Chapter 15

Water Desalination

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Introduction

One of the most visible results of the 75th Texas Legislature Senate Bill 1 (SB1) regional water planning process is the broad public awareness regarding the future water needs of the state. The increased water demands, the state's growing vulnerability to droughts, and the declining availability of conventional water supply sources have placed greater importance on the development of new alternative water supply sources. These factors, coupled with the cost-competitiveness of newer water desalination technologies, prompted Governor Rick Perry and members of the Texas Legislature to pursue the development of large-scale seawater desalination along the Texas Gulf Coast and to facilitate the application of cost-effective desalination technologies in areas with abundant brackish groundwater.

This paper discusses desalination as a water-supply option in Texas, basics of water desalination technologies, and cost factors associated with developing water desalination projects.

Saline Water Availability

The salinity of a water source is measured in terms of the "total dissolved solids" (TDS) content, which is commonly reported in milligrams per liter (mg/l). Based on its salinity, water sources may be classified as follows:

Fresh water	less than 1,000 mg/l TDS
Slightly saline	1,000 to 3,000 mg/l TDS
Moderately saline	3,000 to 10,000 mg/l TDS
Highly saline	Over 10,000 mg/l TDS

Brackish water normally refers to water with salinities between 1,000 to 10,000 mg/l. Seawater salinity is on the order of 35,000 mg/l TDS.

In terms of salinity alone, the U.S. Environmental Protection Agency established a TDS guideline of 500mg/l for drinking water. Water desalination technologies are the means to reduce the TDS concentration to drinking water standards. Commonly, in brackish

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water desalination, the process involves a degree of blending of desalinated water with brackish water to improve the economics of the water treatment.

The U.S. Geological Survey estimates that the Earth's oceans contain approximately 97 percent of the planet's water. Of the remaining 3 percent, approximately 2 percent is locked in the icecaps and glaciers. Only a fraction of the remaining 1 percent is considered to be fresh water available for water supply (U.S. Geological Survey, 1984). Increasing water demands will place a greater burden on the world's water resources. Thus, with the world's population projected to increase from 6 billion in 2000 to 9 billion in 2050 (United States Census, 2003), water planners are diligently searching for cost-effective and environmentally acceptable ways to treat saline water sources to aid in meeting the world's current and future water demands.

The Texas Gulf Coast, with approximately 367 miles of coastline, features numerous sites potentially suitable for seawater desalination. Six of those sites were submitted for consideration in response to Texas Water Development Board (TWDB) Request for Statements of Interest for a Large-Scale Demonstration Seawater Desalination Project (Figure 15-1; TWDB, 2002).

