Expert Statement of Deborah L. Hathaway

NRDC v. Rodgers, et al.

S.S. PAPADOPULOS & ASSOCIATES, INC.
Boulder, Colorado

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1877 Broadway, Suite 703, Boulder, Colorado 80302-5245 · (303) 939-8880

Table of Contents

List of Figures

List of Tables

List of Appendices

Section 1
Introduction

I was retained on behalf of the Friant Water User's Association to provide an expert statement on the nature of losses from and gains to the San Joaquin River, and, on the nature of shallow groundwater conditions and stream-groundwater interactions along certain reaches as may be relevant to the delivery or maintenance of surface water flows to support re-establishment of an anadromous fishery on the San Joaquin River between Friant Dam and the Merced River.

Section 2
Qualifications

I am a principal and Vice President of S.S. Papadopulos & Associates, Inc. (SSPA), a firm which provides consulting services related to environmental and water-resource issues. My area of expertise is hydrology, with emphasis on groundwater hydrology, water resources, conjunctive use, stream-aquifer interactions and environmental hydrology.

I hold a Bachelor of Arts from St. John's College conferred in 1974, a Master of Arts in Secondary Education (Science) from the University of New Mexico conferred in 1977, and a Master of Science in Civil Engineering from Colorado State University conferred in 1982. I am registered as a Professional Engineer in the states of Colorado, New Mexico, New York and Maryland and am certified as a Professional Hydrologist (Groundwater) with the American Institute of Hydrology. I have 25 years experience with hydrologic investigations, involving water supply development, groundwater analyses and modeling, environmental hydrology, water quality assessment and analysis of aquifer-stream interactions.

I have worked with legal counsel, regulatory agencies, municipal and industry representatives and other water resource consultants to evaluate basin hydrogeology, aquifer-stream interactions, assess water supply alternatives, assess water conservation and delivery options and to evaluate conjunctive use of surface and groundwater. I have provided expert testimony in surface water and groundwater issues and have led numerous stakeholder presentations on water resource and water supply matters. A copy of my curriculum vitae and a list of my publications appears in the attachment to this report.

In preparation of this report, I have relied on data and reports prepared or published by various entities, as identified in Section 5. These materials have been used for hydrologic analyses relevant to my assignment. I have relied upon my education, training, and 25 years experience in the field of hydrology in reviewing available information, conducting analyses and formulating the opinions expressed in this report.

Section 3
Summary List of Opinions

Based on my review and my analysis of available data and information, and analyses based on these data, I have reached the following opinions related to seepage and shallow groundwater conditions along the San Joaquin River. The opinions I provide in this report are given to a reasonable degree of scientific certainty and are based on my knowledge, skill, experience, research, training, education, and information and data pertaining to this case available to me at this time. If additional information becomes available, I may supplement my opinions to reflect such additional information.

1. In Reach 1 of the San Joaquin River, extending from Friant Dam to Gravelly Ford, net river losses during the 2005 flood release period occurred in the approximate amounts as shown in Table 1. Net river losses include both channel seepage losses and other losses. In Reach 1, other losses include diversions by riparian users and by the Gravelly Ford canal. Under minimum release conditions absent flood releases, water is released to satisfy riparian uses upstream of Gravelly Ford and little flow passes beyond Gravelly Ford.

2. In Reach 1 of the San Joaquin River, extending from Friant Dam to Gravelly Ford, river losses, under a restoration hydrograph representing a mid-range case between the Hanson Normal-Dry and Normal-Wet flows (Hanson Expert Report), are expected to occur in the approximate calculated amounts as shown in Table 2. Additional losses may occur due to declining seasonal water levels or to riparian vegetation recruitment under restoration conditions. Projected channel losses under the mid-range normal and other alternate restoration scenarios are described in Appendix E.

3. In Reach 2 of the San Joaquin River, extending from Gravelly Ford to the Mendota Pool, the river is typically dry under minimum release periods (approximately 100 - 200 cfs release at Friant Dam) and under these no-flow conditions, no loss occurs.

4. In Reach 2a of the San Joaquin River, extending from Gravelly Ford to the Bifurcation Structure, net river losses during the 2005 flood release period were estimated as shown in Table 1 using available gage records. In Reach 2, the net losses include channel seepage and seepage through levees onto farmland that occurred during late May and early June of 2005.

5. In Reach 2 of the San Joaquin River, extending from Gravelly Ford to the Mendota Pool, river losses, under a restoration hydrograph representing a mid-range case between the Hanson Normal-Dry and Normal-Wet flows (Hanson Expert Report), are expected to occur in the approximate calculated amounts as shown in Table 2. A range of calculated losses is provided based on alternate

antecedent river conditions, with higher seepage losses expected to occur in the first year of project implementation and in subsequent years that follow drier years (years lacking the consistency of flow as identified for the wet or normal restoration hydrograph). The lower end of the seepage loss range will occur under more optimal conditions, when a normal or wet hydrograph has been successfully achieved over a sequence of years. However, absent significant levee improvements, additional seepage beyond what is shown in Table 2 will occur in Reach 2 due to lateral seepage through levees onto adjacent lands during periods of higher flows. My calculations suggest that lateral seepage through levees may have been as high as 450 cfs during late May, 2005. Additional losses may occur due to declining seasonal water levels or to riparian vegetation recruitment under restoration conditions. Projected channel losses under the mid-range normal and other alternate restoration scenarios are described in Appendix E.

