Supplemental Report

of

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on

Friant Service Area

Estimated Increased Energy Use Under the Kondolf Hydrograph Scenario by 2025

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ITRC

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Assignment

I was asked to provide technical information based on the following instructions regarding irrigation water diverted from the San Joaquin River into the Friant-Kern Canal and the Madera Canal:

1. Comment on statement in Kirby's Report – "Improve urban and agricultural water use efficiency – can reduce diversion and pumping requirements and provide some additional supply where irrecoverable losses can be reduced."

2. Describe the energy requirement associated with transfers, purchases, exchanges and recirculation of water starting at the delta, conveyed through the California Aqueduct and Cross Valley Canal to the Friant-Kern Canal.

3. Modified Topic #3 – An estimate of the increased energy use by year 2025 under the Kondolf release scenario.

This report contains my conclusions related to these topics.

Comment on Kirby statement regarding improved water use efficiency

In the Kirby report in paragraph 70, item L (Page 25, Lines 9-11), he states:

"Improve urban and agricultural water use efficiency – can reduce diversion and pumping requirements and provide some additional supply where irrecoverable losses can be reduced."

In Topic #1 of my original report, I show a net extraction of groundwater of approximately 153 thousand acre-feet (TAF) throughout the Friant service area. The Friant service area does not have irrecoverable losses in terms of on-farm water use efficiency. All deep percolation associated with urban and agricultural irrigation inefficiencies of first-time usage is eventually recovered through groundwater pumping. In some other areas of the state, deep percolation (of canal seepage and over-irrigation) either flows to the ocean (e.g., San Francisco) or into a salty groundwater (e.g., on west side of the San Joaquin Valley). But in the Friant service area, the deep percolation flows to groundwater basins that are of good quality and that are the source of irrigation water.

Kirby's statement ignores the very real difference between the spatial boundaries that must be defined whenever "water use efficiency" or "irrigation efficiency" is defined. He is talking about "on-farm" or "house-hold" efficiency, whereas the question is one of "basin" or "project-level" efficiency. In the case of conjunctive use areas, the efficiency of first-time application has little or no importance in determining the basin or service-area efficiency.

As stated in my expert report, any cutback in surface water supply *into the project* will lead to an increase in net groundwater extraction. Net groundwater extraction is the crop irrigation and urban water use demand minus surface inflows regardless of farm or household water use inefficiencies that result in deep percolation. Deep percolation and seepage losses will only impact the gross (not the net) groundwater pumping, which is important in terms of energy usage but not in terms of water required to meet urban and crop demands. To simplify – even if it were possible to achieve 100% water use efficiency (assuming all the inefficiency is due to deep percolation), under current conditions the Friant service area would still have a net groundwater extraction of approximately 153 TAF on average.

Dr. Kirby's statement indicates a mis-understanding of the hydrology of the Friant service area and the surrounding region that immediately borders the area. Grouping the Friant service area into the Tulare Lake and San Joaquin River Hydrologic regions could be the source of confusion. On the west side of the San Joaquin Valley north of Kettleman City, water use efficiency—specifically, distribution uniformity of water application and proper irrigation scheduling —are very important in terms of the amount of surface water that needs to be diverted. Because the west side of the valley has a poor-quality, shallow groundwater table, irrigation water that deep percolates to the groundwater cannot usually be recovered without significant degradation of irrigation water quality. Groundwater on the west side is pumped from deeper aquifers recharged from outside of this area. However, the central region and east side of the San Joaquin Valley (Friant service area) do not have poor-quality, shallow groundwater areas.

Discussion of increased energy required to transfer, purchase, and recirculate water

Dr. Kirby suggests in his report that districts impacted by surface water reduction would be able to make up the reductions through water transfers, purchases, and/or recirculation of San Joaquin River releases. Kirby did not, however, analyze constraints including potential lack of capacity of the conveyance systems, impact on flow directions in the Delta, lack of water availability, and increased energy required to convey this water.

In this section I will concentrate on analyzing the energy required to convey water from the Delta, through the Harvey Banks Pumping Plant, down the aqueduct, through the Dos Amigos Pumping Plant, through the pumps in the Cross Valley Canal, and finally to the Friant-Kern Canal. The figure below shows the path of conveyance and the energy required to pump one acre-foot of water through each facility.