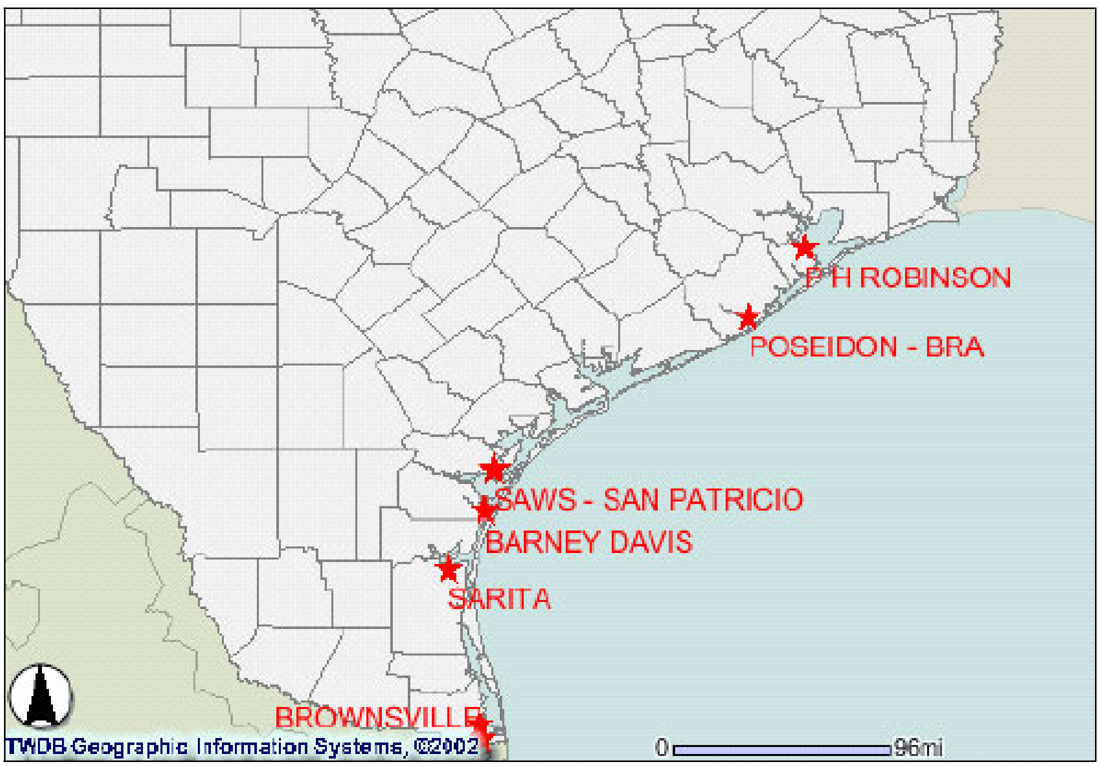

Figure 15-1: Statements of interest for seawater desalination projects.

In addition to the near limitless access to seawater, the state is also rich in brackish groundwater. A recent study estimated that there is 2.7 billion acre-feet of brackish groundwater potentially available as a water-supply source in Texas (LBG-Guyton Associates, 2003). Table 15-1 provides a breakdown of brackish groundwater availability for each of the 16 regional water-planning areas of the state (Figure 15-2):

Table 15-1: Brackish groundwater availability per regional water planning area.

Regional Water Planning Area	**Total Estimated Volume of Brackish Groundwater in all Aquifers (acre/feet)**
A- Panhandle	19,099,600
B- Region B	14,535,000
C- Region C	84,948,900
D- Northeast Texas	55,783,300
E- Far West Texas	125,382,400
F- Region F	372,848,300
G- Brazos	195,540,400
H- Region H	193,382,500
I- East Texas	195,869,400
J- Plateau	8,637,800
K- Lower Colorado	201,952,200
L- South Central Texas	417,767,200
M- Rio Grande	396,068,900
N- Coastal Bend	332,408,800
O- Llano Estacado	91,762,800
P- Lavaca	7,825,900
Total	2,713,813,400

Note. This table is based on Table 6 of the referenced report [LBG-Guyton, 2003]. Total availability per aquifer was calculated by adding the values noted as "In Place" plus "Confined" volumes.

