ATTACHMENT A

EXISTING CONDITIONS
IN THE LOWER DEER CREEK WATERSHED

EXISTING CONDITIONS FOR THE LOWER DEER CREEK WATERSHED

The following document provides an overview of the fishery resource, existing water rights, hydrology, land and water use, geology and hydrogeology for the lower Deer Creek watershed. Information in this document is intended to support development of a Deer Creek Watershed Environmental Flow Augmentation Program. The existing conditions for the lower Deer Creek watershed were developed using data collected by the Northern District Department of Water Resources and it's cooperators during feasibility studies for the Deer Creek Water Exchange Program, data developed from DWR's ongoing Northern Sacramento Valley water resource investigations and information provided by California Department of Fish and Game.

Fishery Resource

Deer Creek represents one of the State's largest undammed watersheds. Several unique habitat features within Deer Creek make it a very important resource for anadromous fish in the Sacramento Valley. Studies conducted in 1988 found that native fish comprise 95 percent of the fish populations in 86 percent of the Deer Creek drainage. Anadromous species with consistent runs up Deer Creek include spring-run chinook salmon, fall-run chinook salmon, winter-run steelhead trout and Pacific lamprey (1998, *Deer Creek Watershed Management Plan*). However, declining populations of several anadromous species has led to the 1999 State and Federal listing of spring-run chinook salmon as a threatened species, the 2000 Federal listing of steelhead trout as a threatened species, and the 1999 State listing of the fall-run and late-fall run chinook salmon as species of concern.

In 1989, the Resources Agency published a report entitled: *Upper Sacramento River Fisheries and Riparian Habitat Management Plan*. Findings from the plan concluded that Deer Creek is one of only a few waterways in the Central Valley that continues to support a native population of wild spring-run chinook salmon and the most serious impact to the Deer Creek fishery is the reduction of transportation flows. The 1989 plan identified the number one solution to increasing transportation flows was to negotiate an agreement with water right holders to pump groundwater into the irrigation systems at critical times in exchange for leaving an equal amount of natural flow in the stream for fish migration.

In 1993, California Department of Fish and Game published a report entitled: *Restoring Central Valley Streams: A Plan for Action*. Findings from this study concluded that Deer Creek has the greatest potential of all Sacramento Valley streams for increasing naturally spawning population of steelhead and spring-run salmon.

In 1998, Deer Creek Watershed Conservancy implemented the *Deer Creek Watershed Management Plan*. As part of the plan, the DCWC adopted several recommendations from the 1989 and 1993 studies, and incorporated as their number one strategy to maintain stream flows necessary for unimpaired fish passage for Chinook salmon and steelhead.

Historically agricultural water diverters within Deer Creek Irrigation District and Stanford Vina Ranch Irrigation Company have cooperated to temporarily reduce their surface water diversions and provide a pulse of increased transportation flow in Deer Creek during times of critical need.

Although these informal methods have helped the fish migration during critical times, Deer Creek Irrigation District, Stanford Vina Ranch Irrigation Company and fishery professionals recognize the need for a long-term solution to the fish transportation issues in Deer Creek.

Since 1998, DCID and SVRIC have worked with state, county and local groups to identify their agricultural water needs and study various scenarios to increase fish transportation flows in Deer Creek. Through the current proposal DCID and SVRIC are working towards a program that would provide increases in fish transportation flow by augmenting their existing water supply with water efficiency improvements and groundwater substitute pumping

Surface Water Rights and Diversions

Established in 1918, Stanford Vina Ranch Irrigation Company (SVRIC) was granted a license by the State Water Commission to divert 15 cfs of Deer Creek. In 1921, SVRIC filed suit against upstream riparian water users claiming excessive upstream diversions were leaving SVRIC with little water. In 1923 the courts adjudicated the entire flow of Deer Creek with 65 percent of the flow granted to SVRIC and 35 percent to DCID. In 1926, changes were made to the adjudication to account for 180 acres north of Deer Creek, that were not serviceable by DCID but had water rights under the 1923 adjudication, and to list a small portion of the water right to Sheep Camp Ditch (south of DCID) for stock water. The 1926 decision grants approximately 66 percent of the Deer Creek flow to SVRIC, 33 percent to DCID and 1 percent to Sheep Camp Ditch. The Deer Creek adjudication is based on the amount of flow measured at the USGS gage above the DCID diversion (see Figure 1).

Deer Creek Irrigation District has one screened diversion located about 0.5 miles downstream from the USGS gage, along the south side of Deer Creek, in the northeast one-quarter of section 23, township 25N, range 01W. Since 1998, the volume of water diverted from Deer Creek by DCID has been measured and continuously recorded using an engineered 8-foot parshall flume located just below the main diversion (see Figure 1). Prior to 1998, the amount Deer Creek flow diverted by DCID was estimated using several weirs located further down the canal from the Deer Creek diversion. Table 1 shows the minimum, maximum and average daily diversion of DCID, between April and October of 2000. The maximum average daily diversion for water year 2000, as measured by the DCID parshall flume, is 42 cfs.

DCID Average Daily Diversion: 2000					
Month	**Average Daily Diversion (cfs)**			**Ave. Monthly Total**	
	Min.	**Max.**	**Average**	**(cfs)**	**(ac-ft)**
April	18	**42**	28	826	1,635
May	15	33	21	661	1,309
June	26	37	32	954	1,889
July	31	36	34	1,052	2,083
August	28	31	29	909	1,800
September	22	33	27	817	1,618
October	5	28	14	419	830
			Total:	**5,638**	**11,163**

Table 1. Deer Creek diversion by DCID; 2000 agricultural season.

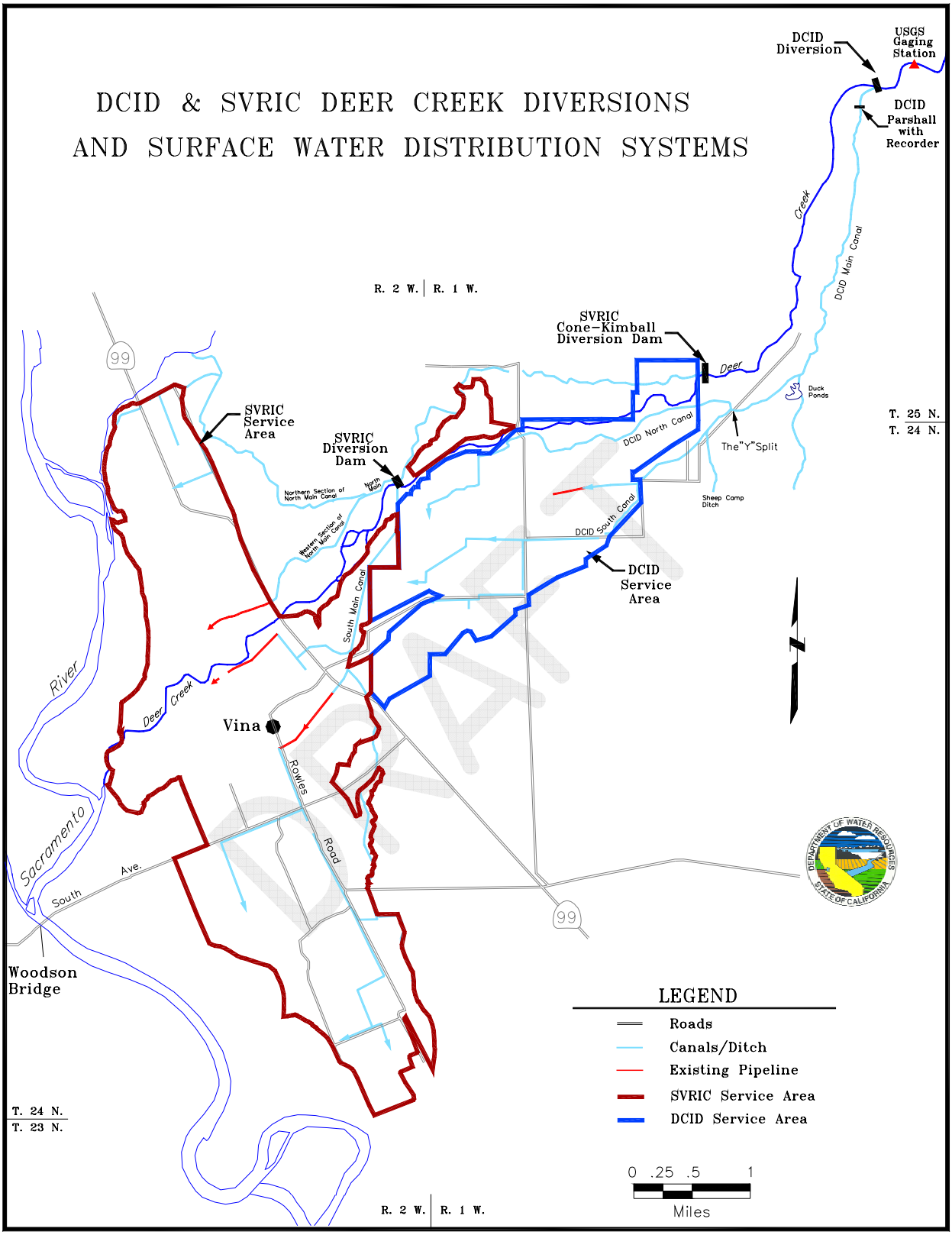

Figure 1. DCID and SVRIC Surface Water Diversions.

Table 2 is the 1999 to 2002 average of DCID's average daily diversions. Table 2 shows that the average annual diversion from DCID, between 1999 and 2002, was 11,192 acre-feet.

DCID Average Daily Diversion: 1999-2002					
Month	**Average Daily Diversion (cfs)**			**Ave. Monthly Total**	
	Min.	**Max.**	**Average**	**(cfs)**	**(ac-ft)**
April	14	37	25	687	1,360
May	22	36	29	883	1,748
June	25	34	30	873	1,729
July	26	32	29	892	1,766
August	28	31	29	890	1,762
September	25	31	27	806	1,596
October	9	31	20	622	1,232
			Total:	**5,653**	**11,192**

Table 2. 1999-2002 Average of DCID's Average Daily Deer Creek Diversion.

Stanford Vina Ranch Irrigation Company has three screened diversions; the Cone Kimball, the North Main and the South Main (see Figure 1). The Cone Kimball diversion is on the north side of Deer Creek in the southeast one-quarter of section 33, township 25N, range 01W. The diversion consists of a submerged 16-inch pipe with a propeller and meter.

The North and South Main canals divert from the north and south side of the SVRIC diversion dam in the southeast ¼ of section 01, township 24N, range 02W. The North Main diversion splits into northern and western canals, and is monitored at the head of each split. The northern split of the North Main diversion is monitored using a 2-foot non-submerged parshall flume, and the western split is monitored using an 8-foot sharp-crested weir.

The largest of the Deer Creek diversions is the SVRIC South Main diversion. Diversions into the South Main Canal are monitored using a 6-foot submerged parshall flume.

Prior to 2000, the SVRIC surface water diversions were manually measured and recorded daily by the SVRIC watermaster. In the fall of 2001 recording equipment was installed along the SVRIC South Main Canal. Currently, the South Main Canal is the only diversion being monitored. Table 3 shows the average daily diversion of SVRIC, as estimated by SVRIC watermaster, between April and October of 2000. Table 3 shows that the estimated seasonal diversion for 2000 was 22,357 acre-feet, with the peak average monthly diversion of about 75 cfs. Unlike the 2000 DCID flow data in Table 1, the SVRIC diversion data in Table 3 is comprised of estimated daily averages only, and doesn't indicate short durations of peak need. Actual peak diversion needs are likely slightly higher than the 75 cfs indicated from the average June 2000 data.

Utilizing the 1997 to 2000 SVRIC watermaster data, the average and maximum daily diversion for SVRIC was calculated and listed in Tables 4 and 5. Table 4 shows that the average annual agricultural diversion by SVRIC, over the four year period between 1997 and 2000, is 22,725 acre-feet.

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Estimated Average Daily SVRIC Diversion: 2000						
Month	**Average Daily Diversion (cfs)**				**Totals**	
	South Main	**North Main (n)**	**North Main (w)**	**Cone Kimball**	**Total Ave. Daily (cfs)**	**Monthly Total (ac-ft)**
April	8.1	6.4	**17.4**	0.0	31.8	1,726
May	34.0	6.6	14.5	5.4	60.4	3,591
June	**50.5**	**6.6**	12.4	**6.1**	**75.4**	4,485
July	50.5	6.6	10.9	5.9	73.9	4,534
Aug.	42.7	6.6	10.9	5.9	66.1	4,057
Sept.	25.9	6.6	11.6	5.9	50.0	2,956
Oct.	22.2	0.0	12.4	5.7	40.4	1,008
Totals (ac-ft)	**13,306**	**2,366**	**4,936**	**1,749**	**NA**	**22,357**
Note: Average daily values were calculated based on daily estimates provided by SVRIC Watermaster						

Table 3. Average Daily Deer Creek diversion by SVRIC for Water Year 2000.

Estimated Average, Daily Average SVRIC Diversion: 1997-2000						
Month	**Average Daily Diversion (cfs)**				**Totals**	
	South Main	**North Main (n)**	**North Main (w)**	**Cone Kimball**	**Total Ave. Daily (cfs)**	**Monthly Total (ac-ft)**
April	14.8	4.4	12.4	3.8	35.4	2,100
May	30.1	4.7	11.4	4.0	50.2	3,082
June	40.1	6.6	11.3	5.5	63.5	3,773
July	48.2	6.3	15.3	5.7	75.5	4,637
Aug.	42.4	6.3	14.9	5.5	69.1	4,239
Sept.	25.7	6.3	13.0	4.8	48.8	2,898
Oct.	12.9	5.4	12.8	5.8	33.8	2,076
Totals (ac-ft)	**12,938**	**2,168**	**5,496**	**2,123**	**NA**	**22,725**
Note: Average daily values were calculated based on daily estimates provided by SVRIC Watermaster						

Table 4. Average, Daily Average Deer Creek diversion by SVRIC between 1997-2000.

Estimated Maximum Daily Average SVRIC Diversion: 1997-2000						
Month	**Average Daily Diversion (cfs)**				**Totals**	
	South Main	**North Main (n)**	**North Main (w)**	**Cone Kimball**	**Total Ave. Daily (cfs)**	**Monthly Total (ac-ft)**
April	22.4	6.4	**17.4**	**7.9**	40.3	3,207
May	42.3	6.6	16.2	5.5	69.8	4,331
June	50.5	**7.6**	17.2	6.1	77.0	4,827
July	**53.6**	6.6	17.2	6.0	**82.2**	5,119
Aug.	48.9	6.6	16.9	6.0	76.2	4,812
Sept.	32.3	6.6	16.9	6.0	60.9	3,655
Oct.	22.2	4.9	15.9	6.0	40.4	3,016
Totals (ac-ft)	**16,432**	**2,734**	**7,090**	**2,627**	**NA**	**28,883**
Note: Average daily values were calculated based on daily estimates provided by SVRIC Watermaster						

Table 5. Maximum Daily Average Deer Creek diversion by SVRIC between 1997-2000.

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Table 5 shows that the maximum daily diversion for the South Main, North Main (total) and the Cone Kimball is 53.6 cfs, 25.0 cfs and 7.9 cfs respectively. Table 5 also shows that the North Main and Cone Kimball diversions run close to maximum capacity throughout the agricultural season, while the South Main diversion is at maximum capacity from June through August.

As mentioned, surface water flow recorder was installed along SVRIC's South Main Canal in the fall of 2001. The recorder collects readings every 15 minutes, and from the 15-minute readings, the average, maximum, and minimum daily flow in the South Main Canal is calculated and recorded. The 2002 and 2003 data from the South Main Canal recorder are provided in Tables 6 and 7. Tables 6 and 7 show that the 2002 and 2003 South Main Canal data collected by the recorder is about 20 percent less than the average values in Table 4, estimated by the SVRIC watermaster for the 1997 through 2000 period. However, the maximum diversion along the South Main Canal provided in Tables 6 and 7 is close to estimated maximum value listed in Table 5.

Based on the data in Tables 5 through 7, the estimated maximum total daily diversion capacity of SCRIC between April and June is 83 cfs (North Main = 25 cfs, South Main = 51 cfs, and Cone-Kimball = 7 cfs).

SVRIC South Main Diversion Data: 2002					
Month	**Average Daily Diversion (cfs)**			**Ave. Monthly Total**	
	Min.	**Max.**	**Average**	**(cfs)**	**(ac-ft)**
April	3.5	7.2	4.5	135	268
May	19.0	**48.0**	40.7	1,263	2,500
June	24.0	38.0	30.4	913	1,807
July	20.0	29.0	23.8	737	1,459
August	20.0	24.0	22.2	689	1,364
September	20.0	24.0	21.6	648	1,283
October	10.0	25.0	17.1	529	1,047
			Total:	**4,914**	**9,731**

Table 6. SVRIC's South Main 2002 Average Daily Deer Creek Diversion.

SVRIC South Main Diversion Data: 2002					
Month	**Average Daily Diversion (cfs)**			**Ave. Monthly Total**	
	Min.	**Max.**	**Average**	**(cfs)**	**(ac-ft)**
April	0.2	0.4	0.3	7.9	16
May	0.4	40.0	10.7	333	659
June	36.0	**52.0**	45.3	1,360	2,693
July	33.0	40.0	36.4	1,129	2,235
August	30.0	44.0	34.7	1,076	2,131
September	14.0	36.0	23.0	698	1,382
October	Oct. data not available			505*	1,000*
* estimated			**Total:**	**5,109**	**10,115**

Table 7. SVRIC's South Main 2003 Average Daily Deer Creek Diversion.

Hydrology

The Deer Creek watershed covers approximately 208 square miles, extending from the Lassen National Forest in Plumas County to the Sacramento River, just north of Woodson Bridge. At a gradient of about 32 feet per mile, Deer Creek maintains a perennial flow as it tracks through the mountains, meadows and steep-sided canyons in the upper and middle watershed, before entering the valley floor and merging with the Sacramento River. The Deer Creek watershed boundary is shown in Figure 2.

