SUPPLEMENTAL REPORT OF DR. STEVEN J. DEVEREL, PH.D

I was asked by Natural Resources Defense Council to evaluate expert reports by Drs. Schmidt, Burt, Hradilek and Harvey regarding potential impacts of a restoration flow schedule on: 1) pumping in Friant districts, 2) groundwater levels in such districts, 3) land subsidence, 4) quality of groundwater, and 5) seepage from the river into adjacent lands.

SUMMARY OF EXPERT OPINION

1. Dr. Schmidt and Dr. Burt assume that, if a restoration flow occurs, most Friant Districts will increase pumping on a 1:1 basis, owing to reduced water deliveries, for 20 years into the future. That prediction is an assumption. It is not a factual finding based on a disclosed scientific method. As shown by Dr. Kirby, the likely increase in and impact of pumping may be much less due to: changes in land- and water-management practices that include fallowing, reduction of irrigated acreage and water purchases and transfers. There is substantial evidence that groundwater banking may also help offset water level declines associated with pumping in Friant districts.

2. Dr. Schmidt uses a predictive tool or model to estimate future groundwater level changes as the result of changes in pumping in individual water districts, if a restoration flow occurs. The model is not sufficiently reliable for predicting changes in groundwater levels for 20 years into the future. This unreliability is a result of problems with the model design and assumptions. Dr. Schmidt relates water level changes to estimated pumping volumes, and Dr. Burt provides pumping estimates. Dr. Burt makes several erroneous statements and assumptions about groundwater and processes affecting groundwater pumping in the Friant districts.

3. Problems with the use of the Schmidt model and pumping estimates include the following. The data points used to develop the linear relation between pumping and water-level changes are not independent. Moreover, only two points were used to create a linear relationship between pumping increases and water level declines. A two-point line does not allow for estimates of uncertainty, which is necessary to reliably predict future water level

changes. There are substantial uncertainties in several variables, including consumptive use estimates.

4. The ability of Dr. Schmidt's model to estimate known water-level changes varies by district. I estimate the average root mean square error to range from 0.3 to over 11 feet, for the period 1987 to 1999. This means that the prediction may be in error by that amount each year. Dr. Schmidt's model does not explicitly include other processes that influence groundwater levels in Friant districts. These processes include groundwater flow across district boundaries.

5. Dr. Schmidt uses his predictions of groundwater level change to predict future subsidence in selected Friant districts. Dr. Schmidt assumes that future subsidence can be predicted by groundwater-subsidence relations developed by the U.S. Geological Survey (USGS) during historic virgin subsidence during the 1920s through the 1970s. The available data and analysis indicates that the historic groundwater-subsidence relation is highly spatially and temporary variable, and is probably not applicable.

6. Dr. Schmidt states that groundwater quality will deteriorate during an unspecified long period of time due to reduced deliveries to Friant districts. Irrigated agriculture is already degrading groundwater in Friant districts as evidenced by data published by the U.S. Geological Survey. Future changes in groundwater quality are difficult to predict due to uncertainty about possible changes in land- and water-management practices. If districts undertake measures, such as securing additional surface water supplies and groundwater banking, to minimize the impact of a restoration flow on their water supply, increases in groundwater salinity can be minimized..

7. Dr. Hradilek proposes slurry walls adjacent to Reaches 2 and 4. The proposed use of slurry walls is not a prudent response to the seepage which may occur as a result of a restoration flow. The incremental seepage (e.g., the change in the existing condition) will probably occur in more limited areas than apparently presumed by Dr. Hradilek in his testimony. Where incremental seepage occurs, alternatives to slurry walls such as drainage are appropriate. In Reach 4, slurry walls could create additional high groundwater areas by impeding natural groundwater flow. There is currently little data that point to a future need

for seepage mitigation in Reach 4. Drainage systems appear to be more viable seepage mitigation measure.

MATERIALS RELIED UPON TO FORM MY OPINION

8. In formulating the opinions stated in this expert report, I have considered the materials specifically identified in my original and this supplemental report as listed below.

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Johnson, H., Brown, E. and Robie, R. 1980. Ground Water Basins in California: A Report to the Legislature in Response to Water Code Section 12924. Department of Water Resources Bulletin 118-80.

Lower Tule River Irrigation District. June 2003. Application For A Groundwater Storage Program Construction Grant For The Lower Tule River Irrigation District Water Supply Enhancement Program. Submitted to the Department of Water Resources under the Safe Drinking Water, Clean Water, Watershed Protection and Flood Protection Act (Proposition 13)

McBain and Trush, Inc. (eds). 2002. San Joaquin River Restoration Study Background Report. Prepared for Friant Water Users Authority and Natural Resources Defense Council.

Mullen, J. and Nady, P. 1985. Water Budgets For Major Streams In The Central Valley, California, 1961 – 1977. U.S. Geological Survey, Open File Report 85-401.

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Other materials

http://cdec.water.ca.gov/cgi-progs/previous/FLOWOUT (EXCEL spreadsheet provided)

http://science.calwater.ca.gov/workshop/calsim_docs_05.shtml (EXCEL spreadsheet provided).

California Department of Water Resources. Groundwater level data for multiple wells Downloaded from http://wdl.water.ca.gov/gw/admin/main_menu_gw.asp.

STATEMENT OF EXPERT OPINION

I. Increased Pumping To Meet Demand

9. Dr. Schmidt and Dr. Burt state that decreases in future water deliveries to Friant Districts, as a result of a restoration flow schedule, will be directly replaced by pumping groundwater for 20 years into future. That prediction is an assumption. It is not a factual finding based on a disclosed scientific method. I conclude that it is unlikely that pumping will replace decreased surface water supplies on a 1:1 basis, for the following reasons.

10. Decreased Friant surface water supplies can be replaced by alternative supplies. These include purchased and transferred water and excess surface water flows to recharge groundwater.[1] There are already several examples within the Friant Districts where managed groundwater recharge and groundwater banking occurs. Purkey (1998) and Thomas (2001) describe the potential for groundwater banking and artificial recharge in the San Joaquin Valley and within the Friant service area and point to additional future banking opportunities. Also, URS (2002) describes the possibilities for groundwater banking and artificial recharge in the Friant districts. All the alternatives analyzed in the URS report contain some level of groundwater banking.

11. The fact that several Friant districts already use groundwater banking and others are planning for groundwater banking points to possibilities for increased groundwater banking in the future. Examples follow.

a. The Fresno Irrigation District has been recharging groundwater through the use of recharge ponds for over 40 years to take full advantage of their SWP entitlement (Albert Steele, California Department of Water Resources, personal communication, 2005). Fresno Irrigation District is planning a

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[1] Dr. Ken Kirby described the possibilities for additional water supplies in Friant districts.

project that will divert an average of approximately 11,500 acre-feet per year (AFA) (Fresno Irrigation District, 2003; Thomas, 2001).

b. The City of Fresno operates the Leaky Acres recharge facility where water percolates through the first 10 feet of sediment, is collected by tile drains, and is injected through the impervious clay to the underlying aquifer.

c. The Arvin-Edison Water Storage District, through groundwater recharge, has raised groundwater levels and reduced (by dilution) the concentration of boron in the groundwater (Arvin-Edison Water Storage District, 2003). The recharge to groundwater over 50 years in this district is estimated to be 204,000 acre-feet (AF).

d. The Lower Tule River Irrigation District (2003) facilities provide groundwater recharge through the unlined earthen canals along with recharge and wildlife habitat basins. The overall impact of the excess surface water supply is to reduce the groundwater overdraft that occurs within the basin and assist the domestic water users that rely only on groundwater for their water supply.

e. The Kaweah Delta Water Conservation District (Fugro, 2003) successfully uses groundwater recharge facilities. Several Friant districts are part of this water conservation district.

