Appendix B. Historic Groundwater Levels and Surface Water Flow

This appendix describes the groundwater level and surface water flow data used to develop maps of depth to the water table, and for various analyses and model calibration. The methods used to develop the groundwater table maps are also described. Groundwater hydrographs are presented in Section B.4, and surface water data are presented in Section B.5.

B.1 Groundwater Level Database

The groundwater level database for the SJRRP consists of approximately 75,000 groundwater level records for nearly 2,800 wells located within five miles of the SJRRP study area. The period of record extends back to the early 1900s, but almost 90 percent of the available records represent the period from 1960 to present. The frequency of groundwater level measurements for any particular well is generally limited to biannual spring and fall measurements, although monthly, weekly, daily, and even hourly records are available for some or all of the wells installed by the SJRRP.

Groundwater level records were obtained from the DWR's Water Data Library (WDL) online database, the U.S. Geological Service (USGS), and from CCID. Additional data will be added as it becomes available, including measurements from SJRRP cross-section monitoring wells in Reaches 1 and 2, data from the Mendota Pool Group, and recent measurements compiled by the DWR, but not yet available in the WDL database.

B.2 Methodology for Developing Water Table Maps

Maps of depth to the water table (DTW) for selected years were created using a standard kriging interpolation method. Standard kriging takes into account two important aspects of estimation – distance and clustering. The basic technique for standard kriging uses a weighted average of neighboring samples (well locations with corresponding DTW data) to estimate unknown values of DTW at neighboring locations. The results were optimized by applying variogram models known to work well with spatially continuous data (gaussian, exponential, and spherical) and examining the semi-variogram, a graph which models the difference between a value at one location and the value at another according to the distance and direction between them. The optimization process resulted in semi-variograms exhibiting a linear behavior near the origin (a straight line could be fitted to the first few points on the semi-variogram), and the selection of a spherical variogram model based on the intersection location of the straight line with the range of the semi-variogram (Isaaks, 1989).

Figures B-1 and B-2 depict the results of the semi-variogram models for each data set used to develop the DTW maps. The y axis, or semivariance, depicts how closely the values at a given distance (x axis) are spatially correlated. At shorter distances, spatial correlation is greater, resulting in lower values of semivariance. The distance at which each of the modeled variogram lines begins to reach an asymptote corresponds to the range of the semi-variogram. The range defines the maximum distance at which spatial correlation between given well locations can be estimated. As expected, spatial correlation distance is less for years with sparse well coverage throughout the study area (e.g., 2010) and greater for years with relatively dense well coverage (e.g., 1981, 1983, 1988). For example, in 1983, empirical data fit the model line to a distance of approximately 75,000 ft (~ 14 miles); whereas in 2010, spatial correlation distance was less than 50,000 ft (< 9 miles).

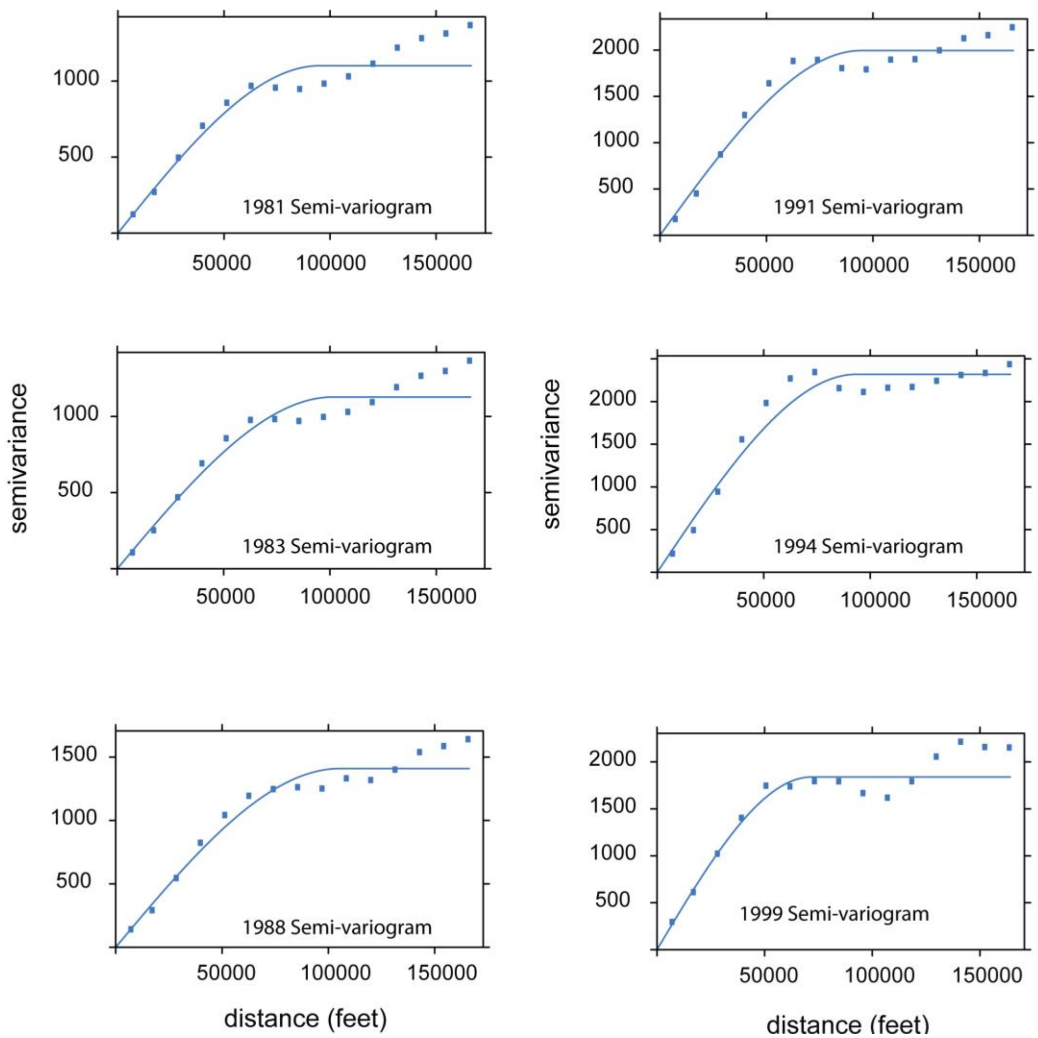


Figure B-1. Semi-Variogram Results Corresponding to the Kriged Depth to Water Table Maps for Selected Years from 1981 through 1999

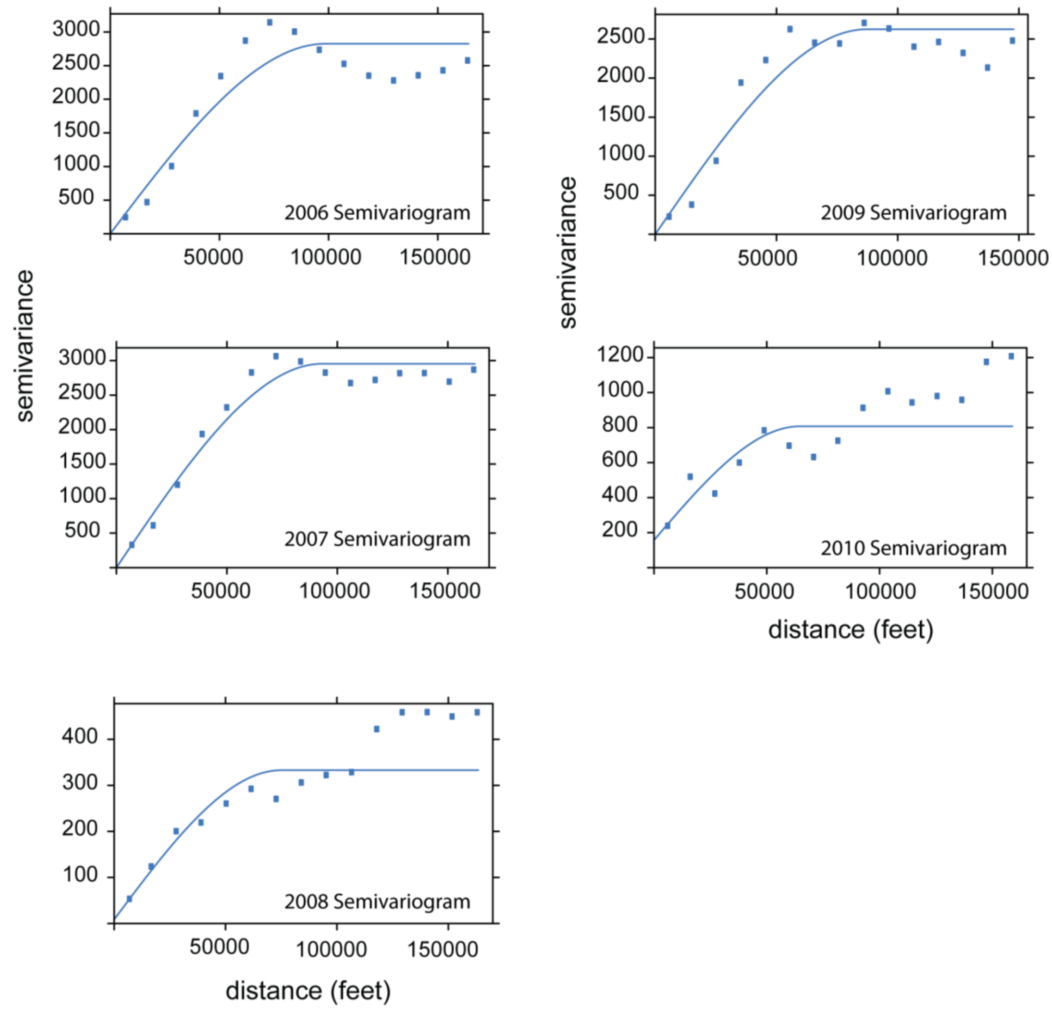


Figure B-2. Semi-Variogram Results Corresponding to the Kriged Depth to Water Table Maps for Selected Years from 2006 through 2010

Table B-1 presents the minimum, maximum, and mean differences between interpolated and known DTW values for each year mapped. The location of the maximum difference in DTW for all years was located in Reach 1A and is a result of only a few wells near the San Joaquin River representative of local shallow groundwater conditions, and a greater number of wells located away from the river in a region where the water table is relatively deep.

