TECHNICAL EVALUATION OF OPTIONS FOR LONG-TERM AUGMENTATION OF THE COLORADO RIVER SYSTEM

BRACKISH WATER DESALINATION TECHNICAL MEMORANDUM

BY:
JIM LOZIER, P.E.
CH2M HILL

ROB HUEHMER, P.E.
CH2M HILL

JUAN GOMEZ, PhD., P.E.
CH2M HILL

Q/C:
RICK BOND, P.E.
BLACK & VEATCH

BRAD HEMKEN, P.E.
BLACK & VEATCH

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EXECUTIVE SUMMARY

Purpose

The Seven Colorado River Basin States (Seven States) have authorized Colorado River Water Consultants (CRWC) to provide a Technical Evaluation of Options for Long-Term Augmentation of the Colorado River System (Project). This Technical Memorandum (TM), one of a series of TMs being prepared as part of the Project, presents results of an evaluation of brackish water desalination.

Scope

The TMs are the second step in an iterative process to develop, screen, and evaluate long-term water supply augmentation options. The TMs build upon and expand White Papers developed during the initial weeks of the evaluation process. In this TM, recent and proposed brackish water desalination projects in Arizona (AZ) and California (CA) are briefly described. Potential project sites are shown on Figure ES-1. Technical factors reviewed include source water availability, collection, treatment (process selection and brine disposal), and distribution system issues. Construction cost and operating cost opinions are provided for each project.

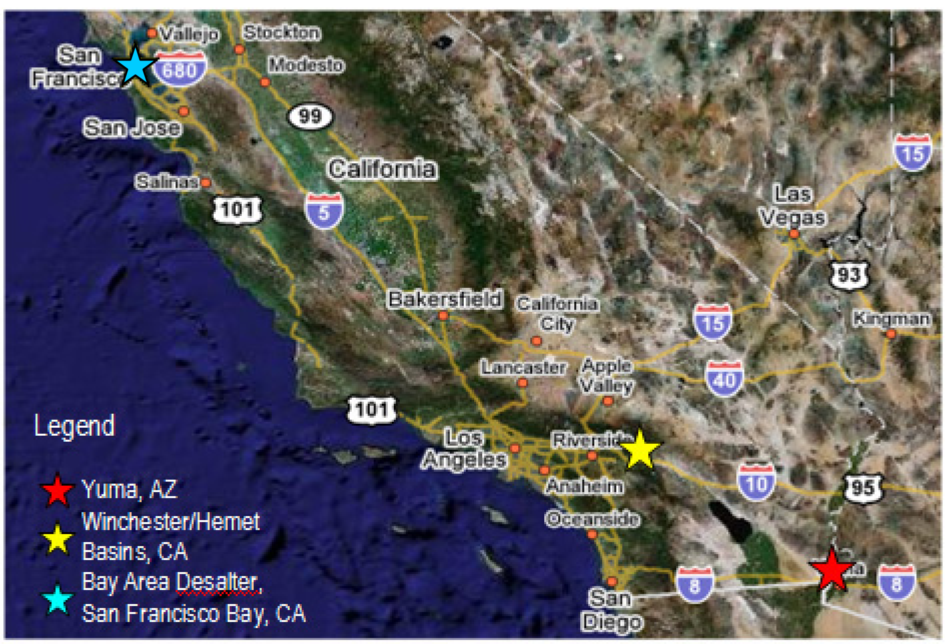

Figure ES-1
Location of Candidate Brackish Water Desalination Plants

Findings

Each of the six TMs evaluated augmentation options against eight criteria. These criteria, and the results of the evaluation for the brackish water desalination option are presented in Table ES-1.

Table ES-1
Summary of Findings Related to Brackish Water Desalination

Parameter	Findings
Location of Supply	Three brackish water sources were investigated, including: a groundwater mound located in the vicinity of Yuma, AZ; an unallocated groundwater source in Riverside County, CA; and an estuarial surface water (a tributary to San Francisco Bay) located in Contra Costa County, CA.
Quantity of Water Potentially Available	The quantity of available water is not well characterized for each of the sites. For the Yuma supply, it is estimated that groundwater storage is in the range of 600,000 to 800,000 acre-feet (AF). Annual amounts are estimated to be 4,000 to 50,000 AFY or greater. Use of this source is limited not by the raw water availability, but by the demand for finished water in the region (~27,000 acre-feet per year [AFY]). No reliable estimates exist on the quantity of water available from the Winchester/Hemet basin (Riverside, CA), though it is expected to be less than 10,000 AFY. For the Mirant Pittsburg surface water source in Contra Costa County, CA current studies are investigating plants as large as 120-million gallons per day (mgd) (134,000 AFY).
Water Quality	Water quality at all three sites is variable. Total dissolved solids (TDS) range from 1,000 to 2,000 milligrams per liter (mg/L) in the Yuma source, with wider variations at the Winchester/Hemet source and Contra Costa County source. The source water quality is well within the range that reverse osmosis can adequately treat.
Technical Issues	Many treatment alternatives are available, but brine disposal issues can be significant, particularly for the surface water source in Contra Costa County, CA. Adequate brine disposal alternatives exist for both groundwater sources using either regional brine lines or bypass canals.
General Reliability of Supply	The Yuma and Contra Costa County supplies are anticipated to be reliable year-round. The probable need for recharge in the Winchester/Hemet basin to avoid water mining and potential related issues limits the production to 8 months per calendar year.
Environmental Issues	Environmental issues are similar at all three sites and primarily relate to concentrate disposal and general siting of the facility. Intakes (entrainment and impingement) and concentrate disposal are most significant for the Contra Costa County source.
Permitting Issues	Permitting issues are similar.

Table ES-1 Summary of Findings Related to Brackish Water Desalination	
Parameter	**Findings**
Cost	Costs range from $640 $/AF to $1,950/AF. (Based upon the three alternatives presented in Table ES-2.)

The cost estimates prepared previously by others (URS and Boyle 2003; Jobst 2007) for each facility were updated using Engineering News Record (ENR) indices. The resulting construction and operating cost estimates are presented in Table ES-2.

Table ES-2
Unit Water Cost Summary

Parameter	Unit	Project		
Project	-	Yuma Desalter	Winchester/Hemet Basin	Mirant Pittsburg
Location	-	Yuma, Arizona	Riverside County, CA	Contra Costa County, CA
Plant Capacity	*mgd*	48	4	40
Annual Production[1]	*AF*	51,079	4,257	42,565
Construction Costs				
Total Construction Costs	*$*	170,060,000	60,000,000	300,000,000
Amortized Construction Cost[2,3]	*$*	11,660,000	3,610,000	19,520,000
Annual Costs				
Annual Construction Payments	*$*	11,660,000	3,610,000	19,520,000
Annual Operating Cost	*$*	21,400,000	3,780,000	23,430,000
Total Annual Costs	*$*	33,060,000	7,390,000	42,950,000
Unit Water Cost	***$/AF***	**640**	**1,950**	**1,070**
Notes				
[1]Online Factor		0.90		
[2]Interest Rate	%	5%		
[3]Period	years	30		

[#]These costs do not include additional treatment costs at downstream East Bay Municipal Utility District (EBMUD) filtration facilities or alternative distribution system modifications.

