Executive Summary

Pilot Study results have confirmed that seawater desalination at the Brownsville Ship Channel is technically feasible. Although the ship channel presents a challenging water source due to extreme variations in quality (especially turbidity, suspended solids, and temperature), a microfiltration pretreatment system followed by reverse osmosis (RO) adequately treated raw seawater to potable standards. The data and information gained during the Pilot Study is sufficient to develop a full-scale, 25 mgd desalination plant. This design, however, must be conservative (and therefore expensive) to accommodate the raw water variability and probable environmental events, such as red tides and hurricanes, that were not experienced during piloting but are likely under long-term production.

The Brownsville Public Utilities Board (BPUB) therefore proposes to construct a 2.5 million gallons per day (mgd) demonstration-scale seawater desalination plant and research facility at the Port of Brownsville. The proposed Demonstration Project would have several advantages. First, the additional water provided by the demonstration facility will provide 9 percent of the total BPUB demand by 2012, further diversifying their water supply sources. Next, this phased approach will allow for an evaluation of system performance over several years of operation prior to an investment in full-scale capacity. This data is expected to yield a more efficient overall treatment system design and lower the cost of future expansions as they occur. Finally, the demonstration facility will include the capability for continued testing of the latest desalination technologies for this and other future seawater desalination facilities along the Texas coast. Such technologies include applications for pretreatment, energy recovery, sustainable energy supply, and larger (potentially more efficient) membranes.

The total estimated cost for the proposed 2.5 mgd Demonstration Project is $67,479,000. Approximately half of this amount reflects an investment in full-scale capacity infrastructure, such as the intake and concentrate disposal systems. This investment is expected to significantly reduce the costs of future expansions at the facility. BPUB proposes to finance a portion of this project using a $20 million loan from the Texas Water Development Board (TWDB). In addition, implementation of the proposed project will also require supplemental funding in the form of a $28.2 million grant from the State and $19.3 million financed under the TWDB State Participation Fund.

BACKGROUND

In 2004, a Feasibility Study determined that the Lower Rio Grande Valley region would be confronted with a water supply deficit by 2050 and that seawater desalination was a viable alternative (Dannenbaum and URS 2004). Based on data and information available at the time, the Feasibility Study estimated the total probable costs for a full-scale 25 mgd facility to be approximately $152 million. The study recognized that some form of supplemental (grant) funding would have to be provided to bridge the gap between what such a facility would cost and what local utilities could afford to pay. Since that time, substantial increases in the costs for fuel, electricity, steel, and petroleum-based products have been observed.

In 2007, BPUB and TWDB partnered together to implement a seawater desalination Pilot Study. The pilot facility was located on the north shore of the Brownsville Ship Channel on land made available by the Port of Brownsville. The primary purpose of the pilot was to provide an opportunity to evaluate actual performance of proposed water treatment systems under site-specific conditions. Piloting results would then be used to refine the designs and cost estimates for a full-scale (25 mgd) seawater desalination facility. The *Brownsville Seawater Desalination Pilot Project* operated from February 2007 to July 2008, and this Final Pilot Study Report presents its results and recommendations.

PILOT STUDY APPROACH

Two alternative site locations were considered for the pilot facility: Boca Chica Beach (coastal) and the Brownsville Ship Channel (inland approximately 11 miles) (Figure ES-1). Although the raw water quality was expected to be generally poorer at the ship channel site, the pilot facility was located there because of power supply, cost, security, and access considerations. As such, the site represents a worst-case source water quality testing scenario.

Because the objective of a seawater desalination project is to produce potable drinking water from the ocean, the Pilot Study established testing protocols approved by the Texas Commission on Environmental Quality. The performance of each pretreatment and primary treatment (RO) process was then evaluated and documented. The original study scope developed by BPUB and TWDB called for the comparison of two types of pretreatment technologies: 1) conventional (rapid mix/flocculation/clarification/filtration), and 2) ultrafiltration (a membrane-based technology). However, at the outset of the project, BPUB decided to increase the scope and value of the Pilot Study by including two additional membrane-based pretreatment units. The project budget was thereby increased by almost $1.0 million and funded by BPUB. This side-by-side comparison of four different pretreatment technologies resulted in an unprecedented level of study complexity (Figure ES-2).

