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

COST NORMALIZATION OF ALL OPTIONS TECHNICAL MEMORANDUM

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Final: June 2007
Released: March 2008

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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 seven TMs being prepared as part of the Project, presents the methodology for cost normalization of all options mentioned in the six preceding TMs.

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. Six of the TMs evaluate potential long-term water supply augmentation options: brackish water desalination, conjunctive use, ocean water desalination, stormwater storage, transbasin imports/ exports, and vegetation management. This seventh TM discusses a cost normalization analysis, which uses universal economic values (e.g. discount rate, inflation rate, life cycle) to evaluate all of the options and provide a single cost evaluation summary. The final result is a dollar per acre-foot (AF) value for each option.

Findings

Table ES-1 summarizes the cost normalization for the six long-term options. A consistent methodology allows for relative comparison of the economic benefits (or cost) of each option under the same circumstances. Although future conditions might be different from those predicted in this TM, they would affect all options in a similar manner. A change in assumptions about the future could change the best financial option.

The financial factors discussed in this TM are only one of eight parameters that will be used to evaluate the selected options. The other parameters include location of supply, quantity of water potentially available, water quality, technical issues (collection, treatment, and distribution), general reliability of supply, environmental issues, and permitting issues. A normalized cost is only one measure of an option's overall acceptability.

Table ES-1
Summary of Findings

Option	Water Production (AFY)	Unit Cost-Economic ($/AF)	Unit Cost-Financial ($/AF)	First Year O&M ($ Millions)	Capital Cost ($ Millions)
Brackish Water Desalination					
Yuma	51,100	950	640	21	170
Winchester/Hemet Basin	4,000	2,770	1,950	4	60
Mirant Pittsburg	40,300	2,020	1,070	23	300
Conjunctive Use					
Arizona Interstate Banking	30,000	520	420	37	0
Semitropic	37,500	580	420	4	146
Chino	8,300	960	620	2	25
Hayfield	26,700	470	470	1	159
Ocean Water Desalination					
Alamitos 20 mgd	20,200	2,020	1,470	14	235
Alamitos 40 mgd	40,300	1,880	1,350	27	417
Alamitos 50 mgd	50,400	1,850	1,320	33	511
Alamitos 80 mgd	80,600	1,780	1,260	52	763
Bay Area 40 mgd	40,300	2,220	1,410	38	285
South Bay 50 mgd	50,400	2,420	1,730	48	595
Rosartio 50 mgd	50,400	1,700	1,280	32	503
San Onofre 50 mgd	50,400	1,800	1,230	36	392
San Onofre 100 mgd	100,800	1,680	1,120	69	675
Stormwater Storage	40,000	500	620	6	280
Transbasin Imports and Exports					
Snake River	33,000	900	770	12	212
Clarks Fork River Option 1	75,000	1,800	2,100	38	1,846
Clarks Fork River Option 2	75,000	1,750	1,830	40	1,490
Bear River	50,000	860	730	16	321
Mississippi River	675,000	2,060	1,870	525	11,367
Vegetation Management					
Virgin River Region	17,200	110	100	<1	24
Lower Colorado River Region	154,000	36	30	3	32

AFY acre-feet per year
mgd million gallon(s) per day

Conclusions

The conclusions drawn from this TM are as follows:

- Brackish Water Desalination and Ocean Water Desalination have similar costs for most projects. The larger projects tend to achieve an economy of scale that lowered their unit cost of water. The Yuma Desalting Plant (YDP) was significantly less expensive than the other desalting plants because the evaluation considered an advantage of existing capacity to reduce the initial investment and reduce operations costs. The YDP has a normalized financial cost of $640 per AF. The remaining desalting options have unit financial costs ranging from $1,070 to $1,950 per AF.

- The normalized economic cost of transbasin imports of water varied between $730 and $2,100 per AF.

- Conjunctive use and vegetation management have the lowest financial cost ranges of $420-$620 per AF and $30-$100 per AF, respectively. For these two options, it is difficult to determine the water yield.