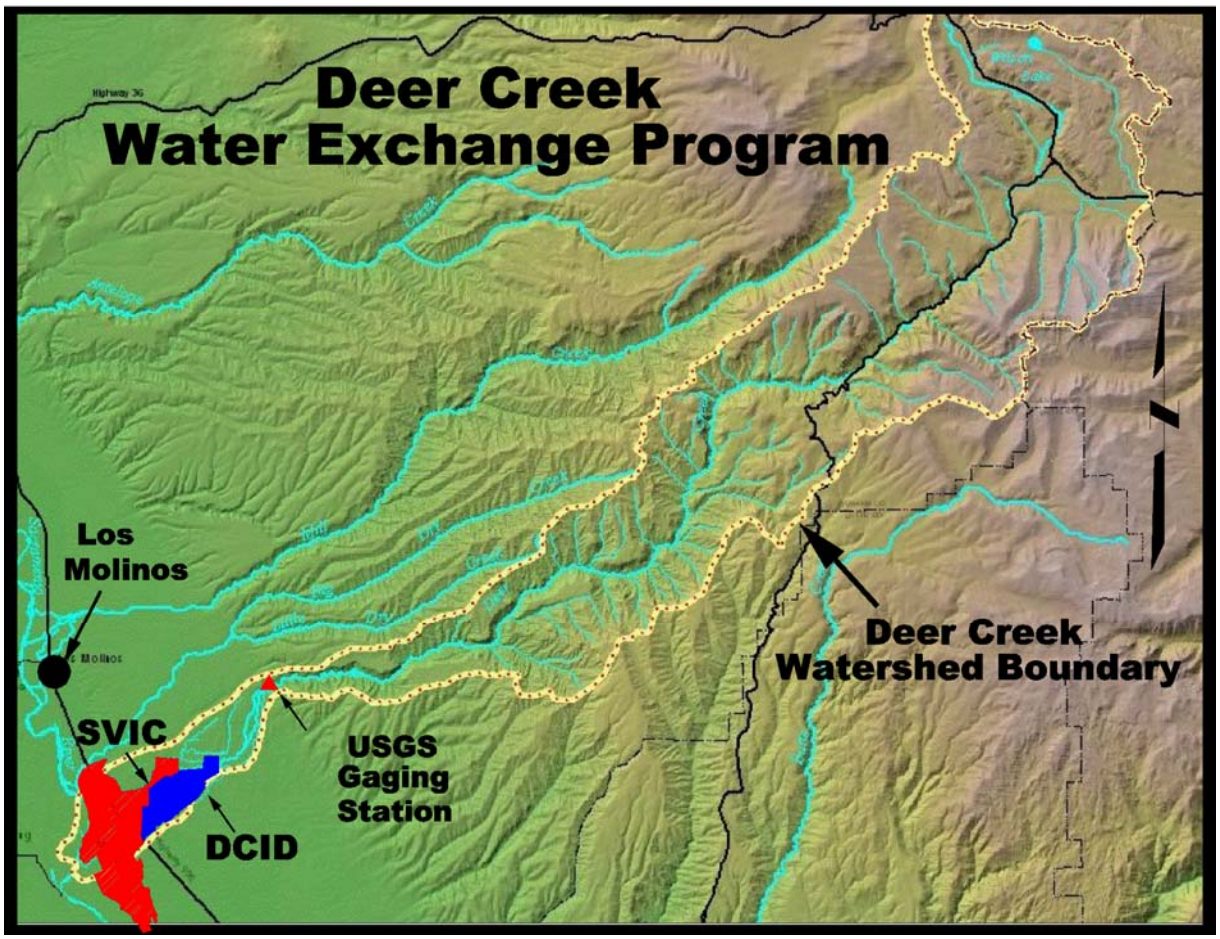

Figure 2. Deer Creek Watershed.

Adjudication for the lower section of Deer Creek is based on the flow measured at the USGS gaging station (*Deer Creek Near Vina*, station number: 11383500). The following section examines Deer Creek hydrology utilizing 1920 to 2002 mean daily flow data from the USGS gage for all years (average year scenario) and for dry or critically dry years.

Dry and critically dry years were determined based on review of local precipitation, Deer Creek flow and the Sacramento River Index 40-30-30 Water Supply Index. The Sacramento River Index is a regional indicator of the annual water supply for the northern Sacramento Valley. The index incorporates the sum of the unimpaired monthly runoff measured in the Sacramento River at Bend Bridge, the Feather River inflow to Lake Oroville, the Yuba River at Smartville, and the

American River inflow to Folsom Lake. Unimpaired runoff represents the natural water production of a river basin; unaltered by upstream diversions, storage, and export of water to, or import of water from, other basins. The Sacramento River Index is calculated as the sum of 40 percent of the current April through June flow, 30 percent of the current October through March flow, and 30 percent of the index for the previous water year. Based on the calculated runoff in million acre-feet, each year of the index is then classified as wet, above normal, below normal, dry, or critical. Figure 3 shows the Sacramento River Index since 1906 and the classification range for each year.

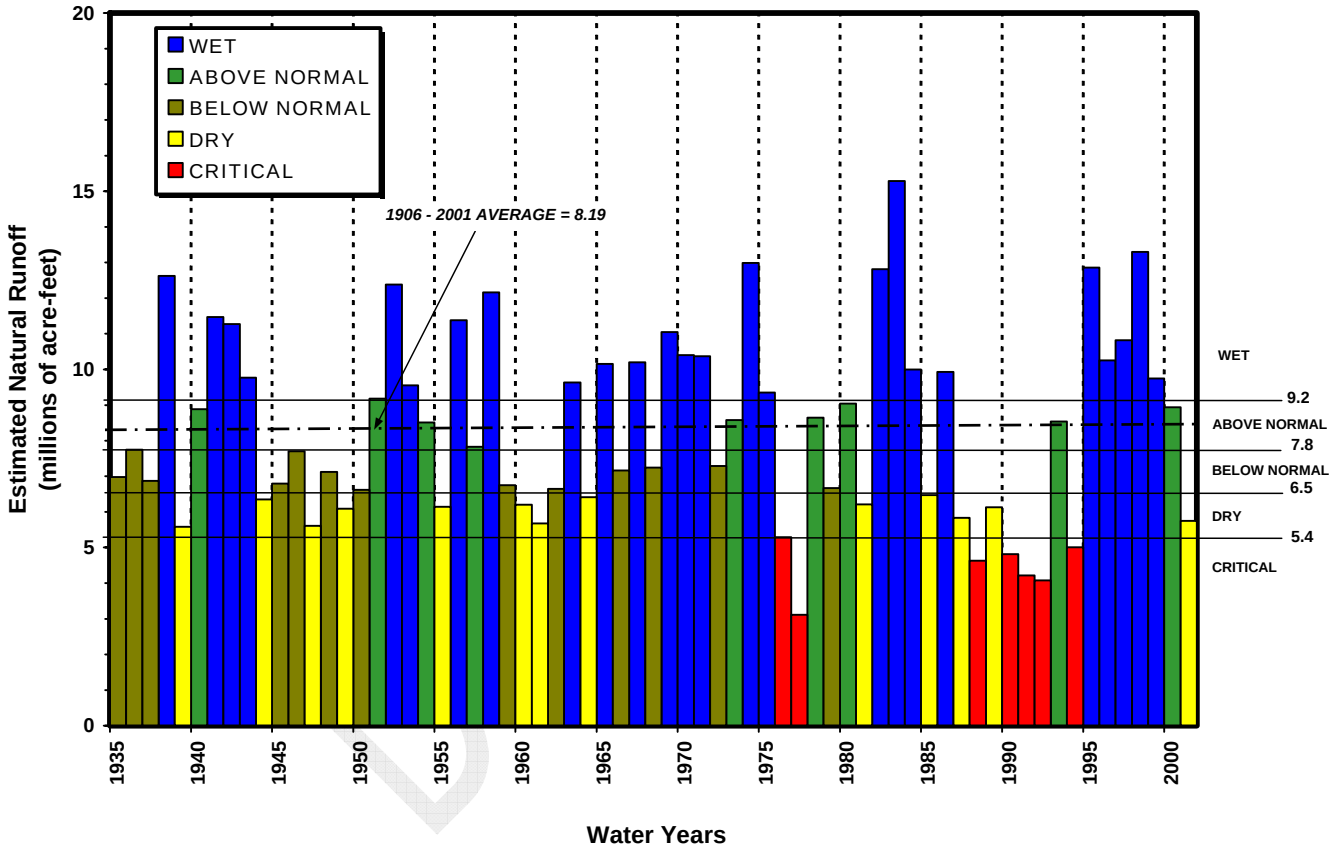

Figure 3. Sacramento River 40-30-30 Water Supply Index; 1935-2001.

Local precipitation and flow were analyzed using annual precipitation data for the City of Red Bluff and the total annual Deer Creek flow, as measured at the USGS gage. A hydrograph showing the City of Red Bluff precipitation along with the total annual flow from Deer Creek is illustrated in Figure 4.

Based on the precipitation and hydrology data shown in Figures 3 and 4, fourteen dry or critically dry years were selected to represent a drought year scenario and further evaluate the potential frequency of program operations during dry and critically dry years. Dry and critically years include: 1939, 1944, 1953, 1955, 1964, 1976, 1977, 1981, 1985, 1989, 1990, 1991, 1992, and 1994. Flow data from these years represent a worst-case water year scenario and helps to determine the maximum potential need for additional fish transportation flows.

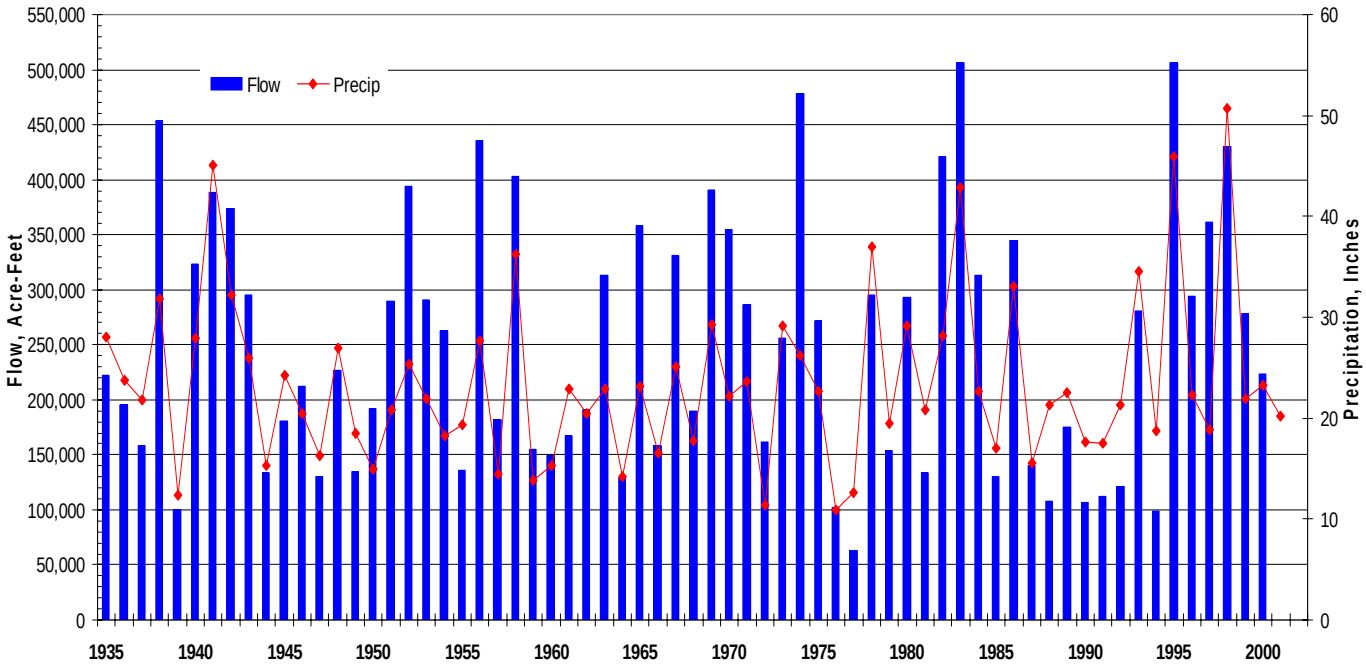

Figure 4. Deer Creek Flow along with Red Bluff Precipitation; 1935-2001.

Figures 5 and 6 are hydrographs of the average minimum, average maximum and average mean daily flow in Deer Creek, between April and October utilizing the data from all years, and dry to critically dry years. The hydrograph in Figure 5 presents the mean daily data from all year types and shows that there is a wide range of flow rates during early spring and late fall, with maximum mean daily flows exceeding 6,000 cfs. Figure 6 illustrates the mean daily flow data associated with dry and critically dry years and shows that, although the range of flow is still quite great, the peak flow values drop by several orders of magnitude during periods of drought. In both of the hydrographs, the scale required to illustrate the average maximum mean daily flow tends to limit interpretation of the average minimum and average mean daily flow data curves. The hydrographs in Figures 7 and 8 help evaluate the average minimum and average mean daily flow data by eliminating the average maximum daily flow data from the graph and overlaying the maximum combined diversion requirement of 125 cfs for DCID and SVRIC.

Figures 7 is a hydrograph of the Deer Creek average minimum and average mean daily flow for all year types. Figure 7 indicates that, between July and October, the average mean daily flow in Deer Creek less than DCID and SVRIC's combined maximum diversion requirement. Figure 7 also shows that the average minimum daily flow in Deer Creek is less than DCID and SVRIC's combined maximum diversion for entire agricultural diversion period of April through October.

Figure 8 is a hydrograph of the Deer Creek daily flow data during dry and critically years. Figure 8 illustrates that the average mean daily flow for dry and critically dry years is less than DCID and SVRIC's combined maximum diversion for entire April through October agricultural diversion period. Figure 8 also shows that the average minimum daily flow in Deer Creek, during dry years, is significantly less than the agricultural diversion requirement, averaging about 50 cfs during April, 30 cfs during May and 20 cfs during June.

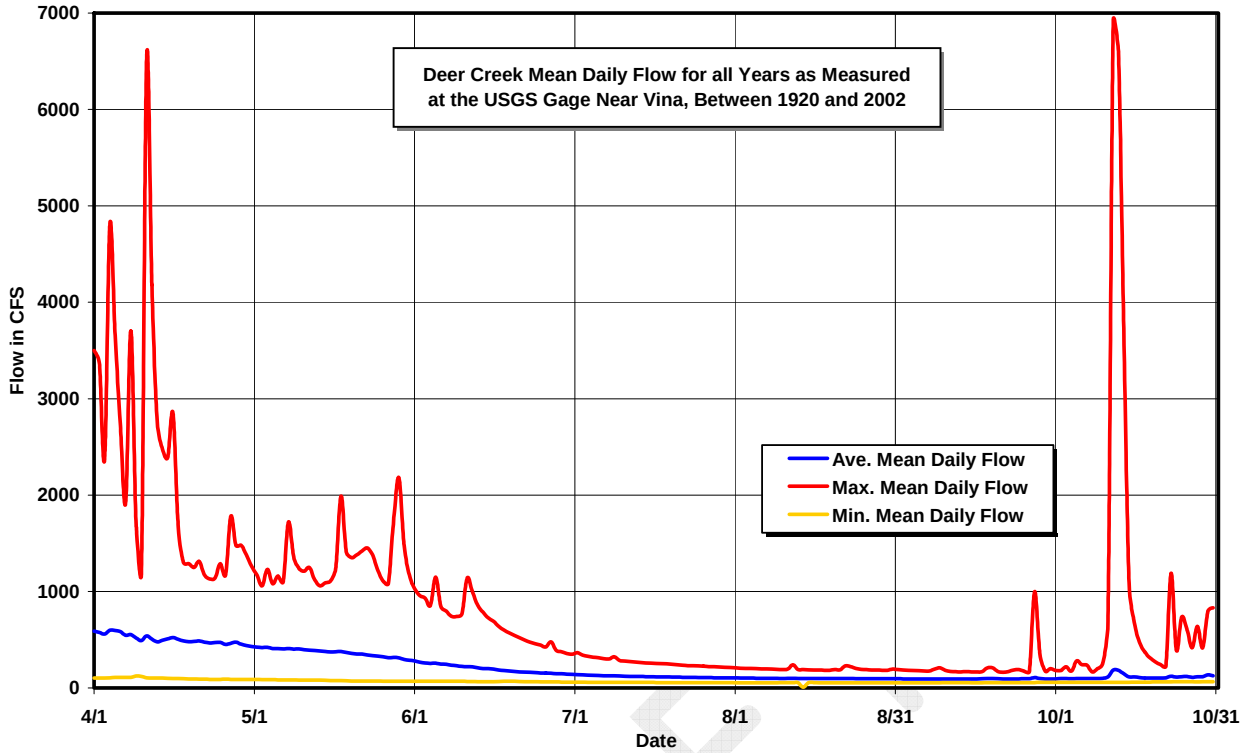

Figure 5. Average Minimum, Maximum and Mean Daily Flow for Deer Creek, for all Years Between 1920 and 2002.

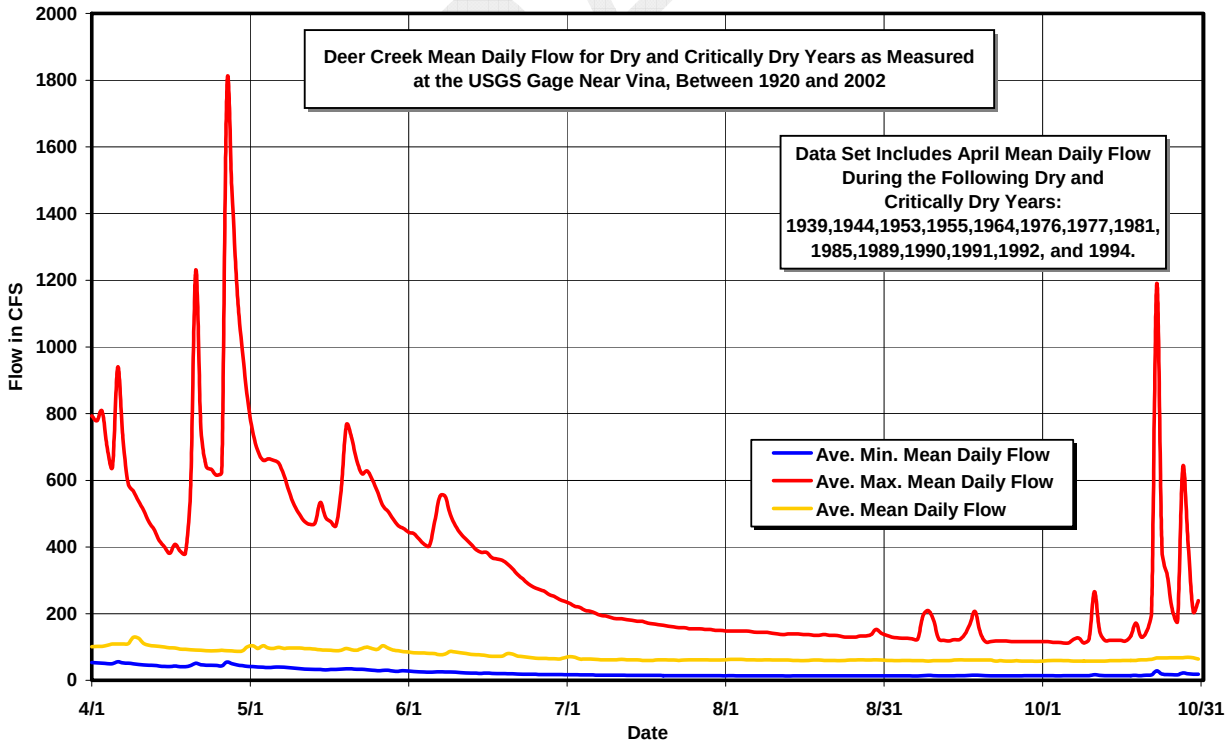

Figure 6. Average, Minimum, Maximum and Mean Daily Flow for Deer Creek, during Dry and Critically Dry Years.

