APPENDIX F

ENVIRONMENTAL CONSTRAINTS

Brian J. Van Lienden, Brad D. Newlin, Pia M. Grimes and Stacy K. Tanaka

June 26, 2001

Unlike agricultural and urban demands, environmental demands in the CALVIN model are not represented in terms of the economic value of deliveries. Instead, environmental demands are represented as monthly minimum instream flow requirements on river and Delta reaches and minimum water supply requirements for refuge areas. These requirements vary by month and year and are intended to represent the minimum acceptable amount of water for environmental uses at their current (pre-CVPIA) levels. This chapter explains CALVIN's approach and assumptions in modeling minimum instream flow requirements, refuge demands, and the associated limitations.

MINIMUM INSTREAM FLOW REQUIREMENTS

Although minimum instream flow requirements are used throughout the state, CALVIN's aggregated modeling approach limits these flow constraints to those directly applicable to a canal or river reach included on the CALVIN schematic. Many minimum instream flow requirements vary monthly and by year type. Year types (wet, above normal, normal, below normal, dry, and/or critical) are classified by some type of index. A monthly pattern of flow requirements then corresponds with each year type, and a times series of minimum flows can be constructed from year types for the 1922-1993 hydrologic sequence modeled in CALVIN. Other more complex requirements depend on concurrent storage, flow, water quality, or other conditions. These latter relationships cannot be to represented dynamically in CALVIN’s network flow programming formulation. Instead, a pre-determined time series of minimum flows from a simulation of concurrent conditions is used in CALVIN. Because CALVIN is calibrated to match DWRSIM run 514 surface storage and flow conditions, DWRSIM run 514 time series are generally used for these more complex minimum flow requirements. Table F-1 summarizes the links in CALVIN with the minimum instream flow requirements and indicates the data source and basis of each requirement.

Table F-1. CALVIN River Reaches with Environmental Flow Constraints

River	CALVIN Links	Location	Data Source	Flow Values (cfs)			Function of
				min	max	avg	
American	D64_C8	From urban diversions to mouth	PROSIM NAA Node 16	188	500	315	Year type, 40-30-30 Sacramento Basin Index[a]
American	D9 to D64	Below Nimbus Dam to urban diversions	PROSIM NAA Node 15	250	3000	1624	Trigger, Folsom Storages from DWRSIM 514

Calaveras	SR-NHL to C41	Release from New Hogan Dam down to month	SANJASM NAA Node 130	2	2	2	Year type, 60-20-20 San Joaquin Index
Clear Creek	SR-3_D73	Below Whiskeytown Lake	PROSIM NAA Node 3	50	100	58	Year type, Shasta Index[b]
Delta Outflow	Required Delta Outflow_Sink	Delta outflow into S.F. Bay	Time series from DWRSIM 514 output for CP541	3000	28468	7771	Complex concurrent conditions
Feather	C25 to C32	Below Thermolito outflow to confluence with Bear River	PROSIM NAA Node 11	1000	1700	1294	Year Type, Oroville Index[c]
Feather	C32 to D43	From Bear River confluence to mouth	PROSIM NAA Node 12	1000	1700	1294	Year Type, Oroville Index[c]
Merced	D645_D646	Above confluence with San Joaquin R.	SANJASM NAA Node 50	16	228	109	Year type, 60-20-20 San Joaquin Index
Merced	D649_D695	Above confluence with San Joaquin R.	SANJASM NAA Node 55	16	228	109	Year type, 60-20-20 San Joaquin Index
Mokelumne	SR-CR to D98	Releases from Camanche Reservoir to CVPM 8 diversions	SANJASM NAA Node 175	0	467	121	Year type, 60-20-20 San Joaquin Index
Mokelumne	D98 to D515	From CVPM 8 diversions to confluence with Delta	SANJASM NAA Node 179	0	467	121	Year type, 60-20-20 San Joaquin Index
Mono basin	SR-GL_ SR-ML	Aggregate of Rush, Parker, Walker, and Lee Vining Creeks	SWRCB Decision 1631	72	137	102	Mono basin projected inflow
Owens Lake	C120_SR-OL	Owens Lake Dust Mitigation requirements	Modified from GBUPCD (1998)	15	146	55	Remediation measures
Sacramento	D5_D73	Below Keswick Reservoir	PROSIM NAA Node 4	3250	6000	3464	Trigger, Shasta Storages from PROSIM NAA
Sacramento	D76a to C69	Below Red Bluff	PROSIM NAA Node 5&6	3250	3900	3298	Year type, Shasta Index[b]
Sacramento	D61_C301	Navigation control point	PROSIM NAA Node 7	4000	5000	4306	Year Type, 40-30-30[a]
Sacramento	D503_D511	At Hood	Time series from DWRSIM 514 input	4999	5000	5000	Constant Time Series, Monthly Varying
Sacramento	D507_D509	Rio Vista requirements	PROSIM NAA file xcg_xxx1.na 1	0	4500	1327	Year type, 40-30-30 Sacramento Basin Index[a]

San Joaquin	D676_D616	Below confluence with Stanislaus at Vernalis	Time series from DWRSIM 514 output into CP521	0	6201 cK/	1434 ck?	Complex concurrent conditions
Stanislaus	D653a_D653b	Below Goodwin	SANJASM NAA Node 110	65	2921	270	Time series
Trinity	D94&D40_Sink D94	Trinity Below Lewiston Dam	PROSIM NAA Node 2	300	1591	468	Year type, Shasta Index[b]
Tuolumne	D662_D663	Above confluence with San Joaquin R.	SANJASM NAA Node 75	10	387	164	Year type, 60-20-20 San Joaquin Index
Yuba	C83_C31	Above confluence with American River	CVGSM NAA input (CNJMIN.NDA) At Daguerre Point	72	409	235	Year type, Shasta Index[b] ???

