GULF COAST WASTE DISPOSAL AUTHORITY

TITLE XVI WATER RECLAMATION AND REUSE PROGRAM

INDUSTRIAL WATER MANAGEMENT AND RECLAMATION PERMIAN BASIN FEASIBILITY STUDY ASSISTANCE AGREEMENT NO. R14AC60055

FUNDED IN PART BY
U.S. DEPARTMENT OF INTERIOR BUREAU OF RECLAMATION
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FINAL

MARCH 2017

LBG-GUYTON

TISCHLER/KOCUREK

ENGINEERED PIPELINE SYSTEMS

ALAN PLUMMER ASSOCIATES, INC.

1536-003-03

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GULF COAST WASTE DISPOSAL AUTHORITY
INDUSTRIAL WATER MANAGEMENT AND RECLAMATION
PERMIAN BASIN

FEASIBILITY STUDY

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LIST OF ABBREVIATIONS/ACRONYMS

°F	degrees Fahrenheit
AF	acre-feet (1AF = 7758 bbls) (1 AF = 325,851 gallons)
AF/yr	acre-feet per year
API	American Petroleum Institute
ASR	aquifer storage and recovery
AST	above-ground storage tanks
Ba	barium
bbl	barrel (1 bbl = 0.000129 AF) (1 bbl = 42 gallons)
bbl/d	barrel/day
bbl/yr	barrel/year
BEG	University of Texas Bureau of Economic Geology
$B(OH)_4$	boron, in the form of tetrahydroxyborate
BTEX	benzene, toluene, ethylbenzene, and xylene
Ca	calcium
cP	centipoise
CRMWD	Colorado River Municipal Water District
CWA	Clean Water Act
d	day
Derrington WRP	Bob Derrington Water Reclamation Plant
DGF	dissolved gas flotation
DSHS	Texas Department of State Health Services
EC	electrocoagulation
EOR	Enhanced Oil Recovery
E&P	exploration and production
ESA	Endangered Species Act
FeS	iron sulfide
ft	feet
GAC	granular activated carbon
GCD	Groundwater Control District
GCWDA	Gulf Coast Waste Disposal Authority
Great Plains	Texland Water Supply

LIST OF ABBREVIATIONS/ACRONYMS
(Continued)

H_2S	hydrogen sulfide
HCO_3-	bicarbonate
HDPE	high-density polyethylene
HF	hydraulic fracturing
Kbbl	thousand barrels
KBO_2	potassium metaborate
kgal	thousand gallons
kW-hr	kilowatt hour
LF	linear foot
MF	microfiltration
Mg	magnesium
MG	million gallons (1 MG = 3.06 AF) (1 MG = 23,800 bbls)
MG/yr	million gallons per year
MGD	million gallons per day
mg/L	milligrams per liter
mi	mile
MnS	manganese sulfide
mo	month
MOU	memorandum of understanding
MSW	municipal solid waste
NAICS	North American Industry Classification System
NF	nanofiltration
non-USDW	non-underground source of drinking water
NEPA	National Environmental Policy Act
NORM	naturally occurring radioactive material
NPDES	National Pollutant Discharge Elimination System
OBM	oil-based mud
ODC	Odessa Development Corporation
OEPP	Odessa-Ector Power Partners
O&G	oil and gas
O&G WWTP	treatment facility of wastewater from oil- and gas-fields
O&M	operation and maintenance

LIST OF ABBREVIATIONS/ACRONYMS
(Continued)

PVC	polyvinyl chloride
POTW	publicly owned treatment works
psi	pounds per square inch
Quail Run	Quail Run Energy Center
RCRA	Resource Conservation and Recovery Act
RO	reverse osmosis
RRC	Railroad Commission of Texas
SO_3	sulfite
SO_4	sulfate
South WWTP	GCA Odessa South Regional Wastewater Treatment Plant
Sr	strontium
SWD	salt water disposal well
SWIFT	State Water Implementation Fund for Texas
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
THC	Texas Historical Commission
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSS	total suspended solids
TWDB	Texas Water Development Board
TxDOT	Texas Department of Transportation
UF	ultrafiltration
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USNRC	United States Nuclear Regulatory Commission
uV	ultraviolet
WBM	water-based mud
WWTP	wastewater treatment plant

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EXECUTIVE SUMMARY

The Permian Basin in West Texas is a major production area for oil and gas. It accounts for 14 percent of the total annual oil production in the United States (statistic provided by Railroad Commission of Texas). Providing water to support oil- and gas-field operations and disposing of the aqueous by-products of drilling and production are major challenges in this semi-arid region. Other industrial operations in the region face similar challenges. This report presents the results of a feasibility study for projects designed to reduce the challenges of both supply and disposal by reclaiming industrial wastewaters and providing those waters for recycle on a regional basis.

The study was performed under a grant from the United States Department of Interior Bureau of Reclamation (Reclamation) through the Title XVI Water Reclamation and Reuse Program to the Gulf Coast Waste Disposal Authority (GCWDA). Funding to support the study was also provided by the Odessa Development Corporation (ODC).

