2016 Sierra Valley Groundwater Study Workshop

Burkhard Bohm
Plumas Geo-Hydrology
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Sierra Valley Groundwater Management District

The groundwater studies

- Inventory of Sierra Valley Wells and Groundwater Quality Conditions
  - Published November 29, 2016
- Sierra Valley Aquifer Delineation and Groundwater Flow
  - Published December 27, 2016
- Forest Canopy interception study
  - Based on field experiments in the Blairsden area, 2005-06
  - See Appendix 3–2 of Upper Feather River IRWM plan update 2016 for full Study and appendices

Study Objectives

- To help facilitate an informed discussion about long-range water resources planning in the Feather River Basin (FRB)

- To identify unresolved questions based on field observations and monitoring data

Goals for Today's Presentation

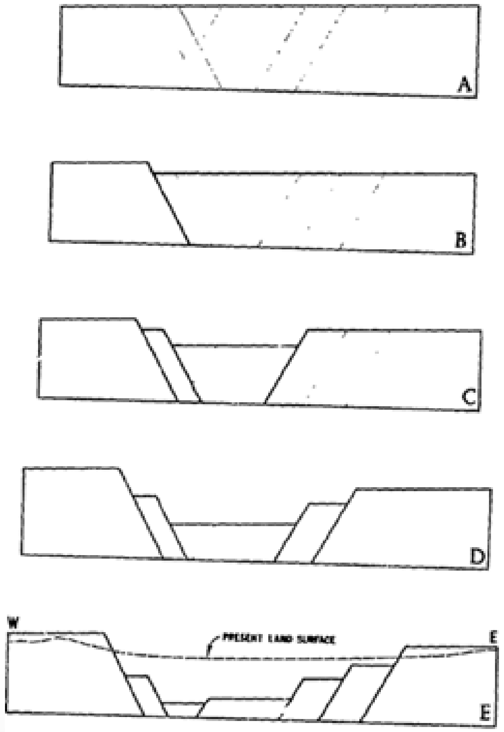
- **Overview of Study Results**
- **Addressing SVGMD's questions, where possible:**
  - Recharge areas – location, protection, maximization strategies?
  - Does backing up water in the NW corner (e.g., via Decker Dam) help recharge groundwater?
  - Groundwater banking – Good strategy here? Where?
  - Groundwater flow direction?
  - Effects of Grizzly Fault (and other faults) on groundwater? Do they isolate pumping areas?
  - Are there areas where shallow and deep aquifers mix? If so, where?
  - Do the studies indicate areas that should be managed with different strategies? If so…
    - Recommended water budgets by management area?
    - Are there sub-areas where it would not impact GW as much to have additional production wells and other areas where no more production wells should be added?
  - What impact do overgrown forests have on groundwater recharge in Sierra Valley?

Outline of Presentation

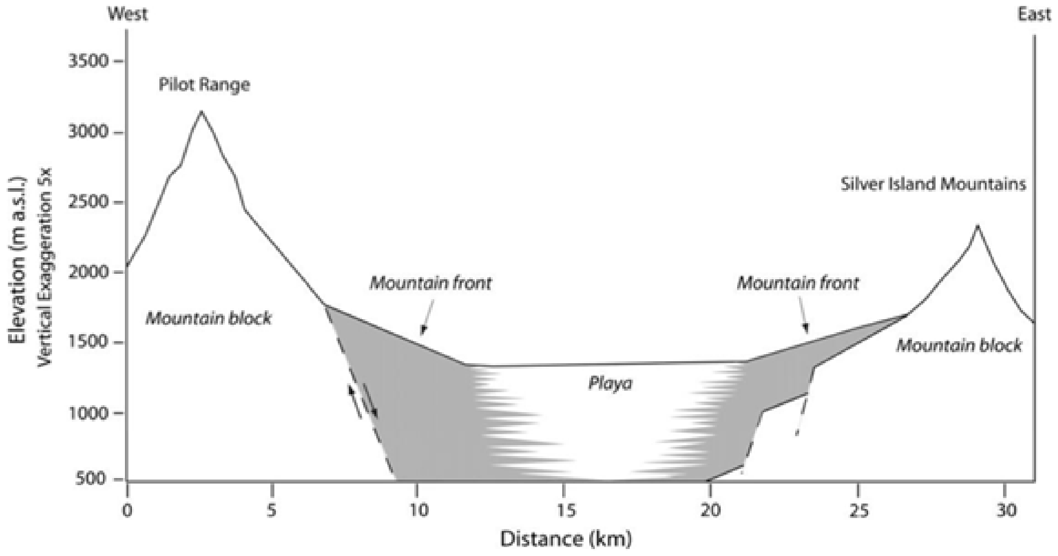
- Sierra Valley Basin Geologic Setting
- GW Recharge and GW Flow Systems
- Sierra Valley Well Inventory
- Water Quality Inventory
- Conclusions
- Forest Water Balance
- Technical Discussion

THE SIERRA VALLEY BASIN GEOLOGIC SETTING

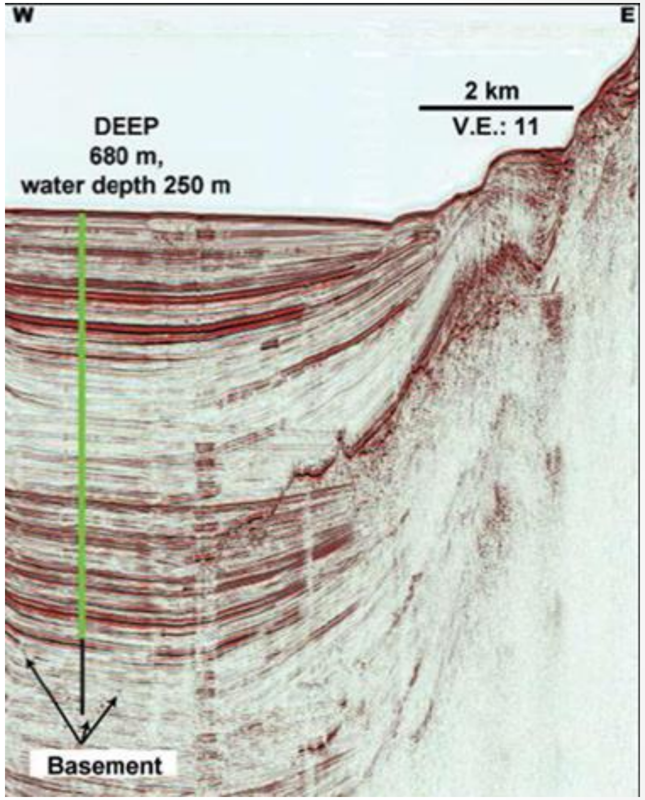
The Evolution of a Fault Trough



Subsiding bedrock blocks



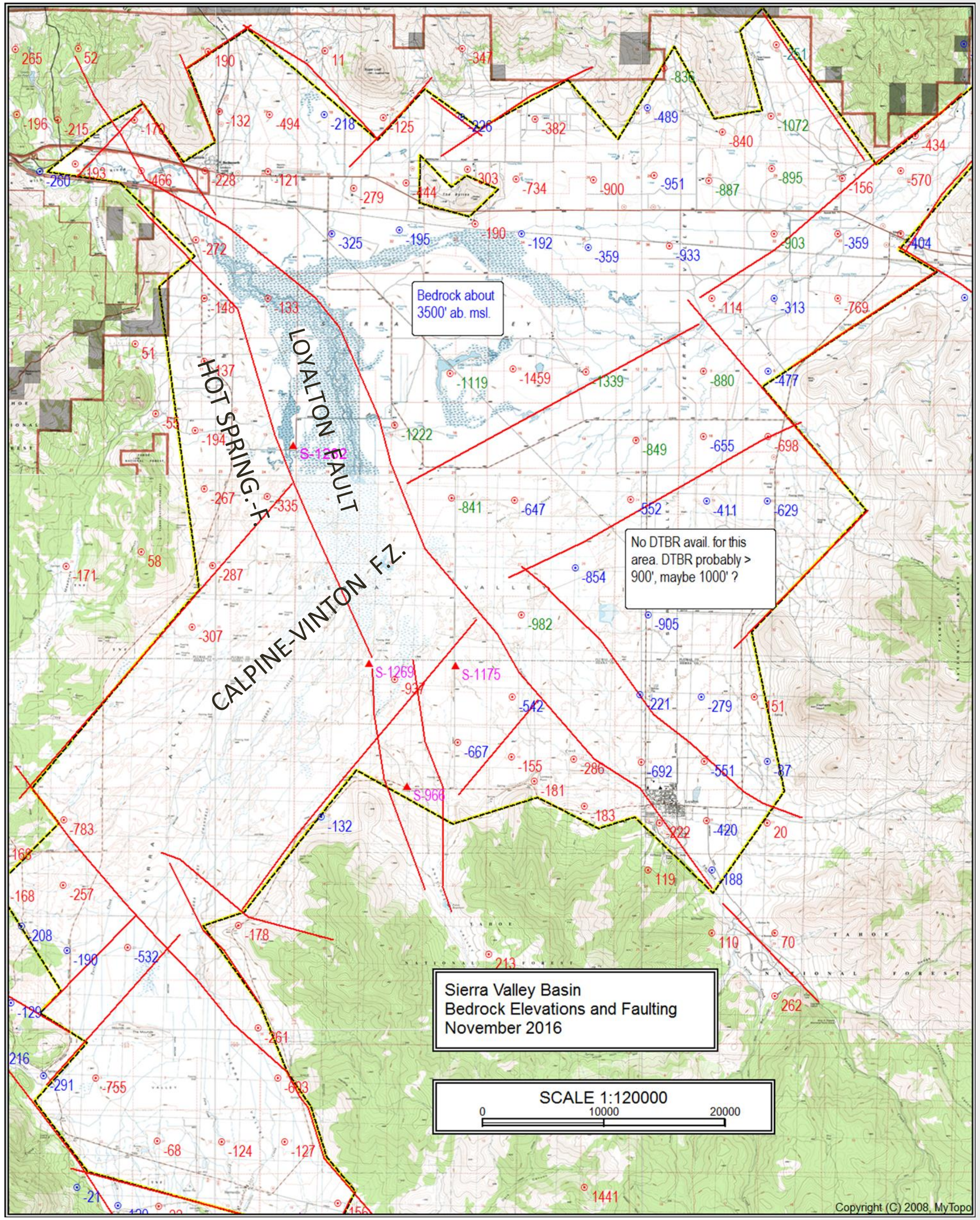
Layers of sediments deposited in fault trough



Thick clay lenses in central Valley; thinner lenses and wedges of coarser material on periphery

Aquifer Delineation:

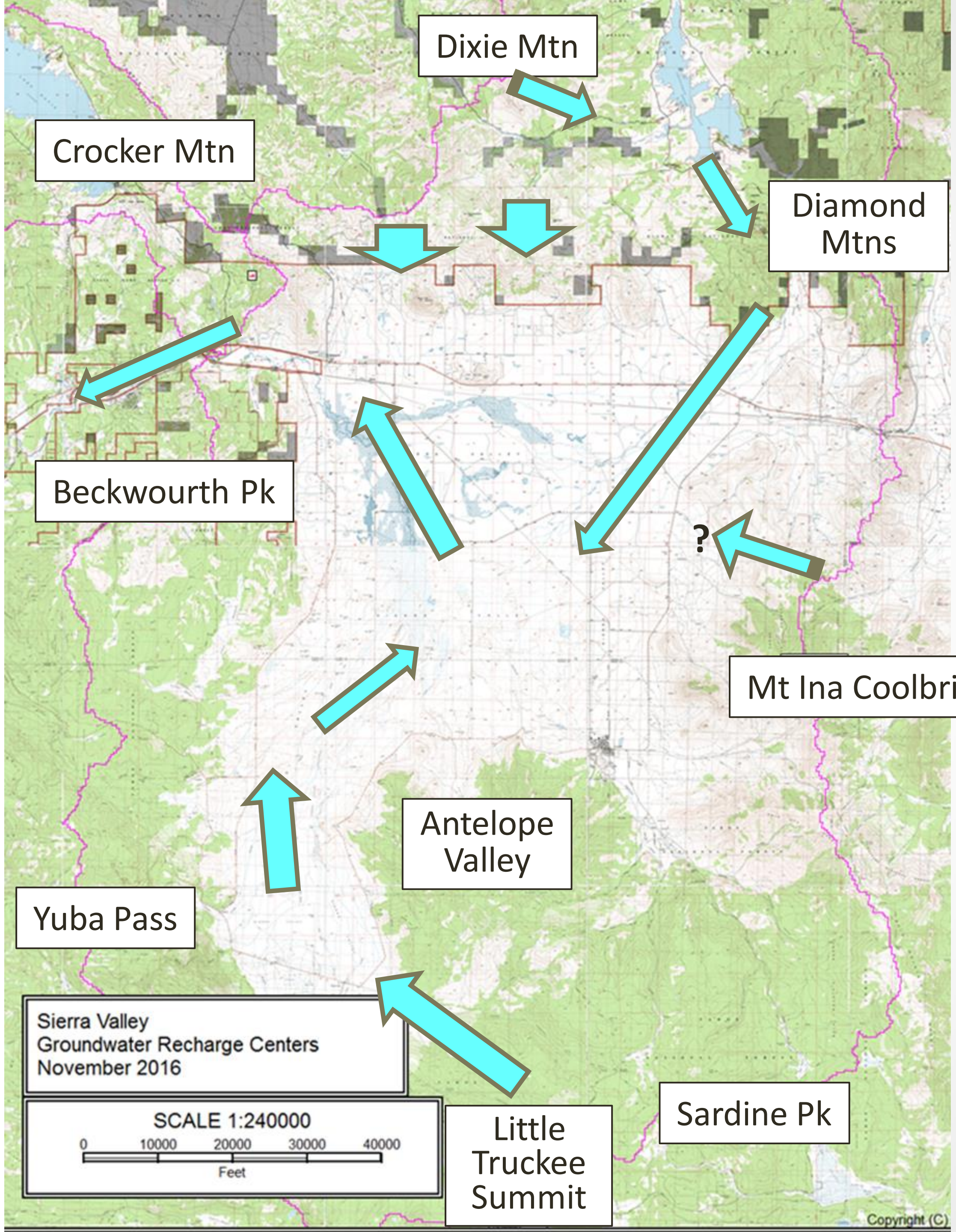
- Boundary faults define the basin periphery; act as “permeable barriers” to GW flow
- Northwest striking faults horizontal motion (“strike-slip”) can be partial barriers to GW flow
- Northeast faults vertical motion (“normal faults”) are more likely conduits for GW flow
- Fault intersections suited for localized groundwater storage (e.g., “The Cedars” test wells)
- Fault zones can be avenues for significant groundwater flow from uplands (e.g. “Calpine-Vinton Fault Zone” in SVB).



Bedrock elevations and faulting in the Sierra Valley Basin

GROUNDWATER RECHARGE
AND
GROUNDWATER FLOW SYSTEMS

Sierra Valley Basin Groundwater Recharge Centers



Purple line is watershed boundary

Arrows indicate groundwater flow

Sierra Valley Basin GW Recharge Centers

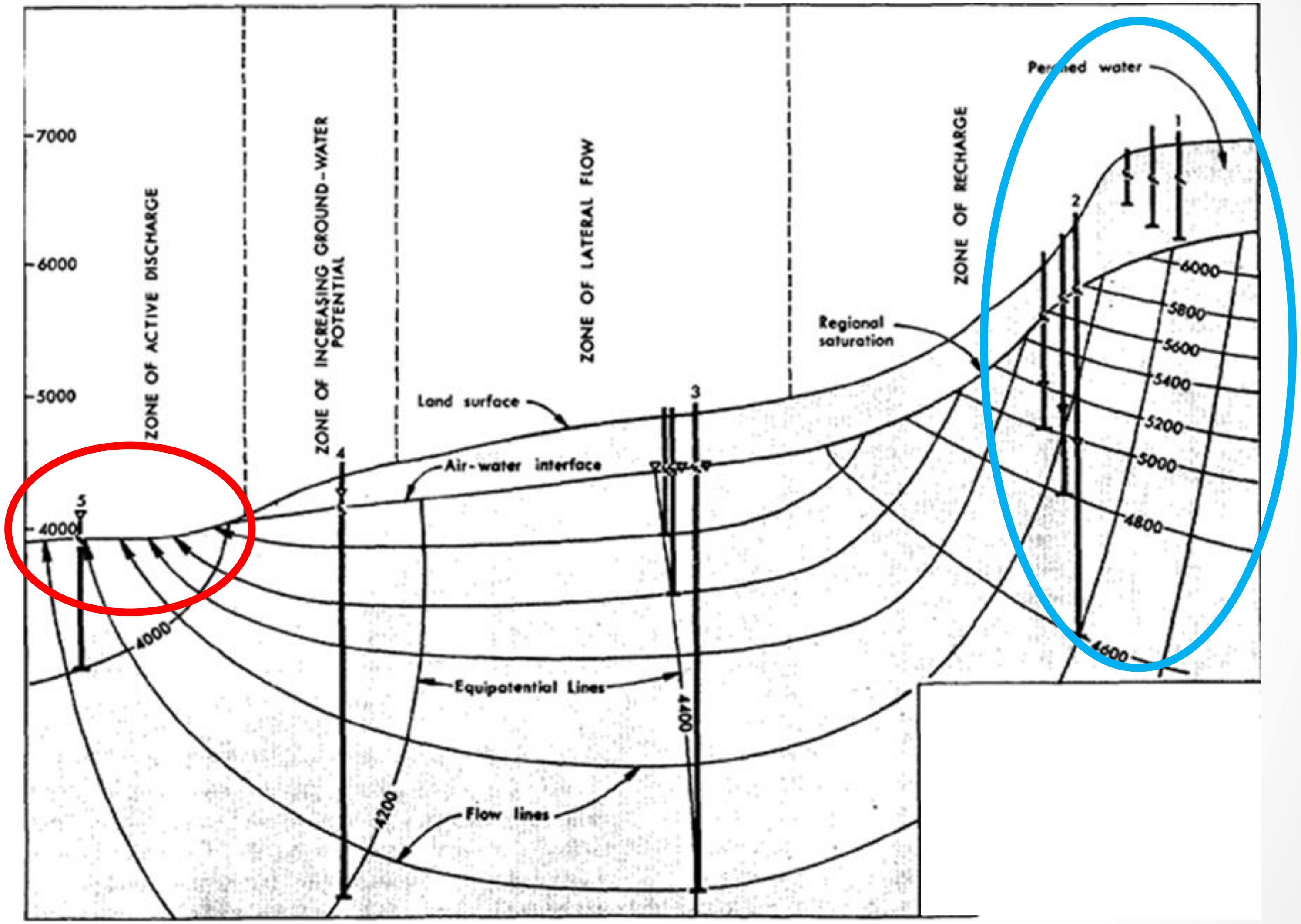
Recharge Center	Comments/Observations
Little Truckee Summit	Possibly the most significant GW recharge area for Sierra Valley
Yuba Pass area	Probably the 2nd-most significant GW recharge area for the Sierra Valley
Dixie Mountain	Probably the 3rd-most significant GW recharge area. Connection via Frenchman Sub-basin.
Diamond Mountains	More data collection is needed.
Beckwourth Peak	GW recharge significance is uncertain. Access needed to collect data from Carman Valley.
Sardine Peak	Including Lemon Canyon, Bear Valley, & Smithneck areas – GW recharge significance for SVB unclear with ambiguous data. Need more sample points.
Crocker Mountain	Low GW recharge significance – most flow is directed down Big Grizzly Valley into the Middle Fork Feather.
Antelope Valley watershed	Insignificant GW recharge area.
Mount Ina Coolbrith	Uncertain significance as a GW recharge area. Ambiguous data.
Chilcoot sub-basin and SV/LV	Important source area. Hydraulic connection to SV not clear. More sampling needed to assess overall and sub-basin GW recharge significance

Summary: Groundwater Recharge in Sierra Valley

- **GW recharge in Southern Sierra Valley:**
  - Deep - groundwater discharge from Cold Creek watershed
  - Shallow - Runoff from the streams draining western uplands (Yuba Pass area)
  - Shallow - Little Truckee River diversion during early summer months
- **The deep “Central Trench” groundwaters are of uncertain origin:**
  - Possibly recharged on ridge between Sierra Valley and Long Valley
  - Discharging into SVB through central valley floor faults (“upwelling”)
- **Aquifers in Valley periphery recharged in adjacent uplands**
  - Most prominently: Dixie Mountain complex in the north
  - GW flowing into Frenchman Basin, then SW along Calpine-Vinton Fault Zone
- **GW flow converges where Hot Springs & Loyalton Faults intersect the Calpine-Vinton Fault-Zone, then flow NW into Middle Fork Feather River**

GROUNDWATER FLOW SYSTEMS - <u>Physical</u> Characteristics

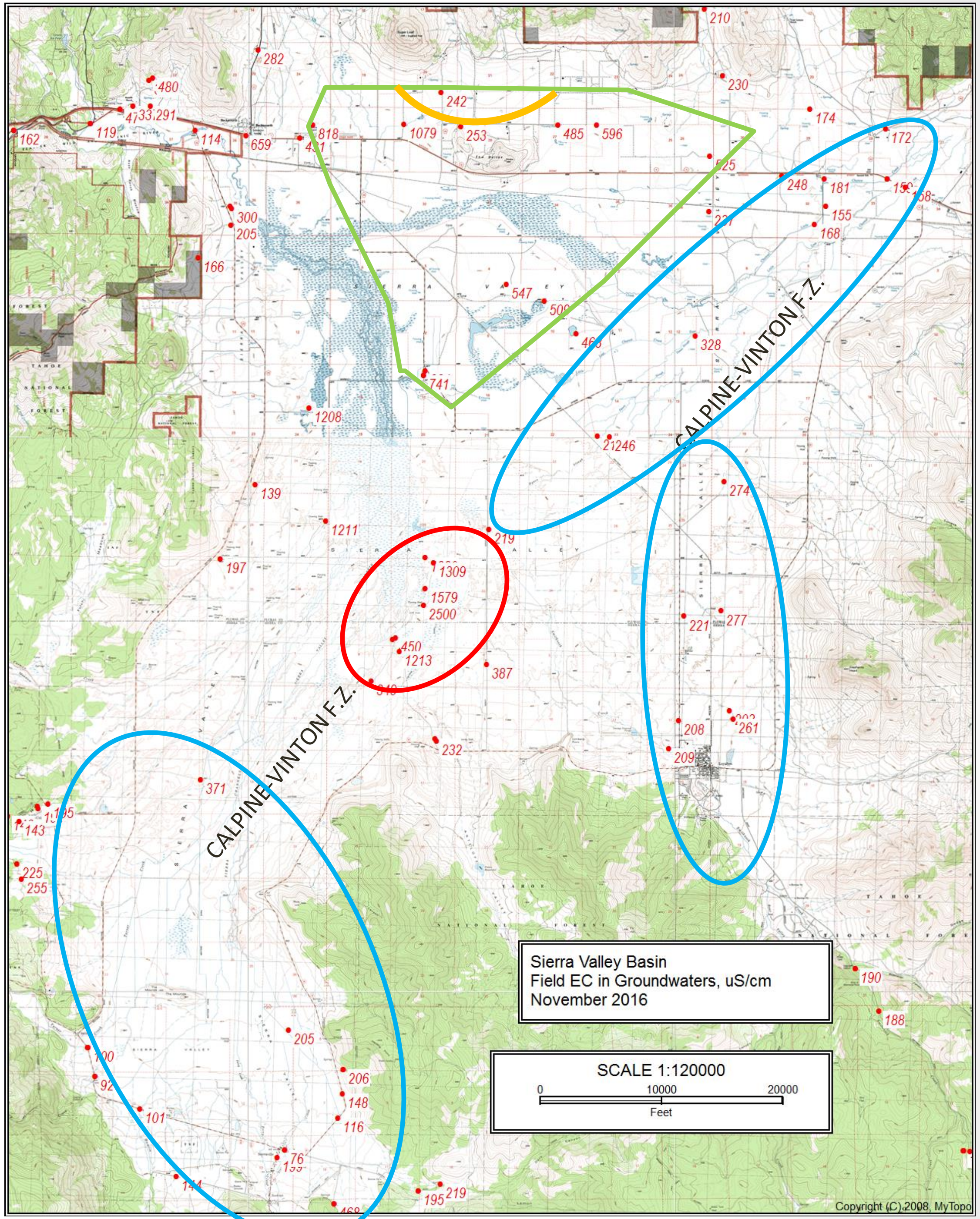
- GW recharged at the highest elevations travels deepest and farthest.
  - In recharge areas GW levels **<u>decline</u>** with increasing well depth.
  - In discharge areas GW levels **<u>increase</u>** with increasing well depth.
    - This effect is enhanced by elevated groundwater temperatures



