1.10 Desalination (SCTN–17)

1.10.1 Description of Option

Desalting seawater from the Gulf of Mexico in the vicinity of San Antonio Bay and/or brackish groundwater present in the aquifers of the South Central Texas Region are potential sources of freshwater supplies for municipal and industrial use. The selection of options for each of these broad categories of desalination depends upon the availability of saline and brackish water. For example, for the purpose of a water supply for the region, the supply of seawater from the Gulf is essentially unlimited. In contrast, the brackish groundwater in the region is neither as available nor is as accessible. Presently, available information about brackish groundwater in the Trinity Group, Edwards Aquifer, and Carrizo-Wilcox Aquifers indicates that quantities available are limited, located at lower strata, typically in low recharge rate aquifers, and, when it is removed, will typically be replaced with freshwater that will degrade in quality by mixing with brackish water. However, consideration of brackish groundwater for a single small community may be practical, but may not be a feasible option for large cities due to limited quantities available.

This section will present desalination information for a range of quantities so that a wide range of costs can be considered. For the major municipal demand center of the South Central Texas Region, the option will be a large-scale desalt plant at San Antonio Bay with the corresponding conveyance system to the major municipal water demand center of the South Central Texas Region. At the community level, the existing City of Seadrift groundwater desalt plant will be described, and a desalt option for Karnes City will be projected.

1.10.1.1 General Desalination Background

The commercially available processes that are currently used to desalt seawater and brackish groundwater to produce potable water are:

- Distillation (thermal) Processes; and
- Membrane (non-thermal) Processes.

The following section describes each of these processes and discusses a number of issues that should be considered before selecting a process for desalination of seawater.

1.10.1.2 Distillation (Thermal) Processes

Distillation processes produce purified water by vaporizing a portion of the saline feedstock to form steam. Since the salts dissolved in the feedstock are nonvolatile, they remain unvaporized and the steam formed is captured as a pure condensate. Distillation processes are normally very energy-intensive, quite expensive, and are generally used for large-scale desalination of seawater. Heat is usually supplied by steam produced by boilers or from a turbine power cycle used for electric power generation. Distillation plants are commonly dual-purpose facilities that produce purified water and electricity.

In general, for a specific plant capacity, the equipment in distillation plants tends to be much larger than membrane desalination equipment. However, distillation plants do not have the stringent feedwater quality requirements of membrane plants. Due to the relatively high temperatures required to evaporate water, distillation plants have high-energy requirements, making energy a large factor in their overall water cost. Their high operating temperatures can result in scaling (precipitation of minerals from the feedwater), which reduces the efficiency of the evaporator processes, because once an evaporator system is constructed, the size of the exchange area and the operating profile are fixed, leaving energy transfer as a function of only the heat transfer coefficient. Therefore, any scale that forms on heat exchanger surfaces reduces heat transfer coefficients. Under normal circumstances, scale can be controlled by chemical inhibitors, which inhibit but do not eliminate scale, and by operating at temperatures of less than 200°F.

Distillation product water recoveries normally range from 15 to 45 percent, depending on the process. The product water from these processes is nearly mineral free, with very low TDS (less than 25 mg/L). However, this product water is extremely aggressive and is too corrosive to meet the Safe Drinking Water Act (SDWA) corrosivity standards without post-treatment. Product water can be stabilized by chemical treatment or by blending with other potable water.

The three main distillation processes in use today are Multistage Flash Evaporation (MSF), Multiple Effect Distillation (MED), and Vapor Compression (VC). All three of these processes utilize an evaporator vessel that vaporizes and condenses the feedstock. The three processes differ in the design of the heat exchangers in the vessels and in the method of heat introduction into the process. Since there are no distillation processes in Texas that can be shown as comparable installations, distillation will not be considered here. However, there are membrane desalination operations in Texas, so the following discussion and analyses are based upon information from the use of membrane technology for desalination.

1.10.1.3 Membrane (Non-thermal) Processes

The two types of membrane processes use either pressure, as in reverse osmosis, or electrical charge, as in electrodialysis reversal, to reduce the mineral content of water. Both processes use semi-permeable membranes that allow selected ions to pass through while other ions are blocked. Electrodialysis reversal (EDR) uses direct electrical current applied across a vessel to attract the dissolved salt ions to their opposite electrical charges. EDR can desalinate brackish water with TDS up to several thousand mg/L, but energy requirements make it economically uncompetitive for seawater, which contains approximately 35,000 mg/L TDS. As a result, only reverse osmosis (RO) is used for seawater desalination.

RO utilizes a semi-permeable membrane that limits the passage of salts from the saltwater side to the freshwater side of the membrane. Electric motor driven pumps or steam turbines (in dual-purpose installations) provide the 800 to 1,200 psi pressure to overcome the osmotic pressure and drive the freshwater through the membrane, leaving a waste stream of brine/concentrate. The basic components of an RO plant include pre-treatment, high-pressure pumps, membrane assemblies, and post-treatment. Pretreatment is essential because feedwater must pass through very narrow membrane passages during the process and suspended materials, biological growth, and some minerals can foul the membrane. As a result, virtually all suspended solids must be removed and the feedwater must be pre-treated so precipitation of minerals or growth of microorganisms does not occur on the membranes. This is normally accomplished by various levels of filtration and the addition of various chemical additives and inhibitors. Post-treatment of product water is usually required prior to distribution to reduce its corrosivity and to improve its aesthetic qualities. Specific treatment is dependent on product water composition.

A "single pass/stage" seawater RO plant will produce water with a TDS of 300 to 500 mg/L, most of which is sodium and chloride. The product water will be corrosive, but this may be acceptable, if a source of blending water is available. If not, and if post-treatment is required, the various post-treatment additives may cause the product water to exceed the desired TDS levels. In such cases, or when better water quality is desired, a "two pass/stage" RO system is used to produce water typically in the 200 mg/L TDS range. In a two pass RO system, the product water from the first RO pass/stage is further desalted in a second RO pass/stage, and the water from the second pass is blended with water from the first pass.

Recovery rates up to 45 percent are common for a two-pass/stage seawater RO facility. RO plants, which comprise about 31 percent of the world's desalting capacity, range from a few gallons per day to 15 MGD. The largest RO seawater plant in the United States is the 6.7-MGD plant in Santa Barbara, California. The largest RO plant in operation in Texas is a groundwater desalt plant at Kenedy with a capacity of 2.86 MGD (Table 1.10-1). The current domestic and worldwide trend seems to be for the adoption of RO when a single purpose seawater desalting plant is to be constructed. RO membranes have been improved significantly over the past two decades (i.e., the membranes have been improved with respect to efficiency, longer life, and lower prices).

