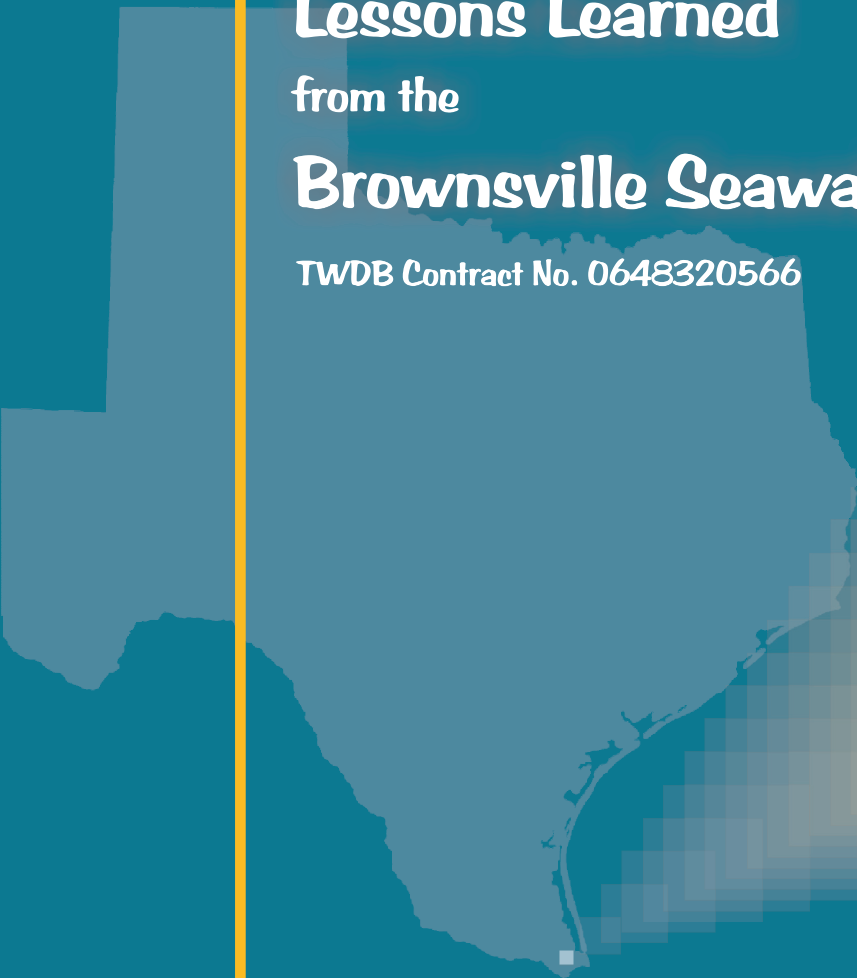
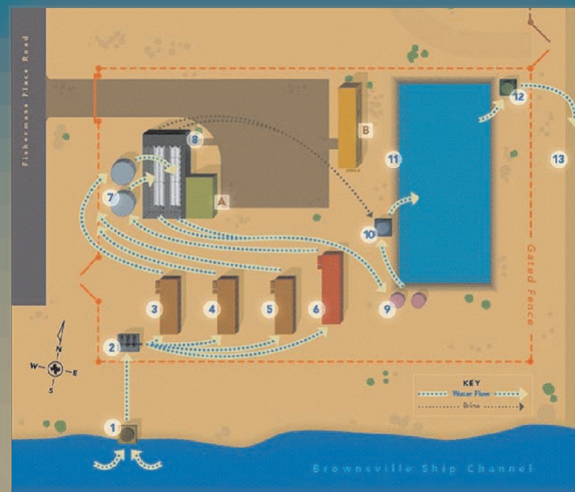
Lessons Learned

from the

Brownsville Seawater Pilot Study

TWDB Contract No. 0648320566





February 2009

TEXAS WATER DEVELOPMENT BOARD

REISS ENGINEERING

PLANNING • DESIGN • CONSTRUCTION

Seawater Pilot Services

TWDB Contract No. 0648320566

Final Letter Report

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Reiss Engineering, Inc.

