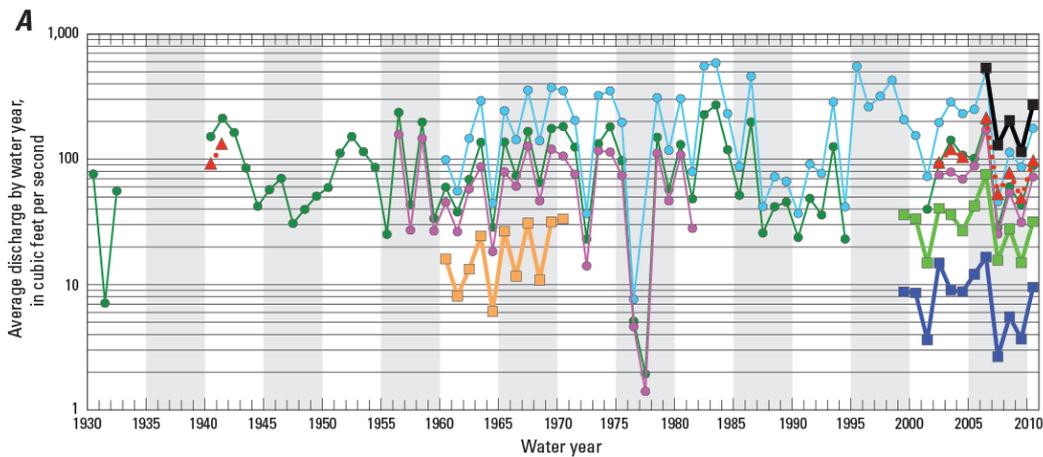
- Mark West Creek
- Santa Rosa Creek
- Laguna de Santa Rosa

EXPLANATION

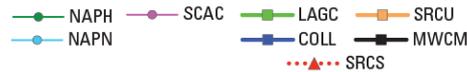
- Santa Rosa Plain watershed boundary
- Major streams
- Minor streams

- USGS stream gages
- USGS stream gages (stage only)
- USGS stream gages (seasonal)

Historic Streamflow

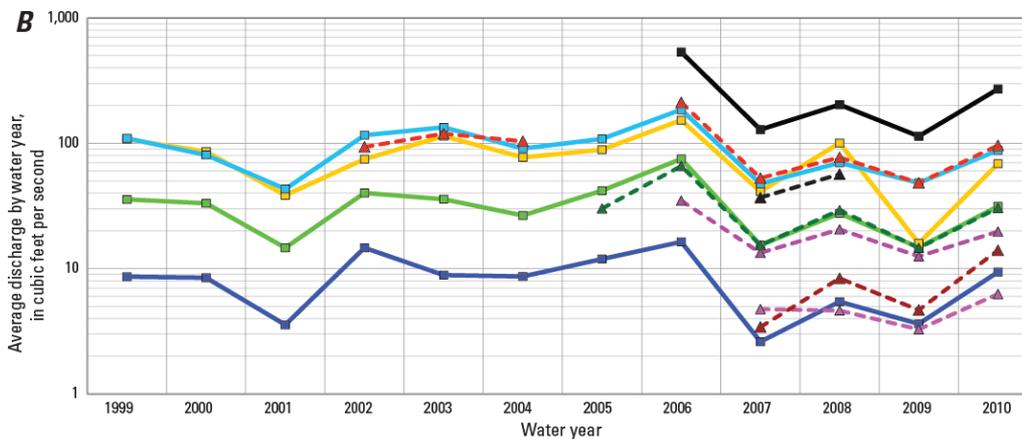


EXPLANATION



Note: Thin lines with circles indicate gages outside of Santa Rosa Plain watershed (SRPW) with continuous records; Thick lines with squares indicate gages inside SRPW with continuous records; Dotted lines with triangles indicate gages inside SRPW with seasonal (Oct-Apr) records only

See figure 7 for location of gages



EXPLANATION



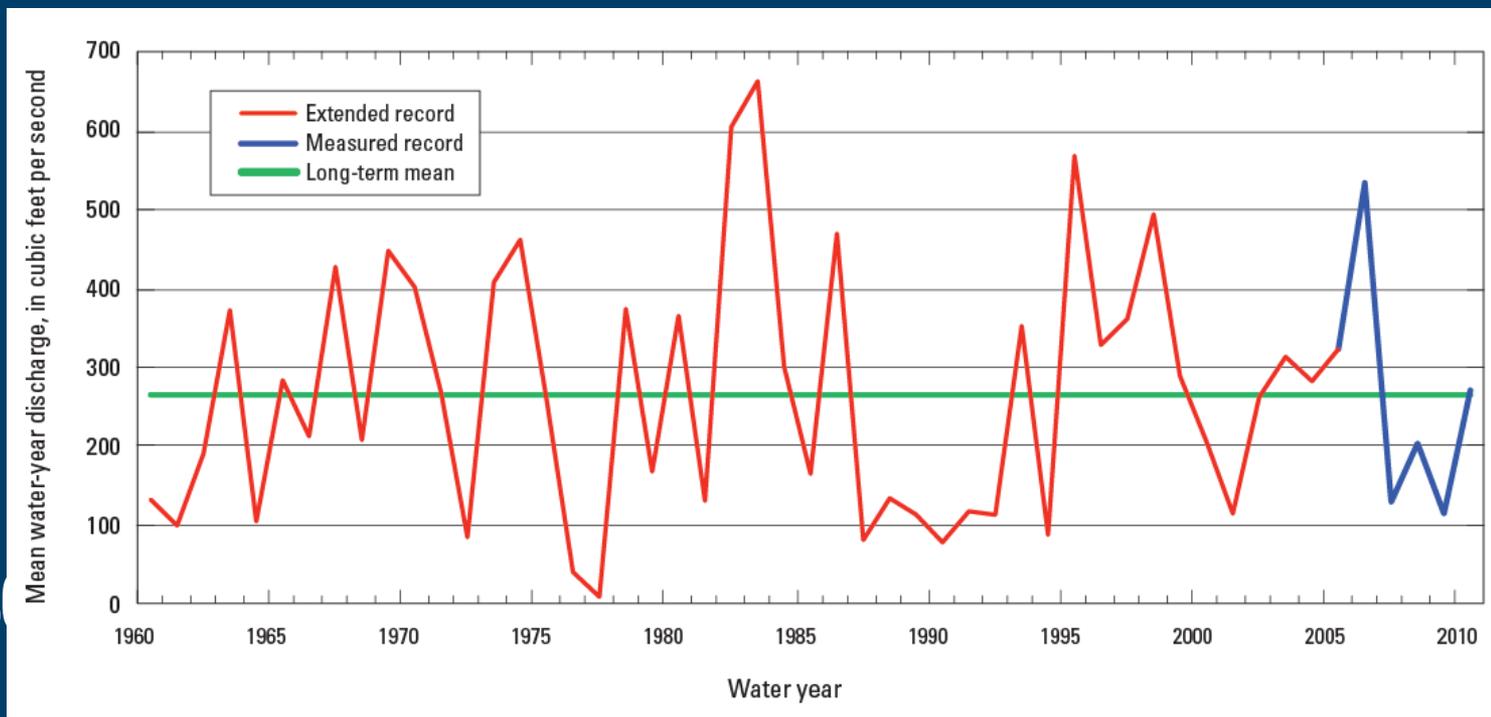
Note: Thick lines with squares indicate gages inside SRPW with continuous records; Dashed lines with triangles indicate gages inside SRPW with seasonal (Oct-Apr) records only