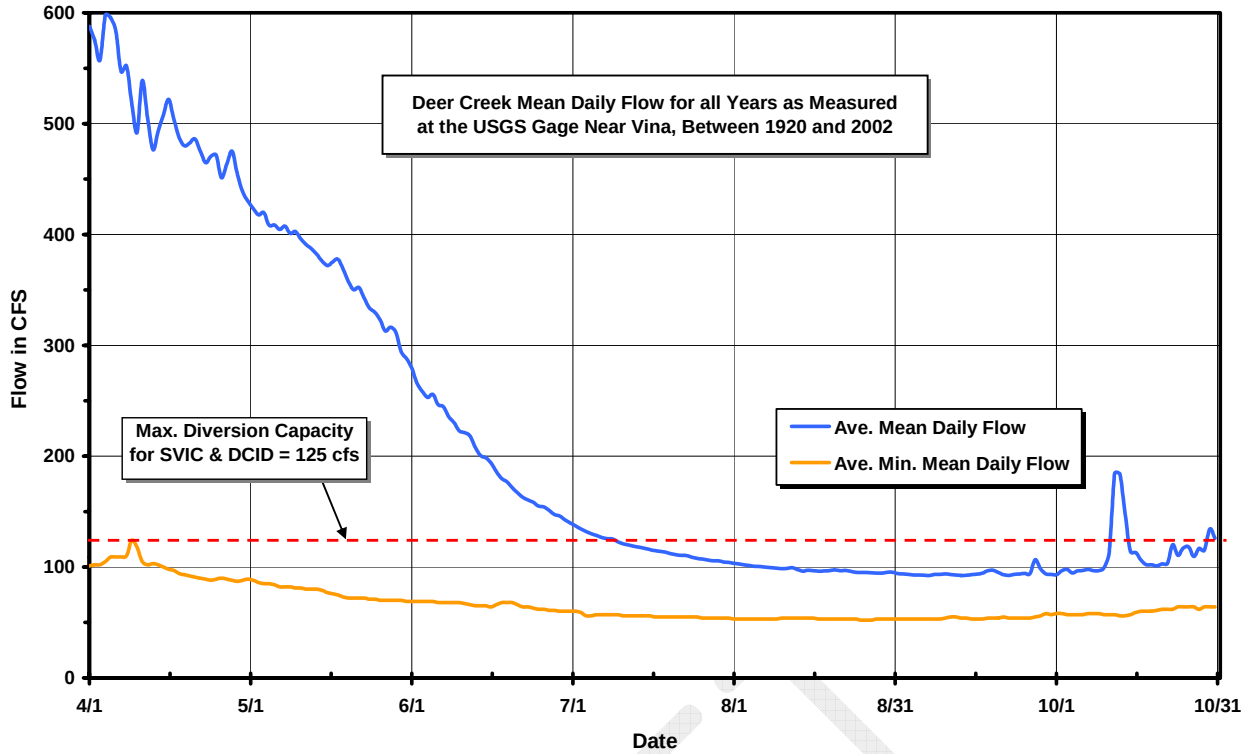

Figure 7. Average Minimum and Mean Daily Flow for Deer Creek; all Years.

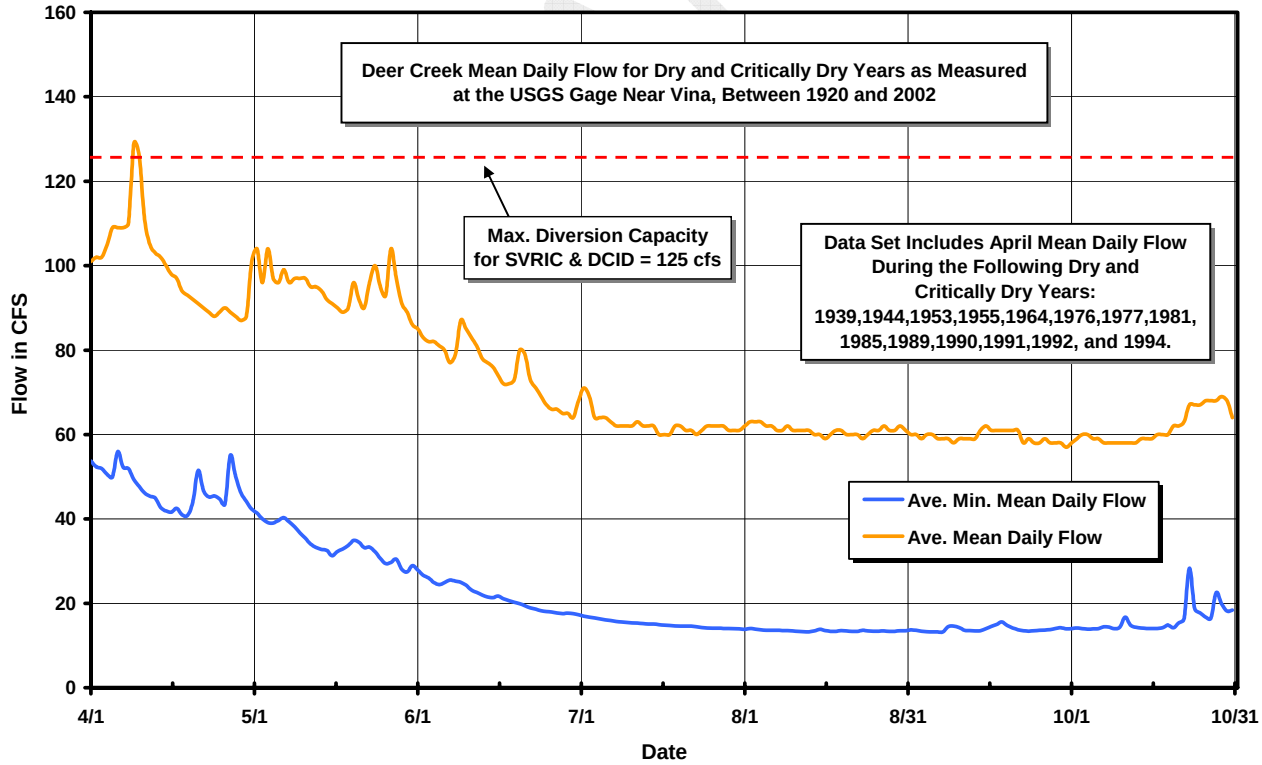

Figure 8. Average Minimum and Mean Daily Flow for Deer Creek; Dry and Critically Dry Years.

Previous fisheries studies indicate that, although the exact amount of flow necessary to provide unimpaired migration for adult salmon and steelhead is unknown, based on the hydrology and geomorphology of similar east-side streams in the Northern Sacramento Valley, a Deer Creek flow of approximately 50 cfs, as measured below the Stanford Vina Ranch Irrigation Company main diversion, could serve as a preliminary fish transportation flow objective.

Studies also identified that, although a dedicated year-around instream base flow of 50 cfs is preferred, providing bypass flows or pulse flows during time of critical need could also successfully enhance fish transportation. The times of critical need for increased fish transportation flow were identified as April, May and June for up-stream migration, and isolated one or two week period in October for adult salmon immigration and/or juvenile salmon emigration. It is also recognized the timing of critical fish transportation flow need is dependent on many variables and can change significantly based on annual climatic conditions, water temperature, etc. Because of the variable nature and timing of the fish transportation flow requirements, future agreements need to allow for flexibility in the timing and amount of bypass flows.

To augment fish flows during the April through June period it is assumed that DCID and SVRIC will divert at their maximum respective capacities of 42 and 83 cfs (125 cfs total), and the by-pass flow objective will be 50 cfs. Thus, starting at 175 cfs (recorded at the USGS gage), as Deer Creek flow drops, DCID and SVRIC begin to bypass a portion of their diversion. The bypass flow contribution for each diverter will increase according to the decrease in Deer Creek flow until at which point the flow in Deer Creek reaches 125 cfs and the maximum bypass contribution of 50 cfs is realized. Individually, DCID and SVRIC would bypass an amount equal to the percentage of their adjudicated entitlement (33% and 66 %). Bypass of the full 50 cfs would correspond to respective contributions of 17 and 33 cfs by DCID and SVRIC.
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The maximum agricultural diversion of Deer Creek water decreases during the month of October. DCID and SVRIC's estimated maximum diversion from Deer Creek during October is estimated at 30 and 50 cfs, for a total of 80 cfs. To augment fish flows during the October out-migration period it is assumed that DCID and SVRIC will be diverting a maximum of 80 cfs total, and a full fish flow objective of 50 cfs will be needed.

The frequency at which Deer Creek flows falls within the operational target interval of 175 to 125 cfs was estimated for average and drought years using the April, May, June and October average mean daily flow data collected from the USGS gaging station. Average year operations were characterized by analyzing the average mean daily flow for all years between 1920 and 2002. Drought years were characterized by analyzing the average mean daily flow during fourteen of the driest years between 1920 and 2002.

Figures 9 through 14 show the estimated frequency of a program operating within the target interval of 175 to 125 cfs during the months of April, May and June using average and drought year data. Figures 15 and 16 show the estimated frequency of a program operating within the target interval of 130 to 80 cfs during the month of October using average and drought year data. A summary of the estimated frequency of program operations during average and drought years are provided in Table 8.

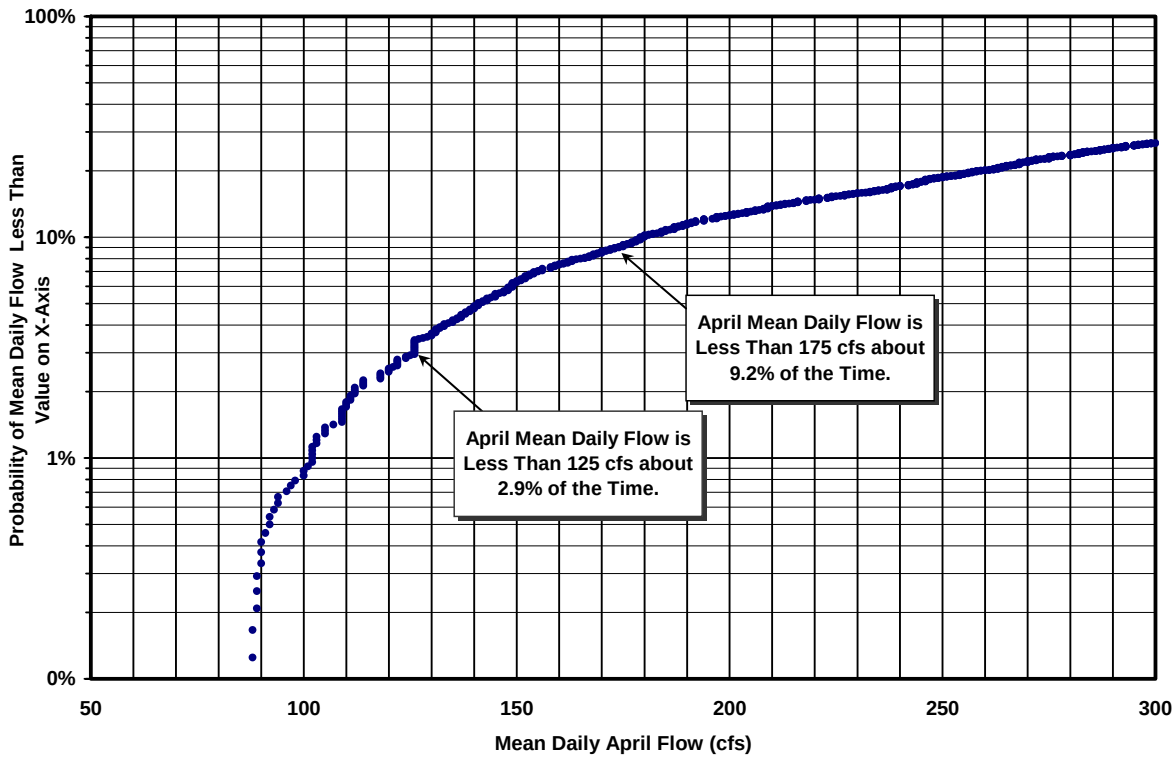

Figure 9. Deer Creek Flow Frequency Index for April; utilizing Mean Daily Flow data from the USGS Gage for all years between 1920 and 2002.

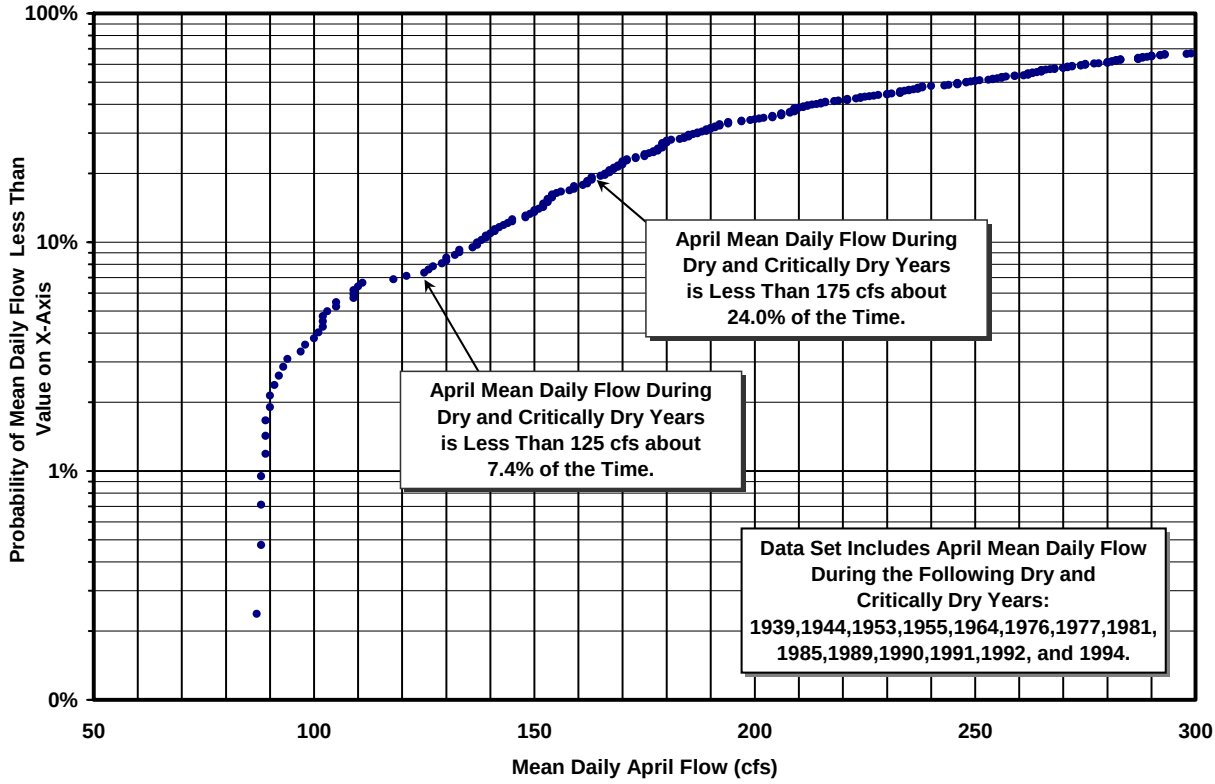

Figure 10. Deer Creek Flow Frequency Index for April; utilizing Mean Daily Flow data from the USGS Gage for Dry and Critically Dry years between 1920 and 2002.

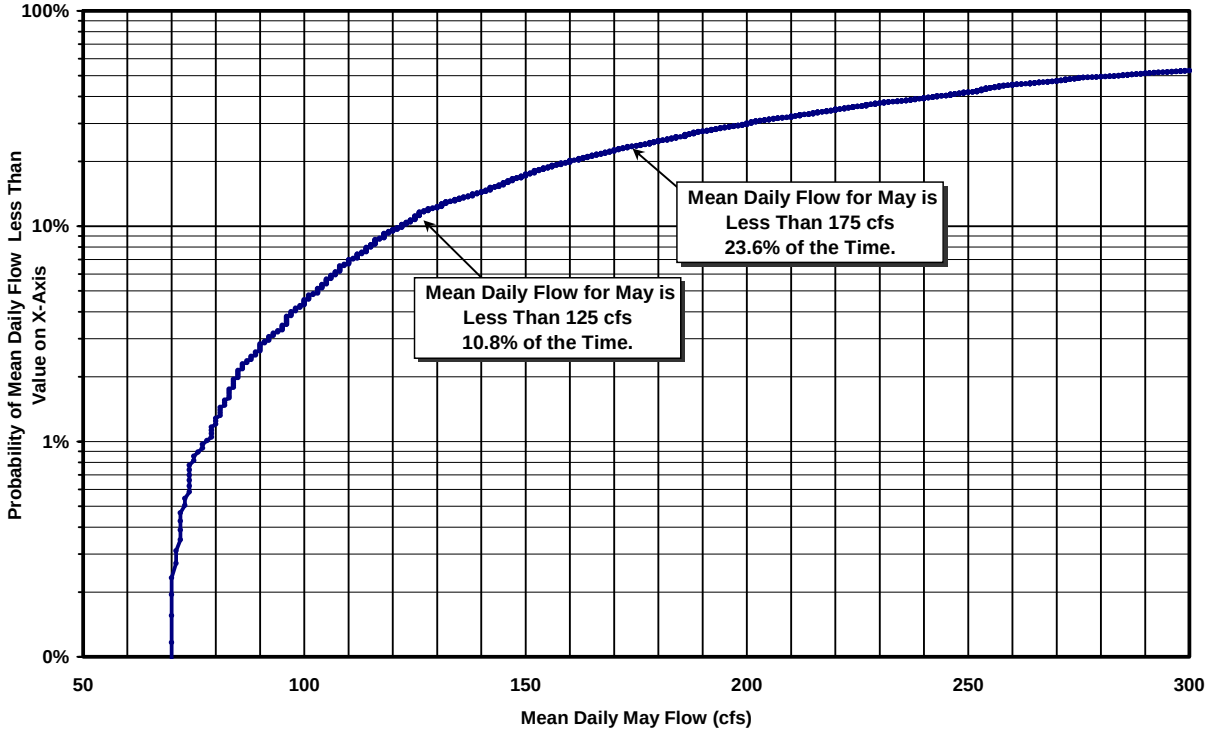

Figure 11. Deer Creek Flow Frequency Index for May; utilizing Mean Daily Flow data from the USGS Gage for all years between 1920 and 2002.

