Central Arizona Salinity Study

Phase II – Brackish Groundwater

September 2006

The Study Partners: City of Glendale, City of Mesa, City of Phoenix, City of Scottsdale, City of Tempe, Arizona-American Water Company, City of Chandler, City of Goodyear, City of Peoria, City of Surprise, City of Tucson, Town of Buckeye, Town of Gilbert, Queen Creek Water Company, Brown and Caldwell and the Bureau of Reclamation

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 Executive Summary

As the population in central Arizona continues to grow, brackish groundwater will need to be added to the water resources portfolio. The use of traditional water resources will be unable to meet the water needs of projected growth scenarios. In order to use brackish groundwater for potable water, the total dissolved solids (TDS) will need to be significantly reduced to make the water palatable to water consumers. In addition, the quality of the treated brackish groundwater must meet all federal and state regulations. This study focuses on a review of several items that need to be addressed to bring brackish groundwater into current water resource plans. These items include regulatory codes, water quantity and quality, and treatment processes. The following is a summary of the key findings of this report.

- Currently, the two most widely-used methods for treating brackish groundwater in the southwestern United States (U.S.) are reverse osmosis (RO) membranes and electrodialysis reversal (EDR). Of the two, RO appears to be more popular because it can remove TDS and many other constituents. EDR primarily treats dissolved ionic constituents, such as Na, Ca, and Mg, which may limit its usefulness. In addition, EDR is a sole source product in that only one company has the patent on the technology; therefore, eliminating the competitiveness.

- To meet water quality goals, it may be beneficial to use a blending scenario, where a portion of the brackish stream is treated and then blended with non-treated water. Blending scenarios may also mitigate the need to post-treat or stabilize water prior to sending to the distribution system as well as decrease treatment costs while keeping water supply flows high.

- The by-product of treating brackish water is brine concentrate. The most common concentrate disposal methods are discharge to lined evaporation ponds or to sanitary sewers. Both methods have problems that may limit the amount of brackish groundwater than can be treated and used. For example, evaporation ponds require extensive land. Therefore, in some instances, it may not be feasible to use evaporation ponds when the available area around the brackish groundwater well is limited. Discharging to a sanitary sewer may be limited due to the capacity of the sewer or wastewater treatment plant (WWTP).

- The product water from desalinating brackish groundwater will need to meet all federal and state water quality regulations. In addition, the volume of groundwater pumped in certain areas in Arizona must meet the Arizona Department of Water Resources (ADWR's) Groundwater Management Code to assure long-term water supplies. There may be some relief of this requirement in "waterlogged" areas, as defined in Section 2.3.10 of ADWR's Third Management Plan for the Phoenix Active Management Area (AMA).

- The availability of brackish groundwater is still under investigation to determine the long-term viability of this water source. However, based on water quality data, it appears that brackish groundwater sources may need to be treated not only to reduce TDS concentrations, but to remove nitrates, arsenic, and silica.

2.0 Introduction

As water supplies in Arizona become more limited and population increases, new water sources are being sought. Two new potential water sources are water reuse (or reclaimed water) applications and brackish groundwater. Reclaimed water is being more extensively used in golf course irrigation, cooling water supply, and groundwater recharge, while brackish groundwater is being used to supplement potable water supplies.

The objective of this study was to determine the viability of using brackish groundwater in central Arizona, which includes the metropolitan and surrounding areas of Phoenix and Tucson. Brackish groundwater is defined as having a total dissolved solids (TDS) concentration between 1,000 and 10,000 milligrams per liter (mg/L). In this range of TDS, water becomes unpalatable for human consumption. In addition, traditional water treatment technologies do not remove TDS. Therefore, advanced treatment technologies, such as membranes, are required to remove TDS. In addition, the concentrations of other water quality constituents, such as arsenic, nitrate, and silica, need to be evaluated to determine the final treatment process required to use brackish groundwater as a potable water source.

In addition to treatment aspects and other water quality issues, the quantity of brackish groundwater supply needs to be examined. The West Salt River Valley (WSRV) groundwater basin in central Arizona includes areas that are known to have TDS levels ranging from 1,000 up to 5,000 mg/L. However, the volume of the brackish groundwater is uncertain and it is unclear if this water source can be used on a sustainable basis. Water resources investigations are needed in other areas to determine potential brackish groundwater supplies.

As with any water source, several regulatory aspects need to be considered. For brackish groundwater, this may include water rights, clean water regulations, and assured water supply.

2.1 Methodology/Area of Study

This report focuses on issues related to brackish groundwater desalination in central Arizona. To better understand the issues, the first task of the study was to conduct a survey of existing brackish water treatment facilities located throughout the southwestern United States to identify potential problems with the treatment of brackish water. Several of these facilities were reviewed and are summarized in Section 3. Issues particular to Arizona include regulatory issues (Section 4), supply quantity and quality (Section 5), and treatment technologies (Section 6).

The quantity and quality section of this study focused on the Phoenix metropolitan area. Special consideration will be focused on a known area of brackish groundwater in the WSRV. This area is defined in ADWR's Third Management Plan as the "waterlogged area" in Buckeye/Goodyear. Further discussions of this particular area can be found in Section 5 and Appendix C of this report.

3.0 Case Studies

Over 30 existing brackish water treatment facilities and reports were reviewed and summarized for this study to determine similarities in TDS concentrations, treatment methods, concentrate management methods, permitting requirements, and environmental or public acceptance. A complete list of the facilities reviewed and summary data sheets are included in Appendix A. Of the 30 facilities, five were selected to be highlighted in Table 3.1 below with additional information in the following sections. These five projects were selected based on having groundwater as the source, utilizing either RO or EDR treatment, and having similar water quality, specifically TDS concentrations, to the central Arizona conditions. The projects presented are all in the southwestern U.S., with TDS values ranging from 800 to 4000 mg/L.

Table 3.1 – Summary of Pertinent Desalting Projects in the Southwestern U.S.

Project	Centerra Well Facility	Gila Bend Facility	Lewis Prison Facility	Chino I Desalter	Goldsworthy Desalter
Location	Goodyear, Arizona	Gila Bend, Arizona	Buckeye, Arizona	Chino, California	Torrance, California
Owner	City of Goodyear	Town of Gila Bend	Lewis Prison	Chino Basin Desalter Authority	Water Replenishment District of Southern California
Source Water TDS, mg/L	>1,900	1,000-2,000	2,000-2,500	871	~3,800
Treatment Method	RO	RO	EDR	RO	RO
Plant Capacity (in millions of gallons per day [MGD])	2.5	1.0	1.35	8.0	2.5
System Recovery (in percent)	79	Unknown	Unknown	90	81.3
Year Online	2002	2002	1988	2000	2001
Capital Cost (in millions [M] of U.S. dollars)	$1.98M	Unknown	$1.1M	$25M	$6.5M
Operating Cost (in U.S. dollars per every thousand gallons [kgal])	$0.93/kgal	Unknown	Unknown	$1.61/kgal	Unknown
Concentrate Disposal	Sanitary Sewer	Evaporation Ponds	Evaporation Ponds	Ocean Outfall	Sanitary Sewer

Notes:
1. *All five treatment systems operate with a brackish groundwater source.*
2. *Detailed summaries of these and other desalting projects are provided in Appendix A.*
3. *RO – Reverse osmosis.*
4. *EDR – Electrodialysis reversal.*

3.1 City of Goodyear RO Facility

The City of Goodyear (COG) in Maricopa County, Arizona, began processing brackish groundwater in 2004 from the City's existing Centerra Well. Brackish water is pumped from the well through approximately 2 miles of raw water transmission pipeline to a 2.5 million gallon per day (MGD) RO water treatment facility located at an existing COG potable water booster pump station and 2 million gallon storage reservoir site. The RO system includes four individual RO treatment trains that will be operated at a minimum recovery of 75 percent.

The Centerra Well was drilled in 1949 to supply irrigation water to local farmers. The well has historically been utilized as an irrigation well, but was converted to a municipal well in 2004. The rehabilitation included installing a 16-inch diameter inner well casing to 500 feet. The inner casing is perforated between 234 and 490 feet. Water quality at the Centerra Well is summarized below in Table 3.2.

Table 3.2 – Groundwater Quality Data from Centerra Well*

Parameter	Value
Calcium, mg/L	163
Magnesium, mg/L	69
Sodium, mg/L	414
Sulfate, mg/L	505
Barium, mg/L	0.04
Nitrate, mg/L	17.9
Silt Density Index, units	1.2 – 5.6
Fluoride, mg/L	0.7
Temperature, degrees Fahrenheit	51.8
TDS, mg/L	1,940
Total Alkalinity ($CaCO_3$), mg/L	193
pH, standard units	7.4
Arsenic, mg/L	0.003

*Data from City of Goodyear, 2004

As shown in Table 3.2, the Centerra Well contains high TDS, in excess of 1,900 mg/L, and nitrate above the state and federal drinking water standards of 10 mg/L. COG's treatment goal is to produce a finished water product with a TDS of 500 mg/L or less and a nitrate concentration (as nitrogen) of 10 mg/L or less. To meet the treatment goals, a water blending scenario is used. The Centerra Well will pump 3.2 MGD raw water to the treatment facility, of which 2.7 MGD will be sent to the RO units and the remaining 0.5 MGD will bypass the RO units to be blended with the RO product water. The blended product is anticipated to have a TDS concentration of 479 mg/L and a nitrate concentration of 5.29 mg/L. TDS concentration in the 0.7 MGD concentrate rejected from the RO units is projected to be 7,447 mg/L.

Pretreatment includes a cartridge filtration system to remove larger particles as well as the addition of a threshold inhibitor compound to prevent the precipitation of sparingly soluble salts in the concentrate stream. Sodium hypochlorite is used for disinfection of the finished water prior to discharging into the storage reservoir. Concentrate is disposed in the sanitary sewer.

3.2 Town of Gila Bend RO Facility

In 2002, the Town of Gila Bend (Town), located in southern Maricopa County, completed the construction of a 1-MGD RO facility to treat groundwater. The facility includes three independent treatment trains. Groundwater for the facility is supplied from a series of wells located 5 miles south of the Town. TDS concentrations in the groundwater average between 1,000 to 2,000 mg/L. Concentrate from the RO system is disposed in evaporation ponds located at the RO facility site.

In 2004, the Town started experiencing problems with the system. The RO system has been producing about 300 gallons per minute (gpm) for 16 to 17 hours per day using two treatment trains. This is significantly less than the design capacity of 1 MGD. The problem has been attributed to inadequate pretreatment. High chloride concentrations in the groundwater have corroded the stainless steel membrane housings. In 2005, the Town began replacing the existing stainless steel housings with fiberglass housings. The first replaced housing skid has been operating for over six months and it appears this will fix most of the problems with the system.

3.3 Lewis Prison EDR Facility

The Lewis Prison EDR Facility is a 1.35 MGD treatment plant with 3 EDR units, constructed to treat groundwater, which is supplied by two wells with TDS concentrations of approximately 2,000 mg/L. The facility is expandable up to 1.8 MGD with 4 units. Pretreatment includes acid addition and cartridge filtration. The EDR permeate is post-treated with caustic solution to provide pH adjustment and chlorination for disinfection. The system has had problems operating at the rated capacity; therefore, the recovery rate is down and more concentrate is generated. The concentrate is disposed of in onsite evaporation ponds. These evaporation ponds are close to exceeding capacity due to the problems associated with the EDR units.

3.4 Chino I Desalter

The Chino I Desalter, located in Chino, Orange County, California, was commissioned in 2000 and built to treat high TDS groundwater with high nitrates. The facility was constructed by the Santa Ana Water Production Authority (SAWPA) then transferred to the Chino Basin Desalter Authority (CDA). The system consists of a 6.7 MGD RO system and bypass facilities for a combined production capacity of 8.4 MGD. The system is operated at 80 percent recovery. In 2005, the plant expanded to 13 MGD by adding ion exchange and volatile organic compound (VOC) removal towers to the facility.

The Chino Desalter was designed to produce potable water with a TDS concentration of less than 350 mg/L and nitrate concentration less than 25 mg/L. The source water (groundwater) has an average TDS of 871 mg/L. Pretreatment methods include acid addition, threshold inhibitor addition, and cartridge filtration. The treatment process includes a 6 MGD RO stream, a 4 MGD ion exchange stream, and a 3 MGD VOC removal stream. The RO permeate is decarbonated and blended with the two other treatment streams to achieve the desired TDS and nitrate goals. Concentrate from the RO system is sent to an ocean outfall through the Santa Ana Regional Interceptor (SARI).

3.5 Goldsworthy Desalter

The objective of the Goldsworthy Desalter, located in Torrance, Los Angeles County, is to provide an additional source of local potable water utilizing a portion of the West Coast groundwater basin currently contaminated by seawater. The average TDS of source water to the Goldsworthy Desalter is approximately 3,800 mg/L. Pretreatment technologies include cartridge filtration, sulfuric acid addition, and threshold inhibitor injection. RO is used as the primary treatment method. The RO permeate is further processed by decarbonation and sodium hydroxide addition prior to blending. Blending goals include using as much bypass volume as possible to achieve a TDS goal of 500 mg/L. The RO treatment capacity is 2.5 MGD with the option to expand to 5 MGD. Overall, the recovery rate of the system is 81.3 percent. Concentrate from the RO system is discharged to the sewer system.

4.0 Legal, Legislative, and Regulatory Issues of Drinking Water

Groundwater quality and quantity are regulated by several different agencies prior to its distribution for potable use. Water quality is primarily regulated by the U.S. Environmental Protection Agency (EPA). In some instances, the EPA has allowed states to assume primacy over these regulations, as is the case with Arizona. Additionally, Arizona has delegated its primacy authority to Maricopa and Pima, Arizona's most populated counties. Issues related to groundwater quantity in central Arizona are regulated by ADWR.

4.1 National Environmental Regulations

Listed below are water quality regulations that may affect the distribution of brackish water for potable uses. Brackish water may have other constituents dissolved in the water and it is important to catalog what regulations may impact the distribution of this water.

Safe Drinking Water Act, 1974, Amended 1986 and 1996

The Safe Drinking Water Act (SDWA) was established in 1974 and authorized the EPA to establish and enforce safe drinking water standards. The SDWA is the primary federal legislation that regulates drinking water in the U.S. The 1996 amendment was enacted to specifically address source water protection, water plant operator training, funding for water system improvements, and dissemination of public information on water systems.

As part of the SDWA, the EPA established Maximum Contaminant Limits (MCLs) on various chemical constituents to ensure that public health is adequately protected. An MCL is the maximum allowable concentration of a specific constituent in public drinking water considered to be safe by the EPA. Primary MCLs are enforceable and are established as the maximum permissible level for contaminants in the water that may cause adverse public health effects. Secondary MCLs are based on aesthetic qualities (taste, odor, color), and are not enforceable. Secondary MCLs are established for contaminants that may have cosmetic or aesthetic effects, but are not considered to present a risk to human health. An example of a secondary MCL is TDS; with a limit of 500 mg/L. TDS concentrations above this limit may impair the taste of water, cause scale build-up on water-dependent appliances, and/or prohibit the growth of plants.

A list of the primary and secondary MCLs is provided in Appendix B.

EPA's Proposed Ground Water Rule

The proposed Ground Water Rule still under review by the EPA at the end of 2005 is proposed by the EPA to promote disinfection of groundwater sources for public drinking water supplies for the purpose of protecting against microbial contaminants. Current standards require the use of disinfection only for drinking water sources consisting of surface water and/or groundwater under the direct influence of surface water as well as residual chlorine level in the distribution system. The Proposed Ground Water Rule would require a hydrologic sensitivity analysis be conducted for public drinking water systems that are not currently disinfecting groundwater and a 99.99 percent virus inactivation/removal. The sensitivity analysis would determine if the aquifer has the potential for microbial contamination. Currently, the EPA considers karst, gravel and/or fractured bedrock aquifers sensitive to microbial contamination. Public drinking water systems would be required to add microbial monitoring for fecal indicators and treatment if microbial indicators were found in the groundwater. Additionally, public drinking water systems would be required to monitor the treatment system to assure that treatment levels are continually met.

Radionuclides Rule

Regulations for radionuclides in community drinking water systems were first promulgated in 1976; the standards became effective in December 2003. Primary MCLs were established for radium 226 + radium 228, radon, uranium, gross alpha particle activity, and beta and photon emitters to reduce the risk of cancer. The southeastern U.S. is affected by this rule in particular because of naturally high levels of radionuclides. The EPA estimates that only 795 systems throughout the U.S. will require treatment for these contaminants.

Lead and Copper Rule

The Lead and Copper Rule was adopted in 1991 for the purpose of protecting public health by reducing corrosivity. The typical source of lead and copper is from plumbing fixtures; therefore, testing for lead and copper is done at the tap. Monitoring schedules are dependant on size of the water system as well as whether or not there have been exceedances in previous test results.

Stage 1 Disinfectants and Disinfection Byproducts Rule (D/DBP)

This rule was developed to limit residual disinfectant in finished water, since disinfectants may react with naturally-occurring organics to form unintended byproducts. This rule applies to all water systems that use disinfection products. Disinfection byproducts (DBPs) have been linked to causing cancer, reproductive and developmental effects in humans. DBPs include trihalomethanes, haloacetic acids, chlorite and bromate. Adherence to meeting the D/DBP MCLs is performed by monitoring the system and determining the D/DBP concentrations on a running annual average for the system. Water providers who use surface water or groundwater under the influence of surface water and use conventional filtration must also use some sort of enhanced coagulation to remove organic materials which may bond with chlorine to form the DBPs.

Stage 2 Disinfectants and Disinfection Byproducts Rule

Stage 2 of the D/DBP Rule was promulgated on January 4, 2006 and supplements the existing regulations by requiring drinking water suppliers to meet disinfection byproduct

MCLs at each monitoring site in the distribution system; the MCLs for total trihalomethanes and haloacetic acids will remain the same. The new rule will require that the community water systems calculate the running annual average at each specific sampling site in the distribution system rather than a running annual average for all sites. Additional requirements must be met if exceedances occur or if *Cryptosporidium* is determined to be present.