This study focuses on water availability and use in Ector and Midland Counties. It was concluded that the most viable approach for industrial wastewater reclamation in this area is to treat flowback and produced waters from oil and gas operations so that they can be reused within the oil and gas exploration sector for hydraulic fracturing (HF).

Using reclaimed water for HF will be a benefit to all sectors of the economy in this area. It will reduce the volume of freshwater and brackish water used by the oil and gas industry so that those waters are available for other uses. In this water-short area, providing adequate water of suitable quality for municipal, agricultural, steam-electric power generation and other industrial uses is a challenge.

A secondary benefit of a reclaimed water project using oil and gas industry wastewaters will be to reduce the volume of flowback and produced waters disposed in saltwater disposal wells (SWDs). In some areas, concerns are developing that continued use of this practice at its current level will result in over-pressurization of the receiving formation, which could constrain the use of this disposal method in the future.

Three alternative recycling systems and a “No Action” alternative were evaluated. The three recycling systems have the following features in common:

- The wastewaters will be diverted for treatment after going through the tank battery at an SWD.
- The treatment process will be granular media filtration (possibly using walnut-shell filters) to reduce suspended solids and oil in the wastewater. The treated water will then be provided for reuse. It is anticipated the user will provide any additional treatment needed for down-hole use, and the cost estimates for the treatment system are based on providing only filtration. However, additional treatment could be provided, if requested, on a project-specific basis; the cost would be appropriately adjusted.
- Minimal storage will be provided at the treatment plant. The tank battery at the SWD will provide flow equalization for flows into the treatment system. The potential reclaimed water users maintain large storage reservoirs and provide the storage needed at the well during HF operations; so, large storage capacity for reclaimed water is not needed at the treatment site.

In Alternative 1 the treatment system would be located on currently undeveloped land at the site of the Odessa South Regional Wastewater Treatment Plant (South WWTP). This alternative has the advantages of facilitating blending with effluent from the South WWTP to lower total dissolved solids (TDS) concentrations and providing on-site operational staff. The disadvantages are that it will be necessary to construct a pipeline from the SWD to the South Plant, and it will be necessary to truck backwash waters associated with the treatment system to an SWD for disposal.

In Alternative 2 the treatment system would be located on or adjacent to the site of the SWD. The advantages of this alternative are that there is no requirement for a pipeline to transport wastewater for treatment and the backwash waters can be disposed in the deep well at the SWD. The disadvantages are that operators will be remotely located (at the South WWTP) and additional costs will be incurred for instrumentation and monitoring.

In Alternative 3 the treatment system would be located on or adjacent to the site of the SWD. This alternative differs from Alternative 2 in that the reclaimed water would be transported by pipeline back to the South WWTP so that it can be blended with the effluent from the South WWTP, if desired.

In the fourth alternative, the “No Action” Alternative, exploration and production (E&P) companies would continue to rely on fresh and brackish groundwater for HF and to dispose all wastewaters in SWDs.

Based on the analyses performed for this study, the preferred alternative is Alternative 2. However, depending on the location of the SWD providing wastewaters to be treated, the locations of the fields to receive the reclaimed water, and the preference of the participating E&P company(ies) with respect to the quality of water used for HF, either Alternative 1 or Alternative 3 is also viable. The only potentially negative consideration with respect to Alternatives 1 and 3 (due to cost) occurs if the treatment system is small [around 6,000 bbl/d (0.25 MGD)] and the pipeline length is relatively long (around 5 miles).

Alternative 2, the preferred alternative, locates the treatment system on or adjacent to the site of the SWD and does not provide the ability to blend the reclaimed water with the South WWTP effluent. This is the least-cost alternative, and there are additional advantages:

- It will be convenient to transfer the partially treated wastewater from the SWD to the treatment system.
- It will be convenient to dispose of the backwash residual in the SWD deep well.
- A third-party pipeline owner/operator will not be required.
- The permitting and approvals associated with constructing a pipeline will not be required.
- It would be relatively simple to convert Alternative 2 to Alternative 3 at a later time, if blending with effluent from the South WWTP becomes desirable.

The costs for the reclaimed water system consist of both capital costs and operation and maintenance (O&M) costs. The cost estimates assume capital costs will be financed over a two-year period. After the debt is repaid, the cost per barrel of water supplied will decrease dramatically.

The costs can also be categorized in terms of fixed costs and variable costs, as follows:

- The fixed costs are the debt repayment and a portion of the O&M costs. Any contractual agreement for system operation will provide that the fixed costs will be paid on a monthly basis, regardless of the volume of water purchased.
- The remainder of the O&M costs constitutes the variable costs. These costs will be recovered based on the volume of water that is sold.

Table E-1 summarizes the cost per barrel of water provided by the preferred alternative. Fixed costs before and after retirement of the debt service and the variable cost are presented for treatment facilities with capacities ranging from 6,000-to-24,000 bbl/d.