Table 1.10-1.
Municipal Use Desalt Plants in Texas
(>25,000 gpd and as of December 1998)

Location	***Source***	***Total Capacity (MGD)***	***Desalt Capacity (MGD)***	***Membrane Type[1]***
Bayside, City of	Groundwater	0.15	0.15	RO
Dell City, City of	Groundwater	0.11	0.11	EDR
Ft. Stockton, City of	Groundwater	6.5	3	RO
Granbury, City of	Lake Water	0.35	0.35	EDR
Haciendas del Norte (El Paso)	Groundwater	0.133	0.133	RO
Homestead MUD (El Paso)	Groundwater	0.1	0.1	RO
Kenedy, City of	Groundwater	2.86	0.72	RO
Lake Granbury	Lake Water	3.5	3.5	EDR
Robinson, City of	River	2	2	RO
Seadrift, City of	Groundwater	0.24	0.17	RO
Sherman, City of	Lake Water	6.0	6.0	EDR
Sportsman's Paradise	Lake Water	0.1	0.1	RO
Texas Resort Co.	Lake Water	0.144	0.144	EDR

[1] RO = Reverse Osmosis EDR = Electrodialysis Reversal

1.10.1.4 Examples of Relevant Existing Desalt Projects

Seadrift, Texas: In 1996, Seadrift (retail population 1,890) was dependent on the Gulf Coast Aquifer for its water supply. Total dissolved solids (TDS) and chlorides had reached unacceptable levels of 1,592 mg/L and 844 mg/L, respectively. These values exceeded the primary drinking water standard for TDS (1,000 mg/L) and the secondary drinking water standard for chlorides (300 mg/L). Since the community was not located near an adequate quantity of freshwater or a wholesaler of drinking water, the decision was made to install reverse osmosis to treat this slightly brackish groundwater. The city installed pressure filters, two RO units, antiscalent chemical feed equipment, and a chlorinator. The capital cost for the system was $1.2 million and the annual operation and maintenance (O&M) cost is $56,000, resulting in a total debt service plus O&M cost of about $0.88 per 1,000 gallons treated by RO. The capital cost included the cost of facilities in addition to the RO units and their appurtenant equipment. Product water from the RO units is blended with groundwater to meet an acceptable quality level. About 60 percent of the total is from the desalt units.

Tampa, Florida: The water utility, Tampa Bay Water, has selected a 30-year design, build, operate, and own (DBOO) proposal to construct a nominal 25 MGD seawater desalt plant. The plant will use reverse osmosis as the desalt process. The proposal included total capitalization and operations costs for producing high quality drinking water (chlorides less than 100 mg/L). The total cost to Tampa Bay Water is to be $2.08 per 1,000 gallons on a 30-year average, with first year cost being $1.71 per 1,000 gallons. The results of Tampa Bay's competition has attracted international interest in the current cost profile of desalting seawater for drinking water supply, since these costs are only about one-half the levels experienced in previous desalination projects (Leitner, 1999).

Tampa Bay Water selected the winning proposal from four DBOO proposals submitted, which ranged from $2.08 to $2.53 per 1,000 gallons. The factors listed below may be all or partially responsible for these seemingly low costs:

1. Salinity at the Tampa Bay sites ranges from 25,000 to 30,000 mg/L, lower than the more common 35,000 mg/L for seawater. RO cost is sensitive to salinity.
2. The power cost, which is interruptible, is below $0.04 per kilowatt-hour (kWh).
3. Construction cost savings through using existing power plant canals for intake and concentrate discharge.
4. Economy of scale at 25 MGD.

5. Amortizing over 30 years.
6. Use of tax-exempt bonds for financing.

The Tampa bids contrast with another current large-scale desalination project in which distillation is proposed. The current desalt project of the Singapore Public Utility Board, which proposes a 36 MGD multi-stage flash distillation plant, will cost an estimated $5.76 per 1,000 gallons for the first year operation.[1]

1.10.2 Available Yield

Seawater from the Gulf of Mexico is an unlimited quantity within the context of a supply for the South Central Texas Region. However, a problem arises when attempting to quantify brackish groundwater yields, in that brackish groundwater has relatively fewer uses than freshwater. Consequently, published yields for aquifers in Texas focus on freshwater quantities. Although there is documentation of the location of brackish water zones, brackish groundwater yields have not been documented.

There are several limitations on predicting brackish groundwater storage volume and yields. These limitations lessen the attractiveness of using brackish groundwater for regional water supply options. Brackish sources tend to exist in confined aquifers that have no known outcrop or other structure permitting direct flow into the brackish aquifer. This prohibits replenishment of the brackish aquifer through recharge. Thus, pumping from such an aquifer could lead to the ultimate depletion of the supply. However, when brackish groundwater sources have yields that are dependent upon the amount of recharge that can replenish the stored volume in the aquifer, they tend to be in a brackish “zone” located at a deeper level within an aquifer containing freshwater. Because the movement of groundwater is in the direction of the hydraulic gradient, pumping brackish water under this condition leads to movement of freshwater into the brackish water zone, thus contaminating freshwater. This is a water supply scenario that runs contrary to ordinary water resource planning and implementation logic.

For the purpose of developing the options presented in Section 1.10.4, certain assumptions will be made regarding available yields. For the option in which seawater from the Gulf of Mexico is desalted to develop a significant drinking water supply for the major urban area in the region, it is assumed that the availability of Gulf water is unlimited and that its cost is

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[1] Desalination & Water Reuse Quarterly, vol. 7/4, Feb/Mar, 1998.

zero prior to extraction from the source. For the option that involves smaller municipalities, the brackish water source is identified and described in the following paragraphs.

City of Karnes City Option. The City has four wells. One well (Well #6) is about 3,820 feet deep and takes water from the Carrizo Aquifer. It is located about 2 miles from the City. This supply meets current drinking water standards. The other three wells owned by the City are shallower and take water from the Catahoula Aquifer. These wells are identified as back-up or emergency water supplies, but the water quality from the Catahoula Aquifer does not meet current drinking water standards without treatment. The Catahoula Aquifer is a principal aquifer in Karnes County because it is the shallowest source of fresh to slightly brackish water. Water in this aquifer typically exceeds the primary drinking water standard for TDS and the secondary standard for chloride;[2] although it appears that blending with the appropriate freshwater or desalting a portion of supply from the Catahoula Aquifer wells would meet both standards. Therefore, this option considers the cost of desalting the supplies from the Catahoula Aquifer to either increase Karnes City's total supply or to provide a fully compliant supply in the event that the only well that meets drinking water standards (Well #6) fails.

