Appendix F5
Option Characterization – Desalination

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1.0 Introduction

Ocean and brackish water desalination has been proposed to increase the supply in those areas currently relying upon water supply from the Colorado River. A number of desalination options were submitted for consideration in the Colorado River Basin Water Supply and Demand Study (Study). The submittals are summarized in appendix F2 and the original submittals are available via links from the electronic version of appendix F2 on the compact disc that accompanies this report and the version of appendix F2 on the Study website at http://www.usbr.gov/lc/region/programs/crbstudy.html.

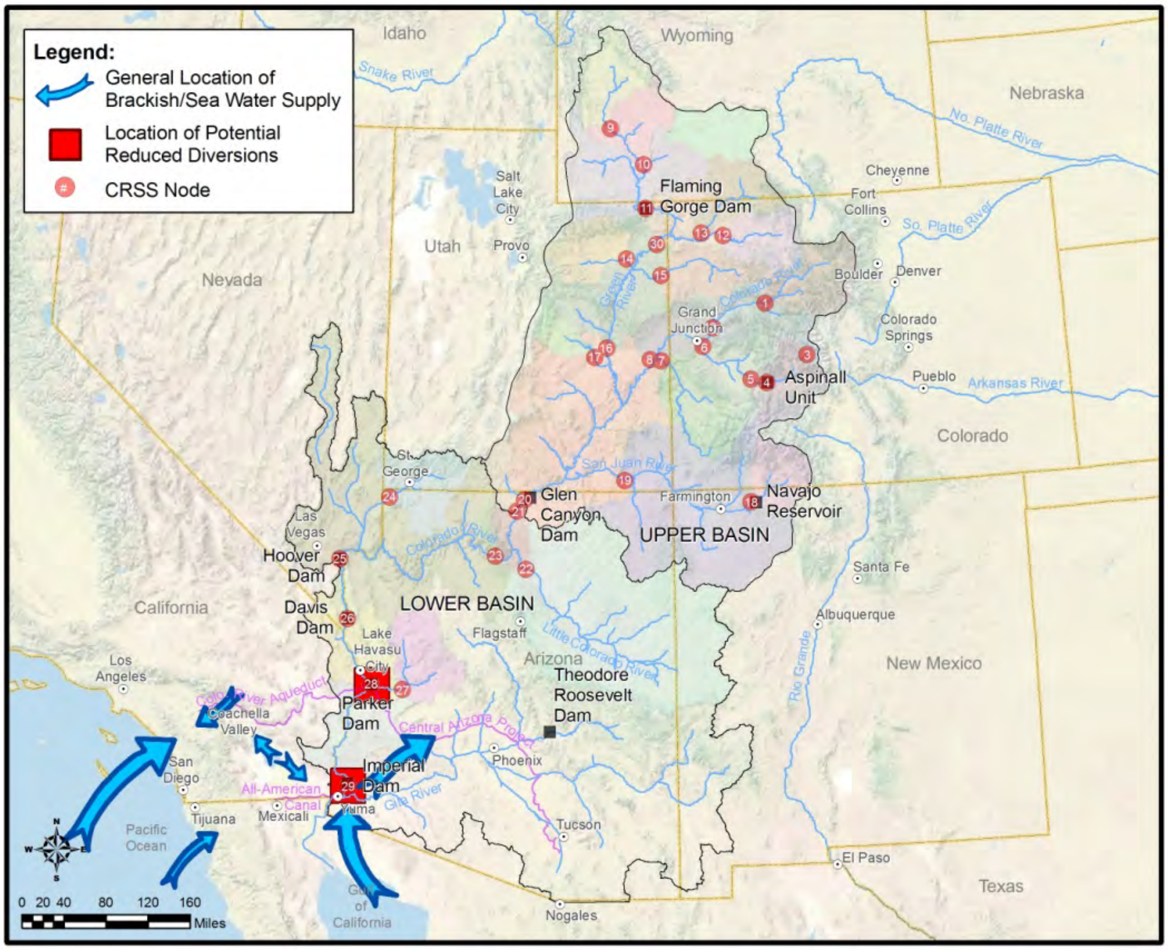
15 options were submitted related to ocean or brackish water desalination. Some of the submittals were related to specific projects with detailed descriptions, while others were provided as general concepts. The submitted options were reviewed and organized into groups according to the source of the desalination water:

- Ocean Desalination
- Desalination of Agricultural Drainwater
- Desalination of Brackish Groundwater

The general location of these options are shown in figure F5-1,with the arrow indicating the flow of desalinated water and the red square indicating the points of reduced Colorado River diversion. Representative options were developed for each option group to represent the distinct nature of the options.