Notes:
[a] 40-30-30 Sacramento Basin Index: Sacramento River flows which have been weighted in consideration of certain flow periods and antecedent conditions.
[b] Shasta Index: Unimpaired inflows into Lake Shasta.
[c] Oroville Index: Unimpaired inflows into Lake Oroville.
[d] SJ 60-20-20 Index: San Joaquin River flows which have been weighted in consideration of certain flow periods and antecedent conditions.
[e] Eight River Index: The sum of the unimpaired flow of the 40-30-30 Index rivers and the 60-20-20 Index rivers.
Sources: USBR 1997a, DWR 1998b, DWR 1993 (for index definitions), SWRCB 1999 (for Vernalis)

CALVIN Approach

For each river, the decision of whether or not to place a minimum instream flow requirement was based primarily on whether that river was given such a requirement in the Department of Water Resources' DWRSIM model (DWR 1998b) and the Bureau of Reclamation's SANJASM or PROSIM models (USBR, 1997a). With the exception of the Yuba River, San Joaquin River at Vernalis, Sacramento River at Hood, and Delta minimum outflow, requirements used for minimum instream flows in the CALVIN model were developed from the minimum flow requirements specified in the input data for PROSIM and SANJASM, as used in the draft CVPIA PEIS no-action alternative. Monthly minimums, year types, indices, and trigger rules for the requirements in PROSIM and SANJASM can be found in the CVPIA PEIS data files (PROSIM NAA files *fwq_20xz.nea*, *yrt_xx1.na1*, and *xcg_xxx1.na1*; SANJASM NAA files *fwreq.n22*, *fwreqts.nf1*, and *yrtype.n22*). In certain cases, minimum instream flow data were available for a particular river in both DWRSIM and in either PROSIM or SANJASM. In such cases, the data from PROSIM or SANJASM were preferred because the requirements in these models were more clearly documented and levels justified in the CVPIA PEIS. Only when PROSIM requirements were substantially different, causing problems when calibrating the CALVIN Base Case to DWRSIM storages and flows, were DWRSIM data used instead.

In the CALVIN schematic, Delta outflow, twelve rivers, and the inflow into Mono and Owens Lakes are required to meet minimum instream flows. The Sacramento and American Rivers have different minimum flow constraints on several reaches. Table F-1 shows the model links on which these constraints are applied and the physical location of these links. Environmental flow requirements have been placed on the majority of the rivers north of the Delta and on nearly all the tributaries of the San Joaquin. Many of the rivers without an explicit minimum instream flow requirement may still be constrained indirectly by environmental flow requirements on other rivers. The Bear River and Cherry and Eleanor Creeks can be considered to have an indirect minimum instream flow requirement in contributing to the downstream constraints on the Feather and Tuolumne Rivers. Similarly, Putah and Cache Creeks, for example, contribute to Delta and downstream Sacramento River requirements via contributions from the Yolo Bypass.

Minimum Instream Flow Requirements Not Included In CALVIN

In addition to the minimum instream flows listed in Table F-1, there are two additional locations where minimums exist and should have been included in CALVIN: Clear Creek Tunnel (D94&D90_SR-3) and the San Joaquin at Vernalis (D676_D616). See Table F-2 for flow requirements.

Table F-2: Non-Imposed Minimum Instream Flow Requirements

River	Link	Location	Data Source	Flow Values (cfs)			Function of
				min	max	Avg	
Clear Creek Tunnel	D94&D40_SR-3	Below Lewiston Lake	PROSIM NAA Node 1	0	3300	1124	Trigger, Clair Engle Storage from PROSIM NAA
San Joaquin	D676_D616	Below confluence with Stanislaus	SWRCB (1999)	0	6201	1434	Complex rules based on concurrent conditions

[a] SJ 60-20-20 Index: San Joaquin River flows which have been weighted in consideration of certain flow periods and antecedent conditions.

The San Joaquin minimum requirements at Vernalis imposed by the State Water Resources Control Board (SWRCB 1999) under the 1995 Bay/Delta Water Quality Control Plan do not appear to be respected in either PROSIM NAA or DWRSIM 514, as output from models shows that this requirement was sufficiently violated. If used in CALVIN, it would have created some important distortions to calibration flows on the San Joaquin River (see Appendix 2H). Instead, the DWRSIM run 514 output flows at Vernalis were imposed on the boundary outflow from the CALVIN regional sub-model of the San Joaquin and South Bay Region (Region 3), and a modified SWRCB flow (reduced in 138 months to match DWRSIM Run 514 flows) was used in the CALVIN statewide unconstrained model to reflect flow conditions imposed at Vernalis.

PROSIM NAA included the Clear Creek Tunnel minimums shown in Table F-2, however DWRSIM Run 514 does not appear to operate Clair Engle for these requirements. In CALVIN the Clear Creek Tunnel requirement was not included to avoid needing large calibration flows on Clair Engle to match DWRSIM 514 storage operations used in the CALVIN Base Case model. From Figure F-1 and F-2 it can be seen that there are numerous times when the flow in DWRSIM Run 514 is below that of the PROSIM NAA requirement (and frequently zero). Similarly, the PROSIM NAA storages in Clair Engle are generally lower than those in DWRSIM Run 514 (see Figure F-3 below).

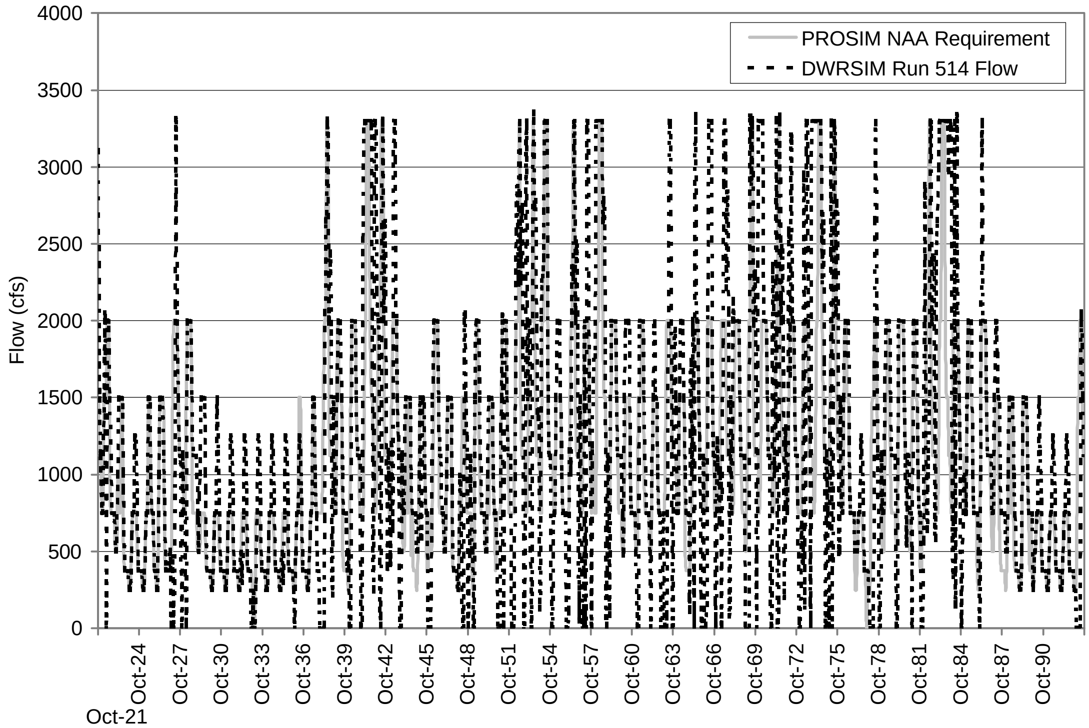

Figure F-1: Comparison of DWRSIM Run 514 Flows and PROSIM NAA Requirements for Clear Creek Tunnel