The municipal water use projections for the City of Karnes City are provided in Table 1.10-2. The maximum daily demand in the city is about 1.72 times the annual average daily use. Therefore, a treatment facility would need to be sized to produce about the flow rate represented by the maximum daily demand. For planing purposes, an average day to maximum day ratio of 1.75 is used to create the treatment capacity shown in the far right column of Table1.10-2.

Certain assumptions will be made regarding the City of Karnes City groundwater desalt option. One assumption is that reverse osmosis will be the selected desalt process. The total dissolved solids found in the Catahoula Aquifer ranges from about 1,200 mg/L to about 1,500 mg/L. Chlorides range from about 500 to 600 mg/L. In order to ensure meeting the chloride standard, a blend of 61.5 percent desalted water with 38.5 percent raw well water is suggested. This blending ratio results in a desalt treatment capacity requirement of 313 gpm for the projected year 2030 demand (Table 1.10-2). Based on published information,[2] the yields in the Catahoula Aquifer are more than sufficient to meet the groundwater quantities shown in Table 1.10-2.

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[2] Ground-Water Geology of Karnes County, Texas, Bulletin 6007, Texas Board of Water Engineers, July 1960.

Table 1.10-2.
Current and Future Municipal Water Use in Karnes City, Texas

Year	Annual Water Use (acft/yr)	Average Water Demand		Maximum Daily Demand (gpm)[1]	Desalt Treatment Capacity (gpm)[2]
		(gpd)	(gpm)		
1998*	365	326,000	226	396	—
2000	468	417,802	290	508	—
2010	435	388,342	270	472	291
2020	442	394,591	274	480	296
2030	468	417,802	290	508	313
2040	491	438,335	304	532	328
2050	515	459,761	319	559	344

[1] Maximum daily demand is 1.75 times average daily demand.

[2] Desalted water at 61.5 percent of the blended supply.

Source: TNRCC inspection report.

1.10.3 Environmental Issues

1.10.3.1 Seawater Desalination

The project area for the proposed desalination plant is in the San Antonio Bay area near the confluence of the San Antonio and Guadalupe Rivers. This location may be beneficial to the overall cost of the desalination process due to the lower salinity levels of the upper estuary, if the variable salinity does not adversely affect operations. Estuaries serve as critical habitat and spawning grounds for many marine species and migratory birds. Estuaries are marine environments maintained in a brackish state by the inflow of freshwater from rivers and streams. The high productivity characteristic of estuaries arises from the abundance of terrigenous nutrient input, shallow water, and the ability of a few marine species to exploit environments continually stressed by low, variable salinities, temperature extremes, and, on occasion, low dissolved oxygen concentrations. The environmental potential effects resulting from the construction of a desalination plant in the vicinity of San Antonio Bay will be sensitive to the siting of the plant and its appurtenances, particularly the intake location, which could potentially impact wetlands and other sensitive areas. Since the brine concentrate discharge point is planned to be located about 11 miles offshore, there would be no impact of this feature upon the estuary.

Also, it is assumed that the outfall will be located and constructed so as to result in little or no effect upon the environment at the discharge location.

Even a large desalination plant, for example a facility using 50 MGD of feedwater, would involve processing about 154 acft of bay water per day, or about 4,800 acft/month. This is a small amount compared to San Antonio Bay (Guadalupe Estuary) inflows, which average 195,000 acft/month (2.5 percent), median inflows of 119,000 acft/month (4 percent), and a bay volume of 668,000 acft (0.7 percent). Only during low flow periods would the water withdrawal from desalination be substantial relative to inflows. For example, the 4,800 acft/month would be 12.8 percent of monthly inflows during months so dry that they occur only 10 percent of the time, and is roughly equivalent to the lowest monthly inflow recorded for the estuary. Bay volumes, inflows, and tidal exchanges with the Gulf of Mexico are so large relative to this alternative that substantial impacts to overall salinity gradients, or to the delivery of nutrients and sediment are not possible.

Many migratory birds are dependent on the quality of estuarine environments in order to complete the foraging and nesting of their migration. Three of the migratory birds known to the San Antonio Bay area are listed as threatened by TPWD: the Reddish Egret (*Egretta rufescens*), the Piping Plover (*Charadrius melodus*), and the Sooty Tern (*Sterna fuscata*). The Piping Plover is also listed as threatened by USFWS, and the Reddish Egret is a candidate for protection.

The water transmission pipeline between San Antonio Bay and Bexar County would be approximately 133 miles long. A construction right-of-way of approximately 140-feet wide would affect a total area of approximately 2,254 acres. The construction of the pipeline would include the clearing and removal of woody vegetation. A 40-foot wide right-of-way corridor, free of woody vegetation and maintained for the life of the project, would total 648 acres. The proposed pipeline route would traverse three of Omernik's[3] ecoregions: the Western Gulf Coastal Plain, the East Central Texas Plains, and the westernmost reaches of the Texas Blackland Prairie. Surveys for protected species would be conducted within the proposed construction corridors where preliminary evidence indicates their existence. Many of these species, such as the Texas Tortoise, the Reticulated Collared Lizard, the Texas Horned Lizard, and the Indigo Snake, appear to be dependent on shrubland or riparian habitat. The Texas Garter Snake may be

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[3] Omernik, J.M., "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77:118-125, 1987.

present in wetland habitats and the Timber Rattlesnake may be found in riparian woody vegetation.

Destruction of potential habitat can be avoided by diverting the corridor through previously disturbed areas, such as croplands. Selection of a pipeline right-of-way alongside the existing habitat could also be beneficial to some wildlife by providing edge habitat; however, the majority of these areas are small and fragmented, so care should be taken to ensure minimum impacts.

Although the Natural Heritage Program does not report the occurrence of any endangered, threatened, or rare species directly along the pipeline right-of-way, some have been reported within a 1-mile corridor. The only endangered specie known to exist within this 1-mile corridor is the Attwater's Greater Prairie Chicken in Goliad and Refugio Counties. The Attwater's Greater Prairie Chicken prefers the coastal prairies grassland in area 0 to 24 inches in vegetation height. Several rare vascular plants on the Texas Organization for Endangered Species (TOES) watch list are known to exist within this 1-mile corridor. Big red sage (Salvia penstemonoides) is listed as candidate species for protection by the USFWS, as well as on the TOES watch list. Coastal Gay Feather (*Liatris bracteata*), Plains Gumweed (*Grindelia oolepsis*), Elmendorf's Onion (*Allium elmendorfii*), Parks' Jointweed (*Polygonella parksii*), and Welder Machaeranthera (Psilactis heterocarpa) are all found in this corridor and are listed on the TOES watch list. Plant and animal species in the project area listed by the USFWS, TPWD, and TOES as endangered or threatened and those with candidate for listing or rare status are presented in Table 1.10-3. All species listed have habitat requirements or preferences that suggest they could be present within the project area.