Table E-1. Opinion of Cost of Preferred Alternative
Fixed Cost, Variable Cost, and Cost per Barrel of Reclaimed Water

Facility Capacity (bbl/d)	Fixed Cost ($/month)		Variable Cost[2] ($/mo)	Unit Cost[2] ($/bbl)	
	With Debt Service[1]	Excluding Debt Service		During Debt Service[1]	After Debt Service
6,000	$74,000	$ 600	$ 6,000	$0.44	$0.03
12,000	$131,000	$1,300	$11,000	$0.39	$0.03
24,000	$213,000	$2,400	$22,000	$0.32	$0.03

(1)Debt service is repaid in 2 years.
(2)Assumes full utilization of the facility.

The participants in the project will be the E&P company(ies); the SWD owner/operator; and GCWDA. Their respective roles are discussed below.

The E&P company(ies) will deliver wastewater to an SWD. The E&P company(ies) will pay the SWD the normal disposal cost. Once the E&P company(ies) picks up the reclaimed water, all facilities associated with moving the water to, within, or between fields will be owned and operated by the respective E&P company. This includes pipelines, pump stations, and storage pits.

GCWDA will own and operate the reclaimed water treatment system pursuant to a contract with the E&P company(ies). Initially, GCWDA will fund capital costs. The repayment period for the capital costs will be short – probably no more than two years. The E&P company(ies) will reimburse GCWDA a fixed monthly amount for debt repayment and fixed O&M costs. The remainder of the O&M costs will be reimbursed based on the volume of wastewater treated.

The SWD owner/operator will accept wastewater and process it through those components of its system that reduce settleable solids and free oil. When requested, the

SWD will divert the partially treated wastewater to the GCWDA treatment system. It is anticipated there will be no charge to the E&P company(ies) or GCWDA for the diverted water since the SWD will have the cost savings of the deferred expense of deep-well injection.

Implementation of the proposed project will contribute to the long-term viability of an oil and gas industry in the Permian Basin that produces cost-competitive oil and gas. The current reliance on groundwater resources carries with it a measure of risk that those resources will be exhausted, either permanently or in times of drought. There is no such risk of resource exhaustion associated with the use of the reclaimed water provided by the proposed project. Furthermore, the success of the proposed project could serve as a model for much more extensive use of reclaimed waters throughout the Permian Basin.

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1 INTRODUCTION

The Permian Basin in West Texas is a major production area for oil and gas. It accounts for 14 percent of the total annual oil production in the United States (Railroad Commission of Texas statistics). Providing water to support oil and gas field operations and disposing of the aqueous by-products of drilling and production are major challenges in this semi-arid region. Other industrial operations in the region face similar challenges. This report presents the results of a feasibility study for projects designed to reduce the challenges of both supply and disposal by reclaiming wastewaters and providing those waters for recycle on a regional basis.

The study was performed under a grant from the United States Department of Interior Bureau of Reclamation (Reclamation) through the Title XVI Water Reclamation and Reuse Program to the Gulf Coast Waste Disposal Authority (GCWDA). Funding to support the study was also provided by the Odessa Development Corporation (ODC).

Water management and reclamation projects in Ector County and Midland County, Texas, are the focus of the study because the center of operations for oil and gas exploration and production in the Permian Basin is in Ector and Midland Counties. In addition, these counties are where the majority of the population of the Permian Basin resides. Conditions and information for the larger Permian Basin are also presented in this report to provide context for the study recommendations.

The feasibility of various regional system projects using non-potable water sources (treated wastewaters and brackish groundwaters) to meet industrial water needs, including oil and gas exploration and production, by establishing centralized collection, treatment, and distribution systems was evaluated. Information that was considered when evaluating the feasibility of alternative projects is as follows:

- Available water sources;
- Quantity and quality requirements of water needs;
- Potential alternatives for treatment, transport, and storage; and
- Estimated cost and feasibility for specific alternatives in Ector and Midland Counties.

The results of the feasibility study and recommendations are presented in this report.

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2 DESCRIPTION OF STUDY AREA

This chapter describes the project participants and the study area. Key physical, socio-economic, and environmental characteristics of the study area are described.

2.1 PROJECT PARTICIPANTS

The project participants of this study were comprised of three organizations that provide financial support and an Advisory Committee that consisted of representatives of various stakeholders. The study was managed by GCWDA, which provided in-kind contributions. Financial support was also provided by ODC and Reclamation. The Advisory Committee was comprised of eleven individuals who work in the Permian Basin and are knowledgeable about the needs of, and the activities conducted in, Ector and Midland Counties.

2.1.1 Gulf Coast Waste Disposal Authority

The GCWDA is a government agency that has the authority to own and operate wastewater treatment facilities and related appurtenances throughout the State of Texas. GCWDA owns and operates four regional wastewater treatment facilities that process liquid waste derived from both industrial and municipal operations. One of the GCWDA treatment facilities, the Odessa South Regional Wastewater Treatment Plant (South WWTP), is located in Odessa, Texas.

In 2013, GCWDA was granted the right to provide additional services. GCWDA may now build, own, and operate water systems to provide non-potable water supplies. GCWDA's intent in pursuing the development of these water systems is to conserve drinking water for human use in Texas by providing industries access to non-traditional sources of water (GCWDA 2015).