- Stormwater storage has highly variable flows which means that determination of economic advantage requires further evaluation.

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 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, and additional storage.

- New supplies. Basin imports/reduction of exports through exchanges, brackish water desalination, coal bed methane produced water, seawater desalination, stormwater management, 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. This seventh TM describes the parameters used to normalize the cost estimates in the other six TMs.

1.5 Technical Memorandum Organization

Following the Executive Summary and Introduction, this TM presents a Technical Discussion of the methodology for normalizing cost estimates. Application of this methodology to the six long-term augmentation options is then described as follows:

- Brackish Water Desalination
- Conjunctive Use
- Ocean Water Desalination
- Stormwater Storage
- Transbasin Imports/Exports
- Vegetation Management

1.6 Abbreviations and Acronyms

The following abbreviations and acronyms are used in this TM.

AF	acre-feet
AFY	acre-feet per year
Bureau	United States Bureau of Reclamation
CRWC	Colorado River Water Consultants
ENR	Engineering News Record
mgd	million gallons per day
O&M	operations and maintenance
Project	Technical Evaluation of Options for Long-Term Augmentation of the Colorado River System
Seven States	Seven Colorado River Basin States
TM	technical memorandum
YDP	Yuma Desalting Plant

2.0 TECHNICAL DISCUSSION

2.1 Overview

This section describes the methods used to make all of the options' cost estimates comparable to the greatest extent. A good comparison of these cost estimates involves the use of similar parameters, such as similar discount rates, life cycles, and amortized costs. The final cost normalization results are presented in Table 2-1 as a dollar per AF value.

2.2 Methodology for Cost Estimates

Cost estimates were developed by estimating individual costs and then normalizing the costs. For this TM, cost normalization describes the method of comparing the various options on a consistent financial basis.

2.2.1 Cost Estimates

Individual cost estimates were determined with the available knowledge for each option. Cost estimates were derived by individual TM authors based on previous reports, existing studies, or experiences on similar projects. The cost of contractor profit and overhead was included in this cost. Contingencies were added to preliminary estimates of the capital costs to capture costs associated with unknown project elements that were not included in the estimate. Contingency factors varied from 15 to 40 percent based on the method of determining costs.

The preliminary estimates in this TM are general estimates of the project cost based on preliminary review of the work. These estimates are useful in comparing options and varying projects but might not provide the final projects costs. The final project cost could range from 30 percent less to 50 percent greater than of the stated estimate.

Costs are displayed in 2007 dollars. Construction costs estimates based on previous year estimates are inflated using the Engineering News Record (ENR) construction cost index. Future prices were inflated at an estimated rate of inflation of 5 percent. For the present worth analysis, construction costs are obligated in 2007 and operations and maintenance (O&M) costs begin in 2008.

Engineering and program management costs were not included in the project costs. Unless stated otherwise, O&M costs were considered together and calculated to be 2 percent of the capital costs. Electrical energy costs were considered separately and included as an additional O&M cost.

Table 2-1 Cost Normalization for Augmentation Options					
Option	**Water Production (AFY)**	**Unit Cost-Economic ($/AF)**	**Unit Cost-Financial ($/AF)**	**First Year O&M ($ Millions)**	**Capital Cost ($ Millions)**
Brackish Water Desalination					
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Mississippi River	675,000	2,060	1,870	525	11,367
Vegetation Management					
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AFY acre-feet per year
mgd million gallon(s) per day

2.2.2 Present Worth and Cost Normalization Analysis

Table 2-2 presents the economic parameters used for the cost normalization for the six options.

Table 2-2
Economic Parameters Used for Cost Normalization

Parameter	Value
Discount Rate	5%
Amortization Period	30 Years
Power Cost	$0.08/kwh
Inflation (for years after 2007)	5%
O&M Costs	2% of capital

The options evaluated included various cash flows, capital expenditures, electrical costs, generated electricity income, operations costs, and water program costs. To compare varying cash flows among the options, a normalized cost of each option was developed. For this TM, normalized costs were defined as the annual cost of the option divided by the average water production, as shown in Equation 2-1.

