Inventory of Sierra Valley Wells and Groundwater Quality Conditions

Prepared for

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1. Introduction

Background

This is a companion report to a larger report summarizing data collection and interpretation in Sierra Valley in 2014/15. The objective is to developing a comprehensive conceptual model of the Sierra Valley hydrologic system. On the long run, this information is needed to develop a comprehensive groundwater resource management plan.

This report encompasses two tasks:

1. A valley-wide well inventory based on well log database obtained from DWR.
2. An inventory of valley-wide groundwater quality data using the DWR historic groundwater chemistry data base.

2. Sierra Valley Well Inventory

Introduction

There are almost 1000 well drillers' reports available for Sierra Valley. The problem is that the well locations are given in the T-R-S system (well number). In other words most of the well locations are indicated only within a one square mile area (5280 by 5280 ft). A small number of well location data (only south of the County line) also include the "tract" (letters A through R), i.e. at best within a 1/16 square mile area (1320 x 1320 ft lot).

Although the entire valley is fairly well covered with wells, aerial coverage by drilling information is rather unevenly distributed. Most wells are located in the northwest and central basin.

Most sections contain several wells, requiring giving screen intervals and total depth (TD) as average depths. With a few exceptions, the wells are all located on private land on the Basin floor area covering parts or all of 11 "townships" (T-R) of the valley floor, an area of about 194 square miles.

A spreadsheet was developed from the well-log tally obtained from Red Bluff and Sacramento DWR offices to organize the data and to extract the well construction data needed.

Well inventory

A comprehensive section-by-section (square mile) well inventory has been prepared using the well log database obtained from DWR. For each section a distribution of well construction has been inventoried, including drilling date, TD, screen interval, and casing diameter.

A total of 956 wells are located within the jurisdictional boundaries of the SVGMD. Of these more than two-thirds (670 wells) are located in Plumas County and less than one-third (286 wells) in Sierra County. Two schematic maps have been prepared indicating how many wells were drilled in each one-square mile section. The second map shows the distribution of wells that have been drilled into bedrock. Most wells have been drilled in the northwest (T23N/R14E).

Based on the well-use table almost three-quarters of Sierra Valley wells are used for residential water supply followed by agricultural irrigation wells (6 percent).

Table 2-1 Well use in Sierra Valley.

Table of well use in Sierra Valley			
type of use	**number of wells**		
domestic	636	74.3%	DOM
irrigation	53	6.2%	IRR
monitoring	42	4.9%	MON
stock	22	2.6%	STK
other	19	2.2%	OTH
public	19	2.2%	PUB
exploration & testing	26	3.0%	EXP &TES
destroyed	12	1.4%	DES
unknown	12	1.4%	UNK
unused	10	1.2%	Unused
industrial	4	0.5%	IND
municipal	1	0.1%	MUN
total	856	100.0%	

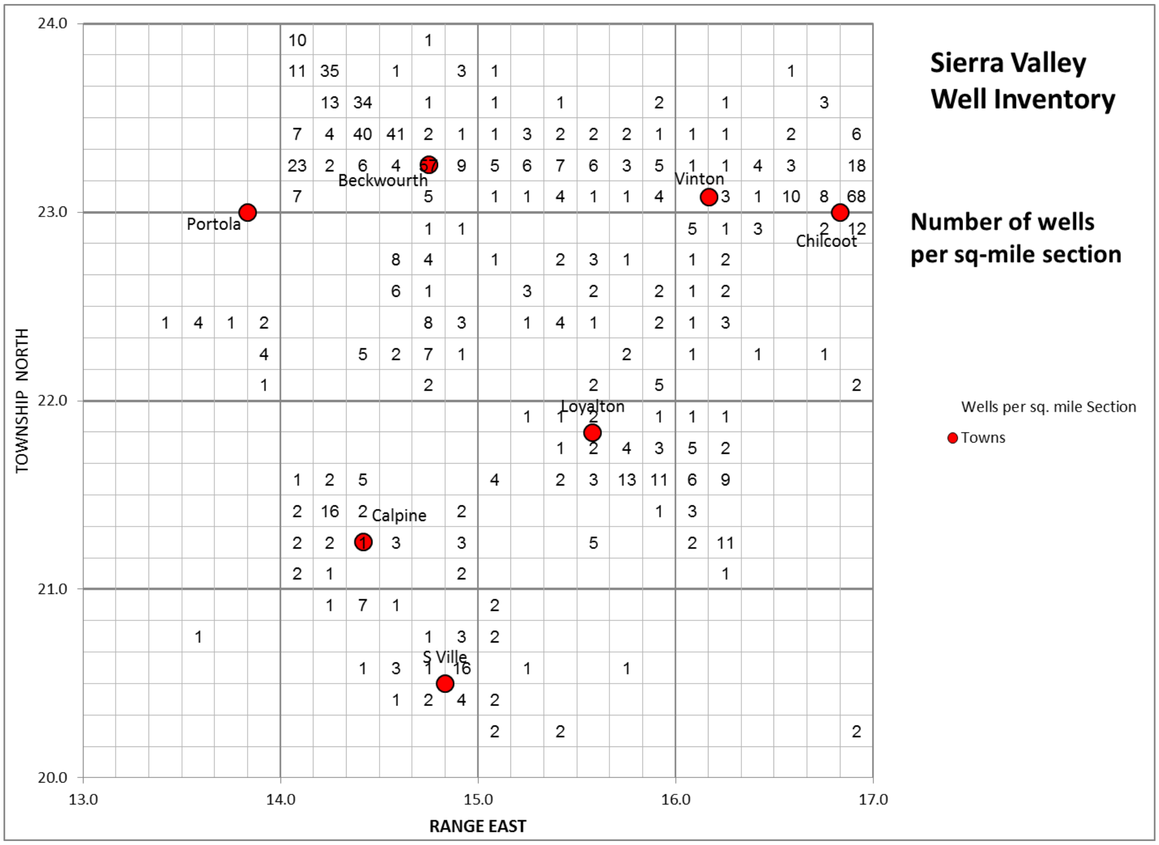
The deepest wells (to almost 1600 ft) are irrigation wells (Chart-3); followed by residential wells (1100 ft). More than one-half (54%) of wells drilled in Sierra Valley are less than 200 ft deep and about one-tenth (12%) of wells are more than 500 ft deep (Chart 4).

Well casing diameter is telling about the use of wells and their expected yield. Among the 512 wells listed in the casing diameter table (only wells for which casing diameters are given), 61% are six inch diameter wells, which are typically residential wells. Diameters greater than six inches are typical for industrial, municipal, public and irrigation wells constitute about 20%. The remaining wells with diameters smaller than 6 inches are probably older wells (given the “odd” diameters which have not been used since more than 40 (?) years. Exceptions maybe the 2-inch wells which are probably more recently installed monitoring wells (piezometers).