I. INTRODUCTION

In 2003, the Texas Legislature allocated $1.5 million to the Texas Water Development Board (TWDB) for feasibility and regional facility planning studies to determine the technical and economic viability of three proposed demonstration seawater desalination projects. These projects had been recommended by TWDB and consisted of the Lower Rio Grande Valley - Brownsville, City of Corpus Christi, and Freeport. The resulting studies concluded that the three proposed projects were technically feasible and included an assessment of the financial requirements for implementing the projects. In 2004, TWDB considered the results of the feasibility studies and recommended that "the state continue advancing toward implementation of a large-scale demonstration seawater desalination facility in Texas".

The 79th Texas Legislature expanded the State's efforts at developing new water supplies through desalination by appropriating $2.5 million for on-site construction and demonstration of seawater desalination pilot plants. The focus of the TWDB desalination program was to facilitate the completion of one or more pilot plant studies and to ensure that these studies were an effective step in accomplishing the goal of developing large-scale seawater desalination supplies in Texas.

Reiss Engineering, Inc. (REI), formerly known as Reiss Environmental, Inc, was contracted by TWDB to provide Seawater Pilot Services to support the TWDB's desalination pilot study program. This included development of technical guidance documents, on-site inspection of pilot operations, technical review of pilot study results, and other related functions. This letter report summarizes the work completed with an emphasis on lessons learned from the pilot study co-funded by TWDB and performed by the Brownsville Public Utilities Board (PUB).

II. WORK COMPLETED

As part of this project, Reiss Engineering provided engineering services in the Application and Implementation phases of the TWDB pilot study program.

During the Application phase, TWDB and Reiss Engineering co-wrote the Guidance Document setting the minimum requirements for acceptance of financial assistance applications for seawater desalination pilot plant studies. The intent of the Guidance Document was to ensure efficient use of the State's resources to support seawater desalination projects that are more likely to be implemented to demonstrate the large-scale use of seawater desalination.

Applications were received for three projects: Brownsville, Corpus Christi and Freeport. After REI and TWDB staff review of the three pilot study applications TWDB selected the Brownsville Seawater Desalination Project to implement a seawater pilot plant study.

The Brownsville seawater pilot study was performed by NRS Consulting Engineers during the 2007-2008 period. The pilot study was located on the North side of the Brownsville Ship Channel. Raw water was withdrawn and pumped from the channel to different pre-treatment units prior to reverse osmosis treatment. The four pre-treatment units consisted of one conventional treatment system (coagulation-flocculation-sedimentation and single stage dual media filtration) and three membrane treatment systems (Pall, Zenon and Norit). The goal of the pre-treatment being to produce a high water quality filtered water that would feed the reverse osmosis membrane treatment system. The treated water from one of the pre-treatment system was pumped to one of the two reverse osmosis units to desalinate.

During the pilot study, concentrate management alternatives were evaluated at desktop level in order to comply with regulatory requirements for discharge to the Gulf of Mexico. Based on the information gathered during the pilot study, cost estimates for the demonstration seawater plant were developed. In addition, potential financing mechanisms were evaluated to finance the demonstration seawater plant.

During this Implementation phase, Reiss Engineering performed pilot inspections, reviewed operational data, and reviewed interim reports associated with the Brownsville Seawater Pilot Study. Reiss Engineering prepared multiple technical review letters addressing pilot system performance. This Final Letter Report is not intended to repeat previous technical review letters but to provide a broader assessment of the Brownsville Seawater Pilot Study relative to the value and benefit it provides to the State of Texas in moving seawater desalination forward and the associated lessons learned.

III. BENEFIT OF A PILOT STUDY AND LESSONS LEARNED

Development of large-scale seawater desalination plants in the State of Texas can ensure a sustainable source of drinking water and represents a key component of alternative water resources planning for the future. Planning and implementing a seawater desalination plant is a complex process and requires action in the areas of funding, environmental considerations, public involvement, design, permitting and others.

A fundamental but vital method used to obtain the information that is needed in these areas is the execution of a field demonstration test of the desalination technology, known as a 'pilot study'. The Brownsville Seawater Pilot Study was developed to support implementation of a seawater desalination facility that, at the time of application to TWDB in 2006, was expected to have a capacity of 25 MGD with an estimated cost of $104 million dollars. A facility of this magnitude would clearly benefit from the technical information obtained through the implementation of a site-specific pilot study.

The following subsections describe the purpose and benefit of various aspects of a desalination pilot study and provide an analysis of the benefit gained and lessons learned from the Brownsville Desalination Pilot Study.