12. Proposed additional flows in the San Joaquin River below Friant will increase river leakage potentially providing about 65,000 acre-feet of recharge to the groundwater system.

II. <u>Predicted Groundwater Levels</u>

13. Dr. Schmidt developed and uses a predictive tool (a model) to encompass the relationships between observed groundwater-level declines and estimated pumping.[2] He uses

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[2] Dr. Burt provides estimates for both "Net Groundwater Extraction" and "Gross Irrigation Well Pumping"; Dr. Schmidt's analysis relies on Gross Irrigation Well Pumping. Net Groundwater Extraction is the volume of pumped groundwater consumed by plant evapotranspiration, whereas Gross Irrigation Well Pumping is the total volume of groundwater extracted from the aquifer by farmers in the Friant Service Area.

historic groundwater pumping estimates provided by Dr. Burt and historic groundwater-level changes to develop a linear relationship of water-level changes to pumping. He uses this relationship to predict future water level declines for 20 years using water delivery estimates and assuming that pumping will replace delivery decreases on a 1:1 basis. The model is not sufficiently reliable to predict changes in groundwater levels for 20 years into the future. This unreliability is a result of problems with the model which I discuss below.

Model Validity

14. Model validity can be examined using traditional scientific criteria which relate to the data used to develop the model and reliability of its predictive results. These criteria can be examined by answering the following questions.

a. What errors (uncertainty) are in the data used to develop the model?

b. How well does the model reproduce observed groundwater-level changes during the period for which it was developed?

c. Does the model represent the physical processes that affect water levels?

15. *What errors (uncertainty) are in the data used to develop the model?* One data point represents the intersection of the observed water-level change and estimated pumping between 1987 and 1999. The second point represents the intersection of the observed water-level change and estimated pumping from 1987-1992. A two-point straight line model is limited and eliminates the possibility to estimate the uncertainty in model results. The two data points employed by Dr. Schmidt are not independent,[3] and the groundwater level change represented by one data point (1987-1992) contains the time period represented by the second point (1987-1999). The 1987-1992 data point therefore has an undue influence on the slope and intercept of the straight-line model.

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[3] Dr. Schmidt's model looks like a regression analysis in that it contains a dependent variable, water level change which was related to an independent variable, pumping. Haan (1977) listed the assumptions for regression analysis. These include independent data points and measured values for the independent variable. Helsel and Hirsch (1992) also describe the assumption of independent residuals for regression analysis. The use of overlapping time periods and estimated values for pumping in Dr. Schmidt's analysis violates these assumptions.

16. Moreover, use of the 1987–1999 period is not representative of long-term average hydrologic conditions. Specifically, 1987–1999 period was drier than 94% of the long term with 6 dry years, 2 normal dry year, 1 normal wet and 4 wet years.

17. The independent variable in Dr. Schmidt's straight-line model, pumping, cannot be measured and was estimated by indirect methods by Dr. Burt.[4] Dr. Burt calculated pumping from reported surface water deliveries, estimated crop water use, and estimated delivery system and water application efficiencies. Because crop water use is estimated, it has an inherent level of uncertainty. In other words, the actual crop water use could have been greater or less than estimated, and therefore the actual pumping that produced the observed water level changes could have been greater or less than estimated.

18. Dr Burt employs the following formula (Equation (1)) to estimate pumping:

$Pumping = [ETirrp - (IDSW) \times CEF \times AE/100] \times 100/AE$

where

$Pumping$ = Calculated gross irrigation well (ground) water pumping;

$ETirrp$ = Estimated evapotranspiration (ET) of irrigation water[5], not derated for bare spots and poor vigor in a field;

$IDSW$ = Reported surface water available to each irrigation district;

CEF = Estimated conveyance efficiency[6] of the irrigation districts divided by 100; and,

AE = Estimated application efficiency[7] of on-farm irrigation.

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[4] On page 3, Dr. Burt explains the difference between net and gross pumping. He cites the paper Burt and Styles (2004). This paper describes appraisal of irrigation systems and does not appear to have anything to do with groundwater pumping. At best, this reference alludes to the inefficiencies associated with irrigation application that are listed as part of the appraisal process. It does not explain the difference between net and gross pumping. It does not detail the losses of irrigation water due to application inefficiencies nor explain how this relates to net pumping.

[5] Evapotranspiration of irrigation water, not derated for bare spots and poor vigor in a field (ETirrp) is the estimated total annual evapotranspiration requirement of the crop less the portion met by precipitation.

[6] Estimated conveyance efficiency (CEF) for each irrigation district reported in Table B1 "Conveyance efficiency, by district" of Appendix B in Dr. Burt's report.

[7] Estimated application efficiency (AE) by irrigation method is reported in Table B2 "AE estimated used in ITRC computations" of Appendix B in Dr. Burt's report.

19. All the estimated terms in Equation (1) have an associated uncertainty, which produce a corresponding uncertainty or error in the calculated pumping. For example, in Table 6-10 of their January 2002 report, "Evaporation from Irrigated Agricultural Land in California," Dr. Burt calculated and reported the confidence interval (uncertainty) for estimated evapotranspiration in California. In the Friant Service Area, which encompasses California Department of Water Resources Reference Evapotranspiration Zones 12 and 15 (see Figure A1 of Dr. Burt's report), the uncertainty in estimated evapotranspiration reported by Dr. Burt is ± 13%. Hence, the possible error in calculated gross groundwater pumpage due to the uncertainty in estimated evapotranspiration is about ± 13%. Potential errors in the remaining estimated terms in Equation (1) can contribute to greater uncertainty in calculated gross groundwater pumpage.

20. The uncertainty in estimated groundwater pumping has a substantial effect on predicted groundwater level declines calculated by Dr. Schmidt's model. Table 1 compares observed average groundwater level changes with values we calculated from Schmidt's model and the potential uncertainty in groundwater pumping. To do this, the average annual groundwater pumping during the period 1987-1999 was adjusted by 13% and then used to re-calculate the groundwater level change using the graphical relationships reported in Appendix B of Dr. Schmidt's report. In all cases, the ±13-percent in estimated average pumping can change calculated annual groundwater-levels changes by several feet in all cases.

Table 1. Estimated Water Level Changes Using Dr. Schmidt's Equation With Errors In Pumping Estimates.