Surface Water Treatment Rule (SWTR)

The Surface Water Treatment rule, which applies to all community and non-community public water supply systems, became effective in 1990. The SWTR was developed to protect the public from Giardia, Legionella, insects, algae, and viruses that are found in surface water and groundwater under the influence of surface water. The SWTR requires that all public water supplies be treated through a system of disinfection and/or filtration.

Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR), Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESTR) and Filter Backwash Recycling Rule

The Long Term 1 Enhanced Surface Water Treatment rule became effective in 2001. The Rule was developed to protect public drinking water systems serving less than 10,000 people and use either surface water or groundwater under the direct influence of surface water from microbial contaminants, specifically *Cryptosporidium*.

The LT2ESTR rule is a follow up to LT1ESTR and applies to all public water systems that use surface water or groundwater under the direct influence of surface water, regardless of size. This rule became effective in 2005.

The purpose of the FBRR is to further protect public health by requiring public water systems, establishes stricter filter requirements including additional monitoring and recycling that may otherwise compromise microbial control. This rule also became effective in 2001.

Arsenic Rule

Long-term exposure to arsenic has been linked to cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate. Non-cancer effects of ingesting arsenic include cardiovascular, pulmonary, immunological, neurological, and endocrine (e.g., diabetes) effects.. Based on health studies, EPA revised the previously established MCL for arsenic by reducing it from 50 mg/L to 10 mg/L. The Arsenic Rule was adopted on January 22, 2001 and became effective on February 22, 2002. The date by which drinking water systems must comply with the new 10 mg/L standard is January 23, 2006.

4.2 Arizona Regulations

In 1980, the Arizona legislature created the Groundwater Management Code to control the state’s limited groundwater resources and provide a means for allocating groundwater resources for Arizona's water demand needs. The Code established the State agency, ADWR, to administer the Code's provisions. The Code also established five "Active Management Areas" (AMAs) within the State where groundwater level declines were most severe. The AMAs include Phoenix, Tucson, Prescott, Pinal, and Santa Cruz and encompass approximately 14,600 square miles of area.

The Code also created a system of groundwater rights that limits groundwater withdrawals, prohibits development of new irrigated farmland, requires new developments to demonstrate that a long-term water supply is available and dependable, and requires the measuring and reporting of groundwater uses for these rights. Management goals were developed for each AMA and these goals were to be met with the implementation of a series of five management plans, each one more stringent than the prior. The management plans consist of conservation requirements for industrial, municipal, and agricultural groundwater users. Currently, the Code is operating in its Third Management Plan (TMP), which covers the period of 2000 through 2009.

In addition to the groundwater rights within the AMAs, the Assured Water Supply (AWS) program evolved from the 1973 Water Adequacy Statute to ensure that new development would have water on a legal, physical, and continual basis for 100 years. The two ways to demonstrate an AWS are through a developer attaining a Certificate of Assured Water Supply (CAWS) for a new development or through a water provider having a Designation of Assured Water Supply (DAWS). Many municipal water providers within the Phoenix AMA have secured a DAWS.

Brackish groundwater is subject to the Code's regulation. Pumping and desalination of this water would require that brackish groundwater be counted against groundwater allotments and would also require the groundwater pumper to pay fees for utilizing this water. Because of the quality of this water, brackish groundwater is a somewhat underutilized water resource. It would be advantageous for water providers to have regulatory relief from pumping restrictions. The following references to statute and rule that indicate where some exemptions from the groundwater code already exists.

A.R.S § 45-411.01 Exemptions from Irrigation Water Duties, Conservation Requirements for Distribution of Groundwater and portions of Groundwater Withdrawal Fees for Portions of Phoenix Active Management Area

A.R.S. § 45-411.01 was written to address shallow groundwater levels in the southwest portion of the Phoenix AMA and allows for the exemption of conservation requirements and portions of withdrawal fees until the end of the Fourth Management Plan Period (December 31, 2019) for lands within the Arlington, Buckeye and St. Johns Irrigation Districts. A review of hydrologic conditions of this area and a re-evaluation of the statute (A.R.S. § 45-411.01) must be done by ADWR before December 15, 2015 to extend this exemption. Located within portions the City of Goodyear and the Town of Buckeye, this area is also known as the "waterlogged area" per Section 2.3.10 of the ADWR Third Management Plan (TMP). Depth to groundwater in this waterlogged area is as shallow as 10 feet below land surface and the TMP acknowledges that this area is plagued with high salinity. CASS Phase 1 further studied water quality in this area and determined that in most cases the groundwater meets the definition of "brackish" due to its high TDS content, which can be over 2,500 mg/L.

Assured Water Supply Requirement Exemption

Under Arizona Administrative Code (A.A.C.) R12-15-705.T, water providers with an AWS certificate and/or within the designated waterlogged area are allowed to exclude the uses of the following types of groundwater:

- Surface water (under certain conditions)
- Contaminated Groundwater (under certain conditions)
    - Groundwater Pumping for Remedial Action (under approval of ADEQ)
    - Groundwater is treated, blended or exchanged to achieve water quality standards
    - Groundwater would have otherwise not been pumped
    - Groundwater is withdrawn before 2025
- Water excluded from conservation requirements under Title 45 due to waterlogging. This exemption is to be reviewed on a periodic basis, not to exceed 15 years.

4.3 Local County/City Regulations

City of Tucson Water Consumer Protection Act (WCPA)

The City of Tucson (Tucson Water) initiated the delivery of Colorado River water to Tucson residents via the Central Arizona Project (CAP) aqueduct in 1992. In 1994, delivery of CAP water was terminated after customers experienced broken water mains and "brown water". High levels of TDS and pH levels different from previous water sources are blamed for the CAP water problems. To ensure that Tucson Water would be prohibited from directly delivering CAP water to water customers in the future, the City of Tucson voters passed the 1995 Water Consumer Protection Act (WCPA) regardless of the opposition of the community's elected officials. The WCPA placed limits on TDS levels and limits on where and how CAP water could be used.

Voters understood the necessity for augmenting water supplies with the use of CAP and, therefore, allowed Tucson Water to recharge CAP. Tucson Water developed the Clearwater Renewable Resource Facility in Avra Valley. This facility is composed of multiple recharge basins used to recharge the aquifer and recovery wells that are used to withdraw the recharged water and pump it into the Tucson Water potable water system. Eventually the amount of TDS in the water pumped from Avra Valley will increase from the current 200 mg/L to around 450 mg/L as more and more CAP water is recharged and recovered.

5.0 Water Supply, Adequacy, Reliability, and Quality

The quantity and quality of brackish groundwater in central Arizona needs to be evaluated to determine the viability of using this source to augment current potable water sources. With brackish water, the main quality constituent of concerns is TDS; however, several other constituents can affect treatment selection and concentrate management strategies. In addition to water quality, groundwater quantity needs to be examined. This can be done within specific areas to determine where new groundwater wells can be added without impact to current pumping practices. As mentioned above in Section 4.2, an area that appears to contain sufficient brackish groundwater is in the waterlogged area near Buckeye/Goodyear. The supply and reliability of this groundwater source is being examined by the West Valley Central Arizona Project Subcontractors (WESTCAPS). The results of the WESTCAPS study are summarized below in section 5.2 with the final report included in Appendix C.

5.1 Brackish Water Quality

5.1.1 TDS

TDS is the sum of the concentrations of dissolved minerals in water. Sources of high TDS include soluble mineral deposits, urban and agricultural runoff, and concentration of salts by evapotranspiration. The concentration of salts by evapotranspiration is particularly important in arid regions, such as central Arizona. As the water placed on crops or landscaping evaporates, or is taken up by the plants root system, the salts are left behind. Subsequent waterings and/or precipitation will mobilize, or leach, the salts in the surface and subsurface soils to the extent that the salts will ultimately reach the underlying groundwater..

As discussed above in Section 4.1, the EPA has established a secondary MCL for TDS. Secondary MCLs are set based on aesthetic properties, such as taste and odor, rather than on health effects. Although there is some research that indicates that high TDS may cause adverse health effects, such as diarrhea, high TDS water is usually rejected as a drinking water source due to the taste or the presence of a particular constituent that exceeds a primary drinking water standard. In general, water with a TDS over 1,200 mg/L is designated at unacceptable for human consumption by the World Health Organization (1996).

Groundwater quality records from ADWR’s Groundwater Site Inventory database, Salt River Project’s (SRP’s) wells, and CASS members were examined to determine the extend of brackish water in the Phoenix AMA. Data from a total of 592 wells within the Phoenix AMA were compiled and reviewed. Summary statistics for the TDS data are shown below.

Table 5.1 – Study Area Well Data

Number of Wells	Maximum TDS (mg/l)	Minimum TDS (mg/l)	Mean TDS (mg/l)	Number of Wells Above 1,000 mg/l	Percentage of Wells above 1,000 mg/l
592	5,700	501	1,471	340	57%

As stated in Section 2.0 above, brackish groundwater is defined as having a TDS concentration between 1,000 and 10,000 mg/L.

The reported location of the 592 wells is shown on Figure 5.1, which are mostly located in the WSRV. The WSRV has historically been dominated by irrigated agriculture, although much of it is currently being developed. A U.S. Geological Survey (USGS) map, published in 1974, indicates that groundwater beneath much of the WSRV has elevated TDS (Osterkamp, 1974). Groundwater in certain portions of the East Salt River Valley (ESRV), which includes Mesa, Chandler, and Tempe, also contains elevated TDS levels. However, there are several municipal production wells located within these areas of elevated TDS that produce groundwater containing less than 1,000 mg/l TDS. The variation of TDS concentrations reported in the different wells is most likely attributable to the total depth of the wells and screened intervals, i.e. the portion of the aquifer producing water. In areas where there are multiple alluvial aquifers, it is common for the uppermost aquifer to contain the highest TDS concentrations while the deeper aquifers have lower concentrations. For this reason, plotting the aerial distribution of TDS can be misleading if the screened interval and total depth of the wells being used is not taken into account.

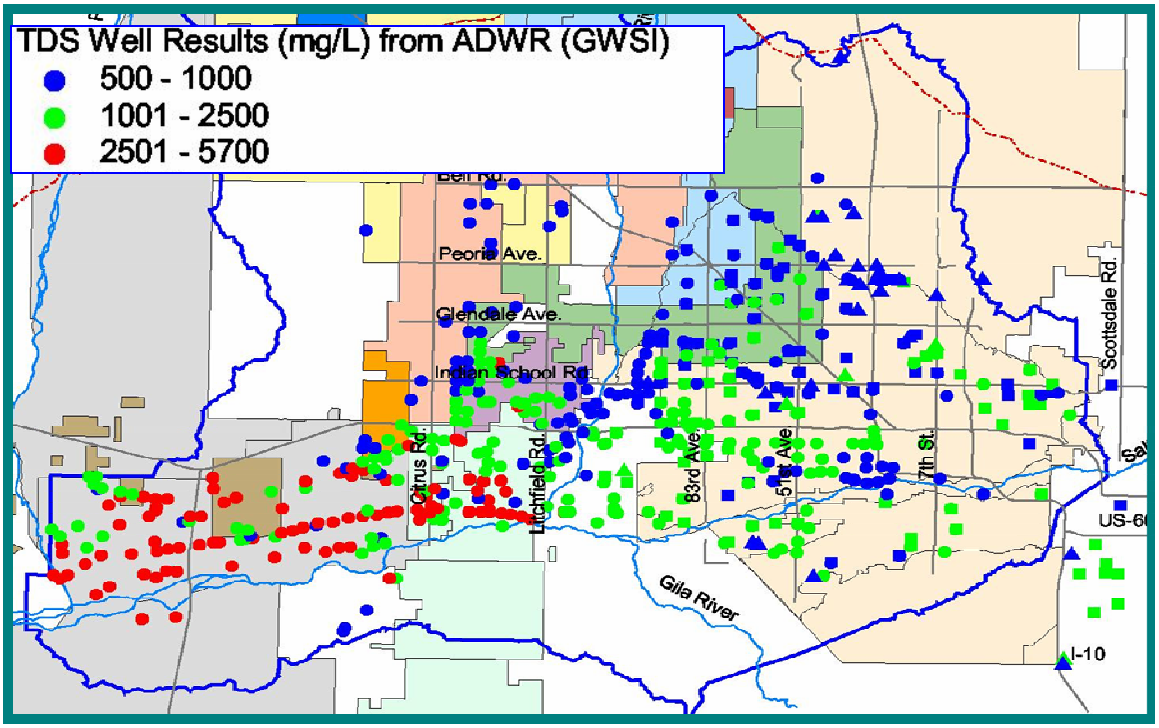

Figure 5.1 – TDS Wells from ADWR

In 2000, the USGS published a detailed study of water quality in the Central Arizona Basins (Cordy, et. al, 2000). The study covered an area of 34,700 square miles in central and southern Arizona and northern Mexico. One of the noted findings in the study was the elevated nitrates and TDS in the shallow groundwater in the WSRV. The USGS noted that in the area of the town of Buckeye, north of the Gila River, corresponding to the ADWR TMP defined "waterlogged area", there are distinctive upper and lower alluvial aquifers separated by low-permeability clay layers. This area has historically been used for agricultural cultivation. The study evaluated water quality data based on well depth and concluded that wells completed in the shallow (uppermost) aquifer had a median TDS concentration of 3,050 mg/l and a median nitrate concentration of 19 mg/l. Wells completed in the deeper aquifer, that is, below the low-permeability clay layer(s), contained a median TDS concentration of 702 mg/l and a median nitrate concentration of 1.9 mg/l. The one or more clay layers, which occurred at depths from 150 to 400 feet below ground surface, provided a protective barrier to the deeper aquifer.

5.1.2 Other Constituents

Dissolved solids typically include the major ions of calcium, magnesium, sodium, potassium, nitrate, sulfate, carbonate, bicarbonate and chloride. However, high TDS water may also contain elevated concentrations of other ions which may exceed primary drinking water standards or interfere with water treatment. The constituents listed in Table 5.2 are from shallow wells located in the waterlogged area near Buckeye. The constituents listed tended to be present in high concentrations in the brackish water wells.

Table 5.2 – Constituents with High Water Quality Levels

Constituent	Number of Wells	Minimum Value	Maximum Value	Mean Value
Nitrate as NO_3 (mg/l)	11	4	102	57
Hardness as CaCO3 (mg/l)	9	41	2200	803
Silica as SiO2 (mg/l)	15	18	56	30

The federal primary MCL and Arizona Aquifer Water Quality Standard (AWQS) for nitrate (as nitrogen) are 10.0 mg/l. Of these wells, 64 percent exceed the MCL and AWQS and would require treatment for potable water uses. This is consistent with the 1974 USGS map (Osterkamp, 1974), which also showed some overlap between the areas of high TDS and high nitrate. Although there are no established drinking water standards for hardness or silica, these constituents can affect the treatment process and should be considered in designing a treatment facility.

5.2 Brackish Water Quantity

Within the WSRV, brackish groundwater is mostly concentrated within the southern portion of the Phoenix AMA, as shown on Figure 5.1, with the highest TDS concentrations being in the waterlogged area. Figure 5.1 also shows the distribution of wells and their respective TDS concentration. In some areas, the wells are clustered together while in other areas they are widely scattered. The distribution of the wells in this area would suggest two separate types of water treatment methodologies be utilized. For those wells clustered together, a wellfield could be constructed that would pump the brackish groundwater to a centralized treatment plant. For the outlying wells, a more individual approach consisting of wellhead treatment would be the most feasible treatment method.. Although the treatment technologies for the two methods may be similar, the economics will be quite different.

Although the areal extent of brackish groundwater in the area of the WSRV has been defined, the quantity, or approximate volume, of this water needs to be evaluated to determine the long-term availability of this source for future potable water uses. The following sections discuss the water availability for the WSRV and ESRV.

5.2.1 WSRV Water Quantity

As discussed above in Section 5.0, WESTCAPS is studying the brackish groundwater quantity in the waterlogged area near Buckeye. This area seems to be the best example of a potential brackish water wellfield, since this area is continually pumped to maintain current groundwater levels. To quantify the amount of water in the area, the ADWR 2002 SRV groundwater model is being used to determine the long term viability of this source. Several modeling scenarios are currently being evaluated. Additional information on the WESTCAPS study will be provided in the final report once the modeling is completed. A complete copy of the study report is included in Appendix C.

5.2.2 ESRV Water Quantity

There is less data available for the ESRV, and therefore, it is difficult to draw conclusions about the availability of brackish groundwater in the ESRV. However, the USGS map and Figure 5.1 indicate that, at least in the shallow aquifer, there are areas containing high TDS groundwater. There may be many individual wells, particularly shallow irrigation wells, in the ESRV that could be converted to drinking water use if treated for TDS and nitrate. The Centerra Well treatment system, described in section 3.1 of this report, is a good example of this type of project.

6.0 Treatment Technology

6.1 RO and Membranes

6.1.1 Process Fundamentals

When two liquid solutions of different concentrations are separated by a *semi-permeable membrane* (a membrane through which water flows more freely than other constituents), water tends to move through the membrane from the dilute (purer) solution into the more concentrated solution (Figure 6-1). This natural phenomenon is known as osmosis. The flow of water will continue until the concentration on each side of the membrane equilibrates or pressure is applied to the concentrated solution. The pressure, which is sufficient to stop osmotic flow, is the *osmotic pressure differential* between the two solutions.

By applying sufficient pressure to the concentrated solution (greater than the osmotic pressure difference) the water flow is reversed. Water molecules from the concentrated side are forced through the membrane to the dilute solution. Salt and other dissolved solids are left behind with the concentrated solution. The purified water is referred to as *permeate* and the concentrated solution of salt and dissolved solids is generally referred to in the water treatment industry as *concentrate*, *by-product*, or *reject*.

