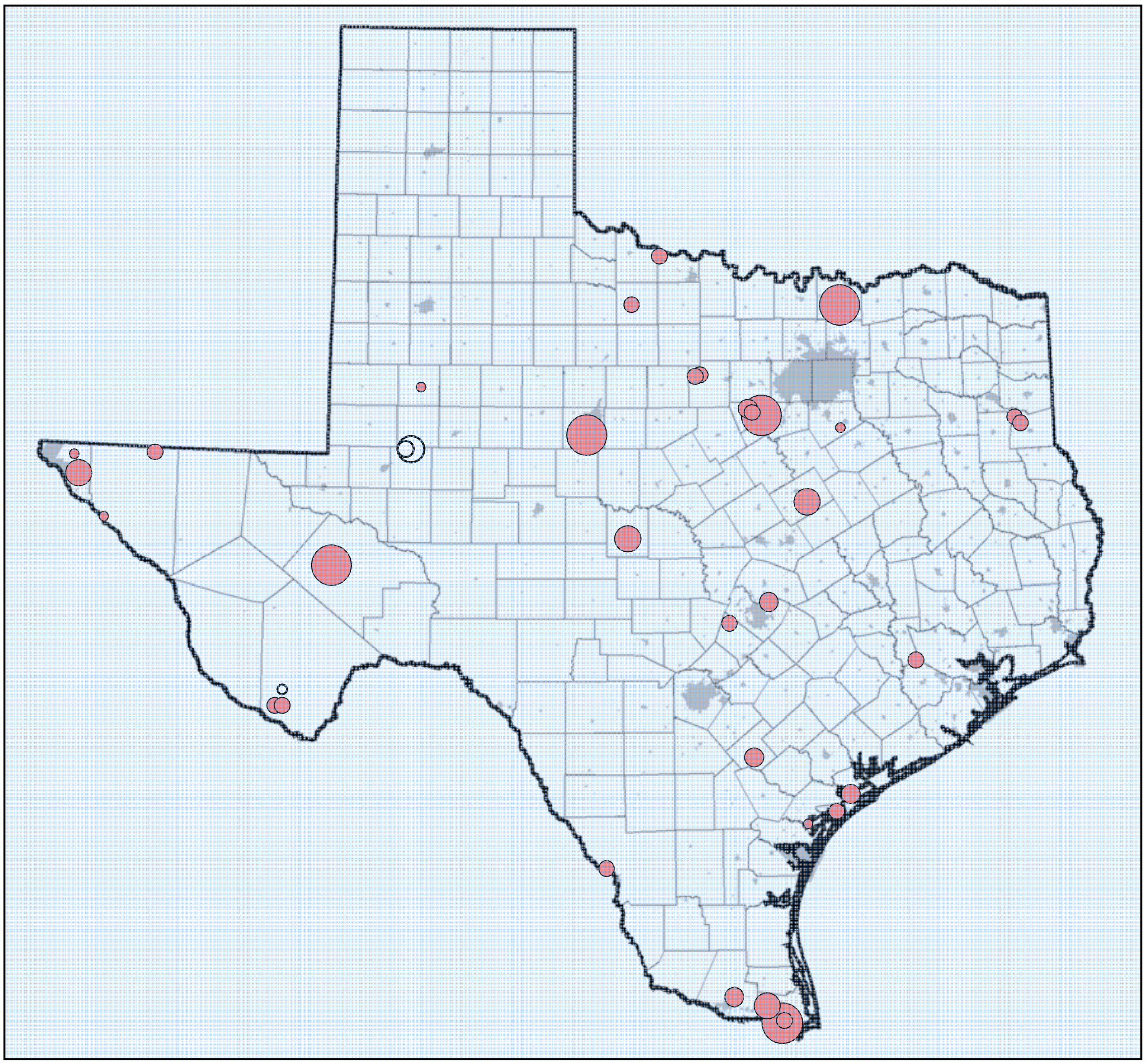
A Desalination Database for Texas



Prepared for

Texas Water Development Board

Bureau of Economic Geology
Scott W. Tinker, Director
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

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Prepared for
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under
Contract No. 2004-483-021

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Glossary and Abbreviations

AFY:	Acre-feet per year
bbl:	Barrel
ED:	Electrodialysis
EDR:	Electrodialysis reversal
GCD:	Groundwater conservation district
GW:	Groundwater
iWUD:	TCEQ water utility database search engine
MGD:	Million gallons per day
MUD:	Municipal utility district
MW	Megawatt
NF:	Nanofiltration
PWS	Public water system
RFQ:	Request for qualifications
RO:	Reverse osmosis
RRC:	Railroad Commission of Texas
RWPG:	Regional water planning group
SW:	Surface water
TCEQ:	Texas Commission for Environmental Quality
TDHS:	Texas Department of Health Services
TDS:	Total dissolved solids
TWDB:	Texas Water Development Board
UF:	Ultrafiltration
UIC:	Underground injection control
WSC:	Water Supply Corporation
WUD:	Water utility database
WWTP:	Wastewater treatment plant

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1 Executive Summary

The State of Texas has a renewed interest in desalination. However, no accurate central database on desalination of Texas facilities existed before this work. Sponsored by the TWDB, The University of Texas at Austin, Bureau of Economic Geology, undertook an exhaustive study of public water systems (PWS) engaged in desalination. A rough estimate of industrial and non-PWS desalination capacity is also given in the report.

California, Florida, and Texas host most of the U.S. desalination capacity, and their respective state agencies currently possess databases of those PWS desalination facilities. However, information publicly available from them is generally basic and falls short of the level of detail sought in this study. Worldwide surveys, generally done by private groups, also generate databases providing a similar level of information. More targeted studies present in-depth information, but they include a limited number of facilities and are generally biased toward larger facilities. This study is thought to be the first at the state level to include all PWS facilities with a design capacity approximately ≥0.025 million gallons per day (MGD).

In the course of the study, more than 100 PWS were contacted, along with a few non-PWS facilities. It appears that the State of Texas currently contains about 38 PWS facilities with a desalination design capacity ≥0.025 MGD (Table 1-1 and Figure 1-1), a cumulative desalination design capacity of ~52 MGD, and another approximately 50 facilities with smaller desalination design capacity, for a cumulative desalination design capacity of <0.5 MGD. Industrial capacity amounts to roughly 60 to 100 MGD in hundreds of units, mainly in the power and semiconductor industries. These industries typically require water of better quality than that of typical municipal water. The food and beverage industry also make use of desalination units. Their quality requirements are closer to those of municipal water treatment plants.

Table 1-1. Summary of results

Type of Desalination Facility	**Number of Facilities**	**Cumulative Design Capacity**
PWS ≥0.025 MGD	38	52 MGD
PWS <0.025 MGD	> 50	<0.5 MGD
Other desalination facilities	> 100	60 - 100 MGD

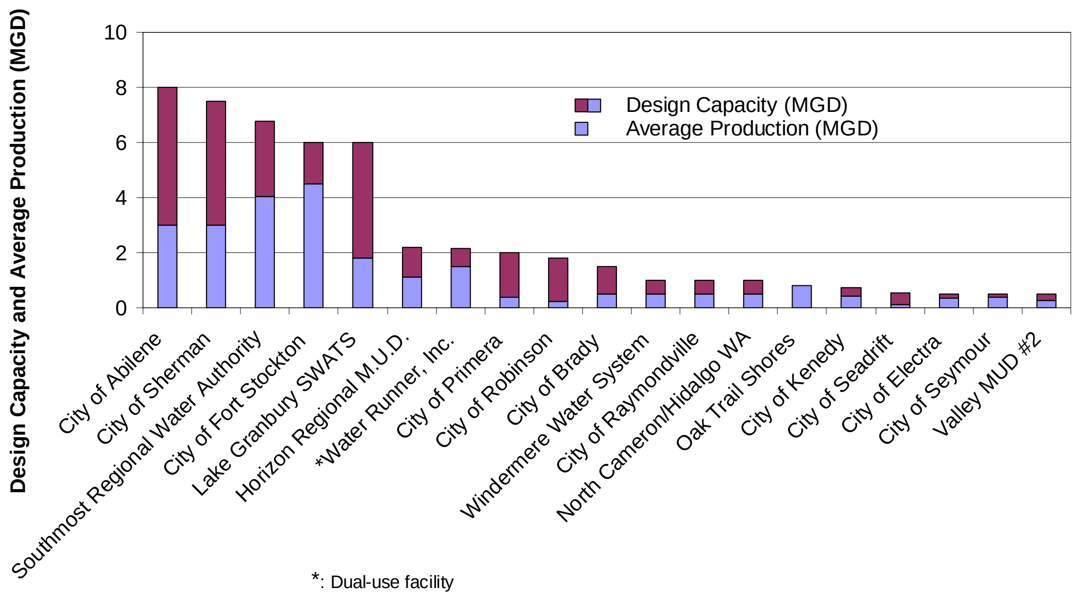


Figure 1-1. Design capacity and average production of the desalination units of the 19 facilities with the highest design capacity sorted by decreasing size

We collected information on design capacity and average production, as well as on permeate blending. The vast majority of facilities use reverse osmosis, although a few use the electrodialysis reversal process. Both surface water and groundwater are used as feedwater, whose average TDS is ~1,800 ppm. Concentrate disposal methods vary: evaporation pond, municipal sewer, surface water, and land application. The past few years have seen an explosion of desalination capacity in the state as a whole (Figure 1-2).

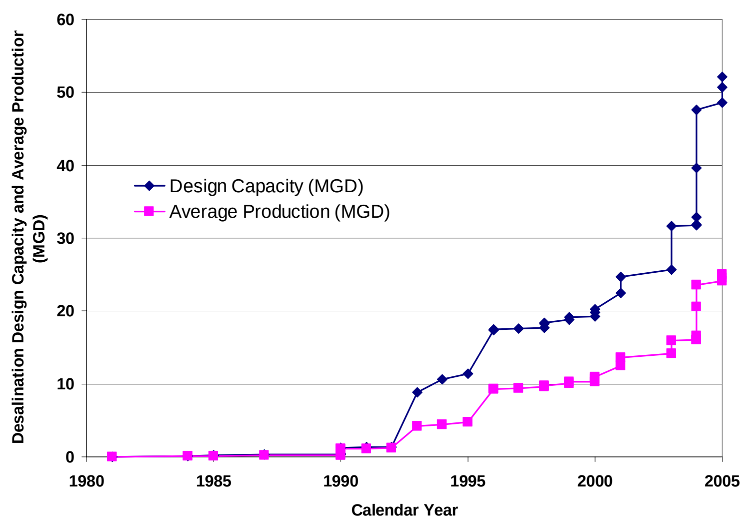


Figure 1-2. Time-cumulative desalination design capacity and average production of Texas PWS facilities

Details of the survey are contained in a database available in both Microsoft Access and SQL format. A discussion of potential database updates is also included.

2 Introduction

The present report documents results for the four tasks described in the scope of work of Contract # 2004-483-021 “Development of a Database for Desalination Facilities in Texas.” Task 1 consisted of surveying similar efforts currently in development in other states (Attachment C: Overview of Recent Surveys—delivered to the TWDB as a letter-report on December 15, 2004), submitting a list of facilities to be surveyed (Attachment D: Detailed Survey Results), proposing a recommendation regarding the cutoff for facilities to be included in the database (0.025 MGD), submitting a recommendation regarding survey of industrial desalination facilities (Attachment E: Road Map for Survey of Industrial Facilities), and working closely with TWDB on the survey form and surveying protocol (Attachment B: Survey Form). Task 2 consisted of contacting facilities identified in Task 1 by mail, fax, or phone and compiling the survey results (main body of report and Attachment D: Detailed Survey Results). Task 3 consisted of designing the database in SQL format (Attachment F: List of files on CD) and suggesting maintenance and update procedures (Section 5). Task 4 lists the final deliverables consisting of the database itself and a report documenting how data were collected, how the database was built, and how to operate it. The draft report and associated deliverables were delivered to the TWDB on June 23, 2005.

2.1 Overview of Other Recent Efforts

A report to the U.S. Bureau of Reclamation (Mickley, 2001), focusing on municipal utilities across the U.S, surveyed 12 facilities in operation in Texas in 1999, for a total of ~22 MGD. Another report (Wangnick, 2002), compiled arguably all existing desalination facilities across the world with a capacity >1 MGD. It suggests that at least 14 utility and 104 nonutility desalination facilities existed in Texas in 2001, totaling ~30 MGD and ~71 MGD, respectively. The survey included nonutility facilities using wastewater as feedwater. Clearly, such nationwide surveys focus on larger facilities, and most smaller facilities are left out. The goal of this study was thus to be as exhaustive as possible and to include all facilities with a design capacity of at least 0.025 MGD. Although some thermal-based facilities exist in the state, particularly in industrial facilities, the focus of this study is on reverse osmosis (RO) and electrodialysis /

electrodialysis reversal (ED/EDR) facilities. Facilities using only ultrafiltration (UF) and nanofiltration (NF) are not included in the study. Attachment C details efforts by other states to develop similar comprehensive databases.

We tried to gather information on the whole desalination sequence from feedwater source to pretreatment to membrane and permeate treatments to concentrate disposal method. We also included a section on cost in the survey. Although it is notoriously difficult to compare costs between facilities because cost breakdown is likely facility-specific, such information was nevertheless useful because no such data had ever been collected in Texas.

As a help to the reader, Website addresses are provided in Attachment G, and the "**" string after a name means that an address is given. Names of those files provided in the companion CD are in `Courier` print.

2.2 Desalination Primer

This section briefly defines terminology used in the report and provides other essential definitions. Two main types of technology are available for desalinating water: membrane based and evaporation based. As described in Table 2-1, evaporation-based technologies such as multistage flash or multiple-effect distillation are more suited to high-salinity waters and/or larger plants because energy requirements are high and almost independent of source water salinity. They also have a small recovery, translating into a large waste stream, which may be hard to dispose of other than sending it to a large body of water. Seawater desalination plants have historically been using such technologies. However, recently constructed seawater desalination facilities rely almost exclusively on membrane technologies. Membrane-based technologies are also widely used in smaller plants and/or for the treatment of brackish water. In this study we focus on membrane-based technologies because they form the overwhelming majority of plants in the continental U.S. and in Texas.

There are two kinds of membrane processes: pressure driven and electro-potential driven. Pressure-driven membrane processes are further described as microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO). MF and UF act only mechanically, blocking bacteria and suspended particles (10–0.05 μm) because they are too large to flow through the membrane pores. UF also blocks colloids and macromolecules (0.05–0.005 μm). In contrast, NF (0.005–0.0005 μm) blocks solutes as small as organic molecules and divalent ions. RO (0.001–0.0001 μm) blocks particles as small as monovalent ions. Both operate mainly through diffusion and chemical interaction between membrane and solutes. NF is also called low-pressure RO, or water-softening membrane. NF removes more calcium and magnesium than chloride, resulting in softer waters. NF also removes more sulfate and bicarbonate than chloride. The two electro-potential-driven processes are electrodialysis (ED) and electrodialysis reversal (EDR). The latter process is very similar to ED, with the added benefit of reduced scaling because potentials are reversed periodically. Below ~3,000 to 3,500 mg/L salinity, both RO and ED/EDR processes can be competitive and can produce low-salinity water at low cost. RO plants are the most widely used in the nation for desalination, with 72 percent of plants using brackish-water RO, 2 percent seawater RO, 15 percent ED/EDR, and 11 percent NF (Mickley, 2001).

Table 2-1. Summary of characteristics of major desalination technologies

Characteristics	**Reverse osmosis (RO)**	**Electrodialysis reversal (EDR)**	**Multistage flash (MSF)**	**Multiple-effect distillation (MED)**
Energy cost	Moderate	High	High	Very high
Energy/Salinity	Increases with salinity	Increases fast with salinity	Independent of salinity	Independent of salinity
Applicable to	All water types	Brackish	Seawater - brine	Seawater - brine
Plant size	Modular	Modular	Large	Large
Bacterial contamination	Possible	Posttreatment always needed	Unlikely	Unlikely
Final product salinity	On demand	On demand	Can be <10 mg/L TDS	Can be <10 mg/L TDS
Complexity	Easy to operate; small footprint	Easy to operate Small footprint	Only large complex plants	Only large complex plants
Susceptibility to scaling	High	Low	Low	Low
Recovery	30–50% (seawater) up to 90% for brackish water	High	Poor (10–25%)	Low but better than MSF

As discussed earlier, desalination concentrates are produced during removal of salts from low-quality water in RO and ED/EDR plants. The amount of concentrate as a percentage of feedwater varies according to desalination method, percent recovery, and chemical additives. In RO systems that produce drinking water, a typical pretreatment consists of acidification and addition of antiscalant chemicals. Disposal of the concentrate could be a major issue in siting of a new facility. Disposal methods include land application and discharge to a surface water body, municipal sewer, or evaporation pond. Another option is deep-well injection.

3 Methods

The primary method of collecting information on Texas facilities was to interview facility operators and/or ask them to fill out a survey form (Attachment B; also in file `Survey form Mun3.doc`). Another method, not pursued in this work, would be to gather data indirectly by contacting membrane manufacturers, chemical providers, and other industry suppliers.

3.1 Sources of Information

The first step in data collection was a query of the TCEQ PWS database (the so-called TCEQ list) for words related to desalination. The TCEQ PWS database is only updated by TCEQ field inspections. Thus, more recent facilities not yet inspected are not included in the database. Locations of these additional facilities were obtained by

1) consulting TWDB** drinking water “State Revolving Loan Program Projects” priority list (loans from 2001 through 2004 are on the TWDB Website),
2) consulting Regional Water Planning Group reports,
3) executing a customized query of the TCEQ Water Supply Plan Review log (only those entries in which the title is clear on desalination potential), and
4) using personal professional contacts.

Otherwise the survey procedure that is the same as that used by TCEQ-listed facilities was followed.

New facilities are designed and built every year, and the database presented in this work is reasonably accurate as of March 2005. A list of potential desalination facilities at diverse stages of completion (from discussion in City Council to feasibility studies to actual construction) is presented in Section 4.2.

3.2 Methodology

The first step of the survey was to send out letters to all facilities from the initial TCEQ list announcing the survey and explaining its purpose. The second step involved calling the facility and reaching the technical staff. This step proved to be time consuming in most cases. The competent person was given the choice of immediately completing the survey verbally over the phone or of sending in the information by mail or fax. The full interview lasted 20 to 30 minutes. The next step, after receipt of the initial response, consisted of mailing the completed survey back to the operators to check for accuracy and completeness and to ask for more information if needed. The new information was then entered into a Microsoft Access database. At the end of the survey phase, only PWS facilities ≥0.025MGD were retained in the database (`TWDB-BEG Water Survey06-13-05_GT0.025MGD.mdb`), then, translated, and imported into a SQL server database (`DesalPlantSql2kBackup`). A tentative methodology for industrial facilities is described in Section 5.

We contacted all facilities with a capacity ≥0.025 MGD on the initial TCEQ list, as well as those facilities revealed through other channels. The final list was split into several categories, including operating desalination facilities with a capacity ≥0.025MGD and future desalination facilities, described in the Results section (Section 4). Other facilities—operating desalination facilities with a capacity <0.025MGD, closed desalination facilities, and contacted facilities with no desalination treatment—are not the focus of this work and are described only in Attachment D.

4 Results

4.1 Public Water System Facilities

A total of 105 public water system facilities were contacted, 38 of which were eventually retained in the final list (Table 4-1 and Table 4-2). An additional 47 facilities also had desalination capabilities but a capacity below the threshold of 0.025 MGD. Attachment D gives a detailed overview of the data collection history.

Table 4-1. Characteristic summary of Texas desalination facilities with capacity ≥0.025 MGD

Plant Name	County	Design Capacity (MGD)	Use	Source	Startup Year	Process	Blending ?	Disposal Method
City of Abilene	Taylor	8	DW	SW	2004	RO	No	EP
City of Sherman	Grayson	7.5	DW	SW	1993	EDR	Yes	Sewer
SWRA	Cameron	6.75	DW	GW	2004	RO	Yes	SW
Lake Granbury SWATS	Hood	6	DW	SW	2003	RO	Yes	SW
City of Fort Stockton	Pecos	6	DW	GW	1996	RO	Yes	Sewer
Horizon Regional M.U.D.	El Paso	2.2	DW	GW	2001	RO	Yes	LA/IRR/ EP
City of Primera	Cameron	2	DW	GW	2005	RO	Yes	SW
City of Robinson	McLennan	1.8	DW	SW	1994	RO	Yes	SW
City of Brady	McCulloch	1.5	DW	GW	2005	RO	Yes	EP
City of Raymondville	Hidalgo	1	DW	GW	2004	RO	No	SW
Windermere Water System	Travis	1	DW	GW	2003	RO	Yes	Sewer
Oak Trail Shores	Hood	0.79	DW	SW	1990	EDR	Yes	SW
City of Kenedy	Karnes	0.72	DW	GW	1995	RO	Yes	SW
City of Seadrift	Calhoun	0.52	DW	GW	1998	RO	Yes	SW
City of Seymour	Baylor	0.5	DW	GW	2000	RO	Yes	SW
Valley MUD #2	Cameron	0.5	DW	GW	2000	RO	Yes	SW/LA
City of Electra	Wichita	0.5	DW	GW	1999	RO	No	LA/IRR
City of Tatum	Rusk	0.29	DW	GW	1999	RO	Yes	Sewer
The Cliffs	Palo Pinto	0.2	DW	SW		RO	No	SW
Holiday	Aransas	0.15	DW	GW	1998	RO	Yes	SW

Plant Name	County	Design Capacity (MGD)	Use	Source	Startup Year	Process	Blending ?	Disposal Method
Beach WSC								
Study Butte Terlingua Water System	Brewster	0.14	DW	GW	2000	RO	No	SW
River Oaks Ranch	Hays	0.14	DW	GW	1987	RO	No	EP
City of Beckville	Panola	0.14	DW	GW	2004	RO	Yes	Sewer
City of Granbury	Hood	0.11	DW	SW	1985	EDR	Yes	Sewer
Midland Country Club - fairways & greens[A]	Midland	0.11	DW/ IRR	GW	2004	RO	No	EP
City of Laredo Santa Isabel R.O.	Webb	0.10	DW	GW	1998	RO	No	Sewer
Dell City	Hudspeth	0.1	DW	GW	1996	EDR	No	LA/IRR
DS Waters of America, LP	Waller	0.09	DW	GW	1997	RO	No	Sewer
Sportsmans World MUD	Palo Pinto	0.083	DW	SW	1984	RO	No	SW
Big Bend Motor Inn	Brewster	0.072	DW	GW	1992	RO	No	EP
Haciendas Del Norte Water Improvement District	El Paso	0.05	DW	GW	1981	RO	Yes	LA/IRR/ EP
City of Bardwell	Ellis	0.036	DW	GW	1990	RO	Yes	Sewer
City of Bayside	Refugio	0.029	DW	GW	1990	RO	No	EP
Water Runner, Inc.[B]	Midland	0.028/ 2.16	DW/ IND	GW	2001	RO	No	LA/IRR
Longhorn Ranch Motel[A]	Brewster	0.023	DW/ IRR	GW	1990	RO	No	LA/IRR
Esperanza Fresh Water Supply	Hudspeth	0.023	DW	GW	1990	RO	Yes	
City of Los Ybanez	Dawson		DW	GW	1991	RO	Yes	
North Cameron /Hidalgo WA	Hidalgo		DW	GW	2005	RO	Yes	SW
SUM		**52.3**						

NOTE: DW=drinking water; IND=industrial; GW=groundwater; SW=surface water; RO=reverse osmosis; EDR=electrodialysis reversal; EP=evaporation pond; IRR=irrigation; LA=land application; SW=discharge to surface water body

[A]: dual use facility: public water supply and irrigation

[B]: dual use facility: public water supply and industrial (bottling company), drinking water capacity from TCEQ list.

Table 4-2 (Revised). Desalination Public Water System facilities ≥0.025-MGD sorted by desalination design capacity

Facility	County	PWS#	Total capacity (including blending) (MGD)	Average production (including blending) (MGD)	Design capacity (MGD)	Average desalination production (MGD)
City of Abilene	Taylor	2210001	8	3	8	3
City of Sherman	Grayson	0910006	10	3.8	7.5	3
Southmost Regional Water Authority	Cameron	0310150	7.5	4.5	6.75	4.05
City of Fort Stockton	Pecos	1860001	7	7[C]	6	4.5
Lake Granbury Surface Water Advanced Treatment System	Hood	1110100	10	5	6	1.8
Horizon Regional M.U.D.	El Paso	0710005	4	1.89	2.2	1.13
Water Runner, Inc.	Midland	1650113	2.16	1.5	2.16	1.5
City of Primera	Cameron	0310094	2.5	0.46	2	0.4
City of Robinson	McLennan	1550010	2.3	0.299	1.8	0.224
City of Brady	McCulloch	1540001	3	1	1.5	0.5
Windermere Water System	Travis	2270161	2.88	1.44	1	0.5
City of Raymondville	Hidalgo	2450001	1	0.5	1	0.5
North Cameron/Hidalgo WA	Hidalgo	1080029	2	1[B]	1[B]	0.5[B]
Oak Trail Shores	Hood	1110004	1.849	0.4	0.792	0.792[C]
City of Kenedy	Karnes	1280002	2.858	1.222	0.72	0.413
City of Seadrift	Calhoun	0290004	0.61	0.18	0.524	0.13
City of Electra	Wichita	2430002	0.5	0.347	0.5	0.347
City of Seymour	Baylor	0120001	3	0.75	0.5	0.4
Valley MUD #2	Cameron	0310059	1	0.75	0.5	0.26
City of Tatum	Rusk	2010034	0.324	0.252	0.288	0.216
The Cliffs	Palo Pinto	1820061	0.2	0.085	0.2	0.085
Holiday Beach WSC	Aransas	0040015	0.2	0.2[C]	0.15	0.15[C]
River Oaks Ranch	Hays	1050099	0.144	0.04	0.144	0.04
Study Butte Terlingua Water System	Brewster	0220035	0.144	0.035	0.144	0.035
City of Beckville	Panola	1830002	0.192	0.1	0.144	0.066
Midland Country Club - fairways & greens	Midland	1650032	0.11	0.08	0.11	0.08
City of Granbury	Hood	1110001	0.55	0.45	0.11	0.09

Facility	County	PWS#	Total capacity (including blending) (MGD)	Average production (including blending) (MGD)	Design capacity (MGD)	Average desalination production (MGD)
City of Laredo	Webb	2400027	0.1008	0.0271	0.1008	0.0271
Dell City	Hudspeth	1150001	0.1	0.05	0.1	0.05
DS Waters of America, LP	Waller	2370070	0.09	0.09	0.09[A]	0.09
Sportsmans World MUD	Palo Pinto	1820050	0.083	0.05	0.083	0.05
Big Bend Motor Inn	Brewster	0220027	0.05	0.041	0.072	0.041
Haciendas Del Norte	El Paso	0710091	0.23	0.11	0.05	0.04
City of Bardwell	Ellis	0700020	0.252	0.063	0.036	0.036
City of Bayside	Refugio	1960007	0.029[A]	0.029	0.029[A]	0.029
City of Los Ybanez	Dawson	0580018	0.025[B]	0.025[B]	0.025[B]	0.025[B]
Longhorn Ranch Motel	Brewster	0220032	0.023	0.023	0.023	0.023[C]
Esperanza Fresh Water Supply	Hudspeth	1150010	0.056[A]	0.056	0.023[A]	0.023
SUM			**75.1**	**36.8**	**52.3**	**25.1**

NOTE: Owing to the few instances with partial information, the following estimates were made:

[A] total set to average
[B] estimation
[C] average set to total

Total design desalination capacity of the 38 desalination facilities above the threshold of 0.025 MGD is 52.3 MGD. Additional capacity of the other 47 facilities contacted with a desalination capacity below the threshold does not change this number (it would be ~53 MGD). A total of 5 facilities with a design capacity of ~34 MGD accounts for most than half (65 percent) of the cumulative design capacity of the state.