Irrigation District	Estimate using Dr. Schmidt's Model	Assumed 13% increase in estimated groundwater pumping	Assumed 13% decrease in estimated groundwater pumping
Arvin Edison	0.6	-5.9	7.1
Chowchilla	-3.4	-6.5	-0.2
Delano-Earlimart	-1.0	-3.0	0.9
Exeter	-0.2	-4.1	3.6
Ivanhoe	-0.5	-2.7	1.7
Lindmore	-1.0	-4.7	2.8

Lindsay Strathmore	-2.0	-9.6	5.6
Lower Tule	3.1	-0.6	6.7
Madera	-2.5	-4.1	-0.9
Orange Cove	0.8	-10.0	11.6
Porterville	-0.5	-5.2	4.2
Saucelito	21.9	6.0	22.5
Shafter-Wasco	-2.9	-8.6	2.8
SSMUD	-2.1	-5.8	1.6
Tulare	6.0	3.25	10

21. Alternatively, the uncertainty in estimated groundwater pumping can be examined by incorporating the ± 13% uncertainty in the redevelopment of Dr. Schmidt's equations. In other words, we can determine how the straight-line equations would change if actual pumpage was different than estimated by Dr. Burt. Figure 1 illustrates the possible range in actual pumping causing the observed groundwater level decline in Chowchilla ID. To create Figure 1, the average annual groundwater pumping during 1987-1999 was adjusted by 13% and used to create uncertainty boundaries for the straight-line relationships developed by Dr. Schmidt. For example, the range in actual pumping causing the observed 4 feet per year groundwater decline is 90,500 AFA to 118,000 AFA.

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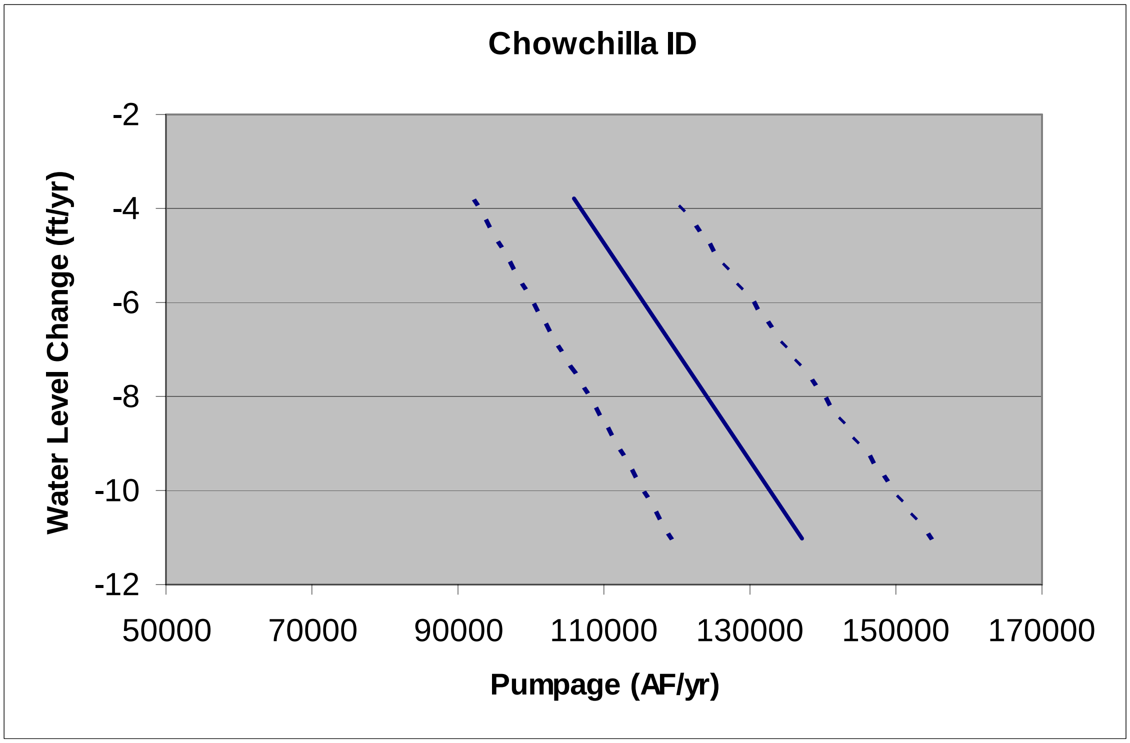

Figure 1. Relation Of Water-Level Decline To Pumping Estimates For Chowchilla Water District. *The solid line represents the original relation developed by Dr. Schmidt. The dashed lines represent the water-level-pumping equation with incorporation of error described in Burt and others (2002).*

22. Groundwater level changes were calculated from the uncertainty boundaries for pumping estimates of Schmidt's relationships for each water district. Table 2 shows that the potential uncertainty in groundwater pumping translates to calculated annual groundwater level declines that may vary by 1.2 to 22.4 feet per year.

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Table 2. Water-Level Predictions Using Dr. Schmidt's Water-Level-Pumping Relations With 13% Uncertainty Boundaries.

District	Lower Boundary Ft./Yr.	Estimated average water-level change using Dr. Schmidt's relationships (Ft./Yr.)	Upper Boundary (Ft./Yr.)	Range of GW level change, Ft./Yr. (Upper boundary minus lower boundary)
Arvin Edison[8]	-331.3	0.6	-291.0	40.3
Chowchilla	-7.0	-3.4	-0.6	6.4
Delano-Earlimart	-2.6	-1.0	1.2	3.7
Exeter	-4.8	-0.2	3.1	7.8
Fresno	-1.5	-0.9	-0.2	1.2
Ivanhoe	-3.0	-0.5	1.5	4.5
Lindmore	-5.3	-1.0	2.3	7.6
Lindsay Strathmore	-10.8	-2.0	4.7	15.5
Lower Tule	-1.2	3.1	6.2	7.5
Madera	-3.9	-2.5	-0.8	3.2
Orange Cove	-11.9	0.8	10.4	22.4
Porterville	-5.9	-0.5	3.7	9.6

23. When uncertainty is incorporated into Dr. Schmidt's water-level-pumping relations, Tables 1 and 2 indicate that there is potentially substantial error in the predicted water level changes.

24. Other estimated groundwater pumping volumes for Friant districts also point to the potential error. For example, gross groundwater pumping estimates in CALSIM in Madera ID and Chowchilla WD differ from Dr. Burt's estimates for 1987 - 1998 by over 30% (USBR, 2005b).

25. On page A-1, Dr. Burt defines irrigation efficiency as equal to irrigation water beneficially used divided by the difference of irrigation water applied and the change in aquifer storage. He references Burt and others (1997) for this definition, but the definition for the Friant districts is inconsistent with that paper. In Burt and others (1997), irrigation efficiency

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[8] The equation representing the relation for Arvin Edison is annual water level change = 50.8-0.000273 x annual pumping. Accounting for the 13 % error results in equations that predict large water level rises for small amounts of pumping.

is equal to irrigation water beneficially used divided by the difference of irrigation water applied and the change in storage of irrigation water. In the paper, Dr. Burt and his coauthors present a block diagram that shows the general water balance for a representative volume where irrigation water is applied. Dr. Burt and his coauthors further state in the paper that "boundaries of the region being discussed and an associated transit-time period must be clearly defined." In Appendix A, Dr. Burt states that the time period is 5-years of recent conditions (1999-2003),[9] and the boundaries are the spatial boundaries of concern are the Friant Service Area and extend down into the aquifer. Dr. Burt does not define how far the boundaries extend into the aquifer.

26. It is important to "clearly" define the boundaries and time scales for the following reasons. First, in most Friant districts, there is a delay in the change in groundwater storage owing to movement of deep percolation water in the unsaturated zone. This can occur over several years. Second, in many districts, there is downward groundwater movement from the semi confined zone to a lower confined aquifer where pumping occurs. Dr. Schmidt's report describes this pumping in Chowchilla WD, Madera ID and Fresno ID. Pumping from the confined zone also occurs in other Friant districts such as Tulare ID. Third, specification of the time period is important because the time frames for groundwater movement are substantially longer than timeframes for application and consumption of irrigation water. As an example, Belitz and Phillips (1995) estimated travel times from the water table to the confined pumping zone that ranged from 250 to 600 years in the San Joaquin Valley.

