Texas Water Development Board

A Review of Concentrate Management for Desalination Plants in Texas

by

Heather Rose, M.S.

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TABLE OF CONTENTS

FIGURES

TABLES

ACRONYMS

RO	Reverse Osmosis
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TWDB	Texas Water Development Board
USBR	U.S. Bureau of Reclamation

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EXECUTIVE SUMMARY

Desalination is a water treatment method that is growing in popularity as more communities turn to saline water sources to meet their water demands. Desalination is a process that removes salts from saline water sources. The most common desalination technologies utilized in Texas are reverse osmosis and electrodialysis reversal. A byproduct of these desalination methods is concentrate (or concentrated saline water). Because concentrate from desalination plants contains high levels of salinity, residual chemicals from the treatment process, and other contaminants, it must be disposed of with consideration.

In 2010, 2016, and 2020, desalination plants in Texas were surveyed by the Texas Water Development Board (TWDB) on their plant operations. Participation in these surveys was voluntary, and all known desalination plants in Texas were invited to participate. These survey data make up the TWDB Desalination Database hosted on the Texas Water Data Interactive website. The database currently holds information on 53 desalination plants in Texas. TWDB staff reviewed these data to determine how desalination plants in Texas are managing their concentrate. This report summarizes the survey results as they pertain to concentrate management.

According to the surveys, desalination plants in Texas dispose of concentrate by surface water discharge, sanitary sewer, evaporation ponds, land application, deep well injection, or an unspecified process. Results showed that 36 percent of desalination plants in Texas discharge their concentrate directly into a nearby surface water body, 28 percent send their concentrate to a sanitary sewer, 15 percent store their concentrate in an evaporation pond, 11 percent use their concentrate onsite via land application, 4 percent dispose of concentrate via deep well injection, and 9 percent of desalination plants surveyed did not provide information on how they dispose of their concentrate.

In Texas, municipal wastewater treatment plants that accept concentrate from desalination plants treat the water by blending it with municipal wastewater. This dilution method is sufficient to treat concentrate while the salinity and volumes are low and the wastewater treatment plant has capacity. However, if a desalination plant sending its concentrate to a

sanitary sewer expands its production substantially, blending with municipal wastewater may not be sufficient and a different concentrate treatment method maybe required.

Other methods of concentrate disposal, such as evaporation ponds, land application, and deep well injection, require unique environmental considerations. With evaporation ponds, the remaining salt must be hauled away via solid waste disposal. Also, operators must ensure evaporation ponds are properly lined to prevent infiltration into groundwater.

Land application can be used for irrigating salt tolerant plants. However, it is important to consider the potential degradation of soil health when applying concentrate. Also, it is critical to contain runoff when irrigating crops with concentrate, as this can cause significant damage to the soil of neighboring properties.

Deep well injection can be a disposal option for desalination plants where the geological conditions are suitable. Plant operators must obtain an injection well permit from the Texas Commission on Environmental Quality (TCEQ) and must ensure there is no potential for contaminating local groundwater. As of August 2020, there are two facilities in Texas utilizing deep well injection: one in El Paso County and one in Bexar County.

Researchers in the public and private sectors have produced studies and developed resources regarding concentrate management. This includes several studies published by the TWDB, and the Concentrate Management Toolbox developed by the U.S. Bureau of Reclamation. Desalination plant operators can use these resources to help make more informed decisions on how to manage their concentrate.

OVERVIEW OF DESALINATION TECHNOLOGIES

Desalination is the process of removing salts found in such raw water sources as seawater, brackish groundwater, saline surface water, or industrial wastewater, including produced water from oil and gas operations. Salt content in water is typically measured by total dissolved solids (TDS), which equates to milligrams of solids (or salts) per liter of water (mg/L). Table 1 below shows a range of typical salinity levels for different raw water sources.

***Table 1**: Typical salinity levels for common water sources in milligrams per liter.*

Raw Water Source	Salinity Range (mg/L)
Distilled Water	0
Rainwater	10
Lake Tahoe	70
Lake Michigan	170
Missouri River	360
Pecos River	2,600
Brackish Groundwater	1,000 – 10,000
Ocean	35,000
Brine Well	125,000
Dead Sea	250,000

Several technologies exist for removing salts from raw water sources, including reverse osmosis, electrodialysis, and electrodialysis reversal. Reverse osmosis and electrodialysis reversal are the technologies currently used in the majority of desalination plants in Texas (TWDB, 2022a).

Reverse Osmosis

Reverse osmosis works by pressurizing a water source and forcing water through membranes. The raw water source is usually pre-treated to remove larger debris and other materials that could damage the reverse osmosis membranes. The product water (or permeate) is what comes out of the reverse osmosis membrane as pure water free from salt and other contaminants. Some treatment plants will add minerals back to the permeate to raise the pH and make it less corrosive. Concentrate (or concentrated brine wastewater) is what remains from the saline water source once the freshwater has been removed as permeate. Figure 1 below shows a schematic of the overall process for a reverse osmosis desalination plant.

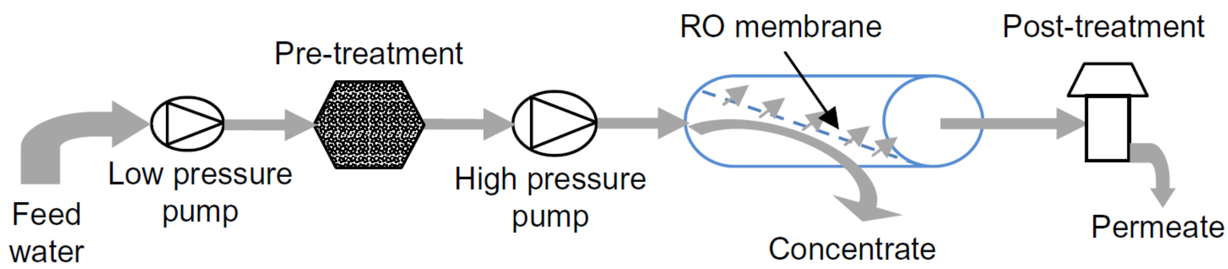

Figure 1: Schematic of principle of operation of a reverse osmosis system. Source: Cherif, 2018

A typical municipal scale reverse osmosis system (producing 2–12 million gallons of permeate per day) has a recovery rate of 75–85 percent for brackish groundwater, and a 50 percent recovery rate for seawater (TWDB, 2022a). Therefore, every 100 gallons of treated brackish groundwater produces between 75–85 gallons of permeate. Similarly, every 100 gallons of treated seawater produces approximately 50 gallons of permeate. The remaining water is rejected concentrate. The recovery rate of the reverse osmosis system is dependent on the TDS of the raw water source. The lower the TDS of the raw water source, the higher the recovery rate, and vice versa.