Conclusions

The conclusions drawn from this TM are as follows:

- There exist currently unallocated brackish water resources suitable for further development within the Seven States. Three of these resources were considered further within this TM.

- 600,000 to 800,000 AF of available water is stored in a groundwater mound in Yuma, Arizona. Development of a desalination facility, based upon retrofit of the Yuma Desalting Plant (YDP), to provide potable water to Yuma, Arizona would account for 51,079 AFY of water, at an estimated unit cost of $640/AF.

- It is estimated that over 15,260,000 AF of brackish water is physically available in Southern CA alone. A determination of the amount of such water that can be developed economically is beyond the scope of this TM. One of the potential sources has been considered within this TM. Development of a 4 mgd desalination plant treating water from the Winchester/Hemet Basin would produce water at a unit cost of $1,950/AF. The sustainable withdrawal and storage of water from the aquifer has not been established, but is estimated to be less than 10,000 AFY. Groundwater recharge is likely required to prevent water mining of the resource with potential detrimental effects.

- Brackish surface waters within the San Francisco Bay watershed are available. Although there are additional environmental concerns relating to the implementation of a surface water plant, it is nevertheless a technically viable water resource. One case, a surface brackish water treatment plant with a capacity of 40-mgd, was considered further. Updated cost estimates for the facility previously proposed (URS and Boyle, 1993) indicate unit water costs of $1,070/AF for the facility. The unit water cost does not include any additional costs associated with re-treatment at EBMUD facilities.

1.0 INTRODUCTION

1.1 Overview

This section describes Project objectives, briefly discusses the program framework within which the evaluation of long-term augmentation options is proceeding, and presents overall Project methodology. Also provided are a brief description of how this TM is organized, a list of abbreviations and acronyms used, and information about the references cited herein.

1.2 Project Rationale (Objectives)

Separate studies and investigations have projected an increase in demands for Colorado River system water and a reduction in long-term runoff of the Colorado River. As part of their proactive response to this scenario, the Seven States have authorized CRWC to provide a technical evaluation of long-term augmentation options. The States will supplement the technical evaluations with legal, administrative, and/or institutional considerations. All phases of the evaluation are being conducted in close coordination with the States and with the two regional offices of the U.S. Bureau of Reclamation (Bureau).

1.3 Other Ongoing Water Management Efforts

The evaluation of long-term options focuses on both previously-identified concepts and applications of new technology or management options. The evaluation was begun in parallel with the Bureau's development of Lower Basin Shortage Guidelines and Coordinated Management Strategies for Lake Powell and Lake Mead Under Low Reservoir Conditions. It also should be noted that each of the Seven States has comprehensive water management programs. Concepts being developed under these independent programs will not be evaluated through the Seven States process.

1.4 Methodology

Evaluation of options is an ongoing and iterative process. In the first phase of the evaluation, White Papers were developed for 12 potential long-term augmentation options developed by CRWC in concert with the Seven States. In parallel with White Paper preparation, the CRWC team met with representatives of each State, the Bureau's two regional offices, and other interested parties. A password-protected Project Website was developed, an Expert Panel was convened, and a workshop was held with the Project's Technical Committee. The workshop focus was on the 12 White Paper options and three additional options suggested by the Expert Panel. Grouped by the purpose they achieve and the benefit provided, the initial options were:

- Firm up supply/reduce shortages: Conjunctive use, reservoir evaporation control, vegetation management, weather modification, stormwater storage, and additional storage.

- New supplies. Basin imports/reduction of exports, through exchanges, brackish water desalination, coal bed methane, produced water, seawater desalination, and water imports using ocean routes.

- Increase water use efficiency/exchange. Reduction of power plant consumptive use, agricultural and urban water reuse, agricultural and urban transfers, and accelerated urban water conservation.

During the workshop with the Technical Committee and a subsequent meeting with the Project Principals, six options were selected for more detailed evaluation at the TM level: brackish water desalination, conjunctive use, ocean water desalination, river imports and exports, stormwater storage, and vegetation management. This TM describes brackish water desalination.

1.5 Technical Memorandum Organization

This TM is organized into three sections, including an introduction, discussion of brackish water alternatives, and conclusions. The TM provides an evaluation of extraction, conveyance, treatment and use of three different brackish water supplies within the western United States (U.S.), one in AZ and two in CA. Two are groundwater, and one is surface water. For each alternative, information has been organized and presented in the following subsections:

- Location of Supply
- Quantity of Water Potentially Available
- Water Quality
- Technical Issues
- General Reliability of Supply
- Environmental Issues
- Permitting Issues
- Costs

1.6 Abbreviations and Acronyms

The following abbreviations and acronyms are used in this TM.

AF	acre-ft
AFY	acre-ft per year
AZ	Arizona
Basin	Colorado River Basin
Bureau	United States Bureau of Reclamation
CA	California
CDHS	California Department of Health Services
CCWD	Contra Costa Water District
CRWC	Colorado River Water Consultants
DAF	dissolved air flotation

EBMUD	East Bay Municipal Utility District
EMWD	Eastern Municipal Water District
ENR	Engineering News Record
EPA	Environmental Protection Agency
ft	foot, feet
gpm	gallons per minute
MCL	maximum contaminant level
MF/UF	microfiltration/ultrafiltration
mgd	million gallons per day
mg/L	milligrams per liter
MODE	Main Outlet Drain Extension
MWD	Metropolitan Water District of Southern California
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance
Project	Technical Evaluation of Options for Long-Term Augmentation of the Colorado River System
RO	Reverse Osmosis
Seven States	Seven Colorado River Basin States
SARI	Santa Ana Regional Interceptor
SCVWD	Santa Clara Valley Water District
SFPUC	San Francisco Public Utilities Commission
TDS	total dissolved solids
TM	technical memorandum
WTP	water treatment plant
U.S.	United States
USGS	United States Geological Survey
YAAG	Yuma Area Ag Council
YAO	Yuma Area Office
YDP	Yuma Desalting Plant

1.7 References

Major reference sources consulted for this TM are listed below.

Bay Area Regional Desalination Project Pre-Feasibility Study Final Report, (2003). Prepared by URS Corporation and Boyle Engineering Corporation.

Brackish Groundwater Reclamation Study (2001). Metropolitan Water District of Southern California, Prepared by Boyle Engineering.

Dickinson, J.E., M. Land, C.C. Faunt, S.A. Leake, E.G. Reichard, J.B. Fleming and D.R. Pool. Hydrogeologic framework refinement, ground-water flow and storage, water-chemistry analyses, and water-budget components of the Yuma area, southwestern Arizona and southeastern California.U.S. Geological Survey Scientific Investigations Report 2006–5135. 2006.