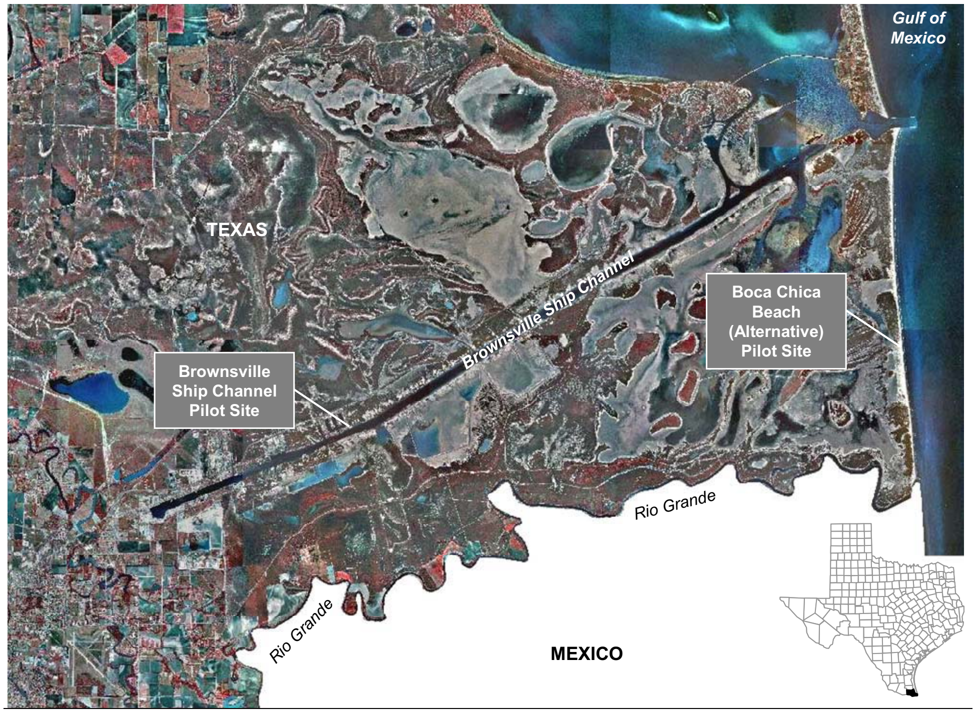

Figure ES-1: Location of the Brownsville Seawater Desalination Pilot Project.

LEGEND

1 Intake
2 Intake pumps
3 Norit ultrafiltration pretreatment unit
4 GE Zenon ultrafiltration pretreatment unit
5 Pall microfiltration pretreatment unit
6 Eimco conventional pretreatment unit
7 Pretreatment filtrate storage tanks
8 Reverse Osmosis treatment
9 Water storage tanks
10 Mixing tanks
11 Lagoon
12 Neutralization tank and discharge point
13 Discharge ditch
A Chemical storage building
B Operations building