III.1. Pilot Unit Operations

Pilot unit operations is an important aspect of a seawater pilot study as was experienced by Brownsville PUB and their engineers, NRS. According to Brownsville PUB staff, operating the pilot study was more difficult than expected. Personnel and resources were difficult to plan for prior to implementation of the study because the project was expanded to include four pretreatment units. In addition each of the pretreatment was unique which made it difficult for the personal to get familiar with each of them and quickly understand the operating and maintenance differences for each unit.

Even though pre-treatment units are operated automatically, presence of personal on-site 8 hours a day is usually required, especially when there are more than two pilot units on-site. Several tasks such checking the good operation of the units, taking samples, performing water quality analysis, ensuring that there are enough chemicals are time consuming. Therefore, a pilot study team should plan for the on-site personal as a full-time employee to ensure the success of the pilot study.

According to Brownsville staff, in the beginning of the project, there were some roles and responsibilities between the consultant and BPUB that were unclear and needed to be better defined. However, as the project progressed, coordination and communication quickly improved and staff worked through those issues in a short amount of time. Therefore, roles and responsibilities during a pilot study should be clearly defined and detailed in a pilot study protocol that should be finalized and understood by the team prior the pilot unit start-up. In addition, the personnel shall be trained by each treatment unit vendor representative to ensure proper operation of the units, once the treatment units are under the responsibility of the pilot study team.

Because the pilot study was a seawater pilot study performed on the coast, the environment was corrosive and Brownsville PUB would recommend for future seawater pilot study to enclose the treatment units so the exposure to corrosive conditions is limited. Enclosure of equipment is preferred to protect the equipment against corrosive conditions, but on the other hand, the costs associated with constructing an enclosure may be prohibitive. Therefore, the pilot study team will have to make a choice and balance costs versus advantage of disadvantages of an enclosure.

III.2. Intake Siting

Pilot testing at a selected location using a proposed treatment process train represents a 'proof of concept' evaluation. Intake siting is important since it directly determines the quality of raw water and subsequent treatment requirements. An offshore intake will provide a more consistent salinity and less influence from surface water runoff and tidal changes. However, intake piping distances and costs as well as permitting efforts can be minimized by use of existing intakes such as at power plants or construction of new, near-shore intakes. These cost and permitting efficiencies must be balanced with potentially increased requirements of the pretreatment systems to condition water with higher suspended solids concentrations, natural organic matter concentrations and temperature. For example, using higher temperature power plant cooling water discharges has the potential to increase biological fouling and will increase salt passage through a reverse osmosis system. The relative significance of these effects must be determined as part of selecting such an intake.

An acceptable level of pretreatment required for one intake location versus another may be difficult to determine at desktop-scale. Pilot-scale testing over an extended period allows direct and scalable assessment of the suitability of an intake location and its associated raw water quality. One outcome can be determination of the impacts of shipping channel traffic on raw water quality. Shipping channel traffic stirs up sediments and has impacted raw water quality at the 25 MGD Tampa Bay Desal I project as well as the 29 MGD seawater facility in Trinidad. All currently proposed seawater desalination projects in Texas include use of near-shore intakes thus would benefit from quantification of the impact of the raw water source on pretreatment needs.

The Brownsville Seawater Desalination project proposed utilization of an intake on the north shore, extending 300 feet into the Brownsville Ship Channel. The pilot study project was constructed directly on the north shore of the ship channel and raw water samples were obtained throughout the course of the pilot study. In addition, samples were taken from the Gulf of Mexico at a location adjacent to Boca Chica Beach.

The intake site experienced wide variations in raw water quality, particularly sediment loading. Correlations were made to passing of ships, wind direction, and other factors. The high sediment loading is consistent with issues encountered at the Trinidad desalination facility as well as the Tampa Desal I facility. Shipping traffic in particular can increase sediment loading and adversely impact desalination water treatment plant operations. As with the Tampa and Trinidad facilities, the Brownsville project is designed to benefit from using a nearby source of water (the ship channel) for the purposes of minimizing raw water pipeline costs, among other reasons. However, the tradeoff is the need for advanced pretreatment and associated costs, as was documented in the Brownsville pilot study.