This appendix summarizes the types of options received, the assumptions made and methods used to characterize the options, and the characterization results. Additional detail related to the options characterization is included in appendix F3. Attachment A of appendix F3 contains more detailed descriptions of the ratings. Attachment B provides the methods used for completing the unit cost calculations. Attachment C presents the detailed characterization information and is available on the compact disc that accompanies this report and on the Study website.

FIGURE F5-1
General Locations of Desalination Options



2.0 Ocean Desalination

This group of options consists of constructing new ocean desalination plants in strategic locations along the Southern California coast or near the international boundary in Mexico. The desalinated water would be delivered to some of the larger existing operational reservoirs in the Metropolitan Water District of Southern California (MWD) system or similar reservoirs in MWD member agencies' systems. This option group also includes constructing new ocean desalination plants along the Gulf of California (Gulf) in the United Mexican States (Mexico). This desalinated water would be delivered to Imperial Dam north of the international boundary, where the water could be left in the river to meet water commitments to Mexico or diverted into the All American Canal. For both the Pacific Ocean and the Gulf desalination plants, the water could be exchanged to Lake Havasu or higher up the river to Lake Mead or Lake Powell, thereby allowing the new supply to benefit water users up and down the river.

Three representative options were developed from this group of options to reflect the various potential desalination plant locations. The representative options consist of the following:

- Pacific Ocean Desalination in California
- Pacific Ocean Desalination in Mexico
- Gulf of California Desalination

2.1 Pacific Ocean Desalination in California

The quantity of yield for this concept is limited by the ability to integrate the new supply into the proposed delivery points or by the hydraulic capacity limitations of a single large pipeline. Based on discussions with MWD, Pacific Ocean desalination concepts are estimated to be limited to 600,000 acre-feet per year (afy) due to integration considerations.

With regard to timing, the Pacific Ocean projects would require well over 20 California and federal permits. California permits such as those from the Coastal Commission, State Lands Commission, Regional Water Quality Control Boards, and Department of Public Health can be challenging to obtain and may affect the viability and/or cost and timing of the particular project. This would be especially true for the potential sizing and transfer components of the proposed projects. It is roughly estimated that 200 million gallons per day (200,000 afy) of Pacific Ocean projects could require 5 years of feasibility, 10 years of permitting, and 5 years of implementation, totaling 20 years.

Several recent studies have included cost estimates for ocean desalination facilities. The 2008 augmentation study included planning-level cost estimates for facilities in Southern California, Baja California, and along the Gulf (Colorado River Water Consultants, 2008). In addition to the information available from these studies, water treatment plant conceptual design and cost estimating tools were used to estimate treatment costs, including intake and outfall facility costs. A cost estimating tool was also used to estimate costs of the pipelines and pump stations that would convey the water from the coast to the selected delivery location. Total capital costs were estimated to range from $2.8 to $3.2 billion depending on location. Annual costs include electricity, chemicals, maintenance, repair, and replacement costs. Electricity costs assume that a project of this size would get favorable electricity rates because of its large and consistent energy demand. Specifically, a cost of $0.10 per kilowatt hour was assumed to cover all aspects of the energy rate. This cost is consistent with current assumptions on electricity costs for ocean desalination plants in the Southern California region (HDR Inc., 2009). The annual costs for maintenance, repair, and replacement are based on a percentage of the capital. With all these considerations accounted, the annual cost per acre-foot (af) of produced water is estimated to be approximately $1,900 per af, with a range between $1,600 per af and $2,600 per af, assuming 200,000 afy construction increments and 50 miles between the plant and delivery location.

In regard to technical feasibility, ocean desalination facilities have been completed in numerous locations around the world, but none at the scale described for the larger supply concepts. Therefore, technical feasibility characterization varies based on scale and precedence for similar options. When considering long-term viability, there is some concern about the potential for increased electricity costs to affect viability. Potential environmental impacts have been the key focus of the regulatory agencies. The main barriers to larger-scale desalination in California have been attributable to concerns regarding: impingement and entrainment at seawater intakes, hyper-saline impacts from brine discharge a planned Ocean Plan amendment to address these impacts currently under development by the California State Water Resources Control Board with anticipated completion by late 2013, limitations from implementation of coastal Marine Protected Areas, areas of Special Biological Significance, and phase-out of once-through cooling intake/outfall use at coastal power plants. These concerns will contribute to permitting and implementation challenges.