Equation 2-1 Cost Normalization

Normalized Cost of Option =

$$\frac{AnnualCostofOption(\$)}{AverageWater\,\mathrm{Pr}\,oduced(AF)} = \text{Unit Cost (\$ per acre-foot)}$$

Normalized costs were calculated using two different methods: economic present worth and financial cost. Because of the significant variation in the type of options being considered, the two methods are provided as additional decision-making tools. The economic present worth compares the long-term investment of each option while financial cost method focuses on the first year funding of each option.

As the financial cost method best reflects actual costs experienced in implementing projects, the financial unit costs were used in the final project report. Financial unit cost estimates for those options not carried forward into detailed Technical Memoranda were prepared on the basis of annual quantities of supply and estimated capital and O&M costs for each option.

2.2.2.1 Economic Present Worth Method

The economic present worth uses a traditional present worth analysis to calculate the present worth of each cash flow including the capital salvage value. The present worth is converted to an annuity to calculate the annual cost. As shown in Equation 2-2, the unit cost of water production for each project is the annual cost divided by the average project yield.

Equation 2-2 Economic Present Worth

$$\text{Normalized Cost of Option} = \frac{(A/P,i,N) * \sum_{n=0}^{N} [CashFlow * (P/F,i,n)]}{AverageWater\ \Pr oduced(AFY)} = \$ \text{ per acre-foot}$$

Where:

N	total number of project years (usually 30 years)
n	year of the cash flow
i	discount rate (Table 2-2)
(A/P,i,N)	conversion factor from a present worth to an annuity
(P/F,i,n)	conversion factor from a future cash flow to its present worth

2.2.2.2 Residual Value

Residual values at the end of the 30-year evaluation period were estimated based on the type of capital investment. As shown in Table 2-3, the residual values varied between 0 percent and 50 percent. Any capital costs associated with the purchase of real estate (land) were ignored in the present worth analysis. The inflation rate was applied to each future year cash flow to increase the value of cash flows in future years. The discount rate was applied to all conversions between future cash flows to the present value.

2.2.2.3 Financial Cost Method

The financial cost is intended to estimate the annual budget requirements in the first year of the project. The capital costs are assumed to be funded by bonding and are converted to even payments. Operations are assumed to be funded on an annual cycle. The calculation uses annuity of the capital costs (e.g. the annual bond payment) plus the average annual operations and maintenance costs in 2007 dollars. As shown in Equation 2-3, the normalized unit cost of water production for each project is the annual cost divided by the average water yield.

Equation 2-3 Financial Cost

Normalized Unit Cost of Project =

$$\frac{(A/P,i,N) * CapitalCosts + AverageO\&M.Cost}{AverageWater\ \Pr oduced} = \$ \text{ per acre foot}$$

Table 2-3 Residual Value of Capital Costs at the End of the 30-Year Evaluation	
Capital Improvements	**Residual Value (%)**
Plant Facilities	0
Evaporation Ponds	0
Pump Stations/Hydropower	20
Pipelines and Tunnels	50
Diversion Structures	50
Land	100
All other improvements	0

2.2.3 Cost Avoidance of Options

Implementation of any option might entail avoidance of the costs required to obtain water from an alternative source of supply. For example, the costs estimated to implement ocean water desalination are based on delivery of a potable supply into the finished water transmission system of the water purveyor. This means that the treatment and transmission costs of alternative supplies could be avoided by implementation of the ocean desalting option. The applicability and magnitude of these avoided costs must be evaluated on a case-by-case basis.

2.2.4 Quality and Location of Water Supply

The quality and location of the delivered water vary with each option. For example, treated water from a desalination plant is not the same as transbasin imported water. Ocean desalination can produce drinking water ready for consumption. A transbasin import generates raw water that could require further treatment. Ocean desalination will be produced near the final user. A transbasin import creates water near the headwaters some distance from the majority of Colorado River water users. This might not be a problem for all options or uses, but should be considered in the final comparison. For this cost normalization TM, the costs associated with the quality and location of the water supply were not considered when comparing each option.

