APPENDIX 2B

REGION 2 RESULTS: LOWER SACRAMENTO AND BAY DELTA

Stacy K Tanaka and Marion W. Jenkins

September 6, 2001

ABSTRACT

The Lower Sacramento Valley consists of significant urban and agricultural demands areas, as well as the Sacramento-San Joaquin Delta, which is the biggest environmental water demand in the state. CALVIN, an economic optimization model, re-allocates and re-operates water within the region to maximize net economic benefits. The Base Case replicates current water management practices and the Unconstrained Case indicates what would happen in an ideal water market. Agricultural and Urban areas are modeled as economically driven demands. Environmental and small urban demands are modeled as fixed deliveries. Results indicate that the Lower Sacramento Valley would benefit from an ideal market. Intra-regional transfers as well as changes in conjunctive use operations make this possible. Expansion of two key reservoirs and the introduction of two proposed conveyance facilities would reduce water scarcity and scarcity costs.

INTRODUCTION

The CALVIN modeling approach sub-divides the state of California into five regions. Region 2 represents the Lower Sacramento Valley and Sacramento-San Joaquin Delta. This appendix describes the major reservoirs, water supply sources, facilities and demands in Region 2. Additionally, this appendix includes descriptions and preliminary results from the Base Case and Unconstrained Case modeling alternatives. The results are analyzed and some initial conclusions are presented.

REGION 2 MODEL DESCRIPTION

Region 2 covers DWR depletion areas 16, 17, 22, 24, 29, 32, 59, 55, 65, 67, 68, 69, and 70, which correspond to Central Valley Production Model (CVPM) agricultural demand regions 5 through 9. Also included in Region 2 are the urban areas of Yuba, Greater Sacramento, Stockton, Napa-Solano County, Contra Costa Water District (CCWD), and East Bay Municipal Utilities District (EBMUD). Storage in Region 2 consists of thirteen reservoirs and five groundwater basins. See Figure B-1.

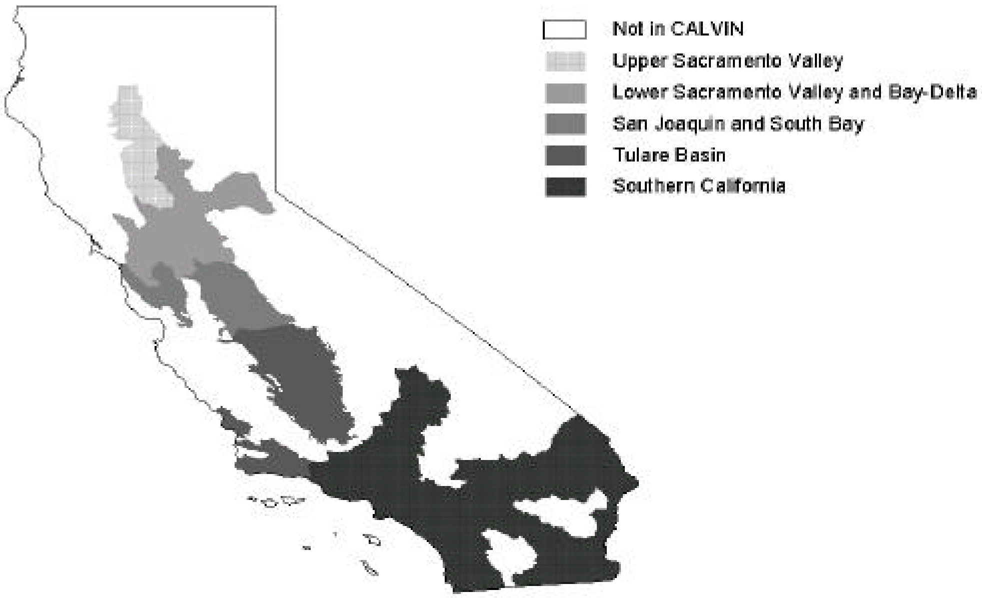


Figure B-1: Region 2: Lower Sacramento Valley and Bay Delta

The thirteen surface water reservoirs include Lake Oroville, New Bullards Bar Reservoir, Englebright Lake, Camp Far West Reservoir, Folsom Lake, Pardee Reservoir, New Hogan Lake, Comanche Reservoir, Thermalito Fore/Afterbay, Clear Lake/Indian Valley Reservoir, Lake Berryessa, EBMUD local Reservoirs, and Los Vaqueros Reservoir. These reservoirs are operated by a variety of federal, state, regional and local agencies.

Flows in the Sacramento River before the confluence with the Feather River and flows from Colusa Basin Drain via Knight's Landing Ridge Cut (KLRC) form the northern boundary of Region 2. The southern boundary of Region 2 follows the Calaveras River across the San Joaquin River at Vernalis to the Tracy and Harvey Banks Pumping Plants. Excess flows in Region 2 travel down and out the Delta as Unconstrained surplus outflow.

The Sacramento River is the key river in the region, however several other significant rivers join with the Sacramento in Region 2. The Feather, Yuba, American, Cosumnes, and Mokelumne Rivers all join with the Sacramento, as well as Greenhorn Creek, Bear River, Dry Creek, Calaveras River, Putah Creek, and Cache Creek. Additional flows enter the Sacramento River from local runoff and gains and losses to groundwater.

Regional water demands are from both agricultural and urban areas, as well as significant environmental requirements for the Delta. Region 2 includes required Delta outflows matching those in DWRSIM Run 514. In addition to the Delta flows, Region 2 also includes environmental demands at the Sutter National Wildlife Refuge and the Gray Lodge Wildlife Area, which have been aggregated into a single demand. Minimum instream flow requirements also exist in Region 2 along the Feather, American, Mokelumne, Calaveras, Yuba and Sacramento Rivers.

Region 2 contains the Yolo Bypass, the North Bay Aqueduct, the Contra Costa Canal, the Folsom South Canal, Mokelumne River Aqueduct, as well as the proposed Isolated Facility (Peripheral Canal). The southern portion of Region 2 contains the pumping facilities for the California Aqueduct and Delta Mendota Canal (Harvey Banks and Tracy Pumping Plants).

Management Alternatives

Two management alternatives were analyzed for Region 2. The first is the Base Case, or Constrained Case. The Base Case constrains CALVIN to operate the system in accordance with current projected operations at the 2020 level of demands. Reservoir operations are constrained to those in the Department of Water Resources Planning Simulation Model (DWRSIM) Case 514. Deliveries are constrained to replicate those in the Central Valley Groundwater and Surface Water Model (CVGSM) No Action Alternative (NAA) developed in the CVPIA Programmatic EIS (USBR 1997)

The second alternative is the Unconstrained Case, which allows for an almost complete economic optimization and representing an "ideal market" policy. Most of the allocation and storage constraints are removed to allow CALVIN to deliver water to places where the greatest economic benefit will be derived. Only a handful of policy constraints remain during the Unconstrained Case. Environmental minimum instream flows, Delta required flows, and fixed refuge deliveries remain in place. Surface reservoirs are constrained by monthly flood control limits to the conservation pool and by minimum operating levels. Groundwater has a maximum storage capacity and a constraint limiting depletion to that in the Base Case. Finally, all physical capacity limitations remain in place.

Base Case Assumptions and Limitations

The Base Case, or constrained model alternative, represents current infrastructure, contractual agreements, and legislative requirements. Deliveries to agricultural and most urban regions are fixed times series. Storages for Lake Oroville, Thermalito Fore/Afterbay, Folsom Lake, Camanche Reservoir, New Hogan Lake and Pardee Reservoir are also fixed time series. Surface deliveries to economically represented urban demands also are fixed or effectively limited by other constraints and the hydrologic calibration in the Base Case. Groundwater pumping to the agricultural regions is constrained to match pumping in CVGSM while urban pumping is not. Very little optimization takes place during the Base Case, mostly for parts of the system where information on Base Case operating constraints was insufficient.

Like all models, CALVIN is subject to some limitations (see Chapter 5 for details). Among those limitations are the ways in which environmental flows are modeled and the way urban and agricultural demands are determined.

Recently California has seen an increase in the regulations regarding environmental water demands. Minimum instream flows for native wildlife, as well as supplies for refuges have begun to play major roles in water allocations and availability. As yet, there are few recognized and accepted economic values that can be assigned to environmental water. For that reason, CALVIN models environmental water demands as constraints on the system. The minimum instream flows are modeled as lower bounds on flow through a link.

The refuge demands are modeled as fixed time series of deliveries that must be met each month of each year. However, the full Level 2 (L2) demands occasionally exceed the available water into the region. When that occurs a modified L2 demand is used. The modified L2 demand is either the full Level 2 demand (when there is sufficient supply) or the entire amount of available water into the region (when there is insufficient supply to meet the full L2 demands). See Appendix 1F for details. Delta environmental flow requirements are modeled as a fixed time series of Delta outflows, insuring that the required amount will be delivered in every month.

Another limitation of CALVIN is that it only uses “normal” year urban and agricultural demands, rather than varying the demands by year type. Similarly water use efficiencies are represented as a fixed value and do not vary by month or year. CVGSM NAA deliveries are Based on variable agricultural demands that generally increase in dry years and decrease in wet ones. Generally, crop water requirements are lower and rainfall higher in wet years, thus lowering applied water demand in wet years. The converse is true in dry years. However use efficiencies tend to be lower in wet years given the ready availability of water and rainfall. The use of average year demands in CALVIN can result in over and/or under estimations of the water demands of a given region in a given year.

Region 2 as been calibrated so that in the Base Case, outflows from the Feather River, American River, Yolo Bypass, Sacramento River at Hood, Eastside Streams, and San Joaquin River at Vernalis, and net consumptive use in the Delta, all match those in DWRSIM Run 514. Calibration requires that water must occasionally be added or removed from the model. Details of the calibration of Region 2 appear in Appendix 2H.

Unconstrained Policy Assumptions and Limitations

The second alternative is the Unconstrained Case, which represents an ideal water market. Most of the Base Case fixed flow constraints are removed for the Unconstrained Case. The model is allowed to deliver water to the agricultural and urban regions Based on economic benefit. The only constraints are the physical limitations of the current system, the necessary flood control pools and the environmental water requirements.

In the Unconstrained Case, end-of-period surface reservoir storages are constrained to match the ending storages in the Base Case. Two end-of-period storage conditions are considered for groundwater. The current alternative has end-of-period storage constrained to match the end-of-period storage in the Base Case, Based on calibration of groundwater to CVGSM NAA. In contrast, an alternative with Unconstrained end-of-period groundwater storage would result in more or less long-term groundwater depletion than the Base Case, depending on the comparative marginal costs and benefits of pumping relative to other supplies in the region.

Finally, the environmental requirements established in the Base Case remain in place. The minimum instream flows and Delta requirements remain unchanged from the Base Case. The refuge demands remain at the modified L2 demand levels.

The Unconstrained Case has many of the same limitations as the Base Case. In addition, CALVIN employs perfect foresight, which allows it to anticipate droughts and floods. This results in over-confident or optimistic over-year storage operations. Prior to wet years carryover storage is too low and prior to dry years carryover storage is too high. Perfect foresight of future reservoir inflows allows the model to reduce spills. Surface deliveries are therefore slightly higher and storage values under the ideal water market allocations tend to be less than they would actually be under realistic conditions of imperfect foresight. Perfect foresight leads to over-performance of existing facilities and an under-valuation of system expansion in the Unconstrained alternative.

COMPARISON OF MODEL RESULTS

The following section presents results from the two management alternatives. For each of the demand regions (agricultural and urban), three results are presented. These are the supply source break down (detailing each demand), the volume of deliveries on an annual average basis, and the level and cost of scarcity (also on an annual average basis). Next the economic indicators (marginal value of water and shadow prices) are discussed. The opportunity costs of the environmental requirements also are presented. Finally shadow prices on the boundary flow constraints are compared with those of Region 1 and 3 to identify the economic incentives for inter-regional water transfers.

Water Delivery Results

In both the Base and Unconstrained Cases, Region 2 experiences scarcities. However, scarcity and scarcity costs are significantly reduced from Base Case levels by re-allocations of water and increases to supply under the Unconstrained policy. *Scarcity*, as used here, is the difference in the amount of water that would be used if water were “freely” available (at a price of zero for agriculture and at the current 1995 price for urban water, without other limitations) minus modeled water deliveries. The scarcities and annual water budget for the region are presented in Table B-1.

Table B-1: Summary of Water Budget (taf/yr)

	Base Case	Unconstrained Case	
	Average	Average	Drought[a]
Max. Water Demands			
Urban	1598	1598	1598
Agricultural	5428	5428	5428
Total	**7026**	**7026**	**7026**
Deliveries (less conveyance losses)			
Surface Water	3920	3954	2936
Groundwater	2485	2486	3492
Reuse [b]	594	585	591
Total	6999	7026	7019
Scarcity	**27**	**1**	**8**

[a] Water years of 1929-1934, 1976-1977 and 1987-1992.

[b] Reuse indicates agricultural re-use as well as urban water recycling.

There is an annual average scarcity of 27 taf/year in the Base Case. The majority of the scarcity (19 taf/year) is to urban areas. The remaining 8 taf/year of scarcity is to agriculture. The

Unconstrained Case has a lower annual average scarcity (1 taf/year) all of which is to urban areas.

The Base and Unconstrained Cases impose the same fixed delivery requirement for the environment, thus producing identical scarcities (see Appendix 1F for details). The environmental deliveries are fixed time series of deliveries and by extension so are any scarcities. Therefore the scarcities were not reported as part of the regional water budget because there was no way to economically optimize the refuge (and Delta) deliveries.

Delivery reliability curve for aggregate urban water deliveries is presented in Figures B-2. A delivery reliability curve for aggregate agricultural water is omitted. Agricultural deliveries in the Base Case are fixed to match the deliveries in CVGSM. Deliveries in individual months and individual years do not necessarily match the average demands used in SWAP. From the regional water budget there was an annual average agricultural scarcity of 8 taf/year, which is about 0.1% of demands on an annual average basis. The Unconstrained Case delivers full agricultural demands in all years, indicating that agricultural areas of Region 2 would benefit from an ideal water market. Agricultural scarcities and associated scarcity costs would be reduced to zero.

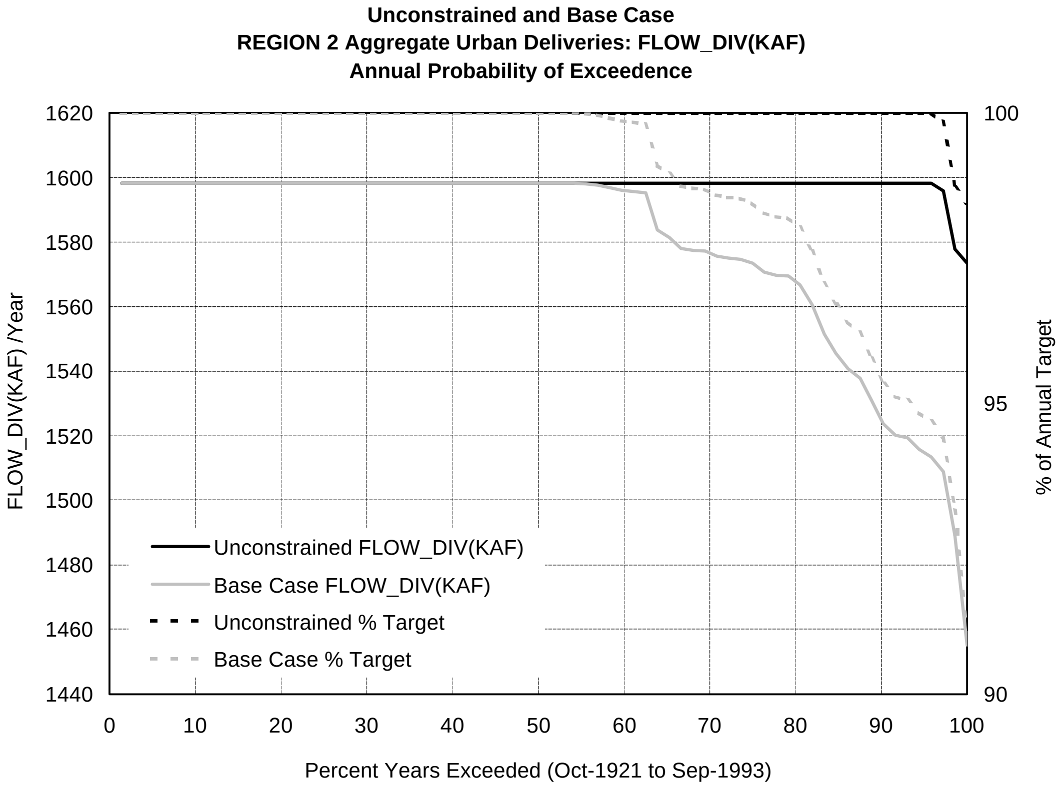


Figure B-2: Total Aggregate Urban Deliveries

Urban deliveries also improve reliability in the Unconstrained Case. An ideal water market would be able to fill demands about 95% of the time, while the Base Case meets full demands about 56% of the time. The Base Case reliability drops off steeply, down to a low of approximately 91%. The Unconstrained Case never deliveries less than 98% of the demand, greatly reducing the frequency and severity of scarcities to urban areas in an ideal market.

Figure B-3 (below) is the total aggregate (urban and agricultural) delivery reliability curve for the Unconstrained Case in Region 2. Over 99% of the demand would be delivered in all years to Region 2 in the Unconstrained Case. In the Base Case the minimum regional reliability is about 90%.

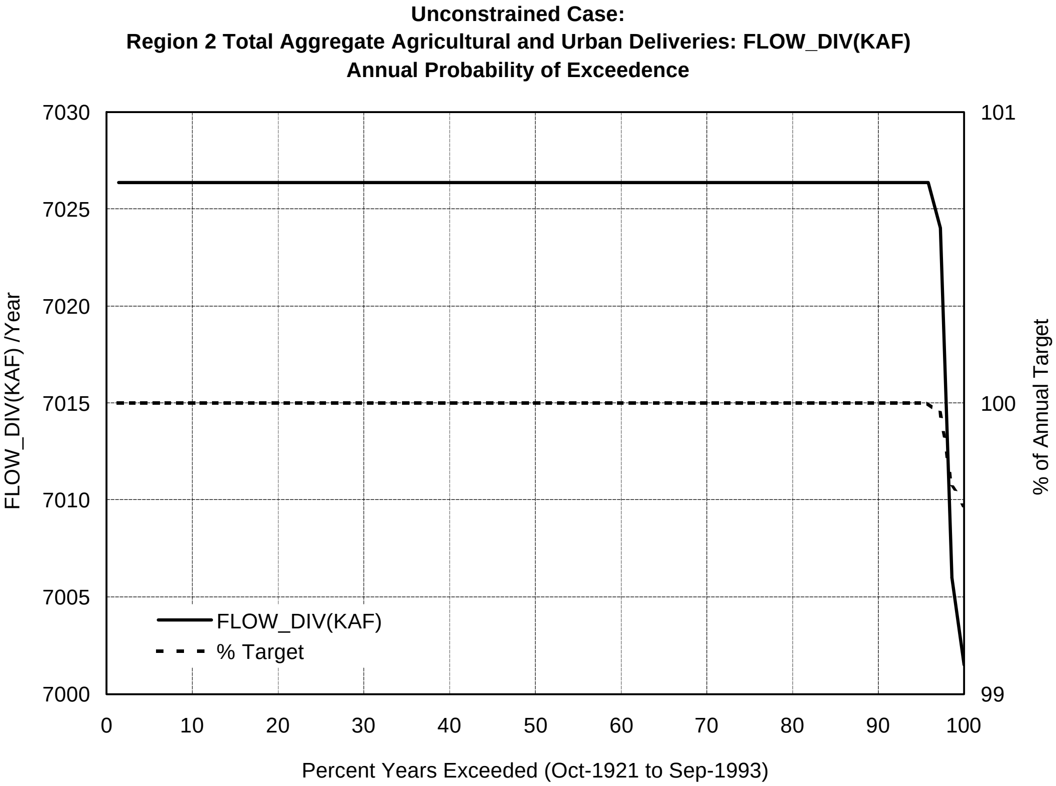


Figure B-3: Total Aggregate Region 2 Deliveries

Groundwater storage is constrained in the ideal market scenario to match the Base Case ending storage. In general the Unconstrained Case groundwater storage levels are lower than the Base Case, except during the 1980's. The long-term variations in storage are also larger, indicating greater use of groundwater for conjunctive operations in the Unconstrained Case (see Table B-3). The Unconstrained Case is able to pump slightly more groundwater in CVPM basin 9 during the 72-year period than in the Base Case because of additional recharge from increased agricultural deliveries. Figure B-4 compares the aggregate storage in the five groundwater basins in Region 2 between the two alternatives.

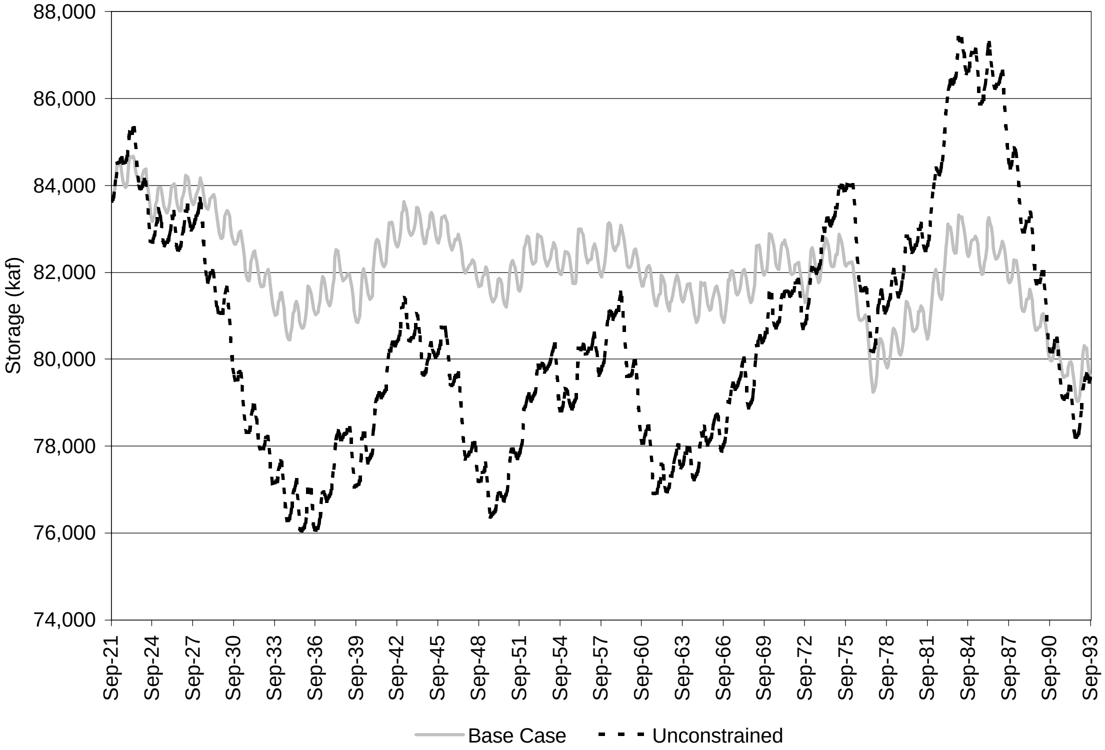


Figure B-4: Aggregate Groundwater Storage Volume

Each of the five basins has different costs associated with pumping that also vary depending with usage (urban or agricultural). Table B-2 presents the costs and Table B-3 presents the volume of groundwater pumped from each of the basins for the Base and Unconstrained Cases. Drought year pumping (average of 1929-34, 1976-77, and 1987-92) increases substantially in the Unconstrained Case compared to the Base Case.

Table B-2: Groundwater Pumping Costs

Groundwater Basin	Demand	Pumping Cost ($/af)
GW-5	CVPM 5	18.8
GW-6	CVPM 6	18.2
GW-7	CVPM 7	28.8
GW-7	Greater Sacramento	57.0
GW-8	CVPM 8	28.6
GW-8	Greater Sacramento	55.0
GW-8	Stockton	70.0
GW-9	CVPM 9	20.4

Table B-3: Groundwater Pumping

Groundwater Basin	Base Case		Unconstrained Case	
	Average (taf/yr)	Drought (taf/yr)	Average (taf/yr)	Drought (taf/yr)
GW-5	558	733	558	1038
GW-6	508	608	508	742
GW-7	342	406	342	396

GW-8	889	1054	889	1071
GW-9	189	179	190	245
TOTAL	**2485**	**2982**	**2486**	**3492**

Surface water storage is also constrained to match the same ending storage as the Base Case. In general the Base Case filled and drained the reservoirs more often than the Unconstrained Case. However, in general the Unconstrained Case kept the reservoirs fuller than the Base Case during both wet and dry periods. This indicates that Region 2 has ‘excess’ water available. See Figure B-5 for details. There was a small persuasion of $0.02/AF to leaving water in the reservoirs as opposed to unvalued releases into the system.

