APPENDIX G

CALVIN OPERATING COSTS

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INTRODUCTION

Embedded into CALVIN's HEC-PRM algorithm are operating costs to represent agricultural and urban water supply costs, fixed head conveyance power benefits, and pumping costs. Economic benefits of head dependent hydropower at reservoir sites are not included in the current version of CALVIN. Operating costs include only those variable components of costs associated with water delivery, including such things as surface conveyance, groundwater pumping, local urban distribution, urban water quality impacts, groundwater artificial recharge, recycling, facility maintenance, and waste water discharge impacts, if any. Capital, administrative, and other fixed costs are excluded from CALVIN analysis.

Variable operating costs are represented in CALVIN in dollars per acre-foot ($/af) on appropriate links. Total operational cost along a link during a one-month period equals the unit cost on that link multiplied by the flow of water across the link in that month.

Operating costs used in CALVIN and reported in this appendix are predominantly based on estimates from studies completed in the 1990s. The kind of costs these data explicitly represent is not always apparent, nor consistent across studies. This causes difficulties for extracting consistent cost estimates across the state. These problems with cost data are not resolved in this initial CALVIN study. Values approximately reflect 1995 dollars, the basis for accounting of costs and benefits in CALVIN. No effort has been made to modify cost estimates to reflect or predict changes to operating costs in 2020 (except for water treatment operating costs associated with implementation of more stringent Safe Drinking Water Act requirements) nor to adjust values within the 1990's decade.

Operating costs are discussed next in the context of (1) agricultural water supply, (2) urban water supply, and (3) conveyance.

AGRICULTURAL WATER SUPPLY OPERATING COSTS

Operating costs included in CALVIN are for groundwater supplies only, which can include ground water pumping and artificial recharge activities. No variable costs for surface water are included because most irrigation district surface water costs are minimal and recovered through fixed costs to members.

It was assumed that in the case of agriculture, groundwater pumping occurs near the point of water use. Consequently, agricultural groundwater extraction costs are limited to O&M of pumping facilities where energy consumption is a major component of variable costs.

Some agricultural areas also manage their groundwater supplies with artificial recharge of imported or local surface water. Operating costs for these agricultural groundwater recharge activities are limited to facility operations and the opportunity cost of land under use, if any.

Variable Costs of Groundwater Pumping

An estimate of $0.20 per acre-foot per foot of lift was assumed for O&M of groundwater pumping in the agricultural sector (including an average $0.20/kwh/af energy costs). This estimate represents a current (1995) statewide average value, which is applied in CALVIN for the 2020 analysis and represents a synthesis of several reference sources (Curley and Knutson 1993; DWR 1997; CPUC 1998). Energy costs alone range from $0.04 to $0.23/kwh/af and vary somewhat within the state. Non-energy O&M costs add 10 - 100% of energy costs to variable pumping costs of groundwater supply in agriculture.

Thus, groundwater pumping costs for agriculture reflect a unit cost of $0.20 per af per ft of lift multiplied by the average depth to groundwater for a particular groundwater subbasin. Differences in groundwater extraction costs in CALVIN are simply due to different average depths to groundwater in each groundwater subbasin (GWSB). Because average depths are used for the entire GWSB, local conditions within the GWSB will naturally vary and, hence, costs for individual users will vary from CALVIN estimates. Head dependent pumping costs (changes in energy consumption per foot of lift as a function of depth) are also not represented at present.

In the Central Valley, average depth to groundwater was calculated as the sum of pumping lift and drawdown (1990 base year, Table Localcst, CVPM), plus the projected change for year 2020 under the CVPM No Action Alternative (Table Gwdchg, CVPM). Outside the Central Valley, depth to groundwater was assessed by review of representative wells, water resources and watermaster reports (Durbin 1978; Danskin 1988; Inyo 1990; WRDSC 1992; SCVWD 1996; CVWD 1998; MBAW 1998). CALVIN subbasins outside the Central Valley that are used for agricultural water supply include Owens Valley, Coachella Valley, and Imperial Valley to a very limited extent. Because agricultural groundwater use in the Owens Valley is small and represented in CALVIN as a fixed diversion, operating costs are not included. Thus, explicit groundwater pumping costs for agricultural purposes outside the Central Valley (requiring a depth to groundwater estimate) only occur in the Coachella and Imperial Valleys. Approximate depth to groundwater and agricultural pumping costs for groundwater basins in CALVIN are summarized in Table G-1.

Table G-1. Agricultural Groundwater Pumping Variable Costs

Agricultural Subregion	CALVIN Groundwater Subbasin	1990 Lift (ft)	Drawdown (ft)	Change in Lift in 2020 (ft)	Total Dynamic Head (ft)	Unit Variable Cost (K$/taf)
CVPM-1	GW-1	130	20	0	150	30.0
CVPM-2	GW-2	120	20	1	141	28.2
CVPM-3	GW-3	100	20	-1	119	23.8
CVPM-4	GW-4	60	20	0	80	16.0
CVPM-5	GW-5	75	20	-1	94	18.8