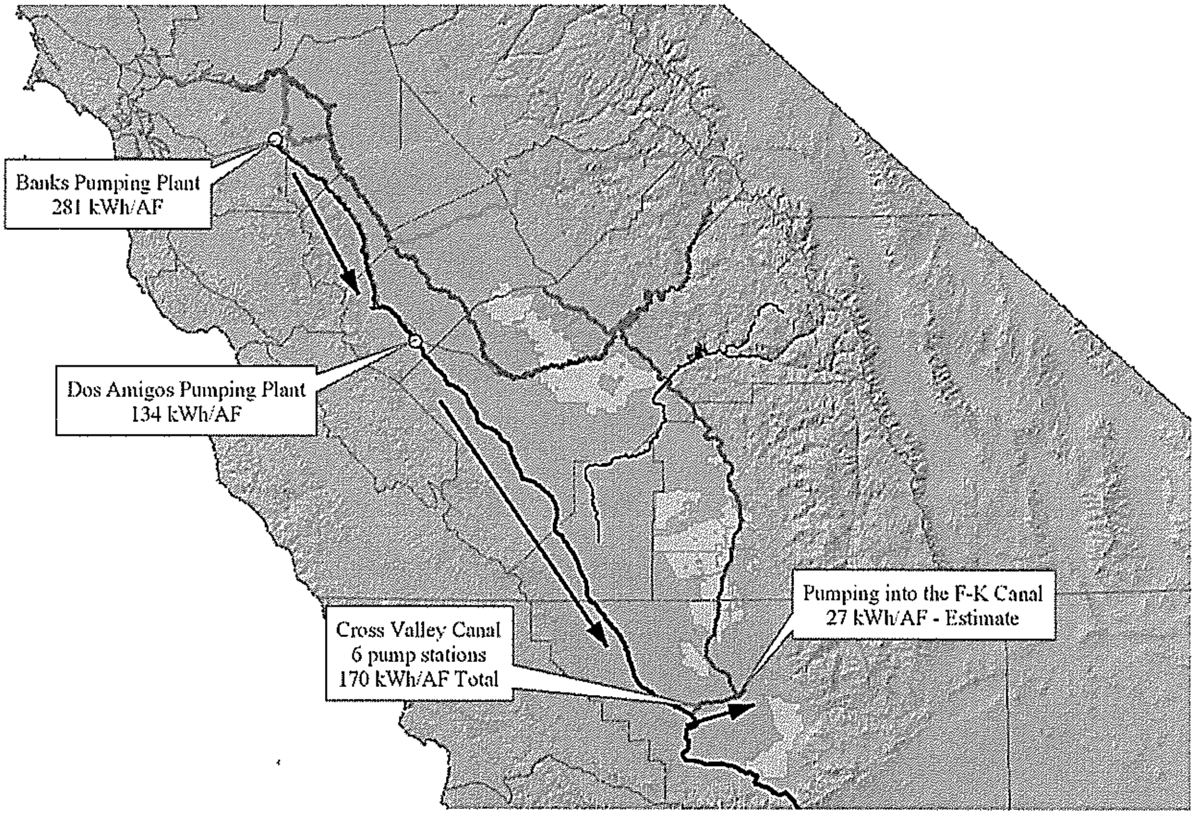

Figure 1. Map showing the path of conveyance from the Delta to the Friant-Kern Canal and pump station energy requirements (source: Calif. DWR)

The total energy required to move water from Banks Pumping Plant to the Friant-Kern Canal is approximately **610 kWh/AF**. Arvin-Edison Water Storage District (AEWSD) is the only Friant contractor downstream of the Cross Valley Canal/Friant-Kern Canal connection. Shafter Wasco WSD and South San Joaquin MUD could also obtain water from the Cross Valley Canal if this water were pumped back up into the F-K Canal. Therefore, the value of 610 includes this 27 kWh/AF.

