APPENDIX 2H

CALIBRATION PROCESS DETAILS

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INTRODUCTION

This appendix describes the methods and major assumptions used to calibrate the hydrologic inflows, agricultural return flows, and agricultural water demands in CALVIN for the Central Valley. Results of the calibration are presented. The objective of calibration is to integrate surface and groundwater hydrologies developed for DWRSIM and CVGSM and reconcile inconsistent assumptions in these two separate hydrologies, as well as reconcile agricultural water demand assumptions with water deliveries in the CVPIA-PEIS (USBR 1997). This is a physical calibration of the mass of water in the Central Valley's interconnected surface and groundwater system.

Some areas where hydrologic understanding of the system seems inconsistent or wanting are identified in the calibration process. Recognizing that several different approaches could have been used to reconcile the interconnected surface and groundwater data used in CALVIN, we examine at the end of this appendix some limitations of the current method.

The general approach to calibrating the CALVIN hydrology is to use DWRSIM as the basis for reservoir operations and rim flows, and CVGSM as the basis for subsurface flows, groundwater pumping, and local surface water accretions and depletions. While there are significant problems with both representations of Central Valley hydrology, each source has its methodological, data, and documentation strengths (and weaknesses). Despite their weaknesses, these two sources represent the most extensive and detailed historical hydrologies for the Central Valley. We have tried to take the best available hydrologic representations and data to achieve a dynamically integrated model of surface and groundwater. To clarify our hydrologic calibration and reconciliation and aid in future hydrologic data development, all calibration parameters in the model are distinct from the original sets of physically based model data.

Major Steps in Calibration of CALVIN

A summary of the overall CALVIN calibration process is presented here. Greater details are provided later in this appendix.

<u>Step 1. Uncalibrated Physical CALVIN Model</u>

Initial flows, demands, and return flows are adopted in CALVIN to represent our understanding of the physical system. However, problems occur with this model's results not appearing to accord with conventional understanding of how the system operates and the distribution of water scarcity within the system. Early versions of this uncalibrated model appear in Howitt et al. (1999) and later versions appear in the updated appendices to Howitt et al. (1999). Problems appear to be fundamental difficulties reconciling a) DWRSIM surface hydrology, b) CVGSM groundwater hydrology, c) Bulletin 160-98 supporting data on on-farm demands, and d) estimated agricultural water deliveries.

Step 2. Adjustment of Agricultural Reuse, Return Flows, and Demands

SWAP agricultural water demands used in CALVIN are adjusted (usually increased) to reflect the greater amounts of water deliveries seen in CVPIA-PEIS NAA (USBR 1997). Return flow coefficients and water reuse factors for agricultural demand regions are adjusted (reuse usually decreased) so net agricultural groundwater extraction (pumping less deep percolation of applied irrigation water) match CVGSM-PEIS NAA under the CALVIN Base Case.

Step 3. Adjustment of Surface Water Flows

Time series of surface inflows (positive and negative) are added to match streamflows in the CALVIN Base Case to those in DWRSIM Run 514a.

Step 4. Hydrologically Calibrated CALVIN Model

The resulting physically-based CALVIN, with adjustments to demands, reuse, return flows, and streamflows matches demands and hydrologies to those accepted for the Central Valley, as represented by DWRSIM and CVGSM.

UNCALIBRATED MODEL DESCRIPTION

The two CALVIN model data sets used in the calibration process are the Unconstrained and Base Case alternatives. The essential sets of data and assumptions represented by these two alternatives are summarized and details described in the appendices to Howitt et al (1999). The reference data sets to which CALVIN is calibrated (made to match) are the CVGSM NAA output from the CVPIA PEIS (USBR 1997) for groundwater, local supplies (Central Valley floor accretions), and deliveries, and DWRSIM Run 514a output for surface water (http://wwwhydro.water.ca.gov/assumptions/calfed/assum514.html).

Uncalibrated Unconstrained Model

The uncalibrated step 1 model is constrained only by conservation of mass, inflows, environmental minimum instream and refuge flows (current or “no action” policy levels), capacity and flood storage constraints on reservoirs, and capacity constraints on conveyance facilities. The objective function is economic, representing the economic value of water for agricultural and urban water users. In this case, all hydrologic inputs and coefficients (such as agricultural reuse rates, farm efficiencies, and return flow rates) are based to the greatest degree possible on a physically explicit understanding of the system, as described in the aforementioned appendices. They are not calibrated to “fit” other model results. Table 2H-1 summarizes sources for the physical data and coefficients used in CALVIN. It also notes inconsistencies, limitations, or other problems with differing sets of these data where known.

Table 2H-1. Central Valley Physical Modeling Data in CALVIN

	Physical Modeling Data	Description	Source	Data and Calibration Issues
1	Local surface water supplies (local accretions and depletions)	Direct runoff from precipitation and net gains/losses in local stream reaches from/to GW in the Central Valley	CVGSM NAA output (strmdt2a.nea)	Differs from DWR depletion analysis due to use of different estimation technique; CVGSM uses an uncalibrated rainfall-runoff model while DWRSIM uses a mass balance analysis that mingles surface and groundwater in estimates.
2	Rim surface water inflows	Inflows from outside the modeled demand areas included in CALVIN; generally net contributions from watersheds upstream of major Valley rim reservoirs	DWR depletion analysis (see Appendix I: Surface Water Hydrology for other sources)	Generally consistent, but differs slightly from PROSIM
3	Conveyance losses in major canals	Includes breakdown of recoverable (to GW) and non-recoverable losses	CVGSM NAA output (cnjdvsp2.nda & cnjswdv3.nea)	Appears to differ from losses reported in wu2a_y.nea CVGSM output; total losses (see 4) are generally lower than 10-15% assumed in depletion analysis/DWRSIM.
4	Conveyance losses in minor canals	Within irrigation district canal losses	Not explicit in any model	Assumed to be included in CVGSM on-farm soil budget accounting (see deep percolation)
5	Agricultural reuse	Regional multiplier effect from reuse of on-farm runoff among farms and between districts within one CVPM region	CVPM NAA input (CVPIA PEIS) (cesdat95.gms)	No other source for this data; Appears to be ignored in CVGSM NAA on-farm applied water volumes
6	Deep percolation of on-farm agricultural applied water	A function of applied water, precipitation, distribution uniformity, irrigation method, evapotranspiration, and soil properties	CVGSM NAA output (soil2a_y.nea)	No other comprehensive source for this data; sum of on-farm deep percolation and runoff is measured by DWR's on-farm agricultural efficiencies which are higher than those implicit in CVGSM's soil budget
7	On-farm runoff of applied water	A function of applied water, precipitation, distribution uniformity, irrigation method, evapotranspiration, and soil properties	CVGSM NAA output (soil2a_y.nea)	No other comprehensive source for this data; sum of on-farm deep percolation and runoff is measured by DWR's on-farm agricultural efficiencies
8	Surface water return flow from CVPM region	Amount that exits a CVPM region to return to streamflow available for downstream uses; modifies on-farm runoff by amount of reuse within a CVPM region	Computed from other physical input and adjusted by CALVIN calibration parameters (see Table 2H-3)	Not explicitly identified in DWRSIM or DWR depletion analysis; CVGSM volume of run-off from land surface is not explicitly corrected for reuse among farms or between districts within a CVPM region; DWRSIM return flows are expressed as a fraction of the sum of surface water diversions and net groundwater pumping.

Table 2H-1 Continued. Central Valley Physical Modeling Data in CALVIN

	Physical Modeling Data	Description	Source	Data and Calibration Issues
9	On-farm efficiency	Ratio of ETAW/AW at on-farm scale	DWR Bulletin 160-98 supporting data (=ETAW/AW)	Differs from agricultural efficiency indicated in soil2a_y.nea of CVGSM NAA output (see points 6 and 7)
10	CVPM regional efficiency	Ratio of (Deep Percolation + Surface Return Flow) to Net Deliveries for each CVPM region (at region-wide scale)	Computed from Reuse and On-farm efficiency	Spills may be missing and within district losses are missing from the computation
11	Deep percolation of urban outdoor applied water	Portion of landscape water that deep percolates	CVGSM NAA output (soil2a_y.nea)	Differs from Bulletin 160-98 assumptions and DWR's depletion analysis.
12	Return of urban indoor AW	Portion of indoor use that returns to main surface water system	CVGSM NAA output (soil2a_y.nea)	Differs from Bulletin 160-98 assumptions and DWR's depletion analysis (assumes 100% return flow)
13	2020 agricultural land use	Amount of acreage in each crop in 2020	DWR Bulletin 160-98	Similar to CVPM data used in the CVPIA-PEIS which is based on Bulletin 160-93 projected land use
14	ETAW by crop	Annual by CVPM region	Bulletin 160-98 planning data	Crop consumptive use estimates vary, depending on original reference ET estimates and crop coefficients. Differs somewhat from CVPM assumptions used in CVPIA PEIS.
15	AW by crop	Annual by CVPM region	Bulletin 160-98 planning data	Uncertainties in leaching, on-farm efficiency, pre-irrigation, etc. can cause widely differing estimates of AW starting from the same ETAW.
16	Monthly AW pattern by crop	By CVPM region, taken directly from monthly pattern of ETAW crop	DWR CU Model extended to whole of Central Valley. Monthly ratio of ETAW/AW assumed constant	Differs from CVGSM agricultural delivery pattern
17	2020 annual AW demand at farm level			Usually significantly smaller than CVGSM agricultural deliveries in the CVPIA-PEIS NAA.

When this uncalibrated model is run, several problems become apparent with the data sets used in CAVLIN and highlight the need for a more empirical model calibration. These major problems include:

- The nearly complete absence of scarcities throughout the 1922-1993 hydrologic period;
- Solution infeasibilities due to mass imbalances from constraints in some locations; and
- Distorted reservoir and Delta operations.

Base Case Model

CALVIN's Base Case model is considered the "base case" or "no action" alternative. It applies constraints to reservoir storages, diversions, and pumping, to replicate current (existing) operating policies and water allocation rules at the projected 2020 level of demand as they are modeled in the CVGSM NAA run and the DWRSIM Run 514a (see the Base Case Appendix of this current report for details). Base Case includes all the same physical and environmental assumptions as the Unconstrained model scenario along with these added operational constraints to represent a "base case" scenario equivalent to these two reference models. Base Case constrained diversion and pumping levels are taken from CVGSM NAA while constrained reservoir storage levels are taken from DWRSIM Run 514a. Exceptions are diversions from the California Aqueduct and Delta Mendota Canal, taken from DWRSIM Run 514a rather than CVGSM NAA. The CVGSM NAA diversion levels, in turn, reflect the results of the PROSIM and SANJASM runs under the "no action" alternative in the CVPIA PEIS (USBR 1997).

Problems with Uncalibrated Physically Based CALVIN Model

Problems with the physically based modeling results, noted above, were thought to arise due to:

1) assumptions about agricultural return flows and their locations;
2) estimates of groundwater pumping and recharge;
3) estimates of on-farm efficiency, reuse rates, and CVPM regional efficiencies; and
4) estimates of local accretions in the Central Valley floor.

The hydrologic calibration adjusts these aspects of the physically based model to better accord with DWRSIM and CVGSM representations of the Central Valley. In addition, large and important discrepancies between estimates of agricultural demands and deliveries were found when running the uncalibrated Base Case model.

CALIBRATON APPROACH

The calibration of CALVIN involves computing spatially disaggregated adjustments to water quantities and loss coefficients to get groundwater and surface water volumes to match those in CVGSM NAA and DWRSIM 514, at least on an annual average basis. Five sets of calibration adjustments are defined and computed as described below. The first three adjustments concern calibration of groundwater to CVGSM NAA. The fourth adjustment involves calibration of agricultural water demands to CVGSM NAA levels of agricultural surface and groundwater deliveries. The last adjustment concerns calibration of surface water flows to DWRSIM Run 514a. The order of presentation that follows is the sequence in which the calibration adjustments are computed during the calibration process.

1. CVPM region-wide groundwater/surface water return flow splits:

Calculation of the split of return flow to groundwater (*GWsplit*) and surface water (*SWsplit* = 1-*GWsplit*) for each CVPM region is derived from the CVGSM NAA volume of deep percolation of agricultural applied water, the CVPM region-wide reuse rate, the average on-farm efficiency (see Table 2H-1 for sources), and the Base Case agricultural surface and groundwater deliveries (see Table 2H-3). The Base Case deliveries are taken from the same modeling set as the volumes of deep percolation (i.e., CVGSM NAA) while on-farm efficiencies come from a different source (Bulletin 160-98 supporting data used to generate the SWAP agricultural demands).

Figure 2H-1 shows the two scales of analysis that must be considered in computing a CVPM region-wide agricultural return flow split: the farm and the CVPM region. The flow split shifts increasingly towards groundwater as larger scales are considered, due to reuse. Table 2H-3 shows the data used to compute the splits for each CVPM region as follows:

Eq.1. $GWsplit = DeepPercolation\ of\ AW\ /\ [CVGSM\ Delivery \times (1 - OnFarm\ Eff \times Reuse\ Rate)]$

Eq.2. $SWsplit = 1 - GWsplit$

where:

DeepPercolation of AW is the average annual volume of deep percolation from applied irrigation water on agricultural land derived from CVGSM NAA results (soil2a_y.nea) and reported in column 7 of Table 2H-3;

CVGSM Delivery is the net supply to the CVPM region in CVGSM NAA and the sum of the amounts reported in columns 2 (groundwater pumping) and 3 (net surface water deliveries) of Table 2H-3. CVGSM net surface water deliveries are actual deliveries received by the irrigation district. They exclude conveyance losses from the point of diversion to the irrigation district but include conveyance losses within the irrigation district boundaries but outside the farm;

OnFarm Eff is the on-farm efficiency based on DWR Bulletin 160-98 supporting data and reported in column 5 of Table 2H-3; and

Reuse Rate, the multiplier of net supplies to the CVPM region to account for reuse of on-farm runoff within the region, is from CVPM as reported in the CVPIA PEIS (USBR 1997).

