CHAPTER 3

CURRENT STATEWIDE INFRASTRUCTURE OPTIONS

“To try to achieve anything is like digging a well. You can dig a hole nine fathoms deep, but if you fail to reach the source of water, it is just an abandoned well.” Mencius (China, circa 300 B.C.) Book VII, PartA, 29.

The Department of Water Resources (DWR) and CALFED are currently considering many different statewide infrastructure options as possible long-term solutions to California’s water scarcity problems. Statewide options in the 1998 California Water Plan update include State Water Project (SWP) reliability improvements, water marketing, multipurpose reservoir projects, and the CALFED Bay-Delta Program (DWR 1998a). CALFED has retained 14 surface water and 16 groundwater storage projects for further study in its Revised Phase II Report (CALFED 1998a). USBR is investigating ground water storage sites throughout the Central Valley to replace water dedicated to the environment by the Central Valley Project Improvement Act (CVPIA) (DWR 1998a). Local agencies continue to consider specific local and regional options.

Many of the options under consideration have been studied and proposed previously. While surface storage continues to be an option, the emphasis has shifted to off-stream and existing storage sites. Groundwater storage and water treatment methods also are increasingly important. Conveyance options can improve the reliability of water deliveries and offer mitigation of environmental impacts. This chapter discusses the current spectrum of infrastructure options, from new surface and groundwater storage to conveyance and treatment methods. Non-structural options, such as water marketing and coordinated operations, and their implications for operational, economic, and financial effectiveness are discussed in Chapter 4.

CONTEXT FOR CURRENT OPTIONS

Water in California can be delivered to environmental, urban, and agricultural uses by the Central Valley Project (CVP) and the SWP, from the Colorado River and other federal projects, and through many local projects. The CVP is the largest water supply system with seven main reservoirs constructed starting in the 1930’s through the 1970’s by the Federal government and having a combined storage capacity of 12 maf (DWR 1998a). The SWP has ten major reservoirs that were constructed during the 1960’s and 1970’s with a combined storage capacity of 5.5 maf (DWR 1998a). In both 1977 and 1991 CVP and SWP deliveries were curtailed significantly by drought.

Major local urban supply projects include the Colorado River, Mokelumne, Los Angeles, and Hetch Hetchy Aqueduct systems constructed, respectively, by the Metropolitan Water District of Southern California (MWD), the East Bay Municipal Utility District (EBMUD), Los Angeles, and San Francisco. These systems have historically produced average annual yields of 1,000 taf, 240 taf, 400 taf, and 270 taf, respectively. The most recent major urban project underway is the Eastside Reservoir being constructed by MWD in Riverside County to better manage wet and dry year fluctuations in SWP and Colorado River deliveries. To be completed in 1999, the 800 taf reservoir will provide a six month disaster emergency supply, drought protection, and peak summer supply.

Major agricultural supply projects include the All-American and Coachella Canals of the Colorado River system constructed in 1938 and 1947, respectively by United States Bureau of Reclamation (USBR) (DWR 1987), the Turlock Irrigation District (TID)/Modesto Irrigation District (MID) system of canals and reservoirs, the Glenn-Colusa Canal, and so on. For further discussion of the origins and historic development of the CVP, SWP, Colorado River and other major projects in California see Bain et al. (1966), Pisani (1984), Gottlieb and Fitzsimmons (1991), and Hundley (1992).

Since construction of the main elements of the SWP, expansion of water supply infrastructure has been very incremental. Following approval of the 1957 California Water Plan, many supply augmentation options have been recommended. Some options have been implemented, others rejected, and still others resurface periodically as summarized in Table 3-1.

Table 3-1. DWR Historic Recommendations for Water Supply Infrastructure[a]

Water Plan Update	Proposed River Development	Proposed Reservoirs	Proposed Conveyance (Canals, Aqueducts, Pipelines)
1966	Mad Van Duzen Trinity Eel	Marysville, Auburn, Spencer, Dos Rios, **New Don Pedro** (1971), **Buchanan** (1975), **New Melones** (1979), **Hidden** (1979)	Folsom South, Peripheral, West Sacramento, East Side **North Bay** (1987), **Coastal** (1968), **California** (1972)
1970	Cottonwood Thomes-Stony Creek	Marysville, Auburn	Folsom South, Peripheral, West Sacramento, East Side **San Felipe** (1987)
1974	Mad Eel Cottonwood Thomes-Stony Creek	Marysville, Auburn, Dutch Gulch, Tehema	Peripheral, Mid-Valley, **Cross Valley** (1975)
1983	Cottonwood Creek	Auburn, Dutch Gulch, Tehema, Shasta Enlargement, Los Banos Grandes	Folsom South, Mid-Valley, Delta Transfer Facility
1987		Auburn, Los Banos Grandes **Kern Water Bank** (transferred to Kern Water Bank Authority prior to completion)	Mid-Valley, Delta Improvement **East Branch Enlargement** (1996)
1993		Auburn, Los Banos Grandes **Eastside** (1999)	**Coastal Phase II** (1997) **Morongo Basin** (1994)
1998		Auburn, Friant Enlargement, CALFED	ISDP, CALFED

Notes:
[a] *Recommended options shown in* ***bold*** *have been constructed with work completed or expected complete in the year given in parentheses*

Source: DWR (1966, 1970, 1974, 1983, 1987, 1993, and 1998a)

The last century has seen the examination of hundreds, if not thousands, of potential reservoir sites in California. The last few decades have seen a more serious examination of off-stream and groundwater storage options. The feasibility of large, watershed-type projects consisting of several new on-stream reservoirs has declined with fewer suitable sites, rising costs, and rising environmental concerns. With passage of the Federal and California State Wild and Scenic Rivers Acts, further development of many North Coast rivers and sections of the American River was precluded. By 1987, most new on-stream reservoir water supply options had been abandoned in order to concentrate on conveyance and additional off-stream storage.