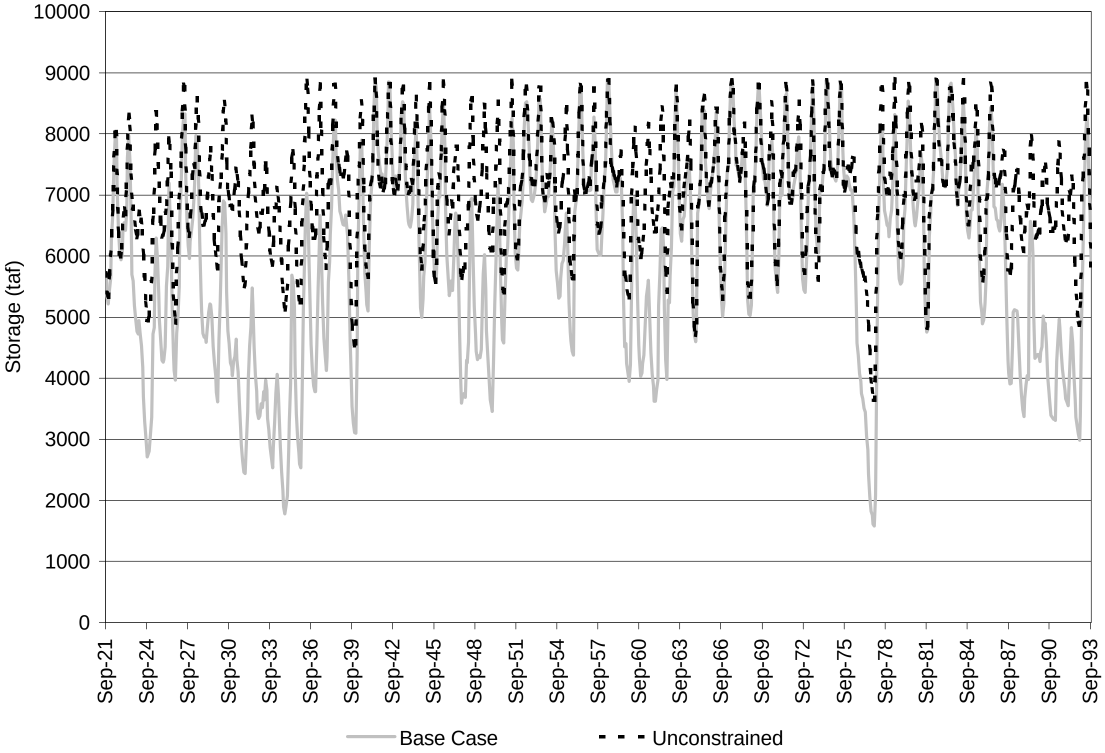


Figure B-5: Aggregate Surface Water Storage Volume

As stated before, CALVIN is an economic optimization model. Its only ‘operating’ rule is to minimize costs (maximize benefits). Ideally, the Unconstrained Case models an ideal water market, which reduces the overall net costs (those due to scarcities and operations). Table B-4 presents the costs of the agricultural scarcities for an average year for both modeling alternatives and for the drought periods of the Unconstrained Cases. Table B-5 presents the same results for the urban scarcities.

Table B-4: Average Agricultural Scarcity and Scarcity Costs

	Base Case			Unconstrained Case		
	Annual Average Scarcity (taf/yr)	% Annual Scarcity	Cost ($1000/yr)	Annual Average Scarcity (taf/yr)	% Annual Scarcity	Cost ($1000/yr)
Average	8	0.1	199	0	0	0

Drought	N/A	N/A	N/A	0	0	0

Table B-5: Average Urban Scarcity and Scarcity Costs

	Base Case			Unconstrained Case		
	Annual Average Scarcity (kaf/yr)	% Annual Scarcity	Cost ($\$10^6$/yr)	Annual Average Scarcity (kaf/yr)	% Annual Scarcity	Cost ($\$10^6$/yr)
Average	19	1.2	35.5	<1.0	<0.1	0.63
Drought	64	4.0	131.6	8	0.5	7.2

From Table B-4 and B-5 it is clear that the overall scarcity costs to the region are substantially reduced in the Unconstrained Case. In the Base Case, a large scarcity cost to the urban areas is associated with a relatively small scarcity volume (19 taf/yr). On the other hand, in the ideal market urban areas face very few scarcities and their associated scarcity costs decrease greatly. Table B-5 illustrates just how ‘valuable’ water is to the urban areas in Region 2. An average scarcity level of less than 1 kaf/yr still incurs an average cost of $630,000/yr. With the agricultural areas, a scarcity of 8 kaf/yr only incurs an average cost of $199,000/yr. However, in the Lower Sacramento Valley there is plenty of “excess” water. This avoids having to reallocate any agricultural water to urban users. Any exchanges between agriculture and urban water users are for water quality purposes and increased conjunctive operations, in general.

Table B-6: Total Scarcity Costs for Region 2

	Base Case Cost ($\$10^6$/yr)	Unconstrained Case Cost ($\$10^6$/yr)	ΔScarcity Costs ($\$10^6$/yr)
Average	35.7	0.6	-35.1

Region 2 includes four sources of operating costs: groundwater pumping, urban water treatment and local distribution, urban water recycling treatment, and surface water pumping. Groundwater pumping costs vary with location and usage (urban or agricultural). Urban surface water treatment costs depend on the supply source while local distribution costs depend on service area conditions. Surface water pumping costs vary from plant to plant. Recycled water costs the same for all urban areas. There is also one fixed head power plant location (Los Vaqueros) where operating benefits accrue. Further information regarding operating costs appears in the Appendix 1G: CALVIN Operating Cost.

The overall operating costs for Region 2 decrease in the ideal market. Table B-7 presents the operating costs (both urban and agricultural combined) for Region 2.

Table B-7: Operating Costs for Region 2

	Base Case Cost ($\$10^6$/yr)	Unconstrained Case Cost ($\$10^6$/yr)	ΔOperating Cost ($\$10^6$/yr)
Groundwater	61.8	67.9	6.1
Surface Water	251.0	233.8	-17.2
REGION 2 TOTAL	**312.8**	**301.7**	**-11.1**

There is a net operating benefit of $11.1 million/year to Region 2 in the ideal market. Groundwater pumping costs increase, but surface water (especially treatment) and recycling water costs decrease. Combined with reduced scarcity costs of $35.1million/yr, under an ideal market the region experiences a $46.2 million net benefit over the Base Case (Table B-8). Essentially, greater conjunctive operations and agriculture-urban water quality exchanges achieve lower operating costs while simultaneously increasing deliveries in the Unconstrained alternative.

Table B-8: Costs by Demand

	Base Case			Unconstrained Case			
	Scarcity Cost ($\$10^6$/yr)	Operating Cost ($\$10^6$/yr)	Total Cost ($\$10^6$/yr)	Scarcity Cost ($\$10^6$/yr)	Operating Cost ($\$10^6$/yr)	Total Cost ($\$10^6$/yr)	Total Reduced Costs ($\$10^6$/yr)
Total Ag	0.2	46.8	47.0	0.0	40.3	40.3	6.7
Total Urban	35.5	129.5	160.9	0.6	124.8	125.5	39.5
REGION 2	**35.7**	**176.3**	**212.0**	**0.6**	**165.**	**165.8**	**46.2**

Under an ideal market both the agricultural and urban scarcity and operating costs decrease. Agriculture would see an average $6.7 million/yr benefit, mostly from reduced operating costs, while urban areas benefit by $39.5 million/yr on average mainly from reduced scarcity. These changes amount to reductions of 14% and 24% in combined scarcity and operating costs, respectively, for the agricultural and urban sectors. An idea market would be economically favorable to the Lower Sacramento Valley and Bay Delta Region.

Agricultural Supply Sources and Reliability

Agricultural demands in the region face a minimal scarcity in the Base Case. The annual average scarcity is 8 taf/yr, about 0.1% of their total demand worth about $199,000/yr in scarcity costs. Under the ideal market, agriculture receives its full demands and incurs zero scarcity costs. Decreased reliance on groundwater in CVPM region 7 reduces operating costs by $6.7 million/year on an annual average basis (Table B-9). Exchanges with urban users in the Greater Sacramento area who increase groundwater pumping in basin 7 (due to lower cost than surface sources) and reduce lower American River diversions, allows CVPM 7 agricultural users to take more (free) Sacramento River water instead of pumping groundwater (see Table B-10 for details).

Table B-9: Costs by CVPM Region

	Base Case			Unconstrained Case			
	Scarcity Cost ($\$10^6$/yr)	Operating Cost ($\$10^6$/yr)	Total Cost ($\$10^6$/yr)	Scarcity Cost ($\$10^6$/yr)	Operating Cost ($\$10^6$/yr)	Total Cost ($\$10^6$/yr)	ΔTotal Costs ($\$10^6$/yr)
CVPM 5	0.0	9.4	9.4	0.0	9.4	9.4	0.0
CVPM 6	0.0	8.1	8.1	0.0	8.1	8.1	0.0
CVPM 7	0.0	8.1	8.1	0.0	2.3	2.3	-5.8
CVPM 8	0.0	18.9	18.9	0.0	18.2	18.2	-0.7
CVPM 9	0.2	2.3	2.5	0.0	2.3	2.3	-0.2
Total Ag	**0.2**	**46.8**	**47.0**	**0.0**	**40.3**	**40.3**	**-6.7**

There are five agricultural areas in Region 2. In the Base Case only CVPM 9 experiences any scarcities on an annual average basis while in the Unconstrained Case, no CVPM region experiences scarcity. The supply mix for each CVPM region changes between the two cases, as shown in Table B-10.

Table B-10: Summary of Agricultural Supplies

	Base Case		Unconstrained Case	
Supply Source (or Point of Diversion)	taf/yr	% Total Supply	taf/yr	% Total Supply
Sacramento East Refuge Diversion	-31		-31	
Bear River above Camp Far West Reservoir	21	1%	10	1%
Feather River above Oroville	13	1%	19	1%
Feather River	946	54%	924	53%
Yuba River	165	9%	187	11%
Sacramento River via drain RD1500	18	1%	18	1%
Lake Oroville Releases	8	0%	14	1%
Groundwater	498	29%	498	29%
Reuse	98	6%	98	6%
CVPM 5 TOTAL	**1737**		**1737**	
Cache Creek at Capay Diversion Dam	118	11%	115	11%
Putah South Canal	139	13%	54	5%
Knights Landing Ridge Cut	90	9%	177	17%
Groundwater	447	43%	447	43%
Reuse	254	24%	254	24%
CVPM 6 TOTAL	**1048**		**1048**	
Bear River	99	17%	153	27%
Sacramento River	135	24%	276	49%
Feather River	9	2%	16	3%
Groundwater	281	50%	79	14%
Reuse	42	7%	42	7%
CVPM 7 TOTAL	**565**		**565**	
Folsom South Canal	45	5%	78	9%
Cosumnes River	11	1%	8	1%
Central San Joaquin ID from Stanislaus River	17	2%	9	1%
Mokelumne Riparian Diversions	79	9%	80	9%
Groundwater	661	74%	637	71%
Reuse	81	9%	81	9%
CVPM 8 TOTAL	**894**		**894**	
Sacramento River	300	25%	358	30%
Delta Cross Channel Diversion	203	17%	224	19%
San Joaquin River [a]	145	12%	173	15%
San Joaquin River [b]	310	26%	208	18%
Groundwater	112	9%	113	10%
Reuse	107	9%	108	9%
CVPM 9 TOTAL	**1176**		**1184**	
TOTAL DEMAND	5428		5428	
Grand TOTAL (Net Deliveries)	4838		4845	
Grand TOTAL (Reuse)	582		583	
GRAND TOTAL (Applied Water)	**5420**		**5428**	
Scarcity (taf/yr)	8		0	
Scarcity Cost ($K/yr)	199		0	
Percent Scarcity	0.1		0	

---

[a] San Joaquin above the confluence with the Mokelumne River.
[b] San Joaquin below the confluence with the Mokelumne River.

CVPM Region 5

CVPM region 5 experiences no scarcity in either the Base or the Unconstrained Case. The area has eight supply sources (see Table B-10). The same amount of surface water and groundwater is utilized in both cases, on average, although not in normal or drought years as shown in Table B-3. The only difference is in the amount of each surface water source that is used. In general Feather River diversions decrease while Yuba River diversions increase.

Groundwater pumping costs are the only operating costs represented in CALVIN in CVPM 5. Because groundwater pumping remains unchanged, operating costs also remain unchanged as shown in Table B-9 since pumping costs are not head dependent in CALVIN.

CVPM Region 6

As with CVPM 5, CVPM 6 does not experience any variation in scarcity between the Base and Unconstrained Cases. In both cases full demands are met 100% of the time and the average supply source split between surface water and groundwater remaines the same (76% surface water, 24% groundwater). The Unconstrained Case, however, decreases the volume of water diverted from Cache Creek and especially the Putah South Canal, replacing it with approximately 143 taf/year more water from the Sacramento River at Knights Landing Ridge Cut. This exchange allows Napa-Solano urban area to take more Putah South Canal water, increasing its total supplies while also reducing its costs.

CVPM 6's only represented operating cost is for groundwater pumping. Because the same total volume of groundwater is pumped over the 72 year sequence in the two cases, operating costs remain the same. In other words, CVPM 6 would neither benefit nor suffer from an ideal market.

CVPM Region 7

In the Base Case, CVPM 7 relies on groundwater to meet 50% of their demands. They pump, on average, 281 taf/year of groundwater at an operating cost of approximately $8.1 million/year. In the Unconstrained Case, CVPM 7 obtains more water from the Sacramento and Bear Rivers, while decreasing groundwater pumping, and still receives full demands. Groundwater pumping drops to 79 taf/year and correspondingly, operating costs drop to $2.3 million/year. As pointed out earlier, substitution of surface for groundwater occurs through an exchange with urban users in the Greater Sacramento Area who replace their Sacramento and Lower American River water with more use of groundwater. This exchange also offers potential environmental benefits on the lower American River. CVPM 7 would benefit the most from the ideal water market out of all the agricultural regions with operating costs decreasing by approximately $5.8 million/year.

CVPM Region 8

CVPM 8 has the highest operating cost of all the agricultural regions in the Base Case and the highest reliance on groundwater (over 70% of demand). It pumps 661 taf/year, on average, from the most expensive basin in Region 2 (Table B-10). In the Unconstrained Case, CVPM 8 decreases pumping slightly by 24 taf/year, a reduction of about $0.7 million/year in operating costs. Again, this occurs by substituting groundwater with increased Folsom South Canal diversions from the lower American River through an exchange with urban users in the Greater Sacramento Area. CVPM 8 also decreases Stanislaus diversions, again substituting Folsom South Canal water, to the benefit of Stockton urban users.

It should be noted that the maximum capacity on the South Folsom Canal diversions to CVPM 8 were set too high. CVPM 8 was able to divert 19.7 taf/month over what is physically possible.

CVPM Region 9

CVPM regions 5 through 8 receive full demands in both the Base and Unconstrained Cases. That is not the case for CVPM 9. CVPM 9 is the only area to experience any change in scarcity between the two alternatives. Figure B-6 is the exceedence plot for CVPM 9.

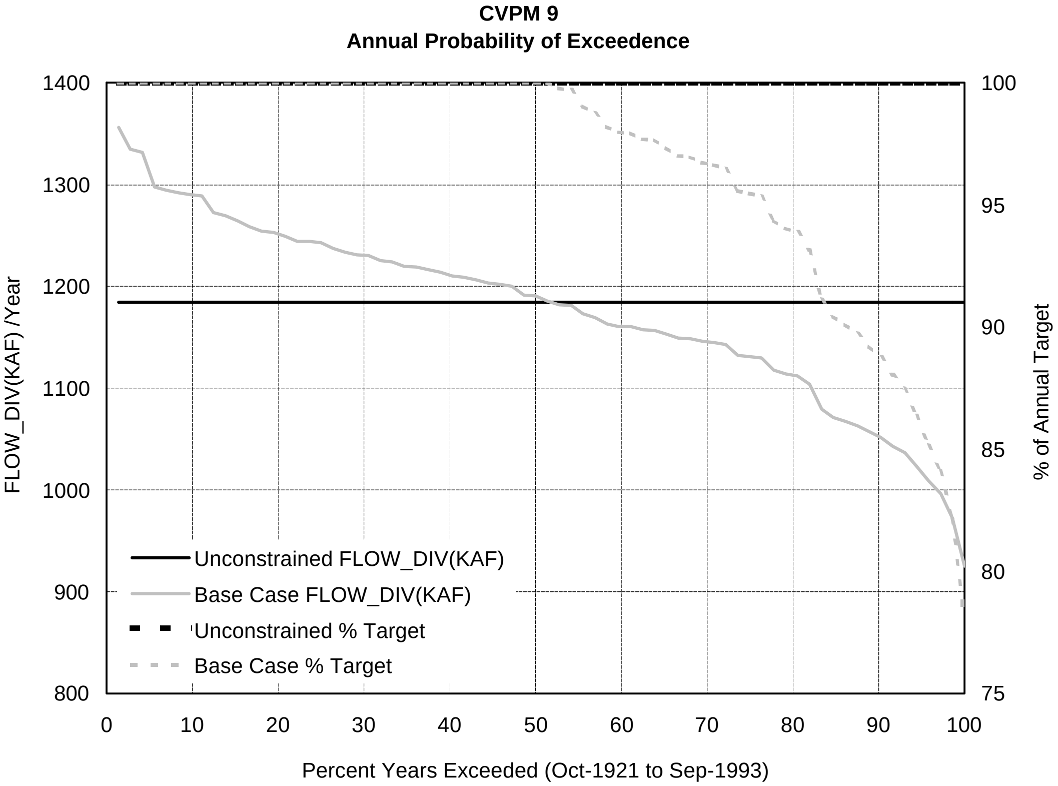


Figure B-6: Exceedence Plot for CVPM 9

The Base Case deliveries equal or exceed average year demands used in CALVIN/SWAP 50% of the time. Deliveries can drop to as low as 78% of average year demands. The average scarcity, comparing Base Case average deliveries to average SWAP demand, is approximately 8 taf/yr or 0.7% of demand. The corresponding scarcity cost is about $0.2 million per year. The Unconstrained Case delivers full average demands 100% of the time and incurs no scarcity costs.

In the Unconstrained Case, CVPM 9 increases deliveries from the Sacramento River, directly and via the Delta Cross Channel, while very slightly decreasing total diversions from the San

Joaquin River. There is a very small increase in groundwater pumping. Overall CVPM 9 sees a decrease in total costs of approximately $0.2 million/year due to the elimination of any scarcity.

Urban Supply Sources and Reliability

The Lower Sacramento Valley and Bay-Delta region included in Region 2 have six economically represented urban demand areas. They are Napa-Solano, the Contra Costa Water District, East Bay Municipal Utilities District, Stockton, Greater Sacramento and Yuba City. Water in the urban areas, in general, has a higher value than it does in the agricultural sectors. Small scarcities to urban areas incur high penalties (as shown in Table B-5).

Table B-11: Costs by Urban Area

	Base Case			Unconstrained Case			
	Scarcity Cost ($\$10^6$/yr)	Operating Cost ($\$10^6$/yr)	Total Cost ($\$10^6$/yr)	Scarcity Cost ($\$10^6$/yr)	Operating Cost ($\$10^6$/yr)	Total Cost ($\$10^6$/yr)	ΔTotal Costs ($\$10^6$/yr)
Napa-Solano	22.0	7.4	29.3	0.0	7.5	7.5	-21.8
CCWD[a]	0.1	44.0	44.1	0.0	43.8	43.8	-0.3
EBMUD[b]	12.5	34.6	47.1	0.6	33.6	34.3	-12.8
Stockton	0.1	4.2	4.3	0.0	3.5	3.5	-0.8
Greater Sacramento	0.0	36.7	36.7	0.0	33.7	33.7	-3.0
Yuba	0.9	2.6	3.5	0.0	2.7	2.7	-0.9
Total Urban	**35.5**	**129.5**	**165.0**	**0.6**	**124.8**	**125.5**	**39.5**

[a] 'CCWD' refers to the Contra Costa Water District. Their operating costs includes the costs associated with treatment, recycling, and pumping at the Old River, Contra Costa, Mallard Slough and Los Vaqueros Pumping Plants.

[b] 'EBMUD' refers to the East Bay Municipal Utilities District. Their operating costs include treatment, recycling, and pumping costs associated with the Mokelumne River Aqueduct, and Walnut Creek Pumping Plant.

As can be seen from Table B-11 (above), there were more scarcities in the Base Case than in the Unconstrained Case. Despite increased allocations and different distributions of supplies, there was still a small scarcity in the Unconstrained Case due to capacity constraints effecting EBMUD deliveries. However, none of the economically driven urban demand regions received less water in the Unconstrained Case. Table B-12 presents the supply mixes for the economically driven urban regions.

Table B-12: Summary of Urban Supplies

	Base Case		Unconstrained Case	
Supply Source (or Point of Diversion)	taf/yr	% Total Supply	taf/yr	% Total Supply
Feather River	5	10%	2	4%
Yuba River	5	9%	30	57%
Lake Oroville	42	81%	21	39%
TOTAL YUBA	**52**		**53**	
Sacramento River	74	11%	0	0%
Lower American River	229	34%	0	0%
Folsom Lake	148	22%	205	30%
Groundwater (GW-7)	61	9%	263	39%
Groundwater (GW-8)	166	24%	210	31%
Recycled	0	0%	0	0%
TOTAL GREATER SACRAMENTO	**679**		**679**	

Calaveras River	16	17%	28	30%
Stanislaus River	43	46%	52	54%
Groundwater (GW-8)	35	37%	15	16%
Recycled	0	0%	0	0%
TOTAL STOCKTON	**95**		**95**	
Putah South Canal	51	48%	115	100%
North Bay Aqueduct	54	52%	0	0%
Groundwater (GW-6)	0	0%	0	0%
Recycled	0	0%	0	0%
TOTAL NAPA-SOLANO	105		115	
Contra Costa Canal	131	97%	133	99%
Recycled	4	3%	2	1%
TOTAL CCWD	135		135	
Mokelumne River	282	97%	296	100%
Recycled	8	3%	1	0%
TOTAL EBMUD	290		297	
TOTAL DEMAND[a]	1374		1374	
GRAND TOTAL (Deliveries)	**1355**		**1374**	
Scarcity (taf/yr)	19		1	
Percent Scarcity	1.4%		0.0%	

[a] 'Total demand' refers to the total demand of the economically driven urban areas. There is an additional 224 taf/yr of fixed urban demands that are not included in the above table.

Yuba City et al.

Yuba City et al. experiences a small scarcity in the Base Case, and none in the Unconstrained. The Base Case scarcity is approximately 0.8 taf/year or 1.6% of their annual average demand and corresponds to a scarcity cost of $0.9 million/year. In the Unconstrained Case, Yuba City incurs a slightly higher operating cost ($0.1 million/yr) for additional deliveries that is more than offset by the elimination of all scarcity costs. See Table B-13 for details. In an ideal market Yuba would see a net benefit of $0.8 million/year.

Table B-13: Yuba City et al. Results

	Base Case		Unconstrained Case	
	Average	Drought	Average	Drought
Annual Average Scarcity (taf)	0.8	2.6	0.0	0.0
Percent Scarcity (%)	1.6	4.8	0.0	0.0
Annual Average Scarcity Cost ($$10^6$)	0.9	2.8	0.0	0.0
Annual Average Operating Cost ($$10^6$)	2.6	2.5	2.7	2.7
Annual Average Total Cost ($$10^6$)	**3.5**	**5.3**	**2.7**	**2.7**

Yuba City et al. is completely dependent upon surface water to meet its demands (Table B-10). In the Base Case it gets almost of all of its supply from Lake Oroville (81%). In the Unconstrained Case it depends more heavily upon supplies from the Yuba River (57%). The remaining supply comes primarily from the Lake Oroville (39%). The remaining 4% of its supply comes form the Feather River below Oroville. All three sources have the same treatment and local distribution operating cost of $50/af.

In the Base Case, deliveries can range from 100% down to about 71% of the demand. Full deliveries occur approximately 75% of the time. The Unconstrained Case delivers full demands 100% of the time. See Figure B-7 for details.