2.1.2 Odessa Development Corporation

The ODC facilitates economic development in Odessa. It operates under a contract from the City of Odessa Chamber of Commerce. Five organizations are represented on the Economic Development Team of the ODC. The organizations are as follows:

- Ector County
- Ector County Hospital District
- City of Odessa
- Odessa College
- Ector County Independent School District

The activities conducted by the ODC are reviewed by the City of Odessa City Council. Actions approved by the ODC must be ratified and approved by the Odessa City Council.

2.1.3 Advisory Committee

The Advisory Committee was formed to assist with the compilation of information and verification of data, as well as to provide advice regarding the concepts, conclusions, and recommendations developed by this study. The members on the Advisory Committee represented various stakeholders. Each member's name and their affiliation are presented in Table 2.1.

Table 2.1 Advisory Committee

Name	Affiliation
DeLynn Ano	RL Environmental, Inc.
Jim Breaux	Odessa Development Corporation
Dennis Danzik	RDX Technologies Corporation
Nick Fowler	Industry
John Grant	Colorado River Municipal Water District
Ian Kerr	Kerr Energy
Thomas Kerr	City of Odessa Utilities
Mike Robinson	Odessa-Ector Power Partners
Armando Rodriquez	Ector County
Ben Shepperd	Permian Basin Petroleum Assoc.
Heather Tash	Concho Resources, Inc.

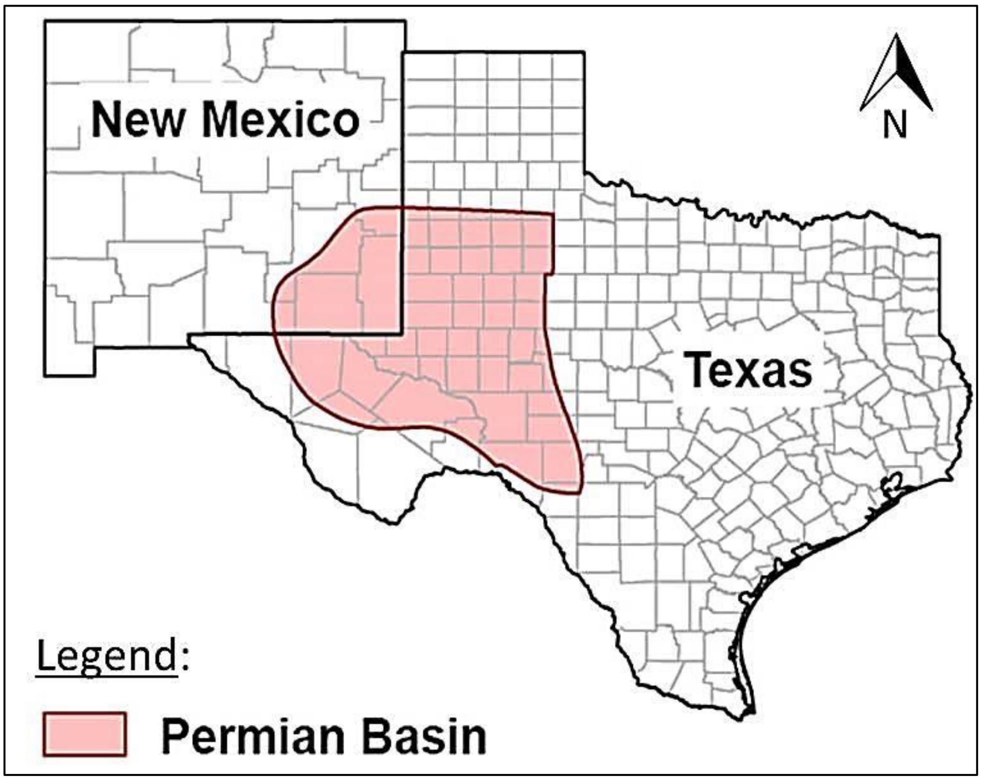
2.2 STUDY AREA

The study area for this project is the Permian Basin with a focus on Ector and Midland Counties. The largest cities in the study area are Odessa, which is in Ector County; and Midland, which is in Midland County.

2.2.1 The Permian Basin

The Permian Basin is a region in western Texas and southeastern New Mexico. The region is approximately 250 miles wide and 300 miles long. The boundaries of the Permian Basin are presented on Figure 2.1.

