

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

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

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

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

23 7. Dr. Hradilek proposes slurry walls adjacent to Reaches 2 and 4. The proposed
24 use of slurry walls is not a prudent response to the seepage which may occur as a result of a
25 restoration flow. The incremental seepage (e.g., the change in the existing condition) will
26 probably occur in more limited areas than apparently presumed by Dr. Hradilek in his
27 testimony. Where incremental seepage occurs, alternatives to slurry walls such as drainage
28 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

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

3
4 **MATERIALS RELIED UPON TO FORM MY OPINION**

5 8. In formulating the opinions stated in this expert report, I have considered the
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5 STATEMENT OF EXPERT OPINION

6 **I. Increased Pumping To Meet Demand**

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

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

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

- 24 a. The Fresno Irrigation District has been recharging groundwater through the
25 use of recharge ponds for over 40 years to take full advantage of their SWP
26 entitlement (Albert Steele, California Department of Water Resources,
27 personal communication, 2005). Fresno Irrigation District is planning a
28

¹ Dr. Ken Kirby described the possibilities for additional water supplies in Friant districts.
Supplemental Report of Dr. Steven J. Deverel
E.D. Cal. No. Civ. 88-1658 LKK

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

- 3 b. The City of Fresno operates the Leaky Acres recharge facility where water
4 percolates through the first 10 feet of sediment, is collected by tile drains,
5 and is injected through the impervious clay to the underlying aquifer.
- 6 c. The Arvin-Edison Water Storage District, through groundwater recharge,
7 has raised groundwater levels and reduced (by dilution) the concentration of
8 boron in the groundwater (Arvin-Edison Water Storage District, 2003). The
9 recharge to groundwater over 50 years in this district is estimated to be
10 204,000 acre-feet (AF).
- 11 d. The Lower Tule River Irrigation District (2003) facilities provide
12 groundwater recharge through the unlined earthen canals along with
13 recharge and wildlife habitat basins. The overall impact of the excess
14 surface water supply is to reduce the groundwater overdraft that occurs
15 within the basin and assist the domestic water users that rely only on
16 groundwater for their water supply.
- 17 e. The Kaweah Delta Water Conservation District (Fugro, 2003) successfully
18 uses groundwater recharge facilities. Several Friant districts are part of this
19 water conservation district.

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

23
24 **II. Predicted Groundwater Levels**

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

27
28 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.

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

8 ***Model Validity***

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

- 12 a. What errors (uncertainty) are in the data used to develop the model?
- 13 b. How well does the model reproduce observed groundwater-level changes
14 during the period for which it was developed?
- 15 c. Does the model represent the physical processes that affect water levels?

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

27 ³ Dr. Schmidt's model looks like a regression analysis in that it contains a dependent variable, water level
28 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.

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

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

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

$$12 \quad \text{Pumping} = [ET_{irrp} - (IDSW) \times CEF \times AE/100] \times 100/AE$$

13 where

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

15 *ET_{irrp}* = Estimated evapotranspiration (ET) of irrigation water⁵, not derated for
16 bare spots and poor vigor in a field;

17 *IDSW* = Reported surface water available to each irrigation district;

18 *CEF* = Estimated conveyance efficiency⁶ of the irrigation districts divided by
19 100; and,

20 *AE* = Estimated application efficiency⁷ of on-farm irrigation.

21
22 ⁴ On page 3, Dr. Burt explains the difference between net and gross pumping. He cites the paper Burt and
23 Styles (2004). This paper describes appraisal of irrigation systems and does not appear to have anything to do
24 with groundwater pumping. At best, this reference alludes to the inefficiencies associated with irrigation
25 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.

26 ⁵ Evapotranspiration of irrigation water, not derated for bare spots and poor vigor in a field (*ET_{irrp}*) is the
27 estimated total annual evapotranspiration requirement of the crop less the portion met by precipitation.