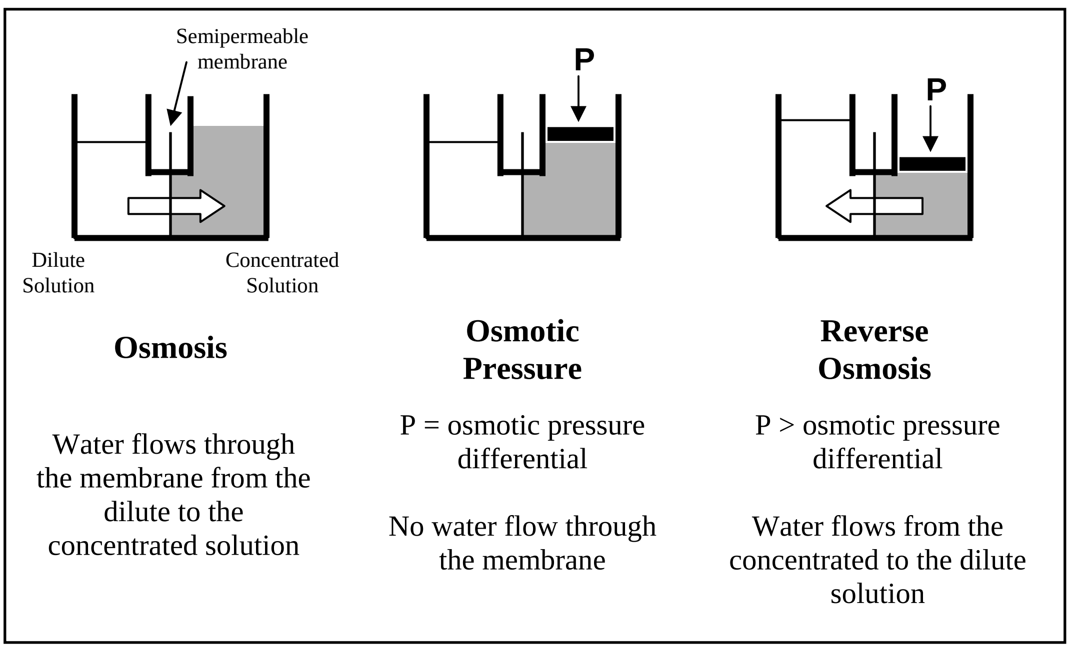

Figure 6.1 – Osmotic Diagrams

6.1.2 Osmotic Pressure and Feed Pressure

The pressure that drives source water (feedwater) through the RO unit is called feed pressure and is a function of the resistance of the membrane itself, source water quality, and headloss through the membrane treatment system; however, it will largely be controlled by the concentration of TDS in the feed water. Because RO is a diffusion-based membrane process, osmotic pressure must be overcome before purified water can be produced.

Osmotic pressure is directly dependent on the salt concentration of the source water. As a rule of thumb, each 100 mg/L of TDS is roughly equivalent to one pound per square inch (psi) of osmotic pressure. Brackish water applications will have an osmotic pressure of 30 to 300 psi, while seawater applications are closer to 550 psi.

Temperature is also an important consideration in determining feed pressure. As temperature varies, so will the feed pressure due to changes in viscosity of the feed water. Lower temperatures require higher feed pressures to produce the same amount of permeate water.

6.1.3 Contaminant Removal Efficiencies

While RO removes the majority of dissolved constituents, there still exists a minimal amount of salt passage, which will be affected by several factors, including:

- Feed water quality,
- Applied feed pressure to affect permeate flow,
- Recovery, and
- Material properties of the membrane itself.

Each membrane has a salt rejection specification, which is measured by the manufacturer before shipment and expressed as a percent removal of sodium chloride (typically 98 to 99.5 percent for RO membranes). As a RO system operates over time, salt rejection can change depending on the level of membrane fouling. There are many ways to calculate salt rejection of a membrane and data normalization plays an important role in evaluating membrane performance.

6.1.4 Flux

Flux is the rate at which water is filtered through a unit area of membrane. Often expressed in gallons per day per square foot (gal/day/ft^2), flux, is a useful tool to allow direct comparison of membrane performance.

As opposed to low-pressure membrane processes (microfiltration and ultrafiltration), diffusion-based membrane systems are run at a constant flux to maintain consistent permeate water quality. Design flux rate is largely determined by feed water quality and is primarily controlled by the pressure applied to the system. Brackish surface water RO applications typically have a design flux of 10 to 14 gal/day/ft^2, while brackish well water applications have a flux of 14 to 18 gal/day/ft^2.

6.1.5 Water Quality Recovery Rates

RO is a cross-flow membrane separation process, which separates the feed stream into a permeate stream and a concentrate or reject stream. The recovery of a RO plant is defined as a percentage of feed water that is recovered as permeate, and is calculated using the following equation.

$$\text{Recovery (\%)} = \frac{PermeateFlow}{FeedFlow} \times 100$$

Salt concentration in the concentrate or reject stream increases logarithmically with recovery rate. For example, at 50 percent recovery, the salt concentration in the reject is about double that of the feed, and at 90 percent recovery, the salt concentration in the reject is nearly 10 times that of the feed.

Recovery rates are largely limited by the concentration of some sparingly soluble salts in the feed water and thus in the concentrate or reject stream. If recovery is pushed beyond the saturation limits of one or more of these constituents, precipitation will begin to occur on the membrane surface, causing scale. Table 6.1 provides a summary of some typical saturation limits. As the membrane fouls, decreased flux and increased salt passage may also occur, adversely impacting permeate water quantity and quality. Consequently, the design recovery rate of a RO plant is established after careful consideration of:

- Desired product quality,
- Solubility limits of the feed water constituents,
- Feed water availability, and
- Concentrate or reject disposal requirements.

Table 6.1 – Typical Saturation Limits for Sparingly Soluble Salts

Sparingly Soluble Salt	Units	Membrane Supplier [1] Concentrate Stream Saturation Limit	Scale Inhibitor Supplier [2] Concentration Stream Saturation Limit
Calcium Carbonate	LSI	+1.8	+1.8 to +3.0
Calcium Sulfate	% Saturation	230	240 to 700
Barium Sulfate	% Saturation	6,000	6,500 to 10,500
Strontium Sulfate	% Saturation	800	3,000 to 3,500
Calcium Fluoride	% Saturation	-	100,000 to 1,300,000
Silica	% Saturation	100	100 to 320
Iron	mg/L	<0.1	0.5
Manganese	mg/L	-	0.5
Aluminum	mg/L	-	0.5

Notes:

LSI: Langelier Saturation Index

Solubility and saturation are dependent on temperature, pH, ionic strength, and pressure.

[1] *Saturation limits specified in standard performance warranty agreement.*

[2] *Saturation limit varies based on scale inhibitor type and supplier.*

6.1.6 Nature of Concentrate Products

When designing a RO system, design software is often used to model the system design and predict the concentrations of salts in the reject stream, based on feed water quality and the specific membrane being used. Once saturation limits are exceeded and precipitation begins, scale forms, clogging the membrane surface. However, chemical anti-scalants can be used to artificially raise the solubility limits of certain salts, and thus control scaling within limits. The saturation limits shown in Table 6.1 are typically used by the scale inhibitor suppliers in standard performance warranty agreements.

6.1.7 Pre-Treatment Requirements

Sulfuric acid, carbonic acid, or hydrochloric acid can be used as pretreatment to RO in order to depress pH and mitigate scaling due to calcium carbonate. Additionally, it is common place to add threshold inhibitor compounds (also referred to as scale inhibitor or anti-scalant) to prevent precipitation of sparingly soluble salts within the RO system. Careful selection of appropriate scale inhibitor may allow the RO plant to operate at higher recoveries and thus control the amount of concentrate requiring ultimate disposal.

Brackish water RO applications may need additional pretreatment units to remove colloidal and suspended solids in order to ensure a low *silt density index* (SDI) in the feed water. The SDI is measurement of the fouling tendency of water based on the timed flow of water through a membrane filter at constant pressure. In general, it is desirable to reduce feed water SDI to less than 5.0 and turbidity to less than 1.0 NTU (nephelometric turbidity units). Automatic backwashing strainers, granular media filtration, microfiltration, and ultrafiltration are all efficient means of particulate removal. However, wellhead treatment systems and large brackish water systems often have only cartridge filters provided as pretreatment.

6.1.8 RO System Configurations

The RO membrane is produced in sheet form - up to 60 inches wide and lengths up to 1,500 feet. The membrane is then assembled into a packaging configuration known as a *spiral wound element*. Figure 6.2 shows the spiral wound packaging configuration.

The spiral wound element consists of two sheets of membrane separated by a grooved, polymer-reinforced fabric material. This fabric both supports the membrane against the operating pressure and provides a flow path for egress of the permeate. The membrane envelope is sealed with an adhesive on three sides to prevent contamination of the permeate. The fourth side is attached to a product water tube, which has perforations within the edge seal so the product water can be removed from the porous product water carrier material. The membrane envelope is rolled up around the central product water tube, with a plastic mesh spacer between the facing membrane surfaces, in a spiral. The mesh spacer not only serves to separate membrane surfaces, but it provides a flow path for, and turbulence in, the feed/reject stream of each element. The elements have an outer wrap to contain the feed/reject stream in the mesh passageway and brine seal to insure that the feed/reject stream goes through the element and not around it.

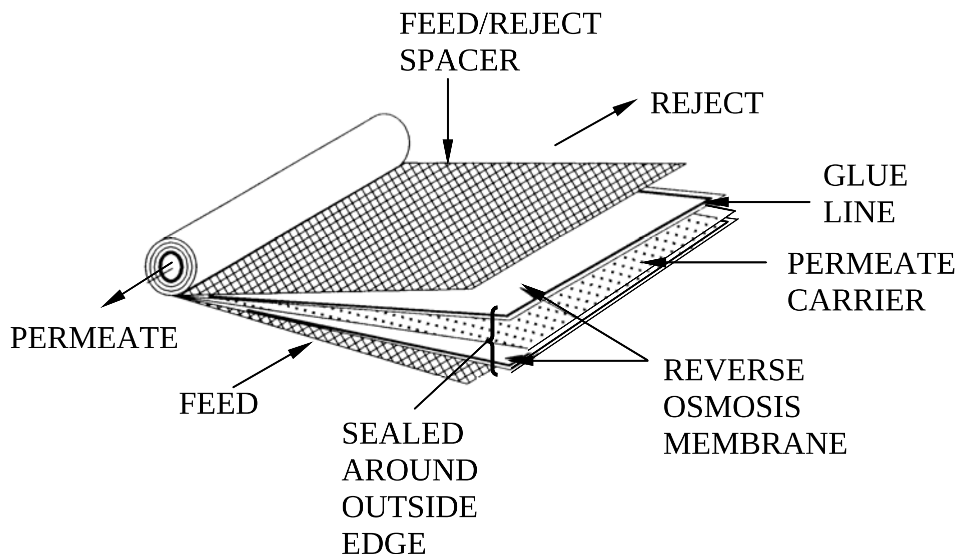

Figure 6.2 – Spiral Wound RO Element Construction

Spiral wound elements are available in lengths from 12 to 60 inches and diameters from 2 to 12 inches. Standard large-scale elements are available in 8-inch diameter and either 40 or 60 inches long. Packaging densities range from 510 to 575 square feet of active membrane surface area per 8 inch x 60 inch element.

Multiple spiral wound elements are installed into a *pressure vessel*, which is usually fabricated from fiberglass reinforced plastic. Pressure vessels are typically designed and fabricated to accommodate combinations of 40- and 60-inch elements and operating pressures of 450 or 600 pounds per square inch gauge (psig), depending on the pressure vessel model.

Figure 6.3 shows a pressure vessel with elements installed. Feedwater enters one end of the pressure vessel and flows through the first element, in which about 10 percent of the feed permeates through the membrane and into the product water tube. The reject from the first element flows to and through the second element and the reject from this element becomes the feed to the next element, and so on. The reject from the last element is routed from the pressure vessel to the high-pressure reject manifold. In a single pressure vessel with six elements, between 40 and 60 percent of the feed water to the pressure vessel is recovered as product water.

To achieve higher recoveries, the overall RO system is configured to operate multiple pressure vessels, each feeding off the reject of the previous pressure vessel. The example shown in Figure 6.4 has three membrane banks or *stages*, operating at 85 percent recovery in a 24:10:5 (vessel) array. Note that the second bank has half as many vessels as the first bank because the second bank feed flow is approximately half that which feeds the first bank. In this way, adequate velocities are maintained through all elements in the system.

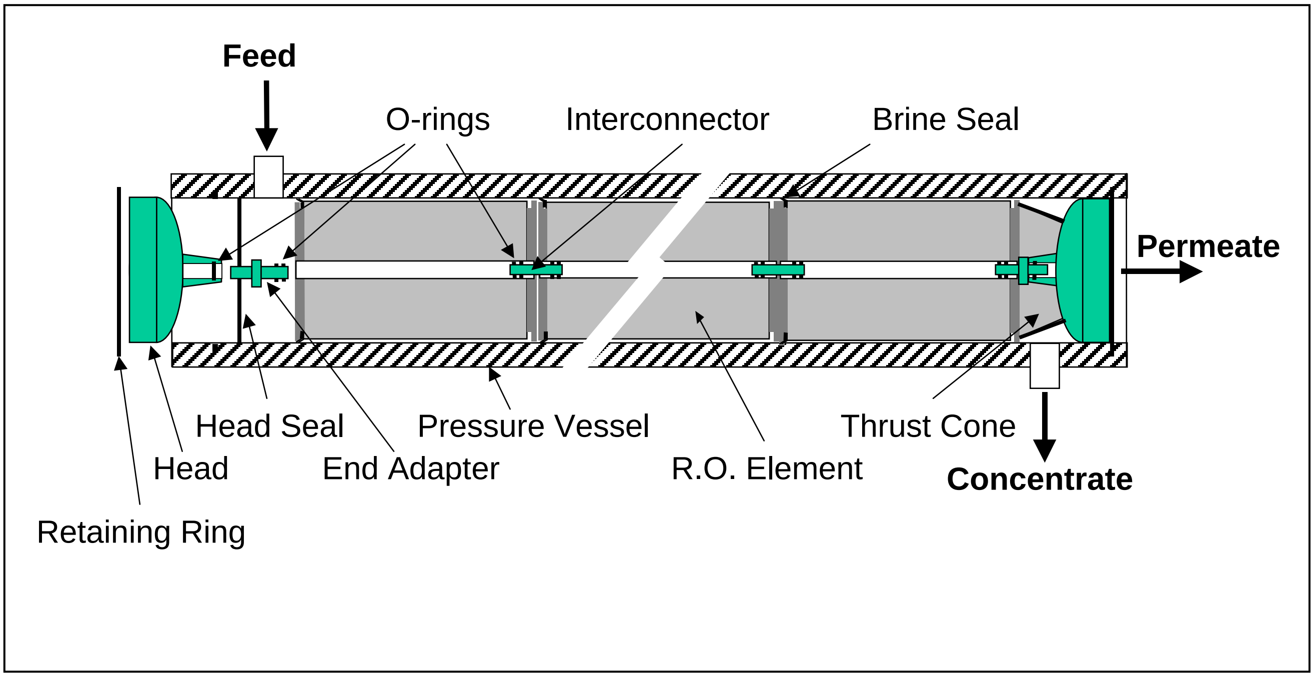

Figure 6.3 – RO Element Assembly within Pressure Vessel

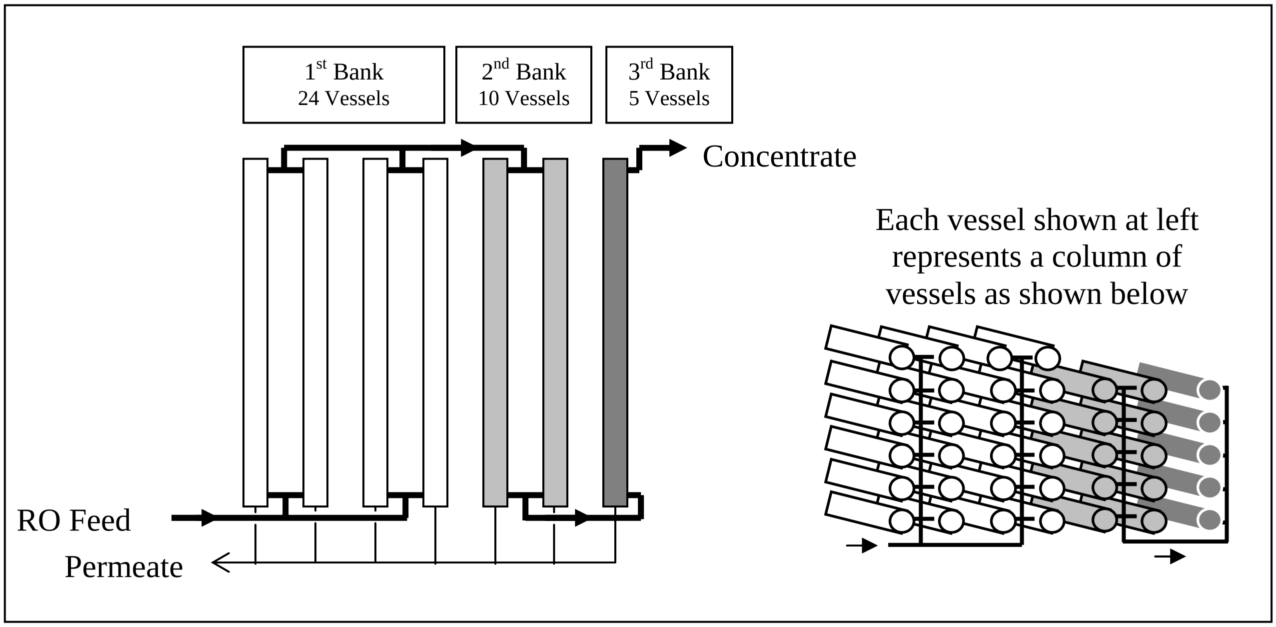

Figure 6.4 – Typical Membrane 24:10:5 Array

6.1.9 Post Treatment Requirements

As a consequence of the RO treatment, the dissolved gas content of the product water can be corrosive to pipes and, hence, post-treatment is used to condition and stabilize the permeate before injection into the distribution system. For stabilization, lime addition is used to add calcium hardness back to the water to generate a water that will not degrade the distribution system. For brackish water systems, stabilization can sometimes be accomplished by using bypass blending, where a portion of the feed water is diverted around the RO system and re-blended with permeate. This reduces the amount of RO treatment equipment and additionally imparts hardness to adjust finished water stability. In most instances, sodium hydroxide is added to adjust pH to an acceptable range.