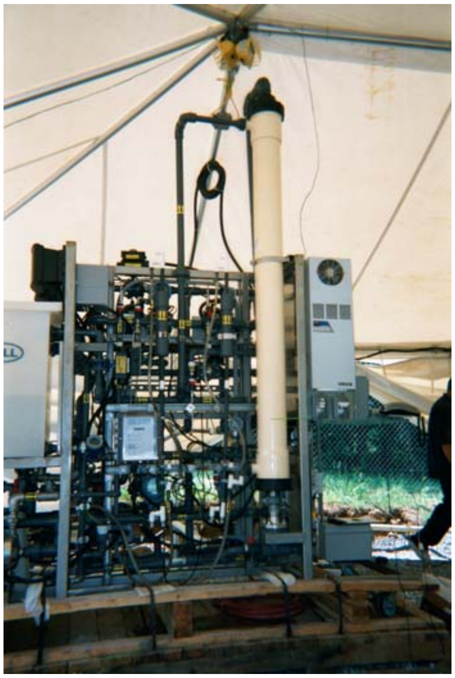
The current plan for the Brownsville Seawater Desalination project is to locate an intake on the south side of the ship channel with an expectation that the sediment loading will be less than that observed during pilot testing. This decision was based on observation of prevailing winds and their impact on turbidity levels. The sampling of the Gulf of Mexico was inconclusive relative to sediment loading differences.

The Brownsville pilot study clearly documented the raw water quality at the selected location. Given the challenges at this location, a shift has been proposed to the new location on the south shore. While estimates can be made of how a desalination system will perform at this new location, pilot or demonstration testing can best document the benefit, if any, of this shift in location.

For future projects in Texas, thorough sampling of raw water quality can be used to screen sites in advance of pilot testing, at a low cost. Specific emphasis on sediment loading in particular is of critical value as it is directly related to the level of pretreatment that will be required. It is important to recognize the relationship between sediment loading and its impact on pretreatment requirements, operational reliability and project costs.

III.3. Pretreatment Systems

Pretreatment system designs can vary considerably and directly affect water treatment plant (WTP) sustainability. The primary issue associated with the original operations of the Tampa Bay Desal I plant was the poor performance of the pretreatment system and the resulting RO system fouling. Pretreatment system approaches are undergoing a rapid change in the industry and represent the most significant design consideration in a seawater desalination facility. Multimedia filtration and membrane filtration options are two competing approaches with the optimal solution remaining a project-specific answer. Pilot studies provide direct comparison of different pretreatment technologies.



From 2003 to 2007, alternative pretreatment assessments were performed as part of pilot studies for the Tampa Bay Water Gulf Coast Desalination project, Marin County California desalination project, US Bureau of Reclamation desalination research program (San Patricio, TX; Cape Canaveral, Florida), and Poseidon Resources Carlsbad California desalination project. A four-season pilot study provides an opportunity to evaluate alternative pretreatment processes over varying raw water quality conditions to confirm the sustainability of the treatment process train.

The Brownsville pilot study also evaluated alternative pretreatment processes. These included a conventional flocculation-clarification-filtration system and three microfiltration/ultrafiltration units. Conventional filtration systems can provide the benefit of lower capital costs but are typically reserved for high quality, low sediment source waters. Microfiltration (MF) and ultrafiltration (UF) systems typically provide very high quality filtrate but at a higher cost.

The Brownsville conventional system was operated for 793 hours, with acceptable filtrate quality achieved approximately 12% of the operational time. As documented in the Brownsville pilot study final report, the conventional system was unable to produce a filtrate of acceptable quality to feed a seawater reverse osmosis system and was eliminated from consideration.

This experience exemplifies the issues of using conventional filtration systems on near shore, high sediment loading water sources. There are numerous pilot studies as well as completed and operational full-scale facilities that demonstrate the limitations of conventional pretreatment on high sediment loading source waters.
The Brownsville pilot study now provides a Texas-specific reference relative to use of

conventional pretreatment. While there may be functional applications of this technology within the state of Texas, the use of raw water sampling to determine sediment loading can be an effective screening tool to ensure appropriate selection of pretreatment technologies that warrant further consideration at pilot-scale.