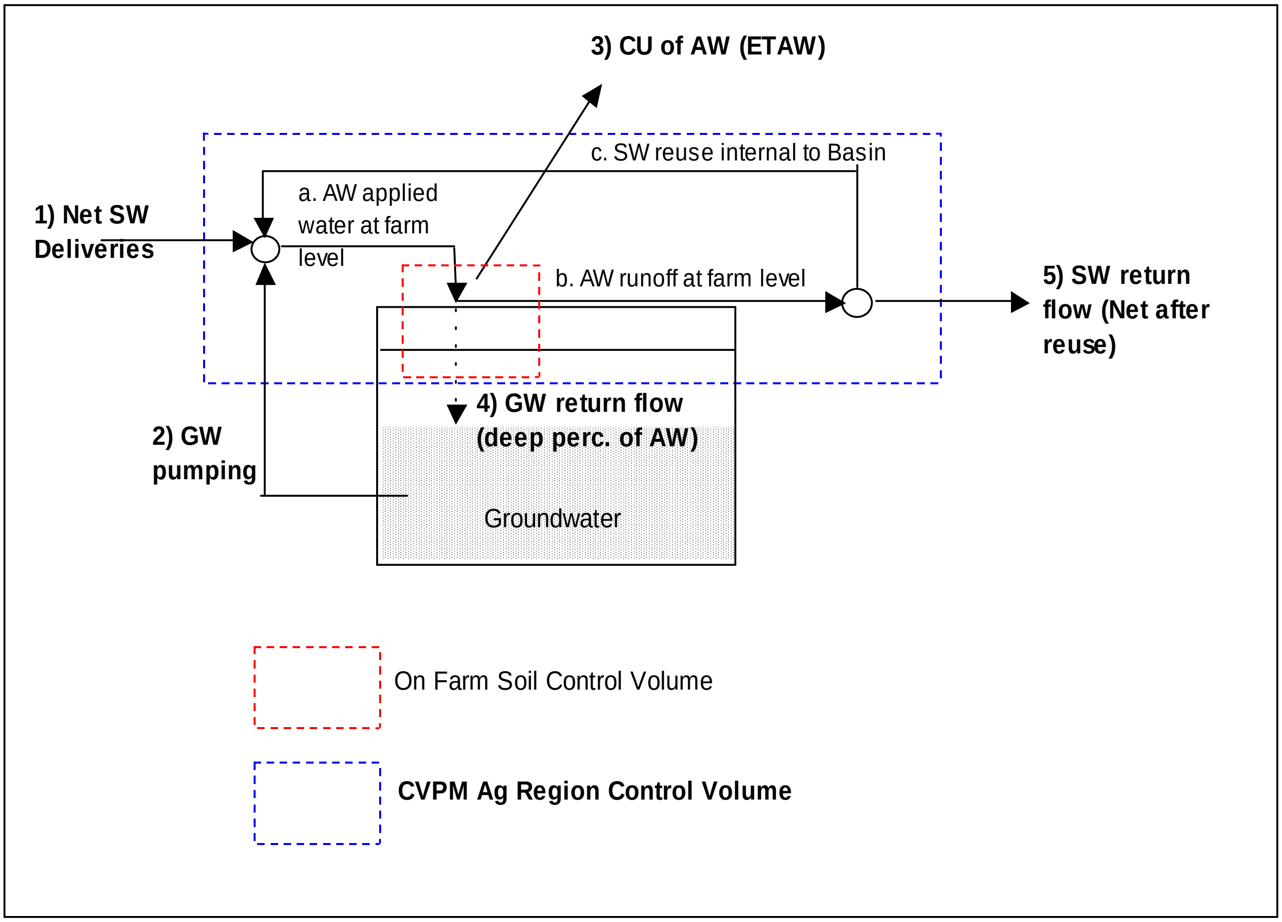


Figure 2H-1. Conceptual Water Balance for Calibrating CVPM Agricultural Water Flows

Notes to Figure 2H-1:
Numbers refer to regional volumes while lower case letters refer to on-farm volumes. Number 3 and 4 are also on-farm volumes if consumptive use and deep percolation of within district canals are ignored or assumed to be included in the on-farm soil control volume. This appears to be the case with CVGSM representation of CVPM agricultural water use.

Definitions for Figure 2H-1:

ON-FARM APPLIED WATER	*= a = 1+2+c*
ON-FARM EFFICIENCY	*= 3/a =1- [(4+b)/a]*
REUSE RATE	*= a/(1+2)*
GW SPLIT	*= 4/(4+5) = 4/(4+b-c) = 4/{4+b-[(1+2)*(ReuseRate-1)]}*
REGIONAL EFFICIENCY	*= 1-[(4+5)/(1+2)] = 3/(1+2)*

In CVPM regions 6, 11, 14, 18, 19, 20, and 21, the calculated groundwater split (from equation 1) is above 1.0, a physically impossible value. This situation is caused by a combination of two problems:

- a reuse rate that is physically inconsistent with (or too high for) the volume of surface water runoff from on-farm applied water for that CVPM region (given the net supply and assumed on-farm efficiency level), and
- an effective agricultural applied water efficiency for the CVPM region in the CVGSM NAA soil budget analysis that is smaller than the DWR Bulletin 160-98 on-farm efficiency used in CALVIN for that region.

In nearly all CVPM regions, the effective regional applied water efficiency in CVGSM (as derived from the soil budget output) is lower than the on-farm efficiency indicated by Bulletin 160-98 ETAW-to-AW ratios. Table 2H-9 compares the two sets of efficiency values and reports the difference. In part, this difference could be explained because CVGSM does not appear to separate distribution canal deep percolation within the CVPM region from on-farm deep percolation in its soil budget accounting. Furthermore, in some areas of the Central Valley, particularly the Tulare Basin Region, agricultural deliveries may sometimes include water used by districts and farmers expressly to recharge groundwater. There appears to be no distinct pathway or accounting term in CVGSM for such recharge of agricultural surface water deliveries.

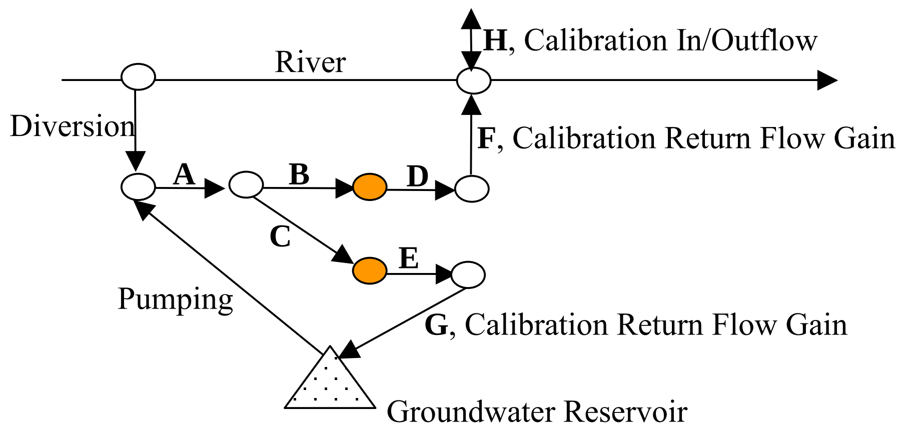
To bring the groundwater split back to a maximum physically meaningful value of 1.0 or less, two calibration adjustments can be made in these problem regions. The first adjustment reduces the reuse rate (described in the reuse adjustments section below). If the groundwater split is still above 1.0 after reducing the reuse rate to its lowest possible value of 1.00 (no reuse), a return flow amplitude adjustment can be calculated (described in return flow calibration link section below). This return flow gain reflects the difference in agricultural efficiency between CVGSM's soil budget and DWR Bulletin 160-98 planning data in regions where DWR efficiency estimates are quite high and most efficiency losses are to groundwater.

2) Reuse adjustments:

Reuse rates from CVPM are adjusted downwards in several CVPM regions because they exceed the available volumes of on-farm surface water runoff occurring in the CVGSM NAA agricultural land soil budget analysis. Table 2H-3 column 4 shows the adjusted (downward) reuse rates required to be physically consistent with on-farm runoff in CVPM regions 6, 11, 14, 18, 19, 20, and 21.

3) Return flow "calibration link" amplitudes:

When no further adjustment to reuse is possible and *GWsplit* remains above 1.0 (indicating that the DWR on-farm efficiency is higher than CVGSM NAA and most agricultural losses occur to groundwater), then an amplitude adjustment on the "calibration link" downstream of each CALVIN agricultural return flow link can be used to calibrate agricultural groundwater return flows so that they match CVGSM NAA under the Base Case scenario (effectively reducing the DWR on-farm efficiency). Figure 2H-2 shows the configuration of these return flow calibration links in relation to the location of other physical and calibration parameters used to characterize agricultural water use in CALVIN.



LINKS:

A: Reuse rate gain

B: Adjusted SWAP Demand * *SWsplit*

C: Adjusted SWAP Demand * *GWsplit*

D & E: CVPM region-wide return flow rate = 1- (*OnFarm Eff* * *Reuse Rate*)

G & F: Calibration link gain (≥ 1) on return flow (same for both links, to adjust GW return flow volume to match CVGSM deep percolation of agricultural applied water)

H: Calibration flows in or out of the system (to adjust surface water volumes to match DWRSIM run 514a and resolve mass balance infeasibilities)

CVPM Agricultural Demand Region – SW and GW return flow portions

Figure 2H-2. Configuration of Physical and Calibration Links for Agricultural Regions

Table 2H-3 column 8 lists the calculated return flow calibration link amplitudes for the four CVPM regions in the Tulare Basin Region that require further adjustments (14, 18, 19, and 20). The calibration gains indicate lower CVGSM agricultural efficiencies than those from DWR and used in CALVIN. If return flow calibration link gain adjustments are not used in CALVIN, then groundwater return flows in CALVIN from agricultural applied water in these regions will be lower than in CVGSM and groundwater depletion in the CALVIN base case scenario will be higher in these areas than what occurs in CVGSM NAA. Whether they are included or not, a fundamental inconsistency in the efficiency levels between DWR and CVGSM will have repercussions for groundwater conjunctive use analysis and its evaluation in many areas of the Central Valley.

4) Boosting SWAP demands:

Significant differences between CVGSM NAA on-farm applied water (deliveries less conveyance losses times reuse rates) and DWR Bulletin 160-98 estimates of average on-farm water demand in 2020 require that an adjustment be made to the 2020 SWAP agricultural demands derived from DWR Bulletin 160-98 supporting data and projections.

Surface and groundwater deliveries over the 72-year hydrologic sequence in CALVIN are taken directly from the time series of deliveries (input file cnjswdv2.nea) derived from PROSIM and SANJAM model runs) and pumping (output file gw2a_y.nea) in the CVGSM NAA model. In most CVPM regions, the annual average sum of these deliveries times the reuse rate exceeds SWAP maximum demands (see Table 2H-7 for comparison of Base Case deliveries at the farm level, including reuse component, compared to SWAP maximum demands based on Bulletin 160-98 projections). We suspect some portion of these deliveries go to unidentified distribution canal losses within the CVPM agricultural districts. Other portions may already include reuse[1] or, as noted earlier, may go towards direct groundwater recharge (mostly south-of-Delta).

This calibration adjustment consists of shifting the SWAP water value functions to the right by a fixed amount so that the annual average 2020 volume of agricultural water demanded at a zero marginal value of water at least equals the Base Case annual average water deliveries. The annual amount of adjustment to SWAP maximum demands is shown in Table 2H-7. It is necessary in all CVPM regions except 2, 3, 9, 14, 15, and 18. Thus, in the CALVIN Base Case only these six CVPM regions could experience scarcity. If SWAP adjustments were calculated by matching the Base Case annual average water deliveries to Bulletin 160-98 2020 projected demands (usually the first or second breakpoint on the SWAP penalty function to the left of the zero marginal value quantity), then all CVPM regions would experience some water scarcity in the CALVIN Base Case. However, this would have made the volume of SWAP adjustments considerably larger than the current 2 maf/yr shown in Table 2H-7.

One problem with this approach is that while average CALVIN demands now match average deliveries in the CVGSM NAA, there are many high-demand years in which the CVGSM NAA deliveries exceed those of CALVIN. This occurs since the agricultural demands in CALVIN do not vary between years, while those of CVGSM NAA do.

Figure 2H-3 illustrates how the average adjustment is applied evenly to the monthly maximum SWAP demands for a CVPM region. The Base Case monthly average deliveries over the 1921-1990 period, taken from CVGSM NAA, are shown for comparison. Bulletin 160-98 demand data and monthly ETAW patterns from DWR's consumptive use model on which the "Raw SWAP" curve in Figure 2H-3 is based, differ considerably from the amount and pattern of water deliveries taken from CVGSM. The adjustment serves to equalize the areas under the two curves of Figure 2H-3 marked "Base Case Delivery" and "Adjusted SWAP". Figure 2H-4 shows one month's SWAP penalty function for the example region, comparing the "Raw" SWAP function with the "Adjusted" one. The penalty function is shifted to the right by the monthly adjustment, while preserving marginal water values as a function of the percentage of scarcity from maximum demand.

[1] CVGSM represents many points of return flow along the model's stream network that are aggregated to a single return flow in CALVIN for each CVPM region, generally located downstream of upstream points of diversion.