Figure 2.1 Boundaries of Permian Basin

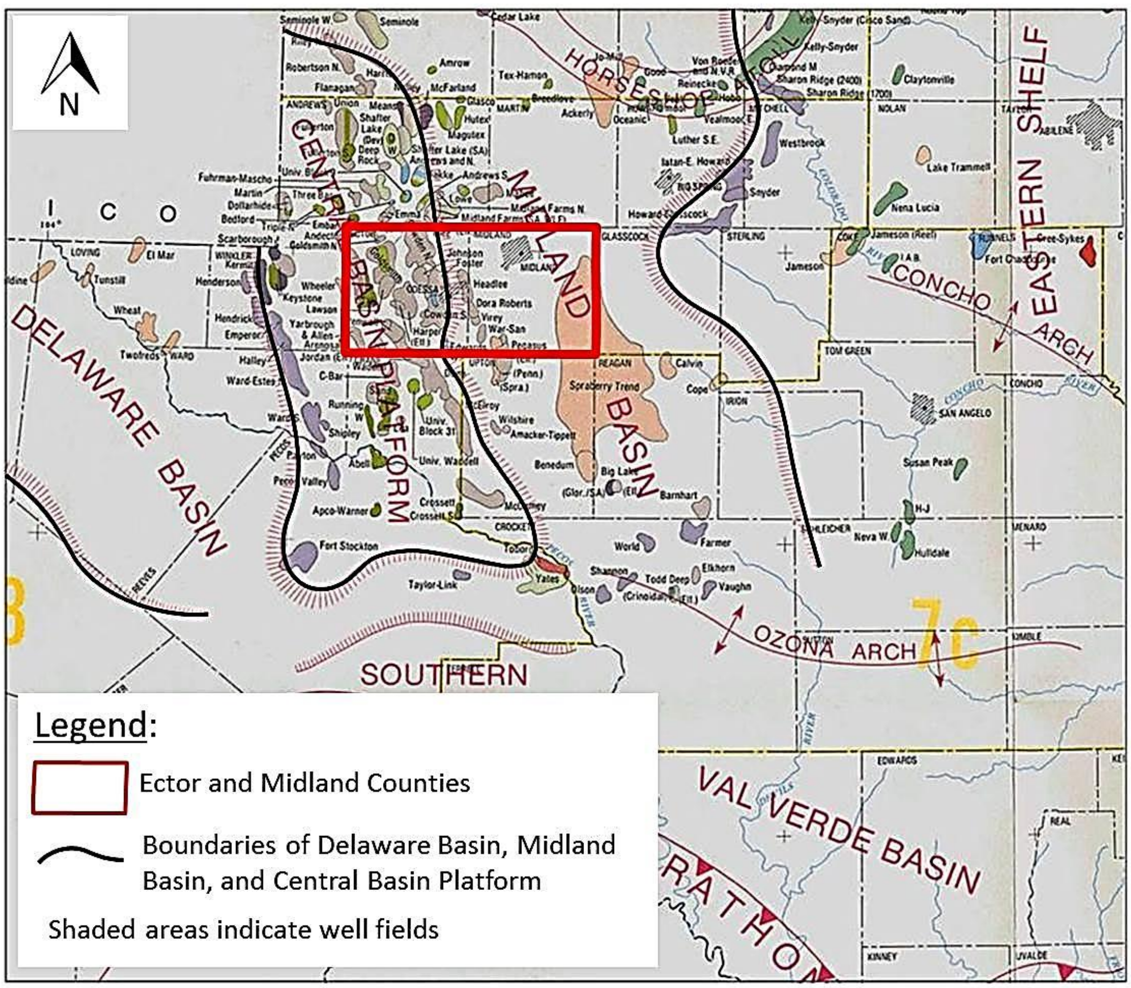


The climate is semi-arid, with an average rainfall of approximately 11-20 inches per year. Precipitation and average runoff increase to the east throughout the Permian Basin (Freese 2010). The topography of the area is mostly flat, with a gentle dip towards the southeast (Bureau of Economic Geology 1996).

The Permian Basin is defined by the subsurface accumulation of Permian Age (approximately 299-251 million years ago) sediments, which are largely fine-grained sandstone, limestone, and shale. These rocks have long been a source of hydrocarbons and minerals to the region.

Oil and gas wells are currently found throughout the Permian Basin. The Permian Basin produced over 270 million barrels (bbls) of oil in 2010 and 280 million bbls of oil in 2011 (RRC 2014a). The Permian Basin accounts for 14% of the nation's crude oil and 57% of Texas' crude oil (RRC 2014a). The major historic oil reservoirs are presented on Figure 2.2.

Figure 2.2 Key Structural Areas and Major Historic Oil Reservoirs in the Permian Basin



Modified from: Galloway et al. 1983

The three distinct geological structures within the Permian Basin are identified as the Midland Basin, Delaware Basin, and Central Basin Platform. The characteristics of each structural area impact the nature of the hydrocarbons found there. (SEPM STRATA 2013). Figure 2.2 shows the locations of these geological structures.

Historically, oil and gas were produced from vertical wells throughout the Permian Basin. The development of technologies that allow for the drilling of horizontal well bores and the fracturing of oil- and gas-bearing strata has opened up substantial opportunities to access and develop major new supplies of oil and gas in the Permian Basin. Horizontal wells are significantly longer than vertical wells and use larger amounts of resources, including water, in their development.

A map of producing oil and gas wells in West Texas is depicted on Figure 2.3. As indicated on Figure 2.3, in Ector and Midland Counties much more oil is produced than gas.

2.2.2 Texas Water Development Board Region F

In 1950, the Texas Legislature created the Texas Water Development Board (TWDB) to develop water supplies and prepare plans to meet the State's future water needs. In 1997, the legislature established a new water planning process that is based on the use of regional planning groups.