MF and UF systems used in the Brownsville pilot study included the Norit, Zenon, and Pall systems. These systems are membrane filters capable of reducing turbidity to near or below detection limits, thereby eliminating any issues of plugging of the downstream reverse osmosis system. However, these systems do not reduce dissolved organic carbon (DOC), therefore any assimilable organic material in the raw water will pass to the reverse osmosis system and can cause biological fouling. In addition, the MF and UF systems themselves can foul due to high sediment loading so it is critical that sustained operational performance be demonstrated by any MF or UF system under consideration.

The Brownsville MF and UF systems experienced a series of mechanical difficulties, extended downtime, and fouling issues. These experiences are not uncommon but were particularly prevalent with this pilot study. One observation regarding this project compared to other pilot studies is that the scope of the pilot was particularly large, with four pretreatment technologies, two reverse osmosis systems, and a large array of project implementation tasks requiring attention. In addition, there was significant reliance upon the equipment manufacturers to facilitate process engineering decision-making.

Two of the systems, the Norit and Zenon systems, were initially considered to exhibit poor performance whereas subsequent review of data mitigated some of the initial concerns. Conversely, the Pall system was operated in a fouled state for periods of time and was initially considered more promising than was determined upon further review.

For future pilot studies, the ability to rapidly interpret and respond to pilot results, particularly pretreatment system performance, is of importance. The scope of the project must be balanced with the expertise and resources of the project team.

III.4. Desalination System

Desalination system designs involve decision-making relative to a number of design criteria such as flux and recovery. The selection of a design approach involves balancing competing interests to develop an optimal WTP that meets all project objectives such as those related to fouling, costs, permitting and environmental considerations. For example, a higher water recovery on an RO system reduces the size and cost of the upstream pretreatment system but requires a higher pressure and associated electrical costs for pumping of the water through the RO system. Draft design criteria are typically 'proof-tested' at pilot-scale to validate the design concept. In addition, design criteria can be varied at pilot-scale, results assessed, and the final design optimized. This can result in project cost savings, improved potential to meet permitting requirements, or other project benefits.

The Brownsville pilot study included the use of two reverse osmosis systems. These systems used 8-inch diameter elements in a full, seven element array. This represents a typical configuration for the first pass of a large-scale seawater desalination system. No second pass system was tested.

The systems incurred significant down-time primarily due to mechanical difficulties and lack of filtrate from the pretreatment units. These issues are common for pilot studies and may have been enhanced in this instance due to the significant scope of the Brownsville pilot study.

With regards to operational performance, the reverse osmosis systems were subject to biological fouling as presented in the final report. Operational times between cleaning were generally on the order of 70 to 90 days, compared to a typical design criterion of cleaning no more frequently than once every 90 days. The cause of the biological fouling was not determined but alternatives to potentially control biological fouling in future studies were presented by the NRS engineering team.

In addition, both the Filmtec and Toray reverse osmosis elements used in the study were found to be irreversibly fouled. Lab techniques were evaluated on individual elements and enhanced cleaning regimes proposed for future studies. While the duration between chemical cleanings approached acceptable targets, the inability to chemically clean the membrane to restore performance is as important as the rate at which it fouls.

For future Texas seawater desalination projects, the ability of a reverse osmosis system to meet cleaning frequency targets as well as the ability to restore performance following a chemical cleaning is of critical importance. In addition, when using 8-inch diameter membranes it is important to ensure that an adequate quantity of pretreated water will be available to supply the RO unit.

III.5. Finished Water Quality

Finished water quality is an area of interest particularly to larger-scale regional desalination facilities planned for the State of Texas. With regulations becoming more stringent and consumers more conscious of drinking water quality issues, water providers are expected to produce higher quality finished water.

For regional providers in Texas, use of desalinated seawater will likely mean blending of desalination finished water with an existing drinking water source. Blending of two different treated waters can and has resulted in distribution system water quality problems for some US communities such as Tucson, Arizona. These re-equilibration effects have included increased corrosion, red color and taste and odor releases.

Pilot testing can confirm that the water quality goals for a proposed desalination facility will be met. In addition, the water from the pilot study can be used to perform distribution system blending studies. Blending studies support post-stabilization/blending approaches to be utilized as part of the integration of this new source of supply into an existing public water system. Communities that have proactively utilized pilot studies and/or blending studies as part of development of reverse osmosis WTPs include the City of Clearwater, Florida; Tampa Bay Water, Florida; Carlsbad, California and others.