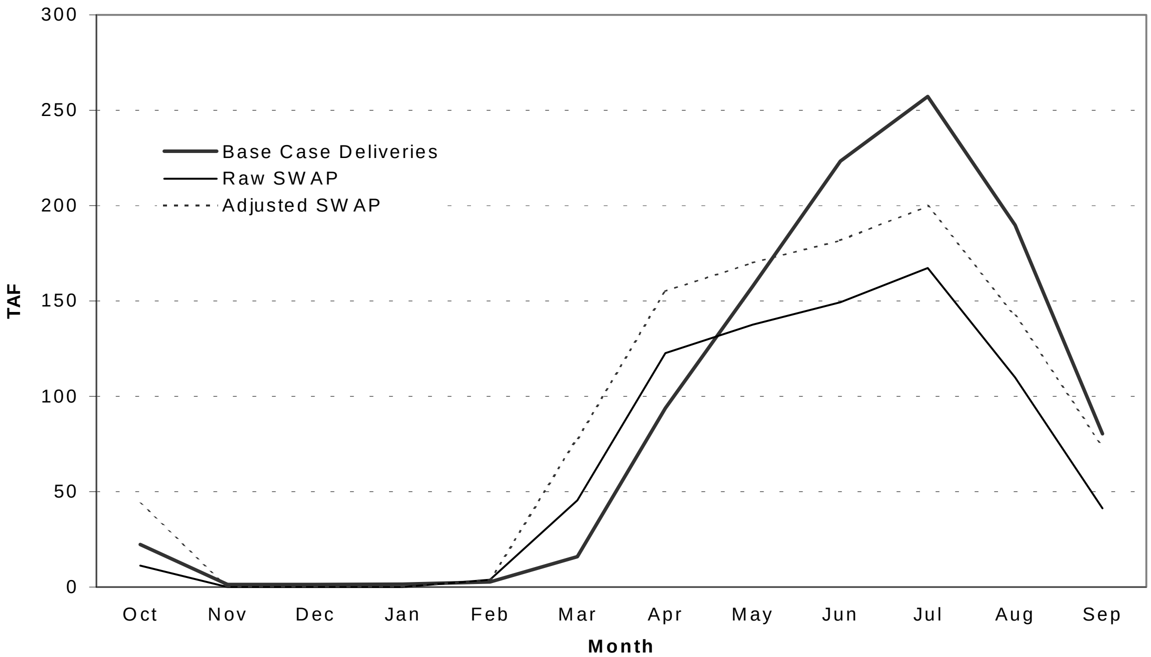


Figure 2H-3. Example of Adjustment to SWAP Demands (CVPM Region 6)

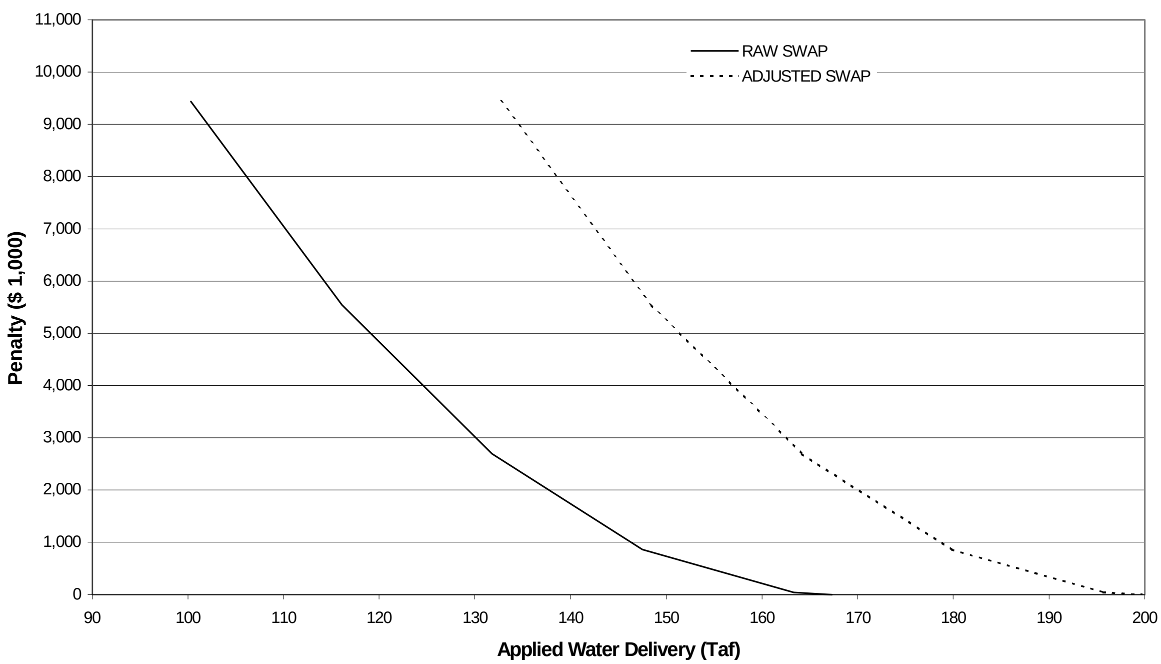


Figure 2H-4. Example Adjusted SWAP Penalty Function (July, CVPM Region 6)

5) Calibration flows added to or removed from CALVIN:

Calibration flows are time series of water added or removed at various locations in CALVIN so that the surface water constraint set is feasible (water balances correctly) and surface water flows match DWRSIM Run 514a flows at key control points in the stream network (see Table 2H-2 for locations) under the Base Case assumptions. These calibration flows serve to rectify inconsistencies in hydrologies and underlying assumptions across the different modeling data sets used in CALVIN.

This is the final set of calibration adjustments, completed only after all the previous adjustments have been applied to the CALVIN model. It is also the only calibration step that requires running the CALVIN model (i.e., the Base Case scenario) and analyzing model results.

CALIBRATION SEQUENCE

Step 1: To manage the calibration process, the CALVIN model is sub-divided from north to south into five sub-regions (see Figure 2-2 of the report and the results appendices for sub-region boundaries). Boundary flows between sub-regions are chosen to coincide with Base Case deliveries and/or DWRSIM Run 514a flows to which CALVIN will be calibrated.

Step 2: Groundwater calibration parameters for each CVPM region are computed analytically according to the method described above and input into each of the Base Case sub-region models.

Step 3a: "Debug" or feasibility links are added to each of the Base Case sub-region models. These allow for the addition or removal of external water at each node in the system, but at an extremely high cost. Because of the high cost they are only used to the extent necessary to close HEC-PRM's mass balance constraint at a node when it is violated by input constraints. In this way, "debug" links serve to identify the temporal and spatial location of any infeasibilities caused by the constraints imposed in the Base Case while a solution is obtained.

Step 3b: The five regional models are run. The resultant "debug" link flows required to resolve surface water mass balance infeasibilities are identified, evaluated, and aggregated into one or two locations for each tributary where they occur. CALVIN groundwater storages are compared to CVGSM NAA to check groundwater calibration, and agricultural and urban scarcities evaluated by comparison to CVGSM NAA and DWR Bulletin 160-98.

Step 3c: The consolidated "debug" flows are subsequently treated as fixed time series of external calibration flows that add or remove water to/from the system. The Base Case regional models are re-run without "debug links" to verify that the constraint set is feasible with these feasibility calibration flows in place.

Step 3d: The results from the Step 3c model run are now evaluated to determine any additional flows (negative or positive) required to calibrate the surface water hydrology to match DWRSIM Run 514a at key points on the main stream network. This is accomplished by comparing CALVIN flows from the step 3c model results with DWRSIM Run 514a flows at the locations identified in Table 2H-2. The monthly pattern and amounts of water to add and remove at each mass balance calibration location are evaluated and likely causes for their occurrence identified (see results below). Time series of the calibration flows needed to "match" DWRSIM flows are created and added to the model from step 3c. As a final check, the Base Case regional models are run for third time.

Step 4: The calibrated Base Case model run results (from step 3d) are processed, evaluated, and reported in the results appendices for each of the five CALVIN sub-regions and summarized in Chapter 4 of this report.

Table 2H-2. Surface Water Calibration Control Points and Equivalent DWRSIM Flows

CALVIN Region	Location	CALVIN Base Case Flows	DWRSIM Run 514a Flows
1 & 2	Sacramento R. below Colusa Drain	C301_D43 link flow	Flows downstream of CP61 and CP70 summed
2	Feather R. at mouth	Sum of link flows in D42_D43, D43a_D43, D42_C34, C33_C34	Flow Downstream of CP49
2	Fremont Weir flow[a]	D43_C306 link flow[a]	Diversion at CP43
2	American R. at mouth	Sum of link flows D64_C8 and T13_D44 minus C8_T4	Flows downstream of CP64+CP84
2	Yolo Bypass into the Delta	C20_D55 link flow	Local inflow to CP55
2	Sacramento R. at Hood	D44_D503 link flow	Flow downstream of CP503
2	Eastside Streams inflow to the Delta	Sum of link flows (D517_D515 + C41_C42 + T27STOC_C42)	Flow downstream of CP517
2	In-Delta Net Consumptive Use (D509)	Sum of link flows (D507_C68 + D515_C68 + D521_C68 + D523_C68 + D507_Sink) minus sum of link flows (CVPM 9S_D507 + Local inflow at D507)	Sum of diversions at CP507+ 515 + 521+ 523 minus sum of local inflows at CP507+ 515 + 521+ 523
2	Delta Diversions (D528 and D507)	Sum of link flows D55_C22, D550_Contra Costa1 PMP, C309_Old River PMP, and D528_Mallard Slough PMP	Sum of diversions at CP55, CP528, and CP57 (NBA, Vallejo and CCWD)
2 & 3	San Joaquin R. at Vernalis (before Calaveras R.)	D616_C42 link flow	Upstream inflow to CP521
2 & 3	Tracy and Banks Pumping from Delta	Tracy PMP_D701 and Banks PMP_D801 link flows	Upstream inflows to CP701 and CP801 (or diversion at CP86+CP59)
3	DMC flow into Mendota Pool[b]	D724_D608 link flow	Flow downstream of CP724 minus diversion at CP733
3 & 4	CAL Aqueduct flow in reach 4 upstream of WWD turnout	D744_C92 link flow	Flows downstream of CP744 and CP828 summed
3 & 4	St. James Bypass/Fresno Slough into Mendota Pool	C54_D608 link flow	Local Inflow into CP608
4 & 5	Cal Aqueduct flow over the Tehachapi Mts.	C103_D865 link flow	Upstream inflow to CP865

[a] *Forced by a constraint to match DWRSIM Run 514a flow in all CALVIN model runs*
[b] *Forced by a constraint to match DWRSIM Run 514a flow in the CALVIN Base Case model*

CALIBRATION RESULTS

The calibration parameters, volumes added to and removed from the model, and calibrated surface and groundwater flows under the Base Case assumptions in CALVIN are presented and discussed in this section. Confirmation of the hydrologically calibrated results is made by comparison to CVGSM NAA groundwater storage levels and DWRSIM Run 514a surplus Delta outflow.

Groundwater Calibration Parameters and Storage Results

The groundwater calibration produced reasonable results consistent with the CVGSM NAA in all but two cases:

1) Basins where CALVIN urban pumping demands are estimated to be higher than those in the CVPIA PEIS experience greater groundwater depletion in CALVIN in the base case compared to CVGSM NAA, and

2) Tulare Basin Region where groundwater calibration was generally problematic, in part because the CVGSM NAA data and modeling for this region is weak.

<u>Groundwater Calibration Parameter Values</u>

Table 2H-3 presents the groundwater calibration parameters determined from the computations described in this Appendix. The values indicate that in CVPM regions 6, 11, 14, 18, 19, 20 (nearly so), and 21 there is no surface water return flow at the region-wide scale. In these regions, all non-consumptive agricultural applied water becomes recharge to the underlying groundwater basin. In the case of CVPM regions 6, 11, and 20, reuse between districts and among farms within the CVPM region effectively uses up all surface runoff at the farm scale (see illustration in Figure 2H-1). In CVPM regions 14, 18, 19 and 21, the non-consumptive volume of agricultural applied water (total return flow), given the level of on-farm efficiency from DWR, is smaller than the volume of deep percolation from agricultural applied water indicated in the CVGSM NAA scenario. These regions require a calibration return flow gain greater than 1.0 in order to match the agricultural deep percolation volumes and groundwater levels in the CVGSM NAA.

Several likely causes for the mis-match in CVPM regions 14, 18, 19, and 21 between DWR's on-farm efficiencies and the CVGSM NAA volumes of agricultural deep percolation are:

1) Agricultural deliveries shown in Table 2H-3 may include water used by districts and/or farmers to intentionally recharge groundwater.

2) Agricultural deliveries shown in Table 2H-3 include unaccounted recoverable losses to groundwater that occur in the distribution canals within irrigation districts between the point of diversion to the district and the point of diversion of each farm receiving water. These losses appear to be implicitly included in the soil budget accounting of CVGSM, accounting for some of the lower CVGSM irrigation efficiencies than those represented by DWR Bulletin 160-98 planning data.

3) On-farm tail water recover, thought to be widely used in parts of the Tulare Region as a way to avoid surface discharge, may effectively result in lower on-farm efficiencies than estimated because of the way it is managed.