27. Also, Dr. Burt states that irrigation efficiency for "Friant Water" as defined by the IE equation is over 90%. There is no documentation of this estimate.

28. *How well does the model reproduce observed groundwater-level changes during the period for which it was developed*? Model reliability is determined by comparing the calculated water-level changes against observed values during the period from which the model

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[9] Dr. Burt acknowledges that 1999-2003 period is below average. Specifically, runoff during this period was 75% of the 1951-2000 period for the San Joaquin watershed. This period is even drier in the Tulare Basin. It is therefore not a representative period for average water supply conditions. (http://cdec.water.ca.gov/cgi-progs/previous/FLOWOUT).

was developed (1987 to 1999). I evaluated water level data in the USBR and URS Water Supply reports (USBR, 1992 and URS, 2002) for the districts for which Dr. Schmidt estimated future water level changes. Since the water level data in the USBR 42nd Annual Water Supply Report (USBR, 1993) and URS (2002) reports follow an accepted and established method for estimating district-wide water level changes within the Friant Service area, it is a reasonable data set for estimating the error in Dr. Schmidt's model calculations.

29. I extracted data from the URS and USBR reports and compared the reported average annual water-level changes from 1987-1992 and 1993-1999 to those predicted by the Schmidt model and report the results in Table 3. The root mean square error (RMSE),[10] an estimate of the error in the annual estimated water level change, ranges from 0.3 ft for Ivanhoe to 36.1 for Saucelito.

Table 3. Evaluation Of The Schmidt Pumping-Water-Level Relations For Estimating Water Level Changes From 1987 – 1992 And 1993 To 1999.

Water District	Measured annual average water level change (ft./yr.), 1987 – 1992	Estimated annual water level change 1987 – 1992 (ft./ yr.) using Schmidt relation	Measured annual average water level change (ft./ yr.), 1993 – 1999	Estimated annual water level change 1993 – 1999 (ft./ yr.) using Schmidt relation	RMSE for water level change using two values
Chowchilla	-10.4	-11	2.3	3.2	0.8
Madera	-5.4	-7.1	0.4	1.4	1.4
Orange Cove	-1.0	-5.3	2.1	3.3	3.1
Ivanhoe	-5.1	-4.7	2.8	3.0	0.3
Tulare	-12.8	-12.5	6.6	22.8	11.4*
Exeter	-5.1	-7.6	3.4	6.1	2.6
Lindsay Strathmore	-2.0	-4.7	2.5	0.3	2.5
Lindmore	-5.6	-7.4	3.5	4.5	1.4
Lower Tule	-11.8	-12.5	5.0	16.4	8.1*
Porterville	-5.1	--7.7	1.5	6.7	4.2

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[10] The formula for the RMSE is the square root of the squared difference of the measured and estimated water level change, divided by the number of measured water levels. The RMSE is a common estimate of the predictive capability of models for estimating groundwater level changes (Anderson and Woessner, 1992). Estimated groundwater level changes are accurate to plus or minus the RMSE.

Saucelito	-10.9	-12.1	4.6	9.5	37.0*
Delano Earlimart	-4.9	-8.0	1.9	4.0	2.6
SSJMUD	-9.0	-25.1	-4.1	-2.7	11.0
Shafter Wasco	-10.2	-12.0	-5.0	2.4	2.3
Arvin Edison	-6.9	-5.6	7.6	5.9	1.5

** Note: The RMSE for Tulare, Lower Tule and Saucelito irrigation districts was affected by a discrepancy in the data in Table 2 of Dr. Schmidt's report. The 1987-1998 averages of the pumpage estimates for these three irrigation districts differ from what was calculated from the historical data in Table 3 of Dr. Burt's report. For the purpose of calculating the error in Dr. Schmidt's relationships, the values recorded in his Table 2 were used here, rather than the historical data.*

30. *Does the model represent the physical processes that affect water levels?* A valid model represents the physical processes that affect water levels. Dr. Schmidt's model assumes pumping is the sole predictor of groundwater level changes. However, groundwater recharge from irrigation and infiltration of San Joaquin River water also affects water levels. Moreover, Department of Water Resources Bulletin 118 (DWR, 1980) indicates that in some of the Friant Districts, water levels have been influenced by activities in adjacent water districts.

31. Specifically, Bulletin 118 stated the following about Chowchilla, Madera and Fresno ID's. Rapid growth in irrigated area to the southwest and north of Chowchilla ID has caused a lowering of groundwater levels in Chowchilla ID. Pumping occurring to the east of Madera ID, where cropped acreage increased during the period 1958-74, was expected to induce greater subsurface outflows from the district and cause a water level decline. The extensive development of irrigated agriculture in the area west of the Fresno and Consolidated IDs is based on ground water, which has lowered water levels in the vicinity of the pumping wells creating a regional drawdown surface (pumping depression). Subsurface outflows from these districts to the cone of depression have resulted in a groundwater level decline in the western portions of Fresno and Consolidated IDs.

32. Dr. Burt also makes contradictory statements about groundwater flow beneath the Friant districts. On page 1 of his report, Dr. Burt states that "canal seepage and on-farm over-irrigation within the Friant service area do not result in a loss of water to the service area

boundaries because of extensive groundwater pumping by individual farmers in most of the districts." On page 2, he states that lateral flow is captured by other districts, which observed groundwater levels show include districts outside the Friant Service area. Also, lateral flow in and out of Friant districts affects Dr. Burt's assumptions about irrigation efficiency in that his selected spatial boundaries may be wrong for considering groundwater storage.

33. Figure 2 shows groundwater level contours developed by the Department of Water Resources for 1999, a normal dry year. The contours show lines of equal groundwater levels, from which the horizontal movement of groundwater beneath the subsurface is inferred; groundwater moves from locations of relatively high levels to lower levels. The groundwater level contour map shows that groundwater moves away from 3 Friant districts: Fresno, Madera and Chowchilla. Throughout most of the Chowchilla Water District, groundwater flow is generally east to west, and the groundwater level contours indicate water moves toward a pumping depression located west of the district. Throughout most of the Madera Irrigation District, groundwater flow is in a northwesterly direction toward a pumping depression located west of the district. In the eastern part of the Fresno Irrigation District, groundwater flows toward a pumping depression beneath the city of Fresno, and in the western part of the Fresno Irrigation District groundwater flows toward a pumping depression located southwest of the district. In another example, Fugro (2003) reported lateral groundwater flow leaving the Kaweah Delta Water Conservation District which contains the Tulare Irrigation District, one of the larger Friant districts.