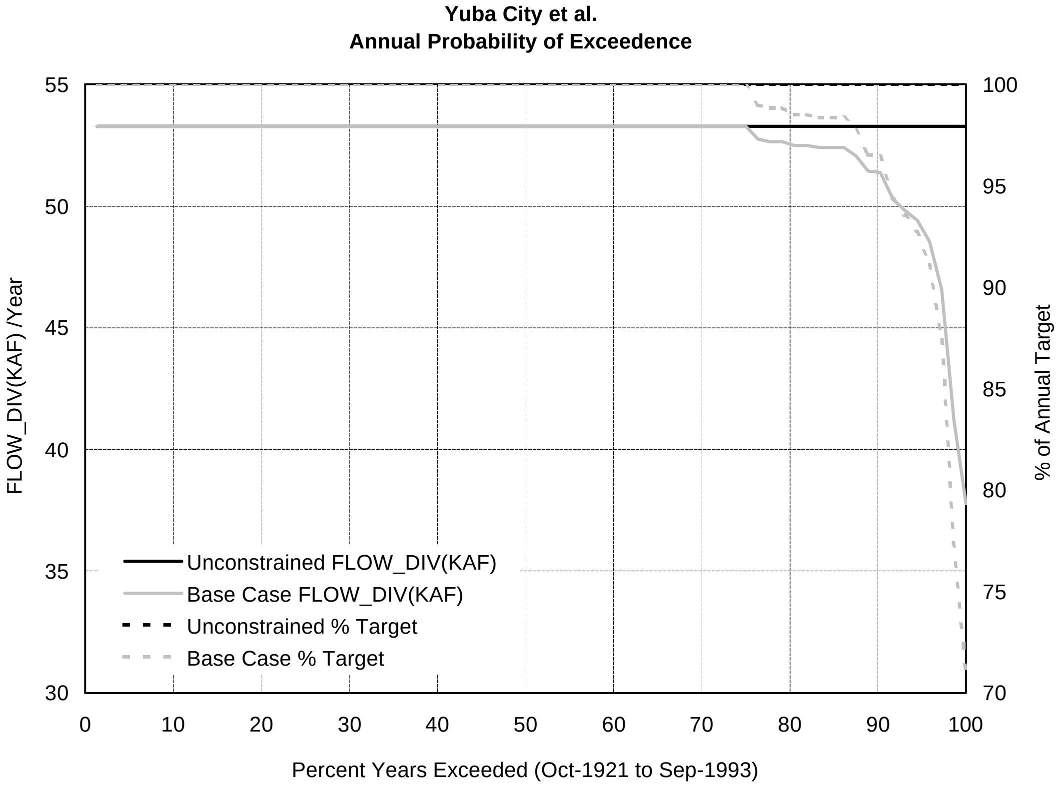


Figure B-7: Yuba City et al. Exceedence Plot

Greater Sacramento

The Greater Sacramento area does not experience any scarcities in either the Base or Unconstrained Cases. Full demands are meet 100% of the time. However, Greater Sacramento has the highest operating cost of all the urban demand areas. See Table B-14 for details.

Table B-14: Greater Sacramento Results

	Base Case		Unconstrained Case	
	Average	Drought	Average	Drought
Annual Average Scarcity (taf)	0.0	0.0	0.0	0.0
Percent Scarcity (%)	0.0	0.0	0.0	0.0
Annual Average Scarcity Cost ($$10^6$)	0.0	0.0	0.0	0.0
Annual Average Operating Cost ($$10^6$)	36.7	37.1	33.7	34.1
Annual Average Total Cost ($$10^6$)	**36.7**	**37.1**	**33.7**	**34.1**

Sacramento has three surface water, two groundwater, and one recycled water supply source. In the Base Case it uses five of the six sources (no recycling). In the Unconstrained Case it uses only the three cheapest (see Table B-15) of the six sources (Folsom lake and the two groundwater basins).

Table B-15: Delivery Costs for Greater Sacramento

Source	Type of Cost	Cost ($/af)
Sacramento River	Surface Water Treatment	70
Lower American River	Surface Water Treatment	60
Folsom Lake	Surface Water Treatment	35
Groundwater (GW-7)	Groundwater Pumping	57
Groundwater (GW-8)	Groundwater Pumping	55
Recycled Water	Recycled Water Treatment	350

The majority of Greater Sacramento's demand is met through groundwater pumping (70%) in the Unconstrained Case, up from about 33% in the Base Case. The remaining 30% comes from Folsom Lake withdrawals. Greater Sacramento eliminated their Sacramento River withdrawals, but increased their Folsom Lake withdrawals by 57 taf/year. In general their increased Lake Folsom withdrawals occurred during the summer months. In both cases, full demands are met 100% of the time. However, in the ideal market, the Greater Sacramento area sees a $3.0 million/year benefit from an 8% reduction in operating costs due to the greater utilization of cheaper water sources (higher quality gravity supplied Folsom Lake water and groundwater).

Stockton

Stockton experiences a small scarcity in the Base Case and none in the Unconstrained. The scarcity is a little more than 0.1% of its demand, but still incurs a cost of $63.8K per year. Operating costs decrease from the Base Case to the Unconstrained, indicating that the region is able to obtain water from less expensive sources. Table B-16 presents the results for Stockton.

Table B-16: Stockton Results

	Base Case		Unconstrained Case	
	Average	Drought	Average	Drought
Annual Average Scarcity (taf)	0.1	0.5	0.0	0.0
Percent Scarcity (%)	0.1	0.5	0.0	0.0
Annual Average Scarcity Cost ($$10^6$)	0.1	0.3	0.0	0.0
Annual Average Operating Cost ($$10^6$)	4.2	5.4	3.5	5.2
Annual Average Total Cost ($$10^6$)	**4.3**	**5.6**	**3.5**	**5.2**

There were higher operating costs in the Base Case than in the Unconstrained, both during average and drought years. However full demands were met only in the Unconstrained Case. Stockton has three water supply sources: two surface and one groundwater source. All four have costs associated with them (Table B-17).

Table B-17: Delivery Costs for Stockton

Source	Type of Cost	Cost ($/af)
Calaveras River	Surface Water Treatment	40
Stanislaus River	Surface Water Treatment	25
Groundwater (GW-8)	Groundwater Pumping	70

In the Unconstrained Case, Stockton gets 54% of its demand from Stanislaus (the lowest cost source). Another 30% comes from the Calaveras River and the remaining 16% comes from groundwater pumping. The supply mix reflects the associated source costs (it uses the least expense first and the most expensive the least).

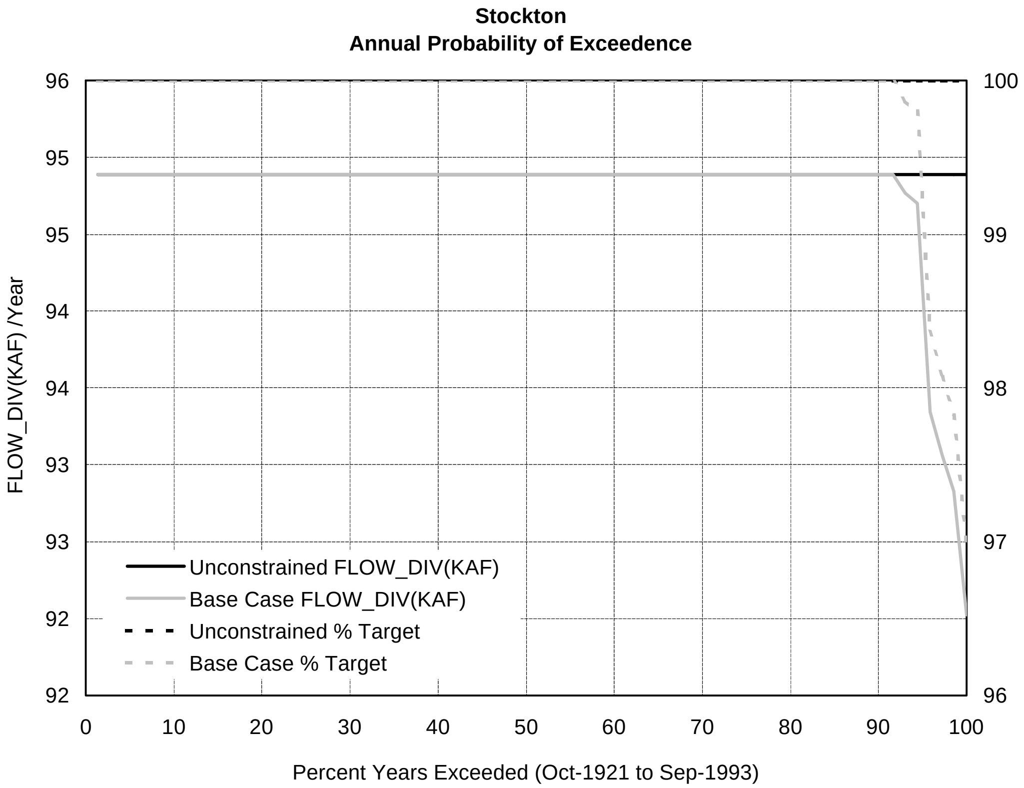


Figure B-8: Exceedence Plot for Stockton

Figure B-8 is the exceedence plot for deliveries to Stockton. In the Base Case deliveries can range from 100% down to about 96% of demand. Full deliveries are made about 91% of the time. In the Unconstrained Case full deliveries are made 100% of the time. In general Stockton would benefit from an ideal market by about $0.8 million/yr: scarcities are eliminated and operating costs are reduced by $0.7 million/year, for a combined 19% reduction in costs.

Napa-Solano

Napa-Solano experiences the largest scarcity of all the urban regions in the Base Case. There is an annual average scarcity of 10.4 taf/year, corresponding to scarcity costs of $22.0 million per year. In the Unconstrained Case, this scarcity is eliminated, but operating costs increase slightly. Table B-18 presents the results for Napa-Solano.

Table B-18: Napa-Solano Results

	Base Case		Unconstrained Case	
	Average	Drought	Average	Drought
Annual Average Scarcity (taf)	10.4	30.0	0.0	0.0
Percent Scarcity (%)	9.0	26.0	0.0	0.0
Annual Average Scarcity Cost ($$10^6$)	22.0	70.6	0.0	0.0
Annual Average Operating Cost ($$10^6$)	7.4	5.9	7.5	7.5
Annual Average Total Cost ($$10^6$)	**29.3**	**76.5**	**7.5**	**7.5**

Napa-Solano has two sources of water modeled in CALVIN: Lake Berryessa water via the Putah South Canal and State Water Project water via the North Bay Aqueduct (NBA). In the Base Case it uses both sources but is only able to delivery full demands 70% of the time (see Figure B-9 for details). In the Unconstrained Case it relies entirely on diversions from the Putah South Canal to fill its demands. Just as with Stockton, in the Unconstrained Case, use of the least expensive water source is maximized through an exchange with CVPM 6 of its NBA water (via Sacramento River diversions) for more Lake Berryessa water. See Table B-19 for the associated costs and Table B-12 for the supply break down.

Table B-19: Delivery Costs for Napa-Solano

Source	Type of Cost	Cost ($/af)
Putah South Canal	Surface Water Treatment	65
North Bay Aqueduct	Surface Water Treatment	75

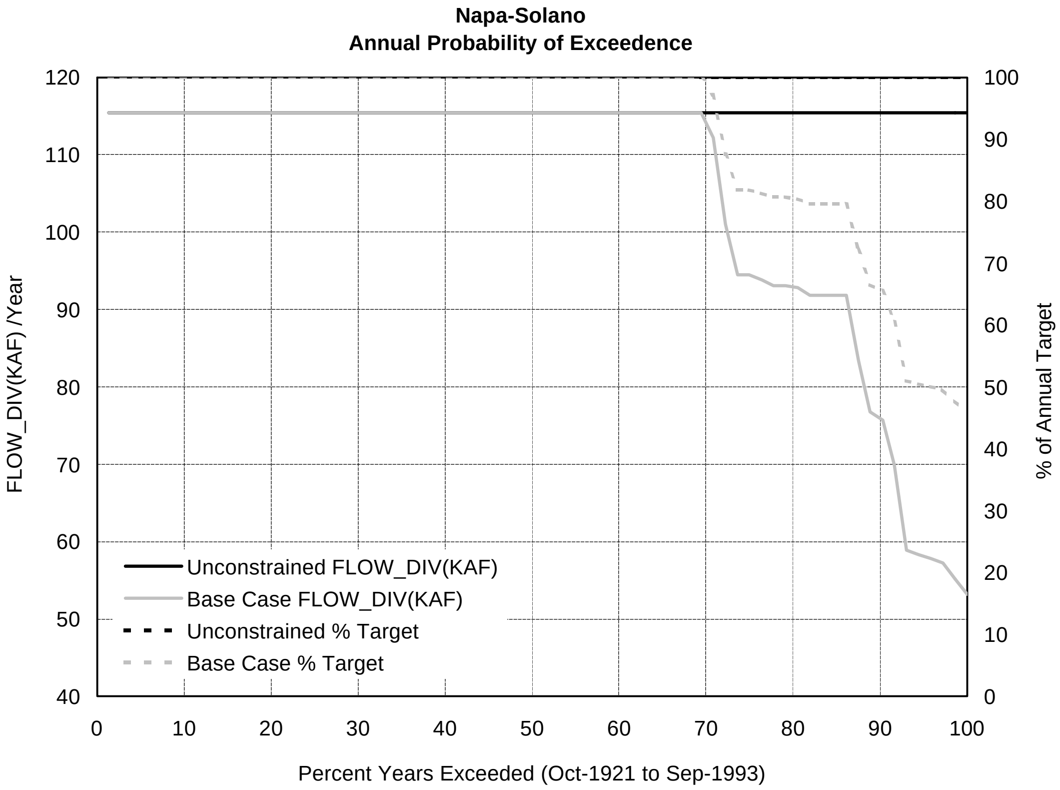


Figure B-9: Exceedence Plot for Napa-Solano

Deliveries in the Base Case range from 100% down to 46% of demand while the Unconstrained Case deliveries full demands 100% of the time (Figure B-9). Operating costs increase by $0.1 million/year from additional deliveries, but are offset by scarcity cost reductions of $22.0 million/year. Therefore, in an ideal market Napa-Solano would see approximately $21.8 million/year in net benefits from increased allocations, a 74% reduction in combined scarcity and operating costs.

Contra Costa Water District (CCWD)

Contra Costa Water District (CCWD) experiences a small level of scarcity in the Base Case that is eliminated in the Unconstrained Case. Operating costs also are reduced for CCWD in the Unconstrained Case by less use of (expensive) recycled water. See Table B-20 and B-12 for details.

Table B-20: Contra Costa Water District Results

	Base Case		Unconstrained Case	
	Average	Drought	Average	Drought
Annual Average Scarcity (taf)	0.1	0.2	0.0	0.0
Percent Scarcity (%)	0.1	0.1	0.0	0.0
Annual Average Scarcity Cost ($$10^6$)	0.1	0.2	0.0	0.0
Annual Average Operating Cost ($$10^6$)	44.0	43.6	43.8	43.6
Annual Average Total Cost ($$10^6$)	**44.1**	**43.8**	**43.8**	**43.6**

CCWD operating costs include the costs associated with four pumping plants that divert Delta water, directly or via Los Vaqueros Reservoir, into the Contra Costa Canal for delivery to CCWD. The four plants are Old River, Contra Costa, Mallard Slough and Los Vaqueros Pumping Plants. There is a proposed Contra Costa Canal diversion to and from the Mokelumne River Aqueduct, which services EBMUD, but it is currently not active.

In addition to deliveries from the Contra Costa Canal, CCWD has some recycled water. CCWD utilizes both sources, although recycling is very limited. Only 3% and 1% of total deliveries are from recycling in the Base and Unconstrained Cases, respectively.

In the Base Case deliveries provide from 100% down to 98% of the demand. Full deliveries are made 95% of the time. The Unconstrained Case delivers full demands 100% of the time. See Figure B-10 for details.

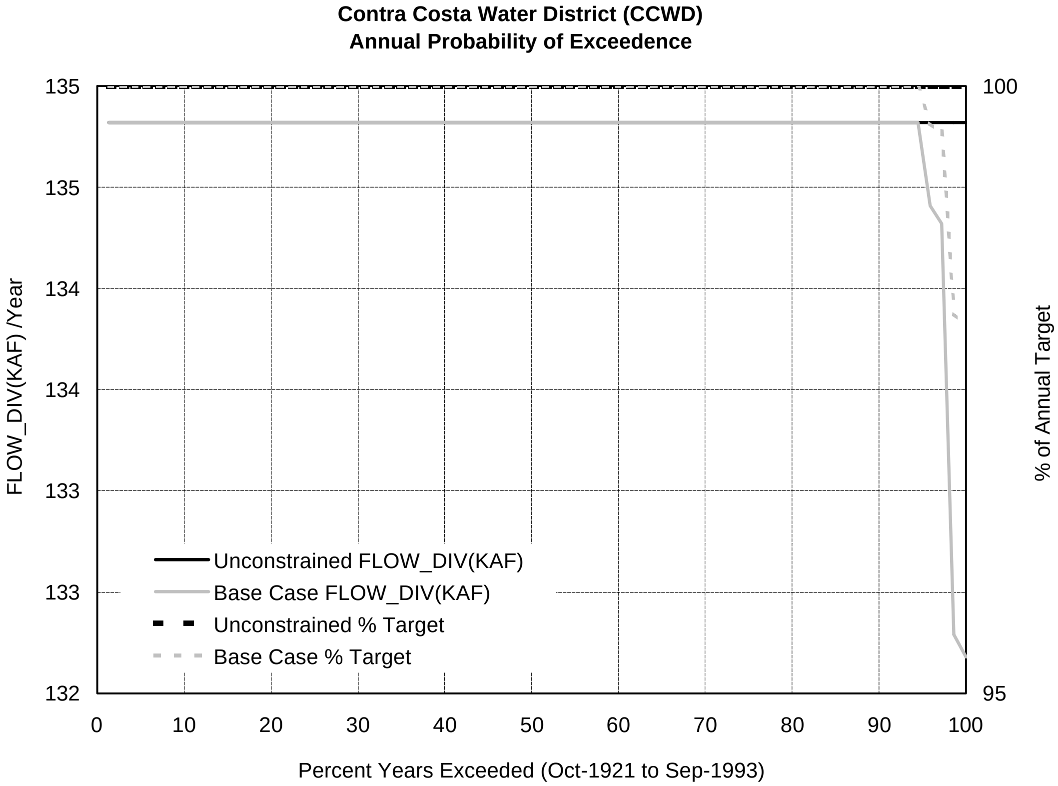


Figure B-10: Exceedence Plot for CCWD

The 0.1% scarcity in the Base Case produces $107K/year of scarcity costs. Operating costs are high because of the very high treatment costs associated with reverse osmosis of Delta water (to remove excess bromides under 2020 drinking water regulations). In general CCWD would see a net benefit of $273K/year in an ideal market.

East Bay Municipal Utilities District (EBMUD)

The East Bay Municipal Unities District (EBMUD) is the only economically driven urban demand area that sees scarcities in both the Base and Unconstrained Cases. In the Base Case EBMUD sees an annual average scarcity of 7.6 taf/year. In the Unconstrained Case, annual average scarcity drops by 6.9 taf/year. Additionally operating costs also decrease for EBMUD between the Base Case and the Unconstrained. See Table B-21 for details.

Table B-21: East Bay Municipal Utilities District Results

	Base Case		Unconstrained Case	
	Average	Drought	Average	Drought
Annual Average Scarcity (taf)	7.6	30.9	0.7	7.5
Percent Scarcity (%)	2.6	10.4	0.2	2.5
Annual Average Scarcity Cost ($$10^6$)	12.5	57.7	0.6	7.2
Annual Average Operating Cost ($$10^6$)	34.6	36.0	33.6	33.5
Annual Average Total Cost ($$10^6$)	**47.1**	**93.7**	**34.3**	**40.7**

EBMUD relies on the Mokelumne River Aqueduct to deliver water to its demand areas. The Mokelumne River Aqueduct has a pumping cost associated with the Walnut Creek Pumping Plant along with water treatment and local distribution costs to EBMUD. Just as with CCWD, EBMUD reduces operating costs by reducing their use of recycled water in the Unconstrained Case. In the Base Case 8 taf/year of recycled water is used, but in the Unconstrained it drops down to less than 1 taf/year. Decreased reliance on recycled water is replaced by increased use of Mokelumne River water via the EBMUD reservoirs (Chabot, Upper San Leandro, San Pablo, Briones, and Lafayette).

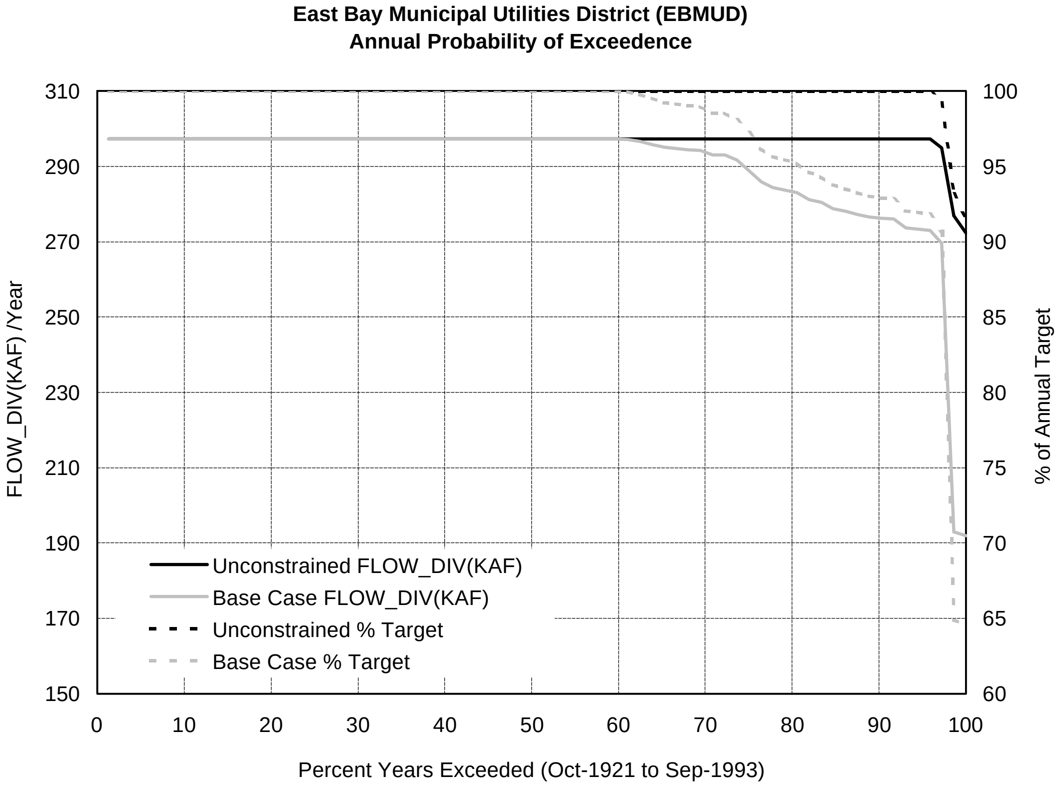


Figure B-11: Exceedence Plot for EBMUD

In the Base Case, delivers to EBMUD range from 100% down to 65% of demand. The Unconstrained range is from 100% to 92% of the demand. In general the Unconstrained Case is more reliable (full demand is delivered 96% of the time) than the Base Case (full demand is delivered only 60% of the time). See Figure B-11 for details.

In an ideal market, EBMUD would see a decrease in both their scarcity and operating costs. Scarcity would decrease by $11.9 million/year and operating costs would decrease by $1.0 million/year. Thus, EBMUD would see a total reduction of $12.9 million/year or 27% of combined scarcity and operating costs.

Changes in Deliveries and Scarcity Costs

The Unconstrained Case delivers more water to both the agricultural and urban areas in the Lower Sacramento Valley and Sacramento-San Joaquin Delta region during the 72-year run.

The minimum, maximum and average annual deliveries either increased or remained the same. CVPM 9 saw increases in deliveries, while the other CVPM regions' level of deliveries remained the same. Napa-Solano saw the greatest increase in their annual deliveries and the greatest improvement in supply reliability. EBMUD had the largest increase in its maximum annual delivery and a small decrease in the minimum. Stockton, CCWD and Yuba also saw increases in their annual average deliveries. Greater Sacramento did not see any change in deliveries as full demands were met in both the Base and Unconstrained Cases. See Table B-22 and B-23 for the changes in annual agricultural and annual urban deliveries, respectively.