Table 2H-3. Agricultural Groundwater Calibration Parameters

CVPM Region	Base Case Deliveries[a] (taf/year)		GW Split of Return Flow	DWR On-farm Irrigation Efficiency[a]	Adj. Reuse Factor[b]	CVGSM Ag. GW Return Flow (taf/yr)[d]	Calibration Return Flow Gain[e]
	GW	Net SW					
1	36.2	117.3	0.44	0.68	1.00	21.4	-
2	508.5	131.2	0.77	0.74	1.00	128.5	-
3	337.8	1,131.6	0.78	0.67	1.05[f]	338.5	-
4	298.8	672.7	0.18	0.67	1.13	41.6	-
5	498.3	1,140.2	0.74	0.66	1.06	371.3	-
6	447.3	346.5	1.00	0.68	**1.32**	81.9	-
7	280.5	242.8	0.55	0.63	1.08	91.2	-
8	661.1	151.6	0.21	0.68	1.10	43.9	-
9	111.6	958.0	0.70	0.70	1.10	172.0	-
10	407.6	1,210.0[g]	0.26	0.62	1.05	146.2	-
11	0.0	833.5	1.00	0.69	**1.04**	236.1	-
12	173.6	556.2	0.38	0.73	1.10	54.6	-
13	910.5	808.5[g]	0.34	0.73	1.10	116.8	-
14	725.6	771.3[g]	1.00	0.78	**1**	415.7	**1.26**
15	1,304.3	583.4[g]	0.40	0.74	1.05	168.6	-
16	56.2	395.5	0.31	0.73	1.10	27.9	-
17	409.5	349.4	0.61	0.74	1.10	86.6	-
18	995.4	942.6	1.00	0.75	**1**	606.4	**1.25**
19	356.3	606.7[g]	1.00	0.79	**1**	280.4	**1.39**
20	295.3	337.1	0.99	0.76	**1.07**	117.2	-
21	533.3	628.7[g]	1.00	0.75	**1**	373.0	**1.28**
Total	9,348	12,915				3,919.8	

Notes:

a Taken from CVGSM NAA, GW = groundwater pumping (see file "Policy 4a Pumping 081600.xls" in Software and Data Appendices), SW = surface water deliveries (see file "CVGSM Diversions 2 edMJ 10192000.xls" in Software and Data Appendices)

b Used in CALVIN to multiply deliveries and increase basin level efficiency; initial values taken from CVPM NAA input to CVPM. Bold values have be reduced from their initial values in the CALVIN calibration.

c Used in CALVIN to model depletion of agricultural applied water at the farm level, taken from DWR Bulletin 160-98 supporting data.

d From CVGSM NAA 1997, derived from Soil Budget (Soil2a_y.NEA output file), see Appendix J (Groundwater Hydrology)

e Calibration factor to adjust agricultural return flows to match those in CVGSM so that GW is calibrated to NAA run. Note that agricultural demands and on farm efficiencies in CVGSM are different from those in other models such as DWRSIM (depletion analysis) and DWR Bulletin 160-98 supporting data.

f Reduced from the CVPIA PEIS value of 1.09 used in CVPM due to explicit inclusion of Colusa Basin drainage return flow in CVGSM NAA deliveries to CVPM 3.

g Total based on Cal Aqueduct and DMC deliveries taken from DWRSIM Run 514a rather than CVGSM, where DWRSIM deliveries are generally lower than CVGSM's (from PROSIM) for the same "no action" or base case operations.

Studies of specific districts have been done to quantify the former two components of deliveries, but such information has not been aggregated into appropriate estimates at the CVPM region scale nor estimated for 2020 levels of development over the hydrologic sequence of concern. This issue is taken up in more depth later in this appendix (see Table 2H-8 and 2H-9).

Issues and Inconsistencies Captured in Calibration Gain Parameters

Some additional issues and inconsistencies probably subsumed in the calibration gain parameters include:

- differences in agricultural demand between Bulletin 160-98, CVPM, and PROSIM/SANJASM (ET crop, monthly pattern, and consumptive use models differ; land use is similar but CVGSM seems to ignore it; reuse is very sketchily addressed in the calibration of CVPM but then seems to be ignored in CVGSM);

- differences in on-farm efficiency between Bulletin 160-98, CVPM, and CVGSM (as modeled in the soil budget for run-off and deep percolation of AW);

- differences in basin efficiency and conveyance losses (recoverable and non-recoverable) in major and minor canals and import/exports between Bulletin 160-98, DWRSIM, and CVGSM (see Table 2H-9 comparing efficiencies and estimates of additional recoverable distribution losses); and

- differences in local water supply assumptions between DWRSIM and CVGSM NAA..

Calibrated Base Case Groundwater Storage Results

Groundwater storage levels from the CALVIN Base Case calibrated model are compared to the CVGSM NAA levels in the tables and figures that follow. Calibrated groundwater storage levels for the Sacramento Valley (CVPM basins1 through 9) are compared to the CVGSM NAA levels in Table 2H-4 and in Figures 2H-5 and 2H-6. Those for the San Joaquin Valley and Tulare Basin (CVPM basins 10 through 21) are compared to the CVGSM NAA levels in Table 2H-5 and Figures 2H-7 and 2H-8.

Limitations in Calibrated Groundwater Storage Results

Several issues and limitations of the calibrated groundwater results are described below. Some of these limitations could be addressed using more complex calibration methods.

Seasonal Variation in Return Flow Coefficients

In CALVIN, link gains/losses are represented by a single constant value. Thus, calibration of groundwater return flow rates is based on annual average behavior over the modeled hydrologic sequence. Inability to model monthly varying return flow rates for agricultural applied water results in smaller amplitudes in the seasonal storage changes in CALVIN compared to those in CVGSM where groundwater return flow (applied water irrigation efficiency) varies by month, being less in summer months (higher efficiencies).

Table 2H-4. Groundwater Calibration Results for CALVIN Regions 1 and 2 (Sacramento Valley)

Ground-water Basin	CALVIN 4a Ave. Depletion taf/yr	CVGSM NAA Ave. Depletion taf/yr	CALVIN 4a MIN Storage taf	CVGSM NAA MIN Storage taf**	CALVIN 4a MAX Storage taf	CVGSM NAA MAX Storage taf**	Reasons for Difference
1	-1.8	0.4	1,710	1,778	2,053	2,089	CALVIN assumes greater urban demand & associated groundwater pumping than CVGSM
2	-8.3	-8.2	10,388	10,369	12,145	12,196	Minor difference due to rounding error in *GWsplit* of agricultural return flow in CALVIN
3	2.8	-0.6	12,565	12,217	13,719	13,784	Rounding error in *GWsplit* of agricultural return flow in CALVIN and larger refuge demands in CALVIN than CVGSM
4	3.2	-1.2	10,056	10,059	10,677	10,632	Rounding error in *GWsplit* of agricultural return flow in CALVIN
Region 1	**-4.1**	**-9.5**	**34,798**	**34,425**	**38,431**	**38,610**	
5	-13.8	2.5	14,252	15,165	15,779	16,529	Rounding error in agricultural return flow *GWsplit* in CALVIN combined with CALVIN larger portion of total pumping for agriculture (with lower fraction return flow) than for urban
6	-26.0	-13.0	16,034	16,711	18,086	18,045	CALVIN assumes a larger portion of total pumping is for agriculture than for urban
7	29.8	-33.3	9,551	7,722	12,270	10,036	CALVIN pumps more from GW-8 and less from GW-7 than CVGSM for Sac M&I (no cost distinction between the two basins so outcome is random)
8	-85.4	-28.9	16,064	20,137	22,675	22,720	
9	37.9	20.3	17,744	17,744	20,808	19,581	CALVIN total urban demand is lower than CVGSM in this region
Region 2	**-57.4**	**-52.3**	**78,981**	**79,116**	**84,675**	**84,689**	

Notes:

a Absolute storage values for CVGSM have been modified to reflect estimates of the usable volume of total storage from CVGSM. This is the basin storage represented in CALVIN.

Table 2H-5. Groundwater Calibration Results for CALVIN Regions 3 and 4 (San Joaquin and Tulare Basin)

Ground-water Basin	CALVIN 4a Ave. Depletion taf/yr	CVGSM NAA Ave. Depletion taf/yr	CALVIN 4a MIN Storage taf	CVGSM NAA MIN Storage taf[a]	CALVIN 4a MAX Storage taf	CVGSM NAA MAX Storage taf[a]	Reasons for Difference
10	17.6	20.8	22,213	22,213	23,885	24,369	CALVIN total urban demand (pumping) is higher than CVGSM in all 4 of these basins
11	-30.6	0.8	8,628	10,916	11,161	11,758	
12	-13.4	-1.4	9,201	10,285	10,531	10,832	
13	0.4	11.9	29,998	31,143	33,462	34,221	
Region 3	**-26.1**	**32.2**	**71,143**	**74,684**	**78,388**	**81,098**	
14	-73.8	0.8	45,262	51,075	54,040	55,433	Without a calibration return flow gain multiplier greater than 1.0, CALVIN's on-farm efficiencies are insufficient to explain the amount of agricultural applied water that deep percolates to ground water in the CVGSM NAA. Unaccounted for recoverable distribution losses and agricultural deliveries used for recharge may be responsible for the some of the on-farm deep percolation recharge identified in CVGSM.
15	-1.1	-8.6	69,548	69,895	74,359	74,365	Round off of *GWsplit* causes small differences in volume of deep percolation return flow
16	-88.3	-17.3	0	5,164	6,775	6,786	Fresno urban pumping demand in CALVIN is larger than CVGSM, along with same reason as Basin 14.
17	-4.2	-4.8	6,621	6,978	8,601	8,577	
18	-94.8	19.6	33,454	40,775	42,455	45,090	Same reason as Basin 14.
19	0.0	80.1	42,681	43,085	45,796	50,023	Same reason as Basin 14.
20	10.7	24.9	22,630	22,630	24,229	25,287	Urban demands are slightly larger.
21	-49.7	48.4	47,786	51,595	52,639	56,499	Same reason as Basin 14.
Region 4	**-301.2**	**143.0**	**269,548**	**293,324**	**306,316**	**316,461**	

Notes:

a Absolute storage values for CVGSM have been modified to reflect estimates of the usable volume of total storage from CVGSM. This is the basin storage represented in CALVIN.

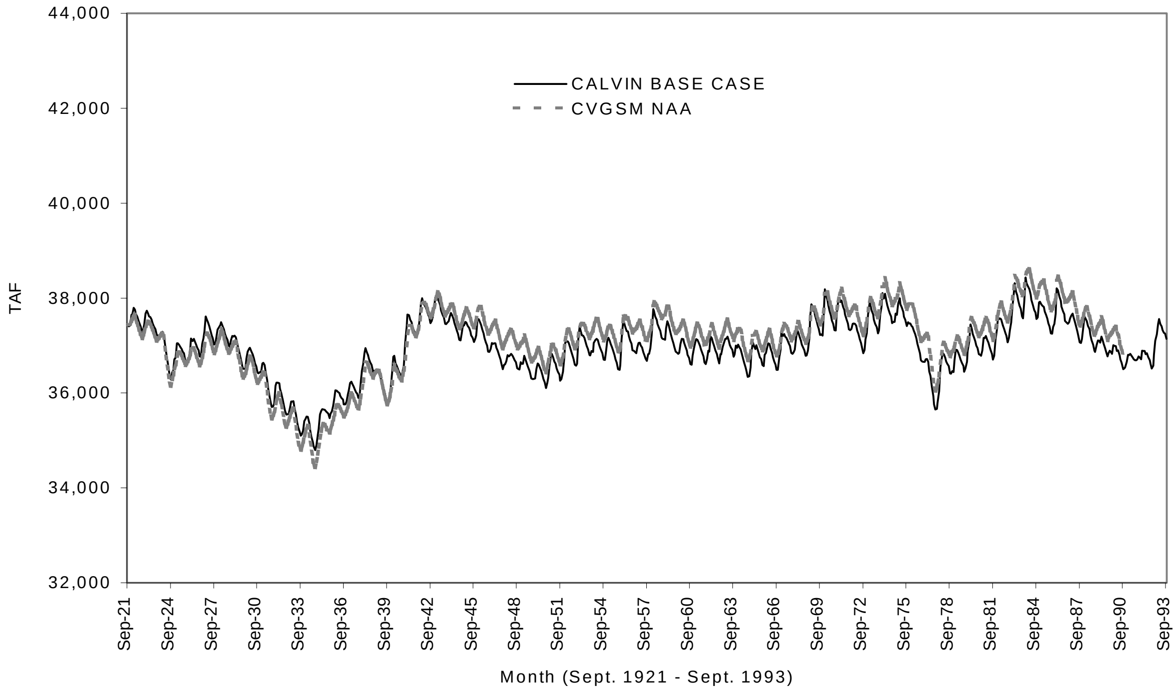


Figure 2H-5. Calibrated Groundwater Results - CALVIN Region 1 (CVPM Basin 1 to 4)

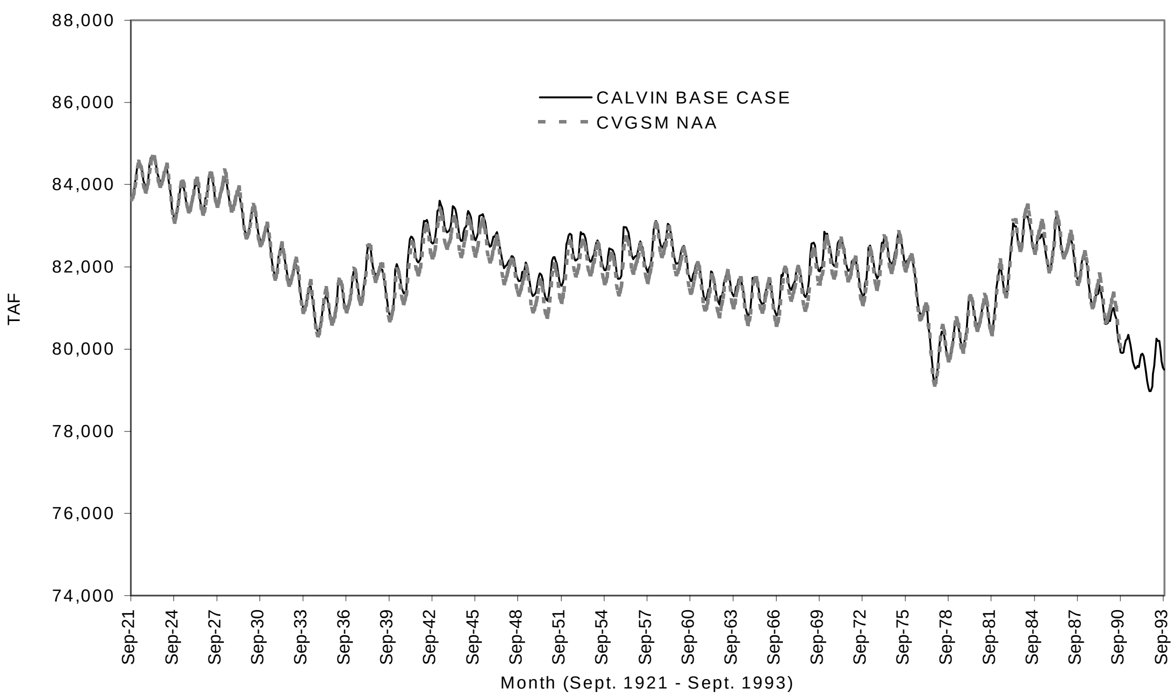


Figure 2H-6. Calibrated Groundwater Results - CALVIN Region 2 (CVPM Basin 5 to 9)

