Colorado River Municipal Water District

REGIONAL WATER RECLAMATION PROJECT

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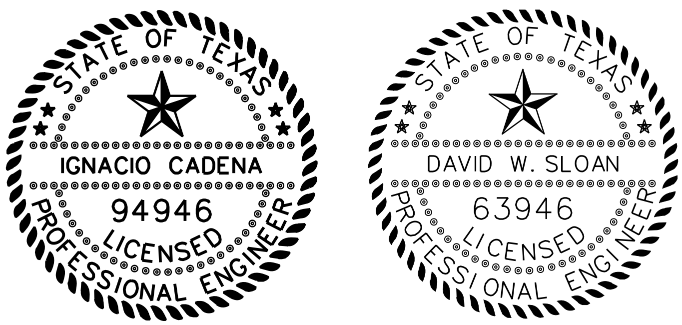
FEASIBILITY STUDY



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Executive Summary

The Permian Basin, like much of the western United States, has been subjected to an unprecedented period of drought over the past seven years. While rains in the second half of 2004 have reduced the severity of the current drought, reservoir levels remain low, and there is some speculation that West Texas runoff response and reservoir yields are fundamentally different than the conditions assumed when the principal reservoirs were planned on the Upper Colorado River. The Colorado River Municipal Water District is therefore seeking new supplies and alternatives to continue to provide a reliable and sustainable water supply to its member and customer cities. A promising source of supplemental supply is the treated wastewater currently discharged by cities in the CRMWD service area. This report explores the feasibility of reclaiming this water to augment existing CRMWD supplies.

Domestic wastewater contains a number of contaminants which are a concern to human health, including various pathogenic organisms and organic substances, both known and unknown. Standard wastewater treatment removes a large portion of these, but the remainder is left to biodegrade in the environment at varying rates. Additional treatment is required before this water can be considered equal to existing raw water supplies and safe for human consumption. Although reclaimed water has been blended with other supplies in other projects, the configuration proposed for the CRMWD system provides little opportunity for natural systems to work, and the treatment sequence must be very reliable to inspire public confidence in the finished water. A treatment sequence is proposed which consists of membrane filtration, reverse osmosis and ultraviolet oxidation.

Three regional projects are proposed, located to serve the District's member cities of Big Spring, Snyder and Odessa, and the key customer city of Midland. Effluent from Odessa and Midland would be treated at a joint facility, while Big Spring and Snyder would have independent facilities.

The Big Spring project is proposed adjacent to the City's wastewater treatment plant and would provide approximately 1.84 million gallons per day (MGD) of reclaimed water into the District's Spence Pipeline east of Big Spring. Desalination reject brine would be discharged to Beals Creek for subsequent interception and storage in Red Draw Reservoir. The concept-level opinion of probable cost for this project is $7.7 million, and annual operating costs are estimated at $505,000, for a projected unit cost of $1.67/1000 gallons. These projected costs are favorable compared to previous estimates, and it is recommended that this project proceed to preliminary design.

The Snyder project is estimated to provide about 720,000 gallons per day from a proposed site adjacent to the Snyder wastewater treatment plant. The District's existing 15 MG balancing reservoir west of the city would be replaced by a similar reservoir at a location near the Snyder water treatment plant and reclaimed water would be pumped to the new reservoir for blending with raw water from Lake J.B. Thomas. Desalination reject brine would be returned to the wastewater treatment plant outfall and blended with the remaining effluent. This configuration will limit the fraction of effluent which can be reclaimed, due to water discharge quality constraints. Additional study will seek feasible disposal options to eliminate the effluent blending constraint. Aquifer storage and recovery (ASR) may be feasible for this project to improve capture of available water and storage for later use with minimal evaporative loss. The conceptual cost of including ASR with the project at a site northeast of Snyder has also been included. The concept-level opinion of probable cost for the project is $7.6 million, and annual operating costs are estimated at $203,000, resulting in a projected unit cost of $2.95/1000 gal.

The final project proposed is to reclaim treated effluent from Odessa and Midland. The project as currently configured provides the additional treatment at a common facility located adjacent to the District's 100 MG Terminal Reservoir between the two cities. The Midland wastewater treatment plant will require upgrade to provide a total secondary treatment capacity of at least 10 MGD, to produce satisfactory effluent for reclamation. The water would then be pumped to the proposed treatment facility at the Terminal Reservoir. Odessa already operates an extensive reclaimed water system for supply to numerous industrial and irrigation customers from their Bob Derrington Water Reclamation Plant. Their transmission line extends along the east side of Odessa, where effluent could be transferred to the District's proposed treatment facility whenever surplus effluent is available. Approximately 3.5 MGD is estimated to be available during winter months or other periods of low irrigation demand.

Up to 10.8 MGD of treated reclaimed water would be blended with water from the Ivie, Spence and Thomas pipelines in the 100 MG Terminal Reservoir. There is also potential for the use of ASR to provide longer term storage with minimal evaporation. Conceptual costs have been developed for including ASR in the project using the City of Midland's abandoned McMillen Well Field as the underground storage aquifer. Disposal of desalination reject brine represents a major obstacle to the implementation of this project. A combination of disposal wells, storage and evaporation reservoirs, and transfers to oil operations at the Mabee Oil Field are assumed as part of the brine handling, representing a large fraction of the overall project cost. The concept-level opinion of probable costs for the project is about $73 million, and annual operating costs are estimated at $2.7 million. The projected unit cost for reclaimed water from the project as currently configured is $2.35/1000 gallons. Due to the expense and logistical obstacles to this configuration, additional concepts should be explored before proceeding with the preliminary design report for this project.

The following is a summary of the projected water which can be reclaimed through this project:

Project	Reclaim Capacity (MGD)	Annual Yield (acre-ft.)	Unit Cost ($/1000 gal.)
Big Spring	1.84	1855	$1.67
Snyder	0.72	726	$2.95
Odessa-Midland	10.8	9759	$2.35

1.00 Water Demands and Supply

The state's regional water planning process was initiated by Senate Bill 1 in 1997. As part of this process, the state of Texas was divided into 16 different planning regions, each responsible for developing a regional water plan. The cities of Big Spring, Odessa, Midland and Snyder are included in the Region F Regional Water Plan.

The share of water demands met by groundwater and surface water has changed over time. Reliance on groundwater is facing serious limitations in West Texas because of water quality problems. The city of Midland and other cities in the state have been switching to surface water because of the increasing salinity and declining quality and quantity of groundwater sources.

The passage of Senate Bill 1 (SB 1) reconfirmed that existing water rights holders who take water out of a reservoir or stream can use and reuse up to 100 percent of the water prior to its discharge to the stream, providing there is no return-flow requirement in the permitted water right itself. Once water is used and is discharged to a waterway, it becomes property of the state. Any water rights holders who wish to divert their water for reuse after it has been discharged must obtain authorization from the TCEQ through a "bed and banks" permit. Under SB 1, this type of indirect reuse might require that some surplus water be returned to the river or stream to protect senior downstream water users and environmental needs. In addition, SB 1 allows the TCEQ to condition new or amended water rights to provide for return flows, potentially limiting the direct reuse of wastewater as well. The diverter may also lose some of the flow to evaporation and other channel losses as the water is delivered downstream.

1.01 Projected Demands

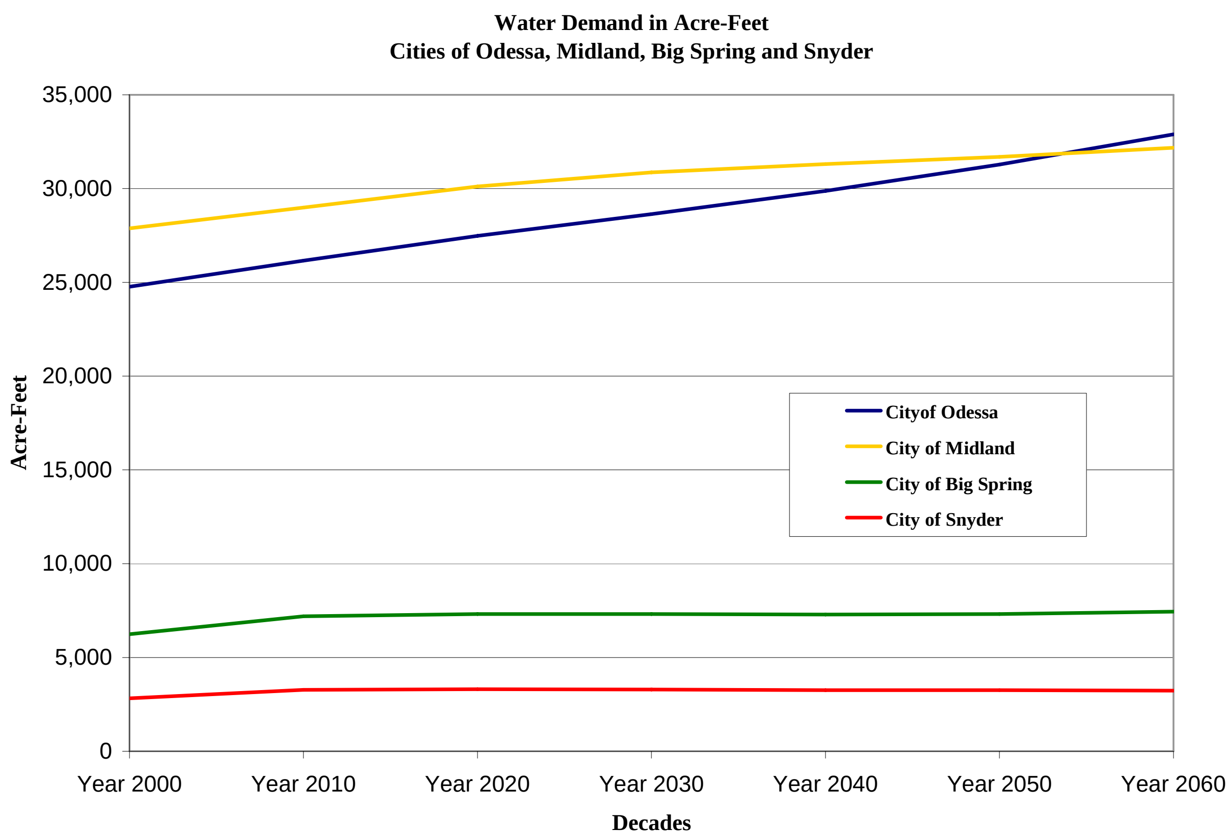
Currently, the regional planning groups are involved in the second phase of water planning, with the next statewide water plan due in 2006. The projected water demands for the Cities of Odessa, Midland, Big Spring and Snyder, include the most updated information available.

The water demand projections (*2006 Region F Water Plan*) for the Cities of Odessa, Midland, Big Spring and Snyder for the year 2010 and the following decades until 2060 are included in **Table 1.1** and shown in **Figure 1.1.** Water demand projections include reductions due to anticipated water conservation through implementation of the state plumbing code. These reductions result in a total demand decline for Big Spring and Snyder.

Table 1.1 Demand Projections (Acre-feet/year) for Odessa, Midland, Big Spring and Snyder

Entity	Year 2000	Year 2010	Year 2020	Year 2030	Year 2040	Year 2050	Year 2060
City of Midland	27,879	28,939	30,056	30,804	31,246	31,631	32,112
Midland Sales		49	52	55	58	60	63
City of Odessa	21,189	21,927	22,687	23,350	24,145	25,222	26,484
Odessa Sales	3,579	4,223	4,793	5,284	5,721	6,063	6,403
City of Big Spring	5,596	6,016	6,077	6,035	5,945	5,915	5,915
Big Spring Sales	645	1,172	1,237	1,282	1,341	1,404	1,527
City of Snyder	2,343	2,792	2,834	2,844	2,829	2,832	2,832
Snyder Sales	484	478	471	449	431	422	403

Figure 1.1 Demand Projections for Targeted Cities in Region F Planning Group.



1.02 Existing Supplies

The City of Odessa receives most of its water from the District's surface water supplies on the Colorado River. CRMWD supplies the City of Odessa with surface water from the O.H. Ivie Reservoir, E.V. Spence Reservoir and Lake J.B. Thomas, through Terminal Reservoir located approximately 11 miles east of the City. The City also receives groundwater from two well fields operated by CRMWD. Ward County Well Field and the Odessa Wells supplement the City with groundwater during the summer months. An additional well field in Martin County is also available to supplement other CRMWD supplies in the Odessa area.

The City of Midland currently obtains water from CRMWD and the Paul Davis Well Field in Martin and Andrews Counties. Additional groundwater is available from the City's McMillen Well Field northwest of Midland, but the city no longer uses this source due to water quality issues, including arsenic and perchlorate. CRMWD supplies water to the City of Midland through Terminal Reservoir that stores surface water from all three major reservoirs they operate. According to the Senate Bill 1 Report for Region F (Freese and Nichols, 2001), the City of Midland will begin to experience a need for water starting 2029 with the expiration of one of the city's two contracts with CRMWD. The City primarily provides water to its municipal customers and a small amount of water to industrial customers.

The City of Snyder obtains its surface water primarily through a 27-inch pipeline from Lake J.B. Thomas. The city also can receive 1 MGD of groundwater from the Snyder Wells. These wells are operated by the District and are scattered throughout the city. The Snyder wells are operated as an emergency reserve.

The City of Big Spring receives its surface water primarily from E.V. Spence Reservoir and Lake J.B. Thomas. The City also receives groundwater from the Martin County Well Field to supplement the water supply during the summer months.

1.03 Potential Sources

Several sources have been identified which may provide significant additional supply to CRMWD or its major customers. Five of these are described below; all have significant development costs and/or obstacles. Other additional sources are available, but have less potential impact on regional water supplies.

A. Reclamation

The passage of Senate Bill 1 reconfirmed that existing water rights holders who take water out of a reservoir or stream can use and reuse up to 100 % of the water prior to its discharge to the stream, providing there is no return-flow requirement in the permitted water right itself. Once water is used and discharged to a stream, it becomes property of the state.

Wastewater collected by medium and large cities in the region represents a significant drought proof source of water. With appropriate treatment, this water can be used for agricultural or landscape irrigation, industrial uses or municipal water supply. The focus of this report is to explore the probable cost and feasibility of reclaiming municipal wastewater effluent to supplement municipal potable water supplies.

B. Lake Alan Henry

Lake Alan Henry is an 115,937 acre-foot reservoir on the Double Mountain Fork of the Brazos River. The reservoir is located southeast of the city of Post in Garza and Kent Counties. It was developed for water supply by the city of Lubbock and the Brazos River Authority. Permit 4146 authorizes use of 35,000 acre-feet per year for municipal purposes from the reservoir. Currently there is no water use from the reservoir, although a small portion of the supply may be used locally in the near future. According to the 2001 Llano Estacado Regional Water Plan, the City of Lubbock has sufficient supplies from other sources to meet its future needs, so all or part of Lake Alan Henry's yield may be available as a supply to the District [reference – Llano Estacado Regional Water Planning Group: Llano Estacado Regional Water Planning Area Regional Water Plan, prepared for the Texas Water Development Board, December 2001]. The reservoir is approximately 25 miles from the city of Snyder and 35 miles from Lake Thomas.

There are several issues associated with developing Lake Alan Henry as a source for the District:

1) Uncertainty regarding the reliable supply from the reservoir. The 2001 Llano Estacado Regional Water Plan assumed that the yield of Lake Alan Henry was approximately 29,900 acre-feet per year. However, according to the TCEQ Brazos Water Availability Model (WAM) report, the yield of the reservoir is estimated to be 9,595 acre-feet per year [reference - HDR Engineering, Inc.: Water Availability in the Brazos River Basin and the San Jacinto-Brazos Coastal Basin, prepared for the Texas Natural Resource Conservation Commission (now TCEQ), December 2001]. A large part of the discrepancy in yield may be attributed to the model theoretically passing water downstream to meet senior water rights. Some form of subordination agreement would be necessary to enhance the yield of the project. Also, there is uncertainty regarding the yield of the reservoir based on recent drought conditions throughout the area.
2) Need for an interbasin transfer authorization for use by the District. Lake Alan Henry is located in the Brazos Basin. Use of water from this source by the District would require an interbasin transfer authorization. Under current Texas law, use of water from Lake Alan Henry would be junior in priority to all other water rights in the Brazos Basin, potentially negating any subordination agreements that might increase the yield of the reservoir.
3) Uncertainty regarding availability of the reservoir. It is uncertain whether the City of Lubbock and the Brazos River Authority would be interested in a permanent transfer of water rights to the District. Because of the substantial

investment in infrastructure to supply water to the District system, a long-term agreement would be required.

4) Elevation difference. Water must be lifted about 500 feet from the Brazos basin into the Colorado basin to be used in the District's service area. This lift will require significant pumping energy, in addition to the friction losses incurred in the required pipeline. This energy will add a significant operating cost to imported water.

C. Midland T-Bar Well Field

The city of Midland has owned an undeveloped well field, known as the T-Bar Well Field, since 1965. The well field consists of approximately 20,230 acres located in northwestern Winkler County and northeastern Loving County. Previous studies for the city indicate that the well field could produce 13,400 acre-feet per year for a period of 60 years. The well field is approximately 70 miles from the city of Midland [reference: Freese and Nichols, Inc. et al.: Region F Regional Water Plan, prepared for the Region F Regional Water Planning Group, January 2001].

Although the city of Midland is a District customer, the city has its own groundwater supplies which it uses to supplement water purchased from the District. The city of Midland plans to develop the T-Bar well field when the city's existing Paul Davis well field in Martin and Andrews Counties is exhausted. Winkler County has a significant amount of undeveloped groundwater resources including the District's five sections of land south of Wink which could be used to supplement supplies from the T-Bar Well Field. Further studies will be required to evaluate the potential for groundwater development in the area.

D. Hovey Trough Groundwater

The Hovey Trough is a proposed project by a group of investors to develop water supplies from a water-bearing alluvial formation located northwest of the Glass Mountains in western Pecos and eastern Jeff Davis Counties. Preliminary studies indicate that the formation may be able to produce 50,000 to 100,000 acre-feet of water per year. The area is approximately 105 miles from the city of Odessa [reference: Pecos County Groundwater Co-Op Groundwater Marketing presentation. Date and author unknown.]

Although the Hovey Trough may be a promising prospect for future water development, a significant amount of additional studies will be required to quantify the amount of water available on a sustainable basis. There is also some concern expressed by the project developers regarding potential impacts on base flows in the Pecos River. Also, water from this source could be expensive due to the long distance it would have to be pumped to reach the District's member and customer cities.

E. Roberts Co. Groundwater

The Panhandle Water Project is a well field and pipeline project proposed by Mesa Water, Inc. The well field would produce water from the Ogallala aquifer in Hemphill, Lipscomb, Ochiltree and Roberts Counties in the Texas Panhandle. Studies performed for Mesa Water indicate that the area could produce between 150,000 and 200,000 acre-feet of water per year. Water reserves exceed projected demands in the four-county area by about 30 million acre-feet. Transportation of the water from the project to the city of Midland would require construction of a 344-mile pipeline.[1]

Developing water from this source would require a substantial investment in a very long pipeline project. The yield of the project exceeds the potential needs of the District. However, because of the large quantity of water available, there is a potential for this to be a viable project for the District if other entities participate in the project. At this time no other potential entity has been identified to participate in a project with the District.

1.04 Drought Impacts

District reservoirs remain in the grip of a severe drought. Despite significant rains over the last couple of years, Lake J.B. Thomas has a supply approximately 31% of its storage capacity, E.V. Spence Reservoir currently has only 15% of its storage capacity and the District's O.H. Ivie Reservoir has a stored supply approximately 42% of its capacity. The District’s main water supply reservoirs are significantly under their designed storage capacity.

An important consideration in evaluating new supplies is the susceptibility of the proposed supplies to drought. The Alan Henry Reservoir, as a surface water supply, will be subject to similar drought pressures to the District’s reservoirs. Its location in a separate river basin may lessen the risk of simultaneous shortage during limited drought conditions. However, for widespread events such as the current drought affecting the entire Southwestern United States, location in an adjacent basin offers little drought protection.

Groundwater sources such as the Midland T-Bar field, the Hovey Trough and Roberts County groundwater, may offer somewhat greater insulation from drought conditions, depending on the volume of water stored in the aquifer and how dependent it is on recharge from surface sources. However, drought conditions tend to put greater pressure on groundwater supplies due to higher irrigation requirements and limits on surface sources. Typically, the Ogallala Aquifer which supplies water to much of the Texas Panhandle, including the Roberts County fields and the northern part of Region F, consists of vast deposits of water which have minimal recharge from surface runoff. These aquifers will not be greatly affected by drought, except that increased usage will

[1] Mesa Water Inc.: Water Supply Study, Providing Groundwater from the Texas Panhandle to Communities throughout the State of Texas, 2000. R.W. Hardin & Associates, Inc.: Groundwater Availability Evaluation Hemphill, Lipscomb, Ochiltree, and Roberts Counties, prepared for Mesa Water, Inc., December 2002.

shorten their useful life. There is little consensus regarding the Hovey Trough characteristics, so drought impacts regarding this supply are largely speculative.

Reclaimed water is dependent on the continued collection and treatment of wastewater from residential, commercial and industrial sources. Provided the population remains stable or increases, it can be assumed these sources will remain available regardless of drought conditions, although mineral content can be expected to increase somewhat during drought conditions. Its dependence on human activity rather than weather phenomena cause it to be considered a “drought-proof” or “drought-resistant” supply.