1.10.3.2 Brackish Groundwater Desalination

As freshwater is extracted from brackish water, a more concentrated brackish water is produced as a waste product. Concentrated brackish water created from the desalination process is about triple the level of total dissolved solids than the brackish aquifer water and must be disposed of properly. For this option, it has been assumed that the brine concentrate will be discharged into the city's wastewater collection and treatment system.

Table 1.10-3.
Important Species Having Habitat or Known to Occur in Counties Potentially Affected by Option Desalination of Seawater (SCTN-17)*

Common Name	***Scientific Name***	***Summary of Habitat Preference***	***Listing Agency***			***Potential Occurrence in County***
			USFWS[1]	***TPWD***[1]	***TOES***[2,3]	
Birds						
American Peregrine Falcon	*Falco peregrinus anatum*	Open country; cliffs	E	E	E	Nesting/Migrant In All Counties
Arctic Peregrine Falcon	*Falco peregtinus tundrius*	Open country; cliffs	T	T	T	Nesting/Migrant In All Counties
Interior Least Tern	*Sterna antillarum athalassos*	Inland river sandbars for nesting and shallow water for foraging	E	E	E	Nesting/Migrant In Karnes, Goliad, Refugio, Dewitt
White-tailed Hawk	*Buteo albicaudatus*	Coastal prairies, savannahs and marshes in Gulf coastal plain		T	T	Nesting/Migrant In Goliad, Refugio
Whooping Crane	*Grus americana*	Potential migrant	E	E		Migrant In All Counties
Brown Pelican	*Pelecanus occidentalis*	Coastal inlands for nesting, shallow gulf and bays for foraging	E	E	E	Nesting/Migrant In Refugio
Reddish Egret	*Egretta rufescens*	Coastal inlands for nesting, coastal marshes for foraging	C2	T		Migrant In Refugio
Wood Stork	*Mycteria americana*	forages in prairie ponds, ditches, and shallow standing water formerly nested in TX		T	T	Migrant In Bexar, Wilson, Refugio, Dewitt
Bald Eagle	*Haliaeetus leucocephalus*	Large Bodies of water with nearby resting sites	T	T	E	Nesting/Migrant In Goliad, Refugio
Zone-tailed Hawk	*Buteo albonotatus*	Arid, open country, deciduous or pine-oak woodland; nests in various habitats and sites		T	T	Nesting/Migrant In Bexar
Black-capped Vireo	*Vireo atricapillus*	oak-juniper woodlands with patchy, distinctive two-layered aspect; shrub and tree layer with open, grassy space	E	E	T	Nesting/Migrant In Bexar
Attwater's Greater Prairie-Chicken	*Tympanuchus cupido attwateri*	Coastal Prairies of Gulf Coastal Plain	E	E	E	Nesting In Goliad, Refugio—Known to occur within 1 mile of pipeline route
Golden-cheeked Warbler	*Dendrpoica chrysoparia*	juniper-oak woodlands; dependent on mature Ashe juniper (cedar) for nests	E	E	E	Nesting/Migrant In Bexar
White-faced Ibis	*Pelagis chihi*	Prefers freshwater marshes, sloughs, and irrigated rice fields	C2	T	T	Migrant In Bexar, Wilson, Refugio
Piping Plover	*Charadrius melodus*	Beaches and flats of Coastal Texas	T	T	T	Migrant In Refugio
Mountain Plover	*Charadrius montanus*	Non-breeding-shortgrass plains and fields, plowed fields and sandy deserts	PT			Nesting/Migrant In Bexar, Wilson
Henslow's Sparrow	*Ammodramus henslowii*	Weedy fields, cut over areas; bare ground for running and walking				Nesting/Migrant In Bexar, Wilson
Reptiles						
Cagle's Map Turtle	*Graptemys caglei*	Guadalupe River System, transition areas between riffles and pools, nests within 30 feet of water's edges	C1		C1	Bexar, Dewitt
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands, grass, cactus, brush	C2	T	T	All Counties
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2			Bexar
Spot-Tailed Earless Lizard	*Holbrookia lacerata*	central & southern Texas; oak-juniper woodlands and mesquite-prickly pear				Bexar, Karnes, Goliad, Refugio
Texas Diamondback Terrapin	*Malaclemys terrapin littoralis*	Bays, coastal marshes of the upper two-thirds of Texas Coast	C2		T	Refugio

Table 1.10-3 (continued)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Agency: USFWS[1]	Listing Agency: TPWD[1]	Listing Agency: TOES[2,3]	Potential Occurrence in County
Texas Tortoise	*Gopherus berlandieri*	Open brush w/ grass understory; open grass/bare ground avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March through November		T	T	Bexar, Karnes, Wilson, Goliad, Refugio
Timber Rattlesnake	*Crotalus horridus*	Floodplains, upland pine, deciduous woodlands, riparian zones, abandoned farms, dense ground cover		T	T	Bexar, Refugio
Gulf Saltmarsh Snake	*Nerodia clarkii*	Brackish to saline coastal waters	C2			Refugio
Scarlet Snake	*Cemophora coccinea*	Sandy soils of East Texas, central and south Gulf Coast		T	WL	Refugio
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thornbush woodland and mesquite savannah of coastal plain		T	WL	Bexar, Karnes, Refugio
Keeled Earless Lizard	*Holbrookia propinqua*	Coastal dunes, Barrier islands and sandy areas				Bexar, Wilson, Goliad, Refugio, Dewitt
Amphibians						
Black-Spotted Newt	*Notophthalmus meridionalis*	Ponds and resacas in south Texas		T	E	Bexar, Refugio
Sheep Frog	*Hypopachus variolosus*	Deep sandy soils of Southeast Texas		T	T	Goliad, Refugio
South Texas Siren (Lg. Form)	*Siren sp. 1*	Moist soils		T		Refugio
Mexican Treefrog	*Smilisca baudinii*	Subtropical woodlands, resacas		T	T	Refugio
Fish						
Guadalupe Bass	*Micropterus treculi*	Clear flowing streams	C2		WL	Bexar
Insects						
Texas Asaphomyian Tabanid Fly	*Asaphomyia texanus*	Found near slow-moving water, eggs laid on objects near water; larvae are aquatic, adults prefer shady areas; males bite, females feed on nectar and pollen	C1			Goliad
Maculated Manfreda Skipper	*Stallingsia maculosus*	Fast erratic flight, larvae feed inside a leaf shelter, pupate in cocoon made of leaves & silk			WL	Bexar, Karnes, Wilson
Plants						
Black Lace Cactus	*Echinocereus reichenbachii* *var. albertii*	Grasslands, thorn shrublands, mesquite woodlands on sandy, somewhat saline soils on coastal prairie	E	E	E	Refugio
Big Red Sage	*Salvia penstemonoides*	Moist Creek and stream bed edges; historic; introduced in native plant nursery trade	C2		WL	Bexar, Wilson—Known to occur within 1 mile of pipeline route
Coastal Gay Feather	*Liatris bracteata*	Black clay soils of midgrass grasslands on coastal prairie remnants.			WL	Refugio—Known to occur within 1 mile of pipeline route
Plains Gumweed	*Grindelia oolepsis*	Early successional patches in coastal prairie on heavy clay soils, sometimes in disturbed habitats in urban areas			WL	Refugio—Known to occur within 1 mile of pipeline route
Elmendorf's Onion	*Allium elmendorfii*	Endemic; deep sands derived from Queen City and similar Eocene formations			WL	Bexar, Wilson, Refugio—Known to occur within 1 mile of pipeline route
Parks' Jointweed	*Polygonella parksii*	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer			WL	Bexar, Wilson—known to occur within 1 mile of pipeline route
Bracted Twistflower	*Streptanthus bracteatus*	Endemic, openings in juniper-oak woodlands, rocky slopes				Bexar