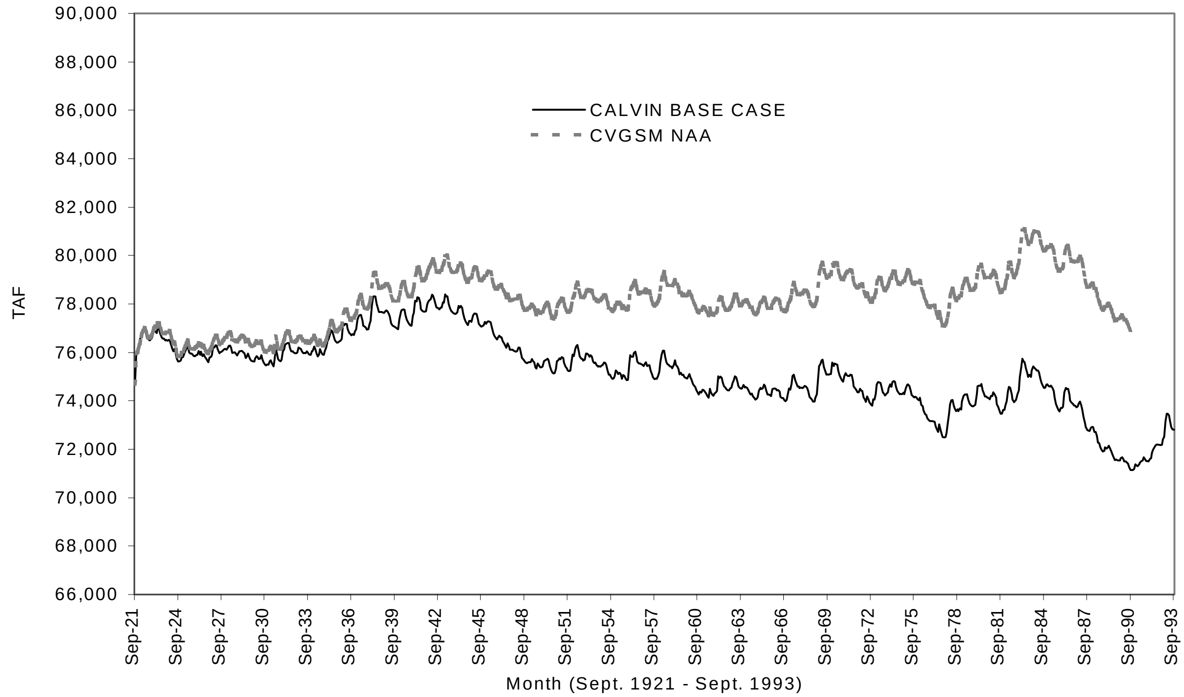


Figure 2H-7. Calibrated Groundwater Results - CALVIN Region 3 (CVPM Basin 10 to 13)

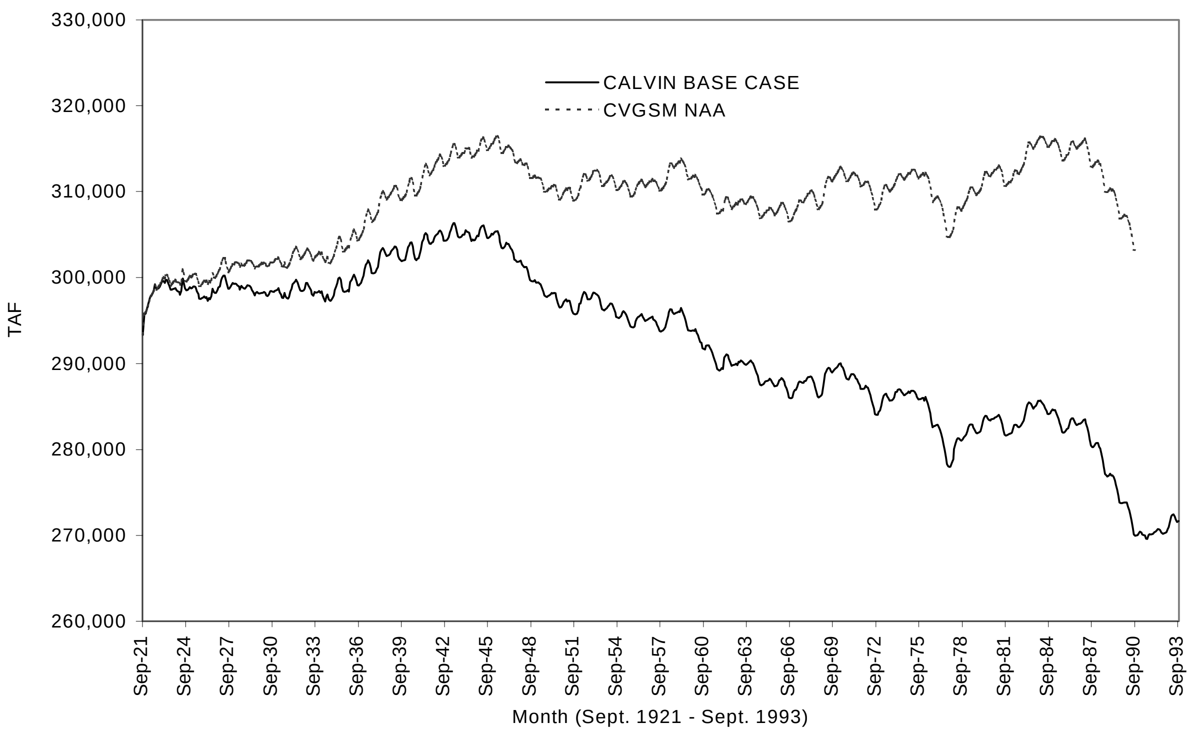


Figure 2H-8. Calibrated Groundwater Results - CALVIN Region 4 (CVPM Basin 14 to 21)

Tulare Basin

Problems with Base Case data make Region 4 (Tulare Basin) particularly difficult to calibrate and reduce confidence in CVGSM results. A detailed discussion of Region 4 appears in Appendix 2I: Base Case Details. Some data problems peculiar to this region include:

- Inflows for the four local rivers in this region appear to be a mixture of unimpaired and impaired historic gage hydrology because no simulation models are available to develop full unimpaired hydrologies. This appears to be particularly problematic on the Tule River.

- Many of the CVGSM NAA diversions and pumping may be taken from unmodified historic gage data, rather than estimates of a base case 2020 static condition. They show a marked change during the 1960's when the major reservoirs in the region were built. This can be seen in the CVGSM NAA groundwater storage pattern that rebounds after 1960, as well as in distinct trend lines seen in the pumping pattern over the 1921-1990 sequence.

Urban Water Demands and Return Flows to Groundwater

Urban pumping and return flow to groundwater are often greater in CALVIN than in CVGSM NAA. This is due to the different methods used in estimating urban water use between the two models (see Howitt, et al. 1999 – Appendix B). Thus, while CALVIN uses the same percentages of return flow to groundwater from urban water use as CVGSM NAA (see files cnjparm.dat and soil2a_y.nea), the annual average volume of net groundwater depletion due to urban demands in CALVIN is higher overall (1.36 maf/yr in CALVIN compared to 1.16 maf/yr in CVGSM NAA).

Table 2H-6 compares CALVIN's net groundwater extraction by the urban sector to that in CVGSM NAA. In CALVIN Regions 1 and 2 (CVPM basin 1 through 9), the amount of urban demand, pumping, and net extraction is generally the same as CVGSM NAA. In both CALVIN Regions 3 (CVPM basin 10 to 13) and 4 (CVPM basin 14 to 21), however, CALVIN has about 100 taf/yr more net urban groundwater extraction than CVGSM NAA due to higher estimated demands. This accounts for all of the increased groundwater depletion in Figure 2H-7 over the 72-year sequence in Region 3 but only about 1/4 of that occurring in Region 4 (see Figure 2H-8.).

Table 2H-6. CALVIN Base Case and CVGSM NAA Urban Pumping and Net Extraction

CVPM Region	CVGSM Urban Demand	CVGSM Urban Pumping (est.)	CVGSM Net Urban GW Extraction	CALVIN Urban Demand	CALVIN Urban Pumping (est.)	CALVIN Net Urban GW Extraction
1	89	30	-15	82	30	-11
2	62	62	30	64	64	31
3	15	18	10	16	16	8
4	5	7	5	5	5	3
CALVIN Reg1	*171*	*117*	*30*	*167*	*115*	*31*
5	84	61	17	124	60	29
6	90	61	13	60	60	28
7	438	123	120	801	290	276
8	325	164	162			
9	120	119	56	77	77	37
CALVIN Reg2	*1,057*	*528*	*368*	*1,062*	*487*	*370*
10	28	27	12	42	42	20
11	169	142	51	232	232	107
12	78	80	39	109	109	52
13	101	110	57	162	162	77
CALVIN Reg3	*376*	*359*	*159*	*545*	*545*	*256*
14	19	4	-6	17	0	-8
15	44	50	27	63	63	31
16	275	270	269	384	338	338
17	75	80	41	84	85	40
18	136	146	74	146	146	69
19	8	10	6	23	23	11
20	31	33	16	57	57	27
21	178	181	180	290	212	197
CALVIN Reg4	*766*	*774*	*607*	*1,064*	*925*	*705*
TOTAL	**2,370**	**1,778**	**1,164**	**2,838**	**2,071**	**1,361**

Agricultural Water Demand Calibration Adjustments

Table 2H-7 presents the amounts that SWAP demands are increased to absorb the Base Case deliveries. These volumes are reported in the second to last column. In the CVPIA PEIS similar excess deliveries were identified (called “miscellaneous deliveries”) as the difference between recent historic deliveries and theoretical demands based on efficiencies and crop consumptive use (USBR 1997). While the total amount of SWAP adjustment in Table 2H-7 compares reasonably well with the volume of miscellaneous deliveries identified in the CVPIA PEIS, the distribution across CVPM regions is somewhat different. CALVIN/SWAP identifies approximately 486 taf/yr of excess deliveries in CVPM regions 1 through 8 where none were identified in the CVGSM NAA. In CVPM regions 10 through 21 there is better agreement between the two analyses.

These adjustments are important to preserve a comparable water balance and level of management flexibility between Base Case and alternative CALVIN runs, as well as between CALVIN and CVGSM representations of Central Valley water demands and management. These increases in agricultural demands amount to almost 10% of average agricultural demands predicted by SWAP and CVPM. Not making these adjustments would allow approximately 2

Table 2H-7. Base Case Agricultural Deliveries and SWAP Adjustments

CVPM Region	Base Case Deliveries to CVPM Region[a] (taf/year)		Adj. Reuse Factor[a]	Base Case Deliveries to Farm (CVPM Deliveries x Adj. Reuse Rate)	Unadjusted SWAP Demand[b] (taf/yr)	**SWAP Adj. (taf/yr)**	CVPM Misc. Deliveries[c] (taf/yr)
	GW	Net SW					
1	36.2	117.3	1.00	153.5	148.0	**5.04**	0
2	508.5	131.2	1.00	639.7	698.8	**0**	0
3	337.8	1,131.6	1.05[d]	1542.6	1,628.8	**0**	0
4	298.8	672.7	1.13	1097.8	1,035.1	**62.7**	0
5	498.3	1,140.2	1.06	1736.8	1,656.5	**80.3**	0
6	447.3	346.5	**1.32**	1047.8	788.5	**259.0**	0
7	280.5	242.8	1.08	565.2	518.8	**46.4**	0
8	661.1	151.6	1.10	894.1	860.9	**33.0**	0
9	111.6	958.0	1.10	1176.5	1,184.5	**0**	0
10	407.6	1,210.0	1.05	1698.5	1,309.2	**389.3**	380.7
11	0.0	833.5	**1.04**	866.8	625.1	**241.8**	256.2
12	173.6	556.2	1.10	802.8	787.1	**15.8**	94.2
13	910.5	808.5	1.10	1890.9	1,643.6	**247.4**	49.2
14	725.6	771.3	**1**	1496.9	1,496.0	**0**	182.2
15	1,304.3	583.4	1.05	1982.0	1,991.9	**0**	73.4
16	56.2	395.5	1.10	496.9	303	**193.8**	138.0
17	409.5	349.4	1.10	834.8	772.4	**62.3**	42.0
18	995.4	942.6	**1**	1938.0	2,160.1	**0**	136.2
19	356.3	708.7	**1**	963.0	849.2	**113.8**	106.6
20	295.3	337.1	**1.07**	676.7	653.8	**22.8**	49.9
21	533.3	628.7	**1**	1162.0	991.7	**170.3**	99.8
Total	9,347.7	13,016.8		23,663.3	22,103	**1,943.7**	1,608.4[e]

Notes:

a See Table 2H-3; bold values are adjusted downward from original CVPM values reported in CVPIA PEIS (USBR 1997).

b Average year quantity of applied water at the farm associated with the point where the marginal value of water goes to zero in the SWAP value functions. Note that this "maximum" demand is greater than the 2020 Bulletin 160-98 planning average year applied water demand (100% demand point on the SWAP value function) as it represents the additional amount demanded as the willingness to pay or marginal value to production of an additional unit of water goes to zero.

c From Table MISDEL of input to CVPM in the CVPIA PEIS (USBR 1997)

d Reduced from the CVPIA PEIS value of 1.09 used in CVPM due to explicit inclusion of Colusa Basin drainage return flow in CVGSM NAA deliveries to CVPM 3.

e Total MISDEL for average is year shown here. In wet years, total MISDEL increase to 2,121.8 taf/yr for CVPM regions 10 through 21 combined..

maf/year of water to become available for reallocation compared to the Base Case and CVGSM. Such reallocations would distort the economic values estimated for new infrastructure, changes in water management, and other management activities.