Table B-1. Minimum, Maximum, and Mean Difference between Interpolated and Measured Depth to Water Table

Year	Well Count	Minimum DTW Difference, ft	Maximum DTW Difference, ft	Mean DTW Difference, ft
1981	654	0.0	22.5	1.2
1983	837	0.0	9.1	0.4
1988	792	0.0	9.0	0.5
1991	743	0.0	11.0	0.6
1994	789	0.0	7.4	0.6
1999	500	0.0	6.4	0.5
2006	503	0.0	5.9	0.6
2007	302	0.0	5.2	0.5
2008	333	0.0	13.3	1.4
2009	295	0.0	5.6	0.4
2010	289	0.0	41.8	6.8

The DTW maps (Figures B-3 through B-13) were created for the fall measurement period (September 15 through November 15) for the years having the greatest number of measurements and/or the greatest interest with respect to particular climatic conditions. The fall period is relatively unaffected by irrigation, minimally affected by rainfall, and generally has the most available groundwater level data. Dry, normal-dry, wet, and normal-wet water year designations were based on the total annual unimpaired runoff at Friant Dam for the water year (October 1 through September 30) as defined by the SJRRP year type. Kriged values depicted with a stippled background and lighter in transparency did not have a well within a two-mile radius; DTW interpolations in these areas should be considered relatively poorly constrained.

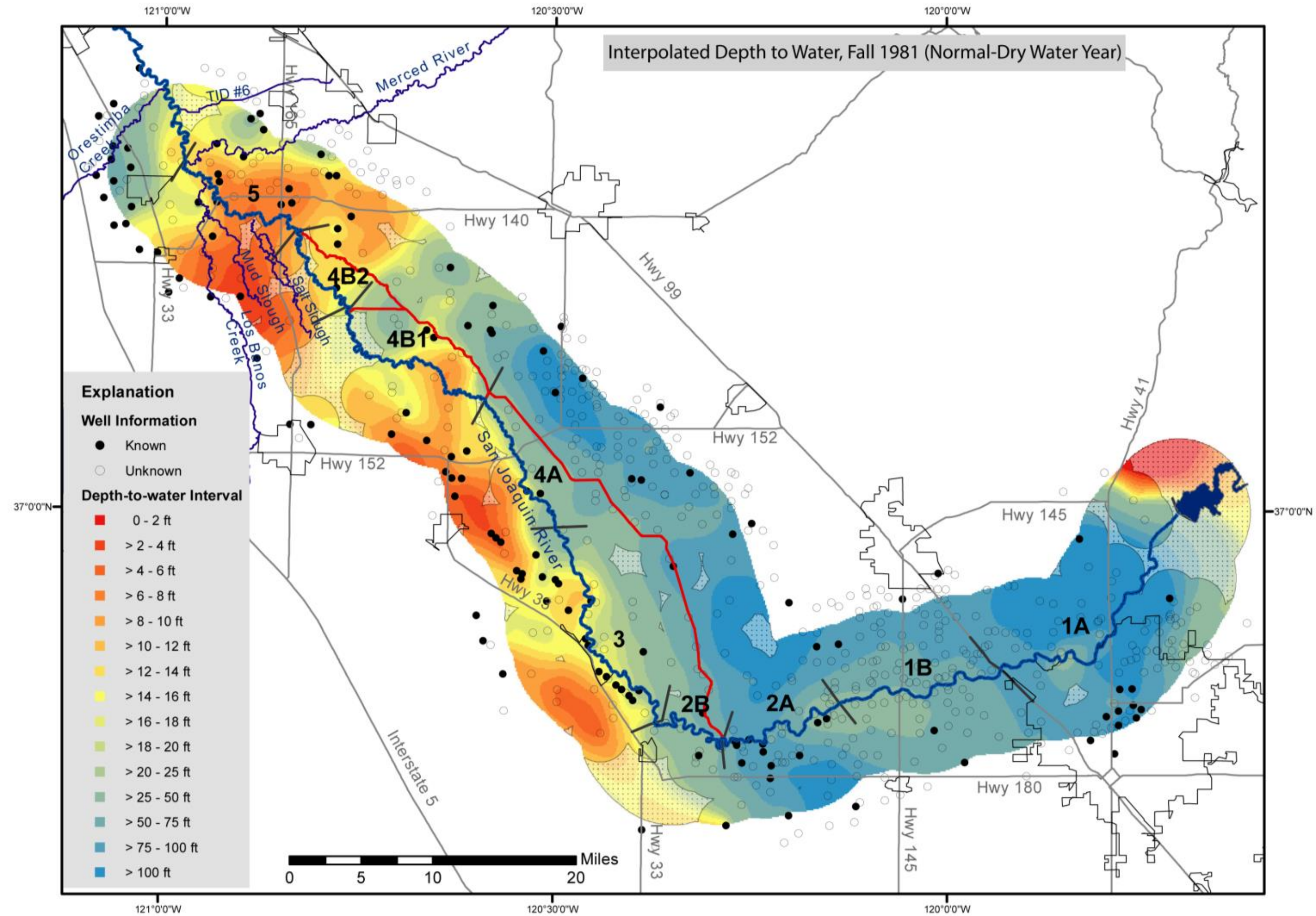
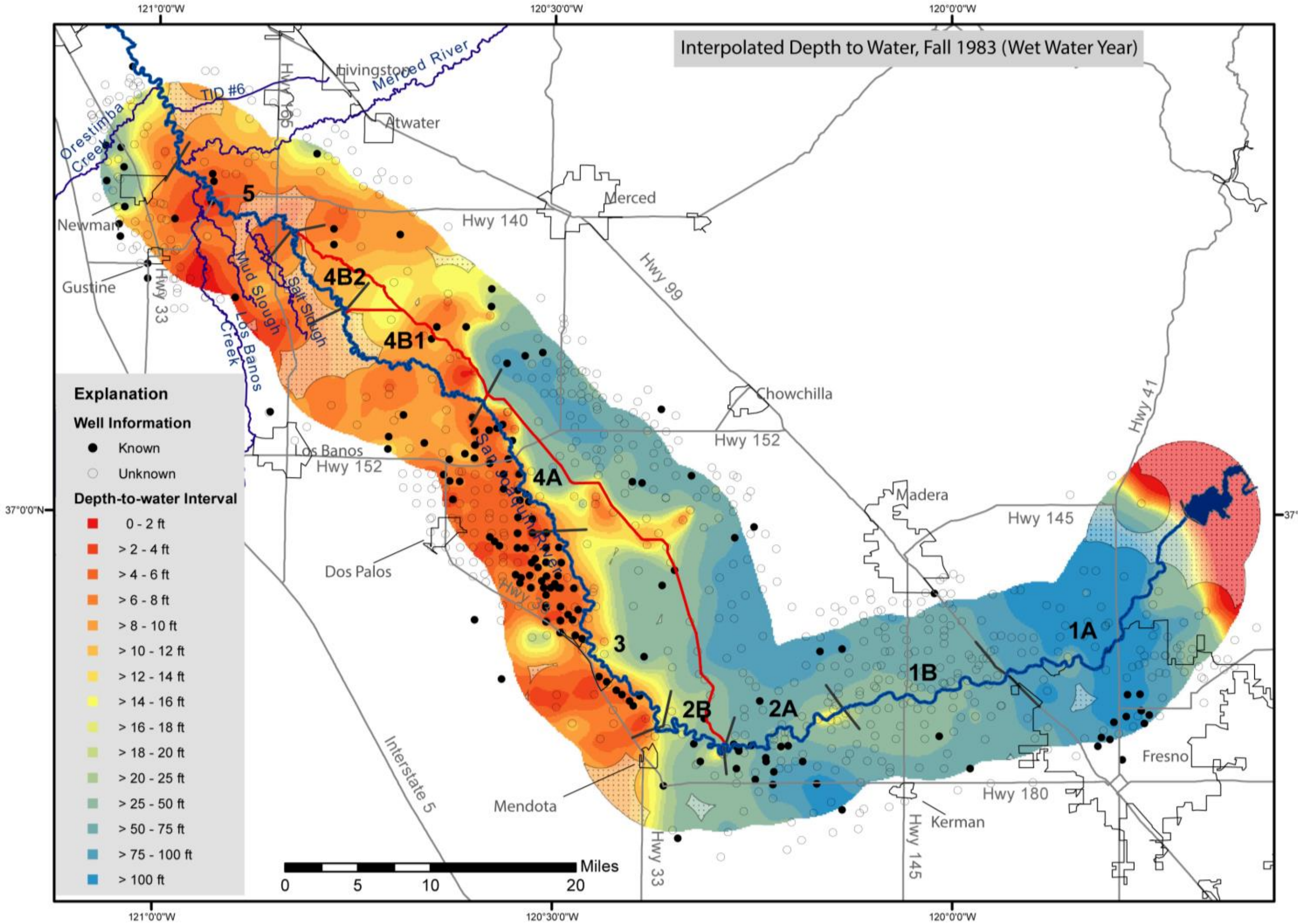


Figure B-3. Interpolated Depth to Water Table Map for Fall 1981 (Normal-Dry Water Year)

Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.