6. In both reaches 1 and 2 of the San Joaquin River, seepage losses are not expected to be constant over the course of a spring hydrograph. Typically, losses will increase and continue at higher than average values through the rising limb of the hydrograph. However, following a period of sustained flows, loss rates will level out and depending on conditions, may decrease. Following the peak of the hydrograph, the river will experience local, short-term gains as water in bank storage returns to the channel. Depending on the relative quantities of such gains and other diversions, the gains will not always be apparent.

7. The application of average loss rates obtained from historic gage data to estimate downstream flows associated with a given upstream flow is error prone in two situations, as noted below.

    - *If the duration of a flow pulse of interest is brief in comparison to the period over which average loss rates were computed*: In particular, if a brief pulse of high flow is planned for the purpose of creating short-term higher flow downstream conditions, the desired flows may not materialize due to the occurrence of significantly higher-than-average losses in the first days or weeks of the pulse. The occurrence of high seepage losses in the early part of a spring pulse is evident from empirical data, for example, as shown for spring 2005 on Figure 2 and Figure 3a, and as seen for previous years such as is illustrated in Appendix B.

    - *If the environmental conditions that existed at the time average loss rates were computed should change:* If regional groundwater levels, antecedent river flow conditions, channel configuration or vegetation coverage are modified from those occurring during the historical observation period, associated channel losses, which reflect a specific environmental regime, may similarly be altered.

Kondolf (Kondolf Expert Report) proposes alternate restoration hydrographs for six year types selected within a range of probable future conditions with respect to water supply. Three of the proposed hydrographs, including those for the year types critical-high, dry and normal-dry, include spring peaks of relatively short duration and are subject to the error noted in the first bullet above. Both the critical-high and the dry hydrographs proposed by Kondolf include a 31-day pulse, consisting of 15 days at 500 cfs and 16 days at 1,500 cfs, for an average of 1,000 cfs during this one-month pulse. Figure 3a illustrates the disposition of flow of very similar magnitude during the first 30 days of the 2005 spring flow. In the case of the spring 2005 pulse, no flow reached the bifurcation structure during an initial period of 750 cfs for six days. During the next 10-day period, with average Friant releases at 1,000 cfs, the average flow at the bifurcation structure was just under 500 cfs; over half of the release was lost in Reach 1 and Reach 2a through this period. During the following 15-day period, consisting of 9 days with a Friant release of approximately 1,500 cfs and approximately 6 days with a Friant release of approximately 2,000 cfs, the resulting flow midway through Reach 2 at the Bifurcation Structure averaged just over 1,000 cfs. These data suggest that the two spring hydrographs proposed by Kondolf for the critical-high and dry periods will experience losses much higher than proposed by Kondolf and that targeted downstream flows will not be achieved during these short-term peaks. Similarly, the Kondolf proposed spring pulse flow for the normal-dry year type consists of a relatively narrow peak; empirical data also suggest that losses during such a pulse will be significantly larger than anticipated by Kondolf. Additional calculations regarding projected restoration conditions that I have made, described in Appendix E and summarized in Figures 3b and 3c, also illustrate the difficulty in achieving targeted downstream flows given the magnitude of projected losses associated with flows in similar range to those used by Kondolf in the normal-dry and dry alternate scenarios for these spring pulse flows of brief duration.

8. Kondolf proposes a 6 to 10-day Friant release of 400 to 700 cfs as a fall run attraction flow in hydrographs for five of his six year types. Given the high losses experienced in Reach 1 and Reach 2 for short duration flow pulses, it is considered unlikely that much, if any, of this flow will result in flow below Reach 2.

9. In Reach 3, from Mendota Pool to Sack Dam, the San Joaquin River traverses a region characterized by relatively high water levels on the south/west side of the river that transition to lower water levels on the east side of the river, reflecting a large cone of depression in the region north of Mendota Pool towards Chowchilla. Particularly in years of lower regional groundwater condition, channel seepage losses will occur in this reach, perhaps in amounts as high as observed in Reach 2. However, in years with higher regional groundwater condition, seepage at lower rates would be expected.

10. In Reach 4A of the San Joaquin River, from Sack Dam to Sand Slough Control Structure, losses will occur where river stage exceeds groundwater elevations.