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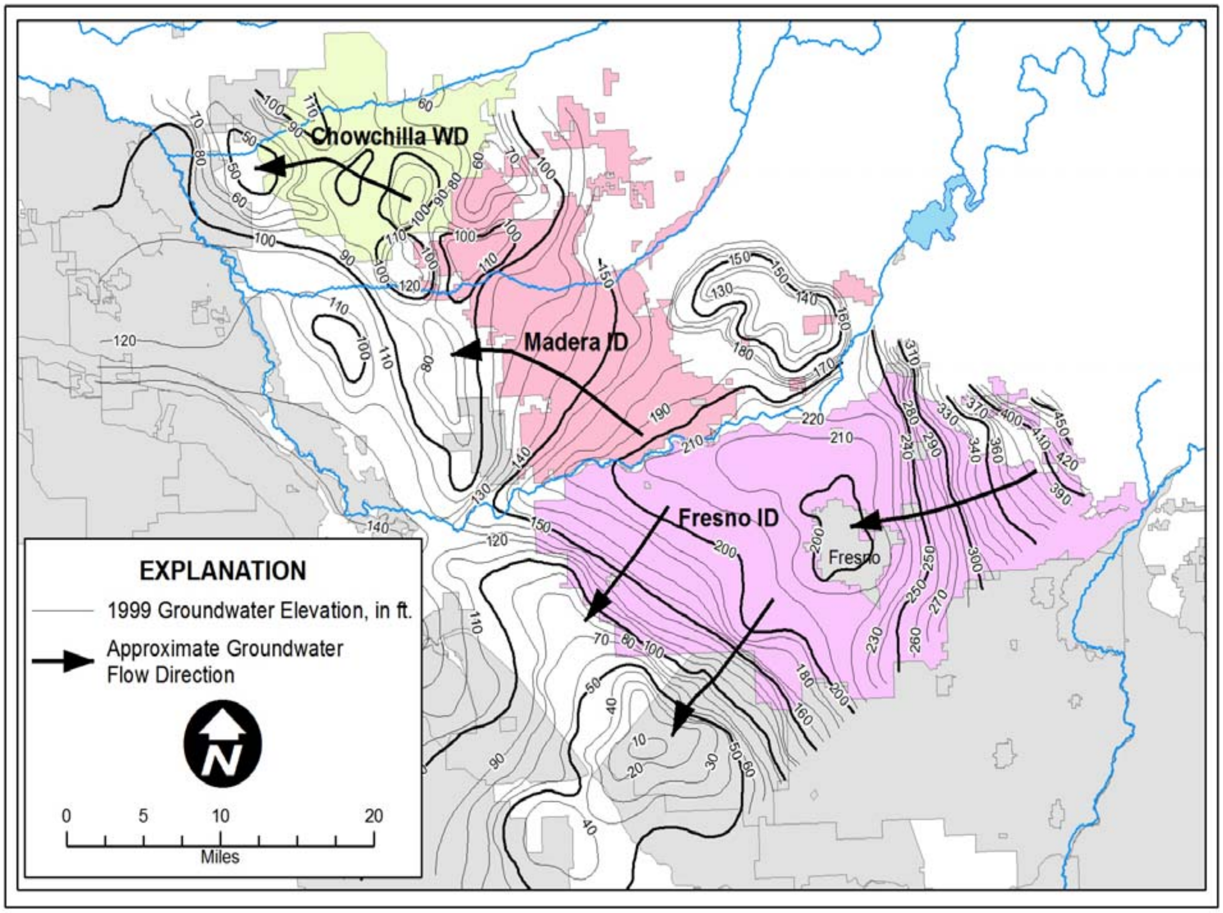

Figure 2. Groundwater Contours And Generalized Directions Of Groundwater Flow For 1999. *(Adapted from Department of Water Resources groundwater level map for the unconfined zone).*

Evaluation of groundwater level change predictions

34. Dr. Schmidt's model was developed from data collected during the period 1987-1998. I gathered subsequent water level data for the some of same wells and summarized the observed groundwater level changes for the period of record after 1998 (1998 to 2003). I then utilized Dr. Burt's reported pumpage to predict the average groundwater level change for selected districts. My results are reported in Table 4. They show that, with the exception of three districts (Tulare, Saucelito, and Arvin-Edison), Dr. Schmidt's model overestimated the average annual groundwater level decline or underestimated the water level rise. The RMSE is 9.9 feet. Without the Saucelito value, the RMSE is 2.8 feet, or ± 24% of the range of measured values.

35. The importance of the error in the water level change relates to the use of Dr. Schmidt's model for estimating water level changes during 20 years. For example, Dr. Schmidt predicted 102 feet of water level decline in Madera in 20 years, or 5.1 feet per year. Using a RMSE of 2.8, the predicted water level decline could range from 46 to 158 feet. This error could be larger if land- and water-management practices change and other processes such as managed groundwater recharge influence future groundwater levels.

Table 4. Results Of The Evaluation Of Estimates Of Groundwater Level Changes Using Dr. Schmidt's Equations For Water-Level Changes To Estimated Pumping.

District	Average pumping 1998 - 2003 (AF)	Average water level change predicted by Dr. Schmidt's model (ft.)	Average observed water level change (ft.)	Predicted minus observed (ft.)*
Madera	165,258	-3.1	-2.6	0.6
Chowchilla	101,808	-2.8	-2.4	0.4
Exeter	20,348	1.7	3.4	1.6
Tulare	68,766	13.4	7.5	5.8
Lower Tule River	125,109	4.3	8.6	-4.3
Saucelito	12,439	33.1	3.3	-29.8
Arvin-Edison	183,109	0.8	-3.0	-3.8
Ivanhoe	15,750	0.3	2.4	2.1
Lindmore	34,097	0.5	2.8	2.3

** Note: RMSE for all data is 9.9 ft. Excluding Saucelito, RMSE = 2.8 ft.*

Predicted future water level changes with estimated water delivery reductions

36. Dr. Schmidt uses his pumping-water level equations to estimate future water level changes with future delivery reductions. Using Dr. Schmidt's water-level relation, I estimated water level changes using data provided by Dr. Kenneth Kirby. Dr. Kirby used the Stiener model to estimate long-term deliveries to the Friant Districts. I used these values and the Schmidt equations developed for the 1987 -1998 data to estimate water-level changes

assuming that pumping will replace surface-water delivery reductions. It is important to note that the use of the Schmidt model for estimating water level changes suffers from the assumption described above that groundwater would replace surface water on a 1:1 basis. This is probably not the case. The Schmidt model also does not account for physical processes affecting groundwater levels. Using a model that accounts for these processes is essential for accurately estimating water level changes and associated uncertainty.

37. Table 5 shows the projected annual water level changes. I estimated the range for water-level change estimates from the RMSE for the data shown in Table 3. Specifically, I used the RMSE for the individual districts shown in Table 3 and added and subtracted the RMSE from the estimated value in column 4 to calculate the values in columns 5 and 6. The Schmidt equations estimate water level changes that range from 17.9 feet per year in Lindsay-Strathmore to -6.9 for Arvin Edison. Table 5 shows that there is a substantial range in water-level change predictions for many districts. In all cases, the predicted annual water level changes using the delivery reductions provided by Dr. Kirby for the hydrograph developed by Dr. Kondolf are substantially lower than those predicted by Dr. Schmidt, owing to the lower pumping estimates resulting from Dr. Kirby's analysis. Specifically, pumping estimates in Table 3 of Dr. Schmidt's report are universally larger that those calculated from delivery data provided by Dr. Kirby (Table 5). I assumed for this analysis that decreased deliveries would be replaced 1:1 by increased pumping.