2.00 Indirect Potable Reuse

2.01 Background and Current Status

Population growth, uneven distribution of water resources and periodic droughts have forced water districts and cities to search for innovative sources of water supply. A traditional way of selecting drinking water supplies has been to use the highest quality source available. Over the years, municipal wastewater effluent has been receiving ever-increasing attention as a potential water source as the easier sources of water become less available. Today, reclaimed wastewater reuse is an important element in water resources planning in many parts of the country.

Beneficial reuse applications vary regionally to reflect groundwater recharge, agricultural reuse, and several industrial and recreational applications. Most reuse has been for *non-potable reuse*, the substitution of reclaimed water for dedicated non-potable uses. Agricultural and landscape irrigation is by far the largest use of reclaimed wastewater. The second major use of reclaimed municipal wastewater is in industrial activities, primarily for cooling and process needs. Depending on the quality required, often additional treatment is required beyond conventional secondary wastewater treatment. The third most common reuse application for reclaimed wastewater is groundwater recharge.

In a few cases, highly treated effluent has been intentionally incorporated into a public water supply source, a practice known as *indirect potable reuse*. Notable examples include reservoir blending at the Upper Occoquan Reservoir in Virginia, which supplies water to several suburban cities near Washington, D.C., reservoir blending by the North Texas Municipal Water District in Lake Lavon, and groundwater recharge in El Paso, Texas and Orange County, California. Extensive testing has demonstrated that reclaimed water can meet drinking water standards. These findings have satisfied some experts that reclaimed water is acceptable as a drinking water source. However, other experts disagree, saying that the water is inherently more risky. The City of Wichita Falls currently has a project in development for supplementing its raw water supply with reclaimed water. TCEQ has approved the concept report and has established a classification of reuse as a raw water supply.

Another reality which must be recognized is the prevalence of unplanned potable reuse. This occurs whenever municipal wastewater effluent is discharged to a water body which serves as a public water source. This is a common occurrence, and while it may go unnoticed by the general public, the potential for recirculating human disease agents is the primary basis for modern water disinfection practice.

2.02 Public Health Issues

Public health concerns regarding the use of reclaimed water center on water quality, treatment reliability, and the difficulty of identifying and estimating human exposure to potentially toxic chemicals and microorganisms that may be present. Public health protection is based on identifying potential contaminants and providing a series of barriers to prevent their passage into the finished water supply.

A. Pathogenic Microorganisms

Diseases are caused by a multitude of microorganisms that are broadly classified based on some of their common microbial characteristics. The principal infectious agents that may be present in reclaimed wastewater can be classified in three groups: bacteria, parasites and viruses.

Bacteria compose a large class of microscopic unicellular organism with a size in the range of 0.2 μg and 15 μg and are responsible for numerous water-borne diseases, including cholera, dysentery and salmonellosis. Waterborne viral diseases that are most common are gastroenteritis and hepatitis A. For parasitic diseases the most common are those associated with *Giardia lamblia* and *Cryptosporidium parvum*. Diseases that are spread via water consumption and/or contact can be severe and sometimes crippling.

To some extent, an assessment of possible public health risk can rely on the vast knowledge that has been developed for water supplies using conventional source waters. As noted previously, many of these source waters include varying amounts of treated domestic wastewater.

B. Emerging Contaminants

Some experts say that disinfected wastewater effluent originating from raw municipal treatment plants may create different and often unidentified disinfection byproducts than those found in conventional water supplies. Since only a small percentage of the organic compounds in drinking water have been identified and the effects of only a few have been determined, the health effects of mixtures of two or more of the hundreds of compounds in any reclaimed water used for potable purposes are not easily characterized. Similar concerns may also apply to many other water supplies, which have various sources of contamination aside from municipal and industrial wastewaters. These may include urban and agricultural runoff, atmospheric pollutants, and naturally occurring contaminants such as arsenic and radon.

Continuous improvement in the field of laboratory analysis provides increasing knowledge of the nature and/or identity of the myriad substances which may be found in our water supplies. Some of these substances have legitimate health implications which should be considered in the general context of water treatment practice, but have particular importance in the evaluation and design of systems for treatment of reclaimed water for human consumption. Recent attention has focused on a broad range of chemicals which have been described as endocrine disruptors, personal care products, and/or pharmaceuticals.

The endocrine system is a combination of glands and hormones that affect biological reproduction, growth, and development. Endocrine disruptors are compounds that can block, mimic, stimulate, or inhibit the production of natural hormones, disrupting the endocrine system's ability to function properly. Endocrine disruptors can be natural or synthetic and persist in the environment and can bioaccumulate. Many chemicals, particularly detergents, resins, pesticides and plasticizers, are suspected endocrine disruptors. Some human and livestock drugs are designed to be persistent in order to be effective.

Endocrine disruption is widespread. Pharmaceuticals, personal care products and their metabolites have been found in wastewater treatment plant effluent, surface water, and groundwater samples. Such endocrine disruptors find their way into the environment via wastewater, landfill leachate and agricultural and urban runoff. Exposure to endocrine disruptors can occur through direct contact with pesticides and other chemicals or through ingestion of contaminated water, food or air.

At present, regulatory action in the United States probably will be delayed until more research is done because most existing data on human-made chemicals focuses on cancer risks. Suspect contaminants appear in EPA's National Toxics Rule and in state regulations governing discharges of toxic substances. However, the rule does not specify which contaminants to monitor. Chemicals that are known human endocrine disruptors are dioxin, PCB's, DDT and some other pesticides. These pesticides were banned in the United States due to their carcinogenic effects, not their estrogenic effects.

In addition to endocrine disruption, some pharmaceutical and other chemicals are causing concern for other traits. Antibiotics from medications and from cleaning products are of interest due to the potential to allow widespread exposure and increased tolerance among the target organisms they are designed to attack. Other medications may have other unintended consequences that are not limited to the endocrine system. Another chemical gaining attention as an emerging contaminant is NDMA. This compound, known also as *N*-Nitrosodimethylamine, has long been recognized as toxic to humans, but has recently been identified as a potential by-product from disinfection with chlorine or chloramines.

Research on endocrine disruptor treatment is just beginning. Before the best practicable treatment processes can be determined, researchers first must identify endocrine disruptors, determine their hazardous concentrations, and develop analytical methods for quantifying the dose response of such chemicals.

2.03 Proposed Concept

CRMWD is investigating the feasibility of reclaiming treated wastewater effluent for subsequent use. This report examines the feasibility of providing adequate additional treatment to blend the reclaimed water into the raw water supply system the District operates. The blending could occur in a raw water pipeline or off-channel raw water reservoir. A secondary goal will be to examine the feasibility of taking reclaimed water during periods of low demand (primarily winter) and using ASR to make the water available during periods of high demand (summer). Adequate treatment must achieve specific water quality goals and must provide reliable barriers to chemical and biological contaminants which pose a threat to public health.

2.04 Quality Requirements

A. Regulatory Requirements

Regulatory agencies are faced with the challenge of developing criteria for the safe use of reclaimed water to augment potable water supplies. The regulatory challenge is to ensure that high quality water supplies are maintained regardless of their source.

Representatives of CRMWD, Freese and Nichols, Inc. and Daniel B. Stephens and Associates met with officials of the Texas Commission on Environmental Quality (TCEQ) on October 12, 2004 to discuss the regulatory requirements that will apply to the proposed CRMWD water reclamation project. The Commission's rules for use of reclaimed water do not address its use for supplementing public water supplies. The overriding guidance provided at the October 12 meeting was that the finished water provided to consumers must meet TCEQ's Rules and Regulations for Public Water Systems, contained in Chapter 290 of the Texas Administrative Code. These rules are also known as the primary drinking water standards.

Specific requirements depend on whether reclaimed water is used as a surface supply or is injected or percolated below ground for storage. TCEQ's surface water blending requirement is that the reclaimed water blending with the existing surface water supply must not hinder the finished water producer's capacity to provide water that complies with primary drinking water standards. No limits on blending ratios or treatment techniques were indicated to apply to this project. Groundwater injection requirements stipulate that reclaimed water must be treated to levels that meet or exceed drinking water standards prior to injection.

B. Accepted Practice and Public Acceptance

A multiple-barrier approach to treatment and disinfection is essential to ensure that reclaimed water is as safe and reliable as any other drinking water supply. Removal of pathogenic organisms has historically been the primary focus of sanitary engineering and water reclamation. Viruses and protozoa are more resistant to disinfection than bacteria, therefore an important aspect of water reclamation is the reliability of treatment processes to inactivate resistant organisms.

The uncertainty of emerging contaminants, like endocrine disrupters, pharmaceuticals, pesticides, fuels and additives, and the lack of monitoring capabilities provides an obstacle towards public acceptance. Although regulations have not been identified for some of these contaminants, public opinion will likely dictate inclusion of credible barriers to their passage. Due to the limited history of large-scale potable reuse projects, it is prudent to provide every reasonable precaution against known health threats.

The existing raw water supply contains high Total Dissolved Solids levels that vary from site to site. Regulations allow a reclaimed water stream to blend with the existing water supply only if the quality of the receiving stream is not compromised. Treated reclaimed water should be as good or better than the existing water supply, and a recognizable quality enhancement should improve the public's perception of the project.

3.00 Technology Update

Several developing technologies have potential applications for the reclamation concepts under consideration. These include membrane processes to efficiently remove various contaminants of concern, desalination to improve water quality by reducing dissolved salts, advanced oxidation and the use of natural underground storage to manage timing differences between new supplies and demand.

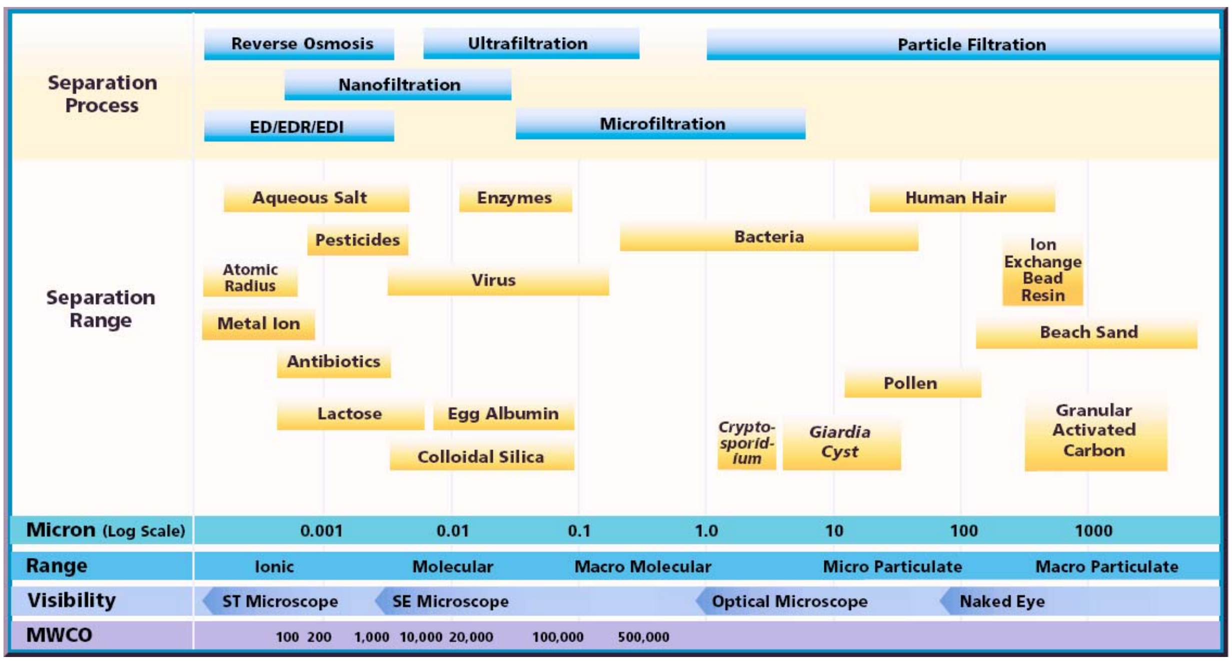
3.01 Membrane Filtration

Membrane filtration is the use of a manufactured surface, normally in the form of a hollow fiber, to separate or remove suspended particles from a liquid. This process is fundamentally different than conventional water treatment techniques and is rapidly changing the water treatment industry. Figure 3.1 illustrates the pore size ranges of various classes of membranes as well as conventional filtration, and shows comparative sizes of various pollutants of interest.

A. Micro-filtration / Ultra-filtration

Micro-filtration (MF) is a pressure-driven membrane process that targets removal of all particulate matter larger than approximately 0.05 μm. MF is an effective barrier to Bacteria, *Giardia* and *Cryptosporidium* and can reduce disinfection requirements by reducing formation of disinfection byproducts. MF provides an effective pretreatment for Nano-filtration (NF) or Reverse Osmosis (RO).

Figure 3.1 Filtration Spectrum



Micro-filters are typically arranged in a hollow-fiber configuration, with pores of about 0.1 to 1.0 μm. Influent water is fed into a vessel that holds the membrane fibers. Treated water is typically collected inside the fibers at one end of the vessel as permeate. The reject will be collected outside the fibers and discharged outside the vessel. Alternatively, in some systems influent is directed inside the fibers and flows out to be collected from the containment vessel.

Ultra-filtration (UF) operates in a smaller filtration range (0.01 to 0.1 μm) and is commonly used for removal of oils, colloids and large molecular weight organics. Micro-filtration and Ultra-filtration differ not only in the particle size removed but also in operating pressure.

B. Membrane Bio-Reactor

A Membrane Bioreactor (MBR) is a wastewater treatment system where membranes replace the secondary clarifier. The MBR process utilizes a micro-filtration or ultra-filtration membrane to perform the liquid/solid separation in an activated sludge process. The membrane is typically submerged in the aeration basin and effluent is drawn through by a vacuum pump. This eliminates the need for a secondary clarifier. The MBR process is more space-efficient than the conventional activated sludge process because of the increased mixed liquor suspended solids (MLSS) concentration in the aeration tank. The high MLSS level allows a larger microorganism population to develop with additional sludge age causing a lower net sludge production and a reduction in potential odor problems.

3.02 Demineralization

Water Demineralization is the removal of salts and dissolved solids from saline water (brackish or seawater). In addition to the removal of minerals, the process removes most biological or organic chemical compounds. Most desalination processes are based on electrodialysis, ion exchange, thermal distillation or membrane separation technologies.

A. Reverse Osmosis

Reverse osmosis consists of separating water from a saline solution by the use of a semi-permeable membrane and hydrostatic pressure. Reverse osmosis is a useful separation method since it permits the passage of water and rejects the passage of most ions and molecules other than water. Reverse osmosis is used to purify water and remove salts and other impurities in order to improve the color, taste or properties of the fluid.

Most reverse osmosis technology uses a process known as crossflow to allow the membrane to continually clean itself. As some of the fluid passes through the membrane the rest continues downstream, sweeping the rejected species away from the membrane. The process of reverse osmosis requires a driving force to push the fluid through the membrane, and the most common force is pressure from a pump. The higher the pressure is, the larger the driving force. As the concentration of the fluid being rejected increases, the driving force required to continue concentrating the fluid increases.

Reverse osmosis is capable of rejecting bacteria, salts, sugars, proteins, particles, dyes, and other constituents that have a molecular weight of greater than 150-250 daltons. The separation of ions with reverse osmosis is aided by charged particles. This means that dissolved ions that carry a charge, such as salts, are more likely to be rejected by the membrane than those that are not charged, such as organics. The larger the charge and the larger the molecule, the more likely it will be removed from the water.

B. Electrodialysis

Electro Dialysis (ED) is a membrane process in which ions are transported through a semi-permeable membrane, under the influence of an electric potential. The membranes are cation or anion-selective, which means that either positive ions or negative ions will flow through. Cation-selective membranes are polyelectrolytes with negatively charged matter, which rejects negatively charged ions and allows positively charged ions to flow through. By placing multiple membranes in a row, which alternately allow positively or negatively charged ions to flow through, the ions can be removed from water.

In some columns concentration of ions will take place and in other columns ions will be removed. The concentrated saltwater flow is circulated until it has reached a value that enables precipitation. At this point the flow is discharged. This technique can be applied to remove ions from water. Particles that do not carry an electrical charge are not removed. Sometimes pre-treatment is necessary before the electrodialysis can take place. Suspended solids with a diameter that exceeds 10 mm need to be removed, or else they will plug the membrane pores. There are also substances that are able to neutralize a membrane, such as large organic anions, colloids, iron oxides and manganese oxide. These disturb the selective effect of the membrane. Pre-treatment methods, which aid the prevention of these effects are active carbon filtration (for organic matter), flocculation (for colloids) and filtration techniques.

C. Other Technology

Technology that has been used for removing salts and minerals from the water include Ion Exchange and Thermal Distillation. These technologies have been used widely in industrial applications and removing a specific contaminant.

Ion exchange is a reversible chemical reaction wherein an ion from a water stream is exchanged for a similarly charged ion attached to an immobile solid particle. These ion exchange particles are either naturally occurring inorganic zeolites or synthetically produced organic resins. The synthetic organic resins are the predominant type used today because their characteristics can be tailored to specific applications.

In a water deionization process, the resins exchange hydrogen ions (H^+) for the positively charged ions (such as nickel. copper, and sodium). and hydroxyl ions (OH^-) for negatively charged sulfates, chromates and chlorides. Because the quantity of H^+ and OH^- ions is balanced, the result of the ion exchange treatment is relatively pure, neutral water. Ion exchange resins are classified as cation exchangers, which have positively charged mobile ions available for exchange, and anion exchangers, whose exchangeable ions are negatively charged. Both anion and cation resins are produced from the same basic organic polymers. Resins can be broadly classified as strong or weak acid cation exchangers or strong or weak base anion exchangers.

Thermal Distillation is the oldest and most commonly used method of desalination. Distillation is a phase separation method where saline water is heated to produce water vapor, which is then condensed to produce freshwater. This distillation process operates on the principle of reducing the vapor pressure of water within the unit to permit boiling to occur at lower temperatures, without the use of additional heat. Distillation units routinely use designs that conserve as much thermal energy as possible by interchanging the heat of condensation and heat of vaporization within the units. The major energy requirement in the distillation process is the heat for vaporization of the feed water.

3.03 Desalination Concentrate Disposal

All desalination processes produce two liquid streams: the desalinated product water and a second stream containing the salts and other contaminants separated from the product water. This stream, referred to as reject, brine or concentrate, is usually difficult to dispose and represents a significant obstacle to most desalination operations. It is still mostly water (98-99.5% by weight) but is unfit for most uses and potential discharge locations. It represents a significant fraction of the original water source (10-35%) and so its disposition is far from trivial, especially for large projects. Typical disposal alternatives are described in the following paragraphs.

A. Evaporation

In a dry area such as the Permian Basin, it is natural to consider evaporation for disposal of unwanted water, and it is a viable alternative for small quantities. Some devices such as mechanical “misters” and mirrors for concentrating solar energy have also been used to enhance natural evaporation. However, for large quantities of concentrate such as those contemplated in this project, the area required for evaporation would be very large. It is assumed that evaporation reservoirs would require a synthetic liner to prevent contamination of shallow groundwater, and periodic dredging would likely be required to remove accumulated solids. It does not appear that evaporation would be feasible as the primary disposal method, although storage reservoirs may be beneficial in managing concentrate disposal, and some beneficial evaporation will occur during storage.

B. Discharge

Historically, most desalination concentrate has been discharged to the ocean, a sanitary sewer system, or to a stream. This is the simplest form of disposal, and is preferable when a suitable discharge location is available. For the proposed Big Spring system, it appears that Beals Creek offers a suitable discharge site. Beals Creek is severely water quality limited by natural mineral deposits in its drainage area, and the District pumps water out of the creek to Red Draw Reservoir to prevent the associated minerals from reaching E.V. Spence Reservoir. It appears the concentrate from the Big Spring reclamation project can be discharged at or near the current Big Spring effluent outfall without significant environmental impacts.

Discharge may also be feasible in Snyder due to the limited quantity of dissolved salts to be removed. However, to manage the salinity in Deep Creek, some effluent would require discharge to blend with the concentrate, thereby limiting the total water yield from the project. Discharge does not appear to be viable for the Odessa-Midland project, due to the lack of a suitable water body in the vicinity. The nearest saline reservoir is Natural Dam Reservoir, which is probably beyond the practical limits for the project.

C. Dedicated Disposal Well

Deep saline aquifers have been used in many locations for disposal of various waste streams, including oil field brines, cooling water blowdown, and desalination concentrate. Where favorable conditions exist, this method is attractive due to its minimal impact on the environment and potentially large capacity to receive liquid wastes. Deep well injection has been the disposal method of choice for oil extraction operations, due to the industry's familiarity with underground operations and a favorable regulatory framework. Unfortunately, this regulatory framework does not extend to the water industry, where permitting injection wells is recognized as a lengthy and expensive process. The flows from large-scale desalination projects are also significantly larger than typical waste flows from oil operations, complicating the transfer of injection experience. There is growing political pressure to grant desalination concentrate wells more favorable permitting conditions, consistent with those in the petroleum industry. If successful, this should make dedicated disposal wells more feasible in the future.