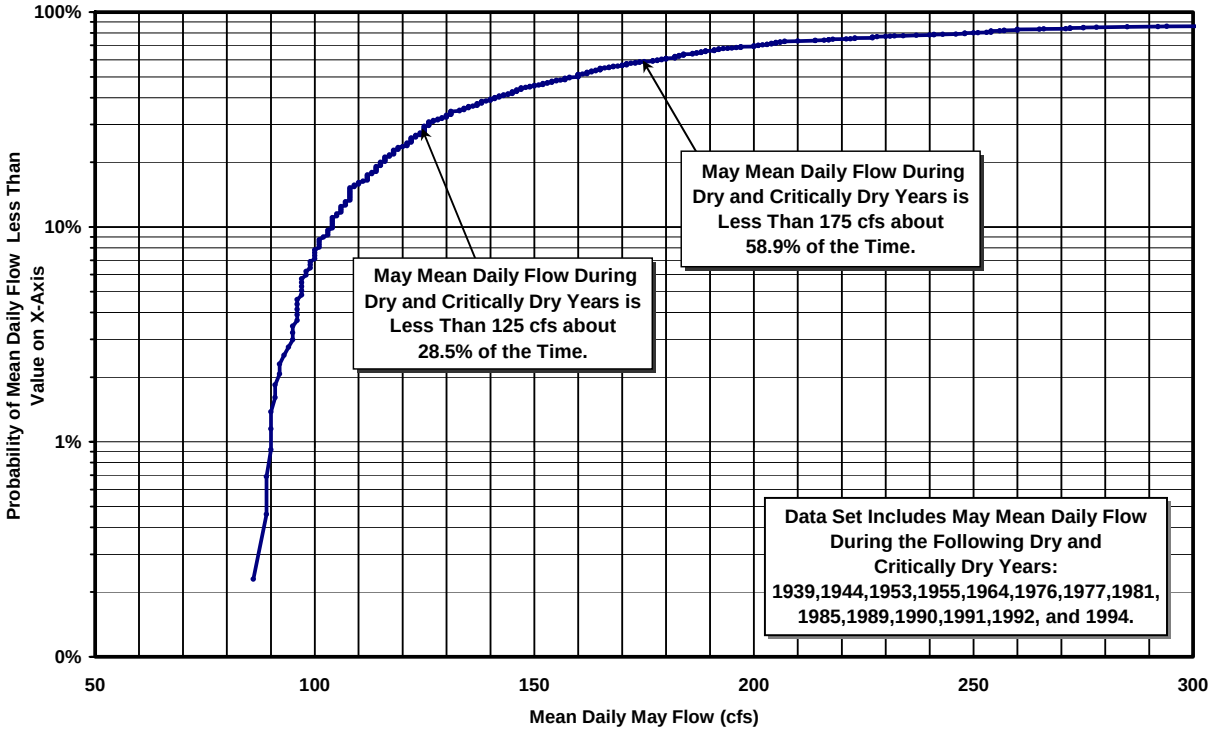

Figure 12. Deer Creek Flow Frequency Index for May; utilizing Mean Daily Flow data from the USGS Gage for Dry and Critically Dry years between 1920 and 2002.

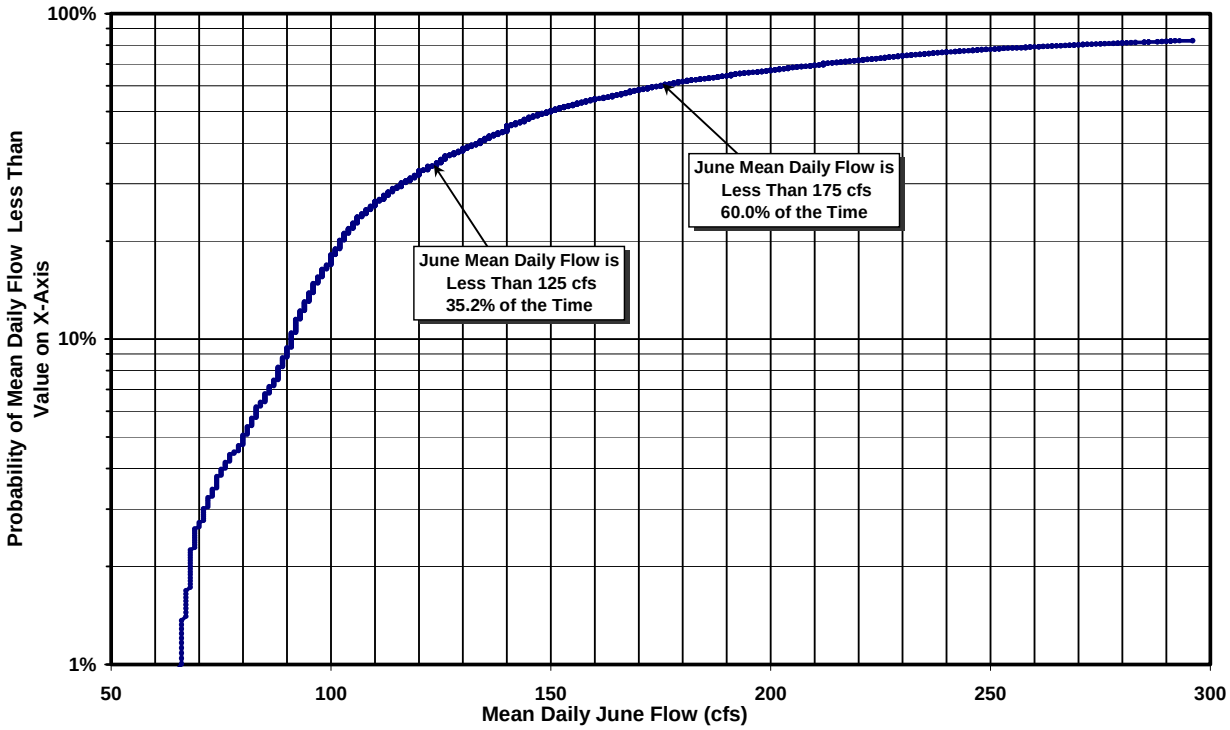

Figure 13. Deer Creek Flow Frequency Index for June; utilizing Mean Daily Flow data from the USGS Gage for all years between 1920 and 2002.

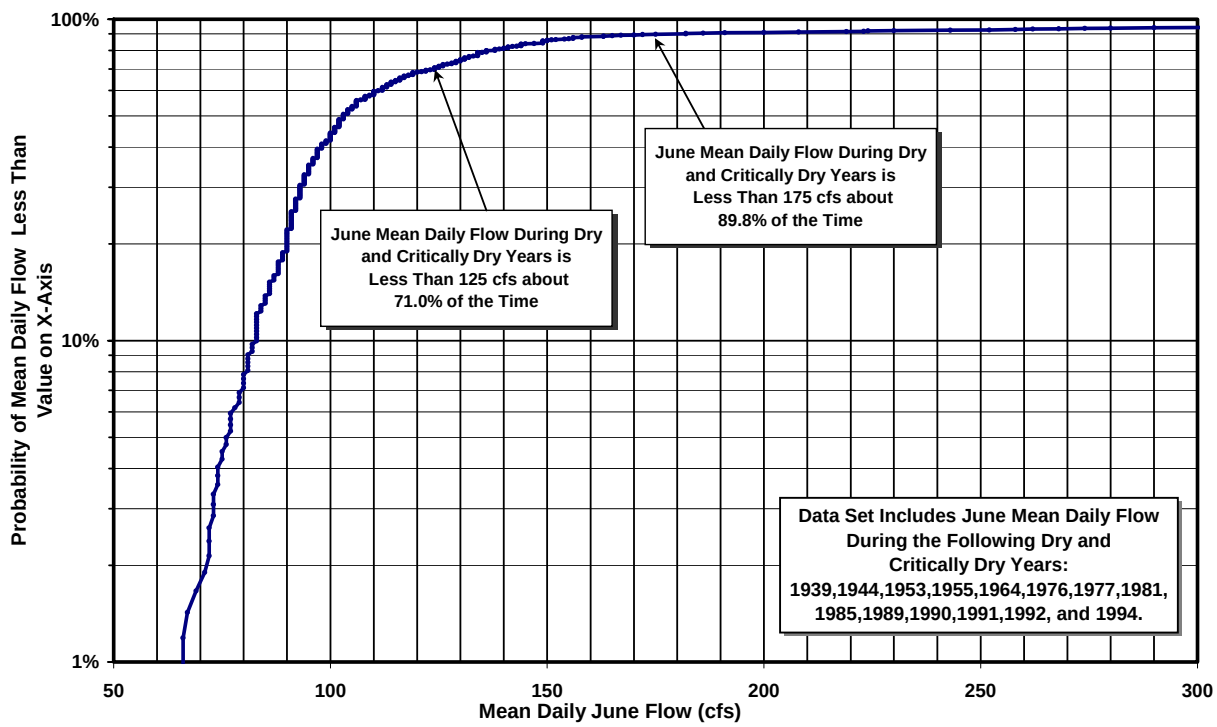

Figure 14. Deer Creek Flow Frequency Index for June; utilizing Mean Daily Flow data from the USGS Gage for Dry and Critically Dry years between 1920 and 2002.

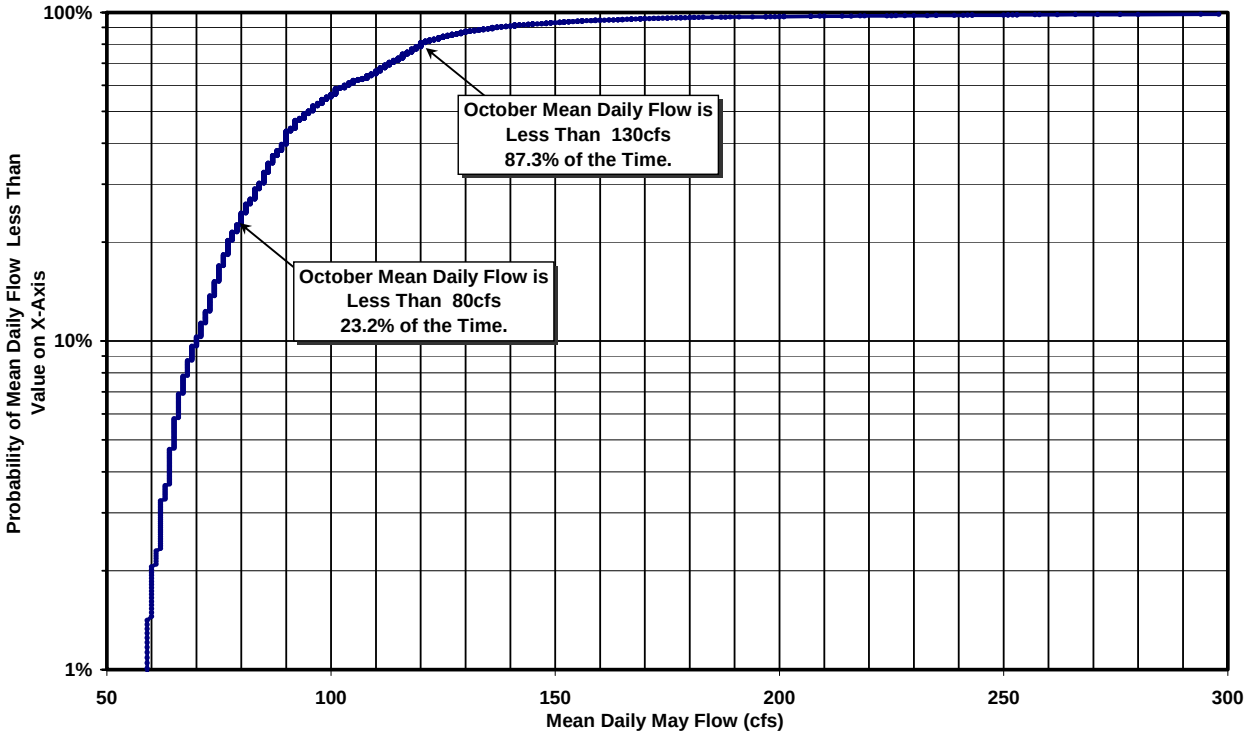

Figure 15. Deer Creek Flow Frequency Index for October; utilizing Mean Daily Flow data from the USGS Gage for all years between 1920 and 2002.

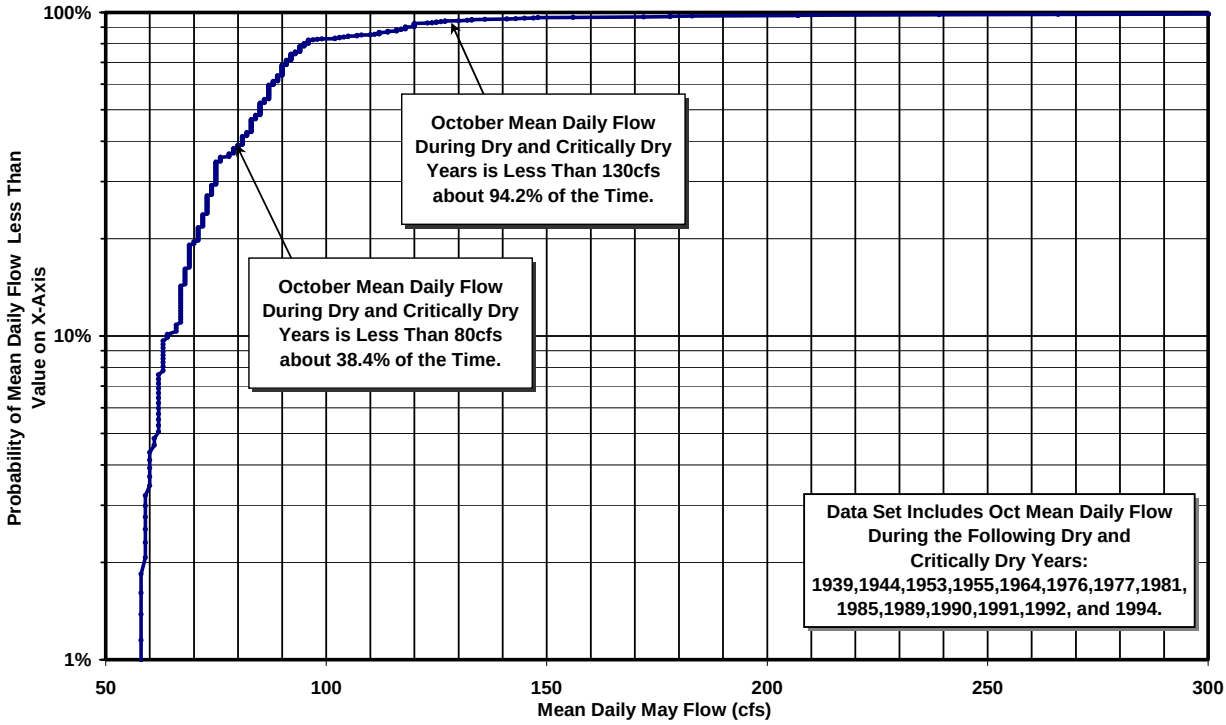

Figure 16. Deer Creek Flow Frequency Index for October; utilizing Mean Daily Flow data from the USGS Gage for Dry and Critically Dry years between 1920 and 2002.

Deer Creek Flow	April		May		June		Oct.	
	Ave Year	Dry Year	Ave Year	Dry Year	Ave Year	Dry Year	Ave Year	Dry Year
Percent Time Flow is < 175 cfs	9.2 %	24.0 %	23.6 %	58.9 %	60.0 %	89.9 %		
Percent Time Flow is < 125 cfs	2.9 %	7.4 %	10.8 %	28.5 %	35.2 %	71.0 %		
Percent Time Flow is < 130 cfs							87.3 %	94.2 %
Percent Time Flow is < 80 cfs							23.2 %	38.4 %

Table 8. Estimated Frequency of Program Operations Based on Deer Creek Hydrology during Average and Dry Years, a 50 cfs Fish Flow Requirement, and Operations Target interval of 175 to 125 cfs.

Applying the Deer Creek hydrology to the agricultural and fish flow requirements, the average annual days of program operation, along with the necessary amount of by-pass flow and associated by-pass volume were calculated for average and dry year years and are presented in Tables 9 and 10. The flow rate and volume data in Tables 9 and 10 are divided into 10-day intervals for the months April, May and June. Estimates of bypassed flow volume for October were calculated assuming that the full 50 cfs flow objective is required over a 15-day period annually.

Table 9 indicates that the total average annual volume of bypassed water between April and June is about 2,264 acre-feet, with approximately 65 percent of the flow requirement coming during June. Based on a one-third and two-thirds split, DCID's portion of April through June period is 764 acre-feet and SVRIC's portion is 1,499 acre-feet. Table 9 shows that the average annual volume of water associated with bypassing 50 cfs over 15-days in October is estimated at 1,485 acre-feet. Total average year program volume (April – October) is estimated at 3,748 acre-feet.

Month	Number Days And Required Flow per 10-Day Interval	Daily Bypass Flow by Purveyor (cfs)		Average Volume per Interval (ac-ft)		
		DCID	SVRIC	DCID	SVRIC	Total
April	1 day @ 12 cfs	4.0	8.0	7.9	15.8	23.7
	1 day @ 37 cfs	12.3	24.7	24.4	48.9	73.3
	1 day @ 50 cfs	17.0	33.0	33.7	65.3	99.0
			April Total	66	130	196
May	2 days @ 12 cfs	4.0	8.0	15.8	31.6	47.4
	2 days @ 37 cfs	12.3	24.7	48.8	97.8	146.6
	4 days @ 50 cfs	17.0	33.0	134.6	261.4	396
			May Total	199	391	590
June	4 days @ 12 cfs	4.0	8.0	31.7	63.4	95.1
	4 days @ 37 cfs	12.3	24.7	97.4	195.6	293.0
	11days @ 50 cfs	17.0	33.0	370.3	718.7	1,089
			June Total	499	978	1,477
			April – June Total	**764**	**1,499**	**2,264**
October**	15.0	17.0	33.0	505	980	1,485
			April - October Total	**1,269**	**2,479**	**3,748**
* October volumes are based on 15-days of fish flow need and program operations.						

Table 9. Estimated Average Annual Days of Program Operation, and the Associated Rate and Volume of Bypass Flow Based on Mean Daily Deer Creek Flow Data for All Years Between 1920 and 2002.

Month	Number Days And Required Flow per 10-Day Interval	Daily Bypass Flow by Purveyor (cfs)		Average Volume per Interval (ac-ft)		
		DCID	SVRIC	DCID	SVRIC	Total
April	2.0 days @ 12 cfs	4.0	8.0	16	32	48
	2.2 day @ 37 cfs	12.3	24.7	54	107	161
	3.0 day @ 50 cfs	17.0	33.0	99	198	297
			April Total	168	337	506
May	3.3 days @ 12 cfs	4.0	8.0	26	52	78
	5.0 days @ 37 cfs	12.3	24.7	122	244	366
	10.0 days @ 50 cfs	17.0	33.0	330	659	990
			May Total	487	956	1,435
June	2.0 days @ 12 cfs	4.0	8.0	16	32	48
	3.0 days @ 37 cfs	12.3	24.7	73	146	220
	22.0 days @ 50 cfs	17.0	33.0	725	1451	2178
			June Total	814	1,629	2,445
			April – June Total	**1,460**	**2,921**	**4,386**
October**	15.0	17.0	33.0	505	980	1,485
			April – October Total	**1,955**	**3,910**	**5,871**
* October volumes are based on 15-days of fish flow need and program operations.						

Table 10. Estimated Average Annual Days of Program Operation and the Associated Rate and Volume of Bypass Flow Based on Mean Daily Deer Creek Flow Data for Dry and Critically Dry Years Between 1920 and 2002.

Table 10 indicates that the total average annual volume of bypassed water between April and June, during dry and critically dry years, is about 4,386 acre-feet, with approximately 55 percent of the April through June flow requirement coming during June. Based on a one-third and two-thirds split, DCID's portion of April through June period is 1,460 acre-feet and SVRIC's portion is 2,921 acre-feet. Table 10 shows that the average annual volume of water associated with bypassing 50 cfs over 15-days in October is estimated at 1,485 acre-feet. Total dry year program volume (April – October) is estimated at 5,871 acre-feet.