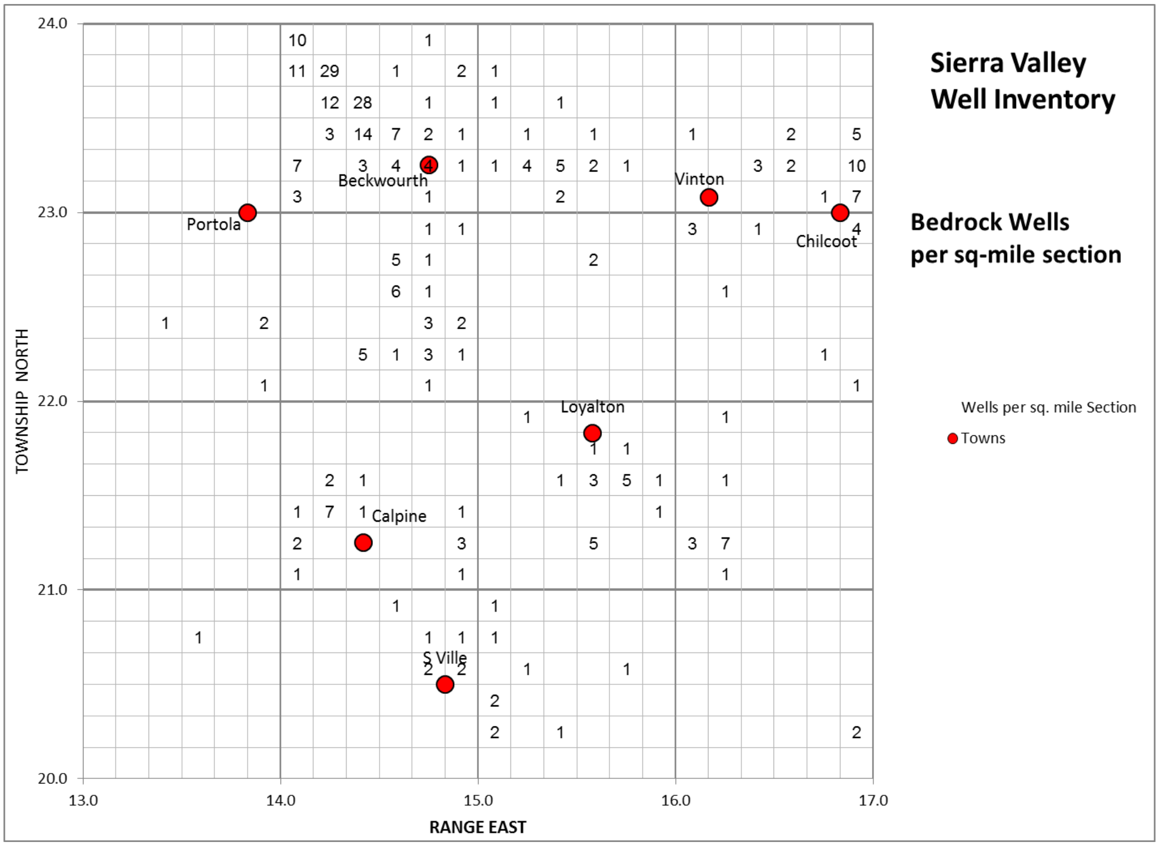
Table of well casing diameters in Sierra Valley.		
casing diameter, inches	**number of wells drilled**	
1	1	0.2%
2	29	5.7%
3	2	0.4%
4	43	8.4%
5	21	4.1%
6	312	60.9%
7	42	8.2%
8	30	5.9%
9	1	0.2%
10	4	0.8%
11	2	0.4%
12	4	0.8%
14	1	0.2%
16	17	3.3%
20	1	0.2%
29	1	0.2%
30	1	0.2%
Total # of wells	512	100.0%

Table 2-2 Well casing diameters.

Chart 2-5 illustrates the history of groundwater development in SV. Of the 845 wells for which drilling dates were given, beginning in 1907, only five percent were drilled before 1970. About 92% have been drilled since 1971, with more than one-third (35%) drilled in the ten-year period 2001-2010.



Map 2-1 Distribution of wells across Sierra Valley. The numbers indicate the number of wells per square mile section.



Map 2-2 Distribution of bedrock wells across Sierra Valley. The numbers indicate the number of wells per square mile section.

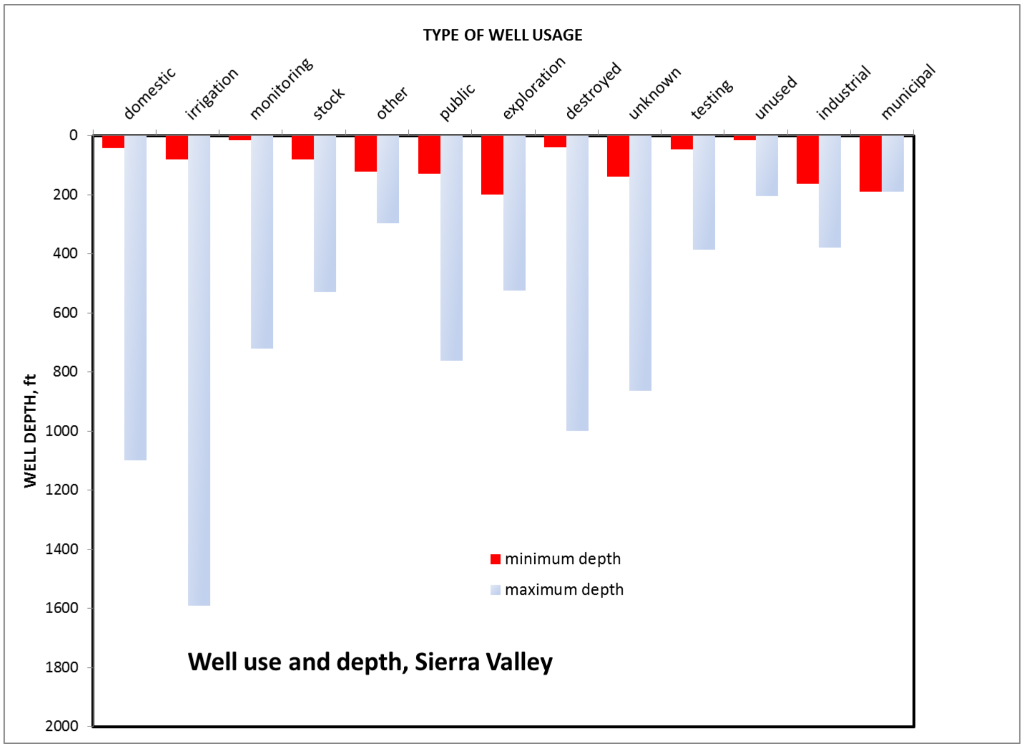


Chart 2-1 Well use application and well depth in Sierra Valley.

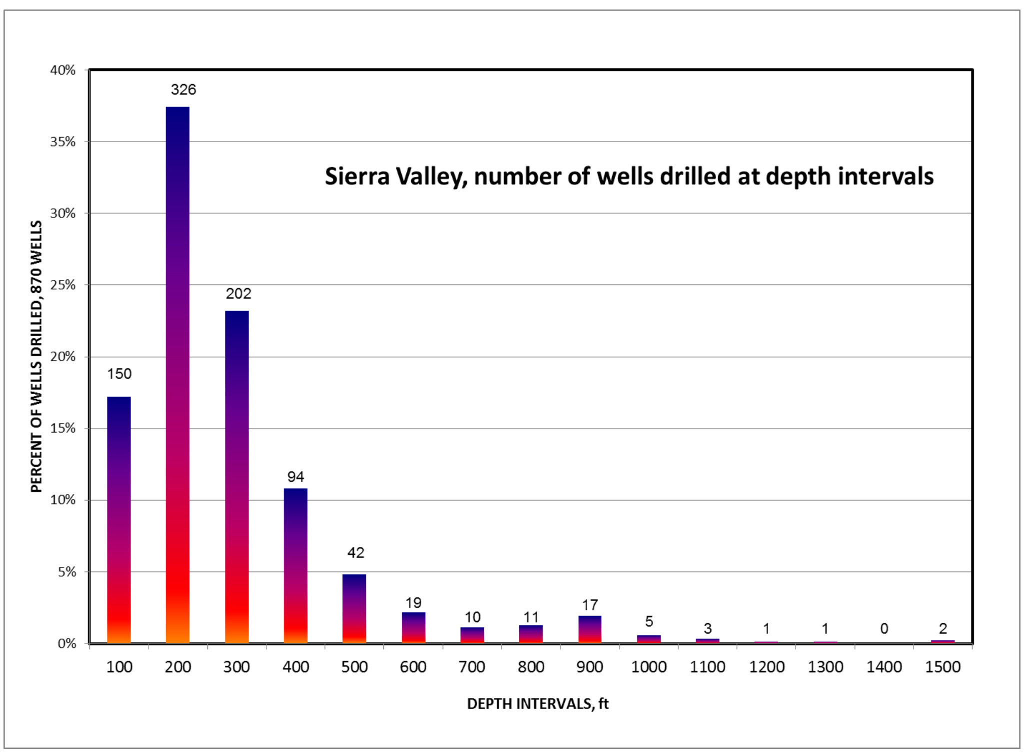


Chart 2-2 Number of wells drilled per depth interval. The vertical bars are percentages of all wells drilled in Sierra Valley. The numbers on top of each bar are actual number of wells drilled to that depth interval.