See figure 7 for location of gages



Mark West Creek Extended Data

- Record for MWCM gage is short
- Need longer record to calibrate model
- Used MOVE.1 w/ NAPN gage to extend MWCM record from 1960-2005



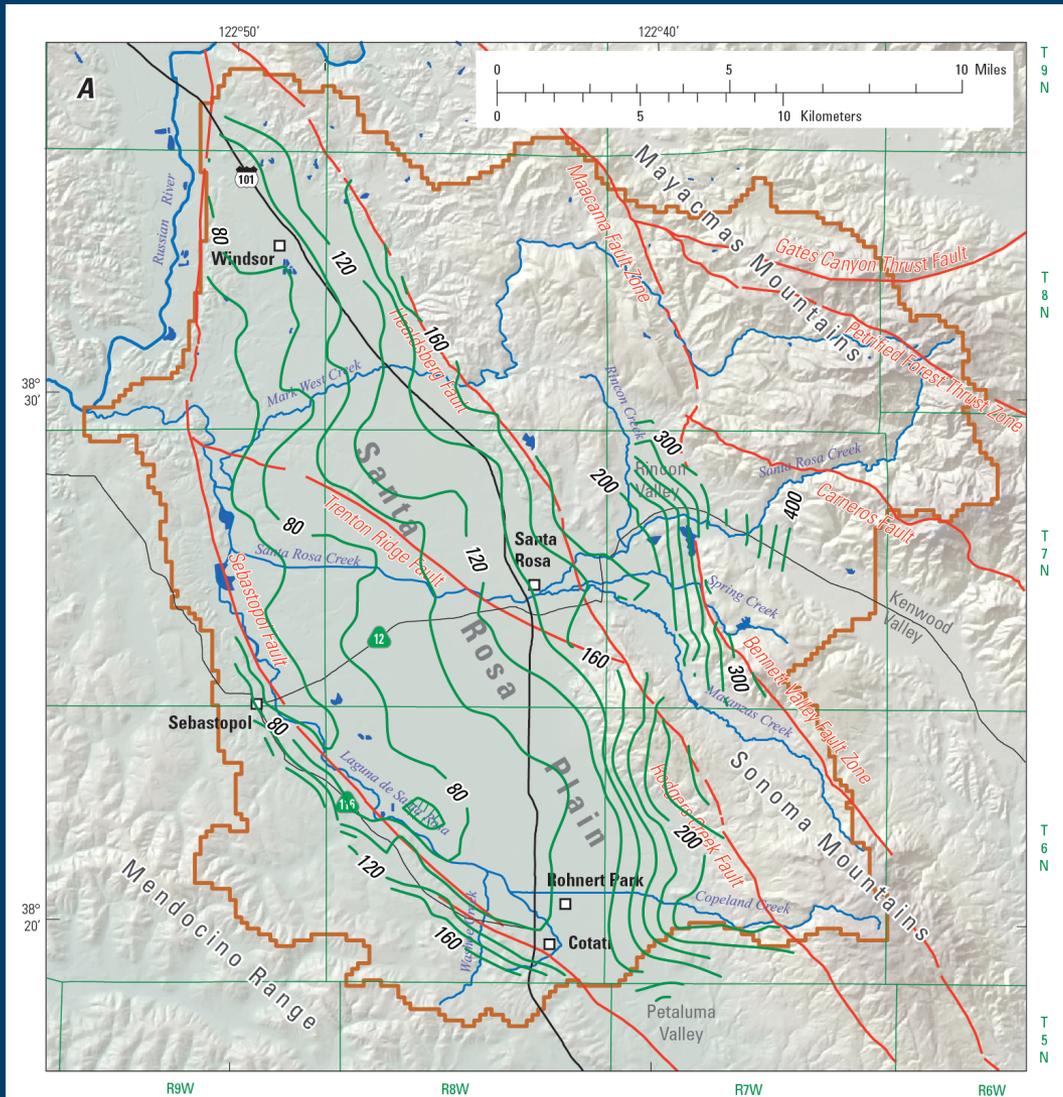
Groundwater Recharge

- **Primary**
 - Infiltration of precipitation
 - Infiltration from streams
- **Minor**
 - Groundwater underflow from neighboring groundwater basins/subbasins.
 - Septic tanks, leaky pipes, irrigation return flow, and frost-protection

Groundwater Discharge

- **Primary**
 - **Baseflow**
 - **Pumping (1976-2010)**
 - **Municipal: 3,900 – 10,100 acre-ft/yr (reported)**
 - **Agriculture: 8,900 – 46,600 acre-ft/yr (est)**
 - **Domestic: 11,000 – 23,200 acre-ft/yr (est)**
 - **ET**
- **Minor**
 - **Springs**
 - **Underflow**