6.1.10 Life Cycle Costs

As RO treatment of brackish water has become more acceptable, the size of the facilities that have been constructed, or are currently in the design or construction phase, has increased. This has led to a better understanding of the actual capital, operating, and construction cost of the water treatment facilities. The life cycle costs, consisting of capital, operating and maintenance (O&M), of five RO facilities are presented below in Table 6.2.

Table 6.2 – Life Cycle Cost of Various RO Facilities

System	Capacity (in MGD)	Capital Cost (in 2005 $)	Annual O&M	Present Worth of O&M	Total Present Worth	$ per Gallons per Day of Permeate
South Coast Water District	0.9	$5,500,000	$419,666	$5,364,734	$10,864,734	$12.07
Irvine Ranch Water District	2.11	$9,832,883	$741,806	$9,482,769	$19,315,652	$9.15
Chino II Desalter	6.5	$14,500,000	$1,699,308	$21,722,866	$36,222,866	$5.57
El Paso RO	15	$29,300,000	$3,694,146	$47,223,585	$76,523,585	$5.10
Orange County Groundwater Replenishment System (GWRS)	70	$82,000,000	$13,344,408	$170,586,315	$252,586,315	$3.61

Notes:

1. *Capacity is based on actual RO system permeate production capacity, not the blended product capacity.*
2. *Capital costs are based on bid prices and adjusted to May 2005 based on the Engineering News Record Cost Index. All of the projects have bid within 6 months of May 2005 with the exception of the OCWD GWRS Project.*

3. *O&M costs were established for all of the facilities based on the same water quality. All of the projects are under construction and, therefore, do not have actual O&M data.*
4. *O&M costs are based on power for RO and product pumping, chemicals (sulfuric acid, threshold inhibitor, chlorine, sodium hydroxide), labor and maintenance costs.*
5. *Maintenance costs were based on an annual expenditure of 1 percent of the capital cost over the life of the system.*
6. *The O&M cost includes the membrane costs from the projects.*
7. *Present Worth was calculated based on 25 year life and 6 percent interest.*
8. *The $ per gallon per day of permeate production based on the present worth takes the overall present worth divided by the gallons per day of treatment capacity.*

Figure 6.5 shows the Capital, O&M, and Present Worth as a function of the RO permeate production capacity. Additionally, the graph shows the $ per gallon per day of treated capacity based on the present worth value.

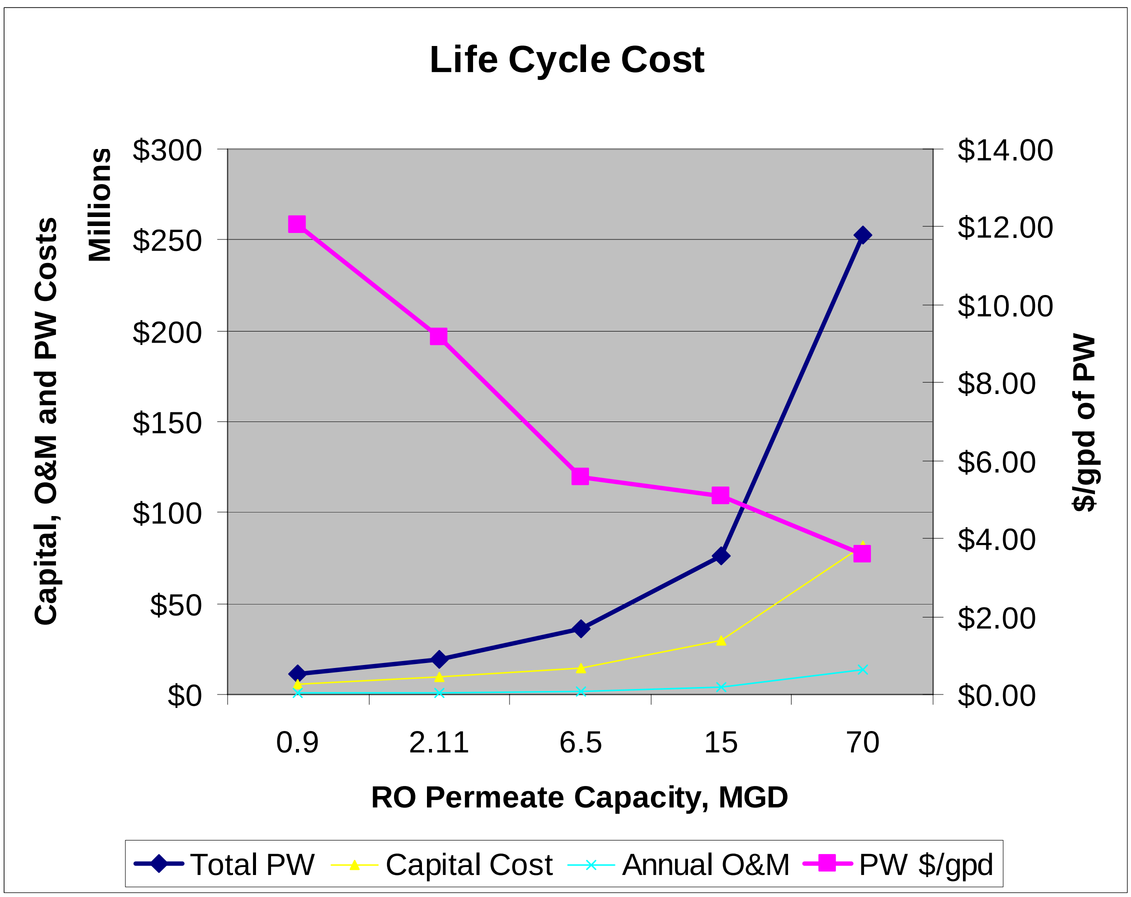

Figure 6.5 – RO System Life Cycle Cost

6.2 Membranes/Nanofiltration

Nanofiltration (NF) is similar to RO in that it is a diffusion-controlled process. However, NF has a slightly larger molecular weight cutoff and can remove particles up to 0.001 microns, which results in lower operating pressures. This makes NF ideal for removal of larger contaminants, such as divalent ions including the hardness elements calcium and magnesium, disinfection by-product precursors, color, and pesticides. However, NF will not effectively remove the smaller monovalent salts, such as sodium chloride, and it is not likely to be an effective solution for desalination.

6.3 Membranes/Forward Osmosis

Forward osmosis (FO) is a developing membrane technology which is being researched at Yale University. Additional development of the process is being conducted by the Bureau of Reclamation and the US Army Corp of Engineers. As with other membrane processes, forward osmosis (FO), works by separating water from dissolved solids via a semi-permeable membrane. However, unlike RO, the FO process utilizes an osmotic pressure gradient by using a “draw solution” which is very high in dissolved solids and has a significantly higher osmotic pressure that the saline feed water. Feed water then flows on one side of the membrane and water is naturally transported from the feed water across the membrane to the ‘draw solution’ side by osmosis. The drawing solute is then removed from the product water and recovered for future use, leaving the high quality permeate water.

The potential advantage of FO is reduced energy costs because it uses osmotic pressure to drive the process and not hydraulic pressure. Since energy used to create hydraulic pressures is typically the most significant cost component of desalination, FO has great economic potential for driving down the cost of desalination.

Further research on thinner membranes and a more suitable drawing solute is required prior to implementation of this technology on a commercial scale. Some of the criteria for the ideal driving solute are; low-cost, easily recoverable from permeate, non-toxic and rejection by the membrane. An experimental solute has been ammonium bicarbonate. Ammonium bicarbonate is highly soluble and can produce very large osmotic pressures which yield high water fluxes. Upon moderate heating, ammonium bicarbonate decomposes into ammonia and carbon dioxide gases that can be separated and recycled, leaving the fresh product water.

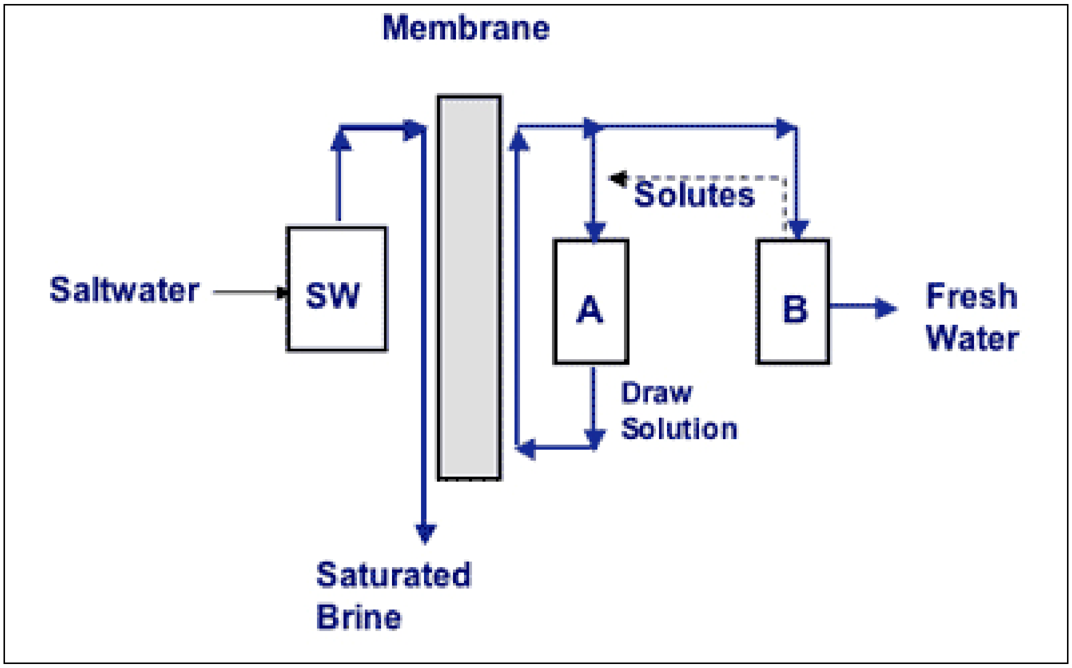

Figure 6.6 – Flow diagram of a FO system

6.4 Electrodialysis (ED) /EDR

6.4.1 Process Fundamentals

Electrodialysis (ED) and EDR (electrodialysis reversal) is the process that desalinates brackish water using electrical currents and semi-permeable membranes. ED works by using a direct electrical current to divide negatively-charged ions (anions) and the positively-charge ions (cations) from its salt solution. A semi-permeable membrane then allows either cations or anions to pass, while blocking the passage of the other ion. For example, a cation permeable membrane allows cations to pass, while it prohibits anions from passing through. ED does not remove bacteria or particles that are not charged. With ED, the membrane surface often becomes clogged (or scaled) with buildup of salts and organic material. In addition, ED does not address organics, microorganisms, and taste and odor constituents.

EDR evolved from ED in the early 1970's to deal with scaling issues seen with ED. EDR is the same process as ED, except the polarity of the anode and cathode is periodically reversed. This reversal dissipates and prevents buildup of scale on the membrane, which in turn reduces the need for using anti-scalant chemicals and improves the overall life of the membrane.

6.4.2 Recovery Rates

Permeate recovery in the newest EDR systems can range from 50 to 94 percent. The rate of recovery will depend on the number of stacks used in the EDR plant. A stack is composed of the source water inlet, semi-permeable membranes, spacers to separate the membranes (thereby providing a "channel" for the water being treated), the electrodes and the end plates. A single stage can remove up to 60 percent of TDS in the source water with additional stacks (stages) required for additional recovery.

6.4.3 Power Consumption

The electric power consumption is directly related to the recovery rate and the salinity of the source water. For example, power consumption is approximately 2 kilowatt hours per 1,000 gallons of product water for a 1,000 mg/l reduction in TDS. The temperature of the source water also plays a role in power consumption. Optimal temperature for source water is 70 degrees Fahrenheit (º F). For each degree above or below 70º F, power consumption will decrease or increase by 1 percent, respectively.

6.4.4 Pre-Treatment Requirements

The use of membranes is often prohibited by the chemical constituents in the source water. EDR does not have as much sensitivity as other membrane technologies, such as RO. Silica, silt density, and turbidity contribute to clogging of the RO membranes, but are not limiting factors for EDR. Iron, manganese, and hydrogen sulfide may cause some fouling of the EDR membrane if levels exceed 0.3 parts per million (ppm) for iron, 0.1 ppm for manganese, and 1 ppm for hydrogen sulfide.

Pretreatment for EDR should involve the removal or reduction of iron and manganese if levels exceed recommended concentrations. Additionally, alkaline scale may build up on the concentrate side of the membrane, but this can be remedied by the addition of acid to the source water. EDR pretreatment should also include filtration to reduce suspended solids in the source water.

6.4.5 Life Cycle Costs

Generally, EDR membranes have a life of 10 years. This timeframe is influenced by whether the membrane is a cation or anion membrane and damage incurred from attempting to clean membranes. Cation membranes usually last longer than anion membranes, because the anion membranes suffer oxidation from chlorine and fouling by organics. Electrode life for EDR is typically 3 years.

The capital cost for a 2-MGD EDR unit is estimated to be about $4.7 million (Watson, 2003). The O&M costs for this size unit are estimated at $0.57 per 1,000 gallons. Therefore, a 25-year life cycle cost at 6 percent interest is approximately $3.00 per gallon per day.

6.5 Thermal Processes - Distillation

Distillation involves heating a saline solution to boiling in order to evaporate the pure water while leaving the salts (dissolved solids) behind in solution. The vapor then condenses on a cooler surface to form liquid water, free from dissolved solids. There are three distillation processes that have been developed for large-scale desalination processes:

- Multiple effect distillation
- Multi-stage flash distillation
- Vapor compression distillation

Two main problems occur with distillation: scaling and corrosion. Scaling is caused by calcium sulfate, calcium carbonate, and/or magnesium hydroxide. These compounds reduce the overall heat transfer of the distillation unit. Therefore, pre-treatment is required to reduce scaling within the process. In addition to scaling, distillation plants are subject to corrosion, which is primarily due to the product water being very aggressive due to the lack of minerals in the water. Therefore, post-treatment is required to stabilize the product water. This can be done by adding chemicals or blending with source water to meet the required water quality goals.

Distillation has the highest capital and O&M costs of all desalination processes. This is mostly due to the significant amount of energy required to boil water. Therefore, distillation plants are often co-located with power-generating facilities. This can reduce the fuel costs by 60 to 70 percent (Watson, 2003).

6.6 Concentrate Management

With each of the desalination technologies discussed above, concentrate is produced. This concentrate is significantly higher in TDS than the source water. In addition, for brackish groundwater sources, other constituents, such as arsenic and nitrates, may also be significantly concentrated. The concentration of these constituents can play a significant role in developing a concentrate management plan.

Currently, there are two main concentrate disposal methods used in Arizona: sewer disposal and evaporation ponds. With sewer disposal, the capacities of both the sewer system and the wastewater treatment plant (WWTP) require the ability to handle the additional loading of TDS, other constituents, and flow. Typically, large WWTP can handle concentrate easily; however, the smaller plants may have treatment problems if the flow or TDS is too high. The second disposal method, evaporation ponds, works well, especially in Arizona’s hot, dry climate. The restrictions with evaporation ponds include the land availability and capital costs for double lining the ponds. For small flow streams, evaporation ponds can be very economical, provided land is available. However, if there are any private or municipal groundwater wells located downgradient of the evaporation pond(s), the well owner(s) may object to having the ponds upgradient of their wells in the event there is a leak. Given the current concentrate management choices, water providers are limited by the amount of brackish water that can be desalinated.

Without better means to deal with concentrate management issues, the use of brackish water for potable means is limited. Additional research and development of technologies is required to deal with the concentrate issue.

7.0 Conclusions

Through the review of existing brackish treatment facilities, regulatory codes, water quantity and quality, and several treatment processes, the use of brackish groundwater in central Arizona to supplement potable water supplies can be determined. Based on the work completed to date, the following conclusions in regard to viability of brackish groundwater desalination can be made.

- **Benchmarking –** Brackish groundwater in the southwestern U.S. is desalted using either RO membranes or EDR. RO seems to be more prominent due to the need to remove other constituents in addition to TDS. The most common concentrate disposal methods include evaporation ponds, discharge to sanitary sewers, and ocean outfalls.

- **Regulatory Issues –** Permeate from the desalination of brackish groundwater will need to meet all federal, state, and local water quality regulations. In addition, pumped groundwater must meet ADWR's Groundwater Management Code to assure long-term water supplies. However, there may be some relief of this requirement in certain waterlogged areas.

- **Water Quantity and Quality –** Water quantity in the WSRV is still under investigation to determine the long-term viability of this water source. However based on water quality data available from ADWR and CASS participants, it appears that this brackish groundwater source will need to be treated for nitrates and silica in addition to TDS.

- **Treatment Options –** RO and EDR are the most viable treatment options at this time for brackish groundwater desalination. However, EDR is a sole source product, which may limit the ability for utilities to use this technology. In addition, feed water quality may dictate which technology should be used. In many cases, it may be beneficial to use a blending scenario in order to meet water quality goals. These blending scenarios may also mitigate the need to post-treat or stabilize water prior to sending to the distribution system.

- **Concentrate Management –** Two main concentrate disposal alternatives are currently being used by desalination facilities: evaporation ponds and sanitary sewer discharge. Both technologies have downfalls that may limit the amount of brackish groundwater than can be utilized. Until new concentrate management options are developed, the use of brackish groundwater is limited.

7.1 Future Research Needs

As the population in the Phoenix metropolitan area continues to grow from 3 million to 12 million, future additional water sources will be needed. Brackish groundwater may provide an additional source; however, there are currently several limitations to implementing the use of this water source. The main limitation is the lack of convenient concentrate management strategies. At present, sewer disposal or evaporation ponds are most commonly used. The drawbacks to evaporations ponds include the large amount of land needed and acceptability by nearby well owners and residential neighbors. Therefore, sewer disposal is generally the most popular option assuming that the surrounding sewer system and WWTP can handle the additional load. Since these concentrate management options are not viable long-term solutions, future research, which focuses on evaluating additional concentrate options/technologies, is necessary.

Along with concentrate management technologies, the further advances of RO and EDR technologies to recover more water, and thus produce less brine, is also desirable. This research may include developing better membranes for RO and EDR or development of new desalination technologies, such as FO.