Table 1.10-3 (continued)

Common Name	Scientific Name	Summary of Habitat Preference	Listing Agency			Potential Occurrence in County
			USFWS[1]	TPWD[1]	TOES[2,3]	
South Texas Rushpea	*Caesalpinia phyllanthoides*	Tamaulipan thorn shrublands or grasslands on shallow sandy to clayey soil over calcareous rock outcrops			WL	Bexar
Correll's False Dragon-Head	*Physostegia Correllii*	Wet soils including roadside ditches, irrigation channels			WL	Bexar
Glass Mountain Coral Root	*Hexalectris nitida*	Mesic woodlands in canyons, lower elevations, under oaks				Bexar
Welder Machaeranthera	*Psilactis heterocarpa*	Coastal prairie; Shrub-infested grasslands and open mesquite-huisache woodlands			WL	Refugio—Known to occur within 1 mile of pipeline route
Sandhill Woolywhite	*Hymenopappus carrizoanus*	Endemic, deep loose sands of Carrizo, disturbed areas				Bexar
Mammals						
Plains Spotted Skunk	*Spilogale putorius interrupta*	Prefers wooded, brushy areas and tallgrass prairie, fields, prairies, croplands, fence rows, forest edges			C2	Bexar, Wilson
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scrub and live oak mottes	E	E	E	Karnes, Wilson, Goliad, Refugio
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	E	Karnes, Wilson, Goliad, Refugio

[1] Texas Parks and Wildlife Department. Unpublished 1999. September 1999, Data and map files of the Natural Heritage Program, Resource Protection Division, Austin, Texas.

* E = Endangered T = Threatened PT = Proposed Threatened 3C = No Longer a Candidate for Protection
C2 = Candidate Category C1 = Candidate Category, Substantial Information WL = Watch List – Potentially threatened, especially in Texas
Blank = Rare, but no regulatory listing status

1.10.4 Options and Cost Estimates

1.10.4.1 Seawater Desalination at San Antonio Bay

This option provides the cost estimates for a major desalination water treatment plant on the Texas coast and the infrastructure for transferring potable water from the coast to the major municipal demand center of the South Central Texas Region. The entire option consists of the intake, water treatment plant, storage tanks, pumping stations and a 133-mile pipeline. The water treatment plant component of the option includes pretreatment necessary to ensure normal life and efficiency of the reverse osmosis membranes. This option is depicted in Figure 1.10-1, and is presented in terms of four firm capacities that demonstrate the potential economy of scale over a range from 25 MGD to 100 MGD. Cost estimating guidelines used for the components of this option are found in Section 5, Cost Estimating, with the basis for estimating the desalination plant costs being the recent experience of other utilities that are involved in similar projects (e.g., technical data from the Tampa Bay Water proposal, referenced earlier in Subsection 1.10.1.3.