Land and Water Use

Deer Creek Irrigation District and Stanford Vina Ranch Irrigation Company have respective water service areas of about 2200 and 6500 acres. Both surface water and groundwater are used to irrigate agricultural lands in the DCID and SVRIC areas. The Department of Water Resources Northern District conducted land and water use surveys of the SVRIC and DCID areas in 1999. As part of the Tehama County Groundwater Investigation, the 1999 DWR land and water use survey was updated to include the 2000 Tehama County Agricultural Commissioner's data, 2000 cropping trends, 2000 water source data and 2000 population census data.

In order to compare changes in DCID and SVRIC's water use over a range of climatic conditions, the land and water use data was examined for normal year and dry year scenarios. The normal year is intended to represent a typical water year scenario, or the amount of surface water diversion and groundwater extraction that can be expected under normal climatic and land use conditions. Based on multiple data sources, 2000 was determined to best represent normal

precipitation, evapotranspiration and runoff conditions. In summary, average year land and water use data for DCID and SVRIC were based on:

- 2000 precipitation, evapotranspiration, and runoff data, and
- 1999 land and water use projected to 2000 agricultural cropping trends and population census.

Examination of dry year land and water use is intended to provide a worst-case scenario, or the maximum water use need that can be expected to occur under naturally dry conditions. The dry year land and water use scenario was establish by applying historic precipitation, evapotranspiration and runoff data from the worst years on record to the existing land use cropping patterns. In summary, the dry year scenario for DCID and SVRIC were based on:

- 1977 precipitation and runoff data,
- 1976 evapotranspiration rates, and
- 1999 land and water use projected to 2000 agricultural cropping trends and population census.

DWR's land and water use surveys are developed by digitizing the gross field acreage from aerial photography, followed by field-truthing over 95% of locations to help verify crop type, water source, and irrigation method. The gross acreage is typically reduced by 5% to account for non irrigated lands such as roads, ditches, and canals. Based on acreage, crop type, soil type, evapotranspiration (ET) data, irrigation water source, and irrigation methods, the land and water use results over a given region are calculated. In areas having a mixed supply of surface water and groundwater, the difference between the agricultural demand and surface water delivery is assumed to be equal to the amount of groundwater extraction. For example, if dry year data indicates surface water supplies are inadequate for agricultural demand, the water demand shortage is assumed to be satisfied by switching the irrigation source from surface water to groundwater, and the well infrastructure required to fulfill this demand is assumed to already be in place. Although much effort goes into making the land and water use surveys as accurate as possible, given the variable nature of agricultural practices, the data is most useful as a local or regional resource planning tool.

Maps showing 1999 land use and water source for the DCID and SVRIC areas are shown in Figures 17 and 18, respectively. A detailed breakdown of the normal and dry year land and water use survey for DCID and SVRIC are presented in Tables 11 through and 14. A summary of the normal and dry year land and water use data, along with surface water diversions are presented in Tables 15 and 16. The unit water demand (acre-feet/acre) and unit water diverted, versus estimated surface water spills and losses for normal and dry years are shown in Tables 17 and 18.

Evapotranspiration or ET of applied water is the calculated amount of applied water necessary for optimum plant growth based on local temperature, evaporation and soils data. The applied water value is the amount of water that is required to fulfill the plants ET need, based on the calculated efficiency associated with the individual irrigation methods identified during the survey. For example, the ET requirement of almonds may stay the same, but the applied water requirement to meet the ET of almonds will be greater for areas utilizing flood versus mirco-sprinkler irrigation methods.

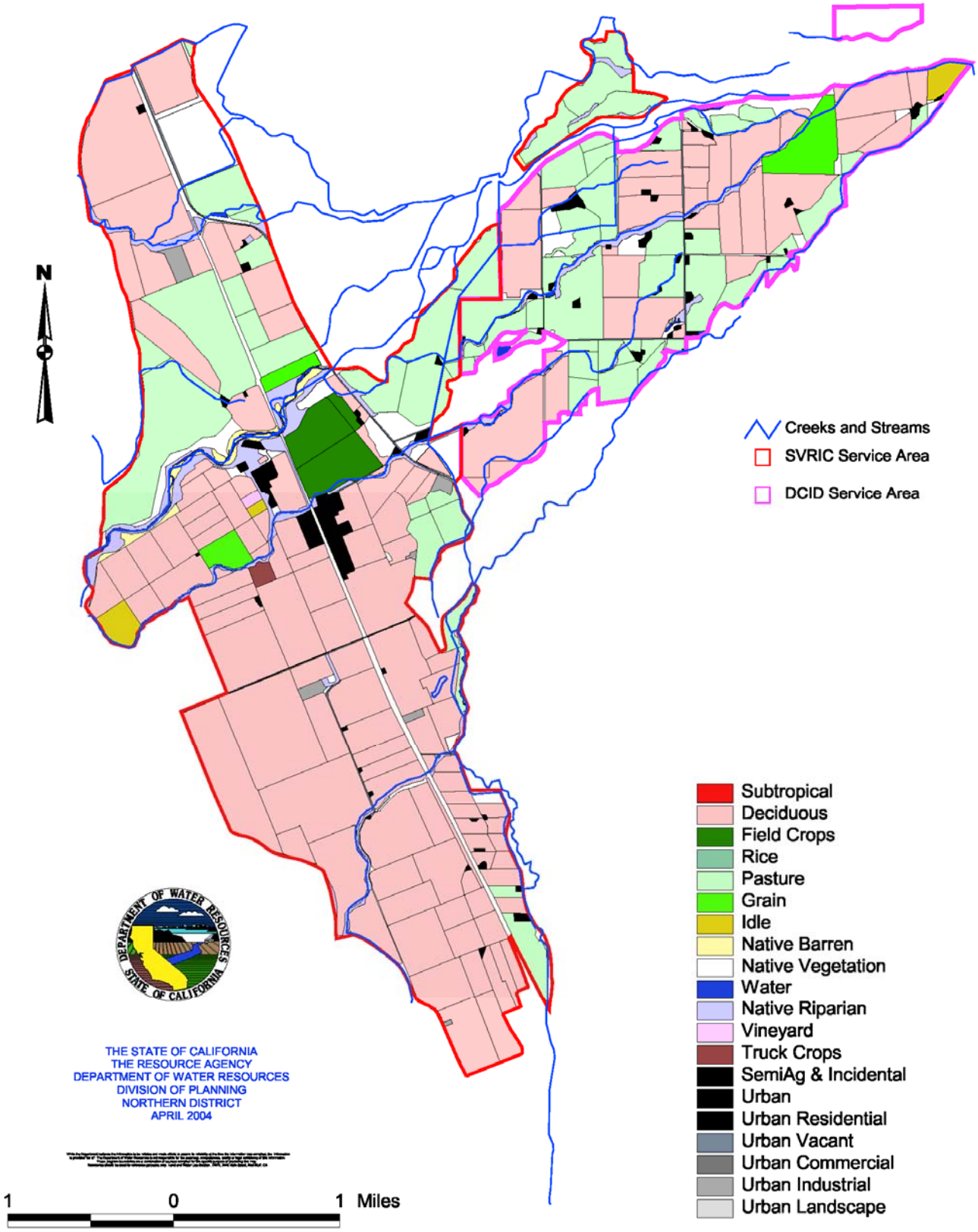

Figure 17. 1999 Land Use for the DCID and SVRIC Service Areas.

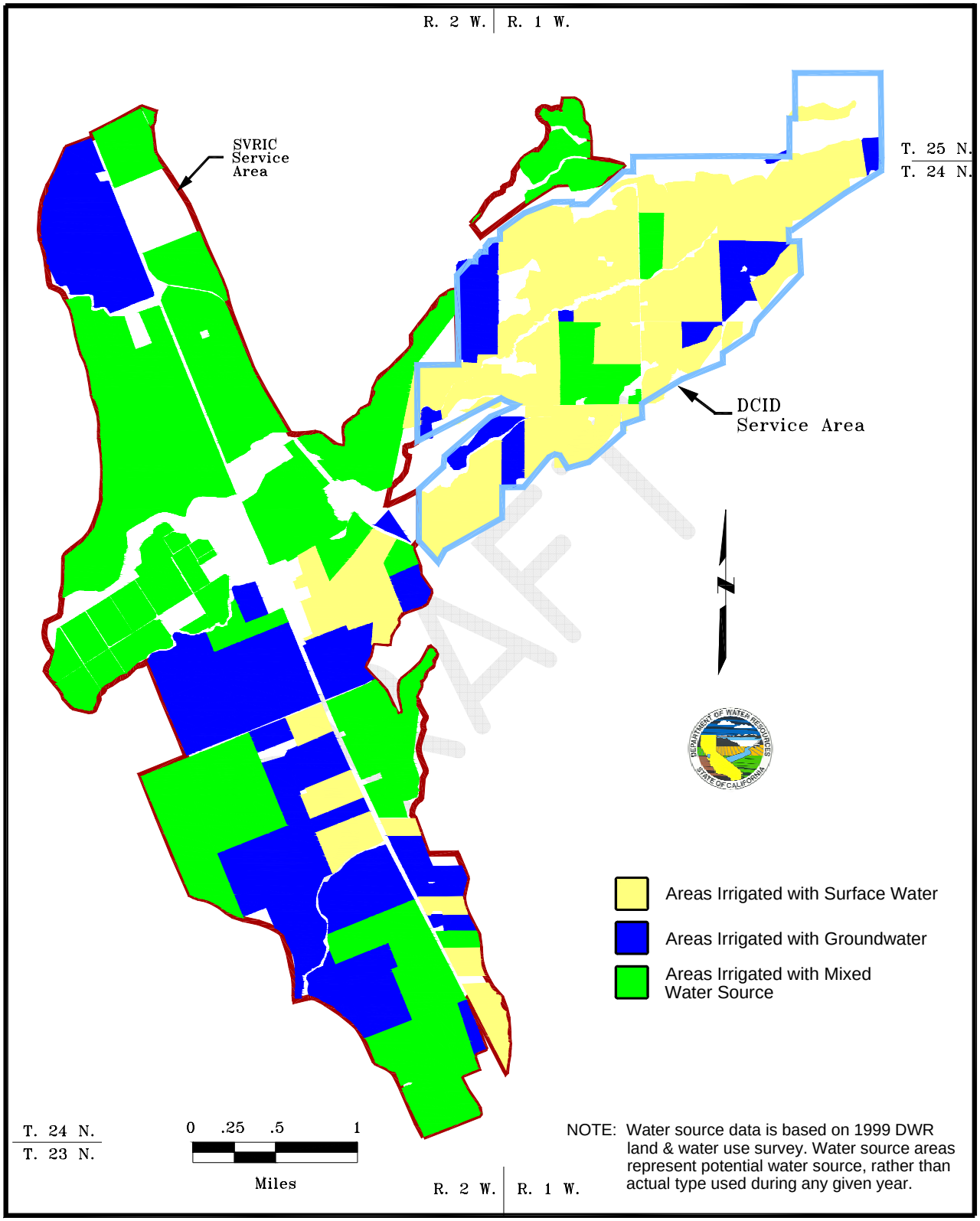

Figure 18. 1999 Water Source Map for the DCID and SVRIC Service Areas.

Crop Type	Net Irrigated Acreage (acres)			ET of Applied Water (acre-feet)			Applied Water (acre-feet)		
	Surface	Ground	Total	Surface	Ground	Total	Surface	Ground	Total
GRAIN	60	0	60	24	0	24	36	0	36
PASTURE	520	10	530	1,716	33	1,749	2,860	45	2,905
PASTURE – X	110	0	110	176	0	176	297	0	297
ALMONDS	400	100	500	1,000	250	1,250	1,440	320	1,760
PRUNES	10	30	40	24	72	96	37	87	124
WALNUTS	270	110	380	675	275	950	972	374	1,346
Totals:	**1,370**	**250**	**1,620**	**3,615**	**630**	**4,245**	**5,642**	**826**	**6,468**

Table 11. Normal Year (1999) Land and Water Use Data for DCID.

Crop Type	Net Irrigated Acreage (acres)			ET of Applied Water (acre-feet)			Applied Water (acre-feet)		
	Surface	Ground	Total	Surface	Ground	Total	Surface	Ground	Total
GRAIN	60	0	60	66	0	66	96	0	96
PASTURE	520	10	530	1,924	37	1,961	3,224	51	3,275
PASTURE – X	110	0	110	220	0	220	363	0	363
ALMONDS	290	210	500	870	630	1,500	1,247	819	2,066
PRUNES	10	30	40	28	84	112	43	102	145
WALNUTS	240	140	380	672	392	1,064	960	532	1,492
Totals:	**1,230**	**390**	**1,620**	**3,780**	**1,143**	**4,923**	**5,933**	**1,504**	**7,437**

Table 12. Estimated Dry Year Land and Water Use Data for DCID.

Crop Type	Net Irrigated Acreage (acres)			ET of Applied Water (acre-feet)			Applied Water (acre-feet)		
	Surface	Ground	Total	Surface	Ground	Total	Surface	Ground	Total
CORN	140	0	140	238	0	238	364	0	364
GRAIN	70	0	70	26	0	26	38	0	38
ALFALFA	450	0	450	1,350	0	1,350	2,070	0	2,070
CUCURBITS	0	20	20	0	18	18	0	26	26
PASTURE	490	30	520	1,617	100	1,717	2,695	140	2,835
MEADOW PASTURE	30	0	30	81	0	81	135	0	135
ALMONDS	0	280	280	0	672	672	0	868	868
WALNUTS	1,020	590	1,610	2,550	1,475	4,025	3,672	1,947	5,619
PRUNES	860	550	1,410	1,978	1,265	3,243	3,010	1,760	4,770
	3,060	**1,470**	**4,390**	**7,840**	**3,530**	**11,370**	**11,984**	**4,741**	**16,725**

Table 13. Normal Year Land (1999) and Water Use Data for SVRIC.

Crop Type	Net Irrigated Acreage (acres)			ET of Applied Water (acre-feet)			Applied Water (acre-feet)		
	Surface	Ground	Total	Surface	Ground	Total	Surface	Ground	Total
CORN	60	10	70	71	11	82	101	16	117
GRAIN	70	70	140	133	133	266	203	189	392
ALFALFA	220	220	440	770	770	1,540	1,188	1,100	2,288
CUCURBITS	0	20	20	0	18	18	0	26	26
PASTURE	370	150	520	1,355	550	1,905	2,266	785	3,051
MEADOW PASTURE	20	20	40	58	58	116	96	82	178
ALMONDS	0	280	280	0	812	812	0	1,064	1,064
WALNUTS	530	1,080	1,610	1,484	3,024	4,508	2,120	3,996	6,116
PRUNES	540	870	1,410	1,494	2,418	3,912	2,304	3,324	5,628
	1,810	**2,720**	**4,530**	**5,365**	**7,794**	**13,159**	**8,278**	**10,582**	**18,860**

Table 14. Estimated Dry Year Land and Water Use Data for SVRIC.

Water Purveyor	Net Irrigated Acreage (acres)		ET of Applied Water (acre-feet)				Applied Water (acre-feet)			Diverted SW (ac-ft)
	Surface	Ground	Total	Surface	Ground	Total	Surface	Ground	Total	Surface
DCID	1,370	250	1,620	3,615	630	4,245	5,642	826	6,468	11,102
SVRIC	3,060	1,470	4,530	7,840	3,530	11,370	11,984	4,741	16,725	20,656
Totals:	**4,430**	**1,720**	**6,150**	**11,455**	**4,160**	**15,615**	**17,626**	**5,567**	**23,193**	**31,758**

Table 15. DCID & SVRIC Normal Year (1999) Land and Water Use Summary with Estimated Surface Water Diversions.

Water Purveyor	Net Irrigated Acreage (acres)		ET of Applied Water (acre-feet)				Applied Water (acre-feet)			Diverted SW (ac-ft)
	Surface	Ground	Total	Surface	Ground	Total	Surface	Ground	Total	Surface
DCID	1,230	140	1,620	3,780	1,143	4,923	5,933	1,504	6,468	11,653
SVRIC	1,810	2,720	4,530	5,365	7,794	13,159	8,278	10,582	18,860	14,734
Totals:	**3,040**	**2,860**	**6,150**	**9,145**	**8,937**	**18,082**	**14,211**	**12,086**	**25,328**	**26,387**

Table 16. DCID & SVRIC Dry Year Land and Water Use Summary with Estimated Surface Water Diversions.

Water Purveyor	Unit ET Demand (ac-ft/ac)	Unit Applied Water (acre-ft/acre)				Unit Diverted Surface Water (ac-ft/acre)	Surface Water Losses (ac-ft and % of Applied SW Demand)					
		Surface		Ground			Spills		Seepage Losses		Total	
DCID	2.6	87%	4.1	13%	3.3	8.1	1,662	15%	4,443	40%	6,105	55%
SVRIC	2.5	72%	3.9	28%	3.2	6.8	1,797	9%	6,365	31%	8,162	40%
Totals/Ave.:	**2.5**	**76%**	**4.0**	**24%**	**3.2**	**7.2**	**3,459**	**20%**	**10,808**	**61%**	**14,267**	**81%**

Table 17. Normal Year (1999) Agricultural Unit Demand versus Diverted Surface Water and Estimated Surface Water Delivery Losses.

Water Purveyor	Unit ET Demand (ac-ft/ac)	Unit Applied Water (acre-ft/acre)				Unit Diverted Surface Water (ac-ft/acre)	Surface Water Losses (ac-ft and % of Applied SW Demand)					
		Surface		Ground			Spills		Seepage Losses		Total	
DCID	3.0	80%	4.8	20%	3.9	9.5	1,748	15%	4,673	40%	6,421	55%
SVRIC	2.9	44%	4.6	56%	3.9	8.1	1,231	8%	4,549	31%	5,780	39%
Totals/Ave.:	**2.9**	**54%**	**4.7**	**46%**	**3.9**	**8.7**	**2,979**	**21%**	**9,222**	**65%**	**12,201**	**86%**

Table 18. Dry Year Agricultural Unit Demand versus Diverted Surface Water and Estimated Surface Water Delivery Losses.

Table 11 shows that in 1999, approximately 1,600 of the 2,200 acres within the DCID service area was in agricultural production. Approximately 920 acres or 56 percent of the agricultural production in DCID consists of deciduous tree crops, while 40 percent consists of pasture. About 26 percent of the DCID tree crops are irrigated with groundwater and 74 percent are irrigated with surface water. One hundred percent of the pasture lands are irrigated with surface water.

Table 11 also shows that Deer Creek surface water accounts for 87 percent of the total agricultural applied water in the DCID service area. Groundwater pumping accounts for the remaining 13 percent of DCID's agricultural applied water. Approximately 10 percent of the DCID service area has the ability to utilize a mixed source of both surface water and groundwater.

Table 12 shows that, during dry years, the ET demand for DCID goes up about 680 ac-ft and applied water increases by about 1,000 acre-feet. Of the 1,000 acre-feet increase of applied water during dry years, it is assumed that about 700 ac-ft is made up through additional groundwater pumping. Analysis of the dry year scenario assumes that cropping patterns remain the same during dry versus normal years. Thus the net irrigated acreage in Tables 11 and 12 are the same. Deer Creek surface water accounts for 79 percent of the total agricultural applied water in the DCID service area during dry years.