Because of possible capacity issues and limited water availability during the irrigation season, at least some portion of the transferred, purchased, and recycled water will have to be delivered out of season and stored in the groundwater aquifer. The actual energy required to accomplish this scenario could be greater than **995 kWh/AF** (610+385 needed for groundwater recovery) on average over the service area, assuming no change in groundwater elevation.

Dan Steiner estimates that under the Kondolf San Joaquin River release scenario, the Friant service area surface water supplies will be reduced by approximately 141,000 AF on average. For simplicity of illustration, assume all of the reduction will be transferred, purchased, and/or recirculated to the Friant service area. The total electricity required will be between 86,000,000 kWh and 140,300,000 kWh per year (with energy requirements of 610 kWh/AF and 995 kWh/AF respectively).

To give perspective on the amount of generation required to provide this energy:

- Semitropic Water Storage District recently installed a 1 MW photovoltaic (PV) solar generating facility (estimated to produce 1.7 million kWh/year) for $6 million.
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- Using the Semitropic WSD as an example, the cost just to install a PV system to support this extra pumping would be about
  - **$304** million for the low estimate
  - **$494** million for the high estimate

The alternative would be to put this additional load on top of the already over-extended electrical grid and generating capacity in California. It is difficult to visualize how this would not have negative impact on California's environment. It would, in fact, be in direct contradiction to efforts by the California Energy Commission, the Legislature, and others to ***reduce*** energy consumption.

Another important consideration is the operation of the Friant-Kern/Cross Valley Canal connection itself, plus the capacity of the Cross Valley Canal.

It is likely that millions of dollars would need to be spent on a large regulating reservoir, additional pumps, new transmission lines, increase in canal lining height, etc. – all with additional annual maintenance and operational requirements.

Topic #3 (Modified from Original Expert Report) – Increased Groundwater Pumping Energy Requirement under the Kondolf scenario

Modified **Table 4** shows the annual increase in groundwater pumping energy requirements for the Kondolf release scenario after 20 years. For this analysis the gross groundwater pumping shown in the Modified **Table 4** is the average gross groundwater pumping from 1999-2003, shown in **Table 3** of my original expert report. Modified **Appendix C** describes the methodology used to determine pumping energy requirements.

The increase in groundwater extraction is equal to the average year reduction in surface water deliveries under the Kondolf Release scenario as modeled by Daniel Steiner.

The estimates in **Table 4** do not include additional pumping energy requirements for areas outside the Friant districts that will be impacted by the lower groundwater levels.

Modified Table 4. Increased groundwater pumping energy requirement after 20 years of average surface water reduction under the Kondolf release scenario.

	A	B	C	D	(D*B)+[A*(D-C)]
	1999-2003	Kondolf	Current (2003)	Kondolf	Kondolf
	Est. Gross Groundwater Extraction	Increase in Groundwater Extraction	Groundwater Pumping Requirement		Increased Energy Requirement after 20 Years
District	**AF/Year**	**AF/Year**	**kWh/AF**	**kWh/AF**	**kWh/Year**
ARVIN-EDISON W.S.D.	199,263	25,570	810	1,280	126,446,425
DELANO-EARLIMART I.D.	25,321	10,863	367	598	12,334,185
SHAFTER-WASCO I.D.	56,056	5,399	646	1,009	25,812,596
SOUTHERN SAN JOAQUIN MUD	50,288	8,439	358	559	14,856,078
SAUCELITO I.D.	14,926	3,504	364	609	5,798,467
TEA POT DOME W.D.	1,982	359	325	564	676,298
TERRA BELLA I.D.	13,686	1,388	295	530	3,942,515
LOWER TULE RIVER I.D.	150,131	20,993	344	632	56,464,067
PORTERVILLE I.D.	25,263	3,043	139	302	5,049,928
TULARE I.D.	82,519	12,138	315	507	21,999,682
EXETER I.D.	21,771	1,993	168	296	3,360,623
IVANHOE I.D.	17,077	968	188	291	2,044,280
LINDMORE I.D.	36,773	3,250	158	348	8,094,350
LINDSAY-STRATHMORE I.D.	14,933	1,317	139	158	486,142
LEWIS CREEK W.D.	1,539	69	129	147	38,253
ORANGE COVE I.D.	44,790	1,877	100	280	8,580,914
STONE CORRAL I.D.	10,015	479	110	291	1,956,542
*FRESNO I.D.**	*73,275*	*5,692*	*180*	*180*	*1,025,725*
*GARFIELD W.D.**	*40*	*168*	*321*	*321*	*53,786*
*INTERNATIONAL W.D.**	*542*	*57*	*124*	*124*	*7,118*
CHOWCHILLA W.D.	109,439	14,777	302	639	46,276,400
MADERA I.D.	183,317	18,186	302	507	46,753,007
GRAVELLY FORD W.D.	19,743	1,063	283	484	4,478,510
Total	**1,152,690**	**141,592**			**396,535,892**