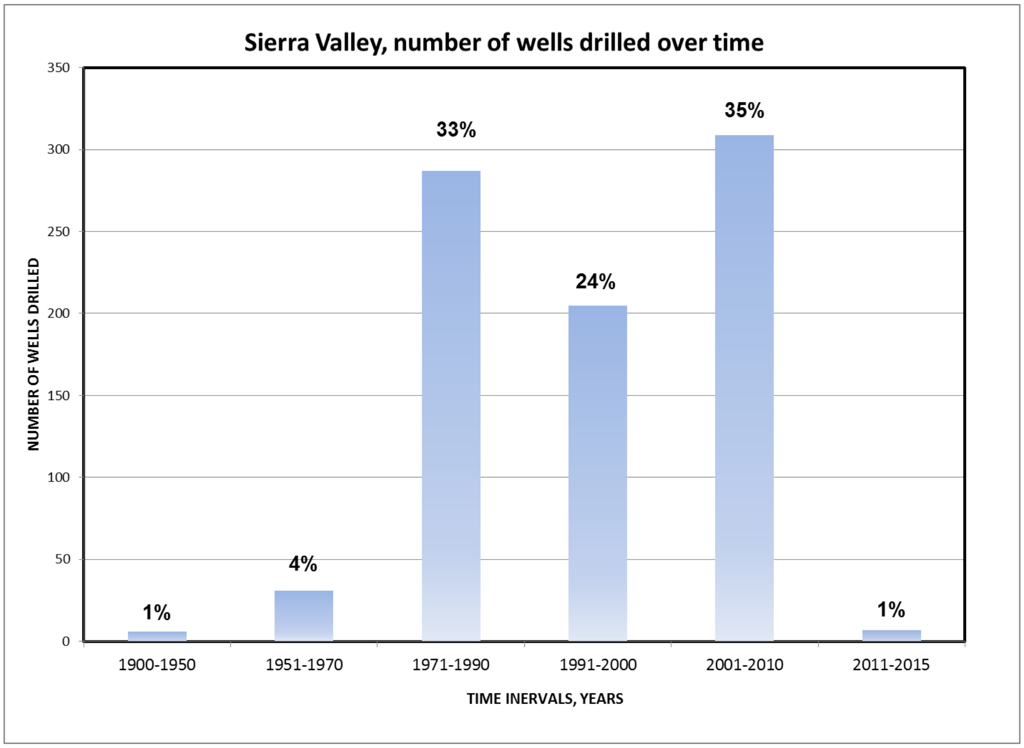


Chart 2-3 Historical trends of groundwater development in Sierra Valley.

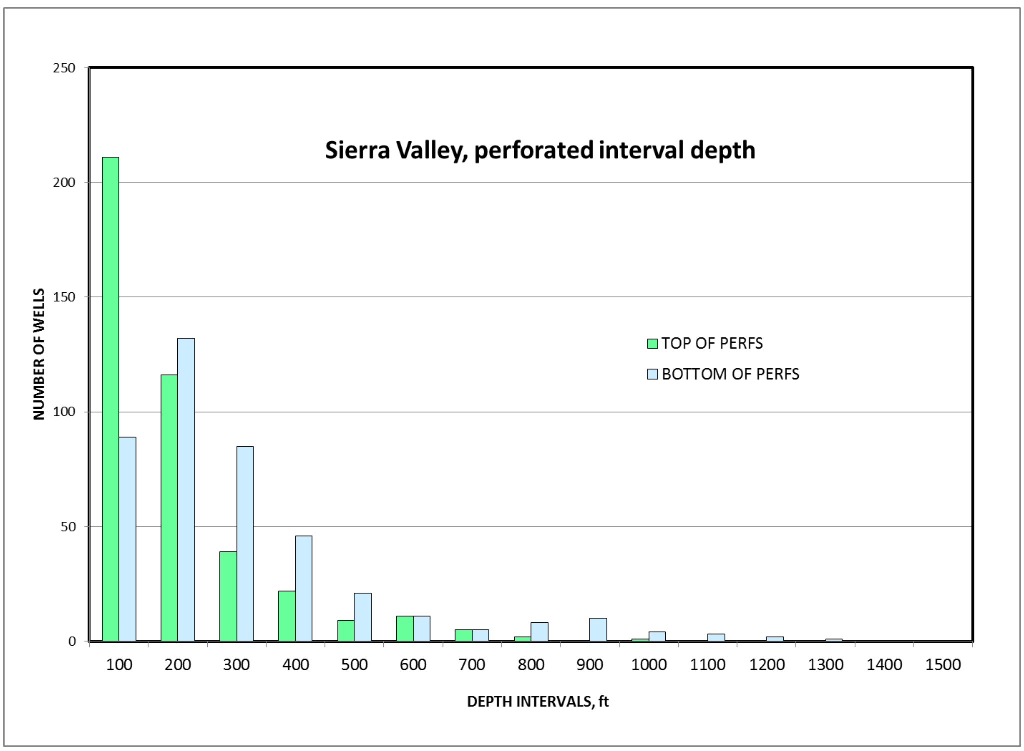


Chart 2-4 Perforated interval depths in Sierra Valley wells. The vertical bars indicate how many wells have their top and bottom of perforations in their respective interval. For example more than 200 wells' tops of perforations are above 100 ft, and about 90 wells have their perforations above 100 ft depth.

3. Inventory of Groundwater Quality in Sierra Valley

Background

By groundwater quality is meant the chemical make-up of the water produced from wells, springs, and streams. This includes major ion chemistry (like chloride, sulfate, etc.), trace elements (e.g. arsenic or chromium), and field data like temperature, electric conductivity (EC), pH, etc. water quality data also include biological data (e.g. coliform bacteria, etc.).

Collecting groundwater quality data has at least three objectives:

1. Assessing the current water quality state and identify parts of the aquifer system that poses a threat to the intended well use (for example retarding crop growth).
2. Detect and identify water quality trends that may hint at future water quality problems, as a result of pumping and groundwater development.
3. Groundwater chemistry data, preferably together with light stable isotopes, serve as a tool to help characterize the aquifer-system, including recharge and discharge zones.

Item 3 is covered in a separate companion report.

An assessment of basin-wide groundwater quality was conducted, using the DWR's historic groundwater chemistry data base, spanning the time period from 1981 until 2002. The objectives of the field data collection program were to:

- augment the existing data base to fill data gaps, and
- To continue the time series until the present.

This report concerns itself only with certain specific water quality parameters to identify potential natural and human source areas of groundwater contamination. In a concurrent report the groundwater chemistry and isotope data were analyzed to help characterize groundwater flow in the basin, and how it connects to the uplands groundwater recharge areas.

The DWR monitoring wells are all equipped with pumps, ready to be sampled. A more involved task was to sample the five nested piezometer sets installed by the SVGMD, which required purging and sampling with a special pump. The two-inch diameter piezometers are of particular interest since their screen intervals are in very well defined discrete depth intervals. This provided an opportunity to conduct a more comprehensive data collection, including not only the major ion chemistry, but also measuring dissolved oxygen, redox conditions and nitrogen species, parameters necessary to characterize the geochemical conditions at depth. Furthermore a select number of piezometers were sampled for tritium analysis.

Groundwater chemistry data base

Sierra Valley groundwater chemistry data have been collected by DWR since the late 1950's. However, most of the early datasets are incomplete and contain only a limited selection of water quality parameters.

The first comprehensive groundwater chemistry data was collected in 1981, including major ion chemistry and selected trace element data from 40 wells (see schematic map). Over the following 14 years DWR continued collecting data and by 1995 a total of 177 samples had been collected from 67 wells. This database was expanded with another 27 wells sampled in 2002 by a contractor working for the SVGMD (data in KDS, 2003). Thereby a substantial groundwater chemistry data record has been established. To date the historical data record includes:

1. A total of 67 Sierra Valley major ion and trace element groundwater chemistry data sets obtained from DWR files. Although the epm-balances range between -24% and 27%, the average ion equivalent balance is 0%. In a few data sets missing major ion values had to be calculated by assuming an equivalent balance of zero.

2. A total of 27 data sets collected in 2002, with equivalent balances between 0 and 10%.

3. Fourteen chemistry data sets from the District's five nested monitoring wells (at five locations, MW-2 through MW-6) sampled at shallow, intermediate, and deep levels. Piezometer chemistry data were obtained from KDS (2003; 2005). These piezometers were resampled in the summer of 2015, including light stable isotopes and tritium. The ion balances are between -6% and 7%.

4. A groundwater chemistry data base of 45 samples collected in 2014 from selected valley floor wells, specifically for the purposes of this project. The equivalent balances are between -8% and 18%. This database was expanded by:

    a. Twelve groundwater chemistry datasets obtained from consulting reports.

    b. Sierra Valley geothermal water chemistry data collected from 13 wells with temperatures between 26 and 73 degrees C. The data were obtained from a State data base and include Campbell HS and the former Marble Hot Wells. Ion balances are between -5% and +6%.