D. Conjunctive Use with Oil Field Operations

A promising variant of disposal wells is the joint use and disposal of concentrate in oil extraction operations. For many years the District has sold brackish or saline water from its diverted water system to petroleum interests for use in oil field flooding operations, which enhance oil well recovery and productivity. Depending on the location, production status, and interest of such operations, this may be a viable disposal alternative, particularly for the Odessa-Midland project. The Texas Water Development Board is providing research to identify opportunities for collaboration between the water and petroleum industries and map/inventory operations which might accommodate concentrate disposal.

E. Zero Liquid Discharge

Technology is also available which can recover additional water from desalination concentrate, increasing the yield from the original source and greatly reducing the volume of waste for disposal. For larger systems, such technology typically consists of a brine concentrator, which distills water from the concentrate stream through a combination of thermal energy and pressure manipulation. If a solid waste output is required, the resulting brine can be further reduced using a crystallizer, which provides additional energy to evaporate sufficient water to form solid salt crystals. These processes have primarily been used for disposal of cooling tower blowdown, but have also been used for desalination concentrate. The equipment is quite expensive and has high energy requirements, so is typically used only where other options do not prove feasible. This option does have the advantage of yielding additional high-purity water. It is unlikely that zero discharge technology will be attractive for this project, but it does establish an upper limit on disposal costs, since it can be placed almost anywhere if sufficient energy is available.

3.04 Ultraviolet Disinfection/Advanced Oxidation

Reclaimed water disinfection is necessary to reduce transmission of infectious diseases and ultimately safeguard public health. Disinfection is also practiced to protect water quality for subsequent downstream use. Sunlight is a natural disinfectant, principally acting as a desiccant. Irradiation by ultraviolet light intensifies disinfection and makes it a manageable undertaking. The primary mechanism of UV light in inactivating microorganisms is direct damage of the cellular nucleic acids.

Disinfection in water reduces the number of disease-causing microorganisms in discharges from wastewater treatment plants and minimizes their dissemination in the receiving water. Disinfection can be accomplished by the use of oxidizing chemicals such as chlorine, bromine, iodine, ozone, potassium permanganate, hydrogen peroxide, and chlorine dioxide. These chemicals can facilitate disinfection if organisms in water or wastewater are exposed to the proper dosage for the appropriate contact time.

Chlorine is widely used for the oxidation of taste and odor chemicals but itself can produce disinfection by-products such as THM's and HAA's. Ozonation can also be used but is expensive, complex to operate and can form bromate.

The use of UV light and hydrogen peroxide can be used to oxidize a wide variety of contaminants found in wastewater. This technology requires the photolysis of hydrogen peroxide with UV light to generate hydroxyl radicals, one of the most powerful oxidants known. These hydroxyl radicals react rapidly with organic constituents in water and break them down in many cases to their elemental form.

UV oxidation benefits include taste and odor control, microbial disinfection and *Cryptosporidia* and *Giardia* disinfection. The process will treat many other dissolved organic compounds present in water, including certain endocrine disruptors, NDMA, pesticides and many algal toxins.

3.05 Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is the process of storing water by injection into a well (or well field) during times when water is available, and recovering the water from the same well during times when it is needed. The water is stored underground in water-bearing formations (aquifers) that may be in sand, sandstone, gravel, limestone, or dolomite. Depending on the water source, the injected water is usually treated prior to injection.

The stored water displaces the water naturally present in the aquifer, creating a large bubble of injected water around the well. The injected water is sometimes confined by overlying and underlying geological formations that are very tight and do not produce water. Sometimes the water is injected into an unconfined aquifer where the top of the native water is restrained only by gravity; however, the injected water will still tend to go in as a bubble, either sitting on top of or contained within the native water, depending on where it is injected. Water recovered from storage usually requires only disinfection before being sent out to the water distribution system.

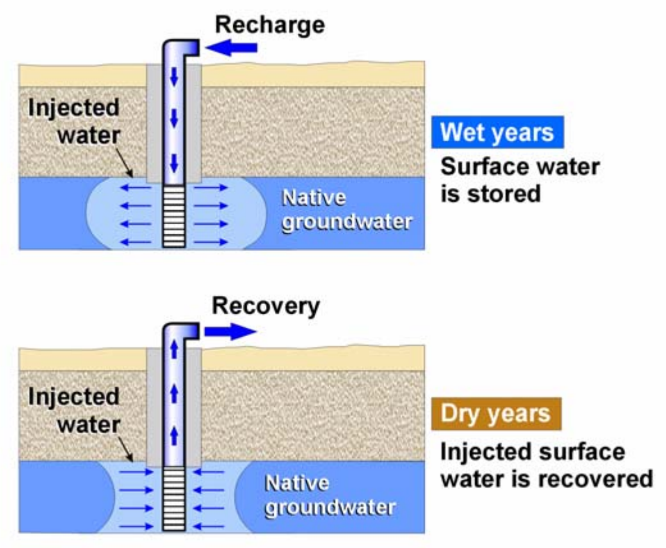
ASR systems can sometimes meet water storage needs at less cost than other supply alternatives, are protected from the evaporation losses that occur with surface storage in reservoirs, and are considered environmentally friendly. Other advantages of ASR systems are that they are reliable water supplies during emergencies, like floods, earthquakes, contamination incidents, pipeline breaks, or potential sabotage. In some cases, ASR can be used to lower net withdrawal rates or even to achieve long-term equilibrium within an aquifer by injecting water when extra water is available from another source, often in the winter when irrigation demands are lower, and withdrawing water during drought periods or to meet summertime peak demands.

Other methods of surface artificial recharge include the following:

- Surface recharge (spreading) basins have been used for many years as a simple way to replenish shallow groundwater systems and to dispose of sewage effluent or stormwater runoff.
- Recharge trenches are shallow trenches dug through top soils to allow direct percolation into the underlying shallow aquifers.
- Dry wells are drilled wells that penetrate caliche or other near surface impermeable layers but do not go all the way to the groundwater table.

These artificial recharge methods are sometimes more economical than ASR, but only work well when there are no impervious layers or sources of contamination that cannot be economically penetrated by the recharge system.

Figure 3.2 ASR concept (example for a confined aquifer)



A. ASR Projects in Texas

There are currently three ASR facilities/projects in Texas: San Antonio, El Paso, and Kerrville. Each of these ASR projects has unique characteristics.

The City of San Antonio has the largest ASR project in Texas. Water will be pumped from the Edwards aquifer during peak periods of rainfall and stored in the Carrizo aquifer (sand) in south Bexar County. The system currently includes 17 wells that can inject approximately 30 million gallons (92 acre-feet) per day when water is available. The second phase of the ASR program is now underway (with a 2005 completion date); this phase of the program includes an additional 17 wells that are expected to increase injection to 64 million gallons (196 acre-feet) per day. Total underground storage is expected to be approximately 7.5 billion gallons (22,500 acre-feet).

The City of El Paso's ASR program consists of 11 wells that can inject over 5 million gallons (15 acre-feet) per day into the Hueco Bolson (sand) near the El Paso airport. The injected water is tertiary-treated reclaimed wastewater from the Fred Hervey Water Reclamation Plant; operation is permitted by the Texas Council on Environmental Quality (TCEQ) as part of the wastewater effluent discharge permit for the treatment plant. El Paso has also studied use of treated surface water from the Rio Grande as a source for ASR. During wet years, excess Rio Grande water would be pumped to and injected by either artificial recharge or ASR injection wells. Both methods of recharge have been demonstrated in the Hueco Bolson and the Mesilla Bolson (on the other side of the Franklin Mountains). An infiltration basin built to test recharge concepts is still in use for recharge of some of the Fred Hervey effluent. Due to lack of rights to use enough water from the Rio Grande and delays in implementation of plans for water importation, El Paso has not yet been able to implement the full-scale ASR and artificial recharge system originally planned.

The City of Kerrville started its ASR operation in 1996 with one well, and currently operates two wells that inject treated Guadalupe River water into the Sligo/Hosston Formation (sandstone and limestone) within the Lower Trinity aquifer. A third ASR well is being planned. ASR represents a key component of the city's water resources management strategy. Wells have been acidized to maximize yield, and injection/production rates are over 1 million gallons (3 acre-feet) per day.

B. ASR Projects in the United States

There are more than 56 operating ASR sites and more than 1,185 ASR wells in the United States. The three states using the most ASR wells are Florida (more than 500 wells), California (approximately 200 wells), and Nevada (approximately 110 wells). Recovery capacities of these ASR systems range from 0.5 to 100 million gallons per day. Florida has both the largest number of ASR wells and the largest ASR facility. These ASR systems are dominantly in limestones and dolomites. The design and operation of the ASR systems in these states are similar to those operating in Texas.

C. Texas Regulatory Requirements for ASR and Artificial Recharge

When using ASR, it is important to ensure that (1) the quality of water in either the injected supply or the native water already in the aquifer is not degraded, and (2) injection of surface water under a right to divert and make beneficial use of surface waters of the State of Texas does not result in a failure to recover and beneficially use the water. ASR injection wells are regulated under the TCEQ Underground Injection Control (UIC) program. The associated regulations require that water injected into an aquifer that is used or potentially can be used for drinking water meets Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs) prior to injection. These MCLs specify standards for primary contaminants like arsenic or nitrate, which are regulated due to human health concerns, as well as secondary standards for constituents such as total dissolved solids (TDS), chloride, and sulfate, which are regulated for aesthetic or economic reasons. The SDWA is a part of federal law; federal drinking water standards promulgated under the law use the secondary standards as goals. The SDWA requires states with primacy to regulate drinking water, like Texas, to implement their own standards, which must be at least as stringent as the SDWA MCLs. Texas has chosen to make the secondary standards enforceable MCLs.

Technically, all of the contaminants in injected water for which there is an MCL must meet the standard. However, in the CRMWD service area, many of the water sources contain TDS and other secondary contaminants at concentrations above the MCLs. TCEQ routinely gives variances to allow delivery of treated water with exceedances of these secondary MCLs. Under this circumstance, TCEQ staff has indicated that there may be some flexibility to allow injection of water that exceeds secondary MCLs but not the existing water quality in the aquifer or the normal secondary parameter levels in the stored water supply.

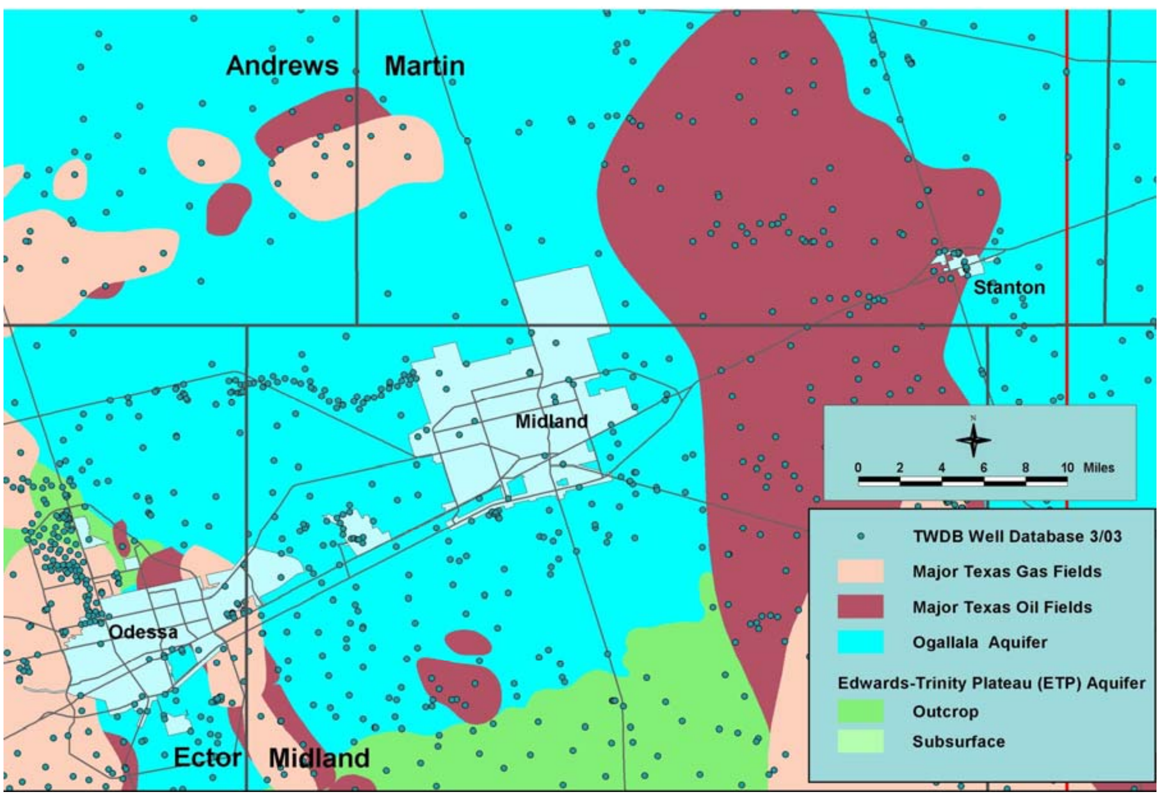
In addition to meeting quality requirements prior to injection, planning and permitting for ASR must ensure chemical compatibility between the injected water and the native water in the aquifer. This determination involves consideration of the geochemistry to ensure that detrimental precipitation or other reactions will not occur.

The ability to recover the injected water is addressed under additional TCEQ requirements for demonstrating control of the injected water. The ability to control the water is demonstrated by ensuring that water will not be lost from the injection zone due to hydrologeological issues or captured by other users of groundwater from the aquifer.

D. General Hydrogeology of the Midland Area

Sediments of the Ogallala Formation are Tertiary in age (2 to 65 million years old) and are a major source of groundwater for the Midland area. The Ogallala is composed primarily of lenses, channels, and layers of sand, gravel, clay, and silt, and is considered to be unconfined (surface water can infiltrate into the aquifer). In the Midland area, Ogallala aquifer wells are generally less than 150 feet deep and water quality is generally fresh (<1,000 mg/L TDS), but may locally be brackish (2,000 to 5,000 mg/L TDS).

Figure 3.3 Aquifers and Oil & Gas Fields in the Vicinity of Midland



Underlying the Ogallala aquifer is the Trinity Group Antlers sand of the Edwards-Trinity Plateau aquifer, of Cretaceous age (150 to 65 million years old). Wells in the Midland area often are drilled through both the Ogallala and Trinity Antlers Sand (less than 200 feet deep). This aquifer is also generally unconfined, is hydraulically connected with the overlying Ogallala aquifer and of similar water quality. The primary aquifer in these counties is the Southern Ogallala, but the sediments thin to the south and often occur above the water table in Ector, Midland, and Glasscock Counties, where the Edwards-Trinity is the predominant aquifer. Within the study area, it is often difficult to differentiate between the groundwater systems that exist within the two aquifers.

Underlying the Edwards-Trinity Plateau aquifer is the Triassic age (250 to 202 million years old) Dockum Group, which consists primarily of interbedded silt and shale. The uppermost portion of the Dockum Group is the low-permeability Chinle shale, which forms the “red beds” encountered beneath much of the Southern High Plains. The Santa Rosa sandstone that occurs beneath the Chinle shale is a widely recognized aquifer, although it generally yields less water than the Ogallala aquifer and water quality is sometimes poor. The Santa Rosa aquifer is confined (water in the aquifer occurs under pressure so the water levels in a well will rise above the top of the aquifer unit) by the overlying Chinle shale. The Santa Rosa aquifer is not being used in Midland County, but Santa Rosa wells do exist in Andrews and Martin Counties. These wells are 1,600 to 1,800 feet deep, with water quality ranging from 2,000 to 4,000 mg/L TDS. These wells are not presently being used for any water supply needs.

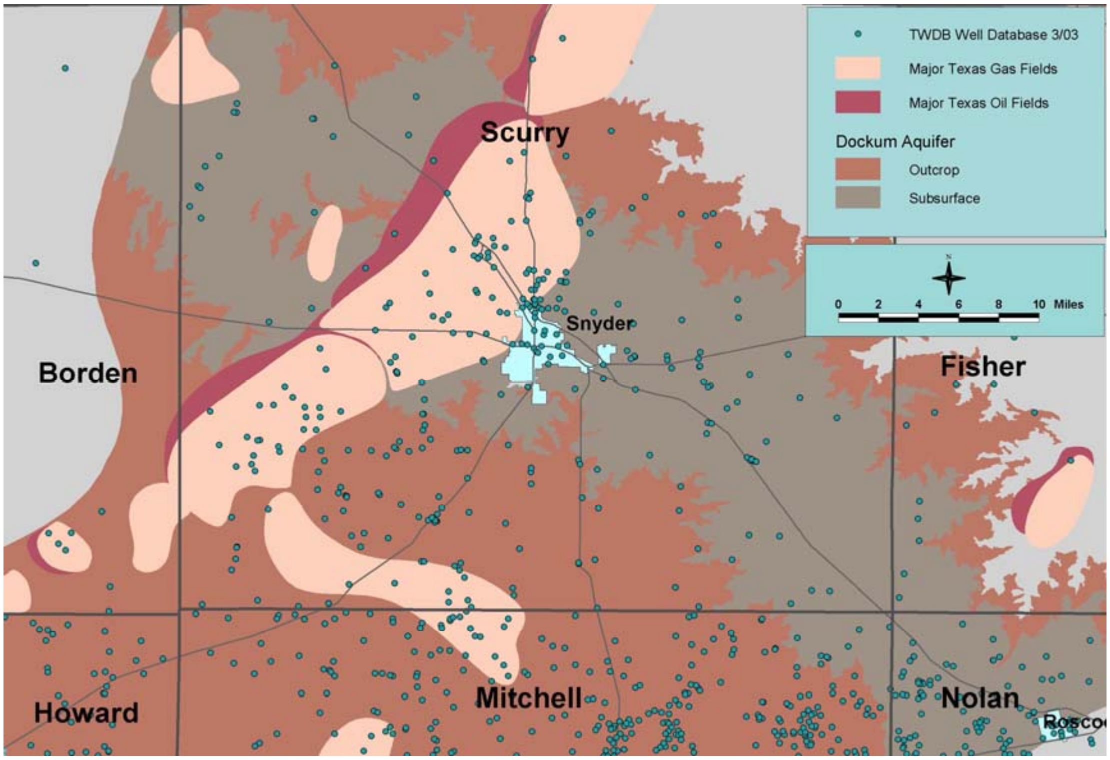
E. General Hydrogeology of the Snyder Area

A thin surface veneer (generally less than 100 feet thick) of the Ogallala Formation covers a north-northwest trending area in the vicinity of the City of Snyder. Very few wells tap the aquifer in this area, possibly because the groundwater has been removed or never existed in significant quantities. Water quality for the wells that do exist is reported to be greater than 1,000 mg/L TDS.

Underlying the Ogallala is the Dockum Group, which includes the Santa Rosa sandstone. The Cretaceous and Jurassic rocks have been completely removed by erosion at this location (Figure 3). The Santa Rosa sandstone forms the major aquifer in the vicinity of the City of Snyder. Dockum wells range from 100 to 800 feet deep in this area, with water quality ranging from less than 1,000 mg/L to 1,800 mg/L TDS

Underlying the Dockum Group is a thick sequence of Permian (290 to 250 million years old) formations (Whitehorse and Blaine) that are generally very poor aquifers and/or have poor water quality.

Figure 3.4 Aquifers and Oil & Gas Fields in the Vicinity of Snyder



F. Recommendations for Screening Midland and Snyder ASR Sites

The ASR potential of the Ogallala Formation and the Antlers sand of the Edwards Trinity Plateau aquifer should be considered for a Midland area ASR. The Ogallala and the Dockum aquifers should be considered for an ASR facility in the vicinity of the City of Snyder.

Characterization of the local hydrogeology is critical in determining the viability of an ASR project. Many geologic and hydrologic factors and other physical conditions should be evaluated, including:

- Aquifer thickness and lateral extent
- Potential storage volume available
- Aquifer storage characteristics (confined or unconfined)
- Depth to water from land surface
- Groundwater flow directions and rates
- Local groundwater pumping history and current pumping volumes and trends
- Historical fluctuations of water levels and groundwater flow directions
- Vertical and lateral variability of the hydraulic properties (hydraulic conductivity and storage coefficient)
- Locations of nearby groundwater and oil and/or gas wells
- Groundwater chemistry

- Aquifer stratigraphy and lithology
- Presence of geological structural features such as faults and folding

This information is important for assessing recovery efficiency of injected or infiltrated water stored in the aquifer, as well as chemical reactions that may occur when injected water mixes with local groundwater. Examples of other considerations include the proximity of potential surface and subsurface contamination sources (oil and gas well fields in Figures 2 and 3), pipeline distance from injection water source to ASR site (construction costs), the size and availability of land tracts necessary to meet ASR storage goals, and previous historical use of promising ASR sites. At this point, no critical flaws are known to exist that would preclude the potential of successful ASR project design for the Midland or Snyder areas.

G. Next Steps

Next steps for evaluating the potential for successful ASR at the Midland and Snyder sites include the following:

- Conduct a detailed review of existing geologic, hydrogeologic, and water quality data in the vicinity of the Midland Airport, the area north of Midland, and the area south of Snyder.
- Identify candidate locations for ASR at each locale.
- Inventory and evaluate existing uses (if any) of the aquifers.
- Recommend appropriate site-specific means of controlling any potential non-CRMWD use of ASR injected water.
- Provide recommendations regarding additional sampling or testing necessary to determine project feasibility.
- Develop a preliminary facility design for both ASR systems to allow storage of surplus reclaimed water and subsequent retrieval when needed.
- Develop an implementation plan for ASR demonstration projects at each site, including required testing and permitting.