1951 Water Levels

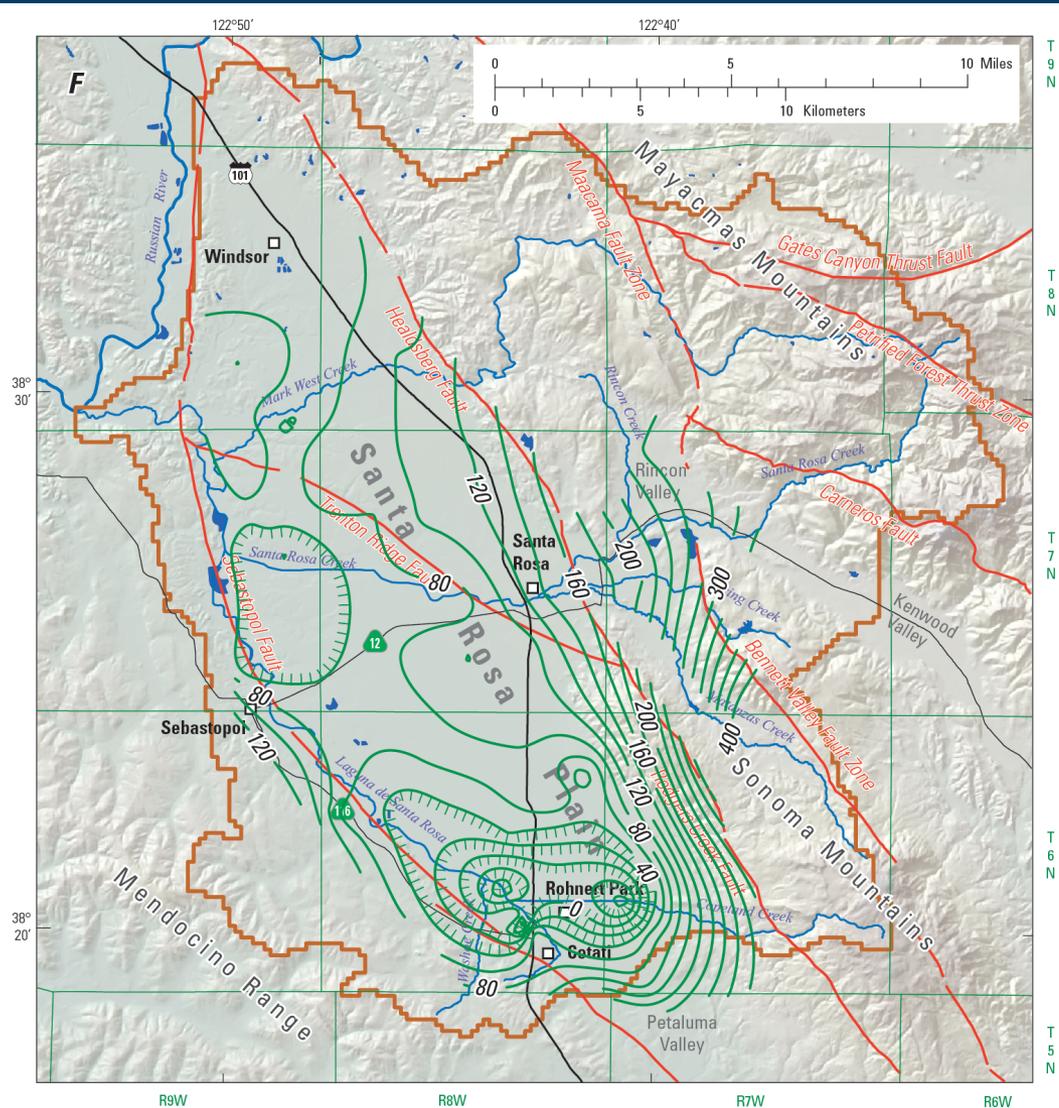


Base from U.S. Geological Survey digital data, 1:1,000,000, downloaded 2003 State Plane Projection, Figzone 402. Shaded relief base from 1:250,000 scale Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

Line of equal water-level altitude, Spring 1951. Contour interval is 20 feet. Hatchures indicate depressions. Modified from Cardwell, 1958



Fall 1990 Water Levels

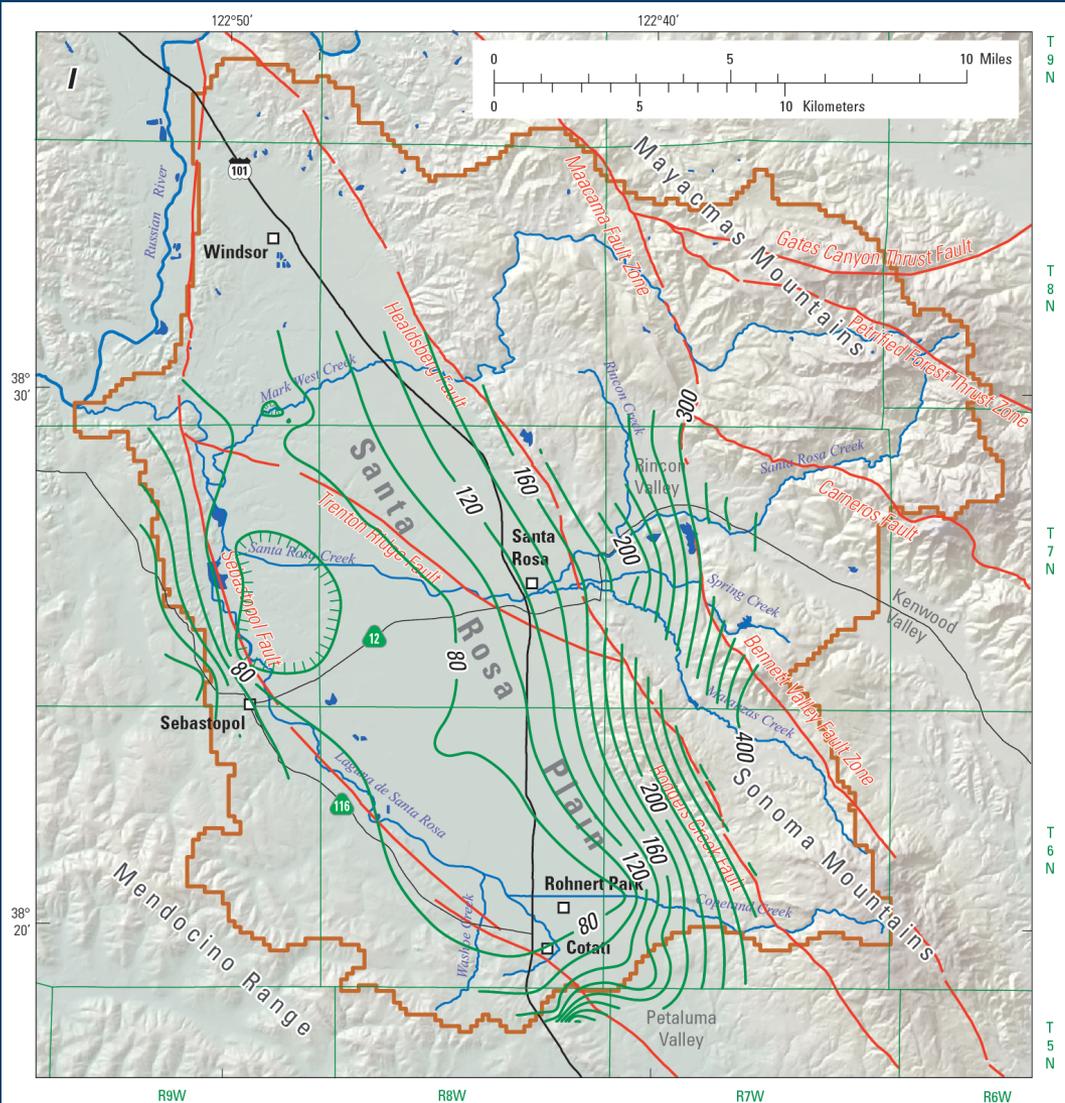


Base from U.S. Geological Survey digital data, 1:1,000,000, downloaded 2003 State Plane Projection, Fipzone 402. Shaded relief base from 1:250,000 scale Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon

— Line of equal water-level altitude, Fall 1990.
 Contour interval is 20 feet. Hatchures indicate depressions