GROUNDWATER FLOW SYSTEMS - <u>Chemical</u> Characteristics

- **Groundwater that travels farther & deeper tends to…**
  - Be more “isotopically depleted” - (smaller isotope values)
  - Have increased Total Dissolved Solids (TDS) and Cl/HCO3-ratios with distance of flow
  - Have increased temperature with increased depth of penetration

Electric Conductivity ("EC") as an indicator of Groundwater Flow Systems



Summary - Sierra Valley Groundwater Source Areas

1. **Southern Sierra Valley:**
   - Cold Creek watershed GW discharge into bedrock and alluvium near Sierraville.
   - Largest source of water in southern Sierra Valley
   - Yuba Pass area produces less GW, more runoff into Sierra Valley
2. **GW flow north into region where Calpine-Vinton fault-zone intersects Hot Springs and Loyalton Faults and wetlands near Marble Hot Springs**
3. **Runoff discharge into Middle Fork Feather River (Rocky Point):**
   - Winter months from a southern source
   - Summer months: Little Last Chance runoff
4. **North-and-central SVB:**
   - "Central trench" GW blending with high-TDS GW from the Beckwourth area (unknown origin)
   - Low TDS GW flow south from the Frenchman Sub-basin through the Calpine-Vinton Fault Zone
   - Also: Probable GW recharge from the Chilcoot Sub-basin
5. **Most important water sources in the SV Basin:**
   - Cold Creek watershed and stream water originating in the Yuba Pass area
   - Groundwater recharge in the Dixie Mountain and Reconnaissance Peak areas

Artesian wells and the “deep aquifer”

- A confining layer can be the cause of, but it is not a necessary prerequisite for, artesian wells
- Artesian wells require upward hydraulic gradients

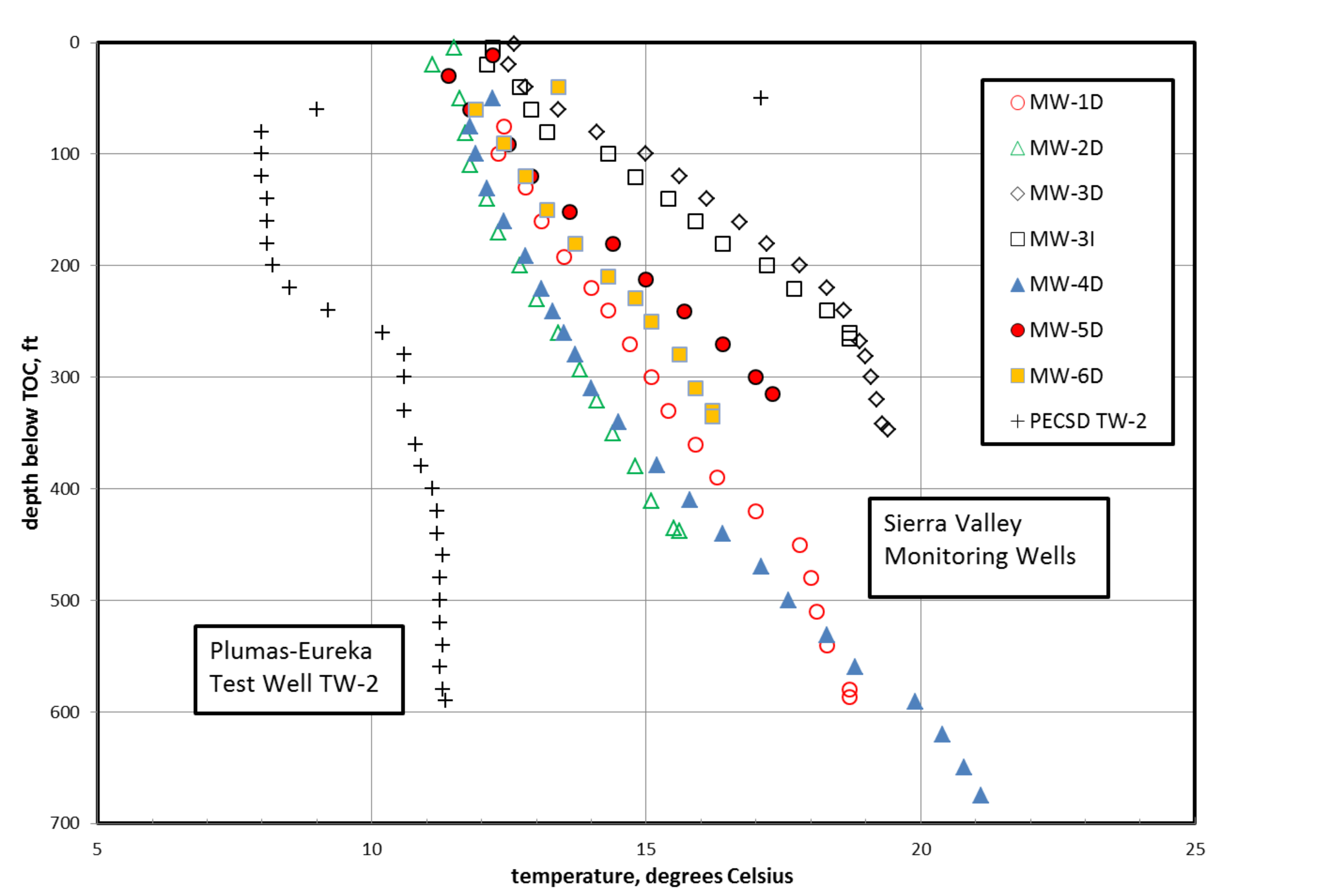
OBSERVATIONS IN SIERRA VALLEY:

- Evidence of a “confining layer” remains sketchy
- Artesian wells used to be common in Sierra Valley
- Rising static water levels with increasing well depth during drilling are commonly observed

Is there a "deep aquifer" in Sierra Valley?
(isolated from a "shallow aquifer?")

- Temperature profiles may not be deep enough to reveal a confining layer or vertical circulation (convection) - see next slide
- Gradual water quality changes with depth indicates circulation between shallow and deep aquifer portions
  - A confining layer would be indicated by "abrupt" water quality changes with depth
- Even if there is a prominent "clay layer," it would not necessarily act as a confining layer, since the clay layers are probably "lens-shaped"