4.00 Potential Effluent Sources

4.01 Big Spring

Big Spring Wastewater Treatment Plant facility is rated by TCEQ to treat up to 3.8 MGD with an average flow of 2.5 MGD. The wastewater flows into a single bed rock media trickling filter and then is pumped to the aeration basin. After the wastewater has gone through the aeration basin it flows into the final clarifier. The City of Big Spring Wastewater Treatment Plant discharges secondary effluent to Beals Creek under TCEQ permit number 10069-001. The City's effluent quality is shown in **Table 4.1.**

Table 4.1 Big Spring WWTP effluent quality.

Constituent	Concentration (mg/l)	Constituent	Concentration (mg/l)
General Chemistry			
Bicarbonate Alkalinity	130.0	Nitrate	7.60
Chloride	798.0	Sulfate	560.0
Fluoride	0.95	Total Organic Carbon	14.9
Total Metals		**Dissolved Metals**	
Calcium	126.0	Barium	0.160
Magnesium	75.7	Iron	0.150
Potassium	28.6	Manganese	0.197
Sodium	453.0	Silica(SiO_2)	4.94
Silica(SiO_2)	5.0	Strontium	2.07

Currently the City of Big Spring does not have any commitments for reuse of its wastewater effluent. The effluent flow leaving the WWTP is discharged to Beals Creek.

Historical data shows two sets of flow information for the City of Big Spring Sewage Disposal Facility. The first set is from July 1999 to May 2002 and shows an average available flow of 2.66 MGD. The second set of data is from January 2004 to September 2004 and shows and average available effluent of 2.06 MGD. Additional monitoring will be required to determine the average effluent that can be expected to be available for reuse.

The maximum and average flows available from the City of Big Spring Sewage Disposal Facility are shown in **Figure 4.1**.

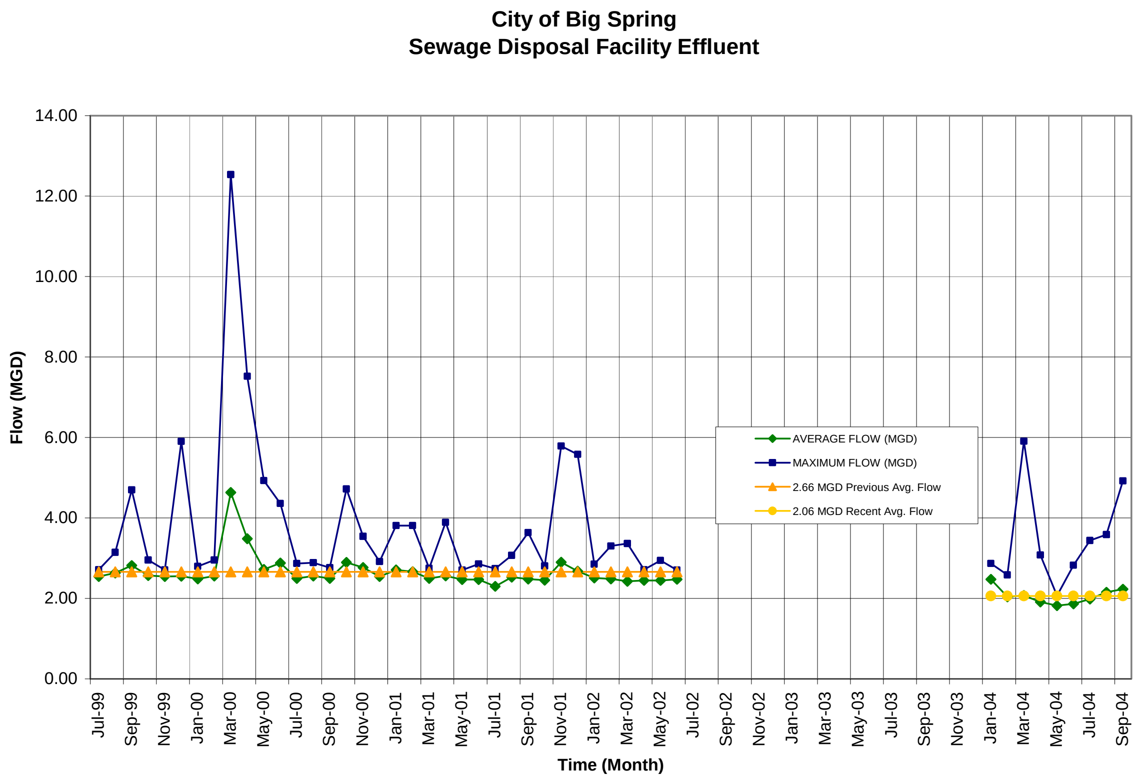


Figure 4.1 Effluent flows from the City of Big Spring Sewage Disposal Facility.

4.02 Odessa (Bob Derrington Plant)

The City of Odessa (Bob Derrington Plant) WWTP is rated by TCEQ to treat an average flow of 11 MGD. The wastewater flows into a carrousel type aeration basin and into a single stage nitrification process. The City of Odessa's Wastewater Treatment Plant discharges to Monahans Draw under TCEQ permit number 0072800.

The City of Odessa currently has commitments for reuse of its reclaimed water. Customers and its usage are shown in **Table 4.2**. Bob Derrington WWTP effluent quality is shown in **Table 4.3.**

Table 4.2 Odessa Reclaimed Water Customers

Customer	Usage	Customer	Usage
Huntsman (Industrial)	3.0 MGD	UTPB Park	unlimited
Odessa Country Club	0.8 MGD	Memorial Garden	unlimited
Ratliff Golf Course	0.8 MGD	Vista La Paz	0.8 MG/week
UT-Permian Basin	0.375 MGD	ODPP (Industrial)	Unlimited
TX Dot	0.130 MGD		

Table 4.3 Odessa WWTP effluent quality.

Constituent	Concentration (mg/l)	Constituent	Concentration (mg/l)
General Chemistry			
Bicarbonate Alkalinity	160.0	Nitrate	ND
Chloride	603.0	Sulfate	432.0
Fluoride	1.17	Total Organic Carbon	14.8
Total Metals		**Dissolved Metals**	
Calcium	118.0	Barium	0.0484
Magnesium	65.4	Iron	0.0374
Potassium	27.9	Manganese	0.0192
Sodium	343.0	Silica(SiO_2)	4.63
Silica(SiO_2)	6.76	Strontium	2.24

Data collected for the City of Odessa's Bob Derrington Wastewater Treatment Plant from August 2002 to July 2004, shows an average available flow of 3.67 MGD. **Figure 4.2** shows the industrial reuse, reclaimed water, total effluent and effluent available for additional reuse from the Bob Derrington Facility.

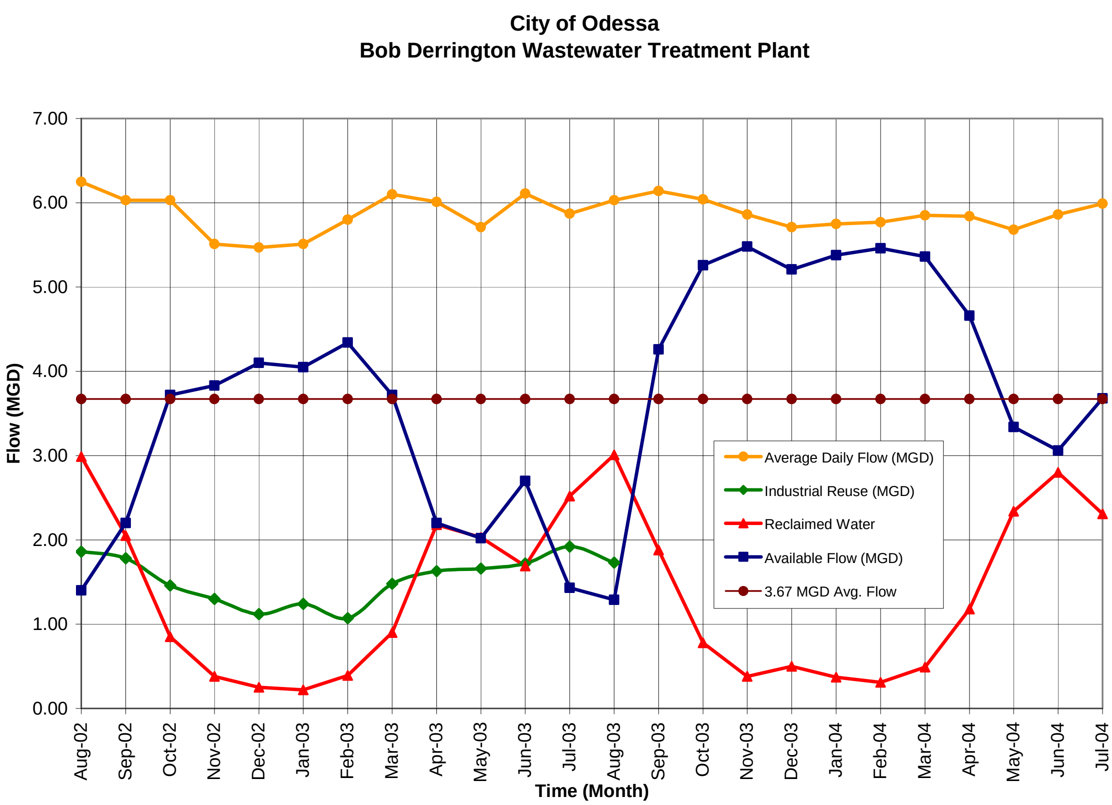


Figure 4.2 Effluent flows from the City of Odessa's Bob Derrington WWTP.

4.03 Snyder

The City of Snyder Wastewater Treatment Plant facility is rated by TCEQ to treat up to 2.31 MGD with an average flow of 1.81 MGD. The wastewater flows into a headworks facility, a carrousel aeration basin and into a secondary clarifier. The secondary effluent is disinfected with ultraviolet light and is discharged into Deep Creek. The City's Wastewater Treatment Plant discharges its effluent under TCEQ permit number 10056-01.

The City of Snyder currently provides a limited flow of treated effluent to the local college, and some effluent is taken immediately downstream for irrigation of adjacent farmland. The City of Snyder WWTP's effluent quality is shown in **Table 4.4.** The City's total dissolved solids (TDS) and chloride concentration in the plant's effluent are currently under the State Standards for drinking water.

Data collected for the City of Snyder Water Reclamation Plant from February 2003 to December 2004, shows an average available flow of 1.00 MGD. **Figure 4.3** shows the average daily flow and the maximum daily flow of 2.402 MGD during the month of November 2004.

Table 4.4 Snyder WWTP effluent quality.

Constituent	Concentration (mg/l)	Constituent	Concentration (mg/l)
General Chemistry			
Total Alkalinity	150.0	Nitrate	3.50
Chloride	142.0	Sulfate	100.0
Fluoride	1.57	Total Organic Carbon	7.25
Total Metals		**Dissolved Metals**	
Calcium	40.0	Barium	0.0465
Magnesium	13.8	Iron	0.0393
Potassium	15.7	Manganese	ND
Sodium	116.0	Silica(SiO_2)	3.73
Silica(SiO_2)	4.86	Strontium	0.791

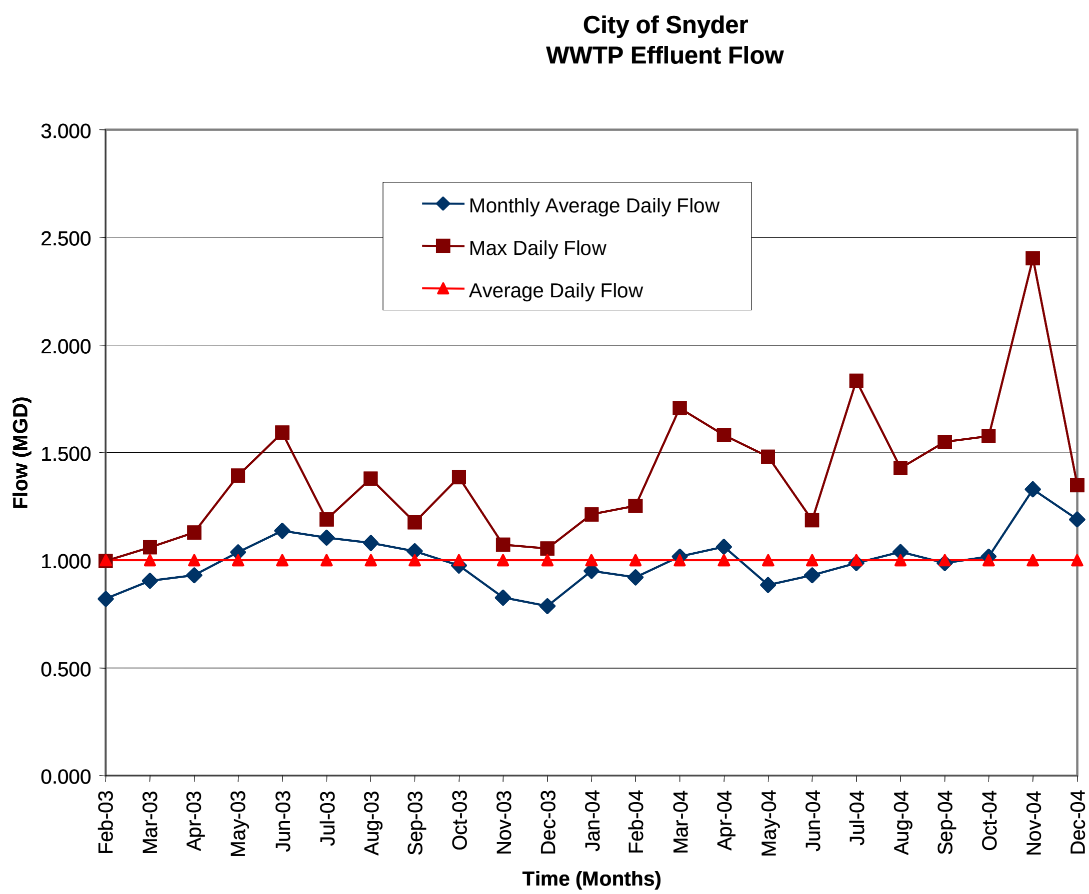


Figure 4.3 Effluent flows from the City of Snyder Water Reclamation Plant.

4.04 Midland

The City of Midland Wastewater Treatment Plant has been rated by TCEQ to treat up to 21 MGD with an average flow of approximately 11.52 MGD. The plant uses a rotary screen unit to remove rags, trash and other solids. Wastewater flows into three (3) primary clarifiers located east of the grit chambers. A portion of the flow from the primary effluent is diverted into two trains with mechanical aeration basins for secondary treatment. A blend of the primary effluent and the secondary treatment overflows into the Spraberry Pump Station wet well and then is pumped to the upset ponds, and to Spraberry Farms located southeast of the WWTP.

The City of Midland does not have a discharge permit and has no commitment for reuse of its wastewater effluent. Currently the City delivers its partially treated effluent to Spraberry farm to be used for irrigation purposes. One hundred percent of the treated effluent is irrigated. The City's effluent quality is shown in **Table 4.5.**

Table 4.5 Midland WWTP effluent quality.

Constituent	Concentration (mg/l)	Constituent	Concentration (mg/l)
General Chemistry			
Total Alkalinity	254.0	Nitrate	1.80
Chloride	656.0	Sulfate	511.0
Fluoride	1.34	Total Organic Carbon	37.25
Total Metals		**Dissolved Metals**	
Calcium	150.0	Barium	0.129
Magnesium	81.0	Iron	0.117
Potassium	25.0	Manganese	0.015
Sodium	372.0	Silica(SiO_2)	11.8
Silica(SiO_2)	12.0	Strontium	3.90

Historical data from the City of Midland's Water Pollution Control Plant from January 2002 to July 2004, shows an average available flow of 11.52 MGD. **Figure 4.4** shows the maximum, minimum and average flow available for additional treatment from the Water Pollution Control Plant.

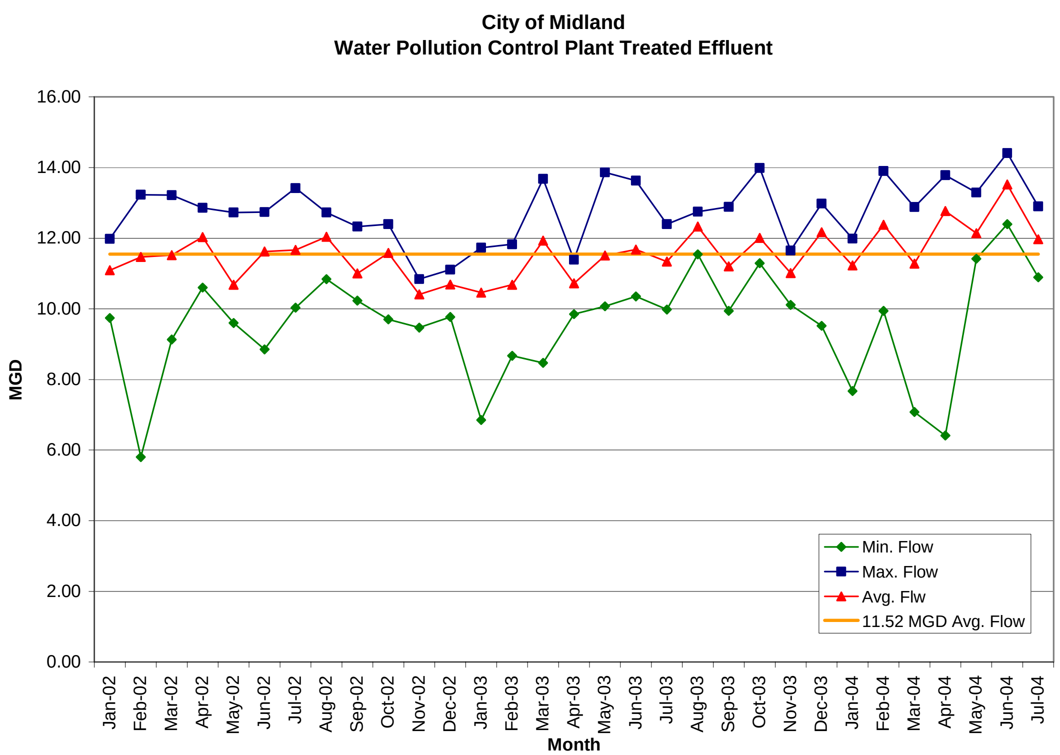


Figure 4.4 Effluent flows from the City of Midland's Water Pollution Control Plant.

4.05 Alon Refinery (Big Spring)

ALON USA Refinery Wastewater Treatment Plant has a maximum permitted daily flow of 2.0 MGD with an average daily flow of 1.22 MGD. ALON USA wastewater is a combination of desalination concentrate, process sewers, storm water, scaltech effluent, and cooling tower blowdown. The wastewater flows into two equalization tanks in series and then into the aeration basin. The wastewater enters the clarifier from the bottom of the inlet column. Clarified effluent is routed to the sand filters to remove some of the remaining TSS and COD. Treated wastewater could be sent to the refinery lake or to the water flood holding basin. This water from the flood holding basin can be sent to the Westbrook water flood outfall, the Otis Chalk water flood outfall or to the Red Draw reservoir outfall.

4.06 Gulf Coast Waste Disposal Authority (Odessa)

Gulf Coast Waste Disposal Authority GCWDA is a regional wastewater treatment facility located south of the City of Odessa. The WWTP treats a portion of Odessa's municipal wastewater, South Grand View and wastewater from other industrial users. The treatment process is an aeration basin followed by a final clarifier and a sand filter. The plant is a Publicly Owned Treatment Works (POTW) and has a discharge permit to release its effluent to Monahans Draw under TCEQ permit number 03776 issued October 30, 2001.

5.00 Proposed Projects

Three projects are proposed to reclaim treated effluent and use it to supplement raw water supplies available to the District and its members and customers. They are at the City of Big Spring, the City of Snyder and a combined facility located between the Cities of Odessa and Midland. Although water quality varies between each source, a common treatment scheme is proposed to achieve a safe, reliable water supply which will enhance the quality of the resulting blended water. The proposed treatment is discussed in the following section, followed by a description of each proposed project. Preliminary cost estimates for each project are located in **Appendix A.** Costs shown are for construction and operation of the proposed facilities and do not include other cost impacts such as projected savings in raw water transmission costs. These related cost impacts are to be quantified during the preliminary design phase of this study.

5.01 Proposed Treatment Scheme

Secondary or better effluent will be provided to each reclaimed water treatment facility. The first treatment step will be membrane filtration, using either microfiltration or ultrafiltration membrane modules, which may be constructed in either a pressurized or submerged configuration. This step will remove particles remaining from previous treatment of the wastewater and associated turbidity. Membrane filtration will also remove protozoan cysts such as *Giardia* and *Cryptosporidia*, as well as most bacteria. Membrane filtration also provides excellent pre-treatment for reverse osmosis, which is proposed as the second treatment step.