Electrodialysis and Electrodialysis Reversal

Electrodialysis is also a desalination method that utilizes a membrane system. However, instead of using pressure to move raw water through membranes, the system uses electric potential. In electrodialysis, there are two types of ion exchange membranes: one that allows the passage of positively charged particles and another that allows the passage of negatively charged particles. The membranes are placed in alternating stacks with electrodes at the end of each stack. Raw water is fed through the system. The electric potential of the electrodes on either end of the membrane stack draws out the positively and negatively charged particles according to their electric charge. This creates two wastewater streams, one for concentrated salt water with positively charged particles (concentrate) and one for concentrated wastewater with negatively charged particles (effluent). Purified water that is charge neutral bypasses the electrodialysis membranes and leaves the system as permeate. Figure 2 shows a schematic of an electrodialysis system.

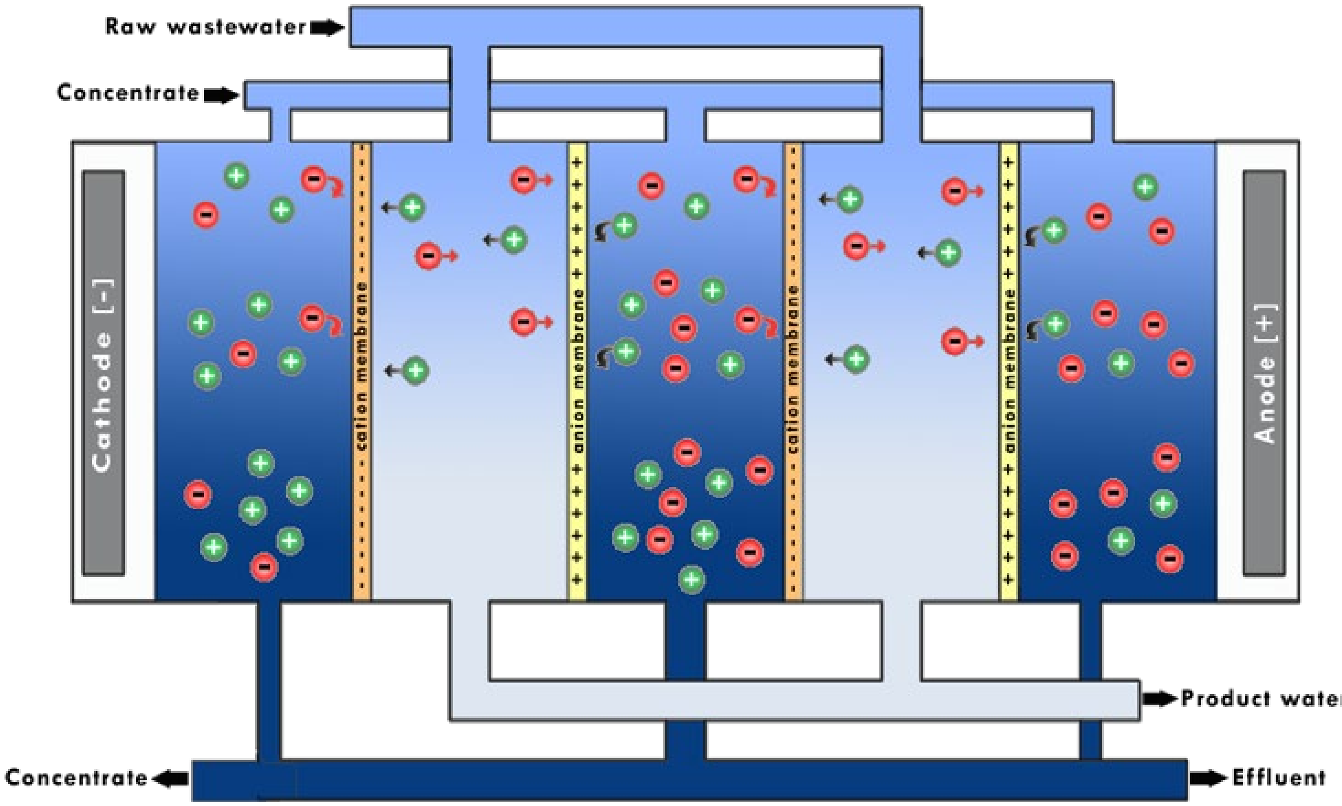

Figure 2: Schematic of electrodialysis process. Source: Ace Environment 2012

A typical electrodialysis desalination plant can recover 85–90 percent of volumes for brackish groundwater (Singh, 2016). This means that for every 100 gallons of brackish groundwater that is treated, 85–90 gallons of produced water will be recovered. The rest will be rejected as concentrate.

Electrodialysis reversal is the same process as electrodialysis; however, operators will reverse the electric potential periodically to prevent buildup of scale and foulants on the membranes. This essentially "backwashes" the membranes and makes for a higher recovery rate (NRS Engineering, 2008).

Electrodialysis and electrodialysis reversal are effective for treating raw water sources with TDS levels of up to 8,000 mg/L (USBR, 2009a). This technology can be used to desalinate brackish groundwater, but it is not used with seawater, which has TDS levels of around 35,000 mg/L.

Electrodialysis and electrodialysis reversal desalination are designed to remove *charged* particles, such as salts and negatively charged particles. Therefore, such neutral particles as silica and most organics are not removed through electrodialysis and electrodialysis reversal treatment. For this reason, water desalinated by electrodialysis and electrodialysis reversal must include post-treatment to remove contaminants that are charge neutral, such as microbes. Alternatively, reverse osmosis is designed to remove all contaminants regardless of electric charge.

Other Technologies

Several other desalination methods exist that utilize membrane and/or thermal technologies in creative ways to maximize efficiencies in the system. These are beyond the scope of this report since they are not being implemented in Texas.

COMMON METHODS OF CONCENTRATE DISPOSAL

Although desalination technologies are evolving to become more efficient, there will always be concentrate produced by these treatment methods that must be managed appropriately. Concentrate could be harmful to aquatic life if discharged in large amounts directly into receiving streams without pretreatment. Concentrate also has the potential to degrade soil health and contaminate groundwater sources. For these reasons, it is important that desalination plants plan for proper disposal of their concentrate. There are many different methods available for disposing of concentrate. Table 2 lists the most common methods currently being used by desalination plants in Texas. Additional information on each listed disposal method can be found in the sections that follow.

***Table 2**: Common methods of concentrate disposal in Texas with descriptions.*

Disposal method	**Description**
Surface water body discharge	Disposal of concentrate into a body of surface water, such as a river or stream. Requires a discharge permit and may require blending with a lower salinity water source.
Sanitary sewer discharge	Disposal of concentrate into a sewer system for processing at a wastewater treatment plant. Requires cooperation with municipal treatment facilities.
Land application	Application of concentrate to land containing plants that have a high tolerance to salt. Ideal for low volumes of concentrates.
Evaporation pond	A large, man-made pond that separates salt and water through evaporation. Ideal in warm, dry climates. Requires solid waste disposal.
Deep well injection	Use of an injection well to dispose of concentrate in the subsurface. Requires the right geologic conditions to protect drinkable water sources. Ideal for high volumes of concentrate.