CVPM-6	GW-6	70	20	1	91	18.2
CVPM-7	GW-7	95	30	19	144	28.8
CVPM-8	GW-8	110	30	3	143	28.6
CVPM-9	GW-9	80	20	2	102	20.4
CVPM-10	GW-10	60	20	-2	78	15.6
CVPM-11	GW-11	75	30	-2	103	20.6
CVPM-12	GW-12	90	30	-2	118	23.6
CVPM-13	GW-13	125	30	-5	150	30.0
CVPM-14	GW-14	350	30	2	382	76.4
CVPM-15	GW-15	210	30	-7	233	46.6
CVPM-16	GW-16	130	30	-11	149	29.8
CVPM-17	GW-17	130	30	-2	158	31.6
CVPM-18	GW-18	200	30	-4	226	45.2
CVPM-19	GW-19	310	30	4	344	68.8
CVPM-20	GW-20	310	30	-4	336	67.2
CVPM-21	GW-21	310	30	8	348	69.6
Owens Valley	GW-OW					
Coachella Valley	GW-CH					
Imperial Valley	GW-IM					
Notes:1990 Lift from cesdat.gms Drawdown from cesdat.gms 2020 Change in Lift from noactavc.gms						

Variable Costs of Artificial Groundwater Recharge

Artificial recharge operations conducted by agricultural users have been difficult to estimate. In many cases, this water is included in irrigation deliveries or agricultural diversions specified in other models. Various land application methods, such as filling leaky distribution system canals are used to recharge agricultural deliveries into the groundwater. For this preliminary CALVIN configuration, the estimated costs of operations and land for agricultural recharge are given in Table G-2.

Table G-2. Agricultural Artificial Recharge Operating Costs in CALVIN

CALVIN Groundwater Basin	CALVIN Link	Rural Area ($5/af)	Extensive Works[b] ($10/af)	Operating Cost[c] ($/af)
GW-14	C89_GW-14[a]	X	-	5.0
GW-16	C52_GW-16[a]	X	-	5.0
GW-17	C52_GW-17[a]	X	-	5.0
GW-18	C57_GW-18[a]	X	-	5.0
GW-19	C96_GW-19[a]	X	-	5.0
GW-20	C62_GW-20[a]	X	-	5.0
GW-21	C97_GW-21[a]	X	-	5.0
GW-OW	C117_GW-OW	X	-	5.0
GW-IM	C151_GW-IM[a]	X	-	5.0
Notes: [a] *Presently in CALVIN, there is zero capacity assigned to artificial recharge on these links.* [b] *Rural areas with extensive artificial recharge works* [c] *Operating cost is equal to the maximum of Rural Area or Extensive Works*				

URBAN WATER SUPPLY OPERATING COSTS

This section discusses issues related to the many different operating costs of urban water supply and explains how these costs are included in CALVIN. The variable costs of surface and groundwater use by urban areas are addressed, followed by those of artificial recharge, reclamation, and wastewater disposal. Water quality and its effects on the economics and operation of urban water supply are also considered. The method of translating these many supply-related cost issues into CALVIN operating cost inputs is then explained. Where possible, specific cost information for each CALVIN urban demand area has been developed. Otherwise, a regional or statewide average estimate is currently used. In many cases, existing cost data are extremely limited and tend to mix overhead, capital and operating expenses together, making it difficult to develop accurate variable cost inputs for CALVIN at this time. Data limitations are reported at the end of this appendix.

Variable Costs of Surface Water

Urban surface water variable operating costs in CALVIN address three cost components: water treatment, water quality damage related to salinity, and within service area distribution. The definitions and issues for each cost component are discussed in the context of different urban demand areas represented in the CALVIN model.

Water Treatment

Water treatment operating costs include the variable costs at treatment plants (i.e., electricity, chemicals, periodic maintenance and repair of equipment, etc.) for treating drinking water to meet required standards. Clearly, different water sources require different levels of treatment and therefore have different costs, both capital and operating. For example, currently, water from the Hetch Hetchy system operated by San Francisco is so pure that it requires only minor treatment consisting of chlorination or filtration and chlorination when mixed with local runoff (http://www.ci.sf.ca.us/puc/). In contrast, exported Delta water that is high in TOC, salinity, and other contaminants (bromide), requires more expensive treatment methods, from both a capital and operating perspective. Data from a variety of sources suggest that variable water treatment costs range from as low as several dollars per acre-foot for filtration and chlorination to as high as $50 to $100 per acre-foot for multi-staged treatment. Table G-3 shows some of the variation in reported current operating costs for drinking water treatment of different surface water sources and different treatment methods across the state. Both source water quality and treatment plant size, through efficiencies of scale, affect cost.