Spring 2007 Water Levels

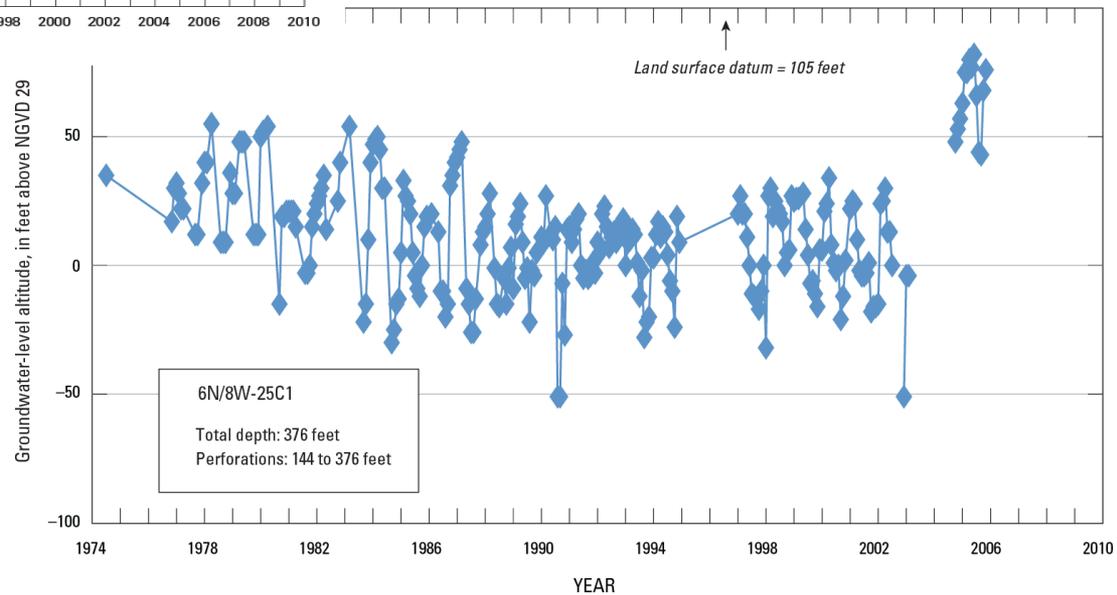
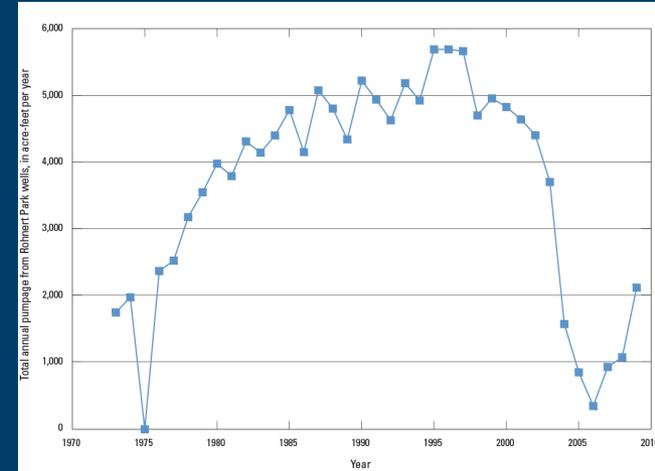
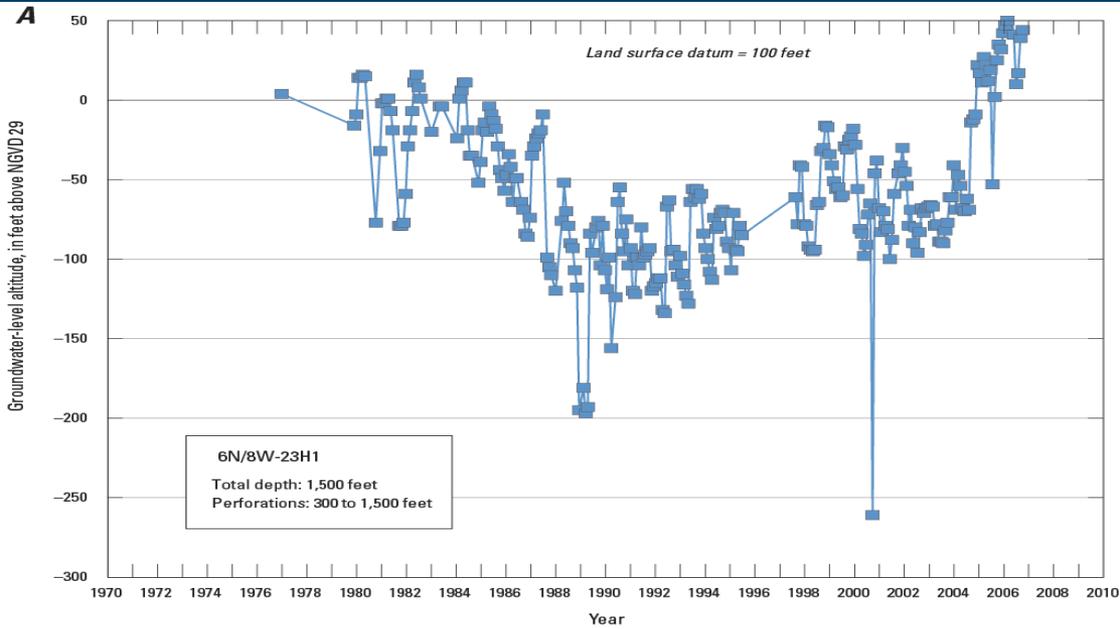


Base from U.S. Geological Survey digital data, 1:1,000,000, downloaded 2003 State Plane Projection, Fzzone 402. Shaded relief base from 1:250,000 scale Digital Elevation Model; sun illumination from northwest at 30 degrees above horizon.

— Line of equal water-level altitude, Spring 2007.
 Contour interval is 20 feet. Hatchures indicate depressions



Cotati Basin SU Hydrographs



Geohydrology Summary

- **4 primary water-bearing formations**
 - **Glen Ellen+Quaternary**
 - **Wilson Grove**
 - **Petaluma**
 - **Sonoma Volcanics**
- **Variable permeability**
- **Gravity: 2 deep basins (Windsor and Cotati)**
- **Complex faulting**

Surface Water Summary

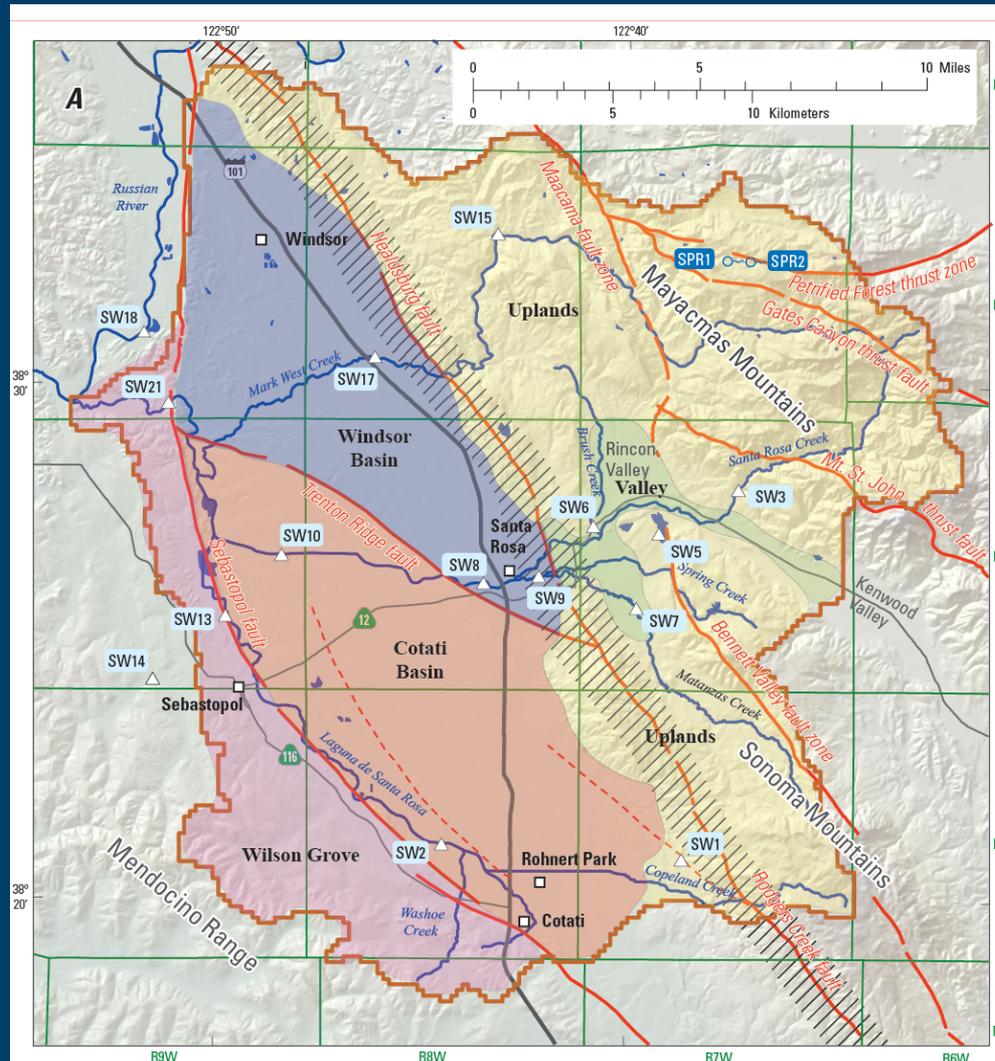
- 15 gages w/ short records
- Highly variable flow
- Rapid response to precipitation
- Groundwater important for summer flow