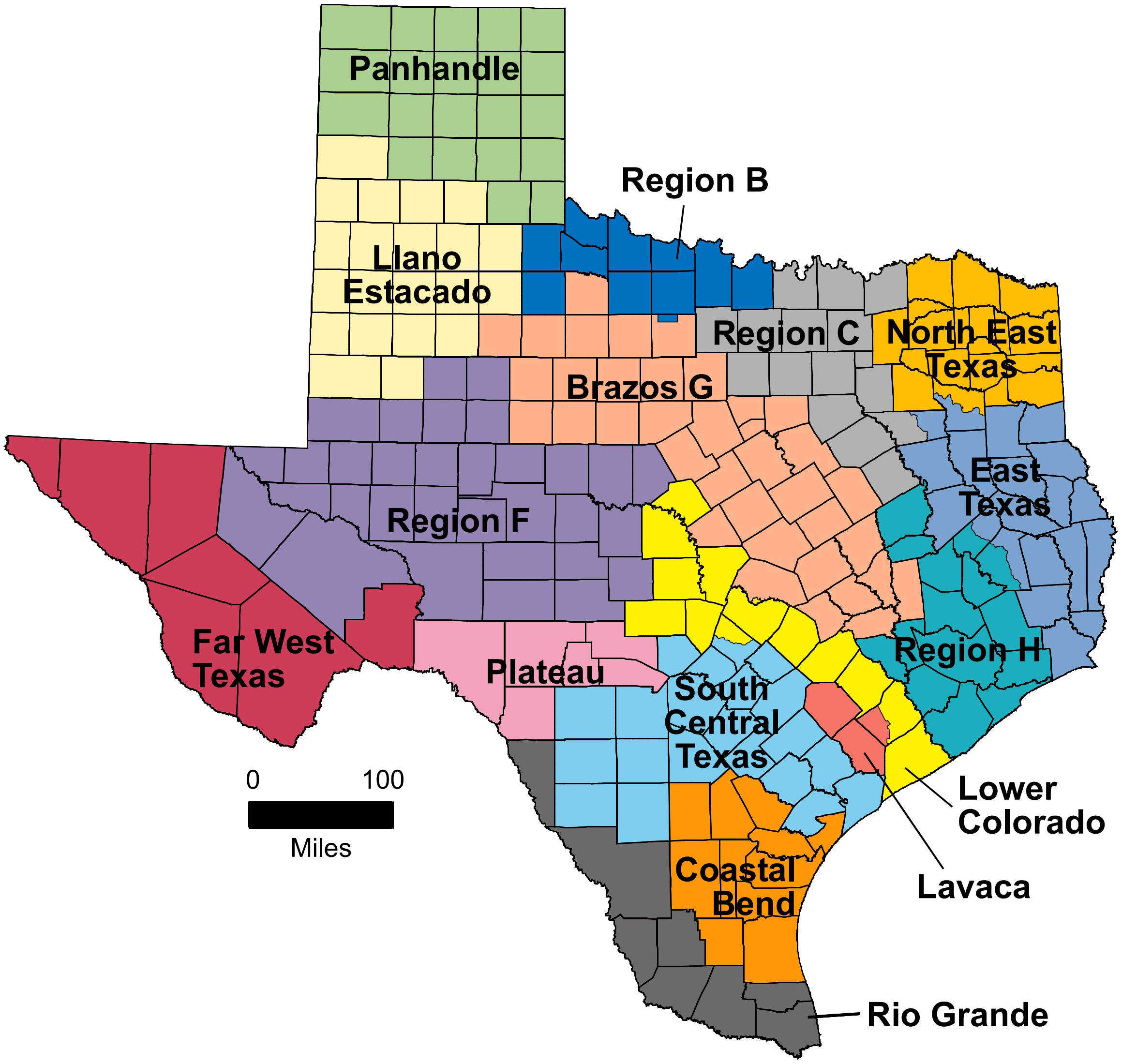

Figure 15-2: Regional water planning areas

Water desalination in the World and in Texas

Desalination of seawater by means of distillation may have been used as early as the 4th century B.C. (V. A. Koezler, as cited by the U.S. Office of Technology Assessment, 1988). In the late 1950s, the first large seawater distillation plants were built in the Middle East. In the 1970s, membrane-based technologies, reverse osmosis, and electrodialysis reversal began to gain ground in the desalination market (U.S. Office of Technology Assessment, 1988). The U.S. Bureau of Reclamation reports that in the period from 1972 to 1999, the installed water desalination capacity in the world increased at an average rate of 370 million gallons per day each year. This indicates that desalination capacity has been increasing at approximately 12 percent a year globally,