Surface Water Body Discharge

In Texas, a desalination plant must obtain a permit from the Texas Commission on Environmental Quality (TCEQ) before discharging any wastewater into a surface water body. All permit requirements for discharge into surface waters are made on a case-by-case basis, except in the case of general permits. Before issuing an individual discharge permit, the TCEQ reviews the desalination plant's concentrate volume and concentration of contaminants. The TCEQ also conducts a thorough analysis of the potential impacts to the receiving water stream given the volume of discharge and concentration of contaminants. If the TCEQ agrees that the environmental impacts of discharged concentrate into the surface water body will be minimal, the TCEQ proposes to issue the discharge permit to the desalination plant, subject to public participation and input. Most discharge permits have flow limits and contaminant concentration limits, such as maximum TDS, and limits on chlorides, sulfates, and select metals. The desalination plant must renew its individual discharge permit once every five years. Upon permit renewal, the TCEQ reserves the right to change the terms of the permit, including reducing the volume of discharge or changing the allowable concentration of contaminants of the discharge. The permit holder must provide the TCEQ with regular samples of their concentrate to ensure the desalination plant is complying with its permit. For new reverse osmosis plants, the TCEQ typically requires that plants submit monitoring data on TDS, chloride, and sulfate for five years. After five years, the TCEQ reassesses which contaminants need to be regularly monitored going forward. Plants that are found to be out of compliance with their discharge permit may be fined by the TCEQ (Mike Lindner, TCEQ oral commun., 2022).

Some desalination plants may blend their concentrate with their source water before discharging to a surface water body. Blending is the process of mixing concentrate with the original raw water source to reduce the overall salinity level of the wastewater. After blending the concentrate with raw water, the final wastewater product can be further treated using other methods or sent to a sanitary sewer for additional blending with municipal sewage water. Blended concentrate can also be directly discharged into surface waters if the desalination plant holds a valid discharge permit with the TCEQ. Blending can help reduce the impact of discharging concentrate into surface waters by reducing the overall salt content in the concentrate.

Sanitary Sewer Discharge

Desalination plants have the option of working with a local wastewater treatment plant to dispose of their concentrate for them. In most cases, a municipal wastewater treatment plant will accept a desalination plant's concentrate as a new wastewater stream and will "treat" the concentrate by blending it with municipal sewer water. This dilutes the salts in the concentrate to a level where the impacts of discharge to surface waters are no longer an issue at current concentrate volumes.

Most municipal wastewater treatment plants do not have the capacity to treat highly saline water, such as concentrate from a desalination plant. Again, salt removal requires advanced treatment technologies, such as reverse osmosis or electrodialysis. In Texas, it is a violation of a municipal wastewater treatment plant's discharge permit if the plant does not report a new wastewater stream to the TCEQ before accepting concentrate. Municipal wastewater treatment plants are required to report any new wastewater streams, such as concentrate, to the TCEQ before discharging to a surface water body. The intent of reporting these changes in wastewater streams to the TCEQ is to ensure wastewater treatment plants can accept these new wastewater streams without violating their existing discharge permits. If there is a potential for permit violation, the TCEQ works with the wastewater treatment plant to strategize methods for treating the new wastewater stream without violating the existing discharge permit (Firoj Vahora, TCEQ, oral commun., 2022).

Land Application

For desalination plants producing low volumes of concentrate, a cost-effective disposal option may be land application. Spray irrigation can be used for plants with high salinity tolerance. Blending may be considered in addition to land application to reduce the overall salinity level and increase the variety of vegetation suitable for irrigation using concentrate. Desalination plants considering land application should consult local ordinances and ensure potential runoff will not impact neighboring properties or surface waters. Facilities should also consider their property's soil health when irrigating using concentrate.

Evaporation Ponds

Evaporation ponds are large, man-made ponds where concentrate is sent to separate salts from water via evaporation. Once the water has evaporated from the concentrate, the remaining salt is transported to a solid waste disposal facility. Evaporation ponds are ideal for desalination plants located in warm, dry climates with access to available land. Evaporation ponds have additional costs, including solid waste removal and disposal fees. Also, groundwater protection regulations usually require the installation of an impervious lining material at the base of the pond to prevent seepage into freshwater aquifers (NRS Engineering, 2008).

Deep Well Injection

Deep well injection, or well disposal, can be an option for desalination plants that have the right geologic conditions at or nearby their facility. Well disposal requires the presence of one or more confining layers between the receiving formation of the concentrate and any other water-bearing formations, such as a groundwater aquifer used as a drinking water source. Under the right conditions, well disposal can properly isolate concentrate without harming nearby surface water bodies, fresh groundwater sources, or degrading local soil health.

Facilities that choose to discard their concentrate using deep well injection must first obtain an Underground Injection Control (UIC) Class I or Class V permit from the TCEQ depending on the quality of the concentrate and other factors. Obtaining a permit can be time consuming and costly. For this reason, most desalination plants seek other disposal options before pursuing deep well injection. Facilities that pursue deep well injection usually have relatively large volumes of concentrate and/or high concentrations of contaminants of concern (such as naturally occurring arsenic, radium, or uranium), making other disposal options infeasible. Induced seismic activity from deep well injection of desalination plant concentrate is considered by the TCEQ when issuing a UIC permit. However, because injection volumes and pressures are relatively low and well siting is carefully evaluated, induced seismicity is usually not a major concern (Lorrie Council, TCEQ, oral commun., 2022).

OVERVIEW OF DESALINATION IN TEXAS

As Texas faces a growing population coupled with water scarcity, more communities are seeking alternative water resources to meet future demand. Texas has an estimated 2.7 billion acre-feet of brackish groundwater in 26 of its major and minor aquifers (LBG-Guyton Associates, 2003), as well as seawater in the Gulf of Mexico. In the 2022 State Water Plan, 11 out of the 16 regional water planning groups in Texas recommended desalination projects as strategies for drought management (Figure 3), including 50 proposed new desalination plants or expansions to existing plants (TWDB, 2022b). If these projects come to fruition, they would significantly increase desalination activity in the state.