Table G-3. Surface Water Urban Operating Costs Data in California

Urban Area	Water Source	Variable Cost	Cost Elements	Source for Cost Data
Napa	North Bay Aqueduct	$22/af	treatment	West Yost Ass., Project No. 062-94-01.07, Technical Memoradum No.2, , Revised Mar 3, 1995
Napa	Stored local runoff	$32/af	treatment + local conveyance	“
Los Angeles (LADWP)	Los Angeles Aqueduct & SWP West Branch water mixture[b]	$17/af	treatment	Melinda Rho, LADWP, 1998

Santa Clara Valley	Local runoff	$48/af	treatment + local conveyance	SCVWD IWRP (1997),Vol 1, p.6-23
Sacramento	Folsom Lake	$60/af	treatment + with-drawal + local distribution	Jim McCormack, Sacramento Water Forum, 1998
Sacramento	Lower American and Sacramento Rivers	$100/af	Treatment + with-drawal + local distribution	Jim McCormack, Sacramento Water Forum, 1998
ACWD	Stored local runoff and South Bay Aqueduct water mixture	$22-$25/af	Treatment	ACWD (1995), Table X-4
MWD	Mostly CRA water with some SWP water	needed		
MWD	Mostly SWP water with some CRA water	needed		
SFPUC	Hetch Hetchy water	needed		
SFPUC	Stored local runoff and Hetch Hetchy water mixture	needed		
Davis	Groundwater	needed	O&M for well head chlorination	
MWD	Sacramento-San Joaquin Delta exports	$224/af	Estimated O&M costs for RO to remove bromide	CALFED (1999)
SWP Urban Contractor Agencies	Sacramento-San Joaquin Delta exports	$87/af	Estimated O&M for GAC	State Water Contractors (1997), Table 3, p. 26
SWP Urban Contractor Agencies	Sacramento-San Joaquin Delta exports	$15.3/af	Estimated O&M for ozone	State Water Contractors (1997), Table 4, p.27

Notes:

[a] *Because SWP has more TOC, the variable costs of treatment are $5/af more than for CR water due to increased use of chemicals and energy for removal (MWD and USBR 1998).*

[b] *Mixture estimated at about 2/3 SWP and 1/3 LAA water based on historic use. Assuming SWP, from other agencies' data in Table G-3, has a variable treatment cost of about $20-$25/af, variable treatment cost of LAA water is estimated at $2-$11/af.*

The empirical data in Table G-3 suggest three water quality tiers for estimating variable operating costs for treatment that might be used across the state when location-specific cost data are unavailable. The first tier would be very pure high Sierra water such as that from Hetch Hetchy, the LAA, or the Mokelumne River at about $5/af for variable treatment costs. The next tier would consist of typical surface water with average levels of contaminants (low to medium TOC), such as local runoff and Colorado River water at about $20/af. The final or third tier would be surface water with high levels of contaminants (high TOC or other pollutants), such as SWP Delta exports and lower valley water that has been exposed to wastewater discharges, agricultural discharges, and organic soils at about $30/af for treatment. These numbers would have to be corrected for any local conveyance, withdrawal, or other additional pumping costs at each location where knowledge permits.

With expected tightening of federal drinking water treatment standards and requirements (under the Safe Drinking Water Act amendments of 1996), the cost of treating Delta water for urban use will increase substantially by 2020 unless there are major breakthroughs in new treatment technology. These new standards and requirements involve limits on disinfection by-products (DBPs) and higher rates of pathogen removal, in particular Giardia and Cryptosporidium (CUWA 1998). Higher pathogen removal rates will affect most sources of surface water in California, forcing generalized use of enhanced coagulation and/or ozonation for disinfection (CUWA 1998; CALFED 1999). A proposed solution to the water quality problems associated with through-Delta water exports, particularly those related to drinking water treatment requirements, is the isolated facility (see infrastructure options in Chapter 3). It has been estimated that, with neither an isolated facility nor significant improvements to through-Delta conveyance, the increased variable costs of urban water treatment in 2020 attributable to these higher standards, will be $248/af (CALFED 1999). This great increase is due to the need to remove bromide in Delta water by membrane filtration, requiring large operating inputs of electricity. Bromide must be reduced from its present levels (averaging around 300 mg/l) to under 50 mg/l to avoid bromate (a DBP) formation under ozone treatment (CUWA 1998; Shum 1998). The incremental additional treatment cost of through-Delta conveyance over isolated conveyance is estimated, under these treatment assumptions, to be $224/af. This figure is $24/af less than the previous figure of $248/af because water through an isolated facility will still need additional ozone treatment in 2020 to achieve the higher levels of disinfection required by the new laws (CALFED 1999).

Urban areas affected by potentially large additional through-Delta water treatment costs consist of SWP and CVP importers south of the Delta, who treat and deliver imported surface water to their customers. Potentially, these areas include the CALVIN urban demand nodes of Contra Costa Water District, Santa Clara Valley, Stockton, Bakersfield, Santa Barbara-San Luis Obispo, Ventura County, Castaic Lake Water Agency, Antelope Valley, and all three MWD areas. Of those for whom imports are a small part of overall supplies, they may very well be able to blend water to avoid membrane filtration. Consequently, in following the recent CALFED economic screening analysis (CALFED 1999), only Delta exports to CALVIN urban areas of CCWD, SCV, and MWD incur the additional $224/af treatment cost, largely to remove bromide associated with through-Delta conveyance, over and above the conventional costs discussed above. Furthermore, because CCWD does not benefit from the isolated facility, it will incur this additional treatment cost under nearly all scenarios. Urban areas that deliver groundwater to customers and use imported Delta water only to recharge groundwater, such as Mojave River and San Bernardino Valley, are assumed to be unaffected by additional through-Delta water quality treatment costs.