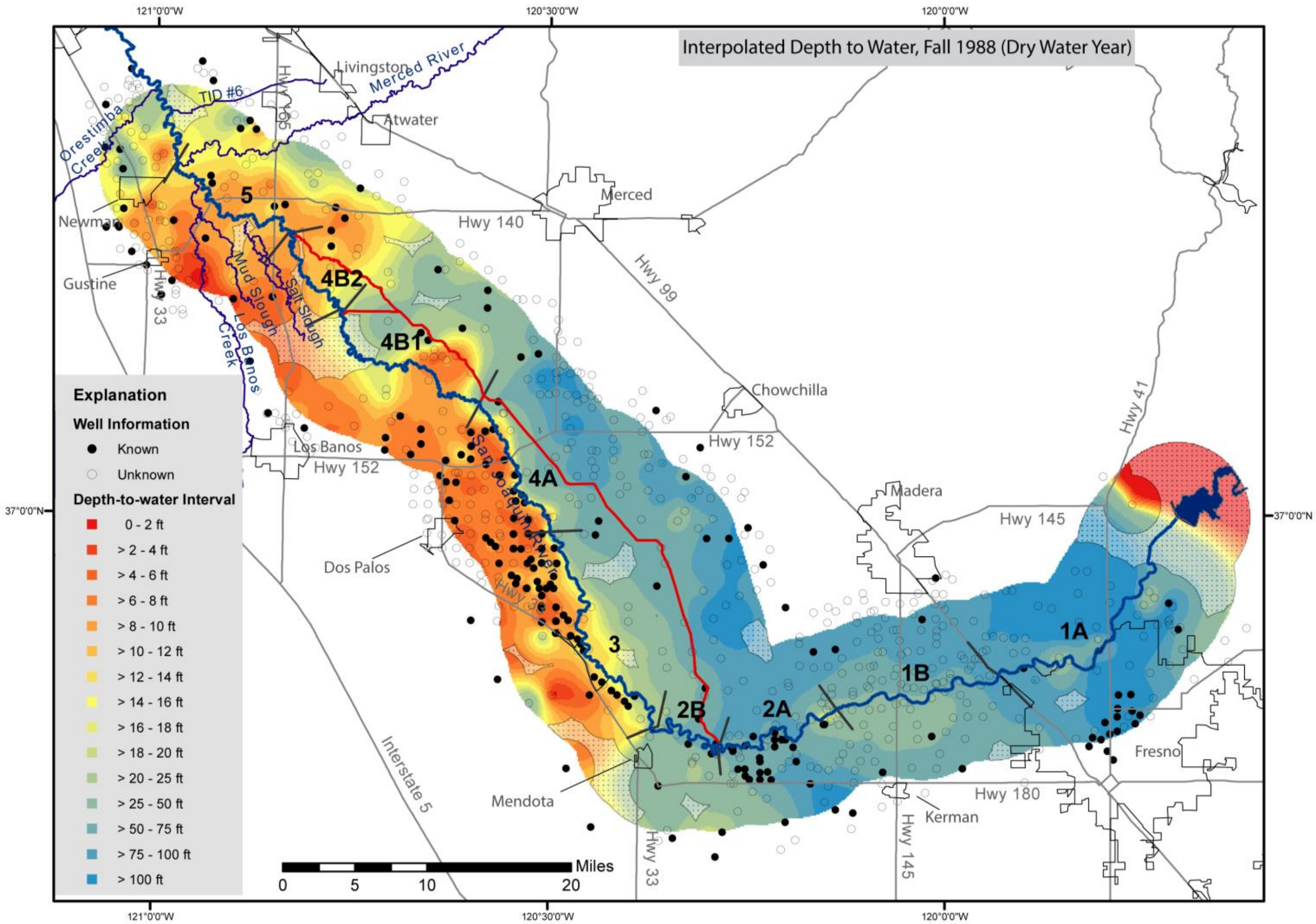


1

2 **Figure B-4. Interpolated Depth to Water Table Map for Fall 1983 (Wet Water Year)**

3 *Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.*

4



1

2 **Figure B-5. Interpolated Depth to Water Table Map for Fall 1988 (Dry Water Year)**

3 *Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.*

4

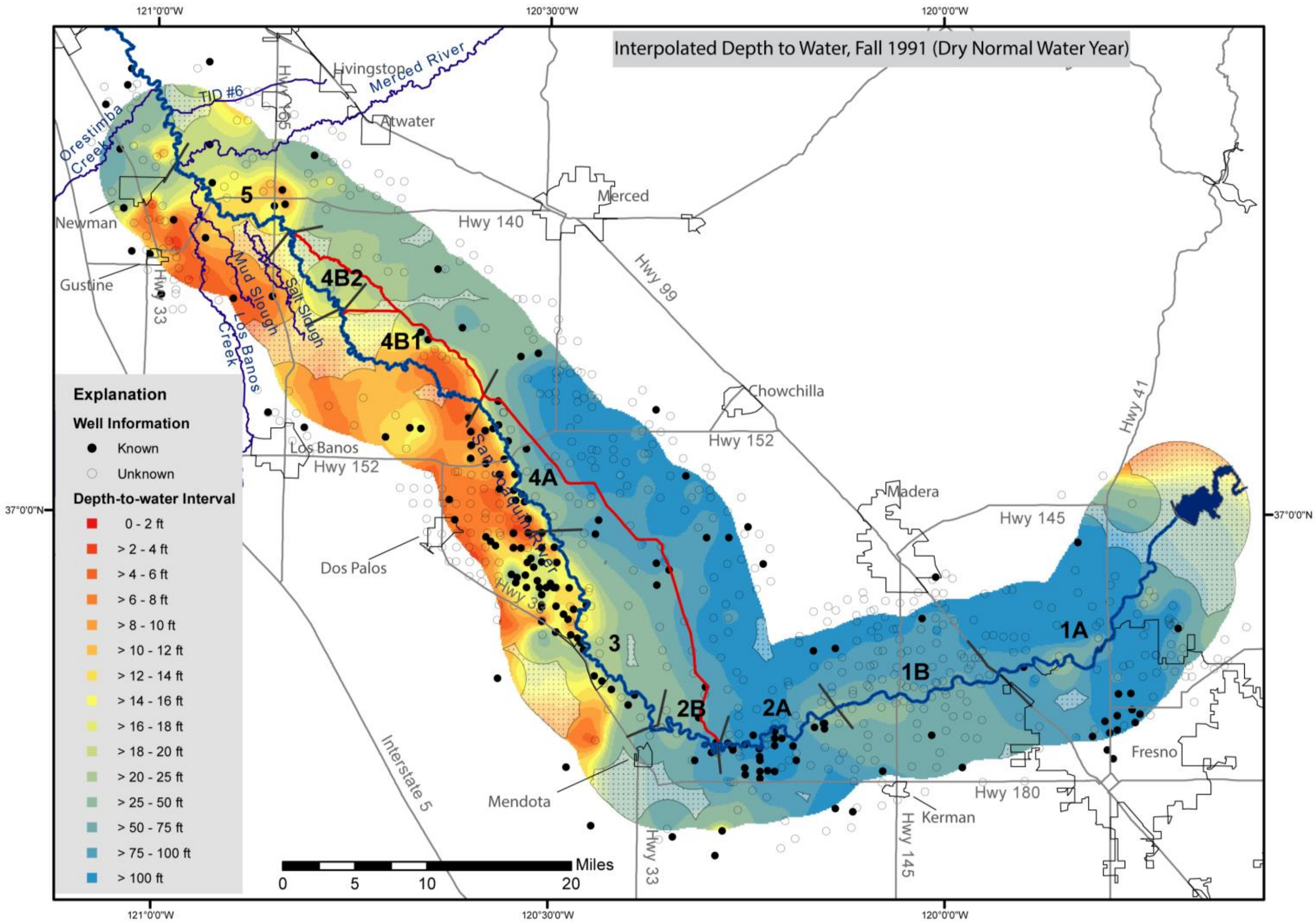


Figure B-6. Interpolated Depth to Water Table Map for Fall 1996 (Normal-Dry Water Year)

Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.