2.3 Discussion of Each Option

Each option has multiple types of options and different ways of evaluating capital costs and O&M costs. A cost range was developed based on the projects evaluated for each technical approach as described in the individual TMs. Figure 2-1 displays the range of project costs determined for each of the six topics.

The range of costs shown on Figure 2-1 does not indicate the certainty of the costs but the range of costs for different projects within each option. For example, the costs for the ocean desalination option have limited variation because the projects evaluated have similar elements and locations. Costs variations are strongly influenced by the economies of scale of the plant. Transbasin imports and exports capital and operating costs among projects vary significantly because of the different geographies and project requirements. As shown in the Transbasin TM, creating a diversion from the Bear River is a significantly less expensive project than a creating a diversion from the Mississippi River.

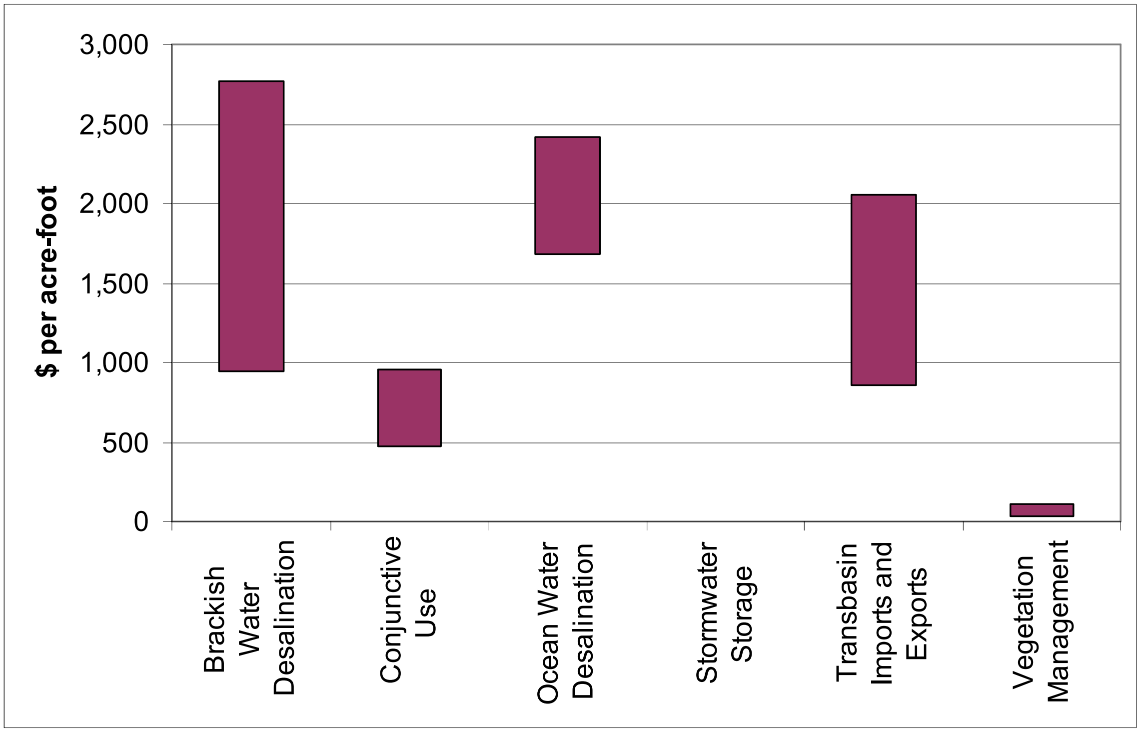

Figure 2-1 Cost Range for Technical Options

2.3.1 Brackish Water Desalination

Capital costs for brackish water desalination vary among projects but generally include cost for a desalination facility, pipelines, and concentrate disposal by a pipeline, evaporation pond, or injection well. Unit costs for the YDP were significantly lower than the other desalting plants (brackish and ocean) because of the utilization of existing unused capacity at an existing plant. This reduced the capital costs and operations costs. Operational history was used as the basis for determining the O&M costs for YDP. Other than the YDP, each desalting plant's annual yield was considered to be 90 percent of the stated capacity of the plant assuming downtime and maintenance and other items.