Groundwater Summary

- Water contained in all 4 formations
- Precipitation primary source of recharge
- Primary discharge:
 - Pumping
 - ET
 - Baseflow
- Flows east to west
- Creeks gain water
- Water levels declined due to pumping and have partially recovered

Chapter C: Water Quality

Surface Water Sites



Shaded relief derived from U.S. Geological Survey National Elevation Dataset, 2006, Albers Equal Area Conic Projection

EXPLANATION

Groundwater storage units

- Cotati Basin
- Windsor Basin
- Wilson Grove
- Upland
- Valley



Rodgers Creek fault zone



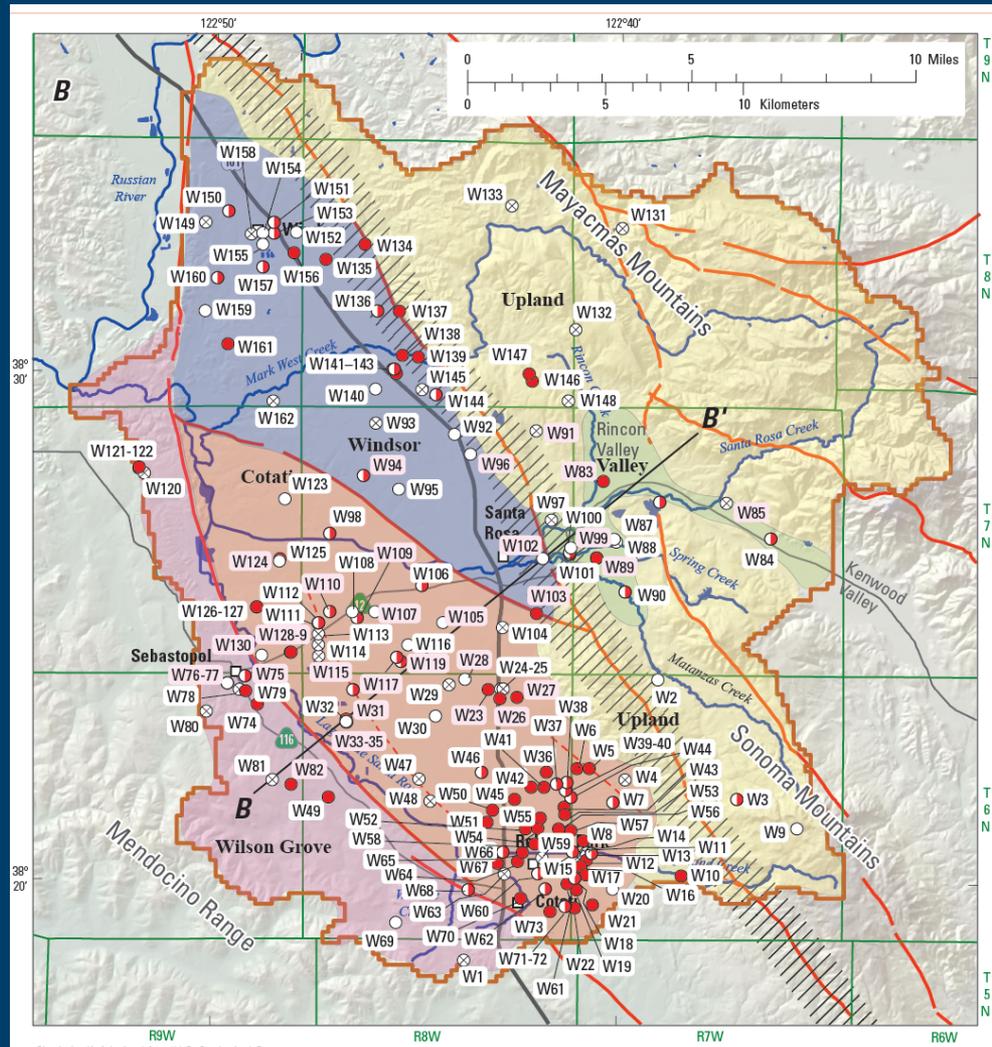
Inferred fault

SPR2 ○ Spring

SW4 △ Surface-water site



Groundwater Sites



Shaded relief derived from U.S. Geological Survey National Elevation Dataset, 2006, Albers Equal Area Conic Projection

EXPLANATION

- | | | | |
|----------------------------------|--------------------------|---|--------------------------------|
| Groundwater storage units | Rodgers Creek fault zone | Well perforated interval | W82 Well used for section B-B' |
| Cotati Basin | Inferred fault | Shallow (0' to 150' below land surface datum) | |
| Valley | Line of section | Mixed | |
| Windsor Basin | | Deep (greater than 150') | |
| Wilson Grove | | Construction unknown | |
| Upland | | | |