28 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 $\pm 13\%$. Hence, the possible error in calculated gross groundwater pumpage due to the uncertainty in estimated evapotranspiration is about $\pm 13\%$. 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 recalculate 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 $\pm 13\%$ 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.

\\

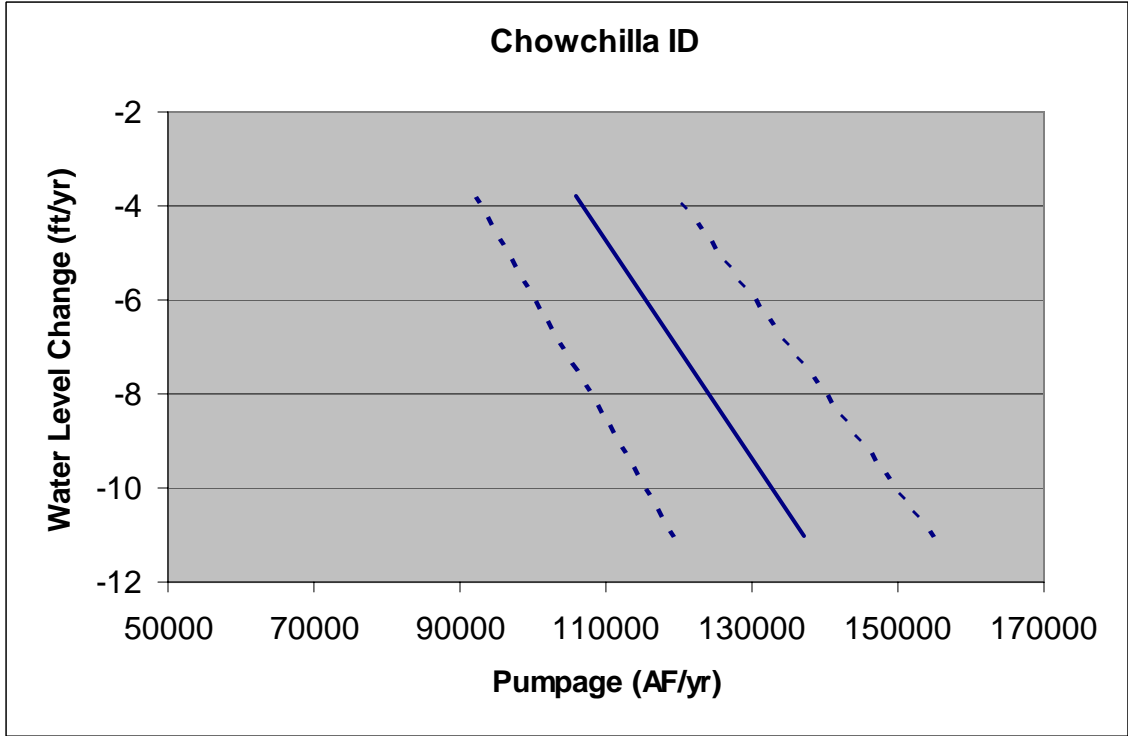


Figure 1. Relation Of Water-Level Decline To Pumping Estimates For Chowchilla Water District. *The solid line represents the original relation developed by Dr. Schmidt. The dashed lines represent the water-level-pumping equation with incorporation of error described in Burt and others (2002).*

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.

\\

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

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.

1 is equal to irrigation water beneficially used divided by the difference of irrigation water
2 applied and the change in storage of irrigation water. In the paper, Dr. Burt and his coauthors
3 present a block diagram that shows the general water balance for a representative volume
4 where irrigation water is applied. Dr. Burt and his coauthors further state in the paper that
5 “boundaries of the region being discussed and an associated transit-time period must be clearly
6 defined.” In Appendix A, Dr. Burt states that the time period is 5-years of recent conditions
7 (1999-2003),⁹ and the boundaries are the spatial boundaries of concern are the Friant Service
8 Area and extend down into the aquifer. Dr. Burt does not define how far the boundaries
9 extend into the aquifer.