* *The change in groundwater level for Fresno ID, Garfield WD, and International WD was assumed to be zero after 20 years because the increase in groundwater extraction was small compared to the combined service area.*

REFERENCES

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Solomon, K. and C.M. Burt. 1998. Irrigation Sagacity: A Measure of Prudent Water Use. Irrigation Science 18(3):135-140.

Modified Appendix C – Topic 3

Estimated Irrigation Water Well Pumping Energy Requirements by Year 2025 Under the Kondolf Release Scenario

Appendix C (Modified from original expert report)

Estimated Irrigation Water Well Pumping Energy Requirements by Year 2025 Under the Kondolf Release Scenario

Reductions in surface irrigation water deliveries associated with increased releases to the San Joaquin River will create increased demand for groundwater pumping. The average gross irrigation water pumping from years 1999-2003 was used for this analysis. These years of detailed study were selected because they represent recent conditions.

1. Present Volume of Groundwater Pumping

For this analysis, I assumed that the average gross volume of groundwater pumping in **Table C1** would not change from the present to year 2025 if there is **NO CHANGE** in deliveries to Friant districts. This assumes no change in irrigated acreage, crop mix, or crop evapotranspiration demands. Undoubtedly, there would be a change in crop mix due to normal market forces – even without a change in water availability from the Friant system. However, it is beyond the scope of this analysis to speculate on those changes.

The overall goal of this analysis is to estimate the increase in energy use after 20 years of surface water ***reductions*** to the Friant districts. Therefore, the gross groundwater pumping by 2025 will be used for the increased energy use estimates.

Table C1. 1999-2003 average volume of gross irrigation well pumping in each district assuming no change in Friant water availability

District	Gross Irrigation Well Pumping 1999	2000	2001	2002	2003	1999-2003 Average Gross Irrigation Well Pumping
	AF	AF	AF	AF	AF	AF
ARVIN-EDISON W.S.D.	162,000	162,794	254,962	232,878	183,680	199,263
DELANO-EARLIMART I.D.	23,714	17,331	30,885	31,273	23,402	25,321
SHAFTER-WASCO I.D.	57,464	54,171	54,105	67,177	47,365	56,056
SOUTHERN SAN JOAQUIN MUD	59,767	42,106	50,945	60,650	37,971	50,288
SAUCELITO I.D.	7,376	1,356	23,294	23,983	18,623	14,926
TEA POT DOME W.D.	302	2,239	2,115	2,346	2,907	1,982
TERRA BELLA I.D.	17,921	15,966	12,031	10,083	12,430	13,686
LOWER TULE RIVER I.D.	119,121	85,455	206,957	200,232	138,889	150,131
PORTERVILLE I.D.	26,048	22,187	26,350	25,288	26,443	25,263
TULARE I.D.	72,751	28,562	134,371	117,218	59,693	82,519
EXETER I.D.	20,785	21,541	21,073	22,175	23,279	21,771
IVANHOE I.D.	16,597	18,289	16,824	18,181	15,496	17,077
LINDMORE I.D.	35,203	37,819	37,366	40,332	33,142	36,773
LINDSAY-STRATHMORE I.D.	12,606	15,881	13,326	13,601	19,252	14,933
LEWIS CREEK W.D.	895	1,913	2,301	1,160	1,424	1,539
ORANGE COVE I.D.	44,136	49,093	42,903	42,918	44,902	44,790
STONE CORRAL I.D.	11,462	10,650	9,800	8,896	9,267	10,015
FRESNO I.D.	33,729	41,752	176,467	79,548	34,879	73,275
GARFIELD W.D.	0	0	44	0	158	40
INTERNATIONAL W.D.	670	690	431	371	550	542
CHOWCHILLA W.D.	76,308	77,632	116,579	149,399	127,277	109,439
MADERA I.D.	155,105	145,597	212,958	211,445	191,482	183,317
GRAVELLY FORD W.D.	20,814	19,847	22,199	18,105	17,749	19,743
Total	**974,775**	**872,871**	**1,468,285**	**1,377,259**	**1,070,259**	**1,152,690**