Most plants ≥0.025 MGD currently produce below their design capacity, with a cumulative production of ~25.1 MGD. Approximately half of the 38 retained facilities blend desalination permeate with untreated feedwater. In this case, total design capacity of the 38 facilities has an additional water production of 22.8 MGD, bringing total capacity of these facilities, including blending, to 75.1 MGD. Similarly, additional average capacity due to blending is ~11.7 MGD, bringing average production with blending to 36.8 MGD.

Figure 4-1 and Figure 4-2 display desalination design capacity and average desalination production for all 38 facilities and are sorted according to desalination design capacity. Figure 4-3 and Figure 4-4 illustrate total desalination design capacity (values are the same if there is no blending). Blending is widespread but not a significant component in most plants. The City of Seymour and the Lake Granbury Surface Water Advanced Treatment System plant have the largest bypass in percentage. Figure 4-5 shows that the spatial distribution of design capacity is not biased toward a particular sector of the state. A total of 12 facilities with a cumulative desalination design capacity of 19.9 MGD report large seasonal variations in production (>25 percent), the largest of which is the City of Sherman, followed by the City of Primera.

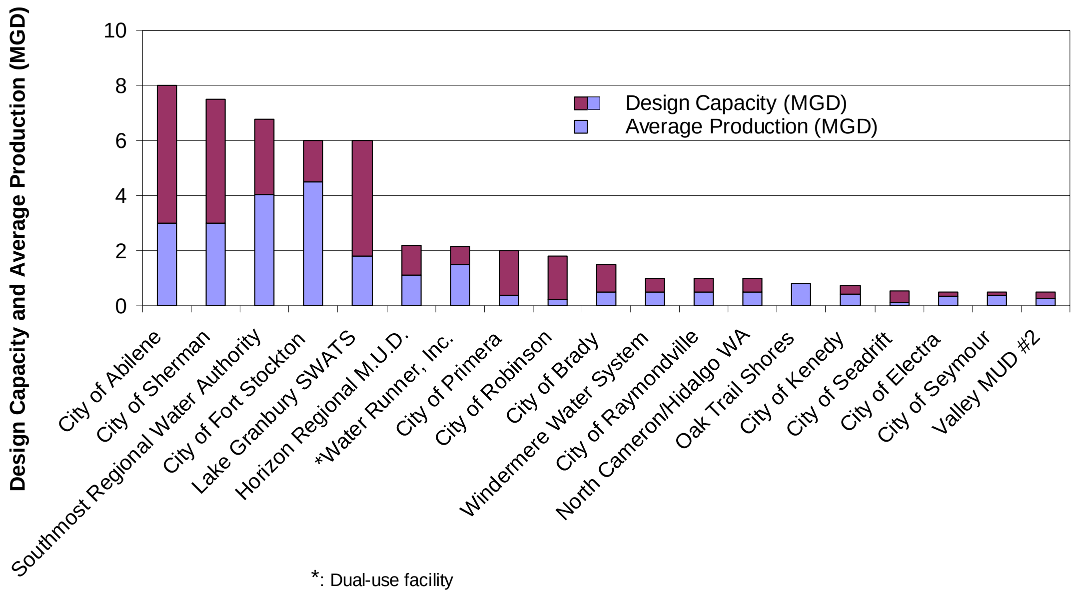


Figure 4-1. Design capacity and average production of desalination facilities above a cutoff value of ~0.5 MGD sorted by decreasing size

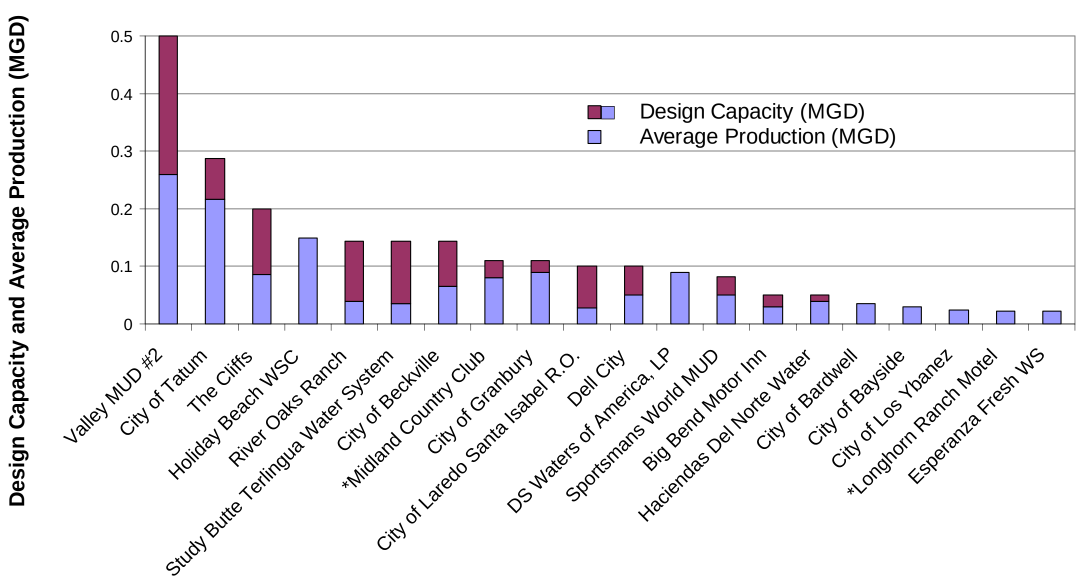


Figure 4-2. Design capacity and average production of desalination facilities below a cutoff value of ~0.5 MGD sorted by decreasing size

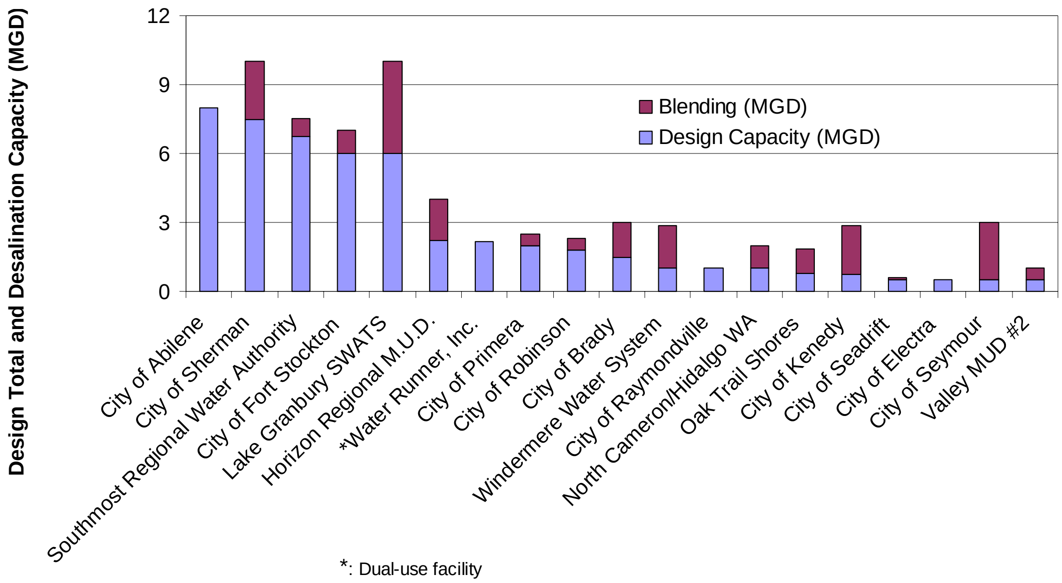


Figure 4-3. Total design capacity with and without blending of facilities above a cutoff value of ~0.5 MGD sorted by decreasing size

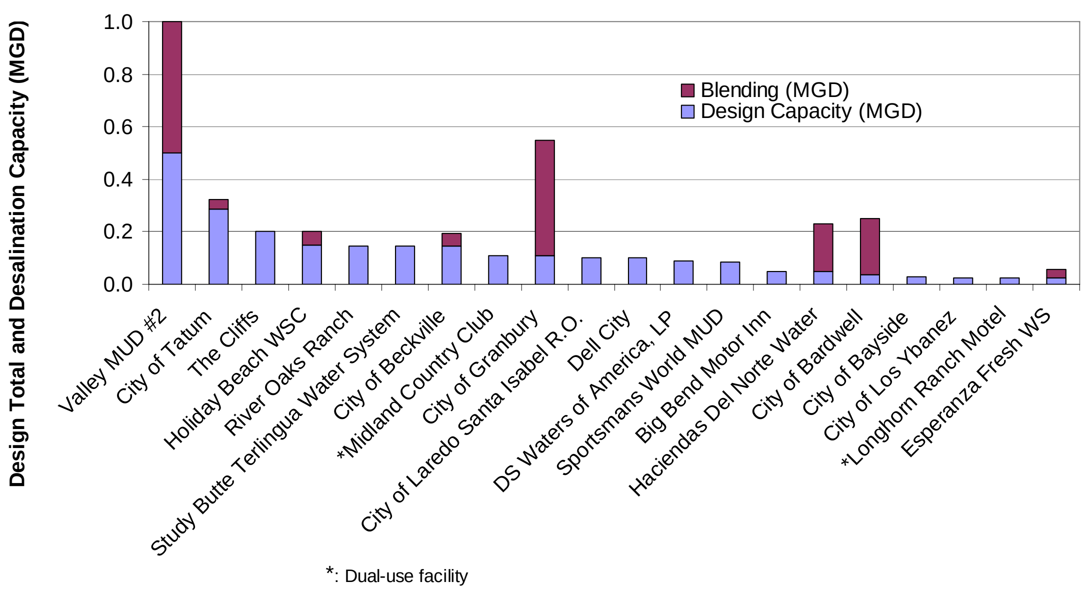
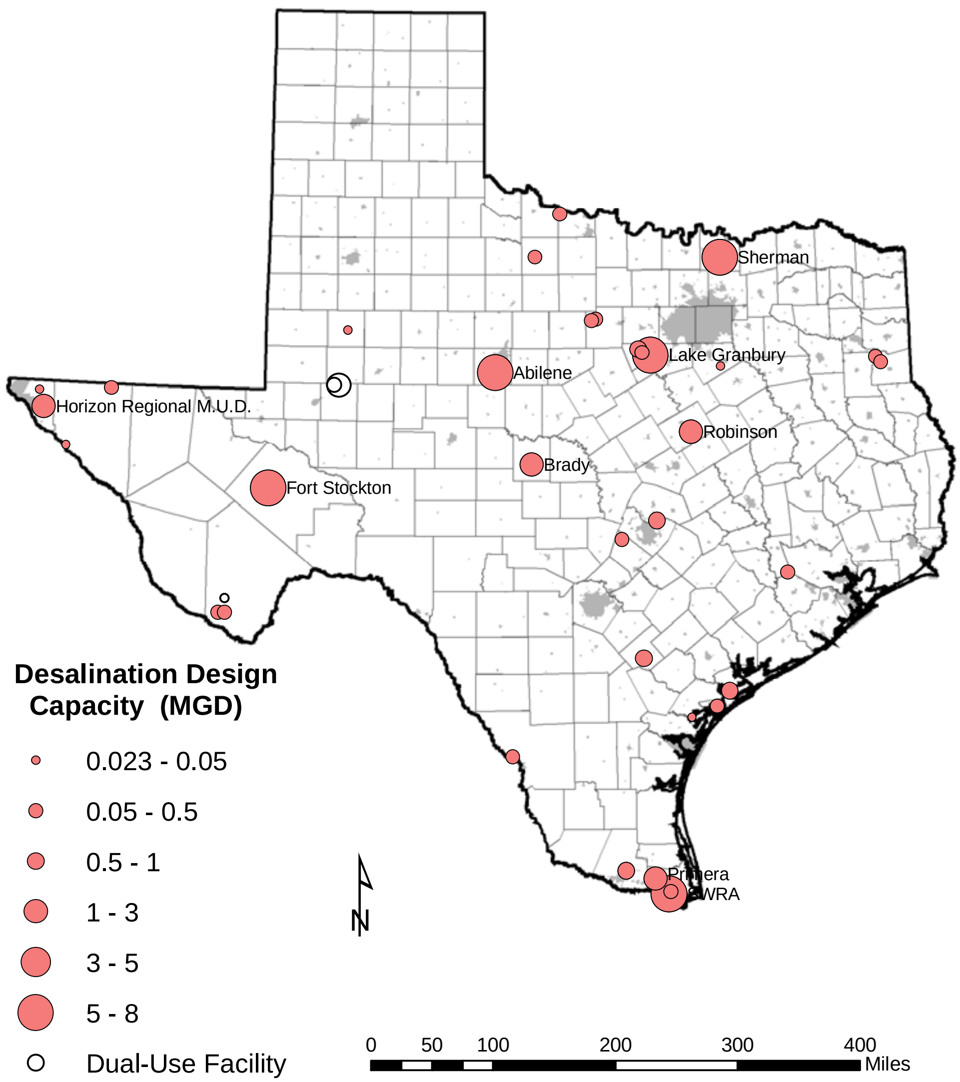


Figure 4-4. Total design capacity with and without blending of facilities below a cutoff value of ~0.5 MGD sorted by decreasing size



NOTE: Location of some facilities is only approximate; Texas Statewide Mapping System projection
Facilities with a desalination design capacity ≥1.5 MGD are named

Figure 4-5. Map of desalination facilities showing design capacity

The first facility still in operation was started in 1981 (Haciendas Del Norte, El Paso County). Desalination capacity increase has been accelerating ever since (Figure 4-6). Figure 4-7 and Figure 4-8 display desalination design capacity and average production of Texas facilities according to the order in which they opened. Figure 4-9 shows that there is no real spatial trend in the distribution of older or newer facilities. Facilities of different startup years are well distributed across the state.

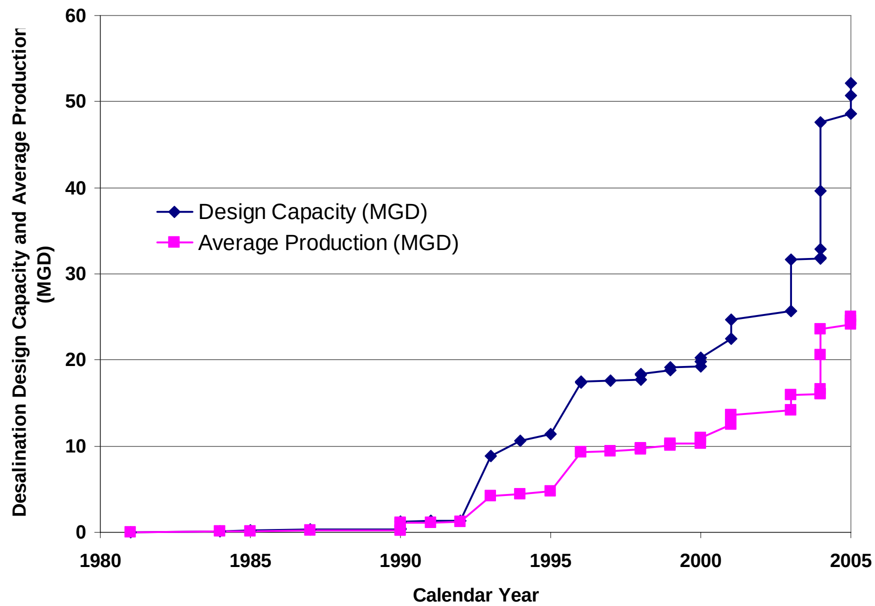
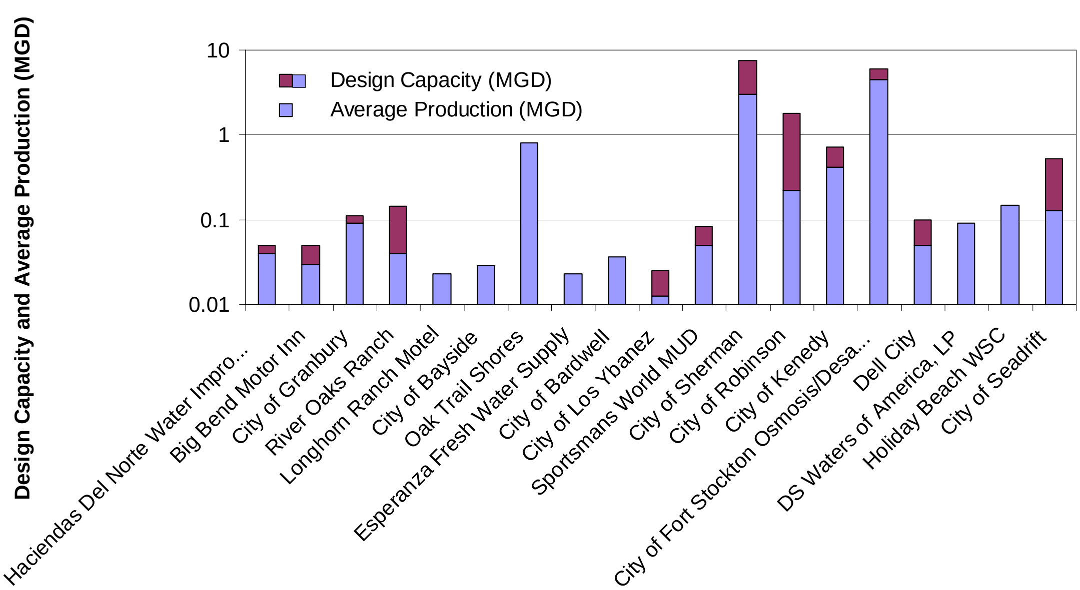
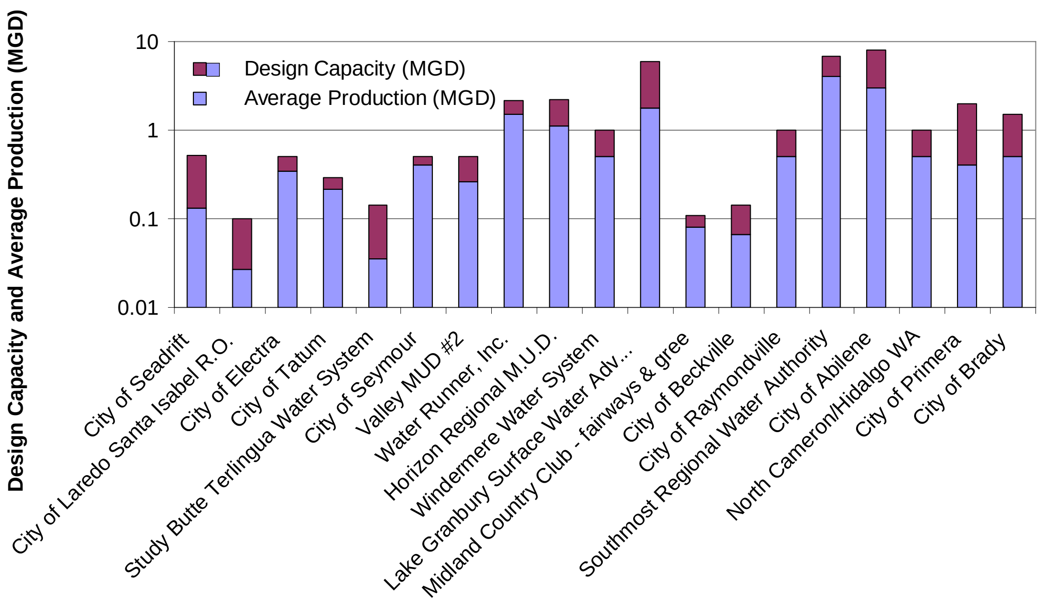


Figure 4-6. Time-cumulative desalination design capacity and average production of Texas PWS facilities



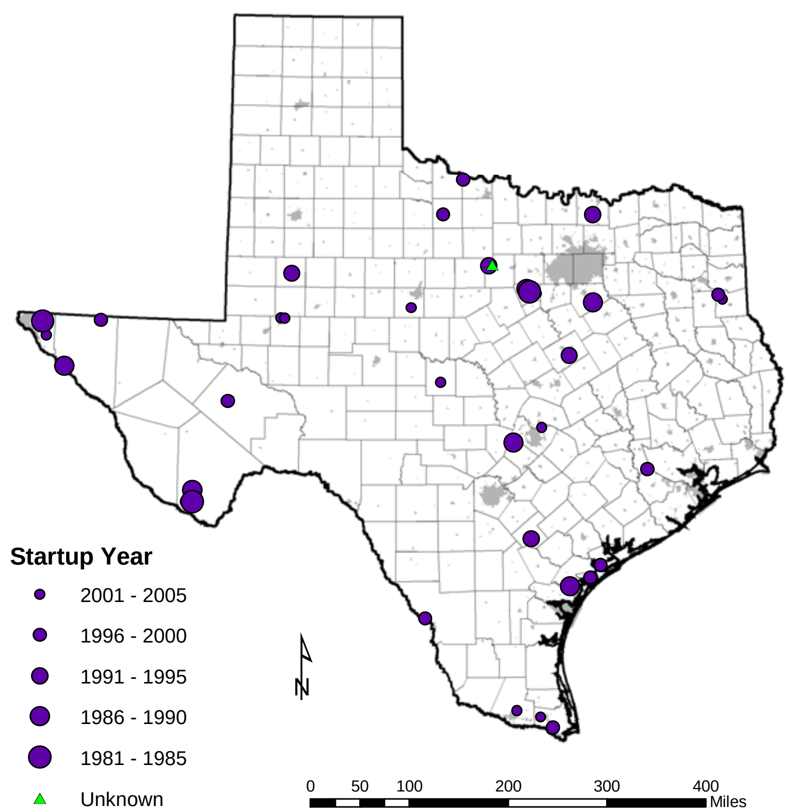
NOTE: Chronological order is only approximate. All facilities opened the same year are listed alphabetically.

Figure 4-7. Design capacity and average production of desalination facilities sorted by startup year (log scale; 1981 through 1998)



NOTE: Chronological order is only approximate. All facilities opened the same year are listed alphabetically.
Startup year for "The Cliffs" facility is missing from the database.

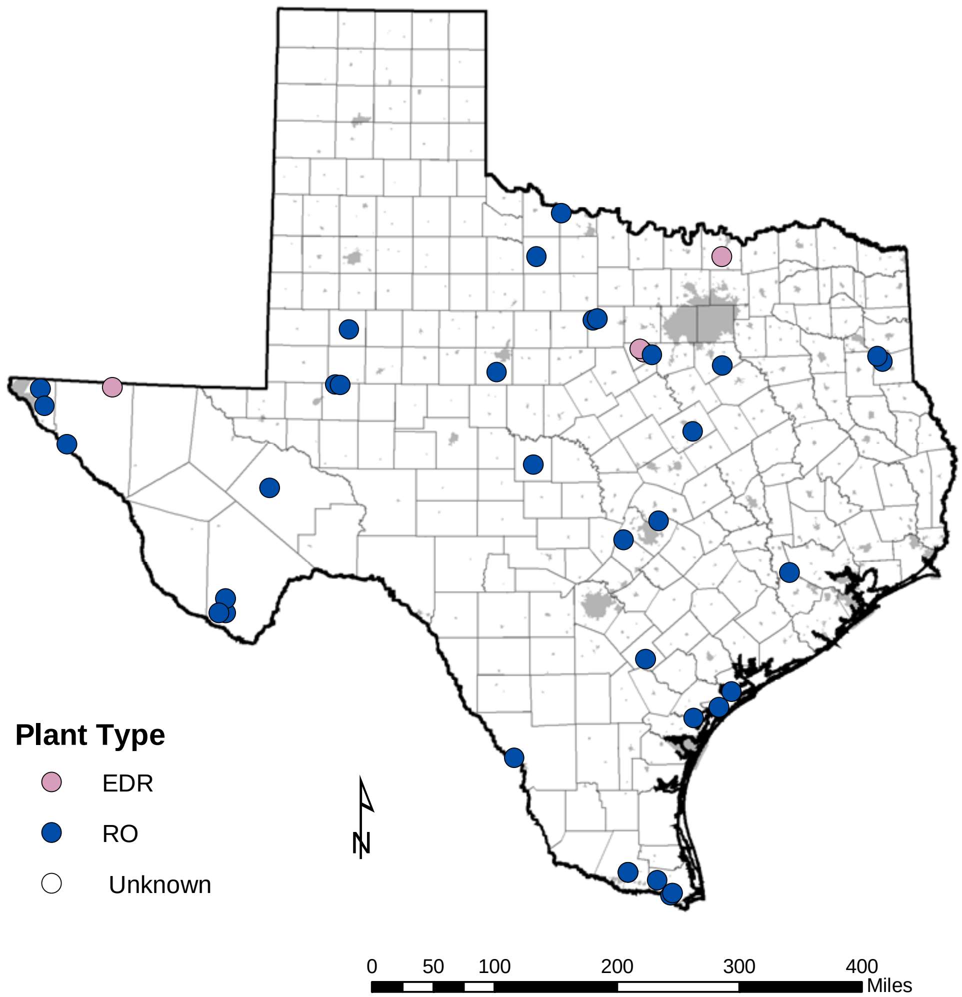
Figure 4-8. Design capacity and average production of desalination facilities sorted by startup year (log scale; 1998 through 2005)



NOTE: Location of some facilities is only approximate; Texas Statewide Mapping System projection

Figure 4-9. Map of desalination facilities showing startup year

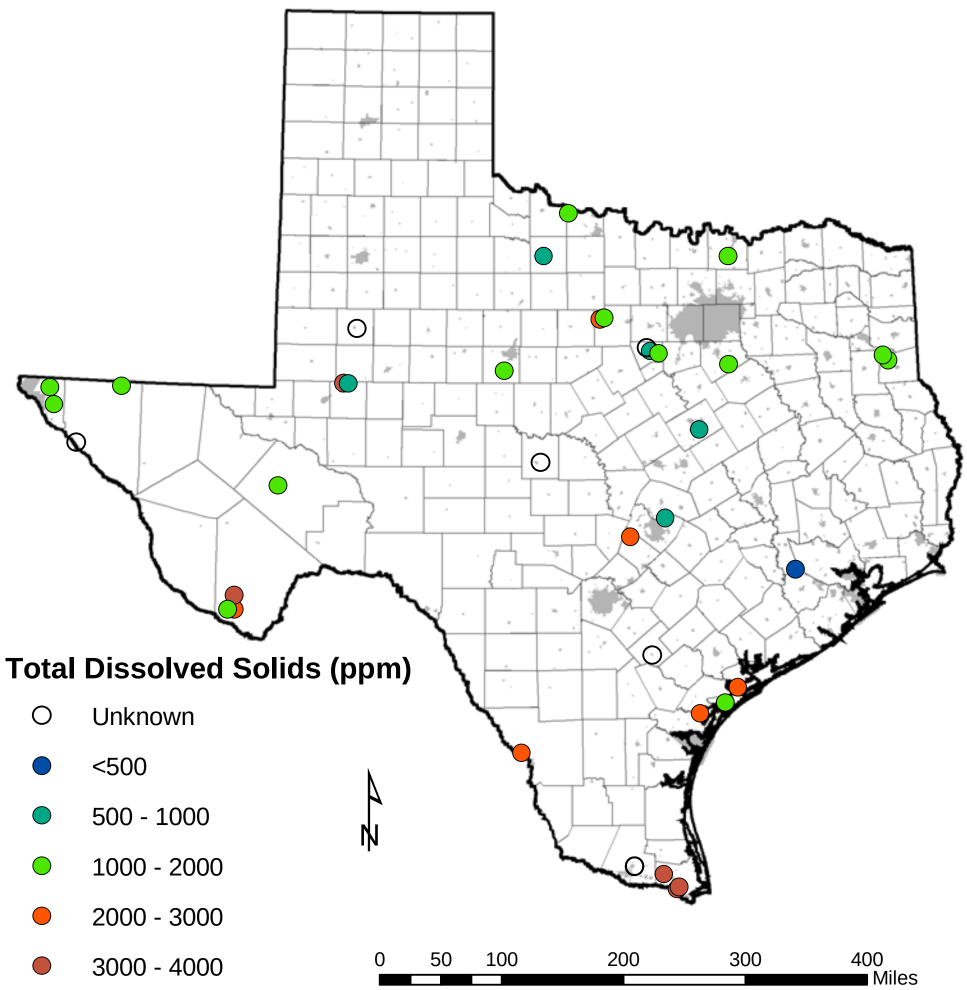
The vast majority of Texas PWS desalination facilities have adopted RO (Figure 4-10). Only four of them currently use EDR (8.5 MGD out of a total of 53.7 MGD, that is, ~18 percent of total design capacity). They are the City of Granbury (0.11 MGD design capacity), Dell City (0.1 MGD), City of Sherman (7.5 MGD), and Oak Trail Shores (0.792 MGD). Some of these facilities plan to upgrade and switch to RO in the near future (Oak Trail Shores and City of Granbury). Some industrial facilities also use ED (e.g., DEFS Fullerton Gas Plant). Most of these facilities are connected to the power grid. Only one plant with production ≥0.025MGD (DS Waters of America, LP) had power generated on site. Site-generated power is more common for industrial facilities.