Engineering News Record, http://enr.construction.com/features/conEco/subs/default.asp (accessed January 2007)

City of Hemet Water Department Urban Water Management Plan 2005, dated Jan 16, 2006.

Howe, J. (2004). The Great Southwest Salt Saga. WIRED 12:11.

Jobst, Brian January 2007. Personal communication.

Yuma Area Ag Council (YAAG), http://www.yaac.net/ (accessed January 26, 2007)

2.0 TECHNICAL DISCUSSION

2.1 Overview

This section briefly describes the White Paper on Brackish Water Desalination, develops groundwater desalination alternatives for Southwestern AZ and Southern CA, a surface water alternative in Northern CA and presents evaluation criteria. For each resource, a single case study is evaluated in terms of location of supply, water quantity, water quality, source reliability, technical issues (collection, treatment and distribution) and environmental and permitting issues. This TM builds on preliminary studies on groundwater desalination 2006 completed earlier in the project.

2.2 Development of Groundwater Desalination Alternatives

Three desalination options are developed in this TM. The location of each of these options is shown on Figure 2-1. Each option is described in more detail below.

Figure 2-1
Groundwater Desalination Project Sites

2.3 Groundwater Resources in Yuma, Arizona

Groundwater resources in Yuma, Arizona were evaluated based upon previous studies conducted by United States Geological Survey (USGS) and discussions with the Bureau.

2.3.1 Location and Amount of Supply

Groundwater is abundant in the Yuma, AZ area. Prior to development, groundwater in the area was derived from direct infiltration of water from the Colorado and Gila Rivers as well as water overflowing the rivers' banks during periods of high instream flows. Following construction of upstream reservoirs and clearing and irrigation of floodplains adjacent to the river, water flows were reversed, with excess irrigation water from the croplands flowing down into the vadose zone and then down gradient to the river, creating a large groundwater mound as the rate of applied irrigation water exceeded the rate of consumption by the groves combined with a low rate of groundwater flow away from the mound.

The Bureau and local irrigation districts operate hundreds of high capacity wells in this area to ensure the water table remains well below the crop root zone and salts present in the irrigation water are sufficiently flushed away from the root zone. This allows for commercial agriculture, a $1.5-billion dollar business in the Yuma area (Yuma Area Ag Council [YAAG] 2007), as well as provides stable infrastructure such as roads and foundations. The extracted groundwater is pumped into canals which, in turn, discharge into the Colorado River. Districts are credited for water returned to the river.

2.3.2 Quantity of Water Potentially Available

The total volume of groundwater pumped in the Yuma area and returned to the Colorado River typically exceeds 500,000 AFY. In addition, in at least one area of Yuma groundwater is accumulating. Below the Yuma Mesa, a mound of groundwater has been developing for several decades. Recent analysis by the USGS (2006) indicates this mound is approximately 600,000 to 800,000 AF of stored water. In short, groundwater is abundant and widely available in the Yuma area for extraction and development.

2.3.3 Water Quality

Water quality sampling of 12 groundwater wells was conducted in the Yuma area in 2005 as part of the USGS study, including four wells located in the Yuma Mesa. The sampling indicated that water quality varies from well to well. Water quality for two wells (Yuma Mesa well YM-10 and drainage well DW-3) is presented on Figure 2-2.

The water quality of both sources is characterized by TDS levels greater than the U. S. Environmental Protection Agency (EPA) secondary drinking water standard, high to very high hardness and sulfate and moderate alkalinity. The water quality of the DW-3 is approximately 50 percent higher in salinity than YM-10. DW-3 contains significantly greater levels of iron, manganese, and arsenic, all of which would need to be reduced in order to meet drinking water standards. However, the salinities in both wells, which are a fair representation of the quality from all wells sampled by the USGS, is well within the range that can be desalinated by membrane processes, in particular reverse osmosis (RO).

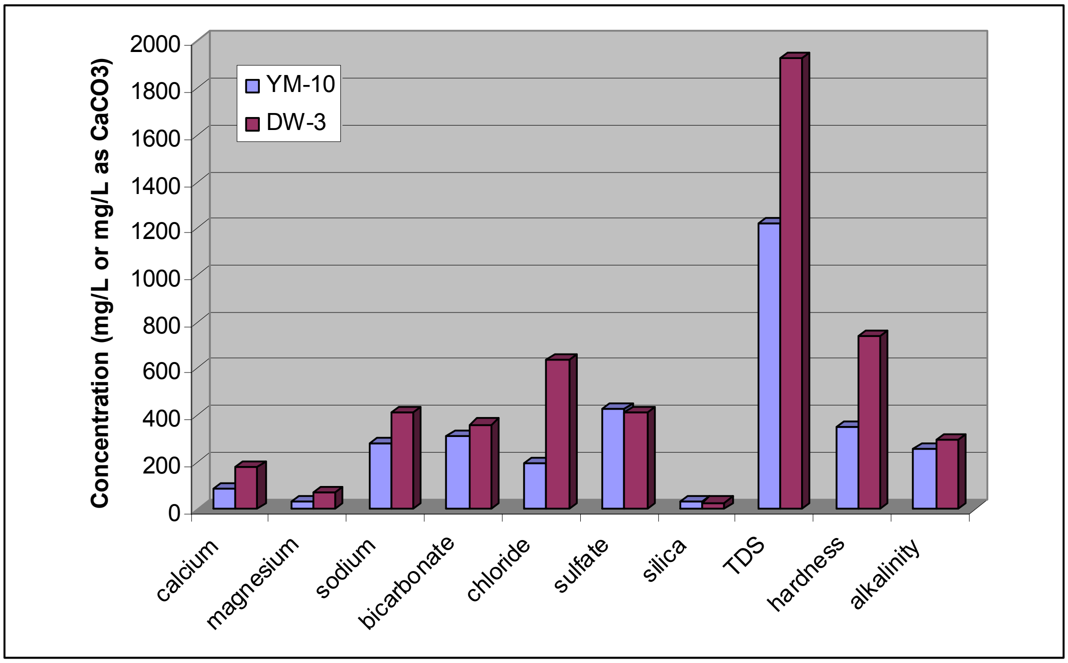

Figure 2.2 Inorganic Ion Profile for Brackish Groundwater in Yuma Area (Wells YM-10 and BW-3, USGS).

2.3.4 Technical Issues

The Bureau's Yuma Area Office (YAO) has been actively conducting a research project to understand the implications of processing groundwater through the YDP instead of processing drainage return flows from the Wellton-Mohawk Irrigation and Drainage District Main Outlet Drain Extension (MODE), the intended feed water to the YDP. This prospect holds appeal since it would likely be less costly to treat groundwater than Wellton-Mohawk flows because the latter is conveyed to the YDP in over 40 miles of open canal. Groundwater, piped directly to the YDP, would not contain the debris, silt, algae, and other contaminants resulting from conveyance in an open canal and which requires extensive and costly treatment at the plant for their removal. To date, experiments that replicate the YDP on a smaller pilot-scale have successfully processed Yuma area groundwater. These experiments indicate only limited retrofitting of the YDP would be necessary to process Yuma area groundwater instead of the MODE water.