Sierra Valley Temperature Gradients



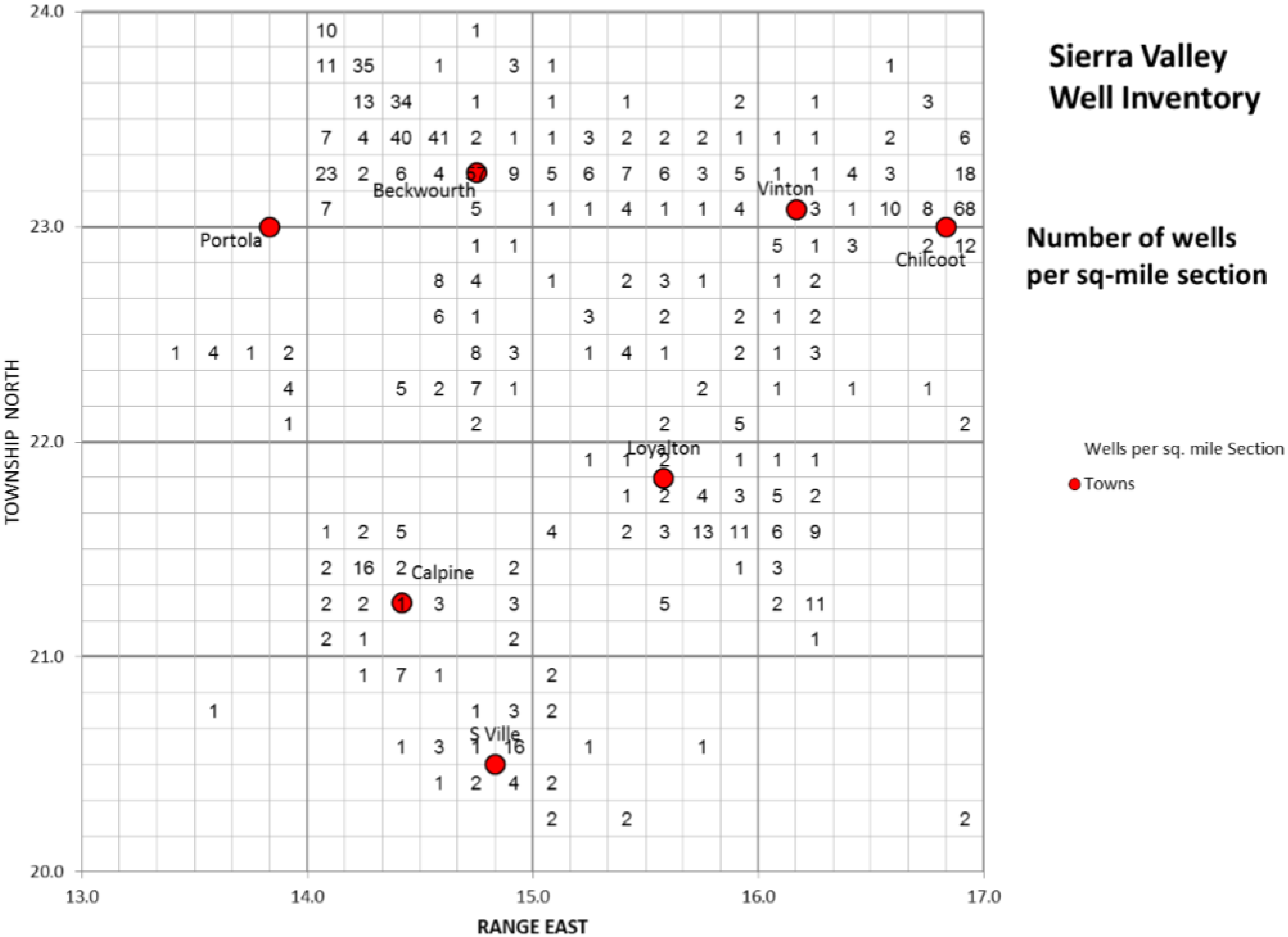
SIERRA VALLEY WELL INVENTORY

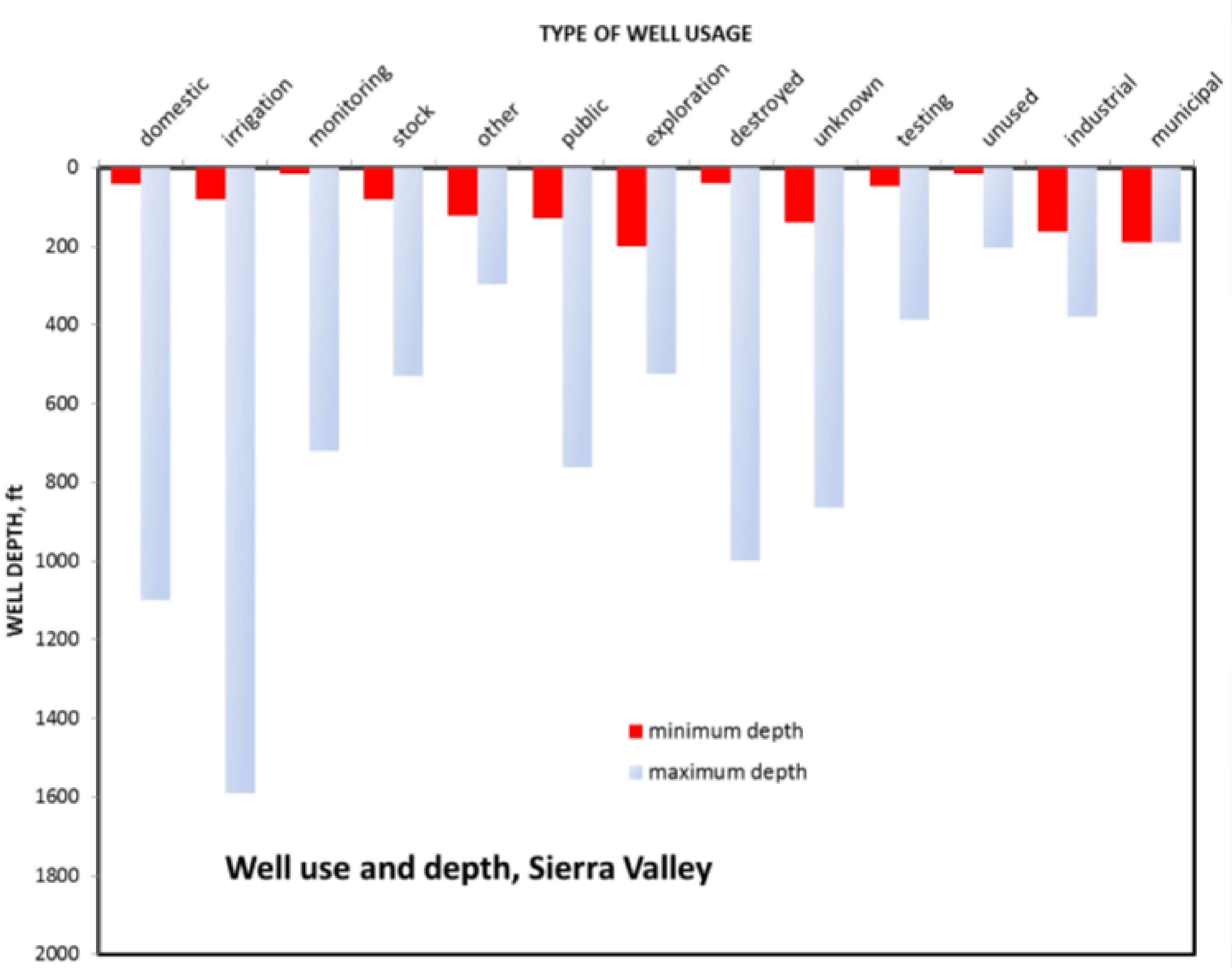
Sierra Valley Well Inventory

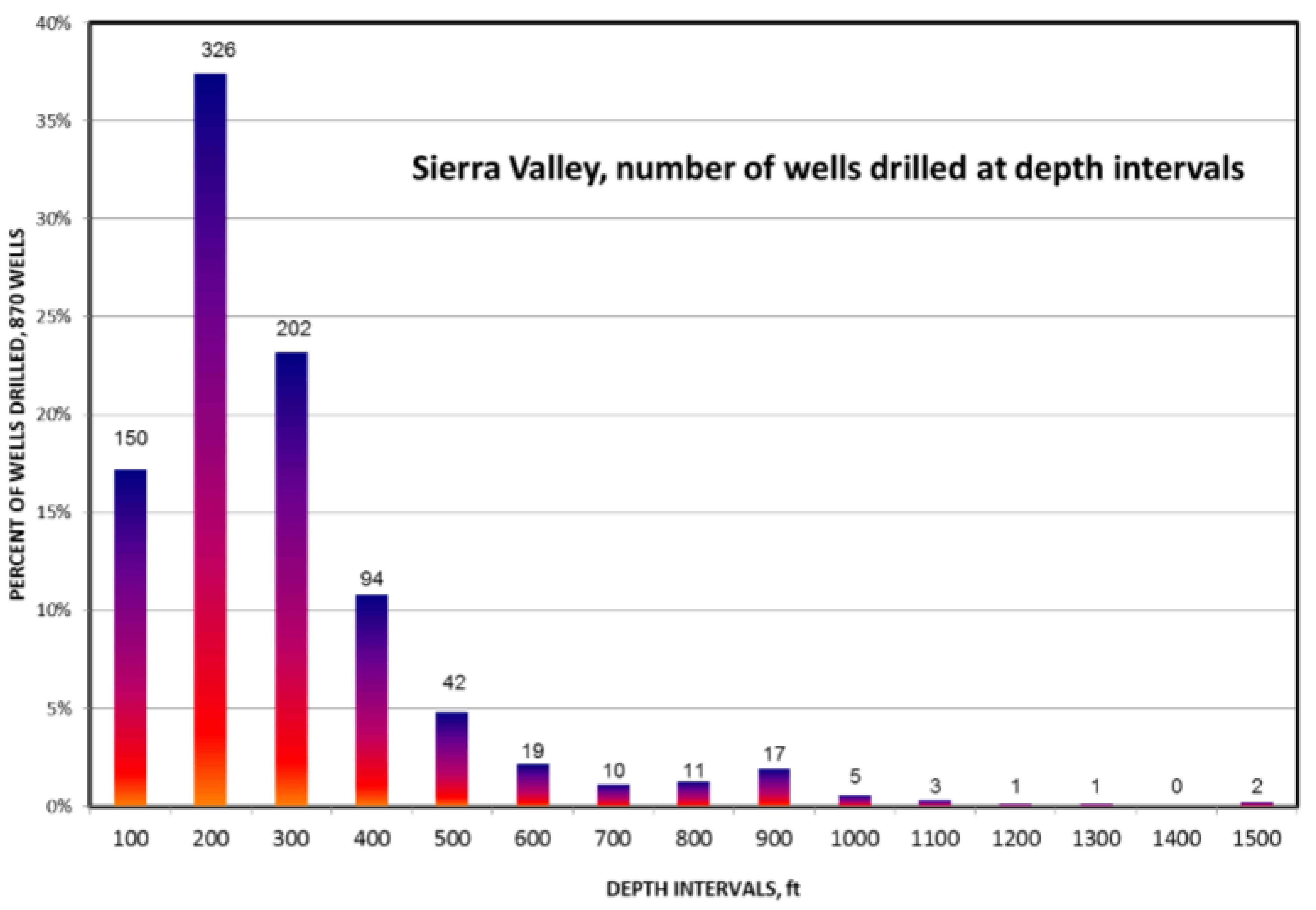
- 956 well driller's logs available within SVGMD
  - 670 in Plumas County; 286 in Sierra County
  - 74% domestic/residential
  - 6% irrigation
- Depth ranges:
  - 54% less than 200 feet deep
  - 12% more than 500 feet
- Casing size for 512 wells given: ~80% are ≤ 6"
- Groundwater development:
  - 92% drilled since 1971
  - 35% drilled between 2001 and 2010

Sierra Valley Well Inventory

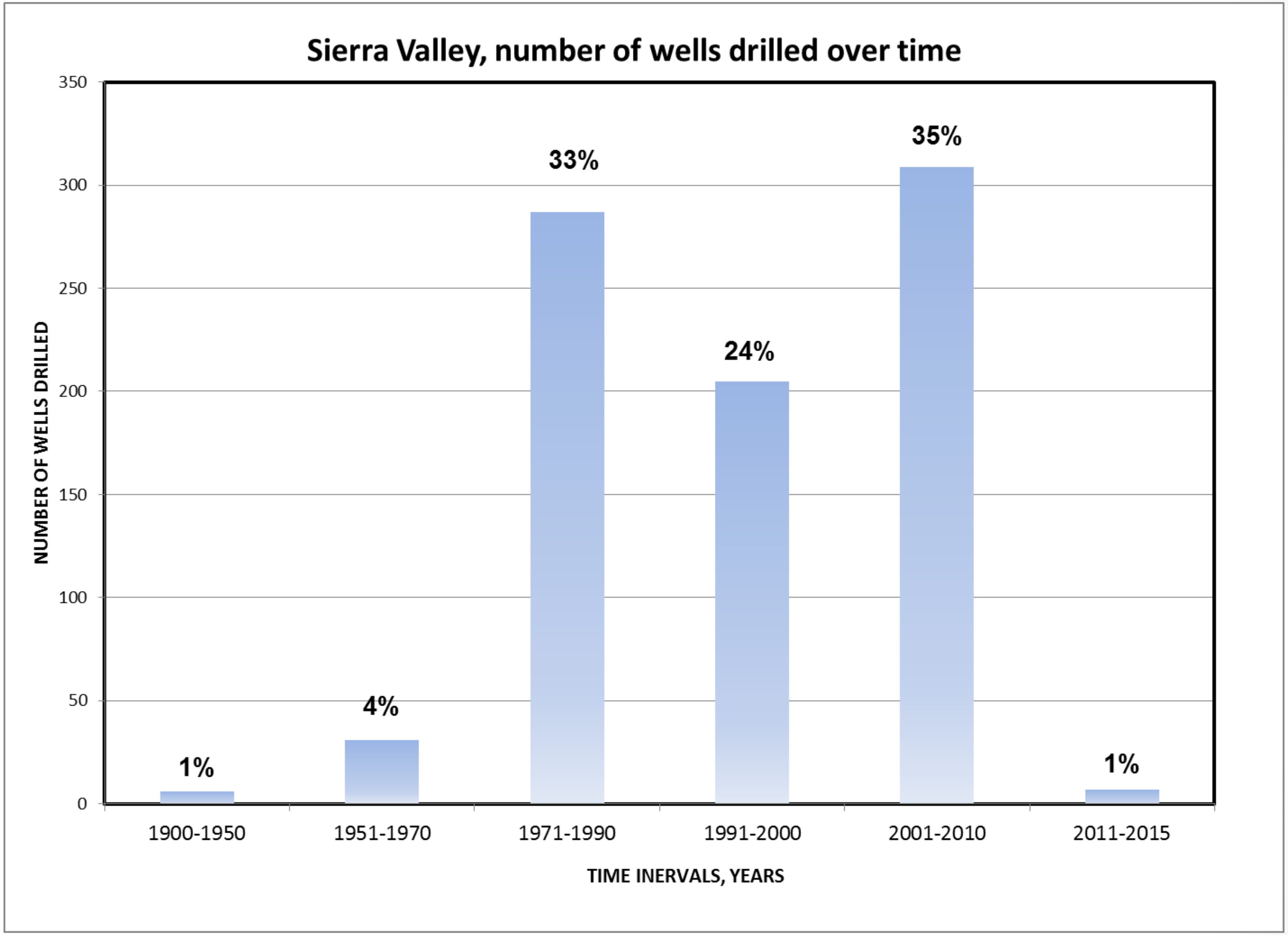
Number of wells per sq-mile section




TYPE OF WELL USAGE
domestic
irrigation
monitoring
stock
other
public
exploration
destroyed
unknown
testing
unused
industrial
municipal
WELL DEPTH, ft
0
200
400
600
800
1000
1200
1400
1600
1800
2000
minimum depth
maximum depth
Well use and depth, Sierra Valley