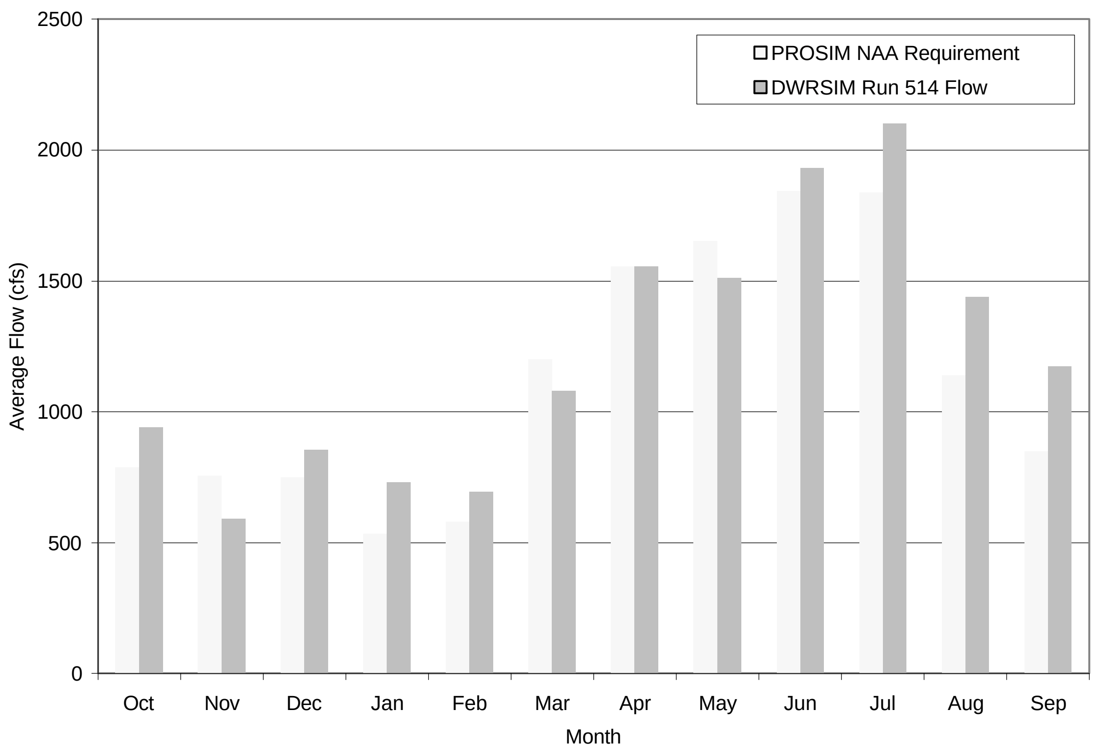

Figure F-2: Comparison of Monthly Average DWRSIM Run 514 Flows and PROSIM NAA Requirements for Clear Creek

In general the DWRSIM Run 514 flows are below those of the PROSIM NAA Clear Creek Tunnel minimums in the spring months (March, April and May) and November. In the remaining months the DWRSIM Run 514 flows are larger than the PROSIM NAA requirements. See Figure F-2.

Differences in Minimum Instream Flow Across Source Data

As stated above, the majority of minimum requirements imposed in PROSIM and SANJASM NAA models were used in CALVIN. While DWRSIM also imposes minimum requirements in most of the same locations as PROSIM, there is little documentation for the rules used and values imposed in DWRSIM.. Table F-3 and F-4 compare some of the DWRSIM Run 514 minimum requirements to those imposed in PROSIM NAA

Table F-3: Comparison of Year Type Based Minimums

River	Link	Location	Data Source	Flow Values (cfs)			Function of
				min	max	Avg	
Sacramento River	D61_C301	Navigation Control Point	PROSIM NAA Node 7	4000	5000	4306	Year Type, 40-30-30 Index
			DWRSIM Run 514	3997	5006	4414	
Clear Creek	SR-3_D73	Below Whiskeytown	PROSIM NAA Node 3	50	100	58	Year Type, Shasta Index
			DWRSIM Run 514	65	202	173	
Trinity	D94&D40_Sink	Below Lewiston Lake	PROSIM NAA Node 2	300	1591	468	Year Type, Shasta Index
			DWRSIM Run 514	299	5578	491	
Merced	D649_D695	Above confluence with San Joaquin R.	SANJASM Node 50	16	228	109	
			DWRSIM Run 514	16	101	59	

In addition to the year type dependent minimum instream flows, there are also minimums that are based on upstream reservoir storages. The same ‘trigger’ rule is used in both PROSIM NAA and DWRSIM Run 514 for the American River below Nimbus Dam and Sacramento River below Keswick, but because reservoir storage operations are somewhat different in DWRSIM Run 514 and PROSIM NAA, the minimums flows imposed in the two models over the 1922-1993 period are slightly different. Table F-4 presents these different minimums.