None of the desalination options rate high for operational flexibility criteria because these options would have high debt service costs that exist even when the option is put into an idle mode. All of the desalination options have relatively high energy requirements. When considering hydropower, recreation, and other environmental impacts, many of these options rely on exchanges along the river to varying degrees, which could result in a change in how the river reaches are operated and could have adverse impacts due to reduced releases or river flows. In regard to water quality, some options have the potential to have a positive impact by reducing salinity levels in specific locations. Socioeconomic impacts are difficult to fully assess because jobs will be created with all of these options, but there is also likely to be a combination of positive and adverse impacts when considering factors beyond simply job creation (e.g., effects on communities). Without more-detailed assessments, neutral conditions were assumed for socioeconomics.

2.2 Pacific Ocean Desalination in Mexico

This concept consists of constructing a desalination plant adjacent to a power plant in Rosarito, Mexico. Quantity of yield for this concept is limited by the ability to integrate the new supply into the regional infrastructure in the San Diego region as well as site constraint considerations. The largest plant size considered to date is 75,000 afy. With regard to timing, feasibility studies have been completed (San Diego County Water Authority, 2010) and additional studies are underway. Permit requirements are similar but possibly not quite as challenging or time-consuming as constructing similar facilities in California. It is roughly estimated that a 56,000 afy plant at this location could require 10 years of permitting, and 5 years of implementation, totaling 15 years. Costs and energy requirements are relatively consistent with the similar Pacific Ocean desalination concepts evaluated for California. This type of option is smaller than some of the other ocean desalination options, and so the criteria related to impact to the Colorado River, including hydropower impacts, recreation impacts, and ecological impacts, all have ratings that are slightly negative, but more favorable than the larger-scale options.

2.3 Gulf of California Desalination

The Gulf desalination concepts are assumed to be limited to 600,000 afy of increased supply, based on the hydraulic capacity constraints of a single large-diameter pipeline. However, if parallel pipelines were installed, larger yields are feasible.

The Gulf projects would require international negotiations and potential mitigation measures that may lengthen the permitting and implementation process. It is estimated that the Mexico options would require the same time for permitting and implementation as the Pacific Ocean projects—roughly 20 years. This assumption considers that feasibility studies have already begun for this representative option.

The same sources of information and cost estimating assumptions were used for the Gulf desalination option as for the Pacific Ocean option. Additionally, a more-detailed cost study on ocean desalination concepts in the Gulf completed in 2009 (HDR Inc., 2009) was referenced. Based on these references, the annual cost of produced water is estimated to be approximately

$2,100 per af. These costs are based on assumptions of 200,000 afy construction increments and considering that approximately 170 miles of conveyance facilities are required to deliver the desalinated water from the Gulf coast to Imperial Dam. The resulting estimate for capital costs is approximately $4.2 billion. When comparing costs to the Pacific Ocean option, the additional cost is associated with the location of the projects and the assumed points of delivery, which involve longer conveyance facilities.

Other key considerations used to characterize the Gulf desalination option were the same as the Pacific Ocean option.

3.0 Desalination of Agricultural Drainwater

This group of options consists of constructing new diversions upstream of the Salton Sea that would capture agricultural drainage water and deliver this water to a regional brackish water desalination facility. The desalinated water would be delivered back to the All American Canal upstream of the East Highline Canal, allowing the water to be delivered to Imperial Irrigation District and by exchange, Coachella Valley Water District customers who rely on the All American Canal system. Simultaneously, an in-kind reduction in diversions is possible from the river at Imperial Dam.

In this case, only one representative option was used—Salton Sea Drainwater Reuse.

3.1 Salton Sea Drainwater Reuse

The quantity of additional yield for this representative option is limited to the amount of agricultural drainage water entering the Salton Sea through the New and Alamo rivers and direct agricultural drainage, and limitations of maintaining the Salton Sea system. Between 300,000 afy and 500,000 afy of sustainable yield was assumed.

This concept changes the flow balance in the Salton Sea, so substantial time would be needed to obtain permits from the California State Water Resources Control Board, and several other permitting entities in California. Impacts of reduced Salton Sea inflows associated with implementation of the Quantification Settlement Agreement (QSA) have been addressed in environmental documentation prepared prior to execution of the QSA. Consistency with the QSA would need to be evaluated, and mitigation for air quality impacts of increased exposed Salton Sea playa would be required. Although these efforts would take time, it is assumed that the option could be done with 5 years of feasibility, 5 years of permitting, and 5 years of implementation, totaling 15 years.