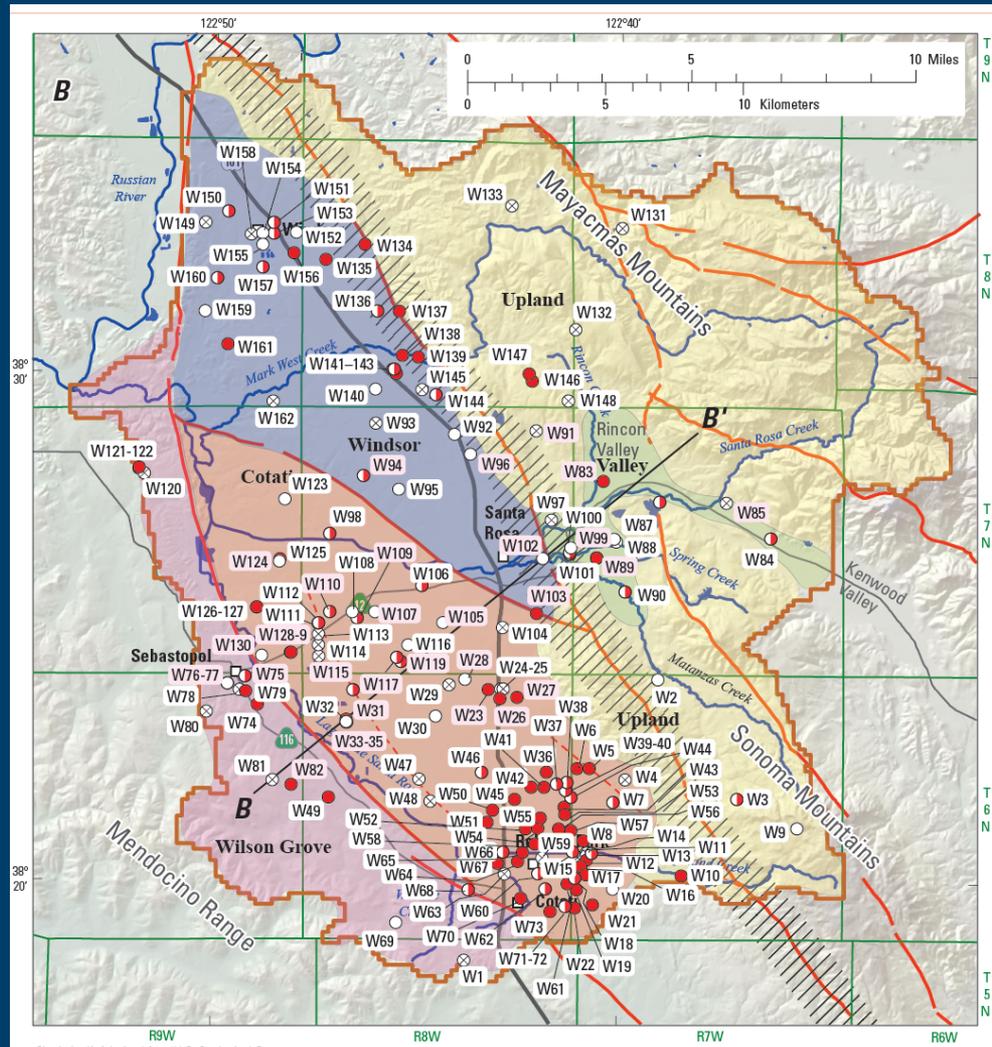
Data Collection Efforts

- **Historic data collection**
 - **Surface water intermittent (CDWR and USGS)**
 - **Groundwater (CDWR, CDPH, USGS)**
- **Recent data collection**
 - **USGS**
 - **Consultants**

Water-Quality Data

- **Major ions**
 - **Cations (positively charged)**
 - Sodium (Na)
 - Calcium (Ca)
 - Magnesium (Mg)
 - **Anions (negatively charged)**
 - Chloride (Cl)
 - Bicarbonate (HCO_3)
 - Sulfate (SO_4)
- **Constituents of potential concern**
- **Stable isotopes of water (^{18}O and ^2H)**
- **Tritium and carbon-14**

Groundwater Sites



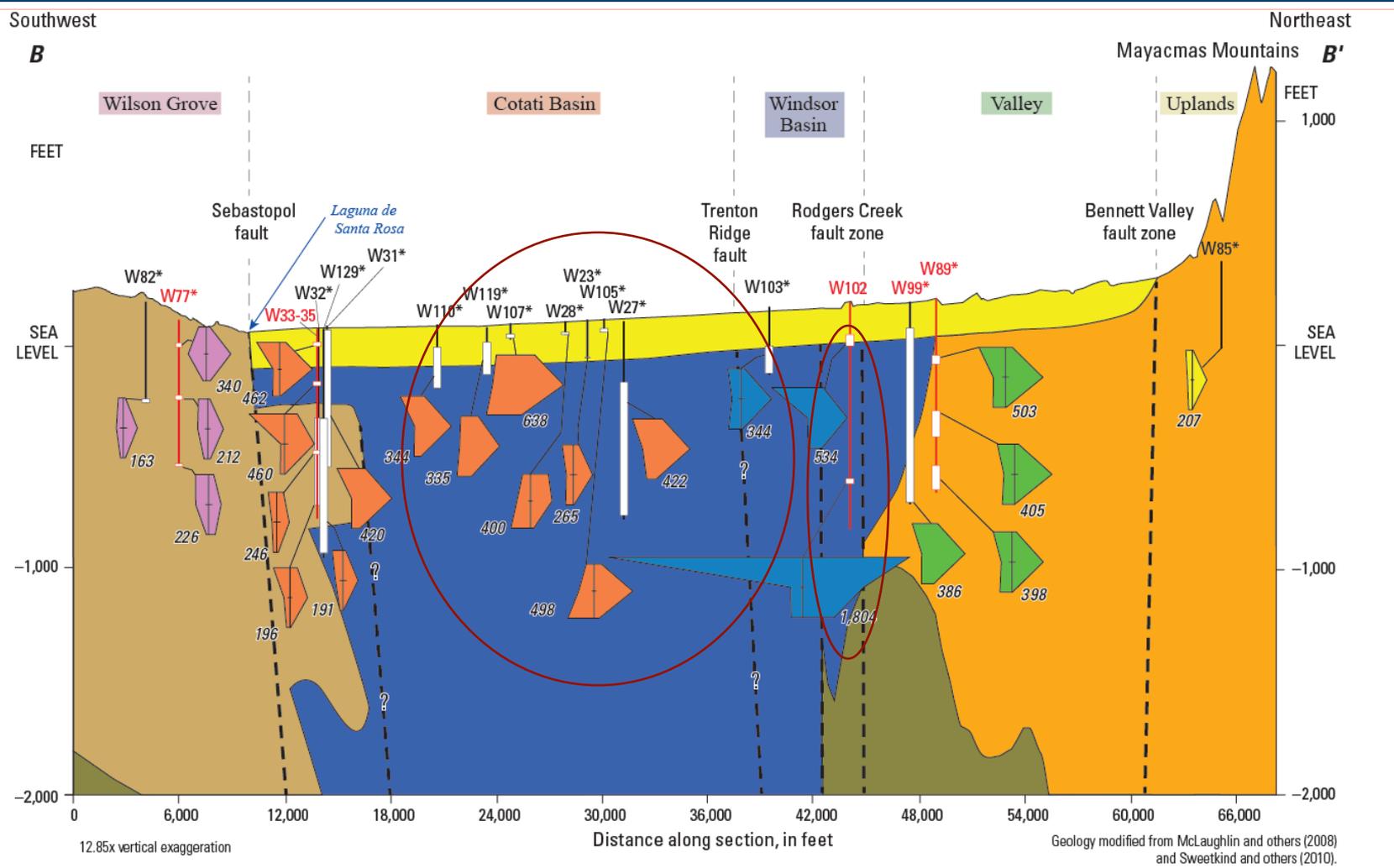
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EXPLANATION

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| Valley | Line of section | Mixed | |
| Windsor Basin | | Deep (greater than 150') | |
| Wilson Grove | | Construction unknown | |
| Upland | | | |