SURFACE WATER STORAGE OPTIONS

Currently proposed new surface water storage options include facilities at on-stream, off-stream, off-aqueduct and in-Delta locations. These options are reviewed and summarized in tables below. The classification of some options as on-stream or off-stream by DWR and CALFED differs. The most recent status of options was reported in CALFED's Revised Phase II Report (CALFED 1998a).

Very preliminary cost estimates are provided for some of these options. CALFED surface storage cost estimates (CALFED 1998a) were initially restricted to environmental documentation and pre-permitting studies. In further developing alternative cost summaries, CALFED (1998b) averaged total capital costs of selected project combinations and then applied these average costs to target regional storage capacities without distinguishing between on-stream and off-stream storage. At a 3 maf development level, Sacramento River tributary surface storage was estimated by CALFED, according to these procedures, to cost $2.9 billion for capital costs, or an average of $954 per acre-foot of storage. San Joaquin River tributary surface storage at a 240 taf level of development was estimated to cost $330 million or $1375 per acre-foot of storage. These estimates are the basis for CALFED costs reported in the following discussions and summary tables unless otherwise noted.

On-Stream Storage Options

On-stream options are summarized in Table 3-2. Of these, Shasta and Millerton Lake enlargements are the only two on-stream options retained by CALFED in its Revised Phase II Report (1998a). This report discontinued pursuit of any new on-stream sites and ended further speculation about Auburn Dam and other previously considered new reservoir construction. Several of the DWR proposed on-stream sites in Table 3-2 are now configured as off-stream sites among CALFED options (see Table 3-3).

Table 3-2. On-Stream Surface Water Storage Options

Reservoir Site	DWR Storage (maf)	DWR Cost Estimate[d] ($M)	CALFED Cost Estimate ($M)	CALFED Storage (maf)
Thomes-Newville[b]	1.4 - 1.9			-
Red Bank[a]	0.35			-
Tehama[a]	0.5 - 0.7			-
Dutch Gulch[a]	0.7 - 0.9			-
Shasta (enlargement)[b]	up to 10 additional	$123 to $5,800		0.29 additional
Kosk[c]	0.8			-
Millville[a]	0.1 - 0.25			-
Wing[a]	0.25 - 0.5			-
Auburn[b]	0.85 - 2.3	$2,300 at 2.3 maf		-
Folsom (enlargement)[b]	0.37 additional			-
Millerton (enlargement)[b]	0.5 - 0.9 additional	$580 at 0.5 maf		0.72 additional

Notes:

[a] Evaluated by DWR as first tier storage facilities for CALFED alternatives

[b] Evaluated by DWR as second tier storage facilities for CALFED alternatives

[c] Evaluated by DWR as third tier storage facilities for CALFED alternatives

[d] DWR estimates: Shasta: preliminary study estimates, Auburn: capital costs in 1995 dollars, Millerton: in 1997 dollars, does not include property purchase, mitigation, utility relocation

Sources: CALFED (1998a, 1998b), DWR (1998a)

Millerton Lake is the 520 taf reservoir behind Friant Dam on the San Joaquin River. Increasing the capacity of Millerton Lake is expected to provide supply for CVP water users, fish and wildlife; increase flood control; and improve San Joaquin River water quality with some negative effects on riparian wildlife habitat and infrastructure (DWR 1995b). Instream flow requirements below Friant Dam may change in quantity and timing of required release by an enlargement of Millerton Lake (DWR 1998a). Impacts of such changes are unknown at this time.

Shasta enlargement options listed by DWR range from raising the dam 6 feet at a cost of $123 million to increasing the dam elevation by 200 feet (9.3 maf additional capacity) at a cost of $5.8 billion. DWR, in preliminary studies, cites 760 taf of supply in average years and 940 taf in drought years for a 9 maf increase in storage capacity. These substantial increases in supply also involve unquantified, but probably substantial, financial and environmental consequences. Raising the dam at Shasta Lake 6.5 feet for a 290 taf increase in storage capacity is among the existing reservoir options retained for further CALFED consideration (CALFED 1998a).

Off-Stream Storage Options

Most off-stream storage options listed in Table 3-3 have passed DWR preliminary evaluation and have been retained by CALFED for further consideration (CALFED 1998a). Thomes-Newville and Red Bank are retained by CALFED with some differences in capacity from DWR's evaluation. Thomes-Newville is potentially larger and the Red Bank Project is limited to the Schoenfield Reservoir (CALFED 1998a). The Sites and Colusa off-stream sites were the most promising options identified in DWR's evaluation of very large reservoirs with few environmental concerns listed and minimal impacts assumed. CALFED (1998a) has retained these two options, with similar storage capacities to those of DWR, for further evaluation and screening.

Glenn Reservoir was evaluated by DWR as "second tier" (less environmentally and economically feasible) because of supply uncertainty. It is more likely that the smaller off-stream options that are part of the proposed Glenn Reservoir, such as Thomes-Newville, will be accepted. Berryessa is also second tier because of financial and environmental concerns. Off-stream conveyance of water to Berryessa would require a 31-mile facility with a 700 foot lift and both wildlife habitat and human activities would be negatively affected (DWR 1998a). CALFED (1998a) has not retained Berryessa as a potential reservoir site. Montgomery Reservoir, potentially located on Dry Creek upstream of the confluence with the Merced River, is considered a local option by DWR (1998a), providing drought year supply and collecting flood spills from Lake McClure on the Merced River. CALFED lists Montgomery Reservoir as a potential part of the Bay-Delta Program with an estimated price of $330 million.