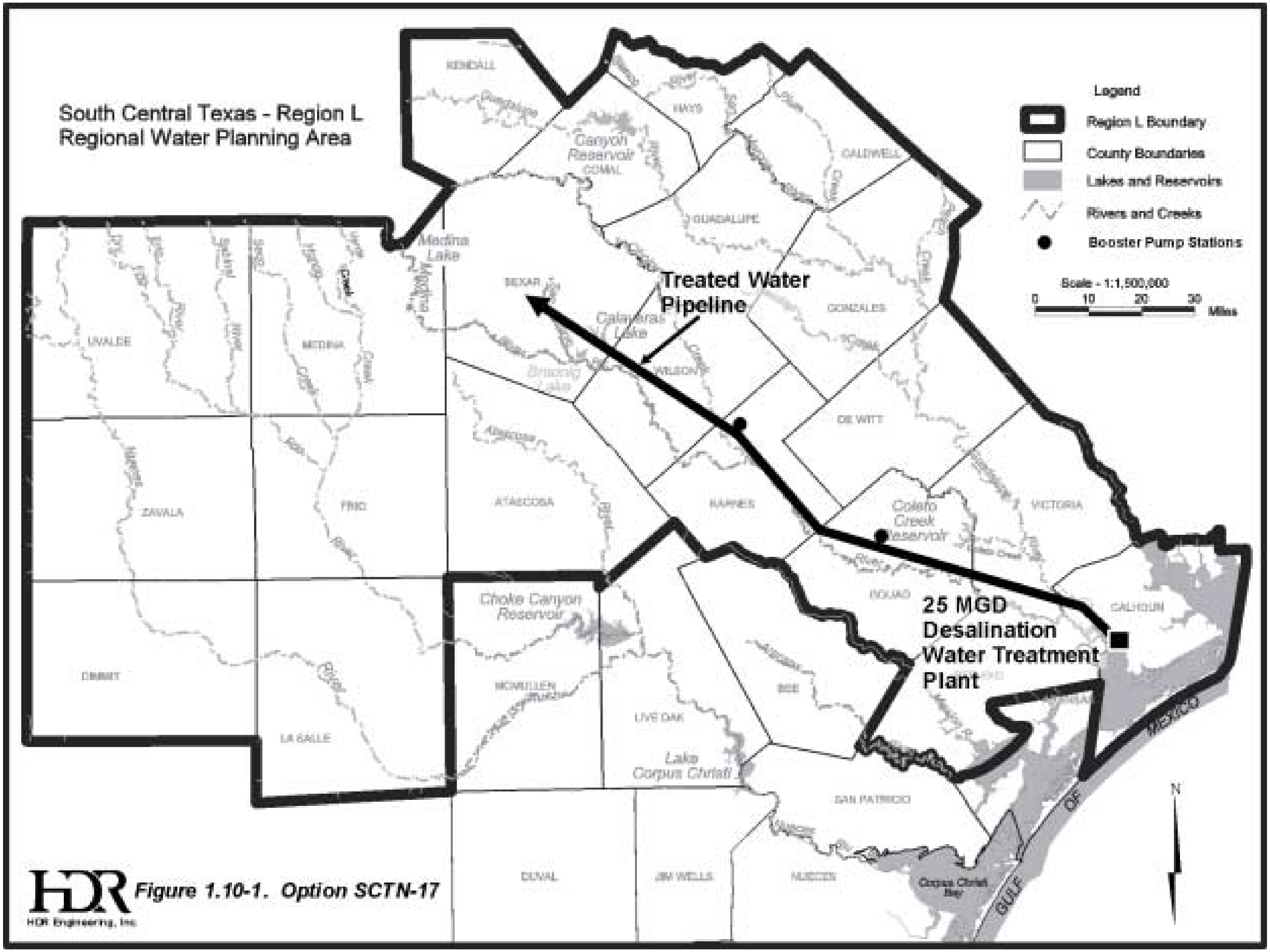

Figure 1.10-1. Option SCTN-17

This approach takes advantage of the development of membrane technology and the resulting reduction in capital and operating costs in comparison to previously available technology. During the past 10 years, the price and operating costs of membranes have declined due to improvements in materials and manufacturing. This contrasts with recent experience with conventional water treatment technology (i.e., costs for conventional water treatment technologies have not been influenced greatly by equipment innovations).

The basic assumptions made to determine the size and characteristics of the components of this desalination option are listed in Table 1.10-4. A 133-mile pipeline route generally along the route of the San Antonio River from San Antonio Bay to the center of Bexar County was assumed. The pumping capacities are equal to the nominal plant capacities, except for the intake, which includes allowance for the quantity equivalent to the concentrated brine reject water. A brine discharge pump station and conveyance line to carry the brine concentrate offshore is also included in the costs.

Table 1.10-4.
Engineering Assumptions for Seawater Desalination Option

Parameter	***Assumption***	***Description***
Raw water salinity	25,000 mg/L	Intake located near mouth of Guadalupe River
Finished water chlorides	100 mg/L	
Treatment capacities	25, 50, 75, 100 MGD	
Power cost	$0.06 per kWh	Assume interruptible power
Pump efficiency	87%	
WTP storage	1 day’s capacity	25, 50, 75, and 100 million gallon sizes
Pipeline diameter	42”, 54”, 66”, 84”	
Booster storage	5 percent of flow	More than 1 hour storage to avoid in-line pumps
Number of booster stations	2	
Land for plant	20 acres	Add 10 acres for each 25 MGD capacity increase
Land for tanks/pumps	3 acres	
Land for easements	735 acres	Pipeline right-of-way
WTP operations/maintenance	$1.00/1,000 gallons	
Pipeline friction factor	C = 130	
Plant production downtime	5 percent	

In this option, the components of the Tampa costs used include the following:

1. Pre-treatment unit process components;
2. Reverse osmosis treatment plant; and
3. Operation and Maintenance of the entire water treatment plant.

Added to the plant costs were costs for 1,000 feet of intake pipeline, the intake structure and intake pumps, the brine concentrate pump station and 11 miles of brine discharge pipeline, one day's storage capacity at the plant, and land costs.

The treatment and delivery components and respective sizes and capacities are summarized in Table 1.10-5. The brine concentrate capacities for each nominal plant capacity are based on a recovery rate of 60 percent. This means that of the 100 percent of flow taken from San Antonio Bay at the plant intake, 60 percent is desalted and 40 percent is returned to the Gulf as concentrated brine *via* a route approximately 11 miles long from the plant location through the barrier island.

Table 1.10-5.
Capacities for Seawater Desalination Plant Option

	Nominal Water Treatment Plant Capacity			
Item/Facility	***25 MGD***	***50 MGD***	***75 MGD***	***100 MGD***
Intake Pump Station (MGD)	41.67	83.33	125	167
Intake Pipeline Diameter (inches)	48	72	84	102
Desalination Water Treatment Plants				
Plant Intake (seawater) (MGD)	41.67	83.33	125	167
Desalted Product Water (drinking water) (MGD)	25	50	75	100
Brine Discharge Pump Station (MGD)	16.67	33.33	50	67
Brine Discharge Pipeline Diameter (inches)	30	42	54	66
Desalted Product Water (MGD)	25	50	75	100
Storage Tank at Plant (MG)	25	50	75	100
Pump Station at Plant and Each Booster Station (gpm)	17,361	34,722	52,083	69,444
Pipeline Diameter (inches)	42	54	66	84
Storage at Booster Pump Stations (MG, each)	1.25	2.5	3.75	5.0
Total Land Acquisition (acres)	755	765	775	785

The estimated costs to desalt seawater range from $868 per acft for the 25 MGD size plant to $856 per acft for the 100 MGD size plant (Table 1.10-6). Since the treatment process is reverse osmosis using membranes, the capital and operating costs of the treatment plant are quite linear with increasing capacity. The few savings due to increased capacity in some plant components such as the intake and brine pump stations, and the intake and brine pipelines are minor because these components comprise a minor part of the plant cost. However, there are some scale savings with increasing capacity to convey the treated water to the municipal demand center. Over the range from 25 MGD to 100 MGD the conveyance unit costs decrease about $753 per acft for the 25 MGD size project to $477 per acft for the 100 MGD size project (Table 1.10-6). The estimated total desalination treatment and conveyance cost from near the mouth of the Guadalupe River to the major municipal demand center of the South Central Texas Region decreases from $1,621 per acft ($4.97 per 1,000 gallons) for the 25 MGD size project to $1,333 per acft ($4.09 per 1,000 gallons) for the 100 MGD size project (Table 1.10-6).

1.10.4.2 Brackish Groundwater Desalination for Karnes City

This option has general applicability within the region. However, the Seadrift example demonstrates that desalination for small communities is economically and technically practical.