<u>Water Quality Damage</u>

Apart from its impact on treatment requirements, water quality, particularly salinity, has economic impacts on consumers and implications for the recovery and productive use of discharged wastewater (i.e., for groundwater recharge, for reclamation, and for landscape or agricultural irrigation). In a major study of the urban costs of salinity in Southern California (MWD and USBR 1998), annual damages in 1998 were estimated at $0.50/af for each 1 mg/l of salt (TDS) above 100 mg/l in the quality of SWP Delta exports, holding Colorado River (CR) constant at 700 mg/l TDS (see Figure 2-21 of the study report based on 660 KAF of annual SWP imports). Likewise, for CR water, the annual damages amount to $0.68 /af for each 1 mg/l of salt above 500 mg/l in its quality, holding SWP salinity constant at 250 mg/l) (see Figure 2-22 of the report based on 990 kaf of CR water imports).

Historically and currently, average salinity of SWP and CR water has been 250 mg/l and 700 mg/l, respectively. Blending SWP water with Colorado River water has been the main strategy to mitigate salinity; however, it has been difficult meeting overall demands while also blending to maintain salinity levels of delivered water at around 500 mg/l. Assuming SWP water is 250 mg/l and Colorado River water is 700 mg/l TDS, incremental average water quality salinity damage costs amount to either $75/af on SWP water or $136/af on Colorado River water. With an isolated facility to bypass the Delta, export water salinity could decrease, potentially reducing salinity damage costs of SWP imports to Southern California.

Local Distribution

This cost component consists largely of pumping-related variable costs to distribute water through the pipe network and maintain system pressure within a service area. It is most influenced by service area topography. Local distribution costs are assumed to apply only to surface water, as groundwater pressurization is included in extraction pumping. Work done for other statewide analyses (CVPIA EIS, CALFED) developed regional estimates of the variable costs of local distribution and treatment shown in Table G-4. Assuming variable treatment costs based on the three proposed tiers of water quality (Table G-4, second column), regional average local distribution costs can be derived from the developed costs in Table G-4 for preliminary use in CALVIN.

Table G-4. Estimated Current Variable Local Distribution and Treatment Costs

Urban Region	Total Variable Cost ($/af)[a]	Estimated Treatment ($/af)	Local Distribution ($/af) (Total – Treatment)
Shasta Area	50	5	45
Sacramento Area	50	20	30
North Bay Aqueduct	75	30	45
SCVWD, South Bay, CVP Service	125	30	95
South Bay Aqueduct	125	30	95
CCWD	75	30	45
Central Valley Cities	50	30	20
Coastal Branch	100	30	70
MWD and S. Lahontan	125	30	95
Bakersfield (KCWA)	50	20	35
Hetch Hetchy to South Bay	125	5	120

Notes:
[a] *Includes treatment and local distribution, from urban water transfer spreadsheet analysis in CVPIA EIS*
[b] *Assumed, based on proposed 3 tier water quality variable treatment cost*

Source: USBR (1997)

Urban Surface Water Operating Costs in CALVIN

The three components of surface water operating costs discussed above must be applied appropriately to the surface water sources of each urban demand area in CALVIN. Table G-5 shows all surface water urban supply sources and their respective cost components, as applied in the present CALVIN model (see Policy 1a in Chapters 6 and 7). These are in 1995 dollar values.

This model version does not include an isolated facility option, but assumes 2020 drinking water treatment regulations are in place. Thus, additional 2020 water treatment costs and possible salinity damage costs associated with Delta exports are included in total operating costs on Delta water for direct use in urban areas such as CCWD, SCV, and MWD. For model runs that include an isolated facility, or through-Delta improvements with significant improvements to export water quality, adjustments to these treatment and salinity damage costs will have to be made.

Values in Table G-5 are independent of pumping and power costs for out-of-service area conveyance, which are discussed in the next section.

Table G-5. Urban Surface Water Operating Costs ($/af) in CALVIN[a]