Reverse osmosis satisfies several treatment objectives. The first is to reduce salinity, which is elevated in the effluent sources above the District's raw water supplies. To provide water which equals the salinity of available raw water, only a portion would require desalination. The rest could bypass the reverse osmosis step and be blended to achieve the desired salinity. However, reverse osmosis also presents the opportunity to remove a wide variety of contaminants with potential health implications such as viruses and most organic molecules, including disinfection byproduct precursors, pesticides, and many pharmaceuticals. By including this step for the entire flow, potential risks from the water's wastewater origins are greatly reduced. The additional reduction in salinity will serve to improve the overall quality of water delivered to customers, and may help in achieving public acceptance and support.

The water quality of the main components involved in the project like the District's reservoirs, WWTP effluents and the anticipated effluent from the proposed reclaim facilities is shown in **Table 5.1**.

Table 5.1 Water Quality Summary Table.

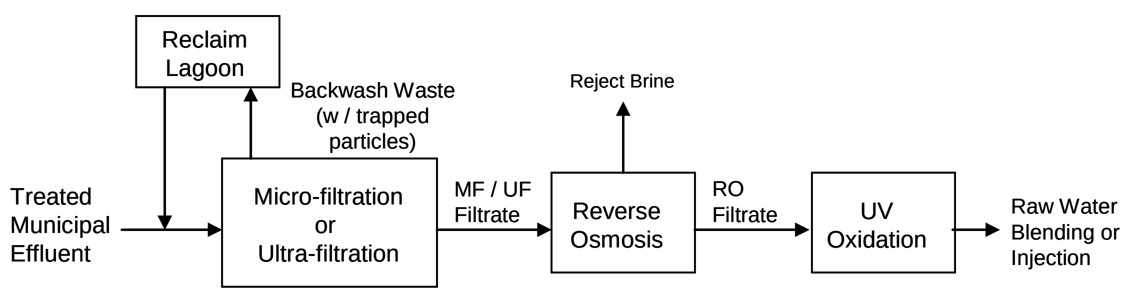
Source	Chloride (mg/L)	TDS (mg/L)	TSS (mg/L)	Conductivity (uhmos/cm)	Hardness (mg/L as CaCO3)	TOC (mg/L)
Big Spring Effluent	798	2257**	15	3671	-	14.9
Big Spring Reclaim	51 *	165 *	-	-	11.7 *	-
Spence Reservoir	575	1548	-	2518	464	-
Snyder Effluent	142	656**	15	1029	-	7.25
Snyder Reclaim	4.5*	37*	-	-	2.6*	-
Thomas Reservoir	73.3	392	-	613	120	-
Odessa Type 2 Effluent	603	1755	15	2854	-	14.8
Midland Effluent	656	2009	20	3268	-	37
Odessa/Midland Reclaim	52*	192*	-	-	20*	-
Ivie Reservoir	440	1352	-	2120	516	-

*Estimated value provided by the equipment manufacturer based on the WWTP effluent characteristics.

**Estimated value based on conductivity.

The final proposed step is UV oxidation. Some type of disinfection is warranted to provide a redundant barrier to any pathogenic organisms which may have breached the membrane treatment barriers. UV disinfection is desirable because it does not form any known undesirable byproducts and will leave no residual to react with raw water after blending. Enhancing the UV process with advanced oxidation provides an effective treatment for several emerging contaminants which can pass RO membranes. This process is relatively inexpensive, and provides benefits not achieved with other components of the wastewater, reclaim or drinking water treatment sequences. **Figure 5.1** shows a schematic of the typical additional treatment proposed for potable reclamation.

Figure 5.1 Typical Additional Treatment Schematic



5.02 Big Spring

The proposed Big Spring Water Reclamation Project would take approximately 2.3 MGD of treated effluent which is currently discharged to Beals Creek and reclaim it for blending into the District's Spence Pipeline which runs along the northeast side of Big Spring. Alon USA could use reclaimed water with little additional treatment for some of their industrial needs. However, some desalinated water would be required to maintain a satisfactory blend of water quality and a dedicated pipeline would be required for the non-potable water to separate it from the water treated for blending with the municipal supply. To treat all water to the desired blending standard results in somewhat higher costs, but provides greater flexibility, since reclamation is independent of Alon's needs or operational practices.

A 0.3 acre pond will be constructed to provide 1 day of storage. The effluent will undergo advanced treatment as described in the previous section prior to blending into the District's raw water pipeline for subsequent distribution and use as a municipal and/or industrial water supply. A new 500,000 gallon concrete ground storage tank will provide 6 hours of storage to the finished water before it is pumped and blended into the Spence Pipeline. A map showing the proposed facilities is included as Exhibit A.

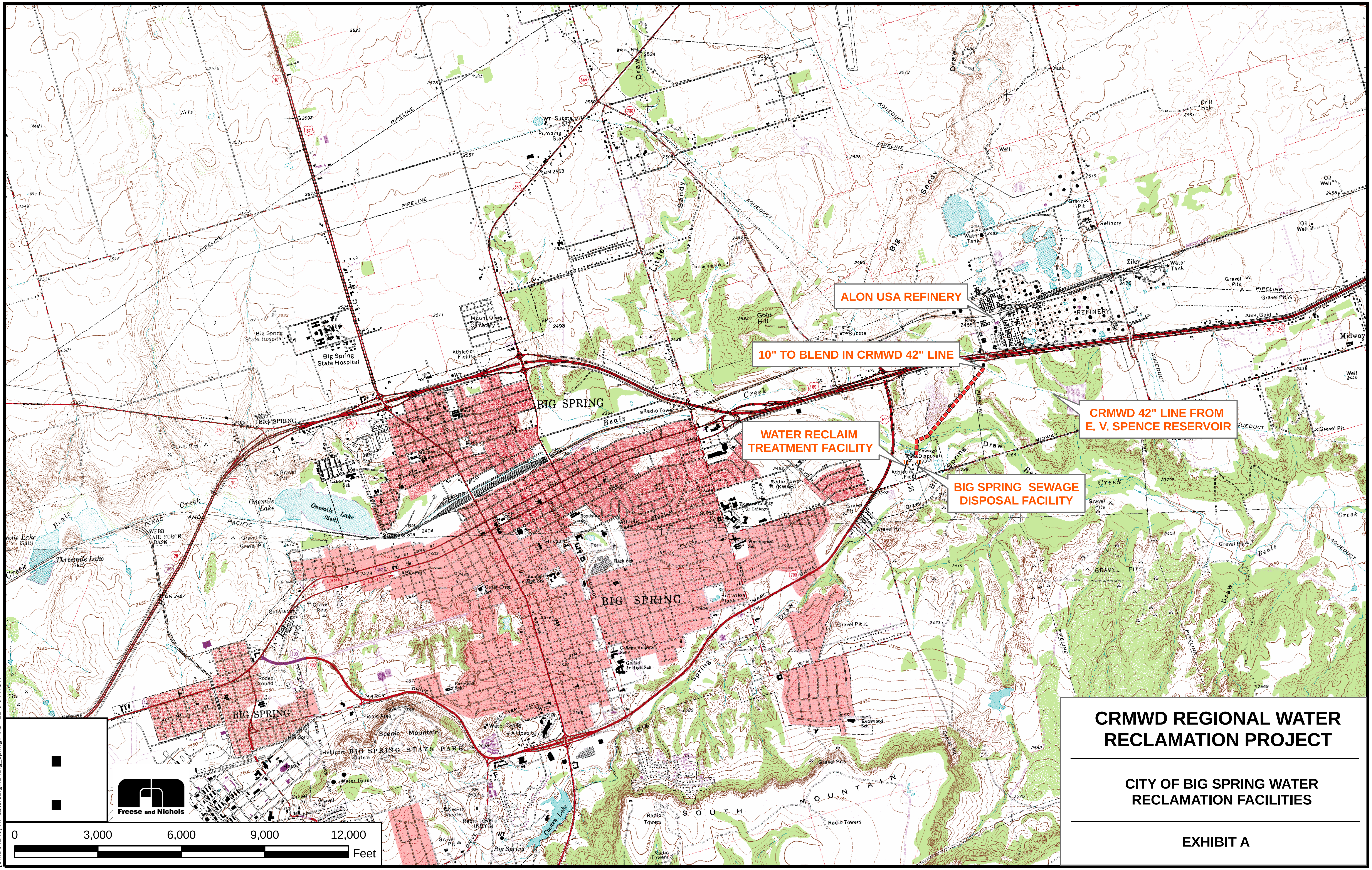
The reject from the low pressure membranes, approximately 230,000 gpd, will be sent to a 0.07 acre lagoon (one day retention) for settling prior to recycle back to the reclaim influent storage pond. Reject from the high pressure membranes will be stored in a 0.15 acre pond before discharge into Beals Creek. The proposed reclaimed water treatment facility will be housed in a 5,000 square foot building.

The total capital cost of the proposed project is estimated to be **$7,723,000**. This cost includes a 25% contingency, a 15% engineering and construction services fee and the construction cost. The estimated annual operation and maintenance cost for the proposed project is **$505,000**. An energy cost of $0.07 per kw-hr was considered and an overall 10% contingency was used.

An estimated cost of $1.67/ 1000 gallons is estimated to deliver treated water to into the E.V. Spence pipeline for reuse. This cost includes transmission from Big Spring WWTP to the proposed Reclaim Facility, advanced treatment and disinfection and transmission into CRMWD's water distribution system.

Table 5.2 Big Spring unit cost per 1000 gallons

Big Spring	
Nominal Available Flow (MGD)	2.3
Reject Flow (MGD)	0.46
Reclaimed Flow (MGD)	1.84
% Utilized (Assumed)	90%
Annual Reclaim Vol. (MG)	604
Estimated Annual Cost	$ 1.01 M
Unit Cost	$ 1.67 /1000 gallons



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5.03 Odessa-Midland

The proposed Odessa-Midland Water Reclamation Project would receive wastewater effluent from the Cities of Odessa and Midland. The city of Odessa currently owns a 24-inch pipeline that runs approximately 10,000 feet from the proposed advanced treatment site. A 12-inch pipeline could deliver 3.5 MGD or more to the Regional Water Reclaim Plant. The City of Midland currently has secondary treatment capabilities of 6 MGD in two trains of 3.0 MGD each. Additional improvements to Midland's WWTP are required to provide additional secondary treatment capacity. This project proposes two additional treatment trains to provide secondary treatment of 5.0 MGD additional for a total secondary capacity of 11 MGD for transfer to the Regional Water Reclamation Facility. Up to 13.5 MGD of treated effluent will be treated at the Regional Water Reclamation Facility, yielding 10.8 MGD of reclaimed water suitable for blending in the District's Terminal Reservoir. CRMWD's reservoir has a capacity of 100 MG and is located approximately half a mile north of the proposed treatment facility. A new pump station and 2.7 MG concrete ground storage tank will provide 6 hours of storage of the reclaimed water at the Regional Facility before it is blended into Terminal Reservoir. A map showing the proposed facilities is included as Exhibit B.

The McMillen well field, an existing well field that is no longer used by the City of Midland, is assumed as a location for aquifer storage and recovery, subject to further investigation. A 14-inch pipeline is included to allow up to 3.0 MGD of reclaimed or blended water to be stored underground for later use. Existing wells, with some modifications, are assumed to be used to inject and extract the water as needed.

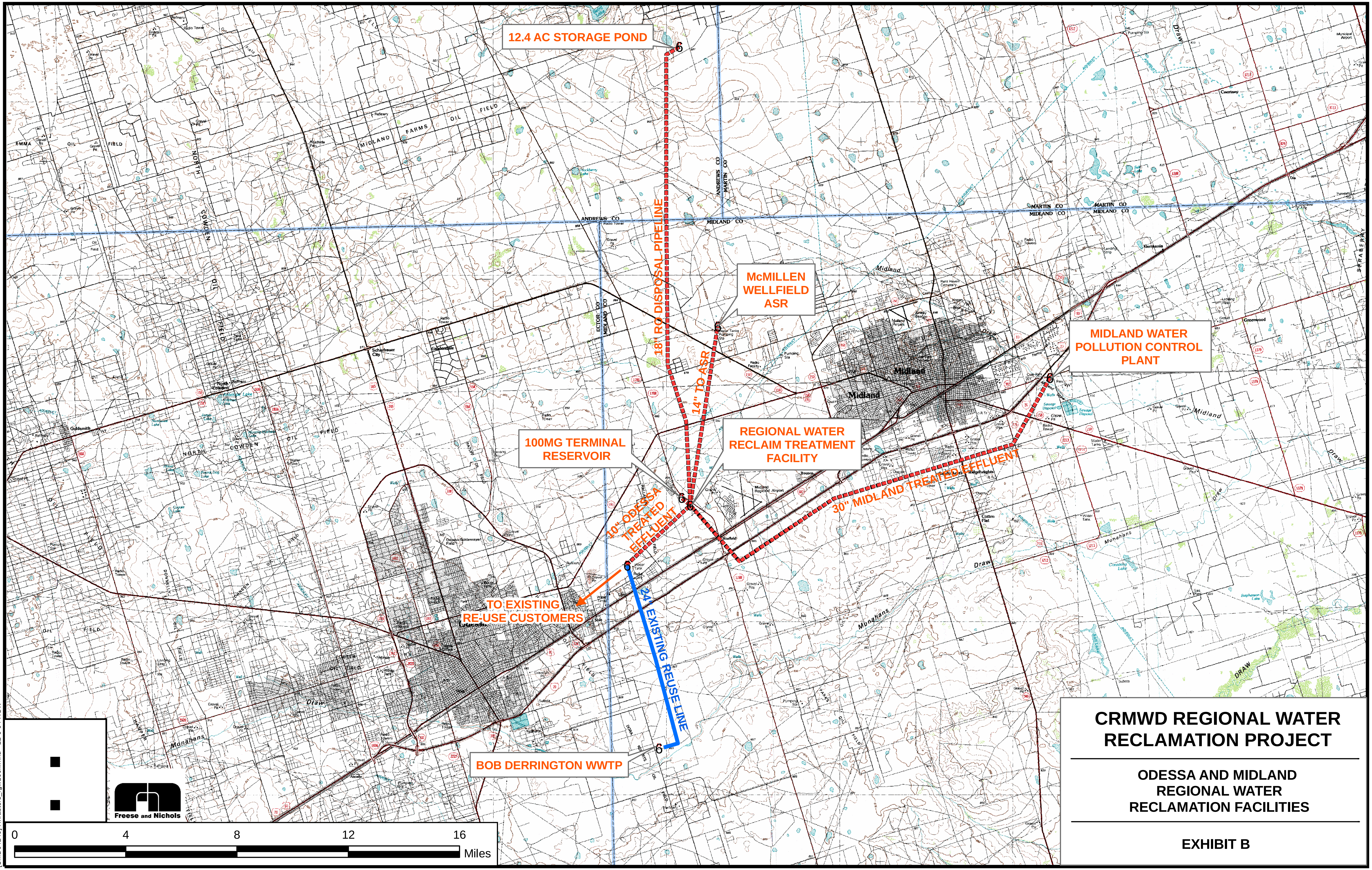
The reject water from the membrane treatment accounts for 4 MGD. The reject from the low pressure membranes, approximately 1.3 MGD, will be directed to a 0.5 acre pond that will provide 1 day of storage. This water will be recycled after settling. Reject from the high pressure membranes will be stored in a 0.8 acre pond before subsequent handling. Four disposal injection wells are also proposed at the treatment site to provide disposal for a portion of the reject flow. The remainder will be pumped to a second 12.4 acre pond located in the Mabee Oil Field. This pond provides 15 days of storage and is located approximately 11 miles northwest of Midland. This reservoir is to facilitate the use of active oil-field operations for use and disposal of the reject brine. The proposed treatment facility will be housed in a 15,000 square foot building.

The total capital cost of the proposed project is estimated at **$73,363,000**. It is worth noting that almost one third of this cost is related to desalination concentrate disposal. The total cost includes a 25% contingency, a 15% engineering and construction services fee and the construction cost. The estimated annual operation and maintenance cost for the proposed project is **$2,702,000**. An energy cost of $0.07 per kw-hr was considered and an overall 10% contingency was used. In addition, the City of Midland's cost to provide additional secondary treatment capacity is estimated at about $10.5 million. Additional operation and maintenance of the expanded secondary system are expected to be more than offset by cost savings from reducing disposal farm operations.

An estimated cost of $2.35/ 1000 gallons is estimated to deliver treated water into Terminal Reservoir for reuse. This cost includes transmission from Odessa's existing reclaimed water system to the proposed Reclaim Facility, transmission from Midland's wastewater treatment plant to the proposed Reclaim Facility, advanced treatment and disinfection and transmission into CRMWD's Terminal Reservoir. This cost also includes the disposal facilities and the allowance for aquifer storage and recovery.

Table 5.3 Odessa/Midland unit cost per 1000 gallons

Odessa/Midland		
Nominal Available Flow (MGD)	Odessa:	3.5
	Midland:	10
	Total:	13.5
Reject Flow (MGD)		2.70
Reclaimed Flow (MGD)		10.80
% Available & Utilized	Odessa:	54%
	Midland:	90%
Annual Reclaim Vol. (MG)	Odessa:	552
	Midland:	2628
	Total:	3180
Estimated Annual Cost		$ 7.47 M
Unit Cost		$ 2.35 / 1000 gallons



CRMWD REGIONAL WATER RECLAMATION PROJECT

ODESSA AND MIDLAND REGIONAL WATER RECLAMATION FACILITIES

EXHIBIT B

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5.04 Snyder

The proposed Snyder Water Reclamation Project would take approximately 0.9 MGD of treated effluent which is currently discharged to Deep Creek and reclaim it for blending into the District's J.B. Thomas Pipeline which enters Snyder from the west. Approximately 0.9 MGD will be available for advanced treatment to allow blending into the District's raw water pipeline for subsequent distribution and use as a municipal water supply. Approximately 0.7 MGD is anticipated to be available after treatment. To minimize fluctuations in raw water quality, it is recommended to blend raw and reclaimed water in the 15 million gallon Snyder terminal storage reservoir along the J.B. Thomas Pipeline. However, the reservoir is several miles west of the city, so a new reservoir is proposed for construction near the Snyder Water Treatment Plant. A new pump station and 180,000 gallon concrete ground storage tank will provide 6 hours of storage to the finished water before it is blended into the District's reservoir. Unlike water from the Spence and Ivie Reservoirs, the current TDS and chloride levels in the raw water delivered from Lake Thomas to the Snyder water treatment plant (WTP) are under state standards. It is anticipated that the water treated at the reclaim facility will have lower TDS and chloride levels, thereby improving the raw water supply. A map showing the proposed facilities is included as Exhibit C.

Aquifer storage and recovery will be considered with this project to balance availability of reclaimed water with timing of water demands. In order to provide an initial estimate of this strategy, an area deemed promising for ASR suitability northeast of Snyder was assumed, and an 8-inch pipeline is shown for transmission of water to and from the ASR site. Two new wells are assumed for injection and extraction of the water.

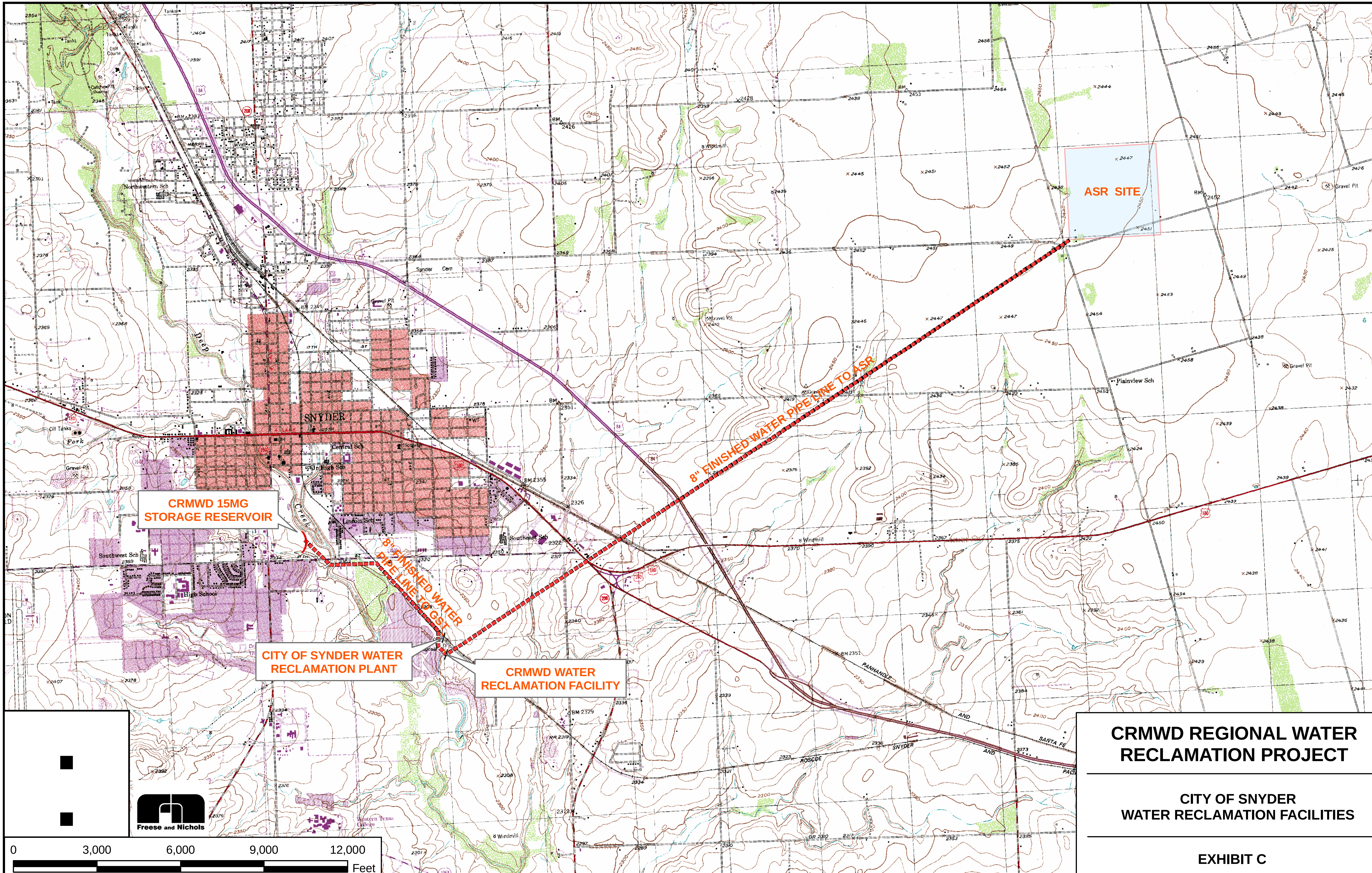
Approximately 100,000 gpd of backwash waste will be discharged from the low pressure membranes. This flow will be directed to a small pond providing a day of storage before this water is recycled back to influent. Reject from the high pressure membranes will be stored in a 0.05 acre pond before it is pumped to the outfall to blend with the wastewater effluent and discharged into Deep Creek. The proposed treatment facility will be housed in a 4,500 square feet building.