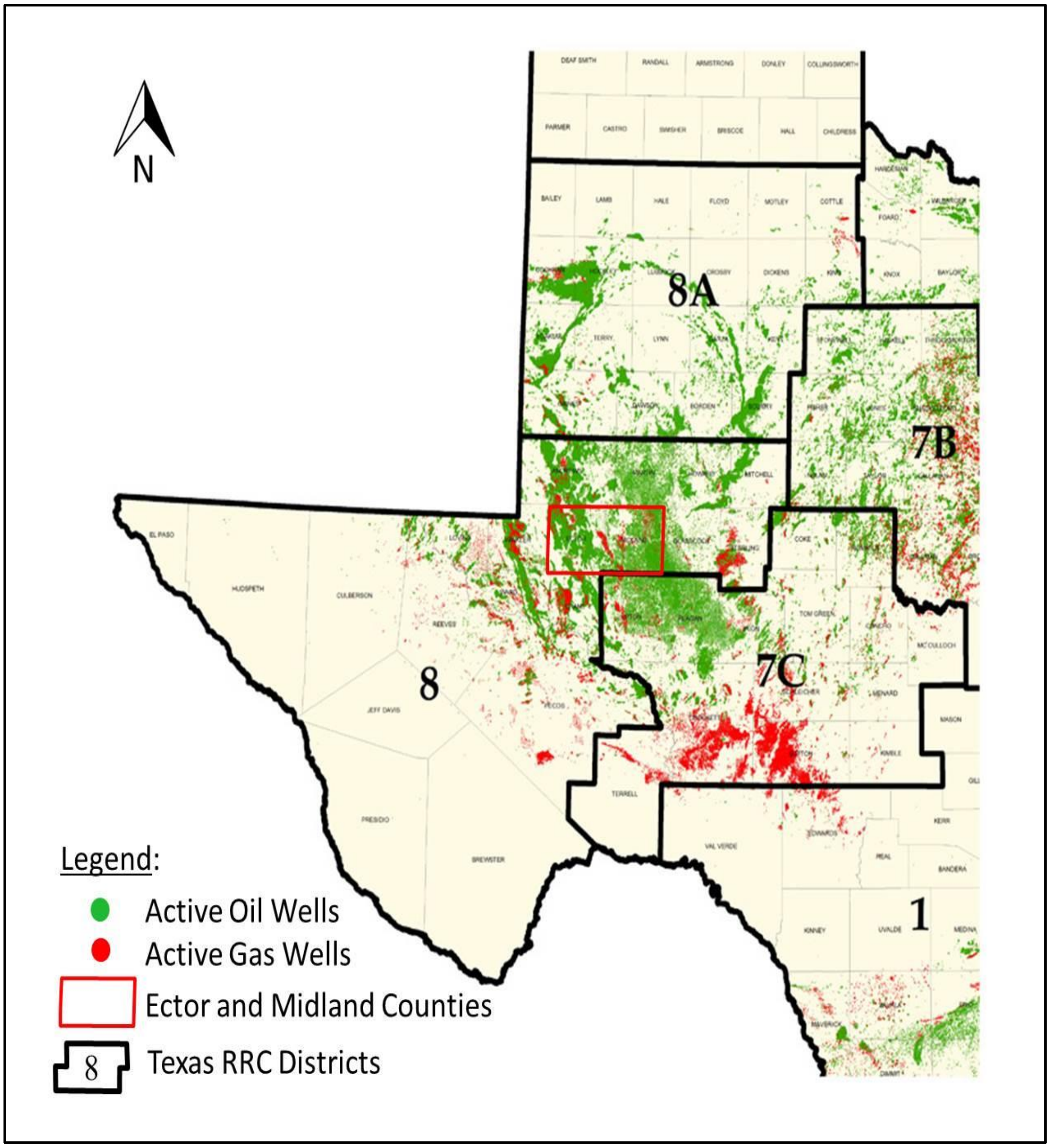
The majority of the counties in the Permian Basin are in the TWDB Region F Regional Water Planning Area. The area that is in Region F is presented on Figure 2.4.

Tasks that are assigned by the TWDB to the planning groups for their respective regions include the following:

- Quantify current and projected population and water demands over a 50-year planning horizon
- Evaluate and quantify current water supplies
- Identify water surpluses and needs
- Identify plans to meet the needs