Table B-22: Changes in Annual Agricultural Deliveries

	Base Case	Unconstrained Case			
	Average (taf/yr)	Minimum (taf/yr)	Average (taf/yr)	Maximum (taf/yr)	ΔAvg (taf/yr)
CVPM 5	1737	1737	1737	1737	0
CVPM 6	1048	1048	1048	1048	0
CVPM 7	565	565	565	565	0
CVPM 8	894	894	894	894	0
CVPM 9	1176	1185	1185	1185	8
TOTAL	5420	5428	5428	5428	8

Table B-23: Changes in Annual Urban Deliveries

	Unconstrained – Base Case		
	Minimum (taf/yr)	Average (taf/yr)	Maximum (taf/yr)
CCWD	0.0	0.1	2.6
EBMUD	-3.6	7.8	104.4
Napa-Solano	0.0	10.2	62.2
Greater Sacramento	0.0	0.0	0.0
Stockton	0.0	0.2	2.9
Yuba	0.0	0.8	15.5
TOTAL	-4	19	188

Figure B-12 represents the changes in maximum, minimum and average annual deliveries in the Unconstrained Case from the average annual deliveries in the Base Case (ex. Unconstrained Case maximum minus Base Case annual average) for agriculture. Figure B-13 represents the maximum, minimum and average change in annual deliveries in the Unconstrained Case from the Base Case for the urban areas. Positive changes indicate that the Unconstrained Case delivered more water to the demand than the Base Case did.

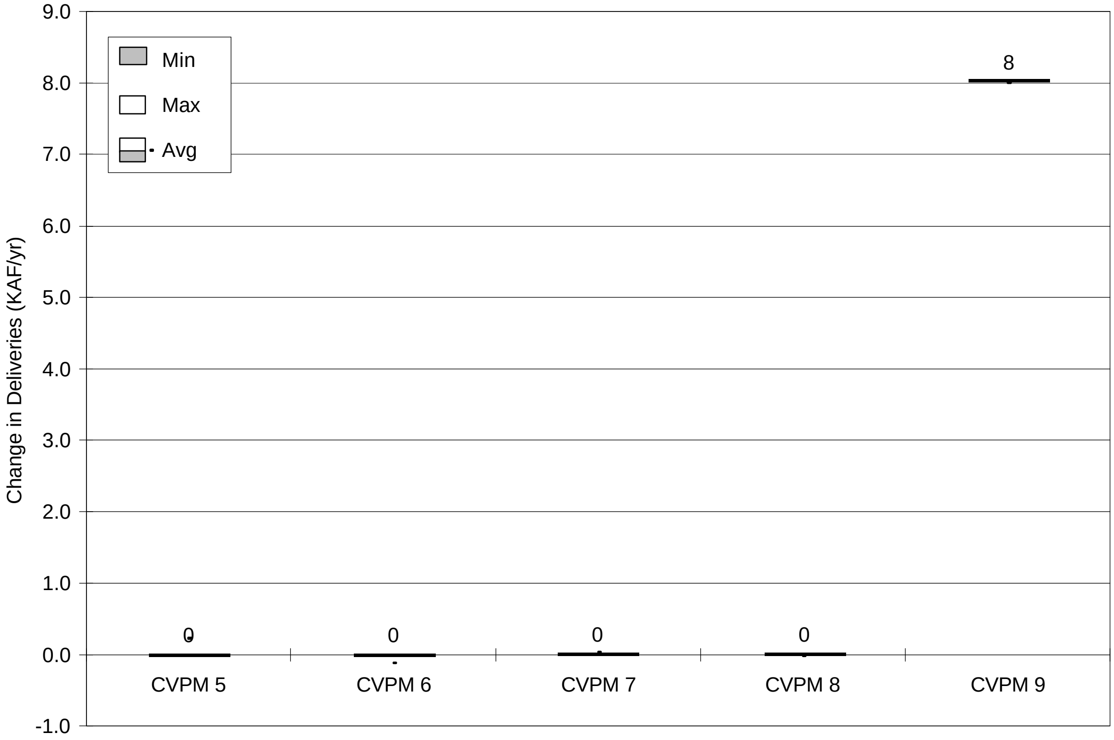


Figure B-12: Changes in Annual Agricultural Deliveries

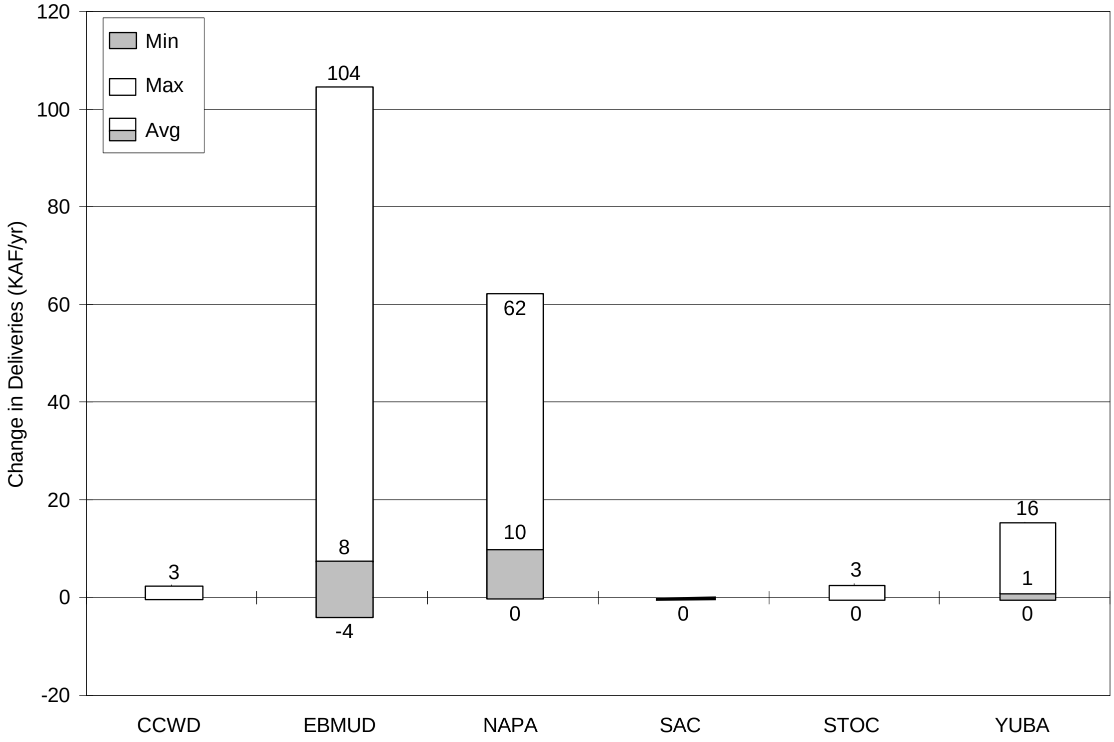


Figure B-13: Changes in Annual Urban Deliveries

Agricultural areas in the Lower Sacramento Valley saw a reduced scarcity benefit of $198K/yr with an ideal market, from elimination of the only Base Case scarcity in CVPM region 9.

On the other hand, urban regions experienced scarcities in both the Base and Unconstrained Cases. However, the average annual scarcity costs were substantially reduced from the Base Case by 98%. The maximum, minimum and average change in scarcity costs are presented in Table B-24. A plot of the changes in scarcity costs is presented in Figure B-14.

Table B-24: Changes in Annual Urban Scarcity Costs

	Unconstrained – Base Case		
	Maximum ($\$10^6$/yr)	Average ($\$10^6$/yr)	Minimum ($\$10^6$/yr)
CCWD	-3.3	-0.1	0.0
EBMUD	-254.0	-11.8	3.4
Napa-Solano	-164.3	-22.0	0.0
Greater Sacramento	0.0	0.0	0.0
Stockton	-1.6	-0.1	0.0
Yuba	-20.6	-0.9	0.0
TOTAL	-443.7	-34.9	3.4

A negative value indicates a reduction in scarcity costs in the Unconstrained Case. Maximum values here indicate the largest reductions between the Unconstrained and Base Cases.

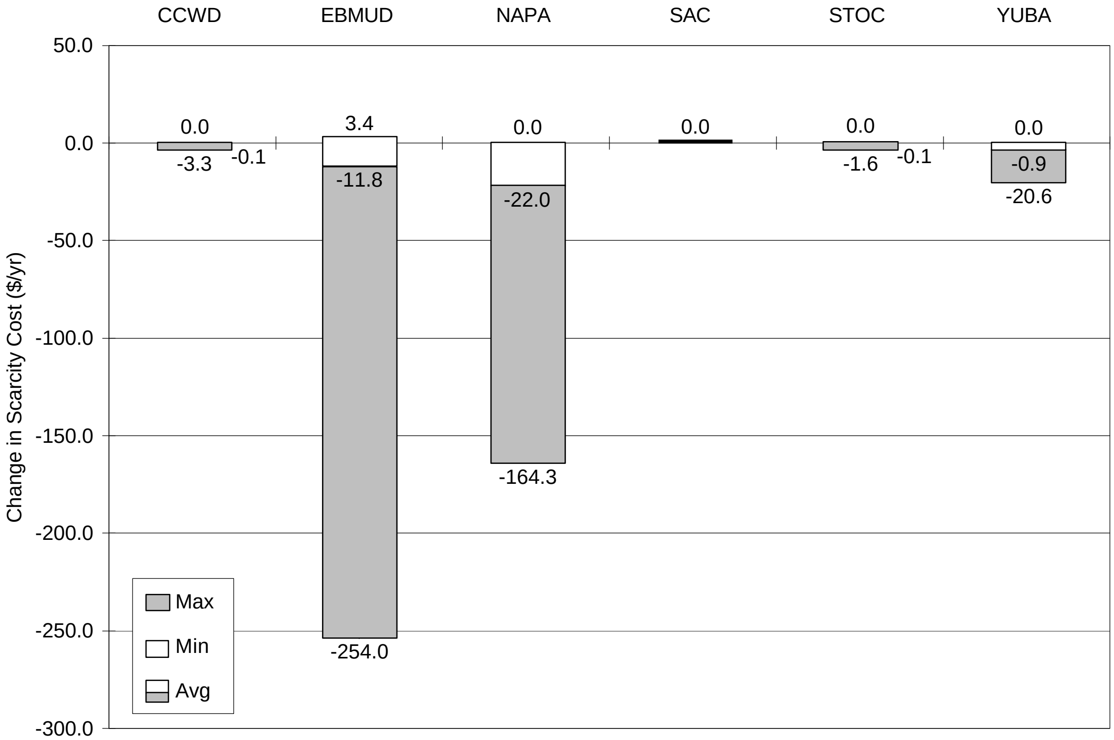


Figure B-14: Changes in Annual Urban Scarcity Costs ($ 10^6/yr)

All of the urban areas, except EBMUD, have zero or negative changes in the scarcity costs. This indicates that those urban areas would see a decrease in scarcity costs in the ideal market. EBMUD has one year when their scarcity costs increase slightly in an ideal market over the Base Case. This occurs in water year 1976, which corresponds to the beginning of a drought period. At all other times, changes in scarcity costs are either negative or zero and reductions far exceed the one EBMUD increase.

The change in water deliveries to the five agricultural areas was re-evaluated using SWAP (see Appendix 2K for details). A comparison of results for the Base Case and the Unconstrained Case are presented in Table B-25. In general, there were almost no changes in crop acreage, gross revenue or net revenue from the Base Case to the Unconstrained Case.

Table B-25: SWAP Results

	Base Case	Unconstrained Case	Change (UC-BC)[a]	Percent Change[b]
Crop Acreage (K-acre)	1502	1502	0	0.0
Gross Revenue ($M)	1462	1462	0	0.0
Net Revenue ($M)	570	570	0	0.0

[a] Numbers may not add up do to rounding

[b] Negative values indicate that there was an increase from the Base Case to the Unconstrained Case.

Environmental Water Requirements

Region 2 has six rivers with minimum instream flow requirements, one aggregate refuge and the required Delta outflow. Required outflows to the Delta are a fixed time series, which guarantees that the required water is released in every time period. The minimum instream flow requirements are modeled as lower bounds, which also guarantees that they are met in every period.

There are five reaches on the Feather River with a minimum instream flow. The requirement ranges from 59.5 to 74.8 taf/month with an annual average of 936 taf. The reaches are continuous and begin at the confluence of Thermalito Fore/After Bay with the Feather River and end at the confluence of the Feather River with the Sacramento River.

Three reaches on the American River below Folsom have minimum instream flow requirements. The larger requirement, averaging 1076 taf/yr, occurs along the first two reaches downstream of the Folsom South Canal diversion, and upstream of any urban withdrawals for Greater Sacramento. The third reach, downstream of the other two and after urban withdrawals to Greater Sacramento, has a much lower requirement averaging 298 taf/yr.

Camanche Reservoir release into the Mokelumne River must meet a minimum instream flow requirement that is imposed on all subsequent reaches of the river until just before it joins with the Sacramento River. The minimums range from 0 to 27.8 taf, depending on the month and average 88 taf/yr.

There is a small minimum instream flow requirement on the Calaveras River beginning with releases from New Hogan Lake and ending upstream of the confluence with the San Joaquin River. The minimums are a constant 0.1 taf in every month. There is also a minimum instream flow requirement on the Yuba River immediately upstream of the confluence with the Feather River. It ranges from 4.3 to 25.5 taf/month.

Finally, the largest minimum instream flow requirement exists on the Sacramento River at Hood, downstream of the Proposed Isolated Facility diversion point and upstream of the Delta Cross Channel. This minimum ranges from 277.7 to 307.4 taf/month and with an annual average of 3,619 taf/yr. Additionally there is a smaller requirement at Rio Vista downstream of agricultural withdrawals to CVPM 9 and upstream of any return flows from the area. This minimum ranges from 0 taf in the dry season to 276.6 taf in the wet season, averaging 964 taf/yr.

The annual average minimum instream flow requirements on the six rivers and the actual annual average flows occurring across these reaches in the Base and Unconstrained Cases are presented in Table B-26.

Table B-26: Environmental Minimum Instream Flows

	Base Case		Unconstrained Case	
	Average (taf/yr)	Drought (taf/yr)	Average (taf/yr)	Drought (taf/yr)
Minimum Instream Flow Requirement				
Feather River	936	827	936	827
American River	1076	626	1076	626
Mokelumne River	88	27	88	27
Calaveras River	1	1	1	1
Yuba River	170	140	170	140
Sacramento River	3619	3619	3619	3619
TOTAL	**5891**	**5240**	**5891**	**5240**
Actual Annual Average Flows				
Feather River	2990	1627	3391	1847
American River	2463	1190	2374	1132
Mokelumne River	970	306	958	267
Calaveras River	151	71	151	73
Yuba River	1635	628	1615	660
Sacramento River	15948	8976	15837	9007
TOTAL	**24156**	**12799**	**24326**	**12986**

The minimum instream flows vary by month, meaning that while the actual annual average flows through the river reach may be greater than the average annual minimums, flows in individual months may be much closer to the required volume. In general, this is not the case. The actual flows through the critical reaches are much larger than the minimum instream flow in individual months. Only the flows through the Feather and American River reaches are at times very close to the minimum requirements. Figure B-15 and B-16 present the average monthly flows for the two rivers.

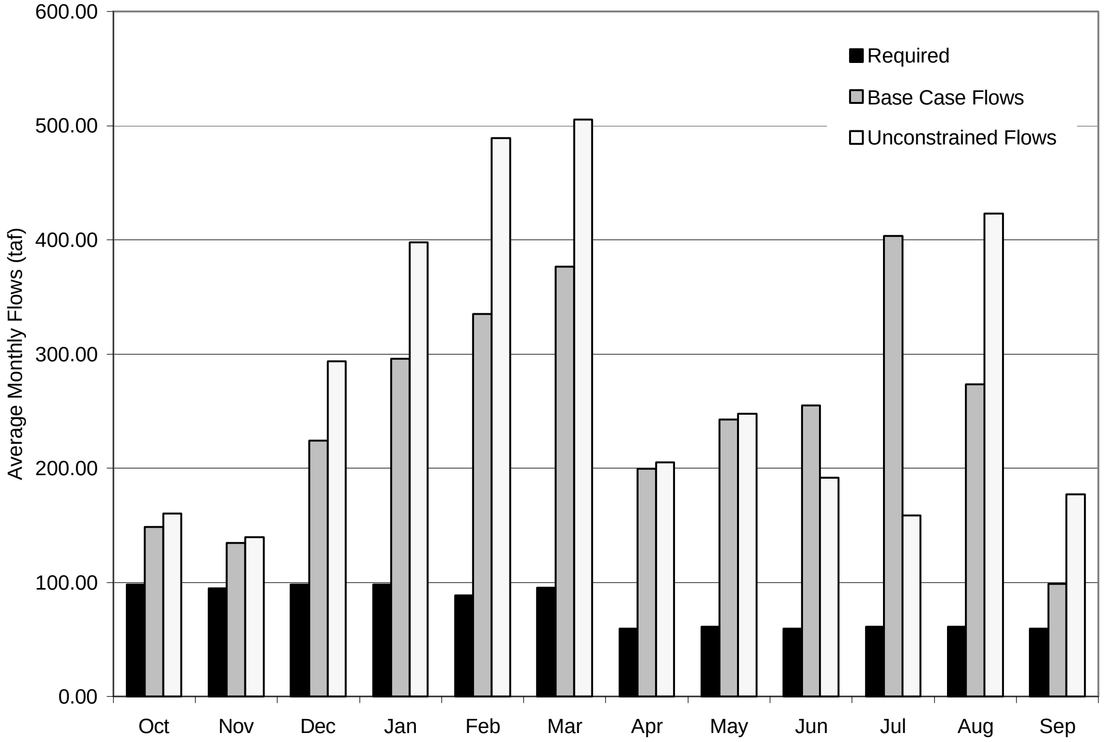


Figure B-15: Average Monthly Flow Comparison for the Feather River

In the Unconstrained Case, the actual flows through the Feather River remain fairly high even during the summer and fall months. In the winter and early months, the flows are much higher than the requirements. On average and in drought years the annual flows through the critical reach are higher in the Unconstrained Case.

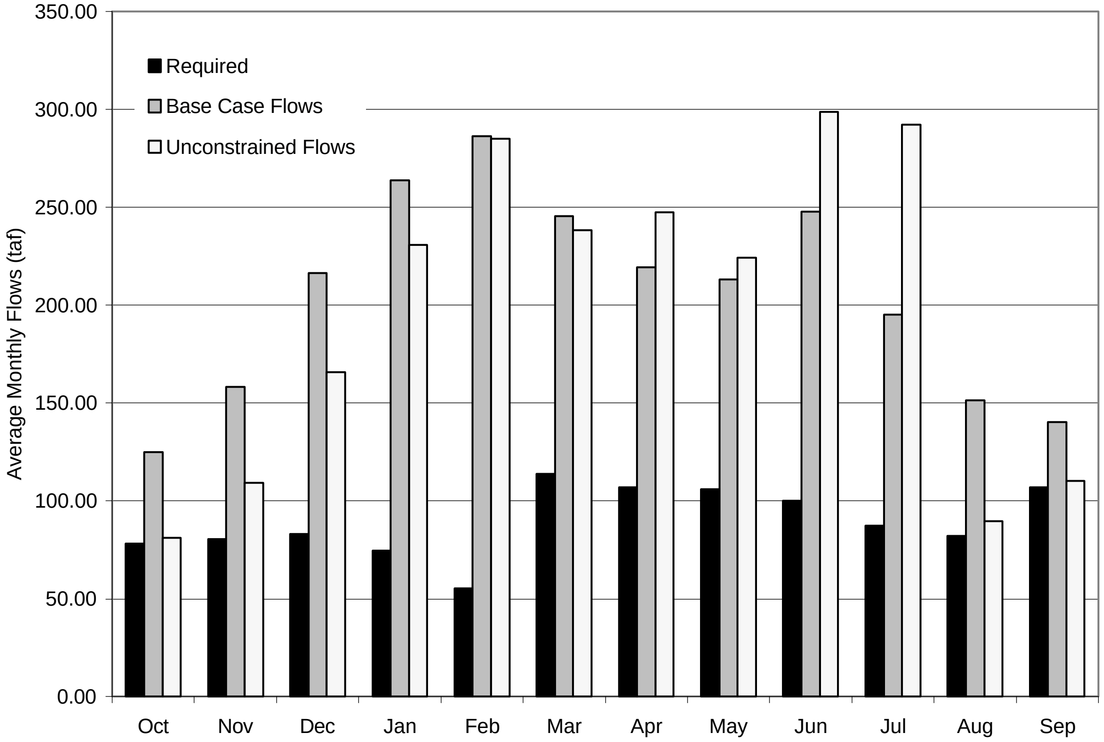


Figure B-16: Average Monthly Flow Comparison for the American River

In the Unconstrained Case the actual flows through the critical American River reach are close to the minimums during the months of August through October. The rest of the months see fairly large actual flows through the reach. The Unconstrained Case actual flows are higher in April through July. The Base Case flows are higher in the remaining months. The annual average and in drought year flow through the critical reach is higher in the Base Case.

The Sacramento East Refuge refers to the Gray Lodge Wildlife Area and the Sutter National Wildlife Refuge. The refuge obtains water from two sources; the Feather River and agricultural return flows from CVPM 5. Historical annual average water deliveries form the basis for the Level 2 (L2) demands. However, there are periods in the Base Case model when the entire surface water volume available to the refuge is less than the L2 demands. In these periods a modified L2 demand is delivered, which causes the refuge to experience scarcities in the Base Case. The same level of requirement is imposed in the Unconstrained Case to maintain comparability. These scarcities, as well as the annual average demand are presented in Table B-27.

Table B-27: Sacramento East Refuge Water Budget

	Average	Drought
Refuge Level 2 Demands	66	66
Refuge Deliveries	57	57
Scarcity	**9**	**9**

It should be noted that the refuge requires approximately 58.9 taf/year. However, conveyance losses require that more water be diverted. Thus, 66.2 taf/year, as reported in Table B-27, must be diverted to guarantee the required 58.9 taf/year at the refuge. However, due to the modified L2 demands used in CALVIN, only 57.3 taf/year is actually diverted, providing approximately 51.0 taf/year after losses.

Additionally there are the required Delta outflows from the Sacramento River. The Delta requires approximately 5593 taf/yr (4087 taf/yr during the droughts). These requirements are enforced and met before any economically driven demands can be fulfilled in all model alternatives. In addition there is the possibility for CALVIN to divert any surplus water in the system to the Delta. In both the Unconstrained and Base Cases there are significant annual average flows in excess of the Delta requirements (Table B-28).

Table B-28: Surplus Delta Outflows

	Base Case		Unconstrained Case	
	Average (taf/yr)	Drought (taf/yr)	Average (taf/yr)	Drought (taf/yr)
Surplus Delta Flows	8738	1016	8660	1219

In general there is less surplus outflow available to the Delta in the Unconstrained Case (by 78 taf/yr), but there is more available during the drought periods (by 203 taf/yr). This would indicate that while on an average annual basis, the Delta would have about 1% less surplus outflow available, during the critically dry periods there would be about 20% more. The annual patterns of surplus outflow are similar for the Base and Unconstrained Cases (Figure B-17).