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Appendix A Benchmarking Project Summaries

Bench Marking Table of Contents

REFERENCE PLANT DATA SHEET	
Location:	Goodyear, Arizona
Owner:	City of Goodyear, Arizona
Contact Person(s):	Tom Galeziewski, PE
Commissioning Date:	08/05/2004 ☒ NA ☐ Other
Capacity/Size	Current Capacity @ 2 mgd
Capacity/Size	Ultimate Capacity @ 2 mgd
Source Water Type/Quality	Ground Water
TDS	1940 ppm
Calcium	163 ppm
Magnesium	69 ppm
Sulfate	505 ppm
Sodium	414 ppm
Chloride	620 ppm
Silica	8.6 ppm
Iron	0.48 ppm
Other Constituents	Barium @ 0.04 ppm Nitrate (as N) @ 17.0 ppm Arsenic @ 0.003 ppm
Pretreatment (See Legend below)	Acid/AScl/CO Acid & CO to be added in future
Desal Process	LPRO
Recovery Rate	75 %
Post Treatment	Chem Stabl/De-carbonation/CO To be added in future
Blending	☐ NA ☒ Ratio 4:1 ☐ Other
Concentrate Disposal	To Sanitary Sewer/CO
Permitting/Regulation Issues	Comment: Permitted by Maricopa County
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ 1.98M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ 0.90M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☒ Other $0.93/1000 gal
Supplemental Information/Description: NA	

Goodyear, Arizona Groundwater Treatment Reverse Osmosis Project

Project Summary

HDR Design-Build, Inc. (HDR) of Phoenix, AZ is currently assisting the City of Goodyear, Arizona (COG) to design and construct facilities to provide approximately 1,800 gallons per minute (gpm) of potable water. The project includes equipping COG's existing Centerra Well, construction of a 2.1-mile raw water transmission pipeline, and a 2.5 million gallon per day (mgd) reverse osmosis (RO) Emergency Water Treatment Facility. Treated water will enter the COG water system through an existing above-ground steel storage tank and booster pump station.

Raw Water Source and Quality

The Centerra Well was drilled in 1949 to supply irrigation water to local farmers. Its total depth is 1,000 feet, with a 20-inch diameter outer well casing extending the entire depth. In 2004, the well was rehabilitated with a 16-inch diameter inner well casing extending to 500 feet. The well has been filled in below a depth of 502 feet, and a concrete plug installed between 490 feet and 502 feet. The inner casing is perforated between 234 and 490 feet. The Centerra Well has historically been utilized as an irrigation well. It was converted to a municipal well as part of this project.

The well's existing equipment was replaced with a new 350 horsepower vertical turbine pump, motor, and variable frequency drive (VFD). The anticipated firm yield of the well is approximately 2,200 gpm. The anticipated well drawdown will be approximately 118 feet. Specific design criteria for the well are listed in Table 1. Water quality at the Centerra Well has been measured with the results summarized in Table 2.

Table 1 – Centerra Well Design Criteria

Well Characteristics	
Borehole Depth, ft	1,000
Borehole Diameter, in	20
Outer Casing	
Diameter, in	20
Depth, ft	1,000
Material	Steel
Inner Casing	
Diameter, in	16
Depth, ft	500
Material	Steel
Screen/Perforation Depths, ft	234 to 490
Slot Size, in	0.085

Gravel Pack	
Depth, ft	240 to 500
Material	Silica Sand
Cement Seal Depth, ft	0 to 240
Static Water Level, ft	116
Pump Characteristics	
Type	Vertical Turbine
Service	Raw Water
Maximum Pump Speed, rpm	1,800
Speed Control	Variable Frequency Drive
Impeller Diameter, in	9.6875
Impeller Type	Enclosed
Number of Stages	6
Primary Design Point	
Flow, gpm	2,400
Head, ft	484
Efficiency, percent	85
Pump Intake Depth, ft	300
Pump Discharge Diameter, in	10
Motor Characteristics	
Motor Power Requirements	480 volt, 3 phase, 60 Hz
Minimum Motor Horsepower	350
Maximum Driver Speed, rpm	1,800
Minimum Motor Efficiency @ 100% Load, percent	94
Power Factor @ 100% Load	90
Service Factor	1.15
Enclosure Type	Explosion Proof
NEMA Design Type	B

Table 2 – Design Raw Water Quality – Centerra Well

Parameter	Value	Parameter	Value
Calcium, mg/L	163	Temperature, °F	51.8
Magnesium, mg/L	69	Total Dissolved Solids, mg/L	1,940

Parameter	Value	Parameter	Value
Sodium, mg/L	414	Total Alkalinity, mg/L $CaCO_3$	193
Sulfate, mg/L	505	pH, units	7.4
Barium, mg/L	0.04	Silt Density Index, units	1.2 – 5.6
Nitrate (as N), mg/L	17.9	Arsenic, mg/L	0.003
Fluoride, mg/L	0.7		

Water Treatment System Summary
The design of the treatment system is based on the quality of water from the Centerra Well. As shown in Table 2, the Centerra Well contains significant amounts of total dissolved solids (TDS), in excess of 1,900 mg/L, and elevated levels of nitrates. The treatment goal is to produce a finished water product with a total dissolved solids (TDS) content of 500 mg/L or less and a nitrate concentration (as N) of 10 mg/L or less.

Based on this water quality data, a reverse osmosis (RO) process was recommended to treat the brackish groundwater and to remove nitrates. The Centerra Well's brackish water will be pumped through the raw water transmission pipeline to the RO emergency treatment facility, located at an existing COG potable water booster pump station and 2 million gallon storage reservoir.

The RO membranes for the treatment facility are units manufactured by GE Infrastructure (formerly Osmonics). The RO system will include up to four individual RO trains, each with a product water (permeate) capacity of 0.5 mgd. Each train consists of a cartridge filter, feedwater booster pump, pressure vessels with membrane elements, interconnecting piping, valves, controls, and instrumentation. Each RO train will be capable of being operated independently of the other RO trains. Each RO train, or skid, will contain 13 pressure vessels in an 8:5 array, with seven spiral wound elements in each pressure vessel. The spiral wound elements are RO membranes consisting of a composite polyamide membrane barrier layer on a polysulfone porous support. Each RO element will have nominal dimensions of eight inches in diameter by 40 inches in length. Each train will be operated at a minimum recovery of 75 percent (i.e., 75 percent of the feed to the train will be recovered as permeate, while 25 percent of the feed will be a concentrate waste stream).

The RO treatment system is designed to have the Centerra Well supply feedwater to the RO system and bypass water to blend with the RO permeate. This will maximize the use of the well's water while allowing drinking water standards to be met. Total inflow to the Emergency Facility is expected to be 3.2 mgd. Utilizing water from the Centerra Well, the emergency RO system with low pressure membranes and 75 percent recovery will produce a high quality permeate. The water treatment modeling of the membranes, performed by GE Infrastructure, projects an overall permeate TDS of 103 mg/L and nitrate concentration of 0.943 mg/L. When 2.0 mgd of RO permeate with a TDS concentration of 103 mg/L is blended with 0.5 mgd of well water with a TDS concentration of 1,940 mg/L, the resultant blended product has a TDS concentration of

479 mg/L. With the design feedwater and 75 percent recovery, the blended product nitrate concentration is projected to be 5.29 mg/L. The 0.7 mgd concentrate TDS is projected to be 7,447 mg/L.

For base conditions, the emergency RO treatment facility will require 3.2 mgd of feedwater from the Centerra Well. This will allow 2.7 mgd of feedwater to be fed to the RO membranes treatment system. At an RO system recovery of 75 percent, the RO membranes will produce 2.0 mgd of permeate, or treated water, and, 0.7 mgd of concentrate or reject water. The 2.0 mgd of permeate water from the membranes will then be blended with 0.5 mgd of bypassed well water, giving a 2.5 mgd of blended potable water.

In the flow conditions described above, the feedwater will need to be delivered to the RO treatment facility at a minimum pressure of 40 psig. The feedwater will be split into an RO feedwater stream and a bypass blend stream. The bypass blend stream will be mixed with permeate from the RO trains and then discharged into COG's potable water distribution system via the existing storage tank and pump station.

The RO feedwater will be split to each train and a threshold inhibitor will be added to prevent precipitation of sparingly soluble compounds (i.e., calcium sulfate, barium sulfate, and silica salts) in the feed/concentrate stream of the RO process. Additionally, the threshold inhibitor will provide a concentrate stream Langelier Saturation Index (LSI) of +2.3 without precipitation of calcium carbonate. After chemical addition, the RO feedwater will be filtered by 1.0 micron cartridge filters. The cartridge filters provide the dual function of protecting the membrane feed pumps and membrane elements from suspended solids in the unlikely event of a well failure and of thoroughly mixing the previously added chemicals.

Effluent from the cartridge filters will then be pressurized by the feed pumps and routed to the membranes. The RO feed pump flow will be controlled by the variable frequency drive associated with the pump motor. The concentrate control valve will be automatically controlled to regulate flow of concentrate and thereby control process recovery. Each train will produce 0.5 mgd of permeate and 0.17 mgd of concentrate. Residual pressure in the concentrate is dissipated across the pressure control valves in each RO train and the concentrate will then flow by gravity to a nearby sewer pipeline for disposal. The permeate and blend water will be treated with sodium hypochlorite for disinfection purposes and then be routed to the onsite storage tank. Connecting flanges and a drop spool will be provided to the permeate line for the future addition of decarbonators, when acid feed is also expected to be added to the treatment process. The acid feed is expected to provide higher recovery from the membranes.

Additionally, a cleaning system for the RO trains is expected to be added in the future. Similar RO systems operating on well water supplies typically require cleaning after a year or more of operation.

RO Treatment System

The purpose of the RO treatment system is to remove dissolved solids and nitrates from the well's feedwater and condition it for use as a high quality potable water. The RO system will be furnished by GE Infrastructure. The emergency RO system will include the following components:

- Threshold inhibitor chemical feed system
- Cartridge filters
- RO membrane feed pumps
- RO trains (pressure vessel racks, pressure vessels, membrane elements, pipe manifolds, valves, instrumentation)
- Exposed interconnecting piping and valves
- Instrumentation and controls, including communication telemetry between the RO treatment facility and the pump controls for the well

The four RO trains will incorporate the raw water bypass control valves, cartridge filters, membrane feed pumps, membrane pressure vessel assemblies, piping, valves, instrumentation, and controls associated with the train. Primary components of the system (excluding chemical feed systems, piping, valves, instrumentation and controls) are summarized in Table 3, and discussed separately below.

Table 3 – Reverse Osmosis System Design Criteria

Cartridge Filters	
Configuration	4 operating (one per train)
Filter Housing	Fil-Trek Model S6GL20-40-3-6F-IP-U
Filter	GE Osmonics Model RO.Zs 01-30-XK
Rated Capacity, mgd	0.92
Maximum Loading Rate, gpm/10-inch equivalent	3.5
Cartridge Element Rating, microns	1.0
Materials: - Housing - Cartridge Elements	 Type 316L stainless steel with EPR seals All food grade polypropylene
RO Membrane Feed Pumps	
Configuration	4 operating (1 per train)
Pump	Grundfos Model CRN 90-3
Capacity @ 1st Operating Point, gpm	440
Head @ 1st Operating Point, feet	335
Materials	Manufacturer's standard all 316 stainless steel; EPR secondary seals; babitted carbon bearings

Drive	Adjustable speed
Maximum Motor Speed, rpm/Enclosure	50 HP, 3600 rpm, 460V, 60 Hz, 3 phase/TEFC
RO Trains	
Number	4 (operating)
Permeate Capacity, mgd	0.5
Recovery, percent	75-85
Pressure Vessel Array Pressure Vessels: - Manufacturer - Design Operating Pressure, psig - Size - Vertical Spacing In Racks, inches - Horizontal Spacing w/in Train, inches	8: 5 Codeline Model 80A45 450 To contain seven 40-inch long x 8-inch diameter membrane elements 12 (on center) 18 (on center)
Membrane Elements: - Number (per train), 40-inch equivalents - Element Manufacturer and Model - Membrane Type - Element Length, inches - Element Diameter, inches - Min. Surface Area, square feet - Avg. Rejection, percent - Avg. Flux at Rated Capacity, gal/ft^2/day	 91 Osmonics OSMO-MUNI-LE/RO-400 Low pressure, polyamide/polysulfone composite 40 8 400 99.0 13.73-17.33
Pressure Vessel Racks: - Number (per train) - Type - Materials - Size	 One T-style frames Welded steel To support 13 vessels (102"x 320")
Concentrate Control Valves: - Type - Size, inches	 V-port ball valve with modulating electric motor actuator 1.5

General information regarding the RO treatment system components is provided below.

Cartridge Filters - Each skid filter will consist of a stainless steel pressure vessel housing a bank of cylindrical wound depth polypropylene cartridge filter elements. The filters will protect the RO system from unexpected upsets in the feed delivery system. The filters are located on the RO skid, prior to the membrane feed pumps and elements.

Membrane Feed Pumps - Each train will be equipped with a non-redundant feed pump. The pump is sized to deliver the required feed flow over the operating range listed in the table above at a recovery range of 75 – 85 percent. The predicted operating pressure for the system will range from a low of 115 psig with new membrane elements up to a maximum of 140 psig. Each pump is equipped with a variable frequency drive to maintain constant train permeate flow as the operating pressures increase with long term operation.

RO Trains - Each RO system, or train, will have a nominal permeate capacity of 0.5 mgd. Pressure vessels for each train will be arranged in a 8:5 array. Each vessel will contain seven 8-inch diameter, 40-inch long spiral wound polyamide/polysulfone membrane elements, resulting in a nominal operating flux of roughly 14 – 17 gallons per square foot per day (gfd) depending on system recovery. Pressure vessels for each train shall be arranged on a rack to support the 13 vessels and allow access to any vessel in the train from the operating floor.

System Piping - The exposed piping and fittings for the facility will be constructed of Schedule 80 PVC pipe and fittings. Isolation valves located on each skid will be Class 150 EPDM lined butterfly valves with Type 316 stainless steel discs for low pressure applications with manual or power actuators as required. Isolation valves on each skid in high pressure lines or interconnected to high pressure lines will be Class 150 high performance stainless steel butterfly valves. Concentrate control valves will be Class 150 v-port ball valves.

Clean-in-Place (CIP) System - *No clean-in-place system will be provided for the Emergency Facility. A CIP will be provided in the future with the permanent treatment facility.*

Decarbonators - *No decarbonators will be utilized in the Emergency Facility. Water quality goals will be achieved by blending with feed water as well as other sources that feed the storage tank located on site. Decarbonators will be added with the acid feed system in the future permanent treatment facility.*

RO Product Distribution System - Upon exiting the RO process trains, the product water will be discharged to an existing storage tank where it will be blended with potable water from COG’s distribution system. Once in the storage tank, the water will be distributed to COG’s customers via the existing booster pump station.

Chemical Feed Systems - Chemicals used at the Emergency Facility will include the following:

- Threshold Inhibitor
- Sodium Hypochlorite

Each RO train will have dedicated chemical feed equipment controlled by the local programmable logic controller (PLC) on each train. Thus, each train can be operated independent of the others. Individual systems are discussed separately below.

Threshold inhibitor feed system - A threshold inhibitor compound will be added to the RO feedwater to prevent the precipitation of sparingly soluble salts in the concentrate stream. The inhibitor compound will be fed full strength from chemical drums to the feedwater via chemical metering pumps. Each RO train will have a separate dedicated chemical metering pump and drum of undiluted threshold inhibitor. Each pump will have a flow range of 0.2 to 2.0 gpd at 60 psi backpressure, and will be controlled by the local PLC provided with each skid. The threshold inhibitor chemical drums will be located adjacent to the emergency RO facility slab on a chemical containment pallet for spill containment.

Sodium hypochlorite feed system - Sodium hypochlorite will be used for disinfection of finished water produced by the RO treatment facility. The dosage point will be located on the finished water header immediately downstream of the emergency RO facility slab, and upstream of the storage tank. One chemical drum equipped with a chemical metering pump will be dedicated to each RO train. Each pump will have a flow range of 0.2 to 2.0 gpd at 60 psi back pressure, and will be controlled by the local PLC provided with each skid. The sodium hypochlorite chemical drums will be located on a chemical containment pallet for spill containment.

RO process waste disposal - The RO concentrate, and the RO permeate dump created during each shutdown of an RO train, will be discharged to air gap devices and routed to a sanitary sewer manhole. Initial concentrate flow when operating all four RO trains is estimated to be 463 gpm. Total concentrate flow could be lower depending on final quality of the well water. In addition to concentrate flows during on-line operation, the concentrate disposal header will also be designed to accommodate well flush flows generated during RO train startup and shutdown. Under plant operations, flushing flows will be as high as 100 gpm for an individual train. This will be considered in excess of concentrate flows associated with other on-line trains.

REFERENCE PLANT DATA SHEET	
Location:	Gila Bend, AZ
Owner:	Town of Gila Bend
Contact Person(s):	Wayne Miller (928) 683-2255
Commissioning Date:	6/1/01 ☐ N/A ☐ Other
Capacity/Size	Current Capacity @ 1 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	
TDS	2000 ppm
Calcium	ppm
Magnesium	ppm

Sulfate	ppm
Sodium	ppm
Chloride	ppm
Silica	ppm
Iron	ppm
Other Constituents	@ ppm @ ppm @ ppm
Pretreatment	Other/Comment:
Desal Process	RO
Recovery Rate	%
Post Treatment	N/A
Blending	☒ N/A ☐ % w/ ☐ Other
Concentrate Disposal	Evap Lagoon
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ N/A ☐ $ ___.___M ☐ Other
Capital Cost, Desal Equipment	☐ N/A ☐ $ ___.___M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: N/A	

Gila Bend RO Facility

Reviewed by: Thomas K. Poulson

Summary:

Gila Bend built a 1 mgd RO facility 5 miles south of the town in their well fields to supply drinking water to their citizens. This plant went on line in the spring of 2002. The feed water comes from several wells in the general vicinity, with a TDS between 1000 to 2000 mg/L.

Pre treatment is unknown at this time.

It was designed as a 1 mgd plant using RO membranes.