38. Table 5 also shows that the average pumping for 1987 to 1998 shown in Dr. Schmidt's Table 2 are comparable to the estimated pumping with the Kondolf hydrograph. Specifically, for all districts except Arvin-Edison, Madera and Tulare, pumping estimates shown in column 4 of Table 5 are essentially equal to or less than the 1987-1998 average pumping from Dr. Schmidt's Table 2 (column 5). For the remaining districts, the difference in estimated pumping is well within the 15% error for estimating pumping described above. This explains the prediction of smaller water level declines or rises associated with the Kondolf hydrograph pumping estimates.

Table 5. Estimated Annual Groundwater Level Changes For Deliveries Estimated By Dr. Ken Kirby Using Equations From Dr. Schmidt's Report.

Water District	Schmidt Table 3 Pumping with existing deliveries (AFA)	Average delivery reduction (AFA) per Kirby	Increased Pumping (AFA) if 1:1 replacement of delivery	1987 – 1998 pumping (Schmidt Table 2)	Estimated water level change using Schmidt equations (ft./ yr.)	Upper estimate for water level change (ft./ yr.)	Lower estimate for water level change (ft./ yr.)	Annual water level change (Schmidt Table 4)
Arvin-Edison	186,000	25,469	211,469	186,000	-6.9	-5.4	-8.4	-10.45
Chowchilla	93,000	14,654	107,654	106,000	-4.2	-3.4	-5.0	-8.8
Delano-Earlimart	26,000	10,637	36,637	36,000	-1.2	1.4	-3.8	-8.3
Exeter	20,000	1,968	21,968	22,000	-0.5	2.1	-3.1	-4.7
Ivanhoe	16,000	952	16,952	19,000	-0.9	-0.6	-1.2	-3
Lindmore	34,000	3,181	37,181	36,000	-1.9	-0.5	-3.3	-7.4
Lindsay-Strathmore	7,000	1,261	8,261	12,000	17.9	20.4	15.4	-2
Lower Tule River	134,000	20,854	154,854	158,000	-2.1	6.0	-10.2	-7.9
Madera	153,000	18,001	171,001	157,000	-3.6	-2.2	-5.0	-5.1
Orange Cove	41,000	1,797	42,797	41,000	-3.1	0.0	-6.2	-5
Porterville	23,000	3,008	26,008	26,000	-0.5	36.5	-37.5	-7.5
Saucelito	15,000	3,459	18,459	22,000	11.4	13.7	9.1	-7.5
Shafter-Wasco	55,000	5,295	60,295	62,000	-1.9	0.4	-4.2	-8.8
SSJMUD	49,000	8,238	57,238	73,000	3.6	14.6	-7.4	-3.5
Tulare	137,000	12,068	149,068	140,000	-5.1	6.3	-16.5	-8.7

39. Dr. Burt's report points to the need for accurate water level change estimates. In Appendix C, Dr. Burt estimated energy requirements for groundwater pumping. In Table C-4, he estimated future irrigation well pumping energy requirements by 2025 for the Spring Release scenario based on water level declines estimated by Dr. Schmidt. There are two problems with Table C-4. First, Dr. Burt lists water-level declines of over 100 feet for districts where Dr. Schmidt did not estimate water-level declines; Tea Pot Dome, Terra Bella, Lewis Creek and Stone Corral. Dr. Schmidt stated that the aquifers in Tea Pot Dome, Terra Bella and Stone Corral consist of thin alluvial deposits of predominantly fine-grained deposits overlying shallow bedrock. Specifically, Dr. Schmidt indicates that alluvial aquifer underlying Stone Corral is generally less than 150 feet thick. Moreover, Dr. Schmidt stated that

additional pumping in Stone Corral, Teapot Dome and Terra Bella is not sustainable with his predicted rates of water-level declines.   Second, the error associated with estimates in water level changes will affect Dr. Burt's energy consumption estimates.

III. Subsidence

40. Dr. Schmidt estimates depths of future subsidence using estimated groundwater level changes. Subsidence in the Friant service area has primarily resulted from dewatering and compaction of subsurface clays. To the extent that there is future compaction and dewatering of subsurface clays, water will be released from groundwater storage and there will be additional subsidence. Dr. Schmidt estimates subsidence based on his water-level decline estimates. Dr. Schmidt appears to base his calculations on two assumptions. First, he appears to assume future subsidence will be a similar function of water level declines as in the past based on USGS data. Second, Dr. Schmidt states that he estimated subsidence assuming the estimated groundwater level declines shown in Table 4 of his report will be realized as a result of the predicted pumping increases. Except for Shafter-Wasco and Southern San Joaquin MUD, he does not provide estimates of uncertainty associated with subsidence predictions. Dr. Schmidt does not document his method or specific data for estimating subsidence.

41. Subsidence predictions based on historic changes in groundwater levels can be unreliable as discussed below. Vega (1984) and Helm (1984) recommended using methods that rely on quantification of physical processes affecting groundwater flow and drainage from clay layers to predict land subsidence.

42. Dr. Schmidt's first assumption that future subsidence will be uniform within a water district or part of a water district, and will have the same relation to groundwater level as occurred historically, is probably not valid.

43. The ratio of subsidence to head declines varies substantially in space and time. For example, in the Los Banos to Kettlemen City area, Bull and Poland (1975) showed that the ratio of subsidence to head decline varied from 0.01 to 0.08 throughout the area studied. Even within a smaller area on the Cantua Creek alluvial fan, ratios varied from 0.01 to 0.04 within a distance of less than 10 miles. This indicates that the head decline to produce 1 foot of

subsidence within the entire area ranged from 12 to 100 feet. Within the Cantua Creek fan, the head decline to produce 1 foot of subsidence ranged from 25 to 100 feet. Thus, a single subsidence value for a single water district is probably not realistic.

44. These and the other USGS groundwater- subsidence ratios described by Dr. Schmidt were generally determined from water level measurements during historic virgin compaction. If water levels decline below historic lows, compaction may occur in different sediments than were compacted during the USGS subsidence measurements. Thus, these previously developed ratios are not applicable for future subsidence predictions. The nature and type of clay in compacting layers can vary spatially and this will affect the extent of compaction.

45. Compaction of clay sediments in the San Joaquin Valley is a transient non-equilibrium situation which results in time-varying water-level to subsidence ratios and observed residual subsidence. For water levels above historic lows, Dr. Schmidt correctly states that there is continued subsidence in many areas of the San Joaquin Valley. Swanson (1998) documented this subsidence as of 1995.[11] Continuing or residual subsidence indicates that non-equilibrium conditions prevail and that pore pressures in compacting sediments have not reached equilibrium with surrounding aquifers. Until or unless equilibrium of pore pressures is attained, the ratio of subsidence to head decline is a transient value (Vega and others, 1984), and the use of a single constant value is not correct.

46. Transient and spatially variable head decline to subsidence ratios makes predicting subsidence difficult using predicted head declines alone.

47. Moreover, it is unclear what wells Dr. Schmidt is using to predict water level declines for estimating subsidence. Information on well depths and screened intervals is not available in the Department of Water Resources database. Therefore other information was relied upon to determine wells screened solely in the confined zone for estimating subsidence and compaction of confining clays.

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[11] Swanson (1998) delineates 9 areas of continuing subsidence in the San Joaquin Valley. These include the area near Mendota Dam, near the Outside Canal and the Delta-Mendota canals, near the Eastside Bypass, along Highway 152, near the Homeland Canal, along the California Aqueduct near Cantua Creek, along the California Aqueduct in the Lost Hills area and southeast of Maricopa and Highway 99 south of Bakersfield. No subsidence problems have been recognized in the San Joaquin River.