Possible Origins of Excess Deliveries

Many data, physical, and operational origins could be possible to explain these discrepancies between estimated demands and CVGSM deliveries. Distribution canal losses and/or deliveries used for intentional groundwater recharge (both components ignored in CALVIN and in CVGSM) are two important and likely explanations for both the SWAP adjustments and the

CVGSM NAA miscellaneous deliveries. Some of these possible origins for excess deliveries are discussed below.

Environmental and Recharge Demands

Some CVGSM surface water deliveries include environmental water (such as Merced NWR) and deliveries for intentional groundwater recharge by farmers and districts. The average annual volume of groundwater recharge reported by Friant Water users (located in CVPM regions 13, 16, 17, 18, 20, and 21) is approximately 450 taf/yr (see Table 2H-8) (USBR's Water Needs Analysis 2000). Ideally, these demands would be represented more explicitly.

Table 2H-8. Estimated Annual Average Recharge of Surface Water by Friant Users

CVPM Region	Base Case Deliveries to CVPM Region[a] (taf/year)		Base Case Deliveries to Farm (CVPM Deliveries x Adj. Reuse Rate)	Unadjusted SWAP Demand[b] (taf/yr)	SWAP Adj. (taf/yr)	Avg, Recharge[b] (taf/yr)	CVPM Misc. Deliveries[c] (taf/yr)
	GW	Net SW					
13	910.5	808.5	1890.9	1,643.6	247.4	111	49.2
16	56.2	395.5	496.9	303	193.8	data missing	138.0
17	409.5	349.4	834.8	772.4	62.3	0	42.0
18	995.4	942.6	1938.0	2,160.1	0	252	136.2
20	295.3	337.1	676.7	653.8	22.8	16	49.9
21	533.3	628.7	1162.0	991.7	170.3	72	99.8
Friant Unit Sub-total				6,525	697	>451	515

Notes:
a From Table 2H-3.
b This is an average year estimate based on 1996 from the USBR Friant Unit Water Needs Analysis, (USBR 2000).

System Losses

Within district distribution losses could account for some of these additional deliveries. By considering the difference between on-farm efficiencies from DWR Bulletin 160-98 planning data (used in SWAP and in CALVIN) and the CVGSM effective agricultural efficiencies for each CVPM region (determined in the CVGSM groundwater calibration), it is possible to estimate a magnitude for these distribution losses. The calculations are presented in Table 2H-9. The last column shows a range of possible additional (non-farm) losses to deep percolation from 842 taf/yr to 1,692 taf/yr. These volumes represent from 3.8% to 7.6% of net Base Case agricultural deliveries reported in the first two columns of Table 2H-9. Thus, additional local system losses could account for at least half of the excess deliveries. Recharge in the San Joaquin and Tulare Basin Regions could amount for another 500 taf/yr, providing a somewhat incomplete understanding of the discrepancy between economic demands, knowledge of on-farm efficiencies, and estimates of agricultural water use.

<Insert table of SWAM values for local distribu system losses and inten recharge, avg. by DAU in SJ Valley>

Seasonal Demand Patterns

Apart from the difference in annual agricultural applied water deliveries and demands, there frequently is substantial disagreement between the monthly patterns of deliveries and the monthly pattern of ETAW based on consumptive use models (see Figure 2H-3 for an example comparing the monthly pattern of base case deliveries to that of SWAP demands). Some of these disagreements might be due to the timing of pre-irrigation and farmer use of soil moisture to irrigate during the rain-flood season when surface water is in abundance and reservoirs evacuate their flood pools.

Table 2H-9. Estimated Additional Deep Percolation System Losses from a Comparison of Agricultural Water Efficiency Estimates

CVPM Region	Base Case Deliveries[a] (taf/year)		DWR On-farm Irrigation Efficiency[a]		CVGSM NAA Efficiency[b]	Diff. DWR-CVGSM efficiency		Est. of Add'l Deep Percolation Losses[c]	
	GW	Net SW	Eff.	Eff.*RU[d]				taf/yr	
			A	B		A	B	A	B
1	36.2	117.3	0.68	0.68	0.61	0.07	0.07	11	11
2	508.5	131.2	0.74	0.74	0.71	0.03	0.07	19	19
3	337.8	1,131.6	0.67	0.70	0.65	0.02	0.05	29	74
4	298.8	672.7	0.67	0.75	0.65	0.02	0.10	19	97
5	498.3	1,140.2	0.66	0.70	0.63	0.03	0.07	49	115
6	447.3	346.5	0.68	0.90	0.72	**-0.04**	0.18	0	143
7	280.5	242.8	0.63	0.68	0.55	0.08	0.13	42	68
8	661.1	151.6	0.68	0.75	0.68	0	0.07	0	59
9	111.6	958.0	0.70	0.77	0.79	**-0.09**	**-0.02**	0	0
10	407.6	1,210.0	0.62	0.65	0.60	0.02	0.05	32	81
11	0.0	833.5	0.69	0.72	0.57	0.12	0.15	100	123
12	173.6	556.2	0.73	0.80	0.66	0.07	0.14	51	102
13	910.5	808.5	0.73	0.80	0.73	0	0.07	0	120
14	725.6	771.3	0.78	0.78	0.74	0.04	0.04	60	60
15	1,304.3	583.4	0.74	0.78	0.73	0.01	0.05	19	94
16	56.2	395.5	0.73	0.80	0.55	0.18	0.25	81	113
17	409.5	349.4	0.74	0.81	0.73	0.01	0.08	8	61
18	995.4	942.6	0.75	0.75	0.69	0.06	0.06	116	116
19	356.3	708.7	0.79	0.79	0.71	0.08	0.08	85	85
20	295.3	337.1	0.76	0.81	0.70	0.06	0.11	38	70
21	533.3	628.7	0.75	0.75	0.68	0.07	0.07	81	81
Total	**9,347.7**	**13,016.8**				**0.038**	**0.078**	**842**	**1,692**

a See Table 2H-3.

b Computed as 1 minus the ratio of deep percolation (from applied water) plus surface runoff from applied water to applied water in the "soil2a_y.nea" output from CVGSM NAA model run in CVPIA PEIS (USBR 1997). Note that deep percolation (DP) is this output file had to be partitioned between rain DP and applied water PD.

*c This is an estimate of additional recoverable losses to deep percolation from deliveries via district canal distribution losses inside each CVPM region. It is computed from the difference between the two efficiencies reported in this table as (DWR Efficiency - CVGSM NAA Efficiency) x Base Case Deliveries (GW+Net SW) in column A and as (DWR Efficiency*Reuse – CVGSM NAA Efficiency) x Base Case Deliveries in column B. Reuse multipliers are reported in Table 2H-3.*

d RU stands for reuse. Column B values are based on adjusting the DWR on-farm efficiency by multiplying it by the reuse factor (reported in Table 2H-3). It provides an upper bound on the estimated difference between on-farm deep percolation and total CVPM region-wide deep percolation from agricultural deliveries, reported as estimated additional deep percolation losses in the last column of this table.

An alternative approach to handling the seasonal mis-match in deliveries and SWAP demands would be to explicitly model soil moisture storage. Although this would permit greater flexibility in the timing of deliveries, it would add another layer of complexity to an already complex model.

Surface Water Calibration Flows and Results

This section presents the surface flows added or removed from the CALVIN network to make Base Case constraints feasible and to calibrate the surface water system to match flows in DWRSIM Run 514a at control points listed in Table 2H-2 (see "Calibration Sequence"). To reiterate points discussed previously and in the Base Case Appendix, data problems and modeling inconsistencies (small and large) among data sets used in CALVIN and captured in the surface water calibration flow volumes reported here, include:

- Difference estimates of local accretions from CVGSM's rainfall-runoff model and DWR's depletion analysis;
- Different estimates of return flows from CVGSM and DWRSIM for urban and agricultural sectors;
- Different representation of "no action" environmental flow requirements by PROSIM (used in CALVIN and the basis for CVGSM surface deliveries) and DWRSIM;
- Different representation of "base case" reservoir operating rules in PROSIM and DWRSIM;
- Different representation of south-of-Delta demands and deficiency rules in PROSIM and DWRSIM;
- Different inflows in DWRSIM and CALVIN where small upstream non-DWRSIM reservoirs (i.e., pre-operated in DWRSIM) are optimized in CALVIN;
- Different urban demands in CALVIN and DWRSIM;
- Different method of computing evaporation from reservoirs in CALVIN and DWRSIM (mostly responsible for small infeasibility calibration flows at reservoir locations); and
- Apparent inconsistency between CVGSM and SANJASM NAA local accretions for the San Joaquin Hydrologic Region.

The required calibration volumes are reported in Tables 2H-9 and 2H-10 by location in each of the four Central Valley sub-regions of CALVIN. Flows added to CALVIN are reported as positive numbers while those removed from CALVIN are reported as negative numbers. Volumes required to satisfy small infeasibilities in Base Case constraints are reported in the top part of each table while flows (usually much larger volumes) required to match DWRSIM flows and calibrate the mass of surface water in the system are reported in the lower half of each table. Infeasibility flows are mostly due to a difference in the method of estimating reservoir evaporation in CALVIN and DWRSIM, but also sometimes are due to round-off of constraint values and small differences in computation of deficiencies affecting reservoir operations between DWRSIM and PROSIM model algorithms. The 72-year average monthly volumes of calibration flow added to and removed from CALVIN to match DWRSIM are plotted in Figure 2H-9 for various surface water calibration locations.

Table 2H-10. Surface Water Calibration Flows in Regions 1 and 2 of CALVIN

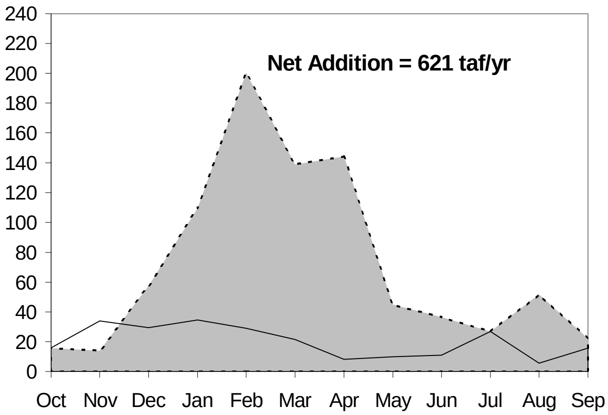
Location	CALVIN NODE	Mean Annual Flow IN (+) (taf/yr)	Mean Annual Flow OUT (-) (taf/yr)	NET CALB FLOW (taf/yr)	Max Flow IN (+) (taf/mo)	Max Flow OUT (-) (taf/mo)
Minor Infeasibility Calibration Flows						
Trinity R. (Clair Engle)	SR-1	+2	-1	+1	5	3
Lake Shasta	SR-4	+1	0	+1	5	0
Stony Creek (Black Butte Reservoir)	SR-BBL	+7	-14	-7	75	43
Region 1	***Sub Total***	**+10**	**-15**	**-5**		
Mokelumne R.	SR-CR	+0.4	0	+0.4	17	0
Calaveras R.	SR-NHL	+4	0	+4	3	0
Bear R.	C35	+1	0	+1	6	0
Consumnes R.	C37	+1	0	+1	13	0
Cache Creek	SR-CL_IVR	+41	0	+41	17	0
Putah Creek	SR-LB	+12	0	+12	16	0
Yuba R.	SR-NBB	+4	0	+4	4	0
Region 2	***Sub Total***	**+63**	**0**	**+63**		
Major Mass Balance Calibration Flows						
Sacramento R. at Red Bluff	C87	+24	0	+24	120	0
Colusa Basin Drain	C305	+36	0	+36	185	0
Sacramento R. below Colusa Basin Drain	C301	+862	-242	+620	1544	1226
Region 1	***Sub Total***	**+922**	**-242**	**+680**		
Upper Feather R.	C23	+34	0	+34	55	0
Lower Feather R.	D43	+469	-668	-199	1393	1660
Upper American R.	D9	+30	0	+30	85	0
Lower American R.	C8 & D44	+79	-21	+58	16	73
Sacramento R. at Hood	D503	+288	-130	+158	197	479
Yolo Bypass	C20	+106	-295	-189	192	927
Eastside Streams	D517	+98	-186	-88	253	234
Eastside Streams	C42	0	-3	-3	0	23
Delta Diversions (Urban)	D507 D528	0 0	-16 -17	-33	0 0	2.0 1.5
In-Delta CU	D509	+61	-441	-380	281	153
Region 2	***Sub Total***	**+1165**	**-1777**	**-612**		
Mass Balance Region 1 and 2	***TOTAL***	**+2087**	**-2019**	**+68**		