The total capital cost of the proposed project is estimated at **$7,622,000**. This cost includes a 25% contingency, a 15% engineering and construction services fee and the construction cost. The estimated annual operation and maintenance cost for the proposed project is **$203,000**. An energy cost of $0.07 per kw-hr was considered and an overall 10% contingency was used.

An estimated cost of $2.95/ 1000 gallons is estimated to deliver treated water to into a proposed 15 MG reservoir in Snyder for reuse. This cost includes transmission from Snyder's WWTP to the proposed Reclaim Facility, advanced treatment and disinfection, the 15 MG reservoir and transmission into the proposed reservoir.

Table 5.4 Snyder unit cost per 1000 gallons

Snyder	
Nominal Available Flow (MGD)	0.90
Reject Flow (MGD)	0.18
Reclaimed Flow (MGD)	0.72
% Available & Utilized	90%
Annual Reclaim Vol. (MG)	237
Estimated Annual Cost	$ 6.99 M
Unit Cost	$ 2.95 / 1000 gallons



CRMWD REGIONAL WATER RECLAMATION PROJECT

CITY OF SNYDER WATER RECLAMATION FACILITIES

EXHIBIT C

6.00 Conclusions and Recommendations

6.01 Feasibility

The use of treated wastewater effluent to supplement the District's existing supply of raw surface water for its municipal and other customers appears feasible. No current or pending regulations appear to unduly restrict this concept. A strict treatment regimen is recommended to provide a water supply which exceeds industry standards and provides reliable barriers to a wide range of contaminants, including pathogenic organisms, minerals and organic compounds, both identified and unidentified. Several projects have successfully demonstrated the augmentation of potable water supplies with reclaimed water; however, this project appears to be unique in its use of a piped raw water delivery system for blending, and will provide limited residence time in exposed storage reservoirs.

Big Spring. The proposed Big Spring project has several advantages which improve its feasibility and cost effectiveness. The key items are its location and access to a viable outlet for disposal of desalination concentrate. The proximity of the City of Big Spring Wastewater Treatment Plant to the District's E.V. Spence pipeline allows blending of reclaimed water and raw water with a minimum of transmission cost. The availability of Beals Creek as a probable brine receiving stream makes this location doubly attractive. Beals Creek currently receives the effluent from the Big Spring plant and is already subject to very high salinity from natural mineral sources. This project appears ideal to demonstrate the overall reclamation concept proposed by the District.

Snyder. The proposed Snyder project appears feasible, but is not as ideally located as the Big Spring project. To provide reclaimed water upstream of the Snyder terminal storage reservoir without excessive pipeline length, a replacement reservoir is proposed, increasing the capital and operating cost of the project. Aquifer storage and recovery may also be feasible. Investigation of nearer locations may allow a reduction in the cost associated with ASR. Yield of the project is also limited if effluent blending is used for concentrate disposal. Potential alternatives include a dedicated disposal well, connection to the District's diverted water system and sale or disposal of the water in the oil field operations west of Snyder.

Odessa-Midland. The obstacles to the Snyder project are magnified for the proposed Odessa-Midland project. Transmission of effluent from both cities to a common treatment facility represents a large cost, both for piping and pumping. The cost for upgrading Midland's treatment works to provide full secondary treatment is also significant, although there would be corresponding savings in abandoning the effluent disposal farms at Spraberry. However, the biggest obstacle to a cost-effective system is disposal of the large stream of desalination brine produced through the reclaimed water treatment. Construction of an adequate network of dedicated disposal wells appears prohibitive; transmission to the Mabee Oil Field for use or disposal will also be expensive, and may have significant operation and maintenance issues as well. An existing oil field east of Midland may represent an alternative disposal site, particularly if the Odessa and Midland projects are separated. Options for recovering water from the concentrate stream, and thereby reducing the volume of waste, will require additional study, but could be important to the feasibility of the project. Alternative configurations should also be considered, including separate treatment for the Odessa and Midland sources and the use of membrane bioreactors at Midland for integrated secondary treatment and membrane filtration. Aquifer storage and recovery will also require additional investigation, and should be considered in the evaluation of alternate project configurations.

6.02 Public Education

Some of the biggest challenges to the successful implementation of potable reuse have been related to public acceptance. Major projects with extensive planning and research have been pursued, most notably in Denver and San Diego, only to stumble in the political arena for lack of public acceptance. These high profile public rejections have spurred new research into how public opinion is formed regarding the concept of water reclamation in general, and especially potable reuse. Some new principles regarding public perception of contamination is already emerging from this ongoing research, and it will be important to consider these insights as the proposed projects mover closer to implementation.

A recent, highly successful public education program by the Orange County Water District in California demonstrates that the public can embrace the concept of potable reuse given the right combination of project circumstances and public involvement and education. OCWD used a very direct approach to educate the public throughout the planning process and achieved a high level of public support. An open public information program is recommended which uses successful elements of the OCWD approach. Hands-on displays, including representative water samples, may be helpful in conveying the transformation of water from wastewater to treated effluent and then to potable reclaimed water.

6.03 Potential Funding Assistance

There are several alternatives for funding assistance for the proposed projects. The Texas Water Development Board (TWDB) provides loans at below market interest rates for wastewater and non point source pollution projects. To apply for this funding, entities need to submit an Intended Use Plan Information Form (SRF-006) and if applicable, the disadvantaged Communities Funding Worksheet (SRF-007). Disadvantaged Community Funds (if applicable) are available at 1% and 0% interest rates. Planning and research funding is also available from the TWDB on a cost-sharing arrangement. The District has applied for a Regional Planning Grant for assistance with the remainder of the current planning effort, and assistance for pilot testing of membrane treatment may be available through a research grant, which typically provides 50% participation from the state.

The Unites States Bureau of Reclamation recently announced (Oct. 26, 2004) its Water 2025 Challenge Grant Program for the Year 2005. The name of the grant is "Water 2025: Preventing Crisis and Conflict in the West". This grant recognizes that state and local governments should have a leading role in meeting these challenges, and that the Department of the Interior should focus its attention and existing resources on areas where scarce federal dollars can provide the greatest benefits to the West and the rest of the nation. The objective of this request for proposal is to invite irrigation and water districts, and other entities with water delivery authority, to leverage their money and resources, in partnership with the Bureau of Reclamation. Emphasis for the "Water 2025 Challenge Grant Program for Fiscal Year 2005" will be directed toward proposals that make more efficient use of existing water supplies through water conservation, efficiency, and water marketing, and that can be completed within 24 months.

The USBR - Desalination Energy Assistance Act of 2004 (Title 16), would have required the Secretary of Energy to make specified incentive payments to the owners or operators of qualified desalination facilities (facilities first used to produce desalinated water after enactment of this Act) for up to ten years to partially offset the cost of electrical energy required to operate such facilities. Although the bill did not pass in the last Congress, it has been re-introduced in the new Congress in 2005 and appears to have significant support.

6.04 Recommended Implementation Schedule

The Big Spring reclamation project concept appears feasible and ready for implementation of the next phase, preliminary design. The Snyder and Odessa-Midland projects are recommended for additional study to refine the concept, especially relating to disposal of desalination concentrate. A preliminary implementation schedule is provided in **Appendix B.**

Appendix A: Cost Estimate

Freese and Nichols

Simon W. Freese, P.E. 1900-1990
Marvin C. Nichols, P.E. 1896-1969

Title: Colorado River Municipal Water District
Regional Water Reclamation Project
Big Spring

Date: Mar. 29, 2005
By: ICA
Chkd: DWS

	QTY	UNIT	UNIT PRICE	TOTAL
Capital Cost				
Land Acquisition				
Total Land Acquisition	2.0	ac	$ 2,000.00	$ 4,000.00
Treatment Equipment				
Microfilatration/Ultrafiltration (MF/UF)	1	L.S.	$ 1,552,500.00	$ 1,552,500.00
Reverse Osmosis (RO)	1	L.S.	$ 1,380,000.00	$ 1,380,000.00
UV/Oxidation	1	L.S.	$ 434,700.00	$ 434,700.00
Total Treatment Equipment				$ 3,367,200.00
Diversion Structure & Pump Station				
Pump Station (2-1715 gpm)	1	L.S.	$ 50,000.00	$ 50,000.00
Total Pump Station				$ 50,000.00
Pump Station (to CRMWD Raw Water Line)				
Pump Station (2-1400 gpm)	1	L.S.	$ 50,000.00	$ 50,000.00
.50 MG Concrete Storage Facility (6 hrs. of flow)	1	L.S.	$ 300,000.00	$ 300,000.00
Total Pump Station				$ 350,000.00
Reject Facilities				
High Pressure Membrane Reject (Piping to Creek)				
0.46 MG RO Reject Lagoon (1 day of storage (0.1 5ac))	1	L.S.	$ 105,000.00	$ 105,000.00
Low Pressure Membrane Reject				
0.23 MG MF/UF Reject Lagoon (1 day storage(.05 ac))	1	L.S.	$ 75,000.00	$ 75,000.00
Total Reject Facilities				$ 180,000.00
Pipeline (Transmission)				
10" Dia. Pipeline (2.3 MGD from WWTP)	1,000	L.F.	$ 50.00	$ 50,000.00
10" Dia. Pipeline (2.07 MGD to CRMWD Pipeline)	4,500	L.F.	$ 50.00	$ 225,000.00
6" Dia. Pipeline (0.46 MGD to Beals Creek)	500	L.F.	$ 30.00	$ 15,000.00
Easement	4.13	acre	$ 1,000.00	$ 4,132.22
Total Pipeline (Transmission)				$ 294,132.22
Building				
Metal Building	5,000	S.F.	$ 90.00	$ 450,000.00
Total Building				$ 450,000.00
Electrical				
Total Electrical: 10% of Equipment Cost				$ 338,320.00
Instrumentation				
Total Instrumentation: 10% of Equipment Cost				$ 338,320.00

Subtotal	$ 5,371,980.00
Contingency (25%)	$ 1,343,000.00
TOTAL CONSTRUCTION COST	**$ 6,714,980.00**
Engineering & Construction Services (15%)	$ 1,007,250.00
TOTAL CAPITAL COST	**$ 7,723,000.00**

Freese and Nichols

Simon W. Freese, P.E. 1900-1990
Marvin C. Nichols, P.E. 1896-1969

Title: Colorado River Municipal Water District
Regional Water Reclamation Project
Big Spring

Date: Mar. 29, 2005
By: ICA
Chkd: DWS

Annual Operation and Maintenance Cost

	QTY	UNIT	UNIT PRICE	TOTAL
Treatment				
MF/UF				
power consumption (kw-hr/ gal)	2,075,000	gal/day	$0.038 / 1000 gal	$ 28,780.25
membrane replacement	2,075,000	gal/day	$0.030 / 1000 gal	$ 22,721.25
chemicals ($ / gal)	2,075,000	gal/day	$0.045 / 1000 gal	$ 34,081.88
RO				
power consumption (kw-hr/ gal)	1,660,000	gal/day	$0.038 / 1000 gal	$ 23,024.20
membrane replacement	1,660,000	gal/day	$0.080 / 1000 gal	$ 48,472.00
cartridge filters	1,660,000	gal/day	$0.030 / 1000 gal	$ 18,177.00
chemicals ($ / gal)	1,660,000	gal/day	$0.018 / 1000 gal	$ 10,906.20
UV				
power consumption & lamp replacement	1,660,000	gal/day	$0.05 / 1000 gal	$ 28,275.33
chemicals ($ / gal)	1,660,000	gal/day	$0.005 / 1000 gal	$ 3,029.50
Total Treatment				$ 217,467.61
Labor				
1 part time employee (28 hours per week)	1,456	Hrs.	$ 24.00	$ 34,944.00
Total Labor				$ 34,944.00
Pumping (Transmission)				
Pumping to Rec. Treatment Facilitiy (power cost)	176,207.40	kw	$0.07 / kw-hr	$ 12,334.52
Pumping to CRMWD raw water pipeline (power cost)	352,414.80	kw	$0.07 / kw-hr	$ 24,669.04
Total Pumping (Transmission)				$ 37,003.55
Annual Maintenance				
Total Annual Maintenance (5% of Equipment Cost)				$ 169,160.00

Subtotal	$ 458,580.00
Contingency (10%)	$ 45,860.00
TOTAL ANNUAL OPERATION AND MAINTENANCE COST	**$ 505,000.00**

Freese and Nichols

Simon W. Freese, P.E. 1900-1990
Marvin C. Nichols, P.E. 1896-1969

Title: Colorado River Municipal Water District
Regional Water Reclamation Project
Odessa - Midland

Date: Mar. 29, 2005
By: ICA
Chkd: DWS

	QTY	UNIT	UNIT PRICE	TOTAL
Capital Cost				
Land Acquisition				
Reclaimed Treatment Plant Land Acquisition	5	ac	$ 5,000.00	$ 25,000.00
Disposal Facilities Land Acquisition	25	ac	$ 1,000.00	$ 25,000.00
Total Land Acquisition				$ 50,000.00
Treatment Equipment				
Microfiltration/Ultrafiltration (MF/UF)	1	L.S.	$ 6,048,000.00	$ 6,048,000.00
Reverse Osmosis (RO)	1	L.S.	$ 5,832,000.00	$ 5,832,000.00
UV/Oxidation	1	L.S.	$ 1,600,000.00	$ 1,600,000.00
Total Treatment Equipment				$ 13,480,000.00
Pump Station (Reclaimed Water to Terminal)				
Pump Station (2-7500 gpm)	1	L.S.	$ 121,770.00	$ 121,770.00
2.7 MG Concrete Storage Facility (6 hr. storage)	1	L.S.	$ 810,000.00	$ 810,000.00
Total Pump Station				$ 931,770.00
Reject Facilities				
High Pressure Membrane Reject				
Pumps (2-1875 gpm)	1	L.S.	$ 109,620.00	$ 109,620.00
2.7 MG RO Reject Lagoon (1 day storage (0.83ac.))	1	L.S.	$ 450,000.00	$ 450,000.00
40.5 MG Brine Lagoon (15 days storage (12.4ac.))	1	L.S.	$ 2,232,000.00	$ 2,232,000.00
Disposal Well	4	ea.	$ 1,500,000.00	$ 6,000,000.00
18" Dia. Pipeline (2.7 MGD to disposal site)	84,500	L.F.	$ 90.00	$ 7,605,000.00
Low Pressure Membrane Reject				
1.5 MG Lagoon (1.0 day storage (0.46ac))	1	L.S.	$ 550,000.00	$ 550,000.00
Total Reject Facilities				$ 16,946,620.00
Pipeline (Transmission)				
30" Dia. Pipeline (11.0 MGD Midland to Rec. WTP)	84,000	L.F.	$ 150.00	$ 12,600,000.00
24" Dia Pipeline (10.8 MGD Finished Water)	3,000	L.F.	$ 120.00	$ 360,000.00
12" Dia. Pipeline (3.5 MGD Odessa to Rec. WTP)	5,280	L.F.	$ 60.00	$ 316,800.00
Easement	122	acre	$ 2,000.00	$ 243,497.67
Total Pipeline (Transmission)				$ 13,520,297.67
Aquifer Storage and Recovery				
14" Dia. Pipeline (2.7 MGD from Rec. Fac. To ASR)	27,000	L.F.	$ 70.00	$ 1,890,000.00
Pumps (2-1875 gpm)	1	L.S.	$ 33,750.00	$ 33,750.00
Well Field Modifications	1	L.S.	$ 50,000.00	$ 50,000.00
Total Building				$ 1,973,750.00
Building				
Metal Building	15,000	S.F.	$ 90.00	$ 1,350,000.00
Total Building				$ 1,350,000.00
Electrical				
Total Electrical: 10% of Equipment Cost				$ 1,391,038.20
Instrumentation				
Total Instrumentation: 10% of Equipment Cost				$ 1,391,038.20

Subtotal	$ 51,034,520.00
Contingency (25%)	$ 12,758,630.00
TOTAL CONSTRUCTION COST	**$ 63,793,150.00**
Engineering & Construction Services (15%)	$ 9,568,980.00
TOTAL CAPITAL COST	**$ 73,363,000.00**

Freese and Nichols

Simon W. Freese, P.E. 1900-1990
Marvin C. Nichols, P.E. 1896-1969

Title:	Colorado River Municipal Water District	**Date:**	Mar. 29, 2005
	Regional Water Reclamation Project	**By:**	ICA
	Odessa - Midland	**Chkd:**	DWS

Annual Operation and Maintenance Cost

	QTY	UNIT	UNIT PRICE	TOTAL
Treatment				
MF/UF				
power consumption (kw-hr/ gal)	10,890,000	gal/day	$0.038 / 1000 gal	$ 151,044.30
membrane replacement	10,890,000	gal/day	$0.030 / 1000 gal	$ 119,245.50
chemicals ($ / gal)	10,890,000	gal/day	$0.045 / 1000 gal	$ 178,868.25
RO				
power consumption (kw-hr/ gal)	8,712,000	gal/day	$0.038 / 1000 gal	$ 120,835.44
membrane replacement	8,712,000	gal/day	$0.080 / 1000 gal	$ 254,390.40
cartridge filters	8,712,000	gal/day	$0.030 / 1000 gal	$ 95,396.40
chemicals ($ / gal)	8,712,000	gal/day	$0.018 / 1000 gal	$ 57,237.84
UV				
power consumption & lamp replacement	8,712,000	gal/day	$0.04 / 1000 gal	$ 111,295.80
chemicals ($ / gal)	8,712,000	gal/day	$0.01 / 1000 gal	$ 31,798.80
Total Treatment				$ 1,120,112.73
Labor				
2 full time employees (40 hours per week/ea.)	4,160	Hrs.	$ 24.00	$ 99,840.00
Total Labor				$ 99,840.00
Effluent to Reclaimed Facility (Pumping)				
Midland to Reclam. Plant (power cost)	3,109,571	kw-hr	$0.07 / kw-hr	$ 217,670.00
Odessa to Reclam. Plant (power cost)	405,635	kw-hr	$0.07 / kw-hr	$ 28,394.45
Total Influent Pumping Facilities				$ 246,064.45
Finished Water to Terminal (Pumping)				
Reclam. Plant to Terminal Reservoir (power cost)	1,778,772.32	kw-hr	$0.07 / kw-hr	$ 124,514.06
Total Product Pumping Facilities				$ 124,514.06
Disposal Facilities				
Pumping to Disposal Facility (power cost)	1,161,663.60	kw-hr	$0.07 / kw-hr	$ 81,316.45
Total Disposal Facilities				$ 81,316.45
ASR (Transmission)				
Pumping (power cost)	730,934.40	kw	$0.07 / kw-hr	$ 51,165.41
Total ASR Pumping (Transmission)				$ 51,165.41
Annual Maintenance				
Total Annual Maintenance (5% of Equipment Cost)				$ 695,519.10
			Subtotal	$ 2,418,532.20
			Contingency (10%)	$ 241,853.22
TOTAL ANNUAL OPERATION AND MAINTENANCE COST				**$ 2,661,000.00**

Freese and Nichols

Simon W. Freese, P.E. 1900-1990
Marvin C. Nichols, P.E. 1896-1969

Title: Colorado River Municipal Water District	**Date:** Mar. 29, 2005
Regional Water Reclamation Project	**By:** ICA
Odessa - Midland	**Chkd:** DWS

Additional Cost Secondary Treatment Facilities at Midland Water Pollution Control Plant