Concurrently, the YAO is also conducting the YDP Potable Water Study. This study is determining what changes would be necessary to the YDP so that it could produce potable quality water for use by local water districts. The proposed process is illustrated on Figure 2-3. This use of the YDP holds appeal because it creates sustained operation of the plant and would produce a high quality drinking water.

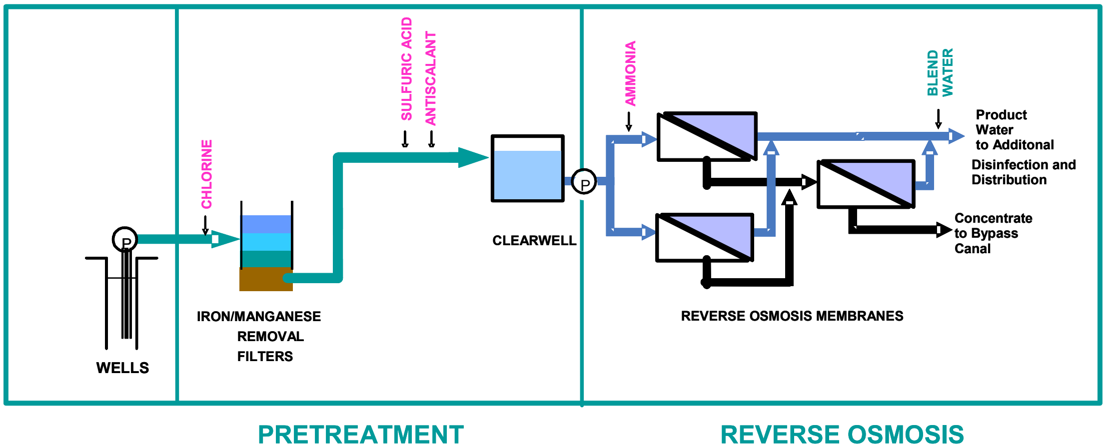

Figure 2-3. Process Schematic for Yuma Desalting Plant Modified to Treat Brackish Groundwater from Yuma Area. (Jobst, 2007).

Existing wells possess sufficient capacity to supply the YDP. New construction required includes conveyance from the wells to the YDP, minor modifications to the treatment process, and finished water pumping station and conveyance to the City of Yuma tie-in. Costs for extraction, conveyance, and treatment of brackish groundwater by the YDP and for pumping and conveyance of the potable water from the YDP to the City of Yuma's existing distribution system were estimated. Currently, only one-third (24-mgd) of the capacity of the YDP is required to meet the water requirements of Yuma; however, long-term planning requirements approach two-thirds capacity (48-mgd).

The Bureau's YAO expect to make the findings of the YDP Groundwater Project Potable Water Study available in 2008. Either of these uses of the YDP, to process alternative feed water or to produce different product water, would require Congressional action. At present, the only authorized use of the YDP is to process Wellton-Mohawk water and discharge product water to the Colorado River.

2.3.5 General Reliability of Supply

The excess groundwater that has accumulated in the mound under Yuma Mesa, between 600,000 and 800,000 AF, represents the accumulation of excess irrigation on the Mesa over a period of several decades. The long-term reliability of groundwater withdrawals from the Yuma area are a function of the sustainability of the groundwater mound. Sustainability can be estimated by accounting for water inputs to and outputs from the groundwater mound and the surrounding region on an annual or longer basis. The USGS study estimated that annual groundwater recharge volumes ranged from a minimum of 263,000 AF to 578,000 AF during the period 1970 to 1999. These volumes represent the difference between the amount of surface and groundwater applied to irrigated areas in the Yuma agricultural area and the amount of water lost to evapotranspiration. From these recharge volumes must be subtracted subsurface (return) flows to the Colorado River as well as groundwater withdrawals in the region in order to realize the approximate net accumulation of groundwater that would sustain annual withdrawals for consumptive use in the Yuma area following appropriate treatment and distribution.

Return flows have been estimated to be approximately 80,000 AFY while groundwater withdrawals have ranged between 200,000 and 300,000 AFY.

Assuming average annual recharge and withdrawal rates of 420,000 and 330,000 AFY, the annual volume of groundwater available for consumptive use is slightly less than 100,000 AFY on an average basis. This estimated volume assumes a continuation of water input and outflow rates in the region as historically observed. Since the 1980s, citrus fields on Yuma Mesa have been replaced with housing developments, resulting in reduced irrigation (groundwater input) and increased groundwater withdrawal for domestic use. This and other land use changes would need to be accounted in properly estimating the amount of groundwater available for long-term withdrawal for consumptive use. It should be noted that the exact amount of groundwater accumulating in the Yuma area which would be available on a sustainable basis cannot be readily determined without more study. The estimates presented here are to be considered very rough and subject to interpretation based on the limited data available for groundwater modeling.

As indicated earlier, groundwater is widely available in the Yuma area. Local geology and macro trends in the area (e.g. some displacement of commercial agriculture with urbanization) indicate groundwater will likely remain widely available in the future. AZ has regulatory authority over how much groundwater is used and for what purposes. The authority of the state and the federal government would need to be considered were the Seven States to determine that use of Yuma groundwater is worth pursuing as a supplemental supply of water.

2.3.6 Environmental Issues

Environmental issues associated with the YDP have largely been addressed during the initial design of the facility. No major new environmental issues are anticipated as a result of re-configuring the facility to desalinate groundwater.

By design, the concentrate would flow into the MODE and be discharged in Mexico at the Cienega de Santa Clara. The Cienega, created and sustained by the continuous flow of MODE water since its construction has been designated as part of the core zone of the Reserva de la Biosfera Alto Golfo de California y Delta del Rio Colorado by the Mexican government. Substitution of YDP RO concentrate in place of MODE water (or blended with MODE water in the case of partial YDP operation) would have a potential impact on the Cienega and its wildlife (Howe 2004).

2.3.7 Permitting Issues

In early 2007, the Bureau commenced demonstration operation of the YDP. This will be the first operation of the plant in well over a decade. The demonstration lasted 3 months and used approximately 10 percent of the plant's full operating capacity. Preparations for this operation included equipment preparation on site as well as meeting the necessary environmental and permitting requirements. These regulatory requirements include compliance with the National Environmental Policy Act, Clean Air Act, Pollution

Prevention Act, and Arizona Environmental Quality Act, among others. Preparations for the demonstration have determined that meeting the regulatory requirements for operation of the YDP is entirely manageable.