Sierra Valley, number of wells drilled at depth intervals
PERCENT OF WELLS DRILLED, 870 WELLS
40%
35%
30%
25%
20%
15%
10%
5%
0%
150
326
202
94
42
19
10
11
17
5
3
1
1
0
2
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
DEPTH INTERVALS, ft


Sierra Valley, number of wells drilled over time
NUMBER OF WELLS DRILLED
350
300
250
200
150
100
50
0
1%
4%
33%
24%
35%
1%
1900-1950
1951-1970
1971-1990
1991-2000
2001-2010
2011-2015
TIME INERVALS, YEARS

SIERRA VALLEY WATER QUALITY INVENTORY

Sierra Valley groundwater quality

- Groundwater quality good for most of the Basin with some localized exceptions
- TDS - Basin wide total dissolved solids (TDS) range from 115 to more than 1400 mg/L
- Lowest TDS levels in southern Sierra Valley
- Elevated TDS in several wells near Beckwourth
    - Up to about 800 mg/L
- Highest TDS is northwest of Antelope Valley
    - Affected by geothermal activity

TDS - Water with a TDS above 500 mg/l is not recommended for use as drinking water (EPA). Water with a TDS above 1,500 to 2,600 mg/l is generally considered problematic for irrigation use on crops with low or medium salt tolerance.

- UCANR

Sierra Valley Groundwater Quality

Boron

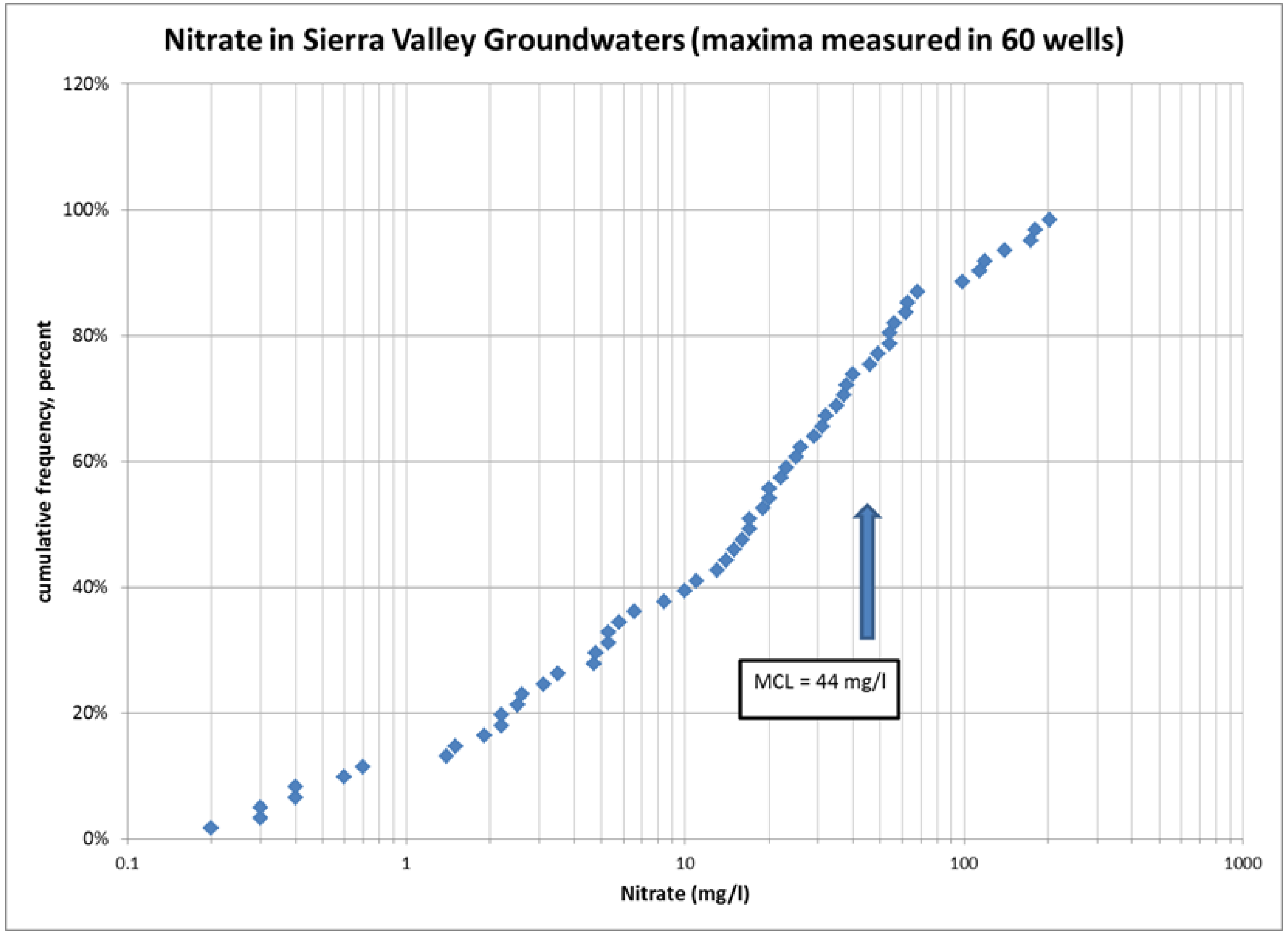
- High Boron levels are associated with elevated groundwater temperatures (geothermal areas) of the Sierra Valley Basin
  - Since most SVB groundwaters have elevated temperatures, many wells have high boron levels.
  - 30% of 122 sampled wells showed boron levels higher than 1 mg/l
  - 80% of these wells exhibited "noteworthy" changes in boron concentration over time (1981– 2002)

Boron:

- Alfalfa, oats, wheat, barley are semi-tolerant to boron, preferring <0.5-2.0 mg/L max - UC Intermountain Alfalfa Management Guide, OK Coop. Ext.
- Boron is an unregulated chemical without an established Maximum Contaminant Level (MCL) in public supply wells. The California State Notification Level (CA-NL) is 1,000 micrograms per liter (=1mg/L). - Ca Water Resource Control Board

Sierra Valley Groundwater Quality

Nitrate - NO_3



Nitrate - Federal drinking water standards permit a maximum level of 44 mg/L of nitrogen as nitrate

CONCLUSIONS

Take away messages from these studies - (1)

1. SV is a complex hydrologic system rather than one uniform groundwater "bathtub."
2. Evidence for distinct shallow and deep aquifers is ambiguous.
3. Sources of nitrate and boron in groundwater are unknown and may be naturally occurring.
4. Areas of potential nitrate and boron concerns for domestic and agricultural uses seem to be isolated and not expanding.
5. Water and land management changes can affect nitrate, TDS, and boron distributions and concentrations over time.
6. Current land uses and land use designations that limit urbanization in Sierra Valley are generally effective at maintaining high water quality for existing domestic uses and agricultural production.

Take away messages from these studies - (2)

1. There are multiple GW recharge source areas in the SVB uplands including:
   - Recharge from fractured bedrock
   - Recharge from stream channels crossing alluvial fans
   - Uncertain recharge from sources outside the SVB (inter-basin GW flow)
2. SVB subareas are recharged by specific upland recharge areas, to converge into and blend in the central portions of the basin.
3. The deepest basin sediments are recharged by the most distant recharge sources.
4. Depending on geologic setting, some uplands areas may act as reservoirs for “carry-over” groundwater storage from unusually “wet” years into normal or dry years.

Recap on SVGMD Questions

1) Recharge areas – location, protection, maximization strategies?
2) Does backing up water in the NW corner (e.g., via Decker Dam) help recharge groundwater?
3) Groundwater banking – Good strategy here? Where?
4) Groundwater flow direction?
5) Effects of Grizzly Fault (and other faults) on groundwater? Do they isolate pumping areas?
6) Are there areas where shallow and deep aquifers mix? If so, where?
7) Do the studies indicate areas that should be managed with different strategies? If so…
    a) Recommended water budgets by management area?
    b) Are there sub-areas where it would not impact GW as much to have additional production wells and other areas where no more production wells should be added?
8) What impact do overgrown forests have on groundwater recharge in Sierra Valley?

What else do we need to know? Next steps?

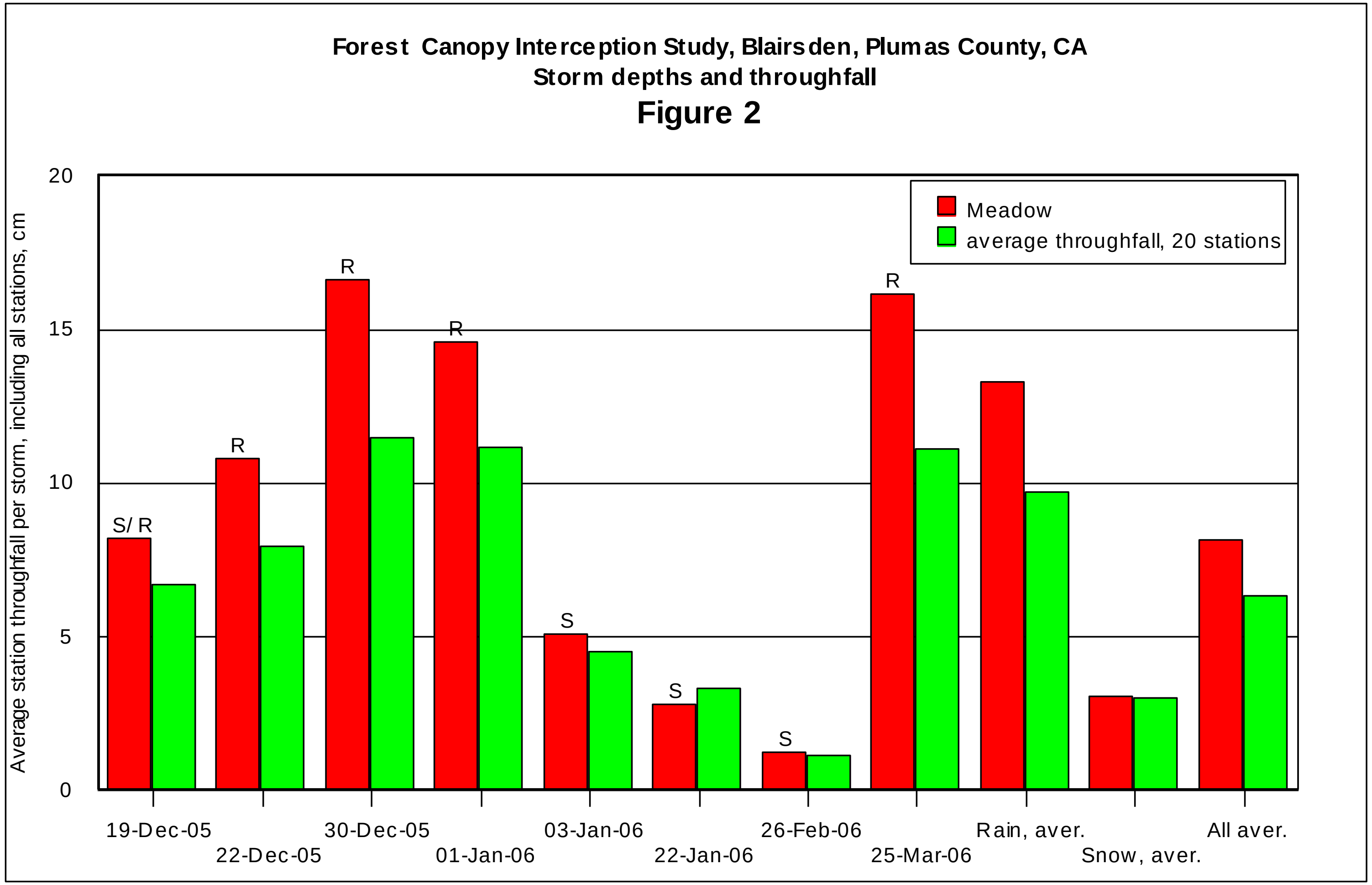
1. Is it necessary to further ascertain GW recharge areas (where and how much)?
2. How much and where does GW flow enter the SVB through bedrock fault zones ?
3. Is a cost-effective groundwater quality monitoring network needed for tracking trends, and are studies needed for establishing “natural” baseline levels for boron and nitrate?
4. Given limited resources, should studies focus on what is changing? Should future studies focus on areas forecasted for increasing domestic and/or agricultural GW demands?
5. How much should studies focus on what areas of the SVB are most vulnerable to change?
6. Should future studies focus on areas with changing surface and/or groundwater hydrology?
7. Is it recommended to compile and map the existing and future types of land-use in key upland recharge areas?
8. Is it recommended to determine the source of high TDS water in the Beckwourth area?
9. Are there any other future study priorities?

