Hydrologic Analysis

San Joaquin River Agreement

Prepared for the
United States Bureau of Reclamation and
San Joaquin River Group Authority

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HYDROLOGIC ANALYSIS - SAN JOAQUIN RIVER AGREEMENT

I. INTRODUCTION

Several interests, including the Department of Interior (Interior) , the San Joaquin River Group Authority and its members, the Department of Water Resources and the Department of Fish and Game, and Central Valley Project/State Water Project Export Interests have developed the San Joaquin River Agreement (SGRA) which provides for a San Joaquin River flow and SWP/CVP export study during the April-May pulse flow period to gather better scientific fisheries information on the lower San Joaquin River while at the same time provide environmental benefits in the lower San Joaquin River and Delta.

The proposed project/action is the acquisition of water by Interior from the San Joaquin River Group Authority and its members to provide a pulse flow at Vernalis during April and May, and the acquisition of other water identified by the SJRA. The water is needed to support the Vernalis Adaptive Management Plan (VAMP) during the pulse flow period and to assist Interior in meeting the Anadromous Fish Restoration Plan, Bay-Delta flow objectives and the U.S. Fish and Wildlife Service 1995 Biological Opinion for Delta Smelt.

As part of the VAMP, Central Valley Project (CVP) and State Water Project (SWP) exports during the VAMP test period (April/May) will be managed to specified levels. These levels in relation to Vernalis flows are less than allowed under current regulatory requirements. The San Joaquin River Agreement provides for the development of an operations plan acceptable to all parties including address of export reductions caused by VAMP.

This technical report presents the results of an analysis that models potential hydrologic effects of an action under which Interior purchases water identified by the SJRA.

II. DESCRIPTION OF THE PROPOSED PROJECT/ACTION

The proposed project/action is acquisition of water by Interior from certain San Joaquin River Group Authority (SJRGA) members for use as a pulse flow at Vernalis during April and May, and the acquisition of other water for use during other times of the year. The SJRGA members that will be providing water are Modesto Irrigation District (MID), Turlock Irrigation District (TID), Merced Irrigation District (Merced), South San Joaquin Irrigation District (SSJID), Oakdale Irrigation District (OID), and the San Joaquin River Exchange Contractors Water Authority (Exchange Contractors). This water is intended to supplement flows of the San Joaquin River during the next twelve years, 1999 through year 2010.

The water provided by the SJRGA will be provided by several potential means, including the increase of flows from tributary reservoirs, the bypass of diversions, indirect substitution of groundwater, reduction of applied surface water, and increased system efficiency.

Water Made Available Through the SJRA

Four components of water will be provided by the SJRGA members:

- Up to 110,000 acre-feet per year towards meeting the VAMP flow target. Water provided under this component will be divided among the SJRGA members. This water is to only be used during the VAMP 31-day test flow period;

- Additional water from willing SJRGA members to achieve full flow targets;

- Additional water from Merced (12,500 acre-feet) during October of all years. This flow will be provided above the "existing flow" in the Merced River during October.

- Additional water from OID (15,000 acre-feet) every year to be available to Reclamation. In addition to this water, any of the (up-to) 11,000 acre-feet of OID VAMP water not provided towards meeting the VAMP flow target is also available to Reclamation.

Determination of VAMP Water

The SJRA defines the determination of water to be provided for VAMP by the SJRGA's members. The SJRGA members will provide, during the pulse flow period, the amount of water needed to achieve the VAMP flow target or 110,000 acre-feet, whichever is less. The water provided by the SJRGA members will be determined as the sum of flows released in excess of flows which would otherwise have been released during the pulse flow period.

The VAMP flow target is determined by a series of procedures and conditions based on the flow at Vernalis which would occur in the absence of the SJRA ("existing flow"), and the San Joaquin Valley Water Year Hydrologic Classification. The SJRA provides a VAMP flow target that will be incrementally larger than the existing flow at Vernalis consistent with the following table:

San Joaquin Valley
Water Year Hydrologic Classification

The San Joaquin Valley Water Year Hydrologic Classification was developed as an index of wetness and water supply availability within the San Joaquin River basin. The index is mathematically derived as the summation of 0.6 times the current year's April through July San Joaquin Valley unimpaired runoff plus 0.2 times the current year's October through March unimpaired runoff plus 0.2 times the previous year's index (with the previous year's index capped at 4.5 million acre-feet). The index is commonly referred to as the 60-20-20 Classification. The streams used in the index are the Stanislaus, Tuolumne and Merced rivers and the San Joaquin River at Friant. The index defines five different year types: wet, above normal, below normal, dry and critical.

Existing Flow At Vernalis (cfs)			VAMP Test Flow Target (cfs)
0	to	1,999	* 2,000
2,000	to	3,199	3,200
3,200	to	4,449	4,450
4,450	to	5,699	5,700
5,700	to	7,000	7,000

* For the purpose of determining water to be provided by the SJRGA's members. The VAMP Test Flow Target is 3,200 cfs.