Additional permits may be required for future operation from:

- Local health departments and air quality agencies
- City and county encroachment, zoning, and other permits

2.3.8 Costs

For the YDP's presently authorized use (desalination of Wellton-Mohawk return flow) operations and maintenance (O&M) costs are accurately known. Should the YDP be used instead to treat groundwater and produce potable water, O&M costs would change and incremental construction costs would be incurred. The Bureau anticipates that, during 2007, new costs for the YDP will be completed and published. These costs will include both any one-time costs for plant retrofitting and any changes (increases or decreases) to expenditures necessary for ongoing operations and maintenance at 24-mgd (1/3 capacity) and 48-mgd (2/3 capacity).

The construction and operating costs for the production of 48-mgd are estimated in Table 2-1. Total construction costs are expected to exceed $170,060,000 with annual operating costs approximately $21,400,000. The estimated accuracy of this conceptual estimate is +50 percent to -30 percent. Costs for YDP plant modifications were provided by HJA Consulting and updated in this study using ENR cost indices (Jobst 2007). It is anticipated that the facility can meet the City of Yuma's long-term water needs (48-mgd) producing over 51,000 AFY at a unit water cost of $640 per AF.

2.4 Southern California Brackish Groundwater

Groundwater degradation in Southern CA caused by elevated levels of nitrate, TDS, and other minerals has been reported to have negatively impacted over 500,000 acres of the Metropolitan Water District of Southern California (MWD) service area over aquifers containing more than 15 million AF as of 1991 (Table 2-2). Figure 2-4 illustrates the location of groundwater resources possessing elevated TDS greater than 1,000 mg/L. These brackish groundwater areas can be considered potential water supplies for use in supplementing existing sources currently in use.

Table 2-1 Construction and Operating Costs		
Parameter		**Project**
Project		Yuma Desalter (48-mgd)
Collection Pipeline 25-mile Collection System 5-mile Raw Water Transmission Desalination Facility Land Cost Building Cost Pretreatment Facilities RO Facility Post Treatment Facilities Brine Disposal (SMRI, New Regional Interceptor Capacity) Distribution Finished Water Pump Station 2-mile Product Pipeline and Connection Design Deficiencies Plant Startup Membranes		 $60,430,000 $12,080,000 $6,920,000 $6,920,000 $9,220,000 $1,820,000 $6,930,000
Subtotal Construction Costs		$104,320,000
Engineering, Construction Management & Startup	15%	$15,650,000
Contractor Overhead	8%	$8,350,000
Interest During Construction	5%	$5,220,000
Insurance	5%	$5,220,000
Contingency	15%	$31,300,000
Subtotal		*$65,740,000*
Total Construction Costs		$170,060,000
Annual Operating Costs		
Labor		$5,270,000
Equipment Replacement		$2,570,000
Membrane Replacement		$2,310,000
Power		$4,520,000
Chemicals		$6,730,000
Total Annual Operating Costs		$21,400,000
Unit Water Cost ($/AF)		$640/AF

Table 2-2 Brackish Groundwater Reserves in the MWD Service Area[1]		
Groundwater Basin Group	**Estimated Area Impacted (acres)**	**Estimated Brackish Water Volume (AF)**
Ventura County	131,000	5,660,000
Los Angeles River	24,000	1,140,000
Upper Santa Ana River	142,000	3,445,000
Orange County	47,000	1,115,000
Santa Margarita River	75,000	2,225,000
San Diego County	109,000	1,675,000
Total	528,000	15,260,000

[1] Extracted from Boyle (1991).

To illustrate how these brackish groundwater supplies could be utilized as additional sources of supply, the use of groundwater from two basins, Winchester and Hemet Basins, was considered and is described in the following sections.

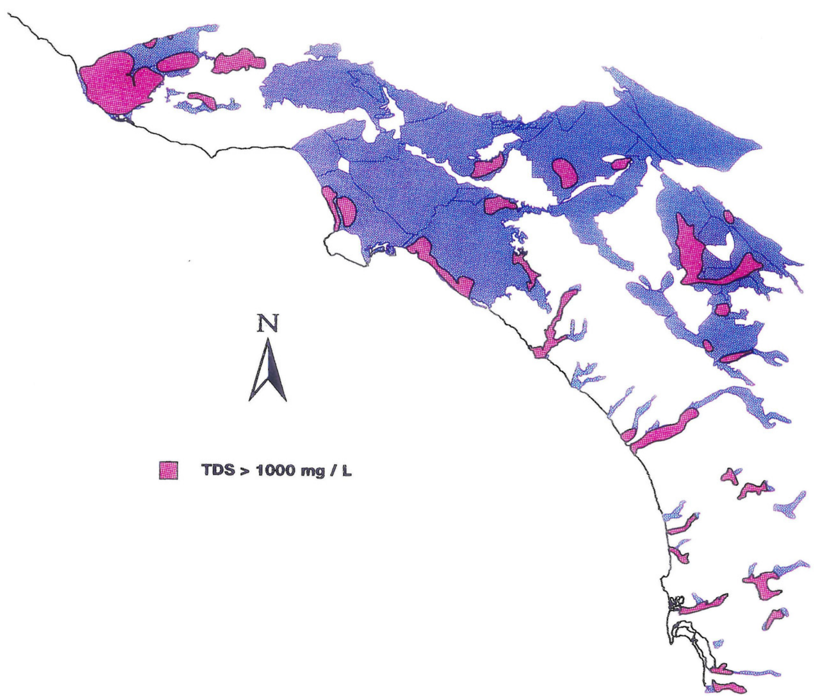

Figure 2-4. Groundwater in Service Area of MWD Possessing TDS Greater than 1000 mg/L (Boyle 1991)

2.4.1 Location of Supply

The Winchester and Hemet Basins are located in Riverside County, CA. A portion of the brackish groundwater adjacent to the study area, including that in the Perris and Menifee Basins, has already been developed as drinking water sources by Eastern Municipal Water District (EMWD). The brackish water underlying Winchester and the western border of the Hemet basin are largely unutilized.

2.4.2 Quantity of Water Potentially Available

Based on preliminary estimates (Boyle 1991), approximately 585,000 AF of water are presently stored within the combined Winchester and Hemet Basins. Only a fraction of this water represents water with elevated TDS. No detailed studies have been conducted to date that characterize the extent of the brackish water resources, however, so the actual amount (volume) of brackish water in these basins is unknown.

The quantity of available water and the sustainable yield from these sources have not been adequately characterized. The sustainable yield has been assumed as less than 10,000 AFY (Boyle 1991). The City of Hemet has identified future opportunities for development of desalinated water facilities along the western edge of the Hemet South sub-basin, where brackish groundwater is found. It is not expected that this option will be considered before 2015 (City of Hemet 2006). No information is currently available related to potential water supply yield.

2.4.3 Water Quality

Groundwater quality from ten wells has been compiled from EMWD well drilling records recorded between 1958 and 1989 (Boyle, 1991). TDS varies substantially within the basins, with average TDS of 4,015 mg/L and maximum TDS of 7,400 mg/L. These values exceed the EPA secondary maximum contaminant level (MCL) of 500 mg/L. Individual constituents comprising the largest fraction of the TDS are calcium, sulfate, and chloride. Table 2-3 summarizes the available groundwater quality.