Off-Aqueduct Storage Options

Storage south of the Delta has been studied for many years as an important component of SWP reliability. In DWR's evaluation of off-aqueduct storage south of the Delta, preliminary modeling results (DWR 1998a) showed that a few large reservoirs (500 taf or more) imposed less of a cumulative environmental impact than several smaller reservoirs. DWR storage ranges below 500 taf are included in Table 3-4 for easier comparison with CALFED off-aqueduct storage options. The evaluated storage options were ranked first by size, then by cost and environmental sensitivity. The five most favorable watersheds are listed first in Table 3-4 with all related dam sites. CALFED includes a substantial enlargement of the recently completed 100 taf Los Vaqueros Reservoir but does not include Los Banos Grandes (LBG) among the reservoir sites retained in its Revised Phase II Report (1998a).

Table 3-3. Off-Stream Surface Water Storage Options

Reservoir Site	DWR Storage (maf)	DWR Cost Estimate ($M)	CALFED Cost Estimate ($M)	CALFED Storage (maf)
Berryessa (enlargement)[b]	up to 11.5 additional			-
Thomes-Newville[a]	1.4 – 1.9			1.8 - 3.1
Glenn[b]	6.7 – 8.7			-
Sites[a]	1.2 – 1.8			1.2 - 1.9
Colusa[a]	3.0			3.3
Red Bank[a]	0.35			0.25
Montgomery	0.24 (local option)	$300/af [c]	$330 [d]	0.24

Notes:

[a] *Evaluated by DWR as first tier storage facilities for CALFED alternatives*

[b] *Evaluated by DWR as second tier storage facilities for CALFED alternatives*

[c] *Drought year cost for around 35 taf yield, not in millions of dollars, DWR preliminary cost estimate for the project is $135 million*

[d] *CALFED estimate is for total capital costs based on combined average method (see discussion in text)*

Sources: CALFED (1998a, 1998b), DWR (1998a)

Table 3-4. Off-Aqueduct Surface Water Storage Options

Watershed	Dam site	DWR Storage (taf)	DWR Unit Cost[a] ($/af of storage)	CALFED Storage (taf)
Garzas Creek	104	250 - 1750	2950 - 1310	139 – 1754
	105	290 - 630	2400 - 1660	
	106	100 - 310	3300 - 1820	
	107	100 - 250	3300 - 2020	
	108	100 - 250	4010 - 2870	
	109	500 - 940	2250 - 1730	
Ingram Canyon	37	250 - 980	3120 - 1400	333 - 1201
LBG/ Los Banos Creek	181	100 - 2000	3350 - 550	
Orestimba	170	250 - 900	2630 - 1410	380 - 1140
	171	250 - 1140	3000 - 1600	
Panoche/Silver Creek	112	250 - 1000	2250 - 1320	160 - 3100
	111	100 - 240	3480 - 2020	
	114	250 - 2000	3560 - 1210	
	45	500 - 990	2300 - 1920	
Los Vaqueros (enlargement)			2500 (CALFED estimate)[b]	965 additional
Quinto Creek	54	110 - 250	3120 - 2370	332 - 381

Notes:

[a] *These estimated capital costs are based on previous cost estimates developed for Los Banos Grandes facilities (DWR 1998a)*

[b] *From CALFED (1998b) for total capital costs*

Sources: CALFED (1998a, 1998b), Appendix 6G of the California Water Plan Update (DWR 1998a)

Authorized in 1984, the feasibility of LBG as an off-stream storage project was being reassessed in 1993 as Delta rules and regulations changed and SWP contractors expressed concern about costs. In the 1998 DWR evaluation of potential CALFED water storage facilities, Los Banos Grandes was found to be simultaneously the most cost effective and least environmentally sensitive site. In the most recent evaluations by CALFED (1998a), LBG is not retained as an off-aqueduct storage option.

In-Delta Storage Options

CALFED also considers water storage on Delta islands as possible options. Some preliminary studies were done on the flooding of Victoria, Woodward, and Bacon Islands with total capital costs estimated at $1.14 billion (CALFED 1998b). The Delta Wetlands Project, being developed privately, offers Bacon and Webb Islands as reservoirs and proposes two other islands for wildlife habitat (Jones & Stokes Associates Inc. 1995).

Table 3-5. In-Delta Surface Water Storage Options

Reservoir Islands	Storage Capacity	Cost estimates
Victoria, Woodward, Bacon	--	$1.14 billion (CALFED)
Bacon , Webb	250 taf combined	$200 - 250/af for marketed water (private development and estimate)

Sources: Jones & Stokes Associates Inc. (1995), CALFED (1998b)

NEW CONVEYANCE OPTIONS

Generally, canals have been associated with irrigation and agricultural endeavors while aqueducts (pipelines) bring water to cities. Continuing this tradition, the CVP, mainly an agricultural water supplier, has the Delta-Mendota, Folsom South, Contra Costa, Friant-Kern, and Madera Canals. In contrast, the SWP, more of an urban water supplier, has the California Aqueduct with its East, West, and Coastal Branches, and the North and South Bay Aqueducts. As major development of rivers in California has slowed, associated conveyance development has likewise been slowed. For example, instream flow requirements and uncertainties surrounding construction of Auburn Dam have suspended further expansion of the Folsom South Canal and its continuation down the Sierra foothills as the proposed East Side Canal. Intended to remedy groundwater overdraft in the San Joaquin Valley, the East Side Canal option has been replaced by proposed conveyance via an alternate route to achieve this objective (see discussion of the Mid-Valley Canal below).

Nearly all new conveyance facilities proposed by the DWR and CALFED (shown in Table 3-6) directly involve the Delta. As the hub of the California water system, effective transfer of water from north to south is a critically important Delta function. The exception in Table 3-6 is the Mid-Valley Canal designed to bring water to recharge areas of serious groundwater overdraft in the San Joaquin and Tulare Lake hydrologic regions.

Interim South Delta Program

Two purposes of the Interim South Delta Program (ISDP) are to:

- improve the reliability of SWP deliveries by increasing the frequency of full pumping capacity at Banks Pumping Plant; and
- increase the dependability of local irrigation water by improving water levels and circulation in south Delta channels.