11. In Reach 4B of the San Joaquin River, from the Sand Slough Control Structure to below the confluence of the San Joaquin River and Bear Creek, groundwater elevations are generally close to the land surface; this reach can function as a gaining or losing reach depending on groundwater levels in relation to river stage.

12. If levees are built to support the restoration hydrographs with high flows in Reach 4B (i.e., in 3,500 to 4,000 cfs range), as proposed by both Hanson and Kondolf, and if these projected flows occur, groundwater levels in adjacent areas are projected to rise and cause waterlogging and seepage onto lands. Mitigation of these effects would require the deepening of the river channel or construction of drains. The feasibility of establishing sufficient grade in the drains, given the regional topography would require evaluation.

13. Reach 4B may experience gains under two circumstances:

    - The reach may experience short term losses under high flow conditions, with short term gains immediately following the pulse flow. To a large extent, appreciable gains following the pulse flow would be attributable to bank storage, or, the return of “seepage loss” water that was stored in bank areas during the pulse.

    - The reach may experience gains in seasons/years with higher groundwater conditions, although these conditions are most likely to occur in winter or spring when seasonal groundwater levels tend to be higher.

14. Because of the active exchange of surface water and shallow groundwater under variable flow conditions, the temperature of channel inflows (“gains” from shallow groundwater) following spring pulses will reflect conditions of the shallow groundwater environment, rather than deep groundwater conditions observed elsewhere in the basin. Temperature of shallow groundwater will be influenced by a combination of factors, including temperature of surface water in the adjacent river channel and other surface water bodies such as ponds, canals or drains; ambient air temperature; and to a limited extent, deeper groundwater which may be interacting with the shallow groundwater. However, gains that occur in winter/early spring due to the occurrence of higher seasonal groundwater levels may reflect a more extensive area of circulation and the associated mean temperature.

15. The temperature of shallow groundwater was recorded in the range of 74 to 76 degrees F at three alluvial wells in Reach 1 in August 1999; and in the range of 65 to 76 degrees F at eight alluvial wells in Reach 2 in October 1999 (Table 3). Excluding one high outlier (at 82.6 degrees F), the median temperature for the

eleven shallow wells is 73.9 degrees F. These temperatures were recorded following the removal of 50 to 140 gallons from the 2-inch diameter wells, which represented a number of well volumes ranging from 19 to 44 times the well volume. The sequence of temperatures, conductivity and pH values recorded during well development reflects stabilization (Appendix G); thus, the final recorded values are considered characteristic of formation water in the shallow groundwater environment near the river.

16. In Reach 5 of the San Joaquin River, from Bear Creek to the Merced River, groundwater levels are very close to the land surface and no significant seepage losses are projected.

17. The Chowchilla Bypass traverses an area with depressed groundwater elevations between the Bifurcation Structure and beyond Highway 152 towards the Sand Slough Control Structure. Throughout this area, the depth to groundwater typically exceeds 50 feet and ranges up to a 100-foot depth in some areas. Seepage losses are expected to occur as water infiltrates through this unlined canal into the underlying alluvial material. The rate of canal seepage could potentially be as high as that projected for the San Joaquin River Reach 2a. Given the depth to groundwater in this area, the projected seepage rates for a dry antecedent condition are most appropriate. Under these assumptions, the average annual seepage rate for the reach between the Bifurcation Structure and the Sand Slough Control Structure may be approximated as that for Reach 2a, or, 7 cfs/mile. However, during periods of large and increasing flows, seepage rates are expected to exceed this average and may reach 10 cfs/mile or higher. Beyond the Sand Slough Control Structure, groundwater elevations are higher with respect to land surface elevations. For this reason, losses below this point are expected to be minimal.

18. Successful recruitment of riparian vegetation will result in an increase in water demand. This demand will increase the magnitude of consumptive loss along the river corridor and will increase the amount of upstream flow necessary to reach downstream flow targets.

19. Historic changes in groundwater levels in the Madera Groundwater Basin or other groundwater basins in the vicinity of the San Joaquin River have been influenced by numerous factors. Factors contributing to declining water levels include pumping of groundwater from wells, evapotranspiration and discharge (i.e., gains) to surface water features. Factors contributing to rising water levels include seepage from canals and rivers and the occurrence of percolation of applied irrigation water through farm fields. During periods of low surface water supply, groundwater declines occur from a combination of: a) increased groundwater pumping to offset surface water deficits, b) reduced deep percolation as irrigators increase their farm efficiency, c) decreased canal and river seepage. Conversely, during periods of high surface water supply, groundwater recovery often occurs due to a) decreased groundwater pumping, b) higher quantities of deep percolation from applied irrigation water, c)

greater canal and river seepage. Historically, large changes in groundwater levels have occurred through periods of high/low water supply. In many areas, groundwater elevation changes in the unconfined aquifer of the surrounding region have exceeded 30 feet over a period of a few years. However, the contribution to such change from river seepage is limited.