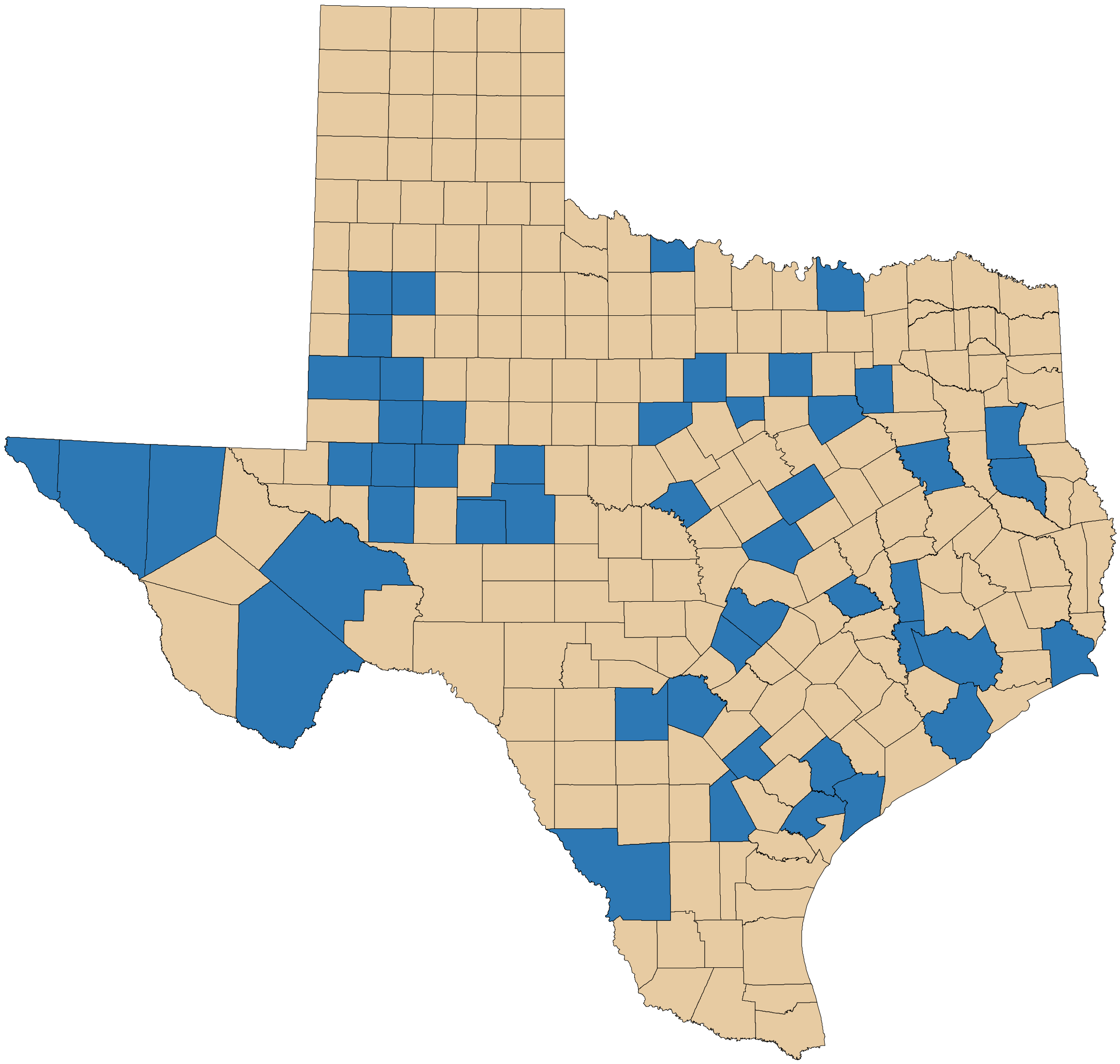

Figure 15-3: Counties with permitted water desalination facilities.

and that it is currently estimated to be in the order of 7 billion gallons per day (BGD). There are more than 8,600 desalination plants installed globally, with approximately 20 percent of those located in the U.S.A. (U.S. Bureau of Reclamation, 2003).

The use of water desalination is not uncommon in Texas. The Texas Commission on Environmental Quality lists a total of 101 permitted water desalination facilities in the state, ranging from small units rated at 2,000 gallons per day (gpd) supplying service stations to large municipal facilities rated as high as 26 million gallons per day (mgd) at the City of Sherman's electro-dialysis desalination plant. Currently, there are 49 counties across Texas with permitted water desalination facilities (Figure 15-3).

Desalination as a water management strategy in the regional water planning process

The Senate Bill 1 regional water planning rules require identification and evaluation of all potentially feasible water management strategies to meet the needs in the planning process. As illustrated in Table 15-2, several of the Planning Groups considered desalination water supply alternatives during the first round of planning (TWDB, 2002). With the increased awareness regarding desalination technology and the development of better information regarding brackish groundwater availability in the state, it is anticipated that many more regions will consider and include desalination projects in their future plans.