The SJRA assigns a numeric adjunct (60-20-20 Indicator) to the San Joaquin Valley Water Year Hydrologic Classification: a wet year is assigned the numeric value of 5, an above normal year is assigned the numeric value of 4, a below normal year is assigned the numeric value of 3, a dry year is assigned the numeric value of 2, and a critical year is assigned the numeric value of 1. In any year when the sum of the current year's 60-20-20 Indicator and previous year's 60-20-20 Indicator is seven (7) or greater, the 31-day flow target will be the flow target one level higher than that established by the table described above (e.g., if the existing flow is 3,500 cfs then the flow target will be 5,700 cfs). This condition is referred to as a "double-step".

As described above, the SJRGA members will provide up to 110,000 acre-feet of water to achieve the VAMP flow target. The SJRA also provides for relaxation of this obligation during sequential dry-year periods (if such a period were to occur during the term of the SJRA). During years when the sum of the current year's 60-20-20 Indicator and the previous two years' 60-20-20 Indicator is four (4) or less (a sequence of dry and critical years), the SJRGA members will not be required to provide water above the existing flow.

Assumed Division of Flow

The SJRGA members have executed an agreement (the "Division Agreement") that identifies the division of the water to be provided for the proposed project/action. The hierarchy for the provision of flow by the SJRGA members is consistent with the following table:

Division of VAMP Pulse Flow Water (AF)					
Entity (in order of providing flow)	First 50,000 AF	Next 23,000 AF	Next 17,000 AF	Next 20,000 AF	Totals
Merced	25,000	11,500	8,500	10,000	55,000
OID/SSJID	10,000	4,600	3,400	4,000	22,000
Exchange Contractors	5,000	2,300	1,700	2,000	11,000
MID/TID	10,000	4,600	3,400	4,000	22,000

This component of contribution will draw from each member up to the following maximum amounts of water: Merced, 55 TAF; OID, 11 TAF; SSJID, 11 TAF; Exchange Contractors, 11 TAF; MID, 11 TAF; and TID, 11 TAF. For the other components of water, an individual entity is responsible. Although the above described hierarchy for providing VAMP flows is established by the Division Agreement, the agreement also allows for other arrangements between the members to provide water, so long as the VAMP pulse flow is met.

III. MODELING

This analysis was conducted to evaluate a range of potential hydrologic effects attributable to the proposed project/action. The SJRA has a term of 12 years (unless extended); however, the hydrologic character of the next 12 years can not be predicted. To evaluate a range of conditions and hydrologic impacts that may occur, the SJRA was evaluated using a long-term hydrologic sequence, the hydrology of the period 1922 through 1992. Within that period of record various sequences of hydrologic events occurred ranging from flood to extended periods of drought.

Two primary operational settings were developed, the No-action setting and the Proposed Project/Action setting. The No-action setting depicts an environment representative of existing hydrology and operations within the Bay-Delta watershed absent the SJRA. This setting includes the CVP and SWP meeting the 1995 Water Quality Control Plan and biological opinions for winter run Chinook salmon and Delta Smelt. Operations for the San Joaquin River include Reclamation operating New Melones to the Interim Plan of Operations, and due to limited availability of water from New Melones the water quality and flow objectives of the 1995 Water Quality Control Plan for the San Joaquin River are not always met.

The Proposed Project/Action setting depicts the performance of the SJRA if it were in place for the entire 71 years of sequential hydrology. The elements of the SJRA that are directly evaluated are the 110,000 acre-feet component of VAMP water, and the Merced October flows, and the OID reallocation water.

Operation Simulation Models

This analysis relied on the interface of three hydrologic models to simulate the potential hydrologic effects of the proposed project/action.

San Joaquin Area Simulation Model (SANJASM)

The Bureau of Reclamation's (Reclamation) SANJASM provided the simulation of the San Joaquin River upstream of the confluence of the Stanislaus River, including the hydrology of west side San Joaquin Valley CVP deliveries.

Stanislaus Operations Model (STNMODAM version)

Reclamation's STNMODAM spreadsheet model provided the simulation of Stanislaus River operations under assumptions of Reclamation's Interim Plan of Operation for New Melones.

Projects Simulation Model (PROSIM)

Reclamation's PROSIM provided the simulation of the CVP and SWP, and the Bay-Delta.

Results of PROSIM are dependent on the flow at Vernalis resulting from SANJASM and STANMODAM. However, the flow and water quality at Vernalis are determined by SANJASM and STANMODAM for which those results are partially dependent on the results of PROSIM. This interaction between the models requires an iterative series of simulations to reach a point of closure between the models. Figure 1 illustrates the interaction between the models. The iteration begins with developing a simulation of non-Stanislaus River hydrology, e.g., the operation of the Merced and Tuolumne Rivers. From that result, non-Stanislaus River flow and water quality information are provided to Reclamation's STNMODAM for integration with a Stanislaus River operation that is consistent with Reclamation's Interim Plan of Operation for New Melones. The results of that step then provide the simulation of flow and water quality conditions at Vernalis, which is then provided to PROSIM for simulation of the CVP and SWP and west side San Joaquin Valley deliveries. The results of that PROSIM study are then re-entered into San Joaquin River operations for a redetermination of Vernalis flows and quality. A PROSIM study is then rerun to provide closure between the revised Vernalis flow and quality conditions and CVP and SWP Delta operations.