FOREST WATER BALANCE STUDY

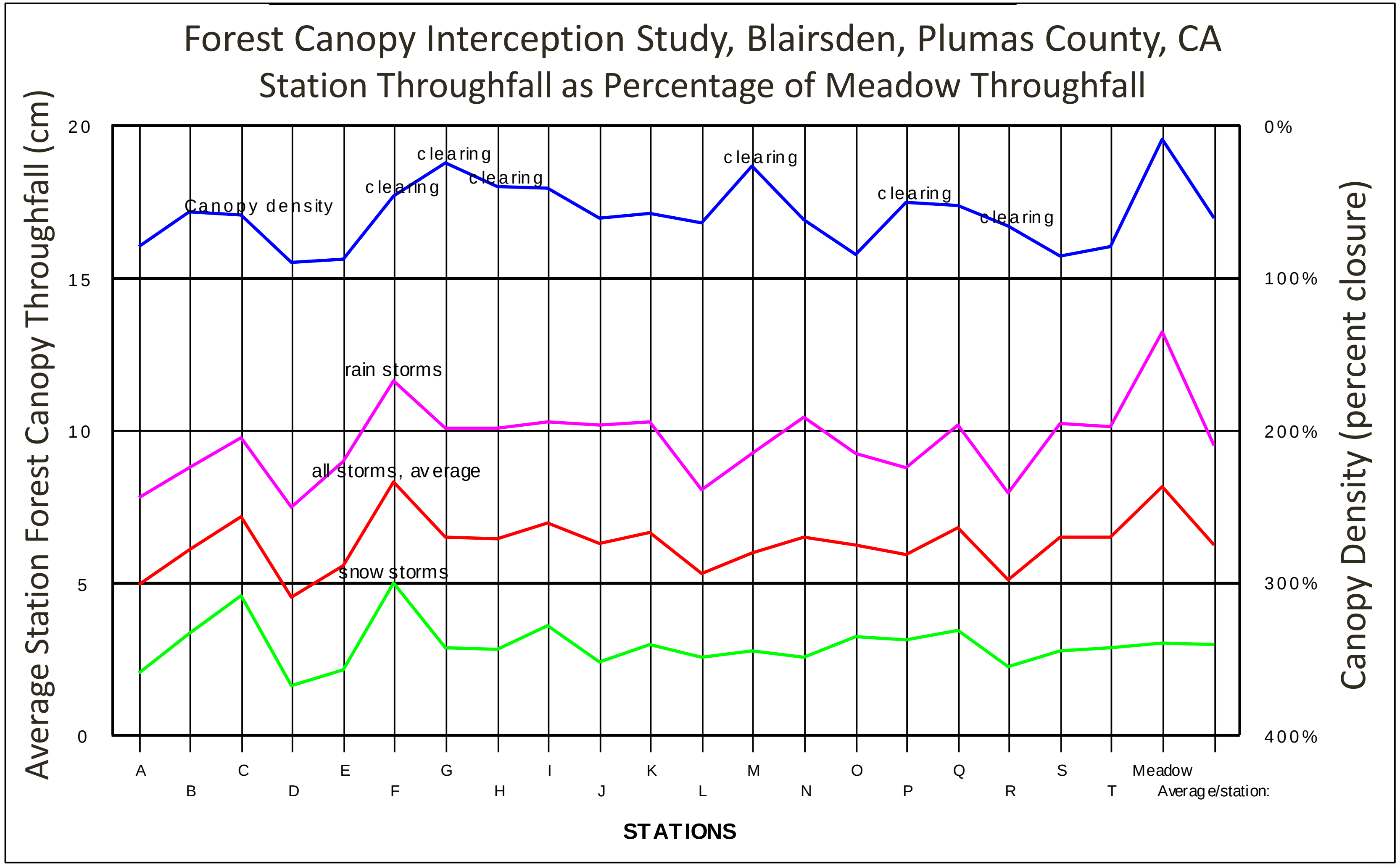
Forest Water Balance Study Highlights

- Overstocked forests diminish groundwater recharge by increased evaporation from forest canopies.
- It has been estimated that by reducing the average forest canopy closure to 40%, precipitation reaching the forest floor can be increased by up to 20%.
  - For example, in a “normal” year around Quincy this would increase forest floor infiltration by 0.39 acre-feet/acre/year, assuming 40” average annual precipitation.
- Uplands GW storage can help diminish impact of droughts on streams.

Storm depth measured in a meadow (red) compared with corresponding 20-station average forest throughfall depth (green) - 8 storms.



Average throughfall depth at each station compared to forest canopy density



Canopy density axis is inverted.

Forest Water Balance Study Highlights

- "Water is one of the most valuable resources coming out of forested watersheds. Forested lands (including about 2,100 large basins) covering 23% of the continental United States contribute a disproportionately larger fraction of 43% of the total water yield." (Sun et al., 2015)
- "… the general consensus in the literature is that overstocked vegetation adversely affects the water budget."