20. Estimates provided by Steven Deverel for hydraulic conductivity for sand, and subsequently used by him to calculate seepage rates into sand beneath the river, are inconsistent with values reported in the literature and are unrealistically low.

Section 4
Bases of Opinions

Data and Documents Reviewed

The opinions stated in Section 3 are based on a number of different types of information, data and evaluations. The nature and types of information and data that were reviewed are summarized below.

- Publicly available technical reports that summarize geologic, hydrogeologic and hydrologic conditions.
- Programmatic reports related to restoration evaluation efforts.
- Data routinely collected and filed with public agencies and available by online search or agency request.
- Data developed as part of restoration evaluation programs and available in program reports or directly from collecting entity.
- Technical analyses conducted by SSPA, including review of data and calculations.
- Field observation of river conditions during the 2005 flood release and prior years.

Publicly available and programmatic reports reviewed are identified in Section 5. Primary data reviewed includes historic and contemporary groundwater elevation data, gaged flow data, lithologic, boring and development logs for wells. These data are also identified in Section 5.

Methods

1. Groundwater elevations within and near the San Joaquin River floodplain have been reviewed. The groundwater elevations form the basis for opinions regarding spatial and temporal change in groundwater elevation that occur now and/or that have occurred previously under various hydrologic regimes; and, support opinions regarding the potential for river loss/gains and surface water/groundwater interactions. Groundwater elevations have been reviewed as time trends at single wells and as contour maps for groups of wells within the region. Locations of wells for which data were reviewed and selected groundwater elevation data are summarized in Appendix C. Figure C-1 and Table C-1 include information relative to shallow alluvial wells located within the floodplain near the river. Figures C-2 through C-4 and Table C-2 include information relative to 477 wells located in the nearby region (obtained from public databases as described in Section 5) along with a spatial distribution of the wells and time trend plots (Figures C-5 through C-7) for wells with a long-term record in the area of interest. Contour maps of groundwater data, published by the DWR, are also included as an attachment in Appendix C to illustrate, in a generalized manner, spatial conditions with respect to groundwater.

2. Gaged flow records for the San Joaquin River at various locations between Friant Dam and the Merced River have been reviewed. These flows form the basis for opinions regarding an approximate magnitude for river losses under recent hydrologic conditions and support understanding of surface water/groundwater interactions. Gaged flow records during the 2005 flood release period and an approximate range of seepage losses reflected in these data are summarized on Figures 1, 2 and 3a and Table 1. Additionally, Appendix B contains plots of flow records in previous years that illustrate, in a general sense, the occurrence of relatively high seepage losses associated with brief periods of increased flows.

3. Field observations of channel conditions and the hydrologic setting of the San Joaquin River and floodplain have been made. These observations support opinions regarding seepage, groundwater conditions and surface water/groundwater interactions. Additionally, field notes provided by personnel of the FWUA have been reviewed. Field notes associated with recent monitoring events conducted by FWUA are provided in Appendix D.

4. Calculations have been made to spatially characterize aquifer conditions and surface water/groundwater conditions in selected river reaches. These calculations are based on:
   - Regional groundwater elevation data as noted above in item 1
   - Floodplain groundwater elevation data as noted above in item 1
   - Flow data as described in item 2
   - Field observations as described in item 3
   - Vegetation and geologic data as characterized in programmatic and public reports (Section 5)
   - River water surface and wetted area characterization as provided by MEI and described in Appendix F
   - Mathematical expressions for the flow of groundwater, as solved numerically with the computer program MODFLOW 2000 (Harbaugh et al, 2000), developed by the United States Geological Survey. The set-up and execution of these equations within a modeling framework is described in Appendix E; along with figures illustrating the information used and the result of the calculations.

These calculations have been made for the following sets of conditions:

a) To simulate the conditions that occurred during the 2005 spring flood release (approximately mid-March to mid-June 2005). The simulated and the observed conditions, with respect to shallow groundwater elevations, are shown in Appendix E, Figure E-16 (a-e). Simulated and observed conditions, with respect to river losses, are described in detail in Appendix E.

b) To simulate the conditions that may occur under a set of potential restoration hydrographs. The simulated conditions with respect to river losses are shown on Table 2 and further detailed in Appendix E. The potential restoration hydrographs are identified as “dry”, “normal” and “wet”. Alternate assumed conditions and the calculations are described more fully in Appendix E.

c) To simulate the conditions that may occur under a set of potential restoration hydrographs proposed in the Kondolf Expert Report. The simulated conditions with respect to river losses are further described in Appendix E.