Although there is only the No-action and Proposed Project/Action settings, four simulations were performed. Due to a combination of modeling constraints (average monthly hydrologic data and a monthly modeling time-step) and the potential for the VAMP test flow period being established anytime during the April through May period, the No-action and Proposed Project/Action were each modeled to occur entirely during the month of April <u>or</u> May.

Modeling Assumptions - No-action Setting

New Melones Reservoir is assumed to operate consistent with the Interim Plan of Operation as modeled within STNMODAM, with the out-migration pulse flow focused during either the month of April or May. As hydrologic and operational conditions of the San Joaquin River upstream of the mouth of the Stanislaus River change with each analysis, the operation of the Stanislaus River will sometimes change as the result of water quality operations.

The allocation of annual water supplies to the uses of fishery, Vernalis water quality, Bay-Delta, and CVP contractors was assumed as follows, dependent on the water supply of New Melones:

New Melones Allocation of Supplies (1,000 acre-feet)				
New Melones		Vernalis		

Storage Plus Inflow		Fishery		Water Quality		Bay-Delta		CVP Contractors	
From	To	From	To	From	To	From	To	From	To
0	1,400	0	98	0	70	0	0	0	0
1,400	2,000	98	125	70	80	0	0	0	0
2,000	2,500	125	345	80	175	0	0	0	59
2,500	3,000	345	467	175	250	75	75	90	90
3,000	6,000	467	467	250	250	75	75	90	90

Allocations to OID and SSJID were assumed consistent with their 1988 agreement with Reclamation.

The Merced and Tuolumne River reservoir systems are modeled to operate to meet diversion demands and minimum instream flow requirements. The FERC required spring pulse flows for the Tuolumne River are assumed to be scheduled coincident with the period of desired supplemental flow in the San Joaquin River (April or May). Releases in excess of minimum flow requirements on the tributaries occasionally occur in accordance with flood control storage reservation requirements.

Primary assumptions for the hydrology and operation of the SWP and CVP include the following:

- Implementation of the State Water Resources Control Board's 1995 Water Quality Control Plan through the operations of the SWP and CVP. At times, full compliance to San Joaquin River flow and quality objectives does not occur. Combined SWP/CVP exports are allowed to pump up to 100 percent of the flow occurring at Vernalis during the spring pulse flow period;

- Delta Smelt and winter run chinook salmon Biological Opinions for the SWP and CVP;

- November 1997 AFRP actions for instream flows in Clear Creek and below Keswick and Nimbus reservoirs, and a Trinity River maximum required release of 340 TAF. No additional AFRP Delta actions other than the 1995 WQCP;

- Current level of hydrology and operations in the San Joaquin Valley, including delivery of Level 4 refuge supplies.

The No-action setting modeling results in Vernalis flow conditions that define the "existing flow" for the SJRA. The results also define the SWP/CVP export levels which are associated with a pre-SJRA setting. The Vernalis flow simulated from this setting is used to calculate the VAMP flow to be provided by the SJRGA members.

Modeling Assumptions - Proposed Project/Action Setting

Subsequent to the determination of the water to be provided by the SJRGA members for the VAMP, and its division among the members, a series of procedures to simulate the Proposed Project/Action setting were employed. These procedures are described as follows.

Water originating from Merced is assumed to occur as increased stream releases from New Exchequer Dam. This release is modeled as an increase in flow above the release which would otherwise be made in the absence of the proposed project/action. Merced's VAMP contribution is added to the Merced River flow that occurred within the No-action simulation. Merced's additional provision of water during October is depicted by increasing Merced's minimum flow requirement during October by 12,500 acre-feet. In certain sequential critical year sequences, surface water diversions by Merced are reduced to accommodate the additional stream releases.

Water originating from MID and TID is also modeled as additional stream releases, in this case from New Don Pedro Dam. As with the Merced release, this release is modeled as an increase in flow above the release which would otherwise be made in the absence of the proposed project/action.

VAMP water originating from OID and SSJID is assumed to occur two different ways: 1) if lower Stanislaus River flow from Goodwin is less than 1,500 cfs, OID and SSJID flows are modeled to occur as an increase in releases below Goodwin, but will not in combination with the existing flow at Goodwin exceed the 1,500 cfs objective, or 2) when Goodwin releases are 1,500 cfs, it is assumed that OID and SSJID will provide their respective flow through diversion bypass via a "hydraulic means" that will not frustrate the 1,500 cfs flow objective on the Stanislaus River. This "hydraulic means" is currently assumed to be a conveyance of water from OID and SSJID to MID occurring over several months and MID releasing the OID/SSJID component of VAMP pulse flow to the Tuolumne River.

Water originating from the Exchange Contractors is assumed to occur as an incremental additional accretion to San Joaquin River near the mouth of the Merced River.

Under the Proposed Project/Action setting, New Melones is assumed to operate consistent with the allocations of the Interim Plan of Operation as described above for the No-action setting with the exception that subsequent to the determination of water available to OID and SSJID, 15,000 acre-feet plus any unrequired VAMP flow from OID (up to 11,000 acre-feet) will be reduced from OID's allocation and diversion. The reduction in diversion will result as additional storage in New Melones and be subsequently reallocated to other uses in subsequent years consistent with the allocations of the Interim Plan of Operation.