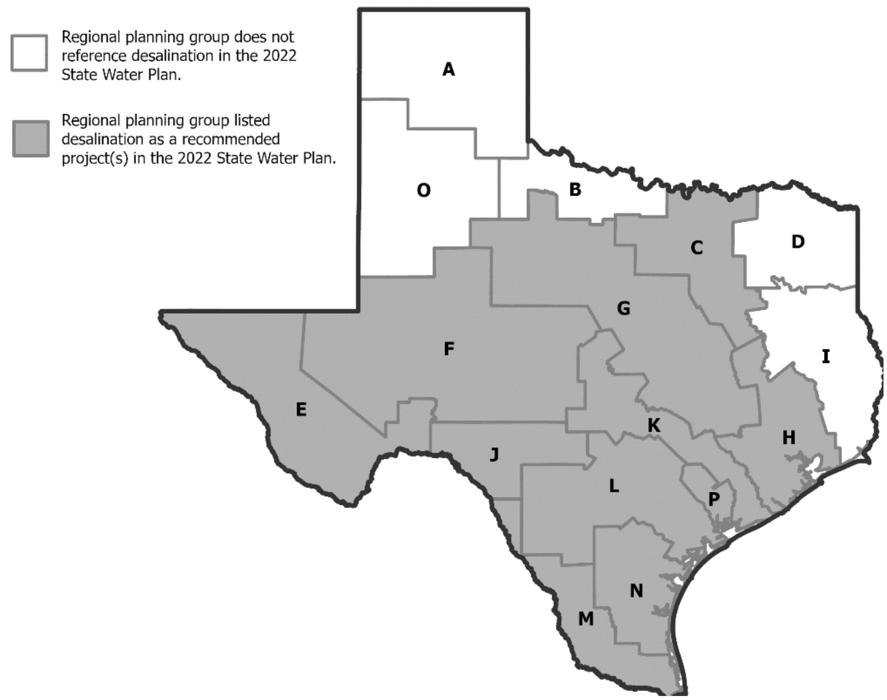

Figure 3: *Regional water planning groups that referenced desalination as a recommended project in the 2022 State Water Plan.*

In the last two decades, municipal brackish desalination capacity in Texas has increased steadily. According to the TWDB 2022 Biennial Desalination Report, there are 53 desalination plants in the state with a capacity greater than 25,000 gallons per day for municipal use. There are 36 facilities that treat brackish groundwater, 16 that treat brackish surface water, and 1 that treats reclaimed water. As of 2022, desalination plants in Texas can treat up to 157 million gallons of brackish water per day for municipal use (TWDB, 2022a).

Reverse osmosis is the predominant desalination technology used in desalination plants in the state, with 96.2 percent of all facilities using this approach. Electrodialysis reversal is the second most used technology at 3.8 percent (TWDB, 2022a). Figure 4 shows the growth of desalination plant capacity in Texas since 1999.

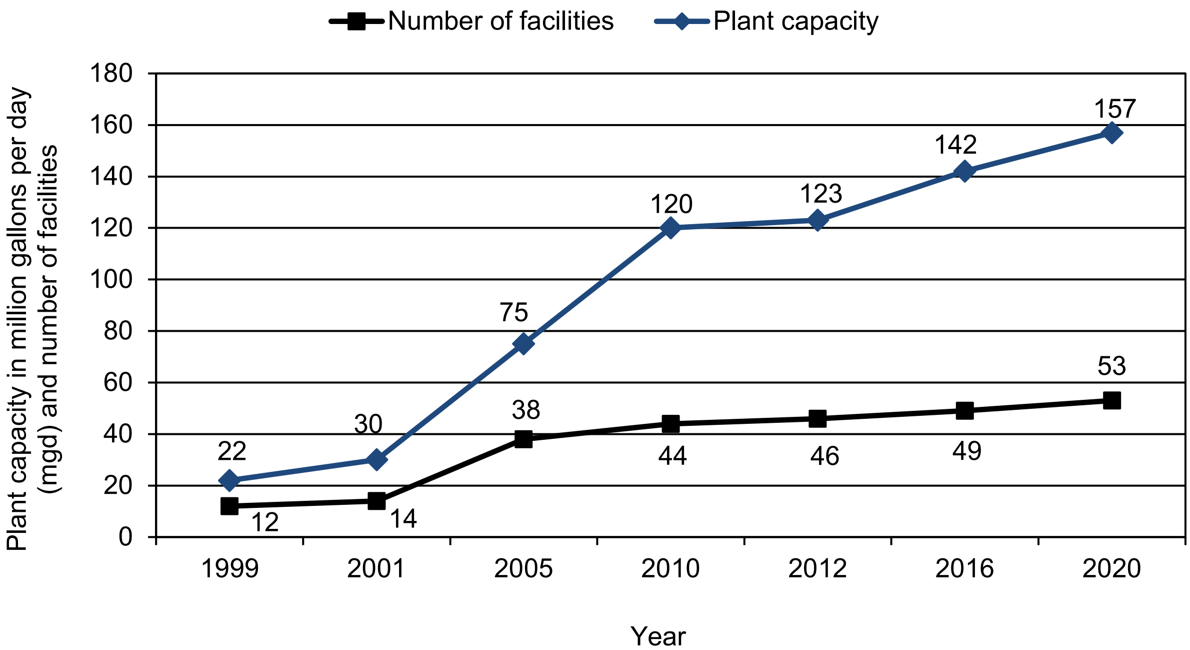

Figure 4: *The growth of municipal desalination facilities and installed design capacity in Texas, 1999 through 2020 (TWDB, 2022a). For detailed data, please refer to table B1 in Appendix B.*

TWDB DESALINATION PLANT DATABASE AND SURVEY

In 2005, the TWDB funded a project to develop a desalination plant database to track the growth of desalination across the state (Nicot et al., 2005). In 2010, 2016, and 2020, TWDB staff updated this database by collecting survey data from existing desalination plants in the database and from new desalination plants identified by staff. The database contains information on desalination plants with production capacities greater than 25,000 gallons per day. Figure 5 shows an image of the TWDB Desalination Plant Database, including the location of plants across the state.