The cost of this option is highly dependent on the assumed salinity concentration of the agricultural drainwater and the method of disposing of the brine stream from the reverse osmosis units. The option recommends using a salinity of 2,500 milligrams per liter (mg/L) for the drainwater and 700 mg/L for the product water to ensure similar or improved water quality for those dependent on the source. Based on this level of salt removal, the size and cost of the treatment plant can be estimated. Also, it is assumed that the brine stream would be of lower salt concentration than the Salton Sea (currently higher than 45,000 mg/L) and therefore could be discharged to the sea. Once these parameters were selected, the same cost tools used to estimate ocean desalination concepts were used to estimate capital costs (approximately $2.1 billion) as well as electricity, chemicals, maintenance, repair, and replacement annual costs for the agricultural drainwater concepts. Based on these assumptions, the cost of produced water is estimated to be approximately $950 per af assuming 200,000 afy construction increments.

In addition to yield, timing, and cost, the Salton Sea drainwater reuse option was characterized for several other criteria. Key considerations related to technical feasibility, permitting, legal, and policy issues were largely covered in the descriptions above related to estimating option timing. In regard to technical feasibility, desalination of agricultural drainwater has been accomplished in numerous locations around the world, but none at the scale described herein. Therefore, the technical feasibility characterization varies based on scale and precedence for similar options. When considering long-term viability, there is some concern about the potential for increased electricity costs to affect viability. The option does not rate high for operational flexibility criteria because it would have high debt service costs even when the option is put into an idle mode. Desalination of agricultural drainwater involves relatively high energy requirements as well. When considering hydropower, recreation, and other environmental impacts, the option relies on exchanges along the river to varying degrees, which could result in a change in how the lower river reaches are operated and could have adverse impacts. Socioeconomic impacts are difficult to fully assess because jobs will be created with all of these options, but there is also likely to be a combination of positive and negative impacts when considering more than just job creation. Without more-detailed assessments, neutral conditions were assumed for socioeconomics.

4.0 Desalination of Brackish Groundwater

This group of options consists of completing relatively small local projects by municipal water providers in Southern California consistent with past similar projects. This group also includes refurbishing the Yuma Desalting Plant back to full-scale production.

Two representative options were developed for this group of options to reflect the differences in potential location of diversion, conveyance infrastructure needs, and associated impacts. The representative options are:

- Southern California Groundwater Desalination
- Brackish Water Desalination in the Yuma Area

4.1 Southern California Groundwater Desalination

This representative option is limited by sustainable groundwater extraction rates, sustainable brine disposal capabilities, or the capacity of existing facilities. Without updating past studies, it is difficult to calculate the amount of remaining sustainable brackish groundwater yield in Southern California. However, a large number of previously identified projects have been implemented, and a rough estimate is that 20,000 afy of additional sustainable yield remains.

With regard to time required to produce desalinated brackish groundwater, groundwater extraction and treatment are proven concepts. Therefore, the timing for projects in this representative option is limited to 5 years of permitting and 5 years of implementation, totaling 10 years.

Similar to the agricultural drainwater option, the cost of this option is highly dependent on the assumed salinity concentration of the extracted groundwater and the method of disposing of the brine stream from the reverse osmosis units. This option was submitted as a general concept for Southern California, without designation of a specific groundwater source in a specific location.

Therefore, it is not possible to accurately estimate the salinity of the source water or the options for brine discharge. Assuming the source water has a salinity concentration of 1,500 mg/L (approximate groundwater total dissolved solids), production water is treated to 350 mg/L, and the resulting brine can be disposed of locally, capital costs are estimated to be approximately $80 million and produced water is estimated to have a unit annual cost of between $600 and $700 per af.

Key considerations related to technical feasibility, permitting, legal, and policy were largely covered in the descriptions above related to estimating option timing. In regard to technical feasibility, groundwater desalination facilities have been completed in numerous locations around the world. When considering long-term viability, there is some concern about the potential for increased electricity costs to affect viability. Operational flexibility was characterized as low because the option would have debt service costs even when the option is put into an idle mode. Like the other desalination options, groundwater desalination has relatively high energy requirements, although fewer requirements than seawater desalination. When considering hydropower, recreation, and other environmental impacts, water exchanges could result in a change in how the lower river reaches are operated and could have adverse impacts. In regard to water quality, some options have the potential to have a significant positive impact in reducing salinity levels in specific locations. Socioeconomic impacts are difficult to fully assess because jobs will be created with all of these options, but there is also likely to be a combination of positive and adverse impacts when considering more than just job creation. Without more-detailed assessments, neutral conditions were assumed for socioeconomics.

4.2 Brackish Water Desalination in the Yuma Area

The yield of brackish groundwater in the vicinity of Yuma, Arizona, is limited to 100,000 afy by the available capacity of the Yuma Desalting Plant.