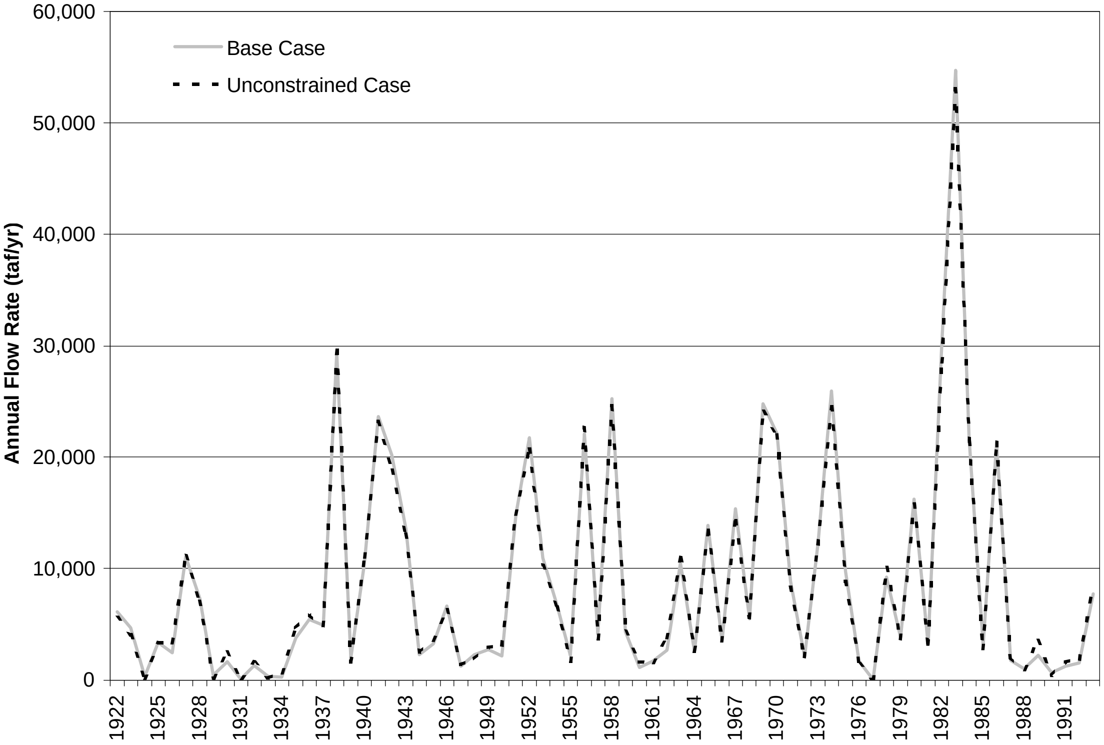


Figure B-17: Surplus Delta Flows

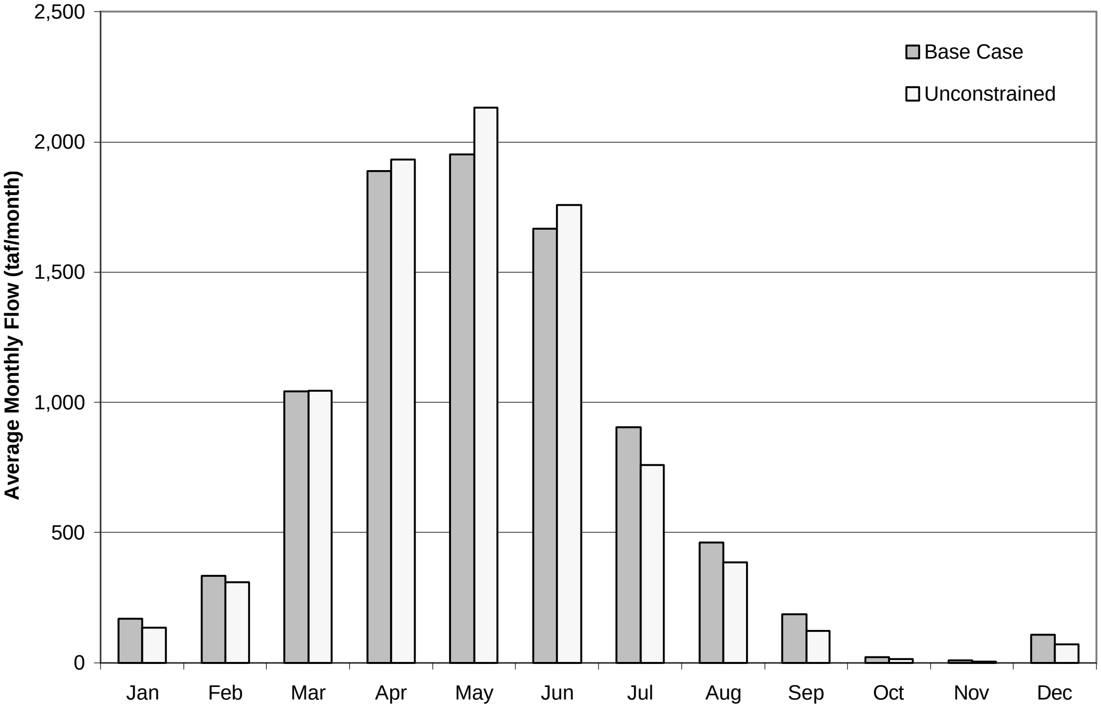


Figure B-18: Monthly Average Delta Surplus Flows

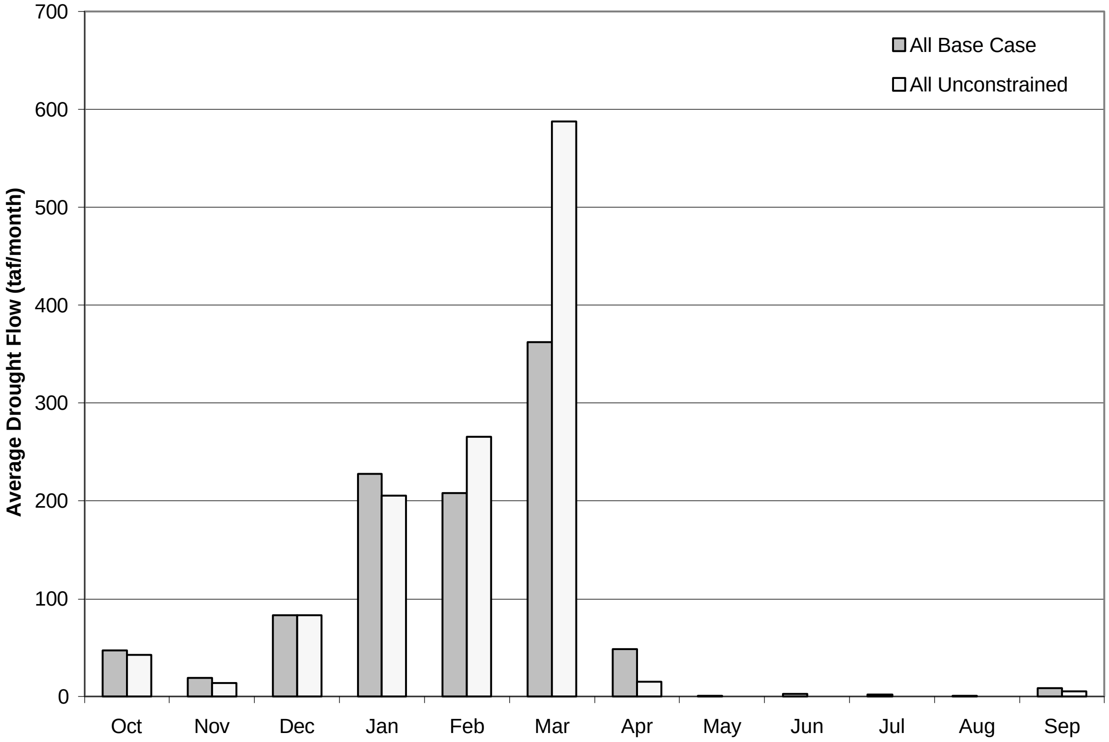


Figure B-19: Average Monthly Drought Surplus Delta Flows

In general there is reduced surplus flow during the summer months of both average and drought periods (Figure B-18 and Figure B-19). Drought year flows remain low (expect in February and March). Average year flows are highest in April, May and June.

Regional Water Values

Additional water is only needed in regions where the demand is not fulfilled. In these regions there would be value to additional supplies. The user's marginal willingness-to-pay for that additional unit of water indicate where and when there is the potential for inter- and intra-regional transfers, as well as changes in environmental requirements.

Water Users' Willingness-to-Pay for Additional Water

Additional water is only needed in regions where the demand is not fulfilled. In these cases the water users will have some amount of money that they would theoretically be willing to pay to get an additional unit of water. Most of the economic results from CALVIN in the Base Case are not meaningful due to the highly constrained deliveries. For that reason, the marginal willingness to pay of agricultural users in the Base Case can only be considered on an average regional level. Region 2 agricultural and urban marginal willingness-to-pay results are included in Table B-29 and Figure B-20.

Table B-29: Agricultural Marginal Willingness to Pay

		Minimum ($/af)	Average ($/af)	Maximum ($/af)
Base Case				
	Regional	n/a	25.0	n/a

Unconstrained Case			
CVPM 5	0.0	0.0	0.0
CVPM 6	0.0	0.0	0.0
CVPM 7	0.0	0.0	0.0
CVPM 8	0.0	0.0	0.0
CVPM 9	0.0	0.0	0.0

In the Base Case, the willingness to pay for an additional unit of agricultural water was approximately $25/af Based on the marginal value of water at CVPM Region 9's Base Case average scarcity level. In the Unconstrained Case, every CVPM region obtained full demands, even during periods of drought. With full demands meet, agricultural users in Region 2 are not willing to pay for any additional water as shown in Table B-29.

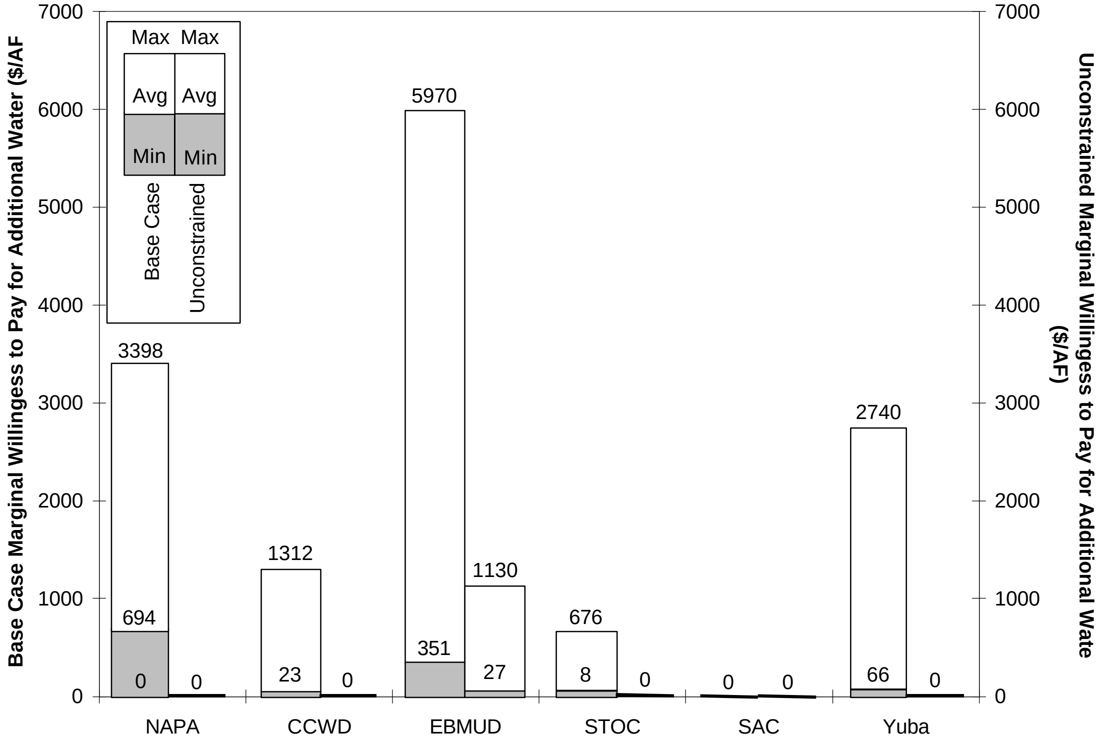


Figure B-20: Urban Marginal Willingness to Pay

The urban areas, unlike the agricultural regions, do not experience full deliveries in every month of the Unconstrained Case. EBMUD has periods of scarcity (during the1976-1977 drought), which produce a maximum willingness-to-pay of $1,130/af. All other urban areas receive full deliveries and thus have no willingness-to-pay for additional water. Despite the remaining scarcity to EBMUD, the Unconstrained Case reduces the large marginal willingness-to-pay values of urban users in the Base Case.

Agricultural scarcity is eliminated in the Unconstrained Case, and urban scarcities minimized to one area during one drought. The marginal willingness-to-pay values for additional water are reduced for all areas (peaks and averages). Therefore, the ideal market is better able to handle periods of droughts and scarcities than the current system for both agricultural and especially urban demands.

Demand for Inter-regional Transfers

Region 2 has five inflows of which three are from the Upper Sacramento Valley (Region 1) and two are from the San Joaquin and South Bay Area (Region 3). There are also two outflows to the San Joaquin and South Bay Area (Region 3).

Table B-30: Marginal Value on Boundary Flows

	Base Case	Unconstrained
Outflow Requirements	Average ($/AF)	Average ($/AF)
Harvey Banks Pumping Plant Releases to Region 3	619.2	0.0
Tracy Pumping Plant Releases to Region 3	619.2	0.0
Sacramento River to CVPM 5 from Region 1	619.2	0.4
Sacramento River Flow from Region 1	619.2	0.0
Knights Landing Diversion from Region 1	629.2	0.2
Stanislaus Flow from Region 3	634.2	12.1
San Joaquin River Flow from Region 3	619.2	0.0

Note: The Delta Outflow is not reported in Table B-30. It is discussed later in the "Shadow Values for Environmental Flows" section.

The marginal value of additional exported or imported water in Region 2 decreases in the Unconstrained Case (Table B-30). This is expected because there are significantly more expensive scarcities in the Base Case, which make additional water to the region more highly demanded.

The marginal value of water to Region 1 and Region 3 under an ideal market can be compared with the marginal value of water to Region 2 to determine the likelihood of inter-regional transfers. Table B-31 presents a comparison of the marginal values of additional water in the Unconstrained Case in each of these regions.

Table B-31: Inter-Regional Comparison of Marginal Values Under an Ideal Market

	Region 1	Region 2	Region 3
	Average ($/AF)	Average ($/AF)	Average ($/AF)
Sacramento River to CVPM 5	45.1	0.4	n/a
Sacramento River Flow from Region 1	44.4	0.0	n/a
Knights Landing Diversion from Region 1	42.0	0.2	n/a
Stanislaus Flow from Region 3	n/a	12.1	11.6
San Joaquin River Flow from Region 3	n/a	0.0	7.2
Harvey Banks Pumping Plant Releases to Region 3	n/a	0.0	-10.3[a]
Tracy Pumping Plant Releases to Region 3	n/a	0.0	-13.2[a]

[a] Negative value indicates that the region would prefer to reduce inter-regional deliveries. In the Case of the pumping plants, the cost of pumping is higher than the benefits of the additional unit of water in Region 3.

As seen in Table B-31, the value of an additional unit of water into Region 2 from Region 1 is lower than the marginal value of the same unit of water in Region 1. This is true for all three inter-regional flows. This would indicate that inter-regional transfers from Region 1 to Region 2 are unlikely to occur on an average basis. In fact, transfers under an ideal market are likely to go from Region 2 to Region 1, with Region 1 retaining more water than under the Base Case. The quantities of scarcity in these three basins also indicate that any market transfers between these three regions are likely to be relatively small.

Similarly Region 3 has a greater marginal value to a unit of flow in the San Joaquin. This indicates that ideally Region 3 would like to keep more San Joaquin River flow and not transfer it to Region 2. However, additional Stanislaus River transfers to Region 2 over the Base Case levels have a slightly greater value than staying in Region 3.

The marginal value of Delta exports is negative in Region 3 at the two transfer locations (Harvey Banks and Tracy Pumping Plants) indicating that exports from Region 1 or 2 to Region 3 would be reduced under ideal market conditions. The negative value to Region 3 indicate that costs of pumping the water from the Delta are greater than the benefits that the region would receive if pumping were to take place. However, when considering the values of additional imports to Regions 4 and 5 (see Appendices 2D and 2E), Delta exports from Region 1 and 2 are likely to increase to these destinations.

Figure B-21 presents the differences in marginal values of an additional unit of water from Region 1 and Region 2 (Region 2 marginal value minus Region 1 marginal value) for the three inter-regional transfer points. Figure B-22 presents the differences in marginal values of an additional unit of water at the two locations were Region 2 transfers water to Region 3. Figure B-23 presents the differences in marginal values of an additional unit of water at the two locations were Region 3 transfers water to Region 2. Positive values on these charts indicate that water would flow into Region 2 while negative values mean water would flow out of Region 2 under a unified ideal market.

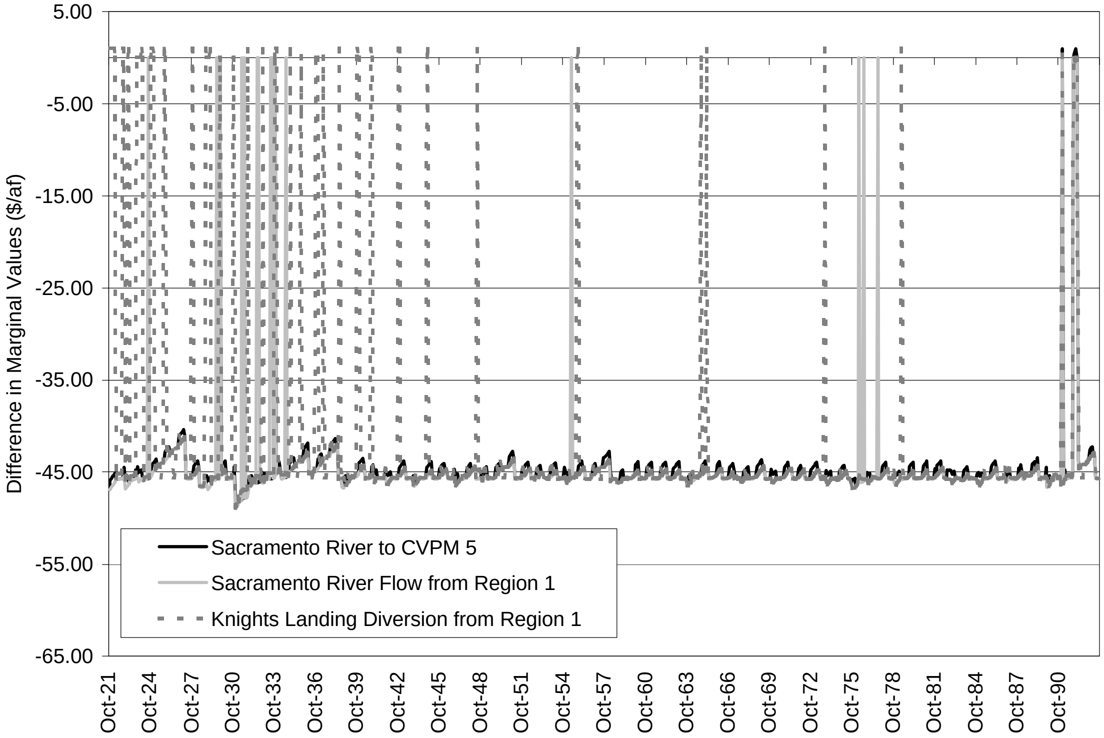


Figure B-21: Difference in Marginal Values between Region 2 and Region 1

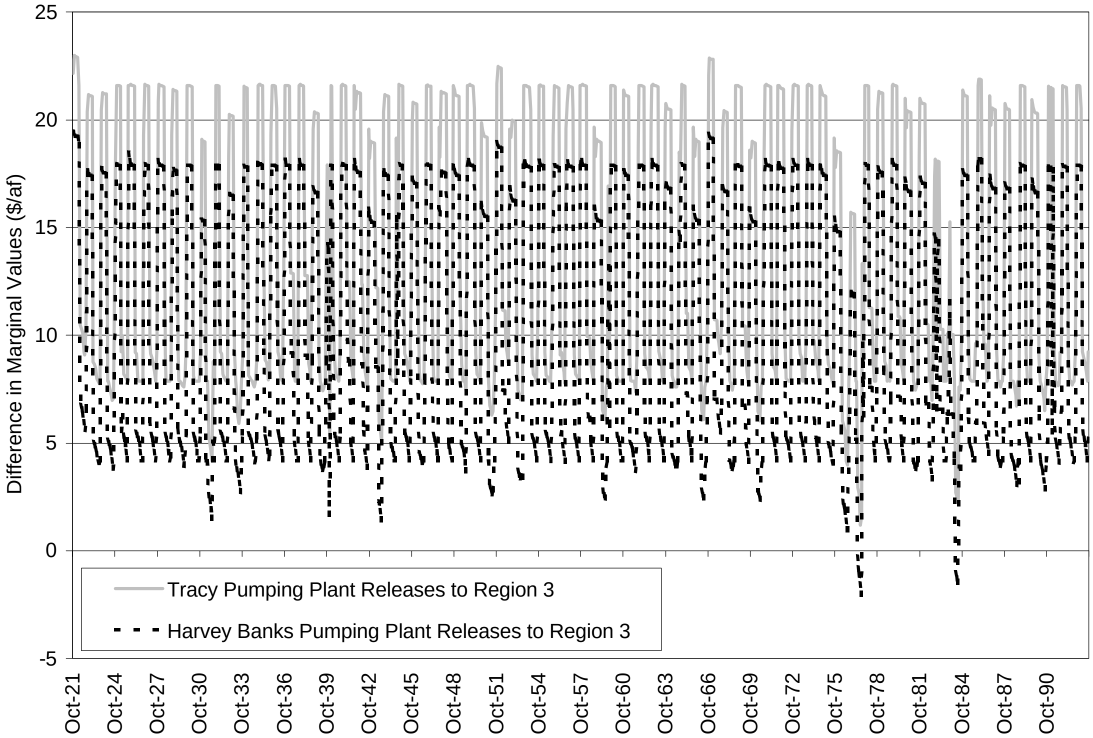


Figure B-22: Difference in Marginal Values at Region 2 Outflow Locations

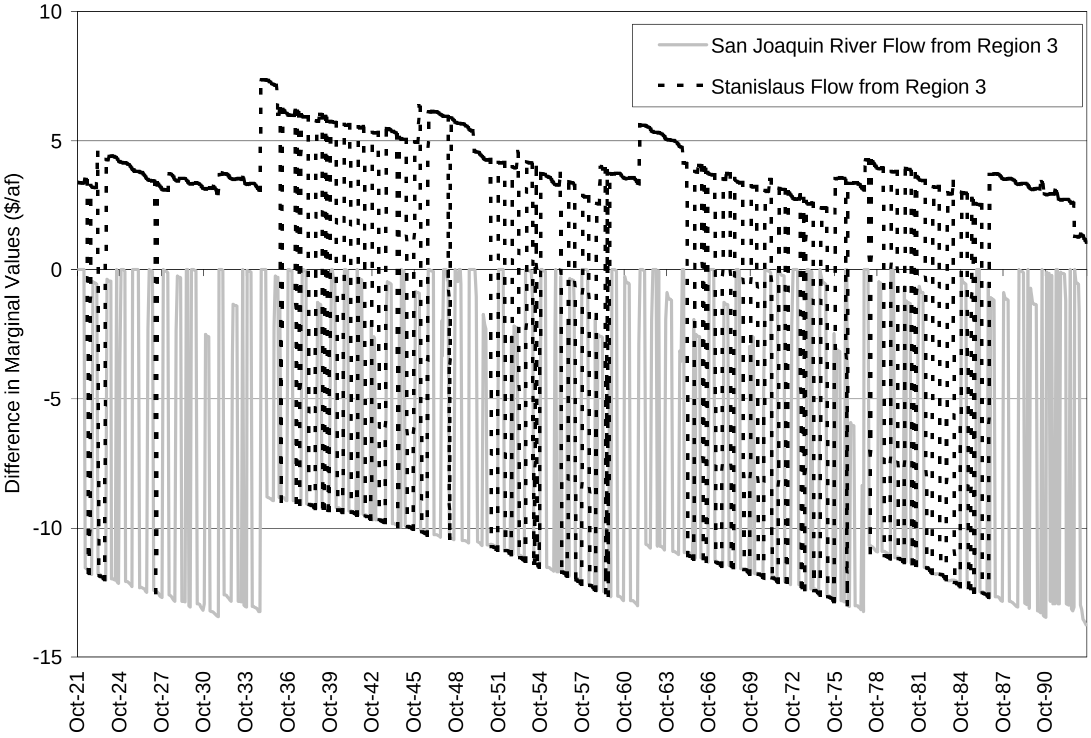


Figure B-23: Difference in Marginal Values at Region 2 Inflows Locations

The marginal value of water is never greater to Region 2 on the Sacramento River than to Region 1. However, there are 19 periods when the marginal values are equal. There are 3 periods when the marginal value of water to Region 2 at Drain RD1500 (CVPM 5 supply) on the Sacramento is greater, and an additional 4 periods when the marginal value is approximately equal. The marginal value of water to Region 2 is greater than the value to Region 1 in the Colusa Basin Drain at Knight's Landing 35 times. There is an additional 30 periods when the values are approximately equal. Additional transfers above the Base Case from Region 1 to Region 2 are only likely to occur under an ideal market during the droughts (especially the 1987-1992) on the Sacramento and sporadically throughout the 72-years from the Colusa Basin Drain.