Recover rate is unknown.

Concentrate is evaporated using to ponds located on the site.

Unknown if any unique permitting or regulatory issues were encountered.

Public outreach was accomplished through "give aways" of bottled water produced at the plant.

I talked to a Wayne Miller, superintendent for water and waste water at the Town of Gila Bend. He stated that the RO plant was having all sorts of problems. It was only producing about 300 gpm for 16 to 17 hours a day (approximately 300,000 gpd much less then the 1 million gpd design) The problems were pretreatment was not adequate. Only two "units were working" currently and a third one was off line. This guy was very evasive with my questions.

I talked to Woody Scoutten (Town Engineer) the problem was with the membrane housing made out of stainless steel. High Chlorides with in months caused pinholes to develop in the housings. They are in the process of being replaced by fiber glass housings. The first skid has had the stainless steel housings replaced by fiber glass and have been operating for 6 months now. Seems to be the fix

REFERENCE PLANT DATA SHEET	
Location:	Tempe, AZ
Owner:	**To be completed soon**
Contact Person(s):	
Commissioning Date:	__/__/____ ☐ NA ☐ Other
Capacity/Size	Current Capacity @ mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Surface Water
TDS	ppm
Calcium	ppm
Magnesium	ppm
Sulfate	ppm
Sodium	ppm
Chloride	ppm
Silica	ppm
Iron	ppm

Other Constituents	@ ppm @ ppm @ ppm
Pretreatment (See Legend below)	NA/Comment
Desal Process	NF
Recovery Rate	%
Post Treatment	NA/CO
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: NA	

REFERENCE PLANT DATA SHEET	
Location:	Buckeye, AZ
Owner:	Town of Buckeye
Contact Person(s):	Rick Morley
Commissioning Date:	__/__/____ ☐ NA ☒ Other EDR upgrade in 1988; new well in 1992
Capacity/Size	Current Capacity @ 1.1 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water
TDS	1551 ppm
Calcium	56 ppm
Magnesium	3 ppm
Sulfate	ppm
Sodium	523 ppm

Chloride	746 ppm
Silica	ppm
Iron	ppm
Other Constituents	HCO3 @ 95 ppm SO4 @ 120 ppm NO3 @ 5 ppm pH @ 8.3
Pretreatment (See Legend below)	NA/Comment
Desal Process	EDR
Recovery Rate	80 %
Post Treatment	NA/CO HCl added to brine stream
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: NA The above parameters are based on information provided by Ionics to Buckeye in 1992. However, Rick Morley provided a brief overview of the system at the August 2004 CASS Brackish Committee Meeting. The incoming TDS is about 1600 mg/L (3500 conductivity). The EDR plant is operating about a 40% reduction to give an effluent TDS around 720-880 mg/L. The effluent is blended with other water source to keep the overall TDS below 500 mg/L. The EDR plant is operated about 4 hours per day. Currently only operating one train since other train was used for parts.	
Legend: Acid - Acid Addition/pH Reduction; ASc1 - Anti-scalant Addition; CO - Comment/Other; Coag - Chemical Coagulation; CtFl - Cartridge Filter; GrFl - Gravity Filters; Mem - Low Pressure Membranes; NA - Not Applicable; PrFl - Pressure Filters; Sed - Sedimentation	

LEWIS PRISON EDR PLANT DATA SHEET	
Location:	Lewis Prison, Buckeye, Arizona

Owner:	State of Arizona; Dept. of Corrections
Contact Person(s):	
Commissioning Date:	
Capacity/Size	Current Capacity 1.35 mgd in 3 trains/units
Capacity/Size	Ultimate Capacity 1.80 mgd in 4 trains/units
Source Water Type/Quality	Well water - 2 wells
TDS	2,000 ppm ±
Calcium Hardness	NA
Total Hardness	NA
Sulfate	NA
Sodium	NA
Chloride	NA
Silica	NA
Iron	NA
Other Constituents	NA
Pretreatment (See Legend below)	Acid, CtFl
Desal Process	EDR (Ionics, Inc.)
Recovery Rate	
Post Treatment	pH adjustment (caustic); chlorination
Blending	No blending
Concentrate Disposal	To Evaporation Ponds - onsite
Permitting/Regulation Issues	None - normal permits obtained
Environmental Issues	None
Capital Cost, Total Plant	N/A
Capital Cost, Desal Equipment	N/A
Operating Cost, Excluding Debt Service	N/A

Supplemental Information/Description:
- Well capacity is 1,200 gpm (each)
- Well borehole is 1,200 ft deep; 28 inch diameter
- Well casing is 16-inch diameter, steel
- The EDR units are Ionics Model Aquamite 50; capacity 0.45 mgd each
- Cartridge filters are 10 micron

Legend:

Acid	- Acid Addition/pH Reduction	GrFl	- Gravity Filters
AScl	- Anti-scalant Addition	Mem	- Low Pressure Membranes
CO	- Comment/Other	NA	- Not Applicable
Coag	- Chemical Coagulation	N/A	- Not Available
CtFl	- Cartridge Filter	PrFl	- Pressure Filters
		Sed	- Sedimentation

REFERENCE PLANT DATA SHEET	
Location:	Central Groundwater Treatment Facility - Scottsdale, Arizona
Owner:	City of Scottsdale
Contact Person(s):	William Vernon
Commissioning Date:	__/__/1994 ☐ NA ☐ Other
Capacity/Size	Current Capacity @ 9 mgd
Capacity/Size	Ultimate Capacity @ 12 mgd
Source Water Type/Quality	Ground Water
TDS	850 ppm
Calcium	65 ppm
Magnesium	55 ppm
Sulfate	110 ppm
Sodium	155 ppm
Chloride	295 ppm
Silica	29 ppm
Iron	nd ppm
Other Constituents	TCE @ 0.1 ppm
Pretreatment (See Legend below)	NA/Comment
Desal Process	RO
Recovery Rate	80 %
Post Treatment	NA/CO
Blending	☐ NA ☒ Ratio 1 permeate:2 source ☐ Other
Concentrate Disposal	CO sewer
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ 7.1M ☐ Other
Capital Cost, Desal Equipment	☒ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☒ Other $.84 M/yr.

Supplemental Information/Description: NA All costs are conceptual. Facility has not been constructed

REFERENCE PLANT DATA SHEET	
Location:	Oceanside, CA
Owner:	City of Oceanside
Contact Person(s):	Bruce McCarter- 760-435-5920
Commissioning Date:	__/__/____ ☐ NA ☒ Other Original 1994, Expansion 2003
Capacity/Size	Current Capacity @ 6 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water
TDS	1300 ppm
Calcium	ppm
Magnesium	ppm
Sulfate	255 ppm
Sodium	ppm
Chloride	475 ppm
Silica	ppm
Iron	ppm
Other Constituents	@ ppm @ ppm @ ppm
Pretreatment (See Legend below)	Acid/AScl/CtFl/CO
Desal Process	RO
Recovery Rate	80 %
Post Treatment	Chem Stabl/De-carbonation/CO
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO Oceanside Ocean Outfall
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other

Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: NA	

City of Oceanside

General Background: The City satisfied much of its supply from wells in the Mission Basin Aquifer until the early 1990's, when seawater intrusion contaminated the aquifer. In early 1994, the City opened the Mission Basin Desalting Facility to recover the brackish groundwater to augment its supplies from imported Colorado River water. The expansion of the Mission Basin Desalter project will add 6.7mgd of brackish groundwater capacity to the existing City of Oceanside 6.37mgd Mission Basin Desalter for a total capacity of 13mgd.

Objective of WTP: The Mission Basin Project provides several regional benefits. First, the project provides an additional dry-year yield. Secondly, the groundwater basin will be replenished seasonally, thus utilizing available conveyance capacity during the winter season. Thirdly, the project will add treated water capacity to the County through production of treated groundwater as well as offsetting a treatment need at the Weese Water Filtration Plant. Finally, the project could potentially serve other agencies within the Authority's service area including the City of Carlsbad, Rainbow Municipal Water District, Vallecitos Water District, and Vista Irrigation District.

TDS of source water: ~ 1200-1500 mg/L
(http://www.sdcwa.org/manage/slr_aug2000.pdf pg 16)

Pretreatment: Acid, Threshold Inhibitor and Cartridge Filtration

Treatment method used: Reverse Osmosis

Blending Stabilization: Bypass Blending and Sodium Hydroxide

Design Capacity: Original 6.37mgd and expansion 6.7mgd for a total of 13mgd Other expansions planned to 20mgd.

Recovery rate of water:80% recovery

How was concentrate managed?: Brine is sent to Ocean Outfall

Any unique permitting/regulatory issues?: potential project impacts to surface water flow or quality; potential project impacts to the salinity of the San Luis Rey River estuary; potential project impacts to terrestrial and aquatic habitats.

Any unique environmental issues?:

Public outreach program?: address public concerns and questions related to the proposed field investigations and to lay the groundwork for possible project implementation.

Economics: expansion project approximately $9million

REFERENCE PLANT DATA SHEET	
Location:	Richard A. Reynolds Groundwater Desal. Facility
Owner:	Sweetwater Authority
Contact Person(s):	Don Thompson
Commissioning Date:	__/__/1999 ☐ NA ☐ Other
Capacity/Size	Current Capacity @ 4 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water
TDS	ppm
Calcium	ppm
Magnesium	ppm
Sulfate	ppm
Sodium	ppm
Chloride	ppm
Silica	ppm
Iron	ppm
Other Constituents	@ ppm @ ppm @ ppm
Pretreatment (See Legend below)	Acid/AScl/CO
Desal Process	RO
Recovery Rate	75 %
Post Treatment	Chem Stabl/De-carbonation/CO
Blending	☐ NA ☒ GW Source Ratio 50:50 ☐ Other
Concentrate Disposal	To Sanitary Sewer/CO Storm Drain

Permitting/Regulation Issues	Comment:
Environmental Issues	Other:
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: Other: Fed by 4 Alluvial Wells and RO Permeate is blended with water from 6 San Diego Formation wells.	

REFERENCE PLANT DATA SHEET	
Location:	Chino I Desalter- Chino, CA
Owner:	Chino Basin Desalter Authority
Contact Person(s):	Craig Parker-Inland Empire Utilities Agency, Tom O'Neill - Jurupa Community Services District
Commissioning Date:	3/3/2000 ☐ NA ☒ Other Expansion To be Complete in 2005
Capacity/Size	Current Capacity @ 8 mgd
Capacity/Size	Ultimate Capacity @ 13 mgd
Source Water Type/Quality	Ground Water High Nitrate and TDS
TDS	871 ppm
Calcium	174 ppm
Magnesium	40 ppm
Sulfate	55 ppm
Sodium	48 ppm
Chloride	102 ppm
Silica	37 ppm
Iron	0 ppm
Other Constituents	Nitrate @ 170 ppm Bicarbonate @ 490 ppm
Pretreatment (See Legend below)	Acid/AScl/CtFl/CO
Desal Process	RO
Recovery Rate	80 %

Post Treatment	Chem Stabl/De-carbonation/CO
Blending	☐ NA ☒ VOC Ratio 8:2 ☒ Other Ion Exchange on Bypass 1, VOC on Bypass 2
Concentrate Disposal	CO Regional Interceptor
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ 25.0M ☒ Other $22.5 million for Expansion
Capital Cost, Desal Equipment	☐ NA ☐ $ 7.0M ☐ Other
Operating Cost, Excluding Debt Service	☒ $ 525/AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: Other: 4 x 1.7 mgd RO trains, 4 mgd Ion Exchange and a Bypass Treated for VOC through Towers.	

Chino I

General Background: Chino I Desalter was commissioned in 2000 and was built to treat high TDS groundwater with high nitrates. The facility was constructed by Santa Ana Water Production Authority (SAWPA) and was then transferred to the Chino Basin Desalter Authority (CDA). The plant is currently being expanded to 13 mgd by adding Ion Exchange and VOC removal towers to the facility. The expansion is to be commissioned in early 2005.

Objective of WTP: The treatment plant was designed to produce potable water with TDS of less than 350 mg/l and less than 25 mg/l of Nitrates.

TDS of source water: 871 mg/l

Pretreatment: Acid, Threshold Inhibitor and Cartridge Filtration

Treatment method used: Reverse Osmosis, Ion Exchange of Bypass Stream, VOC of second bypass Stream.

Blending Stabilization: The RO Permeate is decarbonated and blended with the two bypass streams and then Sodium Hydroxide is added.

Design Capacity: RO is 6 mgd, VOC bypass is 3 mgd and Ion Exchange Bypass is 4 mgd

Recovery rate of water: 80% recovery

How was concentrate managed?: Concentrate is sent to Ocean Outfall through Santa Ana Regional Interceptor (SARI)

Were there water quality constituents of concern other than TDS: Nitrates

Economics: Expansion is a $22 million project

REFERENCE PLANT DATA SHEET	
Location:	Chino II Desalter- Mira Loma, CA
Owner:	Chino Basin Desalter Authority
Contact Person(s):	Tom O'Neill - Jurupa Community Services District
Commissioning Date:	__/__/____ ☒ NA ☒ Other Commissioning Early 2005
Capacity/Size	Current Capacity @ 10 mgd
Capacity/Size	Ultimate Capacity @ 18 mgd
Source Water Type/Quality	Ground Water High Nitrates
TDS	960 ppm
Calcium	186 ppm
Magnesium	27 ppm
Sulfate	73 ppm
Sodium	74 ppm
Chloride	184 ppm
Silica	30 ppm
Iron	0 ppm
Other Constituents	Nitrate @ 150 ppm Bicarbonate @ 345 ppm @ ppm
Pretreatment (See Legend below)	Acid/AScl/CtFl/CO
Desal Process	RO
Recovery Rate	83 %
Post Treatment	Chem Stabl/De-carbonation/CO
Blending	☐ NA ☒ Ratio 60% RO:40% IX ☒ Other Blend Stream Has IX for NO3 Removal
Concentrate Disposal	CO Regional Interceptor

Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☒ $ 22.0M ☒ Other $79 million for Entire Project
Capital Cost, Desal Equipment	☐ NA ☒ $ 5.6M ☐ Other
Operating Cost, Excluding Debt Service	☒ $ 450/AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description:	Other:

Chino II Desalter

General Background: Chino II Desalter is to be commissioned in March 2005. The project is being built to treat high TDS groundwater with high nitrates. The facility is being constructed by the Chino Basin Desalter Authority (CDA). The plant is currently being constructed to produce 10 mgd with RO and Ion Exchange.

Objective of WTP: The treatment plant was designed to produce potable water with TDS of less than 350 mg/l and less than 25 mg/l of Nitrates.

TDS of source water: 900 mg/l

Pretreatment: Acid, Threshold Inhibitor and Cartridge Filtration

Treatment method used: Reverse Osmosis, Ion Exchange of Bypass Stream.

Blending Stabilization: The RO Permeate is decarbonated and blended with the ion exchange bypass stream and then Sodium Hydroxide is added.

Design Capacity: RO is 6 mgd and Ion Exchange Bypass is 4 mgd

Recovery rate of water: 83% recovery

How was concentrate managed?: Concentrate is sent to Ocean Outfall through Santa Ana Regional Interceptor (SARI)

Were there water quality constituents of concern other than TDS: Nitrates

Economics: The Cost of the RO Facility and IX Facilities is approximately $30 million project

REFERENCE PLANT DATA SHEET	
Location:	Torrance, CA
Owner:	West Basin Municipal Water District
Contact Person(s):	Wyatt Won
Commissioning Date:	7/1/1993 ☐ NA ☐ Other
Capacity/Size	Current Capacity @ 1 mgd
Capacity/Size	Ultimate Capacity @ 1 mgd
Source Water Type/Quality	Ground Water
TDS	4000 ppm
Calcium	700 ppm
Magnesium	160 ppm
Sulfate	283 ppm
Sodium	425 ppm
Chloride	2100 ppm
Silica	30 ppm
Iron	0 ppm
Other Constituents	Bicarbonate @ 200 ppm @ ppm @ ppm
Pretreatment (See Legend below)	Acid/AScl/CtFl/CO
Desal Process	RO
Recovery Rate	80 %
Post Treatment	Chem Stabl/De-carbonation/CO
Blending	☐ NA ☐ Ratio 90:10 ☒ Other Based on Treated Water Goals
Concentrate Disposal	CO County Sanitation Districts of LA County
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☒ $ 2.5M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other

Supplemental Information/Description: NA

Marv Brewer

General Background: Began operation in July 1993 by West Basin. 95% of water produced is sold to MWD

Objective of WTP: To provide potable water to Metropolitan Water District

TDS of source water: 4000 mg/L

Pretreatment: Sulfuric Acid, Threshold Inhibitor and Cartridge Filtration

Treatment method used: Reverse Osmosis

Blending Stabilization: Decarbonation and NaOH

Design Capacity: 1.3 mgd RO permeate and 0.2 mgd blend

Recovery rate of water: 80% RO permeate

How was concentrate managed?: Concentrate Disposed of to local sewer and sent to Los Angeles County Sanitation District WWTP.