5. An isotope database collected from uplands springs and streams and valley floor wells, for the purpose of this project.

Database limitations and time trends

Although the purpose of the DWR and SVGMD groundwater chemistry database has to our knowledge never been stated, presumably the objective is to monitor water quality trends over time, in order to detect any water quality changes in response to groundwater pumping. At least this would be a prudent thing to do since groundwater flow gradients have the potential of enhancing flow of poor quality water into the pumping zones, leading to groundwater quality degradation.

The dilemma is, however, that after the initial batch of 40 wells was sampled in 1981, only 26 wells have been resampled, and of these only 11 were resampled during the latest monitoring event in 2002. Furthermore most of the 2002 data sets are incomplete datasets, missing most often the parameters of greatest interest. For example, only ten samples were analyzed for boron, and only four for nitrate.

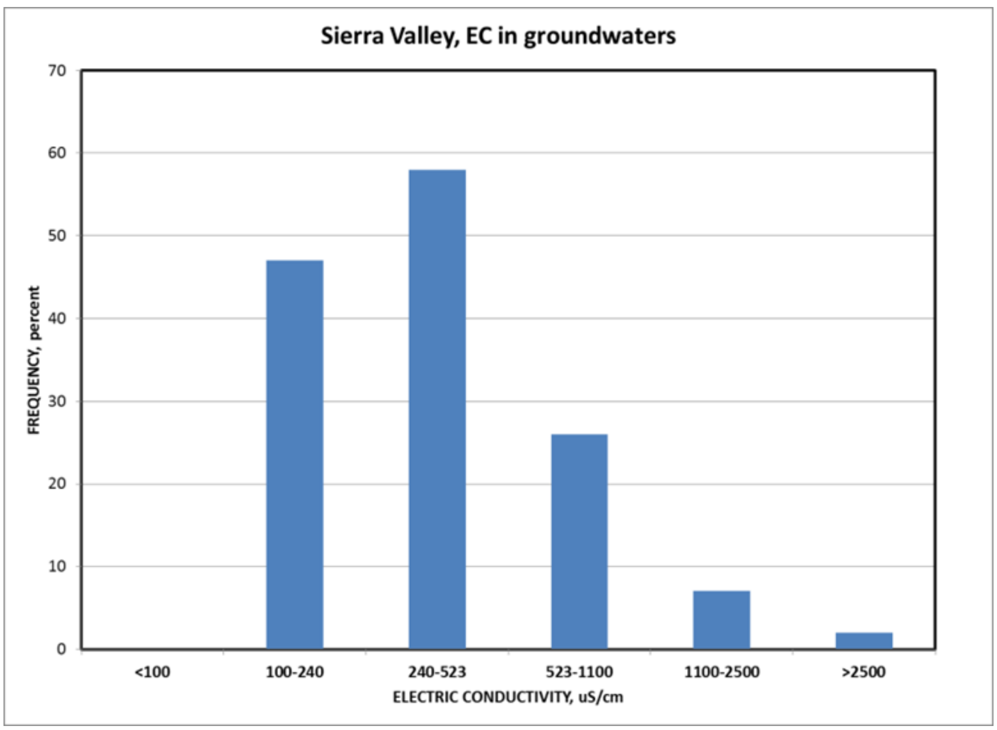


Chart 3-1 Electric conductivity (EC) in Sierra Valley groundwaters. The vertical axis is "number of wells". Note that most groundwaters measured have conductivities less than 500 uS/cm.

This permits virtually no comparison between samples collected over time. The same problem occurs in the wells sampled apparently randomly between 1981 and 2002. This defeats the purpose of the groundwater quality monitoring program.

The inconsistency between sampling events is demonstrated in the schematic map and the table of sampling events.

One objective of the 2014/15 sampling effort was to duplicate the 1981 sampling run by re-sampling all 40 wells sampled in 1981. Unfortunately this has not been possible since no access was given to DWR's field notes to determine the exact well locations (including well owner names, and drilling reports). When it became clear that this well information from DWR was not available it was decided instead, with help from SVGMD's field personnel to sample a selection of irrigation and residential wells in the SVGMD's monitoring well network (the so-called "DMS wells").

The unavailability of well log information for the DWR database for now precludes three-dimensional mapping of water quality parameters.

Major ion chemistry

Total dissolved solids levels in Sierra Valley groundwaters range between about 100 and 1500 mg/l (or 160 to 2500 uS/cm). Including only the DWR groundwater quality data set from 67 wells, the equivalent percentages for the major cations and anions were calculated and plotted in Chart 3-1. The Sierra Valley groundwaters cover a wide range of water types ranging from comparatively low percentages of chloride, sulfate, sodium, and potassium plotting in the lower left corner to high percentages of the same constituents in the upper right corner.

The low TDS waters plot as low sodium waters in the lower left corner evolving to sodium-sulfate waters in the upper right hand corner with more than 1000 mg/L TDS. Sierra Valley groundwater chemistry covers a wide range, a pattern that is symptomatic of groundwater chemistry evolution in silicate rocks and sediments under somewhat elevated groundwater temperatures (up to 40 degrees C). Similar patterns have been observed elsewhere in northeast California (e.g. in the Modoc Plateau and the adjacent Great Basin).

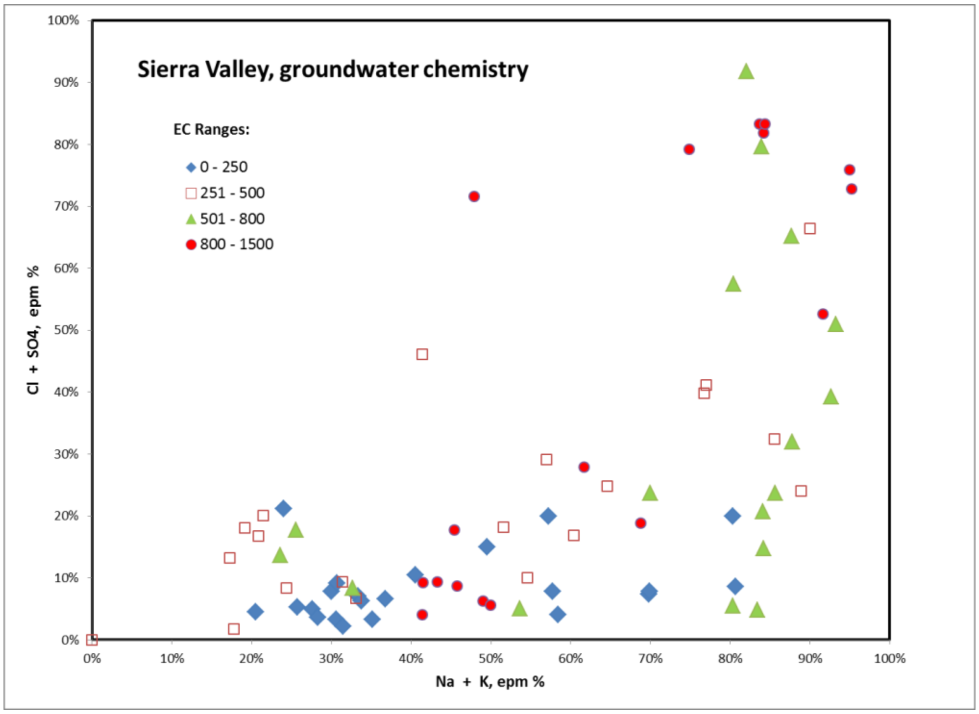


Chart 3-2 Equivalent percentages in Sierra Valley groundwaters. Note how the low chloride-sulfate waters are associated with low EC levels (< 250 uS/cm.

Chloride and sulfate range from 1 mg/L to 545 mg/L and from 1 to 370 mg/L, respectively. Basin wide the TDS ranges from 115 to more than 1400 mg/L.

Geothermal waters

As is typical in these basins in NE California most groundwaters have somewhat elevated temperatures due to the high heat flow that is characteristic for these basins. However, there are locations in faulted bedrock areas buried by the younger sediments where groundwater does penetrate to greater depth, to re-emerge at places like Marble Hot Wells and on the Filipini Ranch.