The Brownsville pilot study documented finished water through sampling of permeate from the reverse osmosis units. The permeate total dissolved solids (TDS) concentration ranged from 132 to 320 mg/L. Chloride concentration ranged from 69 to 161 mg/L. These results demonstrate production of fresh water and are generally acceptable.

Additional testing that might be necessary for acceptance of desalinated water from a regional or large-scale system include data relative to bromide, boron, and re-equilibration effects, among others. Depending on the finished water quality goals required for a given project, a second pass reverse osmosis system may be needed to further treat the permeate from the first pass system.

Defining finished water quality objectives up front is critical to ensuring that the pilot is designed appropriately and that the pilot ultimately does meet those objectives. While the Brownsville pilot study has not yet evaluated post treatment (and re-equilibration in particular), this topic remains a key factor in any regional water distribution system.

III.6. Permitting

Permitting of a large-scale seawater desalination system in Texas requires close coordination with the Texas Commission on Environmental Quality (TCEQ). TCEQ requires a pilot study as part of its approval of a membrane facility, including submittal and approval of a pilot study protocol prior to initiation of pilot activities.

TCEQ currently has two membrane-related Guidance Documents that could impact a seawater desalination project - Review of Pilot Study Protocols for Membrane Filtration effective April 1, 2004 and Review of Pilot Study Reports for Membrane Filtration effective April 1, 2004. The Brownsville project is based on reverse osmosis membrane technology therefore is required to meet TCEQ membrane criteria, particularly since this facility is slated to treat a coastal surface water with the potential for pathogen contamination from surface water runoff.

In addition, discharge of desalination concentrate to coastal waters, as is planned for the Brownsville facility, will require a National Pollutant Discharge Elimination System (NPDES) permit. NPDES permitting is designed to protect the environment with regards to discharge of wastes to receiving water bodies such as the Gulf of Mexico and the affiliated estuary and bay areas. Characterization of concentrate water quality through operation of a pilot system will likely be required by TCEQ as part of the NPDES permitting process for any Texas seawater desalination project. Water quality sampling of concentrate through a pilot study will provide direct and quantitative information on the characterization of the proposed discharge.

An additional permitting component is the characterization of spent cleaning solutions used to restore membrane system performance. Reverse osmosis membrane systems can foul with time and require periodic chemical cleanings using solutions that may contain caustic, acid, surfactants, detergents or chelating agents. Determining the acceptability of discharge of these spent cleaning solutions to the sanitary sewer or other location is commonly facilitated through collection and analysis of spent cleaning solutions associated with a pilot study.

The Brownsville pilot study was designed to meet the TCEQ requirements for the seawater pretreatment and seawater reverse osmosis treatment systems. The study was coordinated around meeting TCEQ Stages 1, 2, and 3 to demonstrate the feasibility of specific operating conditions that would serve as design criteria for the full-scale facility. These requirements are considered the minimum acceptable requirements to achieve TCEQ approval of any membrane treatment plant project, including seawater treatment plants. Given the complex nature of a seawater desalination system, the level of pilot information should likely be well beyond that currently required by TCEQ. As seen in the pilot study, repeatability of the test success (as defined by Stages 2 and 3 of the CEQ requirements) was not always feasible due to the ever changing water quality of the source water.

As was addressed in the Brownsville pilot study, it is recommended that future pilot studies in the State of Texas include 12 months of operation, to capture seasonal differences in raw water quality. Most of the pilot studies implemented in California and in Florida are performed over a 12 month period of operation or more. A scope of services of this nature would be well beyond the requirements of TCEQ, ensuring that both the TCEQ and project needs are met.

In addition, TCEQ may wish to create a guidance document specific to seawater treatment in light of the likely potential of future large-scale seawater desalination systems. A seawater desalination guidance document could be developed that requires more extensive testing related to treatment production performance than that required for a groundwater desalination project.

The Brownsville pilot study was designed to evaluate two options for disposing of the concentrate. Those two options were disposal into the Gulf (via diffusion and outfall) and disposal via a deep well injection. Both options would have to meet TCEQ regulatory requirements. The pilot study report concluded that both options were technically feasible, but since the concentrate disposal into the Gulf was more cost-effective than the deep well injection, the disposal to the Gulf was the option recommended for concentrate disposal.