Capital Cost

	QTY	UNIT	UNIT PRICE	TOTAL
Pump Station (Midland Reclaimed Water)				
Pump Station (2-7640 gpm)	1	L.S.	$ 168,185.70	$ 168,185.70
3.75 MG Concrete Tank at Treatment Facility (6 hr st)	1	L.S.	$ 945,000.00	$ 945,000.00
Total Pump Station				$ 1,113,185.70
Treatment Equipment				
5 MGD Secondary Treatment (at Midland's WWTP)	1	L.S.	$ 6,250,000.00	$ 6,250,000.00
Total Treatment Equipment				$ 6,250,000.00
Subtotal				$ 7,363,190.00
Contingency (%)				$ 1,840,800.00
TOTAL CONSTRUCTION COST				**$ 9,203,990.00**
Engineering & Construction Services (15%)				$ 1,380,600.00
TOTAL CAPITAL COST				**$ 10,585,000.00**

Annual Operation and Maintenance Cost

	QTY	UNIT	UNIT PRICE	TOTAL
Effluent Transmission				
Delivery to Reclaim Facility (10.0 MGD from Midland) power (Pumps Midland WWTP to Rec. WTP)	3,256,573.80	kw	$0.07 / kw-hr	$ 227,960.17
Total Treatment				$ 227,960.17
Treatment				
5 MGD Secondary Treatment (at Midland WWTP) aeration power consumption (74 Hp)	479,675.70	kw	$0.07 / kw-hr	$ 33,577.30
Total Treatment				$ 33,577.30
Subtotal				$ 261,540.00
Contingency (%)				$ 26,160.00
TOTAL ANNUAL OPERATION AND MAINTENANCE COST				**$ 288,000.00**

Freese and Nichols

Simon W. Freese, P.E. 1900-1990
Marvin C. Nichols, P.E. 1896-1969

Title: Colorado River Municipal Water District
Regional Water Reclamation Project
Snyder

Date: Mar. 29, 2005
By: ICA
Chkd: DWS

	QTY	UNIT	UNIT PRICE	TOTAL
Capital Cost				
Land Acquisition				
Total Land Acquisition	2.0	ac	$ 2,000.00	$ 4,000.00
Treatment Equipment				
Microfilatration/Ultrafiltration (MF/UF)	1	L.S.	$ 607,500.00	$ 607,500.00
Reverse Osmosis (RO)	1	L.S.	$ 432,000.00	$ 432,000.00
UV/Oxidation	1	L.S.	$ 190,000.00	$ 190,000.00
Total Treatment Equipment				$ 1,229,500.00
Pump Station (Finished Water to CRMWD GST)				
Pump Station (2-500 gpm)	1	L.S.	$ 40,000.00	$ 40,000.00
15 MG Storage Reservoir in Snyder	1	L.S.	$ 990,000.00	$ 990,000.00
0.18 MG Concrete Storage Facility (6 hrs. of flow)	1	L.S.	$ 180,000.00	$ 180,000.00
Total Pump Station				$ 1,210,000.00
Pump Station (WWTP effluent to Reclaim WTP)				
Pump Station (2-700 gpm)	1	L.S.	$ 40,000.00	$ 40,000.00
1.0 MG Lagoon (1.0 days storage(0.3ac))	1	L.S.	$ 175,000.00	$ 175,000.00
Total Pump Station				$ 215,000.00
Aquifer Storage Recovery				
8" Dia. Pipeline (0.5 MGD from Rec. Fac. To ASR)	27,000	L.F.	$ 40.00	$ 1,080,000.00
Pumps (2-347 gpm)	1	L.S.	$ 35,000.00	$ 35,000.00
ASR Well Facilities	1	L.S.	$ 142,000.00	$ 142,000.00
Total Building				$ 1,257,000.00
Reject Facilities				
High Pressure Membrane Reject (Piping to Outfall)				
Pump Station (2-125 gpm)	1	L.S.	$ 25,000.00	$ 25,000.00
0.18 MG RO Reject Lagoon (1 day storage (0.05 ac.))	1	L.S.	$ 62,500.00	$ 62,500.00
Low Pressure Membrane Reject				
Pump Station (2-70 gpm)	1	L.S.	$ 25,000.00	$ 25,000.00
0.20 MG MF/UF Reject Lagoon (1 day storage (.031 ac.))	1	L.S.	$ 175,000.00	$ 175,000.00
Total Reject Facilities				$ 287,500.00
Pipeline (Transmission)				
8" Dia. Pipeline (0.72 MGD to CRMWD GST)	6,800	L.F.	$ 50.00	$ 340,000.00
8" Dia Pipeline (1.0 MGD to Reclaimed WTP)	1,500	L.F.	$ 40.00	$ 60,000.00
4" Dia. Pipeline (0.18 MGD to Disposal Facility)	1,500	L.F.	$ 20.00	$ 30,000.00
Easement	6.7	acre	$ 1,000.00	$ 6,749.28
Total Pipeline (Transmission)				$ 436,749.28
Building				
Metal Building	4,500	S.F.	$ 90.00	$ 405,000.00
Total Building				$ 405,000.00
Electrical				
Total Electrical: 10% of Equipment Cost				$ 128,430.00
Instrumentation				
Total Instrumentation: 10% of Equipment Cost				$ 128,430.00

Subtotal	$ 5,301,610.00
Contingency (25%)	$ 1,325,410.00
TOTAL CONSTRUCTION COST	**$ 6,627,020.00**
Engineering & Construction Services (15%)	$ 994,060.00
TOTAL CAPITAL COST	**$ 7,622,000.00**

Simon W. Freese, P.E. 1900-1990
Marvin C. Nichols, P.E. 1896-1969

Title: Colorado River Municipal Water District
Regional Water Reclamation Project
Snyder

Date: Mar. 29, 2005
By: ICA
Chkd: DWS

Annual Operation and Maintenance Cost

	QTY	UNIT	UNIT PRICE	TOTAL
Treatment				
MF/UF				
power consumption (kw-hr/ gal)	812,500	gal/day	$0.038 / 1000 gal	$ 11,269.38
membrane replacement	812,500	gal/day	$0.030 / 1000 gal	$ 8,896.88
chemicals ($ / gal)	812,500	gal/day	$0.045 / 1000 gal	$ 13,345.31
RO				
power consumption (kw-hr/ gal)	650,000	gal/day	$0.038 / 1000 gal	$ 9,015.50
membrane replacement	650,000	gal/day	$0.080 / 1000 gal	$ 18,980.00
cartridge filters	650,000	gal/day	$0.030 / 1000 gal	$ 7,117.50
chemicals ($ / gal)	650,000	gal/day	$0.018 / 1000 gal	$ 4,270.50
UV				
power consumption & lamp replacement	650,000	gal/day	$0.05 / 1000 gal	$ 11,071.67
chemicals ($ / gal)	650,000	gal/day	$0.005 / 1000 gal	$ 1,186.25
Total Treatment				$ 85,152.98
Labor				
1 part time employee (12 hours per week)	624	Hrs.	$ 24.00	$ 14,976.00
Total Labor				$ 14,976.00
Disposal Facilities				
Pumping to Creek (power cost)	13,052.40	kw	$0.07 / kw-hr	$ 913.67
Total Disposal Facilities				$ 913.67
Pumping (Transmission)				
Pumping from WWTP to Reclaimed WTP	58,735.80	kw	$0.07 / kw-hr	$ 4,111.51
Pumping to CRMWD 15 MG GST (power cost)	97,893.00	kw	$0.07 / kw-hr	$ 6,852.51
Total Pumping (Transmission)				$ 10,964.02
ASR (Transmission)				
Pumping (power cost)	117,471.60	kw	$0.07 / kw-hr	$ 8,223.01
Total Pumping (Transmission)				$ 8,223.01
Annual Maintenance				
Total Annual Maintenance (5% of Equipment Cost)				$ 64,215.00

Subtotal	$ 184,450.00
Contingency (10%)	$ 18,450.00
TOTAL ANNUAL OPERATION AND MAINTENANCE COST	**$ 203,000.00**

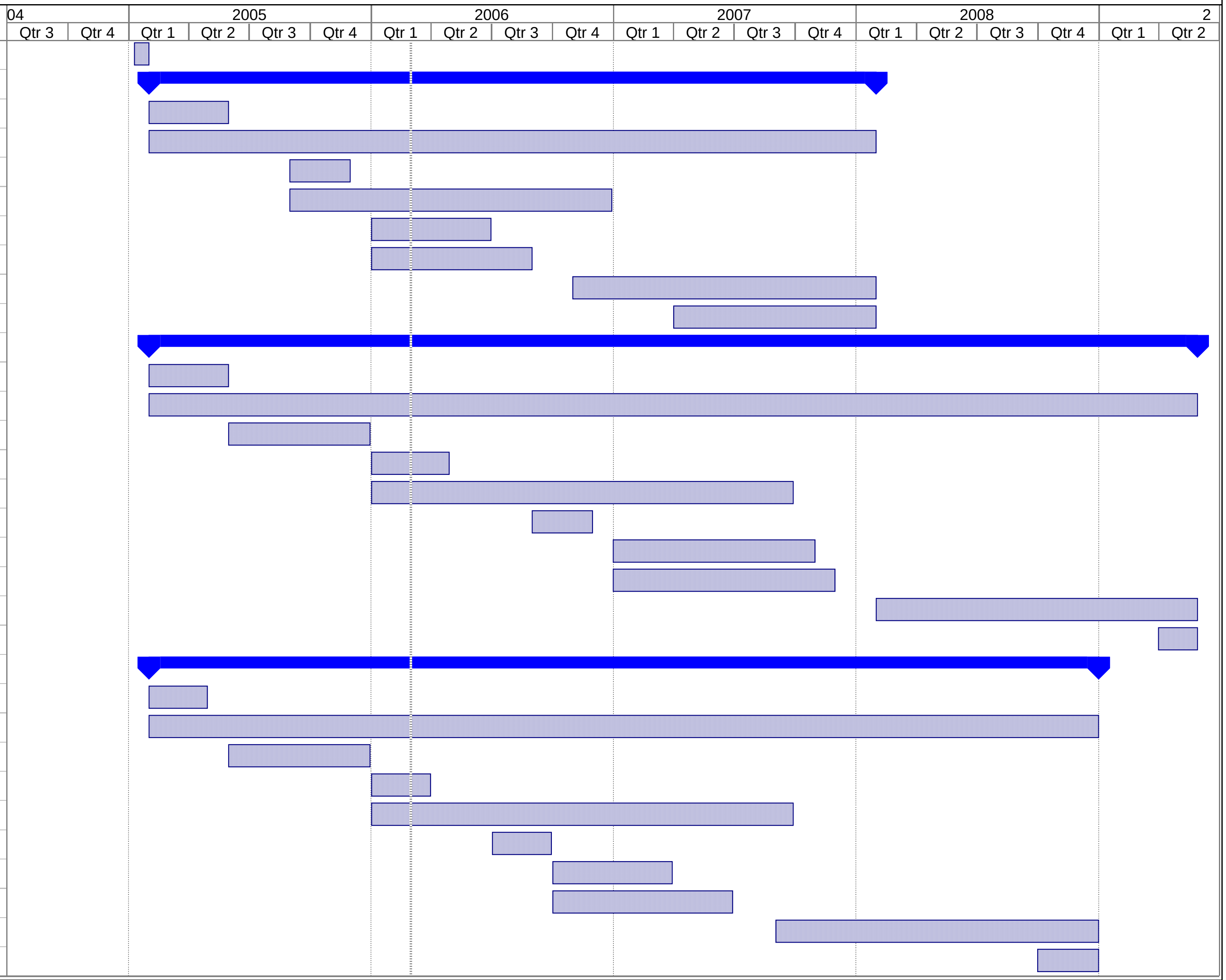
Appendix B: Implementation Schedule

CRMWD
Colorado River Municipal Water District

REGIONAL WATER RECLAMATION PROJECT
PROPOSED IMPLEMENTATION SCHEDULE

Freese and Nichols, Inc.

ID	Task Name
1	Complete Feasibility Study
2	**Big Spring**
3	Preliminary Design Report
4	Public Education
5	Pilot Testing
6	Permitting
7	Easement Acquisition
8	Final Design
9	Construction
10	Startup & Testing
11	**Odessa/Midland**
12	Concept Alternative Evaluations
13	Public Education
14	Groundwater Field Investigations
15	Preliminary Design Report
16	Groundwater Permitting
17	Pilot Testing
18	Easement Acquisition
19	Final Design
20	Construction
21	Startup & Testing
22	**Snyder**
23	Concept Alternative Evaluations
24	Public Education
25	Groundwater Field Investigations
26	Preliminary Design Report
27	Groundwater Permitting
28	Pilot Testing
29	Easement Acquisition
30	Final Design
31	Construction
32	Startup & Testing



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Fort Worth, Texas 76109

Task | Milestone | Project Summary | External Tasks

Appendix C: Glossary of Terms

GLOSSARY OF TERMS

Absolute Pore Size	The maximum pore size for a specific membrane. For microfiltration (MF) membranes it is normally established by using the initial bubble point testing method and is reported in tenths or hundredths of a micron. However, ultrafiltration (UF), nanofiltration (NF) and reverse osmosis (RO) membrane pore sizes are normally too small to accurately establish a reportable measurement in microns and another method is used to establish a molecular cut-off weight (MCW) at which all particles greater than that size will be rejected
Aquifer	A subsurface feature comprised of permeable soil and rock that contains water
Back Flush/Reverse Flow	Terms used by some membrane vendors to describe the backwash cycle for their membrane units. Normal frequency for these cycles are in the range of 15 to 30 minutes with feed waters having turbidity levels in the 10.0 to 50.0 NTU range; and approximately 45 minutes, or greater, with feed waters having turbidity levels less than 10.0 NTU The back flush/reverse flow water is filtrate/permeate water and may have an elevated disinfectant residual to control biological fouling of the membranes.
Best Professional Judgment	Using knowledge and experience to make a decision on an issue that does not have a clear direction or answer, or deciding to take an alternative path to the one recommended based on knowledge and experience.
Bleedby	A continuous stream of feed water that is allowed to discharge from a tank containing immersed membrane units and bypasses the membrane filtration process to waste. This is done to prevent an over accumulation of solids in the tank, increase the filtrate flux rate and increase the duration between CIP and backwash cleaning of the membranes. The bleedby stream is combined with the backwash/back flush/reverse flow waste to discharge to a lagoon. The decant of the waste lagoon is returned to the head of the treatment train
Booster Disinfection	The practice of adding disinfectant in the distribution system to increase disinfectant residual concentration.
Brackish Water	Brackish water is defined by containing higher TDS levels than potable water, but lower TDS levels than seawater (in the range of 1,000 mg/l TDS to 25,000 mg/l TDS) Brackish waters can be found in coastal areas (bays and estuaries, where fresh water mixes with salt water), in aquifers (where it is usually referred to as saline water), and in surface waters (salt marshes, for instance, contain brackish water)
Calculated Maximum Log	(As defined in EPA guidance, where $Q_{filtrate}$ is the actual design flow,

Removal (LR_{max}) = LOG [($Q_{filtrate}$/CF) * Q_{breach}]	CF is the concentrate factor, and Q_{breach} is the flow rate through a 3.0-micron breach in a module's membrane, o-rings or epoxy as detected by the required direct integrity test.)
Clean-in-place (CIP)	Used to describe the chemical cleaning of membranes when the transmembrane pressure or flux rate degrades to a manufacturer's specified level. The process uses an acidic or basic solution, or both in sequence, to remove fouling from the membranes that the backwash/back flush/reverse flow procedures have not removed to recover the specific flux. This procedure ranges in duration from four hours to as long as twelve hours depending on the degree of fouling and manufacturer's specifications. Other chemical cleaning processes used by some membrane vendors are chemical enhanced backwash (CEB), mini CIP, enhanced flux maintenance (EFM) and chemical soaks. These processes are normally associated with the backwash cycles and include the addition of an acidic solution. They are significantly shorter in duration than a CIP procedure and are used to extend the time between the CIP procedures.
Combined Distribution System	The interconnected distribution system consisting of the distribution systems of wholesale systems and of the consecutive systems that receive finished water from those wholesale system(s).
Community Water Systems	A public water system which serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.
Concentrate	Concentrate is the byproduct from desalination. This byproduct contains the contaminants removed from impaired waters during desalination and water purification processes. Concentrates are generally liquid substances that may contain up to 20% of the water that is treated (i.e., for every 100 gallons of impaired waters that are treated, up to 20 gallons of that water is commingled with the removed contaminants).
Concentrate/Reject	Describes the stream of water containing the microorganisms and chemicals rejected by NF and RO membranes.
Conductivity	A measurement of the ability of a solution to carry an electrical current.
Conjunctive Use	The coordinated and integrated management of surface water and ground water resources.
Consecutive System	A public water system that buys or otherwise receives some or all of its finished water from one or more wholesale systems for at least 60 days per year.

Consecutive System Entry Point	A location at which finished water is delivered at least 60 days per year from a wholesale system to a consecutive system
Controlling Month	The month of historical peak DBP levels, or, in the absence of DBP data, the month of highest water temperature by which the IDSE sampling schedule is set.
Conventional Water Treatment Technologies	Typical conventional water treatment consists of six basis steps: screening; coagulation to combine solids so that they settle; sedimentation to settle suspended solids; filtration; disinfection; and storage Sometimes all of these steps are not needed, and sometimes, additional steps are required to meet water quality standards Dissolved ionic species and hydrocarbons in source waters require treatment using chemical additions, soda ash or weak acids, or by filtration with activated carbon or calcite filters Conventional water treatment processes have been employed for more than 100 years.
Cost, Capital	Total capital costs includes the indirect costs associated with the owner's costs of studies, engineering, licenses, interest on working capital, insurance during the construction period as well as the direct capital costs. It is the owner's total investment up to the point that the plant is put into useful operation.
Cost, Indirect Capital	The owner's costs associated with such items as the studies, planning, engineering, construction supervision, licensing, startup, public relations, and training. These costs are a part of the cost of placing the plant in operation and are in addition to the direct capital costs associated with equipment and contracts for construction.
Cross-flow	Where the feed water entering a single MF or UF membrane module/vessel scours across the membrane with a small percentage being "recycled" to the feed water inlet. The advantage is to delay fouling and the backwash and chemical cleaning cycles. A disadvantage is that it requires an additional pump
Dead-end Flow	Where all the feed water entering a MF or UF membrane module/container passes through the membrane
Direct Reuse	Wastewater directly used for Municipal, industrial, and low agricultural purposes and not returned to the watercourse.
Disinfectant	Any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms
Disinfectant Residual	The concentration of disinfectant that is maintained in a distribution

Concentration — system Disinfectant could be free chlorine (the sum of the concentrations of hypochlorous acid (HOCI) and hypochlorite acid (OCI) or combined chlorine (chloramines). It is used in Surface Water Treatment Rules as a measure for determining CT

Disinfection — A process which inactivates pathogenic organisms in water by chemical oxidants or equivalent agents.

Disinfection Byproduct — Compound formed from the reaction of a disinfectant with organic and inorganic compounds in the source or treated water during the disinfection process.

Dual Sample Set — TTHM and HAA5 samples that are taken at the same time and location for the purpose of conducting and ISDE evaluation and determining compliance with the TTHM and HAA5 MCLs.

Electrodialysis — The separation of substances in solution by means of their unequal diffusion through semi-permeable membranes that is conducted with the aid of an electromotive force applied to electrodes adjacent to both sides of the membrane.

Filtrate — Term used by the industry to describe the effluent from MF membranes and sometimes the effluent from UF membranes*.

***Note:** Referring to UF membrane effluent as permeate can be misleading. The term filtrate would seem to be more applicable in regards to the effluents from both MF and UF membranes because of their ability to only remove some microorganisms and particulates. Whereas permeate is more applicable when referring to the effluents from NF and RO membranes because of their ability to also remove chemical constituents. Also, NF and RO membranes generate a concentrated reject stream which neither MF nor UF membranes do. The NF and RO membranes' concentrate streams not only contain high levels of microorganisms, but also high levels of chemicals constituents. The TCEQ Water Quality Section requires a Municipal Permit for the discharge of MF and UF membranes' backwash wastewater, but an Industrial Permit for the discharge of NF and RO membranes' rejected concentrate. The use of filtrate for MF and UF membrane effluents and permeate for NF and RO membrane effluents can also eliminate confusion when identifying water in different treatment stages through an "integrated membrane system." When discussing "integrated membrane systems," the TCEQ staff should always clarify which effluent is being described to eliminate any confusion

Filtrate Flux — (average filtrate flow per rack/tank in gpd) ÷ (total membrane feed side surface area of the membrane rack/tank in sf) expressed in gallons/ square-foot/day (gfd) **OR** when filtrate flux rate at 20° is known and the filtrate flux at another temperature is wanted:

$$(J_t) = J_{20} * e^{[(-0.0239) * (20 - \text{actual water temperature})]}$$

Filtrate Flux (J_{20}) at 20° C — $$(J_{20}) = J_t * e^{[(-0.0239) * (\text{actual water temperature} - 20)]}$$

Finished Water	Water that has been introduced in to the distribution system of a public water systems and is intended for distribution without further treatment, except that necessary to maintain water quality (such as booster disinfection).
Fouling	The reduction in performance of process equipment that occurs as a result of scale buildup, biological growth, or the deposition of materials.
Ground Water	Water normally found underground and obtained from wells. Not to be confused with surface water such as rivers, ponds, lakes, or waters above the water table.
Ground Water Under the Direct Influence of Surface Water	Any water beneath the surface of the ground with (1) significant occurrence of insects or other macroorganisms, algae, or large diameter pathogens such as *Giardia lamblia*, or (2) significant and relatively rapid shifts in water characteristics such as turbidity, temperature, conductivity, or pH which closely correlate to climatological or surface water conditions. Direct indluence must be determined for individual sources in accordance with criteria established by the State. The State determination of direct influence may be based on site-specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation.
Haloacetic Acid	One of the familiy of organic compounds named as a derivative of acetic acid, wherein one to three hydrogen atoms in the methyl group in acetic acid are each substituted by a halogen atom (namely, chlorine and bromine) in the molecular structure
Haloacetic Acids (five)	The sum of the concentrations in milligrams per liter of the haloacetic acid compounds (monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid), rounded to two significant figures after addition.
Heterotrophic Plate Count	A procedure for estimating the number of heterotrophic bacteria in water, measured as the number of colony forming units per 100 mL.
Impaired Water	Impaired water is that which is contaminated by salts, metals, radionuclides, biologic organisms, organic chemicals, fertilizers, pesticides, and a host of other substances that must be removed prior to the water being suitable for potable use
Indirect Potable Reuse	The introduction of highly treated reclaimed water to a surface water or groundwater system that ultimately is used as a potable water supply
Indirect Reuse	Water that is returned to the stream and sent down the "bed and

banks" of a watercourse for reuse elsewhere.