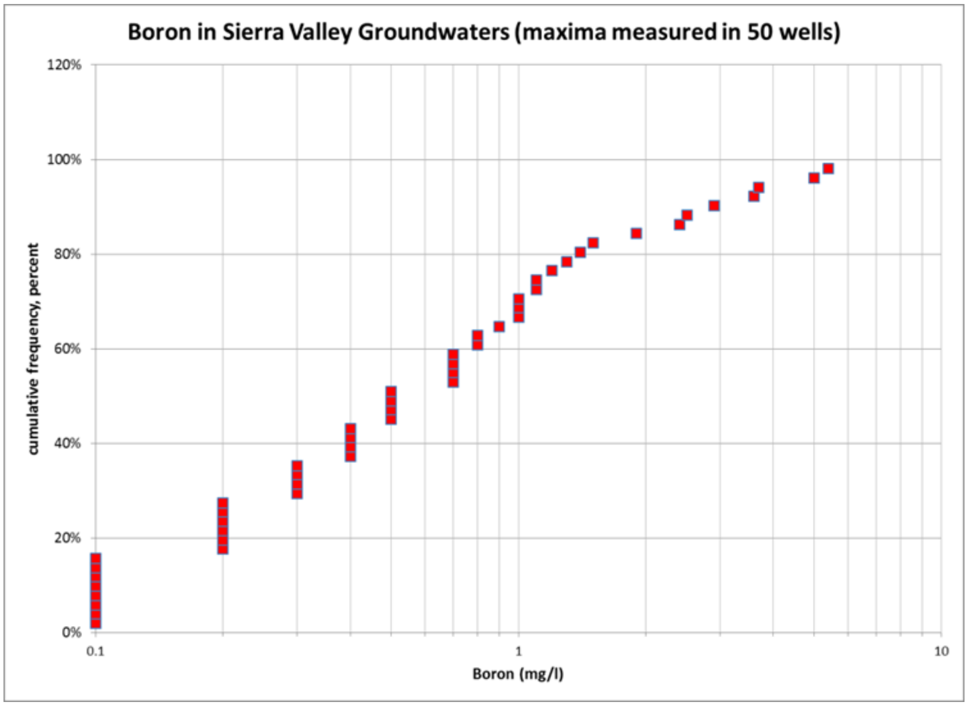


Chart 3-3 Cumulative frequency of boron levels measured in 76 Sierra Valley wells from 1981 until 2002. About 20% of the waters sampled have boron levels greater than 1.5 mg/L.

Water quality parameters of concern

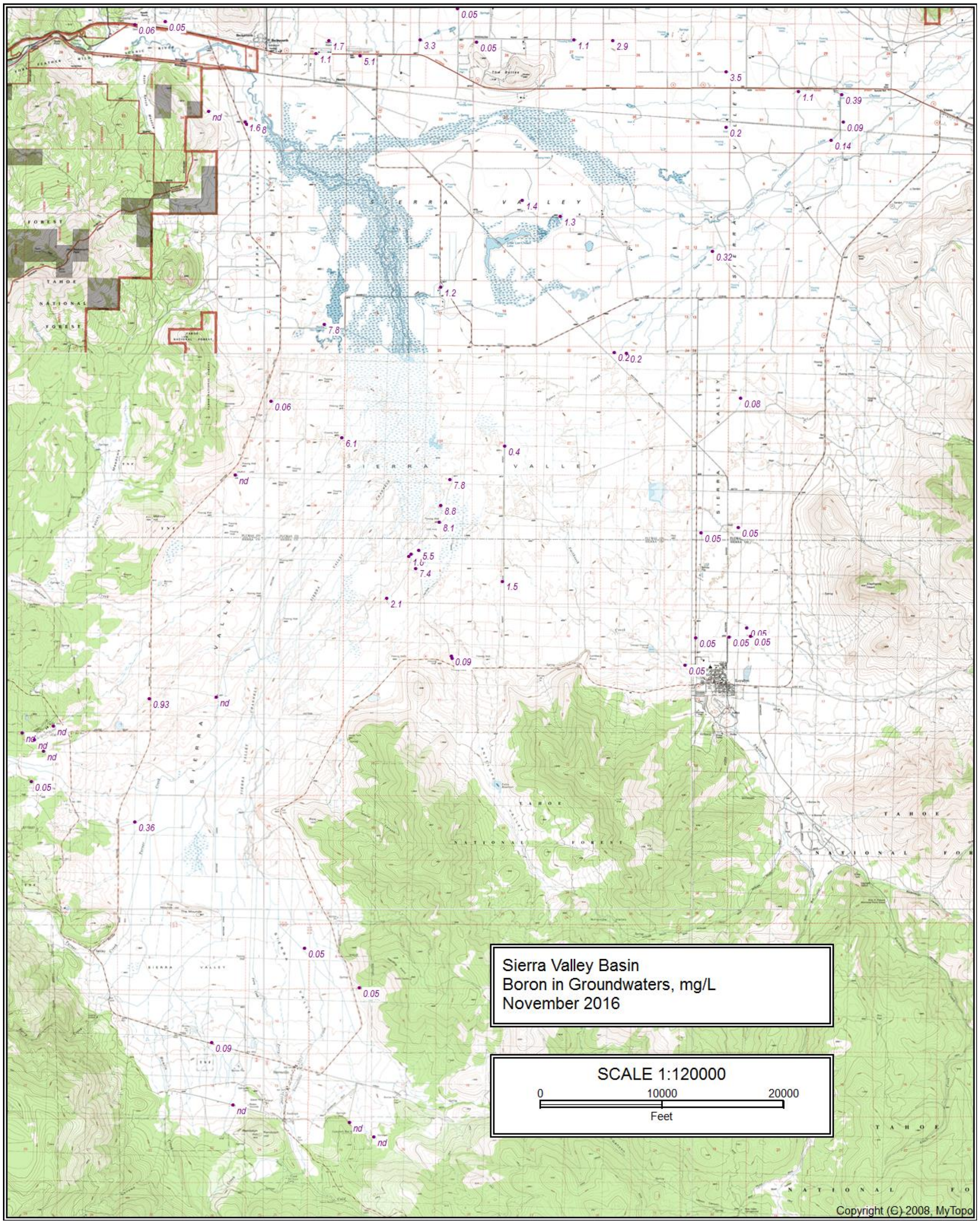
Boron

Elevated boron levels are commonly associated with geothermal waters and can become a limiting factor in growing certain crops. It is highly soluble in natural waters, a weathering bi-product in granitic rocks, and more so in pegmatites (Hem, 1985, p. 129). In Sierra Valley high boron levels correlate with groundwater temperature and TDS. However, the correlations are rather coarse, suggesting other unknown associations might be involved.

Table 2. Classification of Irrigated Water Based on Boron Concentration In Relation to Plant Tolerance

Classification	*Sensitive Plants*	*Semi-Tolerant Plants*	*Tolerant Plants*
		ppm Boron	
Excellent	< 0.3	< 0.6	< 1.0
Good	0.4-0.6	0.7-1.3	1.0-2.0
Fair	0.7-1.0	1.4-2.0	2.1-3.0
Poor	1.1-1.3	2.1-2.5	3.1-3.8
Unsuitable	> 1.3	> 2.5	> 3.8

Boron levels from selected wells in SV are plotted in Map 3-1. Although due to the limitations of the database we are not able to draw a time series plot for boron, a cumulative frequency diagram in Chart 3-3 shows that boron in many wells can be significant. For example 30% of all wells



Map 3-1 mg/L Boron in Sierra Valley groundwaters

sampled had at one time boron levels greater than 1.0, and maximum boron levels can be greater than 5 mg/L (8.1 mg/L in the Filipini geothermal well).

Boron time trends in groundwater

The data are not very well suited to plot time series of boron in groundwater. Nevertheless changes can be noted by visual inspection of the database. This is of great importance since the SVB aquifer system has been significantly stressed in the past 30 years, and will continue to be pumped in the future. Changing boron levels could become one important indicator of pending changes due to aquifer development.

Table 3-1 summarizes the changes observed between successive sampling events. Among 122 samples taken, boron changes were observed in 80% of samples taken, of which 34% were increases, 46% were decreases and 20% showed no change. In other words boron changes were observed in 4/5th of the samples taken. It remains to be seen if these results can be interpreted as an indicator of changes in the aquifer, or whether these are natural fluctuations. But the occurrence of more decreasing than increasing boron levels can not necessarily be interpreted as an indication that conditions are improving

Table of Boron increases and decreases observed in Sierra Valley monitoring wells, 1981 through 2002.		
number of sampling events	207	
B samples taken	122	100%
B increases	41	34%
B decreases	56	46%
no changes	25	20%
# of wells where B increases were observed	26	
# of wells where B decreases were observed	38	
maximum B increase between sampling events	5.4	mg/L
maximum B decrease between sampling events	-5.4	mg/L

Table 3-1 Boron changes in Sierra Valley groundwaters, observed from 1981 until 2002.