REFERENCE PLANT DATA SHEET	
Location:	Torrance, CA
Owner:	Water Replenishment District of Southern California
Contact Person(s):	Melinda Sperry
Commissioning Date:	11/1/2001 ☐ NA ☐ Other
Capacity/Size	Current Capacity @ 2.5 mgd
Capacity/Size	Ultimate Capacity @ 5 mgd
Source Water Type/Quality	Ground Water
TDS	3881 ppm
Calcium	669 ppm
Magnesium	155 ppm
Sulfate	283 ppm
Sodium	425 ppm

Chloride	2095 ppm
Silica	29.2 ppm
Iron	0 ppm
Other Constituents	Bicarbonate @ 204 ppm @ ppm @ ppm
Pretreatment (See Legend below)	Acid/AScl/CtFl/CO
Desal Process	RO
Recovery Rate	80 %
Post Treatment	De-carbonation/CO
Blending	☐ NA ☐ Ratio : ☒ Other Based on Treated Water Goals
Concentrate Disposal	CO County Sanitation Districts of LA County
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☒ $ 6.5M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: NA	

Goldsworthy Desalter

General Background: Desalter for potable supply augmentation and basin salinity control

Objective of WTP: Provide new local potable supply and treat a localized high salinity plume

TDS of source water: ~3,800 mg/L

Pretreatment: Cartridge Filtration, sulfuric acid and threshold inhibitor injection

Treatment method used: Reverse osmosis

Blending Stabilization: Decarbonation, sodium hydroxide addition, blend to with as much bypass as possible to optimize production up to 500 mg/l TDS

Design Capacity: 2.5 mgd RO treatment capacity, expandable to 5.0 mgd

Recovery rate of water: Reverse Osmosis 80% Overall 81.3%

How was concentrate managed?: Discharge to sewer

Were there water quality constituents of concern other than TDS: Chloride

Any unique permitting/regulatory issues?: No

Any unique environmental issues?: No

Public outreach program?: During construction of pipelines in public road

Economics: The cost of construction of the complete facility was approximately $6-7 million including engineering fees

REFERENCE PLANT DATA SHEET	
Location:	Tampa Bay, FL
Owner:	Tampa Bay Water
Contact Person(s):	
Commissioning Date:	__/__/____ ☐ NA ☒ Other Under Construction
Capacity/Size	Current Capacity @ 25 mgd
Capacity/Size	Ultimate Capacity @ 35 mgd
Source Water Type/Quality	Other: Seawater
TDS	15,000 – 25,000 ppm
Calcium	ppm
Magnesium	ppm
Sulfate	ppm
Sodium	ppm
Chloride	ppm
Silica	ppm
Iron	ppm
Other Constituents	@ ppm @ ppm @ ppm
Pretreatment (See Legend below)	NA/Comment 2-stage sand filter
Desal Process	RO

Recovery Rate	50-60 %
Post Treatment	NA/CO Lime Stabilization
Blending	☒ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO Blended with cooling water/ocean discharge
Permitting/Regulation Issues	Comment: yearly inspections by State; 5-year permit
Environmental Issues	Other: Affects to area wildlife minimal
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☒ Other $2.69/1000 gallons
Supplemental Information/Description: Other: See Attached	

Tampa Bay Desalination Facility

General Background: Tampa Bay Water is a regional agency responsible for supplying the needs of a population of approx. 1.8 million. With the demand on the area's aquifers steadily increasing they decided to investigate alternative water sources. The raw water intake is beside the neighbouring power plant's four discharge tunnels, two of which were tapped to divert around 166,000m^3/day of the cooling outflow into the intake structure. Since the power plant already screens its 5.3 million m^3/day cooling stream inflow to exclude marine life, this arrangement avoided any duplication and overcame potential environmental objections to the SWRO plant's seawater feed. From the intake, the water is pumped to the pre-treatment facility.

Objective of WTP: The Tampa Bay seawater reverse osmosis (SWRO) plant was designed to produce an initial 95,000m^3 (25 million US gallons) of water per day

TDS of source water: 15000-25000, Source Water Influenced by Run off and fresh water sources

Pretreatment: Chemical filtration agents and ferric sulfate are added to the inflow, which passes through a two stage sand filter. The media is continuously backwashed, which further helps to lower the silt density index of the exiting water

Treatment method used: The Reverse Osmosis (RO) system has seven independent trains, each comprising a transfer pump, cartridge filters, reverse osmosis membranes, associated high pressure pump and an energy recovery turbine (ERT). An 800hp vertical turbine transfer pump in each train draws raw water from the pre-treatment wet well to the 5 micron cartridge filter assembly. The water then enters the RO process itself.

Blending Stabilization: Water is Stabilized after treatment with lime for discharge to the potable water systems

Design Capacity: 25MGD

Recovery rate of water: 50%-60%

How was concentrate managed?: The high pressure concentrate returns to the ERT for energy recovery and is then mixed with the power station cooling water in a ratio of 70:1 to dilute its high salinity before finally being discharged The highly salty byproduct will flow into the Big Bend power plant's cooling water canal, where it will be diluted in the 1.4 billion gallons the canal carries each day.

Were there water quality constituents of concern other than TDS: Boron in the Seawater can be an impact

Any unique permitting/regulatory issues?: The state permit requires that the plant conduct several types of monitoring on a daily, weekly and quarterly basis. Also, state officials will do inspections at least once a year. The plant's permit is good for five years, but can be revoked earlier.

Any unique environmental issues?: Concerns on the increased salinity of the area waters and wildlife effects were taken into consideration. Independent studies showed that the plant alone would have little affect on the salinity of the water "because it's just such a drop in the bucket when you compare it to the total quantity of water in the bay.

Economics: $2.69/1000 gallons after fixing of pretreatment issues

REFERENCE PLANT DATA SHEET	
Location:	St. Lucie West, Florida
Owner:	St. Lucie West Water District
Contact Person(s):	Ilan Wilf, Hydranautics
Commissioning Date:	04/00/1996 ☐ NA ☐ Other
Capacity/Size	Current Capacity @ 1 mgd
Capacity/Size	Ultimate Capacity @ 1 mgd
Source Water Type/Quality	Ground Water Good

TDS	588 ppm
Calcium	107 ppm
Magnesium	6 ppm
Sulfate	30 ppm
Sodium	49.3 ppm
Chloride	80 ppm
Silica	23.4 ppm
Iron	2.6 ppm
Other Constituents	Alkalinity @ 290 ppm THM Potential @ .08 - .120 ppm @ ppm
Pretreatment (See Legend below)	NA/Comment ASci, CtFl
Desal Process	RO
Recovery Rate	85 %
Post Treatment	NA/CO pH Adjustment With Caustic Soda
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO Not Discussed
Permitting/Regulation Issues	N/A Not Discussed
Environmental Issues	N/A Not Discussed
Capital Cost, Total Plant	☒ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☒ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☒ $ 163.05/MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: NA	

REFERENCE PLANT DATA SHEET	
Location:	Las Vegas, NV
Owner:	Southern Nevada Water Authority
Contact Person(s):	Mike Goff
Commissioning Date:	__/__/____ ☐ NA ☒ Other Pilot Operation Summer 2002
Capacity/Size	Current Capacity @ 5 mgd

Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water Wide Range of TDS
TDS	2300-4500 ppm
Calcium	504 ppm
Magnesium	369 ppm
Sulfate	2620 ppm
Sodium	250 ppm
Chloride	480 ppm
Silica	77-99 ppm
Iron	0 ppm
Other Constituents	F @ 1.1 ppm NO3 @ 133 ppm @ ppm
Pretreatment (See Legend below)	Acid/AScl/CO
Desal Process	RO
Recovery Rate	55 %
Post Treatment	Chem Stabl/De-carbonation/CO
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO Brine Concetrators
Permitting/Regulation Issues	Comment: Must Meet IESWTR
Environmental Issues	Other: Concentrate Disposal
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: Other: Evaluated RO, Lime +RO, EDR, RO +Thermal Concentrators, EDR + Brine Concentrators	

SNWA Report

General Background: Southern Nevada Water Authority is looking at brackish water desalination as option for supplying water to Southeastern Las Vegas Valley Area as part of their overall Water Resources Plan. There is a significant amount of brackish water in the local aquifer, with high TDS that could potentially be used for potable water source.

The SNWA performed a technology evaluation study and recovery optimization pilot study on the water in 2002 to determine the available treatment options for desalination of the brackish groundwater.

Objective of WTP Pilot Study: Determine optimum recovery and treatment train configuration for a backish water desalination facility.

TDS of source water: 2300 to 4500 mg/l, High Silica Concentrations between 77 and 99 mg/l

Pretreatment: Acid/TI /Cartridge Filter and potentially Lime Softening.

Treatment method used: Pilot used high rejection RO membranes

Blending Stabilization: Blending was possible, however, may require treatment due to IESWTR requirements

Design Capacity: Eventual capacity of proposed facility was 5 mgd

Recovery rate of water: RO = 55%, Lime+RO = 80% and HERO=95%

How was concentrate managed?: Evaluated Brine Concentrators and Evaporation and Thermal Processes.

Were there water quality constituents of concern other than TDS: Silica and Nitrates

Any unique permitting/regulatory issues?: Would potentially require compliance with IESWTR due to influence of surface water on the groundwater source.

REFERENCE PLANT DATA SHEET	
Location:	El Paso, TX
Owner:	El Paso Water Utilities
Contact Person(s):	Bill Hutchinson
Commissioning Date:	__/__/____ ☐ NA ☒ Other Under Construction
Capacity/Size	Current Capacity @ 27.5 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water
TDS	2250 ppm
Calcium	ppm
Magnesium	ppm

Sulfate	ppm
Sodium	ppm
Chloride	ppm
Silica	ppm
Iron	ppm
Other Constituents	@ ppm @ ppm @ ppm
Pretreatment (See Legend below)	NA/Comment
Desal Process	RO
Recovery Rate	81-85 %
Post Treatment	NA/CO
Blending	☐ NA ☐ Ratio : ☒ Other 15.5 mgd from RO & 12 mgd from wells
Concentrate Disposal	CO Deep Well Injection
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☒ $ 67M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☒ $ 700/AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: Other: Target TDS 600-700 mg/L	

LAKE GRANBURY, TEXAS RO PLANT DATA SHEET	
Location:	Lake Granbury, Texas
Owner:	Brazos River Water Authority, Waco, Texas
Contact Person(s):	
Commissioning Date:	
Capacity/Size	Current Capacity 6.0 mgd permeable
Capacity/Size	Ultimate Capacity - no expansion anticipated at this time
Source Water Type/Quality	Surface water from Lake Granbury - a reservoir on the Brazos River

TDS	3.30 to 1,750 ppm; avg. = 1,140 ppm
Calcium Hardness	154 to 163 ppm; avg. = 159 ppm
Total Hardness	190 to 205 ppm; avg. = 199 ppm
Sulfate	47 to 550 ppm; avg. = 230 ppm
Sodium	390 ppm avg.
Chloride	93 to 669 ppm; avg. = 444 ppm
Silica	7.2 ppm avg.
Iron	<0.5 ppm
Other Constituents	Barium = less than 0.05 ppm after lime softening, raw water barium is approx. 0.15 ppm Strontium approx. 1.7 ppm
Pretreatment (See Legend below)	GrFl, lime softening, re-carbonation, ultra filtration, acid, AScl, CtFl
Desal Process	Reverse Osmosis (RO); Supplier: Osmonics, Inc.
Recovery Rate	85 %
Post Treatment	pH adjustment; chlorination
Blending	Yes ☒ Ratio varies depending on demand
Concentrate Disposal	Return to Lake Granbury/Brazos River
Permitting/Regulation Issues	None - normal permits obtained
Environmental Issues	None
Capital Cost, Total Plant	
Capital Cost, Desal Equipment	
Operating Cost, Excluding Debt Service	
Supplemental Information/Description: The RO Plant is operated in parallel with a conventional WTP and in conjunction with an older EDR Plant. All processed water streams are combined (blended) for distribution to several retail water supply entities.	

REFERENCE PLANT DATA SHEET	
Location:	Fort Stockton, Texas
Owner:	City of Fort Stockton
Contact Person(s):	
Commissioning Date:	7/1/97 ☐ N/A ☐ Other
Capacity/Size	Current Capacity @ 3 mgd

Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	
TDS	1433 ppm
Calcium	ppm
Magnesium	ppm
Sulfate	ppm
Sodium	253 ppm
Chloride	360 ppm
Silica	ppm
Iron	ppm
Other Constituents	hardness @ 560 ppm @ ppm @ ppm
Pretreatment	Cartridge Filters ultraviolet disinfection
Desal Process	RO
Recovery Rate	80 %
Post Treatment	Aeration? pH adjustment
Blending	☐ N/A ☐ % w/ ☒ Other does not mention how much
Concentrate Disposal	Other: blend-effluent-crops
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ N/A ☐ $ ___.___M ☐ Other
Capital Cost, Desal Equipment	☐ N/A ☒ $ 3.75M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☒ $ 123k/MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: N/A	

REFERENCE PLANT DATA SHEET	
Location:	Cypress Water Treatment Plant
Owner:	City of Witchita Falls, Texas
Contact Person(s):	Unknown

Commissioning Date:	__/__/____ ☒ NA ☐ Other
Capacity/Size	Current Capacity @ 14 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Surface Water :Lake Kemp
TDS	1200 ppm
Calcium	ppm
Magnesium	ppm
Sulfate	400 ppm
Sodium	ppm
Chloride	400 ppm
Silica	ppm
Iron	ppm
Other Constituents	Turbidity @ ppm DOC @ ppm @ ppm
Pretreatment (See Legend below)	AScl/Coag/Sed/Mem/CtFl/CO
Desal Process	RO
Recovery Rate	%
Post Treatment	NA/CO
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	To Sanitary Sewer/CO
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: NA	

Wichita Falls, Texas

General Background: Cypress Water Treatment Plant was constructed to treat a high TDS surface water from Lake Kemp. The water in Lake Kemp has high chloride levels and high sulfates. The water from the lake has typically been used for irrigation. The City of Wichita Falls performed a pilot program on the lake water to determine pretreatment requirements and then constructed a 14 mgd facility. The facility recently began operation.

Objective of WTP: The treatment plant was designed to produce potable water with low sulfates and chloride.

TDS of source water: 900-1200 mg/l

Pretreatment: Cagulation and Sedimentation followed by Microfiltration

Treatment method used: Reverse Osmosis

Blending Stabilization: RO Permeate is stabilized with sodium hydroxide.

Design Capacity: MF Capacity is 14 mgd, RO capacity is approximately 12 mgd

Recovery rate of water: 80% recovery

How was concentrate managed?: Unknown

Were there water quality constituents of concern other than TDS: DOC, TOC, Turbidity, Taste & Odor

Implementation of a 3 MGD Reverse Osmosis Plant (Fort Stockton, Texas)
Keith A. Rutherford

Reviewed by: Thomas K. Poulson

Summary:

City of Fort Stockton, Texas operates a 3 mgd RO desal plant since 1997 for 8,524 residents and 1000 inmates. Well water is treated with a TDS of 1500 to 1400 mg/L. Besides TDS, chlorides (370 mg/L), sodium (260 mg/L) and Hardness (590 mg/L $Caco_3$) are over the State's drinking water standards.

Four reverse osmosis units produce a total of 3.04 mgd permeate using two stage trains at a recovery rate of 80%.

Pretreatment consists of ultraviolet disinfection to prevent bacteria from growing on the membranes. Sulfuric acid is added to the disinfected water to lower pH to prevent calcium carbonate from precipitating out. Then antiscalant is added. Two 5 micron filters are the final step before the RO units. Operating PSI between 175 and 200. Salt rejection rate of approximately 95%.

The permeate is blended with well water then goes through post treatment consisting of degasification done with blowers to strip CO_2 form the water and raise the pH to 7.3. Caustic solution is used when the air stripper does is not sufficient. Then the water moves through a chlorinator to two large storage tanks.

The brine is pumped 7 miles mixed with WWTP effluent and used to irrigate crops. Three other options were considered evaporation ponds (too expensive), surface discharge to the Pecos River (40 miles away and NPDES permit), and injection wells (concerned of long term environmental impacts and permitting)

No mention of government regulations or environmental issues except for discharge options which were not selected because of them.

This paper had a very good cost analysis of R.O. and EDR. O&M costs were higher for the RO $369,077 versus $361,301 for EDR. But the capital costs for RO were lower $3,752,520 versus $4,261,692 for EDR. The RO option was selected and actual O&M costs for 1998 was $306,567.

REFERENCE PLANT DATA SHEET	
Location:	New Castle County, Delaware
Owner:	United Water
Contact Person(s):	HDR Engineering, Inc.
Commissioning Date:	__/__/____ ☐ NA ☒ Other FEASIBILITY STUDY
Capacity/Size	Current Capacity @ 24 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Surface Water
TDS	NA ppm
Calcium	NA ppm
Magnesium	NA ppm
Sulfate	NA ppm
Sodium	NA ppm
Chloride	35 ppm
Silica	NA ppm
Iron	.005 ppm

Other Constituents	@ ppm @ ppm @ ppm
Pretreatment (See Legend below)	AScl/Coag/PrFl/CtFl/CO Use of polymer and coagulant in SW treatment
Desal Process	RO
Recovery Rate	80 %
Post Treatment	NA/CO
Blending	☐ NA ☐ Ratio : ☒ Other
Concentrate Disposal	CO study determined that
Permitting/Regulation Issues	Comment: Potential issues with concentrate management
Environmental Issues	Other: Concentrate disposal into surface water may have impacts.
Capital Cost, Total Plant	☐ NA ☒ $ _____._____M ☒ Other 4,380,000/year for 20 years
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: Other: Chloride exceeding the secondary MCL is more of the issue than TDS itself for this plant.	
Legend: Acid - Acid Addition/pH Reduction; AScl - Anti-scalant Addition; CO - Comment/Other; Coag - Chemical Coagulation; CtFl - Cartridge Filter	GrFl - Gravity Filters; Mem - Low Pressure Membranes; NA - Not Applicable; PrFl - Pressure Filters; Sed - Sedimentation

United Water Delaware Stanton WTP Desalination Feasibility Study
HDR Engineering, Inc., January 2003

Reviewer:
Laura Chavez

Summary:
HDR Engineering, Inc. conducted a feasibility study on mechanical desalination for United Water in New Castle County, Delaware. The two selected methods of desalination that were reviewed were Reverse Osmosis (RO) and Electrodialysis Reversal (EDR). United Water takes surface water from White Clay Creek and in drought, this water supply exceeds the secondary MCL for chloride, which is the primary reason for this

study. Although White Clay Creek is tidally influenced, information on TDS levels was not mentioned. This water has a highly variable turbidity level, which may affect potential membrane treatment. The paper recommended that turbidity of feedwater entering the RO unit be less than 0.2 NTU and have a level of less than 5 SDI. Fouling of the membranes is not as apt to occur with EDR, but pretreatment should occur for iron (>0.3 mg/L), manganese (>0.1 mg/L), free chlorine (>.05 mg/L) and turbidity (>0.2 NTU). During the severe drought of 2002, the SDI in White Clay Creek was about 15.

Another issue of concern with desalination is the "re-equilibrium process". The re-equilibrium process occurs when corroded, but stable plumbing come to a new equilibrium with water that has a different chemistry than when the corrosion developed. When this occurs, the build-up of corrosion is loosened and released into the distribution system, potentially causing aesthetic (red water) problems and regulatory problems (non-compliance with lead and copper rule). This loosening can also cause leaks in infrastructures and cause customers to use more water to flush the corrosion.