OID/SSJID VAMP water that is released at Goodwin to the Stanislaus River (within the 1,500 cfs flow objective) and OID water that is reduced from OID's allocation of New Melones supplies are assumed as reductions to OID's diversions during the months of March, April, September and October.

Hydrology and operation assumptions of the CVP and SWP are the same between the No-action setting and the Proposed Project/Action setting.

Adjustment of New Melones Operations due to Reallocation of OID Water

As a result of OID decreasing its diversion of its entitlement from Reclamation, the allocation of water to the fishery (and other uses) increases. In instances when the No-action release to the Stanislaus River was less than 1,500 cfs, this additional allocation of fishery water would result in releases from Goodwin to the Stanislaus River higher than would occur without the OID reallocated water. If left unadjusted, this revised Goodwin release in combination with the VAMP flows provided by the SJRGA members would overshoot the Vernalis flow target. This occasional occurrence was remedied by shifting any excess in Vernalis flow caused by the OID reallocation water from the assumed month of VAMP to the other potential pulse flow month.

IV. SIMULATIONS AND RESULTS

Results of this analysis are available from Reclamation upon request (hard copy) and are accessible from the Internet at *www.mp.usbr.gov.mp140.vampdir.html*. The following listed files contain the results of the SANJASM and STANMODAM simulations of the No-action and Proposed Project/Action settings.

No-Action Setting - April

- VAB_IT3.BIN (SANJASM binary output file)
- VAB_IT3.WK4 (STANMODAM spreadsheet)

No-Action Setting - May

- VMB_IT3.BIN
- VMB_IT3.WK4

Proposed Project/Action Setting - April

- VAP_IT1.BIN
- SJRA_A_1.WK4

Proposed Project/Action Setting - May

- VMP_IT1.BIN
- SJRA_M_1.WK4

Numerous hydrologic parameters can be extracted from these data files. Table 1 lists the parameters that were extracted for consideration. Figure 2 provides a geographical representation of the area analyzed by the studies, and the general location of the parameters depicted in the modeling.

Additional information not directly included in the previously described data files is provided in Tables 2 through 5. Table 2 provides a listing of the San Joaquin Valley Water Year Hydrologic Classification for the years 1922 through 1992. Table 3 and Table 4 illustrate the determination of VAMP pulse flow water for the months of April and May, respectively, and Table 5 illustrates the modeled division of VAMP pulse flows between the SJRGA's members

Figure 1
Representation of Interaction Between Modeling Tools.

Table 1
Hydrologic Analysis Parameters
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Stanislaus River

New Melones Storage (TAF)
1 April No-action
2 April Proposed Action
3 April - difference
4 May No-action
5 May Proposed Action
6 May - difference

Goodwin Release to River (cfs)
7 April No-action
8 April Proposed Action
9 April - difference
10 May No-action
11 May Proposed Action
12 May - difference

New Melones Fish Release (TAF)
13 April No-action
14 April Proposed Action
15 April - difference
16 May No-action
17 May Proposed Action
18 May - difference

New Melones WQ Release (TAF)
19 April No-action
20 April Proposed Action
21 April - difference
22 May No-action
23 May Proposed Action
24 May - difference

New Melones Bay-Delta Release (TAF)
25 April No-action
26 April Proposed Action
27 April - difference
28 May No-action
29 May Proposed Action
30 May - difference

New Melones DO Release (TAF)
31 April No-action
32 April Proposed Action
33 April - difference
34 May No-action
35 May Proposed Action
36 May - difference

New Melones CVP Delivery (TAF)
37 April No-action
38 April Proposed Action
39 April - difference
40 May No-action
41 May Proposed Action
42 May - difference

New Melones Optional Delivery (TAF)
43 April No-action
44 April Proposed Action
45 April - difference
46 May No-action
47 May Proposed Action
48 May - difference

Tuolumne River

New Don Pedro Storage (TAF)
49 April No-action
50 April Proposed Action
51 April - difference
52 May No-action
53 May Proposed Action
54 May - difference

La Grange Release to River (cfs)
55 April No-action
56 April Proposed Action - Including Routed Water from OID/SSJID
57 April - difference
58 May No-action
59 May Proposed Action - Including Routed Water from OID/SSJID
60 May - difference
61 April Proposed Action - Routed Water from OID/SSJID
62 May Proposed Action - Routed Water from OID/SSJID

Merced River

New Exchequer Storage (TAF)
63 April No-action
64 April Proposed Action
65 April - difference
66 May No-action
67 May Proposed Action
68 May - difference

Merced River below Diversion (cfs)
69 April No-action
70 April Proposed Action
71 April - difference
72 May No-action
73 May Proposed Action
74 May - difference

Merced ID Diversion (TAF)
75 April No-action
76 April Proposed Action
77 April - difference
78 May No-action
79 May Proposed Action
80 May - difference

Table 1
Hydrologic Analysis Parameters
(Page 2/2)

<u>San Joaquin River</u>

Below Mouth of Merced River (cfs)

81 April No-action
82 April Proposed Action
83 April - difference
84 May No-action
85 May Proposed Action
86 May - difference

Below Mouth of Tuolumne River (cfs)

87 April No-action
88 April Proposed Action
89 April - difference
90 May No-action
91 May Proposed Action
92 May - difference