There are 664 months when the marginal value of water is greater to Region 2 on the Stanislaus. The remaining 200 months have higher marginal values in Region 3, indicating that additional transfers to Region 2 would be unlikely during these periods, and in fact, would be reduced. Region 2's marginal values are greater than Region 3's during the three drought periods for this inter-regional river. On the other hand, the marginal value of water on the San Joaquin is never significantly (> $0.01/af) higher in Region 2, indicating that transfers of San Joaquin River water would occur from Region 2 back to Region 3 under an ideal market.

For the two locations where Region 2 transfers water to Region 3, there are only 7 months when the marginal values are higher in Region 3 and only at the Banks Pumping Plant. Four of these occur during the 1976-1977 drought. The other three occur in the summer months of 1984. However, because the marginal value of water is higher in Region 2 at the Tracy Pumping Plant during these same periods, the increased exports at Banks would likely be compensated by reduced exports to Region 3 at the Tracy Pumping Plant. Apart from these seven periods, Region 2 would rather retain more Delta water than pump it to Region 3 via either the Tracy or Harvey Banks Pumping Plants.

In general the comparison of marginal values indicates that reductions in exports from Region 1 to Region 2 and from Region 2 to 3 would occur under an ideal market limited to these three regions. During periods of drought, when water is scarcer in all regions, these general directions of market transfers are likely to shift unpredictably at specific locations. The influence of marginal water values in Regions 4 and 5, however, would potentially reverse these general flow patterns resulting in increased exports from any of Regions 1-3 to Regions 4 and/or 5.

Shadow Values of Environmental Flows

Region 2 has two locations in the Base Case and three locations in the Unconstrained Case where the environmental minimum instream flows are binding (Table B-32). In the Base Case, the high shadow values reflect the urban scarcities costs. In the Unconstrained Case the required minimum flows on the American, Mokelumne and Yuba rivers are requiring that demand areas pump additional groundwater. However, in none of the reaches are the values ever high.

Table B-32: Environmental Shadow Values

	Base Case			Unconstrained Case		
	Min ($/af)	Avg ($/af)	Max ($/af)	Min ($/af)	Avg ($/af)	Max ($/af)
American River	0.0	0.0	0.0	0.0	0.0	0.2
Mokelumne River	0.0	101.7	5870.4	0.0	0.1	0.9
Yuba River	0.0	0.0	0.0	0.0	0.0	0.2
Sacramento River	0.0	54.6	3783.4	0.0	0.0	0.0

The high shadow value on the Mokelumne River minimums in the Base Case reflect the marginal willingness to pay of the urban users in EBMUD. EBMUD's only source of water is from the Mokelumne River Aqueduct, which diverts water from Pardee Reservoir at the top of Mokelumne River. Reduction in Mokelumne river minimums would make additional water available for EBMUD, holding agricultural diversions constant to CVPM 8. Similarly the high shadow values on the Sacramento River reflect the urban scarcities, primarily to Napa-Solano. A reduction in the Sacramento River minimums would allow Napa-Solano to divert more water via the North Bay Aqueduct, holding all agricultural diversions constant. It should be noted than in the Base Case the agricultural deliveries were modeled as fixed time series. If this had not been the Case, the Mokelumne River and Sacramento River marginal values would be smaller, reflecting a trade between CVPM 8 and 6 with EBMUD and Napa-Solano.

In general the environmental shadow values are below $1/af/month in the Unconstrained Case, which indicates that the environmental flow constraints are not causing any scarcities in the region. On the American River the maximum shadow value is $0.2/af while on the Yuba it is less than that. The maximum on the Mokelumne River is approximately $0.9/af, which is again very low.

The shadow values on the Sacramento East Refuge and Delta outflow requirements are high in the Base Case, but low in the Unconstrained Case (Table B-33). On an average basis there is no value to changing the Sacramento East Refuge demands or reducing the Delta outflow requirements in the Unconstrained Case. Just as with the instream flow requirements, the consumptive environmental demands are not causing the remaining Unconstrained Case scarcities in Region 2.

Table B-33: Refuge and Delta Shadow Values

	Base Case			Unconstrained Case		
	Min ($/af)	Avg ($/af)	Max ($/af)	Min ($/af)	Avg ($/af)	Max ($/af)
Sacramento East Refuge	0.0	72	3245	0.0	0.0	0.0
Delta Outflow	n/a	619	n/a	0.0	0.0	0.0

POTENTIAL FOR CHANGES

The results for the Lower Sacramento Valley and Sacramento-San Joaquin Delta regional CALVIN model can be used to identify locations for facility expansion (with their potential economic values), identify opportunities for improved surface and groundwater conjunctive operations, examine the economic impacts of environmental water requirements, and identify promising water transfers.

Promising Areas for Facility Expansion

“Hot spots” of potentially valuable increases in storage and conveyance capacity can be identified from the marginal and dual values that are part of the model results. The shadow values presented in the following section represent the economic value of facility expansion to water supply only and only in the Lower Sacramento Valley and Sacramento-San Joaquin Delta. These values do not include the value of hydropower for increasing storage capacities, increasing head and operational flexibility to release at peak times. Also the perfect foresight operations of CALVIN tend to depress the economic values of facilities overall.

Storage Hot Spots

There are thirteen surface water storage facilities in Region 2 (Table B-34). The largest is Lake Oroville on the Feather River and the smallest is Thermalito Fore and After Bay, also on the Feather River. In the Unconstrained Case all of the reservoirs, except for Oroville, experienced periods when expanded capacity would be beneficial to the system.

Table B-34: Region 2 Reservoirs

	Capacity (taf)	Max Flood Pool (taf)	Dead or Emergency Pool (taf)
Lake Oroville	3538	751	30
Thermalito Fore and After Bay	55	0	15
Lake Folsom	975	0	83
Camp Far West Reservoir	103	0	1
Clear Lake/Indian Valley Reservoir	613	128	0
Camanche Reservoir	438	194	4
EBMUD Reservoirs [a]	153	20	83
Englebright lake	67	5	50
Lake Berryessa	1602	0	10

Los Vaqueros	105	0	72
New Bullards Bar Reservoir	930	330	251
New Hogan Lake	317	165	18
Pardee Reservoir	210	27	12

[a] EBMUD Reservoirs refer to Chabot, Upper San Leandro, San Pablo, Briones and Lafayette Reservoir

Of the thirteen reservoirs in Region 2, only two have periods when increased capacity would yield significant benefits to the system (greater than $1/af/month). Those surface water facilities are Pardee Reservoir on the Mokelumne River and the EBMUD aggregated local Reservoir System (Table B-35). In general the greatest benefits for Pardee and the EBMUD Local Reservoirs expansion come only during the 1976-1977 drought. For the remaining years, the shadow values on the EBMUD reservoirs are essentially zero. Figure B-24 and Figure B-25 present the monthly shadow values for Pardee and the EBMUD Reservoirs, respectively.

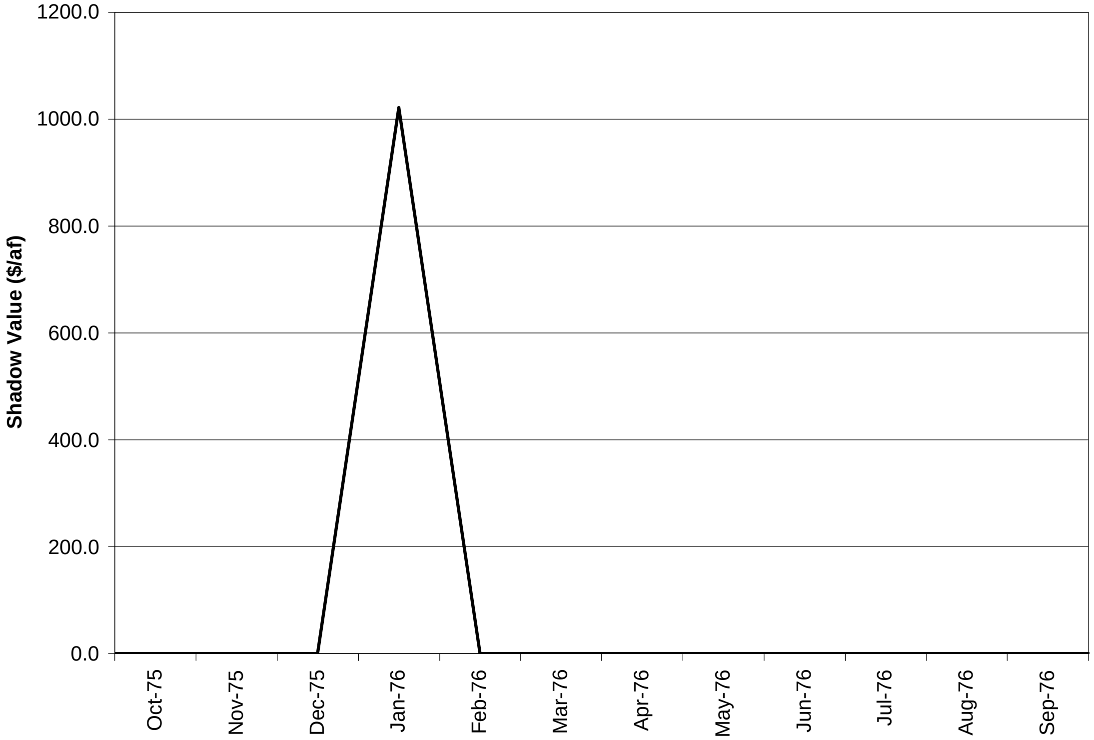


Figure B-24: Monthly Shadow Values for Pardee Reservoir

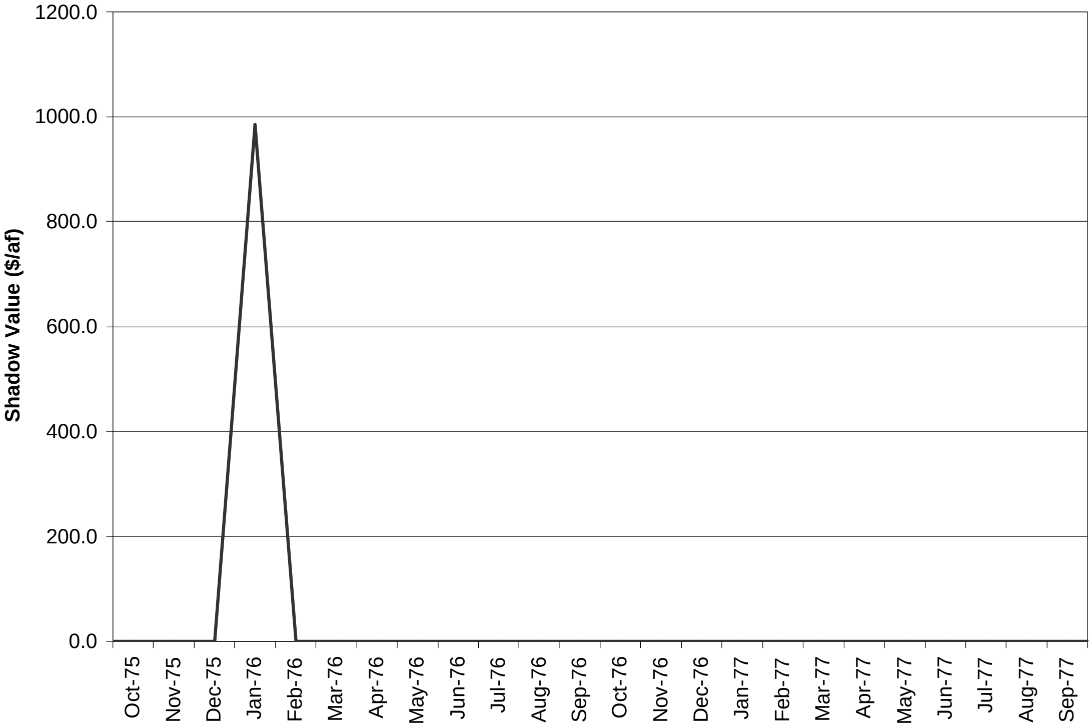


Figure B-25: Monthly Shadow Values for the EBMUD Reservoirs

Both Pardee Reservoir and the EBMUD Reservoir System service the EBMUD urban demands. Water from Pardee can be diverted to EBMUD via the Mokelumne River Aqueduct and into the EBMUD local Reservoir System. EBMUD faced scarcities from February of 1976 through November of 1977. The greatest value to increasing the capacity of the two reservoirs occurred in January of 1976, one month before scarcities began.

Table B-35: Average Annual Shadow Values for Region 2 Reservoirs

	Increase the Capacity ($/af)	Decrease the Dead Pool ($/af)
Lake Oroville	0.0	0.0
Thermalito Fore and After Bay	0.2	0.0
Lake Folsom	0.2	0.0
Camp Far West Reservoir	1.2	0.9
Clear Lake/Indian Valley Reservoir	0.2	0.0
Camanche Reservoir	0.2	0.0
EBMUD Reservoirs [a]	13.7	17.3
Englebright lake	0.2	0.0
Lake Berryessa	0.2	0.0
Los Vaqueros	0.2	4.8
New Bullards Bar Reservoir	0.2	0.0
New Hogan Lake	0.3	0.1
Pardee Reservoir	14.5	14.8

[a] EBMUD Reservoirs refer to Chabot, Upper San Leandro, San Pablo, Briones and Lafayette Reservoir

Also, the Camp Far West Reservoir, which releases to the Bear River that joins with the Feather River, has an average benefit of $1.2/af/month to increasing its capacity. The majority of the highest value periods occur from March to May, with peak values of over $6/af/month. As expected, the peak values occurred in the early spring months before and during the major droughts.

The remaining ten surface water facilities have average monthly shadow values of less than $1/af/month. New Hogan Lake has a value of $0.3/af/month, while the other nine reservoirs and lakes reach capacity but have no significant shadow values.

In addition to the surface water storage areas in Region 2, there are also five groundwater basins. As stated earlier, the end-of-period groundwater storages in the Unconstrained Case are constrained to be the Base Case ending level in all basins. During the 72-year Case, the capacities of the groundwater basins are not binding. However, there are economic benefits from increasing the ending storage constraint by one-acre foot (Table B-36) in all five basins.

Table B-36: End of Period Shadow Values for Region 2 Groundwater Basins

	End of Period Storage Shadow Value ($/af)
GW-5	18.8
GW-6	18.1
GW-7	22.0
GW-8	28.6
GW-9	20.4

The shadow values on the end-of-period storages indicate that CALVIN would like to be able to retain more water in the groundwater basins, to reduce the pumping costs. Increases in the end-of-period groundwater storage constraint under an ideal market indicate that the region has more than adequate supplies of surface water and can afford to reduce their groundwater consumption.

Conveyance Hot Spots

Region 2 has seven major conveyance facilities (not including pumping plants). Of those seven, five have maximum upper bound capacity constraints. The Putah South Canal, Mokelumne River Aqueduct, North Bay Aqueduct and Delta Cross Channel have no lower bounds and a constant monthly upper bound. The Folsom South Canal and aggregate Winters, Moore and West Adams Canals have no lower bound and constant upper bounds. The remaining conveyance facility, the Yolo Bypass, has neither upper nor lower bounds. Only one of the major conveyance facilities has binding upper constraints. In general none of the existing conveyance facilitates would yield any benefits to the system if expanded (Table B-37).

Table B-37: Average Conveyance Shadow Values (Increasing Capacity by 1 acre-foot per month)

	Annual Average ($/af/month)
Delta Cross Channel	0.0
Folsom South Canal	0.0
Mokelumne Aqueduct	0.0
North Bay Aqueduct	0.0
Putah South Canal	0.0

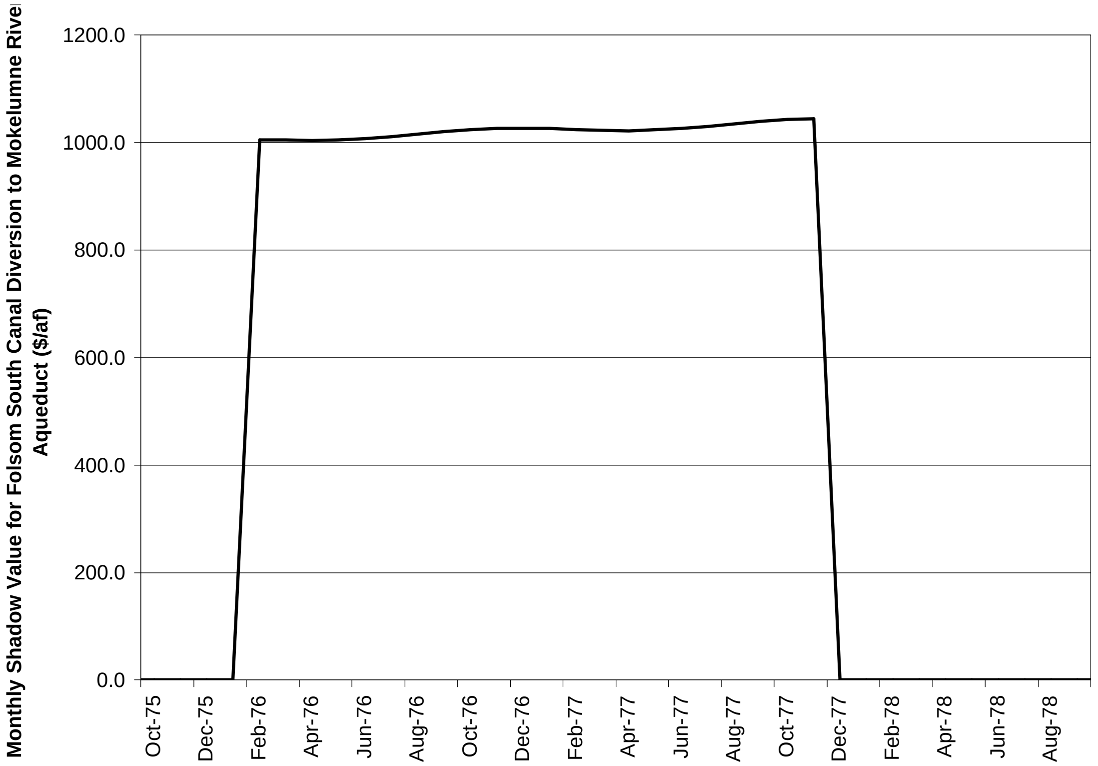
Winters, Moore & West Adams Canal	0.0
Yolo Bypass	0.0

There are also two proposed conveyance facilities in Region 2: the extension of the South Folsom Canal to the Mokelumne Aqueduct and a connector between the Contra Costa Canal and Mokelumne Aqueduct. Both proposed faculties have shadow values that indicate there would a net benefit to the system if they were available for use (Table B-38).

Table B-38: Proposed Facilities' Annual Shadow Values (Increase Capacity by 1 acre-foot per Month)

	Maximum ($/af/month)	Annual Average ($/af/month)
Folsom South Canal to Mokelumne Aqueduct	1,045	26
Mokelumne Aqueduct to Contra Costa Canal	150	126
Contra Costa Canal to Mokelumne Aqueduct	800	20

The Folsom South Canal could potentially divert water to the Mokelumne Aqueduct. There is a maximum benefit of $1,045/month to increase capacity by 1 acre-foot/month. The benefits average to $26/month to increase the capacity by 1 acre-foot/month. However, the benefits exist only during and just prior to the 1976-1977 drought (Figure B-26). At all other times, there is no benefit to the diversion.



B-26: Shadow Values for Folsom South Canal Diversion to Mokelumne River Aqueduct

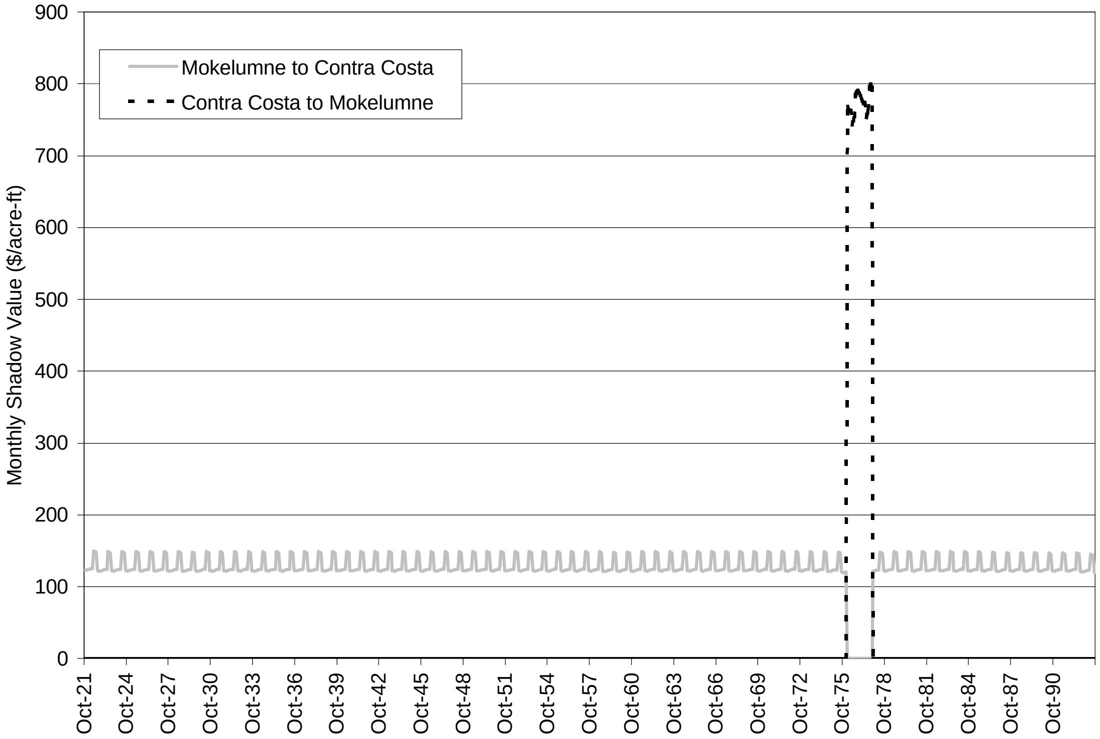


Figure B-27: Contra Costa Canal and Mokelumne River Connector Shadow Values

The region would benefit in almost every month from the connector between the Contra Costa Canal and the Mokelumne Aqueduct. On a monthly average basis there is greater benefit to being able to transfer the Mokelumne Aqueduct water to the Contra Costa Canal (Figure B-27). Only prior to and during the 1976-1977 drought is the value of additional water through the connector greater to EBMUD. If the connector can transfer water either direction, then the average benefit is increased to $145/af/month (Figure B-28).

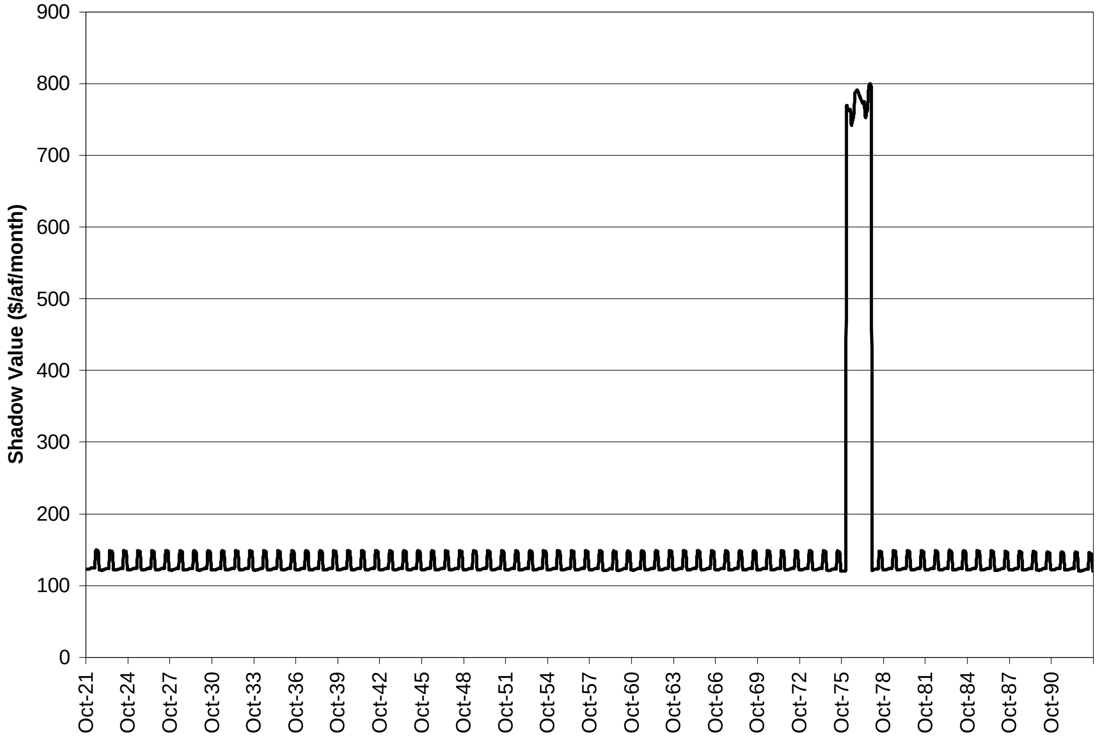


Figure B-28: Reversible Connector between Mokelumne Aqueduct and Contra Costa Canal

Operations and Conjunctive Use Opportunities

Re-operation of the surface water reservoirs and increased conjunctive use opportunities alter the way water is distributed and stored given the existing infrastructure. It should be noted that the CALVIN model results are idealized in the sense of perfect foresight, and do not reflect hydropower, water temperature, and real time flood control operations. The results are interesting and useful, but are not conclusive from the broader operational context.