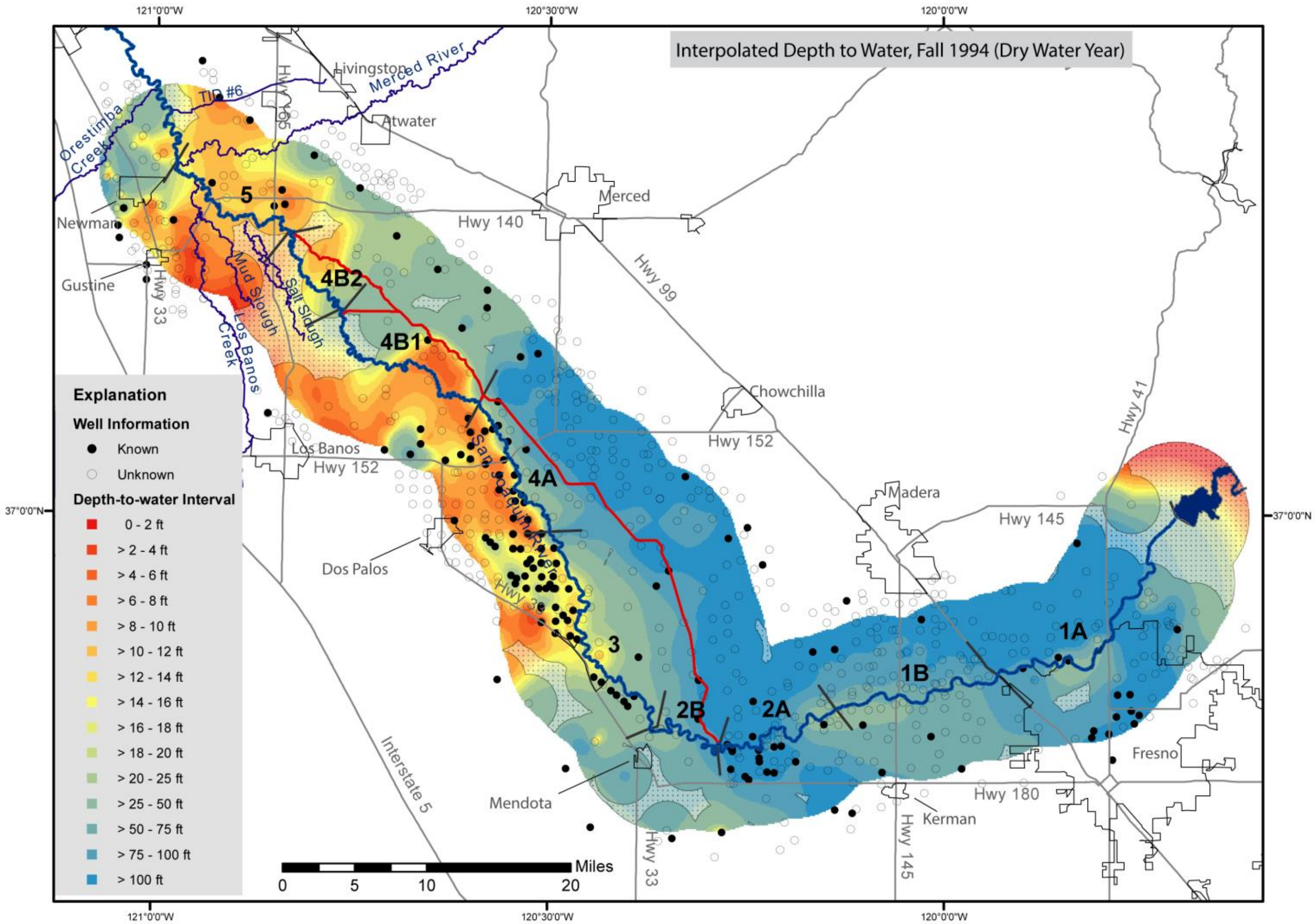


Figure B-7. Interpolated Depth to Water Table Map for Fall 1994 (Dry Water Year)

Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.

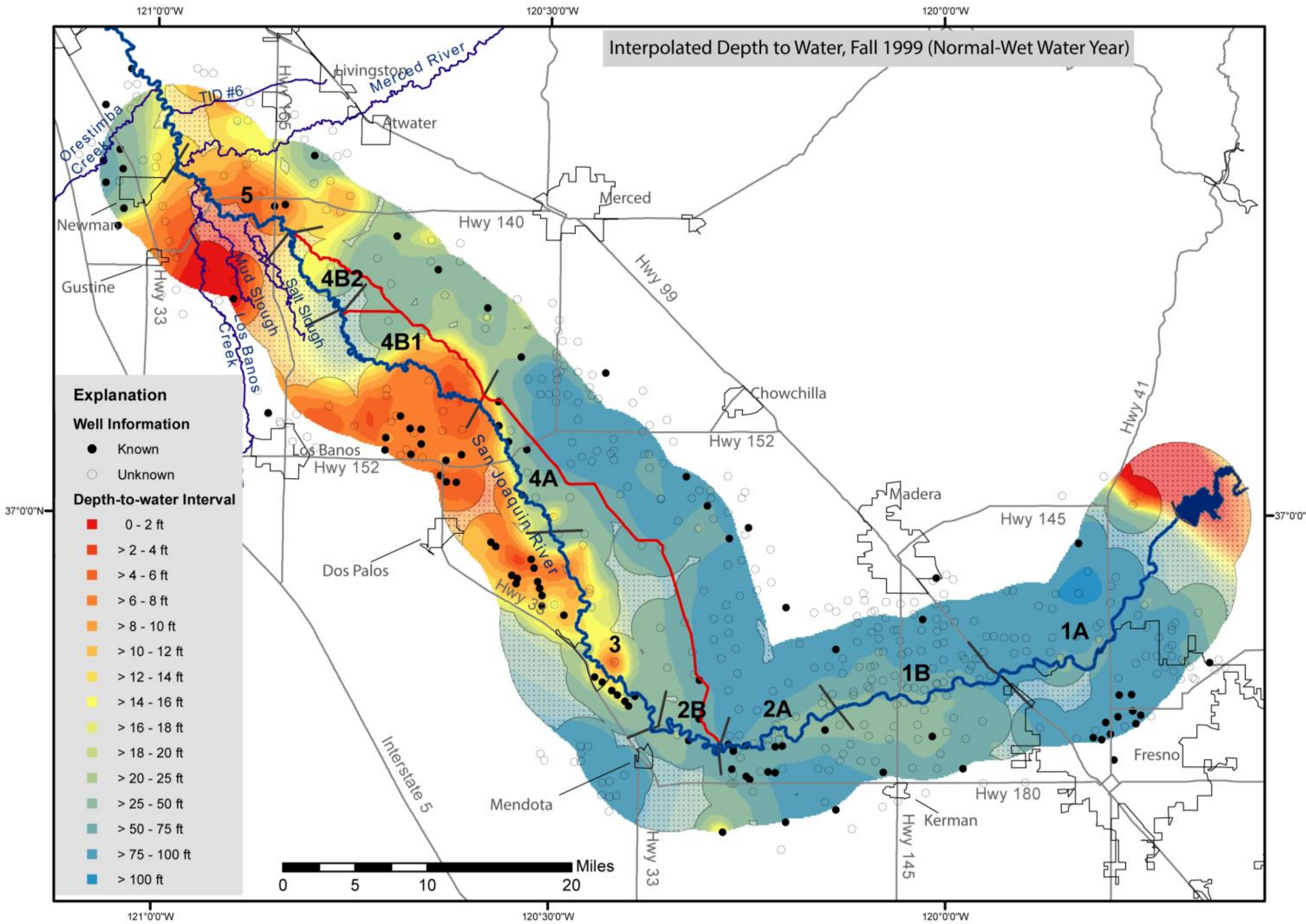
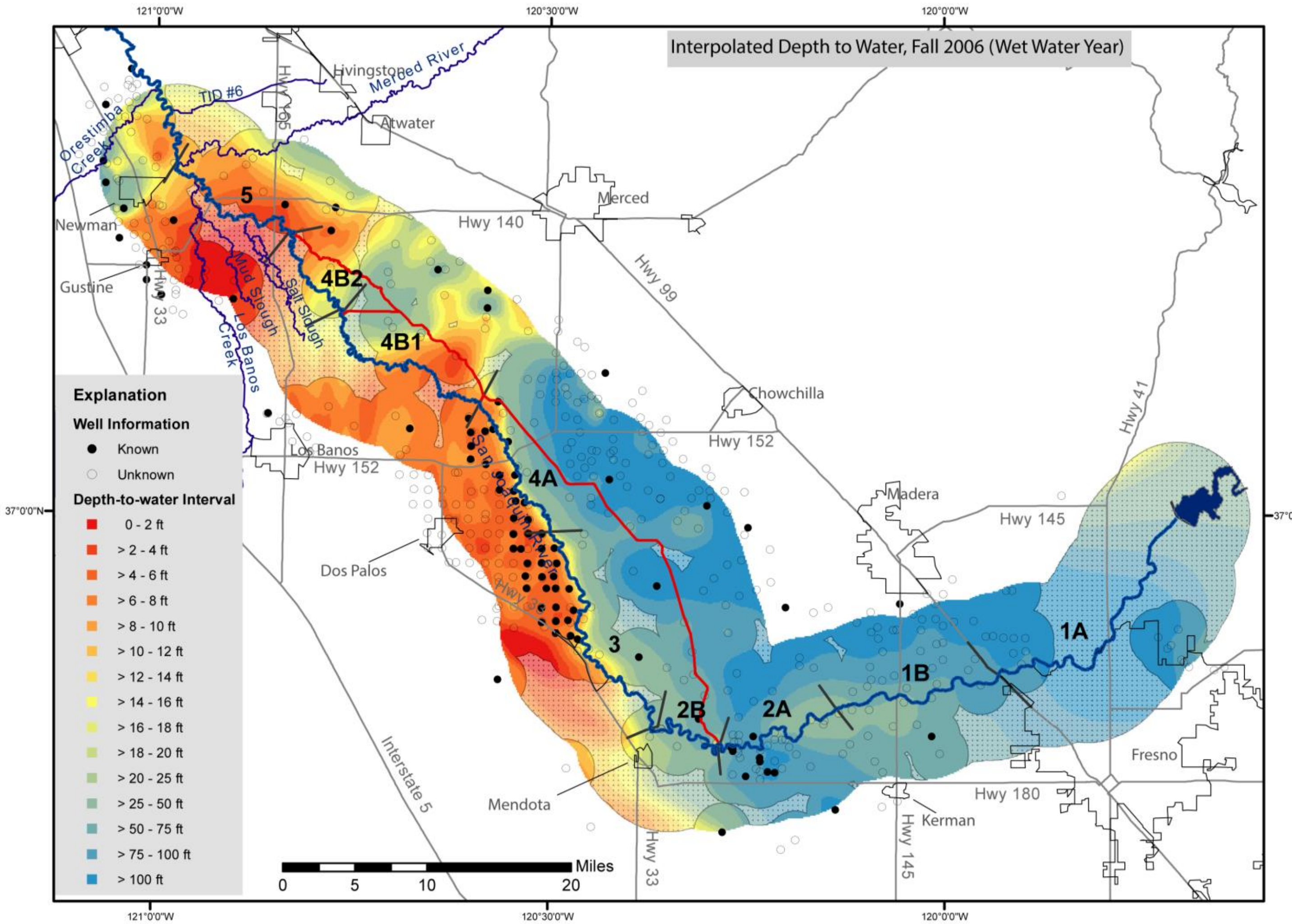


Figure B-8. Interpolated Depth to Water Table Map for Fall 1999 (Normal-Wet Water Year)

Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.