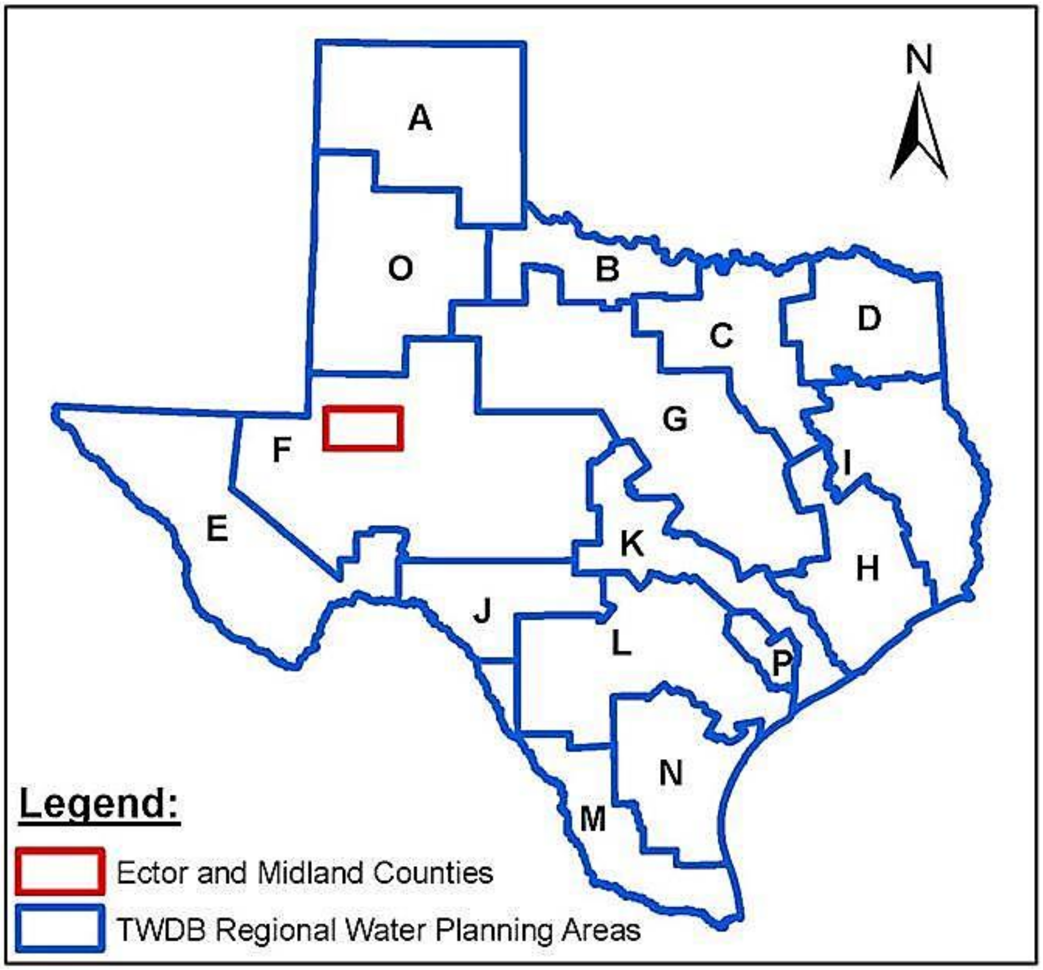
The plans are up-dated every five years. The latest approved water plan for Region F was completed in 2016. Information and data from the 2016 plan are presented in this report.

Figure 2.3 Oil Wells and Gas Wells



Source: RRC 2014a

Figure 2.4 Texas Water Development Board Regional Water Planning Areas



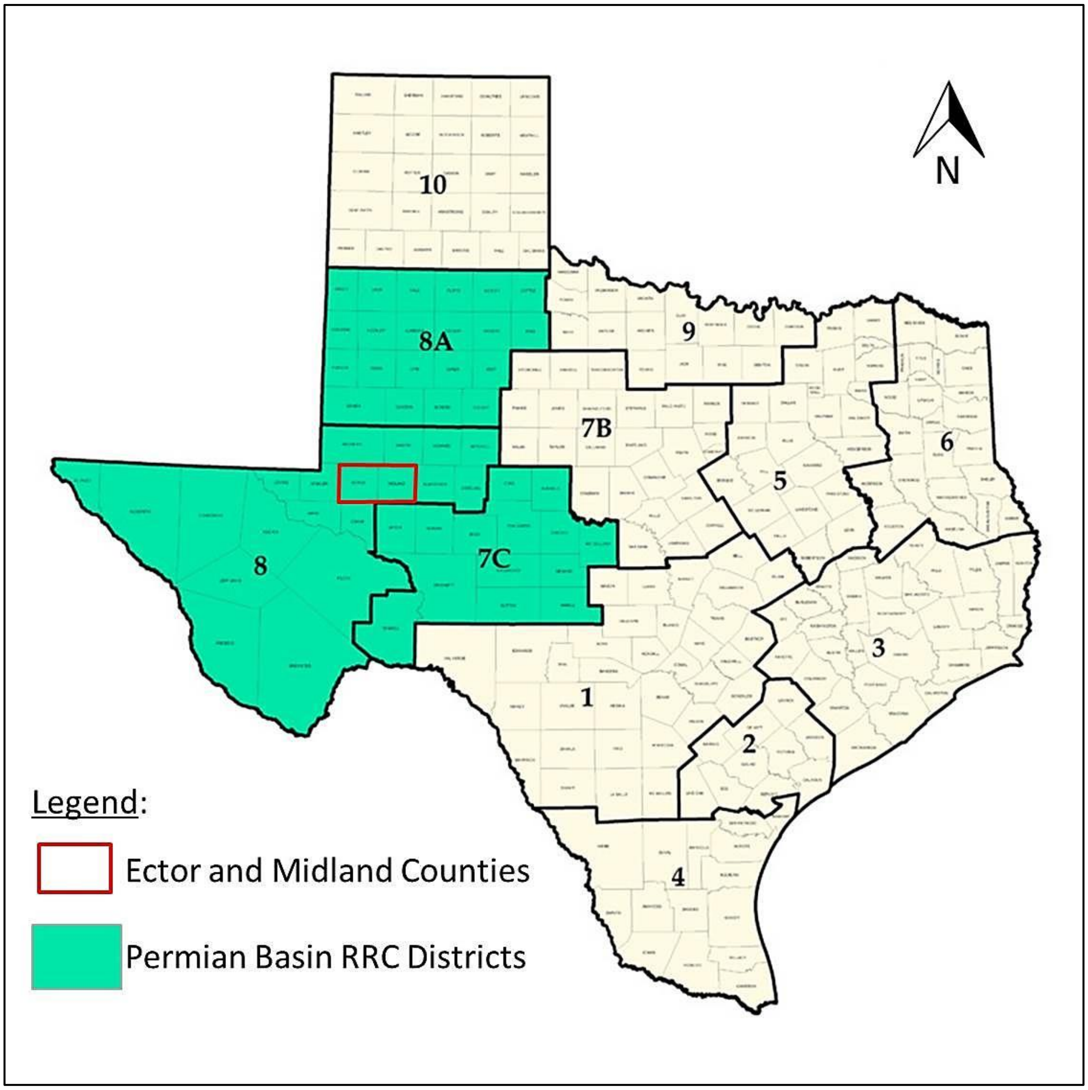
Source: Texas Water Development Board, 2015