Table F-4: Minimum Instream Flows Based On Reservoir Storage

River	Link	Location	Data Source	Flow Values (cfs)			Function of
				Min	Max	Avg	
American	D85_D64	Above confluence with Sacramento	PROSIM Node 15	250	3000	1624	Trigger, Folsom Storage from PROSIM NAA
			PROSIM Node 15	250	3000	1484	Trigger, Folsom Storage from DWRSIM Run 514

Clear Creek Tunnel	D94&D40_SR-3	Below Lewiston Lake	PROSIM Node 1	0	3300	1124	Trigger, Clair Engle Storage from PROSIM NAA
			PROSIM Node 1	0	3300	1281	Trigger, Clair Engle Storage from DWRSIM Run 514
Sacramento	D5_D73	Below Keswick	PROSIM Node 4	3250	6000	3464	Trigger, Shasta Storage from PROSIM NAA
			PROSIM Node 4	3250	6000	3460	Trigger, Shasta Storage from DWRSIM Run 514

The American River minimum instream flow requirements are approximately 140 cfs larger based on PROSIM NAA storages. On the other hand, the Clear Creek Tunnel requirements are approximately 157 cfs smaller when based on the PROSIM NAA storages, but largely because DWRSIM Run 514 does not operate Clair Engle for the Clear Creek Tunnel PROSIM minimums and consequently has higher Clair Engle storages (Figure F-3). Figure F-4 presents the storages from PROSIM NAA and DRWSIM Run 514 for Lake Folsom. It is fairly evident that the two differ significantly. The differences between the two storage time series produce the different average minimum instream requirements, despite using the same trigger rule. Similarly, there exists differences in the storages for Lake Shasta (Figure F-5).