NOTE: Location of some facilities is only approximate; Texas Statewide Mapping System projection

Figure 4-10. Map of desalination facilities showing desalination technique

Feedwater TDS varies from 470 to 3,840 ppm (Figure 4-11). An arithmetic average weighted by desalination design capacity yields a value of ~1,760 ppm, whereas an average by facility gives a similar value of ~1,870 ppm. Mode of distribution is in the range of 1,000 to 1,500 ppm (Figure 4-12). The primary reason for building the facilities is often a high TDS (high chloride, sulfate, sodium, hardness, or alkalinity), but there are regulatory reasons as well. The City of Electra and the City of Seymour want to eliminate nitrate. The City of Kenedy is concerned about arsenic. The City of Bardwell, the Big Bend Motor Inn, and Windermere Water System facilities are concerned about high fluoride. Radionuclides are an issue for the Study Butte Terlingua Water System and the City of Brady. Perchlorate is of concern to the Gaines County Golf Course (facility <0.025 MGD).



NOTE: When a TDS range was given during the survey, arithmetic average of range bounds was chosen as the representative value. Location of some facilities is only approximate; Texas Statewide Mapping System projection

Figure 4-11 (Revised). Map of desalination facilities showing TDS of feedwater

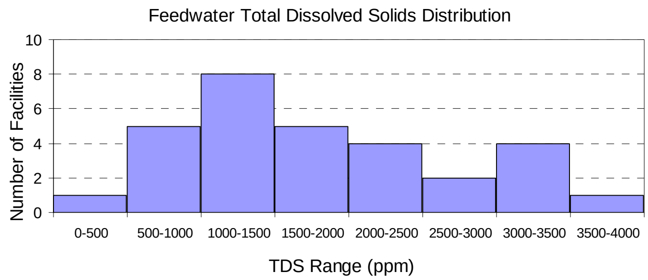
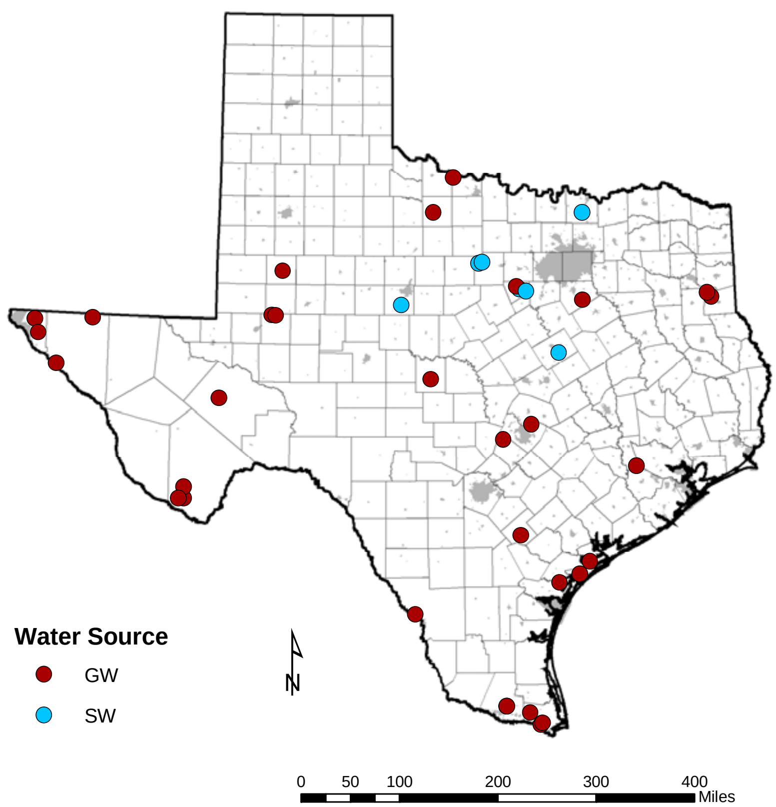


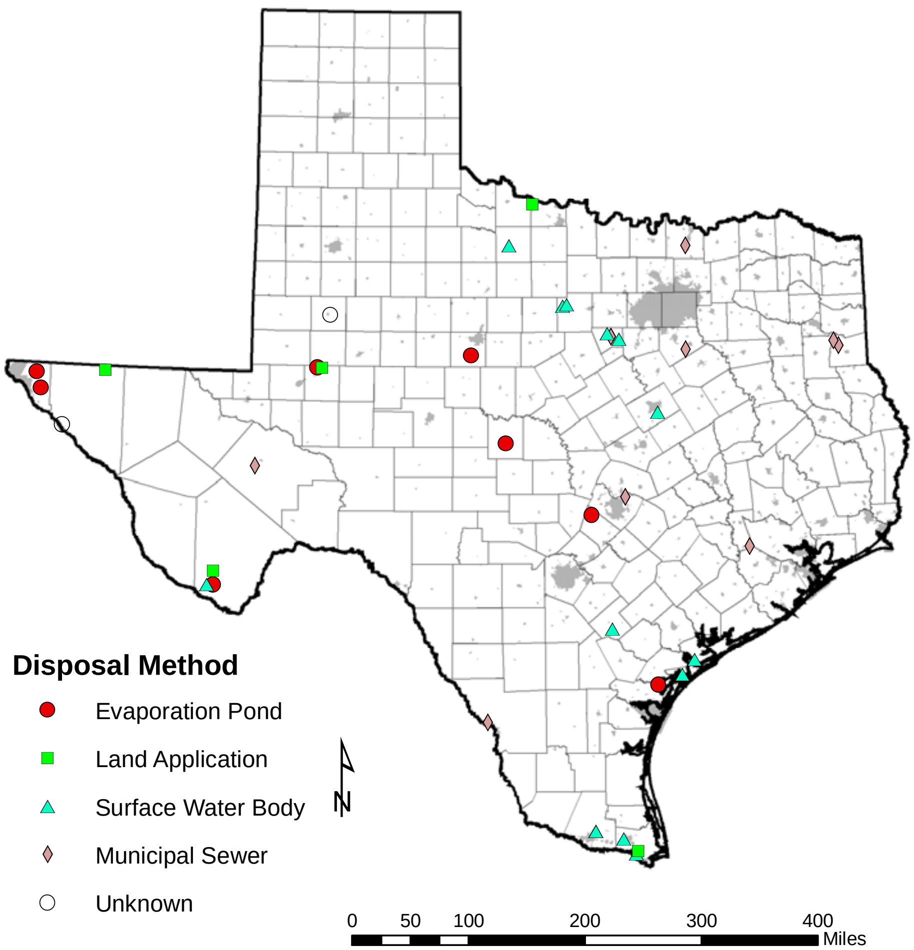
Figure 4-12. Feedwater TDS distribution

Source water is either a surface water body or, more commonly, groundwater (Figure 4-13). No PWS seawater desalination facility currently exists in Texas. Of 38 facilities, 8, including the large facilities of Abilene, Sherman, and Lake Granbury SWATS, use surface water. They total 24.5 MGD of the state desalination design capacity (that is, ~45 percent of 52.3 MGD). They are located mainly where surface water is abundant, mainly in the northeastern corner of the state. Concentrate disposal methods are displayed in Figure 4-14. There is no obvious trend in the spatial distribution of the different methods. Table 4-3 presents disposal method statistics.



NOTE: Location of some facilities is only approximate; Texas Statewide Mapping System projection

Figure 4-13. Map of desalination facilities showing feedwater origin



NOTE: Location of some facilities is only approximate; Texas Statewide Mapping System projection

Figure 4-14. Map of desalination facilities showing concentrate disposal method

Table 4-3. Concentrate disposal method statistics

Method	Number of facilities	Cumulative design capacity (MGD)
Evaporation pond	8	12.1
Land application	5	3.3
Municipal sewer	9	15.3
Surface water body	14	20.7
Unknown	2	0.02
Total	*38*	*52.3*[A]

NOTE: [A] Sum of individual rows may differ from "Total" row owing to rounding

We were able to collect information from more than half of the facilities (25) on capital costs (Table 4-4 and Figure 4-15). Computed over a period of 20 years, neglecting inflation, most capital costs to 1,000 gal are below $1/1,000 gal (Figure 4-16). Data on operating costs are too disparate for a statistical study to be undertaken.

Table 4-4. Facility capital cost statistics (total design capacity includes blending)

Facility	County	Cost (million $$)[A]	Total design capacity (MGD)	Capital cost /1,000 gal[B]
City of Sherman	Grayson	20	10	0.27
Lake Granbury SWATS	Hood	30	10	0.41
City of Abilene	Taylor	60	8	1.03
Southmost Regional Wat. Auth.	Cameron	27	7.5	0.49
City of Fort Stockton	Pecos	6	7	0.12
Horizon Regional M.U.D.	El Paso	6.8	4	0.23
City of Seymour	Baylor	2	3	0.09
City of Brady	McCulloch	9.4	3	0.43
Windermere Water System	Travis	1.5	2.88	0.07
City of Primera	Cameron	9	2.5	0.49
City of Robinson	McLennan	6	2.3	0.36
Valley MUD #2	Cameron	0.8	1	0.11
City of Seadrift	Calhoun	1.2	0.61	0.27
City of Granbury	Hood	0.6	0.55	0.15
City of Electra	Wichita	1.7	0.5	0.47
City of Bardwell	Ellis	0.1	0.252	0.05
Haciendas Del Norte	El Paso	2	0.23	1.19
Holiday Beach WSC	Aransas	0.385	0.2	0.26
City of Beckville	Panola	0.4	0.192	0.29
Study Butte Terlingua Wat. Syst.	Brewster	1.348	0.144	1.28
Midland Country Club	Midland	0.09	0.11	0.11
Sportsmans World MUD	Palo Pinto	3.5	0.083	5.77
Big Bend Motor Inn	Brewster	0.02	0.05	0.05
City of Los Ybanez	Dawson	0.3	0.025	1.64
Longhorn Ranch Motel	Brewster	0.034	0.023	0.2

NOTE: [A]Not corrected for inflation; [B]assuming a life of 20 years

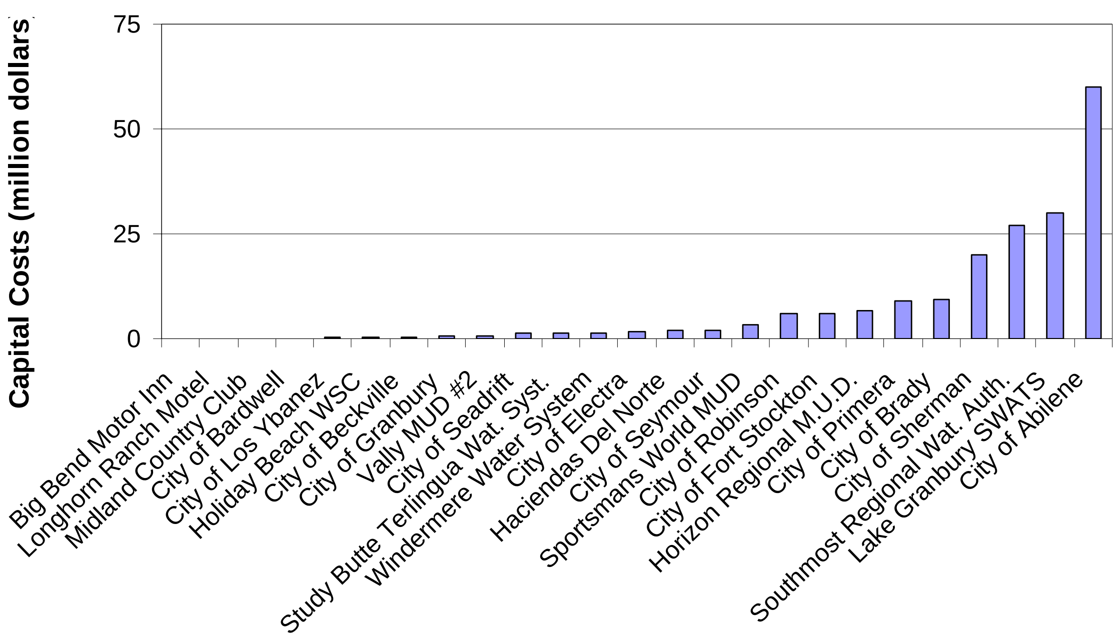
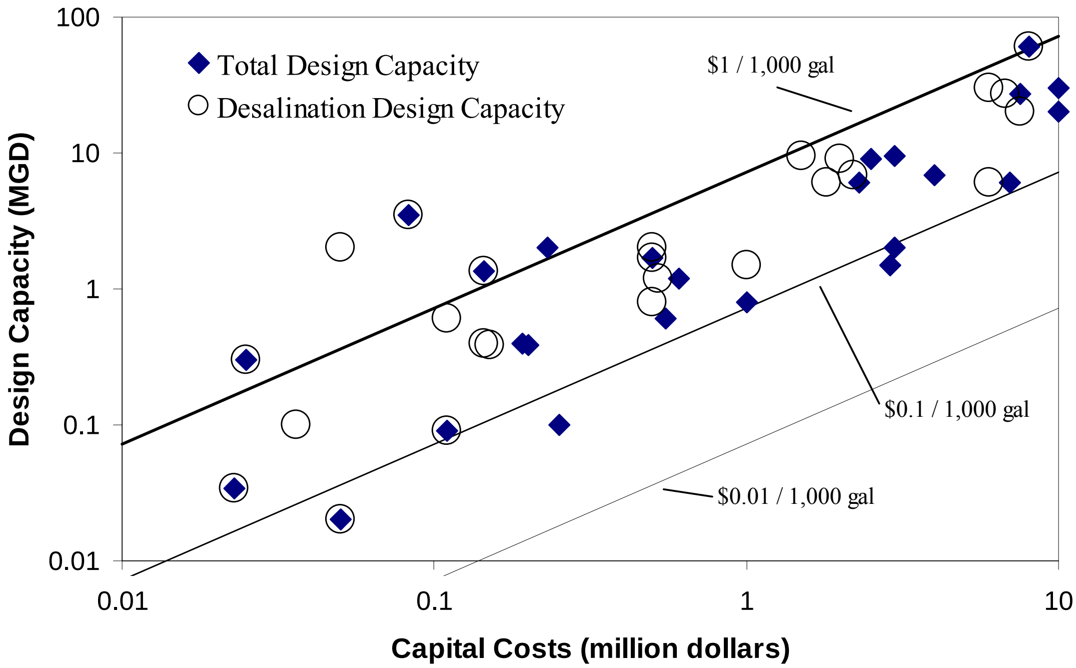


Figure 4-15. Capital costs of a few desalination facilities (not corrected for inflation)



NOTE: Cost per 1,000 gal assumes a plant life of 20 years. If plant has no blending, total design and desalination design capacity are superimposed. If there is blending, each plant is represented by two points, representing capital cost divided by either total or desalination design capacity over 20 years.

Figure 4-16. Comparison of capital costs and total design capacity

4.2 Future Plants

In the course of this study we informally collected information about future desalination facilities. A nonexhaustive list of future facilities is provided in Table 4-5. It includes potential facilities for Millersview-Doole, Fort Hancock, Central Texas WSC in Bell County, Sylvester-McCaulley WSC in Fisher County, Wichita Falls, and the large joint facility El Paso/Ft. Bliss (27.5 MGD). The City of Granbury will switch from EDR to RO and increase its desalination capacity from <1 MGD to 6 MGD. The probability of completion of these facilities is rated high. Other cities, such as San Angelo, San Antonio, and Karnes City, have also demonstrated some interest in desalination. However, at this time no feasibility studies have been undertaken. The three Gulf seawater desalination facilities whose feasibility studies are funded by the TWDB are included in the table with no details. As the Regional Water Planning Group 2005 reports become available later this year, the ability to discern the demand for desalination facilities will develop.

Table 4-5. Future facilities

City/Facility (county)	Information Source	Estimated design capacity (MGD)	On the horizon	Comments
High certainty of completion				
Joint facility El Paso / Ft. Bliss (El Paso)	RWPG Report Region E	27.5	2006	Cost: $35,000,000; groundwater; injection wells for concentrate disposal, blending
Wichita Falls (Wichita)	Website1; RWPG Report Region B	12		Feedwater from Lake Kemp
Central Texas WSC (Bell)	Survey Interview	6-10	2010	Lake water
City of Granbury (Hood)	Survey Interview	6	2008-2009	Lake Granbury
Dupont Textiles&Interiors (Victoria)	Website2	4.3		Industrial facility in Victoria, TX
Millersview Doole WSC (Concho)	Survey Interview	2	2005-2006	Ivie Reservoir will be feedwater and also used for concentrate disposal; Cost: $5,000,000; average production at 0.875 MGD; 2 MGD with blending; total design capacity at 3.5 MGD
Sylvester-McCaulley WSC (Fisher)	Survey Interview	0.2	2006-2007	Cost: $350,000; groundwater
Fort Hancock WCID (Hudspeth)	Survey Interview		2006-2007	Cost: $2,000,000; arsenic is a concern, along with TDS; groundwater; concentrate disposal through evaporation ponds
Possibly on the horizon				
TWDB-funded feasibilities studies for 3 gulf sites	TWDB Website	75		Seawater desalination plants
San Antonio (Bexar)	Recent posting of an RFQ	20		
Corpus Christi on Padre Island		3.5		
Brazos River Authority (Stephens)	TWDB	1-3		
Karnes City (Karnes)	RWPG Report Region L	0.5		
San Angelo (Tom Green)	Pers. Com.			
Highly speculative				
On Lake Texoma (Cooke)	RWPG Report Region C			
Wilcox and Gulf Coast aquifers	RWPG Report Region L		2035	

NOTE: Website1: http://cwftx.net/pubworks/Default.htm; last accessed 06/2005
Website2: http://www.waterdesalreport.com/horizon.htm; last accessed 12/2004

4.3 Roadmap for Industrial Facilities

There is much less easily retrievable information about industrial facilities than there is about municipal facilities. However, it is likely that industrial facilities currently comprise the bulk of desalination facilities in numbers, if not in production, as can be inferred from a previous and more thorough survey of industrial installations conducted by IDA. The IDA inventory for the state of Texas (Wangnick, 2002) suggests that out of a total desalination design capacity of ~100 MGD in Texas as of December 31, 2001 (109 facilities described), only ⅓ (30 MGD) are for municipal use (14 facilities described).

Industrial facilities most likely to include desalination units are from power, electronics, chemical and petrochemical, pharmaceutical, beverage and food, textile, and paper industries. RO membranes have been used since the 1960's in most of those applications. Baker (2004, p. 221) stated that worldwide,~50 percent of all RO membranes are for desalination of brackish and seawater, and 40 percent are for ultrapure water used in the electronics, pharmaceutical, and power industries, whereas the remaining 10 percent are for niche application, such as food processing. A quick reading of the IDA inventory presented in Attachment E shows that power facilities are the most numerous (see `Desalting Plants Inventory_JP0.xls`). The inventory also shows that evaporation-based methods are in use in Texas, particularly in older units and when wastewater or seawater is used as a feed. The largest of these is at the Union Carbide plant in Texas City, with a total capacity >2 MGD. It is also one of the oldest, in operation since 1968. Most recent evaporation-based facilities (the latest started up in 2001) are integrated within power plants. They use wastewater as feedwater and follow a vapor compression process.

Attachment E presents a rough approximation for quantitative description of desalination capacity of industrial facilities. The uncertainty of the following numbers is large, possibly as high as 100 percent, but they show that desalination units in the industry make up more than half of the total number of units in the state. Probably between 30- and 45-MGD desalination capacity exists for steam generation, and an additional and growing capacity of 10 MGD in the food and beverage industry. Ultrapure water needs of the semiconductor industry were estimated in the 15- to 30-MGD range. When other usages, also discussed in Attachment E, are added in, total industrial capacity for desalination of the state of Texas is in the 60- to 100-MGD range. This figure is consistent with the Wangnick (2002) study relative to ratio of industrial capacity to total capacity.

Data collection for industrial facilities cannot follow a procedure similar to that of public water supply because there is no centralized database. Desalination is part of many diverse industrial processes. Desalting typically occurs both at the beginning and the final stages of an industrial process. In the latter case, economy created by recycling and legislation regulating effluent disposal directly suggest that some treatment of wastewater is beneficial. The former case is the most relevant to the problem at hand, however. Although the main sources in Wangnick (2002) are plant operators, sources also include membrane suppliers, suppliers of chemical additives, and national and international organizations—hence the occasional lack of exact location of a plant or nonmention of the customer in Table D3. Also, Wangnick (2002) stated that data reliability of RO plants is lower than that of thermal and ED plants because of the large number of suppliers and facilities.

5 Database Updates and Future Work

In addition to the initial data gathering phase still needed for industrial facilities, regular updates to the PWS database must also be undertaken. An overview of the work is presented in Figure 5-1.

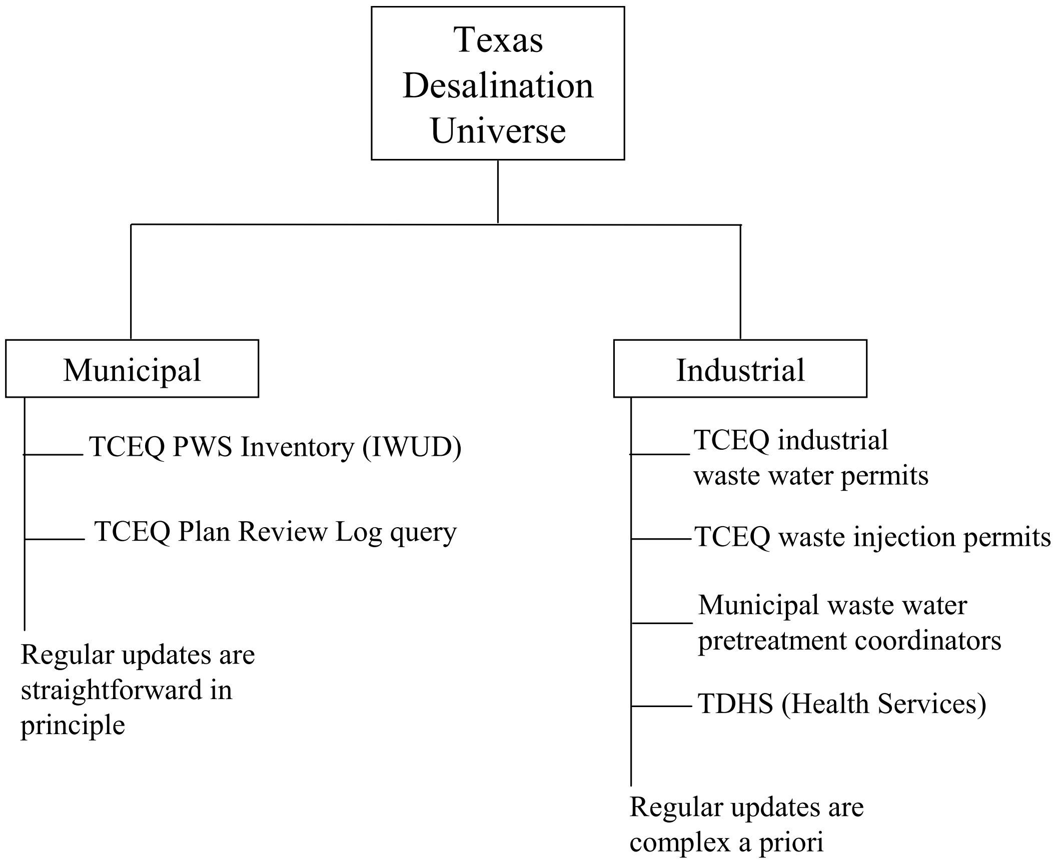


Figure 5-1. Simplified approach to a living desalination database

5.1 Update to Texas PWS Desalination Database

As of 2005, there is no easy mechanism or procedure to update the Texas PWS desalination database, short of undertaking similar surveys occasionally. The easiest approach would be to periodically have Public Water System officials report treatment and production updates in the PWS IWUD inventory (online TCEQ Water Utility Database**). Redesign and changes to the database would be technically straightforward to implement but would possibly involve TCEQ rulemaking to bring it about. Periodic queries of the WUD inventory will show capacity, production, and process changes. Because TCEQ reviews of PWS (material feeding IWUD) focus on those older facilities, initial data entry of most recent facilities (built 2004–2006) would have to be researched individually outside of IWUD. TCEQ field staff inspect treatment facilities every 3 years on average.

To build a more complete database, it is also possible to mine TCEQ files to populate the database with inactive and closed facilities (list given within Table D1).

5.2 Exhaustive List of Industrial Desalination Operators

To build the industrial database, we propose to initially spot candidates using regulatory linkages to collect information on industrial desalination operators and then to contact them individually. This approach may be the only way to collect accurate information. Those desalination facilities having a drinking-water component are already captured with other PWS facilities. They are, however, a small fraction of the industrial desalination universe. For all other facilities, researching industrial permits is the most sensitive option (Figure 5-1). If a facility discharges mainly desalination waste, the permit will specify origin of waste. Unfortunately, in most cases, discharge waste is a mixture originating from different processes, only one of which could be RO. A systematic review of these permits may be the fastest way to generate a complete list. Another related approach could involve contacting individual cities. Most facilities must have a pretreatment permit from the municipal owner of the wastewater system because they discharge their waste to municipal wastewater collection systems. An estimated 50 to 100 such pretreatment coordinators exist in the state. Additionally, the Waste Permit Division at TCEQ has 200 to 300 waste discharge permits that would be worth reviewing individually, including UIC Class I and Class V injection wells. The Railroad Commission of Texas (RRC) could also have data on Class II injection wells used to dispose of desalination concentrate. The food, beverage, and pharmaceutical industries are subject to supplementary regulatory oversight through the Texas Department of State Health Services, where additional information can be collected. Attachment E presents a long list of industrial facilities. A more systematic approach would involve contacting all of them. Once initial construction of the database is completed, periodic updates could be harder to complete than that of the PWS database.