Vernalis flow (cfs)

93 April No-action
94 April Proposed Action
95 April - difference
96 May No-action
97 May Proposed Action
98 May – difference
99 Vernalis Quality (TDS)
99 April No-action
100 April Proposed Action
101 April - difference
102 April - Non-compliance with No-action
103 April - Non-compliance with Proposed Project/Action
104 April - Difference with No-action Compliance
105 May No-action
106 May Proposed Action
107 May - difference
108 May - Non-compliance with No-action
109 May - Non-compliance with Proposed Project/Action
110 May - Difference with No-action Compliance

<u>Other Information</u>

111 Allocation of VAMP Pulse Flow Water
112 San Joaquin Index

Figure 2
Area Location Map

Table 2
San Joaquin Valley Water Year Hydrologic Classification

Water Year	Index	Type
1922	4,544,266	Wet
1923	3,549,800	Above
1924	1,419,960	Critical
1925	2,929,392	Below
1926	2,300,478	Dry
1927	3,558,896	Above
1928	2,632,779	Below
1929	2,004,556	Critical
1930	2,015,911	Critical
1931	1,201,582	Critical
1932	3,410,716	Above
1933	2,440,943	Dry
1934	1,440,989	Critical
1935	3,556,198	Above
1936	3,739,440	Above
1937	3,897,088	Wet
1938	5,910,218	Wet
1939	2,198,200	Dry
1940	3,364,440	Above
1941	4,425,888	Wet
1942	4,440,778	Wet
1943	4,023,556	Wet
1944	2,761,511	Below
1945	3,589,102	Above
1946	3,304,020	Above
1947	2,183,004	Dry
1948	2,698,601	Below
1949	2,531,320	Below
1950	2,853,264	Below
1951	3,138,053	Above
1952	5,165,011	Wet
1953	3,025,800	Below
1954	2,720,960	Below
1955	2,300,392	Dry
1956	4,463,078	Wet
1957	3,008,616	Below
Water Year	Index	Type
1958	4,772,923	Wet
1959	2,208,800	Dry
1960	1,854,560	Critical
1961	1,375,912	Critical
1962	3,073,382	Below
1963	3,572,476	Above
1964	2,186,695	Dry
1965	3,804,739	Wet
1966	2,511,948	Below
1967	5,251,790	Wet
1968	2,213,800	Dry
1969	6,094,560	Wet
1970	3,182,800	Above
1971	2,884,560	Below
1972	2,155,912	Dry
1973	3,498,382	Above
1974	3,903,676	Wet
1975	3,848,135	Wet
1976	1,571,027	Critical
1977	840,805	Critical
1978	4,583,561	Wet
1979	3,668,400	Above
1980	4,731,480	Wet
1981	2,441,000	Dry
1982	5,446,000	Wet
1983	7,219,800	Wet
1984	3,688,800	Above
1985	2,403,560	Dry
1986	4,305,112	Wet
1987	1,863,622	Critical
1988	1,476,924	Critical
1989	1,964,385	Critical
1990	1,514,877	Critical
1991	1,954,175	Critical
1992	1,558,035	Critical