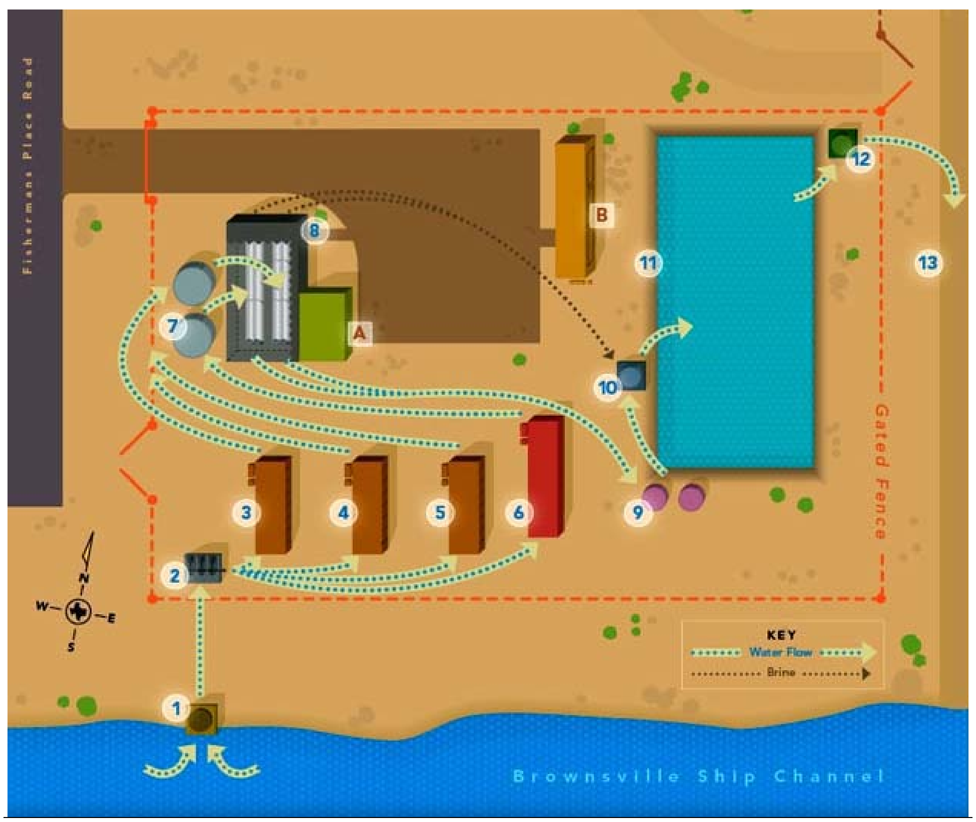

Figure ES-2: Layout of the Brownsville Seawater Desalination Pilot Project.

RESULTS AND CONCLUSIONS

Raw Water Characterization

During the Pilot Study, source water quality was characterized at both potential full-scale site locations, including the inland site on the Brownsville Ship Channel and the ocean site off-shore of Boca Chica Beach in the Gulf of Mexico. In the ship channel, large fluctuations in turbidity and suspended solids were observed. These variations were attributed mainly to the passing of cargo ships in the Brownsville Ship Channel (Figure ES-3) and predominant (southeasterly) wind direction and speed. Water quality in the Gulf of Mexico varied less, but samples were not taken during adverse weather conditions when variability would be expected to increase and overall quality decrease. Therefore, pilot data for the Gulf of Mexico do not reflect the worst-case water quality scenario for the open ocean that would occur during hurricane or other severe storm events.

Figure ES-3: Photograph of the effect of a cargo ship passing on raw water turbidity in the Brownsville Ship Channel.

Intake System

The Pilot Study utilized a wetwell, pumps, and intake screen to provide raw water from the ship channel to the pretreatment systems. Although this configuration was effective at the pilot-scale, a permanent intake system for a seawater desalination production facility will incorporate features that provide sufficient feed volume while minimizing the collection of suspended solids and protecting marine life. The recommended design includes a lengthy and wide constructed intake channel that connects the Brownsville Ship Channel to the intake screen assemblies and raw water pump station. This design would increase raw water settling time, thereby minimizing total suspended solids and turbidity introduced into the pretreatment systems. In addition, locating the facility on the south side of the ship channel may also reduce adverse water quality conditions imposed by prevailing southeasterly winds at the site.

Pretreatment System

It is widely understood that pretreatment is the most critical component of a successful seawater desalination facility. This is especially true given the raw water quality variability observed at the Brownsville Ship Channel. During the Pilot Study, four pretreatment systems were subjected to protocol tests: 1) Eimco Conventional System, 2) GE Zenon Ultrafiltration, 3) Norit Ultrafiltration, and 4) Pall Microfiltration. Each pretreatment system was tested at various operating conditions to document loading rates, pressure losses, water production efficiency, filter backwash rates and frequencies, and chemical types and dosing rates. For each, optimum process settings were established in which water production was maximized while minimizing chemical use and waste generation. The removal efficiency of potential membrane fouling agents (i.e., particulates, total organic carbon, etc.) was also measured and system reliability evaluated in terms of treatment consistency. Robustness was evaluated in terms of raw water quality variations. The overall goal was to maximize runtime by minimizing downtime associated with mechanical and membrane failures, thereby developing a cost effective pretreatment system for the production facility.