CALVIN Urban Node	Water Source	CALVIN Link	Treatment (w/o IF)	Salinity Damage	Local Distribution + Conveyance[h]	Total $/af
Redding	Lake Shasta	SR-4 to Redding	5	-	45	50[j]
Yuba et al	Feather R.	SR-6 to C24	5	-	45	50
Yuba et al	Feather R.	C25 to C24	5	-	45	50
Yuba et al	Yuba R.	C31 to C24	5	-	45	50
Sacramento	Folsom Lake	SR-8 to T4	5	-	30	35
Sacramento	Lower American R.	D64 to T4	20	-	30+10	60
	Sacramento R.	C8 to T4	30	-	30+10	70
Napa-Solano	SWP via NBA	C22 to T14	30	-[c]	45	75
Napa-Solano	Berryessa via S. Putah Canal	C21 to T14	20	-	45	65
CCWD	Delta water at Rock Slough	D550 to CCosta PMP	30+224[g]	-[d]	45	299+sd
CCWD	Delta water at Old River	C309 to Old R PMP	30+224	-[d]	45	299+sd
CCWD	Delta water at Mallard Slough	D528 to MallSL PMP	30+224	-[d]	45	299+sd
CCWD	EBMUD Mokel-umne R. transfer	C201 to C71	5	-	45	-45
EBMUD	Mokelumne R.	C39 to WalCk PMP and to C201	5	-	95	100
EBMUD	CCWD Delta water transfer	C71 to C201	-[e]	-[e]	50 (95-45[l])	50
EBMUD	American R. transfer via S. Folsom	C173 to C39	0 (5-5[l]) to 15 (20-5[l])	-	-	0-15[b]
SCV	Local runoff	C315 to T7	20	-	95	115
SCV	SWP or CVP imports	D896 to T7 & D714 to T7	30+224	-[c]	95	349
SCV	Hetch Hetchy	SR-ASF to T7	5	-	95	100
SFPUC	Hetch Hetchy	SR-ASF to T20	5	-	120	125
SFPUC	SCV transfer	T7 to C97	-5[l]	-	-120[l]	-125[l]
Stockton	Stanislaus R.	C43 to T26	5	-	20	25
Stockton	Calaveras R.	C41 to T26	20	-	20	40
Fresno	Friant-Kern Canal transfer	C49 to T24	20	-	20	45
Bakersfield	KCWA purchase	C97 to T28	20	-[c]	20	40
Santa Barbara-San Luis Obispo	SWP Delta exports via CB	Badger PMP to D849	30+224	-[c]	70	324
Ventura County	SWP Delta exports via WB	SR-29 to C106	30+224	-[c]	95	349[j]
Castaic Lake WA	SWP Delta exports via WB	D888 to D889	30+224	-[c]	95	349
Antelope Valley	SWP Delta exports via WB	D884 to T6	30+224	-[c]	95	349
Antelope Valley	SWP Delta exports via EB	D868 to T6	30+224	-[c]	95	349
Mojave River	SWP Delta exports via EB	D871 to T3 (not used)	-	-	-	NA
El Centro et al.	Colorado R. via All	C312 to El	20	136	30	186[j]

	American Canal	Centro				
Central MWD	All including local	C161 to T5	-[e]	-[e]	95	95
Central MWD	LAA	C159 to C161	5	-	-[f]	5
Central MWD	SWP Delta exports via WB	D888 to C161	30+224	-	-[f]	254
Central MWD	SWP Delta exports via EB	D867 to C161	30+224	-	-[f]	254
MWD (all)	SWP Delta exports via EB	C129 to C138 & SR-27 to C140	30+224	-	-[f]	254
MWD (all)	Colorado R.	C136 to C138	20	136	-[f]	156
Eastern & Western MWD	All including local	C154 to T34	-[e]	-[e]	95	
San Diego	All including local	T40 to T30 & C156 to T30	-[e]	-[e]	95	

Notes:
[a] Without an isolated facility, all applicable urban areas incur $224/af additional treatment operating cost on Delta exports
[b] Depends on whether withdrawal point is from Folsom Lake or from the lower American River
[c] No salinity damage cost is used here because is is assumed that SWP water is blended with much larger quantities of other supplies to eliminate impacts
[d] Salinity damage costs vary by month as a function of Delta salinity at each location. A cost penalty is used to combine the fixed (299) and variable salinity costs into monthly varying operating costs for each source.
[e] This cost is already accounted for on an upstream CCWD Delta intake link
[f] This cost is accounted for on one of these downstream links: C161 to T5, C154 to T34, T40 to T30, or C156 to T30.
[h] Taken mainly from the last column of Table G-4
[g] Through Delta additional WT costs to remove bromide by membrane filtration
[i] Correction for cost on downstream or upstream link(s)
[j] Not actually included in CALVIN since this is a fixed diversion
[k] Additional charge for river withdrawal pumping cost

Variable Costs of Groundwater Supply

Urban groundwater costs in CALVIN include the variable costs of pumping and any treatment. In general, the only treatment required for groundwater is chlorination, done at the well head. Local distribution costs are not added to these groundwater variable costs because it is assumed that pressurization from extraction is sufficient to distribute groundwater in the pipe network.

Pumping and Chlorination

Variable urban groundwater pumping costs summarized in Table G-6 are largely based on interpretation of published groundwater extraction costs for urban areas and information contained in local watermaster and planning reports (WRDSC 1992; DWR 1997; DWR 1998; CVWD 1998; MWAW 1998). Besides energy and maintenance of pumping facilities, operating costs are assumed to include chlorination and collection works operations. Collection works refer to piping and other hydraulic works that may be employed to bring well water to a concentrated point where the groundwater is treated before distribution to urban customers. The accounting assumptions in published cost data are rarely defined so it is often unclear whether costs cited include all these variable components of groundwater pumping costs and exclude such fixed costs as capital investments, overhead, replacement, and/or additional distribution costs. In this phase of project work, no effort is made to verify the accounting basis of published cost data.

In areas without published cost estimates for groundwater pumping, estimates have been made based on costs in similar areas with published data. Operating costs for urban groundwater pumping by smaller dispersed and rural communities in the Central Valley, represented as fixed urban diversions at each CVPM groundwater subbasin, are not included in CALVIN because these groundwater extractions are fixed.