1

2 **Figure B-9. Interpolated Depth to Water Table Map for Fall 2006 (Wet Water Year)**

3 *Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.*

4

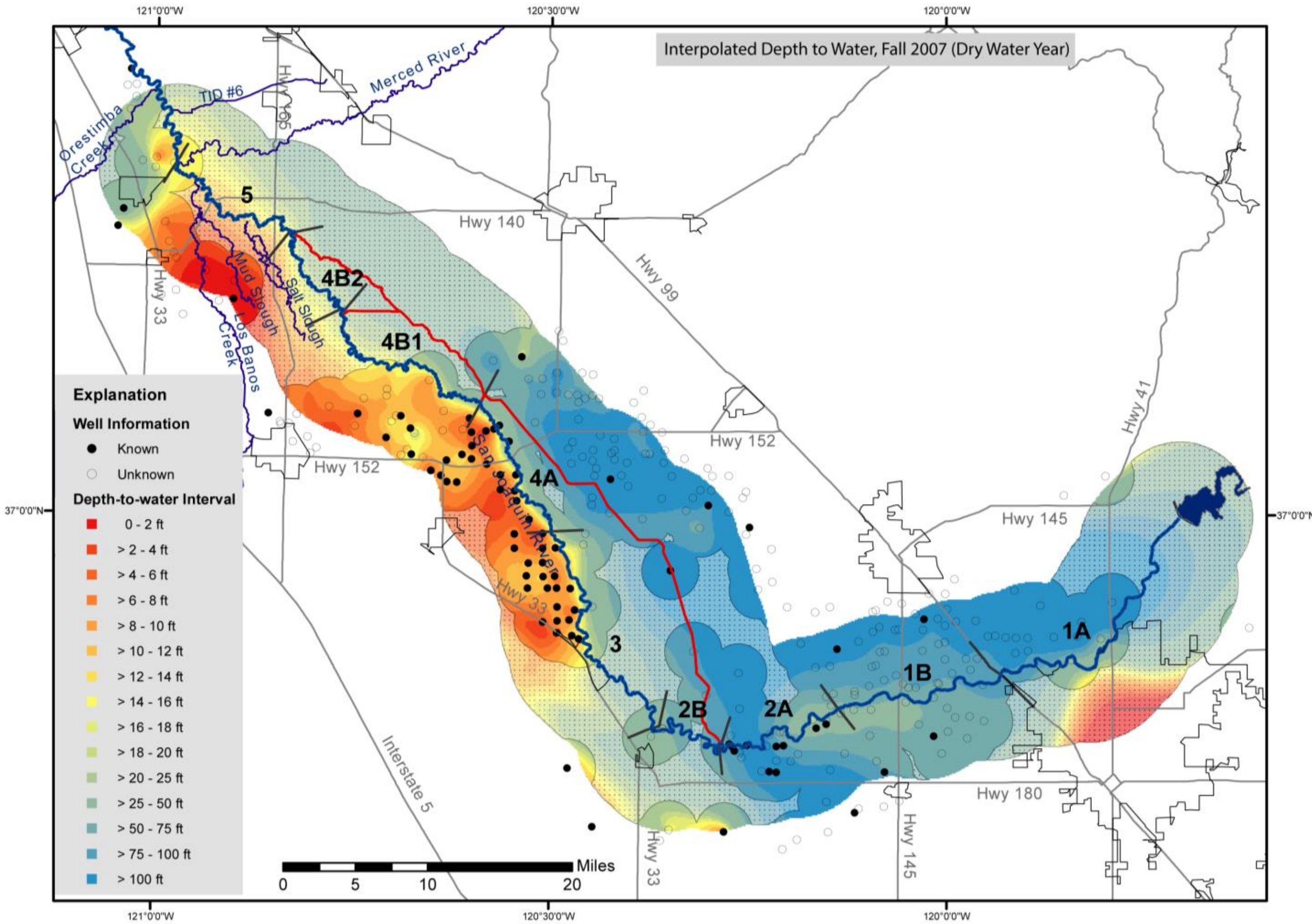


Figure B-10. Interpolated Depth to Water Table Map for Fall 2007 (Dry Water Year)

Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.

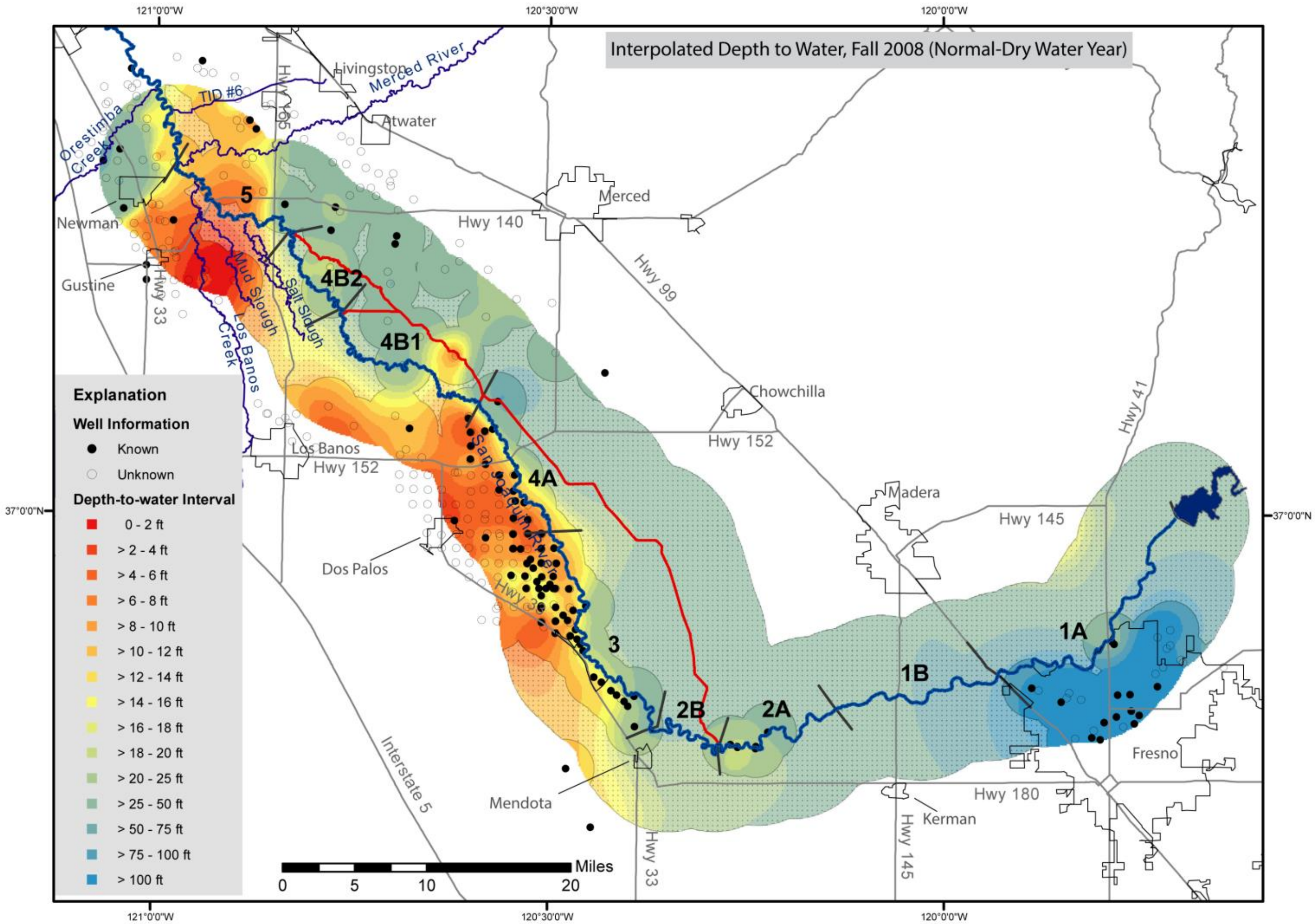


Figure B-11. Interpolated Depth to Water Table Map for Fall 2008 (Normal-Dry Water Year)

Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.