Recommendation: Given the limitations of the database, a similar trend analysis may have to be also conducted on other water quality parameters, for example nitrate.

Nitrate

Nitrate is a form of nitrogen that is a rather ubiquitous water quality parameter in the environment. Nitrate is very soluble, and is the oxidized ionic species of NO2. In groundwaters with reducing chemical conditions (low to no oxygen) nitrogen can occur in the form NO2 (nitrite), and more rarely as NH3 (ammonia). Unless specially sampled for using the appropriate preservatives, the nitrite and ammonia species oxidize as soon as they get in contact with the atmosphere. If the groundwater conditions were reducing the reduced nitrogen species are oxidized into NO3 since most monitoring programs do not measure redox potential or use special preservatives for NO2 and NH3. For a more in-depth presentation of nitrogen chemistry, the interested reader is referred to Hem (1985, p. 124).

Therefore NO3 values in this database are probably total nitrogen measured as NO3. Since natural nitrate concentrations in groundwater are usually low, high nitrate values are always suspect, possibly indicating groundwater pollution either by agricultural fertilizers, manure, or underground septic leachfields (on-site residential wastewater disposal).

High concentrations of nitrates in drinking water can have serious health impacts, so tracking and monitoring nitrate levels is very important. However, it is beyond the scope of this report to track these trends over time due to the database limitations discussed above (see page 12). Furthermore, seasonal variations in nitrate concentrations are common. For these and other reasons, further nitrate trend study and analysis is recommended.

It is also important to understand the susceptibility of nitrate to well conditions. At this stage no well data are available – data like screen-depths, well depth, age of well, etc. Numerous factors such as well location, well construction, well age and condition, and well depth can all affect the nitrate concentrations found in a given well. The nitrate concentrations presented in this report should be used as an indicator for general aquifer conditions and justification for further study. They should **not** be interpreted as directly representing conditions found in drinking water.

In the nitrate frequency diagram of Chart 3-4 about 25% of all samples collected from 1981 until 2002 exceeded the drinking water standard of 44 mg/L (maximum of 203 mg/L). This is in contrast with the much lower values measured in 2014/15 (maximum of 8.3 mg/L). Map 3-2 shows nitrate values measured from 1981 until 2002 (DWR data base, red squares), and in 2014/15 (blue diamonds). Although the two datasets are from different wells, they are in many cases from the same areas (see Map 3-2). The reason may be that wells in each data batch are of different depth intervals. The answer may be found in the well construction data. For that purpose well ownership and exact well location descriptions are required.

The high nitrate values in the first data set are difficult to explain since many areas in Sierra Valley are not cultivated, are not used for pasture, or do not have residential development and onsite septic systems. To better understand this, it would be helpful to know the natural background level of nitrate. After all, the Sierra Valley Basin is filled with lacustrine sediments which tend to contain abundant organic deposits (peat), which may be one source of naturally-occurring nitrate concentrations.

This could be done by means of cumulative frequency diagrams plotted on probability graph paper, to identify sub-populations of nitrate data. An alternate approach would be to employ nitrogen isotope techniques. Eventually a more targeted study of nitrates in Sierra Valley may be needed.

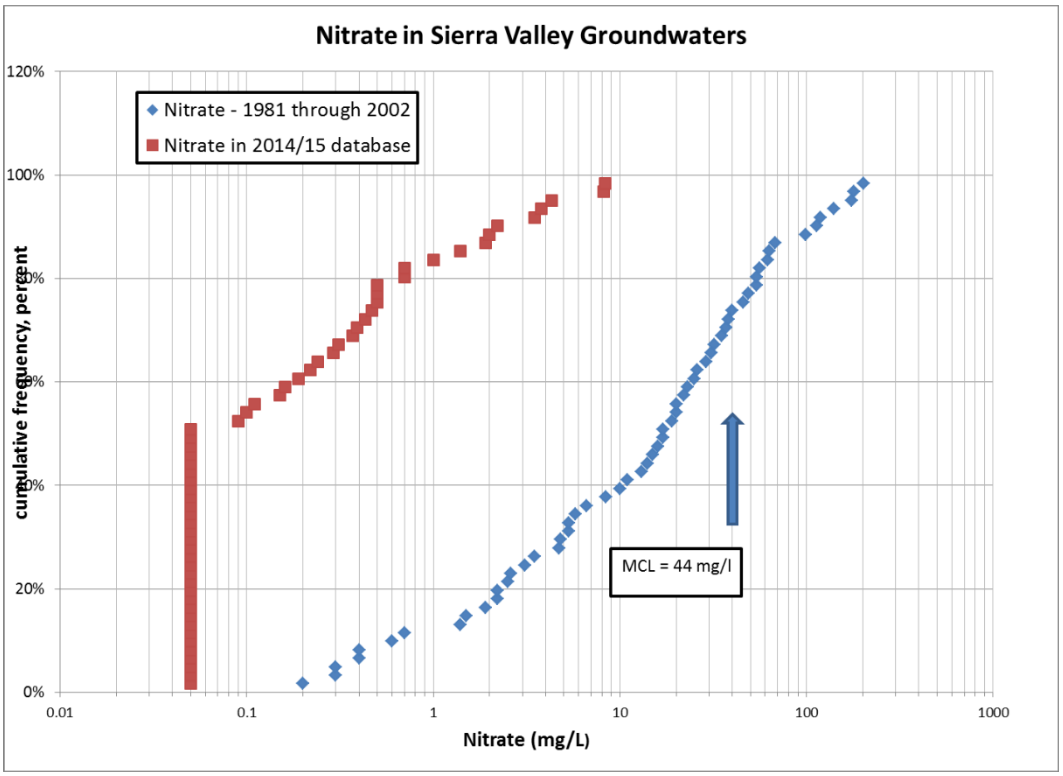
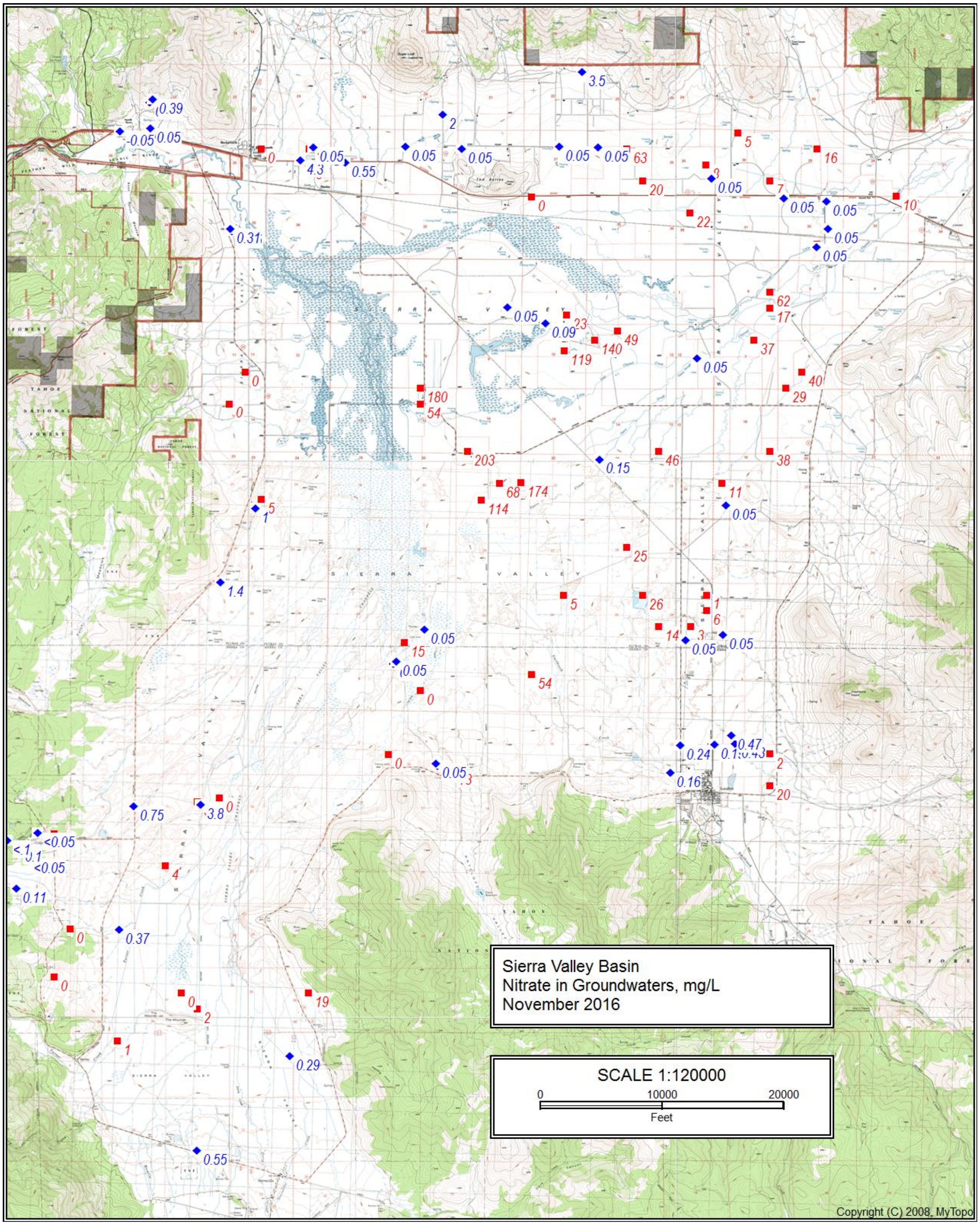