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7 Attachment List

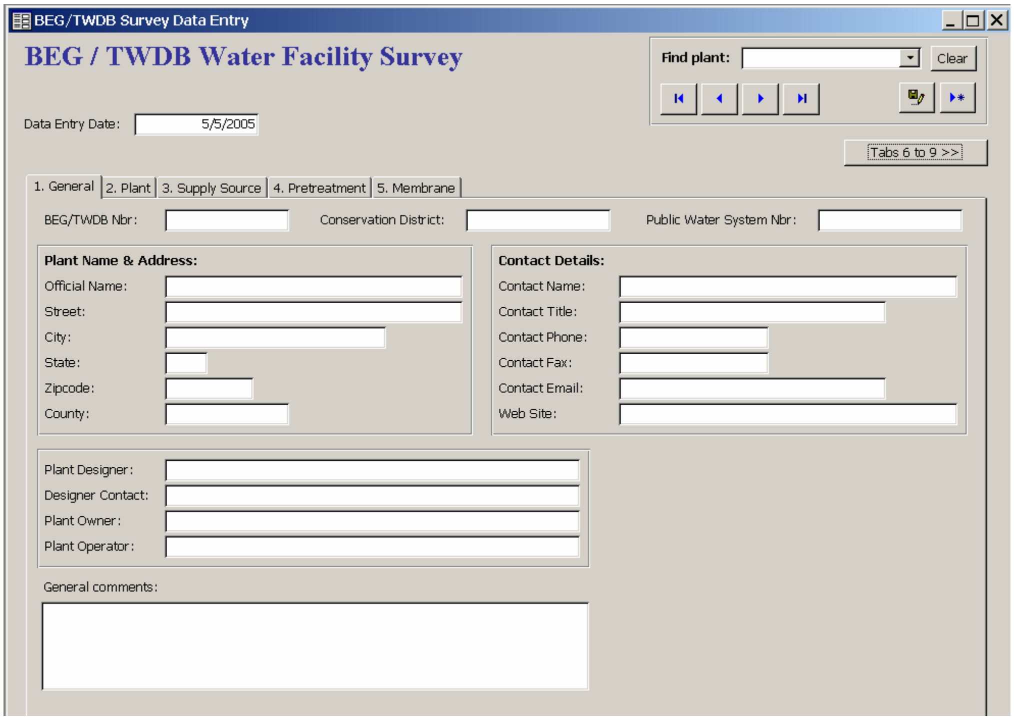
Attachment A:	Database Description
Attachment B:	Survey Form
Attachment C:	Overview of Recent Surveys
Attachment D:	Detailed Survey Results
Attachment E:	Road Map for Survey of Industrial Facilities
Attachment F:	List of Files on CD
Attachment G:	Useful Website Addresses
Attachment H:	Responses to Review Comments

Attachment A: Database Description

The survey form presented in Attachment B was initially translated into a Microsoft Access electronic format (Figure A1). It consists of 10 fields chronologically following, more or less, the water treatment process. The first field, “General Information,” contains administrative and contact information. The second field, “Plant Information,” includes total and desalination capacity, as well as average and permitted production. The reasons for building the plant also belong in this field. The third and fourth fields, “Raw Water Supply Source” and “Pretreatment of Desalination Unit Feed,” deal with the raw water supply and its pretreatment. Pretreatment requested information is somewhat detailed. The fifth field, “Membrane Information,” asks for specifics on the membrane operation, including replacement and cleaning frequency. Sixth and seventh fields, “Posttreatment of Throughput” and “Posttreatment of Concentrate,” are short and self descriptive. The eighth field, “Concentrate Disposal,” details concentrate disposal issues. Ninth and tenth fields, “Problems” and “Costs Issues,” complete the survey. Comment boxes are also provided in each field to add complementary information not fitting into the regular set of questions.

It is proposed that a user interface be built, allowing simple or multiple queries for

- Location: county
- Year facility built
- Water use: drinking water and/or other usages
- Water source: surface water, groundwater
- Plant type: reverse osmosis, electrodialysis reversal
- Desalination capacity, total capacity
- Blending or no blending
- Feed TDS
- Discharge type: evaporation pond, surface water, land application, WWTP, (injection well)
- Pre- and posttreatments
- Reason for plant: TDS, contaminants
- Capital cost of plant



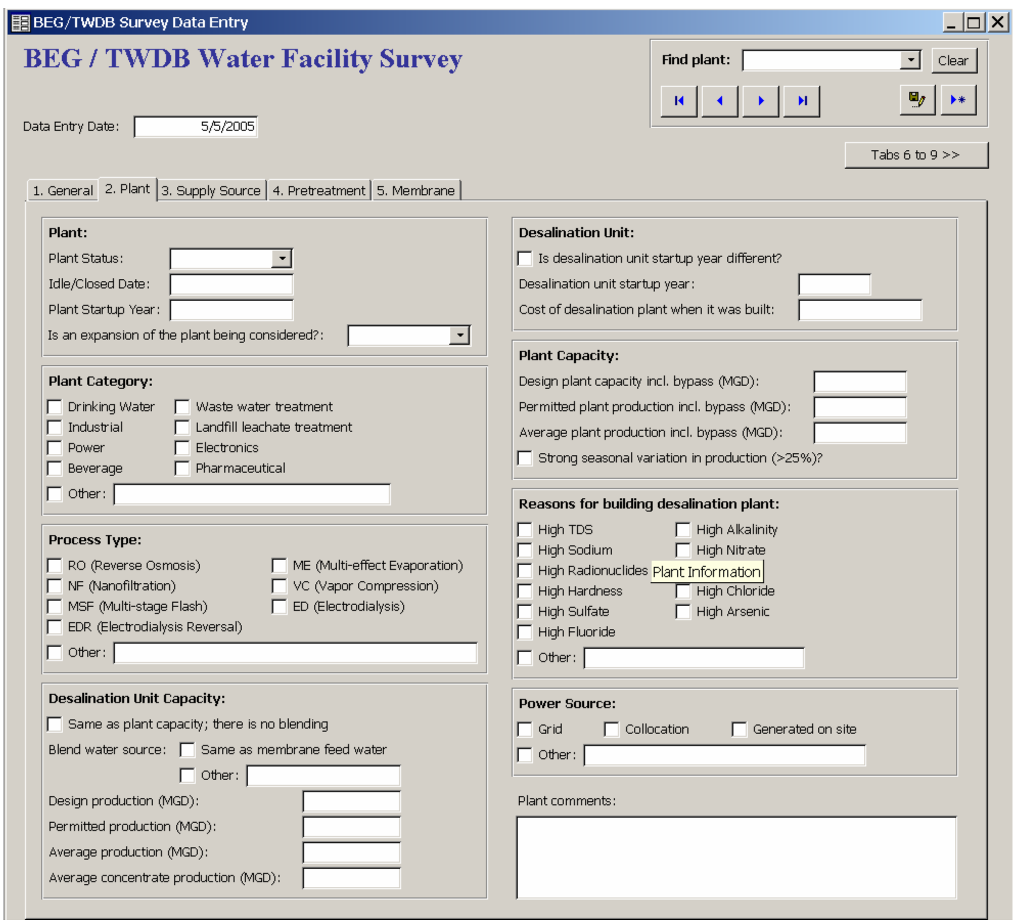
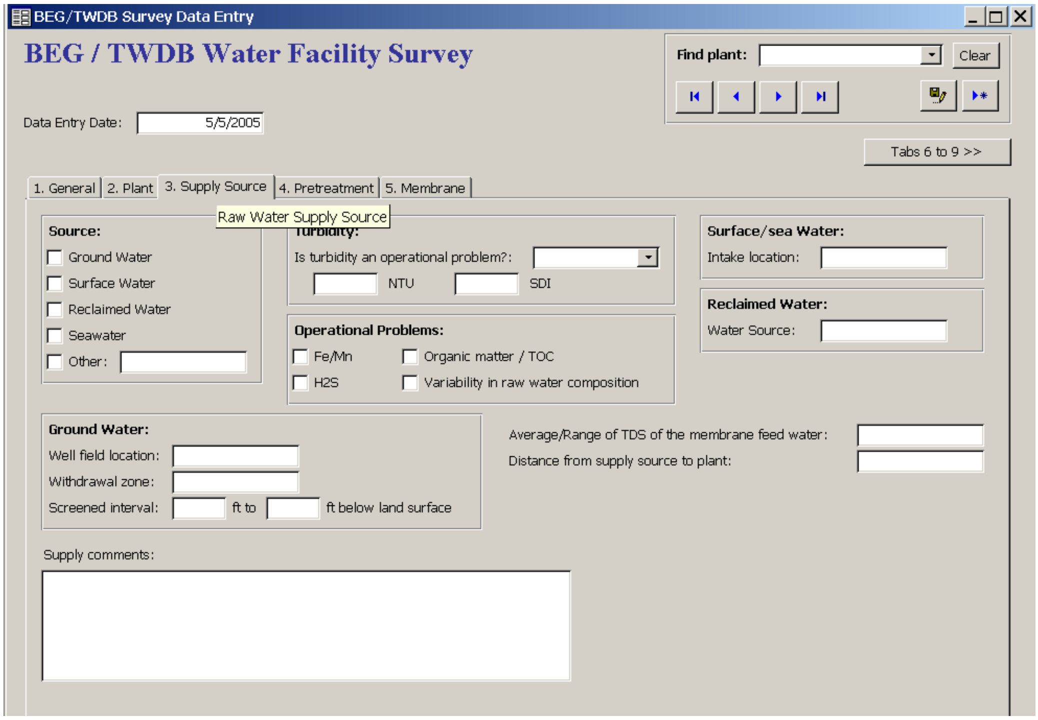


Figure A1. Screen captures of fields of database in Microsoft Access format



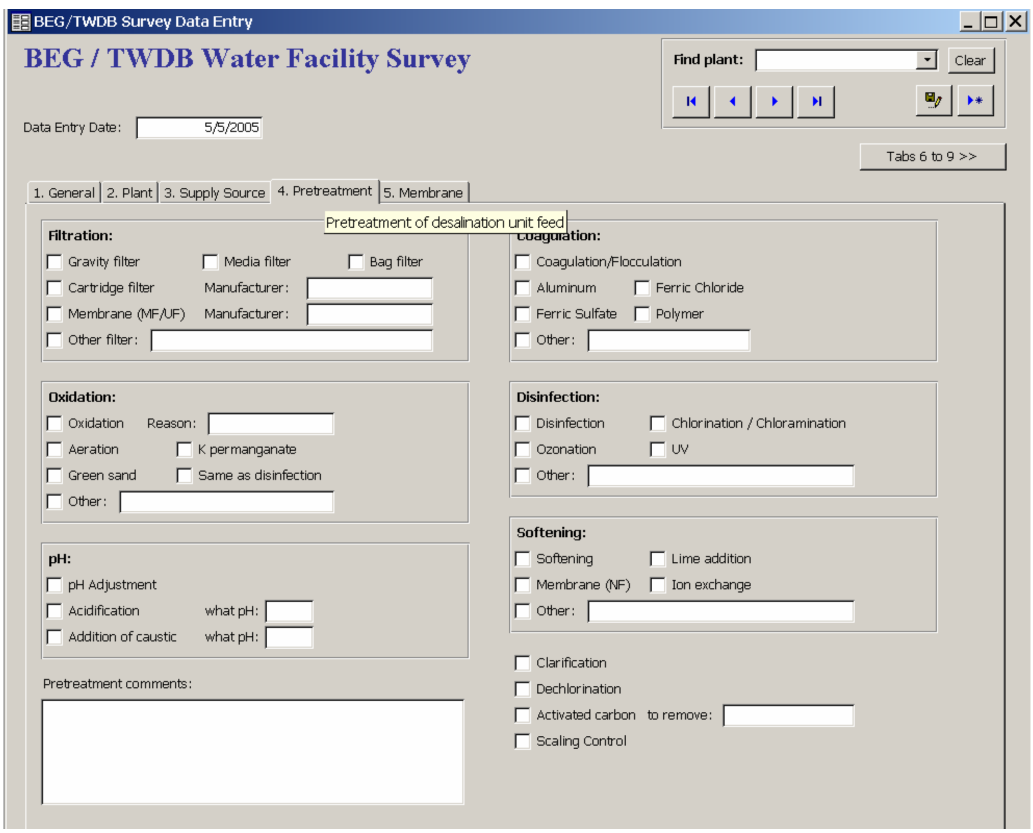
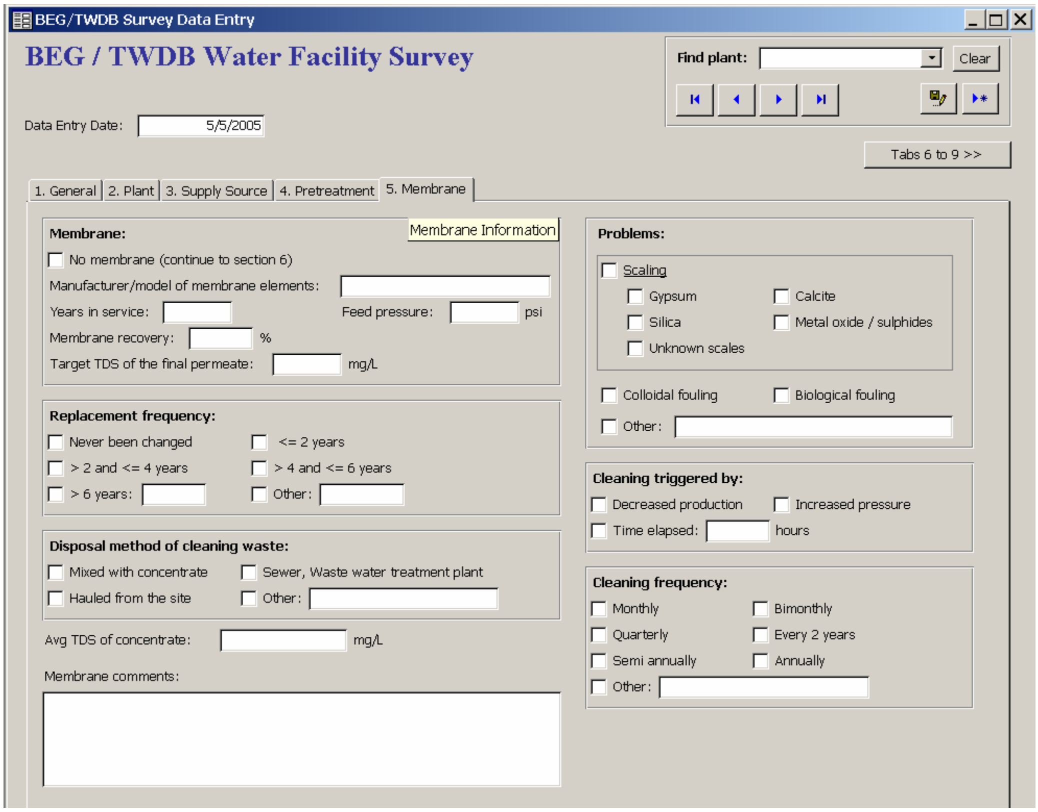


Figure A1. Screen captures of fields of database in Microsoft Access format (continued)



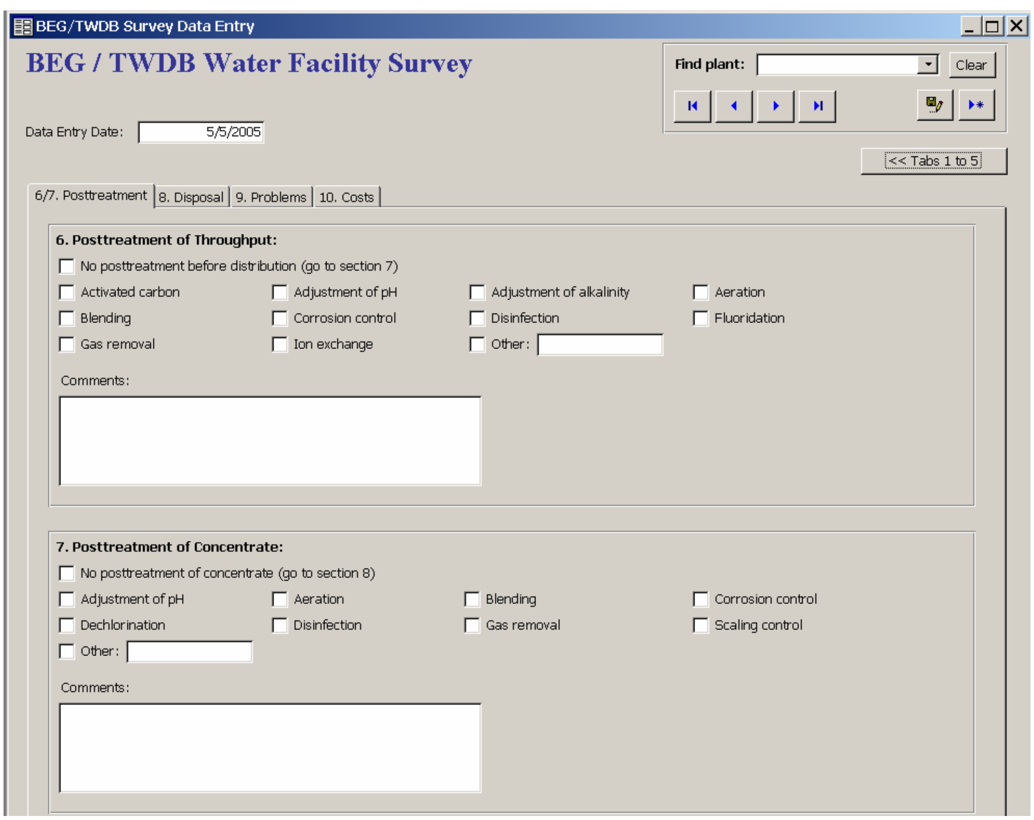
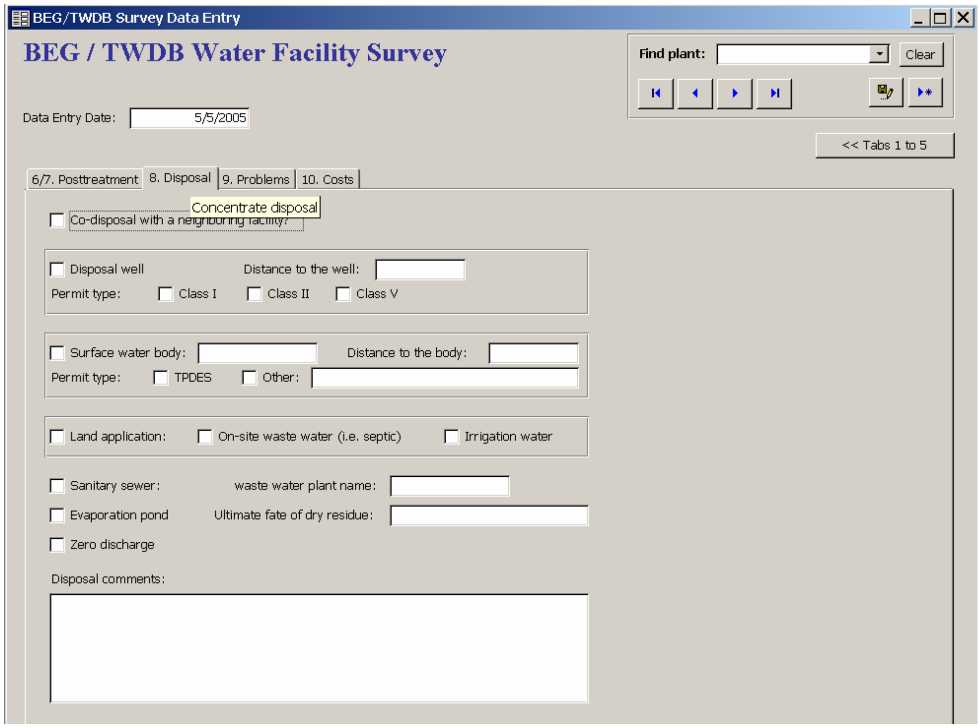


Figure A1. Screen captures of fields of database in Microsoft Access format (continued)



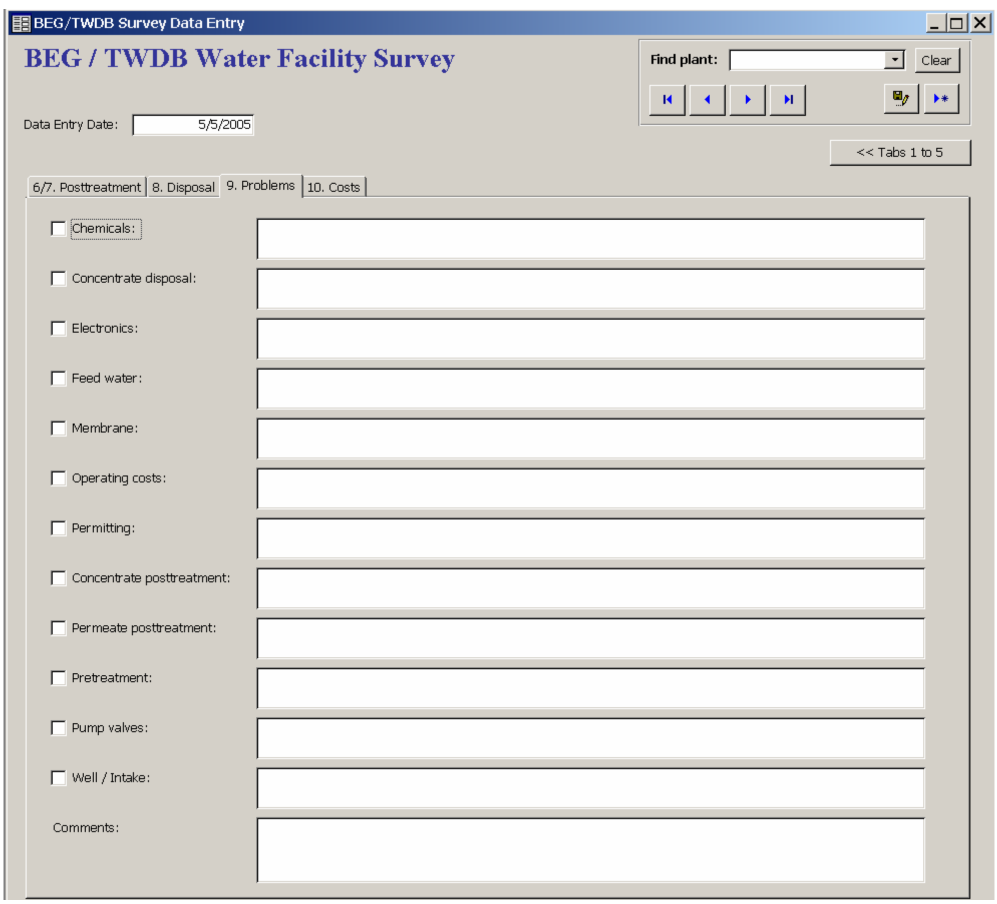


Figure A1. Screen captures of fields of database in Microsoft Access format (continued)

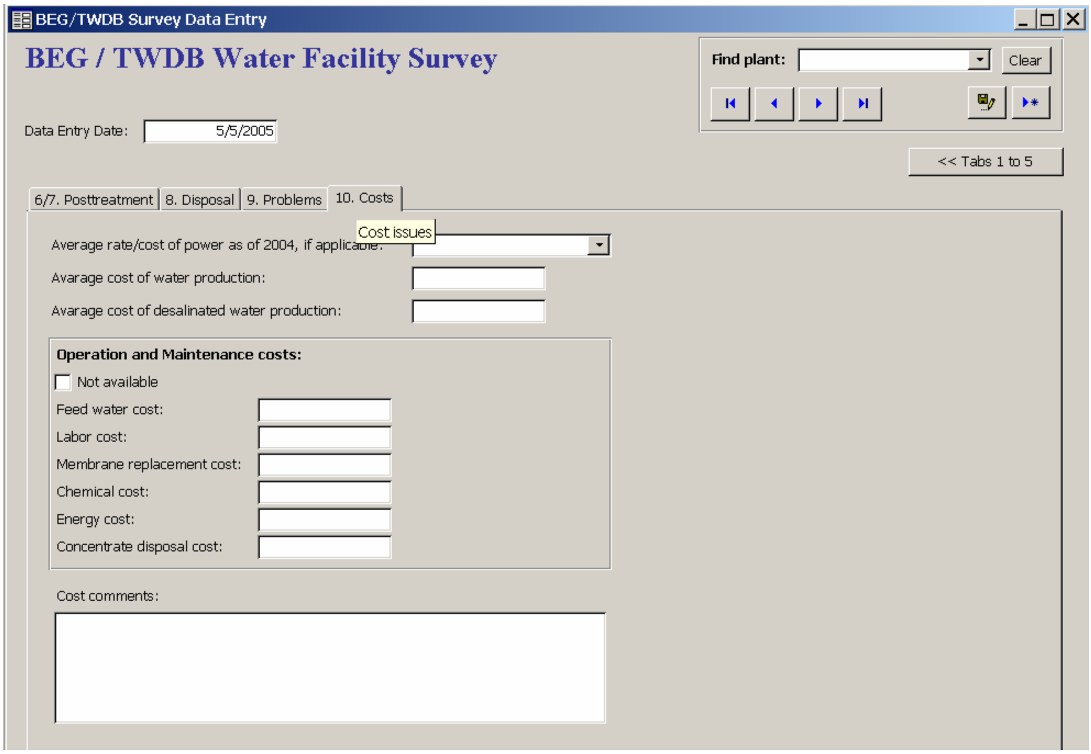


Figure A1. Screen captures of fields of database in Microsoft Access format (continued)

Attachment B: Survey Form

QUESTIONNAIRE FOR MUNICIPAL FACILITIES
Data entered on: ________________

1- GENERAL INFORMATION:
BEG/TWDB Number:
____
Plant Name and address:
Official
Name:____
Address:
____
____
____
____
County:____
______
Water/Ground Water Conservation District (if applicable):
____
Public Water System No (if applicable):
____

Contact Name:
____
Contact Title:
____
Phone:
____
Fax:
____

Email:
____
Website:
____

Plant Designer:
____
____
______
*Contact*____
______
Plant Owner:
____
____
______

Plant Operator: ____
____
______

2- PLANT INFORMATION:
Plant status in the past few months: □Operating; □Idle since ______; □Closed since _______
Year of plant start-up:__________________
Is desalination unit start-up year different? □No □Yes :______________
Cost of desalination plant when it was built:________________
Plant Category (check all that apply):
□Drinking water production; □Wastewater treatment; □Landfill leachate treatment
□Industrial: □Power; □Electronics; □Beverage; □Pharma.; □Chemical; □Other:______
□Other:____

Process Type (check all that apply):
□RO (Reverse Osmosis) □EDR (Electrodialysis Reversal) □ED (Electrodialysis)
□NF (Nanofiltration) □ME (Multieffect Evaporation)
□MSF (Multistage Flash) □VC (Vapor Compression)
□Other:_________________
Plant Capacity
Design plant capacity including bypass (MGD): _________________________________
Permitted plant production including bypass (MGD): _____________________________
Average plant production including bypass (MGD): ______________________________
Strong seasonal variation in production (>25%)?: □No □Yes
Desalination Unit Capacity
□Same as plant capacity; there is no blending
Blend water source: □same as membrane feedwater; □other:________________
Design production (MGD): ____
Permitted production (MGD): _______________________________________
Average production (MGD): _____________________________________
Average concentrate production (MGD): ______________________________________
Power Source: □Grid; □Collocation; □Generated on site; □Other:________________________
Reasons for building desalination plant (check all that apply):
□High TDS □High hardness □High alkalinity □High chloride
□High sodium □High sulfate □High nitrate □High arsenic

□High radionuclides □High fluoride □High Fe/Mn
□Other:__________
Is an expansion of the plant being considered? □No □Yes

3- RAW WATER SUPPLY SOURCE:
□Groundwater; □Surface water; □Reclaimed water; □Seawater; □Other:__________
Average/Range of TDS of the membrane feedwater:_____________
Is turbidity an operational problem? □No □Yes: ___NTU;____SDI
Are the following operational problems present?
□Fe/Mn □H_2S □Organic matter/TOC □Variability in raw water composition
Distance from supply source to plant:____
If groundwater:
Well field location:_____________ Withdrawal zone:______________________
Screened interval: ________ ft to ________ft below land surface
If surface/seawater, intake location: ___________
If reclaimed water, water source___________

4- PRETREATMENT OF DESALINATION UNIT FEED
Filtration (check all that apply):
□Gravity filter □Media filter □Bag filter
□Cartridge filter. Manufacturer if applicable:___________________________________
□Membrane (MF/UF). Manufacturer if applicable:_______________________________
□Other___________
Coagulation/flocculation: □No □Yes
□Alum □Ferric chloride □Ferric sulfate □Polymer □Other:_____________
Clarification: □No □Yes
Oxidation: □No □Yes
Why?____
□Aeration; □K permanganate; □Green sand; □same as disinfection; □Other__________
Softening: □No □Yes
□Lime addition □Membrane (NF) □Ion exchange
Disinfection: □No □Yes
□Chlorination/chloramination □Ozonation □UV
□Other
Dechlorination: □No □Yes
Activated carbon: □No □Yes: to remove______________
pH adjustment: □No □Yes □Acidification: what pH?:__□Addition of caustic?: what pH?:___
Scaling Control: □No □Yes.