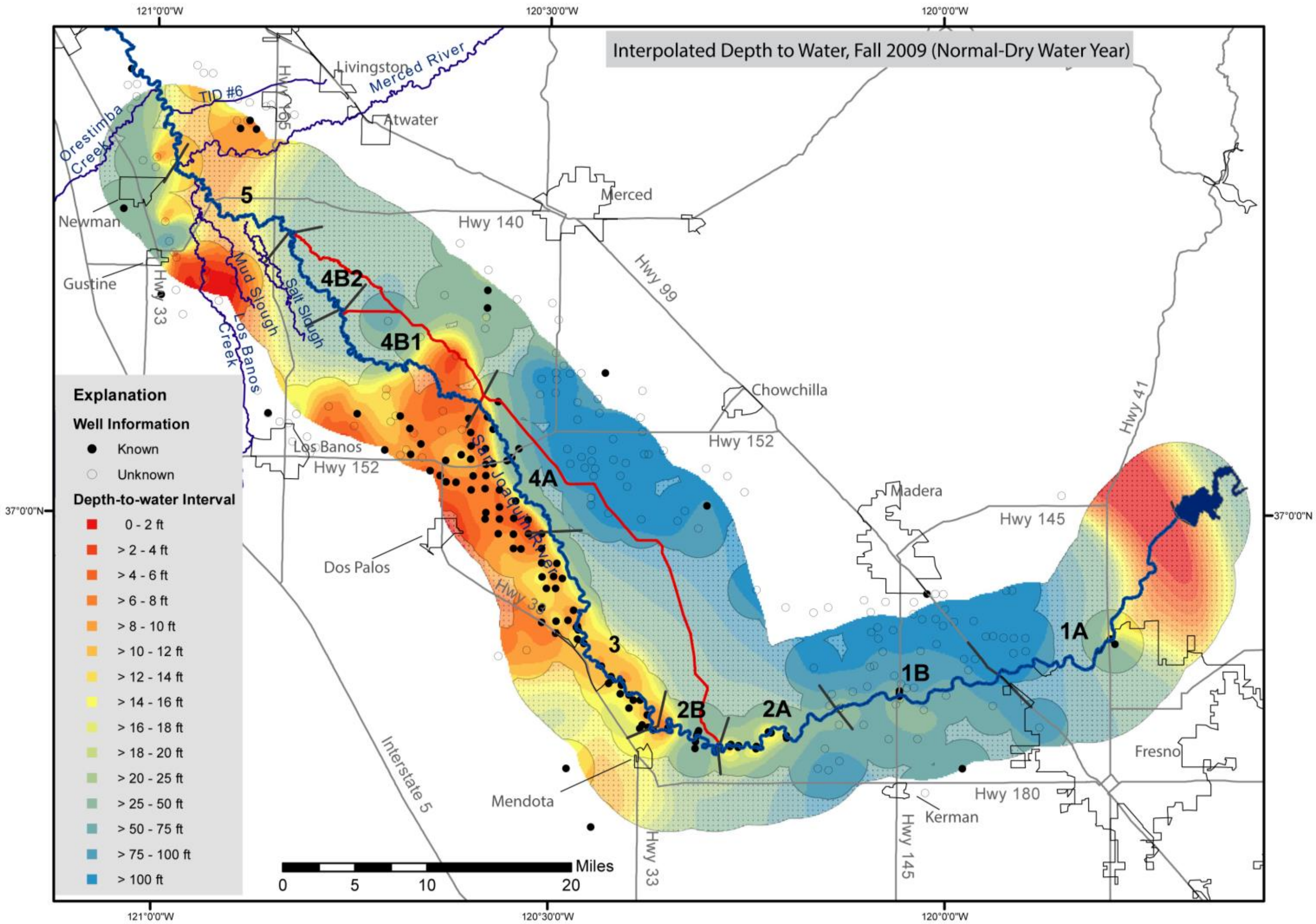


Figure B-12. Interpolated Depth to Water Table Map for Fall 2009 (Normal-Dry Water Year)

Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.

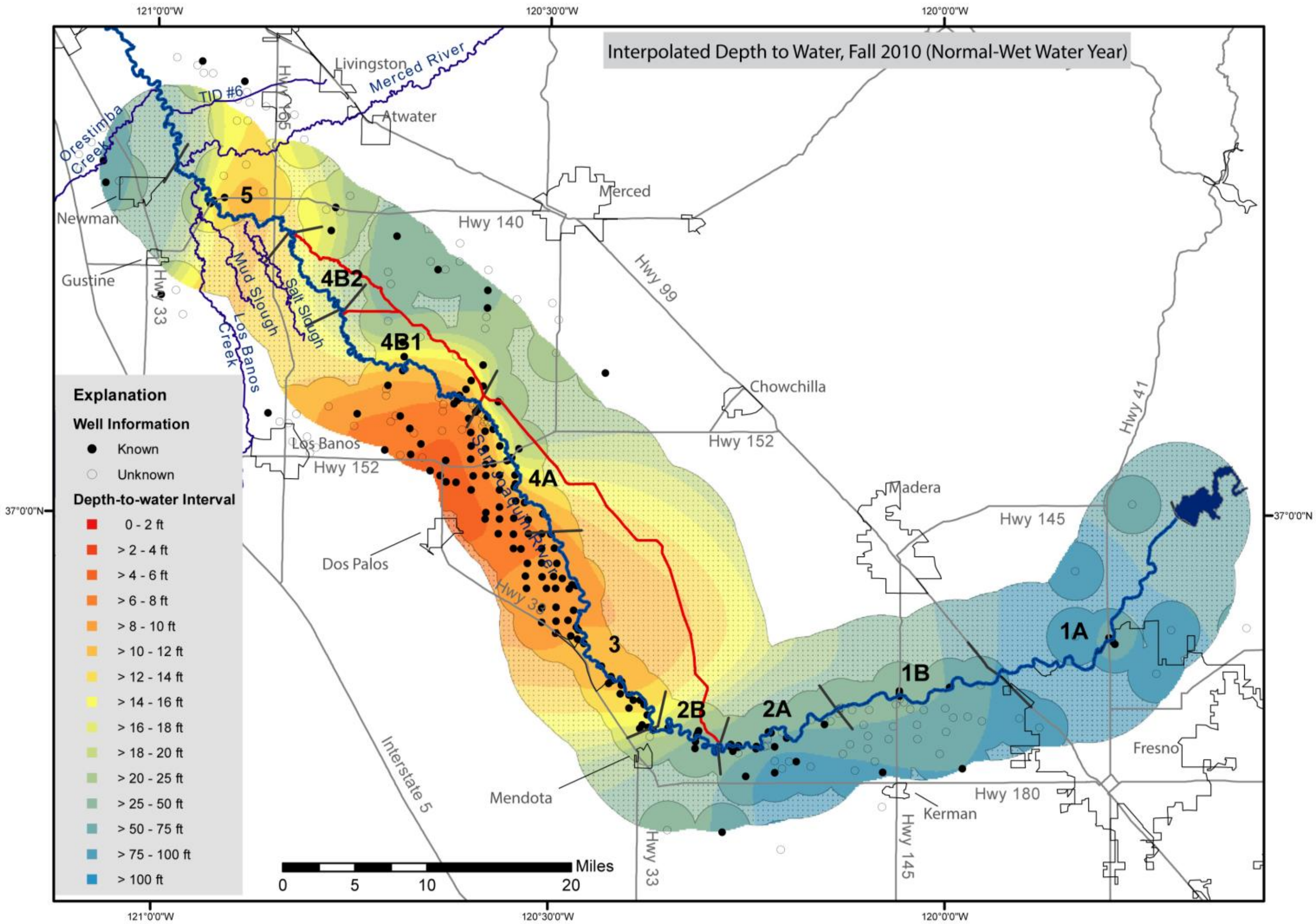


Figure B-13. Interpolated Depth to Water Table Map for Fall 2010 (Normal-Wet Water Year)

Note: Stippled areas are not within two miles of a well; interpolated values in these areas should be considered relatively poorly constrained.

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B.3 Maps of Historical Groundwater Table Elevation

Maps of historical groundwater table elevation are being developed using the same database used to create the maps of depth to the water table and will be included in future versions of the SMP. Greater error will be associated with these maps because elevations associated with the monitoring wells (measuring points and land surface) are subject to a combination of errors associated with methods used to derive these elevations, and land subsidence, which is ongoing and exceeds eight feet in some places in the Restoration Area.

B.4 Representative Hydrographs

Hydrographs have been generated for a variety of well types along the San Joaquin River where a long-term record of measurements is available. Representative hydrographs for shallow wells with relatively long-term records along Reach 2B are shown in Figure B-14.

B.5 Surface Water Flow

Locations of all gaging stations for which data are available are shown in Figure B-15. This section presents historical records of end-of-month storage at Millerton Lake (Figure B-16), average annual flow and selected hydrographs from various streamflow gaging stations along the San Joaquin River (Figures B-17 through B-21), and gaging station information by reach of the San Joaquin River (Tables B-2 through B-8). Data for all of these gaging stations are compiled in a database for use in various SJRRP analyses and model calibration.

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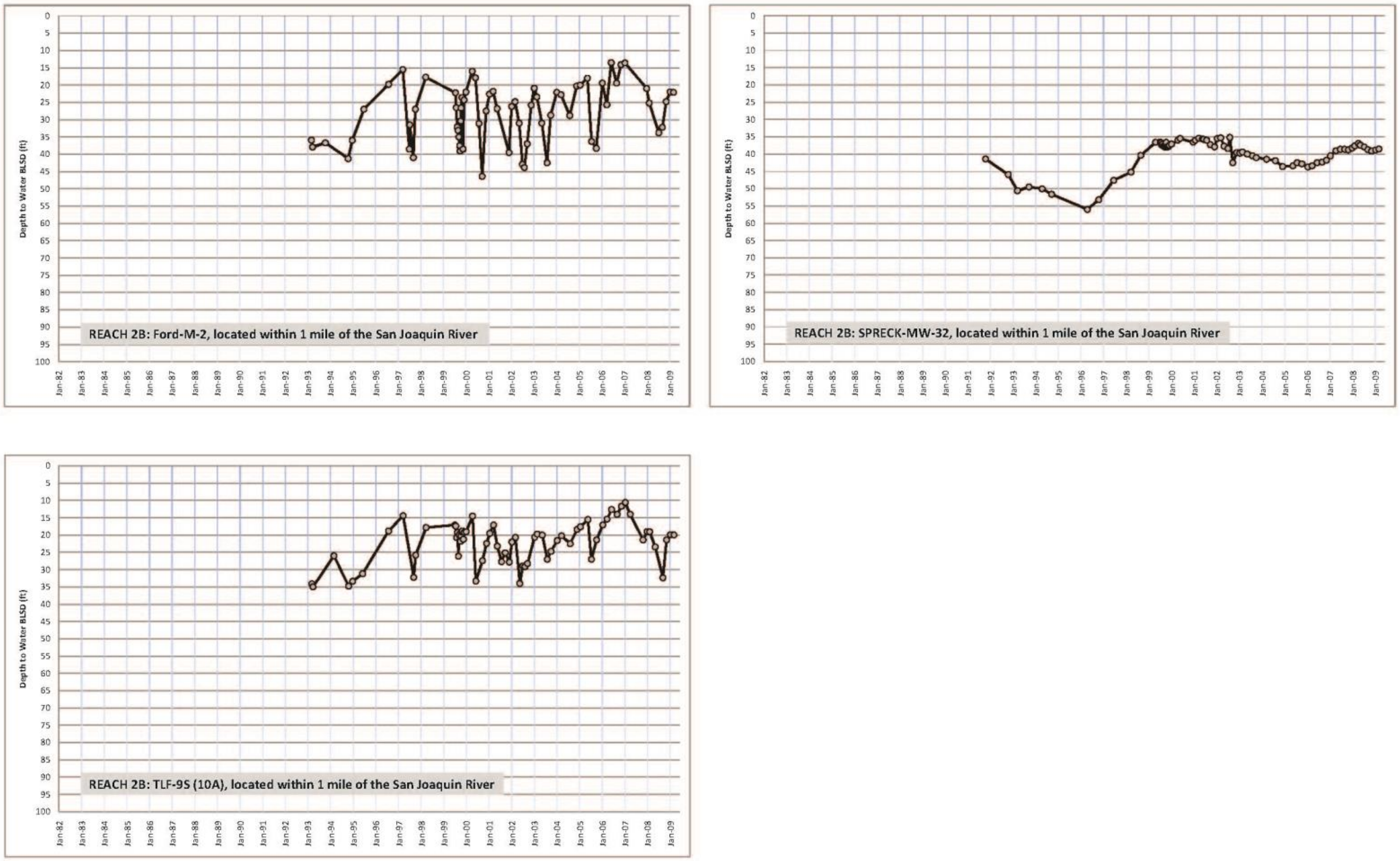