Of the five components composing the ISDP preferred alternative (Figure 3-1), three address SWP reliability, one improves fishery conditions, and one enhances local water supply dependability. The CALFED Bay-Delta Program concurs with the ISDP on the new intake structure at Clifton Court Forebay and on an operable barrier on Old River (to improve the survival rate of San Joaquin River salmon) but recommends that Clifton Court Forebay diversions be sized to meet the full Tracy Pumping Plant (CVP) export capacity of 4600 cfs. In addition, it proposes a physical intertie between SWP and CVP, connecting the Delta Mendota Canal (CVP) with the Clifton Court Forebay (SWP), to enhance system reliability for both. Cost estimates for two variations of this intertie are shown in Table 3-6. Additionally, a 400 cfs capacity intertie between the Delta Mendota Canal (CVP) and the California Aqueduct (SWP) was proposed in the Revised Phase II Report (CALFED 1998a).

Table 3-6. Conveyance Facilities

Project	Description	Cost estimate ($M)
Interim South Delta Program (DWR)	Five components leading to an average supply augmentation of 120 taf per year, or 125 taf in an average year and 100 taf in drought years	$53.9
CCFB/DMC Intertie[a] (CALFED)	1) New fish screens at Skinner and Tracy + 2800 linear ft. earth canal; 2) New fish screens at Skinner and Tracy + new intake at CCFB + 2800 linear ft. earth canal	$370 $400
DMC/CAA 400 cfs Intertie[b] (CALFED)	Up to 400 cfs of pumping from the DMC to the CAA possible to overcome conveyance impediments downstream	
5,000 cfs Isolated Facility (CALFED)	Open, unlined channel, diversion at Hood, and siphon under major waterways	$1,100
15,000 cfs Isolated Facility (CALFED)	Open, unlined channel, diversion at Hood, and siphon under major waterways	$1,700
Mid-Valley Canal (DWR)	Beginning at either the CAA or an enlarged DMC, with a north branch nearly parallel to the Madera Canal and a south branch nearly parallel to the Friant-Kern Canal	$600 - $700[c]

Note:
[a] *CCFB = Clifton Court Forebay (SWP), DMC = Delta Mendota Canal (CVP)*
[b] *DMC = Delta Mendota Canal (CVP), CAA = California Aqueduct (SWP)*
[c] *Cost in 1980 price levels from DWR (1983)*

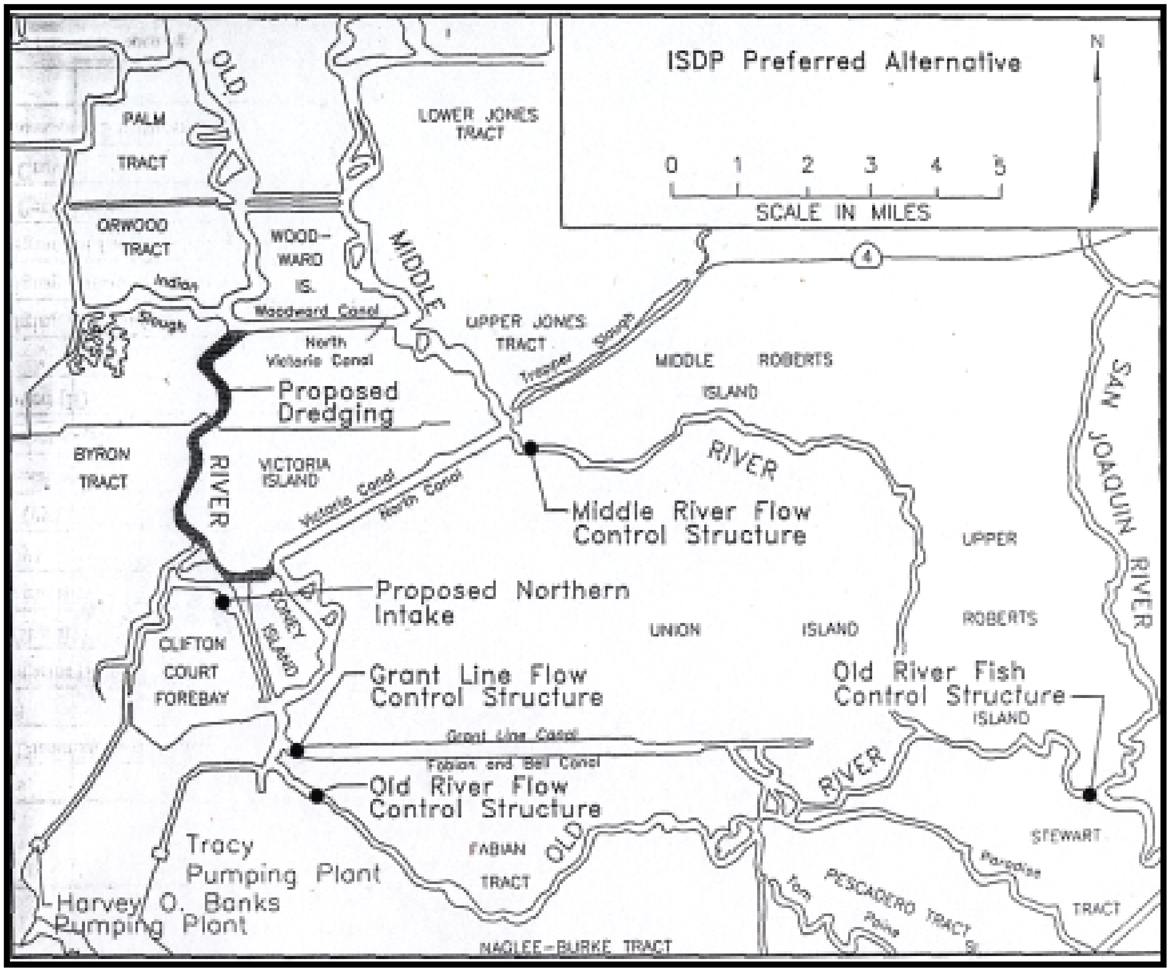
Sources: DWR (1983, 1996), CALFED (1998a, 1998b)

“CALFED’s strategy is to develop a through-Delta conveyance alternative based on the existing Delta configuration with some modification, evaluate its effectiveness, and add additional conveyance and/or other water management actions, if necessary, to achieve CALFED goals and objectives” (CALFED, 1998a). Other CALFED modifications and proposed actions to develop through-Delta conveyance include changes in dredging practices, some channel modifications, and the reconstruction of all Delta levees “to a particular standard…[possibly the USACE] PL 84-99 standard” (CALFED 1998a). With ISDP, full export capacity would be possible from the Delta. Only if these fail will an isolated facility be pursued.