5- MEMBRANE INFORMATION:
□No membrane, go to Section 6

Manufacturer/Model of membrane
elements:____
Years in service: _____________years
Feed pressure: __________________psi
Membrane recovery: ______________%
What is the target TDS of the final permeate?:____________________mg/L
Problems encountered:

□Scaling: □calcite; □gypsum; □silica; □Metal oxide/sulphides;

□other:__________________ □don't know nature of scales

□colloidal fouling: □biological fouling

Membrane replacement frequency:

□never been changed □≤ 2 years

□> 2 and ≤ 4 years □> 4 and ≤ 6 years

□> 6 years:_____________ □Other (irregular,..??):____________

Current membrane cleaning frequency:

□monthly; □bimonthly; □quarterly; □semiannually; □annually

□every 2 years; □other:_______________

Membrane cleaning triggered by:

□Decreased production; □Increased pressure; □Time elapsed: _________hours

Disposal method of cleaning waste:

□Mixed with concentrate □Sewer, Wastewater treatment plant

□Hauled from the site □ other:_______________

Average TDS of the concentrate:_________________

6- POSTTREATMENT OF THROUGHPUT

□No posttreatment before distribution, go to Section 7

□Activated carbon □Adjustment of pH □Adjustment of alkalinity □Aeration

□Blending □Corrosion control □Disinfection □Fluoridation

□Gas removal □Ion exchange □Other:____________________

7- POSTTREATMENT OF CONCENTRATE

□No posttreatment of concentrate, go to Section 8

□Adjustment of pH □Aeration □Blending □Corrosion control □Dechlorination

□Disinfection □Gas removal □Scaling Control □Other:__________________

8- CONCENTRATE DISPOSAL

Co-disposal with neighboring facility? □No □Yes

□Disposal well: Distance to well:______________________________

Permit type: □Class I □Class II □Class V

□Surface water body:______________ Distance to water body_________________________
Permit type: □TPDES □Other: ____________
□Land application: □on-site wastewater (i.e., septic) □irrigation water
□Sanitary sewer, wastewater treatment plant name:_______________________________________
□Evaporation pond. Ultimate fate of dry residue:____
□Zero-discharge

9- PROBLEMS

□Chemicals:
____
____
______

□Disposal of concentrate:
____
____
______

□Electronics:
____
____
______

□Feedwater:
____
____
______

□Membrane:
____
____
______

□Operating costs:
____
____
______

□Permitting:
____
____
______

□Posttreatment of concentrate:
____
____
______

□Posttreatment of permeate:
____
____
______

□Pretreatment:
____
____
______

□Pump/Valves:
____
____
______

□Well/Intake:
____
____
______

10- COST ISSUES

Average rate/cost of power as of 2004 if applicable:

□Not available	□<1¢ /kWh	□>1¢ and ≤3¢ /kWh
□>3¢ and ≤5¢ /kWh	□>5¢ and ≤10¢ /kWh	□>10¢ /kWh

Average cost of water production:____

Average cost of desalinated water production:____

Operation and Maintenance costs:

□Not available

Feedwater cost
____

Labor cost
____

Membrane replacement cost
____

Chemical cost
____

Energy cost
____

Concentrate disposal cost
____

Attachment C: Overview of Recent Surveys

Until now, an accurate database containing information on desalination facilities did not exist for Texas. Although there have been several compilation studies of desalination facilities across the world and the United States, none tried to collect an exhaustive list of these facilities. This attachment not only focuses on Public Water Supply systems (PWS) but also discusses other facilities making use of desalination. The symbol ** indicates that a full Web address is given at the end of the document in Attachment G.

C.1 Review of Previous Studies

Several market research firms keep tabs on developments in desalination fields at the world scale (e.g., McIlvaine Company**; Global Water Intelligence**; Water Desalination Report**; Business Communications Company**; The McGraw-Hill Companies**) and are a good source of information. The information, proprietary and only accessible for a fee, is regularly updated. The firm's goal of including desalination facilities across the world does not mean that only large facilities are surveyed. In addition, they often provide information about future desalination facilities. However, level of technical detail provided is often limited, and databases are not always updated when a facility is decommissioned.

In alternate years, the International Desalination Association** (IDA), in association with Wangnick GMBH**, a German consulting firm, publishes an inventory of desalting facilities (Wangnick, 2002; also available on the Web for a fee at http://pam.wangnick.com/). A total of 123 desalination facilities in Texas, including industrial facilities, are listed (Table D3). The company tries to gather data about facilities whose production is >100 m^3/day (0.026 MGD), but the actual cutoff value for reporting an individual unit is 600 m^3/day (0.156 MGD).

In the United States, the most recent national survey is by Mickley (2001), who surveyed 149 facilities across the country. The cutoff rate was 0.025 MGD, and the survey included UF and MF. Texas was represented by 11 RO/EDR facilities. The focus of the study was the fate of the membrane concentrate, but the survey provided other detailed technical information about these facilities. An updated survey is in the works (Scott Irvine, U.S. Bureau of Reclamation, personal communication). Tetratech (Christopher et al., 2004; Hudkins et al., 2004) did a publicly unavailable study of a few desalination facilities across the nation, and two Texas facilities were contacted. The focus of the work was mainly membrane cleaning practices. Furukawa (1994) did a now-obsolete survey of research facilities.

The WateReuse Foundation**, in association with the California Department of Water Resources (CDWR**), is in the process of gathering data on desalination facilities in California, as well as nationwide (Wade Miller, Executive Director at the WateReuse Foundation, personal communication).

To gather up-to-date information, American Water Works Association** (AWWA) through Mr. Sherman May, Chair of the California/Nevada chapter, and AWWA Research Foundation** (AWWARF) were contacted. AWWARF has launched a worldwide survey of MF/UF facilities with a capacity >1 MGD (`AWWARF-Membrane Knowledge Base Project 2763 SCOPE.pdf`).

C.2 Other Current U.S. Efforts at the State Level

In addition to regularly updated international surveys that often use indirect information (chemical additive or membrane suppliers, newspapers, and journals), there are also locally initiated efforts to consolidate current information. States with the most desalination facilities are Florida, California, and Texas (Mickley, 2001). Illinois, Iowa, Nevada, and North and South Carolina also have more than five desalination facilities, according to Mickley (2001).

California

California is home to several water-resources-related organizations and agencies active in gathering data about desalination. The California/Nevada chapter of AWWA is also active in helping diverse organizations gather data.

The California Department of Water Resources** Desalination Task Force, headed by Mr. Keene, has been responsive to our inquiries. A preliminary and partial database is available in the companion CD in the file `Desalting Plants - Master 11x17.xls`, courtesy of Dr. Fawzi Karajeh, Chief of the Water Recycling and Desalination Branch at the CDWR. The database provides data for about 95 facilities using seawater, brackish water, surface water, and wastewater as feedwater. It includes several industrial facilities, particularly power plants.

As mentioned earlier, the WateReuse Foundation, in association with the California Department of Water Resources, is also currently building a desalination database. In addition, the study collects information on water reuse and conservation.

Desalination Research and Innovation Partnership** (DRIP) is currently doing a worldwide survey (http://www.dripronfsurvey.com/) with the collaboration of Montgomery-Watson Harza** (MWH). DRIP is a coalition of California public utilities formed for the purpose of improving current knowledge on desalination (`DRIP Program.pdf`). The goal of this project is to compile a comprehensive database of existing RO/NF facilities worldwide, including California. The study is focused on facilities with capacities ≥1 MGD.

The California Energy Commission**, under the direction of Mr. Cesar Lopez, is sponsoring the development of a Knowledge Base for Desalination Technology for MF/UF facilities with the San Diego Water Authority** on seawater desalination facilities. The study involves mainly an evaluation of pretreatment options.

The California Coastal Commission** presents a list of seawater facilities with minimal information in `CA Coastal Act 14a-3-2004-desalination.pdf`.

Florida

The State of Florida is currently engaged in no specific effort to gather data on state desalination facilities. Mr. Steve Duranceau from Boyle Engineering** provided us with an inventory of facilities in Florida (`FDEP Listing of RO and NF WTPs.doc`), which originated at the Florida Department of Environmental Protection, Drinking Water Section**. The database contains information on 134 facilities, all for public water systems.

Attachment D: Detailed Survey Results

D.1 Description of the Data Collection Process

The first step in data collection was a query of the TCEQ PWS database (file `DESAL TCEQ.xls`, communicated by Mr. Anthony Bennett from TCEQ, Water Supply Division), hereafter referred to as the "TCEQ list." An inventory of the TCEQ list (Table D1) shows a total of 99 entries, but only 70 entries with a water production of 0.025 MGD or larger. Please note that the total production given in the table may include blending of desalination unit permeate and separate water treatment units, including those with no desalination capabilities. One of the goals of the study was to determine the extent of blending. The 29 facilities presented in Table D2 with a capacity <0.025 MGD represent stores, gas stations, schools, etc., that are likely to subcontract maintenance. It was decided that the time spent contacting those facilities would be better spent investigating industrial facilities. During the actual study it was realized that several facilities with a listed nominal capacity ≥0.025 MGD actually have a smaller production. These facilities are not listed in the final database. They are, however, provided as a complement to this study in a Microsoft Access database (`BEG TWDB Water Survey06-13-05_ALL.mdb`). In addition, a few of these facilities are no longer active. Because the TCEQ database is only periodically updated, more recent facilities are not yet included in the TCEQ public water supply database. The bottom section of Table D1 presents a list, thought to be reasonably exhaustive, of those facilities. Table D3 displays results from the IDA inventory (Wangnick, 2002) for the state of Texas. It includes both industrial and PWS desalination facilities.

At the end of the survey, a total of 105 public water system facilities were called, 38 of which were eventually retained in the final list (Table D4). Part of the remainder consists of 19 facilities whose desalination capacity is below the threshold of 0.025 MGD (although total capacity can be ≥0.025 MGD in a few cases). Other facilities (a total of 18) had become inactive since they were last visited by the TCEQ staff. We were unable to gather much information on those facilities. Among these, some had dropped the RO/EDR process for a classical treatment because the source-water quality had improved. Another 12 facilities never had desalination treatments. A total of four contacted facilities have not built their plants yet (more on future plants in Section 4.2). Another five facilities, all in the West Texas oil and gas province of the Permian Basin, use the RO permeate chiefly for industrial purposes (above-ground treatment of gas and fresh-water injection for waterflooding reservoirs). A tiny fraction of the desalination production is used for drinking water. We were unable to gather data on nine, mostly small, facilities. The decision was made to focus time and resources on larger facilities.

An additional 29 facilities, having already a total capacity <0.025 MGD on the TCEQ list, were not contacted (Table D2). It should be noted that, per our experience with the 18 smaller facilities that we called, total capacity numbers for small facilities (<0.025MGD) as provided by the TCEQ overestimates desalination capacity by a large amount. Those small facilities typically use small RO units for drinking water, but not for other domestic uses that utilize a far greater fraction of the total consumption.

Inactive/dismantled facilities and dissolved water supply entities (Table D4) fall into two categories: large industrial facilities and small PWS facilities. One of the largest industrial facilities, the City of Harlingen Waste Water Treatment plant, had a design capacity of 5 MGD. This facility was recently decommissioned and is not included in this study. The desalination units of the Freeport McMoran sulphur plant in Culberson County of West Texas have also been deactivated (capacity of ~4 MGD). Other industrial facilities are related mostly to oil and gas production in West Texas. The Duke Energy Field Services (DEFS) Spraberry plant uses ~1 percent of its RO production for drinking water. On the other hand, the DEFS Pegasus plant currently uses all of its production for industrial purposes. All these facilities are included in the TCEQ list because, at some point in time, they have provided or provide drinking water for the personnel working in the plants. Most small plants or installations had been shut down because needs are now filled by the local drinking-water distribution network. These industrial facilities also include the TMPA Gibbons Creek power plant near Bryan, Texas. However, Midland Country Club, which uses desalinated water for irrigation (0.11 MGD + 0.001 MGD drinking water), has been retained in the final list.

Table D1. Initial working list for municipal facilities (Public Water Supply Desalination Facilities provided by TCEQ). Facilities contacted but not on TCEQ list are added at the end of the table.

System/City/Facility name	County	PWS ID	Survey status	Total production as provided by TCEQ (MGD)
Harlingen Waterworks System	Cameron	0310002	Inactive/Dissolved	31.393
City of Sherman	Grayson	0910006	Final List	25.840
Lake Granbury Surface Water Advanced Treatment System	Hood	1110100	Final List	14.200
City of Fort Stockton	Pecos	1860001	Final List	14.147
DEFS Goldsmith East Plant	Ector	0680205	Inactive/Dissolved	11.729
DEFS Goldsmith Plant	Ector	0680068	Industrial	11.729
Horizon Regional Municipal Utility District	El Paso	0710005	Final List	8.481
Freeport McMoran Sulphur Inc	Culberson	0550024	Inactive/Dissolved	3.960
City of Granbury	Hood	1110001	Final List	3.520
City of Robinson	McLennan	1550010	Final List	2.380
City of Electra	Wichita	2430002	Final List	2.228
City of Kenedy	Karnes	1280002	Final List	1.921
City of Seadrift	Calhoun	0290004	Final List	1.540
City of Tatum	Rusk	2010034	Final List	1.136
Oak Trail Shores	Hood	1110004	Final List	1.130
Pan Energy Coyanosa Gas Plant	Pecos	1860022	Inactive/Dissolved	0.864
Power Resources Inc C R Wing Plant	Howard	1140027	Inactive/Dissolved	0.800
DEFS Fullerton Plant	Andrews	0020004	Industrial	0.757
Altura Energy Ltd Midland Farms	Andrews	0020007	Inactive/Dissolved	0.475
DEFS Pegasus Plant	Midland	1650049	Industrial	0.067
DEFS Spraberry Plant	Midland	1650026	Industrial	0.432

System/City/Facility name	County	PWS ID	Survey status	Total production as provided by TCEQ (MGD)
Haciendas Del Norte Water Improvement District	El Paso	0710091	Final List	0.418
Burleson County MUD 1	Burleson	0260005	No Desal	0.317
Esperanza Water Service Co Inc	Hudspeth	1150010	Final List	0.310
C & L Processors Jameson Gas Plant	Coke	0410011	Inactive/Dissolved	0.288
City of Bardwell	Ellis	0700020	Final List	0.266
Study Butte Terlingua Water System	Brewster	0220035	Final List	0.252
DS Waters of America, LP	Waller	2370070	Final List	0.216
Parker Technologies	Midland	1650034	Inactive/Dissolved	0.210
Texas Boys Ranch	Lubbock	1520072	<0.025	0.199
Country View Estates	Medina	1630026	<0.025	0.183
Sportsmans World MUD	Palo Pinto	1820050	Final List	0.173
City of Bayside	Refugio	1960007	Final List	0.171
City of Laredo	Webb	2400027	Final List	0.158
Goodyear Proving Grounds	Tom Green	2260018	No Desal	0.120
US Coast Guard Station Freeport	Brazoria	0200577	<0.025	0.115
Novo Industries LP	Harris	1013042	Inactive/Dissolved	0.115
City of Los Ybanez	Dawson	0580018	Final List	0.114
TMPA Gibbons Creek SES	Grimes	0930040	Industrial	0.108
River Oaks Ranch	Hays	1050099	Final List	0.101
Amerada Hess Adair Plant	Terry	2230014	<0.025	0.101
Dell City	Hudspeth	1150001	Final List	0.099
Kenneth Copeland Ministries	Tarrant	2200302	No Response	0.090
Worley Welding Works Inc	Hockley	1100040	<0.025	0.086
The Bend Condominiums	Palo Pinto	1820071	No Response	0.086
C & W One Stop 14	Tom Green	2260100	<0.025	0.086

System/City/Facility name	County	PWS ID	Survey status	Total production as provided by TCEQ (MGD)
Gaines County Golf Course	Gaines	0830019	No Desal	0.072
Gaines County Park	Gaines	0830018	<0.025	0.072
Midland Country Club	Midland	1650032	Final List	0.070
Eisenhower Park	Bexar	0150499	<0.025	0.065
Big Bend Motor Inn	Brewster	0220027	Final List	0.060
EBAA Iron Inc Water System	Eastland	0670035	Inactive/Dissolved	0.060
Reinforced Earth Co	McLennan	1550135	Inactive/Dissolved	0.060
Occidental Permian Ltd N Cowden	Ector	0680151	No Desal	0.059
Kent Kwik Convenience Store 312	Midland	1650086	No Response	0.057
Kent Kwik Convenience Store 315	Midland	1650096	No Response	0.057
Regency Gas Service	Pecos	1860020	<0.025	0.057
Villa Condominiums Assn	Palo Pinto	1820029	Inactive/Dissolved	0.050
Conoco Forsan Field Office	Glasscock	0870010	Inactive/Dissolved	0.047
Phillips 66 Clemens Terminal	Brazoria	0200551	Inactive/Dissolved	0.043
Longhorn Ranch Motel	Brewster	0220032	Final List	0.043
Occidental Permian Ltd S Cowden	Ector	0680175	<0.025	0.043
ConocoPhillips Mertzon Plant	Irion	1180005	<0.025	0.043
Texas Water Station	Martin	1590011	<0.025	0.043
Camp Constantin	Palo Pinto	1820036	Inactive/Dissolved	0.041
Wades General Store	Tom Green	2260059	<0.025	0.036
International Garment Processors	El Paso	0710166	No Response	0.033
Diamond W Longhorn Ranch	Bexar	0150504	No Response	0.029
Onyx Environmental Services	Jefferson	1230082	<0.025	0.029
Depot Water Store	Ector	0680198	<0.025	0.028
Goulds Pumps Inc	Lubbock	1520235	<0.025	0.028

System/City/Facility name	County	PWS ID	Survey status	Total production as provided by TCEQ (MGD)
Water Runners Inc	Midland	1650113	Final List	0.028
Bedl Inc Ole Gin Steak House	Tom Green	2260103	<0.025	0.028
Willow Condominiums	Palo Pinto	1820049	Inactive/Dissolved	0.027
Additional Facilities Contacted				
Holiday Beach	Aransas	0040015	Final List	
City of Seymour	Baylor	0120001	Final List	
Chaplines Mobile Home Development	Brazoria	0200181	No Desal	
Valley MUD #2	Cameron	0310059	Final List	
Southmost Regional Water Authority	Cameron	0310150	Final List	
City of Primera	Cameron	0310094	Final List	
Millersview Doole WSC	Concho	0480015	Future RO	
Lower Valley Water District	El Paso	0710154	No Desal	
Loop WSC	Gaines	0830011	<0.025	
North Cameron/Hidalgo WA	Hidalgo	1080029	Final List	
City of Mount Calm	Hill	1090005	No Desal	
City of Brady	McCulloch	1540001	Final List	
City of Miles	Runnels	2000002	No Desal	
City of Breckenridge	Stephens	2150001	No Desal	
City of Abilene	Taylor	2210001	Final List	
City of Wichita Falls	Wichita	2430001	No Desal	
City of Raymondville	Willacy	2450001	Final List	
Medina WSC	Bandera	0100013	No Desal	
Key Largo Utilities	Brazoria	0200401	No Response	
Hop & Shop 25	Brooks	0240012	<0.025	

System/City/Facility name	County	PWS ID	Survey status	Total production as provided by TCEQ (MGD)
Craft Turney WSC	Cherokee	0370016	No Response	
East Montana Water System Butterfield	El Paso	0710118	Inactive/Dissolved	
Mountain Shadow Water	El Paso	6001122	No Response	
Fort Hancock WCID	Hudspeth	1150005	Future RO	
The Cliffs	Palo Pinto	1820061	Final List	
City of Beckville	Panola	1830002	Final List	
Windermere Water System	Travis	2270161	Final List	
City of Granger	Williamson	2460002	No Desal	
Twin Cove Resort	Zapata	2530024	Inactive/Dissolved	
Central Texas WSC	Bell	0140161	Future RO	
Sylvester-McCaulley WSC	Fisher	0760012	Future RO	

Table D2. Small desalination facilities from TCEQ list

Public water system name	County	PWS ID	Survey status	Total Production as Provided by TCEQ (MGD)
Saint Albans Episcopal Church	Travis	2270281	<0.025	0.024
Back To Basic Christian Day Care	Brazoria	0200509	<0.025	0.022
Blue Nile Water Co	Midland	1650114	<0.025	0.022
Speedy Stop 46	Victoria	2350044	<0.025	0.018
Mullin ISD	Mills	1670013	<0.025	0.017
BP America Production Company Crane Gas Plant	Upton	2310029	<0.025	0.016
Old Ocean Federal Credit Union	Brazoria	0200507	<0.025	0.014
Circle K 2157	Live Oak	1490028	<0.025	0.014
Midland Coating Plant B	Midland	1650109	<0.025	0.014
Water Wagon Water Hauling Service	Tom Green	2260091	<0.025	0.014
Austin Waldorf School Inc	Travis	2270254	<0.025	0.014
Cummins Southwest Inc	El Paso	0710164	<0.025	0.006
International Family Missions	El Paso	0710161	<0.025	0.002
TPWD Parrie Haynes Youth Ranch	Bell	0140159	<0.025	0.000
Genes Country Store	Brazoria	0200559	<0.025	0.000
Plateau Truck & Auto Center	Culberson	0550016	<0.025	0.000
Collier Water Store	Ector	0680206	<0.025	0.000
Vista Montana Court	El Paso	0710086	<0.025	0.000
Jackies Exxon	Gaines	0830021	<0.025	0.000
American Spring Wire Corp	Harris	1013137	<0.025	0.000
City of Hubbard	Hill	1090002	<0.025	0.000
Windmill Farms	Kaufman	1290043	<0.025	0.000
Acuff Steak House	Lubbock	1520120	<0.025	0.000
Pinkies Mini Mart 53	Lubbock	1520135	<0.025	0.000
Bunny Ranch	Lubbock	1520138	<0.025	0.000
Petes Drive In 4	Lubbock	1520184	<0.025	0.000
Pinkies Mini Mart 51	Lubbock	1520204	<0.025	0.000
Water Tech Inc	Midland	1650105	<0.025	0.000
Ranger Station	Midland	1650112	<0.025	0.000

NOTE: Facilities on this table were not contacted

Table D3. IDA inventory of Texas desalination facilities sorted by decreasing capacity (from Wangnick, 2002). Municipal facilities have an orange (dark) background; power facilities have a yellow (light) background. Key is at bottom of table.

Location	County	Total capacity (MGD)	Units	Process	Customer	Water quality	User
Brazos River		5.749	3	RO	City	RIVER	MUNI
Harlingen		4.927	4	RO	Fruit of the Loom	WASTE	INDU
Denison	Grayson	4.500	3	ED	Texoma Utility	RIVER	MUNI
Unknown Facility		4.079	4	ED		PURE	INDU
Eugene		3.910	1	RO		WASTE	INDU
Unknown Facility		3.500	3	ED		RIVER	MUNI
Brazos River		3.500	4	ED	River Authority	RIVER	MUNI
Seymour	Baylor	3.012	2	RO	City	BRACK	MUNI
Ft. Stockton	Pecos	3.000	2	RO	Pecos Country	BRACK	MUNI
Unknown Facility		2.457	9	RO		PURE	INDU
Texas City	Galveston	2.160	2	MSF	Union Carbide	BRACK	INDU
Freeport	Brazoria	2.016	3	RO		RIVER	INDU
Robinson	McLennan	2.000	1	RO	City of Robinson	BRACK	MUNI
Harlingen		2.000	2	RO	Waterworks	RIVER	MUNI
Dallas	Dallas/Collin/Denton	1.876	1	RO	Texas Instruments	BRACK	INDU
Unknown Facility		1.836	3	RO		PURE	INDU
Unknown Facility		1.685	5	RO		PURE	INDU
Choco Bayou		1.584	1	RO	Oxichem	RIVER	INDU
Unknown Facility		1.501	1	ED		BRACK	
Unknown Facility		1.500	5	RO		PURE	DEMO
Unknown Facility		1.500	5	RO		PURE	INDU
Unknown Facility		1.500	1	ED		RIVER	MUNI
Freeport	Brazoria	1.400	1	RO	Dow	RIVER	INDU
Dallas	Dallas/Collin/Denton	1.189	1	RO		WASTE	INDU
Corpus Chris	Live Oak	1.152	2	RO		BRACK	INDU

Location	County	Total capacity (MGD)	Units	Process	Customer	Water quality	User
Texas City	Galveston	1.152	1	RO		RIVER	INDU
Unknown Facility		1.152	4	EDI			INDU
Austin	Travis/Williamson	1.112	3	RO		PURE	INDU
Austin	Travis/Williamson	0.976	3	RO		PURE	INDU
Freeport	Brazoria	0.925	1	ME	US DOI	SEA	MUNI
El Paso	El Paso	0.872	2	RO	Chevron	RIVER	INDU
Unknown Facility		0.864	3	HYBRID		PURE	INDU
Unknown Facility		0.864	2	RO		RIVER	INDU
Big Spring	Howard	0.864	1	RO		WASTE	INDU
Texarkana	Bowie	0.864	1	VC	International Paper	WASTE	INDU
Martin Lake		0.864	1	VC	Utilities	WASTE	POWER
Lubbock	Lubbock	0.860	2	RO		BRACK	INDU
Austin	Travis/Williamson	0.824	4	RO		PURE	INDU
Texarkana	Bowie	0.806	1	VC	International Paper	WASTE	INDU
Gregory	San Patricio	0.792	1	RO	Ferguson	BRACK	INDU
Austin	Travis/Williamson	0.756	1	RO	IBM	BRACK	INDU
Martin Lake		0.721	1	RO	Utilities	WASTE	POWER
Monticello		0.721	1	RO	Texas Utilities	WASTE	POWER
Dallas	Dallas/Collin/Denton	0.720	1	RO	Texas Instruments	BRACK	INDU
Totum		0.700	3	RO	Texas Utility	BRACK	POWER
Dallas	Dallas/Collin/Denton	0.608	1	RO		WASTE	INDU
Guadalupe		0.581	1	VC	TIE	WASTE	POWER
Texas City	Galveston	0.576	1	RO		BRACK	INDU
Choco Bayou		0.576	1	RO		RIVER	INDU
Deer Park		0.576	1	RO		RIVER	INDU
Three Rivers	Live Oak	0.576	2	RO		WASTE	INDU
Unknown Facility		0.549	2	EDI		PURE	INDU
Stafford	Fort Bend/Harris	0.546	2	RO	Texas Instruments	BRACK	INDU