The City uses three wells for a dependable water supply in the event the principal well is out of service. Groundwater in these three wells is slightly saline and does not meet either the primary drinking water standards for total dissolved solids nor the secondary standards for chloride. These wells take water from the Catahoula Aquifer, which has adequate quantity, but is known for its slightly brackish water. This option provides an estimate of the cost of desalting a portion of the Catahoula water supply so that the city could either 1) provide a compliant backup water supply, or 2) reverse the current operation by using the desalted water for the principal supply and the Carrizo Aquifer well as the backup supply (Section 1.10.2). Since the Carrizo well is much deeper and is located two miles from the City, some operating cost savings might accrue to the city were it to use this Carrizo well as the backup. An estimate of the savings is not provided, however, since data are not readily available with which to make such estimates.

Table 1.10-6.
Cost Estimate Summary for Desalination of Seawater (SCTN-17)
(Second Quarter 1999 Prices)

Item	*Estimated Costs 25 MGD*	*Estimated Costs 50 MGD*	*Estimated Costs 75 MGD*	*Estimated Costs 100 MGD*
Capital Costs				
Water Treatment Plant (25; 50; 75; 100 MGD)	$111,151,000	$220,207,000	$328,846,000	$426,971,000
Transmission Pump Stations (4;3;3;3)	$22,406,000	$24,102,000	$30,169,000	$34,565,000
Transmission Pipeline (42; 60; 72; 84 in. dia.; 133 miles)	$78,846,000	$118,489,000	$173,539,000	$203,685,000
Distribution	$32,200,000	$64,400,000	$83,350,000	$102,300,000
Total Capital Cost	**$244,603,000**	**$427,198,000**	**$615,904,000**	**$767,521,000**
Engineering, Legal Costs, and Contingencies	$81,669,000	$143,594,000	$206,889,000	$258,448,000
Environmental & Archaeology Studies and Mitigation	$3,495,000	$3,447,000	$3,664,000	$3,751,000
Land Acquisition and Surveying (678; 684; 694; 704 acres)	$6,418,000	$6,532,000	$6,652,000	$6,771,000
Interest During Construction (2.5 years)	$33,602,000	$58,051,000	$83,277,000	$103,606,000
Total Project Cost	**$369,787,000**	**$638,822,000**	**$916,386,000**	**$1,140,097,000**
Annual Costs				
Debt Service (6 percent for 30 years)	$26,852,000	$46,391,000	$66,549,000	$82,795,000
Operation and Maintenance:				
Pipeline, Pump Station, Tank, Distribution	$1,634,000	$2,392,000	$3,270,000	$3,859,000
Water Treatment Plant (Except Energy)	$2,928,000	$4,823,000	$6,117,000	$6,842,000
WTP Energy Costs (156; 337; 531; 715 x 10^6 kWh @ $0.06 per kWh)	$9,378,388	$20,197,814	$31,869,580	$42,911,203
Pumping Energy Costs (81, 130, 186, 232 x 10^6 kWh @ $0.06 per kWh)	4,604,000	7,253,000	10,363,000	12,899,000
Treatment Only				
Total Annual Cost	**$24,317,790**	**$48,807,473**	**$73,501,334**	**$95,864,458**
Available Project Yield (acft/yr)	**28,004**	**56,008**	**84,012**	**112,016**
Annual Cost of Water ($ per acft)	**$868**	**$871**	**$875**	**$856**
Annual Cost of Water ($ per 1,000 gallons)	**$2.66**	**$2.67**	**$2.68**	**$2.63**
Conveyance Only				
Total Annual Cost	**$21,078,598**	**$32,249,341**	**$44,667,246**	**$53,441,745**
Available Project Yield (acft/yr)	**28,004**	**56,008**	**84,012**	**112,016**
Annual Cost of Water ($ per acft)	**$753**	**$576**	**$532**	**$477**
Annual Cost of Water ($ per 1,000 gallons)	**$2.31**	**$1.77**	**$1.63**	**$1.46**
Total				
Total Annual Cost	**$45,396,388**	**$81,056,814**	**$118,168,580**	**$149,306,203**
Available Project Yield (acft/yr)	**28,004**	**56,008**	**84,012**	**112,016**
Annual Cost of Water ($ per acft)	**$1,621**	**$1,447**	**$1,407**	**$1,333**
Annual Cost of Water ($ per 1,000 gallons)	**$4.97**	**$4.44**	**$4.32**	**$4.09**

Assumptions that were made to size and configure a desalination system for a portion of Karnes City's system are in Table 1.10-7. To accomplish this option two actions for modifying the City's water system are needed. The first is the reverse osmosis unit. This could be located on city property at Well #4. The second would be new pipelines carrying raw well water to the plant from both Well #5 and Well #3 and treated water from the plant back to the vicinity of each well. These linkages are needed because the distribution system is configured to distribute water from each well rather than from a central location. There is sufficient storage tank capacity in the City's system.

Table 1.10-7.
Engineering Assumptions for Brackish Groundwater Desalination Option

Parameter	Assumption	Description
Raw water salinity	1,400 mg/L	Range from 1,200 to 1,500 mg/L
Finished water chlorides	100 mg/L	
Treatment capacity	295 gpm	
WTP storage	0	Use existing tanks
Booster pumps	0	Use existing tanks
Land for plant	0	Use existing city property
WTP operations	$1.20/1,000 gallons	
Reconfigure distribution piping	9,600 feet of 6-inch	Connect three wells to one plant, then distribute treated water to vicinity of original well
Pipeline friction factor	C = 140	C-900 PVC pipe

The RO plant capacity would be about 313 gpm and the raw well water to blend with would be about 185 gpm (based on the year 2030 demand of 508 gpm from Table 1.10-2). The resulting blend would meet both the primary drinking water standards for total dissolved solids and the secondary standards for chloride. The estimates shown in Table 1.10-8 result in a total production cost of about $574 per acft ($1.70 per 1,000 gallons) of water produced using reverse osmosis. Amortization of the capital costs are based on 6 percent interest for a 30-year period. Power cost is assumed to be 6 cents per kilowatt-hour. Table 1.10-8 suggests that this option for a local water supply could be competitive with a regional freshwater supply option, particularly when surface water treatment would be necessary. For example, estimates of costs of many other options being considered for the South Central Texas Region are higher than the cost estimate for this option.