Table 2-3 Groundwater Quality in the Winchester/West Hemet Area[1]					
Constituent	**Units**	**Limit**	**Low***	**High***	**Average***
TDS	mg/L	500[#]	940	7,400	4,015
pH	-	8.5	6.3	7.7	7.2
Total Hardness	mg/L as $CaCO_3$	-	328	1,808	777
Calcium	mg/L	-	97	1,320	420
Magnesium	mg/L	50	21	379	116
Potassium	mg/L	-	2.0	31.0	9.0
Sodium	mg/L	-	140	825	445
Total Alkalinity	mg/L as $CaCO_3$	-	-	497	207
Bicarbonate	mg/L	-	56	497	230
Carbonate	mg/L	-	0.0	0.0	-
Chloride	mg/L	250	217	3,230	1,163
Fluoride	mg/L	1.4	0.0	0.60	0.36
Nitrate	mg/L as NO_3	45	0.0	43.0	14.8
Sulfate	mg/L	-	150	2,000	666
Boron	µg/L	-	100	5,700	1,836

[1] Extracted from Boyle (1991).
 # Goal; maximum continuous TDS MCL is 1,000 mg/L.
** The water quality data represents a range of the water quality found in the 10 wells and does not represent low, average and maximum design water quality.*

2.4.4 Technical Issues

A conceptual design for a desalination plant utilizing brackish water from the Winchester/Hemet Basins was previously developed (Boyle, 1991). The proposed facility, intended to produce 4.0-mgd of potable water from March through October (eight months per year), consists of four major components: collection, treatment, concentrate disposal, and distribution. Based on the original Boyle study, the desalination plant would be taken off-line from November through February, and potable water from EMWD would be utilized to recharge the Winchester/Hemet basin through the existing wells.

Collection. Construction of a pressurized collection system to convey water from the existing well-fields to a centralized desalination plant is required. A 64,000 (ft) long collector pipe connecting ten wells, with a total capacity of 3,500 gallons per minute (gpm), is proposed to convey water to the brackish plant. The proposed treatment facility is located at the crossing of the San Diego Aqueduct and Simpson Road. Since the current sustainable yield of the water source is unknown, Boyle anticipated that artificial recharge of the aquifer would be required.

Treatment. The proposed desalination plant consists of pretreatment, desalination, and post-treatment. Each is described in additional detail below.

Pre-treatment. Pre-treatment is utilized to remove water contaminants that contribute to fouling of the RO desalination process. Pre-treatment consists of sand separators, iron and manganese removal, filtration and chemical conditioning of the water. In the adjacent Perris Valley basin, iron and manganese, silica, and dissolved gases have been identified as typical contaminants mitigated in the pre-treatment step for the recently constructed Perris Desalter.

Desalination. Pre-treated water is pressurized and fed to RO, a membrane based process widely used in the removal of dissolved constituents from water. Dissolved constituents are preferentially rejected by the membrane, resulting in a product water with significantly reduced levels of dissolved substances. A total of 4-mgd of potable water would be produced (consisting of 3.6-mgd of desalinated water and 0.4-mgd of bypass flow) with a TDS of 500 mg/L to meet the EPA secondary MCL. The contaminants are concentrated into a continuous 1.5 mgd waste stream (concentrate).

Post-treatment. Product water (permeate) from the RO process is disinfected using chlorine and then chemically conditioned to reduce corrosivity caused by insufficient hardness and alkalinity and low pH. Conditioning of the water by adding one or more chemicals, typically sodium hydroxide and carbon dioxide, is required.

Concentrate Disposal. The single largest technical challenge to the implementation of inland desalination plants is the disposal of the waste stream produced. Historically, RO concentrate has been disposed using a number of different methodologies, including deep-well injection, evaporation ponds, mechanical evaporator/crystallizers, infiltration and discharge to a surface water. In the proposed facility, waste brine (1.5 mgd) would be pumped to an extension of the Santa Ana Regional Interceptor (SARI) line that parallels the San Diego Aqueduct and conveys brines to the Pacific Ocean.

Distribution. Finished water will be distributed from the plant using the existing finished water main located beneath Simpson Road. The original study (Boyle 1991) did not evaluate if changes to the distribution system are required for this additional capacity.

2.4.5 General Reliability of Supply

The aquifers underlying the study area are slowly recharged by underflow from the Hemet Basin, with some recharge from surrounding hillside runoff. Average well yields in the area have been estimated at approximately 300 gpm. Wells at the Perris well field have reported yields ranging from 300 to 1250 gpm.

No comprehensive studies have been performed on the sustainable yield of the brackish groundwater. However, it has been assumed as less than 10,000 AFY. Conservative estimates of the total water storage in the combined Winchester and Hemet basins exceed 585,000 AF, though only a portion of this water is brackish. As described in Section 2.5.4, the sustainability of the groundwater supply would be improved by seasonal recharge of finished water from the EMWD distribution system during low demand winter months.

2.4.6 Environmental Issues

Environmental issues related to groundwater desalination are grouped into two categories: Groundwater withdrawal and concentrate disposal.

Although comprehensive studies of the groundwater resources in the Winchester/Hemet Basin have not been completed, the proposed withdrawal of groundwater from the basin is anticipated to exceed the rate of recharge, a condition commonly known as water mining. Potential impacts of water mining include increased risk of land subsidence. Implementation of aquifer recharge using other sources, such as treated Colorado River Aqueduct or State Water Project waters, can mitigate the risk of land subsidence.

Concentrate disposal is typically an important environmental consideration with inland desalination systems. The proposed discharge of concentrate into the existing SARI line mitigates environmental impacts within the basin.

2.4.7 Permitting Issues

A number of major permits may be required for implementation. Table 2-4 lists the typical major permits.

Table 2-4
Major Permitting Activities for Winchester/Hemet Site

Permit	Lead Time	Regulated Activities	Lead Agency
National Pollutant Discharge Elimination System (NPDES) Permit/Waste Discharge Permit/Water Quality Certification	2 months to 6 months	Discharges to waters of the state (concentrate, cooling water, other)	California Regional Water Quality Control Board, Cal-EPA, and U.S. EPA
National Pollutant Discharge Elimination System permit	12 months	Discharge of Brine	Regional Water Quality Control Board
Amended Drinking Water Permit/ Source Water Assessment and Protection Plan	2 month to 6 months	New water supply (source water characteristics, watershed conditions, reliability features)	California Department of Health Services

Additional permits may be required from:

- Local health departments and air quality agencies
- City and county encroachment, zoning, and other permits

2.4.8 Costs

Costs for implementation of the 4-mgd Hemet desalter as developed previously (Boyle, 1991) were updated to 2007 costs using ENR indices. It was assumed that the desalter would operate 90% of the time or about 4,000 AFY. The estimated accuracy of this conceptual estimate is -30 percent to +50 percent. Table 2-5 provides a summary of the estimated construction and annual operating costs for the proposed groundwater desalination facility. It is estimated that the construction cost would be approximately $57,140,000 while the O&M cost would be $3.78 million annually. The unit water cost for producing an estimated 4,000 AFY is $2,770 per AF.