Isolated Facility

Potential CALFED isolated facility configurations are sized from 5,000 to 15,000 cfs. If constructed, the facility would move water in a new canal or pipeline from a Sacramento River diversion at Hood to Clifton Court Forebay. A 5,000 cfs facility could convey about one-third of the full export capacity of the SWP and CVP facilities while a 15,000 cfs facility could supply full export capacity. The main purpose is improvement of export water quality and quantity. By avoiding contact with Delta water via an isolated facility, the salt content and organic compounds of water conveyed south of the Delta are reduced. The impact of an isolated facility on water quality within the Delta is less clear, although entrainment of aquatic species would certainly decrease.

Figure 3-1. Interim South Delta Program Components



Notes: Five project components:

1. *construction and operation of a new intake structure at the SWP Clifton Court Forebay*
2. *channel dredging along a reach of Old River just north of Clifton Court Forebay*
3. *construction and seasonal operation of a barrier in spring and fall to improve fishery conditions for salmon migrating along the San Joaquin River*
4. *construction and operation of three flow control structures to improve existing water level and circulation patterns for agricultural users in the south Delta*
5. *increased diversions in Clifton Court Forebay up to a maximum of 20,430 acre-feet per day on a monthly averaged basis resulting in the ability to pump an average of 10,300 cfs at Banks Pumping Plant*

Source: DWR (1996)

CALFED describes the isolated facility as a likely option for the future only if through-Delta conveyance proves an ineffective means of attaining CALFED Bay-Delta Program goals and objectives. More water storage and an intertie between the CVP and the SWP just south of the pumping plants is expected to increase the possible transfer opportunities through the Delta, while the development of procedures for Delta water transfers enlarges access. Proposed procedures to resolve difficulties encountered in cross Delta transfers include more flexible operating criteria, procedures for access to facilities, and disclosure of transfer windows and risk factors.

Non-Delta Conveyance Options

The purpose of a Mid-Valley Canal is not to bring new agricultural land into production. The 1994 Water Plan update identifies the Mid-Valley Canal as “the best option to develop a long-term solution to the valley overdraft problem” (DWR 1994a). The 1998 update (DWR 1998a) concurs and adds the enhancement potential for wetlands, wildlife habitat, and recreation. CALFED (1998a) does not specifically mention a Mid-Valley Canal but assumes its existence for two groundwater storage options south of the Delta (see Table 3-7). However, this canal option depends on a sufficient increase in water transferred through the Delta, as do most storage options already mentioned.

GROUNDWATER STORAGE OPTIONS

Groundwater storage options were divided into the following categories in Bulletin 160-70: terminal regulation of imported water supplies; regulation of surplus imported water; and conjunctive use. Terminal regulation provides a buffer between uniform monthly deliveries and non-uniform monthly demands. Regulation of surplus water and conjunctive use perform the same service of storing excess water during wet years for latter use in dry years. The 1998 California Water Plan update (DWR 1998a) lists three constraints on using groundwater storage: availability of recharge water; availability of storage capacity; and the wheeling capability of conveyance. Hydrologic regions vary in the severity of these constraints. Although the San Joaquin Valley has over 50 maf of available aquifer storage capacity, limited recharge water availability constrains the amount of water that can be stored in the ground (DWR 1998a). In contrast, the Sacramento Valley has recharge water but aquifer storage availability is constrained. In the following discussion, groundwater storage options are divided by location north or south of the Delta. Conjunctive use options, discussed at the end of this section, coincide with some of these storage locations.

Groundwater Storage Options North of Delta

Table 3-7 shows groundwater storage options that are being investigated north of the Delta by a variety of agencies. Among the list are nine potential locations north of the Delta included in CALFED’s (1998a) preliminary storage inventory. These locations are not specific and in most cases quantities are not determined, pending further study. Total Sacramento Valley groundwater storage for conjunctive use is assumed to be around 250 taf (CALFED 1998a). A representative capital cost for this total storage volume is $57.9 million or $232 per acre-foot of storage. This estimate is derived from the average of the storage capacities and total capital costs for three potential locations (Eastern Sutter County, Thomes Creek Fan, and Yuba County). As an element of CALFED's ongoing Integrated Storage Investigation, groundwater and conjunctive use will be a continuing and important focus (CALFED 1999e).

In the 1998 California Water Plan update, DWR presented groundwater storage options from USBR's *Least Cost CVP Yield Increase Plan*. Locations for these options, reported in Table 3-6, are also general, with each reference to a city in Table 3-6 indicating a different feasible site. Storage capacities for these sites are estimated for comparison purposes. Within Glenn and Yuba Counties the annual yield listed is for predicted developable yield. Yield for the other DWR/USBR options in Table 3-7 is based on active recharge from flood flows on adjacent rivers (DWR 1998a).