Recovery of RO is 80% and 85% for EDR. This becomes an issue for the water treatment plant because current capacity of the conventional water treatment plant is 24 mgd. EDR and RO would require a capacity of 28 to 31 mgd respectively because of losses in the concentrating step. Therefore capacity becomes an issue for both types of treatment.

The high-estimate annual cost for a 24 mgd plant for RO was $4,380,000 and for EDR was $6,720,000. Although EDR was more expensive than RO, EDR was the recommended desalination process for United Water because of capacity and pretreatment issues. HDR recommended that some other alternative such as, Aquifer Storage and Recovery, be considered other than mechanical desalination because of the high costs, arduous regulatory hoops and limited times when use of desalination would be required.

The options for concentrate management that were reviewed and issues with this option are summarized in the following bullets:

- Surface Water Discharge – most viable option, but will require
- Discharge to Sewer System – the quantity of discharge makes this option infeasible.
- Ocean Discharge – the distance to the ocean and regulatory considerations makes this option infeasible.
- Land Applications – this option is limited by the availability of land and regulatory considerations.
- Evaporation Ponds – this option is limited by the availability of land and regulatory considerations.
- Deep Well Injection – assumed that regulatory acceptance in Delaware would be difficult.

Using Electrodialysis to Meet Drinking Water Requirements
Review by B. Kelso

Overall the Paper gave a summary of background information on the development of ED and EDR.

- First ED plant in 1954 in Arabia.
- Buckeye, AZ first ED plant in US in 1962.
- EDR patented in mid-sixties. Significant improvement over ED.
- Almost all ED plants have been upgraded to EDR.

Report included a table of thirteen EDR plants in Arizona and neighborhood states. Flows ranged from 20 – 4200 gpm. TDS concentrations ranged from 1000-4000 ppm. Source waters included surface and groundwater.

The report also included summaries for 3 existing EDR plants (see below).

REFERENCE PLANT DATA SHEET	
Location:	Buckeye, AZ
Owner:	Town of Buckeye
Contact Person(s):	
Commissioning Date:	__/__/____ ☐ NA ☒ Other 1988 for EDR
Capacity/Size	Current Capacity @ 0.9 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water
TDS	1587 ppm
Calcium	95 ppm
Magnesium	24 ppm
Sulfate	219 ppm
Sodium	446 ppm
Chloride	700 ppm
Silica	19 ppm
Iron	ppm
Other Constituents	@ ppm @ ppm @ ppm
Pretreatment (See Legend below)	NA/Comment
Desal Process	EDR
Recovery Rate	%

Post Treatment	NA/CO
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☒ $ 1.1M (1997 dollars) ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☒ Other $2/1000 gallons
Supplemental Information/Description: NA	
REFERENCE PLANT DATA SHEET	
Location:	Dell City, TX
Owner:	Dell City
Contact Person(s):	
Commissioning Date:	__/__/____ ☐ NA ☒ Other 1996
Capacity/Size	Current Capacity @ mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water
TDS	1200-3000 ppm
Calcium	206 ppm
Magnesium	63.2 ppm
Sulfate	564 ppm
Sodium	19.6 ppm
Chloride	17.8 ppm
Silica	ppm
Iron	ppm
Other Constituents	Hardness @ 774 ppm @ ppm @ ppm
Pretreatment (See Legend below)	NA/Comment
Desal Process	EDR

Recovery Rate	%
Post Treatment	NA/CO
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO Used for irrigation
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☒ $ 1.1M (1997 dollars) ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☒ Other $2/1000 gallons
Supplemental Information/Description: NA	
REFERENCE PLANT DATA SHEET	
Location:	Buckeye, AZ
Owner:	Lewis Prison
Contact Person(s):	
Commissioning Date:	__/__/____ ☐ NA ☒ Other 1988
Capacity/Size	Current Capacity @ 1.35 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water
TDS	2000-2500 ppm
Calcium	ppm
Magnesium	ppm
Sulfate	ppm
Sodium	ppm
Chloride	ppm
Silica	ppm
Iron	ppm
Other Constituents	@ ppm @ ppm @ ppm
Pretreatment (See Legend below)	NA/Comment

Desal Process	EDR
Recovery Rate	80-85 %
Post Treatment	NA/CO
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	Evaporation Lagoon/CO
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☒ $ 1.1M (1997 dollars) ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☒ Other $2/1000 gallons
Supplemental Information/Description: NA	

Full-scale Evaluation of Reverse Osmosis Concentrate Water Quality for Compliance with Surface Water Discharge Regulations

Authors: David Laliberte, Catherine Keenan, John Ten Eyck, and Roy P. Kain

Reviewer:
Laura Chavez

Summary:
The City of Vero Beach, Florida has run a Reverse Osmosis (RO) facility for eleven years, at the time this paper was written, using the original membranes. Scaling became an issue on the membranes and it was decided that they should be replaced after the City attempted to clean the membranes. Three different manufacturers' membranes were selected for side-by-side testing on using the same source water. The quality of the concentrate stream was the issue for the plant because concentrate is disposed of into a canal past the tidal salinity barrier under a National Pollutant Discharge Elimination System (NPDES) permit. To keep this permit, Vero Beach must utilize a mixing zone prior to sampling the blended stream and maintain annual averages for hydrogen sulfide, dissolved oxygen, total phosphorus, total nitrogen, iron, toxicity, gross alpha activity and radium.

Concentrate from the membranes was tested for acute and chronic toxicity testing on *Mysidopsis bahia* shrimp in 5 concentration levels for each membrane. It was found that calcium and fluoride were key indicators in the toxicity tests.

REFERENCED PLANT/PAPER DATA SHEET	
Paper Title:	Desalination Concentrate Management and Issues in the United States
Location:	216 treatment plants in 50 States
Owner/Author:	Michael C. Mickley, P.E., Ph.D.
Contact Person(s):	Michael C. Mickley, P.E., Ph.D.
Commissioning Date:	Varies, From earlier than1993 thru 2001
Capacity Size:	Smallest Plant = 0.025 mgd
Capacity Size:	Largest Plant > 10 mgd
Source Water Type/Quality	Varies - Surface and Groundwater
TDS	Varies
Calcium	Varies
Magnesium	Varies
Sulfate	Varies
Sodium	Varies
Chloride	Varies
Silica	Varies
Iron	Varies
Other Constituents	Varies
Pretreatment (See Legend Below)	Varies including MFs before NF and RO
Desal Process	All Membranes (MF, UF, NF, RO & ED)
Recovery Rate	Varies
Post Treatment	Varies
Blending	Varies
Concentrate Disposal	Varies, surface discharge, disposal to sewer, deep well, evaporation pond, spray irrigation, & reuse
Permitting/Regulation Issues	NPDES permits need to be obtained/modified; deep well injection permitting
Environmental Issues	Varies
Capital Cost, Total Plant	Varies
Capital Cost, Desal Equipment	Varies
Operating Cost, Excluding Debt Service	Varies
Supplemental Information/Description:	This paper provides a good summary of the number and types of membrane plants that are over 0.025 mgd built before 2002, including their concentrate disposal

Water logging within the Buckeye Water Conservation and Drainage District
Leonard C. Halpenny

Reviewed by: Thomas K. Poulson

Summary: This report is not complete. Sections and entire chapters were not released by ADWR. But what is in the report is interesting. The first point that is made is that the water logging of the southwest Salt River Valley is due to farming practices and not as many believe the 91st Avenue WWTP effluent. Although, obviously the WWTP is now contributing to the water logged area.

The first chapter, which is chapter 3, is a brief history of irrigation in this area. The first land (902 acres) irrigated in the Buckeye Irrigation District was done so in 1887. By 1915 there was a total of 19,865 acres of farmland under irrigation. Water logging was sever in the early 1920's. All of the water was being attained from the Gila River. The U.S. Department of agriculture recognized the water logging problem in 1927 (Harper, W.B., and Youngs, F.O., 1927, Soil Survey of the Buckeye-Beardsley Area, Arizona: U.S. Dept. Agric., Bur. Of Chem. And Soils, Series 1927, Bull. 3. 43 p.), "Several thousand acres of comparatively low lying lands of the Buckeye irrigation district are affected with a high water table and such quantities of alkali salts that crop production is precluded."

Roosevelt Dam was completed 1911, which made possible additional irrigation for crops. Over the years different sources of water were used as litigation by various groups argued over water rights. Salt River water, Gila River water and in recent years effluent have all been the sources of water.

Gillespie Dam was completed in 1921.

Table 6-1 shows 47 BIC wells which the water table rose up to 68 feet between the years of 1960 and 1983.

Table 6-3 shows TSS (total soluble solids) in 34 BIC wells with in a range of 1578 mg/L to 4871 mg/L. (Definition: Soluble salts is the measurement of all the elements (ions) dissolved in the soil water. This is very similar to TDS except what is meant by soil water?)

The arithmetic average TSS for BIC wells (un-weighted as to volume) for all samples in 1982 was 3,258 mg/L TSS.

REFERENCE PLANT DATA SHEET	
Location:	Avondale, AZ
Owner:	Reclamtion study

Contact Person(s):	
Commissioning Date:	2/22/96 ☐ N/A ☐ Other
Capacity/Size	Current Capacity @ 2 mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	
TDS	2100 ppm
Calcium	ppm
Magnesium	ppm
Sulfate	ppm
Sodium	ppm
Chloride	670 ppm
Silica	ppm
Iron	ppm
Other Constituents	@ ppm @ ppm @ ppm
Pretreatment	Gravity Filters antiscalent
Desal Process	NF
Recovery Rate	%
Post Treatment	Chemical Stabilization
Blending	☐ N/A ☐ % w/ ☐ Other
Concentrate Disposal	Evap Lagoon
Permitting/Regulation Issues	N/A
Environmental Issues	Other: biofouling decreased membrane performance
Capital Cost, Total Plant	☐ N/A ☐ $ ___.___M ☐ Other
Capital Cost, Desal Equipment	☐ N/A ☒ $ 6.78M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: N/A	

Maricopa Groundwater Treatment Study
Bureau of Reclamation

Reviewed by: Thomas K. Poulson

Summary:

The cities of Avondale, Chandler and the Gila River Indian Community partnered with Reclamation to test two methods of desalination of water drawn from well s5 located in the City of Avondale. Reverse Osmosis and Electrodialysis (ED) were the methods of desalination chosen for the pilot testing. The contaminants of concern were nitrates and turbidity. Secondary contaminants were chlorides and total dissolved solids (TDS).

Nitrate levels were about 21 mg/L (way above the primary standard of 10 mg/L). Turbidity was approximately 10 (way above the primary standard of .5). The TDS of the well water was approximately 2,100 mg/L (way above the secondary standard of 500 mg/L). The concentration of chlorides was approximately 670 mg/L (way above the secondary standard of 250).

Pre treatment for the RO unit consisted of conventional water treatment (rapid mix, flocculation basin, stilling well, pressure clarifier, multi-media pressure filter) then to the RO feed tank. From the feed tank anti-scalent and acid were added and a cartridge filter before the RO membranes. The membranes were FilmTec BW30-2540 (the report was written in 1996). No post treatment was used as the permeate and the concentrate were disposed. But blending would be used in actual production to produce the required water quality.

Pre treatment for the ED was the same conventional water treatment as with RO. No anti scalent or acid was used but a cartridge filter right before the ED membranes. No post treatment was used. But blending would be used in actual production to produce the required water quality.

The RO had a feed rate of approximately 20 L/min which works out to be about 7,600 gal/day. Although I could not find data on the ED unit flow rate it must have been similar to the RO piloting.

Since this was pilot testing no unique regulatory or environmental issues were brought up.

The results of the 6 week pilot testing indicated that although the RO produced much better quality water there was a 11 percent drop off of permeate flow. The membranes were autopsied after the test and there was scaling and biofouling. "*The decision not to disinfect prior to the RO unit resulted in the deposition of biological matter onto the cartridge filter. Biofouling may have contributed to decreased membrane performance.*" The RO recovery rate was not found but typically that runs about 75% in a two stage system.

The ED unit had a 80% recovery rate but the water was of much lower quality.

The conclusions drawn from the pilot testing was that when the TDS of groundwater is about 1100 mg/L less and the nitrate concentration is about 23 mg/L or less ED is recommended. A 2 mgd ED plant (no brine disposal) would cost about $6,730,000 and annualized costs (20 years, 6.5%) would be $610,000.

If the TDS is greater then 1100 mg/L then nanofiltration (Huh!!??) is recommended. (although nanofiltration was not piloted, it was thought that it would work and be cheaper to operate then RO because the water quality goals were not that sever). A 2 mgd nanofiltration plant (no brine disposal) would cost $6,780,000 and annualized costs would be $615,000.

A conclusion I came to is that pretreatment better resolve all issues before building a production RO facility.

Brine Disposal from Land Based Membrane Desalination Plants: A Critical Assessment
Reviewed by B. Kelso

This paper summarizes/compares three concentrate management technologies: Deep Well Injection, Evaporation Ponds, and Solar Ponds. Generally mentions 300 mgd plant being considered by MWD as purpose for looking at these three technologies, but does not necessarily relate the technologies to a specific type of desal projects (i.e. groundwater, surface water, or salt water). Technologies are very basic. Final conclusion recommends MWD use an ocean outfall for disposal of concentrate.

REFERENCE PLANT DATA SHEET	
Location:	Chandler, Arizona
Owner:	City of Chandler
Contact Person(s):	Doug Toy, City of Chandler
Commissioning Date:	__/__/____ ☒ NA ☐ Other
Capacity/Size	Current Capacity @ mgd
Capacity/Size	Ultimate Capacity @ mgd
Source Water Type/Quality	Ground Water
TDS	1300 - 1800 ppm
Calcium	ppm
Magnesium	ppm
Sulfate	ppm

Sodium	ppm
Chloride	ppm
Silica	ppm
Iron	ppm
Other Constituents	Nitrate @ <5 - >30 ppm
Pretreatment (See Legend below)	NA/Comment
Desal Process	RO
Recovery Rate	%
Post Treatment	NA/CO
Blending	☐ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: Other: The purpose of this study was to identify possible uses for high TDS groundwater from the shallow aquifer. The study concludes that this water may be used for irrigating "low appearance turf" or salt tolerant landscaping.	

REFERENCE PLANT DATA SHEET	
Location:	Suffolk Groundwater Treatment Plant
Owner:	City of Suffolk, VA
Contact Person(s):	Unknown
Commissioning Date:	7/1/1990 ☒ NA ☐ Other
Capacity/Size	Current Capacity @ 4 mgd
Capacity/Size	Ultimate Capacity @ 15 mgd
Source Water Type/Quality	Ground Water
TDS	560 ppm

Calcium	ppm
Magnesium	ppm
Sulfate	ppm
Sodium	185 ppm
Chloride	ppm
Silica	ppm
Iron	ppm
Other Constituents	Flouride @ 4.8 ppm @ ppm @ ppm
Pretreatment (See Legend below)	AScl/CtFl/CO
Desal Process	EDR
Recovery Rate	94 %
Post Treatment	Chem Stabl/CO
Blending	☒ NA ☐ Ratio : ☐ Other
Concentrate Disposal	CO Unknown
Permitting/Regulation Issues	N/A
Environmental Issues	N/A
Capital Cost, Total Plant	☐ NA ☐ $ _____._____M ☐ Other
Capital Cost, Desal Equipment	☐ NA ☐ $ _____._____M ☐ Other
Operating Cost, Excluding Debt Service	☐ $ /AF ☐ $ /MG ☐ $ /CCF ☐ Other
Supplemental Information/Description: Other: Product Quality = 140 mg/l TDS, 1.2 mg/l F, 50 mg/l Sodium, Currently Expanding to 15 mgd	

Newport News, VA EDR

General Background: Project was implemented by the City of Suffolk, Virginia to meet water demand. The local groundwater proved to be the best alternative source of water, however it had high fluoride and sodium in the water. The evaluation included RO and Electrodialysis Reversal (EDR) and activated alumina. Activated Alumina was eliminated from consideration since it would not remove sodium. EDR ended up providing the best alternative due to the high recovery rates and the lower operating costs at the high recovery.

Objective of WTP: Fluoride and Sodium Removal

TDS of source water: 560 mg/l, 4.8 mg/l Flouride, 185 mg/l sodium

Pretreatment: Cartridge

Treatment method used: Electrodialysis Reversal (EDR)

Blending Stabilization: Not with EDR, complete treatment of feed stream.

Design Capacity: 3.8 mgd

Recovery rate of water: 94.5%

How was concentrate managed?: Discharge to a local creek for dilution

Were there water quality constituents of concern other than TDS: Fluoride

Any unique permitting/regulatory issues?: Unknown

Appendix B List of Primary and Secondary MCLs

EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Acrylamide	TT[8]	Nervous system or blood problems;	Added to water during sewage/wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10 micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG=4[1]

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

1

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl_2)	MRDL=4.0[1]	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG=4[1]
D	Chlorine dioxide (as ClO_2)	MRDL=0.8[1]	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG=0.8[1]
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT[7]; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	Cryptosporidium	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

2

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT[8]	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	Giardia lamblia	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT[3]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT[7]; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero
M	*Legionella*	TT[3]	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock	0.04
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

3

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and *E. coli*)	5.0%[4]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[5]	Coliforms are naturally present in the environment as well as feces; fecal coliforms and *E. coli* only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a[6]
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT[3]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

4

	Contaminant	MCL or TT[1] (mg/L)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT[3]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

NOTES

1 Definitions:

- Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
- Maximum Contaminant Level (MCL)—The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- *Cryptosporidium* (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- *Giardia lamblia*: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- *Legionella*: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing <10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

4 No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E. coli* fecal coliforms, system has an acute MCL violation.

5 Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

8 Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

LEGEND

D	Disinfectant	IOC	Inorganic Chemical	OC	Organic Chemical
DBP	Disinfection Byproduct	M	Microorganism	R	Radionuclides

5

National Secondary Drinking Water Standards

National Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

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Appendix C West Valley Brackish Groundwater Appraisal Study