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

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

23 28. *How well does the model reproduce observed groundwater-level changes during*
24 *the period for which it was developed?* Model reliability is determined by comparing the
25 calculated water-level changes against observed values during the period from which the model
26

27 ⁹ Dr. Burt acknowledges that 1999-2003 period is below average. Specifically, runoff during this period was
28 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

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

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

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

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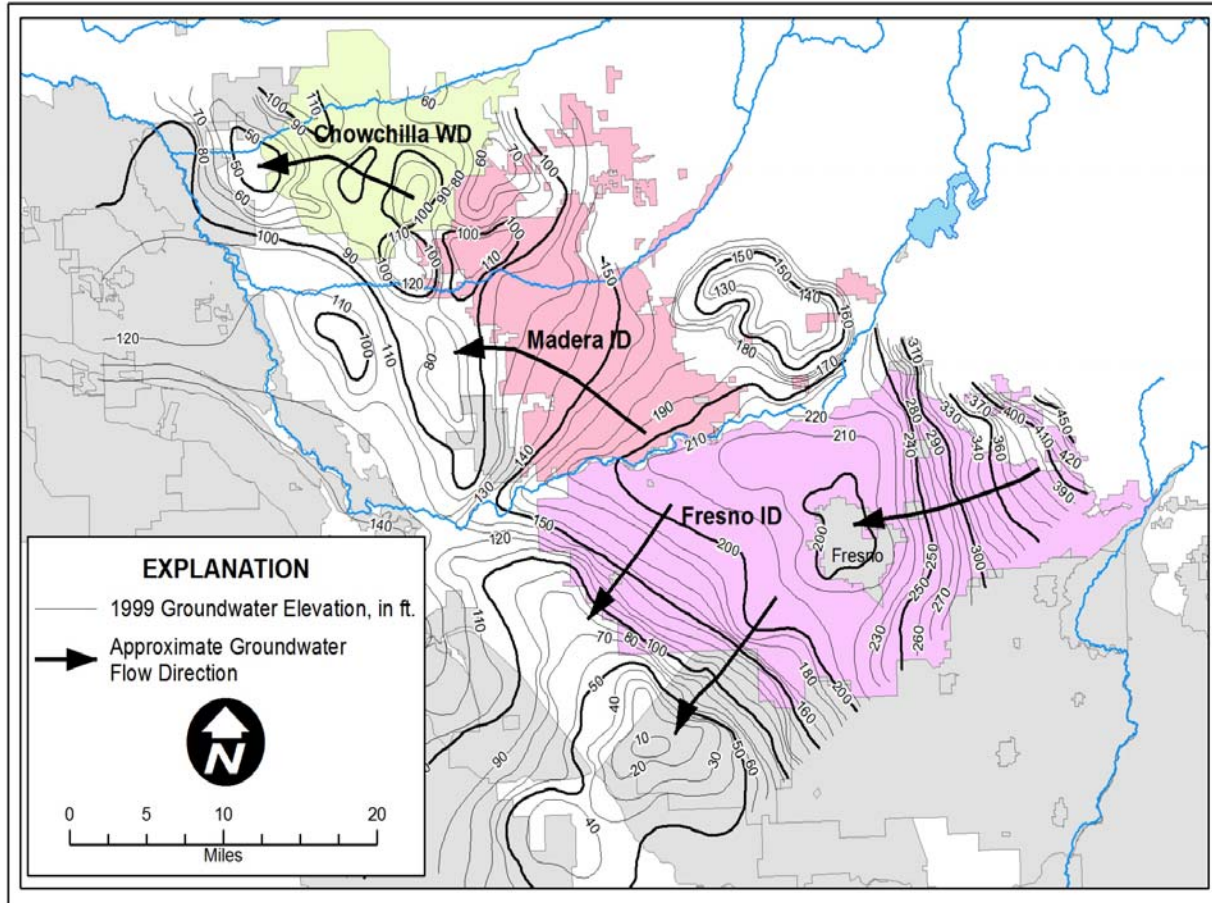


Figure 2. Groundwater Contours And Generalized Directions Of Groundwater Flow For 1999. (Adapted from Department of Water Resources groundwater level map for the unconfined zone).