Table 2-5.
Construction and Annual O&M Cost Summary

Parameter	
Project	Winchester/Hemet
Capacity	4-mgd
Estimate Year	2006
Collection Pipeline	
6-inch (3,500 ft)	$230,000
8-inch (23,500 ft)	$1,990,000
10-inch (12,500 ft)	$1,320,000
12-inch (3,500 ft)	$450,000
14-inch (4,000 ft)	$600,000
16-inch (500 ft)	$90,000
Desalination Facility	
Land Cost	$490,000
Building Cost	$820,000
Pretreatment Facilities	$5,000,000
RO Facility	$6,660,000
Post Treatment	$140,000
Residuals Handling	$12,400,000
Mechanical	incl.
Electrical	incl.
Sitework	$520,000
Distribution	$170,000
Pipeline and connection	
Groundwater Replenishment	$4,160,000
Subtotal Construction Costs	$35,040,000
Contingencies and Services	$22,100,000
Total Construction Costs	$57,140,000
Annual Operating Costs	
Pretreatment Facilities	$0/yr
Treatment	$2,030,000/yr
Post Treatment	$100,000/yr
Pipeline	$40,000/yr
Brine Disposal	$20,000/yr
Site Facilities	$40,000/yr
Replenishment	$1,090,000/yr
Well Pumping	$460,000/yr
Total Annual Operating Costs	**$3,780,000**/yr
Unit Water Cost	**$1,950/AF**

2.5 San Francisco Bay Area Regional Desalination Project

The utilization of unallocated water resources in the San Francisco Bay area is being studied jointly by EBMUD, San Francisco Public Utilities Commission (SFPUC), Santa Clara Valley Water District (SCVWD) and Contra Costa Water District (CCWD). The agencies, through the Bay Area Regional Desalination Project, are examining the feasibility of a regional desalination plant at a number of sites utilizing either seawater or brackish surface water as the raw water source. Of the 22 projects under preliminary consideration, six consider the use of brackish surface water. Figure 2-5 illustrate the potential locations under consideration (URS and Boyle, 2003).

NO.	SITE	NO.	SITE
1	C&H Sugar Refinery, Crocket	8	Oceanside, San Francisco
2	Mirant Contra Costa Plant, Antioch	9	BDPL 1&2 at Dumbarton Point
3	Mirant Pittsburg Plant, Pittsburg	10	Near Bay Bridge
4	Palo Alto Water Pollution Control Plant Site	11	Mallard Slough
5	Pico Power Plant Site, Santa Clara	12	San Francisco Airport
6	Los Esteros Power Plant Site, San Jose	13	Barge-Mounted Plant
7	Treasure Island Site, San Francisco		

Figure 2-5. Potential Sites for a Bay Area Desalter (URS and Boyle, 2003)

In order to illustrate a typical treatment system utilizing one of these brackish surface water sources, a conceptual desalination plant with a capacity of 40-mgd located in Contra Costa County, CA is used.

2.5.1 Location of Supply

Significant brackish surface water supplies are present in and around the greater San Francisco Bay area, including near the proposed site. The proposed site is located near the existing 2,060 MW Mirant Pittsburg power plant and the EBMUD raw water aqueduct.

2.5.2 Water Quality

The water quality in the vicinity of Mirant Pittsburg varies due to tidal and rainfall events. The TDS ranges from a low of 70 mg/L to a high of 5,737 mg/L, with average concentrations of 2,137 mg/L. These values are well within the range that can be successfully treated using brackish water RO processes. Table 2-6 provides additional water quality parameters for the proposed site.

Table 2-6.
Raw Water Quality in the Vicinity of Mirant Pittsburg from 1996 – 2000 (URS and Boyle, 2003)

Constituent	Units	Limit	Low	High	Average
TDS	mg/L	1,000	70	5737	2137.8
pH	-	8.5	6.22	8.4	7.67
Total Hardness	mg/L as $CaCO_3$	-			
Calcium	mg/L	-	3.9	276	35.2
Magnesium	mg/L	50	5.6	190	78.7
Potassium	mg/L	-	1.2	200	20.2
Sodium	mg/L	-	10	1600	595.2
Total Alkalinity	mg/L as $CaCO_3$	-	22	82	61.6
Bicarbonate	mg/L	-			
Carbonate	mg/L	-			
Chloride	mg/L	250	13	3100	776
Fluoride	mg/L	1.4	NR	NR	NR
Nitrate	mg/L as N	10	0.23	3.7	1.56
Sulfate	mg/L	-	10	420	151.5
Silica	mg/L	-	13	23	17
TOC	mg/L	-	0.5	5.7	2.7

2.5.3 Technical Issues

A conceptual desalination plant utilizing brackish water from the Mirant Pittsburg site was previously developed (URS and Boyle 2003). The previous analysis did not examine costs for product conveyance or additional treatment at EBMUD facilities. The proposed treatment and conveyance scheme assumes the surface brackish water supply will be treated using direct filtration followed by single pass brackish water RO. This will produce a product water having a TDS in the 300 mg/L range. This water will be discharged to and blended with raw water in the EBMUD aqueduct system for conveyance to the District's existing water treatment plant (WTP) and potable water distribution system. The facility was envisioned to produce 40-mgd of potable water.

Collection. Raw water is extracted using an intake and pumped to the proposed desalination facility located adjacent to the existing power facility.

Treatment. The proposed desalination plant consists of pretreatment, desalination, and post-treatment. Each is described in additional detail below.

Pre-treatment. Pre-treatment is utilized to remove water contaminants that contribute to fouling of the RO desalination process. Surface water supplies typically possess levels of suspended solids, algal and other contaminants that require more advanced pretreatment than groundwater supplies. For the proposed brackish surface water facility, pre-treatment consists of microfiltration/ultrafiltration (MF/UF), potentially with pre-coagulation. Technical challenges include the mitigation of MF/UF fouling caused by seasonally high concentrations of algae, potentially requiring the need for dissolved air flotation (DAF) prior to the MF/UF process.

Desalination. Pre-treated water is treated by RO. The RO product water has reduced levels of TDS, comparable to those in the existing finished waters produced by the member agencies. Effects of blending of this supply with the existing supply must be evaluated.

Post-treatment. Minimal post-treatment is required for blending into the EBMUD raw water aqueduct.

Concentrate Disposal. In the proposed facility, it is assumed that the RO concentrate would be discharged into the San Francisco Bay or one of its tributaries, possibly after blending with treated wastewater (effluent). This would require a NPDES permit.

Distribution. Finished water will be distributed from the plant using the existing raw water aqueduct, located approximately 2,000 ft away.