Table 3
Determination of VAMP Pulse Flow Water
April Pulse Flow

(1) Index 602020	(2) Year Class	(3) Water Year	(4) Current Year 1 Crit 5 Wet	(5) Current Plus Previous Year	(6) Current Plus 2 Previous	(7) April Vernalis Existing Flow (CFS)	(8) Flow Target (CFS)	(9) Suppl. Flow Required (CFS)	(10) Suppl. Flow Required (TAF)	(11) Suppl. w/ 110 Cap Invoked (TAF)
4,544,266	Wet	1922	5	9	12	10,088	7,000	0	0	0
3,549,800	Above	1923	4	9	13	6,559	7,000	441	27	27
1,419,960	Critical	1924	1	5	10	1,778	2,000	222	14	14
2,929,392	Below	1925	3	4	8	4,713	5,700	987	61	61
2,300,478	Dry	1926	2	5	6	3,495	4,450	955	59	59
3,558,896	Above	1927	4	6	9	6,617	7,000	383	24	24
2,632,779	Below	1928	3	7	9	5,611	7,000	1,389	85	85
2,004,556	Critical	1929	1	4	8	2,314	3,200	886	54	54
2,015,911	Critical	1930	1	2	5	2,334	3,200	866	53	53
1,201,582	Critical	1931	1	2	3	1,470	2,000	0	0	0
3,410,716	Above	1932	4	5	6	5,484	5,700	216	13	13
2,440,943	Dry	1933	2	6	7	2,471	3,200	729	45	45
1,440,989	Critical	1934	1	3	7	1,617	2,000	383	24	24
3,556,198	Above	1935	4	5	7	7,889	7,000	0	0	0
3,739,440	Above	1936	4	8	9	7,812	7,000	0	0	0
3,897,088	Wet	1937	5	9	13	10,157	7,000	0	0	0
5,910,218	Wet	1938	5	10	14	22,643	7,000	0	0	0
2,198,200	Dry	1939	2	7	12	3,903	5,700	1,797	110	110
3,364,440	Above	1940	4	6	11	7,164	7,000	0	0	0
4,425,888	Wet	1941	5	9	11	11,349	7,000	0	0	0
4,440,778	Wet	1942	5	10	14	7,735	7,000	0	0	0
4,023,556	Wet	1943	5	10	15	8,576	7,000	0	0	0
2,761,511	Below	1944	3	8	13	5,080	7,000	1,920	118	110
3,589,102	Above	1945	4	7	12	7,971	7,000	0	0	0
3,304,020	Above	1946	4	8	11	5,803	7,000	1,197	74	74
2,183,004	Dry	1947	2	6	10	2,562	3,200	638	39	39
2,698,601	Below	1948	3	5	9	4,077	4,450	373	23	23
2,531,320	Below	1949	3	6	8	3,517	4,450	933	57	57
2,853,264	Below	1950	3	6	9	3,840	4,450	610	37	37
3,138,053	Above	1951	4	7	10	5,399	7,000	1,601	98	98
5,165,011	Wet	1952	5	9	12	12,156	7,000	0	0	0
3,025,800	Below	1953	3	8	12	4,307	5,700	1,393	86	86
2,720,960	Below	1954	3	6	11	4,895	5,700	805	50	50
2,300,392	Dry	1955	2	5	8	2,685	3,200	515	32	32
4,463,078	Wet	1956	5	7	10	6,576	7,000	424	26	26
3,008,616	Below	1957	3	8	10	4,340	5,700	1,360	84	84
4,772,923	Wet	1958	5	8	13	15,080	7,000	0	0	0
2,208,800	Dry	1959	2	7	10	3,450	5,700	2,250	138	110
1,854,560	Critical	1960	1	3	8	2,453	3,200	747	46	46
1,375,912	Critical	1961	1	2	4	1,783	2,000	0	0	0
3,073,382	Below	1962	3	4	5	4,857	5,700	843	52	52
3,572,476	Above	1963	4	7	8	6,626	7,000	374	23	23
2,186,695	Dry	1964	2	6	9	2,418	3,200	782	48	48
3,804,739	Wet	1965	5	7	11	7,214	7,000	0	0	0
2,511,948	Below	1966	3	8	10	3,522	5,700	2,178	134	110
5,251,790	Wet	1967	5	8	13	15,097	7,000	0	0	0
2,213,800	Dry	1968	2	7	10	3,517	5,700	2,183	134	110
6,094,560	Wet	1969	5	7	12	24,593	7,000	0	0	0
3,182,800	Above	1970	4	9	11	5,786	7,000	1,214	75	75
2,884,560	Below	1971	3	7	12	4,223	5,700	1,477	91	91
2,155,912	Dry	1972	2	5	9	2,595	3,200	605	37	37
3,498,382	Above	1973	4	6	9	7,988	7,000	0	0	0
3,903,676	Wet	1974	5	9	11	8,324	7,000	0	0	0
3,848,135	Wet	1975	5	10	14	8,458	7,000	0	0	0
1,571,027	Critical	1976	1	6	11	2,476	3,200	724	45	45
840,805	Critical	1977	1	2	7	1,626	2,000	374	23	23
4,583,561	Wet	1978	5	6	7	18,120	7,000	0	0	0
3,668,400	Above	1979	4	9	10	7,635	7,000	0	0	0
4,731,480	Wet	1980	5	9	14	8,609	7,000	0	0	0
2,441,000	Dry	1981	2	7	11	3,735	5,700	1,965	121	110
5,446,000	Wet	1982	5	7	12	25,315	7,000	0	0	0
7,219,800	Wet	1983	5	10	12	27,742	7,000	0	0	0
3,688,800	Above	1984	4	9	14	5,349	7,000	1,651	102	102
2,403,560	Dry	1985	2	6	11	3,492	4,450	958	59	59
4,305,112	Wet	1986	5	7	11	12,240	7,000	0	0	0
1,863,622	Critical	1987	1	6	8	2,542	3,200	658	40	40

1,476,924	Critical	1988	1	2	7	1,748	2,000	252	16	16
1,964,385	Critical	1989	1	2	3	2,039	2,039	0	0	0
1,514,877	Critical	1990	1	2	3	1,711	2,000	0	0	0
1,954,175	Critical	1991	1	2	3	2,312	2,312	0	0	0
1,558,035	Critical	1992	1	2	3	1,815	2,000	0	0	0