Influence Zone	The portions of the distribution systems supplied with water from a particular source of supply.
Integrated Membrane System	A treatment train that uses either MF or UF membranes in front of either NF or RO membranes to achieve an acceptable finished water quality. The MF or UF membranes are used for the removal of microorganisms and particulates and to generate an acceptable feed water quality for the NF or RO membranes. The NF or RO membranes are then used to remove unacceptable chemical constituents from all, or a split flow of the combined MF or UF filtrate. If the MF or UF membranes' filtrate flow is split, then the combined NF or RO membranes' permeate will be blended with the combined MF or UF membranes' filtrate bypass stream.
Integrity Test, Direct	An offline method of testing an individual membrane rack/tank under pressure or vacuum to detect defects of a minimum specified size and larger in the individual membrane units components. Currently, the TCEQ requires that a direct integrity test be conducted at least once a week and after each CIP. The test pressure must be able to detect at least a 3.0-micron defect for a system using membrane filtration to receive the TCEQ's removal credit of 2.0-log for *Cryptosporidium* oocysts and 3.0-log for *Giardia lamblia* cysts. Two direct integrity test commonly used for MF and UF membranes are the pressure (or vacuum) decay and the bubble hold tests. A direct integrity test for NF and RO membranes is a dye test.
Integrity Test, Indirect	A method of continuous monitoring of a membrane rack/tank during online operation to verify that there has not been a significant failure of one, or more, of this membrane unit's components which has reduced its effectiveness as a removal barrier. It corresponds to individual turbidimeters on granular media filters. Please note that current technology does not allow for the detection of a single cut or broken Hollow Filber (HF) membrane in a rack/rank of tens of membrane modules/elements.
kWh	Kilowatt-hours. A measure of electrical usage.
Locational Running Annual Average	The average of samples taken at a particular monitoring site during the previous four calendar quarters.
Maximum Contaminant Level	The maximum permissible level of a contaminant in water which is delivered to any user of a public water system.
Maximum Contaminant Level Goal	The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. Maximum contaminant level goals are non-enforceable health goals.

Membrane	A semi-permeable film. Membranes used in electrodialysis are permeable to ions of either positive or negative charge Reverse osmosis membranes ideally allow the passage of pure water and block the passage of salts
Membranes , Nanofiltration (NF)	Low-pressure (50 to 150 psi) operated membranes; of a spiral-wound, HF or flat sheet design; and are reported as having nominal pore sizes of approximately 0.001 microns with an approximate pore size range between 0.001 microns and 0 003 microns (or a MCW range from 200 to 7,000).
Membranes, Ultrafiltration (UF)	Ultra, low-pressure or vacuum (20 to 75 psi) operated membranes; of a spiral-wound, HF or flat sheet design; and are reported as having nominal pore sizes of approximately 0.01 microns with an approximate pore size range between 0.003 microns and 0.2 microns (or a MCW range from 8,000 to 300,000).
Membranes, Microfiltration (MF)	Ultra, low-pressure or vacuum (15 to 30 psi) operated membranes; of a spiral-wound, hollow-fiber (HF) or flat sheet design; and reported as having nominal pore sizes of approximately 0.1 microns with a pore size range between 0.05 and 2.0 microns.
Membranes, Reverse Osmosis (RO)	Constructed in three pressure operating ranges that are not related to the above types They can be operated and referred to as either low pressure RO (125 to 300 psi), medium pressure RO (350 to 600 psi) or high pressure (800 to 1,200 psi); of a spiral-wound, HF or flat sheet design; and are reported as having pore sizes up to 0 0015 microns (or a MCW up to 900).
Mixing Zone	An area in the distribution system where water flowing from two or more different sources blend.
Monitoring Site	The location where samples are collected.
Net Capacity	(MGD of net potable water available to customers) = [(MGD of gross filtrate/permeate produced) -- (MGD of total filtrate/permeate water used in-plant)]
Nominal Pore Size	A representative number for a specific membrane's pore sizes only. It is a size above which a specified number of particles of a select nature are rejected under select conditions for a membrane It is neither the maximum or minimum pore size for the membrane.
Noncommunity Water System	A public water system that is not a community water system.
Nontransient Noncommunity Water System	A public water system that is not a community water system and that regularly serves at least 25 of the same persons over 6 months per year

On-demand Removal	On-demand removal describes the time-relevant removal of selected contaminants to meet local requirements (i e., removing what you want to remove when you want to remove it).
Osmosis	Movement of water from a dilute solution to a more concentrated solution through a membrane separating the two solutions.
Percent (%) Element Recovery	100 * [(filtrate flow in gpd) ÷ (feed flow + recycle flow in gpd)]
Percent (%) Loss of Original Specific	Flux = 100 * [1 – (specific flux, adjusted to 20°C, of a membrane rack/tank at startup of the membrane filtration facility ÷ specific flux, adjusted to 20°C, of the membrane rack/tank after any CIP and direct integrity test)]
Percent (%) Recovery of Specific Flux (after a CIP)	100 * [1 – (specific flux at end of a filtration run ÷ specific flux at beginning of the next filtration run after a CIP)]
Percent (%) System Recovery	100 * [(filtrate flow in gpd) ÷ (feed flow in gpd)]
Permeate	Term used by the industry to describe the effluent from NF and RO membranes and sometimes the effluent from UF membranes*. ***Note:** Referring to UF membrane effluent as permeate can be misleading The term filtrate would seem to be more applicable in regards to the effluents from both MF and UF membranes because of their ability to only remove some microorganisms and particulates Whereas permeate is more applicable when referring to the effluents from NF and RO membranes because of their ability to also remove chemical constituents. Also, NF and RO membranes generate a concentrated reject stream which neither MF nor UF membranes do. The NF and RO membranes' concentrate streams not only contain high levels of microorganisms, but also high levels of chemicals constituents. The TCEQ Water Quality Section requires a Municipal Permit for the discharge of MF and UF membranes' backwash wastewater, but an Industrial Permit for the discharge of NF and RO membranes' rejected concentrate The use of filtrate for MF and UF membrane effluents and permeate for NF and RO membrane effluents can also eliminate confusion when identifying water in different treatment stages through an "integrated membrane system." When discussing "integrated membrane systems," the TCEQ staff should always clarify which effluent is being described to eliminate any confusion.
Pilot Plant	An experimental unit of small size, usually less than 0.1 mgd capacity, used for early evaluation and development of new improved processes and to obtain technical and engineering data.
Pretreatment	The processes such as chlorination, clarification, coagulation, scale inhibition, acidification, and deaeration that may be employed on the feed water to a water supply purification or desalination plant to minimize algae growth, scaling, and corrosion.
Public Sector	Includes all public agencies, including Federal, State, and local

governments, and non-profit research institutions

Public Water System	A system for the provisions to the public of piped water for human consumption, if such system has a least fifteen service connections or regularly serves an average of at least twenty-five individuals at least 60 days out of the year Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system A public water system is either a "community water system" or a "noncommunity water system".
Recycle	In addition to its normal meaning in treatment plants, this also refers to an unfiltered stream from a membrane rack operated in cross-flow mode that is returned directly to the feed water inlet of the membrane after any pretreatment processes. This process is normally used with UF membrane units.
Residence Time	The time period lasting from when the water is treated to a particular point in the distribution system. Also referred to as water age.
Residual Disinfection	Also referred to as "secondary disinfection " The process whereby a disinfectant (typically CL or CLM) is added to finished water in order to maintain a disinfection residual in the distribution system
Running Annual Average	The average of monthly or quarterly averages of all samples taken throughout the distribution system, as averaged over the preceding four quarters.
Saline Water	Water with dissolved solids exceeding the limits of potable water Saline water may include seawater, brackish water, mineralized ground and surface water and irrigation return flows
Salinity	Salinity is a term used to describe the amount of salt in a given water sample Salinity is usually referred to in terms of total dissolved solids (TDS), and is measured in milligrams of solids per liter (mg/l). Seawater has a worldwide average of 35,000 mg/l TDS. Brackish waters contain between 1,000 mg/l and 25,000 mg/l TDS. Drinking water contains between 400 and 800 mg/l TDS
Salt	Salt, as referred to in this document is a catch-all term that incorporates a variety of substances found in source waters, including: calcium, sodium, magnesium, carbonate, bicarbonate, sulfate, chloride. Salts may also include lesser amounts of potassium, selenium, boron, manganese, fluoride, nitrate, iron, and arsenic. It is important to note that the salts referred to in this document are not the same as table salts (NaCl)

Scale	Salts deposited on heat transfer or membrane surfaces that retard the rate of heat transfer or ion or water permeation.
Scale Inhibitor	An agent that ties up and thus inactivates certain metal ions. It may be added to a feed water to extend the limits of saturation of scaling substances. Also known as antiscalant or sequestering agents.
Seawater	Seawater is that water found in the oceans. Seawater has a worldwide average concentration of 35,000 mg/l TDS, ¾ of which is NaCl.
Service Connection	Used in the definition of public water system, does not include a connection to a system that delivers water by a constructed conveyance other than a pipe if: (1) the water is used exclusively for purposes other than residential uses (consisting of drinking, bathing, and cooking, or other similar uses); (2) the State determines that alternative water to achieve the equivalent level of public health protection provided by the applicable national primary drinking water regulation is provided for residential or similar uses for drinking and cooking; or (3) the State determines that the water provided for residential or similar uses for drinking, cooking, and bathing is centrally treated or treated at the point of entry by the provider, a pass-through entity, or the user to achieve the equivalent level of protection provided by the applicable national primary drinking water regulations.
Specific Flux at 20°C	Empirically derived equation developed by the membrane manufacturer *or* $(J_{20}) = J_{tm} * e^{[(-0.0239) * (\text{actual water temperature} - 20)]}$
Specific Flux or Permeability	$J_{tm} = P_{feed} - P_{filtrate}$ (for dead-end flow) $[(P_{feed} - P_{concentrate}) \div 2] - P_{filtrate}$ (with a concentrate/waste stream)
Stage 2A	The period beginning [3 years after rule promulgation] until the dates specified for compliance with Stage 2B, during which systems must comply with Stage 2A MCLs.
Stage 2B	The period beginning [6 years after rule promulgation] for systems serving at least 10,000 people; [8.5 years after rule promulgation] for systems serving fewer than 10,000 people that are required to do *Cryptosporidium* monitoring under the Long Term 2 Enhanced Surface Water Treatment Rule; [7.5 years after rule promulgation] for all other systems serving fewer than 10,000 people, during which systems must comply with Stage 2B MCLs.
State	The agency of the State or Tribal government which has jurisdiction over public water systems. During any period when a State or Tribal government does not have primary enforcement responsibility

	pursuant to section 1413 of the Act, the term "State" means the Regional Administrator, U.S Environmental Protection Agency.
Subpart H Systems	Public water systems using surface water or ground water under the direct influence of surface water as a source that are subject to the requirements of 40 CFR 141.2 (h).
Surface Water	Surface waters are those waters contained in flowing sources (rivers, streams, etc.) and in still sources (oceans, seas, lakes, man-made reservoirs, etc.)
Synthetics	Man-made contaminants (industrial chemicals, pharmaceuticals, etc.)
Total Chlorine Residual	The sum of combined chlorine (chloramine) and free available chlorine residual.
Total Trihalomethanes	The sum of the concentration in milligrams per liter of the trihalomethane compounds (trichloromethane, [chloroform], dibromochloromethane, bromodichloromethane, and tribromomethane [bromoform], rounded to two significant figures
Tracer Study	A procedure for estimating hydraulic properties of the distribution system, such as residence time. Where more than one water source feeds the distribution system, tracer studies can be used to determine the zone of influence of each source
Traditional Sources of Water	'Traditional' water sources referred to in this document are primarily surface waters and ground waters that are neither brackish, saline, nor seawater.
Transmembrane Pressure	(TMP) = [(membrane inlet pressure + membrane outlet pressure in psi) ÷ 2] – (filtrate pressure in psi)
Trihalomethane	One of the family of organic compounds that can simulate the hydraulic, and in some cases, water quality behavior of water in a distribution system
Unconventional Sources of Water	Unconventional water sources referred to in this document are those that are produced during oil and gas extraction activities and coal bed methane production, or that are contained in saline aquifers
Water Distribution System Model	A computer program that can simulate the hydraulic, and in some cases, water quality behavior of water in a distribution system.
Wholesale System	A public water system that treats source water and then sells or otherwise delivers finished water to another public water system for at least 60 days per year Delivery may be through a direct connection or through the distribution system of another consecutive system

ACRONYMS

AA	Atomic Absorption
AFT	Alternate Filtration Technology
ALCR	Air-Liquid Conversion Ratio
ANSI	American National Standards Institute
AOC	Assimilable organic carbon
AOP	Advanced oxidation process
APHA	American Public Health Administration
ASTM	American Society for Testing Materials
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
BAC	Biologically Active Carbon
BAT	Best available technology
BCAA	Bromo-chloro-acetic acid
BDL	Below direction limit
BDOC	Biodegradable organic carbon
BF	Baffling factor
BMP	Best Management Practices
BOD	Biological oxygen demand
CA	Cellulose Acetate
CAM	Correlated Airflow Measurement
CCP	Comprehensive/composite correction program
CCPP	Calcium carbonate precipitation potential
CCR	Consumer Confidence Report
CDBAA	Chlorodibromoacetic acid
CFR	Code of federal regulations
CIP	Clean-in-place
CL	Control Limit
COD	Chemical oxygen demand
CPE	Comprehensive performance evaluation
CSTR	Continuous Stirred Tank Reactor
CT	Contact Time
CTA	Comprehensive technical assistance
CWS	Community water system
DAF	Dissolved air flotation
DBP	Disinfection Byproduct
DBPFP	Disinfection by-product formation potential
DBPP	Disinfection by-product precursor
DBPR	Disinfectants and Disinfection Byproducts Rule
DCAA	Dichloroacetic acid
DOC	Dissolved organic carbon
DOX	Dissolved organic halogen
DPB	Disinfection by-product
DPB1R	Stage 1 Disinfection By-Product Rule
EBCT	Empty bed contact time
EC	Enhanced coagulation
ED	Electrodialysis
EDR	Electrodialysis Reversal
EPA	Environmental Protection Agency
EPS	Extended Period Simulation
ES	Enhanced softening
ESWTR	Enhanced Surface Water Treatment Rule
ETV	Environmental Technology Verification
FACA	Federal Advisory Committee Act
FBRR	Filter Backwash Recycle Rule
FP	Formation potential
FR	Federal Register
G	Velocity gradient G
GAC	Granular activated carbon
GC	Gas chromatograph
GPCD	Gallons per capita per day
GWR	Groundwater rule
GWUDI	Groundwater Under the Direct Influence (of surface water)
HAA	Haloacetic acid
HAA5	Haloacetic acid
HAAFP	Haloacetic acid formation potential
HDT	Hydraulic detention time
HFF	Hollow Fine Fiber
HLR	Hydraulic loading rate
HPC	Heterotrophic Plate Count
ICR	Information Collection Rule
IDSE	Initial Distribution System Evaluation
IESWTR	Interim Enhanced Surface Water Treatment Rule

IMS	Integrated Membrane System
ISO	International Organization for Standardization
IVP	Integrity Verification Program
LCA	Limited compliance assistance
LCL	Lower Control Limit
LCR	Lead and Copper Rule
LED	Light Emitting Diode
LRAA	Locational Running Annual Average
LRC	Log Removal Credit
LRV	Log Removal Value
LSI	Langelier saturation index
LT1ESWTR	Stage 1 Long Term Enhanced Surface Water Treatment Rule
LT1FBR	Stage 1 Long Term Enhanced Surface Water Treatment and Filter Backwash Rule
LT2ESWTR	Stage 2 Long Term Enhanced Surface Water Treatment Rule
LTA	Limited technical assistance
LTESWTR	Long Term Enhanced Surface Water Treatment Rule
MCAA	Monochloroacetic Acid
MCF	Membrane Cartridge Filtration
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
M-DBP	Microbial and Disinfection Byproduct
MDL	Method detection limit
MF	Microfiltration
MGD	Million gallons per day
MIB	Methylisoboreol (A smell compound)
MOR	Monthly operating report
MRDL	Maximum residual disinfectant limit
MRDLG	Maximum residual disinfectant limit goal
MTBE	Methyl-tert-butyl ether
MW	Molecular weight
MWCO	Molecular weight cut off
NA	Not Applicable
NDP	Net Driving Pressure
NDPT	Non-destructive Performance Test
NDWR	National Drinking Water Regulations
NF	Nanofiltration
NOAEL	No observed adverse effects level
NOM	Natural organic matter
NPDWR	National Primary Drinking Water Regulation
NSF	National Sanitation Foundation
NTNCWS	Non-transient, non-community water system
NTU	Nephelometric turbidity unit
OEM	Original Equipment Manufacturer
PA	Polyamide
PAC	Powered activated carbon
PAC1	Polyaluminum chloride
PAN	Polyacrylonitrile
PE	Performance evaluation
PES	Polyethersulfone
PFR	Plug Flow Reactor
PODR	Point of diminishing returns
POU	Point of use
PP	Polypropylene
PPB	Parts per billion
PPM	Parts per million
PS	Polysulfone
PVC	Polyvinyl chloride
PVDF	Polyvinylidene Fluoride
PWS	Public water system
QA	Quality Assurance
QC	Quality Control
QCRV	Quality Control Release Value
RAA	Running annual average
RMP	Risk management program
RO	Reverse osmosis
SDI	Silt Density Index
SDS	Simulated distribution system
SDWA	Safe Drinking Water Act
SEM	Scanning Electron Microscopy
SERPC	Southeast Texas Regional Planning Commission
SHMP	Sodium Hexametaphosphate
SLR	Surface loading rate for filters, A.K.A. HLR
SMCL	Secondary maximum contaminant levels
SMP	Standard Monitoring Program
SOC	Synthetic organic chemical

SOR	Surface overflow rate
SSDR	Stock Solution Delivery Rate
SSS	System-Specific Study
SUVA	Specific ultraviolet absorbance
SW	Surface water
SWTR	Surface Water Treatment Rule
T	Detention time/temperature
T_{10}	Effective contact time
TBAA	Tribromoacetic acid
TC	Trichloroacetic acid
TCAA	Trichloroacetic Acid
TCEQ	Texas Commission on Environmental Quality
TCF	Temperature Correction Factor
TCPP	Total Challenge Particulate Population
TCR	Total Coliform Rule
TDS	Total Dissolved Solids
TEEX	Texas Engineering Extension Service
THM	Trihalomethane
THMFP	Trihalomethane formation potential
TMP	Transmembrane Pressure
TNCWS	Transient Noncommunity Water System
TOC	Total organic carbon
TON	Threshold odor number
TOX	Total organic halogen
TSS	Total Suspended Solids
TT	Treatment technique
TTHM	Total trihalomethanes
TTHM	Total Trihalomethanes
TTHM	Total Trihalomethanes
TWDB	Texas Water Development Board
TWUA	Texas Water Utilities Association
UCL	Upper Control Limit
UF	Ultrafiltration
UFC	Uniform formation conditions
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
UV254	Ultraviolet-254
VCF	Volumetric Concentration Factor

CONVERSION FACTORS

Pounds per Acre (lbs/ac) x 1.121 = Kilograms per Hectare (kg/ha)

Kilograms per Hectare (kg/ha) x 0.8922 = Pounds per Acre (lbs/ac)

Pound (lb) = 0.4536 Kilogram (kg)

Kilogram (kg) = 2.205 Pounds (lbs)

English ton = 0.9072 Metric tonne

Metric tonne = 1.102 English ton

Water Equivalents Table

1 Acre ft. = 43,560 cu. Ft. = 325,851 gal

1 cfs = 449 gpm = 724 Acre ft./year = .646 mgd

1 mgd = 1121 Acre ft./year

1 cubic ft. = 7.48 gal. = 62.4 lbs.

1 gal. = 8.341 lbs.

1 psi = 2.31 feet of water