Of the four tested, only one pretreatment unit was able to meet the pretreatment objectives (i.e., operate for a minimum of 30 days without performing a clean-in-place, providing high quality filtrate, minimizing chemical consumption, maximizing filtrate flux, and performing without exhibiting irreversible fouling tendencies on the membrane surface). This unit was the Pall Microfiltration system, which successfully operated for periods of 66 days and 72 days during two separate pilot runs. The Norit Ultrafiltration, GE Zenon Ultrafiltration, and conventional pretreatment systems failed to prove sustainable operation without exhibiting significant fouling tendencies and, in the extreme case, irreversible fouling on the membrane surface.

Reverse Osmosis System

Three RO membranes were tested during the pilot: 1) Toray TM820C-400, 2) FilmTec SW30HR LE-400i, and 3) Toray TM820-400. Two RO pressure vessels (Trains A and B) were loaded with seven membrane elements each (Figure ES-4). The RO piloting objective was to determine the optimum operating parameters that could be carried over to the full-scale production facility. This objective included maximizing operation of the RO units while evaluating salt passage, normalized permeate flow, flux, recovery, cartridge filter changeout frequency, and intervals between cleanings. Results of the Pilot Study determined that both FilmTec and Toray were successful in meeting the project goals and would therefore be acceptable for use at the full-scale facility.

Figure ES-4: Photograph showing the loading of an RO element into the pressure vessel.

Finished Water Quality

Pilot Study results indicate that a treatment system consisting of microfiltration followed by RO and post-treatment is capable of treating raw seawater from the Brownsville Ship Channel to a quality that meets all primary and secondary water quality standards without the need for additional treatment. Post treatment requirements include a combination of chemicals such as caustic soda (pH control), sodium bicarbonate for alkalinity, and calcium chloride for addition of calcium. This combination of chemicals will produce stable, non-corrosive water.

Concentrate Disposal

During the Pilot Study, concentrate produced from the desalination process was recombined with the permeate and other filtered materials in an on-site lagoon prior to discharge back into the ship channel. However, for a full-scale facility producing 25 mgd of potable water, approximately 30 mgd of concentrate with salinity twice that of the raw water would require disposal.

Two potential methods of concentrate disposal were evaluated as part of the Pilot Study: 1) Class I injection wells, and 2) diffusion into the Gulf of Mexico. Both methods were determined to be technically feasible, but diffusion was found to be significantly less expensive to construct and operate. The diffusion method would include a transfer pump station and 12-mile pipeline from the desalination plant to a location approximately 0.5 miles into the Gulf of Mexico east of Boca Chica Beach.

A preliminary design for a multi-port diffuser array in the Gulf of Mexico was developed and flow and dispersion characteristics modeled. Based on longshore currents and water depths in the vicinity, the model predicted brine concentrations to be near ambient conditions within 125 feet of the diffuser array. Chemical water quality standards in the Gulf of Mexico exist only for dissolved oxygen and pH, which are not expected to be affected by concentrate discharge. There are no standards for total dissolved solids. Regulatory requirements for the discharge of RO concentrate will likely be focused on avoiding adverse impacts to the coastal ecosystem.

RECOMMENDATIONS

Full-Scale Facility

Based on Pilot Study results, a full-scale (25 mgd) seawater desalination plant at the Brownsville Ship Channel would cost approximately $182 million (2008 dollars) (Table ES-1). To ensure long-term operational success of the plant, about 26 percent of this total accounts for a conservative pretreatment design consisting of conventional treatment elements ahead of the microfiltration pretreatment system.

Table ES-1: Comparison of Feasibility Study and Pilot Study total project cost estimates for a full-scale (25 mgd) seawater desalination plant.

Project Component	Feasibility Estimate [a] (2004)	Pilot Study Estimate (2008)
Desalination Plant	$90,167,000	$126,612,000
Concentrate Disposal System	$30,583,000	$21,217,000
Finished Water Transmission System	$9,232,000	$12,180,000
Project Implementation Costs	$21,406,000	$22,400,000
Total Capital Costs	**$151,388,000**	**$182,409,000**

[a] *Source*: Dannenbaum and URS (2004).