48. Lastly and related to the second assumption, estimated water-level declines are subject to substantial error and disregard future potential changes in land- and water-management practices which may substantially change the magnitude of predicted water level declines and therefore estimated subsidence.

IV. Water quality

49. Dr. Schmidt concludes that reduced surface water deliveries, as a result of a restoration flow schedule, will lead to increased groundwater salinity. He does not quantify the increase and provides no data or analysis to support this conclusion.

50. Groundwater TDS concentrations in the eastern San Joaquin Valley are generally less that 500 mg/L (Bertoldi and others, 1991). The groundwater major-ion chemistry generally reflects surface water draining the Sierra Nevada which recharges the groundwater system (Davis and others, 1957). However, the major—ion chemistry and the TDS concentrations of the groundwater have been altered by agricultural irrigation. TDS concentrations are increasing in some locations. Irrigation water that percolates through the root zone is altered because plants use most of the water and leave salts in the remaining water that percolates to the subsurface. Moreover, irrigation water leaches nitrogen and other elements from fertilizers and amendments that also contribute to TDS concentrations and result in increased concentrations of other constituents.

51. For example, Burow and others (1998) presented evidence for groundwater quality degradation in the eastern San Joaquin Valley. They described the correlation of elevated nitrate and salinity as represented by electrical conductivity in groundwater affected by irrigation of permanent and row crops (the nitrate is from agricultural fertilization). Several of their sites for vineyards and corn, alfalfa and vegetables were in Friant districts. Therefore, the current evidence indicates that irrigation is already degrading groundwater quality in Friant districts.

52. It is currently unclear how reduced deliveries will affect the quality of the deep percolation water over the long term and further analysis is required to estimate the possible incremental increase in the TDS. The analysis of possible impacts of increased pumping

should include measures than can be undertaken by districts to reduce impacts of pumping. These include securing additional surface water supplies and groundwater banking.

V. Seepage

53. Dr. Hradilek describes strategies for mitigating levee seepage resulting from a restoration flow schedule. He outlines engineering designs and associated construction costs related to salmon spawning rehabilitative measures recommended by Dr. Michael Harvey as follows.

54. Dr. Harvey recommends the reconstruction of the levees from San Joaquin River mile (RM) 227-216 to improve levee stability and increase flow capacity. He states that redesign or replacement of the Bifurcation Structure can reduce backwater effects, but advocates installation of a slurry wall to a depth of 60 feet to mitigate seepage. According to Dr. Hradilek's report, the costs estimated for 9 miles of slurry walls along the south bank, and 11 miles of slurry walls along the north bank total $88,705,000.

55. Dr. Harvey states that seepage problems along RM 216-204.8 can be overcome in one of two ways: either by improving 22 miles of existing levees (including installation of slurry walls), or by improving the north levee and removing the south levee and replacing it with a set-back levee. Dr. Hradilek recommends new set-back levees to allow for increased conveyance, with slurry walls along the entire length of the new levees. Estimated costs for 22 miles of slurry walls along this section are $97,575,000.

56. Using hydraulic modeling, Dr. Harvey identifies Reach 4A as a potential seepage risk area contingent to an increase in flow capacity in accordance with habitat reconstruction plans.

57. In order to accommodate proposed increase in flow, Dr. Harvey recommends the removal and set-back of 22 miles of levees from RM 168 – RM 157.2 in Reach 4B. Because of the shallow water table in this area, he also proposes the installation of 44 miles of drains. Dr. Hradilek's proposes the construction of 60-foot deep slurry walls to prevent underseepage at the new levees on both sides of the river. This would require a total of 44 miles of slurry walls, with an estimated cost of $195,149,000.

58. Measures proposed by Dr. Hradilek are excessive because the level of seepage attributable to additional restoration flows is overstated, and slurry walls are not an appropriate seepage mitigation solution in this circumstance.

59. Based on the current level of hydrologic analysis, it is uncertain whether increased seepage will result from restoration flows in the River. Seepage results from water movement in response to a hydraulic pressure difference between the River channel and adjacent lands, and thus seepage is largely determined by the stage of the river relative to groundwater levels on adjacent lands. Quantification of seepage to lands requires an analysis of the relation of water levels in the river and adjacent groundwater levels. If and when restoration measures cause an increase in river stage relative to groundwater levels that results in a hydraulic gradient towards adjacent lands, seepage can occur. Conversely, if restoration measures result in decreased stage, relative to groundwater levels, then reductions in seepage may occur.

60. Below I summarize available information about seepage in Reaches 2 and 4.

61. McBain and Trush (2002) identified levee seepage as a concern along Subreach 2A, from RM 220 to about RM 216 when high flows occur. They described seepage occurrence along approximately six miles of Subreach 2B. However, in making this statement, the authors refer to their Figure 5-7, which shows only RM 220 - RM 216 (within Subreach 2A) as being affected by “levee seepage and levee failures”.

62. Operations at the Chowchilla Bifurcation Structure and the Mendota Pool currently increase river stage and thereby appear to increase the hydrostatic pressure gradient between the river and adjacent lands. This backwater effect may cause seepage in Subreach 2A (and possibly along 2B). (McBain and Trush, 2002). Changes in the operations of Mendota Pool or the Chowchilla Bifurcation structure which decrease the backwater effect of these facilities, particularly at relatively high flows, are likely to decrease any seepage impacts that may occur

63. Unmitigated seepage from the River does not appear to currently occur in Reach 4.

64. Historic groundwater levels along Reach 4 indicate a shallow (generally within 15 feet of land surface) water table in the vicinity of the river. Groundwater levels have been measured at levels several feet above the elevation of the riverbed.

65. Groundwater flows toward the river along Reach 4 from the western San Joaquin Valley (McBain and Trush, 2002; Schmidt 1997).

66. The proposed use of slurry walls is not a prudent response to the seepage which may occur as a result of a restoration flow. The incremental seepage (e.g., the change in the existing condition) will occur in more limited areas than apparently presumed by Dr. Hradilek in his testimony. Where incremental seepage occurs, alternatives to slurry walls will be prudent.

67. Below, I summarize inconsistencies and problems with Dr. Hradilek's proposal relative to available information about seepage and drainage in the San Joaquin Valley and possible incremental effects relative to proposed additional river flows.

68. Slurry walls are being proposed along more than 20 miles of the levee in Reach 2. However, McBain and Trush (2002) only identified 3 or 4 miles of levee in Reach 2a and about 6 miles in Reach 2b, reportedly at risk to seepage. It is therefore unclear why 22 miles of slurry walls are required along the entire reach from the bifurcation structure to the Mendota Pool. The number of river miles requiring slurry walls appears overstated, given what is currently known about river seepage.

69. There is evidence that the bifurcation structure and Mendota Pool can cause backwater and may be part of the seepage problem under historic and present-day operations in which high flows occurred about one-third of the time.

70. Dr. Kondolf reports that additional flow releases will result in higher flows relative to historic conditions in some the wet-normal years in the early spring. Dr. Kondolf also reports that additional restoration flows can potentially reduce the magnitude and duration of high flows in wetter years. Based on this information, it does not appear that increases in seepage warrant the level of seepage mitigation proposed by Dr. Hradilek. However, additional analysis is required to quantify the relation of River stage to adjacent groundwater levels.