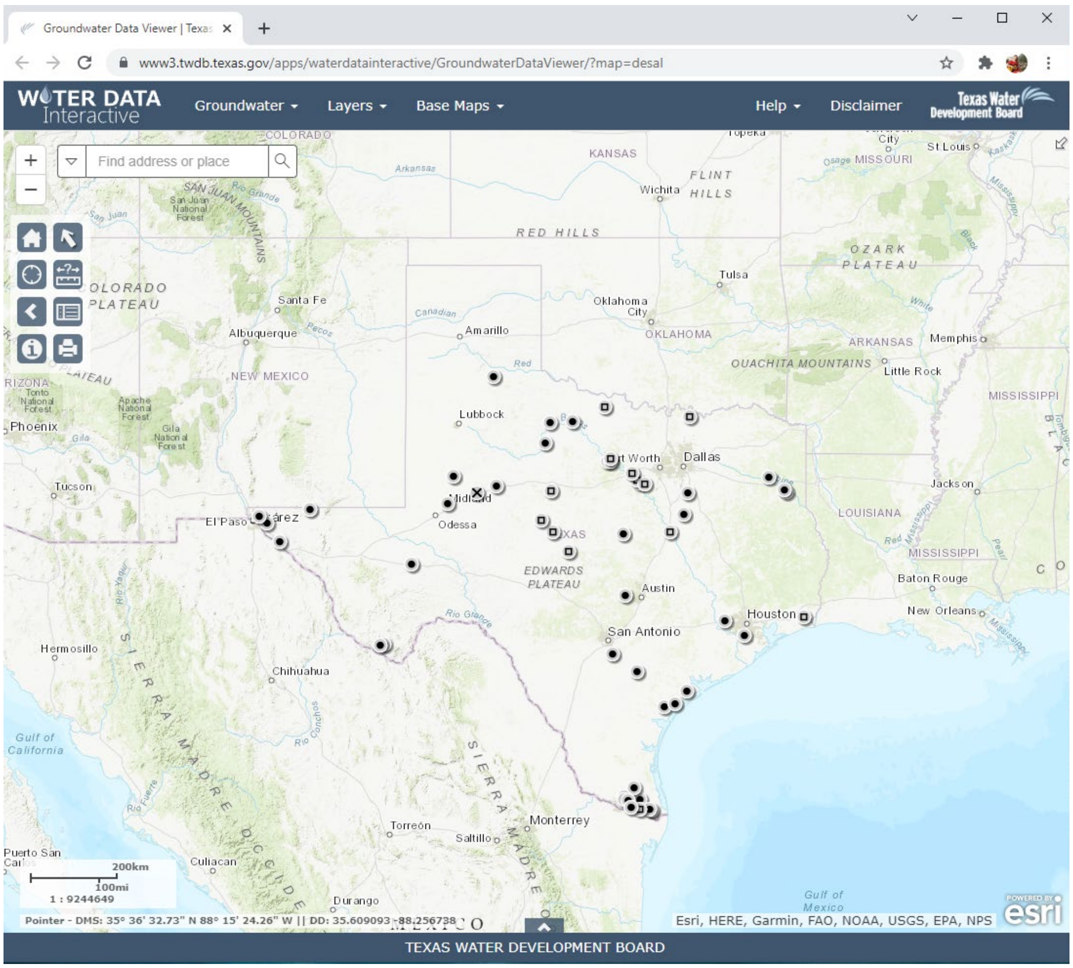

Figure 5: *TWDB's Desalination Plant Database.*

*Available on the **[Desalination Plant Database webpage](#)**.*

The database is updated approximately every five years. TWDB staff work directly with the TCEQ to obtain a list of existing desalination plants in operation. TWDB staff use the information provided by the TCEQ to identify new desalination plants in operation, identify desalination plants not in the database, and remove any desalination plants from the database that have closed since the previous survey. TWDB staff in the Innovative Water Technologies Department contact all known desalination plant operators, request their participation in the desalination plant survey, and update their contact information. The survey is either emailed to desalination plant operators as a Microsoft Word document or mailed to the operator if a printed copy is requested. Desalination plant operators in Texas submit their self-reported survey responses to the TWDB, and then TWDB staff analyze the results. Appendix A of this report is a copy of the 2020 survey sent to desalination plant operators.

The data in this report are based on responses to survey questions regarding concentrate production and concentrate management from desalination plants that participated in the 2020 survey. Survey participation was optional, and responses to survey questions are taken at the word of the survey respondent. As a result, survey data may be subject to error.

There are existing desalination plants in Texas that chose not to participate in the TWDB survey or that participated but did not answer all questions regarding concentrate management. As a result, there may be information gaps in this report. Additionally, survey information is gathered approximately every five years, and it is possible that plants change their operation methods during the periods between surveys.

CONCENTRATE DISPOSAL METHODS USED IN TEXAS

Figures 6 and 7 show the concentrate disposal methods used by the 53 desalination plants in Texas that responded to the 2020 TWDB Desalination Survey. The majority of desalination plants discharge their concentrate directly into a nearby surface water body or send their concentrate to a sanitary sewer for blending and discharge.

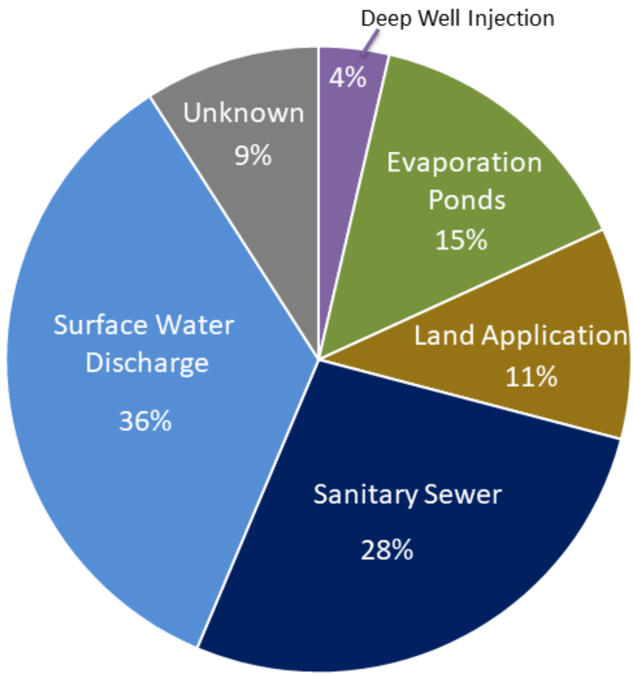

Figure 6: *Concentrate disposal methods by percent.*

For detailed data, please refer to table B2 in Appendix B.

Figure 7 shows the location and concentrate disposal method for desalination plants across the state of Texas.