After considering the costs of other water supply alternatives available for the future needs of Brownsville, BPUB determined that it could afford up to $70 million for a 25 mgd seawater desalination project. This would leave an infeasible funding gap well over $100 million. In addition, the full anticipated regional water demand envisioned for the full-scale facility is not expected to materialize for several years. Therefore, **it is recommended that a full-scale (25 mgd) seawater desalination facility NOT be implemented at this time due to the magnitude of the required funding gap and the current lack of full demand by BPUB and regional partners.**

Demonstration Production Facility

Based on the Pilot Study results and conclusions, **it is recommended that a 2.5 mgd demonstration-scale seawater desalination plant be designed and constructed on the south shore of the Brownsville Ship Channel.** In anticipation of future expansion to full-scale (25 mgd) capacity, several key components of the Demonstration Project would be implemented at full-scale, including the intake system, concentrate disposal system, and land acquisition.

A phased project development approach will best mitigate the risks and uncertainties associated with seawater desalination (Figure ES-5). Such an approach will allow an evaluation of system performance over several years of operation prior to an investment in full-scale capacity. This data is expected to yield a more efficient overall treatment system design and lower the cost of future expansions as they occur. The demonstration facility will also include the capability for continuous testing of the latest desalination technologies for this and other future seawater desalination facilities along the Texas coast. Such technologies include applications for pretreatment, energy recovery, sustainable energy supply, and larger (potentially more efficient) RO membranes.

Project Phase	FEASIBILITY	PILOT	DEMONSTRATION	PRODUCTION	PRODUCTION
Knowledge of Costs and Process at End of Phase	*Uncertainty*			*Certainty*	
Status of Brownsville Seawater Desalination Project	*Completed (2004)*	*Completed (2008)*	Pending (2012)	Future (2025)	Future (2050)
Production Capacity	-	-	2.5 mgd	12.5 mgd	25 mgd
Percent of Full-scale	-	-	10%	50%	100%

Figure ES-5: Phase project approach and the relative degree of risk and uncertainty associated with seawater desalination.

BPUB is willing to continue their investment in seawater desalination because surface and groundwater sources continue to be limited. Surface water in the Rio Grande is vulnerable to recurring drought conditions and Mexico treaty non-compliance, while brackish groundwater is limited by individual well production and aquifer recharge rates. Up until 2004, BPUB was 100 percent dependent on the Rio Grande as a water supply source. In response to the extreme drought early in that decade, BPUB developed the Southmost Regional Water Project, the largest coastal brackish groundwater desalination project in the state. Brackish desalination accounted for 22 percent of BPUB water production in 2007. The proposed demonstration project would account for 9 percent of BPUB total production in 2012 and further reduce dependency on the Rio Grande to 65 percent (Figure ES-6). The proposed project would also set the stage for subsequent expansions of seawater desalination capacity as BPUB water demands increase and regional partners are developed.

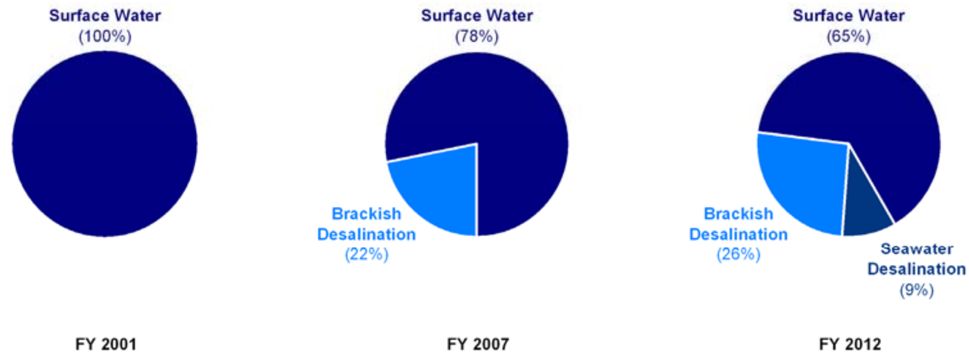

Figure ES-6: BPUB water production by source, current and projected with the proposed Demonstration Project.