For future Texas seawater projects, the capability to discharge concentrate via one option or the other is critical to the project. The technical feasibility and the costs to discharge could be detrimental to the project and should be evaluated early in the project.

III.7. Costs and Funding

One of the key issues when developing a seawater desalination project is the difficulty in establishing reasonably accurate, site-specific project cost estimates. Typically, well-defined costs are needed to support funding efforts at a time in the development of the project that design specifics are only being generated 'on paper'. As a project progresses, a pilot study can be utilized to optimize and clarify process design alternatives as described above. The resulting knowledge and information is fed back into the project costing effort. As a result of these efforts, capital and operating cost estimates become better defined and more 'real'. The ability to more accurately assess total project costs is one of the most important benefits resulting from a pilot study.

The Brownsville pilot study was designed to capture a wide range of design considerations that impact costs. This includes intake location, pretreatment requirements, reverse osmosis system requirements, plant capacity and others. As was determined during the course of the pilot study, each of the key components of the project must be robust and capable of treating the high sediment content water from the ship channel. This requires appropriate intake design, advanced pretreatment, and further research into factors not fully concluded during the pilot study, such as biogrowth control and post-treatment of the finished water. Therefore a smaller scale demonstration facility (2.5 MGD versus the originally anticipated 25MG D facility) is proposed to further study the optimization of seawater treatment before the expansions of the seawater facility up to the ultimate capacity. It is proposed to design that facility for expansion to 5.0 MGD and ultimately for expansion to 25 MGD.

An additional benefit of the Brownsville pilot study was to update the cost estimate for the project. The current proposed 2.5 MGD demonstration facility has an estimated cost of $38 million dollars, and the expansion to 5.0 MGD has an estimated cost of $67 million dollars. This includes design of certain components such as the 42-inch pipeline for an ultimate brine disposal system capacity of 25 MGD.

The cost for the ultimate 25 MGD facility is currently estimated to be $182.5 million dollars, or $7.28 per gallon per day capital cost. This updated estimate is significantly higher than the original estimate of $104 million dollars provided in the 2006 pilot study application to the TWDB. This exemplifies the benefit of site-specific pilot testing, to further refine the funding needs of a project.

The total amortized capital and operations and maintenance costs for the 2.5 MGD demonstration project are estimated to be $4.06 per 1,000 gallons of water produced. This represents an excellent cost reference point for future Texas seawater projects. With the economy of scale associated with a larger facility, these costs would drop and would likely fall within the range of other proposed or operational facilities. Larger facilities have total estimated costs on the order of $2.50 to $4.00 per 1,000 gallons (Water Desalination Report, Volume 44 Issue 34 - 22nd September 2008). It is expected that future Texas projects will also be in this range. However, a pilot study should still be a key tool to develop more refined project cost estimates.

IV. SUMMARY

Development of a large-scale seawater desalination system in the state of Texas is greatly enhanced through pilot testing, including the work completed in the Brownsville seawater desalination pilot study.

During the Brownsville pilot study multiple challenges were encountered. Those challenges were either addressed during the study, when feasible, or may have to be addressed during subsequent phases of the project. The seawater pilot study generated data that will be used for the implementation of a demonstration seawater facility. In addition, many lessons were learned during the study that will be either useful for the implementation of the full-scale facility or for other desalination projects in the State of Texas.

According to BPUB staff, the pilot study was a success in that BPUB gained a better understanding of the intensity of the operations and maintenance requirements of a seawater desalination facility. Especially, the corrosive conditions of a seawater environment shall not be overlooked and will require extensive preventive maintenance to keep all equipment in proper working condition.

Overall, the complexity of a seawater desalination facility should not be overlooked. When compared to a more common groundwater reverse osmosis facility, seawater reverse osmosis facilities are more complex, are more site-specific, and are more costly to construct and operate. However, the benefits of a sustainable source of water supply clearly ensure a place for seawater desalination in the future of the state of Texas.

V. REFERENCES AND CREDITS

References

TWDB Biennial Report, "The importance of pilot studies in the development of large-scale seawater desalination plants", December 2004 by Reiss Engineering

Water Desalination Report, Volume 44 Issue 34 - 22nd September 2008

Credits

Some of the pictures are from "Final Pilot Study Report – Texas Seawater Desalination Demonstration Project", October 2008, by NRS.

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