Table G-6. Urban Groundwater Pumping Variable Costs

CALVIN Urban Node	Groundwater Subbasin	Groundwater O&M Pumping Costs ($/af)	Source for Cost Estimate
Sacramento	GW-7	55	Jim McCormack (1998) and Table 6-6 of DWR (1993)
Sacramento	GW-8	55	Jim McCormack (1998) and Table 6-6 of DWR (1993)
Stockton	GW-8	70	Table 6-6 of DWR (1993)
Fresno	GW-16	80	Table 6-6 of DWR (1993)
Bakersfield	GW-21	128	Table 6-6 of DWR (1993)
SCV	GW-SC	85	Table 6-6 of DWR (1993)
Antelope Valley	GW-AV	70	DWR (1998) and Templin et al. (1995)
Mojave River Valley	GW-MJ	35	DWR (1998) and MBAW (1998)
Coachella Valley	GW-CH	50	DWR (1998) and CVWD (1998)
Central MWD	GW-OW	20[a]	(see Table G-1)
Central MWD	GW-MWD	30	DWR (1998) and WRDSC (1992)

Notes:
[a] *Based on $0.20 per af/ft lift and approximately 100 ft pumping lift taken from agricultural pumping cost estimates.*

Variable Costs of Groundwater Recharge

There are four different classifications or types of urban groundwater recharge (or return flow pathways to groundwater) considered in CALVIN. Each type is discussed next, along with its cost components and representation in CALVIN.

Deep Percolation of Urban Applied Landscape Water

A portion of urban applied water used for landscape irrigation deep percolates into the groundwater basin underlying an urban area. According to DWR (1998), approximately 20% of urban applied water, on a statewide average basis, returns to groundwater via this pathway. There is obviously no cost for this “natural” type of groundwater recharge. In CALVIN, this component is accounted for differently, depending on the type of urban demand node and groundwater basin it is associated with (see Appendix B1). For example, deep percolation recharge is explicitly modeled for economically represented urban demand nodes in the Central Valley as a fixed (lower bound) time series on the link from the wastewater treatment node to the appropriate CVPM groundwater basin. The deep percolation quantity is set equal to 20% of monthly maximum target demand for the respective urban area. For urban areas and groundwater basins outside the Central Valley, deep percolation is not explicitly modeled in CALVIN. The limited analysis of natural recharge for these groundwater basins indicates that deep percolation of urban applied water is included in the estimates of natural recharge taken from planning documents and used to construct inflow time series for these basins in CALVIN.

Incidental Recharge of Discharged Wastewater Return Flows

A portion of wastewater discharged into streams can end up infiltrating into the underlying groundwater basin. This recharge pathway is considered "incidental" to the location and timing of wastewater discharges and is highly variable in any given year. It is important mainly in groundwater basins underlying stream courses with little natural flow, either due to upstream water diversions or a dry climate.

Areas where incidental recharge from urban wastewater discharges may be an important component of groundwater balance in California include the Tulare Lake, South Coast, and South Lahontan hydrologic regions. In CALVIN, only the groundwater basins of the Tulare Lake and South Lahontan region are explicitly represented so that incidental recharge is included only on return links from urban areas in this region (Fresno, Bakersfield, Antelope Valley, and Mojave River). Any estimated incidental recharge amount is added to the cost-free deep percolation fixed volume (described above) prescribed on a direct link from the wastewater treatment plant node to the appropriate basin without cost. It is estimated as ¼ of the wastewater return flow volume or 10% of total urban applied water on a monthly basis, unless specific local documentation indicates that no such recharge occurs (as in Antelope Valley).

Sometimes, wastewater discharges can be managed to maximize the amount of streambed infiltration. When this occurs, by using barriers to retain wastewater at favorable infiltration sites, the recharge is no longer considered incidental but becomes "artificial" recharge and incurs costs described below under artificial recharge.

Artificial Recharge with Wastewater Return Flows (AR WW)

In the case where treated wastewater is directly recharged to an aquifer, an incremental wastewater reclamation treatment cost is assessed at $33/af. By law, direct recharge of reclaimed wastewater requires additional treatment to remove nutrients and further minimize health risks. This incremental cost reflects the difference between treatment of effluent for discharge to a water body (which is required at wastewater treatment plants and not included in the model) and treatment for direct recharge (Richard et al., 1992).

In the current version of CALVIN, urban areas with groundwater recharge where incremental wastewater treatment costs are incurred include SCV (T19 to GW-SC) and Coachella Valley (T11 to GW-CH). This type of direct recharge of wastewater also occurs in the Metropolitan Water District (MWD) service area. However, locally managed groundwater in the MWD service area has not been modeled explicitly in the current version of CALVIN. Only additional conjunctive use aquifer capacity for storing imported water is now modeled for the Central MWD CALVIN node.

Artificial Recharge with Imported or Local Surface Water (AR SW)

Conveyance and spreading operations variable costs are considered for artificial recharge of imported or local water supplies under the assumption that no pre-treatment is needed. Representation of these facility operating costs are explained next.

Operating Costs of Groundwater Recharge Facilities in CALVIN

This component of artificial recharge operating costs in CALVIN is intended to represent O&M of spreading basins and related works, and the opportunity cost of the land taken up by them. These cost elements are very difficult to specify because recharge O&M costs are rarely cited separately from capital costs and/or other groundwater banking project costs. Two preliminary cost estimates are applied statewide in CALVIN for this phase of the project: (a) $5/af in rural areas (unless they are known to have extensive recharge facilities) and in places that manage natural streambeds as recharge areas, and (b) $10/af in urban areas and in those rural areas or managed streambeds known to have extensive recharge facilities. The lower cost is indicative of lower land values and lower O&M costs to operate facilities in rural areas compared to urban areas. The higher $10/af cost reflects the higher value of urban land and higher urban operating costs. In one rural case, Mojave River Valley, $10/af was assigned for artificial recharge due to extensive piping network to bring water to the natural riverbed where water is recharged.