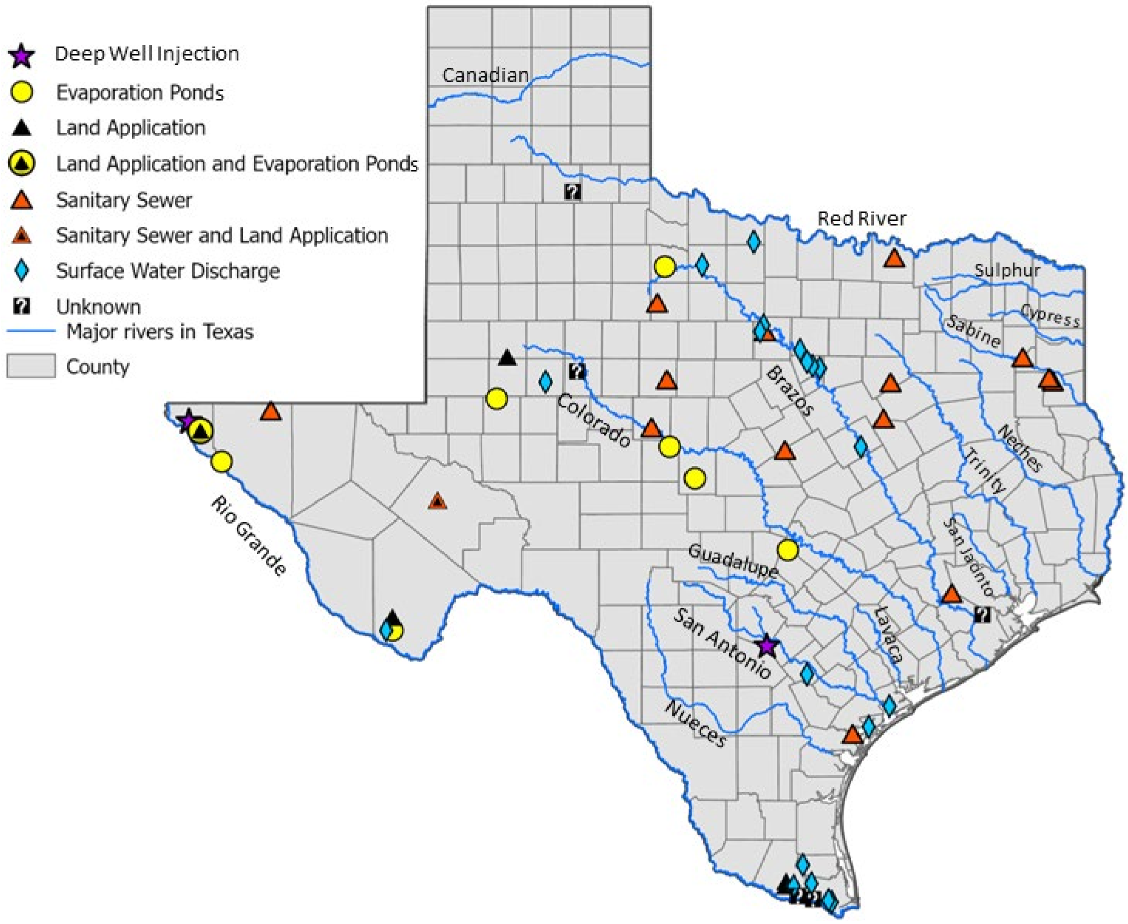

Figure 7: *Map of concentrate disposal method by location.*

Discharge to Surface Water

Survey results indicate that the most common concentrate disposal method in Texas is surface water discharge, with 19 desalination plants (or 36 percent of plants) currently discharging concentrate to surface water bodies. When plant operators were asked if they treat their concentrate before discharging directly into surface waters, 12 reported that they do not treat their concentrate before discharge, 5 shared that they blend their concentrate before direct discharge, and 2 cited using alternative treatment methods before discharging to a surface water body (Figure 8).

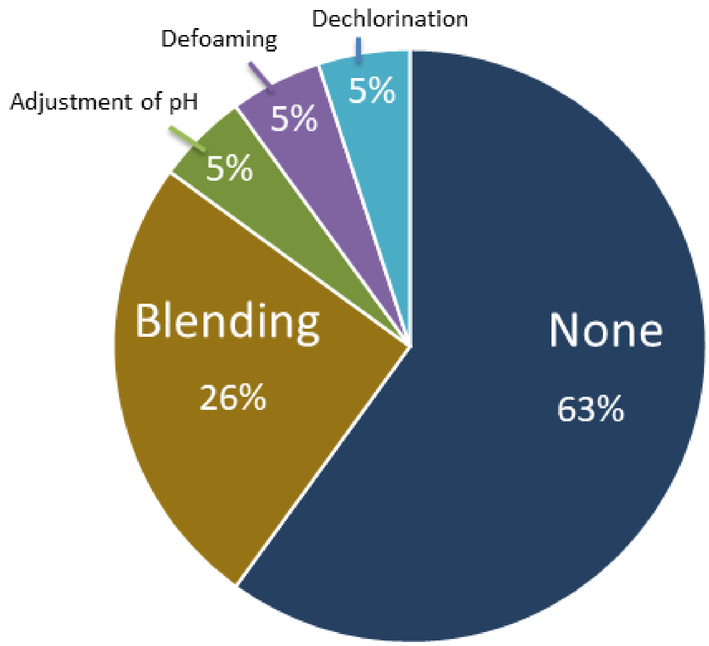

Figure 8: *Treatment methods utilized for concentrate before discharge to surface water.*

For detailed data, please refer to table B3 in Appendix B.

All surveyed desalination plants in Texas have valid discharge permits from the TCEQ and are operating within the terms of their permits. The current overall volume of concentrate being discharged to surface water bodies has been deemed low enough by the TCEQ such that there are no concerns regarding impacting aquatic life in receiving streams. However, with potential for the construction of more desalination plants in Texas to meet water demand, the volumes of concentrate being discharged into surface water bodies may increase over time. Discharge permits to surface water bodies are issued on a first-come, first-served basis. The TCEQ also reserves the right to deny future desalination plants permission to discharge into surface water bodies if the overall volume of concentrate being discharged becomes too large (Michael Lindner, TCEQ, personal commun., 2022).

Some surface water bodies in Texas are saline in nature and may benefit from increased flows caused by concentrate discharge (this includes the northern section of the Brazos River and the Pecos River). Additional flow volumes from concentrate discharge assist flows in these areas, particularly in times of drought. However, if salinity levels in these water bodies rise above current levels due to increased concentrate discharge, aquatic life may be impacted.

Discharge to Sanitary Sewer

The second most utilized concentrate disposal method is sending concentrate to a sanitary sewer for treatment and discharge, with 15 desalination plants (or 28 percent of plants) currently using this approach. No plants surveyed indicated that they pretreat their concentrate before sending it to a sanitary sewer.

Other Disposal Methods

Eight plants (or 15 percent) send their concentrate to evaporation ponds. Six plants (or 11 percent) use their concentrate for land application. Two plants (or 4 percent) dispose of their concentrate via deep well injection. It should be noted that some plants specified they use more than one disposal method, such as a combination of evaporation ponds and land application. Most desalination plants located near a surface water body dispose directly into a surface water body or use a sanitary sewer. Otherwise, the concentrate disposal method appears to have been determined based on local conditions and circumstances.

Of the desalination plants surveyed, five (or 9 percent) did not specify their concentrate disposal methods. Future surveys will emphasize this question so TWDB staff can obtain information that is as accurate as possible on disposal methods of concentrate in the state.

CONCENTRATE MANAGEMENT LITERATURE AND TOOLS AVAILABLE

Concentrate management has been a popular research topic in Texas for almost 20 years. Researchers in the public and private sectors have produced studies and developed resources that can be used by desalination plant operators to help make more informed decisions on how to manage their concentrate.

The Texas Water Development Board has funded several studies on concentrate management options for desalination plants. Table 3 shows a list of these studies, including their descriptions and completion dates.