2.5.4 General Reliability of Supply

One of the major advantages of brackish surface water desalination is the availability of an abundant source of supply. The utilization of brackish surface water will provide a reliable source of water, with few constraints on withdrawal when compared to groundwater desalination sources.

2.5.5 Environmental Issues

Environmental issues for the implementation of this facility are varied. Most prevalent environmental issues relate to source water intake and RO concentrate disposal. Source water intake design must satisfactorily address mitigating the impact of impingement and entrainment of marine flora into the system.

Discharge of concentrate into the Bay down stream of the intake may have negative toxicity impacts upon biota in the vicinity of the discharge. The construction of a riverbed diffuser may be required to mitigate these impacts.

2.5.6 Permitting Issues

A number of major permits are anticipated to be required for implementation of the proposed facility, including those detailed in Table 2-7.

Table 2-7
Proposed Major Permits Required

Permit	Lead Time	Regulated Activities	Lead Agency
Clean Water Act Section 404 Permit	12 months	Impacts of dredge or fill materials on special aquatic sites and wetlands (intake facility, pipelines at creek crossings)	U.S. Army Corps of Engineers
Rivers and Harbors Act Section 10 Permit	12 months	Impacts on navigable waters (intake and outfall structures)	U.S. Army Corps of Engineers
National Pollutant Discharge Elimination System (NPDES) Permit/Waste Discharge Permit/Water Quality Certification	2 months to 6 months	Discharges to waters of the state (concentrate, cooling water, other)	California Regional Water Quality Control Board, Cal-EPA, and U.S. EPA
Coastal Development Permit (CDP)/Consistency Determination	12 months	Impacts on state waters, immediate shoreline, or lands subject to the pubic trust	California Coastal Commission
Amended Drinking Water Permit/Source Water Assessment and Protection Plan	2 month to 6 months	New water supply (source water characteristics, watershed conditions, reliability features)	California Department of Health Services
California Endangered Species Act Section 2081 Permit/California Fish and Game Code Section 1601Streambed Alteration Plan	12 months	Streambed alteration (intake, outfall, pipelines)	California Department of Fish and Game

2.5.7 Costs

Estimated costs for the brackish surface water desalination facility at the Mirant-Pittsburg site as developed previously (URS and Boyle, 2003) were updated to 2007 costs using ENR indices. The estimated construction and operating costs shown in Table 2-8 do not include the cost of re-treatment of the desalinated water (as part of the blended aqueduct supply). If this is required because sufficient capacity in the EBMUD's existing WTPs is not available, then the cost of water will increase proportionately. The estimated accuracy of this conceptual estimate is +50 percent to -30 percent. Table 2-8 provides a summary of the estimated construction and annual operating costs for the proposed groundwater desalination facility. Construction cost is expected to be approximately $193 million for the 40-mgd facility, with annual operating costs approximately $19 million. Assuming the 40 mgd plant is operated at an average of 90% of capacity, it is estimated that 40,300 AFY of water can be supplied, with a unit water cost of $1,580 per AF.

Table 2-8
Estimated Construction and Operating Cost Opinion

Parameter	
Project	Mirant Pittsburg
Estimate Year	2006
Plant Capacity	40-mgd
Construction Cost	
Raw Water Intake	$2,400,000
Filtration	$34,700,000
RO Facility	$50,500,000
Electrical & Instruments/Control Systems	$14,800,000
Chemical Feeds and Storage	$4,500,000
Buildings	$7,400,000
Site Civil	$7,400,000
Product Water Facilities	$24,100,000
Concentrate Disposal	$2,400,000
Other Facilities	$54,700,000
Subtotal	$202,900,000
Contingency & Services	$97,000,000
Total Construction Costs	**$300,000,000**
Annual Operating Costs	
Labor	$1,150,000
Power	$13,770,000
Membrane Replacement	$1,040,000
Chemicals	$3,220,000
Miscellaneous Maintenance	$4,250,000
Total O&M Cost	**$23,430,000**
Unit Water Cost	**$1,070**

[#]These costs do not include additional treatment costs at downstream EBMUD filtration facilities or alternative distribution system modifications.

3.0 CONCLUSIONS

The cost estimates prepared previously by others (URS and Boyle 2003; Jobst 2007) for each facility were updated using ENR indices to 2006 dollars. The resulting construction and operating cost estimates are presented in Table 3-1.

The conclusions drawn from this TM are as follows:

- There exist currently unallocated brackish water resources suitable for further development within the Seven States. Three of these resources were developed further within this TM.

- 600,000 to 800,000 AF of available water is stored in a groundwater mound in Yuma, Arizona. Development of a desalination facility, based upon retrofit of the YDP, to provide potable water to Yuma, AZ, would produce 51,079 AFY of water, at an estimated unit cost of $640/AF.

- It is estimated that over 15,260,000 AF of brackish water is physically available in Southern CA alone. A determination of the amount of such water that can be developed economically is beyond the scope of this TM. One of the potential sources has been considered within this TM. Development of a 4,257 AFY desalination plant treating water from the Winchester/Hemet Basin would produce water at a unit cost of $1,950/AF. The sustainable withdrawal and storage of water from the aquifer has not been established, but is estimated to be less than 10,000 AFY. Groundwater recharge is likely required to prevent water mining of the resource with potential detrimental effects decreasing the net yield of the Project.

- Brackish surface waters within the San Francisco Bay watershed are widely available. Although there are additional environmental concerns relating to the implementation of a surface water plant, it is nevertheless a viable water resource. One case, a surface brackish water treatment plant with a capacity of 40-mgd, was developed further. Updated cost estimates for the facility previously proposed (URS and Boyle, 1993) indicate unit water costs of $1,070/AF for the facility. The unit water cost does not include any additional costs associated with re-treatment at EBMUD facilities.

Table 3-1 Unit Water Cost Summary				
Parameter	**Unit**	**Project**		
Project	-	Yuma Desalter	Winchester/Hemet Basin	Mirant Pittsburg
Location	-	Yuma, Arizona	Riverside County, CA	Contra Costa County, CA
Plant Capacity	*mgd*	48	4	40
Annual Production[1]	*AF*	51,079	4,257	42,565
Construction Costs				
Total Construction Costs	*$*	170,060,000	52,560,000	300,000,000
Amortized Construction Cost[2,3]	*$*	11,660,000	3,610,000	19,520,000
Annual Costs				
Annual Construction Payments	*$*	11,660,000	3,610,000	19,520,000
Annual Operating Cost	*$*	21,400,000	3,780,000	23,430,000
Total Annual Costs	*$*	33,060,000	7,390,000	42,950,000
Unit Water Cost	***$/AF***	**640**	**1,950**	**1,070**
Notes				
[1]Online Factor		0.95	0.90	0.90
[2]Interest Rate	%	5%	5%	5%
[3] Period	years	30	30	30

[#]These costs do not include additional treatment costs at downstream EBMUD filtration facilities or alternative distribution system modifications.