Estimated Costs and Required Capital Infusion

The proposed Demonstration Project would cost a total of approximately $67,479,000. Approximately half of the cost of the proposed Demonstration Project ($30.9 million) includes infrastructure developed to provide for future full-scale capacity, especially the intake system, brine discharge pipeline to the Gulf of Mexico, and other site facilities. Implementation will require supplemental funding in the form of a grant from the State of $28.2 million and utilization of $19.3 million from the TWDB's State Participation Fund for a portion of the oversizing of the facility. BPUB proposes to finance $20 million through the TWDB Water Infrastructure Fund toward the implementation of this project (Table ES-2).

Table ES-2: Recommended uses and sources of funds, proposed Demonstration Project.

		Biennium	
	Total	**2010-2011**	**2012-2013**
Use of Funds			
Design Determination Studies	$2,967,000	$2,967,000	-
Environmental Review and Permitting	$1,079,000	$1,079,000	-
Final Design and Specifications	$5,935,000	$5,935,000	-
Construction Support Services	$2,698,000	-	$2,698,000
Startup Support Services	$846,000	-	$846,000
Construction[1]	$53,954,000	$10,791,000	$43,163,000
Total Uses of Funds	**$67,479,000**	**$20,772,000**	**$46,707,000**
Percent of Total	*100%*	*31%*	*69%*
Sources of Funds			
BPUB Loan From WIF	$20,000,000	$8,300,000	$11,700,000
State Grant	$28,200,000	$12,472,000	$15,728,000
State Participation Program	$19,279,000	-	$19,279,000
Total Sources of Funds	**$67,479,000**	**$20,772,000**	**$46,707,000**

[1] A detailed construction cost estimate, including how much is allocated to full-scale infrastructure, is presented in Table 5-7 (Page 5-29) of this report.

From the beginning, it has been understood that seawater desalination would not be the least expensive option to expand treatment capacity. Nevertheless, BPUB has pursued seawater desalination as a means of diversifying its water supply sources by including the only drought resistant supply available. The financial goal of BPUB for the project is to develop a seawater desalination project that is no more costly than one of its other water alternatives. For seawater desalination, this will require a capital infusion from a public source.

Under the proposed funding scenario (see Table ES-2), the cost to BPUB at start up is projected to be $4.06[2] per 1000 gallons (Table ES-3). If grant funding was not provided, the estimated cost would be $7.05[3] per 1000 gallons. However, these values are somewhat misleading considering the amount of the proposed project dedicated to future capacity. As the facility is ultimately expanded and technology improves and is tested, future costs are expected to be much lower due to the initial investment made. With the proposed Demonstration Project, the combined BPUB water cost would increase to $2.43 per 1,000 gallons in 2012, or by approximately 8 percent.

Table ES-3: Current and projected BPUB costs for all water supply sources.

		Current (FY 2007)	Projected (FY 2012)
Water Production			
	Surface Water Plant 1 (Rio Grande)	3,352	2,738
	Surface Water Plant 2 (Rio Grande)	2,970	2,738
	Southmost (Brackish Desalination)	1,763	2,190
	Seawater Desalination	-	803
	Total YTD	**8,085**	**8,468**
Unit Costs of Water Produced ($ per 1,000 gallons)			
Surface Water Treatment	O&M	$1.75	$1.75
	Debt Service	$0.50	$0.50
	Subtotal Surface	$2.25	$2.25
Brackish Groundwater Desalination	O&M	$1.28	$1.28
	Debt Service	$1.02	$1.02
	Subtotal Brackish	$2.30	$2.30
Proposed Demonstration Project	O&M	$0.00	$2.80
	Debt Service[a]	$0.00	$1.26
	Subtotal Seawater	$0.00	$4.06
Total for All BPUB Water Supply Sources	**O&M**	**$1.65**	**$1.73**
	Debt Service	**$0.61**	**$0.71**
	Total Combined BPUB Cost	**$2.26**	**$2.43**

Source: Current data provided by BPUB Public Finance Division, June 2008.
[a] Assumes grant of $28.2 million, debt service of $20 million by BPUP amortized for 25 years at 3%, and $19.3 million financed under the State Participation Program.