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 $\pm 24\%$ 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 Stienner 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

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

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

20 38. Table 5 also shows that the average pumping for 1987 to 1998 shown in Dr.
21 Schmidt's Table 2 are comparable to the estimated pumping with the Kondolf hydrograph.
22 Specifically, for all districts except Arvin-Edison, Madera and Tulare, pumping estimates
23 shown in column 4 of Table 5 are essentially equal to or less than the 1987-1998 average
24 pumping from Dr. Schmidt's Table 2 (column 5). For the remaining districts, the difference in
25 estimated pumping is well within the 15% error for estimating pumping described above. This
26 explains the prediction of smaller water level declines or rises associated with the Kondolf
27 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

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

4 5 **III. Subsidence**

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

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

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

25 43. The ratio of subsidence to head declines varies substantially in space and time.
26 For example, in the Los Banos to Kettlemen City area, Bull and Poland (1975) showed that the
27 ratio of subsidence to head decline varied from 0.01 to 0.08 throughout the area studied. Even
28 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

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

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

11 45. Compaction of clay sediments in the San Joaquin Valley is a transient non-
12 equilibrium situation which results in time-varying water-level to subsidence ratios and
13 observed residual subsidence. For water levels above historic lows, Dr. Schmidt correctly
14 states that there is continued subsidence in many areas of the San Joaquin Valley. Swanson
15 (1998) documented this subsidence as of 1995.¹¹ Continuing or residual subsidence indicates
16 that non-equilibrium conditions prevail and that pore pressures in compacting sediments have
17 not reached equilibrium with surrounding aquifers. Until or unless equilibrium of pore
18 pressures is attained, the ratio of subsidence to head decline is a transient value (Vega and
19 others, 1984), and the use of a single constant value is not correct.

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

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

27 ¹¹ Swanson (1998) delineates 9 areas of continuing subsidence in the San Joaquin Valley. These include the
28 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.

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

5
6 **IV. Water quality**

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

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

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

27 52. It is currently unclear how reduced deliveries will affect the quality of the deep
28 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

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

3
4 **V. Seepage**

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

9 54. Dr. Harvey recommends the reconstruction of the levees from San Joaquin
10 River mile (RM) 227-216 to improve levee stability and increase flow capacity. He states that
11 redesign or replacement of the Bifurcation Structure can reduce backwater effects, but
12 advocates installation of a slurry wall to a depth of 60 feet to mitigate seepage. According to
13 Dr. Hradilek's report, the costs estimated for 9 miles of slurry walls along the south bank, and
14 11 miles of slurry walls along the north bank total \$88,705,000.

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

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

24 57. In order to accommodate proposed increase in flow, Dr. Harvey recommends
25 the removal and set-back of 22 miles of levees from RM 168 – RM 157.2 in Reach 4B.
26 Because of the shallow water table in this area, he also proposes the installation of 44 miles of
27 drains. Dr. Hradilek's proposes the construction of 60-foot deep slurry walls to prevent
28 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.

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

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

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

15 61. McBain and Trush (2002) identified levee seepage as a concern along Subreach
16 2A, from RM 220 to about RM 216 when high flows occur. They described seepage
17 occurrence along approximately six miles of Subreach 2B. However, in making this statement,
18 the authors refer to their Figure 5-7, which shows only RM 220 - RM 216 (within Subreach
19 2A) as being affected by “levee seepage and levee failures”.