Table 13 shows that in 1999, approximately 4,390 of the 6,500 acres within the SVRIC service area was in agricultural production. Approximately 3,300 acres or 75 percent of the agricultural production in SVRIC consists of deciduous tree crops, while 23 percent consists of pasture and alfalfa. The remaining 2 percent of agricultural land is in corn and grain crops. About 43 percent of SVRIC's tree crops are irrigated with groundwater and 57 percent are irrigated with surface water. Almost 100 percent of the pasture, grain and corn are irrigated with surface water. Overall, Deer Creek surface water accounts for 71 percent of SVRIC's total agricultural applied

water, with groundwater pumping accounting for the remaining 29 percent. Unlike DCID, almost one-half of the SVRIC service area has the well infrastructure and distribution facilities to apply either surface water or groundwater for agricultural production.

Table 14 shows that, during dry years, the ET demand for SVRIC goes up about 1,790 acre-feet and applied water increases by about 2,130 acre-feet. During dry years estimates indicates that applied surface water will decline by about 3,700 acre-feet and groundwater use will increase by about 5,840 acre-feet. During dry years versus normal years, surface water declines from 77 to about 44 percent of the total agricultural applied water in the SVRIC service area.

Tables 15 and 16 summarize the net irrigated acreage, ET of applied water, applied water, and estimated surface water diversion for the DCID and SVRIC areas during the 1999 agricultural season and during estimated dry year conditions.

Table 15 shows that the diverted amount of surface water by DCID and SVRIC during normal years is approximately twice the applied surface water demand. It is important to realize that surface water diversion amounts for SVRIC are estimated based on watermaster observation and may be slightly high based on resent flow measurements at SVRIC's South Main Diversion. However, relative proportions of surface water diversion to applied water for SVRIC is similar to DCID values which utilize the diversion data recorded at the parshall shown in Figure 1. It is also important to realize that, although the amount of surface water diversion is significantly higher than the applied crop requirements, it is the amount that is currently necessary for successful agricultural production under the existing surface water distribution system and on-farm irrigation practices.

Table 16 shows that, during dry year conditions, DCID's surface water diversion is estimated to actually increase by 550 acre-feet from a normal water year, while SVRIC's dry year surface water diversion declines by about 5, 920 acre-feet or 28 percent of normal year estimates. The result is that the majority of DCID's agricultural water demand can still be met by surface water, while SVRIC is required to increase groundwater pumping to offset the reductions in surface water diversion during dry years. The estimated difference between normal year and dry year surface water diversions for DCID and SVRIC could be partly the result of the difference in location between the two diversions. DCID's Deer Creek diversion is approximately 6 miles upstream of SVRIC's main diversion facility.

Tables 17 and 18 provides a unit breakdown of the volume of water per acre associated with estimated water demand and surface water diversion for normal versus dry years. The tables also provide an estimate of the percent and volume diverted surface water that goes to groundwater seepage and spills. Spilled water is surface water that is redirected back to Deer Creek, or into nearby sloughs, due to the difficulties in scheduling and redistributing surface water within the delivery systems, and due to the unavailability of off-system reservoirs to store, regulate and reuse the redistributed surface water.

The normal year (1999) land and water use data in Table 17 indicates that approximate 15 percent of DCID's diverted surface water is spilled and 40 percent goes to seepage losses along the distribution system. Surface water spills account for about 9 percent of the SVRIC losses, while 31 percent goes towards canal seepage. The total percent of diverted surface water that is lost within the DCID and SVRIC distribution systems is estimated at 55 and 40 percent, respectively. Since spills and losses are largely a function of the construction and operation of

the existing distribution facilities, the percentages of these losses shown in Tables 17 and 18 are assumed to remain relatively the same during normal versus drought years.

Efficiency improvements to the distribution systems at DCID and SVRIC have the opportunity to significantly reduce the overall amount of system losses while maintaining existing agricultural water demand.

Comparison of the Unit Applied Water columns in Tables 17 and 18 illustrate the differences in applied groundwater versus surface water for DCID and SVRIC during normal and dry years. Limitations in the dry year surface water supply for SVRIC result in the percentage of overall water supply coming from surface water dropping from 72 to 44 percent for normal versus dry years. Conversely, the percentage of overall water supply coming from groundwater increased from 28 to 56 for normal versus dry years.

Losses within Lower Deer Creek

Surface water losses within Deer Creek between the USGS gage and the SVRIC dam were estimated from April 2002 through April 2003 and are shown in Figures 19 and 20. Upstream and downstream flow control was provided by the USGS gage at the head of the reach and the DWR gage, below the SVRIC Dam, at the base of the reach. DCID diversion data were provided by the recorder operating at DCID 8-foot parshall flume located about 0.5 miles downstream of the USGS gage. SVRIC diversion data were provided by the recorder operating along the South Main Canal, and by using diversion estimates of 25 cfs for the North Main and 6 cfs for the Cone Kimball diversions.

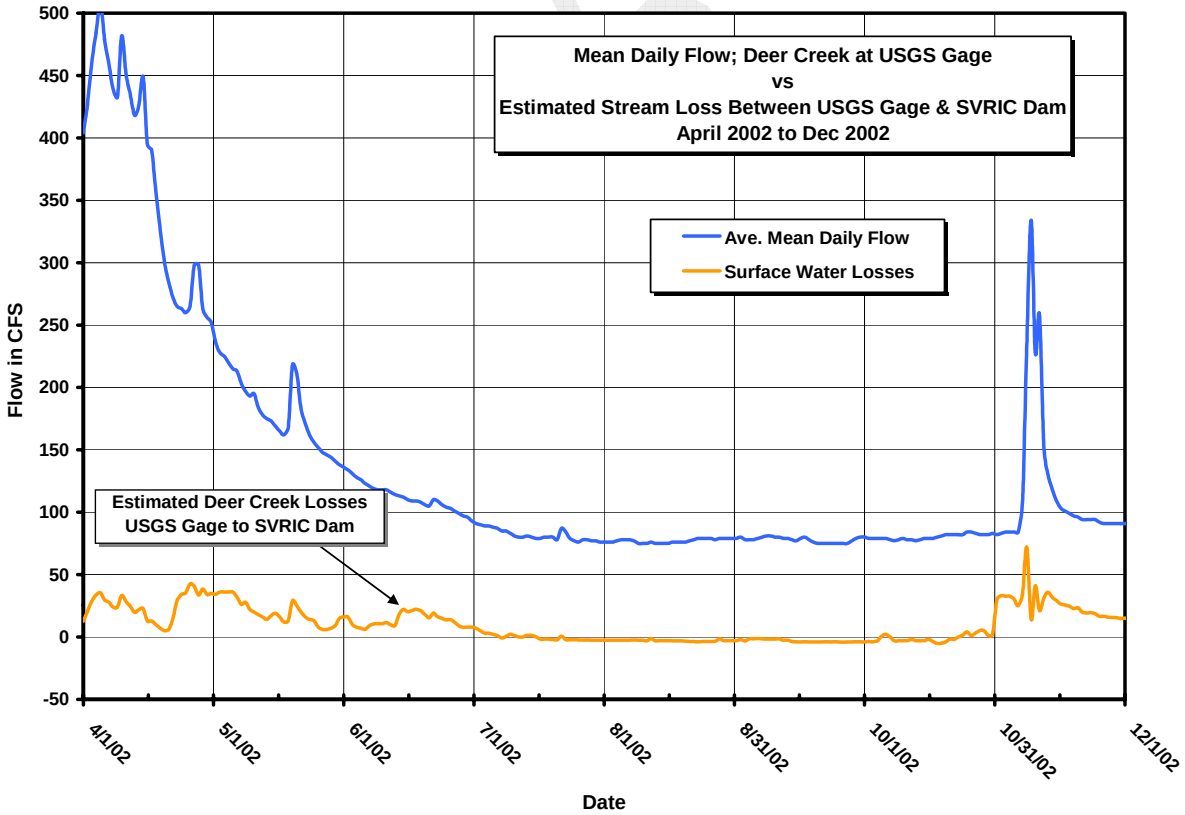

Figure 19. Deer Creek Flow versus Losses Between USGS Gage and SVRIC Dam April through December 2002.

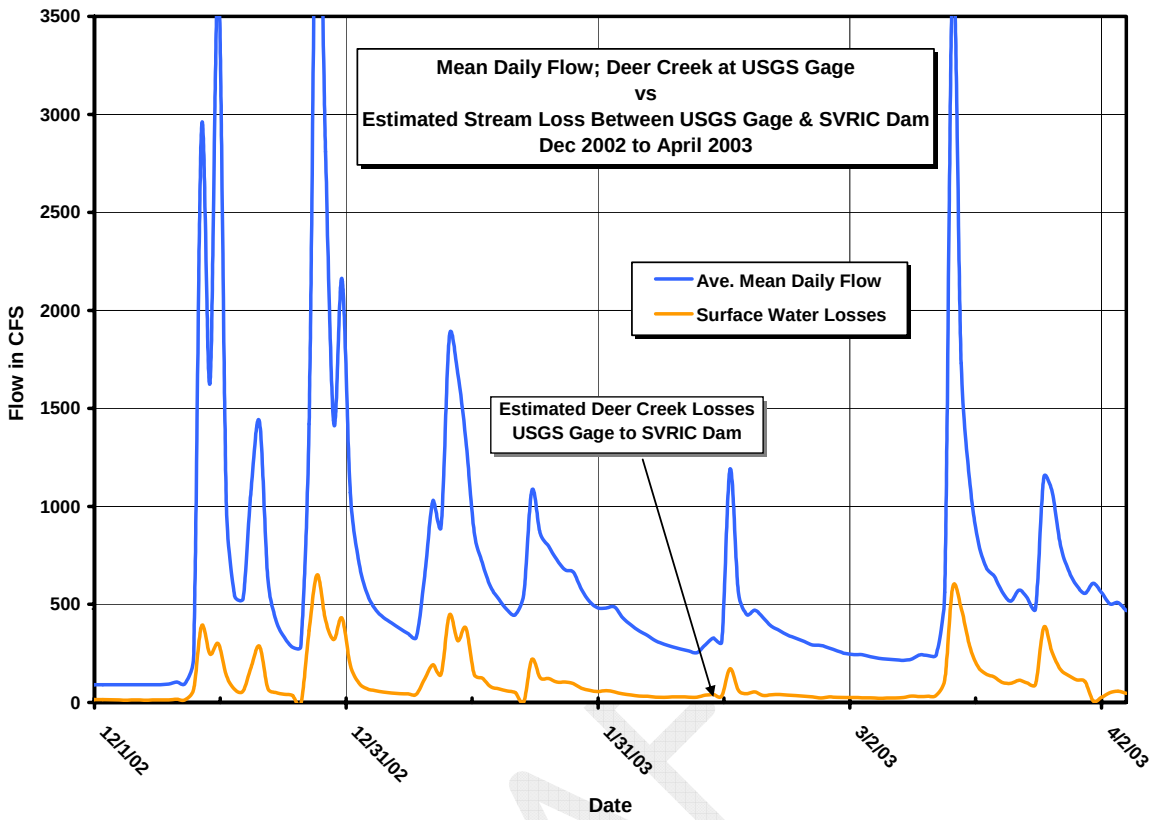

Figure 20. Deer Creek Flow versus Losses Between USGS Gage and SVRIC Dam December 2002 through April 2003.

Figure 19 shows that from April to the end of June estimated losses along the reach range from 5 to 40 cfs. Figure 19 also shows, as flows diminish into the summer months and drop below 80 to 90 cfs (as measured at the USGS gage), Deer Creek stops loosing water and starts gaining small amounts of water from the upper groundwater aquifer. The upper groundwater aquifer appears to continue to maintain a small base-flow of water to Deer Creek until runoff from fall precipitation increases the Deer Creek flow during winter months.

Figure 20 shows the estimated stream losses through the winter months. Data in Figure 20 would indicate that much of the aquifer recharge comes during periods of high flow in the winter months.

Data presented in Figures 19 and 20 should be considered estimates only. Additional diversion data for SVRIC's North Main and Cone Kimball diversions, and field flow check along Deer Creek are needed before more accurate estimates regarding losses along the lower reach of Deer Creek can be made.

Regional Geology and Groundwater Bearing Units

Tehama County lies within the northern portion of the Sacramento Valley Groundwater Basin. The Sacramento Valley Groundwater Basin extends from Red Bluff to the Sacramento-San Joaquin Delta, and is bordered by the Coast Ranges to the west and the Cascade Range and Sierra Nevada mountains to the east. It covers an area of 4,900 square miles which includes all of Sutter county and part of Butte, Glenn, Tehama, Colusa, Yuba, Yolo, Solano, Placer and Sacramento counties.

The Sacramento Valley is a structural basin filled with up to 5 miles of marine and continentally derived sediments deposited almost continuously from the Late Jurassic period to the present. The oldest of these valley sediments were emplaced in a marine environment and typically contain saline or brackish groundwater. Younger sediments were deposited under continental conditions and generally contain fresh groundwater. Sediments thin near the margins of the basin, exposing the older rocks the underlying the Sacramento Valley sediments.

Deformational structures within the Sacramento Valley portion of Tehama County include several faults and folds. The Chico Monocline is a northwest-trending southwest-facing flexure that roughly follows the northeastern boundary of the Sacramento Valley Region, extending from Chico to Red Bluff. In Tehama County, the Chico Monocline deforms the Tuscan Formation and has a dip of up to 25 degrees, where it acts as an eastward aquifer boundary (DWR Bulletin 118-6, 1978). South of Chico, Tuscan beds deformed by the monocline have a gentler slope of approximately 2 to 5 degrees.

The surface geology of the Sacramento Valley portion of Tehama County is comprised primarily of alluvial deposits whose source area is the eroded material derived from surrounding mountain ranges. These sediments were deposited as alluvial fan, terrace, and basin deposits by a network of streams and rivers flowing into the Sacramento Valley. Along the front of the foothills, alluvial fan and terrace deposits of the Riverbank and Modesto formations mark the edge of the valley sedimentary units.

Regionally, the base of post-Eocene continental deposits is commonly considered the approximate base of fresh groundwater in the Sacramento Valley. Within the central portion of Tehama County, adjacent to the Sacramento River, the base of fresh groundwater occurs at depth of about 1700 feet below ground surface. Along the margins of the valley portion of Tehama County, the base of fresh groundwater migrates slightly upward with the tilting marine sediments.

In the Sacramento Valley portion of Tehama County, fresh groundwater-bearing units include the Tehama, Tuscan, Riverbank and Modesto formations. Groundwater in these formations exist largely within the primary porosity associated with the spaces between the individual sand and gravel deposits, and within the secondary porosity associated with fractures and jointing of the more competent volcanic rocks within portions of the Tuscan Formation.

The volcanic sediments of the Tuscan Formation interfinger with the non-marine and non-volcanic sediments of the Tehama Formation in the subsurface. This contact is considered to occur at depth in the vicinity west of the Sacramento River.

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Local Geology and Groundwater Bearing Units

Deer Creek Irrigation District lies within the southeastern portion of Tehama County, along the northeastern Sacramento Valley Groundwater Basin. The local geology surrounding the project area is shown in Figure 21. An explanation of the geologic units is provided in Figure 22. Figure 21 also shows the location of two cross-sections through the Deer Creek area. Section A-A' is shown in Figure 23 and Section B-B' is shown in Figure 24. Section A-A is a portion of a more regional cross-section located just south of the Deer Creek that was developed as part of the Department of Water Resources Bulletin 118-7 mapping project. Section B-B' is a more local cross-section through the project area that was developed from program-related drilling and aquifer sampling.

The principal groundwater bearing unit in the Deer Creek project area consists of the Pliocene Tuscan formation. Both domestic and irrigation wells in the area rely on the Tuscan formation as the primary source of water. Quaternary terrace deposit such as the Riverbank and Modesto formations also occur in the area, but only those wells directly adjacent to Deer Creek encounter sufficient thickness to make these formations a reliable source for domestic and irrigation water.

The Tuscan Formation is composed of a series of volcanic mudflows, tuff breccias, tuffaceous sandstone, and volcanic ash layers. Mudflows originated in the vicinity of present-day Lassen Peak and most likely filled ancient stream channels as they flowed toward the valley. Upon reaching the valley, the mudflows fanned out across the valley floor. Some larger lahars may have continued to flow southward in the valley along various drainage channels. The Tuscan Formation is described as four separate but lithologically similar units, Units A through D, which in some areas are separated by layers of thin tuff or ash units (Helley and Harwood 1985).

Unit A consists of the oldest and deepest of the Tuscan Formation deposits, while Unit D is the youngest. However, Unit D is exposed only in localized areas northeast of Red Bluff. Thus, in the project area Unit C is the youngest and shallowest of the Tuscan Formation deposits. The stratigraphic sequence and estimated thickness of the Tuscan deposits is shown in Figures 23 and 24.

Units A and Unit B are lithologically very similar and are commonly grouped together and described as the "Lower Tuscan". Both units contain a fairly even distribution of lahars volcanic conglomerate, volcanic sandstone and siltstone. However, Unit A does have the slight distinction of comprising a small percentage of metamorphic clasts within the interbedded deposits. In addition, Unit A contains the Nomlaki Tuff, a dacitic pumice tuff, near basal portion of the unit. The Nomlaki Tuff occurs throughout the valley within the basal sections of the Tuscan, Tehama, and Laguna formations.

In the Butte County portion of the valley, Tuscan Unit B is a very productive water bearing system. Because of the lithologic similarity to Unit B, it is hypothesized that Unit A could also be a productive groundwater source. However, very few wells are constructed solely in Unit A of the Tuscan, so accurate production estimates for this aquifer zone are unavailable.