Surface Water Operations

Between the Base Case and the Unconstrained Case, the volume of surface water used by Region 2 did not change significantly (from 9571 taf/yr to 9605 taf/yr). However, the distribution of surface water and operations of the reservoirs differed between the two model alternatives.

Of the thirteen surface water reservoirs in Region 2, the Unconstrained Case kept six of them fuller on an annual average basis. However despite the majority of the reservoirs being kept emptier, the aggregate average monthly surface water storage was higher in the Unconstrained Case (by 1043 taf/month). This can be primarily attributed to the higher levels in Lake Oroville (Figure B-29). In the Base Case, Oroville had an average monthly storage of 2.3 maf/month. In the Unconstrained Case the average monthly storage increased by 0.7 maf/month (32%). None of the reservoirs that experienced decreased storages in the Unconstrained Case were in the same magnitude. In addition to Oroville, Lake Berryessa was also kept fuller (by 289 taf/month).

The four biggest re-operations (Based on percent change) occurred in Lake Oroville, Thermalito Fore and Afterbay, Lake Berryessa and, the aggregate EBMUD reservoirs. The first four saw an increase in their average monthly storages. Lake Oroville was discussed previously.

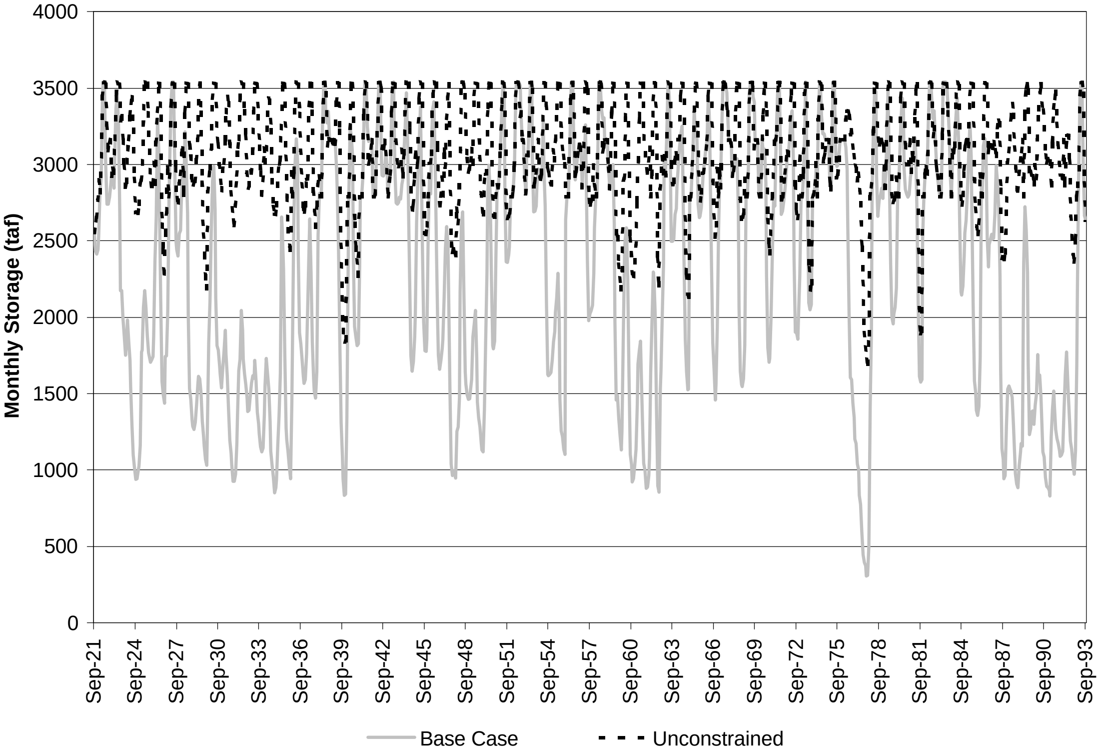


Figure B-29: Monthly Lake Oroville Storages

Thermalito Fore and Afterbay was kept fuller during the Unconstrained Case. Thermalito saw the greatest relative increase in average monthly storage. In the Base Case the average monthly storage was 11 taf/month, in the Unconstrained Case the average monthly storage was 54 taf/month. During the entire 72-year period, the Unconstrained Case kept Thermalito fuller than the Base Case (Figure B-30).

In the Unconstrained Case Lake Berryessa did not experience the severe drawdowns during the three droughts and for the period in the early 1950's (Figure B-31). The storage level in the lake did decrease during the drought (compared with non drought years), however it did not fall as low as it did in the Base Case. The annual average storage was 1.1 maf/month in the Base Case and 1.4 maf/month in the Unconstrained Case.

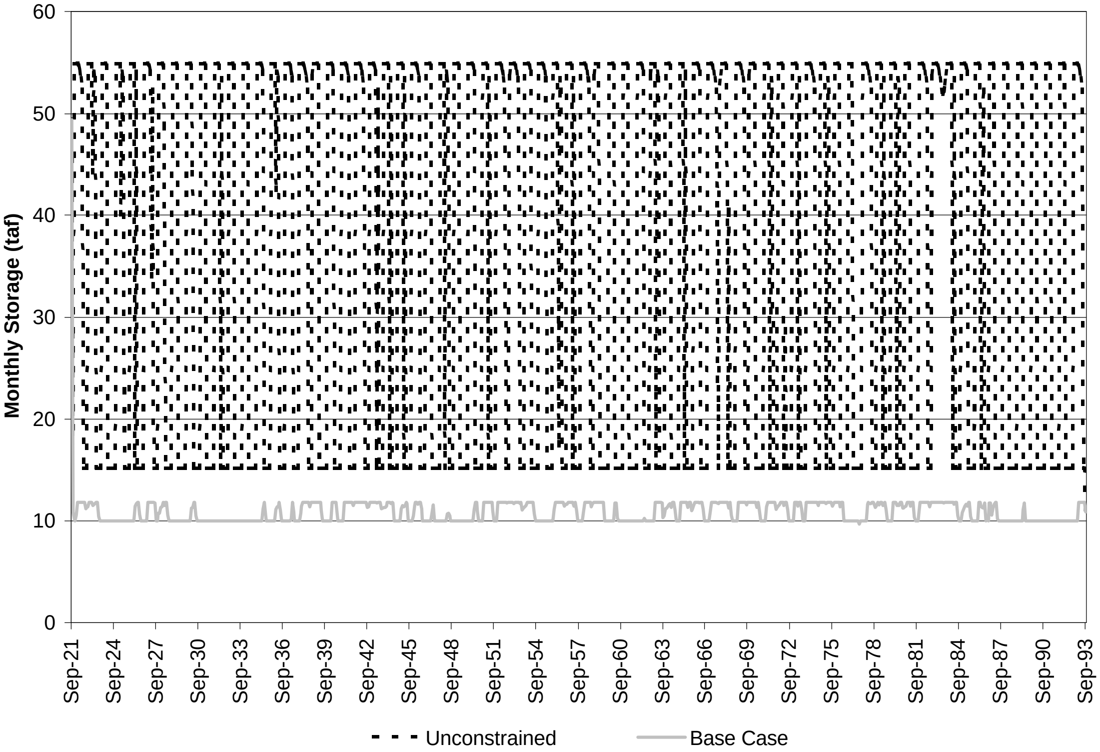


Figure B-30: Monthly Thermalito Fore and Afterbay Storages

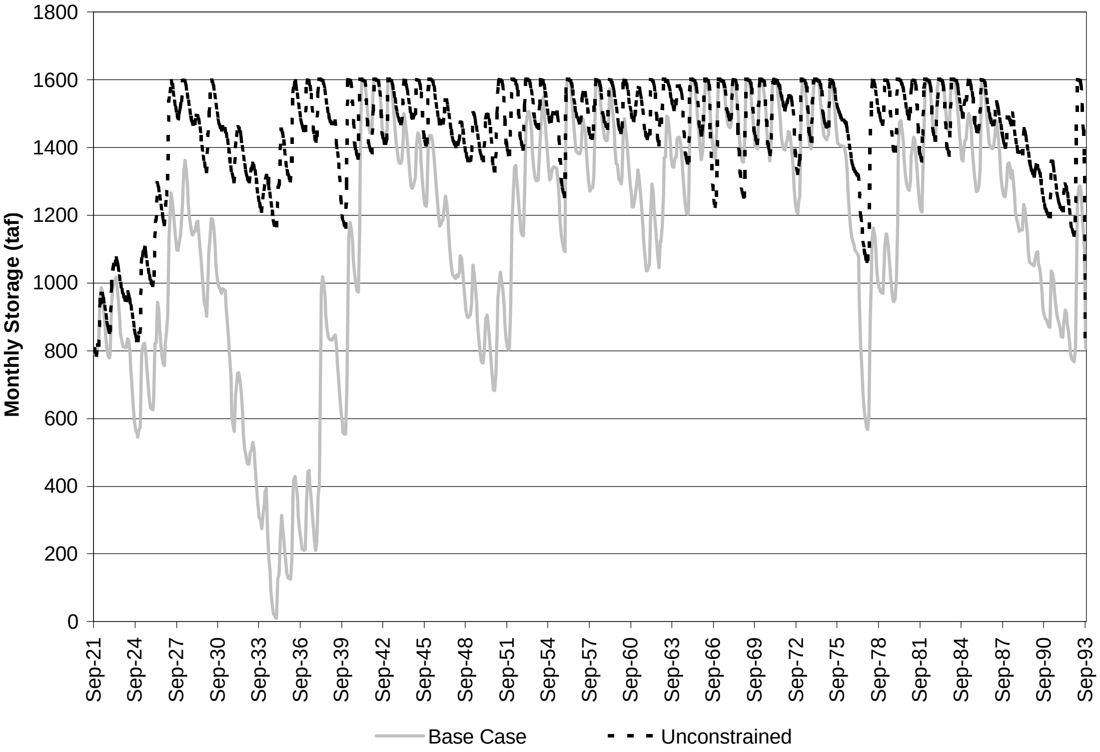


Figure B-31: Monthly Lake Berryessa Storages

Two reservoirs that show significant changes in individual operations were Camanche Reservoir and Pardee Reservoir. The two reservoirs are operated in series on the Mokelumne River. Camanche saw increases in its storage, while Pardee experienced a 12% percent decrease in monthly storages. Storing water in either reservoir has the same economic value to CALVIN, thus it is somewhat random as to where the model will choose to store a unit. Thus Camanche and Pardee are looked at together as storage on the Mokelumne. In the Base Case the average monthly storage was 456 taf/month, while in the Unconstrained Case it was 503 taf/month (Figure B-32).

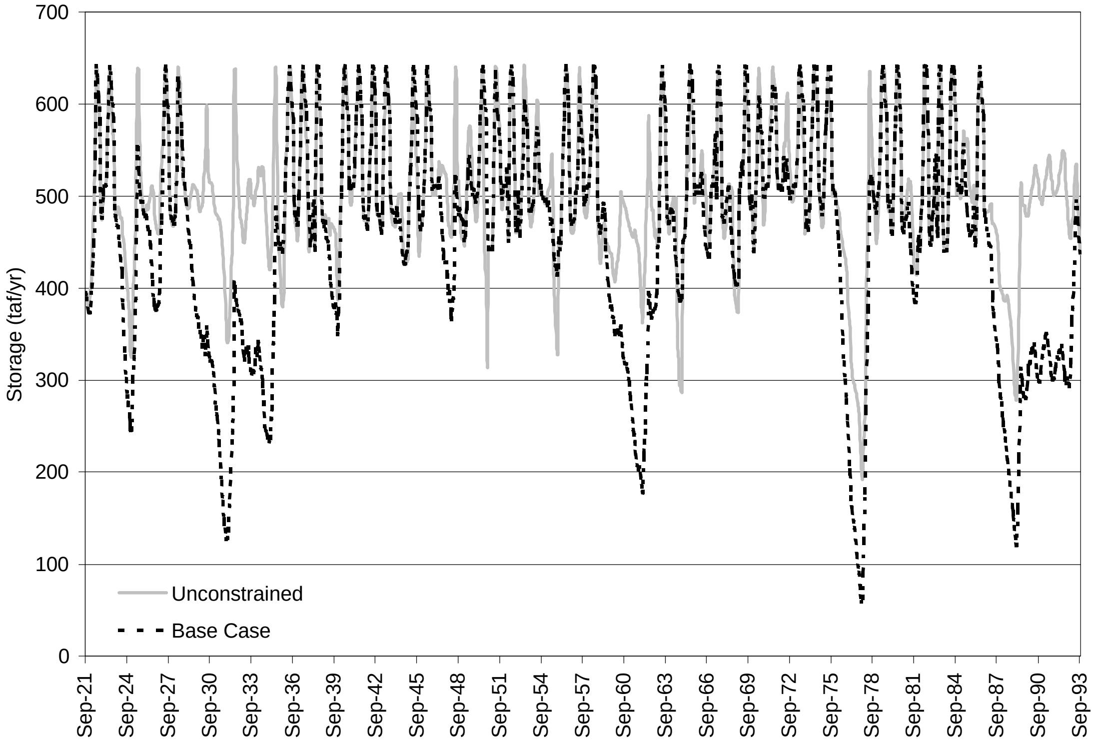


Figure B-32: Monthly Pardee Reservoir Storages

The most significant individual detail is that Pardee reservoir is drawn down to a greater extend during the 19760-1977 drought, when EBMUD experienced scarcities. In the winter before the drought the reservoirs were filled to capacity and then nearly drained. EBMUD would have benefited if additional water could have been stored in Pardee, but there is insufficient flows into the reservoir as the drought continues to alleviate the scarcities.

The aggregate EBMUD reservoirs were also kept emptier in the Unconstrained Case. It experiences the largest percent decrease (20%). The pattern of storages were fairly regular, expect for the period just prior to the 1976-1977 drought (Figure B-33).

Lake Folsom was also kept emptier in the Unconstrained Case. The average monthly storages were 543 taf/month and 506 taf/month in the Base and Unconstrained Cases, respectively. The Base Case seemed to empty the lake in the winter months and fill it up during the summer months. In the Unconstrained Case the lake was still filled in the summer months, but emptied more during the winter (Figure B-34).

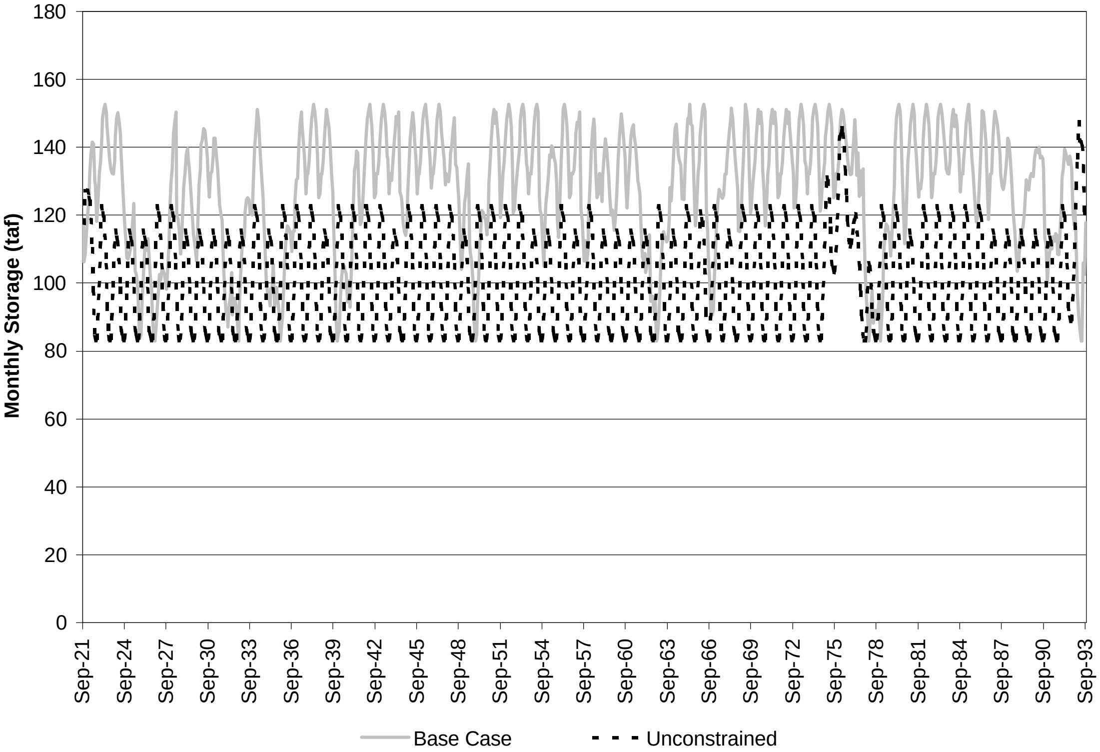


Figure B-33: Monthly Aggregate EBMUD Reservoir Storages

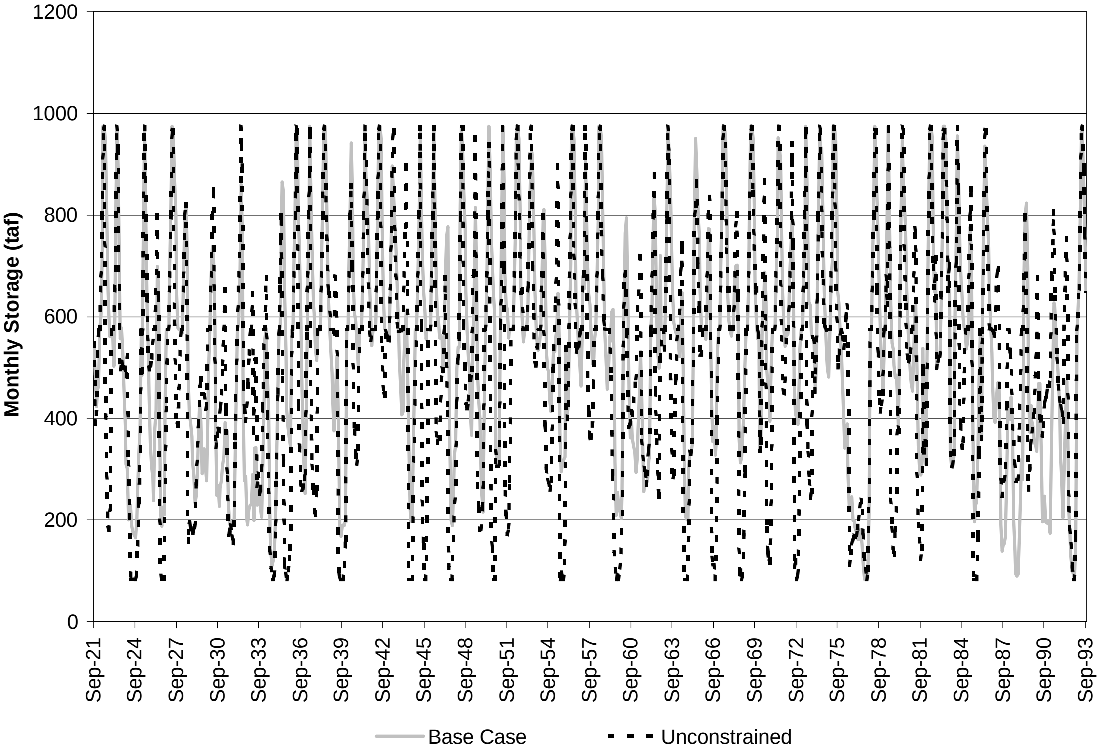


Figure B-34: Monthly Lake Folsom Storages

The distribution of surface water between the eleven demands (5 agricultural, 6 urban) varied between the Base Case and the Unconstrained Case. Overall agricultural users increased their surface water deliveries by 232 taf/year, while urban users decreased their surface water consumption by 198 taf/year.

Within the agricultural users, each CVPM region reacted differently. CVPM 5 and 6 did not significantly increase the amount of surface water they consumed. CVPM 7, 8 and 9 increased their surface water consumption, with CVPM 7 receiving the largest increase. Within the urban users, Stockton, Napa-Solano, and EMBUD increased their surface water deliveries, while Greater Sacramento decreased theirs. Yuba and CCWD experienced almost no change in surface water deliveries (less than a 2 taf/year increases).

Conjunctive Use Operations

Conjunctive use refers to the use of a combination of groundwater and surface water to meet a region's demand. All of the agricultural users and two of the six urban users (Greater Sacramento and Stockton,) have access (modeled in CALVIN) to both surface and groundwater sources. In the Base Case and the Unconstrained Case, all the agricultural and urban users with GW access utilized both sources.

Overall, agricultural users in the Lower Sacramento Valley decreased their groundwater withdrawals and increased their surface water consumption. CVPM 5 used the same amount of surface water on average (1140 taf/year). The remaining CVPM regions increased their surface water delivers with CVPM 7 gaining the largest increase. In turn the volume of groundwater consumed for agriculture decreased in the Unconstrained Case. CVPM 5 and 6 pumped the same amount, and CVPM 9 pumped a small amount more (less than 1 taf/year). CVPM 7 and 8 decreased their pumping. As expected the decrease in CVPM 7 pumping exactly matches the increase in surface water deliveries. Table B-39 presents the comparison of Base and Unconstrained surface and groundwater consumption. Figure B-35 presents a comparison between Base Case and Unconstrained Case groundwater pumping for agriculture.

Table B-39: Conjunctive Use in Agricultural Areas in Region 2

	Base Case			Unconstrained Case		
	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW[a] (%)	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW[a] (%)
CVPM 5	1140	498	70/30	1140	498	70/30
CVPM 6	347	447	44/56	346	447	44/56
CVPM 7	243	281	46/54	445	79	85/15
CVPM 8	152	661	19/81	176	637	22/78
CVPM 9	958	112	90/10	964	113	90/10
REGION 1	**2839**	**1999**	**59/41**	**3071**	**1774**	**63/37**

[a] SW/GW (%) refers to the percentage of delivery from a surface source (SW) and the percentage of delivery from groundwater (GW). ex. CVPM 5 Base Case: 1140/(1140+498)=70% and 498/(1140+498)=30%.

In terms of the drought periods, all of the agricultural users significantly increased their groundwater pumping from that of a non-drought year (Table B-40). The agricultural users increased pumping by over 900 taf/year on average during the three drought periods.

Table B-40: Conjunctive Use in Agricultural Areas in Region 2 (Comparison of Non-Drought and Drought Years)

	Non-Drought			Drought		
	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW (%)	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW (%)
CVPM 5	1140	498	70/30	660	978	40/60
CVPM 6	346	447	44/56	113	681	14/86
CVPM 7	445	79	85/15	422	101	81/19
CVPM 8	176	637	22/78	37	775	5/95
CVPM 9	964	113	90/10	909	168	84/16
REGION 2	**3071**	**1774**	**63/37**	**2142**	**2703**	**44/56**

Overall, urban users in Region 2 decreased their surface water deliveries and increased their groundwater withdrawals. Greater Sacramento reduced the amount of surface water they consumed, but increased groundwater withdrawals to offset the reductions in surface water.

Stockton increased their surface water deliveries and decreased their groundwater pumping. Napa-Solano did not have any modeled groundwater in either cases, but did increase their surface water deliveries in the Unconstrained Case.

Table B-41: Conjunctive Use in Urban Areas in Region 2

	Base Case			Unconstrained Case		
	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW[a] (%)	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW[a] (%)
Yuba	52	0	100/0	53	0	100/0
Greater Sacramento	452	227	67/33	205	473	30/70
Stockton	60	35	63/37	80	15	84/16
Napa-Solano	105	0	100/0	115	0	100/0
CCWD	131	0	100/0	133	0	100/0
EBMUD	282	0	100/0	296	0	100/0
REGION 2	**1081**	**262**	**80/20**	**883**	**488**	**64/36**

[a] SW/GW (%) refers to the percentage of delivery from a surface source (SW) and the percentage of delivery from groundwater (GW). ex. Greater Sacramento Base Case: 452/(452+227)=67% and 227/(452+227)=33%.