***Table 3**: List of studies funded by the Texas Water Development Board on desalination concentrate.*

Title of study	Description	Year completed
Permitting Guidance Manual to Dispose Desalination Concentrate into a Class II Injection Well	The objective of this study was to develop a manual that describes the process by which a Class II injection well can be permitted as a Class I injection well for the disposal of desalination concentrate.	2013
Demonstration of a High Recovery and Energy Efficient RO System for Small-Scale Brackish Water Desalination	The primary objective of this project was to demonstrate a reverse osmosis system with a configuration of parallel elements for small-scale desalination with high recovery and energy efficiency.	2012
An Assessment of Osmotic Mechanisms Pairing Desalination Concentrate and Wastewater Treatment	This report describes work conducted to evaluate a hybrid forward osmosis/reverse osmosis process to recover water from treated wastewater effluent for beneficial use.	2011
Continuous Flow Seawater RO System for Recovery of Silica-Saturated RO Concentrate	The El Paso Water Utilities desalination plant underwent large-scale testing to evaluate the silica reduction in reverse osmosis concentrate, using lime addition and vibratory shear enhanced processing (VSEP) technology.	2011
San Antonio Water System Brackish Groundwater Desalination Facility Enhanced Recovery Alternatives Evaluation and Pilot Test Report	The project performed a pilot test and assessed the cost and technical feasibility of the Vibratory Shear Enhanced Process (VSEP) as a tool for reducing the volume of brackish groundwater desalination concentrate. Additionally, the project developed a model for evaluating enhanced recovery processes to aid in selecting concentrate management solutions for brackish groundwater desalination.	2010
Improving Recovery: A Concentrate Management Strategy for Inland Desalination	The objective of this research was to develop strategies to increase the recovery in reverse osmosis (RO) desalination of brackish groundwater. The researchers investigated two possible systems to enhance recovery in conventional RO systems: anti-scalant deactivation and precipitation and electrodialysis.	2010

Title of study	Description	Year completed
Self-Sealing Evaporation Ponds for Desalination Facilities in Texas	In this report, the researchers examined evaporation ponds and the possibility of incorporating a low-permeability layer (precipitant) into the pond-liner system as a liner component or possibly as the liner itself. One goal of this analysis was to investigate the regulatory requirements and barriers of using self-sealing ponds, and to see if this strategy proved to be a technically viable alternative to standard pond liners. Another part of the work consisted of understanding the favorable chemical conditions, natural or induced, for the precipitation of such a compound(s). The third and final facet of this work was to investigate the savings or extra costs of this approach.	2009
Desalination Brine Discharge Model	To improve modeling of desalination brine discharge, this project investigated an existing high salinity outflow from a small embayment (Oso Bay) into a larger embayment (Corpus Christi Bay). The premise of this investigation was that the existing high salinity outflow from the narrow Oso Bay channel is similar to what might be postulated from a large-scale desalination plant.	2006

Several tools and resources have been developed that plant operators can use to assist with managing their concentrate.

In 2020, the U.S. Bureau of Reclamation (USBR) and industry partners developed a Concentrate Management Toolbox aimed for water planners and water treatment plant operators in the U.S. The toolbox was created by the USBR with input and oversight from the engineering firm Plummer and Associates in partnership with the North Texas Municipal Water District using funds from the USBR. The tool is a Microsoft Excel based decision tree where water treatment plant operators can input specific information on their plant operations, along with certain constraints and preferences they have. The tool will then recommend a concentrate management technology for ultimate volume reduction and/or disposal based on the given inputs. The tool is open source, so anyone can update or add to the list of available technologies for concentrate treatment or disposal. The tool does not provide specific cost information for each disposal method, but it does offer general information on the relative expense of disposal options. The concentrate management toolbox is available for download on the USBR website (USBR, 2020).

The USBR has also published resources on concentrate management that are available to desalination plant operators. Examples include

- Desalination and Water Purification Research and Development Program Report No. 123 Membrane Concentrate Disposal: Practices and Regulations (published in 2006), and
- Desalination and Water Purification Research and Development Program Report No. 155 Treatment of Concentrate (published in 2009).

In 2006, the Water Research Foundation also published a report entitled *Beneficial and Non-Traditional Uses of Concentrate* that desalination plants can refer to for concentrate disposal options.

These are just some of the studies and tools available for those looking to learn more about concentrate management.

CONCLUSION

As more communities in Texas turn to desalination to meet their water needs, plant operators will need to consider concentrate management for their operations. Most desalination plants in Texas are currently disposing their concentrate directly into nearby streams and waterways or working with local municipal water treatment plants to dispose their concentrate into sanitary sewers. At the time of this report's publication, the TCEQ is not concerned about the impacts on ecosystems and aquatic life from current concentrate disposal volumes. However, if volumes of concentrate being discharged into waterways significantly increases, the TCEQ reserves the right to deny discharge permits and desalination plants may need to pre-treat their concentrate or turn to alternative methods for concentrate disposal.

Using existing concentrate management tools, desalination plant operators can research the best options currently available for disposing of their concentrate. Although most desalination plants in Texas currently discharge their concentrate waste directly into surface water bodies or send it to a sanitary sewer, as treatment technologies improve and become more economically viable, they may turn to more innovative uses of their concentrate in the future.

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APPENDIX A: COPY OF SURVEY QUESTIONS FOR DESALINATION PLANT OPERATORS

Section 1: General Information	
Official plant name:	
Mailing address:	
County:	
Physical address:	
Latitude and longitude (physical location):	
Ground water conservation district:	
Public water system number:	
Contact name:	
Contact title:	
Phone:	
Fax:	
Email:	
Web site:	
Plant designer:	
Plant owner:	
Plant operator:	

Section 2: Plant Information				
Plant operating status:	☐ Operating	☐ Idle, since:		☐ Closed, since:
Year of plan start-up:				
Year of desalination unit start-up:				
Cost of desalination plant when built:				
Plant category (check all that applies):				
☐ Drinking water	☐ Wastewater treatment	☐ Industrial		☐ Beverage
☐ Pharmaceuticals	☐ Chemical	☐ Landfill leachate		☐ Power
☐ Electronics	☐ Other, specify:			
Is blending used:			☐ No	☐ Yes
Plant design capacity including blending (MGD):				
Plant permitted production including blending (MGD):				
Plant average production including blending (MGD):				
If blending is used, select water source:				
☐ Same as raw water		☐ Same as membrane feed water		
☐ Other, specify source and TDS (mg/L):				
Target TDS of blend water (mg/L):				
Target TDS of finished water (mg/L):				
Process type used (check all that applies):				
☐ Reverse Osmosis	☐ Electrodialysis Reversal	☐ Electrodialysis		☐ Multi-effect Evaporation
☐ Nanofiltration	☐ Vapor Compression	☐ Multi-Stage Flash		☐ Other:
Desalination unit design production (MGD):				
Desalination unit permitted production (MGD):				
Desalination unit average production (MGD):				
Concentrate permitted production (MGD):				
Concentrate average production (MGD):				
Power source:		☐ Grid	☐ Co-location	☐ Other:
Future plant expansion?		☐ No	☐ Yes	
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 Iron / Manganese		☐ Other:

Section 3: Raw Water Supply Source				
Water Source (check all that apply):				
☐ Groundwater	☐ Surface water	☐ Seawater	☐ Other:	
Distance from raw water source to plant:				
If groundwater source, specify the following:				
Well field location (feet):		Withdrawal zone (feet):		
Screened interval: _____________ feet to _____________feet below land surface				
If surface or sea water, specify intake location:				
If reclaimed water, specify water source:				
TDS of raw water (mg/L):				
TDS of membrane feed water (mg/L):				
Seasonal variation in production >25%:	☐ No	☐ Yes		
Is turbidity an operational problem?	☐ No	☐ Yes, _________NTU and _______SDI		
Present operational problems (check all that apply):				
☐ Variable raw water composition	☐ Manganese (Mn)	☐ Iron (Fe)		
☐ Total Organic Carbon (TOC)	☐ Hydrogen Sulfide (H_2S)	☐ Organic matter		

Section 4: Pretreatment before Desalination Unit				
Filtration method (check all that apply):				
☐ Gravity filter	☐ Media filter	☐ Bag filter	☐ Other:	
☐ Cartridge filter, enter manufacturer and size:				
☐ Membrane (MF/UF), enter manufacturer:				
Coagulation/flocculation:		☐ No	☐ Yes	
If coagulation/flocculation is used, select method (check all that apply):				
☐ Ferric sulfate	☐ Ferric chloride	☐ Alum	☐ Polymer	☐ Other:
Clarification, select one:		☐ No	☐ Yes	
Oxidation :		☐ No	☐ Yes, specify why:	
If oxidation is used, select method (check all that apply):				
☐ Aeration	☐ K permanganate	☐ Green sand	☐ Disinfection	☐ Other:
Softening:		☐ No	☐ Yes	
If softening is used, select method (check all that apply):				
☐ Membrane (Nanofiltration)		☐ Lime addition	☐ Ion exchange	
Disinfection:		☐ No	☐ Yes	
If disinfection is used, select method (check all that apply):				
☐ Chlorination	☐ Chloramination	☐ Ozonation	☐ UV	☐ Other:
Dechlorination:		☐ No	☐ Yes	
Activated carbon:		☐ No	☐ Yes, to remove:	
pH adjustment:		☐ No	☐ Yes	
If pH adjustment is used (check applicable):				
☐ Acidification, specify pH:		☐ Addition of caustic, specify pH:		
Scaling control:		☐ No	☐ Yes	

Section 5: Membrane Information (No membrane, go to Section 6)			
Manufacturer of membrane elements:			
Years in service (years):			
Feed pressure (psi):			
Membrane recovery (%):			
Target TDS of the final permeate (mg/L):			
Problems encountered (check all that apply):			
☐ Scaling	☐ Calcite	☐ Gypsum	☐ Silica
☐ Sulphides	☐ Metal oxide	☐ Colloidal fouling	
☐ Biological fouling	☐ Unknown nature of scales	Other:	
Membrane replacement frequency (check applicable):			
☐ Never been changed	☐ ≤ 2 years	☐ > 2 and ≤ 4 years	
☐ > 4 and ≤ 6 years	☐ > 6 years	☐ Other:	
Current membrane cleaning frequency (check applicable):			
☐ Monthly	☐ Bimonthly	☐ Quarterly	
☐ Semi-annually	☐ Annually	☐ Other:	
Membrane cleaning triggered by (check all that apply):			
☐ Decreased production	☐ Increased pressure	☐ Time elapsed ________hours	
Disposal method of cleaning waste (check all that apply):			
☐ Mixed with concentrate	☐ Hauled from the site		
☐ Sewer/Wastewater treatment plant	☐ Other:		
Average TDS of concentrate (mg/L):			
Flow equalization between stages:	☐ Valve throttling	☐ Booster pump	

Section 6: Permeate Posttreatment (No posttreatment before distribution, go to Section 7)			
Post-treatment (check all that apply):			
☐ Activated carbon	☐ Adjustment of pH	☐ Ion exchange	☐ Aeration
☐ Blending	☐ Corrosion control	☐ Disinfection	☐ Fluoridation
☐ Adjustment of alkalinity	☐ Gas removal	☐ Other:	

Section 7: Concentrate Posttreatment (<u>No</u> posttreatment of concentrate, go to Section 8)		
Post-treatment (check all that apply):		
☐ Adjustment of pH	☐ Aeration	☐ Blending
☐ Gas removal	☐ Scaling control	☐ Disinfection
☐ Corrosion control	☐ Dechlorination	☐ Other:

Section 8: Concentrate Disposal				
Concentrate disposal method (check all that apply):				
☐ Disposal Well	☐ Surface water	☐ Land Application		
☐ Evaporation pond	☐ Zero-discharge	☐ Sanitary Sewer		
Co-disposal with neighboring facility		☐ No	☐ Yes	
Disposal well:		☐ No	☐ Yes, distance to well:	
If disposal well is used, select permit type:		☐ Class I	☐ Class II	☐ Class V
If disposal to surface water body, provide name and distance to water body:				
If disposal to surface water body, select permit type:		☐ TPDES	☐ Other:	
If land application, select method:		☐ Septic	☐ Irrigation water	
If sanitary sewer, enter wastewater treatment plant name:				
If evaporation pond, enter ultimate fate of dry residue:				

Section 9- Operational Issues	
Chemicals:	
Disposal of concentrate:	
Electronics:	
Feed water:	
Membrane:	
Operating costs:	
Permitting:	
Posttreatment of concentrate:	
Posttreatment of permeate:	
Pretreatment:	
Pump/Valves:	
Well/Intake:	

Section 10- Cost Information		
Average rate/cost of power as of 2015 (check 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:	
Feed water cost:	
Labor cost:	
Membrane replacement cost:	
Chemical cost:	
Energy cost:	
Concentrate disposal cost:	

APPENDIX B: DATA TABLES

Table B1: *Growth of municipal desalination facilities and installed design capacity in Texas, 1999 through 2020 (TWDB, 2022a).*

Year	1999	2001	2005	2010	2012	2016	2020
Number of desalination facilities	12	14	38	44	46	49	53
Plant capacity in million gallons per day	22	30	75	120	123	142	157

Table B2: *Percent of plants surveyed utilizing disposal method.*

Surface water discharge	Sanitary sewer	Evaporation pond	Land application	Disposal well	Unknown
36%	28%	15%	11%	4%	9%

Table B3: *Percent of treatment methods utilized by desalination plants that discharge concentrate into a surface water body.*

Blending	Adjustment of pH	Defoaming	Dechlorination	None
28%	15%	11%	4%	36%