71. It is questionable whether levee seepage from the river along Reach 4 will occur if flow is increased. Historic data indicates that groundwater levels have been above the bottom of the river, and groundwater flows towards the river from west to east. For seepage to be problem, increased flows must result in hydraulic gradients away from the river in a location where historical data indicate flow is towards the river. It is unclear how groundwater-surface water interactions will change as a consequence of increased flows in Reach 4.

72. Proposed slurry walls, which are specified to a depth of 60 feet, could potentially interfere with the natural, shallow groundwater flow along Reach 4. Since groundwater levels are generally within 15 of land surface west of the River, slurry walls that extend over 20 feet below land surface could impede the natural flow of groundwater from west to east and cause additional high groundwater problems. The shallow groundwater problem west of reach 4 is the primarily the result of irrigation with surface water. Slurry walls could exacerbate the shallow groundwater problem by preventing the natural flow of groundwater from west to east near and beneath the River.

73. Seepage and high groundwater problems in the San Joaquin Valley are typically mitigated using drainage systems. Interceptor ditches and tile drains are in operation along the back side of levees in Reach 2A and within 4 miles of the river in Reach 4 to collect shallow groundwater (McBain and Trush, 2002; Deverel and others, 1984). In many instances, drainage ditches have been modified to periodically redirect the water to beneficial uses in other fields (McBain and Trush, 2002). Drainage systems along the Delta Mendota Canal pump seepage water into the canal.

74. Consistent with recommendations by Dr. Harvey, drainage systems are a more reasonable solution if seepage is a problem. Additional hydrologic analysis is required to determine if and where seepage mitigation is required.

75. Dr. Harvey proposes the installation of 44 miles of drains from RM 168.2 – RM 147.3 in Reach 4B because of existing shallow water levels in this area. This reach of the river, however, is abutted by several miles of wildlife refuge. The Grasslands Wildlife Management Area extends for approximately 1.2 miles on the east side of the river and 2.4

miles on the west side. The San Luis National Wildlife Refuge abuts Reach 4B upstream of the Mariposa Bypass for 4.5 miles on the west side of the river. Since agricultural lands are not adjacent to the entire length of this reach, it is apparent that the extent of the proposed drains is overstated. Dr. Hradilek does not address the installation of subsurface drains in his report.

76. There are numerous examples of subsurface drainage systems adjacent to water conveyance features in the San Joaquin Valley. For example, tile drains and closed sumps were installed in the Firebaugh Canal Water District during construction of the Delta-Mendota Canal (DMC). The DMC is unlined in this portion of its reach (USBR, 1953). These drainage systems, which collect seepage from the canal, have operated for over 50 years (USBR, 2005a) and are currently being used to return subsurface drain water to the canal.

77. Drainage systems operate in similar ways in other parts of California. For example, drainage systems in the Sacramento-San Joaquin Delta collect seepage through levees that separate farmed areas as much as 30 feet below channel water elevations. Crops use this seepage water and drainage systems pump water back to the channel. This system of drainage has operated since the early 1900’s.

VI. <u>Supplementation of August 15, 2005 Expert Report</u>

78. In my August 15, 2005 report, I described and showed the relation of Delta Mendota Canal deliveries to river gains in Figure 1.22. I have subsequently determined that some of the data used in the graph was in error. I now attach Figure 3 and provide the following as my correct opinion on this issue. My conclusion expressed on the relation of estimated River gains in Reach 4 relative to deliveries has not changed. I elaborate here.

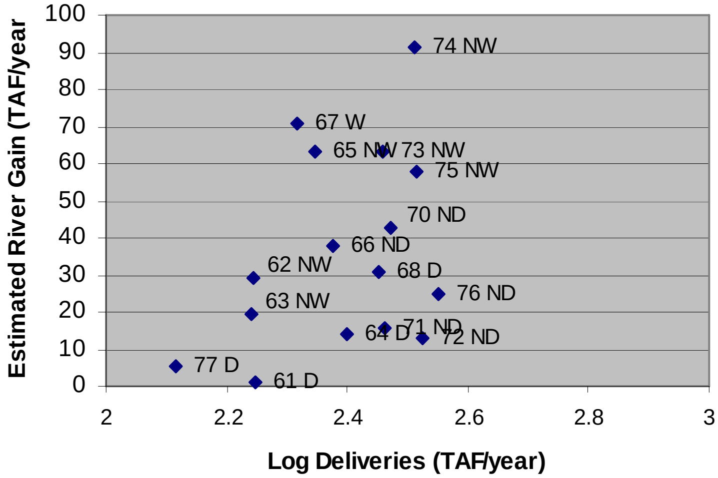

Figure 3. Relation Of Measured Gains In Reach 4 To Deliveries.[12] *Labels next to data points in show the year and water year type (W = wet, NW = normal wet, ND = normal dry D = dry).*

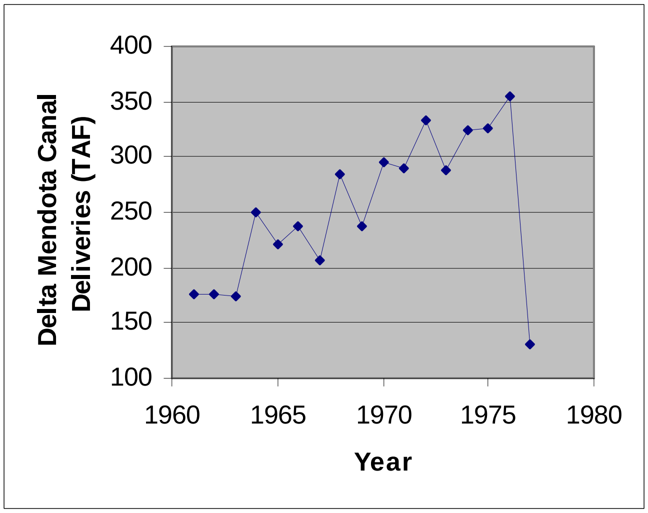

Figure 4. Annual Deliveries From 1961 to 1977.

79. I related the magnitude of gain in River Reach 4 related to deliveries via the Delta Mendota Canal (DMC) and San Luis Canal from 1961 to 1977. Figure 3 shows the relation of annual river gains estimated by Mullen and Nady (1985) to annual deliveries to

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[12] River gains and deliveries for 1969 were excluded from the graph.

selected water districts via the Delta Mendota and San Luis Canals.[13] These canals were increasing deliveries during this time period in areas upgradient of River Reach 4 (Figure 4) and probably contributed to increased groundwater levels. Figure 3 indicates that increasing water deliveries may have contributed to increasing River gains in Reach 4. Specifically, gains tend to increase with increasing deliveries. Figure 3 also shows that water year type also substantially influences the relation. Dry and normal dry year types generally show indicate less gain relative to deliveries. Wet and normal wet year types generally show more gain relative to deliveries. In general, deliveries to the western San Joaquin Valley resulted in increasing groundwater levels in the western San Joaquin Valley since the 1950's (Belitz and Heimes, 1990).

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[13] Water districts included are ass follows Centinella, Central California I.D, Davis, Eagle Field, Grassland, Hamburg, Mercy Springs, Oro Loma, Panoche, Quinto, Romero, San Luis, and Widren. Water delivery data is from annual USBR Reports of Operations from 1961-1977.

Dated: September 19, 2005

Steven J. Deverel, PhD.