Note: BLSD = Below land surface datum

Figure B-14. Hydrographs for Shallow Wells along Reach 2B

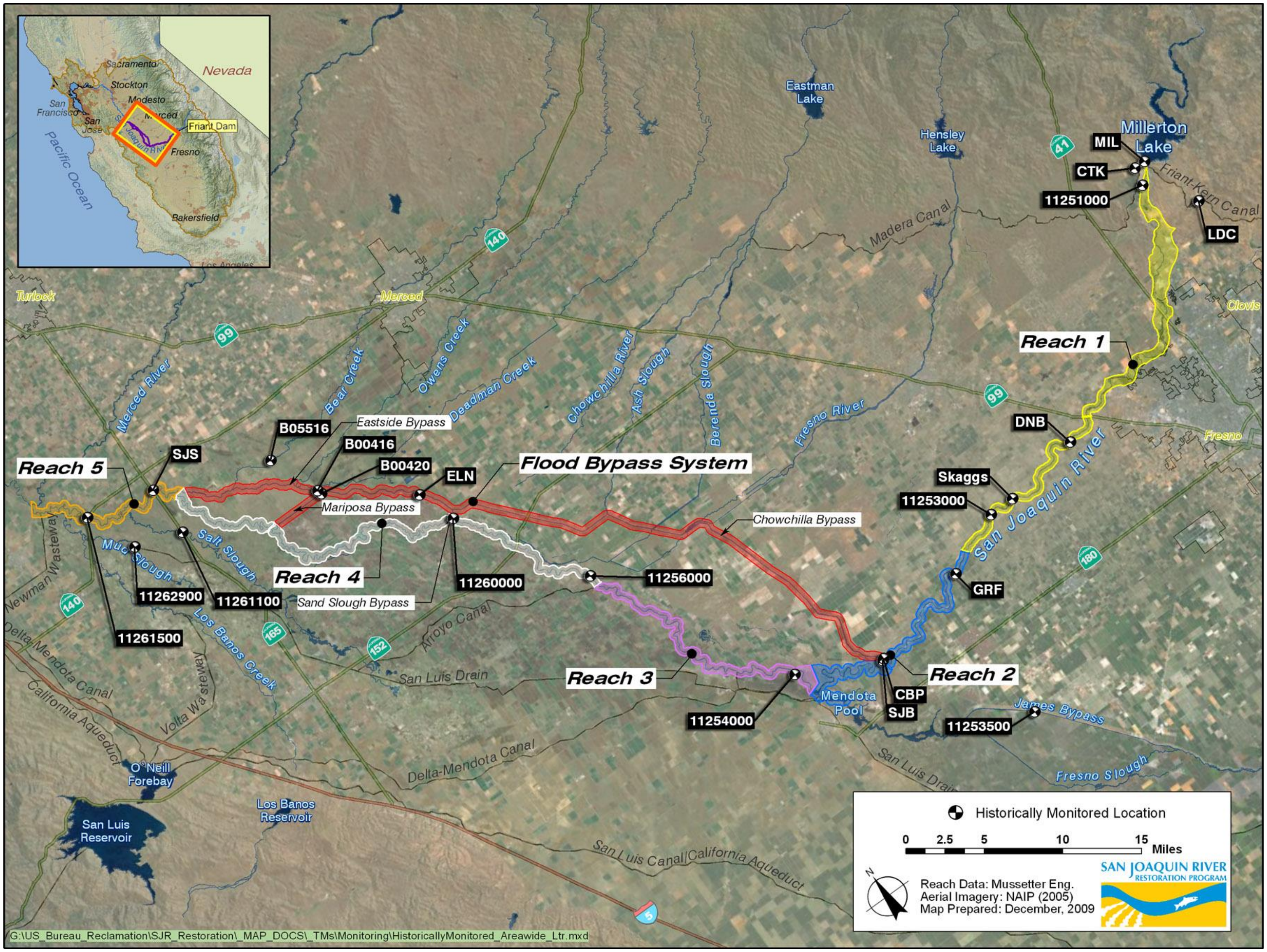

Figure B-15. Locations of Historically Monitored Streamflow Gages with Available Data

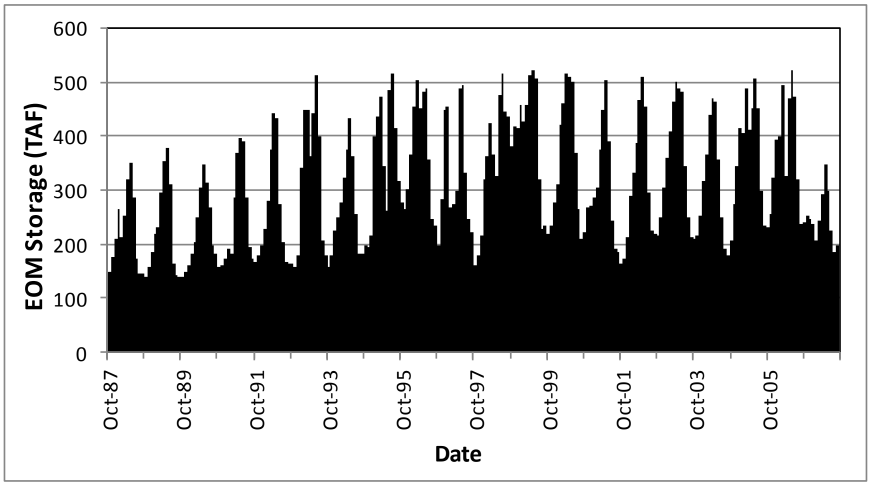

Figure B-16. End-of-Month Storage at Millerton Lake, Water Years 1988–2007

Table B-2. Streamflow Gages in Reach 1A

Station Name	USGS Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record[1]	Average Streamflow (cfs)	Maximum Daily Average Streamflow (date measured)
San Joaquin River release from Friant Dam	MIL	267.6	1,675	1974 – 2007	707	25,556 cfs (January 4, 1997)
San Joaquin River below Friant Dam	11251000	266.0	1,676	1950 – 2007[2]	703	36,800 cfs (January 3, 1997)
Cottonwood Creek near Friant Dam	CTK	NA	35.6	1974 – 2007	7	783 cfs (January 27, 1983)
Little Dry Creek near Friant Dam	LDC	NA	57.9	1974 – 2007	22	2,457 cfs (March 11, 1995)

Source: CDEC 2008; USGS 2008
Notes:
1 Calendar years.
2 Period of record coincides with start of diversions from Friant Dam (1950).
Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

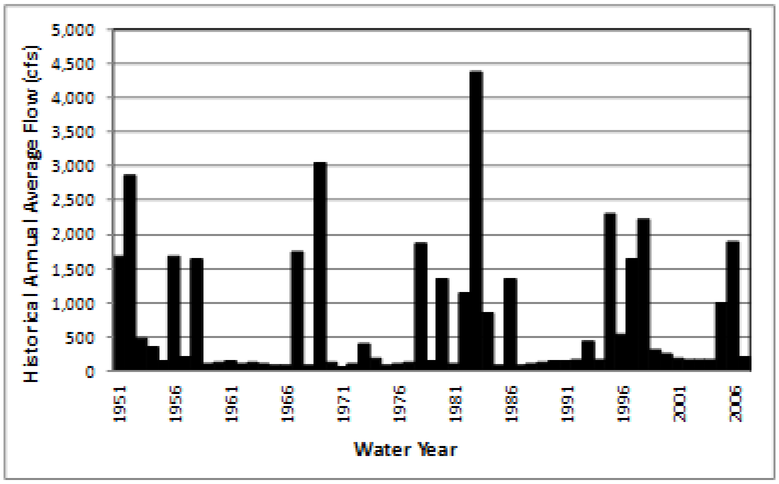

Figure B-17. Historical Annual Average Flow for below Friant Dam

Table B-3. Streamflow Gages in Reach 1B

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record[1]	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River at Donny Bridge	DNB	240.7	NA	1988 – 2007	122	7,900 (December 30, 1996) [2]
San Joaquin River at Skaggs Bridge	NA[3]	232.1	NA	1974 – 2007	215	7,900 (December 30, 1996)[2]
San Joaquin River near Biola	11253000	NA	1,811	1952 – 1961	514	7,860 (April 7, 1958)

Source: CDEC 2008, USGS 2008, Reclamation 2007

Notes:

[1] Calendar year.

[2] This maximum daily average streamflow was exceeded in the January 1997 flooding event.