5. Regarding hydraulic conductivity estimates, I have reviewed ranges reported in the general literature on hydrogeology (i.e., Davis 1969, Freeze and Cheery, 1979), and reports specific to the San Joaquin Valley, as noted in Section 5. Based on this review, saturated hydraulic conductivity values as noted by Deverel are considered to be unrealistically low. Davis, 1969, cites values for sand in the San Joaquin Valley to be generally within a range of 3 to 300 meinzer units. With a conversion factor of 1 meinzer unit equal to 0.134 ft/day (Davis and DeWeist, 1966), this equates to a range of 0.4 to 40 ft/day, with an approximate median of 9 ft/day. Davis also notes that in valleys of large rivers, the coarser channel deposits generally have permeabilities of from 1 to 200 darcys, with a median value close to 50 darcys; applying a conversion factor of approximately 1 darcy equal to 2.5 ft/day (Davis and DeWeist, 1966), this range would equate to about 2 to 500 ft/day and a median of 125 ft/day. Freeze and Cherry (1979) report a range of hydraulic conductivity values from 0.1 to 1000 darcys, with a mid-range of 1 to 100 darcys for clean sand; this would equate to a range of about 2.5 to 250 ft/day. Numerous reports specific to the San Joaquin Valley similarly report values within this range (Williamson, 1989; Phillis and Belitz, 1990; Belitz and Phillips, 1995; CH2MHill, 1992; BSK & Associates, 1994). In contrast, Deverel derives a value of 8.6 x 10-7 ft/sec and also notes a mean value of 1.2 x 10-6 ft/sec; these values equate to 0.07 ft/day and 0.1 ft/day. Deverel applies the latter value of hydraulic conductivity to calculate an infiltration volume over an assumed wetted channel area.

Section 5
Information Reviewed

Documents

Documents reviewed include those identified below.

Ayres Associates, 1999. *Survey and mapping report* – topographic and bathymetric surveys for the San Joaquin River from Friant Dam to Gravelly Ford (RM 267 to RM 229).

Belitz, Kenneth and F.J. Heimes, 1990. *Character and Evolution of the Ground-Water Flow System in the Central Part of the Western Dan Joaquin Valley, California.* U.S. Geological Survey Water-Supply Paper 2348.

Belitz, K. and S.P. Phillips, 1992. *Simulation of water-table response to management alternatives, central part of the western San Joaquin Valley, California.* U.S. Geological Survey Water-Resources Investigations Report 91-4193.

Belitz, K. and S.P. Phillips, 1995. *Alternative to agricultural drains in California's San Joaquin Valley: Results of a regional-scale hydrogeologic approach.* U.S. Geological Survey Water-Resources Investigations Report 95-1328.

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Gronberg, J.M. and K. Belitz, 1992. *Estimation of a water budget for the central part of the western San Joaquin Valley, California.* U.S. Geological Survey Water-Resources Investigations Report 91-4192

Gronberg, J.A.M., K. Belitz, and S.P. Phillips, 1990. *Distribution of wells in the central part of the western San Joaquin Valley, California.* U.S. Geological Survey Water-Resources Investigations Report 89-4158.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000. *Modflow-2000, The U.S. Geological Survey Modular Ground-Water Model-User Guide to Modularization Concepts and the Ground-Water Flow Process.* U.S. Geological Survey Open-File Report 00-92.

HDR Inc., Jones & Stokes Associates Inc., Kamman Hydrology & Engineering Inc., McBain & Trush Inc., Mussetter Engineering Inc., Science Applications International Corporation, Stillwater Sciences, and Trinity Associates, 2002. *San Joaquin River Restoration Study Background Report.* December.

Ireland, R.L., 1986. *Land Subsidence in the San Joaquin Valley, California, as of 1983.* U.S. Geological Survey Water Resources Investigations Report 85-4196.

Ireland, R.L., J.F. Poland, and F.S. Riley, 1984. *Land Subsidence in the San Joaquin Valley, California, as of 1980.* U.S. Geological Survey Professional Paper 437-I.

Jones & Stokes Associates, Inc., 2001. *San Joaquin River Restoration Gaming Models – Description of Methods and Assumptions.*

Jones & Stokes Associates, Inc., 1999. *Evaluation of opportunities for riparian restoration and open space uses - San Joaquin River: Firebaugh to Mendota Dam Corridor. Draft.*

Jones & Stokes Associates, Inc., 1998. *Analysis of Physical Processes and Riparian Habitat Potential of the San Joaquin River, Friant Dam to the Merced River.*

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Laudon, J. and K. Belitz, 1991. *Texture and Depositional History of Late Pleistocene-Holocene Alluvium in the Central Part of the Western San Joaquin Valley, California.* Bulletin of the Associates of Engineering Geologists Vol. XXVIII, No. 1, 1991, pp. 73-88.

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Phillips, Steven P., Sherrill Beard and R.J. Gilliom. *Quantity and Quality of Ground-Water Inflow to the San Joaquin River, California.* U.S. Geological Survey, Water-Resources Investigations Report 91-4019.

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URS Corporation. 2002. *Water Supply Study: Development of Water Supply Alternatives for use in Habitat Restoration for the San Joaquin River*. October.