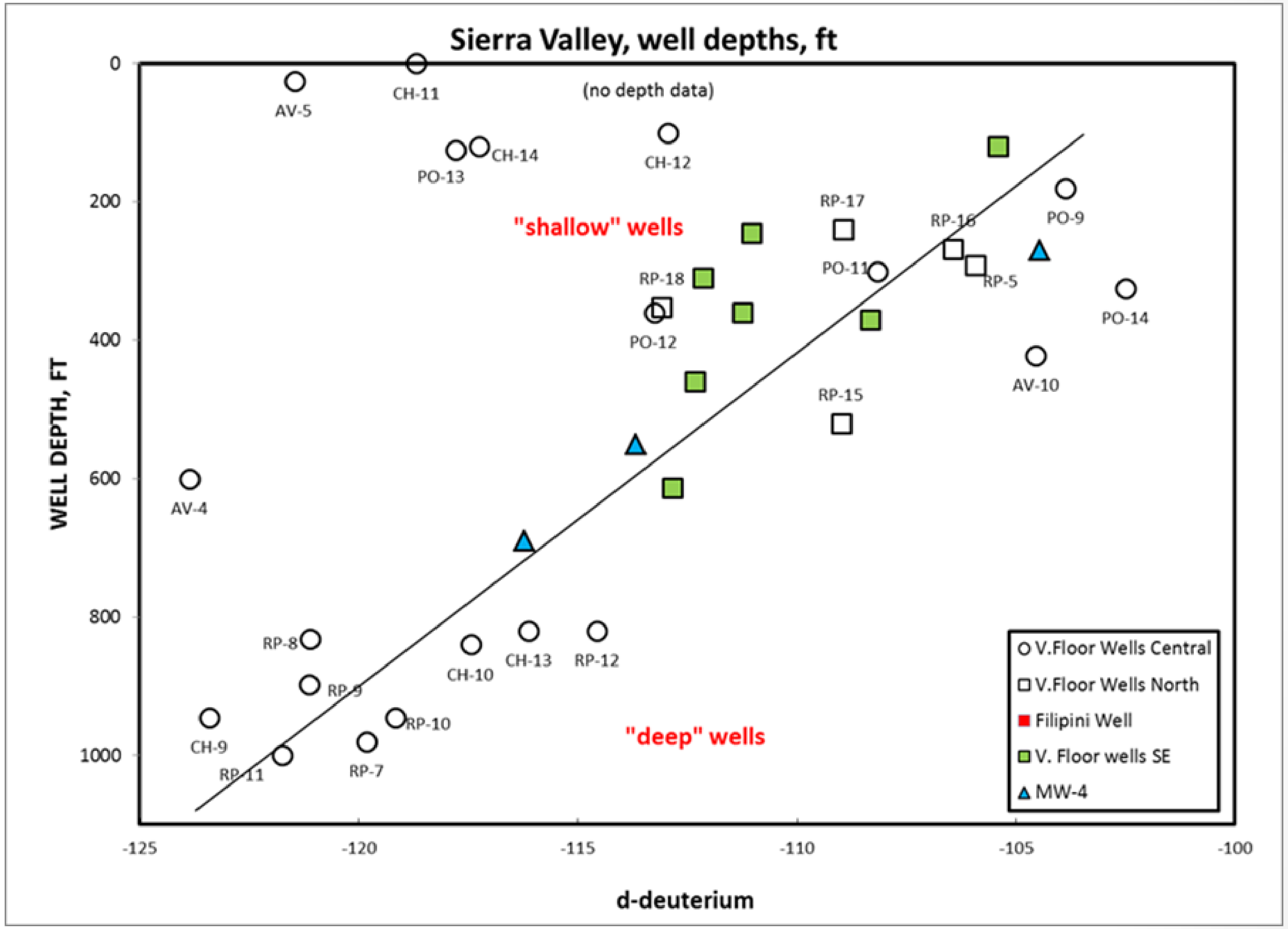
The end

is near …

Technical discussion

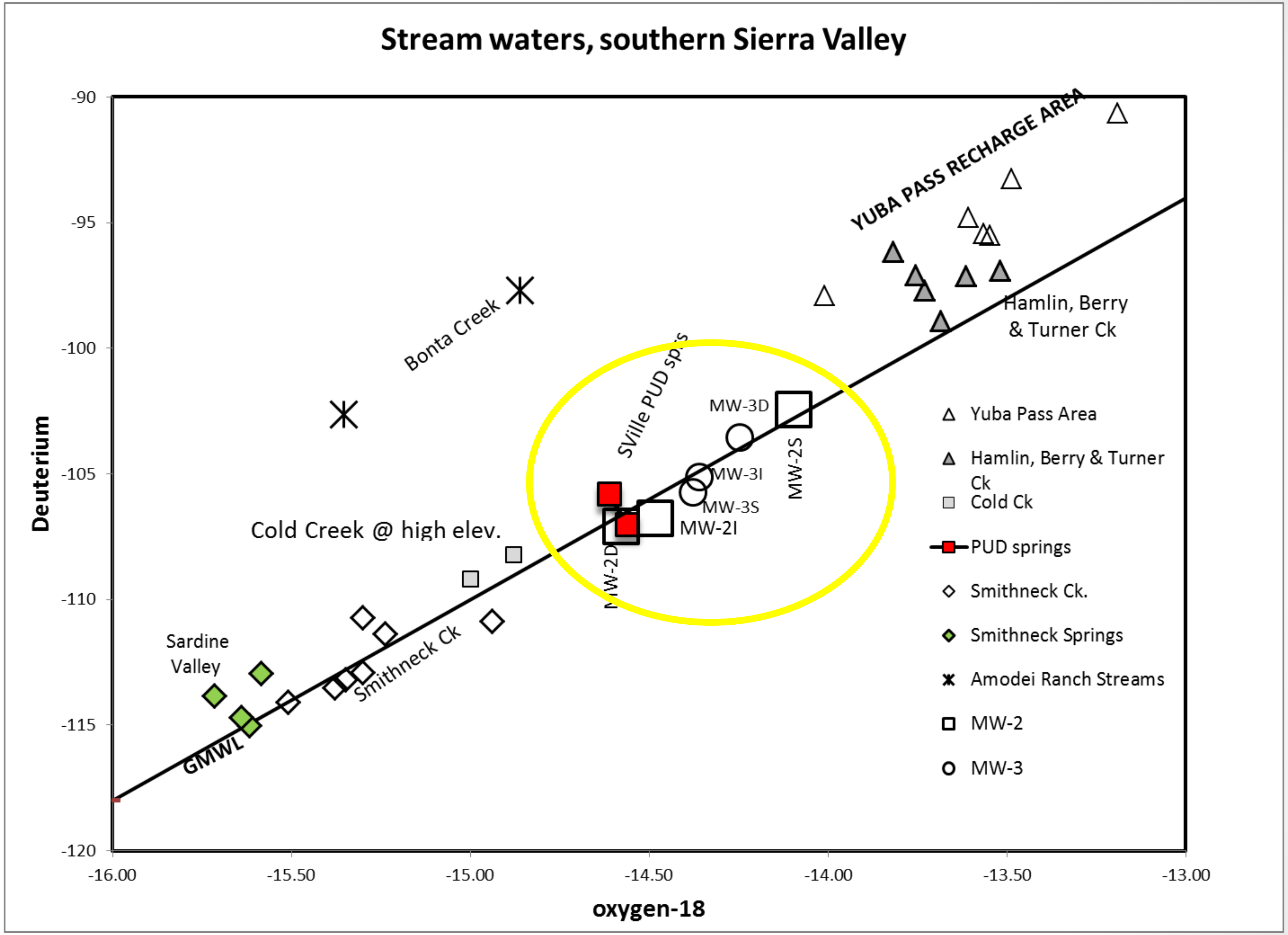
WELL DEPTH AND ISOTOPES IN WELLS

- Continuous trend toward more isotopically depleted groundwater with depth
- Indicates GW circulation between shallow and deep basin formations
- In agreement with conceptual model of groundwater flow systems

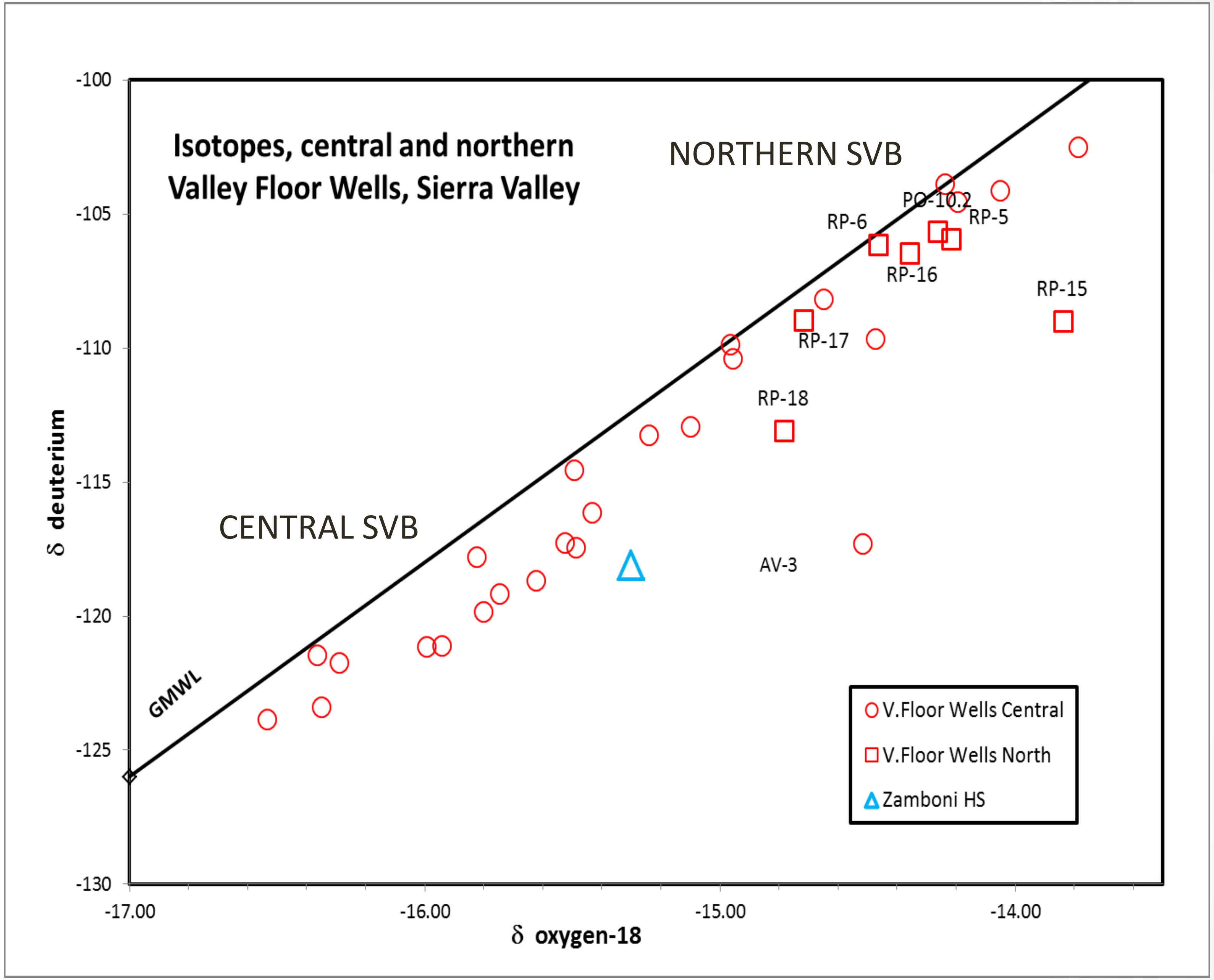


Sources of Stream & Groundwaters in Southern Sierra Valley

- Deep GW inflow from southern uplands (MW-2D)
- Shallow GW inflow from western uplands (MW-2S)
- Vice versa further north at MW-3