20 62. Operations at the Chowchilla Bifurcation Structure and the Mendota Pool
21 currently increase river stage and thereby appear to increase the hydrostatic pressure gradient
22 between the river and adjacent lands. This backwater effect may cause seepage in Subreach
23 2A (and possibly along 2B). (McBain and Trush, 2002). Changes in the operations of Mendota
24 Pool or the Chowchilla Bifurcation structure which decrease the backwater effect of these
25 facilities, particularly at relatively high flows, are likely to decrease any seepage impacts that
26 may occur

27 63. Unmitigated seepage from the River does not appear to currently occur in Reach
28 4.

1 64. Historic groundwater levels along Reach 4 indicate a shallow (generally within
2 15 feet of land surface) water table in the vicinity of the river. Groundwater levels have been
3 measured at levels several feet above the elevation of the riverbed.

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

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

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

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

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

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

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

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

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

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

26 75. Dr. Harvey proposes the installation of 44 miles of drains from RM 168.2 – RM
27 147.3 in Reach 4B because of existing shallow water levels in this area. This reach of the
28 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

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

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

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

17
18 **VI. Supplementation of August 15, 2005 Expert Report**

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

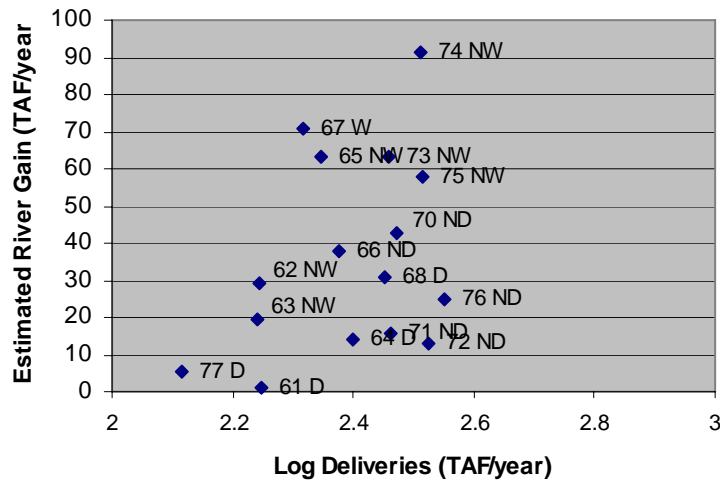


Figure 3. Relation Of Measured Gains In Reach 4 To Deliveries.¹² Labels next to data points in show the year and water year type (W = wet, NW = normal wet, ND = normal dry D = dry).

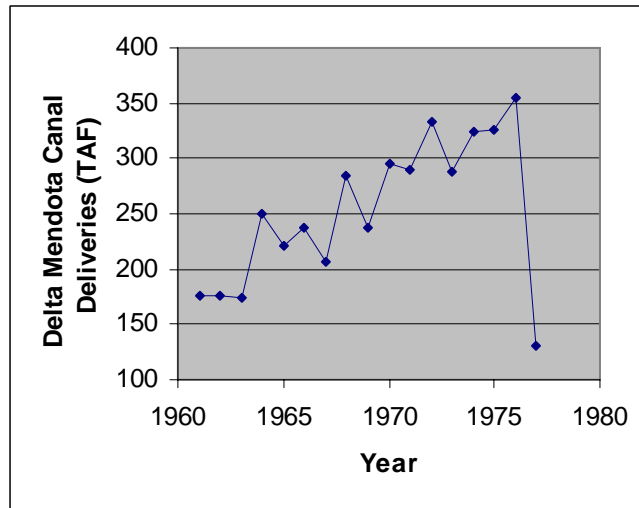


Figure 4. Annual Deliveries From 1961 to 1977.

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

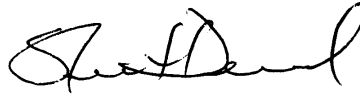
¹² River gains and deliveries for 1969 were excluded from the graph.

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

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28 ¹³ Water districts included are as 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.

1 Dated: September 19, 2005

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6 Steven J. Deverel, PhD.

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