[2] Debt service of $20 million (BPUP) amortized for 25 years at 3% utilizing the TWDB Water Infrastructure Fund would be $1.26/1000 gallons plus $2.80/1000 gallons for O&M costs.

[3] Debt service of $67.5 million (BPUP with no grant funding) amortized for 25 years at 3% utilizing the TWDB Water Infrastructure Fund would be $4.25/1000 gallons plus $2.80/1000 gallons for O&M costs.

ADVANTAGES AND CHALLENGES

The proposed Demonstration Project holds several advantages over conventional surface water treatment and brackish desalination facilities. For BPUB, one of the most important advantages is the diversification of its supply. For the State of Texas, the demonstration of the viability of seawater desalination technology in the State is of prime importance. Other key perspectives about the viability of the demonstration project are discussed below:

Advantages

- *Addresses the need for water production for the BPUB* – the 2.5 mgd production capacity of the proposed Demonstration Project will be fully utilized by BPUB. A larger plant at this time would have excess capacity with a much greater investment and risk.
- *Lower near-term investment* – the implementation of the demonstration project has a lower overall initial cost compared to the full-scale plant. A total investment of $67 million compared to $182 million. Nearly 50% of the demonstration cost is for future capacity.
- *Reduction of risk* – A full-scale investment $182 million now incurs some risk in that the Pilot Study yielded good data for a demonstration plant but left some unanswered questions for full production. The Demonstration Project is expected to further refine data in efforts to reduce the overall cost of the full-scale facility.
- *Potential for cost savings in full-scale* – the Pilot Study yielded the need for a higher level of pretreatment and associated costs. The Demonstration Project will be equipped to modify operations to optimize the design data and solicit competition from vendors for the full-scale facility.
- *Development of operational flexibility in demonstration* – the demonstration facility will allow for the testing of a wide variety of conditions such as primary treatment ahead of membrane pretreatment for a portion of the flow to measure cost savings/increases as a result of this flexibility.
- *Provides an opportunity to conditionally permit full-scale facility based on actual demonstration-scale operational data* – the proposed Demonstration Project would provide the opportunity to evaluate the effects of concentrate disposal in the Gulf of Mexico on a smaller scale over a period of years, reducing the environmental risk of full-scale permitting conditions developed solely on artificial modeling results.
- *Operate over a longer term to assure all water qualities* – the Pilot Study operated for a period of 18 months with some short-term successes. The development of the demonstration plant will provide an opportunity for the plant to experience varying conditions over multiple seasons. One potentially complicating phenomenon that did not occur during piloting was the presence of a red tide event.
- *Improvement of intake and its effects on operation and future design parameters* – the pilot was unable to maximize the intake efficiency therefore yielding a highly variable water quality with extreme peaks of turbid water. On the positive side, the pilot yielded good results for poor water conditions. It is anticipated

that an improved intake will yield a reduction in cost and improve the reliability of the demonstration and full-scale plants.

- *Demonstrate to the State the effectiveness of seawater desalination along the Texas coast* – the establishment of an inland desalination facility will give confidence to other areas of the state to evaluate this water supply alternative.
- *Developing excess capacity in certain facility components makes full-scale facility more cost effective to build* – major components of the Demonstration Project, such as intake canals and concentrate discharge lines, would be designed and constructed for full-scale (25 mgd) conditions. These capital costs, sunk in present-day dollars, would reduce the expense of future expansion.

As with any project, there are disadvantages to the implementation of a demonstration plant. The following describes disadvantages to the demonstration plant.

Challenges

- *Higher unit cost of water produced* – economies of scale play a large part in the development of a desalination facility. The demonstration plant includes almost 50 percent in extra cost that cannot be fully utilized until future expansion. For the plant to be cost effective, grants and low interest loans must be utilized to complete the Demonstration Project.
- *Less capacity for future needs* – the initial (smaller) desalination plant would provide less capacity for future needs and regional supply possibilities.
- *Perception of not being "big enough"* – the demonstration plant does not have the "big" or large-scale tag and may be perceived as too small.