2. Estimated increase in groundwater extraction per year under Kondolf release scenario

Table C2 shows the increase in annual groundwater extraction due directly to reduction in surface deliveries (from Dan Steiner's model). The actual average annual volume of surface water reduction for irrigation districts under the Kondolf release scenario is 141,592 AF.

Table C2. Increase in average annual groundwater extraction from Dan Steiner's surface water reductions to each district under the Kondolf release scenario

District	Steiner Est. Increase in Groundwater Extraction AF/Year
ARVIN-EDISON W.S.D.	25,570
DELANO-EARLIMART I.D.	10,863
SHAFTER-WASCO I.D.	5,399
SOUTHERN SAN JOAQUIN MUD	8,439
SAUCELITO I.D.	3,504
TEA POT DOME W.D.	359
TERRA BELLA I.D.	1,388
LOWER TULE RIVER I.D.	20,993
PORTERVILLE I.D.	3,043
TULARE I.D.	12,138
EXETER I.D.	1,993
IVANHOE I.D.	968
LINDMORE I.D.	3,250
LINDSAY-STRATHMORE I.D.	1,317
LEWIS CREEK W.D.	69
ORANGE COVE I.D.	1,877
STONE CORRAL I.D.	479
FRESNO I.D.	5,692
GARFIELD W.D.	168
INTERNATIONAL W.D.	57
CHOWCHILLA W.D.	14,777
MADERA I.D.	18,186
GRAVELLY FORD W.D.	1,063
Total	**141,592**

3. Present irrigation well pumping energy requirements per unit volume of water pumped

Table C3 shows the current estimated pumping depth, estimated pump total dynamic head, pump efficiency, and pumping energy requirement.

Ken Schmidt provided pumping depth data from his analysis of the DWR Spring 2003 groundwater elevations. These values were checked independently by myself and my staff, and were found to agree with the values in **Table C3.**

The total dynamic head (TDH) is the pumping depth plus estimates for discharge pressure and column loss (drawdown is included in the pumping depth estimates). For this analysis, an additional 11 feet of pumping depth were added to account for discharge pressure and column loss.

The current average on-farm pump efficiency in each district is shown in **Table C3,** based on an ITRC database containing over 5000 pump tests from throughout the State conducted from 2000-2004. The original pump efficiency data was summarized by county, and then summarized/estimated for each district.

Gross irrigation well pumping energy requirements are calculated as:

$$\mathbf{KWh/AF = 1.023 \times TDH/(PP_{EFF}/100))}$$

Table C3. Current energy requirements for irrigation water well pumping in Friant service area

	Current			
District	Initial Pump Depth (Schmidt)	Total Dynamic Head	Pumping Plant Efficiency	Groundwater Pumping Energy Requirement
	ft	%	%	kWh/AF
ARVIN-EDISON W.S.D.	410	421	53.2	810
DELANO-EARLIMART I.D.	180	191	53.2	367
SHAFTER-WASCO I.D.	325	336	53.2	646
SOUTHERN SAN JOAQUIN MUD	175	186	53.2	358
SAUCELITO I.D.	175	186	52.3	364
TEA POT DOME W.D.	155	166	52.3	325
TERRA BELLA I.D.	140	151	52.3	295
LOWER TULE RIVER I.D.	165	176	52.3	344
PORTERVILLE I.D.	60	71	52.3	139
TULARE I.D.	150	161	52.3	315
EXETER I.D.	75	86	52.3	168
IVANHOE I.D.	85	96	52.3	188
LINDMORE I.D.	70	81	52.3	158
LINDSAY-STRATHMORE I.D.	60	71	52.3	139
LEWIS CREEK W.D.	55	66	52.3	129
ORANGE COVE I.D.	40	51	52.3	100
STONE CORRAL I.D.	45	56	52.3	110
FRESNO I.D.	85	96	54.5	180
GARFIELD W.D.	160	171	54.5	321
INTERNATIONAL W.D.	55	66	54.5	124
CHOWCHILLA W.D.	150	161	54.5	302
MADERA I.D.	150	161	54.5	302
GRAVELLY FORD W.D.	140	151	54.5	283