The major challenge for full-scale operation of the Yuma Desalting Plant is minimizing the impact to the Cienega de Santa Clara. In lieu of using Wellton-Mohawk Irrigation and Drainage District drainage water, saline Yuma Mesa groundwater could be considered as source water for the plant. A recent 9-month pilot run at one-third capacity utilizing this drainage water produced promising results (Reclamation, 2012). Therefore, the timing for this option is limited to 5 years of permitting and 5 years of implementation, totaling 10 years.

For full-scale operation of the Yuma Desalting Plant, the brackish groundwater is known to have a total dissolved solids concentration of about 1,500 parts per million, and disposal of the waste brines would be to the Gulf via the Main Outlet Drain Extension. The unit annual cost of produced water is estimated at $640 per af.

Other key considerations were similar to the other desalination options.

5.0 Characterization Results

A summary of the characterization findings are shown in table F5-1. The top portion of the table shows the estimated quantity of yield, earliest timing of implementation, and estimated cost. The bottom portion of the table shows the 17 criteria and associated ratings (“A” through “E”) and is color-scaled. In general, “C” is typically designated as mostly neutral; “A” is largely positive; and “E” is largely negative. Refer to appendix F3 for specific criteria descriptions and rating scales.

TABLE F5-1
Summary Characterization Ratings for Desalination Options

Representative Option	Quantity of Yield	Timing	Cost
Desal-Pacific Ocean-CA (Step 1)	200,000	20	1,850
Desal-Pacific Ocean-CA (Step 2)	200,000	25	1,850
Desal-Pacific Ocean-CA (Step 3)	200,000	25	1,850
Desal-Pacific Ocean-Mexico	56,000	15	1,500
Desal-Gulf (Step 1)	200,000	17	2,100
Desal-Gulf (Step 2)	200,000	22	2,100
Desal-Gulf (Step 3)	200,000	27	2,100
Desal-Gulf (Step 4)	200,000	27	2,100
Desal-Gulf (Step 5)	200,000	27	2,100
Desal-Gulf (Step 6)	200,000	27	2,100
Desal-Salton Sea Drainwater (Step 1)	200,000	15	1,000
Desal-Salton Sea Drainwater (Step 2)	200,000	20	1,150
Desal-Salton Sea Drainwater (Step 3)	100,000	25	1,300
Desal-SoCal Groundwater	20,000	10	750
Desal-Yuma Area Groundwater	100,000	10	600

Representative Option	Quantity of Yield	Timing	Cost	Technical Feasibility	Implementation Risk	Long-Term Viability	Operational Flexibility	Permitting	Energy Needs	Energy Source	Other Environmental	Recreation	Socioeconomics	Policy	Legal	Hydropower	Water Quality
Desal-Pacific Ocean-CA (Step 1)	D	C	C	B	B	C	D	D	D	C	C	C	C	C	D	C	B
Desal-Pacific Ocean-CA (Step 2)	D	D	C	C	B	C	D	D	D	C	D	C	C	C	D	D	B
Desal-Pacific Ocean-CA (Step 3)	D	D	C	C	C	D	D	E	D	C	D	D	C	C	D	D	B
Desal-Pacific Ocean-Mexico	E	C	C	A	B	C	D	D	D	C	C	C	C	C	D	C	C
Desal-Gulf (Step 1)	D	C	D	B	B	C	D	D	D	C	C	C	C	C	D	C	C
Desal-Gulf (Step 2)	D	D	D	C	B	C	D	D	D	C	D	C	C	C	D	C	C
Desal-Gulf (Step 3)	D	D	D	C	C	D	D	E	D	C	D	D	C	C	D	D	C
Desal-Gulf (Step 4)	D	D	D	D	C	D	D	E	D	C	D	D	C	C	D	D	C
Desal-Gulf (Step 5)	D	D	D	D	D	D	D	E	D	C	D	D	C	C	D	D	C
Desal-Gulf (Step 6)	D	D	D	D	D	D	D	E	D	C	D	D	C	C	D	D	C
Desal-Salton Sea Drainwater (Step 1)	D	C	B	B	C	A	D	C	C	A	C	C	C	D	D	C	C
Desal-Salton Sea Drainwater (Step 2)	D	C	B	C	D	B	D	D	C	A	D	C	C	D	D	C	C
Desal-Salton Sea Drainwater (Step 3)	D	D	B	C	D	B	D	D	C	A	D	C	C	D	D	D	C
Desal-SoCal Groundwater	E	B	B	A	A	B	C	B	C	C	C	C	C	A	B	C	B
Desal-Yuma Area Groundwater	D	B	B	A	B	A	C	C	C	C	D	C	C	A	C	C	C

6.0 References

Bureau of Reclamation (Reclamation). 2012. *Yuma Desalting Plant Pilot Run Final Report.*

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