Table 2H-11. Surface Water Calibration Flows in Regions 3 and 4 of CALVIN

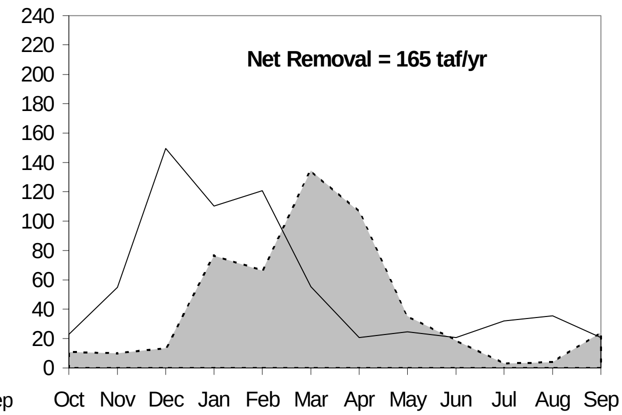
Location	CALVIN NODE	Mean Annual Flow IN (+) (taf/yr)	Mean Annual Flow OUT (-) (taf/yr)	NET CALB FLOW (taf/yr)	Max Flow IN (+) (taf/mo)	Max Flow OUT (-) (taf/mo)
Minor Infeasibility Calibration Flows						
Stanislaus R.	SR-10	0	-16	-16	0	3
Stanislaus R.	D670	0	0	0	0.005	0
Tuolumne R.	SR-81	0	-11	-11	0	154[a]
Merced R.	SR-20	0	-8	-8	0	2
Chowchilla R.	SR-53	0	-4	-4	0	1
Fresno R.	SR-52	0	-3	-3	0	1
Upper San Joaquin R.	D605	+1	0	+1	26	0
Lower San Joaquin R.	D694	+4	0	+4	13	0
Cal Aqueduct (Del Valle Reservoir)	SR-15	0	0	0	0.01	0
Cal Aqueduct (Del Valle Reservoir)	D801	0	0	0	0.005	0
Cal Aqueduct (San Luis Reservoir)	D744	+14	-17	-3	25	11
Region 3	***Sub Total***	**+19**	**-59**	**-40**		
CAL Aqueduct	C103	+1	0	+1	5	0
Tule R. (L. Success)	SR-LS	+6	0	+6	29	0
Friant-Kern Canal	C49	0	0	0	0.005	0
Region 4	***Sub Total***	**+7**	**0**	**+7**		
Major Mass Balance Calibration Flows						
Stanislaus R.	D16	+7	0	+7	50	0
Upper Tuolumne R.	SR-HHR & SR-LL-LE	+33[a]	0	+33[a]	407[a]	0
Lower Tuolumne R.	D662	+16	0	+16	16	0
Upper Merced R.	D642	+47	0	+47	23	0
Lower Merced R.	D646	+29	0	+29	22	0
Chowchilla R.	D634	+20	0	+20	26	0
Fresno R.	D624	+60	0	+60	30	0
Millerton	SR-18	+7	0	+7	29	0
Upper San Joaquin R.	D608	+18	0	+18	33	0
Lower San Joaquin R.	D616	+119	-553	-434	283	381
Region 3	***Sub Total***	**+356**	**-553**	**-197**		
Kings R. (Pine Flat Reservoir)	SR-PF	+61	0	+61	372	0
Kern R. (L. Isabella)	SR-LI	+26	0	+26	123	0
Kaweah R. (Lake Kaweah)	SR-LK	+55	0	+55	77	0
Region 4	***Sub Total***	**+142**	**0**	**+142**		
Mass Balance Regions 3 and 4	***TOTAL***	**+498**	**-553**	**-55**		

Notes:

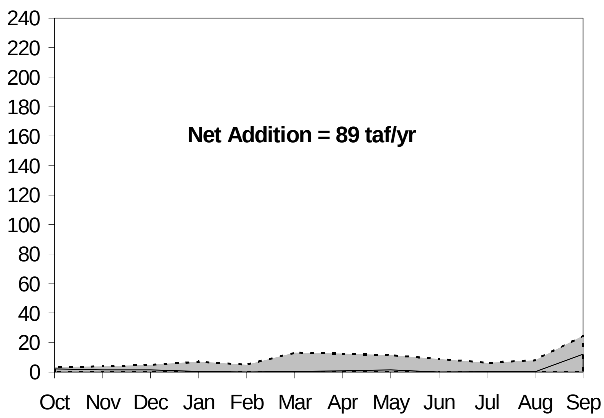
[a] Calibration flow for Oct. 1921 to Sept. 1992 is considerably smaller = +23 taf/yr and the monthly maximum considerably lower than the 407 taf reported. Water year 1993 causes big additional calibration flow to be added due to a major deviation between DWRSIM and the CDEC data used to extend the SANJASM hydrology for the upper Tuolumne above New Don Pedro. The large unique maximum calibration flows of 154 taf/mo and 407 taf/mo occur during this last year.



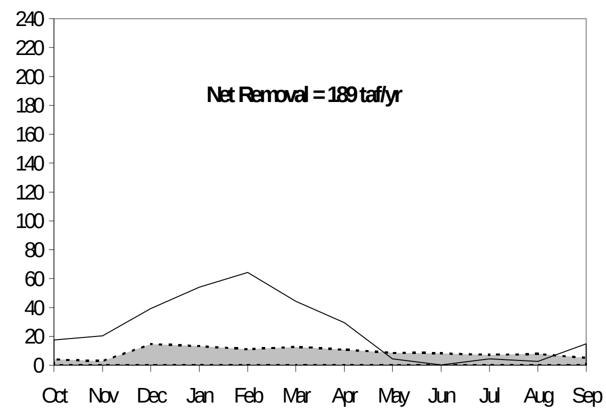
a) Sacramento River below Colusa Drain



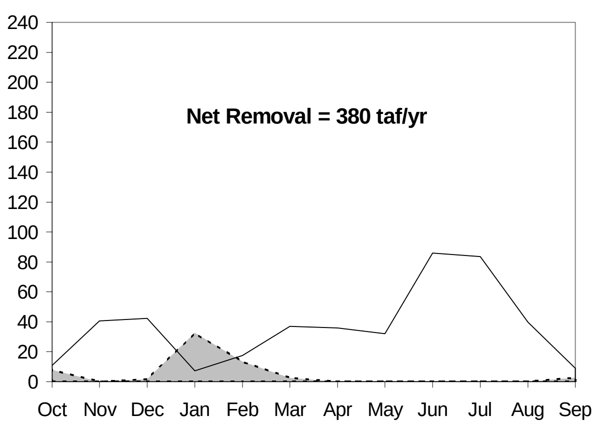
b) Feather River



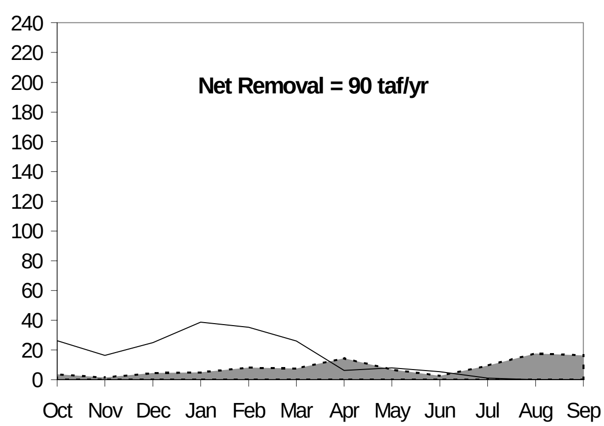
c) American River



d) Yolo Bypass

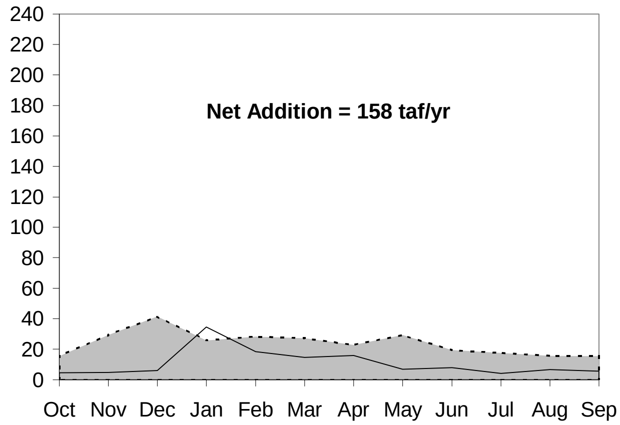


e) In-Delta Consumptive Use

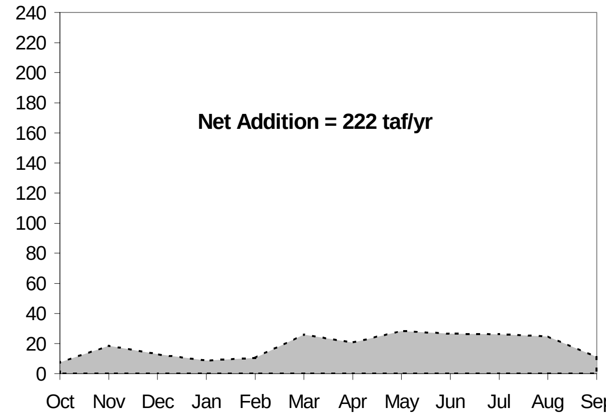


f) Eastside Streams

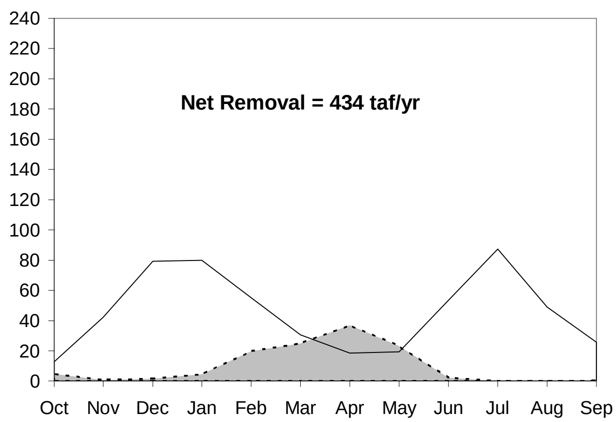
Figure 2H-9. Average Monthly Surface Calibration Water Added and Removed



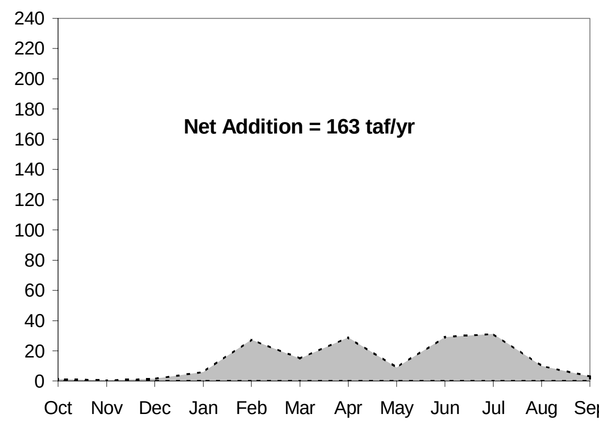
g) Sacramento River at Hood



h) San Joaquin Tributaries



i) San Joaquin at Vernalis



j) Tulare Basin Rivers

Figure 2H-9. Continued. Surface Calibration Water ▒ Added and □ Removed

Overall, the net amount of water added to CALVIN in the Central Valley is 38 taf/yr. While this is quite small, at specific locations the mass imbalances are quite large, with the largest imbalance requiring a net addition of 620 taf/yr to the Sacramento River below the Colusa Basin Drain and just above the Feather River junction (chart "a", Figure 2H-9). On a monthly basis, the largest imbalances of around 1,500 taf/month occur also at this Sacramento River location and on the Feather River between Thermolito Afterbay and its month (chart "b"). The next largest average annual imbalances occur on the Lower San Joaquin River at Vernalis in CALVIN Region 3 (-434 taf/yr) and in net consumptive use in the Delta in CALVIN Region 2 (-380 taf/yr) (see charts "i" and "e").

The amount and especially the timing of peak local runoff in CVGSM and DWRSIM appear to differ in a several locations in the Sacramento Valley. This is particularly remarkable and often pronounced in wet years for the Upper Sacramento River (chart "a"), Lower Feather River (chart "b"), the Lower Sacramento River west-side contributions to Yolo Bypass (chart "d"), Eastside streams (chart "f"), and the lower San Joaquin River (chart "i"). These problems are illustrated by the large maximum monthly calibration flows reported in Tables 2H-10 and 2H-11 for these locations.

At other locations, rather small consistently regular monthly calibration flows (without any large maximums) and little or no removal of water tend to suggest imbalances are not a problem with differing estimates of net runoff timing and magnitude, but a more consistent mass balance accounting problem related to assumptions about the volume of surface diversions and return flows along reaches, and the level of environmental flows in some cases like the American River.

Confirmation of CALVIN's calibration surface water system is shown in Figure 2H-10, comparing the calibrated surplus Delta outflow from CALVIN to that in DWRSIM Run 514a (8,760 taf/yr average). A small difference in outflow remains in CALVIN after the calibration, , averaging 22 taf/yr less than DWRSIM Run 514a.

The largest net additions of water occur in CALVIN Regions 1 and 4. CALVIN Regions 2 and 3 have net removals of water. In each region, the different likely reasons for these calibration flows are discussed next.

Region 1 Calibration Flows

Discrepancies between DWRSIM and CVGSM estimates of the inflow from the Northeast streams to the Upper Sacramento River is the biggest cause of calibration water added to this region in CALVIN. The flows occur mainly during the months from December through April (see chart "a" in Figure 2H-9). DWRSIM's volume for this local accretion is higher than the rainfall-runoff modeling estimate in CVGSM. In addition, rim inflow data in CVGSM for Cow, Battle, and Cottonwood Creek in the Upper Sacramento Valley are taken directly from USGS gage historic records.