Well W102 and Flow Across RCFZ

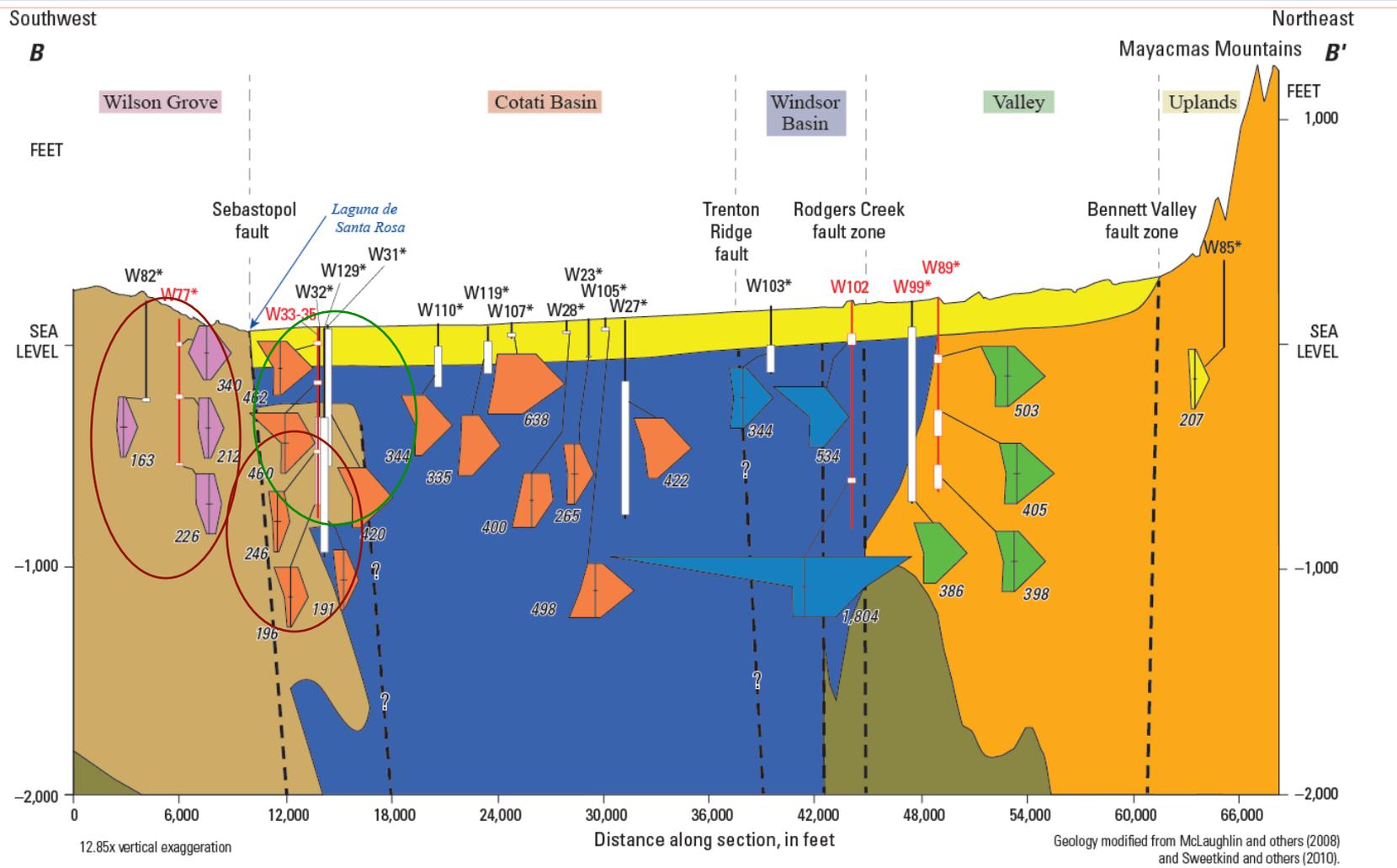


EXPLANATION

Glen Ellen Formation	Petaluma Formation	Fault, sense of offset not shown	STIFF DIAGRAM SCALE	W82* Well map number (asterisk indicates well projected to section)
Wilson Grove Formation	Undifferentiated basement	Reported Total dissolved solids (TDS) value	Na Cl	Well (black = production well, red = observation or discrete-depth sampled test well)
Sonoma Volcanics			Ca HCO₃	Well perforation (white box)
			Mg SO₄	

10 8 6 4 2 2 4 6 8 10 (meq/L)

Flow Across Sebastopol Fault

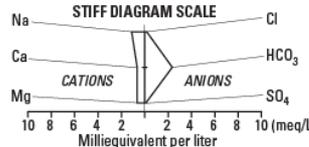


- Glen Ellen Formation
- Wilson Grove Formation
- Sonoma Volcanics
- Petaluma Formation
- Undifferentiated basement

EXPLANATION

Fault, sense of offset not shown

Reported Total dissolved solids (TDS) value



W82* Well map number (asterisk indicates well projected to section)

Well (black = production well, red = observation or discrete-depth sampled test well)

Well perforation (white box)

Constituents of Potential Concern

- Chloride (Cl): 2% > 250 mg/L
- Dissolved solids (DS): 13% > 500 mg/L
- Nitrate (NO₃): 2% > 10 mg/L
- Arsenic (As): 12% > 10 µg/L
- Boron (B): 7% > 1,000 µg/L
- Iron (Fe): 43% > 300 µg/L
- Manganese (Mn): 73% > 50 µg/L

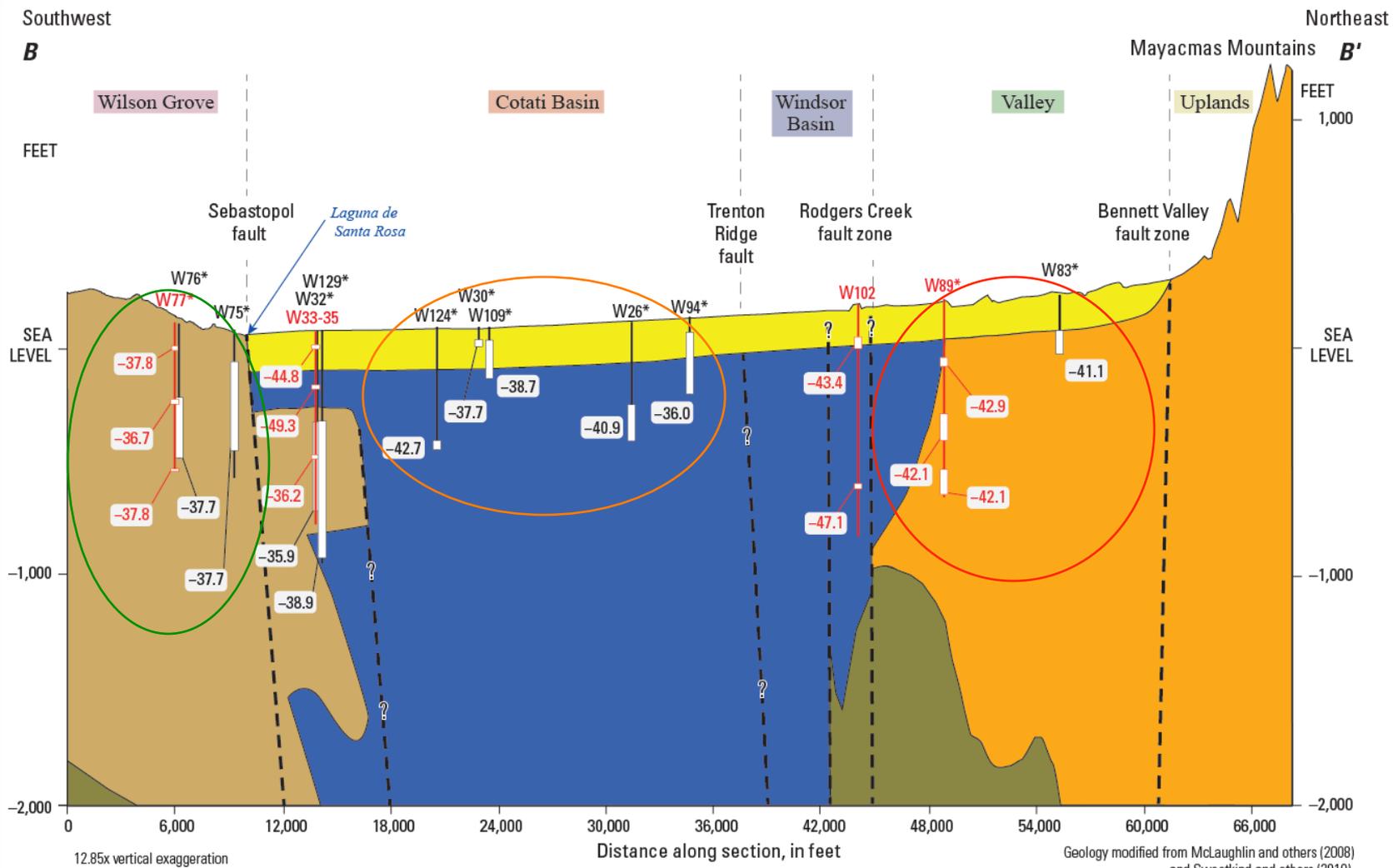
Source and Age of Water

- oxygen-18 (^{18}O) and deuterium (^2H)
- tritium (^3H)
- carbon-14 (^{14}C)