U.S. Army Corps of Engineers, 1999. *Sacramento and San Joaquin River Basins comprehensive study interim report.*

Williamson, A.K., D.E. Prudic, and L.A. Swain, 1989. *Ground-water flow in the Central Valley, California.* U.S. Geological Survey Professional Paper 1401-D.

Woodward-Clyde Consultants, 1994. *Groundwater study of Mendota pool and vicinity.*

Plaintiff's Expert Reports: G. Mathias Kondolf and Steven J. Deverel

Data

Groundwater Data

Shallow alluvial wells: 13 shallow alluvial monitoring wells are located along 4 transects. Data has been collected by the FWUA during the 2005 spring flood release period, as wells as during selected previous time periods. Transducers were present in most of the wells during the spring 2005 release period. Data from the transducers are available in Excel spreadsheet format; additionally, field notes and hand measurements have been provided by the FWUA for review. This information is further described in Appendices C, D, and G.

California Department of Water Resources and CDEC Groundwater Elevation Database: Groundwater elevation data for 476 wells located within the modeled area have previously been acquired for the historic period from the California Department of Water Resources (SSPA, 2000). These records have been supplemented with data collected over the subsequent 5-year period through request to Eric Senter at the CDEC. These records include groundwater elevation obtained on a semi-annual basis. These records are further described in Appendix C-2

Flow Data

U.S. Bureau of Reclamation (USBR) gaged records and field measurements: Flow records were acquired from the USBR for the release at Friant Dam, for flow at Gravelly Ford, and flow at the San Joaquin River below the Bifurcation Structure. Additionally, field data sheets documenting field measurement of flow during the spring 2005 period were acquired. These documents are provided in Appendix B.

Other Flow Records: Other flow records, including hourly data for the gage at Chowchilla Bypass and operational records for the distribution of flow at the Bifurcation Structure are documented in Appendix B.

Mussetter Engineering Inc. (MEI) hydraulic modeling results of the San Joaquin River from Friant Dam to Mendota Dam: HEC2 model results of water surface elevation under various flow scenarios and associated average river bottom elevations along cross sections were obtained from MEI. Water surface boundaries in GIS format that identified river width at various flow levels were similarly obtained. These materials are further documented in Appendix F.

Mussetter Engineering Inc. (MEI) hydraulic modeling results of the San Joaquin River from Mendota Dam to the Merced River: HEC2 model results were obtained for the sections from Mendota Dam to Sand Slough, under various proposed flow scenarios, and from Mariposa Bypass to Bear creek, under high flow conditions. These data included estimated water surface elevation and average river bottom elevation at cross sections along the river. A GIS layer of the proposed levee structure and a hydraulic properties analysis presenting estimated river depth for various flows under proposed development conditions was acquired for the section from Sand Slough to Mariposa Bypass. Estimated river thalweg and average river bottom elevation was acquired for Sand Slough to Bear Creek at cross sections along the river. These materials are further documented in Appendix F.