Chart 3-4 cumulative frequencies of nitrate measured in Sierra Valley wells between 1981 and 2002, and in 2014/15.



Map 3-2 Nitrate in Sierra Valley groundwaters. Red squares are data collected 1981 through 2002. Blue diamonds are data collected in 2014/15.

Sodium Adsorption Ratio (SAR)

The tendency of irrigation water to replace calcium and magnesium adsorbed in the soil with sodium can be expressed by the sodium-adsorption ratio (SAR) (Hem 1985, p. 216, 161). High SAR values indicate a potential of sodium replacing calcium and magnesium adsorbed to certain clay minerals in the soil, thereby eventually damaging the structure of the soil.

The SAR is calculated as

$$SAR = [Na^+]/\sqrt{(0.5*[Ca^{2+}] + [Mg^{2+}])}$$

Where the ion concentrations are in milli-equivalents per liter (Hem 1985, p. 161).

A cumulative frequency diagram was prepared for the SAR values calculated for the 1981-2002 Sierra Valley monitoring events (97 data points). An evaluation of the significance of these SAR values is beyond the scope of this report.

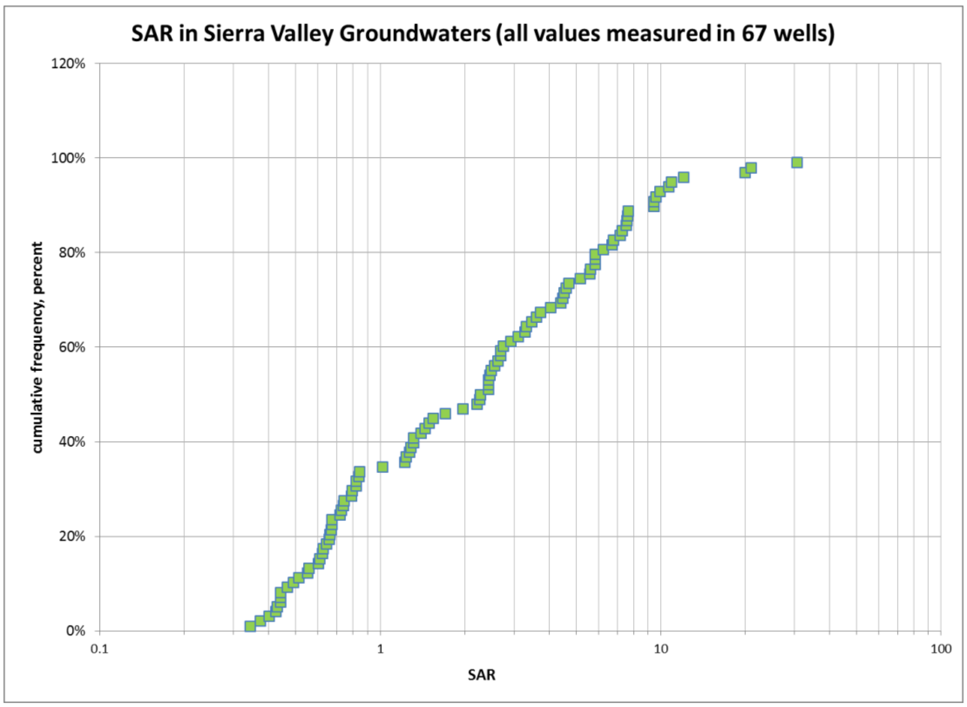


Chart 3-5 Cumulative frequencies of SAR measured in Sierra Valley groundwaters between 1981 and 2002.

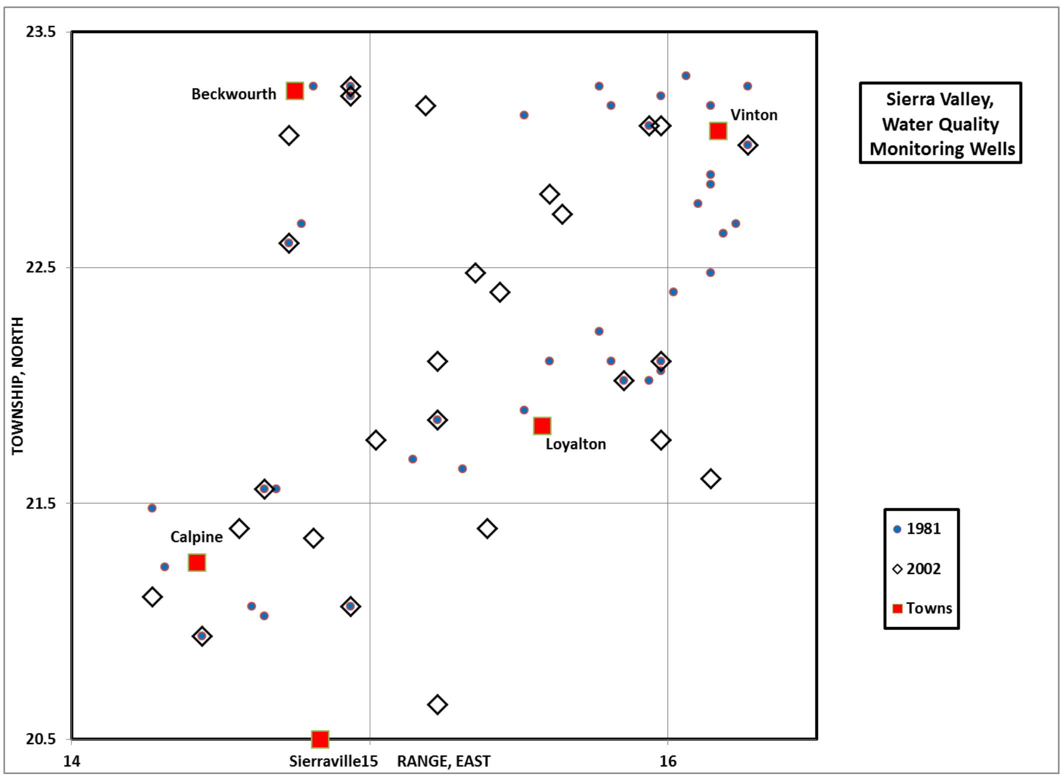
Summary and conclusions

Sierra Valley groundwater chemistry is highly variable. The variability, however, appears to be more aerially than vertical. Nevertheless vertical variability is evident in the southern monitoring wells and is expected to become more evident once we have been provided with the well log numbers for each of the wells that are part of DWR's groundwater quality monitoring network.

In a companion report it will be demonstrated with the chemistry and isotope data that applying the terms "shallow" and "deep" aquifer is justified. However, a few words are in order about how depth intervals and regional extent of these aquifers are determined.

The screened intervals indicated in the driller's logs provide information true to the definition of the term 'aquifer': a permeable, water-bearing geologic formation that provides water to a pumping well under economically sustainable conditions (Freeze and Cherry, 1979). Undoubtedly the objective of well construction is always to maximize well yield, thereby fitting the abovementioned aquifer definition.