Location	County	Total capacity (MGD)	Units	Process	Customer	Water quality	User
Unknown Facility		0.528	1	RO		PURE	INDU
San Marcos	Comal/Bexar	0.528	2	VC	ANP	WASTE	POWER
Dallas	Dallas/Collin/Denton	0.527	2	RO	Mostek	BRACK	INDU
Unknown Facility		0.518	1	ED	Semiconductor	PURE	INDU
Corpus Christi	Live Oak	0.505	1	RO	Oxichang	RIVER	INDU
Texas City	Galveston	0.504	1	RO		BRACK	INDU
Carrollton	Denton/Dallas/Collin	0.480	1	RO		BRACK	INDU
Bremond	Robertson	0.464	2	VC	Zachry	BRINE	INDU
Kenedy	Bee/Karnes	0.461	1	RO	City	BRACK	MUNI
Kenedy	Bee/Karnes	0.461	1	RO	City	RIVER	INDU
Irving	Dallas	0.460	1	RO		BRACK	INDU
Unknown Facility		0.432	1	EDI		PURE	INDU
Glenrose	Somervell	0.432	2	RO		BRACK	POWER
Unknown Facility		0.432	1	ED		BRACK	
Conroe	Montgomery	0.432	1	RO		BRACK	INDU
Comanche Peak	Comanche	0.432	1	RO	Texas Utility	RIVER	POWER
El Paso	El Paso	0.432	1	RO	Power	RIVER	POWER
Carrollton	Denton/Dallas/Collin	0.431	2	RO		BRACK	INDU
Odessa	Midland/Ector	0.400	1	ME	Tire & Rubber	WASTE	INDU
El Paso	El Paso	0.400	1	RO	El Paso Electricity	BRACK	POWER
Unknown Facility		0.383	1	RO		BRACK	INDU
Unknown Facility		0.374	1	ED		RIVER	MUNI
Irving	Dallas	0.367	1	RO		BRACK	INDU
Round Rock	Travis/Williamson	0.360	1	RO		BRACK	INDU
Monticello		0.360	1	VC	Utilities	WASTE	POWER
Deer Park	Harris	0.360	1	RO		BRACK	INDU
Jacksonville	Cherokee	0.360	1	RO	Electric Auth.	BRACK	POWER
Houston	Harris	0.359	2	RO	Houston Lighting	BRACK	POWER

Location	County	Total capacity (MGD)	Units	Process	Customer	Water quality	User
Morgan Creek		0.338	1	RO	Tugco	BRACK	INDU
Mt. Pleasant	Titus	0.335	1	RO		BRACK	INDU
Lubbock	Lubbock	0.325	1	RO		BRACK	INDU
Unknown Facility		0.317	1	ED		BRACK	INDU
Sherman	Grayson	0.317	2	RO	Texas Instrument	RIVER	INDU
Matagorda	Matagorda	0.317	2	RO	Light & Power	BRACK	POWER
Unknown Facility		0.309	1	ED		WASTE	IRR
Dallas	Dallas/Collin/Denton	0.305	1	RO	Mostek	BRACK	INDU
Kenedy	Bee/Karnes	0.300	1	RO	City	BRACK	MUNI
Brownsville	Cameron	0.291	1	MSF	Union Carbide	SEA	INDU
Unknown Facility		0.288	1	ED		BRACK	INDU
Unknown Facility		0.288	1	ED		BRACK	INDU
Unknown Facility		0.288	1	ED		BRACK	INDU
Unknown Facility		0.288	1	ED		BRACK	INDU
Unknown Facility		0.288	1	RO		BRACK	INDU
Austin	Travis/Williamson	0.288	1	RO		BRACK	INDU
Dallas	Dallas/Collin/Denton	0.288	1	RO	Texas Instruments	BRACK	INDU
Sherman	Grayson	0.288	1	RO	Folgers Coffee	BRACK	INDU
EI Paso	El Paso	0.288	1	RO	Electric Co	BRACK	POWER
Unknown Facility		0.250	1	ED		BRACK	MUNI
Irving	Dallas	0.230	1	RO		BRACK	INDU
Irving	Dallas	0.230	1	RO		BRACK	INDU
Irving	Dallas	0.230	1	RO		BRACK	INDU
Dallas	Dallas/Collin/Denton	0.217	1	RO	TW-Electric	BRACK	INDU
EI Paso	El Paso	0.217	1	VC	Asarco	WASTE	INDU
Dallas	Dallas/Collin/Denton	0.217	1	RO	TW-Electric	BRACK	POWER
Carrollton	Denton/Dallas/Collin	0.216	1	RO	Mostek	BRACK	INDU
Bruni	Webb	0.216	1	RO		WASTE	INDU

Location	County	Total capacity (MGD)	Units	Process	Customer	Water quality	User
Gary	Panola	0.216	1	RO	Municipality	BRACK	POWER
Austin	Travis/Williamson	0.202	1	RO	Motorola	BRACK	INDU
Unknown Facility		0.202	1	RO	Sid Richardson	RIVER	INDU
Unknown Facility		0.200	1	ED		BRACK	INDU
Austin	Travis/Williamson	0.200	1	RO	Motorola	BRACK	INDU
Waco	McLennan	0.185	1	RO	TU Electric	RIVER	INDU
Irving	Dallas	0.184	1	RO		BRACK	INDU
Irving	Dallas	0.184	1	RO		BRACK	INDU
Irving	Dallas	0.184	1	RO		BRACK	INDU
Dayton	Liberty	0.173	1	RO	Power & Light	BRACK	POWER
Round Rock	Travis/Williamson	0.173	1	RO		BRACK	INDU
San Antonio	Comal/Bexar	0.173	1	RO		BRACK	INDU
Grand Prairie	Dallas/Ellis/Tarrant	0.160	1	ME		SEA	INDU

Key to table:

Process		**Equipment**		**Feature**		**Quality**	
ED	Electrodialysis	FLASH	Flash evaporator	EDR	ED Reversal	BRACK	3,000<TDS<20,000
EDI	Electroionization	FM	Flat membrane	ER	Energy recovery in RO plants	BRINE	TDS>50,000
HYBRID	Hybrid process	HFM	Hollow fiber membrane	MVC	Mechanical vapor compression	PURE	TDS<500
ME	Multieffect evaporation	MTU	Membrane type unknown			RIVER	TDS<3,000
MSF	Multistage flash	OTHER	All other equipment			SEA	20,000<TDS<50,000
RO	Reverse osmosis	ST	Submerged tube evaporator			WASTE	
VC	Vapor compression	SWM	Spiral wound membrane				
		VTE	Vertical tube falling film evaporator				

Table D4. Summary of survey results

Facility category	Number	Comments
Total number of PWS facilities contacted	105	
Description of subsets of facilities contacted		
Accepted in final list (≥0.025 MGD)	38	Total desalination design capacity for Texas PWS is 52.3 MGD (see Table 2-1)
Future RO	4	Those contacted facilities have been added to Table 4-5
Inactive/Dissolved	18	The capacity of those inactive/dissolved facilities we contacted amount to ~0.15 MGD. However, summing up total production of currently inactive/dissolved facilities from TCEQ list yields 50 MGD of mostly industrial facilities, including 31.4 MGD for the Harlingen Waterworks System, 11.7 MGD for the DEFS Goldsmith East Plant, and 4 MGD for the Freeport McMoran Sulphur Inc. plant.
Industrial	5	The capacity of those mostly industrial facilities we contacted amount to <1. Summing up total production from TCEQ list yields 13 MGD, most of it due to a single plant (11.7 MGD for the DEFS Goldsmith Plant). Compared with that of other similar installations, this number is extremely high.
No desalination	12	We contacted those facilities because we had reasons to believe that they have had desalination at some point in time.
No response	9	We were unable to gather data from those, mostly small, facilities. Six out of the nine facilities have a cumulative total capacity of 0.35 MGD (from TCEQ list). We estimate ther cumulative capacity to be >0.35 and <0.5[c]
<0.025MGD	19	We called those facilities because the TCEQ list suggested they all were above the threshold of 0.025 MGD. Summing up total production from the TCEQ list yields 1.5 MGD, a large overestimation of the numbers gathered by the survey (~0.14 MGD).
SUM	*105*	
Facilities <0.025MGD and not contacted	29	They amount to <0.2 MGD. This number, computed from the initial TCEQ list, represents a very conservative upper bound as suggested by the small facilities we did call and because it is not clear how much blending is done.

D.2 Revisiting Earlier Datasets

A comparison with data from Mickley (2001), displayed in Table D5, will give a time dimension to this study because the Mickley (2001) survey was performed in 1999. Figure 4-6 confirms that desalination design capacity has more than doubled since that time. In addition, cumulative design capacity of these 11 plants increased from 17.8 MGD to >20 MGD. These results are also graphically displayed in Figure D1. This figure shows that, although some plants havre increased their production or are unchanged, a few have possibly decreased theirs.

Table D5. Comparison of results with those of Mickley's study (2001)

	Mickley (2001) study			**This study**		
Plant name (county)	**Design desalination capacity**	**Average Production**	**With bypass**	**Design desalination capacity**	**Average production**	**Total production**
City of Sherman (Grayson)	6.	5.5	10	7.5	3.	10.
Lake Granbury (Hood)	7.5	5	7.5	6.	1.8	10.
Harlingen Waterworks System (Cameron)	4.	3	4	N/A	N/A	N/A
City of Fort Stockton (Pecos)	3.	2	6.5	6.	4.5	7.
City of Granbury (Hood)	0.62	0.278	0.343	0.11	0.09	0.55
Sportsmans World (Palo Pinto)	0.144	0.04[A]	0.144[A]	0.083	0.05	0.083
Oak Trail Shores (Hood)	0.14	0.144	0.25	0.792	0.4	1.849
Dell City (Hudspeth)	0.10	0.10	0.10	0.10	0.05	0.10
Haciendas Del Norte (El Paso)	0.08	0.08	0.16	0.05	0.04	0.23
River Oaks Ranch (Hays)	0.076	0.069	0.076	0.144	0.04	0.144
Esperanza (Hudspeth)	0.058	0.059	0.086	0.023	0.023	0.056
Big Bend Motor Inn (Brewster)	0.05	0.03	0.3	0.072	0.041	0.072

NOTE: All capacity and production values in MGD
[A]Mickley (2001) gave 0.04 MGD total capacity with bypass and 0.144 MGD for average production. Values were switched in agreement with our own results.

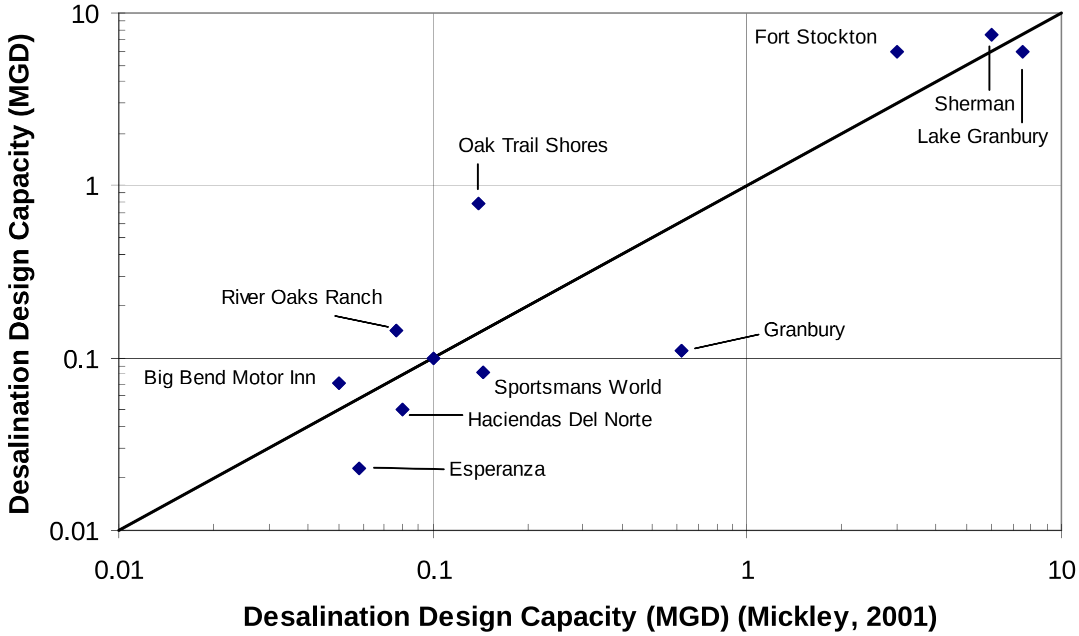


Figure D1. Comparison of desalination design capacity compiled during this study (y-axis) and Mickley's study (2001) (x-axis)

Attachment E: Road Map for Survey of Industrial Facilities

Industrial processes are extremely diverse and varied. They relate to brackish/seawater desalinations in several ways: membranes are used throughout most industrial processes that deal with fluids (liquids and gas). Membranes can treat a multitude of industrial fluids (milk, wastewaters, gases). Membrane material and structure are much more diverse than the ones typically used for public water supplies. Brackish/seawater is used as input for some industries, but wastewater is a more common occurrence.

Desalination needs for industrial facilities fall into three broad categories: steam generation for power, heating and other related needs, feedwater for the beverage and food industry, and demineralized, ultrapure water needs for the microelectronics industry. Of the three categories, feedwater for the beverage and food industry is the closest to that of municipal facilities because it is also generated for human consumption. Ultrapure water generation is the most remote to municipal needs because the process often starts with municipal tap water.

The procedure to collect data about industrial desalination facilities can follow two paths: a systematic regulatory approach as described in Section 5.2 or a more opportunistic methodology as detailed below. Because it was not feasible to contact all industrial desalination facilities in the course of this study, we established the following approach:

1) learning about relevant industrial processes (through literature search and personal contacts in the industries) and making a judgment call on whether the water treatment component was similar to that of public water supply desalination units,
2) contacting trade groups and associations to find out how many units might exist in Texas, and
3) surveying larger units or contacting the corporate office of important players in relevant industries.

For example, the soft drink industry clearly needs water as a raw product. Water is often desalted and altered by ion exchange or membrane processes during production, as a function of feedwater quality. With information about the industrial process and knowledge of the number and size of bottling plants, size and number of desalination units can be estimated. Beer and food industries could follow a similar process. Surveying the power industry requires, again, a basic understanding of where and why desalination/desalting units are needed and knowledge of number and size of facilities.

E.1 Desalination in Industrial and Other Facilities

E.1.1 Steam Generation

Makeup water for boilers represents one of the most widespread uses of steam in Texas. The power industry generates a large amount of pressurized steam to feed electricity-generating turbines for general distribution to the public. In addition, many large industrial sites do not rely on the power grid to meet their energy requirements, but instead generate electricity on site, thus requiring boilers and desalination units in most instances. Besides, many types of industrial facilities such as chemical plants, oil refineries, paper-production plants, or food-processing plants, often produce steam for heating or for mechanical drive. Other large entities, such as university campuses, also use steam for heating. Many facilities produce steam for both uses. Steam is generated through the use of hydrocarbon or nuclear fuel. Ideally, the same water would be constantly recycled after being initially vaporized and then condensed after use; however, periodic blowdowns and purges require that new water be added to the cycle at a rate between 4 and 8 percent, or sometimes higher, of the boiler feedwater.

In general quality of the water that must be maintained is a function of operating pressure (Scott, 1995, p. 541). The higher the operating pressure, such as in turbines, the more stringent the requirements. High-pressure boilers also have lower blowdown ratio requirements, as low as 1 percent, because the makeup water is of better quality to start with. Boiler makeup water is traditionally either softened by ion exchange or demineralized by both cation and anion exchange. In the latter case, depending on the initial TDS of the feedwater, an initial NF/RO treatment is also often done. For example, The University of Texas at Austin power station produces ~360,000 pounds of steam per hour, has a combined capacity ~100 MW, and also generates steam for heating. Boilers require a total of ~0.06 MGD on annual average. City of Austin Utilities tap water (TDS of 250–300 ppm) provides the raw water. It goes through a sponge filter, is dechlorinated, and then is acidified to a pH of 5.5. A reverse osmosis membrane then brings the permeate conductivity to 10 μScm^{-1} (equivalent to a TDS of 1–5 ppm). The treatment finishes with gas removal, followed by cation and anion exchange (resins exchanging cations for H^+ and anions for OH^-). The conductivity of the final boiler makeup water is ~0.1 μScm^{-1} (~0.05 ppm). Gas removal, especially for O_2, is an important part of the process. This procedure is fairly typical (Scott, 1995). Other facilities use fresh or brackish surface or groundwater, seawater, or wastewater as raw water. The general trend of the industry is to improve water quality to minimize blowdowns.

Throughout the course of this study another power facility operator was interviewed. The TMPA Gibbons Creek power plant has a nominal power of 420 MW. It consumes ~0.1 MGD (including ~0.003 MGD for drinking water). The water TDS after desalination unit is 5 ppm. Feedwater at ~250 ppm is drawn from a dedicated surface water body. Feedwater follows a conventional but intensive pretreatment with filtration, coagulation-flocculation-clarification, and chlorination.

Most electricity in the U.S. and Texas is produced by steam turbines, in which the heat released by burning fuel (coal, natural gas, oil, waste products) or nuclear fission reactions produces steam in a boiler. The steam is then directed to turbines for electricity to be produced. Steam turbines constitute the bulk of the base loads of electric utilities. Approximately 75 percent (60 and 15 percent for organic and nuclear fuel, respectively), of the generating capacity currently needed by the country is provided. In generally smaller gas/combustion turbines, combustion products contact turbine blades directly, with no need for steam generation. It covers 8 percent of the country's needs, and most of the remainder is covered by hydraulic turbines.

The Department of Energy/Energy Information Agency** (DOE/EIA) compiles data for energy sources and use across the country. DOE/EIA (2002 and 2003) provided an exhaustive list of utility and nonutility power plants as of December 31, 2000. Installed power-generation capabilities for utilities (nonutilities) in the U.S. and in Texas are ~600,000 MW (210,000 MW) and 65,000 MW (19,000 MW), respectively (Table 17 of DOE/EIA, 2002, and Tables 1 and 8 of DOE/EIA, 2003). Approximately 43 (26) and 30 (2) percent is coal-based, respectively. In Texas, almost 60 (90) percent of facilities are natural-gas capable. An additional 38,000 MW was scheduled at the time to be operational by 2005. Few facilities use oil as a primary energy source.

The petroleum refining and chemical manufacturing industry also consumes a lot of steam, in addition to its power and heating requirements (DOE/OIT, 2004). These are used in distillation or fractionating towers, where different components of crude oil or other feedstock are separated. For example, chemical sites that have ethylene (olefins) plants generate a lot of steam but are also huge consumers (usually net importers of steam) owing to their refrigeration requirements for high purity separation of ethylene and propylene (Doug Kelly, personal communication). As indicated by the numerous small units present in West Texas, field-water needs during oil and gas production may also require desalination units. The pulp and paper industry makes use of steam as well, particularly to dry paper products. Specialty paper plants use makeup water at a particularly high rate.

E.1.2 Beverage and Food Industry

The beverage and food industry makes extensive use of membranes in its processes (Pepper, 1990; Cuperus and Nijhuis, 1993). Most processes involve separating particles in suspension from the carrying fluid. The beverage industry comprises mainly carbonated and noncarbonated soft-drink facilities, carbonated and noncarbonated bottled-water facilities, and breweries. The soft drink and bottled water industry traditionally processes feedwater by deionization and ion exchange, and in some cases by distillation (evaporative process). However, bottlers are under increasing pressure to maintain quality standards, and there is a push in the industry to use more membrane treatment such as UF and RO. Given the diversity of the industry and of the processes involved, it is difficult to estimate the fraction of state beverage production that has undergone desalination.

E.1.3 Ultrapure Water Needs

The microelectronics industry typically uses ultrapure water to rinse off chemical substances between multiple etching steps of integrated circuit manufacturing. The Samsung Austin Semiconductor L.P. plant in Austin, Texas, has several RO systems that produce water of variable quality, but with a conductivity of 0.1 μScm^{-1} or less. The standard for the industry is a conductivity of 0.055 μScm^{-1} (Scott, 1995, p.540), equivalent to ~0.025 ppm. It is also equivalent to a resistivity of 18 Mohm.cm. The electrically neutral chemical species of oxygen and silica must also be removed at the ppb level, as well as contaminants. The general desalination unit flow chart is similar to that described in Section E.1.1. After passing through multimedia and cartridge filters, tap water is pushed through cellulose acetate RO membranes (thus, no need for dechlorination), and gas removal and cation and anion exchange follow. Desalination unit average production is ~1 MGD. Another contacted microelectronics facility, Cypress Semiconductor Corp. in Georgetown, Texas, follows the same flow chart.

The pharmaceutical industry also requires large amounts of ultrapure water for the manufacture of drugs and for preparation of injected treatments. The industry generally accepts water with a conductivity of 3 μScm^{-1} (~1 ppm).

E.2 Semiquantitative Estimation of Desalination Output in Industrial Facilities

E.2.1 Steam Generation

There is no easy way, short of calling the facility, to determine beforehand whether an industrial facility uses a membrane-based or thermal-process desalination in addition to ion exchange. In this section, we try to relate power capacity to desalination capacity with a few benchmark facilities. Although the facilities listed in Table D3 that are from the IDA inventory (Wangnick, 2002) undoubtedly overlap many facilities listed in Table E1 and Table E3 (from DOE/EIA, 2002), only 13 facilities can be clearly attributed to both. They are summarized in Table E4, and they are also displayed in Figure E1, where three other facilities that we contacted and interviewed (The University of Texas at Austin, Austin, TX; Samsung Austin Semiconductor L.P., Austin, TX; TMPA Gibbons Creek plant in Grimes County, TX) are added.

In Figure E1, four facilities outside the general trend (top line) with high desalination capacity and low power capacity are, from the top down, the Union Carbide Texas City plant, International Paper Texarkana mill, Solutia/Monsanto Chocolate Bayou plant, and Fina Big Spring Refinery. The straight line is described by the equation Desal(MGD)=4.6×10^{-4} × Power(MW) + 0.32. The two utilities known to produce steam mainly for electricity production yield the following equation (bottom straight line in Figure E2): Desal(MGD)=1.9×10^{-4} × Power(MW).

Extrapolation from the two utility data points (Comanche Peak nuclear power plant in Somervell County and TMPA Gibbons Creek facility) yields a desalination capacity for power generation of $\sim 1.9\times10^{-4} \times 60{,}000$(MW) = 12 MGD for 94 utilities. A major assumption is that all facilities practice some kind of desalination. However, preliminary research shows that an unknown fraction of these facilities do only water softening and/or ion exchange. The 68 nonutility facilities add another 15 to 30 MGD through nonpower generation. Extrapolating from the straight line derived in the previous paragraph yields $4.6\times10^{-4} \times 19{,}000$(MW) + 0.32 = 9 MGD, which clearly underestimates desalination capacity because steam is used for more than electricity production in nonutility facilities. These applications may, however, not need water quality as high as required for the turbines. It should also be noted that facilities do not work at 100 percent of their capacity all the time. This fact adds another layer of uncertainty to the calculation.

A similar conclusion can be reached by comparing results from water-use surveys and power-utility capacities in each county, as presented in Figure E2. It shows that an approximation of desalination needs is 61,800 MW × 0.0048 × 5% = 15 MGD.

Another approach to derive these approximations is to assume a blowdown ratio of 5 percent over all facilities. Total steam-electric water demand for the state in 2000 was 607,000 AFY (TWDB, 2002), that is, ~540 MGD, which translates to 540 × 0.05= 27 MGD. This number may also include some cooling water. In some states, steam condensing is done with a secondary closed loop that includes cooling towers. Heat is rejected by allowing some cooling water to evaporate in the cooling towers. However, in Texas, when large bodies of water are available, water is circulated against the stream flux in a once-through system, is returned to the source, and is thus not consumed. This water is separate from the steam cycle and typically does not go through a desalination process, but a simpler treatment instead.

E.2.2 Beverage and Food Industry

Beverage and food industry water requirements are process-dependent. The Folgers coffee plant in Grayson County is cited in Wangnick (2002) with an RO capacity of 0.288 MGD and with brackish water as feed. The Austin, Texas, Coca Cola plant operator interviewed does not use desalination, but, as already mentioned, the responsible engineer noted that there is a move in the industry toward RO. Table E6, Table E7, and Table E8 list more than 500 companies representing several thousands of facilities. Desalination requirements can be separated into two categories: pure water needed strictly for the process and pure water needed as raw material. In the latter case, the following assumptions are made:

- Only 20 percent of the beverage industry uses feedwater desalination. Intermediate membrane and other manufacturing separation processes are not included.
- All desalinated water ends up on a store shelf, albeit with further processing, such as addition of juice concentrate.
- There is no net export or import of beverages.
- The population of Texas is ~20 million people.
- Each Texan consumes ¼ gallon a day of processed beverages.

Therefore, a very approximate value of desalination production for raw material of 1 MGD may be computed. Actually, given that a single plant needs >25 percent of this amount for purely manufacturing processes, the total desalination capacity of the beverage and food industry is most likely dominated by manufacturing needs, not raw material demand.

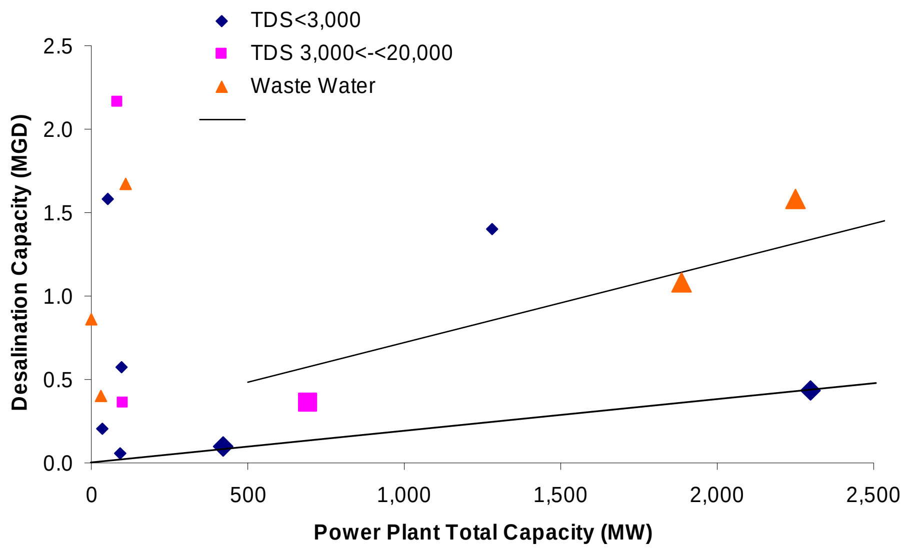
E.2.3 Ultrapure Water Needs of the Semiconductor and Pharmaceutical Industries

Although ultrapure water requirements are more uniform in this section than in previous sections, there is no easy way to correlate plant size and/or manufacturing numbers to desalination production. Collecting disparate information compiled from a few microelectronics plants yields ~1 MGD for the Austin Samsung plant (interview) and the following values for those facilities listed in Wangnick (2002) in Table E10: a total of ~3.75 MGD for five Texas Instrument plants in Dallas, Houston, and Sherman; 0.76 MGD for the now-closed Austin IBM manufacturing unit; a total of ~1 MGD for three Dallas Mostek facilities; and 0.4 MGD for two Austin Motorola facilities. These total ~6 MGD for 5 of the 27 microelectronics companies listed in Table E11. It is then reasonable to assume that ultrapure water needs for the electronics industry in Texas are bracketed by 15 and 30 MGD.

The pharmaceutical industry also requires ultrapure water in some of its manufacturing processes. These plants are more numerous, smaller, and more likely to be less demanding in desalted water than those of the microelectronics industry. It is difficult to estimate their water needs other than by interviewing representatives of a selection of the facilities listed in Table E9, but most likely they are <10 MGD.