Region 2 Calibration Flows

On the Feather River, differences between CVGSM's rainfall-runoff modeling and DWR depletion analysis in the timing (mostly) and volume (somewhat) of peak runoff in wet years is indicated by the very large monthly calibration inflows and outflows required to balance CALVIN Base Case Feather River outflow with DWRSIM's (see chart "b", Figure 2H-9). Dynamic reservoir operation on the Bear and Yuba Rivers in CALVIN may also contribute somewhat to the timing and volume mismatch between CALVIN and DWRSIM on the Feather River. Similar discrepancies between CVGSM and DWRSIM in the timing and amount of local accretions contribute to the causes of CALVIN calibration inflows and outflows for the Yolo Bypass (chart "d") and the Eastside streams (chart "e"). Yolo Bypass and Eastside streams calibration outflows in winter months (pattern of removed water in these charts) indicate that CVGSM estimates lower depletions during large runoff events than DWRSIM's depletion analysis. On the other hand the pattern of small but regular calibration inflows (added water pattern) on the Yolo Bypass suggest a problem with estimates of agricultural surface return flows and local diversions between the two models.

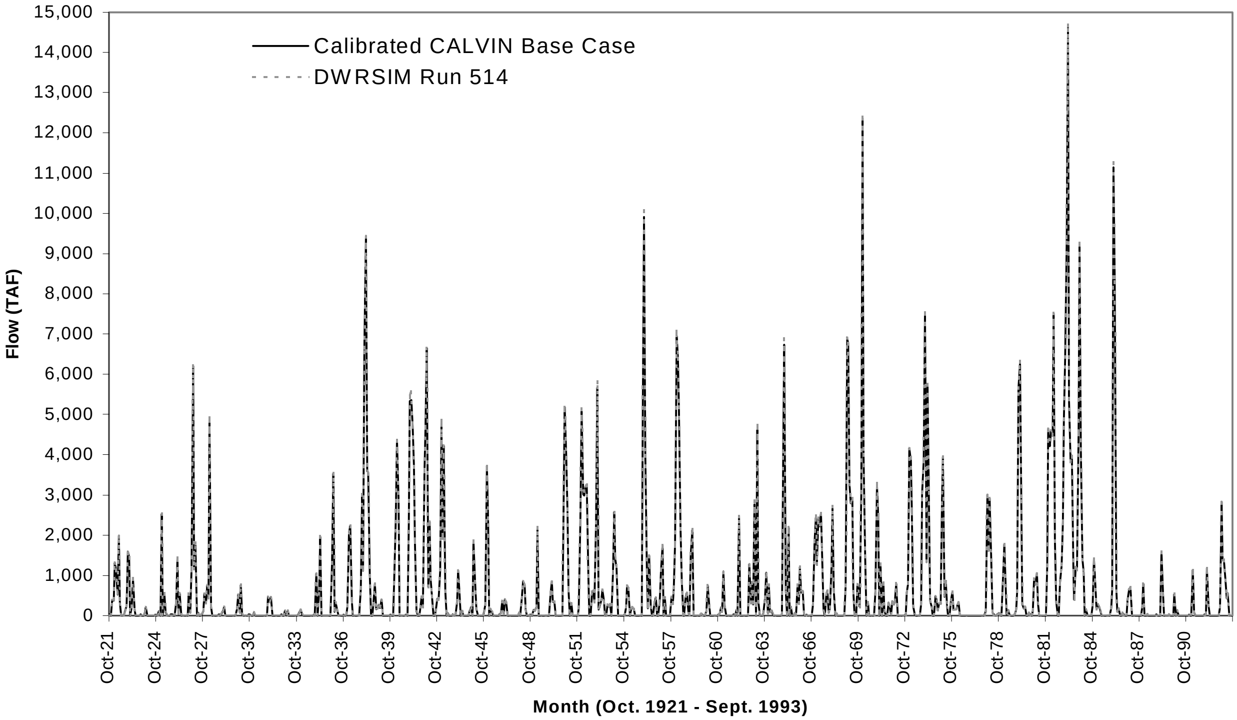


Figure 2H-10. Calibrated Surplus Delta Outflow

The American River calibration flow (see chart "c") exhibits a very different pattern from the other Region 2 calibration locations, requiring a small but consistent inflow throughout the year that can be traced, in part, to differences between PROSIM/CVGSM and DWRSIM representations of American River environmental flows and diversions. These appear to be generally higher in CVGSM/PROSIM than in DWRSIM and are reflected in the different Folsom reservoir operations under PROSIM NAA and DWRSIM Run 514a (see Appendix F: Environmental Constraints).

When the Sacramento River reaches Hood, CALVIN Base Case streamflow (from below the Colusa Bain Drain) is reasonably close to that of DWRSIM Run 514a. Only 158 taf/yr of net calibration flow must be added to CALVIN, representing just under 1% of the mean annual Base Case flow at this location (15,934 taf/yr). The monthly additions and removals of calibration water shown in chart "g" of Figure 2H-9 demonstrate a more regular pattern across months that might be explained by a combination of inconsistent estimates of Sacramento River surface return flows and diversions between the Feather River junction and Hood, in addition to some inconsistency in timing of accretions and depletions between CVGSM and DWRSIM.

It is unclear why CVGSM has a lower estimate of net in-Delta consumptive use compared to DWRSIM during the growing season from March to September (see chart "e"). The calibration magnitude is rather large and significant.

Region 3 Calibration Flows

Mass imbalances between DWRSIM Run 514a and CALVIN on almost all of the tributaries (Stanislaus, Tuolumne, Merced, Chowchilla, and Fresno Rivers) of the San Joaquin River require the addition of calibration water (chart "h"). There is no removal of water required. These additions are thought to be due to several possible causes:

- differences between SANJASM's estimates of "gains" and CVGSM's estimates of net local accretions;
- lower volumes of agricultural surface return flow in CALVIN than in CVGSM; and
- use of a single aggregated downstream location for each CVPM surface return flow in CALVIN compared to several spatially disaggregated stream locations in CVGSM.

The reuse factor in CALVIN accounts for some of the reduced volume of surface return flow compared to CVGSM, while CVGSM represents greater disaggregation of surface return flow locations. Rather small monthly maximum calibration flows added (see second column from right of Table 2H-11) and lack of any removed water (see last column) would support the theory that imbalances have less to do with estimates of net runoff timing and magnitude but reflect a more consistent mass balance accounting problem related to agricultural surface diversions and return flows along these tributary rivers.

An exception to the foregoing analysis of tributary mass imbalances is on the upper Tuolumne River, concerning runoff above New Don Pedro and the operation of the Hetch Hetchy System reservoirs (see SR-HHR and SR-LL-LE calibration flows in Table 2H-11). There is a consistent imbalance between DWRSIM inflows to New Don Pedro and SANJASM hydrologic inflows to the Hetch Hetchy System reservoirs that may be explained by different assumptions in the two models concerning the level of SFPUC diversions (on the order of 20-25 taf/yr higher in SANJASM NAA assumptions). In addition, there is a large anomaly in the runoff estimates above New Don Pedro for 1992-93.

All the calibration flows added to the upstream tributary rivers on the San Joaquin are removed at Vernalis, along with additional removed water. This further supports the explanation that data problems on the San Joaquin River concern estimates of agricultural return flows and riparian diversions along its tributaries. The pattern of calibration outflows on the San Joaquin at Vernalis (chart "i") are indicative of underestimates of the timing and volume of local depletions in CVGSM along the San Joaquin River.

Region 4 Calibration Flows

All calibration flows in this region are additions of water (from January to August) to the four local rivers that are needed to resolve infeasibilities with Base Case local agricultural surface diversion constraints from CVGSM (see chart "j"). It is thought that these calibration inflows are due mostly to CALVIN's aggregation of agricultural surface return flows to a single downstream location below any diversion points in contrast to spatially disaggregated locations used for surface return flows on these rivers in CVGSM. (Whether agricultural surface return flows in the Tulare Basin region actually make it back to the river system is a separate matter regarding CVGSM's representation of the Tulare Basin.)

CVGSM uses USGS gage historic records to represent inflows to the Tule and Kaweah River (rather than estimates of 2020 projected reservoir releases on these rivers) causing additional calibration problems .

Additional mass imbalances contributing to the Region 4 calibration inflows are likely due to CALVIN's simplified method of computing evaporation on the four regional reservoirs. However, good "base case" independent estimates of reservoir evaporation to evaluate errors in CALVIN's evaporation are lacking because a regional model of reservoir operations for planning purposes has not been developed.

Region 5 Calibration Flows

The only calibration flows required in Region 5 are due to differences in reservoir evaporation estimates between CALVIN and DWRSIM. The resultant calibration flows amount to a net total removal of approximately 30 taf/yr along the East and West Branch of the California Aqueduct in CALVIN.

IMPLICATIONS OF THE CALIBRATION

A number of implications concerning the consistency, reliability, and quality of Central Valley and statewide modeling data emerge from the calibration results. Some of these implications are specific to limited areas of the Central Valley while others are systematic.

Surface and Groundwater Hydrology

Hydrology, especially explicitly separate data on the different components of local surface and groundwater resources needs more work in some parts of the Central Valley, especially the Sacramento Valley and Tulare Basin. Revision of the Sacramento Valley hydrology is now part of the joint DWR-USBR hydrology development effort.

Ungaged Streams and Local Accretions

Estimated accretion from runoff and ungaged streams using mass balance accounting (DWR's depletion analysis) and regression analysis(used for SANJASM) do not match with the rainfall-runoff model used in CVGSM in a many places (i.e., Upper Sacramento Valley, Yolo Bypass, Feather River, Eastside Streams, and San Joaquin River , see Figure 2H-9). Separate accounting of surface and groundwater and further calibration of the rainfall-runoff model should reduce these discrepancies. Better estimates of the locations and volumes of riparian diversions and surface return flows may also be needed to improving estimates of local accretions and depletions.

In-Delta Consumptive Use

A large discrepancy exists between DWR's and CVGSM's estimates of in-Delta consumptive use and net in-Delta depletion. CVGSM's estimates are nearly 400 taf/yr lower than those in DWRSIM.

Agricultural Water Systems

The current level of uncertainty in regional agricultural water use, reuse, distribution losses, and basin efficiency throughout the Central Valley has a significant effect on prescribed model operations and scarcity results. These effects are especially important for investigating conjunctive use opportunities in the Central Valley.

Tulare Basin Region Conjunctive Use Operations

The current developed level of conjunctive use operations in the Tulare Lake region are not well understood for modeling purposes, leading to significant uncertainties in estimating agricultural applied water use, active recharge, distribution losses, efficiencies and groundwater depletion in this region. CVGSM's surface flow representation in this area is particularly poor.

Groundwater-Surface Water Interactions in Tulare Region

The calibrated CALVIN representation of the agricultural system in the Tulare Basin Region suggests that net groundwater extraction in Tulare Basin may be more that 500 taf/yr greater than indicated by CVGSM under the base case. Assuming higher irrigation distribution losses (or diverting some deliveries to recharge) in CALVIN in the Tulare Basin Region would reduce this discrepancy. However, there is uncertainty about the fundamental reliability of CVGSM NAA estimates of 140 taf/yr long-term groundwater recovery in this region (compared to over 670 taf/yr of long-term groundwater overdraft indicated in DWR Bulletin 160-98 water accounting estimates). An alternative calibration approach is proposed in Appendix 2H that might improve the representation of agricultural water use in this region.

LIMITATIONS

The current CALVIN calibration approach described in this chapter suffers from some remaining limitations and unresolved problems. These are presented below:

1) The method used to adjust SWAP average demands is rather simple and crude and creates distortion in the allocation of supplies in CALVIN in non-average year types. Better representation of inter-annual variability in agricultural water demands is needed. Also, additional effort to adjust the monthly use patterns is desirable in some regions, preferably through explicit improvements in calibration of SWAP. Efforts are underway to improve the HEC-PRM computer code to handle inter-annual variability in economic demands.

2) Policy implications of CALVIN and other modeling results in the Tulare Basin Region, particularly those pertaining to groundwater management will be difficult to make given the weak source data and difficultly getting the groundwater calibration approach to work in this region.

3) More recent events, such as implementation of CVPIA b(2) environmental water provisions, appear to have reduced agricultural deliveries from that in the CVGSM NAA run. Some revision of CALVIN model environmental constraints is likely to be in order.

An alternative calibration approach to model soil moisture storage as a way to handle the mismatch in deliveries and SWAP demands was proposed earlier in this appendix. Future efforts to improve CALVIN's calibration might start by evaluating this and other possible solutions to limitations outlined in this report.

CONCLUSIONS

This appendix concludes with some recommendations for future hydrologic and modeling data development. These emerge from the effort and learning acquired in this calibration exercise and provide some direction for data improvements for those interested in the continued modeling of water resources in California.

1. Figure out the Tulare Basin

The Tulare Basin has extremely important significance for statewide water operations and resolving the Bay-Delta. It is an important area of conjunctive use operations. Data, modeling effort, and technical understanding of water resources in this region are particularly poor. CVGSM groundwater responses and long-term estimates of recover conflict with DWR's projections of significant depletion. Resources and effort should be devoted to improving the modeling and data for this region.

2. Resolve the imbalance between planning estimates of agricultural water demands and modeling estimates of actual deliveries.

Accurate and consistent statewide data is needed to represent agricultural system water use at farm, district, and basin/regional scales. A physically-based "flow path" accounting model of statewide water demands and supplies, maintaining separation of surface and groundwater flows, provides a framework to develop and manage this kind of data at different scales. CVGSM is a starting point for building such a physically-based comprehensive accounting of all surface and groundwater flows.

3. Develop accurate representations of and data for agricultural return flows to surface & groundwater.

The methodology from the previous point applies here as well. Some important implications from conjunctive use studies depend on getting these representations right. One question that emerges from our calibration is to what degree CVGSM's groundwater representation and return flows are right. If they are, this would suggest some need to re-examine planning estimates of agricultural efficiency.

4. Reconcile different estimates and analysis methods for hydrology in the Central Valley, particularly the Sacramento Basin.

Efforts underway between DWR and USBR will hopefully resolve the discrepancies in hydrology for the Central Valley.

Calibration will always be necessary in water resources modeling, especially for big models like CALVIN. As seen here, such calibration can be useful for identifying specific data problems that need improvement.