Groundwater basins with urban artificial recharge are listed in Table G-7. Cost components and assumptions are identified for each recharge link. Incidental recharge through unmanaged streambed infiltration and deep percolation of urban applied water, as explained above, are not included in this table, as they have no costs and have previously been identified in urban return flows summarized in Table B1-4 of Appendix B1.

Table G-7. Urban Artificial Recharge Operating Costs in CALVIN

CALVIN Groundwater Basin	CALVIN Link	Water Source	Facility Costs[b] ($/af)	Add'l Treatment ($/af)	Total Cost[c] ($/af)
GW-SC	T19 to C316	wastewater	-[d]	33	33
GW-SC	C316 to GW-SC	Imported + local + wastewater	10	-	10
GW-AV	D868 to GW-AV[a]	SWP imported water	5	-	5
GW-MJ	C124 to GW-MJ	SWP imported water	10	-	10
GW-CH	C145 to GW-CH	CR imported water	10	-	10
GW-CH	T11 to GW-CH	wastewater	10	33	43
GW-MWD[e]	C161 to GW-MWD	Imported + local surface water	10	-	10

Notes:
[a] Presently in CALVIN formulation, there is zero capacity assigned to this artificial recharge link.
[b] Based on rural or urban area and extent of artificial recharge facility works as described in text
[c] Total cost is sum of facility and any additional treatment variable costs.
[d] Accounted for on downstream link C316 to GW-SC
[e] This groundwater basin represents aggregated additional groundwater storage capacity in the MWD service area that has been identified for storing excess imported and local surface water and does not involve use of reclaimed wastewater.

Variable Costs of Recycling/Reclamation for Urban Use

The cost of recycled water is highly variable throughout the state depending on treatment plant location, operation, and conveyance available for generating and delivering recycled water to a local customer. It also depends on the recycled water treatment standards that must be met for the particular application. Because collecting reclamation plant specific data across the state is beyond the scope of this research project, we have taken general estimates from Bulletin 160-98 on the costs of recycled water and developed three costs levels.

<u>Non-potable Direct Use – Low Cost</u>

In DWR (1998), the low cost estimate of recycled water is $500 per acre foot and includes amortized capital as well as operating costs of producing and delivering urban recycled water for non-potable use. For purposes of this preliminary work, the variable component of this lower cost, first phase recycling is estimated at $350/af and applied statewide in CALVIN for all planned 2020 urban non-potable recycling capacity.

<u>Non-potable Direct Use – High cost</u>

DWR (1998) estimates the cost of additional higher cost non-potable urban recycling at $1000/af for capital and operating costs. This second tier (or phase) of recycling reflects higher distribution costs of delivering recycled supplies to the locations where additional volumes could be used, and higher reclamation treatment costs to retrofit or expand treatment at existing wastewater plants. For purposes of CALVIN, a statewide estimated variable cost of $830/af is assumed for these additional recycling activities which are not currently planned for 2020. This higher non-potable cost is not now applied in CALVIN, but would be used in modeling scenarios that examine the benefits of increased recycling capacity beyond planned 2020 capacity represented in the current model.

<u>Potable Indirect Use</u>

Discussions of using recycled water for potable use via indirect storage and mixing with other supplies is underway in various urban areas in the state (San Diego and Santa Clara Valley). Project estimates of variable operating costs suggest that additional treatment of wastewater for potable use before storage and mixing would require reverse osmosis treatment in addition to GAC and other high cost methods, bringing operating costs to $1000/af or more. Presently, no potable recycling projects are planned nor represented in CALVIN.

<u>Wastewater Discharge Impact Costs</u>

Studies suggest that a per acre-foot discharge fee may be imposed in the future on wastewater discharges into San Francisco Bay, which could be as high as $500/af (CALFED 1999). Since implementation of such a charge is still highly uncertain, no accounting has been made of this in CALVIN. However, if the issue is resolved and such a charge is retained, it can be added to CALVIN urban wastewater return flow links into San Francisco Bay.

GENERAL POWER BENEFITS AND CONVEYANCE COSTS

Hydropower

Two types of hydropower may be addressed: constant elevation drop and variable elevation drop reservoir hydropower.

Constant head hydropower

Using data from DWR Bulletin 132-97, an average unit kWh/af was calculated by dividing 1996 power delivered (Table 11-2, in $/kWh) by 1996 water deliveries (Table B-6, in af) for each power plant. Assuming a statewide $0.07/kWh for all large-scale energy operations, SWP power plants averaged $0.07/af/ft of head. This number was applied to every power station represented in CALVIN as revealed in Table G-8.

Variable head reservoir hydropower

Power generated from reservoirs is usually highly dependent on the reservoir levels, continuously changing with varying releases, inflows, and evaporation. Although this element of hydropower is not included in this initial analysis, it is not beyond the capabilities of CALVIN and has been included in past studies using HEC-PRM (Citations?).