A complicating factor is that the formations between the shallow and deep aquifers also contain water, though the formations probably have significantly smaller bulk permeabilities – at least low enough to not make them attractive for well construction. Nevertheless, the chemical data suggest a continuum of values, which can be interpreted as a "leaky confined aquifer" setting.



Map 3-3 Water quality monitoring well locations in Sierra Valley, 1981 and 2002. Note the limited overlap of sampling locations between sampling events.

Sierra Valley Monitoring Wells - Water Quality:																			
Monitoring events - time & location						total # of historic samples:			204										
							# of Wells sampled:		40	10	3	5	7	22	27	23	25	15	27
	priority wells:	38	2						Year sampled:										
WQ-Well #	State Well Number	priority	sampled	Easting	Northing	Name	DMS-#	Date first sampled	1981	1982	1983	1984	1985	1986	1987	1989	1993	1995	2002
WQ-62	23N/16E-36P07							3/10/1989								1	1	1	
WQ-64	23N/16E-36L 04							4/5/1989								1	1	1	
WQ-61	23N/16E-33A02							3/10/1989								1	1	1	
WQ-32	23N/16E-32Q01	2		738871	4409060	D&S NW 10 E38	DMS 14	7/9/1981	1										1
WQ-31	23N/16E-30R01	1						7/9/1981	1										
WQ-30	23N/16E-30C01	1		736711	4411894	Green Gulch NW 6	DMS 11	7/9/1981	1						1				
WQ-29	23N/16E-29G01	1	1	738698	4411155	Green Gulch NW 5	DMS 13	7/9/1981	1										
WQ-71	23N/15E-36H02							9/17/2002											1
WQ-28	23N/15E-36G01	2		735499	4409495	D&S NW 7	DMS 09	7/9/1981	1										1
WQ-40	23N/15E-34D01							7/10/1981	1										
WQ-70	23N/15E-29N02	2		728246	4410341	Goodwin South New	DMS 52	9/16/2002											1
WQ-27	23N/15E-26R01	1		734699	4410262	Green Gulch NW 2	DMS 07	7/9/1981	1						1				
WQ-26	23N/15E-26G01	1		733905	4411403	Green Gulch NW 1	DMS 08	7/9/1981	1										
WQ-25	23N/15E-25J 01	1		736264	4410709	Green Gulch NW3	DMS 10	7/9/1981	1						1				
WQ-67	23N/14E-35L04							4/18/1989								1			
WQ-57	23N/14E-35L02							5/2/1985					1			1	1	1	1
WQ-09	23N/14E-26H02	1						7/8/1981	1					1					
WQ-24	23N/14E-25K02	2						7/9/1981	1	1							1		
WQ-56	23N/14E-25K01	2						5/2/1985					1	1	1	1			1
WQ-08	23N/14E-25G02	2						7/8/1981	1					1		1	1	1	1
WQ-23	22N/16E-19M01	1	1	736694	4402730	Bar One OW2	DMS 218	7/9/1981	1					1	1				
WQ-22	22N/16E-19A01	1		737486	4403795	Bar One NW 14	DMS 42	7/9/1981	1										
WQ-21	22N/16E-17D01	1		738318	4405523	D&S NW 9b	DMS 41	7/9/1981	1					1	1				
WQ-20	22N/16E-08P01	1		738427	4405658	D&S NW 9a	DMS 18	7/9/1981	1			1		1	1				
WQ-19	22N/16E-07G01	1		737388	4406549	D&S NW 12	DMS 17	7/9/1981	1										
WQ-18	22N/16E-06R02	1		737686	4407369	D&S NW 11	DMS 16	7/9/1981	1										
WQ-17	22N/16E-06J 04							7/9/1981	1	1				1	1	1	1	1	
WQ-16	22N/15E-36Q01	1		736186	4398984	Bar One OW 5	DMS 28	7/9/1981	1					1					
WQ-15	22N/15E-36N01	1		735114	4398966	Bar One OW 6	DMS 27	7/9/1981	1										1
WQ-14	22N/15E-36H01	2		736167	4399785	Bar One OW 3	DMS 26	7/9/1981	1					1	1		1		1
WQ-13	22N/15E-36 J01	2						7/9/1981	1										
WQ-12	22N/15E-35H01	2						7/9/1981	1	1				1	1		1		
WQ-11	22N/15E-34G01	2		732802	4399725	Bar One OW 8	DMS 25	7/9/1981	1						1		1		
WQ-78	22N/15E-32F01							10/8/2002											1
WQ-10	22N/15E-26K03	1						7/9/1981	1					1	1		1		
WQ-60	22N/15E-24D01							3/10/1989								1	1		
WQ-77	22N/15E-21L04							10/8/2002											1
WQ-44	22N/15E-21L01/04							7/14/1982		1									
WQ-43	22N/15E-21K01							7/14/1982		1						1			1
WQ-42	22N/15E-21J 01							7/14/1982		1	1						1		
WQ-53	22N/15E-21D02							4/16/1985					1		1	1	1	1	1
WQ-48	22N/15E-21D01							8/25/1983			1								
WQ-65	22N/15E-17F03							4/6/1989								1	1		
WQ-41	22N/15E-17C03	1						7/14/1982		1									
WQ-59	22N/15E-17C01	1						7/9/1987							1	1	1	1	
WQ-47	22N/15E-11F01							7/15/1982		1				1	1				
WQ-52	22N/15E-11E01							7/12/1984				1	1	1	1				
WQ-76	22N/15E-10J01							9/30/2002											1
WQ-58	22N/15E-10H02							5/3/1985					1						
WQ-46	22N/15E-10C01	2		731972	4406546	Roberti Big	DMS 01	7/15/1982		1					1				
WQ-51	22N/15E-10B01	2		732136	4406948	Roberti New	DMS 02	7/12/1984				1			1				1
WQ-66	22N/14E-23R01							4/18/1989								1	1	1	
WQ-02	22N/14E-14F02							7/7/1981	1										1
WQ-01	22N/14E-11Q01	1						7/7/1981	1					1					
WQ-50	21N/16E-18H01							7/11/1984				1		1	1	1	1		1
WQ-63	21N/16E-07R01							4/5/1989								1			
WQ-39	21N/15E-17A01	1						7/10/1981	1										
WQ-69	21N/15E-12H01	**1**		736446	4396582	Cassida West	DMS 31	9/16/2002											1
WQ-38	21N/15E-07R01	1						7/10/1981	1										
WQ-68	21N/15E-07E01							9/16/2002											1
WQ-37	21N/15E-05P01	1						7/10/1981	1										1
WQ-54	21N/15E-05D01							5/1/1985					1	1	1	1	1	1	
WQ-49	21N/15E-03M03	2		732220	4397631	Macey West	DMS 37	8/26/1983			1								
WQ-07	21N/15E-03M02							7/8/1981	1			1		1	1	1	1	1	
WQ-06	21N/14E-36K01							7/8/1981	1					1	1	1	1	1	1
WQ-36	21N/14E-34R01							7/10/1981	1										
WQ-35	21N/14E-34K01							7/10/1981	1										
WQ-45	21N/14E-32G01							7/15/1982		1				1	1	1	1	1	1
WQ-05	21N/14E-29J 01							7/8/1981	1					1	1	1			
WQ-75	21N/14E-23R01							9/30/2002											1
WQ-55	21N/14E-22L01							5/2/1985					1		1		1		1
WQ-34	21N/14E-20B02	1						7/10/1981	1										
WQ-04	21N/14E-15J01							7/8/1981	1					1	1	1	1	1	1
WQ-33	21N/14E-14M01							7/10/1981	1										
WQ-72	20N/15E-17C04							9/30/2002											1
WQ-03	20N/14E-04G02	2						7/8/1981	1					1	1	1	1	1	1

Table 3-2 Table of sampling events in Sierra Valley, 1981 till 2002.

4. Bibliography

Hem JD, 1985. Study and interpretation of the chemical characteristics of natural water. US Geol. Survey Water Supply Paper 2254. 263 pages.

Freeze A and J Cherry, 1979. Groundwater. Englewood Cliffs, N.J. 604 pages.

Piper, 1944. A graphic procedure in the geochemical interpretation of water analyses. Amer. Geophys. Union Trans., v. 25, 914-923.

Sinclair AJ, 1973, Selection of threshold values in geochemical data using probability plots, J. Geochem. Explor. V. 3, pp.129-149.