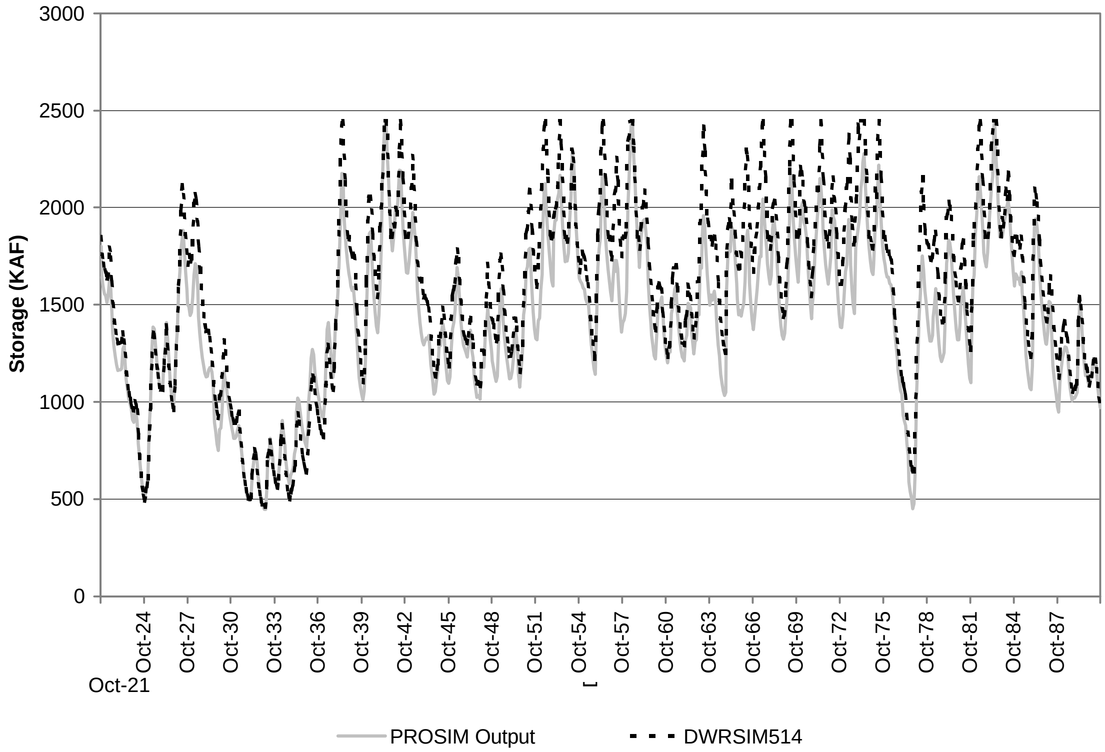

Figure F-3: Comparison of PROSIM NAA and DWRSIM Run 514 Storages for Clair Engle

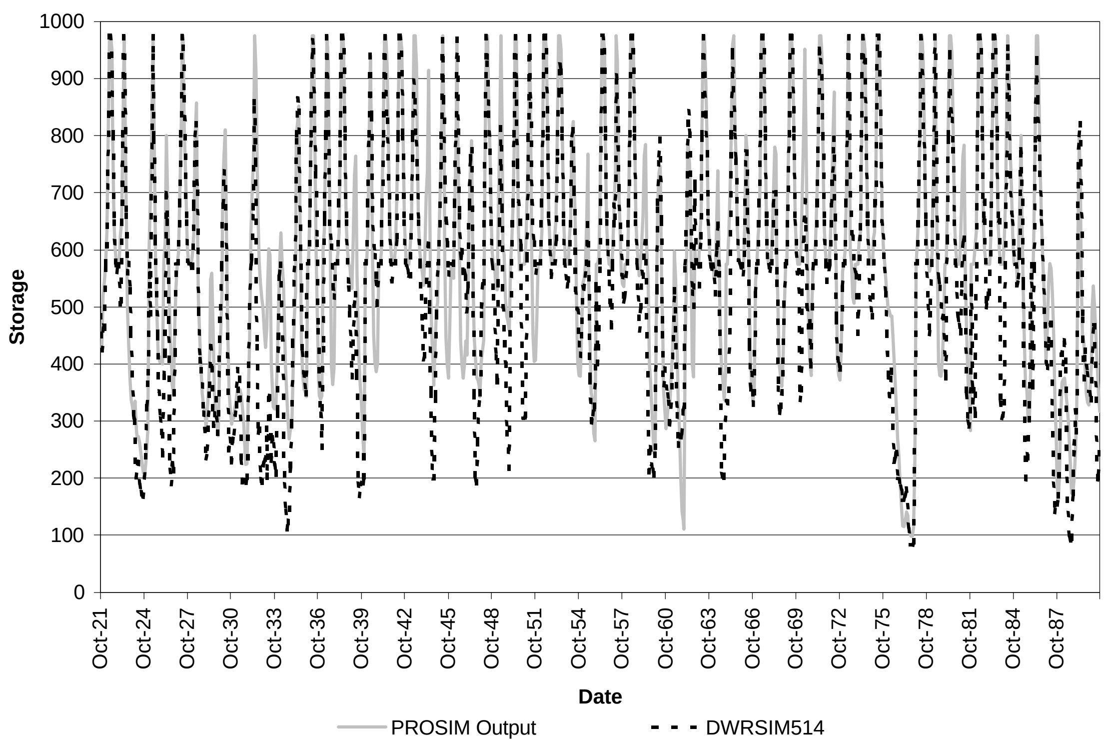

Figure F-4: Comparison of PROSIM NAA and DWRSIM Run 514 Storages for Lake Folsom

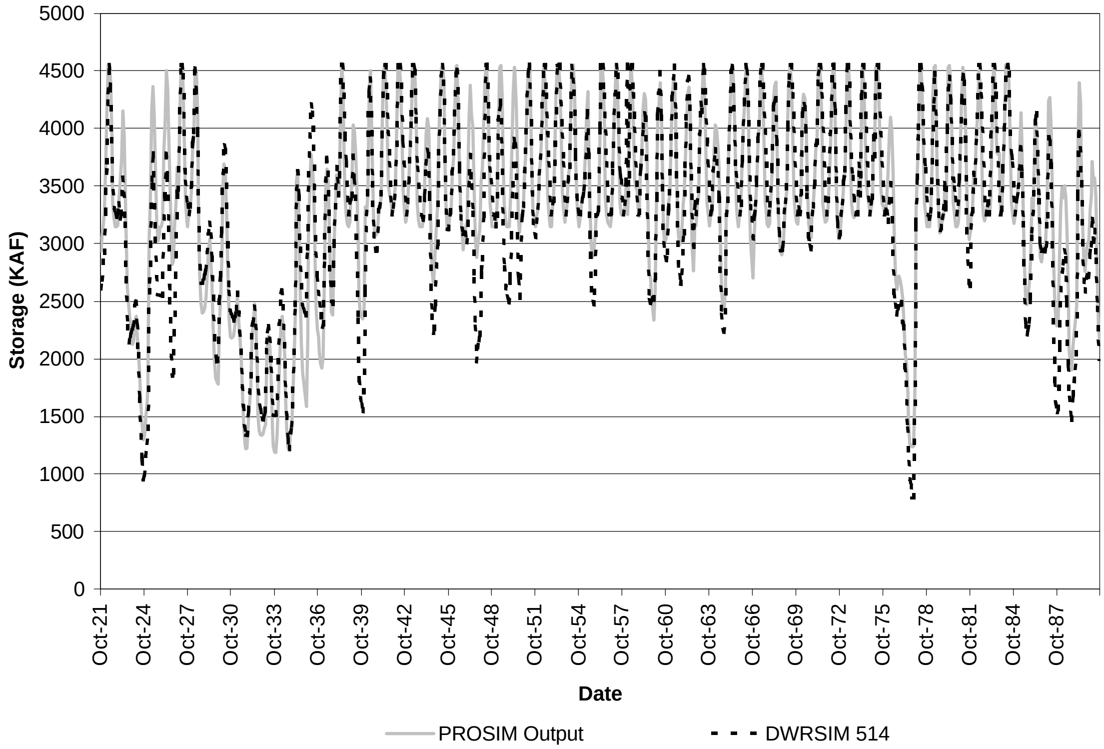

Figure F-5: Comparison of PROSIM NAA and DWRSIM Run 514 Storages for Lake Shasta

Considerations for Instream Flow Requirements on Specific Rivers

In representing the various instream flow requirements, several simplifications were necessary to compensate for CALVIN's monthly time step and network flow optimization requirements. Some watersheds require additional assumptions and calculations.

American River

An important consideration for the American River is that PROSIM and DWRSIM minimum instream flow values are much smaller than recommended by USFWS subsequent to the 1990 Hodge's Decision (Environmental Defense Fund et. al. vs. East Bay Municipal District 1972). Table F-2 reflects these stricter inflow standards compared to those shown in Table F-1. CALVIN applies the PROSIM NAA trigger rule to DWRSIM Run 514 Folsom storages to minimize calibration problems in CALVIN's Base Case (see Appendix 2H).

PROSIM and DWRSIM values neglect these flows since both efforts do not explicitly include the Folsom South Canal, the conveyance facility that would help deliver American River water to the EBMUD service area. Although CALVIN does include a capacity on the Folsom South Canal, any further analysis of American River diversions should consider the flow regime recommended in Table F-2.

Table F-2. USFWS Minimum Instream Flows for the Lower American River

Month	Year Type (all values in cfs)[a]			
	Wet	Normal	Critical	Critical Relaxation
October	2500	2000	1750	800
Nov-Feb	2500	2000	1750	1200
Mar-May	4500	3000	2000	1500
June	2500	3000	2000	500
July	2500	2500	1500	500
August	2500	2000	1000	500
September	2500	1500	500	500

Note:
[a] The source these values are cited from does not indicate which index is used.
Source: Jones and Stokes 1997

Mono Basin

From a water supply perspective, two tiers of environmental constraints exist in the Mono Basin, which aggregate the inflow from Rush, Parker, Walker, and Lee Vining Creeks. Each creek has an instream flow requirement, as directed in SWRCB Decision 1631. In addition to the instream flow requirement, the City of Los Angeles is required to maintain a Mono Lake elevation of 6,391 feet above mean sea level (msl) or accept a reduced diversion schedule as specified in SWRCB Decision 1631. Considering minimum instream flow requirements only, approximately 45 taf/yr (citation?) of Mono Basin water is available for supply and power generation for the October 1921-September 1993 time period. When also taking into account Mono Lake refilling needs, DWR (1998a) estimates the Mono Basin can supply the City of Los Angeles with 31 taf/yr after lake-level requirements are satisfied.

Rather than determining which SWRCB flow schedule to use, CALVIN requires Mono Lake to reach 6,391 ft above msl (or 2,939 taf according to area-elevation-capacity relationships provided in Vorster 1983) at the end of every March (the beginning of the Eastern Sierra Nevada water year). CALVIN assumes this elevation has been reached in 2020 and the City of LA can divert water from the Mono Basin subject to minimum instream flow constraints and maintaining the specified lake level.

The only outflow from Mono Lake is evaporation. Annual figures from Vorster (1983) were converted to monthly values with the assumption that Mono Lake has the same evaporation pattern as Lake Isabella on the Kern River. These figures are net evaporation, which account for precipitation and inflow to Mono Lake from sources other than Rush, Parker, Walker, and Lee Vining Creeks.