Desalination Technologies

Desalination is the process of removing dissolved solids–primarily salts–from water. There are various methods to separate the salts from the water to render it useful for drinking purposes. The two most common and generally proven large-scale methods are distillation processes and membrane-based processes.

Distillation processes consist of applying heat to the source water to create vapor and then capturing the condensed vapor to produce pure water. This approach may be more cost-competitive in cases where the salt-content in the source water is greater than 10,000 mg/l. Also, it is more economically attractive if operating in conjunction with steam power generation because the steam released from the power generation plant can be advantageously used as input into the desalination plant. Distillation technologies account for approximately one-half of the world's installed desalination capacity, and it is more commonly used in areas of the world with large supplies of fossil fuel (U.S. Bureau of Reclamation, 2003).

Table 15-2: Regional Water Planning Groups considering water desalination management strategies in the 2001 Regional Water Plans

Region	Source of Saline Water
B	Surface Water-Lake Kemp
E	Brackish groundwater
L	Surface Water-Gulf of Mexico
M (*)	Gulf of Mexico, brackish groundwater
N	Gulf of Mexico, brackish groundwater
P (**)	Surface Water-Gulf of Mexico

(*) Region M amended its Approved Regional Water Plan in August 2003 (?) to include both brackish groundwater and seawater (Gulf of Mexico) desalination water management strategies.
(**) Region P considered a surface water (Gulf of Mexico) desalination project to potentially serve as a water supply source in Region L.

Membrane-based technologies utilize semi-permeable membranes to separate the salts from the water. There are two types of membrane processes: electro-dialysis reversal (EDR) process and reverse osmosis (RO) process.

The EDR process utilizes electricity to energize opposing electrodes to attract and separate out positive and negative ions of the dissolved salts from a saline water supply. The ions are attracted to the electrodes and travel through semi-permeable membranes that screen the ions from the water stream. Thus, salt water flowing through an EDR unit loses dissolved salts and the resulting stream is pure water. EDR systems may be used with water containing low amounts of TDS. However, when TDS levels exceed 3,000 mg/l, RO systems are typically the preferred choice for desalination.

Osmosis is a chemistry term that, in this context, refers to the natural tendency of water to flow through a semi-permeable membrane and dilute liquids with higher salinity. This tendency is measured in terms of the osmotic pressure. In a water desalination operation, the RO process utilizes pressure as the driving force to overcome the osmotic pressure and to *reverse* the flow through the membrane; the membrane prevents the flow of the dissolved solids while allowing the flow of water (permeate). Typical RO operating pressures range from 200 to 450 psi for brackish groundwater plants and 800 to 1,200 psi for seawater plants (Pankratz and Tonner, 2003).

A by-product of the desalination process is a highly concentrated saline stream that requires careful management and disposal. Some of the most common methods of disposal are: solar evaporation ponds, deep-well injection, and open-ocean discharge.

Advantages/disadvantages of water desalination

Water desalination, particularly membrane or filtration technologies, provide a superior quality product regardless of the source water quality. For the State of Texas, the leading advantage that water desalination offers is the ability to add drought-proof supplies to the state's water supply portfolio.

Other advantages that water desalination has over more conventional water supply sources are:

<u>Sizing of facilities</u>: Water desalination is commonly described as a "hardware technology", meaning that it is accomplished by means of pumps, filters, and other pieces of equipment. This feature results in smaller size facilities when compared with other conventional water supply alternatives, such as surface-water reservoirs. Also, water desalination lends itself to modular expansions, meaning that additional capacity may be added with relative ease by increasing the numbers of filtration elements. This flexibility is important when trying to minimize or optimize the initial capital investments to better match the projected water demands on the project.

<u>Ability to incorporate technology innovations</u>: An advantage of the hardware nature of water desalination is that it allows for new cost-saving innovations, such as foul-resistant

membranes and improved energy recovery devices, to be incorporated into existing operational plants with relative ease.