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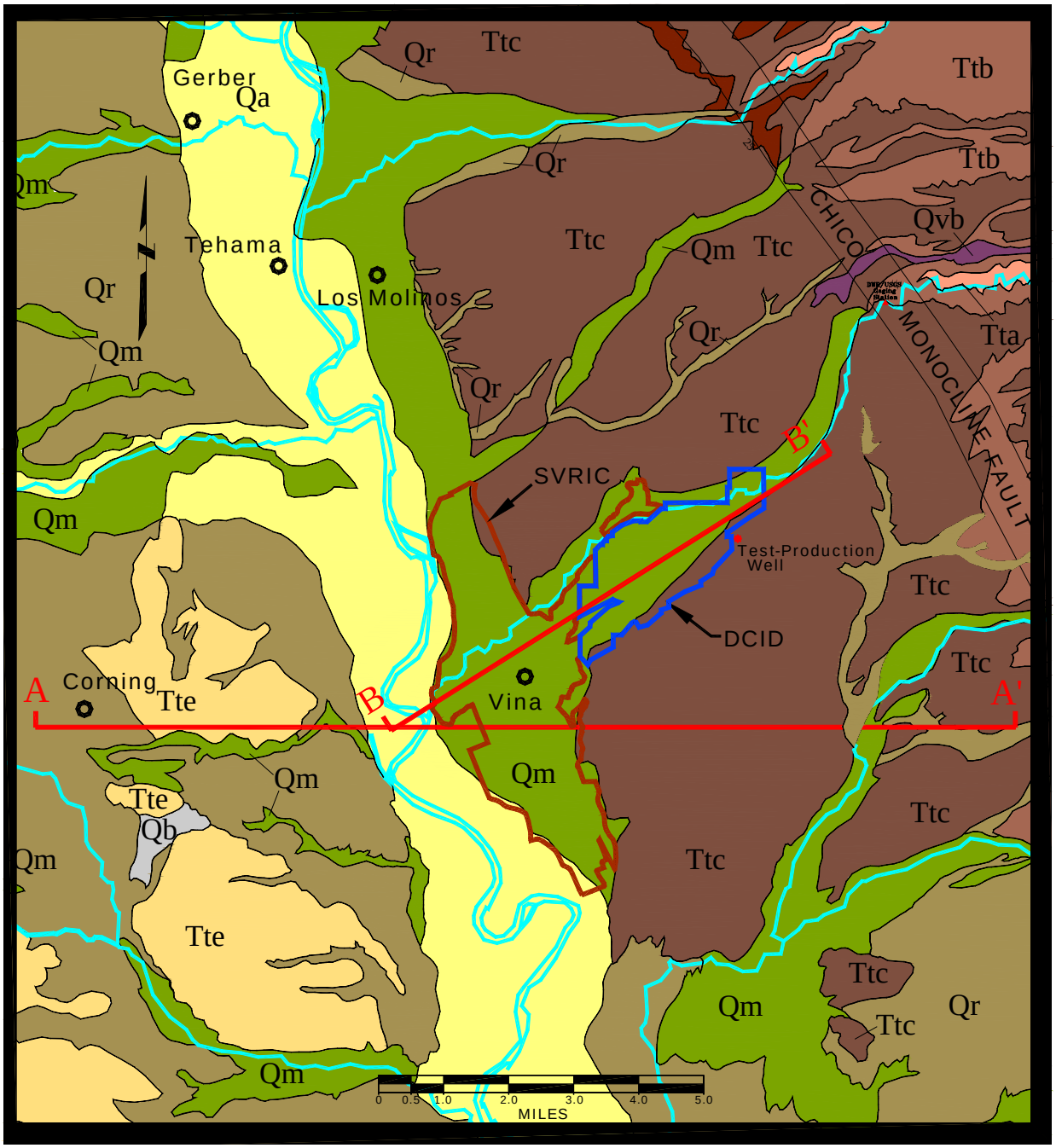


Figure 21. Regional Geologic Map of the Project Area (modified from DWR Bull. 118-7 Draft).

DESCRIPTION OF MAP UNITS

Qa — **Alluvium** (Holocene)-Includes surficial alluvium and stream channel deposits of unweathered gravel, sand and silt, maximum thickness 80 ft. *(adapted from Helley & Harwood, 1985)*.

Qb — **Basin deposits** (Holocene)-Fine-grained silt and clay derived from adjacent mountain ranges, maximum thickness up to 200 ft. *(adapted from Helley & Harwood, 1985)*.

Qm — **Modesto Formation**, undifferentiated (Pleistocene)-alluvial fan and terrace deposits consisting of unconsolidated weathered and unweathered gravel, sand, silt and clay, maximum thickness approximately 200 ft. *(adapted from Helley & Harwood , 1985).*

Qr — **Riverbank Formation**, undifferentiated (Pleistocene)-alluvial fan and terrace deposits consisting of unconsolidated to semi-consolidated gravel, sand and silt, maximum thickness approximately 200 ft. *(adapted from Helley & Harwood, 1985).*

Tte — **Tehama Formation** (Plio-Pleistocene)-includes Red Bluff Formation on west side. Pale green, gray and tan sandstone and siltstone with lenses of pebble and cobble conglomerate, maximum thickness 2,000 ft. *(adapted from Helley & Harwood, 1985).*

Ttc — **Tuscan Unit C** (Plio-Pleistocene)-includes Red Bluff Formation on east side. Volcanic lahars with some interbedded volcanic conglomerate and sandstone, and reworked sediments, maximum thickness 600 ft. *(adapted from Helley & Harwood, 1985, DWR Bulletin 118-7 (in progress), 2001).*

Ttb — **Tuscan Unit B** (Pliocene)-Layered, interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone, maximum thickness 600 ft. *(adapted from Helley and Harwood, 1985; DWR Bulletin 118-7 (in progress), 2001).*

Tta — **Tuscan Unit A** (Pliocene)-Interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone containing metamorphic rock fragments, maximum thickness 400 ft. *(adapted from Helley & Harwood, 1985; DWR Bulletin 118-7 (in progress), 2001).*

Tn — **Neroly Formation** (Miocene)-marine to non-marine sediments, tuffaceous andesitic sandstone with interbeds of tuff and tuffaceous shales and occasional conglomerate lenses, max. thickness 500 ft. *(adapted from Redwine, 1972; Wagner and Saucedo, 1990).*

Tupg — **Upper Princeton Gorge** (Late Oligocene to Early Miocene)-Non-marine sediments composed of sandstone with interbeds of mudstone and occasional conglomerate and conglomerate sandstone, maximum thickness 1,400 ft. *(adapted from Redwine, 1972).*

Ti — **Ione Formation** (Eocene)-Marine to non-marine deltaic sediments, light colored, commonly white conglomerate, sandstone and siltstone, which is soft and easily eroded, max. thickness 650 ft. *(adapted from DWR Bulletin 118-6, 1978; Creely, 1965).*

Tlpg — **Lower Princeton Gorge** (Eocene)-includes Capay Formation. Marine sandstone, conglomerate and interbedded silty shale, maximum thickness 2,400 ft. *(adapted from Redwine, 1972).*

JKgvs — **Great Valley Sequence** (Late Jurassic to Upper Cretaceous)-Marine clastic sedimentary rock consisting of siltstone, shale, sandstone and conglomerate, maximum thickness 15,000 ft.

Notes:
1. Due to the interfingering relationship and uncertain contact between the Tuscan and Tehama Formations, the contacts should be considered diagramatic.

CORRELATION OF MAP UNITS

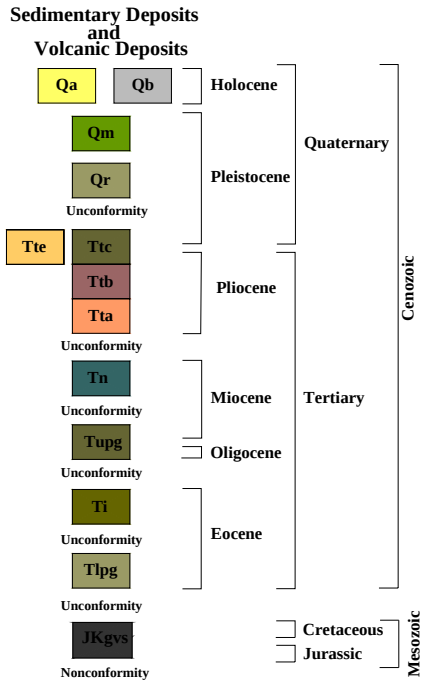


Figure 22. Description of Geologic Map Units (modified from DWR Bull. 118-7 Draft).

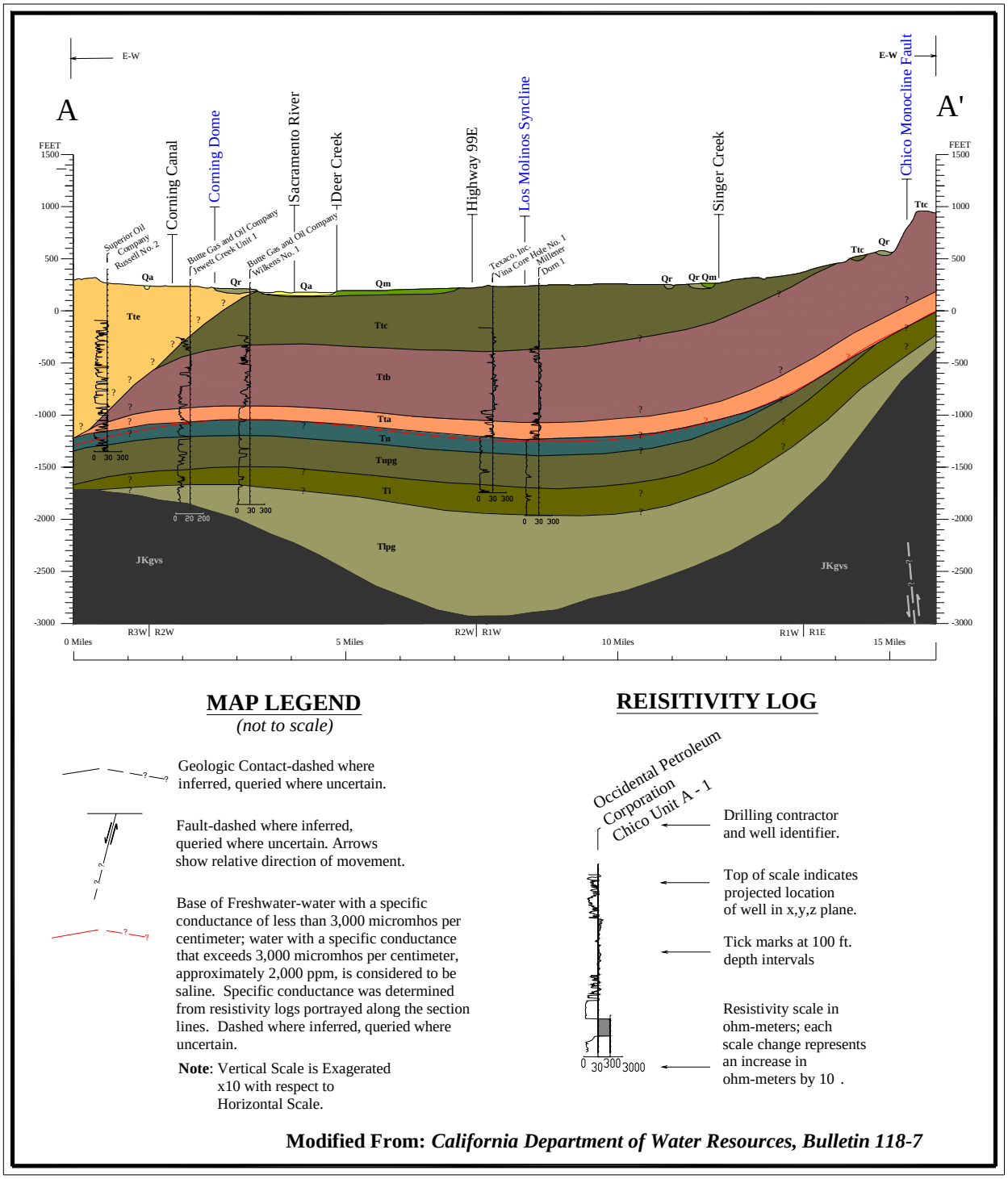
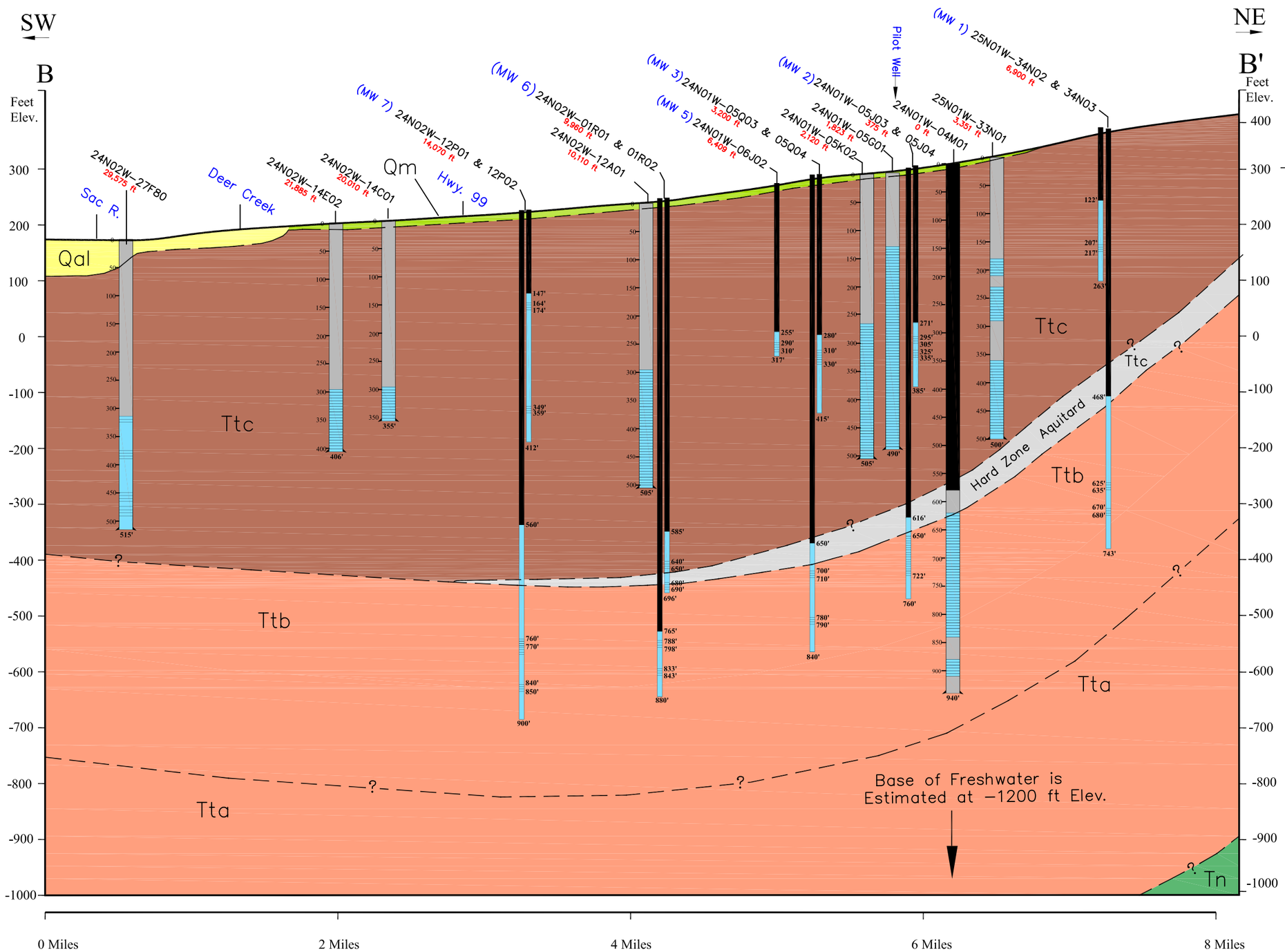


Figure 23. Geologic Cross-Section A-A' Located South of the Deer Creek Project Area.

Figure 24

Geologic Cross-Section B-B' Located Through the Deer Creek Project Area



Geologic Map Legend

Geologic Contact-dashed where inferred, queried where uncertain.

Note: Vertical Scale is Exagerated x10 with respect to Horizontal Scale.

Production Well Legend

State Well Number → 25N01W-33N01

Distance from Pilot Well → 3,351 ft

Depth Below Groundsurface

Blank Casing Interval

Perforated Casing Interval

Total Depth of Well → 355'

Monitoring Well Legend

State Well Number → (MW 1) 25N01W-34N02

Distance from Pilot Well → 6,737 ft

Well Seal Interval → 468'

Gravel Packed Interval

Well Screen Interval → 207' 217'

Total Depth of Well → 263'

Figure 24 shows that, in the DCID area, Unit B of the Tuscan begins at depth of about 400 to 600 feet. None of the agricultural wells in the DCID or SVRIC area appear to draw from either the Tuscan B or A Units.

Unit C consists of more massive mudflow or lahar deposits with some interbedded volcanic conglomerate and sandstone. Towards the eastern foothill area, these lahars are well cemented and form the cap rock for the ridges and canyons the border the eastern drainages. Evidence of wood fragments found in Unit C suggests fast-moving, massive mudflows at the time of deposition. In the subsurface, the low-permeability lahars in Unit C form thick, confining layers for groundwater contained in the more permeable sediments of Unit B. Unit C is also commonly referred to as the "Upper Tuscan".

In the lower Deer Creek area most of the agricultural and domestic wells draw from Unit C of the Tuscan Formation. Figure 24 shows the construction and distribution of local wells along the B-B' section line. The area indicated as "hard zone" on the map is thought to be a well cemented mudflow that appeared in several drilling logs. This deep mudflow seems to form a hard cap, or aquitard, above the Unit B in this area. Other less continuous "hard zones" also occur in the shallower portions of Unit C in the project area. Combined with flood application of agricultural water, these discontinuous mudflow layers contribute to a perched aquifer for wells constructed less than about 200 feet deep. Agricultural wells drawing solely from the upper Tuscan in the project area tend to produce between 800 and 2000 gallons per minute.

Groundwater Levels and Direction of Groundwater Flow

Groundwater levels in the project area are a function of location and well depth. In the eastern DCID area, wells deeper than 200 feet tend to exhibit groundwater levels ranging from 80 to 110 feet below ground surface. Wells less than 200 feet in this area tend to tap into a perched aquifer zone which results in water levels between 30 and 50 feet below ground surface. Further to the west, towards the Sacramento River, the disparity between groundwater levels in shallow versus deep wells lessens, and the depth to groundwater decreased overall.

Groundwater hydrographs illustrate changes in groundwater levels over time. Hydrographs representing the seasonal and long-term groundwater level changes in the domestic and agricultural wells are presented in Figures 25 and 26.

Figure 25 is a hydrograph for well 24N/01W-05J01M. Well 24N/01W-05J01M is a domestic well producing from the shallow portion of the upper Tuscan. Groundwater levels in this well were measured on a monthly basis in 1971, a semi-annual basis (spring-fall) from 1971 to 1995, and is currently being monitored four times a year during March, July, August and October. The hydrograph for well 24N/01W-05J01M shows that the seasonal fluctuation in groundwater levels typically ranges about 5 feet. Examining the hydrograph over the last few years, which included summer monitoring, indicates that the highest groundwater levels typically take place in the summer months during periods of flood irrigation. Conversely, the lowest seasonal levels occur in the winter months when applied irrigation water is kept to a minimum. Long-term comparison of spring-to-spring water levels in Figure 25 shows very little decline during the 1976-77 and 1986-94 droughts, and overall, a fairly stable aquifer system.