Stable Isotopes

- ^{18}O and ^2H stable isotopes of O and H
 - Infer source and evaporative history of water
 - Precip condensed at higher altitudes and cooler temps are isotopically lighter (more negative)
- Samples collected in fall 2008 and spring 2009 from 15 surface-water sites
- Samples collected from 32 wells

Stable Isotopes- B-B'



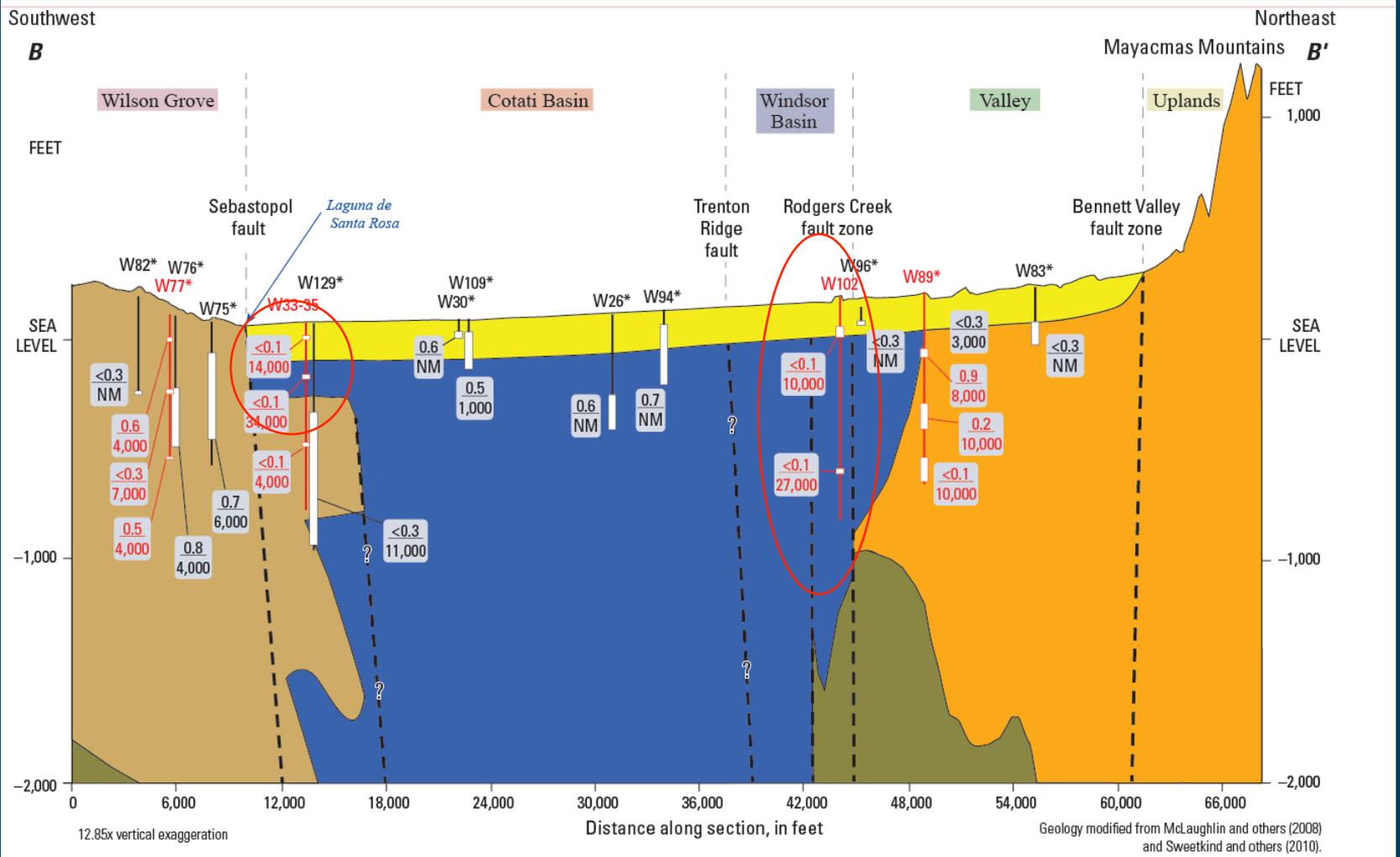
EXPLANATION

- | | | | | |
|------------------------|---------------------------|----------------------------------|-----------------------|---|
| Glen Ellen Formation | Petaluma Formation | Fault, sense of offset not shown | Deuterium, in per mil | Well map number (asterisk indicates well projected to section) |
| Wilson Grove Formation | Undifferentiated basement | | | Well (black = production well, red = observation or create-depth sampled test well) |
| Sonoma Volcanics | | | | Well perforation (white box) |

Age Dating

- Collected tritium (^3H) and carbon-14 (^{14}C)
 - 35 ^3H samples from 30 wells
 - 16 ^{14}C samples from 11 wells
- ^3H
 - Natural and anthropogenic
 - 12.32 yr half life
 - Spike in ^3H from nuclear testing in 1952-62
 - Tracer of modern water
- ^{14}C
 - 5,730 yr half life
 - Tracer of older water

Extreme Ages



EXPLANATION

- Glen Ellen Formation
- Wilson Grove Formation
- Sonoma Volcanics

- Petaluma Formation
- Undifferentiated basement

- Fault, sense of offset not shown

- <0.3 11,000
- Tritium, in tritium units (TU)/ uncorrected C-14 age, in years before present
- NM, not measured
- <, less than

- W82 — Well map number (asterisk indicates well projected to section)
- Well (black = production well, red = observation or discrete-depth sampled test well)
- Well perforation (white box)

Water-Quality Summary

- **Major Ions**
 - Limited vertical mixing between shallow and deep
 - Rodgers Creek fault zone and Sebastopol fault restrict flow
- **Stable Isotopes (recharge source)**
 - Light in uplands
 - Heavier in SRP
- **Age Dating**
 - Modern recharge in shallow wells
 - Vertical flow restricted by clays in GE and PF
 - ^{14}C indicate 1,000 to 34,000 year old water at depth

Chapter D: Conceptual Model

Data Gaps

- **Depth-dependent water-level and water-quality data**
- **Variability in some water-quality data cannot be explained using available data. Additional data collection is needed.**
- **Report (or improve tools to estimate) agricultural and domestic pumping.**

What's Next?

- **Coupled watershed/groundwater-flow model completed.**
 - **Model development and calibration**
 - **Estimated ag pumping methodology**
 - **Simulation results**
 - **Water budget**
 - **Recharge distributions**
 - **Streamflow**
 - **Effect of pumping on budget components**
- **Effects of potential climate change**
- **Report in USGS internal review**

Web Links

- **Report: <http://pubs.usgs.gov/sir/2013/5118/>**
- **CAWSC: <http://ca.water.usgs.gov/>**

Questions?