Figures

Figure 1
2005 Flood Release, Gaged Flow

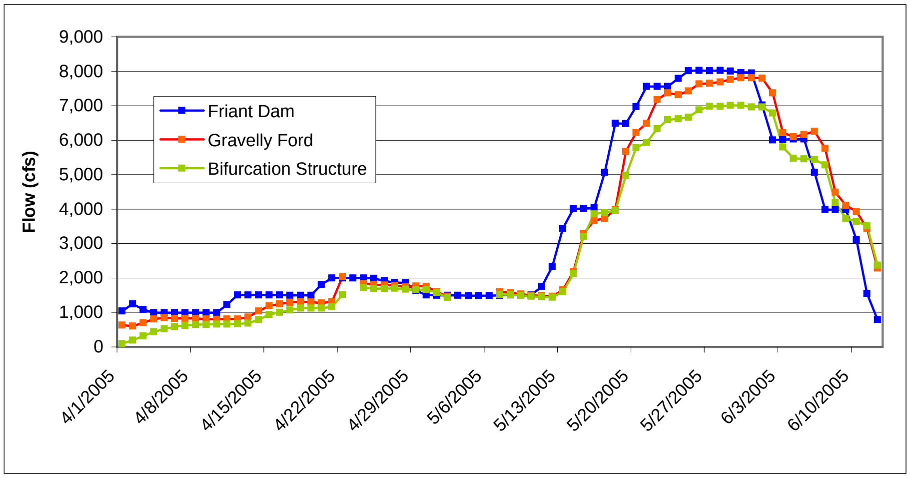


Figure 2
2005 Flood Release, Estimated River Losses
5-Day Average

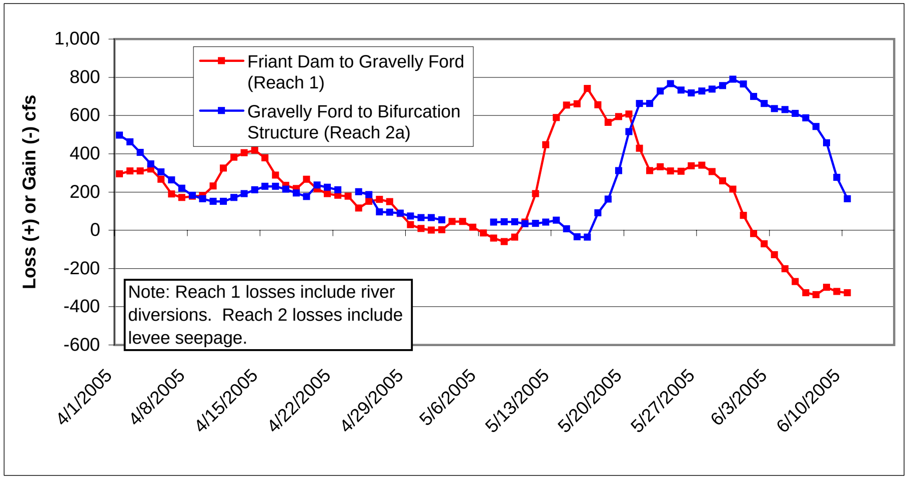
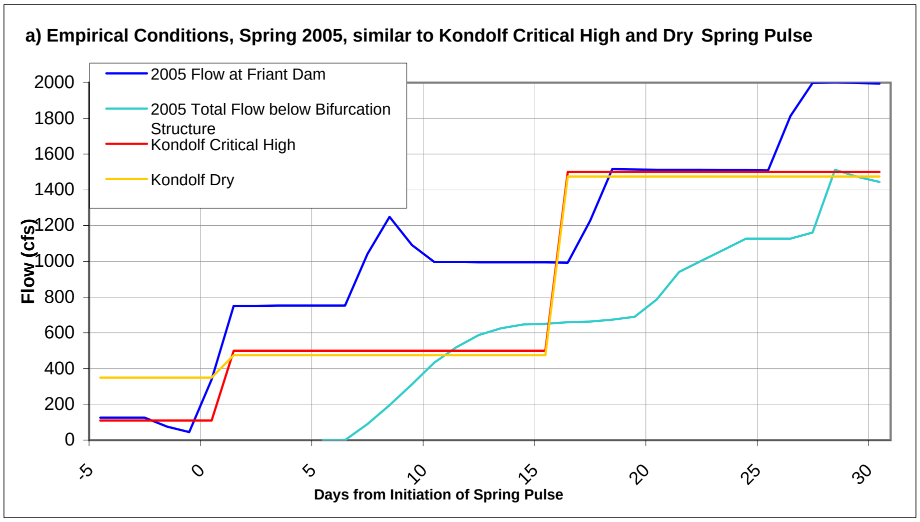
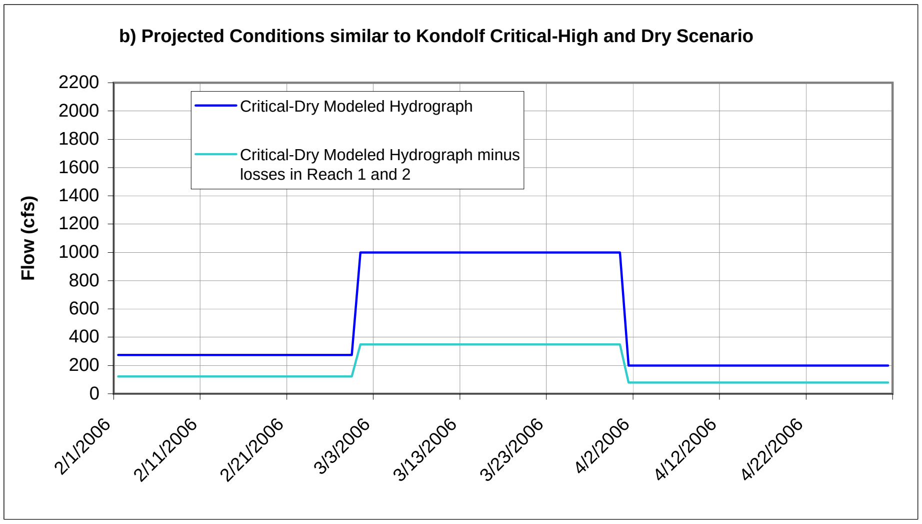
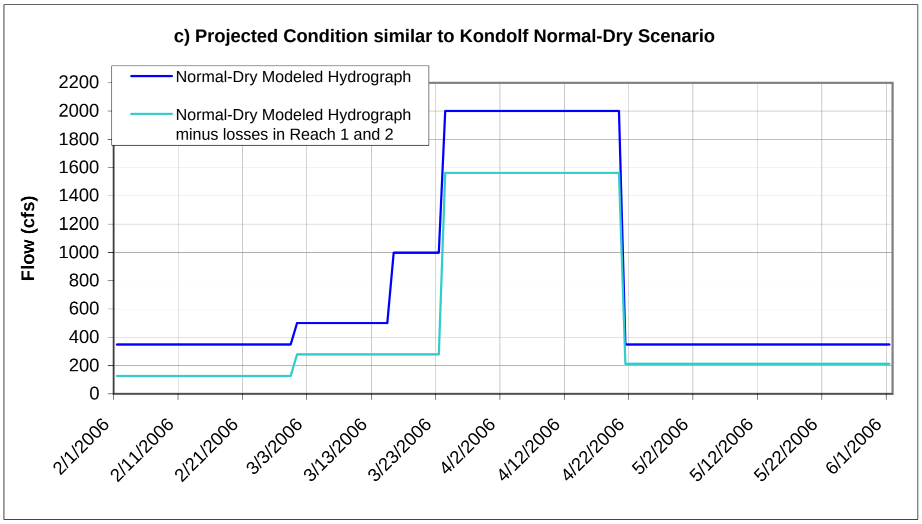