Table 1.10-8.
Cost Estimate for Brackish Groundwater Option

Item/Facility	*Unit Cost*	*Quantity*	*Units*	*Estimate Cost*
Pipe	$30.00	9,600	ft	$288,000
Water Treatment Plant	$500,000	1	Each	$500,000
Total Capital Cost		**1**		**$788,000**
Engineering, Legal Costs and Contingencies				
Pipeline Project	30%	$288,000	$	$86,400
All other Facilities	35%	$500,000	$	$175,000
Environmental & Archaeology Studies and Mitigation	80%	$10,890	$	$8,720
Surveying	10%	$288,000		$28.800
Interest During Construction		1	yr	$44,000
Total Project Cost				**$1,141,802**
Annual Costs				
Debt Service (6%, 30 years)	6.0%	30	yr	$83,000
Pipeline & Tank O&M	1.0%	288,000	$	$2,880
Water Treatment Plant O&M	$1.20	152,205	K-gal	$182,646
Purchase of Water	$0.00	0	acft	$0
Total Annual Cost				**$268,526**
Available Project Yield (acft/yr)		**476**	**acft/yr**	**476**
Annual Cost of Water ($ per acft)				**$564.30**
Annual Cost of Water ($ per 1,000 gallons)				**$1.70**

1.10.5 Implementation Issues

1.10.5.1 Seawater Desalination

Implementation of this option requires overcoming several financial, environmental, and technological impediments. The capital cost is likely to be a somewhat serious limitation. The cost estimate shows that while the treatment cost, based on the recent Tampa experience for a planned 25 MGD desalination facility may be competitive, transferring water from the coast to the municipal demand center of the South Central Texas Region makes the total cost quite high in relation to other options.

There are several environmental issues that must be considered. The first is the location of the intake in San Antonio Bay. It will be an advantage to take slightly lower salinity water, as is appears to be in Tampa, rather than Gulf water. However, to accomplish this means that dilution with freshwater from the San Antonio and Guadalupe Rivers is necessary. Studies will need to be performed to ensure that the removal of the somewhat diluted Bay water causes no harmful effects on plant and animal life in the Bay. Another issue with the desalt plant is the disposal of the concentrated brine created from the desalination process. Disposal would have to occur at a location and in a manner that also did not disrupt plant or animal life in the Bay or in the Gulf. A further complication is the permitting of a 133-mile pipeline across rivers, highways, and private rural and urban property.

Technological issues include: 1) confirming that desalination as proposed with membranes is the appropriate technology; 2) confirming that blending desalted seawater with the other water sources in the municipal demand distribution system can be successfully accomplished; and 3) obtaining an adequate source of electric power to drive the desalination process using membranes. The cost model on which this option is based does not necessarily represent costs of an operating project, but, rather, is the recent Tampa Bay Water proposal using the design-build-operate-own contracting approach. Substantial verification of technology would need to be accomplished prior to building this option. Blending differing treated waters is critical for the wellbeing of the customers and the distribution system. The characteristics of the desalted water are likely to be dramatically different from other drinking water in the major municipal demand center of the South Central Texas Region. Considerable investigation would be needed to determine whether blending should occur, and, if so, how to do it. Finally, in spite of recent improvements in membrane technology, desalting seawater will require large amounts of electric power. Normally, this need is met by locating desalination plants near power plants.

1.10.5.2 Brackish Groundwater Desalination

Implementation of small community water supply sources from brackish groundwater sources include financial and technological issues. For a municipal water demand of about

500,000 gallons per day, the Karnes City option showed that desalination could improve the quality of a backup supply or could perhaps replace a more vulnerable freshwater supply as the primary source. However, the estimated cost, while comparable to conventional treatment, is much higher than communities experience when they do not have to treat their groundwater, except to disinfect. Therefore, the best applications may be for systems like the City of Seadrift where no freshwater supplies are located nearby. Then desalination may compete economically with projects transporting fresh raw water or treated water over a distance of several miles.

There are two technological issues confronting a small utility that might consider desalination. The first is how to make the more centralized desalt plant compatible with a distribution system that is likely constructed to be compatible with two or more wells. Normally, this would be resolved in the design engineering process, as it could be at Karnes City. For example, for the potential Karnes City option, it was assumed that two of the existing wells would supply feedwater directly to the location of the third well where desalination and blending would occur. Then treated water would be transferred back to the vicinities of the two wells. In this way, no wholesale overhaul of the community's distribution system would be needed.

The second technological issue is the relative complexity of desalination compared to the relative simplicity of a fresh groundwater supply, requiring only extraction from the ground, storage, disinfection and distribution. Desalt plants encounter scaling, corrosion, and chemical challenges that require relatively highly trained and experienced treatment staff. Therefore, the smaller communities might consider contract operations rather than developing in-house expertise to operate desalt plants.

Evaluations of the two options discussed in this section are presented in Table 1.10-9. Although the Karnes City option is not a regional option, it is evaluated below because the application of treating brackish groundwater for individual communities could have application within the South Central Texas Region by providing an attractive local option to a larger, regional system.

Table 1.10-9.
Evaluations of Regional Water Management Options: Seawater Desalination and Brackish Groundwater Desalination

Impact Category	Comment(s)
Seawater Desalination	
a. Quantity reliability and cost of treated water	• Highly reliable quantity • Moderately high treatment cost • Total cost high due to conveyance costs
b. Environmental factors	• Environmental impact to estuary • Disposal of concentrated brine created from process • Construction and maintenance of 133-mile transmission pipeline corridor
c. State water resources	• No apparent negative impacts on other water resources • Potential benefit to urban demand center water resources due to increased reclaimed water supply
d. Threats to agriculture and natural resources in region	• Temporary damage due to construction of pipeline
e. Recreational	• Seawater intake in San Antonio Bay will have markers to protect boaters and intake equipment
f. Comparison and consistency equities	• Same cost model used to estimate total costs • Seawater desalination cost modeled after bid, but not constructed, comparable project
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Very high
j. Effect on navigation	• Screens are needed on intake to protect boaters
Brackish Groundwater Desalination	
a. Quantity reliability and cost of treated water	• Unknowns regarding extend and yields of brackish aquifer • Moderately high treatment cost
b. Environmental factors	• Disposal of concentrated brine created from process • Typically in low recharge rate aquifers or confined aquifers; use could lead to the depletion of aquifer • Extracted brackish water possible replaced by freshwater from a higher strata aquifer, thereby removing and contaminating accessible freshwater
c. State water resources	• For brackish aquifer, improves state water resources • For freshwater aquifer having brackish lower zone, potentially contaminates fresh groundwater
d. Threats to agriculture and natural resources in region	• None
e. Recreational	• None
f. Comparison and consistency equities	• Same cost model used to estimate total costs
g. Interbasin transfers	• Not applicable
h. Third party social and economic impacts from voluntary redistribution of water	• Not applicable
i. Efficient use of existing water supplies and regional opportunities	• Very high
j. Effect on navigation	• Not applicable