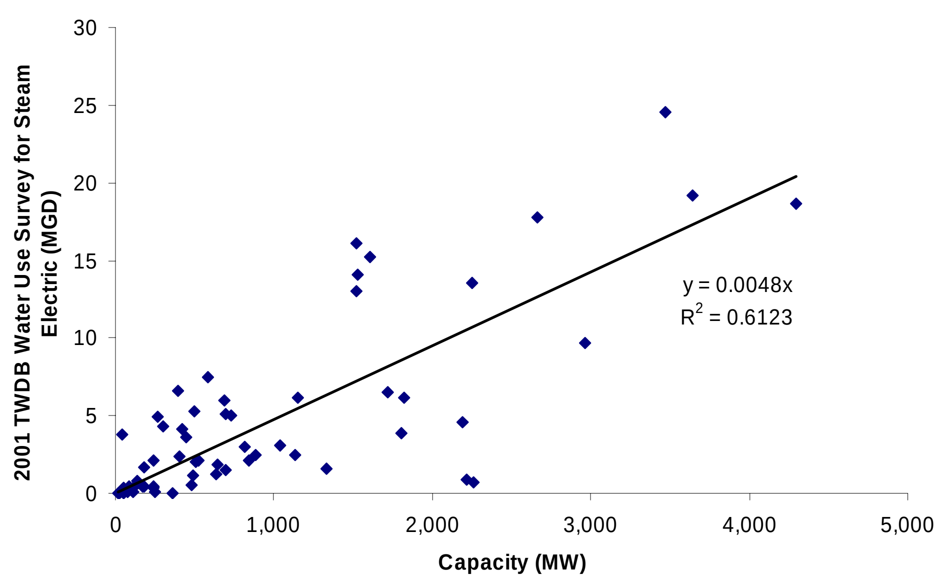
E.2.4 Water Needs from Other Industries

Wangnick (2002) also listed a few other industries with RO units. The textile industry is, for example, a consumer of desalinated water. A garment plant in Harlingen, Texas (see Filteau et al., 1995) is listed as having one of the largest desalination facilities in the state at ~ 5 MGD, with wastewater as feedwater (this plant was decommissioned in 2004), and, therefore, desalination of wastewater is a common occurrence. Evaporation-based processes become competitive relative to RO when water TDS increases. The paper industry is a voracious consumer of steam (two International Paper mills desalinate ~0.8 and ~0.85 MGD of wastewater through a vapor compression process). It is unclear whether these numbers are already included in the steam generator data described in an earlier section.



Source: DOE/EIA (2002 and 2003); Wangnick (2002); this work
NOTE: Larger symbols represent utilities; smaller symbols represent nonutilities. Top straight line represents linear fit to all points except the anomalous four with the highest desalination capacity. The line does not go through the origin because not all steam production is used for generating electricity. Bottom straight line represents linear fit through the two facilities known to use most, if not all, desalinated water for electricity production (Comanche Peak and Gibbons Creek plants).

Figure E1. Regression plot showing relationship between power and desalination capacity of selected power facilities



Source: TWDB 2001 Water Use Survey Summary for Counties; DOE/EIA (2002)
NOTE: Brazos, Matagorda, and Somervell Counties were not included in the regression

Figure E2. Crossplot of water use and power capacity for electrical utilities

Table E1. Electricity generation summary statistics

	Number of plants	Nameplate capacity (MW)
Utilities		
Fossil steam	93	58,495
Nuclear	2	5,139
Gas turbine	22	3,481
Hydroelectric	26	659
Other	18	142
Nonutilities		
Fossil steam		
Gas turbine		

Source: Table E2 from DOE/EIA (2002)
NOTE: Sum of plants is larger than total number of sites because each type of primary mover at a site is counted as a separate plant

Table E2. Inventory of electric utility power plants in Texas in 2000 using steam process as primary mover. Utilities are sorted by company. Key is below.

Energy source		**Primary mover type**	
BIT	Bituminous coal	ST	Steam turbine
DFO	Distillate fuel oil	Comb	Combined cycles. They include (from source nomenclature): **CA**=Combined Cycle Steam Part; **CS**=Combined Cycle Single Shaft (combustion turbine and steam turbine share a single generator); and **CT**=Combined Cycle Combustion Turbine Part (type of coal must be reported as energy source for integrated coal);
LIG	Lignite		
NG	Natural gas		
NUC	Nuclear		
SUB	Subbituminous coal		

Company	Plant (county)	Energy source	Net summer capacity (MW)	Primary mover type
Texas total			**65,383**	
Steam primary mover subtotal			**61,835**	
Austin Energy	Decker Creek (Travis)	NG	764	ST
Austin Energy	Holly Street (Travis)	NG	569	ST
Brazos Electric Power Coop Inc	North Texas (Parker)	NG	76	ST
Brazos Electric Power Coop Inc	R W Miller (Palo Pinto)	NG	403	ST
Brownsville Public Utils Board	Si Ray (Cameron)	NG	38	ST
Bryan City of	Bryan (Brazos)	NG	109	ST
Bryan City of	Dansby (Brazos)	NG	110	ST
Central Power & Light Co	Barney M Davis (Nueces)	NG	697	ST
Central Power & Light Co	Coleto Creek (Goliad)	BIT	632	ST
Central Power & Light Co	E S Joslin (Calhoun)	NG	249	ST
Central Power & Light Co	J L Bates (Hidalgo)	NG	182	ST
Central Power & Light Co	La Palma (Cameron)	NG	206	ST
Central Power & Light Co	Laredo (Webb)	NG	174	ST
Central Power & Light Co	Lon C Hill (Nueces)	NG	545	ST
Central Power & Light Co	Nueces Bay (Nueces)	NG	559	ST
Central Power & Light Co	Victoria (Victoria)	NG	482	ST
Denton City of	Spencer (Denton)	NG	179	ST

Company	Plant (county)	Energy source	Net summer capacity (MW)	Primary mover type
El Paso Electric Co	Newman (El Paso)	NG	266	ST
El Paso Electric Co			232	Comb
Entergy Gulf States Inc	Lewis Creek (Montgomery)	NG	520	ST
Entergy Gulf States Inc	Neches (Jefferson)	NG	265	ST
Entergy Gulf States Inc	Sabine (Orange)	NG	1,824	ST
Garland City of	C E Newman (Dallas)	NG	92	ST
Garland City of	Ray Olinger (Collin)	NG	335	ST
Greenville Electric Util Sys	Powerlane Plant (Hunt)	NG	89	ST
Lower Colorado River Authority	Fayette Power PRJ (Fayette)	SUB	1,605	ST
Lower Colorado River Authority	Sim Gideon (Bastrop)	NG	1,040	ST
Lubbock City of	J Robert Massengale (Lubbock)	NG	23	ST
Lubbock City of			84	Comb
Lubbock City of	Ty Cooke (Lubbock)	NG	104	ST
Medina Electric Coop Inc	Pearsall (Frio)	NG	75	ST
Reliant Energy HL&P	Cedar Bayou (Chambers)	NG	2,260	ST
Reliant Energy HL&P	Deepwater (Harris)	NG	178	ST
Reliant Energy HL&P	Greens Bayou (Harris)	NG	406	ST
Reliant Energy HL&P	Limestone (Limestone)	LIG	1,532	ST
Reliant Energy HL&P	P H Robinson (Galveston)	NG	2,213	ST
Reliant Energy HL&P	Sam Bertron (Harris)	NG	808	ST
Reliant Energy HL&P	South Texas (Matagorda)	NUC	2,500	ST
Reliant Energy HL&P	T H Wharton (Harris)	NG	229	ST
Reliant Energy HL&P			664	Comb
Reliant Energy HL&P	W A Parish (Fort Bend)	SUB/NG	3,641	ST
Reliant Energy HL&P	Webster (Harris)	NG	374	ST
San Antonio Public Service Bd	A Von Rosenberg (Bexar)	NG	482	Comb
San Antonio Public Service Bd	J K Spruce (Bexar)	SUB	555	ST
San Antonio Public Service Bd	J T Deely (Bexar)	SUB	830	ST
San Antonio Public Service Bd	Leon Creek (Bexar)	NG	160	ST
San Antonio Public Service Bd	Mission Road (Bexar)	NG	100	ST
San Antonio Public Service Bd	O W Sommers (Bexar)	NG	880	ST
San Antonio Public Service Bd	V H Braunig (Bexar)	NG	865	ST
San Antonio Public Service Bd	W B Tuttle (Bexar)	NG	420	ST
San Miguel Electric Coop Inc	San Miguel (Atascosa)	NG	391	ST
South Texas Electric Coop Inc	Sam Rayburn (Victoria)	NG/DFO	25	ST
Southwestern Electric Power Co	Knox Lee (Gregg)	NG	479	ST
Southwestern Electric Power Co	Lone Star (Morris)	NG	50	ST
Southwestern Electric Power Co	Pirkey (Harrison)	LIG	580	ST
Southwestern Electric Power Co	Welsh (Titus)	LIG	1,584	ST
Southwestern Electric Power Co	Wilkes (Marion)	NG	882	ST
Southwestern Public Service Co	Celanese (Gray)	SUB	26	ST
Southwestern Public Service Co	Harrington (Potter)	SUB	1,066	ST
Southwestern Public Service Co	Jones (Lubbock)	NG	486	ST

Company	Plant (county)	Energy source	Net summer capacity (MW)	Primary mover type
Southwestern Public Service Co	Moore County (Moore)	NG	48	ST
Southwestern Public Service Co	Nichols (Potter)	NG	457	ST
Southwestern Public Service Co	Plant X (Lamb)	NG	444	ST
Southwestern Public Service Co	Tolk (Lamb)	SUB	1,080	ST
Texas Municipal Power Agency	Gibbons Creek (Grimes)	SUB	420	ST
Texas-New Mexico Power Co	TNP ONE (Robertson)	LIG	298	ST
TXU Electric Co	Big Brown (Freestone)	LIG	1,150	ST
TXU Electric Co	Collin (Collin)	NG	153	ST
TXU Electric Co	Comanche Peak (Somervell)	NUC	2,300	ST
TXU Electric Co	DeCordova (Hood)	NG	818	ST
TXU Electric Co	Eagle Mountain (Tarrant)	NG	674	ST
TXU Electric Co	Graham (Young)	NG	645	ST
TXU Electric Co	Handley (Tarrant)	NG	1,441	ST
TXU Electric Co	Lake Creek (McLennan)	NG	326	ST
TXU Electric Co	Lake Hubbard (Dallas)	NG	921	ST
TXU Electric Co	Martin Lake (Rusk)	LIG	2,250	ST
TXU Electric Co	Monticello (Titus)	LIG	1,885	ST
TXU Electric Co	Morgan Creek (Mitchell)	NG	844	ST
TXU Electric Co	Mountain Creek (Dallas)	NG	902	ST
TXU Electric Co	North Lake (Dallas)	NG	723	ST
TXU Electric Co	North Main (Tarrant)	NG	80	ST
TXU Electric Co	Parkdale (Dallas)	NG	330	ST
TXU Electric Co	Permian Basin (Ward)	NG	731	ST
TXU Electric Co	River Crest (Red River)	NG	110	ST
TXU Electric Co	Sandow (Milam)	LIG	444	ST
TXU Electric Co	Stryker Creek (Cherokee)	NG	693	ST
TXU Electric Co	Tradinghouse (McLennan)	NG	1,393	ST
TXU Electric Co	Trinidad (Henderson)	NG	244	ST
TXU Electric Co	Valley (Fannin)	NG	1,134	ST
West Texas Utilities Co	Abilene (Taylor)	NG	18	ST
West Texas Utilities Co	Fort Phantom (Jones)	NG	362	ST
West Texas Utilities Co	Lake Pauline (Hardeman)	NG	45	ST
West Texas Utilities Co	Oak Creek (Coke)	NG	85	ST
West Texas Utilities Co	Oklaunion (Wilbarger)	SUB	690	ST
West Texas Utilities Co	Paint Creek (Haskell)	NG	238	ST
West Texas Utilities Co	Rio Pecos (Crockett)	NG	98	ST
West Texas Utilities Co			43	Comb
West Texas Utilities Co	San Angelo (Tom Green)	NG	124	Comb

Source: DOE/EIA (2002)
NOTE: This is not the full inventory of electric utility power plants in Texas. Only facilities using steam process as primary mover included.

Table E3. Inventory of nonutility electric power plants in Texas in 2000 using steam process as primary mover. Utilities sorted by company. Key is below.

Energy source		**Primary mover type**	
AB	Agriculture byproducts	ST	Steam turbine
BL	Black liquor	Comb	Combined cycles. They include (from source nomenclature): **CA**=Combined cycle steam part; **CS**=Combined cycle single shaft (combustion turbine and steam turbine share a single generator); and **CT**=Combined cycle combustion turbine part (type of coal must be reported as energy source for integrated coal)
DFO	Distillate fuel oil		
LIG	Lignite		
NG	Natural gas		
OG	Other gases		
OTH	Other		
PC	Petroleum coke		
WDS	Wood/wood waste solids		

Company	Plant	Energy source	Net summer capacity (MW)	Energy type
Texas total			**16,512**	
Steam primary mover subtotal			**14,276**	
Abitibi Consolidated	Sheldon Texas	NG	76.1	ST
AES Corp	AES Deepwater Inc	PC	171.1	ST
Air Products & Chemicals Inc	Port Arthur	NG	34.9	Comb
Alcoa Inc	Sandow	LIG	336.6	ST
Alcoa World Alumina LLC	Pt Comfort Operations	NG	60.7	ST
BASF Corp	Freeport	NG	79.8	Comb
BP Amoco PLC	Power Station 3	NG	99.1	Comb
BP Amoco PLC	Power Station 4	NG	164.4	Comb
BP Chemicals-Green Lake	BP Chemicals Green Lake Plant	OG	36.1	ST
CalEnergy Co Inc	C R Wing Cogeneration Plant	NG	197.9	Comb
Calpine Corp	Pasadena Cogeneration LP	NG	654.4	Comb
Calpine Corp-Texas City	Texas City Cogeneration LP	NG	387.1	Comb
Carbide/Graphite Group Inc	Seadrift Coke LP	OG	7.1	ST
Celanese Engineering Resin Inc	Celanese Engineering Resin Inc	NG	37.7	Comb
Clear Lake Cogeneration LP	Clear Lake Cogeneration Ltd	NG	324.4	Comb
CoGen Funding LP	CoGen Lyondell Inc	NG	484.8	Comb
Denver City Energy Assoc LP	Mustang Station	NG	448.1	Comb
Donohue Inc	Lufkin Texas	NG	79.3	ST
Dow Chemical Co	The Dow Chemical Co Texas Operations	NG	1281.1	Comb
E I DuPont De Nemours & Co	Sabine River Works	NG	90.5	Comb
Encogen One Partner Ltd	Encogen One	NG	228.8	Comb
Engineered Carbons Inc	Engineered Carbons Borger Cogeneration	OG	27.9	ST
Fina Oil & Chemical Co	Big Spring Texas Refinery	NG	1.4	ST
Formosa Plastics Corp	Formosa Utility Venture Ltd	NG	528.8	Comb
Frontier Generation LP	Frontera Generation Facility	NG	439.4	Comb
Goodyear Tire & Rubber Co	The Goodyear Tire Rubber Co	NG	30	Comb
Gregory Power Partners LP	Gregory Power Facility	NG	399	Comb

Company	Plant	Energy source	Net summer capacity (MW)	Energy type
Grupo Mexico	ASARCO Inc El Paso TX	NG	4.7	ST
Guadalupe Power Partners LP	Guadalupe Generating Station	NG	982.4	Comb
Hidalgo Energy Center LP	Hidalgo Energy Center	NG	430	Comb
Imperial Sugar Co	Fort Bend Utilities Co	NG	5.8	ST
Ingleside Cogeneration LP	Ingleside Cogeneration	NG/OTH	454.1	Comb
Inland Container Corp	Inland Paperboard and Packaging	BL	46.1	ST
International Paper Co	Texarkana Mill	WDS/BL	108.6	ST
Lone Star Steel Co	Lone Star Steel Co	NG	31.8	ST
Midlothian Energy LP	Midlothian Energy Facility	NG	994	Comb
Minnesota Mining & Mfg Co	Central Utility Plant	DFO/NG	2	ST
Mirant Corp	Mirant Texas LP Bosque County Plant	NG	292.4	Comb
Mobil Oil Corp	Beaumont Refinery	NG	158.4	ST
Morton International Inc	Morton Salt Co Grand Saline	NG	1.4	ST
Motiva Enterprises LLC	Port Arthur Refinery	NG	24	ST
Motiva Enterprises LLC			85.1	Comb
Newgulf Power Venture Inc	Newgulf	NG	78.5	Comb
Norit Americas Inc	Norit Americas Inc Marshall Plant	LIG	1.8	ST
Owl Energy Resources Inc	Houston Chemical Complex Battleground Site	NG	171.9	Comb
Oxy Vinyls LP	Deer Park Plant	NG	94.9	Comb
Oyster Creek Ltd	Oyster Creek Unit VIII	NG	428.4	Comb
Panda Energy International Inc	Lamar Power Project	NG	938.2	Comb
Premcor Refining Group Inc	Port Arthur Refinery	NG	72.3	Comb
Reynolds Metals Co	Reynolds Metals Co Sherwin Plant	NG	33.5	Comb
Rhone-Poulenc Inc	Rhodia Inc Houston Plant	OTH	6.2	ST
Rio Grande Sugar Growers Inc	Rio Grande Valley Sugar Growers Inc	AB	7.1	ST
Rock-Tenn	Rock Tenn Dallas Mill	NG	6	ST
Sabine Cogen LP	Sabine Cogen LP	NG	87.3	Comb
Shell Oil Co-Deer Park	Shell Deer Park	NG	101	ST
Sid Richardson Carbon Ltd	Borger Plant	OG	34.9	ST
Simpson Paper Co	Pasadena Paper Company	NG	13.4	ST
Snider Industries Inc	Snider Industries Inc	WDS	4.7	ST
Solutia Inc-Chocolate	Chocolate Bayou Plant	NG	51.5	ST
Southern Energy Wichita Falls	Southern Energy Wichita Falls LP	NG	68.8	Comb
Tenaska Frontier Partners Ltd	Tenaska Frontier Generation Station	DFO/NG	821.1	Comb
Tenaska III Inc	Tenaska III Texas Partners	NG	215	Comb
Tenaska IV Texas Partners Ltd	Tenaska IV Texas Partners Ltd Cleburne Cogen	NG	243.1	Comb
Texas Petrochemicals Corp	Texas Petrochemicals Corp	NG	33.6	ST

Company	Plant	Energy source	Net summer capacity (MW)	Energy type
Union Carbide Corp-Seadrift	Seadrift Plant Union Carbide Corp	NG	144	Comb
Union Carbide Corp-Texas City	Texas City Plant Union Carbide Corp	NG	82.6	Comb
University of Texas at Austin	University of Texas at Austin	NG	5.5	ST
University of Texas at Austin			87.8	Comb
Valero Refining Co	Valero Refinery	OG/NG	60.2	ST
Westvaco Corp	Westvaco Evadale	BL	55	ST

Source: DOE/EIA (2003)

NOTE: This is not the full inventory of electric utility power plants in Texas. Only facilities using steam process as primary mover included

Table E4. Facilities described in both IDA and DOE/EIA inventories

Type[C]	Plant	Energy source[B]	Net summer capacity (MW)[B]	Primary mover type[B]	Capacity (MGD)[A]	Desalination process[A]	Feedwater[A]
U	Comanche Peak (Somervell)	NUC	2,300	ST	0.432	RO	River
U	Martin Lake (Rusk)	LIG	2,250	ST	1.585	VC/RO	Waste
U	Monticello (Titus)	LIG	1,885	ST	1.081	RO/VC	Waste
U	Stryker Creek (Cherokee)	NG	693	ST	0.36	RO	Brack.
N	The Dow Chemical Co Texas Operations	NG	1,281	Comb	1.4	RO	River
N	Big Spring Texas Refinery	NG	1.4	ST	0.864	RO	Waste
N	The Goodyear Tire Rubber Co	NG	30	Comb	0.4	ME	Waste
N	Texarkana Mill	WDS/BL	109	ST	1.67	VC	Waste
N	Deer Park Plant	NG	95	Comb	0.576	RO	River
N	Shell Deer Park	NG	101	ST	0.36	RO	Brack.
N	Borger Plant	OG	35	ST	0.202	RO	River
N	Chocolate Bayou Plant	NG	51	ST	1.584	RO	River
N	Texas City Plant Union Carbide Corp	NG	83	Comb	2.16	MSF	Brack.
	Subtotal		**4,639**		**7.074**		**Nonwaste**
	Total		**8,914**		**12.674**		**All types**

Source: [A]=Wangnick (2002); [B]=DOE/EIA (2002 and 2003)

NOTE: See Table D3, Table E2, and Table E3 for keys; [C]: U=utility, N=nonutility

Table E5. Texas refineries showing distillation capacity

Company	Location	Capacity (bbl/day)
Age Refining Inc	San Antonio	9,112
Alon USA LP	Big Spring	61,000
Atofina Petrochemicals Inc	Port Arthur	175,068
BP Products North America Inc	Texas City	437,000
Citgo Refining & Chemical Inc	Corpus Christi	156,000
ConocoPhillips	Borger	145,800
ConocoPhillips	Sweeny	217,000
Crown Central Petroleum Corp	Pasadena	100,000
Deer Park Refining LTD Ptnrshp	Deer Park	333,700
ExxonMobil Refining & Supply Co	Baytown	557,000
ExxonMobil Refining & Supply Co.	Beaumont	348,500
Flint Hills Resources LP	Corpus Christi	259,980
La Gloria Oil & Gas Co.	Tyler	55,000
Lyondell Citgo Refining Co LTD	Houston	270,200
Marathon Ashland Petro LLC	Texas City	72,000
Motiva Enterprises LLC	Port Arthur	250,000
Premcor Refining Group Inc	Port Arthur	255,000
Valero Energy Corp	Sunray	155,000
Valero Energy Corp	Three Rivers	90,000
Valero Refining Co Texas	Corpus Christi	134,000
Valero Refining Co Texas	Houston	83,000
Valero Refining Co Texas	Texas City	204,250
Western Refining Co LP	El Paso	99,000

Source: Energy Information Administration http://tonto.eia.doe.gov/oog/info/state/tx.html

Table E6. Bottling companies monitored by Texas Department of State Health Services. List also includes ice packaging companies (about ¼ of all facilities)

Firm	# of Fac.	Firm	# of Fac.
3F Developers LLC	1	Accurate Water	1
Advance Kar Wash	1	Agua Beverage Incorporated	1
Agua Pura	2	Albertson's Packaged Ice Inc	136
All About Water	1	All Day Food Store	1
All-Pure Water Store	1	American Water Care Inc	1
Annie's Country Store	2	AN's Water Inc	1
Aqua Bella	1	Aqua Blue	1
Aqua Clear	3	Aqua Express	1
Aqua First	1	Aqua Fresh Water Store	1
Aqua Purification Inc	1	Aquapure	4
Aqua-Sure Water Store	1	Aqua-Tex	1
AV Lopez Packaged Ice Inc	3	Avant Premium Water And Ice	33
Avant Water Works	10	Best Water Store	1
Beverlys	1	Big Spring Water & Ice	4
Blue Sage Enterprises LLC	1	Brookshire's Packaged Ice Inc	14
BYOB Water Store	1	CAP-MOR Limited - Watermill Express	42
Castano's	1	Cedar Valley Grocery Inc	1
Chas Super Market	1	Choice Wash Of Bellville Inc	1
Choi's Water Inn	1	Classic Six Drive Thru	1
Country Faucet LLC	1	Country Store	1
Country Waterworks	1	Crystal Water	1
Crystal's Convenience	1	Culligan Store Solution	133
Culligan Water Solutions	28	Dallas / Ft Worth Dr Pepper Bottling Co	1
Debbie's Best Water Store	1	Diamond G Store	1
Diamond Water Tower	1	Don's Grocery & Deli Inc	1
Drinking Water	1	DS Waters Of America LP	3
Eco Smart Texas	1	Ecowater Systems	1
El Centro Exxon	1	El Papalote Drinking Water	1
El Paso Falls-Watermill Express	25	Entrepure Industries Inc	13
Family Nutrition Center	1	Fast Water LLC	1
Fiesta	46	Food City-Packaged Ice Inc	1
Food N Go	1	Freer Water Factory	1
Gardendale Grocery	1	Gerald Hall Enterprises	1
Glacier Water Services Inc	1787	Globe Supermarket-Packaged Ice Inc	1
Gourmet Donuts & Water Plaza	1	Green Jay Corp	1
Gregory S Gayler	5	Guardian Storage & Carwash LLC	1
Gw Services Inc	27	H20 Express	14
Harmony Brook Inc	206	Harvest #21393-Packaged Ice Inc	1
HEB-Packaged Ice Inc	160	Henrys Cash & Carry	1
Honey's Drive In	1	Hunts-A-Plenty-Packaged Ice Inc	1

Firm	# of Fac.	Firm	# of Fac.
J & R's Convenience Store	1	Jimmy's Liquor	1
John M Semple - U Bottle Water Service	16	Jovita's Convenience Store-Packaged Ice Inc	1
Juniors Express 2	1	Karl's Water & Video	1
Kims Water LLC	1	Kroger-Packaged Ice Inc	163
Kwik Kar Wash	1	La Express Water Tower	2
La Noria Water	1	La Pasada-Packaged Ice Inc	1
Laughlin Shoppette	1	Lee Taylor - L & L Enterprises	6
Leon Valley Water Co Llc - Leon Valley	4	Lone Star Pure Water	1
Martin's Water Jug	1	Maxor Express	1
MCCM Ltd - Watermill Express	19	McPherson Produce	1
Melin's Drive Inn	1	Mom & Pop	1
Moreno's Kwik Stop	1	Move-N-Take Enterprises	1
National Water Service Inc - Whole Foods Market	13	Natures Promise	1
Neighborhood Market - Culligan	2	New West Products Inc	1
Nimbus Drinking Water Systems Ltd	4	Nullison C Store	1
Oasis Auto Wash Inc	1	Oasis Carwash & Water	1
O'Grady Drink Drinking Water	1	Olmos Mart	1
Pacific Pure Water	1	Packaged Ice - Foys Supermarket	1
Packaged ice - JE Merrit @ Exxon Refinery	1	Packaged Ice Inc - 107 Drive In	1
Packaged Ice Inc - Arlans #6	1	Packaged Ice Inc - Big 8	2
Packaged Ice Inc - Diamond	4	Packaged Ice Inc - Entex 1	1
Packaged Ice Inc - Exxon Bop	1	Packaged Ice Inc - Food City	2
Packaged Ice Inc - Food King 7	1	Packaged Ice Inc - Gerlands	6
Packaged Ice Inc - Gonzalez Mini Mart	1	Packaged Ice Inc - Handy Andy	5
Packaged Ice Inc - Harvest IGA	2	Packaged Ice Inc - Jerrys Grocery 5	1
Packaged Ice Inc - Juniors 5	4	Packaged Ice Inc - Kmart #3948	1
Packaged Ice Inc - L & E Grocery	1	Packaged Ice Inc - La Fiesta	4
Packaged Ice Inc - Levels Food	1	Packaged Ice Inc - Lone Star Meats	1
Packaged Ice Inc - Lopez	8	Packaged Ice Inc - Lowes	9
Packaged Ice Inc - M Rivas Food	1	Packaged Ice Inc - Malones	3
Packaged Ice Inc - McAllen Grocery	1	Packaged Ice Inc - Metro Food 2242	1
Packaged Ice Inc - Paleface Grocery	1	Packaged Ice Inc - Quick Stop	1
Packaged Ice Inc - Rubens Grocery	1	Packaged Ice Inc - Save A Lot	7
Packaged Ice Inc - Sterling Chemical	1	Packaged Ice Inc - Super Saver	8
Packaged Ice Inc - Triple J	1	Packaged Ice Inc - Valley 66 #2	1
Packaged Ice Inc - Veras King O Meats	1	Parks Convenience Center #2	1
Park's Water Inc	1	Paske Shell	1
Perfect Water	3	Phoenix Drinking Water	1
Pure H20	2	Pure Water	34