Table 3-7. Groundwater Storage Options North of the Delta

General Location	Program/Source	Capacity (taf)	Annual Yield (taf)	Estimated Cost of Storage
Butte Basin	CALFED			
Cache Creek Fan	CALFED			
Colusa County	CALFED			
East Sutter County	CALFED	280		$240/af
Sacramento County	CALFED			
Stony Creek Fan	CALFED			
Sutter County	CALFED			
Thomes Creek Fan	CALFED	220		$245/af
Yuba County	CALFED	280		$213/af
SW and W of Orland, Tehama Colusa Canal and vicinity Within Glenn County	DWR/USBR[a]	360[b] N/A[b]	90 55	
S of Chico, near Wheatland, E. of Sutter Bypas, and NE of Rio Linda Within Yuba County	DWR/USBR[a]	280[b] N/A[b]	85 25	
NW of Woodland and SW of Davis (near Dixon), Yolo Bypass nearby	DWR/USBR[a]	120[b]	30	
NE of Galt, SE of Elk Grove, SE of Lodi, and S of Manteca	DWR/USBR[a]	400[b]	185	

Notes:

[a] *Taken from USBR's "Least Cost CVP Yield Increase Plan"*

[b] *"Capacity is taken to be the amount of water that can be recharged and extracted over any area without causing a water level fluctuation of more than 30 feet compared to historical water levels and has been estimated using a large-scale regional [groundwater] model. Values are not maximums and are used for comparison purposes." (DWR 1998a)*

Sources: CALFED (1998a, 1988b), DWR (1998a)

Groundwater Storage Options South of Delta

Table 3-8 shows groundwater storage options that have been investigated south of the Delta. Total groundwater storage capacity south of the Delta for conjunctive use from among the seven CALFED locations in Table 3-8 is assumed to be around 500 taf (CALFED 1998a). This average capacity and total capital costs of storage were determined using the Kern River Fan, Madera Ranch, and Folsom South Canal Area locations (the Folsom South option is not included in the Revised Phase II Report). At 500 taf of groundwater storage development, the representative total capital cost estimate is $137 million or $237 per acre-foot of storage.

DWR considers two of the south-of-Delta CALFED groundwater storage options as local supply. The 1998 California Water Plan update lists Stockton East as a local option, with re-operation of Farmington Reservoir on Littlejohns Creek of the Stanislaus River for year-round groundwater recharge to reduce persistent local groundwater overdraft. DWR also considers Madera Ranch a local option because it was expected to supply only one group of CVP contractors. USBR has been investigating Madera Ranch for use as a water reserve account, but not specifically as a conjunctive use option to replace CVPIA water dedicated for environmental purposes. Surplus water from the Delta, probably conveyed to the Mendota Pool would be used for its recharge. As with the DWR/USBR "Least Cost CVP Yield Increase Plan" options north of the Delta, each reference to a city in Table 3-8 indicates a different site estimated to be feasible. The combined evaluated storage capacity of these DWR/USBR south-of-Delta groundwater sites is over one million acre-feet with an estimated annual yield of over 500 taf.

Table 3-8. Groundwater Storage Options South of the Delta

General Location	Program/Source	Capacity (taf)	Annual Yield (taf)	Estimated Cost
Stockton East	CALFED DWR (local)		8[e] to 22	$100/af storage
James ID/Raisin City WD, Mid-Valley Canal reaches 1-3	CALFED			
Kern River Fan	CALFED DWR	930 up to 1000	up to 140[e]	$257/af storage
Madera Ranch	CALFED DWR (local)	350 390	70	$328/af storage $226/af yield
Mendota Pool (N Branch Mid-Valley Canal)	CALFED			
Mojave River Basins	CALFED			
Semitropic WSD	CALFED DWR	900	114	
NW of Volta, Oro Loma	DWR/USBR[a]	275[b]	200	
N of Modesto	DWR/USBR[a]	100[b]	20	
E of Atwater, NE of Merced, W of La Vina, NE of Red Top	DWR/USBR[a]	350[b]	140	
N of Raisin City, S of Kingsburg, S of Hanford, W of Visalia, SW of Tipton	DWR/USBR[a]	Unknown	125	
W. of McFarland, SW of Bakersfield	DWR/USBR[a]	500[b]	50	
Kern Water Bank	DWR[c]	3000[d]	400[d]	

Notes:

[a] *Taken from USBR's "Least Cost CVP Yield Increase Plan"*

[b] *"Capacity is taken to be the amount of water that can be recharged and extracted over any area without causing a water level fluctuation of more than 30 feet compared to historical water levels and has been estimated using a large-scale regional [groundwater] model. Values are not maximums and are used for comparison purposes." (DWR 1998a)*

[c] *Capacity and annual yield describe the original project before transfer to the KWBA (DWR 1997)*

[e] *Drought year estimate*

Sources: CALFED (1998a, 1998b), DWR (1993, 1997, 1998a)

The Kern Water Bank (KWB) was developed in cooperation with the Kern County Water Agency to increase SWP dependability through increased storage of local water supplies, and to reduce local effects of groundwater overdraft. The original proposed project consisted of eight elements: Kern Fan, Kern County Water Agency Improvement District Number 4, Water Storage Districts of Semitropic, North Kern, Cawelo, Rosedale-Rio Bravo, and Kern Delta, and Buena

Vista and West Kern Water Storage Districts jointly (DWR 1993). Since transfer of KWB control from DWR to the Kern Water Bank Authority and the sale of the Kern Fan element property to designated agricultural contractors (directed by the Monterey Agreement), the project elements have often been referred to separately. Some of the smaller elements, such as Buena Vista and Cawelo, are now listed as local groundwater storage options in the 1998 California Water Plan update.

Conjunctive Use

The recharge of groundwater basins in wet years is a natural consequence of floodwaters. As floodwaters are controlled, natural recharge often diminishes and must be managed. One effective management method is conjunctive use in a groundwater basin. Conjunctive use projects, sometimes called groundwater banking, emulate natural processes by recharging an aquifer during wet years in preparation for drought.