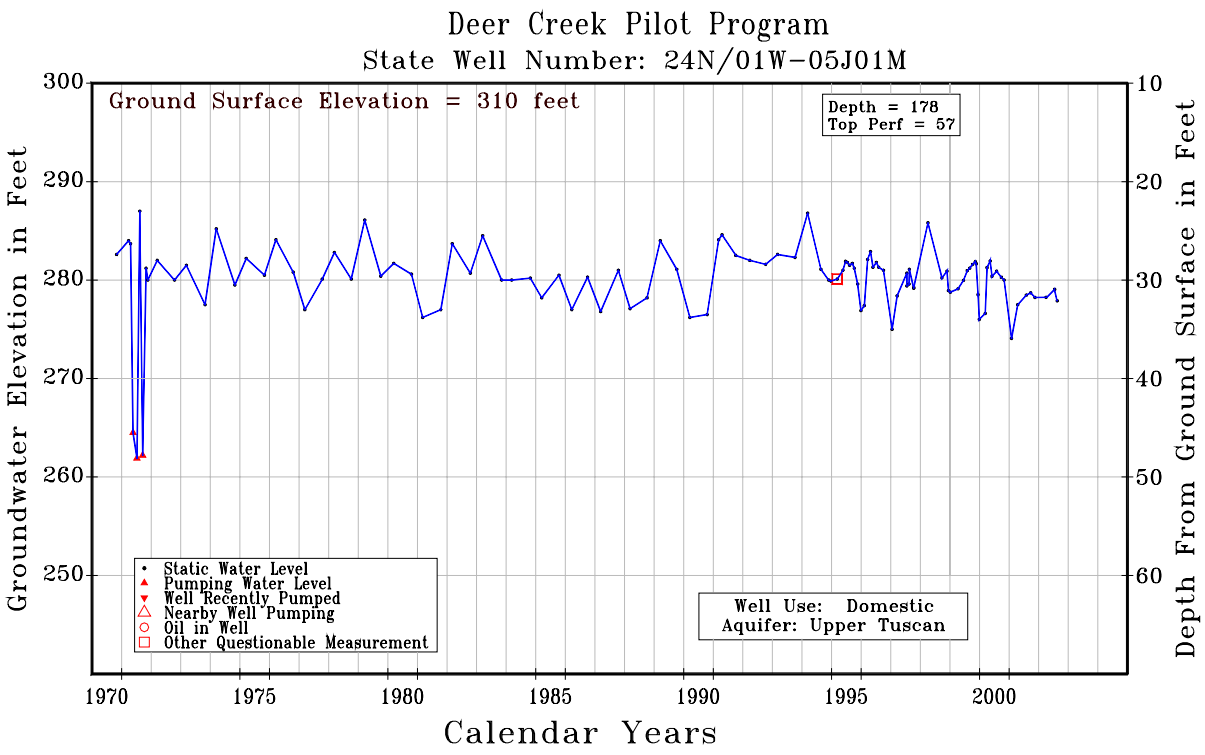


Figure 25, Groundwater Hydrograph for Domestic Monitoring Well 24N01W-05J01

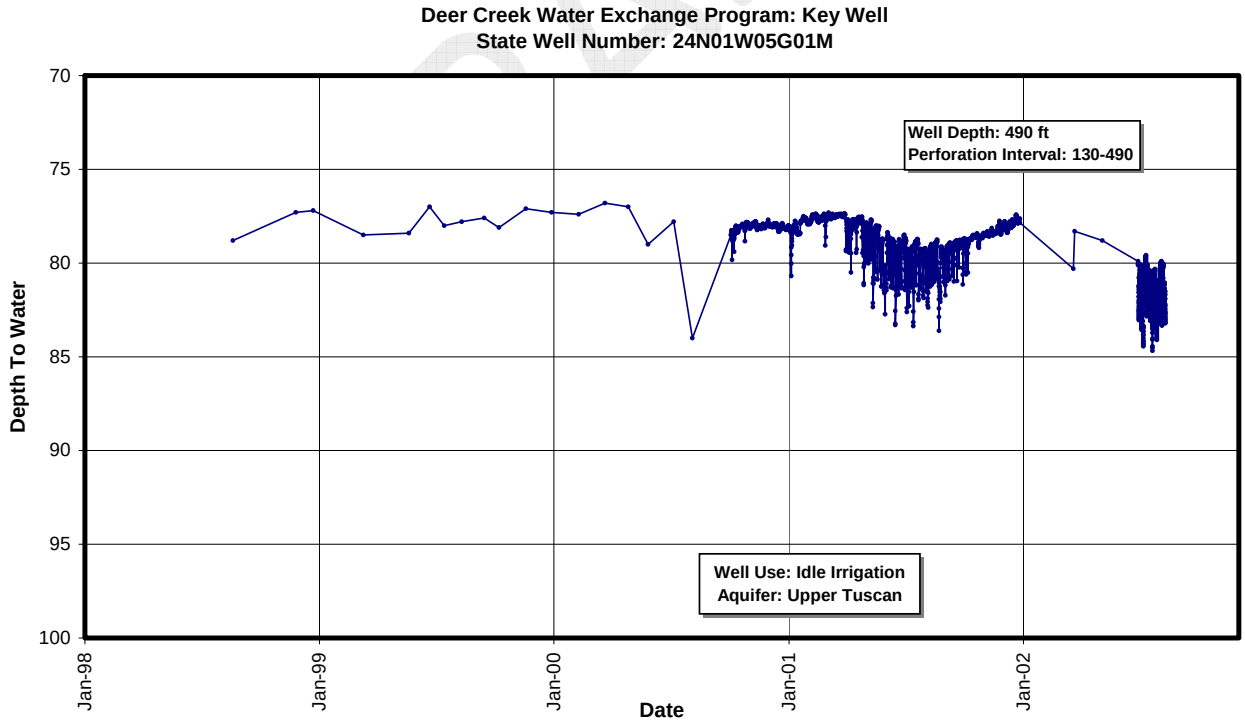


Figure 26, Groundwater Hydrograph for Idle Agricultural Well 24N01W-05G01

Figure 26 is a hydrograph for well 24N/01W-05G01M. Well 24N/01W-05G01M is an idle agricultural well producing from the lower portion of the upper Tuscan aquifer. Groundwater levels in this well were measured on a monthly basis from 1999 to late 2000, when a continuous data logger was installed. Although this well is located less than 1000 feet from the domestic well illustrated in Figure 25, the depth to groundwater averages about 50 feet deeper due to the deeper construction of the well. The hydrograph in Figure 26 shows that the points that make up the average background trend indicate that the seasonal fluctuation in groundwater levels is typically less than 5 feet. The short duration drawdown spikes indicate interference from nearby agricultural wells which produce from the same aquifer interval. Short-term interference from surrounding agricultural pumping is estimated at 5 feet.

Figure 27 is a hydrograph for well 24N/02W-23G01M. Well 24N/02W-23G01M is an active irrigation well located along South Avenue in the SVRIC area. The well produces from the shallow portion of the upper Tuscan. Groundwater levels in this well were measured on a semi-annual basis (spring-fall) from the late 1950's to 1995, and is currently being monitored four times a year during March, July, August and October. The hydrograph for well 24N/02W-23G01M shows that spring-fall fluctuations in groundwater levels in the SVRIC area typically range from about 5-8 feet, while recent summer data indicate a spring to summer fluctuation of up to 15 feet. Long-term comparison of spring-to-spring water levels in Figure 27 shows drawdown and recovery from the 1987 through 1994 drought, followed by a slight decline in spring groundwater levels since 2000.

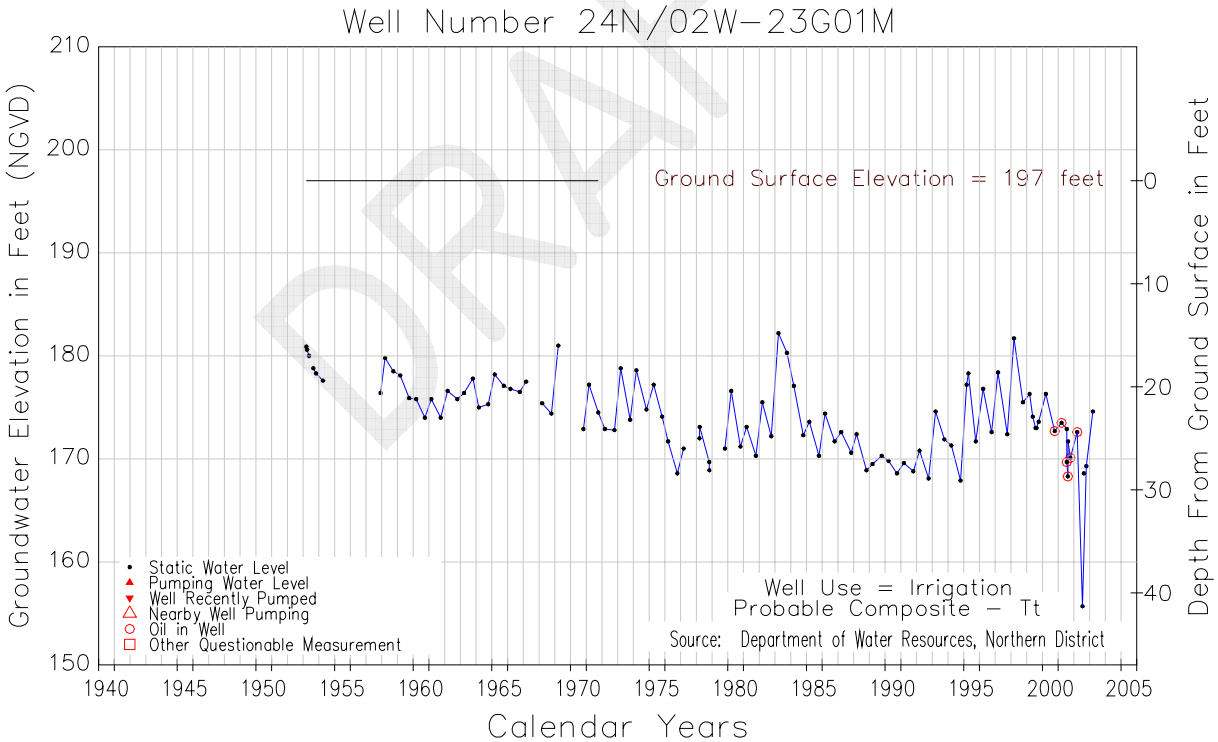


Figure 27, Groundwater Hydrograph for Idle Agricultural Well 24N01W-05G01

Groundwater level data were also used to develop groundwater elevation contour maps for the Sacramento Valley portion of Tehama County. Groundwater contour maps were developed using 2001 spring and summer groundwater level data from monitoring wells in Tehama, Butte and Glenn counties. Groundwater contours are used to help estimate the direction and gradient of groundwater movement and the seasonal changes in groundwater levels. Groundwater levels for

2001 are considered representative of a normal water year. Groundwater contour maps of the Sacramento Valley portion of Tehama County are shown in Figures 28 and 29.

Figure 28 is a groundwater elevation contour map for spring 2001. The groundwater contour lines in Figure 28 represent levels of equal groundwater elevation. Spring groundwater levels are commonly the highest of the year and best reflect the natural groundwater table distribution and direction of movement. Figure 28 shows that the spring groundwater levels vary from an elevation of about 140 feet along the Sacramento River in southern Tehama County, to an elevation of about 500 feet along the west and northwestern portions of the valley. Similar to topographic contour lines, the spacing of groundwater contour lines is an indication of the surface slope, or groundwater gradient. Figure 28 shows that adjacent to the Sacramento River the groundwater gradient is relatively flat and increases along the edges of the valley.

The direction of groundwater movement is illustrated in Figure 28 by a series of red arrows drawn perpendicular to the groundwater elevation contours. Figure 28 shows that the regional pattern of spring groundwater movement is generally towards Sacramento River and the axis of the valley floor. In the lower Deer Creek area, groundwater moves in a southwesterly direction, paralleling the direction of Deer Creek flow.

Figure 29 is a contour map showing the seasonal changes in groundwater levels between spring and summer of a 2001. The contours lines in Figure 29 represent areas of equally changing groundwater levels between the spring and summer measurement periods. Figure 29 shows that the seasonal groundwater level fluctuations in the Sacramento Valley portion of Tehama County range from 0 to -40 feet. The areas of greatest groundwater level decline between spring and summer correspond to those areas where groundwater is extracted for agricultural uses during the summer months. Within the lower Deer Creek area, the 2001 spring-summer change in groundwater levels is about -5 feet.

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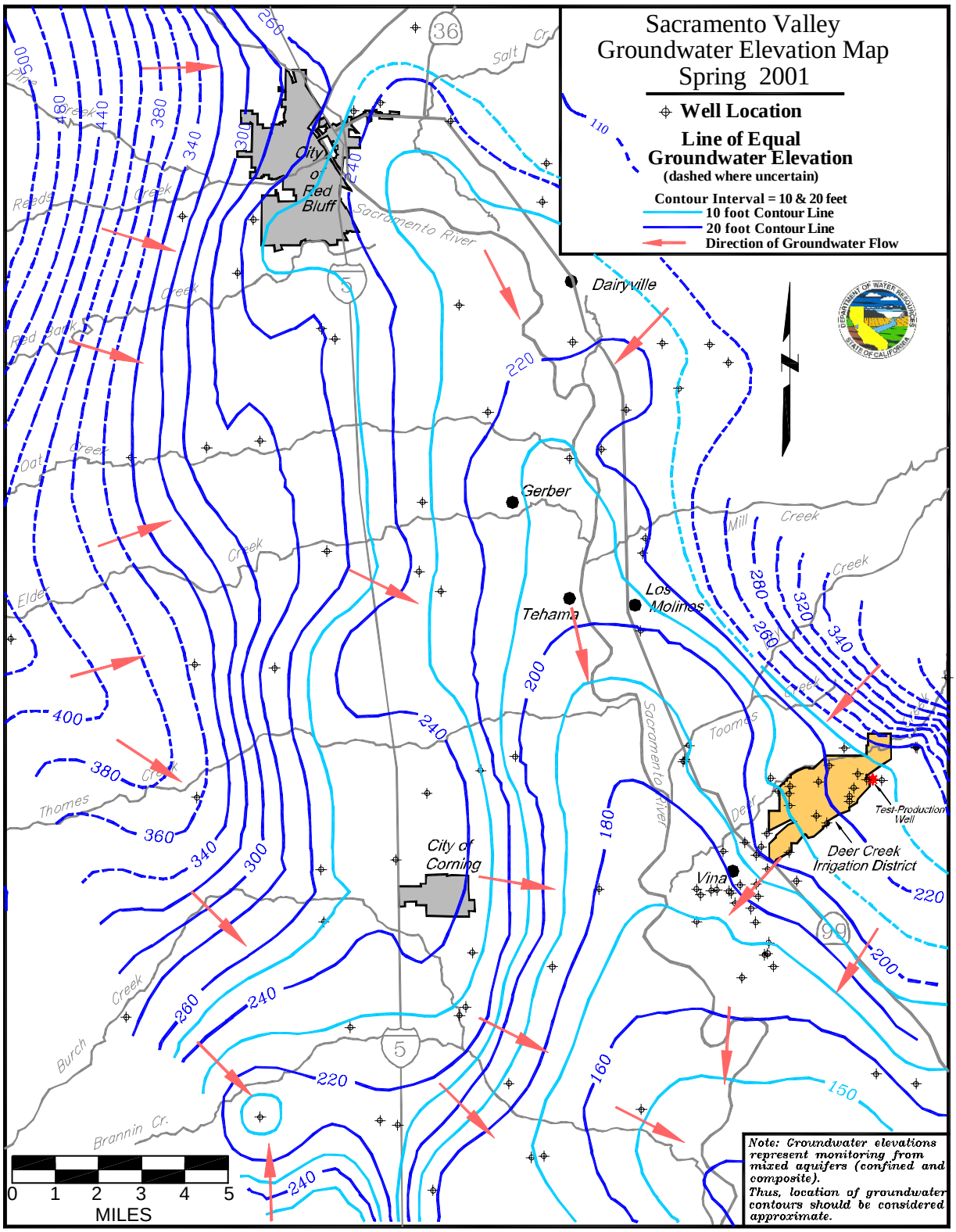

Figure 28. Tehama County, Spring 2001Groundwater Contour Map

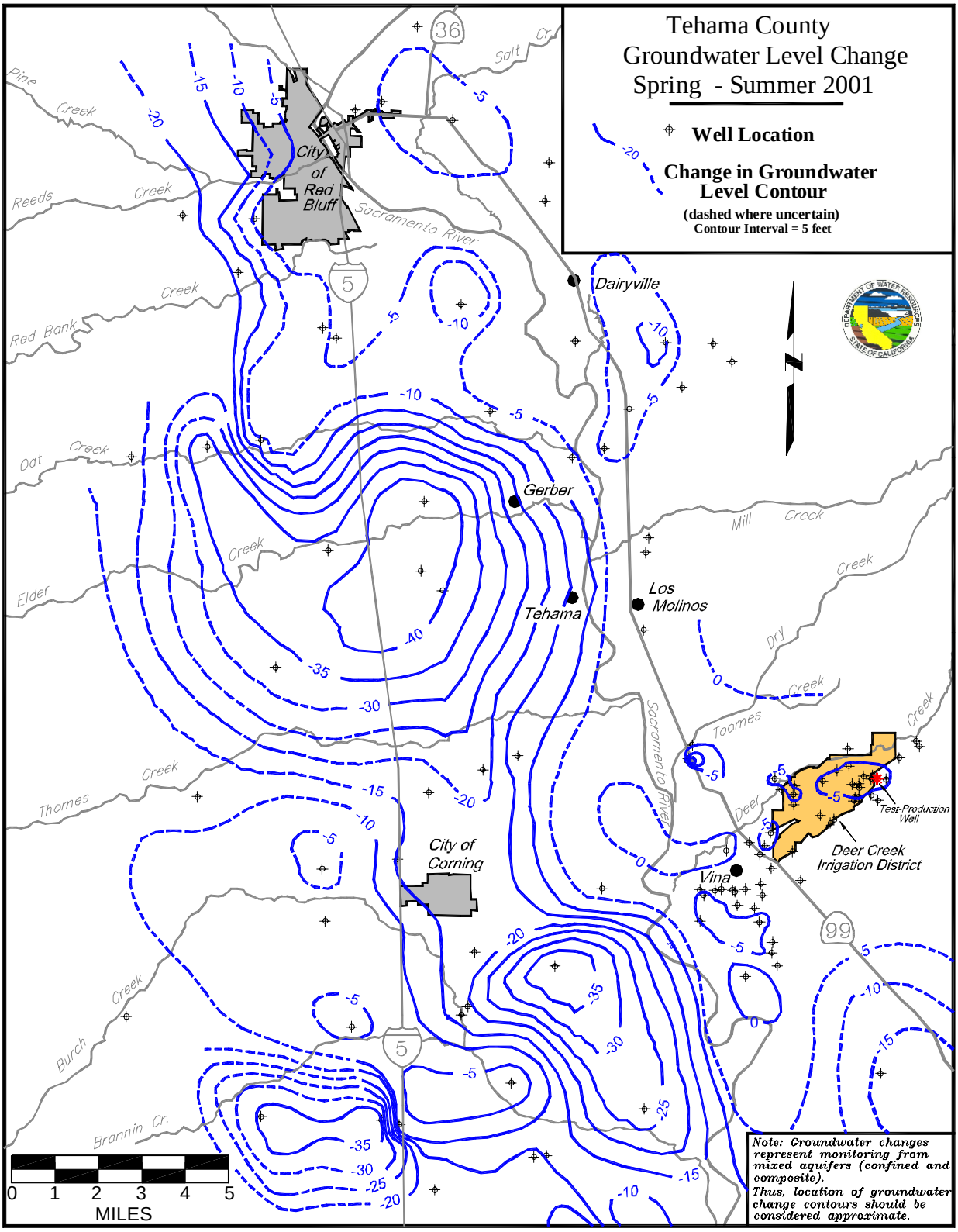

Figure 29. Tehama County, Spring-Summer 2001Groundwater Level Change Map