Siting flexibility: in the case of brackish groundwater facilities, there is a relative advantage over conventional surface-water supply alternatives with regards to the location of the treatment plant that may be located closer to the final point of use and thus minimizing treated water transmission costs.

The most noticeable disadvantage of water desalination is its high use of energy. Approximately one third of the operational costs of a water desalination facility is the power consumption. If the power costs increase, there is a direct impact to the cost of the desalinated water.

Cost of Desalination

The cost of water desalination varies depending on water source access, source water salinity and quality, specific desalination process, power costs, concentrate disposal methodology, project delivery method, and the distance to the point of use.

Source water quality dictates the type and level of pre-treatment required. The objective of the pre-treatment phase is to remove suspended matter in the source water and to condition the water by adding anti-scalants and lowering the pH to improve the RO membrane performance and operational life. There is also a post-treatment phase that typically includes re-mineralization of the product water, pH adjustment, and disinfection. Power costs in water desalination may account for 30 to 60 percent of the operational costs, thus, slight variations in power rates directly impact the cost of treated water.

Safe disposal of the concentrate may be a significant cost factor. The preferred disposal methods for large seawater desalination facilities is dilution by use of existing outflows, such as cooling water effluent of power generation facilities, or open sea discharges. Brackish groundwater facilities don’t have such large volumes of concentrate to dispose of as compared to seawater desalination plants; disposal alternatives include a wider array of options, including evaporation ponds, discharge to a municipal wastewater collection-treatment system, and deep-well injection. The TWDB is currently exploring the potential for use of depleted oil and gas well fields for disposal of concentrate under a Class II permit (TWDB, 2003). If this is determined to be a feasible and permissible option, it will significantly enhance the overall cost-competitiveness of brackish groundwater desalination in rural areas of the state.

Typical production costs of brackish groundwater desalination plants range from $0.71 to $2.37 per 1,000 gallons (Table 15-3) (HDR, 2000).

Table 15-3: Brackish water treatment cost for water needing minimum pre-treatment.

Item	Estimated Costs*					
	0.1 MGD	0.5 MGD	1 MGD	3 MGD	5 MGD	10 MGD
Project Cost ($)**	674,000	1,519,000	2,570,000	5,564,000	6,062,000	12,827,000
Annual Cost ($) ***	86,544	222,103	396,522	945,840	1,450,519	257,9977
Unit Cost ($/1,000 gal)	2.37	1.22	1.09	0.86	0.79	0.71
* TDS ranging from 1,000 to 3,000 mg/l. Feedwater pressure 300 psi. Power cost $0.06 per kWh. Does not include costs for source water development, concentrate disposal, finished water storage, pumping and distribution, environmental/archeology, land acquisition and surveying.						
** Includes water treatment plant, engineering and legal costs, 35 percent contingencies and 1-year interest on capital during construction.						
*** Includes O&M costs plus debt service at 6 percent for 30 years.						

Note. Information contained in this table consolidates data from Table ES-1 of the HDR report.

The City of Fort Stockton operates a brackish 6 MGD RO treatment tlant. The plant has been successfully operated for 7 years, and, during that period of time, production costs have declined from $1.92/1,000 gal, initially, to a current cost of $1.37/1,000 gal. Cost savings have been gained by negotiating better electric power rates for electricity and operational optimization of the plant.

Another current Texas example illustrating the declining cost of the technology is the Southmost Regional Water Authority's plant, expected to begin full-scale operation in April 2004. This plant is rated at 7.5 MGD, and production cost will be $1.10/1,000 gallons. The facility is designed to accommodate a future expansion of additional 7.5 MGD.

Conclusions

Water desalination is both a proven and growing technology that is gaining cost-competitiveness with other water-supply options. Water desalination technology lends itself to modular sizing of the facilities, which allows for optimization of capital investment to match the demand for water. In addition to having access to seawater, Texas has a large volume of available brackish groundwater distributed throughout the state. Current research regarding feasibility of concentrate disposal by injecting it into depleted oil and gas well fields may increase the economic feasibility of water desalination in rural areas of Texas.

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