Owens Lake

As a result of recent litigation, the City of LA is required to provide air quality remediation measures in the dry Owens Lake bed. Excessive surface water withdrawals and groundwater pumping in the region have caused dust storms with very high levels of particulate matter. To alleviate this problem, LA is required to provide one of three combinations of remediation techniques: 1) shallow flooding of the lake bed requiring 4 acre-feet per acre, 2) managed vegetation requiring 2 acre-feet per acre, or 3) gravel coverage requiring no water (See Table F-

3). GBUPCD (1998) assumes a mix of alternatives requiring 51 taf/yr, which is reflected in the Table F-3 calculations and is represented as a fixed diversion in CALVIN. Ono (1999), however, suggests that the City of LA might choose a combination of alternatives, lowering their total requirement to only 40 taf/yr. As shown in the table below, this is the requirement imposed in CALVIN.

Table F-3. Water Requirements for Owens Lake Remediation[a,b]

Month	Managed Vegetation (taf/month)	Shallow Flooding (taf/month)[c]	Total Owens Lake Requirement (taf/month)	CALVIN Requirements (taf/month)
October	0.7	1.9	2.5	2.04
November	0.4	1.2	1.6	1.47
December	0.4	1.2	1.6	0.95
January	0.5	1.5	2.0	1.99
February	0.9	2.7	3.6	1.24
March	1.4	4.0	5.4	1.26
April	2.0	5.7	7.7	1.6
May	2.5	7.3	9.8	2.8
June	2.9	8.2	11.1	4.2
July	2.6		2.6	6.05
August	1.9		1.9	7.69
September	1.2		1.2	8.7
TOTAL			**51**	**40**

Notes:
[a] Assuming the City of LA selected the following control measures: 8400 acres of shallow flooding, 8700 acres of managed vegetation, and 5300 acres of gravel.
[b] Assuming the same evaporation pattern as Lake Isabella on the Kern River.
[c] No flooding is required between August 1 and September 14 (the whole month of September neglected).

Sacramento-San Joaquin Delta Outflow

Minimum instream flows within the Sacramento-San Joaquin Delta have not been modeled explicitly for each river within the Delta. Instead, minimum flows through the Delta are guaranteed with a single minimum outflow requirement into the San Francisco Bay.

X2, the location of the 2 parts per thousand isohaline, is used to identify the estuarine entrapment zone. Various EPA X2 requirements greatly affect the Delta outflow constraint. DWRSIM uses various methods to calculate the X2 position, which changes the monthly total outflow constraint. Since CALVIN lacks the ability to make an X2 calculation, CALVIN's Delta outflow constraint is the minimum Delta outflow time series resulting from DWRSIM model run DWRSIM_2020D09B-Calfed-514-output (DWR 1998b).

Salton Sea

Although no water supply is available from the Salton Sea, it is included in the CALVIN schematic to maintain a physical representation and since it is a major focus of concern in the South Lahontan hydrologic region. Return flows are the only CALVIN inflows included in the Salton Sea and the only outflow is evaporation. Although the New and Alamo Rivers are represented on the network schematic diagram (Figure 6-3 and 6-4 in main report), these rivers have zero inflows since they are used for limited industrial water purposes only (Montgomery Watson 1996).

Although detailed area-elevation-capacity relationships exist for the Salton Sea, CALVIN can not mimic the results of more detailed water balance simulation models.

Monthly figures for the Salton Sea were obtained from Hughes (1967) and Ferrari et. al. (1995). These values were given for inconsistent time increments (15-32 days), so monthly evaporation was roughly estimated based on the corresponding dates. Hughes (1967) found annual evaporation to be around 72 inches per year, while the currently accepted value is 66 inches per year. Accordingly, the values in Hughes (1967) and Ferrari et al. (1995) were normalized to equal 66 inches per year.

Table F-4. Days Maximum Daily Average EC of 2.64 mmhos/cm Must be Maintained[a]

PMI[b]	Chipps Island				
(taf)	FEB	MAR	APR	MAY	JUN
≤ 500	0	0	0	0	0
750	0	0	0	0	0
1000	28	12	2	0	0
1250	28	31	6	0	0
1500	28	31	13	0	0
1750	28	31	20	0	0
2000	28	31	25	1	0
2250	28	31	27	3	0
2500	28	31	29	11	1
2750	28	31	29	20	2
3000	28	31	30	27	4
3250	28	31	30	29	8
3500	28	31	30	30	13
3750	28	31	30	31	18
4000	28	31	30	31	23
4250	28	31	30	31	25
4500	28	31	30	31	27
4750	28	31	30	31	28
5000	28	31	30	31	29
5250	28	31	30	31	29
≥ 5500	28	31	30	31	30

Notes:
[a] The 2 ppt isohaline (X2) is measured as 2.64 mmhos/cm surface salinity.
[b] PMI is the best available estimate of the previous month's Eight River Index.
The number of days for values of the PMI between those specified are determined by linear interpolation.
Source: SWRCB 1999, Table II-4

San Joaquin River

The Final Environmental Impact Report for Implementation of the 1995 Bay/Delta Water Quality Control Plan (SWRCB 1999) is the source for the required pulse and X2 flow data at Vernalis. Technical Appendix 4 of the SWRCB Report provides a monthly time series (DWRSIM run 1995C06F-SWRCB-469, 11/96) of required minimum flows for water years 1922 through 1994 at the 1995 level of development. The required flows at Vernalis are based on the San Joaquin Valley 60-20-20 Index for determination of water year type and the Eight

River Index. The unimpaired runoff from the four Sacramento River Index rivers and the four San Joaquin River Index rivers is summed to produce the Eight River Index (DWR 1998a). The previous month's Eight River Index (PMI) is used to indicate how many days the Delta X2 standard must be maintained at a specified location such as Chipps Island (Table F-4) during the current month. February through June are the months regulated by the X2 standard.

Minimum flows at Vernalis from February through June (Table F-5) are described as meeting either high or low objectives depending on the required X2 position (Table F-4). The higher flow is required when the X2 position is at or downstream of Chipps Island, and the lower flow is allowed when the X2 position is upstream of Chipps Island. The water year type (San Joaquin 60-20-20 Index) determines the high and low flow quantities.

Table F-5. Feb-June Minimum Flows at Vernalis (cfs)

Year Type	FEB 1 - APR 14 & MAY 16 - JUN 30	APRIL 15 - MAY 15
Wet	2130 or 3420	7330 or 8620
Above Normal	2130 or 3420	5730 or 7020
Below Normal	1420 or 2280	4620 or 5480
Dry	1420 or 2280	4020 or 4880
Critical	710 or 1140	3110 or 3540

Source: SWRCB 1999, Appendix 2

Minimum flows at Vernalis during the month of October follow unique rules. For all water years, the minimum flow is 1000 cfs plus up to a 28 taf (455 cfs) pulse flow. Application of this pulse flow results in a minimum flow for October that usually depends on the actual flow at Vernalis (Table F-6). The required minimum flow ranges from 1455 cfs to a maximum of 2000 cfs, with one exception. If a critical year follows a critical year, the 28 taf pulse flow is not required and the minimum flow for October is 1000 cfs.