Most hydrologic regions have some groundwater banking/conjunctive use projects to augment drought water supplies. Class II water from the CVP, generally only available in wet years, is used for recharge by Friant-Kern contractors in the Tulare Lake hydrologic region. This groundwater banking operation (Kern Water Bank) has been underway since 1985. The use of groundwater instead of surface water during the last drought enabled Sacramento Valley agriculture to continue, and made surface water available for downstream uses. MWD has a policy of discounting pricing for winter season deliveries to encourage groundwater recharge (DWR 1998a). DWR estimates an average of 100 taf/year of supply is produced as a result of this policy. The MWD has also identified the potential for 200 taf of additional groundwater supply during drought through development of local basin storage capacity.

Although the effects of conjunctive use projects can be regional or statewide, their individual scope is usually local. Table 3-9 lists new local conjunctive use options retained by DWR in the last update (DWR 1998a) some of which coincide with options in Table 3-7 and 3-8. Several projects with insufficient documentation and those with yields less than a thousand acre-feet per year are excluded from the list (DWR 1998a). Conjunctive use options lacking feasibility studies or environmental documentation include several banking projects in the Colorado River region and a joint EBMUD/San Joaquin County project. The Colorado River projects are under discussion by MWD and others. The EBMUD/San Joaquin County project would provide out-of-service area storage and improved system reliability for EBMUD during drought years while reducing groundwater overdraft in the San Joaquin County basin under consideration. In the Central Coast region, groundwater is the primary water source and overdraft induced saltwater intrusion is a major problem. Conjunctive use projects in this region serve the dual purpose of reducing such impacts of groundwater overdraft and providing supply during drought.

As noted earlier under groundwater storage options, CALFED (1998a) estimates storage capacity for preliminary studies of conjunctive use to be about 250 taf and 500 taf in the Sacramento and San Joaquin Valleys, respectively. Withdrawal and recharge capacities of these CALFED groundwater storage options, for study purposes, are designed at around 500 cfs (DWR 1998a). However, DWR (1998a) cautions that currently “a lack of recharge water limits opportunities for conjunctive operation in the San Joaquin Valley”.

WATER RECYCLING AND DESALINATION OPTIONS

Water recycling and desalting have been researched, methods and technologies tested, and pilot plants run for decades. Over the past decades these two options have held out promise for water supplies. Because they tend to be fully within the control of local agencies to plan, design, and build, these options are often considered local although their impacts can have regional and statewide significance. CALFED (1999b) notes that although recycling can have a regional or statewide impact, projects are local and locally funded. In contrast, other new supply development projects have been planned, financed, and built by regional, state, and federal agencies. To remedy this disparity somewhat, federal cost sharing is now authorized through the Reclamation, Recycling and Water Conservation Act of 1996 and the Water Desalination Act of 1996 (DWR 1998a). The following sections provide some background to and present the statewide status of current recycling and desalination infrastructure options.

Table 3-9. New Local Conjunctive Use Options Retained by DWR[a]

Region	Projects Retained	Project Name/Comments	Potential Yield Drought (taf)	Costs of Yield
North Coast	0	Limited by aquifer storage	-	$150/af
San Francisco Bay	2	Milliken Creek Lake Hennessey/Conn Creek	2 5	$150 - 280/af
Central Coast	2	College Lake Seaside Basin	2 1	$130 - 410/af
South Coast	1	Local groundwater banking	130	$350/af
Sacramento River	2	New wells (Redding, Butte, and Colusa Basins)	-	$30 - ?/af
San Joaquin River	2[c]	Stockton East Water District Madera Ranch	8 (22)[b] 70	$100 - 230/af
Tulare Lake	4	City of Clovis Kern Water Bank Buena Vista Water Storage District Cawelo Water District	11 339 29 13	$50 – 280/af
South Lahontan	0	Declining groundwater levels, lack of surface water, adjudication and recharge with SWP water	-	
North Lahontan	0	Groundwater uneconomical replacement for surface water, wildlife impacts	-	
Colorado River	0[d]	Coachella overdraft, MWD study to stabilize the basin and bank water using Colorado water	-	

Notes:

[a] *Table 3-8 shows new conjunctive use projects under DWR consideration. It does not catalog existing conjunctive use applications.*

[b] *Yield goes up to 22 taf for average conditions*

[c] *EBMUD/San Joaquin option not retained by DWR because study is not yet complete*

[d] *MWD option not retained by DWR because study is not yet complete*

Source: DWR (1998a)

Water Recycling

Although not discussed in the 1966 update, recycling wastewater has been studied by the DWR at least since the preparation of Bulletin 67 in 1959. By 1970, recycled water was being used at Golden Gate Park in San Francisco, by the Whittier Narrows Water Reclamation Plant in Southern California for downstream groundwater recharge, and in San Diego County (DWR

1970). The 1974 Water Plan update described reclaimed or recycled water as the "primary alternative to further surface development for meeting California's future water needs" (DWR 1974). Unplanned water recycling has always occurred in inland watersheds through use of return flows. Planned water recycling is a more recent and generally a coastal phenomenon driven by increasing demands on a finite freshwater supply. Planned water recycling was expected to become an increasingly significant part of the water supply in 1974, especially in the South Coast region where wastewater is discharged largely to the ocean.

Benefits of water recycling include new supply, reduced wastewater discharge, and improved water quality. DWR only counts new supplies generated from recycling when the outflow of treated wastewater would otherwise flow to a salt sink or the ocean. Currently, coastal discharge of wastewater is more than 2 maf and is expected to exceed 3 maf in the next 20 years (CALFED 1999b). CALFED (1999b) considers water recycling a significant means to improve water supply reliability in California, one of the primary objectives of their program. From their perspective, benefits of water recycling include reduced demand for Delta exports (improved availability of Delta supplies for all purposes), improved timing of diversions, increased carryover storage, reduced fish entrainment, reduced discharge of treated wastewater into useable surface water, and improved water quality.