4. Future irrigation well pumping energy requirements per unit volume of water pumped

The increase in groundwater pumping will cause a drop in groundwater levels. This impacts the energy requirement in two ways: (i) the water must be pumped from a greater depth (increased TDH) and (ii) the pumping plant efficiency (PPEFF) decreases.

TDH is calculated as the existing pumping depth plus the change in pumping depth under the Kondolf release scenario and includes column losses and discharge pressure (drawdown is included in pumping depth). As the TDH increases and PPEFF decreases, the kWh/AF increases – meaning it requires more energy to pump one acre-foot (AF) of water.

As the groundwater level drops, not only does more water need to be pumped, but more energy is required to pump that additional water. In addition, it requires additional energy to pump the existing groundwater demands.

Table C4 shows the increased energy requirement per volume of irrigation water pumped by district by year 2025 under the Kondolf release scenario. The increase in pumping depth shown in the table was estimated by Ken Schmidt. Heading descriptions and calculation explanations are outlined in the previous section.

Table C4. Estimated future irrigation well pumping energy requirements by 2025 under the Kondolf release scenario

	Current	Under Kondolf release scenario by Year 2025			
District	Initial Pump Depth (Schmidt)	Change in Pump Depth (Schmidt)*	Total Dynamic Head	Pumping Plant Efficiency	Groundwater Pumping Energy Requirement
	ft	ft	ft	%	kWh/AF
ARVIN-EDISON W.S.D.	410	142	563	45.0	1,280
DELANO-EARLIMART I.D.	180	72	263	45.0	598
SHAFTER-WASCO I.D.	325	108	444	45.0	1,009
SOUTHERN SAN JOAQUIN MUD	175	60	246	45.0	559
SAUCELITO I.D.	175	82	268	45.0	609
TEA POT DOME W.D.	155	82**	248	45.0	564
TERRA BELLA I.D.	140	82**	233	45.0	530
LOWER TULE RIVER I.D.	165	102	278	45.0	632
PORTERVILLE I.D.	60	62	133	45.0	302
TULARE I.D.	150	62	223	45.0	507
EXETER I.D.	75	44	130	45.0	296
IVANHOE I.D.	85	32	128	45.0	291
LINDMORE I.D.	70	72	153	45.0	348
LINDSAY-STRATHMORE I.D.	60	6	77	50.0	158
LEWIS CREEK W.D.	55	6**	72	50.0	147
ORANGE COVE I.D.	40	72	123	45.0	280
STONE CORRAL I.D.	45	72**	128	45.0	291
FRESNO I.D.	85	0	96	54.5	180
GARFIELD W.D.	160	0	171	54.5	321
INTERNATIONAL W.D.	55	0	66	54.5	124
CHOWCHILLA W.D.	150	120	281	45.0	639
MADERA I.D.	150	62	223	45.0	507
GRAVELLY FORD W.D.	140	62**	213	45.0	484

* A positive change in pump depth values indicates a drop in groundwater level – which is the same as an increase in pumping depth. Some confusion is often associated with the positive or negative sign that is shown with these numbers. These values could be shown as either a negative (indicating a decrease in groundwater level) or a positive (indicating an increase in pumping depth); the result is the same – an increase in total dynamic head.

****Ken Schmidt did not estimate the drop in groundwater level for some smaller districts in the service area. In creating this table, it was assumed that similar groundwater elevation drops would occur in these districts as others nearby.**