Table F-6. October Minimum Flows at Vernalis (cfs)

Actual Flow	Required Flow
< 1000	1455
1000 - 1545	Actual Flow + 455
≥ 1545	2000

Source: SWRCB 1999, Appendix 2

Minimum required flows at Vernalis for the months of January, July, August, September, November, and December are zero. As South Delta water quality and quantity needs are determined, these six unregulated months could be affected.

In CALVIN the minimum required flows at Vernalis are, on average lower than those set by the State Water Resources Control Board (SWRCB). The annual average requirement in CALVIN is 948.4 taf/year opposed to the 1030.9 taf/yr set by the SWRCB. In the base and regional unconstrained cases, CALVIN uses the flows in DWRSIM Run 514 as fixed flow requirements. In the statewide case, the DWRSIM Run 514 flows were compared to the SWRCB requirements and the lower of the two was used. (See file “Req Min for Vernalis in Statewide Model.xls” in Statewide/P1 folder for details.)

Stanislaus River

In contrast with the majority of other instream flow requirements used in CALVIN, the Stanislaus River requirements depend on complex rules accounting for New Melones Reservoir storage, projected inflows, projected water supply and water quality demands, and target carryover storage. Also, the distribution pattern of this quantity is annually specified by DFG based on wildlife and fishery needs (USBR 1997a).

Both SANJASM and DWRSIM require a separate component for the calculation of Stanislaus instream flows (ISTNFISH and Stanislaus River Water Allocation Processor). Since CALVIN cannot represent such a procedure, SANJASM was used as a preprocessor for Stanislaus River requirements and thus all assumptions inherent to SANJASM's preprocessor apply to CALVIN.

FISH AND WILDLIFE REFUGE DEMANDS

California's refuge areas have been consolidated into six refuge nodes: the Sacramento East, Sacramento West, San Joaquin, Mendota, Kern, and Pixley Refuges. Each of these areas have environmental water supply requirements. The requirements for the San Joaquin, Mendota, and Kern Refuges are represented by time series of minimum flow diversions from DWRSIM_2020D09B-Calfed-514-main.dat. The San Joaquin Refuge requirement is the diversion time series at DWRSIM Run 514 control point 723, the Mendota Refuge is the diversion time series at control point 732, and the Kern Refuge is the diversion time series at control point 753. The water supply requirements for the Sacramento East and West Refuges are based on recent historic (level 2) refuge requirements of several water districts within each of these geographical areas. Monthly refuge requirements for these water districts can be found in USBR (1997b, c, d). Table F-7 summarizes CALVIN's Base Case representation of fish and wildlife refuge demands.

Table F-7. CALVIN Deliveries to Fish and Wildlife Refuges

Aggregate Refuge	Sources	Link	Refuges Included	Deliveries (taf/month)		
				Min	Max	Avg
Kern	DWRSIM 514 output CP753	C95_KERN REFUGES	Kern NWR	0.7	5.6	3.0
Pixley	USBR 1997b	C60_PIXLEY NWR	Pixley NWR	0	0	0
Sac West Refuges[a]	USBR 1997d	C302_SAC W REF	Sacramento, Delevan, and Colusa NWR	0.6	17.5	6.9
Sac East Refuges[a]	USBR 1997c	C311_SAC E REF	Sutter and Gray Lodge NWR	1.0	11.6	4.6
San Joaquin[b]	DWRSIM 514 output	D723_San Joaquin Refuges	Volta WMA Freitas SJBAP Salt Slough SJBAP China Island SJBAP	0.7	7.2	3.0

Mendota Pool[b]	DWRSIM 514 output	D732_Mendota Wildlife Area	Grassland WD Los Banos WMA Kesterson NWR San Luis SWR Mendota WMA Merced NWR West Gallo SJBAP	2.9	63.9	20.1

Notes:
[a] Sacramento West and East Refuge deliveries are reported as volumes of water deliveried into the refuge. Conveyance losses have already been accounted for.
[b] DWRSIM aggregates these values but does not explain which refuges are included.
SJBAP = San Joaquin Basin Action Plan
NWR = National Wildlife Refuge
SWR = State Wildlife Refuge
WMA = Wildlife Management Area

Sacramento West Refuge

The Sacramento West Refuge represents the aggregate Sacramento National Wildlife Refuge (NWR), Delevean NWR and Colusa NWR. The three refuges are surrounded primarily by agricultural lands (CVPM 3 in CALVIN). The historic water deliveries into the refuges are considered the Level 2 deliveries. Table F-8 present the aggregate monthly demands for the Sacramento West Refuge.

CALVIN attempts to replicate the Level 2 demands. However there are periods when Base Case allocations are insufficient to meet the full Level 2 demands. In those periods a modified Level 2 (deficiency) is imposed. The refuge can obtain its water from the surface water supply sources only. In periods when the entire Base Case available surface water supply for CVPM 3 is insufficient to meet full Level 2 demands, the refuge experiences scarcities. Also note there is a conveyance factor of 0.78 applied to the refuge supplies. Table F-8 presents the average monthly delivery to the Sacramento West Refuge after conveyance losses and modifications.

Table F-8: Sacramento West Refuge Water Demands and Deliveries

	Full Level 2 Demands	Average Modified Level 2 Deliveries
January	4.05	2.60
February	3.30	2.09
March	1.10	0.83
April	1.17	1.17
May	3.99	3.99
June	6.00	6.00
July	8.43	8.43
August	11.38	11.38
September	14.39	14.06
October	17.49	16.44
November	13.75	10.07
December	8.30	5.73
Annual Average	93.35	82.79

The Sacramento West Refuge experiences approximately 10.6 taf/year of scarcity. The majority of the scarcities occur during the winter months of the critically dry periods.

Sacramento East Refuge

The Sacramento East Refuge represents the aggregate Sutter National Wildlife Refuge (NWR) and Grey Lodge Wildlife Area (WA). The two refuges are primarily surrounded by agricultural lands (CVPM 5 in CALVIN). The historic water deliveries to the refuges are considered the Level 2 deliveries. Table F-9 present the aggregate monthly demands for the Sacramento East Refuge.