2.3.2 Conjunctive Use

Capital costs for conjunctive use include well construction, pipelines, electrical substations, and environmental studies. The maximum capacity of the potential groundwater reservoirs varies. O&M costs varied based on the project.

The Arizona Water Bank is already functioning and has a fee structure. The existing fee structure was used to evaluate the project. No capital costs are associated with the project, just charges and fees associated with participating. The average annual O&M cost was calculated for the twenty years of the project. However, the water yield was the average over thirty years to make this option comparable to the other projects in the TM.

2.3.3 Ocean Water Desalination

Several potential project locations and sizes were identified for ocean desalination. Capital costs for ocean water desalination include a desalination facility, associated conveyance systems, and concentrate disposal. O&M has been estimated for this option based on the current knowledge of the potential projects. Because costs of ocean water desalination are highly dependent on power costs, an energy cost sensitivity analysis was performed for this option only and is presented in the Ocean Water Desalination TM. Each desalting plant's annual yield was considered to be 90 percent of the stated capacity of the plant assuming downtime and maintenance and other items.

2.3.4 Stormwater Storage

This TM focused on the use of Painted Rock Reservoir to supplement Colorado River flow.

2.3.5 Transbasin Imports/Exports

Main capital costs for the river transbasin imports and exports option will include pump stations, pipelines, and tunnels. Other items that might need to be built with this option include diversion structures, energy-generating facilities from hydroelectric power, and canals. Annual O&M costs were estimated to be between 0.2 percent and 2 percent of capital costs based on the type of capital improvement; $15 per inch-diameter per linear foot pipe was used to estimate capital costs. This option is sensitive to power costs. Electrical consumption (and generation) was calculated for each alternative.

2.3.6 Vegetation Management

There were no traditional capital costs for this option because it does not require development of permanent structures. However, for cost normalization analysis, initial costs for removing salt cedar, and subsequent revegetation, were considered capital costs. Subsequent expenditure to maintain an area after initial removal of salt cedar was considered O&M costs. O&M costs are reduced after 10 years assuming that a consistent program of vegetation control will reduce future costs.

2.4 Findings and Conclusions

Table 2-1 above summarizes the normalization of costs for the six options reviewed in the previous TMs. A single methodology allows for relative comparison of the economic benefits (or cost) of each option under the same circumstances. The future conditions could be different than those predicted in this TM, but generally, future conditions are expected to affect all options in a similar manner. However, change in assumptions about the future could change the best financial option.

Financial factors discussed are one of several criteria that will be used to select options. Other criteria could include climate change, environmental impact, political environment, permitting conditions, reliability, and risk. A normalized cost should only be used as one measure of an option's acceptability.

Stormwater storage, specifically improvements to Painted Rock Reservoir, are not recommended based on this economic evaluation because the analysis of the improvements indicates that this option will provide minimal additional water.

The less expensive options include vegetation management and conjunctive use. Conjunctive use requires a water surplus in "wet" years. In addition, it is not sustainable through a prolonged drought as it can only produce a limited volume of water.

Vegetation management will provide good economic value, but its economic performance will be difficult to monitor in terms of actual water production. Seasonal changes cause significant variations in river flows, making it difficult to attribute water to particular vegetation control measures. Also, it would be difficult for the funding agency to obtain the water produced by this project. Currently, additional water provided by this option would not be directly distributed to the funding agency but according to existing water rights and law. This might only benefit the funding agency in specific circumstances.

The other three options - ocean desalination, brackish water desalination, and transbasin imports and exports - significantly vary in project's costs. Because the projects within an option are independent, a funding agency could fund the least expensive projects from each option.