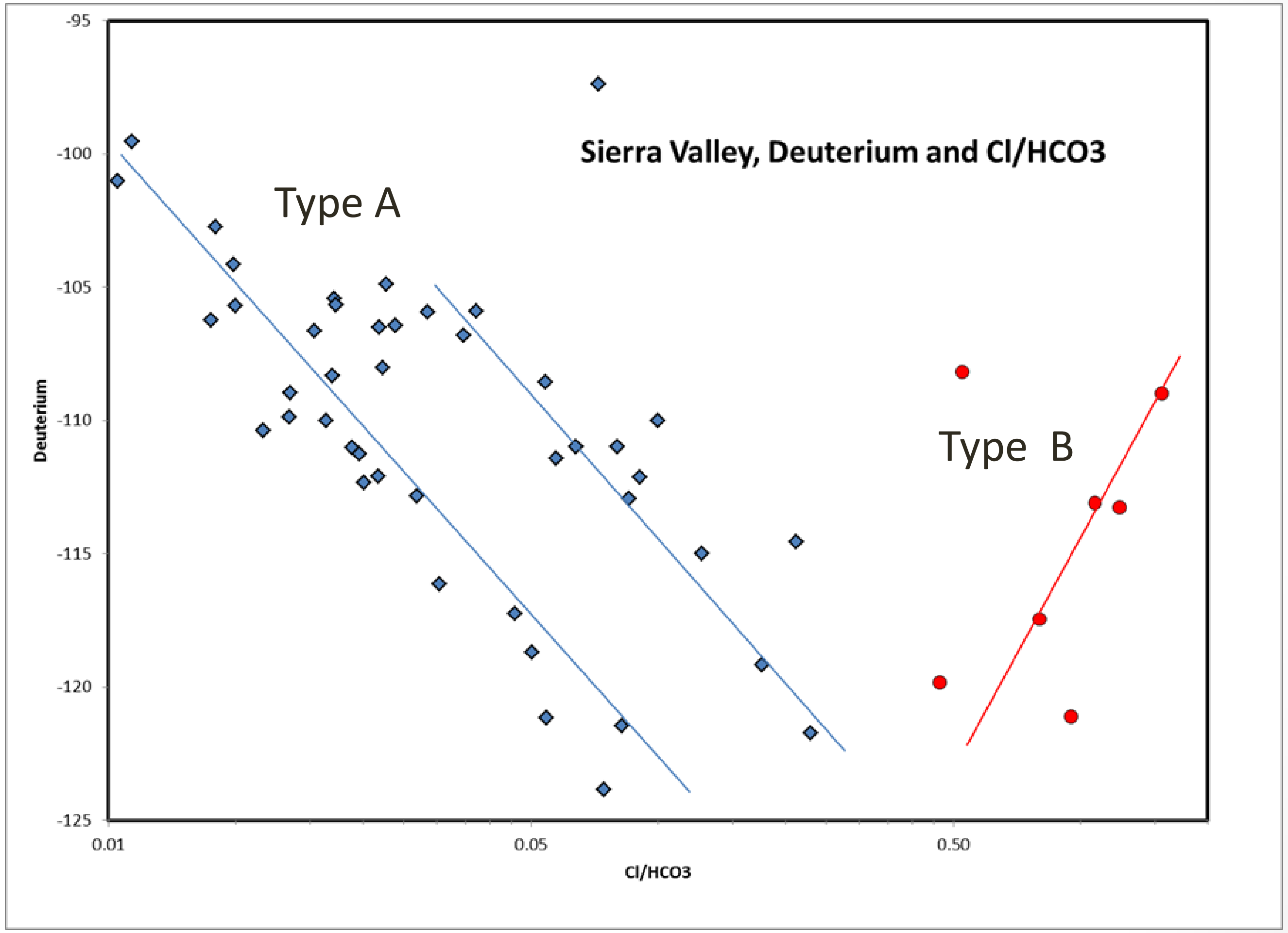


Light stable isotopes, geographic trends in central and northern SVB



GROUNDWATER CHEMISTRY AND ISOTOPES

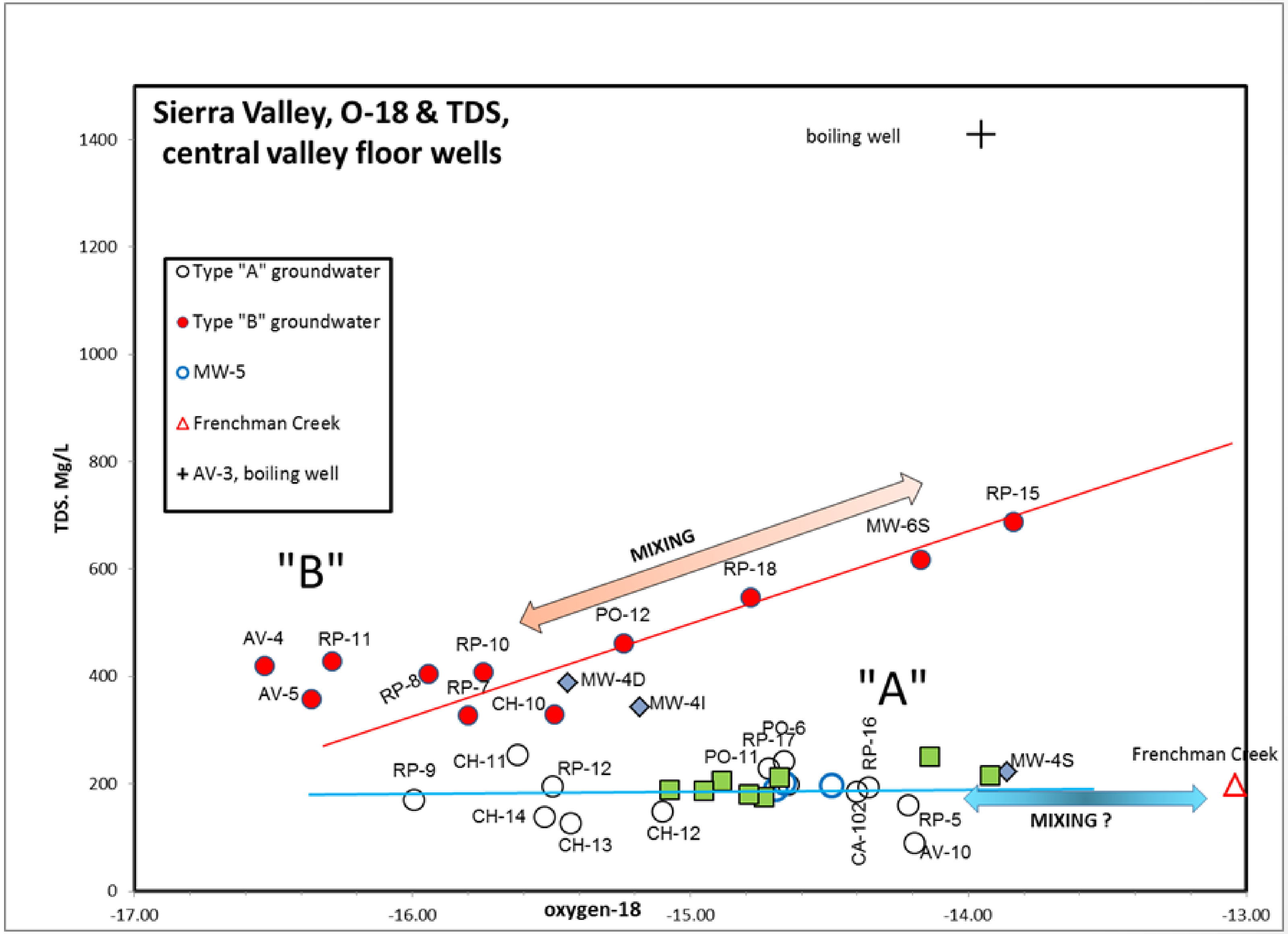
- **Cl/HCO3-ratios increase with decreasing deuterium isotope**
  - This is as expected in conceptual model of a GW flow system
- Since TDS increases with Cl/HCO3-ratio, and decreasing deuterium, TDS increases with depth
  - **Increasing Deuterium with increasing Cl/HCO3 is an "anomaly"**

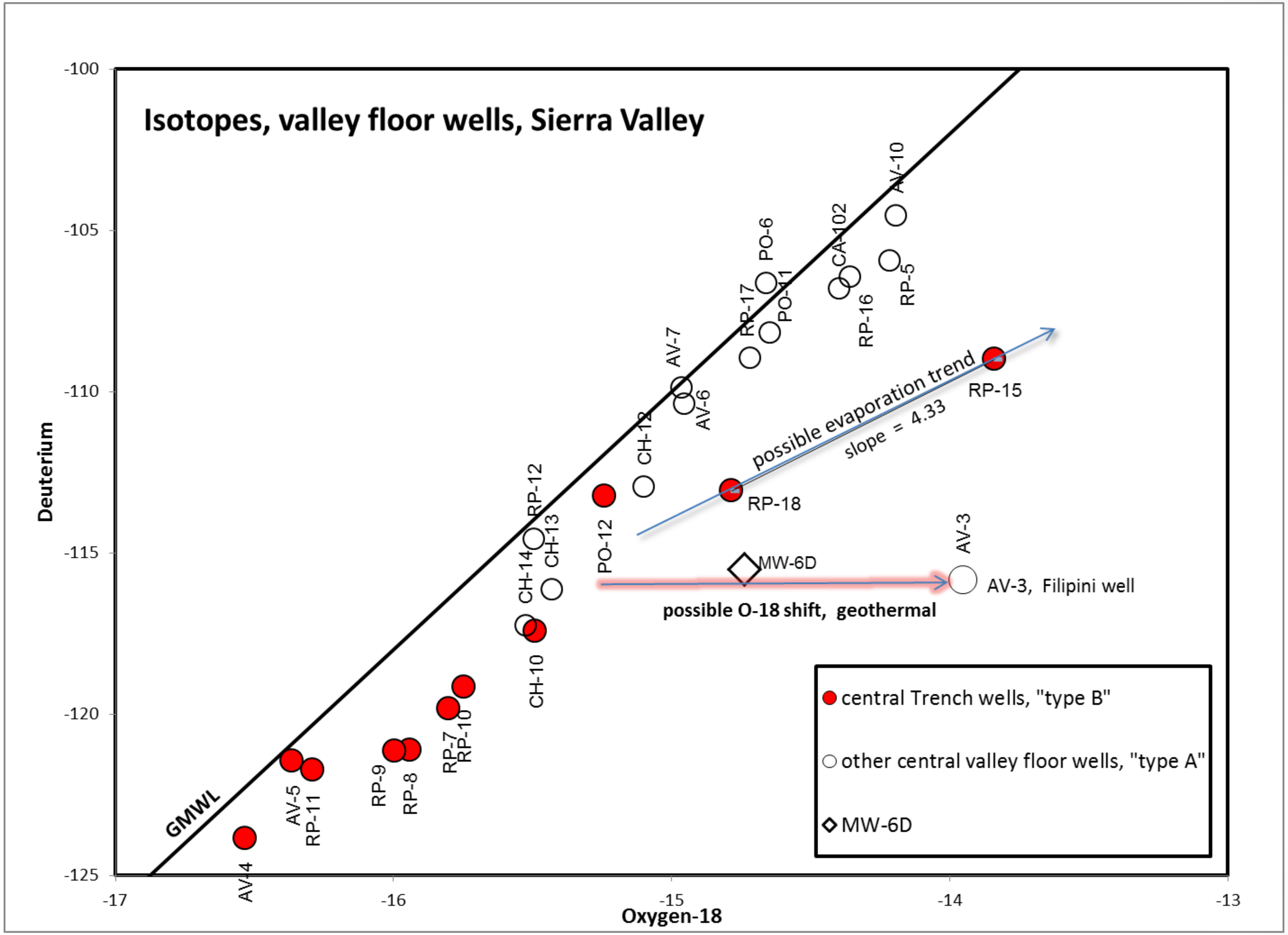


North & Central Valley floor wells

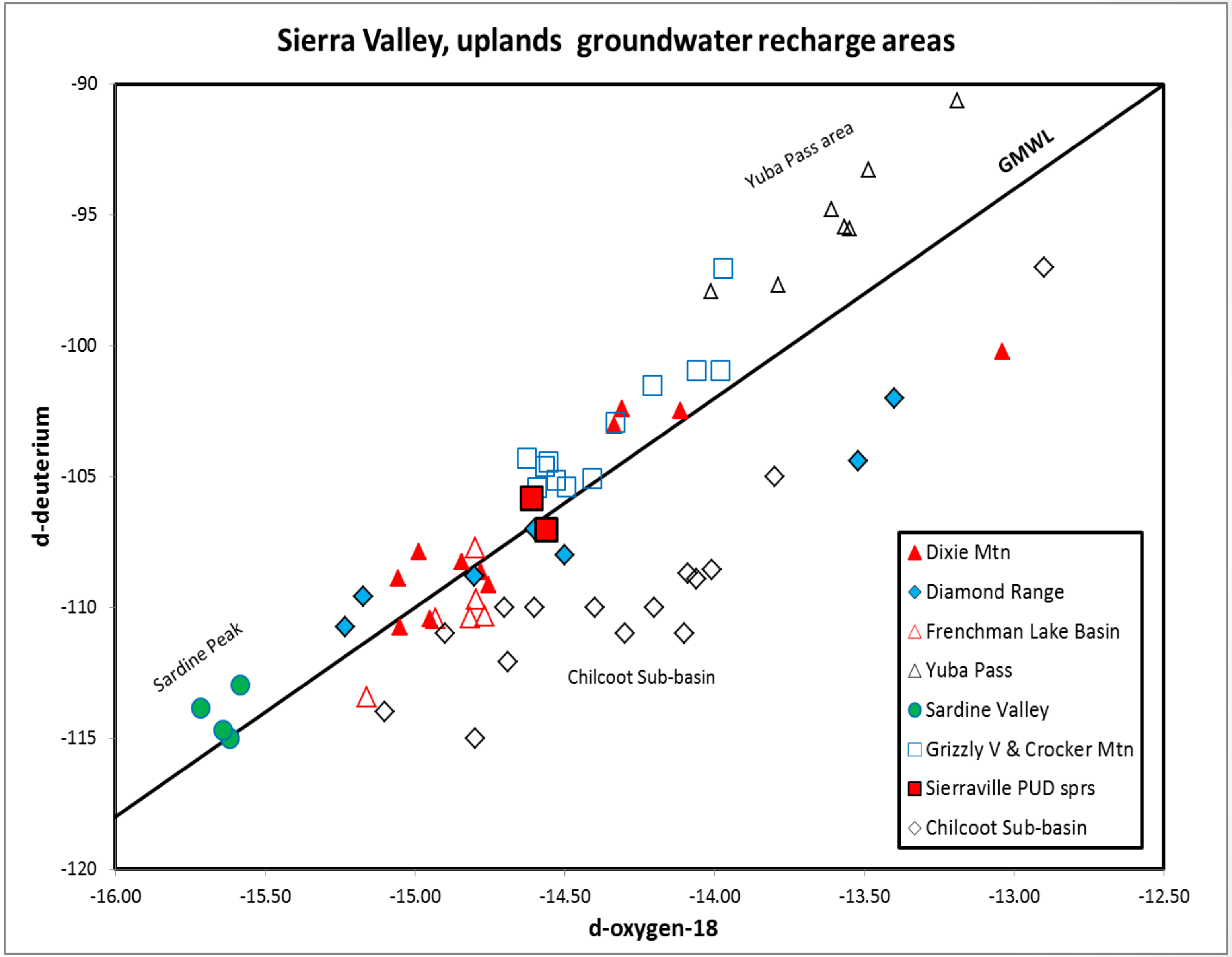
Type A waters -- from valley periphery

Type B waters -- from center of the valley




Isotopes, valley floor wells, Sierra Valley
Deuterium
Oxygen-18
-100
-105
-110
-115
-120
-125
-17
-16
-15
-14
-13
GMWL
AV-10
PO-6
CA-102
RP-5
RP-17
PO-11
RP-16
AV-7
AV-6
possible evaporation trend
slope = 4.33
RP-15
CH-12
RP-12
RP-18
CH-13
PO-12
CH-14
MW-6D
AV-3
AV-3, Filipini well
possible O-18 shift, geothermal
CH-10
RP-7
RP-10
RP-9
RP-8
AV-5
RP-11
AV-4
central Trench wells, "type B"
other central valley floor wells, "type A"
MW-6D

Light stable isotopes from selected recharge areas, Sierra Valley



- northeastern recharge areas plot below the GMWL
- southern recharge areas plot above the GMWL