Table 4
Determination of VAMP Pulse Flow Water
May Pulse Flow

(1) Index 602020	(2) Year Class	(3) Water Year	(4) Current Year 1 Crit 5 Wet	(5) Current Plus Previous Year	(6) Current Plus 2 Previous	(7) May Vernalis Existing Flow (CFS)	(8) Flow Target (CFS)	(9) Suppl. Flow Required (CFS)	(10) Suppl. Flow Required (TAF)	(11) Suppl. w/ 110 Cap Invoked (TAF)
4,544,266	Wet	1922	5	9	12	8,053	7,000	0	0	0
3,549,800	Above	1923	4	9	13	5,549	7,000	1,452	89	89
1,419,960	Critical	1924	1	5	10	1,491	2,000	509	31	31
2,929,392	Below	1925	3	4	8	4,022	4,450	428	26	26
2,300,478	Dry	1926	2	5	6	2,681	3,200	519	32	32
3,558,896	Above	1927	4	6	9	5,181	5,700	519	32	32
2,632,779	Below	1928	3	7	9	3,797	5,700	1,903	117	110
2,004,556	Critical	1929	1	4	8	2,027	3,200	1,173	72	72
2,015,911	Critical	1930	1	2	5	1,949	2,000	51	3	3
1,201,582	Critical	1931	1	2	3	1,244	2,000	0	0	0
3,410,716	Above	1932	4	5	6	3,910	4,450	540	33	33
2,440,943	Dry	1933	2	6	7	2,182	3,200	1,018	63	63
1,440,989	Critical	1934	1	3	7	1,247	2,000	753	46	46
3,556,198	Above	1935	4	5	7	6,091	7,000	909	56	56
3,739,440	Above	1936	4	8	9	5,319	7,000	1,681	103	103
3,897,088	Wet	1937	5	9	13	9,274	7,000	0	0	0
5,910,218	Wet	1938	5	10	14	23,955	7,000	0	0	0
2,198,200	Dry	1939	2	7	12	3,321	5,700	2,379	146	110
3,364,440	Above	1940	4	6	11	5,906	7,000	1,094	67	67
4,425,888	Wet	1941	5	9	11	9,500	7,000	0	0	0
4,440,778	Wet	1942	5	10	14	6,703	7,000	297	18	18
4,023,556	Wet	1943	5	10	15	8,589	7,000	0	0	0
2,761,511	Below	1944	3	8	13	4,475	7,000	2,525	155	110
3,589,102	Above	1945	4	7	12	5,841	7,000	1,159	71	71
3,304,020	Above	1946	4	8	11	5,549	7,000	1,452	89	89
2,183,004	Dry	1947	2	6	10	2,218	3,200	982	60	60
2,698,601	Below	1948	3	5	9	3,520	4,450	930	57	57
2,531,320	Below	1949	3	6	8	2,995	3,200	205	13	13
2,853,264	Below	1950	3	6	9	3,243	4,450	1,207	74	74
3,138,053	Above	1951	4	7	10	4,963	7,000	2,037	125	110
5,165,011	Wet	1952	5	9	12	15,451	7,000	0	0	0
3,025,800	Below	1953	3	8	12	4,101	5,700	1,599	98	98
2,720,960	Below	1954	3	6	11	4,394	4,450	56	3	3
2,300,392	Dry	1955	2	5	8	2,614	3,200	586	36	36
4,463,078	Wet	1956	5	7	10	6,866	7,000	134	8	8
3,008,616	Below	1957	3	8	10	4,345	5,700	1,355	83	83
4,772,923	Wet	1958	5	8	13	13,370	7,000	0	0	0
2,208,800	Dry	1959	2	7	10	3,061	4,450	1,389	85	85
1,854,560	Critical	1960	1	3	8	2,047	3,200	1,153	71	71
1,375,912	Critical	1961	1	2	4	1,593	2,000	0	0	0
3,073,382	Below	1962	3	4	5	3,330	4,450	1,120	69	69
3,572,476	Above	1963	4	7	8	5,483	7,000	1,517	93	93
2,186,695	Dry	1964	2	6	9	2,191	3,200	1,009	62	62
3,804,739	Wet	1965	5	7	11	5,874	7,000	1,126	69	69
2,511,948	Below	1966	3	8	10	3,190	4,450	1,260	77	77
5,251,790	Wet	1967	5	8	13	18,378	7,000	0	0	0
2,213,800	Dry	1968	2	7	10	3,207	5,700	2,493	153	110
6,094,560	Wet	1969	5	7	12	22,281	7,000	0	0	0
3,182,800	Above	1970	4	9	11	5,158	7,000	1,842	113	110
2,884,560	Below	1971	3	7	12	4,069	5,700	1,631	100	100
2,155,912	Dry	1972	2	5	9	2,305	3,200	895	55	55
3,498,382	Above	1973	4	6	9	5,874	7,000	1,126	69	69
3,903,676	Wet	1974	5	9	11	6,524	7,000	476	29	29
3,848,135	Wet	1975	5	10	14	6,719	7,000	281	17	17
1,571,027	Critical	1976	1	6	11	2,207	3,200	993	61	61
840,805	Critical	1977	1	2	7	1,433	2,000	567	35	35
4,583,561	Wet	1978	5	6	7	13,804	7,000	0	0	0
3,668,400	Above	1979	4	9	10	6,313	7,000	687	42	42
4,731,480	Wet	1980	5	9	14	9,077	7,000	0	0	0
2,441,000	Dry	1981	2	7	11	3,272	5,700	2,428	149	110
5,446,000	Wet	1982	5	7	12	17,305	7,000	0	0	0
7,219,800	Wet	1983	5	10	12	25,762	7,000	0	0	0
3,688,800	Above	1984	4	9	14	4,849	7,000	2,151	132	110
2,403,560	Dry	1985	2	6	11	3,033	3,200	167	10	10
4,305,112	Wet	1986	5	7	11	9,711	7,000	0	0	0
1,863,622	Critical	1987	1	6	8	2,204	3,200	996	61	61