Table B-42: Conjunctive Use in Urban Areas in Region 2
(Comparison of Non-Drought and Drought Years)

	Non-Drought			Drought		
	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW[a] (%)	Surface Water (taf/yr)	Groundwater (taf/yr)	SW/GW[a] (%)
Yuba	53	0	100/0	53	0	100/0
Greater Sacramento	205	473	30/70	173	505	26/74
Stockton	80	15	84/16	36	59	38/62
Napa-Solano	115	0	100/0	115	0	100/0
CCWD	133	0	100/1	134	0	100/0
EBMUD	296	0	100/0	283	0	100/0
REGION 2	**883**	**490**	**64/36**	**794**	**566**	**58/42**

In general groundwater pumping to the urban areas either increased or remained the same during drought years (Table B-42). Greater Sacramento and Stockton increased pumping during drought periods. Note that CCWD, EBMUD and Yuba do not access to groundwater, thus they cannot increase their pumping due to drought conditions.

Groundwater re-charge is of major importance to the lasting sustainability of an aquifer. Areas that withdraw, but do not re-charge the aquifer at an equal rate, suffer from declining groundwater tables and decreasing yield. However, the end-of-period groundwater storage was constrained to be the same in both modeling alternatives.

Due to the cost of groundwater pumping, it is only efficient to pump when the cost of the pumping is less than the value of the unit of water or the cost of an alternative source. Because the Base Case replicates the current infrastructure, contractual agreements, and legislative requirements, this is not always the case. However, in the Unconstrained Case, water is allocated Based on minimizing the operating and scarcity costs. It then makes sense that the lower cost surface water is delivered to the agricultural users and groundwater pumping increases for Greater Sacramento. The cost of pumping groundwater from the two available aquifers is cheaper than the treatment cost of the surface supplies available to Greater Sacramento. Therefore Sacramento is willing to pump additional groundwater in the Unconstrained Case, which allows for increased surface water deliveries to CVPM 7, thus reducing their operating costs as well.

An issue to note with groundwater use in Region 2 is that in practice not all water users have access to surface water. In cases where a user does not have access to surface water, groundwater must be used. The result is that every region would have some minimum amount of groundwater pumping. Table B-43 presents the minimum groundwater withdrawals in one calendar year that occurred in CVGSM NAA and in the Base Case.

Table B-43: Minimum Groundwater Pumping

	Minimum CVGSM NAA Withdrawal (taf/year)[a]	Minimum Unconstrained Withdrawal (taf/year)[a]
CVPM 5	388.2	2.6
CVPM 6	356.6	209.7
CVPM 7	233	72.4
CVPM 8	525.5	447.4
CVPM 9	82.7	101.2

[a] Note that the minimum withdrawals are reported in taf per calendar year (January to December).

In the Unconstrained Case, four of the five CVPM regions withdraw less groundwater than the minimum from the Base Case. Only CVPM 9 withdraws more groundwater than the Base Case minimum. Further details regarding groundwater-pumping minimums are presented in Chapter 5: Limitations.

Cooperative Operations

The Unconstrained Case indicates that the Lower Sacramento Valley would benefit from an ideal regional water market. Regional scarcities would be eliminated, operating costs reduced, and system reliability improved. The only demand region that would not benefit as greatly from an ideal market is EBMUD, but the cause of their scarcity is not a lack of water, but rather a storage constraint.

Table B-10 presented the change in scarcity and operating costs for the five agricultural regions between the Base and Unconstrained Cases. None of the agricultural regions experienced an increase in total costs. CVPM 9 experienced a small increase in operating costs ($24K/year) due to the increased groundwater pumping that was more than offset by their decreased scarcity costs of $200K/year.

Table B-12 presented the change in scarcity and operating costs for the six urban regions. All of the urban regions would see a net benefit of having an ideal water market established. The greatest benefits would be to Napa-Solano and EBMUD (despite its continued scarcity). Napa-Solano would see a slight increase in their operating costs ($0.1($10^6$)/year), but their scarcity cost would be reduced by $22($10^6$)/year. Yuba would also see an increase in their operating costs ($0.1($10^6$)/year), but their scarcity cost would be reduced by $0.9($10^6$)/year. Greater Sacramento did not experience any scarcities in either Case, but would see a reduction in their operating costs in the Unconstrained Case. The remaining urban areas would see decreases in both their scarcity and operating costs.

Environmental Requirements

Environmental minimum instream flows, refuge demands, and Delta requirements have significant impacts on water distribution and allocations within the Lower Sacramento Valley. In the Unconstrained Case, the environmental requirements do not seem to be the cause of scarcities in the region and small increases in requirements are unlikely to impose any scarcity costs. However, large increases in these demands may result in increased scarcities to the urban and agricultural regions.

Increasing Environmental Flows

In an ideal water market the environmental requirements do not pose significant restrictions on allocations within Region 2. As presented in Table B-32, there is little value to reducing the minimum instream flows (and correspondingly little cost to increasing them), even on river reaches where the requirements are binding. The maximum benefit (cost) was approximately $0.9/af for reduced (increased) instream flows on the Mokelumne River.

In addition to the minimum instream flow requirements are the two consumptive environmental demands: the Sacramento East Refuge and the Delta. The Sacramento East Refuge diverts water that would otherwise be available for CVPM 5. The refuge's full level two demands are lowest in the winter and spring and highest in the summer and fall and repeat on an annual basis (Figure B-36). The highest demand occurs in September and the lowest occurs in February and March. In general the period of highest refuge demand (May through October) overlaps with the period of highest demand for CVPM 5 (April through August). Despite this, there is little value (or cost) to decreasing (increasing) the refuge demands by one unit. The maximum value (cost) would be less than $1/af/month.

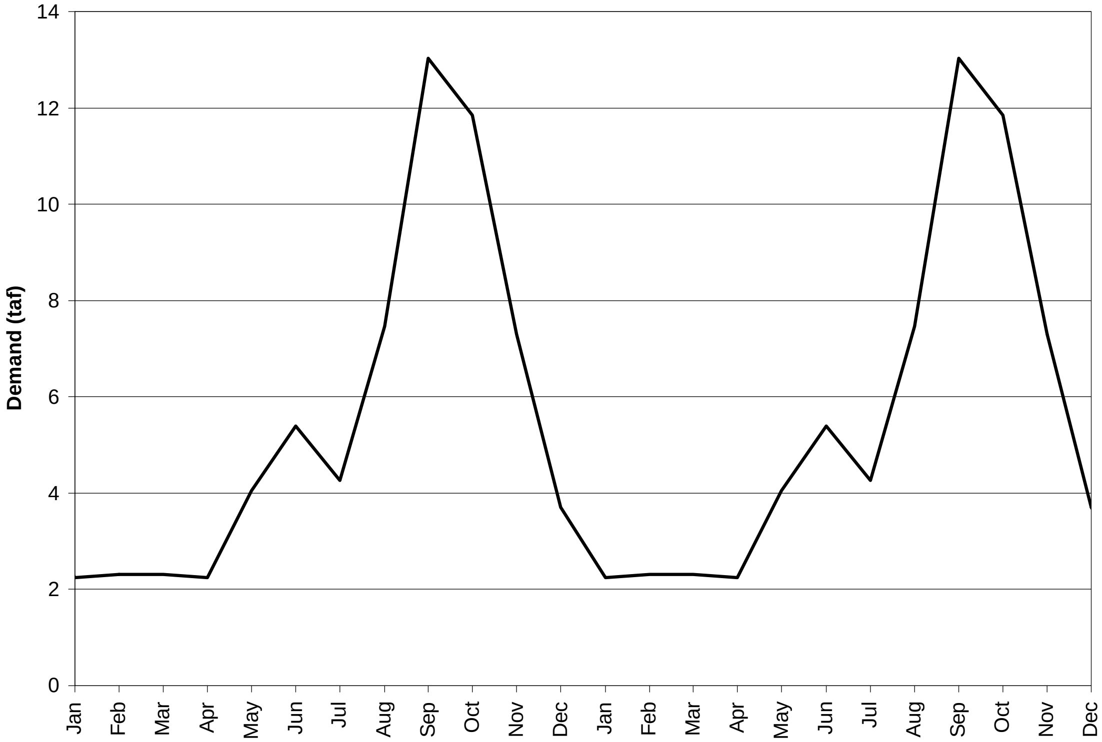


Figure B-36: Sacramento East Refuge Level 2 Demands

However, the shadow values for Sacramento East Refuge reflect the modified level two demands that were in place during the Unconstrained Case. The refuge actually requires an additional 9 taf/year to be delivered at full level 2. The increased demand may result in changes in allocations and distribution of water within the system, which could result in increased value to the environmental water that is not reflected with the modified level two demands.

The other major source of environmental water demand is outflows [these are non-consumptive minimum flow-by requirements for the Sacramento-San Joaquin Delta. The Delta outflow requirements vary by month and by year. In general the greatest demands occur in February and March and the lowest demands occur in September. See Figure B-37 for details. In the Unconstrained Case there was no economic benefit to reducing the Delta requirements by one unit. This is expected given that there were surplus delta outflows made in many of the months during the 72-year Run.

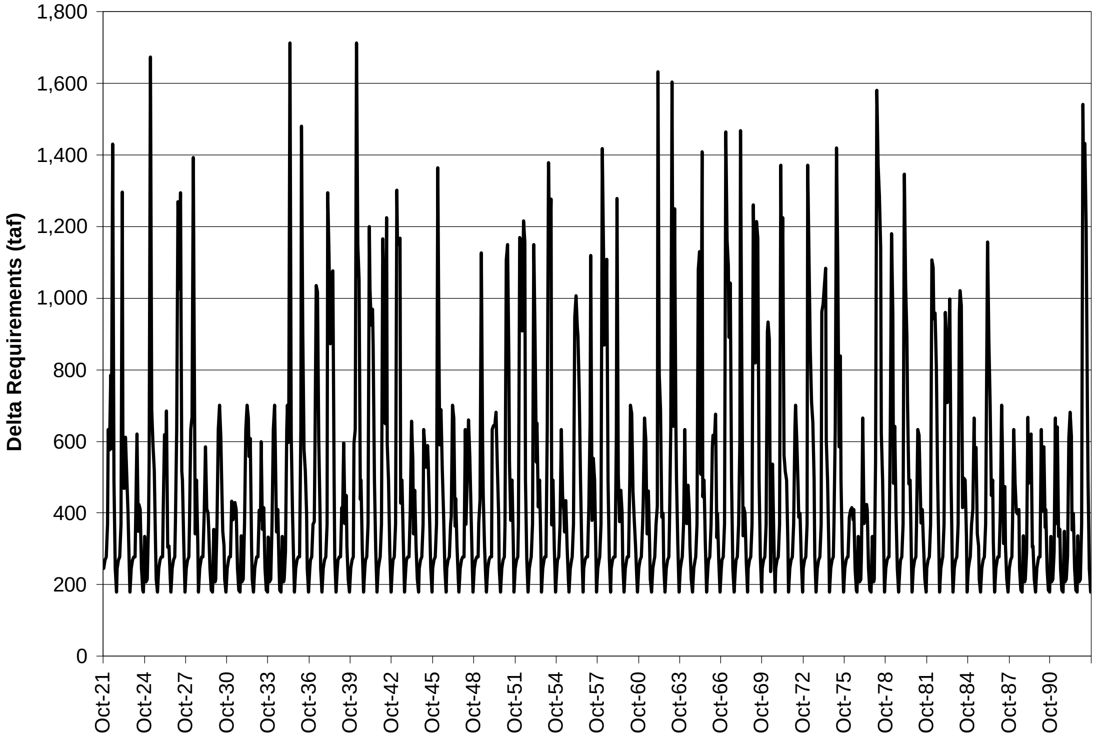


Figure B-37: Delta Required Outflows

It should be noted that the environmental water demands are Based on water needs of the environment, whether for fish, habitat, restoration, etc. in a given month, at their recent historic operating levels (pre-CVPIA 1997 operations). These demands do not have economic values placed on them in CALVIN and are not modeled as economically driven demands. Changes to the requirements to maximize the agricultural demands may increase environmental degradation. Increases in the annual environmental water deliveries may not be beneficial if the water is not available during the month when the environment needs it.

Water Transfers

Users can transfer and exchange water between one another depending on the economic benefits of such transfers. The transfers can be between urban and agricultural users as well as between individual agriculture and individual urban users. The results from the Unconstrained Case of CALVIN reflect those transfers made that would improve the overall net benefits to the region. Overall, relatively little net water would change hands with an unhindered water market, although significant exchanges of water would occur. This would lead to modest, but significant reductions in scarcity and operating costs, especially to individual users.

Costs and Benefits of Intra-regional Transfers

Transfers between agricultural and urban users, as well as between individual agricultural and individual urban users are possible in an ideal market. Region 2 minimized scarcities by exchanging surface water between users, changing the use of groundwater pumping rates, and re-operating surface water storage conjunctively with groundwater storage.

Currently all agricultural users employ a mixture of surface and groundwater (Table B-39). The current split favors surface water (59% to 41% regionally). Some areas could decrease their surface water demands and increase groundwater pumping and vice-versa. The ideal water market would see a slight change in the overall average surface water to groundwater split (63% to 37%) and a large change in the drought year split (44% to 56%).

Urban users, where possible, also use a combination of surface and groundwater. However, only two urban areas have access to groundwater (Greater Sacramento and Stockton). The remaining urban areas rely entirely on surface water (and to a much lesser extend water recycling). Currently the urban areas use much more surface water than groundwater (80% to 20% regionally). In the Unconstrained Case, urban users still rely more heavily on surface water than groundwater but increase reliance on groundwater (64% to 36% regionally).

Under Unconstrained conditions, urban users decreased their surface water consumption and relied more on groundwater, while the agricultural users increased their surface water consumption and decreased their groundwater pumping. Despite the increase in groundwater pumping by some of the urban areas, the urban operating costs decreased. This was due to increased lower cost pumping by Greater Sacramento and the use of lower cost surface sources. Examples are Greater Sacramento, which obtained more water from groundwater and Folsom Lake and less from the American and Sacramento Rivers downstream of Lake Natoma in the Unconstrained Case. Deliveries from the Folsom Lake have a lower associated cost than those from the Sacramento River by $35/af. Another example is Napa-Solano, which eliminated more expensive deliveries from the North Bay Aqueduct by increasing deliveries from the Putah South Canal. The Putah South Canal's operating costs are lower than the North Bay Aqueduct's by $10/af.

None of the CVPM regions incurred increased costs in the Unconstrained Case. Operating and scarcity costs either remained the same or decreased in the ideal market. CVPM 5 and 6 were economically unaffected by the ideal regional market. Neither their scarcity nor their operating costs changed. Both regions received the same amount of surface water and pumped the same volume of groundwater, on average, in both the Base and Unconstrained Cases. This would indicate the CVPM 5 and 6 would be indifferent to an ideal regional water market. However increased surface water usage in non-drought years and increased groundwater pumping in drought years would probably require new water infrastructure such as more pumps and distribution canals. This may cause CVPM 5 and 6 to have economic hesitations regarding implementation of an ideal water market.

CVPM 7 and 8 saw no change in the scarcity costs. However, both CVPM 7 and 8 increased their surface water deliveries and decreased their groundwater pumping. The decreased groundwater pumping lead to decreases in operating costs. Overall CVPM 7 and 8 saw a reduction in their total costs, which indicates that they should be willing to participate in an ideal regional water market, but might also require some new infrastructure to increase access to surface water in their regions

CVPM 9 saw a slight increase in their operating costs due to an increase in groundwater pumping. However, their scarcity costs were eliminated by increased surface water deliveries in conjunction with the increased groundwater. Overall CVPM 9 saw a decrease in their total costs, which would indicate that they would be willing to participate in an ideal regional water market.

None of the urban demand areas incurred increased scarcity costs, but two did see increased operating costs. Napa-Solano and Yuba experienced increased operating costs. However both increases were small relative to their reductions in scarcity costs. Napa-Solano saw the greatest reduction in their scarcity costs in the ideal market (\$22(10^6)/year). Yuba's reduction in scarcity costs was nine times greater than the increase in operating costs. Overall both urban demands saw decreases in their total costs, which indicates that they should be willing to participate in an ideal regional water market.

The only urban demand that did not have scarcities eliminated was EBMUD. However, despite being the only economically driven demand area to still incur scarcities under an ideal market, EBMUD did see significant reductions in their scarcity costs (from \$12.5(10^6)/year to \$0.6(10^6)/year). Their operating costs also decreased by approximately \$1 million/year. Overall EBMUD saw a decrease in their costs, which would indicate that they too should be willing to participate from an ideal regional market.

Of the remaining urban areas, Greater Sacramento, Stockton and Contra Costa Water District, all saw decreases in total costs. Stockton and Contra Costa Water District saw decreases in both scarcity and operating costs. There was no change in Greater Sacramento's scarcity costs, but there was a decrease in the operating costs. Again the reduction in costs indicates that these urban areas should be willing to participate in an ideal regional water market.

Overall the Lower Sacramento Valley appears to benefit from an ideal regional market, although the total benefit is small relative to the region's economy, or even water-Based portions of the regional economy. Implementation would depend upon cooperation between the various users. Users that see a decrease in both operating costs and scarcities costs would be more favorable toward the market. Users that see an increase in either (or both) of the costs would be less favorable. All economic demands saw decreases in scarcity costs and five of the nine saw decreases in operating costs as well. All users saw decreases in total costs. In general this would indicate that the users should have some economic willingness to institute an ideal regional water market.

Regional Economic Impacts of Transfers

The annual changes in water deliveries to the agricultural regions had only minimal effect on the regional agricultural production. In Region 2, the agricultural users would, theoretically, compete with urban users for water. However, there is sufficient water to fulfill both demands (EBMUD experiences scarcities due to storage capacity constraints). Re-allocation would involve exchanges between the urban and agricultural users. However, both the agricultural and urban users economically benefit from the water market (reduced scarcity and operating costs). Thus it would be beneficial to the region for intra-regional transfers to occur.

Water Transfers and Environmental Water

Environmental water use is modeled as constraints in CALVIN. Water transfers between the environmental demands (consumptive use) and the agricultural and urban demands cannot be determined Based on an economic optimization approach alone.

The two refuges that comprise the Sacramento East Refuge (Sutter National Wildlife Refuge and the Gray Lodge Wildlife Area) are migratory waterfowl habitats. The Bureau of Reclamation (1997) has defined seven primary goals designed to improve, protect and expand the current refuges. Three of the seven goals would make decreases in the refuge flows especially difficult:

1. "Maintenance of additional acres of both summer water and permanent pond habitat types for both
2. "Maintenance of water depths, using year-round water delivery, that provide optimum foraging conditions for the majority of avian species."
3. "Control of undesirable vegetation species, such as cocklebur, using deep irrigation and maintenance

All three of the above goals are designed to insure water deliveries to the refuge during the summer months, when agricultural demands are highest. At this point, since there is little economic value to reducing the refuge demands, it seems inefficient to reduce the refuge deliveries below the modified level two demands. One of the few ways in which diversions could be reduced without decreasing refuge deliveries would be to find a way to reduce the consumptive losses on the way to the refuge. On the other hand, results indicate that it would be possible to increase environmental deliveries without impacts to agricultural and urban users under an ideal market.

Just as with the Sacramento East Refuge, the Delta deliveries are made to protect wildlife, habitat and restoration within the San Joaquin Delta region. Reductions in deliveries could significantly hurt those efforts. Since there was no economic benefit to reducing the deliveries, it is unlikely that transfers from the Delta (in the way of demand reductions) would be implemented and further allocations to the Delta might be possible without economic losses.

REGIONAL WATER MANAGEMENT IMPLICATIONS

In the current water management system, water is not delivered in the most economically efficient manner, however the system is still fairly well operated and by and large, water within the region appears to be well allocated in terms of economic benefits. Nevertheless, scarcities are not distributed throughout the region strictly to minimize costs or improve reliability. An ideal water market could reduce the costs and improve reliability.

The results from CALVIN can indicate potential areas where modest improvements could be achieved through changes in operations and allocations. However it is important to keep in mind that the results presented in the previous sections indicate that the benefits derived from an ideal market in the Lower Sacramento Valley would be small relative to the economic value of water in the region. They would, however, be rather large and significant for some of the individual agencies and users.

The regional water delivery reliability would improve. Small agricultural scarcities would be eliminated, which result in a corresponding elimination of scarcity costs. Agricultural users would also see a decrease in their operating costs. Urban scarcities would be significantly decreased and the associated scarcity costs reduced. Urban users would also see a decrease in their operating costs. It is unclear how the environment would do in an ideal market because of the lack of environmental economic data. However, the very low opportunity costs of environmental flows indicated under an ideal market suggest positive opportunities and much more flexibility to increase environmental requirements without harm to other users. If fact, greater conjunctive operations indicated in the ideal market would tend to increase operating flexibility for adaptive management in order to respond to greater instream flow needs as they arise.

Ten of the thirteen surface water reservoirs would see an increase in the annual average storage in the ideal market. The increased storage means that additional water will be available during the critically dry years as well as during high demand months. The three reservoirs with lower annual average storages are used as water sources in greater quantities in the ideal market. In general an ideal market would also be able to improve system reliability without any major changes in the current reservoir capacities. Expansion of only two reservoirs in the system would only provide significant benefits during the critically dry years.

The groundwater basins, because of the constrained end-of-period storage volume, see almost no change in their annual average pumping volumes and long-term depletion. However, the system has enough surface water that it would like to be able to store more water in the groundwater basins. Increased storages in groundwater basins could provide additional water for critically dry years.

There are minimal benefits to expanding most of the region’s current conveyance capacities. Only the proposed connector between the Mokelumne Aqueduct and Contra Costa Canal would provide significant benefits on a monthly average basis, mainly for reducing urban operating costs. Changes in the environmental requirements (minimum instream flows and consumptive use requirements) would also not provide significant benefits or costs to the system

Inter-regional transfers from Region 1 and Region 2 are unlikely to occur in an ideal market. The value of water to Region 1 appears to be significantly higher than the value it has to Region 2. Inter-regional transfers from Region 3 to Region 2 are likely to occur on Stanislaus and the two pumping plants (Harvey banks and Tracy), but unlikely to occur on the San Joaquin. The value of water to Region 2 is less than the value to Region 3 on the San Joaquin, which is why a transfer would be unlikely. Intra-regional exchanges with little net transfer of water between all the users (urban and agricultural) are likely to occur in the ideal market.

CALVIN is, in essence, indicating that Region 2 would benefit somewhat overall from an ideal market. There would be decreases in both the regional operating and scarcity costs. Overall, the ideal water market would reduce the total costs of Region 2 by $46.2 million per year, which is approximately a 13% reduction in total scarcity and operation costs. This indicates that there are some places where operations and allocations could be improved in the Lower Sacramento Valley, but on a whole the region is fairly well operated from an economic perspective of agricultural and urban water supply.

REFERENCES

Department of Water Resources (DWR), 1998. *The California Water Plan Update, Bulletin 160-98, Volume 1.* Sacramento, California: DWR

Department of Water Resources (DWR), 1998. *The California Water Plan Update, Bulletin 160-98, Volume 2.* Sacramento, California: DWR

Howitt, R.E., Lund, J.R., Kirby, K.W., Jenkins, M.W., Draper, A.J., Grimes, P.M., Ward, K.B., Davis, M.D., Newlin, B.D., Van Lienden, B.J., Cordua, J.L., and Msangi, S.M. (1999), Center for Environmental and Water Resources Engineering, University of California, Davis. http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/

U.S. Department of the Interior, Bureau of Reclamation (USBR), 1997. *Central Valley Project Improvement Act, Draft Programmatic Environmental Impact Statement (PEIS), Technical Appendix, Volume Seven.* Sacramento, California: USBR

U.S. Department of the Interior, Bureau of Reclamation (USBR), Mid-Pacific Region, 1997. *Final Environmental Assessment/Initial Study, Proposed Finding of No Significant Impact/Negative Declaration for the Conveyance of Refuge Water Supply Project, East Sacramento Valley Study Area.* Sacramento, California: USBR

U.S. Department of the Interior, Bureau of Reclamation (USBR), Mid-Pacific Region, 1992. *Long-term Central Valley Project operations criteria and plan CVP-OCAP.* Sacramento, California: USBR