Firm	# of Fac.	Firm	# of Fac.
Pure Water Express	2	Pure Water Station	1
Pure Water World	1	Purely Water	1
Pure-N-Clear	1	Quality Water Company Inc	3
Quick Mart	1	R Jen Inc	26
R O Systems Co Inc	10	Randall's-Packaged Ice Inc	58
Reddy Ice Corp	186	Reyna's Deli & Country Store	1
Rivas Bakery	1	Roger's One Stop	1
Ross Travel Center	1	Route 66 Water Bottling Co	1
S & S Water Store	1	Saenz Meat Market	1
Save-A-Lot-Packaged Ice Inc	1	Sealy Food Store	1
Sierra Springs Water Co	2	Simon David-Packaged Ice Inc	1
Snow Palace	1	Southwest Foods Water Plant	1
Sowell Liquor & Beer	1	St Joseph Water Corp	12
Stenseng Distributing Inc	12	Super Soak Car Wash Inc	1
Super Stop #1	1	Super Water Express	3
Tejano Mart	5	Texas Pure Water	1
Texas Sweetwater Express Service	1	Texas Water & Gift Mart	1
The Alamo Drive-In	1	The Clear Water Store	1
The Jug	1	The Water Barrel	3
The Water Drop	1	The Water Factory Co	1
The Water Hole	1	The Water House	1
The Water Keg - Nutrition Center	1	The Water Place	1
The Water Shop	1	The Water Spout	4
The Water Store - De Maiz Tortilleria	1	The Water Store/Tower Drive Thru	1
The Water Store-C & N Country Store	1	The Water Works	2
Tom Thumb-Packaged Ice Inc	55	Travel Mart Convenience-Midland	1
U Bottle Water Service	2	Ultra Fuel & Oil	1
Valley West Plaza	1	VTS Fresh Water	2
Wal-Mart-Packaged Ice Inc	106	Water 4 U	1
Water Barrel Enterprises Inc	3	Water Castle	1
Water Depot	1	Water Drop Express	2
Water Event Inc	1	Water Express	2
Water Fresh	1	Water Haven	1
Water Hut	1	Water Inn	12
Water N Go	1	Water Point Systems	90
Water Provisions To Go	1	Water Station	1
Water Store	1	Water To Go	7
Water Wizard I Ltd	9	Water Works	1
Water World	1	Water Xpress	3
Watermill Express	470	Waterplex	6
Wayne Chenault - Water Villa	5	Wellspring Mfg Inc	5
Wet Water Wash Inc	3	Winston Water Cooler Ltd	1
Wmsc	2	Wright Stop #354	1
Yi Sing Pure Water	1	You N I Neighbor Food Store	1

Table E7. Soft drink companies monitored by Texas Department of State Health Services

Firm	# of Fac.	Firm	# of Fac.
Ab-Tex Beverage Ltd	1	Aloe Commodities International Inc	1
Aloe'ha Beverage Corporation	1	America's Beverage Company	1
Austin Coca Cola Bottling Co	2	Better Beverages Ltd	1
Big Bend Coca-Cola Bottling Co	1	Borden	1
Bordens Dairy	1	Chosen Frozen Inc	1
Coca Cola Bottling Co Of North Texas	1	Coca-Cola Bottling Co	1
Coca-Cola Enterprises Inc	1	Coca-Cola Enterprises Inc-Southwest	1
Dr Pepper Bottlers Brownwood Inc	1	Dr Pepper Bottling Co of Dublin	1
Dr Pepper Bottling Co Of Houston	1	Dr Pepper Bottling Co Of Texas Inc	1
Gandy's Dairies Inc	1	HEB Grocery Co/Milk & Beverage Plant	1
Lilly Dairy Products Inc	1	Lone Star Beverage Company LLC	1
Lufkin Coca-Cola Bottling Co	1	Magnolia Coca Cola Bottling Co	1
Mariano's Specialty Products	1	Merrytime Products Co Inc	1
Pepsi Bottling Group	1	Pepsi Cola Bottling Co Of Corpus Christi	1
Shasta Beverages Inc	1	Southwest Canners Inc	1
Stokely Van Camp Manufacturing Inc	1	Temple Bottling Company Ltd	1
The Pepsi Bottling Group	1	The Victoria Beverage Co Inc	1
Truco Enterprises Inc	1	Valley Coca Cola Bottling Company	1

Table E8. Breweries monitored by Texas Department of State Health Services

Firm	# of Fac.	Firm	# of Fac.
Alamosa Wine Cellars	1	Anheuser-Busch Inc	1
Becker Vineyards	1	Bell Mountain Vineyards Inc	1
Comfort Cellars Winery	1	Delaney Vineyards Inc	2
Dry Comal Creek Vineyards Inc	1	Fall Creek Vineyards	1
Fifth Generation Inc	1	Glazer's Wholesale Drug Co Inc	1
Grape Creek Vineyard Inc	1	Holloman Distributing Co	1
Homebrew Headquarters Inc	1	Homestead Vineyards & Winery Inc	1
Houston Distributing Co	2	La Buena Vida Vineyards	1
Llano Estacado Winery Inc	1	Lone Star Beer Distributing Co	1
Messina Hof Wine Cellars Inc	1	Miller Brewing Company	1
Oley Distributing Co	1	Permian Distributing Inc	1
Pheasant Ridge Winery	1	Piney Woods Country Wines	1
Real Ale Brewing Co	1	Republic Beverage Co	1
Saint Arnold Brewing Co	1	Sister Creek Vineyards	1
Ste Genevieve Wines	1	Su Vino Winery	1
Tower Beverage Of Nacogdoches	1	Val Verde Winery	1
Wimberley Valley Winery	1		

Table E9. Drug manufacturing companies monitored by Texas Department of State Health Services

Firm	# of Fac.	Firm	# of Fac.
21st Century Homeopathics Inc	1	A - Med Medical Inc	1
A M Home Medical	1	A-Plus Medical Equipment	1
AAA Medical & Oxygen Supply	1	AAA Medical Oxygen Supply	1
AGS Labs Inc	1	Abassi Wholesale & Distributing Co	1
Able Medical Products Inc	1	Acetylene Oxygen Co	2
Acetylene Oxygen Company	4	Activ Medical	1
Active Organics Inc	1	Adams Respiratory Therapeutics	1
Advanced Home Health Services	1	Advocare International LP	1
Aeriform Corporation	5	Air Liquide America LP	7
Air Products & Chemicals Inc	3	Air Sense Inc	1
Air Supply of North Texas	1	Airgas Gulf States	1
Airgas Mid South Inc	1	Airgas Puritan Medical	1
Airgas-Southwest Inc	24	Alamo Respiratory Services Inc	1
Alcon Manufacturing Ltd	1	Alk Abello Inc	1
Allergan Sales LLC	2	Alliance Medical Supply Inc	1
Alliance Pharmaceutical Inc	1	Allied Medical	1
Aloe Commodities International Inc	1	Aloe Dynamics Inc	1
Aloe Laboratories Inc	1	Aloe Vera Of America Inc	1
Alrick Enterprises LLC	1	Alt-Med Labs Inc	1
AmPharmCo Inc	1	Amarillo Medical Oxygen	1
American Animal Health Inc	1	American Homepatient	4
American Medical Equipment	1	Ameripac Inc	1
ApotheCure Inc	1	Apria Healthcare Inc	14
Argyle Welding Supply Co Inc	1	Aslung Pharmaceutical LP	2
Atlantis Laboratories Inc	1	Avail Medical Products Inc	1
B & J Welding Supply Ltd	1	BASF Corp	1
BOC Gases	1	Bailey Oxygen & Tool Co Inc	1
Ballay Pharmaceuticals Inc	1	Banyan International Corporation	1
Barker Healthcare Products Inc	1	Bayer Environmental Science	1
Beauticontrol Inc	1	Bio-Derm Laboratories Inc	1
Bio-Medical & Pharmaceutical Mfg Corp	1	Biotics Research Corporation	1
Body Chemistry Manufacturing Inc	1	Bolyard's Respiratory Svcs& Homecare Equipment	1
Bowie Home Medical Equipment	1	Brazos Valley Welding Supply Inc	1
Brenntag Southwest Inc	2	Britkare Home Medical Ltd	1
CPS Medical Inc	1	CRC-Cardio Respiratory Care Inc	1
Capellon Pharmaceuticals Ltd	1	Cardinal Health	2
Cardinal Health Medical Products & Services	1	Carrington Laboratories Inc	1
Carroll Company	1	Carter Bloodcare	1
Central Admixture Pharmacy Services Inc	2	Champs Medical	1

Firm	# of Fac.	Firm	# of Fac.
Champs Medical Ltd	1	Chemolee Lab Corp	1
Chest Diagnostic Therapeutic Services Inc	1	City Of Houston Fire Department	1
Clavel Corporation	1	Coastal Bend Rural Medical Equipment Inc	1
Coastal Welding Supply Inc	1	Coats Aloe International Inc	1
Colgate Oral Pharmaceuticals Inc	2	Community Action Inc Hays Caldwell & Blanco Cos	1
Community Council Of South Central Texas Inc	1	Community Medical Equipment	1
Conroe Welding Supply Inc	1	Consumers' Choice Products Inc / Sasco	1
Corsicana Welding Supply Inc	1	Creative Beauty Innovations Inc	1
Creative Fragrances Ltd	1	Custom Nutrition Laboratories Inc	1
Cut Heal Animal Care Products Inc	1	Cyclotope	1
DPT Laboratories Ltd	2	De La Rosa Pharmacy & Medical Equipment	1
Del Rio Welders Equipment Inc	1	Deltex Pharmaceuticals Inc	1
Denison Oxygen Supply	1	DuPuy Oxygen & Supply Co Inc	1
ETOX Inc	2	Eagle Home Medical Corp	1
Economy Medical Rental Inc	1	Elge Inc	1
FMC Corp	1	Falls Welding Supply Inc	1
Family Medical Equipment and Supply	1	Faspac Packaging LP	1
Ferguson Enterprises	1	Fire Protection Service Inc	1
First Fitness International Inc	1	Fisher County Dura-Med Equip	1
Fitch Industrial Welding Supply Inc	1	FluoroMed LP	1
Freedom 2 Go LLC	3	Fruit Of The Earth Research Laboratories Inc	1
GDMI Inc	1	GM Pharmaceuticals Inc	1
Garland Welding Supply Co Inc	1	Gentiva Health Services	1
Gold Cross Medical Supplies Inc	1	Goodier Cosmetics Inc	1
Goodlite Products Inc	1	Great Southern Laboratories	1
Hampshire Chemical Corporation	1	Hanna Isul Skin Therapy Inc	1
Health Care Labs Inc	1	Healthline Medical	1
Heartland Medical Supply Inc	1	Hill Country Medical Equipment	1
Home Care Supply	1	HomeCare Medical Equipment Inc	1
Homecare Dimensions Inc	1	Hometown Medical Equipment Inc	1
Horizon Industries	1	Horsemans Dream Inc	1
Hospice Of El Paso Inc	1	Hospira Inc	1
Houston Welding Supply Co Inc	1	Huish Detergents Inc	1
Humco Holding Group Inc	1	IV Flush LLC	1
Identipak Inc	1	Immudyne Inc	1
Inmon Respiratory Services Inc	1	Integra Spinal Specialties	1
Iso-Tex Diagnostics Inc	1	Ivedco LLC	1
JD Medical Supplies Inc	1	JP's Specialty Welding & Supply LLC	1
Jungle Laboratories Corporation	1	Kimberly-Clark Corp	1

Firm	# of Fac.	Firm	# of Fac.
L & L Home Care Services Inc	1	L & M Pharmaceuticals	1
LSI	1	Lakeland Respiratory & Medical	1
Land O'Lakes Purina Feed LLC	1	Larrison Medical Inc	1
Leddy Medical Services Inc	1	Lee Medical Supply Co	2
Lees Pharmacy & Medical Equipment Co	1	Life Support Systems Inc	1
Lifegas LLC	5	Lily Of The Desert	1
Lincare Inc	19	Longview Home Medical Equipment	1
Lubbock Oxygen & Medical Gases Inc	1	Lubbock Welding Supply Inc	1
Lyondell Chemical Company	1	MDM Home Medical Equipment LLC	1
MG Industries	1	MSC Development Inc	1
Major Medical Supply	1	Major Medical Supply Inc	1
Mary Kay Inc	1	Matheson Tri-Gas #810	17
McGinnis Welding Supply Co	1	McNeil Consumer & Specialty Pharmaceuticals	1
McDonald Welding Supply Inc	1	Med Care Medical Supply of North Tx Inc	1
Med-Air	1	Medi-Flex Inc	1
Medical Rentals & Sales	1	Mediceutical Laboratories Ltd	1
Merrick Medicine Co Inc	1	Messer GT & S LP	1
MetroPak Systems Inc	1	Midland Memorial Hospital	1
Mission Pharmacal Co	1	Monahans Pharmacy Inc	1
Morton Salt	1	Mylan Bertek Pharmaceuticals Inc	1
N B Wholesale	1	NCH Corp	1
NPTA - National Pharmacy Technician Association In	1	Naterra International Inc	1
National Alloy & Industrial Gases Inc	1	Natures Formula Partners LLP	1
New World Health Inc	1	North Texas CardioPulmonary Inc	1
Novum Solutions Inc	1	OMNII Oral Pharmaceuticals	1
Oiltanking Texas City LP	1	Onecare Respiratory	1
Oxy Healthcare Services Inc	1	Oxycare Plus Inc	1
Oxygen Resources Inc	1	PETNET Pharmaceuticals Inc	3
PHHS Medical Repackaging	1	PPG Industries Inc	1
PRN Medical Services Inc	1	Patient Care Systems Inc	1
Penreco	1	Perrone Pharmacy Inc	1
Petra Chemical Company	1	Pharma Fab	1
Plaza Home Care Inc	1	Praxair Inc	7
Preferred Medical Services Inc	1	Premier Products	1
Prescription Air	2	Primary Care Division/City of Austin HHS/Travis Co	1
Pro Medical	1	Professional Compounding Centers Of America	1
Professional Medical	1	Professional Welding Supply Inc	1
Proportional Technologies Inc	1	Protec Laboratory	1
Puritan Medical Products	2	Quest Chemical Corporation	1
Quest Separation Technologies Inc	1	R & A Labs Aloe Pro International	1

Firm	# of Fac.	Firm	# of Fac.
RCS Management Corporation	1	Refunds Etc	1
Regional Nuclear Pharmaceuticals of Dallas LLC	1	Reheis Inc A General Chemical Co	1
Reliant Processing Group LLC	1	Respicare	1
Respiratory & Medical Home Care Unlimited Inc	1	Revision Inc	1
Rhema Medical	6	Rite Weld Supply Inc	1
Rolling Plains Medical Supply	1	Royalty Welding Supply Inc	1
SSB Group Contract Filling LLC	1	Safe Solutions Inc	1
San Angelo Home Medical	1	San Antonio Extended Medical Care Inc	1
Sanh Hon Duong	1	Sarah Aloe Essence Cosmetics	1
Scott Medical Supply	1	Shell Chemical Company	1
Skinceuticals Enterprises	1	Skinceuticals Inc	1
South Plains Health Provider Organization Inc	1	South Texas Blood & Tissue Center	1
Southern Medical Inc	1	Southwest Research Institute	1
Sovereign Pharmaceuticals Ltd	1	Special Care Home Medical & Pharmacy	1
Spectra Pharm Inc	1	Stamford Medical Supply	1
Stanislaw R Burzynski MD PhD	1	Stat Medical	1
Summa RX Laboratories Inc	1	Sun City Medical Supply	1
Sun Country Medical Equipment Inc	1	Sure-Life Laboratories Corp	1
Swiss American Products Inc	1	TIGI Linea LP	1
Taylor Home Health	3	Taylor Medical Supply	1
Temple Welding Supply Co Inc	1	Tennis Elbow Corp	1
Texas Correctional Industries	2	Texas DME Inc	1
Texas Medical Inc	1	Texas Vet Lab Inc	1
Texoma Medical Center Inc	1	Texstar Medical Equipment	1
The Colgin Companies	1	The Corpus Christi Medical Center-Doctors Regional	1
The Dallas Group Of America Inc	1	The Dow Chemical Co	1
The Home Health Store of Tomball Inc	1	Third Coast Terminals	1
Trace Radiochemicals Inc	2	Tri-Vedco	1
Trinity Chemical Corp	1	Trinity Coatings Co Inc	1
USA Packaging A Div Of NCH Corp	1	UTHSCSA Research Ctr PET Pharmacy Services	1
Ultra Pure Solutions Inc	1	Union Carbide Corp	1
United Welding Specialties	1	Univar USA Inc	2
VacciCel Inc	1	Virbac AH Inc	1
Walgreens Home Care Inc	2	Walson Inc	1
Welder's Supply Co	1	Wellcare Respiratory & HME Inc	1
Westair Gas & Equipment LP Co	2	Wheelchair & Walker Rentals Inc	1
Wichita Medical Supply Company	1		

Table E10. Microelectronics facilities in Texas from IDA inventory

Location	County name	Total capacity [MGD]	Process	Customer	Water quality
Dallas	Dallas/Collin/Denton	1.876	RO	TEXAS INSTRUMENTS	BRACK
Austin	Travis/Williamson	0.756	RO	IBM	BRACK
Dallas	Dallas/Collin/Denton	0.720	RO	TEXAS INSTRUMENTS	BRACK
Stafford	Fort Bend/Harris	0.546	RO	TEXAS INSTRUMENT	BRACK
Dallas	Dallas/Collin/Denton	0.527	RO	MOSTEK	BRACK
TX		0.518	ED	Semiconductor	PURE
Sherman	Grayson	0.317	RO	TEXAS INSTRUMENT	RIVER
Dallas	Dallas/Collin/Denton	0.305	RO	MOSTEK	BRACK
Dallas	Dallas/Collin/Denton	0.288	RO	TEXAS INSTRUMENTS	BRACK
Carrollton	Delton/Dallas/Collin	0.216	RO	MOSTEK	BRACK
Austin	Travis/Williamson	0.202	RO	MOTOROLA	BRACK
Austin	Travis/Williamson	0.200	RO	MOTOROLA	BRACK
Total		**6.471**			

Source: Wangnick, 2002

Table E11. Selected semiconductor and electronics manufacturing companies in Texas

3M	Advanced Micro Devices	AMX
Apple Computer	Applied Materials	Applied Micro Circuits
Atrion	Cirrus Logic	Compaq Computer
Cypress Semiconductor	Dell Computer	Emerson Process Managemt
Freescale	IBM	Intel
Minco Technology Labs	Mostek	Motorola
National Semiconductor	Optek Technology	Samsung Semiconductor
SigmaTel	Silicon Laboratories	Solectron Texas
STMicroelectronics	Texas Instruments	Tokyo Electron

Source: Wangnick (2002); search on Kompass.com for “semiconductor”; http:\\www.austinchamber.org

Attachment F: List of files on CD

MAIN DIRECTORY
DesalPlantSql2kBackup
Database in SQL format (38 facilities $\geq$0.025 MGD)

File List.doc
This attachment

Final_Report.doc
Final_Report.pdf
Electronic version of this report.

TWDB-BEG Water Survey06-13-05_GT0.025MGD.mdb
Database in Microsoft Access format (38 facilities $\geq$0.025 MGD)

TWDB-BEG Water Survey06-13-05__GT0.025MGD.xls
Database in Microsoft Excelformat (38 facilities $\geq$0.025 MGD)

Folder "APPENDIX B"
Survey form Mun3.doc
Electronic version of survey form

Folder "APPENDIX C"
AWWARF-Membrane Knowledge Base Project 2763 SCOPE.pdf
Description of AWWARF project 2763 about the development of a database on low-pressure membrane facilities

CA Coastal Act 14a-3-2004-desalination.pdf
Copy of the Seawater Desalination and the California Coastal Act

DRIP Program.pdf
Information about the DRIP program in California

FDEP Listing of RO and NF WTPs.doc
Membrane treatment plants in Florida

Folder "APPENDIX D"
Desalting Plants Inventory_JP0.xls
Wangnick (2002) dataset

DESAL TCEQ.DBF:
Original file obtained from the TCEQ. It contains 121 facilities, but some are duplicates.

DESAL TCEQ.xls
TCEQ-listed facilities with no duplicates. A total of 99 facilities are listed and sorted by total production.

DESAL OTHER.xls
Desalination facilities obtained through other means (Web search, TWDB, TCEQ customized search)

Folder "GIS"
DesalPlants larger0.025MGD_3.mxd
GIS coverage of desalination facilities (38 facilities ≥0.025 MGD). Note that geographic coordinates are approximate for some of the facilities. Coordinates in decimal degrees, Texas Statewide Mapping System projection. The following shape files are included in addition to the desalination facilities: Cities / Groundwater Conservation Districts / Counties / Texas Outline

Folder "Other Files"
MickleyAssoc.mdb
Database from Mickley (2001) containing results from survey covering the whole U.S.

TWDB-BEG Water Survey06-13-05_ALL.xls
All database information organized in an Excel spreadsheet

TWDB-BEG Water Survey06-13-05_ALL.mdb
Database in Microsoft Access format (all interviewed facilities)

Attachment G: Useful Website Addresses

Boyle Engineering: http://www.boyleengineering.com/index_ie.htm
Business Communications Company: http://www.buscom.com/membrane/C201R.html
California Coastal Commission: http://www.coastal.ca.gov
California Department of Water Resources:
http://www.owue.water.ca.gov/recycle/desal/desal.cfm
California Energy Commission: http://www.energy.ca.gov/
Department of Energy/Energy Information Agency:
http://www.eia.doe.gov/index.html
Desalination Research and Innovation Partnership (DRIP):
http://www.mmenvirosoft.com/drip_website
Florida Department of Environmental Protection:
http://www.dep.state.fl.us/water/drinkingwater/index.htm
Global Water Intelligence: http://www.globalwaterintel.com/
International Desalination Association (IDA): http://www.idadesal.org
IWUD:
http://www.tceq.state.tx.us/permitting/water_supply/ud/iwud.html
The McGraw-Hill Companies: http://www.mcgraw-hill.com/markets/info_media.html
McIlvaine Company: http://www.mcilvainecompany.com
Montgomery-Watson Harza (MWH): http://www.mw.com
Public Utility Commission of Texas:
http://www.puc.state.tx.us/electric/directories/index.cfm
San Diego Water Authority: http://www.sdcwa.org/
TWDB project loan list:
http://www.twdb.state.tx.us/data/projectstatus/projectstatus_toc.asp
Wangnick GMBH: http://www.wangnick.com/home.htm
Water Desalination Report: http://www.waterdesalreport.com
Watereuse Foundation: http://www.watereuse.org/

Attachment H: Answers to Review Comments

TEXAS WATER DEVELOPMENT BOARD
Review Comments on the Draft Report
"Development of a Database for Desalination Facilities in Texas"
Contract # 2004-483-021

1. On the cover, show only the Texas map, and remove the inserted graphs/tables, etc. (make the cover more presentable on glossy paper).
   Extraneous graphs have been deleted.

2. The 'Table of Contents' page and the pages following it need to be improved for format. Denote attachments as A-xx rather than as IV.1.2.3… etc. (Simplify numbering).
   Attachments are now indicated by letters (A through H).

3. On page 1 (Executive Summary) the first figure is shown as Fig. 4.1. This numbering is incorrect – refer to the figure as ES-1.
   Numbering has been corrected.

4. All figures in reports submitted to us need to be in color.
   Report will be delivered in color.

5. Each figure needs to have a legend.
   Legends have been added to all figures when missing.

6. Insert tables and figures where they are referred to in the text (NOT at the end of the chapter)
   Tables and figures have been inserted in the text except in appendices where multiple long tables would interrupt the natural reading flow.

7. Page 4 – The statement that 'MSF and MED are more suited to seawater desalination' seems inappropriate (and should be deleted), since the current trend is overwhelmingly toward the use of RO for seawater desalination.
   Statement has been rephrased. The purpose of the initial statement was to emphasize that most (if not all) MSF and MED facilities are seawater desalination facilities, not that all seawater desalination facilities are MSF and MED.

8. Page 4 – Explain the difference between ED and EDR.
   Explanation added.

9. Page 5 – Please state if it has been verified from TCEQ that there is not a single case of deep well injection being used in Texas for concentrate disposal.
   The statement has been deleted. Although this survey of PWS facilities suggests that there is none, it is possible that industrial facilities do use deep-well injection

as a mean to dispose of the concentrate. Applications for deep-well injection of concentrate may also have been submitted but not followed-through.

10. Page 7 – Does TCEQ list have 70 or 99 entries? – Unclear (2nd paragraph).
TCEQ list has 99 entries but only 70 with a water production ≥0.025 MGD. Sentence rephrased. Sentence is now part of Attachment D.

11. Page 9 – It is confusing from the text on lines 3 & 4, whether the 19 facilities are above or below 0.025 MGD – Please write clearly.
Confusion arises from the fact that blending can occur. Total design capacity (with blending) can be ≥0.025 MGD and desalination design capacity can be <0.025 MGD. Sentence rephrased. Sentence is now part of Attachment D.

12. Section 4 - The results section discusses too many different data sets that it is confusing to the reader. Please present only one correct data set (yours) in the results section with all others in appendices if necessary.
All the data not directly relevant to the final result section have been moved to a new attachment (Attachment D).

13. The terminology in table 4.2 is confusing – Please refer to desalination capacities as design capacity and total capacity (including blending). The design capacity column should precede total capacity column. PWS # is not needed, but include the county name.
County name is now provided in addition to PWS#. "Total design capacity" is now called "Total capacity (including blending)" and "Desalination design capacity" is now called "Design capacity." Similarly, "Average production" is now called "Average production (including blending)" and "Average desalination production" is now called "Average production."

14. A single table is needed in Section 4 that shows the 38(?) PWS desalination facilities in a nutshell (need a reproducible table for presentations). The table should have facility name, county, desalination capacity, source water (groundwater, river, etc), desalination process (RO/ED etc). In the color map showing the 38 locations, please label (identify) the ten largest facilities in Texas.
A summary table has been added (Table4-1 of final report).

15. Please send one final report (in color) for preliminary approval by October 20, 2005 before submitting all copies of the final report.
Preliminary report have been delivered on as requested

The TWDB also provided marked-up copies with comments and notes. Non trivial comments are reproduced below with a description of their resolution.

C1: Simplify the main body of the report
Only results have been kept in the main body of the report. All other materials have been moved, mainly to (new) Attachment D.

C2. Report needs to include a description of the contracted tasks and how they were addressed.
A description of the tasks has been added.

>==============================<

<u>TCEQ Comments</u>

Database for desalination by J.P. Nicot, Steven Walden, and others

1. Page 5. The statement that deep-well injection is not practiced in Texas is incorrect. Several permits have been issued.
   The statement meant that no desalination concentrate is being injected in deep-well injection. The statement has been deleted. See answer to comment 5 of TWDB.

2. General comment - writing style is confusing, needs improvement.
   Structure of the report has been modified.

3. Page 8 section 3.2 – the word 'database' needs to be added after SQL server
   Word added.

4. Every figure should include a legend.
   Legends have been added to all figures when missing.

5. Page 42 – 47 The notes (footnotes) are not capitalized. They refer to coordinates in decimal degrees, but no coordinates are shown. Delete the second sentence about decimal degrees if it is not applicable.
   Sentence about decimal degrees in footnotes deleted. Actual projection used to developed the maps from coordinates in decimal degrees has been added (Texas Statewide Mapping System).

6. Page 49 – The figure is a comparison and shows 'Mickley's data' for the x-axis. What is the y-axis? Figures need more attention and labeling.
   The y-axis represents results from this survey. Caption to the figure has been updated. Figure is now in Attachment D.

Attachment I: List of Changes in Revision 1

Since the publication of the initial version of this report in October 2005, a few minor errors have been found. It should be noted that no additional survey or update to the initial survey has been performed in this Revision 1, only corrections to the initial report:

Column “County” in Table 4-2 has been modified. The table in the initial report had the county names shifted in a haphazard fashion. County names have been paired with the correct facilities.

Map of Figure 4-11 has been corrected. It initially showed all facilities with no TDS data as having a TDS<500ppm. A new “unknown” category has been added.