CALVIN attempts to replicate the Level 2 demands. However there are periods when Base Case allocations are insufficient to meet the full Level 2 demands. In those periods a modified Level 2 is imposed. The two refuges are supplied primarily by the Sutter Extension Water District (SEWD) and the Biggs-West Gridley Water District (BWGWD). Based on USBR (1997b), the Sutter NWR receives 85% of its deliveries from agricultural return flows. However agricultural water is only available from April through September. For those months it was found that all available agricultural return flows are insufficient to meet the 85% of the refuge demands. Similarly Gray Lodge obtains approximately 40% of its demand from agricultural return flows. During the irrigation months (April through September) there are sufficient agricultural return flows to meet 40% of Gray Lodge's demand. The remaining monthly demands for each refuge must be made up from CVPM 5 supplies of groundwater and Thermolita Afterbay water.

In periods when the entire CVPM 5 Base Case surface and groundwater supply is insufficient to meet full Level 2 demands, the refuge experiences scarcities. Also note there is a conveyance factor of 0.89 applied to the refuge deliveries. Table F-9 presents the average monthly delivery to the Sacramento East Refuge after conveyance losses and modifications.

Table F-9: Sacramento East Refuge Water Demands and Deliveries

	Full Level 2 Demands (taf/month)	Average Modified Level 2 Deliveries (taf/month)
January	2.00	1.79
February	2.05	1.15
March	2.05	2.05
April	2.00	2.00
May	3.60	3.60
June	4.80	4.80
July	3.80	3.80
August	6.65	6.65
September	11.60	11.30
October	10.55	8.42
November	6.50	6.50
December	3.30	2.74
Annual Average	58.90	54.81

The Sacramento East Refuge experiences approximately 4.1 taf/year of scarcity. As with the Sacramento West Refuge, the majority of the scarcities to the Sacramento East Refuge occur during the winter months of the critically dry periods.

SUMMARY

CALVIN includes 12 minimum instream flows, 6 refuges, the Bay Delta outflows and the Mono-Owens minimum as environmental requirements in the system.

Table F-10: Summary of Environmental Requirements

	Average Annual Requirement (taf/yr)
Minimum Instream Flows	
Trinity River	357
Clear Creek	42
Sacramento River (Nav. Control Point)	3117
Feather River	936
American River	1076
Mokelumne River	88
Calaveras River	1
Yuba River	170
Sacramento River (above Hood)	3619
Stanislaus River	196
Tuolumne River	119
Merced River	79
Refuge Requirements	
Sacramento West Refuge	106
Sacramento East Refuge	62
Volta Refuges	36
San Joaquin/Mendota Refuges	237
Pixley	0
Kern	11
Bay Delta Outflow	
Bay Delta	5593
Mono/Owens Requirement	
Mono Lake Inflows	74
Owens Lake Dust Mitigation	40
TOTAL	**15958**

LIMITATIONS

Environmental benefits are not modeled explicitly in CALVIN. Only the benefits associated with the included constraints, minimum instream flow constraints, and fish and wildlife refuges, may be analyzed from the perspective of urban and agricultural water users. Environmental water use is not optimized.

Environmental flows in the Sacramento-San Joaquin Delta have been simplified. Flows on individual river reaches within the Delta have not been modeled explicitly.

The environmental flow requirements for some river reaches involve complex operating rules that cannot be easily represented as a simple time series. In many cases, therefore, the time series used in CALVIN is based upon an assumed system operation not necessarily corresponding with the operation recommended by the model.

The refuges represented in the model are aggregations of many, much smaller refuge areas. These aggregations may allow the model to make refuge deliveries more efficiently than is actually possible.

REFERENCES

DWR (1998a), *California Water Plan Update, Bulletin 160-98*, Vol 1 and 2, California Department of Water Resources, Sacramento, CA.

DWR (1998b), *DWRSIM Model – 2020D09B-Calfed-514*, California Department of Water Resources, Sacramento, CA.
Data files: DWRSIM_2020D09B-Calfed-514-main.dat

DWR (1993), *California Water Plan Update, Bulletin 160-93*, Vol 1, California Department of Water Resources, Sacramento, CA.

Ferrari, Ronald L. and Paul Weghorst (1995), *Salton Sea 1995 Hydrographic GPS Survey*, U.S. Bureau of Reclamation, Denver, CO.

Great Basin Unified Air Pollution Control District (GBUPCD 1998), *Owens Valley PM_{10} Planning Area Demonstration of Attainment State Implementation Plan, Appendix K*, Bishop, CA, November 16.

Hughes, G.H. (1967), *Analysis of Techniques Used to Measure Evaporation From Salton Sea, California*, Geological Survey Professional Paper 272-H.

Jones and Stokes Associates (1997), *East Bay Municipal Utility District Supplemental Water Supply Project*, Jones and Stokes Associates, Sacramento, CA.

Montgomery Watson (1996), *County of Imperial: Imperial County Groundwater Study*, Final Report, June.

Ono, D. T. (1999), Air Pollution Control Officer, Great Basin Unified Air Pollution Control District, per conversation, September.

SWRCB (1999), Final Environmental Impact Report For Implementation of the 1995 Bay/Delta Water Quality Control Plan, State Clearinghouse Number 97-122056, State Water Resources Control Board and California Environmental Protection Agency, Sacramento, CA.

USBR (1997a), Central Valley Improvement Act Programmatic Environmental Impact Statement, U.S. Bureau of Reclamation, Sacramento, CA.
Data files: CVPIAPEIS/Disk2/cvgsm/naa/Input/ CNJMIN.NDA
Data file documentation: CVPIAPEIS/Disk1/cgm/cgm-Ch3.pdf beginning on page III-7

USBR (1997b), *Conveyance of Water Supply Environmental Assessment and Initial Study: East Sacramento Valley Study Area*, U.S. Bureau of Reclamation, Sacramento, CA.

USBR (1997c), *Conveyance of Water Supply Environmental Assessment and Initial Study: San Joaquin Study Area*, U.S. Bureau of Reclamation, Sacramento, CA.

USBR (1997d), *Conveyance of Water Supply Environmental Assessment and Initial Study: West Sacramento Valley Study Area*, U.S. Bureau of Reclamation, Sacramento, CA.

Vorster, P. (1983), *A Water Balance Model for Mono Lake, California,* Masters Thesis, California State University, Hayward.