In 1995, DWR and WateReuse Association of California conducted a survey of planned water recycling in the state amounting to 577 taf by 2020 (DWR 1998a). Most respondents planned to use the recycled water for irrigation, either for landscaping or agriculture. Out of 211 uses mentioned in the survey, 63% were for irrigation, 15% for industrial use, 10% for groundwater recharge, 6% for seawater barriers, 2% for environmental purposes, and 7% were listed as "other". Many of the planned recycling projects listed more than one use for their reclaimed water. Water reuse figures for 1995, shown in Table 3-10, also demonstrate that the dominant uses are irrigation and groundwater recharge.

Table 3-10. 1995 Total Water Recycling By Category

Category	Amount (taf/year)	Percent of Total
Agricultural Irrigation	155	32
Groundwater Recharge	131	27
Landscape Irrigation	82	17
Industrial Uses	34	7
Environmental Uses	15	3
Seawater Intrusion Barrier	5	1
Other[a]	63	13
Total	485	100

Notes:
[a] *Includes snow making, dust suppression, fire fighting and recreational ponds.*

Source: DWR (1998a)

Cost is often the limiting factor in development of a recycled water supply, although relative cost has decreased as more stringent treatment is required for wastewater disposal. Other factors that may offset cost are California Water Code definitions of waste and unreasonable use in the application of potable water to non-potable purposes, and the increasing scarcity of available fresh water supplies for growing urban populations.

The potential for additional water recycling by 2020 is significant (Table 3-11). The base level of 577 taf of water recycling for 2020 includes the current 485 taf (Table 3-10) plus full capacity production at existing plants and completion of new plants currently under construction (DWR 1998a). Additional options by 2020 in Table 3-10 are based on the 1995 DWR and WateReuse Association of California survey. The two major options under study are the Bay Area Regional Water Recycling Program and the Southern California Comprehensive Waste Reclamation and Reuse Study. The South Coast region generates the most new water through recycling. As a regional option likely to be implemented by 2020, the South Coast plans to repurify 367 taf per year at $500 per acre-foot. The San Francisco and Central Coast regions also plan to implement more water recycling programs by 2020, enough to produce 24 taf and 29 taf per year, respectively, both at around $500 per acre-foot (DWR 1998a). Major impediments to water recycling include salt management, treatment and redistribution costs, and a lack of public acceptance for potable reuse. If these can be overcome, "statewide urban water recycling could reach over 2 maf annually" (CALFED 1999b).

Table 3-11. 2020 Water Recycling Options and Resulting New Water Supply

Projects	Total[a] Water Recycling (taf/year)	New[b] Water Supply (taf/year)
Base	577	407
Potential Options	835	655
Total	1412	1062

Notes:

[a] Base includes the 485 taf at 1995 levels shown in Table 3-9

[b] New water supply means that portion of the recycled water that would have otherwise been lost to a salt sink or the ocean according to DWR

Source: DWR (1998a)

Water Desalination

Bulletin 160-66 identified four methods of desalination: distillation, membrane, crystallization, and chemical processes. In 1966, it was expected that distillation would be used on seawater and membrane processes such as reverse osmosis on brackish water. By 1974, DWR (1974) noted that there was virtually no water supply produced by desalting in California. Updates to the California Water Plan have identified cost, especially the cost of energy, as being the limiting factor in the development and use of desalination. Desalting costs increase with feedwater salinity. Thus, brackish groundwater recovery and wastewater desalting, with their significantly lower salt content than seawater, are more readily pursued, except where seawater is the only likely source or supplemental source of supply (Table 3-12). Generally, economical desalting of seawater remains unrealized at this time. Currently, 89% of the installed desalting plant capacity in California is reverse osmosis where at least 50 percent of the operating costs are energy (DWR 1998a).

Table 3-12. Statewide Current Desalting Plant Capacity and Costs

Type	Groundwater Recovery	Wastewater Desalting	Seawater Desalting
Installed Capacity	45 taf/year	13 taf/year	8 taf/year[a]
Cost Range	$300/af - $900/af[b]		$1,000/AF - $2,000/af[b]

Notes:

[a] Most on standby as drought reserve

[b] From South Coast region estimates

Source: DWR (1998a)

Although desalting is not mentioned by DWR (1998a) as a statewide supply augmentation option likely to be implemented by the year 2020, the South Coast and San Francisco hydrologic regions both have brackish groundwater recovery listed as likely local options. While the current seawater desalting capacity of 8 taf is included as average and drought year supply for DWR's 2020 projections, seawater desalting research continues. MWD, in cooperation with the federal government and the Israel Science and Technology Foundation, is completing final design of a research distillation plant with plans to demonstrate that a full scale plant could desalt seawater at a rate of 85 taf per year for $1000 per acre-foot.

CONCLUSION

California has a wide variety of infrastructure options available for improving long term water supplies. These options all entail considerable expense, and would provide benefits which would vary seasonally and yearly, based on hydrologic and demand conditions. More importantly, the benefits of such new facilities are likely to depend greatly on how the sizing and operation of each facility is integrated into California’s already complex water supply plumbing system. The integration and operation of structural options has significant institutional and non-structural aspects essential to the effective operation of California’s water supply system. The integrated economic and engineering analysis methods of this research project, described in Chapter 6, provide a technical approach to assess the performance and benefits of these available infrastructure options, at statewide, regional, and local scales, under different operating alternative.

Looking over the range of structural options available, some bits of conventional wisdom emerge:

1. Few new surface water storage options appear attractive compared with many groundwater storage options;

2. The availability of water and conveyance to service new storage is a major additional problem and cost for almost any new storage facility;

3. Water reuse has become a significant augmentation option, though limited by cost and the unacceptability of reuse;

4. Desalination has become more economically viable for water recycled and brackish waters, but has yet to become a significant option for seawater treatment in California.