[3] Data obtained from U.S. Department of the Interior, Bureau of Reclamation (2007)

Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

Table B-4. Streamflow Gage in Reach 2A

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River at Gravelly Ford	GRF	236.9	NA	1974 – 2007	652	37,843 (January 4, 1997)

Source: CDEC 2008
Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

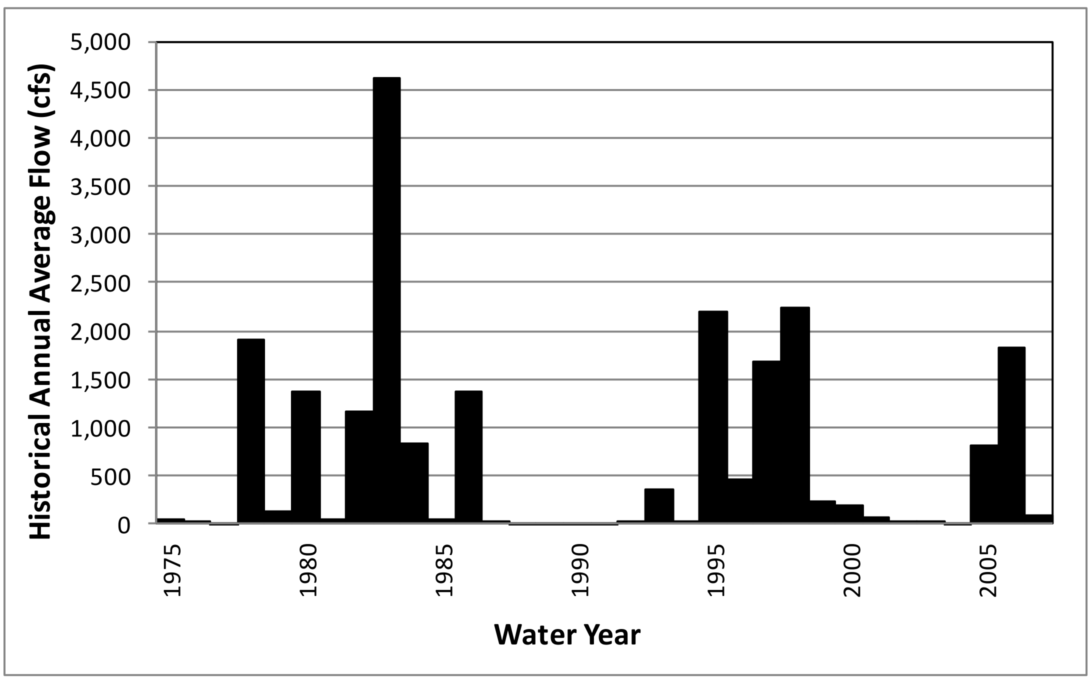

Figure B-18. Historical Annual Average Flow for San Joaquin River at Gravelly Ford

1 **Table B-5. Streamflow Gage in Reach 2B**

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River below Chowchilla Bypass Bifurcation Structure	SJB	217.8	NA	1974 – 1986, 1988 – 1997, 2005 – 2007	159	2,660 (May 23, 1978)

Source: CDEC 2008
Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

2 **Table B-6. Streamflow Gage in Reach 3**

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River near Mendota	11254000	217.8	3,940	1950 – 1954, 1974 – 2007[1]	545	8,770 (May 29, 1952)

Source: USGS 2008
Note:
[1] Period of record coincides with start of diversions from Friant Dam (1950).
Key:
CDEC = California Data Exchange Center
cfs = cubic feet per second
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

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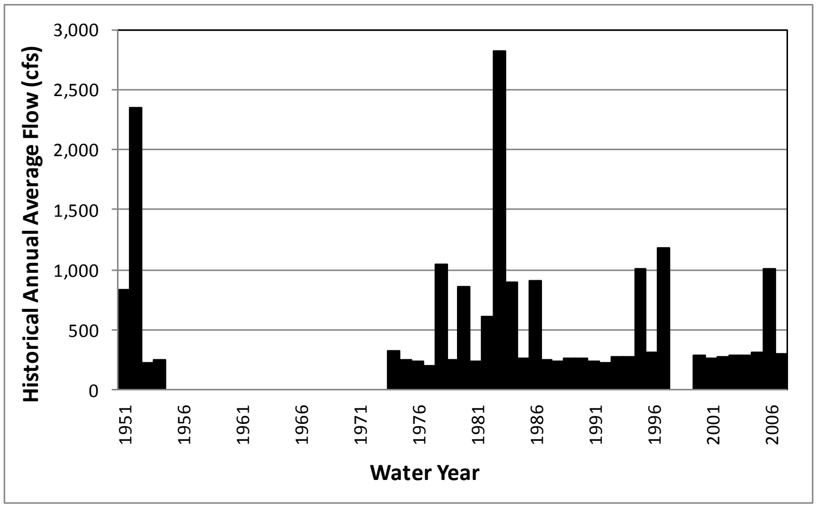

Figure B-19. Historical Annual Average Flow for San Joaquin River near Mendota

Table B-7. Streamflow Gages in Reach 4A

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River near Dos Palos	11256000	NA	4,669	1950 – 1954, 1974 – 1987, 1995[1]	478	8,170 (June 5, 1952)
San Joaquin River near El Nido	11260000	NA	6,443	1939 – 1949[2]	705	3,700 (June 22, 1942)

Source: USGS 2008

Notes:

[1] Period of record coincides with start of diversions from Friant Dam (1950).

[2] Period of record is during Friant Dam construction and filling.

Key:

CDEC = California Data Exchange Center

cfs = cubic feet per second

ID = identification

NA = not applicable/not available

No. = number

USGS = U.S. Geological Survey

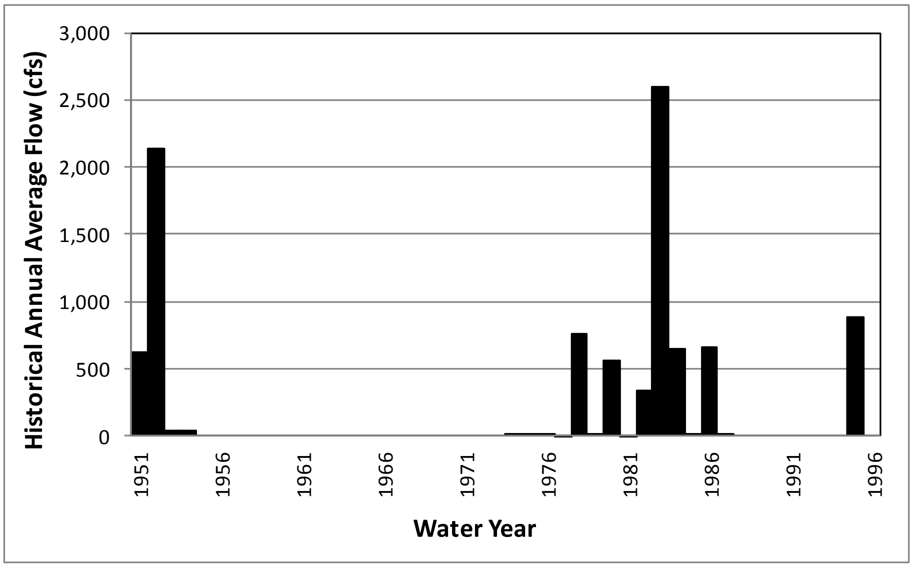

Figure B-20. Historical Annual Average Flow for San Joaquin River near Dos Palos

Table B-8. Streamflow Gages in Reach 5

Gage Name	USGS Gage Station No. or CDEC ID	River Mile	Drainage Area (square miles)	Period of Record	Average Streamflow (cfs)	Maximum Daily Average Streamflow (cfs) (date measured)
San Joaquin River near Stevinson	SJS	118.2	NA	1981 – 2007	1,042	23,900 (January 28, 1997)
Salt Slough at HW 165 near Stevinson	11261100	NA	NA	1985 – 2007	206	810 (February 20, 1986)
San Joaquin River at Fremont Ford Bridge	11261500	118.2	7,615	1950 – 1971, 1985 – 1989, 2001 – 2007[1]	640	22,500 (April 8, 2006)
Mud Slough near Gustine	11262900	NA	NA	1985 – 2007	101	1,060 (February 9, 1998)

Source: CDEC 2008; USGS 2008

Note:

[1] Period of record coincides with start of diversions from Friant Dam (1950).

Key:

CDEC = California Data Exchange Center
cfs = cubic feet per second
HW = highway
ID = identification
NA = not applicable/not available
No. = number
USGS = U.S. Geological Survey

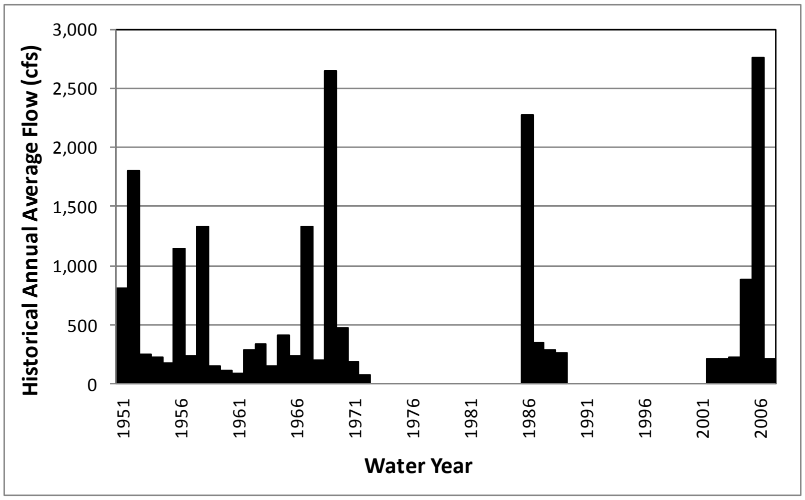

Figure B-21. Historical Annual Average Flow at Fremont Ford Bridge