Table G-8. Power Plants Included in Initial CALVIN Study

CALVIN Name	Description	Link	Operator	Drop (ft)	Benefit ($/af)
AAC PWP	All American Canal	AAC PWP_C151	IID	175	12.25
Alamo PWP	Alamo	Alamo PWP_D868	DWR	118	8.26
Cast PWP	Castaic	Cast PWP_D887	DWR/ LADWP	1,048	73.36
Devils PWP	Devil Canyon	Devil PWP_C129	DWR	1,357	94.99
Gian PWP	Gianelli	Gian PWP_D816	DWR	197	13.79
Mojave PWP	Mojave Siphon	Mojave PWP_SR-25	DWR	106	7.42
ONeill PWP	ONeill	ONeill PWP_D712	USBR	50	3.50
Owen1 PWP	Mono Basin	Owen1 PWP_C114	LADWP	2,300	161.00
Owen2 PWP	Owens Valley	Owen2 PWP_C122	LADWP	1,960	137.20
Warne PWP	Warne	Warne PWP_SR-28	DWR	650	45.50

Pumping Costs

Surface water pumping costs were included in this initial study where data were readily available. Pumping costs for local distribution systems within the service area of each agricultural or urban demand area are included implicitly in the agricultural value functions and explicitly in urban surface water operating costs (see previous section). Data for surface water pumping costs were most readily available from DWR, and this information was extrapolated to other systems.

SWP Pumping Plants

Using data from DWR Bulletin 132-97, an average unit kWh/af was calculated by dividing 1996 power delivered (Table 11-1, in $/kWh) by 1996 water deliveries (Table B-6, in af) for each pumping plant. Assuming a statewide $0.07/kWh for all large-scale energy operations, SWP pumping plants averaged $0.09/af/ft of head. Multiplying $0.09/af/ft of head by each pumping head for each pumping plant results in $/af cost, as revealed in Table G-9.

An exception to this methodology is the CRA pumping plants, which purchase relatively inexpensive power from Parker and Hoover Dams, approximately $0.01/kWh. Thus, CRA pumping costs were multiplied by $0.013/af/ft of head (or 1/7 the average pumping costs).

Table G-9. Pumping Plants Included in Initial CALVIN Study

CALVIN Name	Description	Link	Operator	Lift (ft)	Cost ($/af)
Badger PMP	Badger Hill	Badger PMP_D849	DWR	187	16.83
Banks PMP	Banks	Banks PMP_D801	DWR	249	22.41
Buena PMP	Buena Vista	Buena PMP_D860	DWR	209	18.81
CCosta PMP	Contra Costa	CC1 PMP_SR-LV	CCWD	124	11.16
Chrism PMP	Chrisman	Chrism PMP_D864	DWR	524	47.16
CRA PMP	Colorado R. Aqueduct	CRA PMP_C136	MWD	1,617	21.25
DValle PMP	Del Valle	DValle PMP_SR-15	DWR	60	5.40
DAmigo PMP	Dos Amigos	DAmigo PMP_D744	DWR/ USBR	125	11.25
East PMP	Eastside Reservoir	East PMP_SR-ER	MWD	235	21.15
Edmons PMP	Edmonston	Edmons PMP_C103	DWR	1,970	177.3
Gian PMP	Gianelli	Gian PMP_SR-12	DWR	290	26.10
IF PMP	isolated facility	IF PMP_D59	?	NI	NI
LPeril PMP	Las Perillas	LPeril PMP_Badger PMP	DWR	61	5.49
LBG PMP	Los Banos Grandes	LBG PMP_SR-22	USBR	NI	NI
LV PMP	Los Vaqueros	LV PMP_SR-LV	CCWD	285	25.65
MallSL PMP	Mallard Slough	MallSL PMP_C71	CCWD	0	0
Old R PMP	Old River	Old R PMP_C310	CCWD	285	25.65
ONeill PMP	O'Neill	ONeill PMP_D814	USBR	50	4.50
Oso PMP	Oso	Oso PMP_D884	DWR	238	21.42
PB PMP	Pearablossom	PB PMP_C124	DWR	569	51.21
SBay PMP	South Bay	SBay PMP_D891	DWR	611	54.99
Tracy PMP	Tracy	Tracy PMP_D701	USBR	240	21.60
WalCk PMP	Walnut Creek	WalCk PMP_C201	EBMUD	NI	51.80
WR PMP	Wheeler Ridge	WR PMP_D862	DWR	209	18.81

Notes:
NI = Information needed; not included in initial CALVIN study

LIMITATIONS AND OBSERVATIONS

In the literature, it is often difficult to decipher what is and is not included in published cost estimates. Often capital investment is included with operating costs. Also, costs are often lumped totals that include different sources and qualities of water, making it even more difficult to break out costs by source and type. Sometimes this is due to standard data format of reports or because microlevel information is not always tracked within agencies, especially if water is mixed before treatment and/or distribution. Finally, some agencies are reticent to publish microeconomic data that they consider confidential information. By definition, the costs utilized in CALVIN should represent operating costs only, meaning variable O&M. Efforts were made to exclude capital costs. In a future phase II of this project, operational costs in CALVIN should be revisited, with a closer examination of the components of published costs.

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