Figure 3
Projected Downstream Flows during Spring Pulses of Short Duration/Low Magnitude similar to Kondolf Critical-High, Kondolf Dry and Kondolf Normal-Dry Restoration Flows







Tables

Table 1
2005 Flood Release
Net River Losses and Estimated Channel Seepage

Dates	Average Friant Release (cfs)	Net River Losses (gage difference), cfs		Estimated Channel Seepage Losses, cfs	
		Reach 1	Reach 2a	Reach 1	Reach 2a
3/2/2005-3/25/2005	128	31	no flow	31	no flow
3/26/2005-4/11/2005	946	*257*	320	*182*	320
4/12/2005-5/16/2005	1,919	*213*	115	*138*	115
5/17/2005-5/31/2005	7,432	387	*611*	387	*less than 611*
6/6/2005-6/11/2005	3,619	*-304*	*367*	*-379*	*less than 367*

Notes:
Net losses shown in italics include a significant non-seepage component, as noted below.
Reach 1: Net river losses include both channel seepage losses and reach diversions.
Rainfall was reported as 3.33; 0.45; 2.21 and 0.0 inches for March, April, May and June respectively (at Friant Dam).
Reach diversions are likely small during periods of significant rainfall.
Reach 1 net river losses are reduced by 75 cfs (estimated river diversions) to estimate channel seepage losses, except for periods impacted by rainfall.
Reach 1 gains from tributaries are not reflected in the loss calculation; therefore, losses for periods with inflow (March) are estimated conservatively low.
Reach 2: Net river losses include channel seepage and seepage laterally through levees to adjacent fields.
Significant levee seepage to fields was observed during late May.

Table 2
Projected Net River Losses for Hanson Restoration Hydrograph (Normal-Dry, Normal-Wet Range)

Losses**	Reach 1*, cfs	Reach 2, cfs	Reach 3	Reach 4a, cfs	Reach 4b, cfs	Reach 5, cfs	Chowchilla Bypass, cfs
Average Annual Loss ***	139 - 148	53 - 126	loss	7	loss	negligible/gains	230 - 310
Peak Losses****							
February (1,000 cfs river)	198 - 205	238 - 375	NE	NE	NE	NE	NE
March (2,000 cfs river)	216 - 221	107 - 164	NE	NE	NE	NE	NE
April (4,000 cfs river)	312 - 316	140 - 186	NE	63	loss*****	NE	NE

* Reach 1 losses include an estimated 75 cfs riparian diversion
** Losses represent a range for alternate antecedent conditions
*** Not reflecting summer increases due to declining water table or increased riparian vegetation recruitment
**** Peak losses shown by month are for projected period corresponding most closely to the calendar month shown;
***** Significant losses and local flooding would result from this case; modified simulation with simulation of drains or other mitigation measures in adjacent areas is needed to provide quantitative estimate.

NE - Not estimated

Table 3
Groundwater Temperature at Shallow Alluvial Wells near San Joaquin River, Gravelly Ford-Mendota Area

Well	Date	Temperature (°F)	Purge Volume, gallons	Number of Well Volumes Purged
FA-1	8-12-99	76.8	130	--
FA-2	8-12-99	74.2	60	--
FA-3	8-12-99	74.9	120	--
FA-4	10-14-99	73.9	50	27.2
FA-5	10-14-99	69.9	50	25.4
FA-6	10-14-99	75.7	55	32.9
FA-7	10-20-99	68.2	110	30.6
FA-8	10-15-99	70.3	65	19.3
FA-9	10-20-99	65.6	100	27.7
MA-1	10-20-99	82.6	90	44.3
MA-2	10-20-99	76.7	140	38.6
MA-3	10-15-99	66.3	60	14.3

Source: DeFlitch, D and John Cain, 2002 (Appendix C of Report in Appendix E, Technical Report: Alluvial Groundwater)