1,476,924	Critical	1988	1	2	7	1,521	2,000	479	29	29
1,964,385	Critical	1989	1	2	3	1,695	2,000	0	0	0
1,514,877	Critical	1990	1	2	3	1,558	2,000	0	0	0
1,954,175	Critical	1991	1	2	3	1,728	2,000	0	0	0
1,558,035	Critical	1992	1	2	3	1,180	2,000	0	0	0

Table 5
Modeled Division of VAMP Pulse Flow Water
(Values in 1,000 acre-feet)

April Pulse Flow

Water Year	Merced	OID SSJID	Exchange Contractors	MID TID	Total
1922	0	0	0	0	0
1923	25	2	0	0	27
1924	14	0	0	0	14
1925	36	10	5	10	61
1926	34	10	5	10	59
1927	24	0	0	0	24
1928	45	18	8	15	85
1929	29	10	5	10	54
1930	28	10	5	10	53
1931	0	0	0	0	0
1932	13	0	0	0	13
1933	25	10	5	5	45
1934	24	0	0	0	24
1935	0	0	0	0	0
1936	0	0	0	0	0
1937	0	0	0	0	0
1938	0	0	0	0	0
1939	55	22	11	22	110
1940	0	0	0	0	0
1941	0	0	0	0	0
1942	0	0	0	0	0
1943	0	0	0	0	0
1944	55	22	11	22	110
1945	0	0	0	0	0
1946	37	15	7	15	74
1947	25	10	4	0	39
1948	23	0	0	0	23
1949	32	10	5	10	57
1950	25	10	2	0	37
1951	53	18	9	18	98
1952	0	0	0	0	0
1953	45	18	8	15	86
1954	25	10	5	10	50
1955	25	7	0	0	32
1956	25	1	0	0	26
1957	45	17	7	15	84
1958	0	0	0	0	0
1959	55	22	11	22	110
1960	25	10	5	6	46
1961	0	0	0	0	0
1962	27	10	5	10	52
1963	23	0	0	0	23
1964	25	10	5	8	48
1965	0	0	0	0	0
1966	55	22	11	22	110
1967	0	0	0	0	0
1968	55	22	11	22	110
1969	0	0	0	0	0
1970	38	15	7	15	75
1971	46	18	9	18	91
1972	25	10	2	0	37
1973	0	0	0	0	0
1974	0	0	0	0	0
1975	0	0	0	0	0
1976	25	10	5	5	45
1977	23	0	0	0	23
1978	0	0	0	0	0
1979	0	0	0	0	0
1980	0	0	0	0	0
1981	55	22	11	22	110
1982	0	0	0	0	0
1983	0	0	0	0	0
1984	55	20	9	18	102
1985	34	10	5	10	59
1986	0	0	0	0	0
1987	25	10	5	0	40
1988	16	0	0	0	16
1989	0	0	0	0	0

May Pulse Flow

Water Year	Merced	OID SSJID	Exchange Contractors	MID TID	Total
1922	0	0	0	0	0
1923	45	18	9	17	89
1924	25	6	0	0	31
1925	25	1	0	0	26
1926	25	7	0	0	32
1927	25	7	0	0	32
1928	55	22	11	22	110
1929	37	15	7	14	72
1930	3	0	0	0	3
1931	0	0	0	0	0
1932	25	8	0	0	33
1933	37	11	5	10	63
1934	25	10	5	6	46
1935	31	10	5	10	56
1936	55	21	9	18	103
1937	0	0	0	0	0
1938	0	0	0	0	0
1939	55	22	11	22	110
1940	37	15	6	10	67
1941	0	0	0	0	0
1942	18	0	0	0	18
1943	0	0	0	0	0
1944	55	22	11	22	110
1945	37	15	7	13	71
1946	45	18	9	17	89
1947	35	10	5	10	60
1948	32	10	5	10	57
1949	13	0	0	0	13
1950	38	15	7	15	74
1951	55	22	11	22	110
1952	0	0	0	0	0
1953	53	18	9	18	98
1954	3	0	0	0	3
1955	25	10	1	0	36
1956	8	0	0	0	8
1957	45	16	7	15	83
1958	0	0	0	0	0
1959	45	18	8	15	85
1960	37	15	7	13	71
1961	0	0	0	0	0
1962	37	15	7	10	69
1963	48	18	9	18	93
1964	37	11	5	10	62
1965	37	15	7	11	69
1966	41	15	7	15	77
1967	0	0	0	0	0
1968	55	22	11	22	110
1969	0	0	0	0	0
1970	55	22	11	22	110
1971	55	18	9	18	100
1972	30	10	5	10	55
1973	37	15	7	11	69
1974	25	4	0	0	29
1975	17	0	0	0	17
1976	36	10	5	10	61
1977	25	10	0	0	35
1978	0	0	0	0	0
1979	25	10	5	2	42
1980	0	0	0	0	0
1981	55	22	11	22	110
1982	0	0	0	0	0
1983	0	0	0	0	0
1984	55	22	11	22	110
1985	10	0	0	0	10
1986	0	0	0	0	0
1987	36	10	5	10	61
1988	25	4	0	0	29
1989	0	0	0	0	0

1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0

1990	0	0	0	0	0
1991	0	0	0	0	0
1992	0	0	0	0	0