2.2.3 Ector and Midland Counties

Ector and Midland Counties are the center of operations for most activities in the Permian Basin. The major cities in the study area are Odessa, which is in Ector County, and Midland, which is in Midland County. The populations of Odessa and Midland Counties recorded in the 2010 Census are 137,130 and 136,872, respectively. (United States Census Bureau 2014).

Ector and Midland Counties are within Regional Water Planning Area F as defined by the TWDB, and they are within District 8 as defined by the Railroad Commission of Texas (RRC) Oil and Gas Division. Figure 2.5 presents the boundaries of Texas RRC Districts. The location of Ector and Midland Counties is indicated by the red box.

Figure 2.5 Railroad Commission of Texas Oil and Gas Division District Boundaries



3 EXISTING WATER SOURCES

The sources of water in Ector and Midland Counties are managed by wholesale water providers. Available waters are groundwater, surface water, and treated wastewaters, including wastewater generated from oil and gas operations, industrial operations, and municipalities. This chapter presents information on both availability and quality of waters in Ector and Midland Counties. The primary sources of the information presented in this chapter are the *2016 Region F Water Plan* and a 2011 report by Reclamation concerning produced water in the western United States (Guerra and Dundorf 2011).

3.1 WATER PROVIDERS

There are three relevant wholesale water providers for Ector and Midland Counties: Colorado River Municipal Water District (CRMWD), City of Odessa, and Texland Great Plains Water Supply (Great Plains) (Freese 2015). The City of Midland is a retail water provider in Midland County.

CRMWD supplies water from the surface water supplies in Lake J.B. Thomas, E.V. Spence Reservoir, and O.H. Ivie Reservoir. It also operates well fields in Ward and Martin Counties. CRMWD transmits water to the cities and customers it supplies via more than 600 miles of 18-inch to 60-inch water transmission lines.

The City of Odessa is a CRMWD member city; all of its water supplies are provided by CRMWD. The City of Odessa sells treated water to the Ector County Utility District, rural residents, municipal irrigation users, and industrial users in Ector County. (Freese 2015).

Great Plains provides water from wells in the Ogallala Aquifer in Andrews County. Great Plains owns and operates an extensive distribution system and provides water for oil and gas operations throughout Region F, a steam-electric operation in Ector County, and some rural residents in Ector County (Freese 2015).

Midland's municipal supply comes from CRMWD and well fields in Andrews, Loving, Martin, Midland, and Winkler Counties. In 2013, the City of Midland developed additional water supplies when the City completed the construction of more than 70 miles of pipeline from 44 groundwater production wells located in Winkler and Loving

Counties. Additional property has been acquired by the City of Midland in Winkler County. The City plans to construct more groundwater production wells to augment their water supply.

3.2 SOURCES OF WATER

The sources of water for Ector County and Midland County are fresh and brackish groundwater; surface waters from O.H. Ivie Reservoir, E.V. Spence Reservoir, and Lake J.B. Thomas; and treated wastewaters. Each source is discussed in more detail below.

For this report, water is considered fresh when it contains less than 1,000 milligrams per liter (mg/L) total dissolved solids (TDS). Brackish water has a TDS concentration of up to 35,000 mg/L. Water with a TDS concentration of greater than 35,000 mg/L is classified as saline.

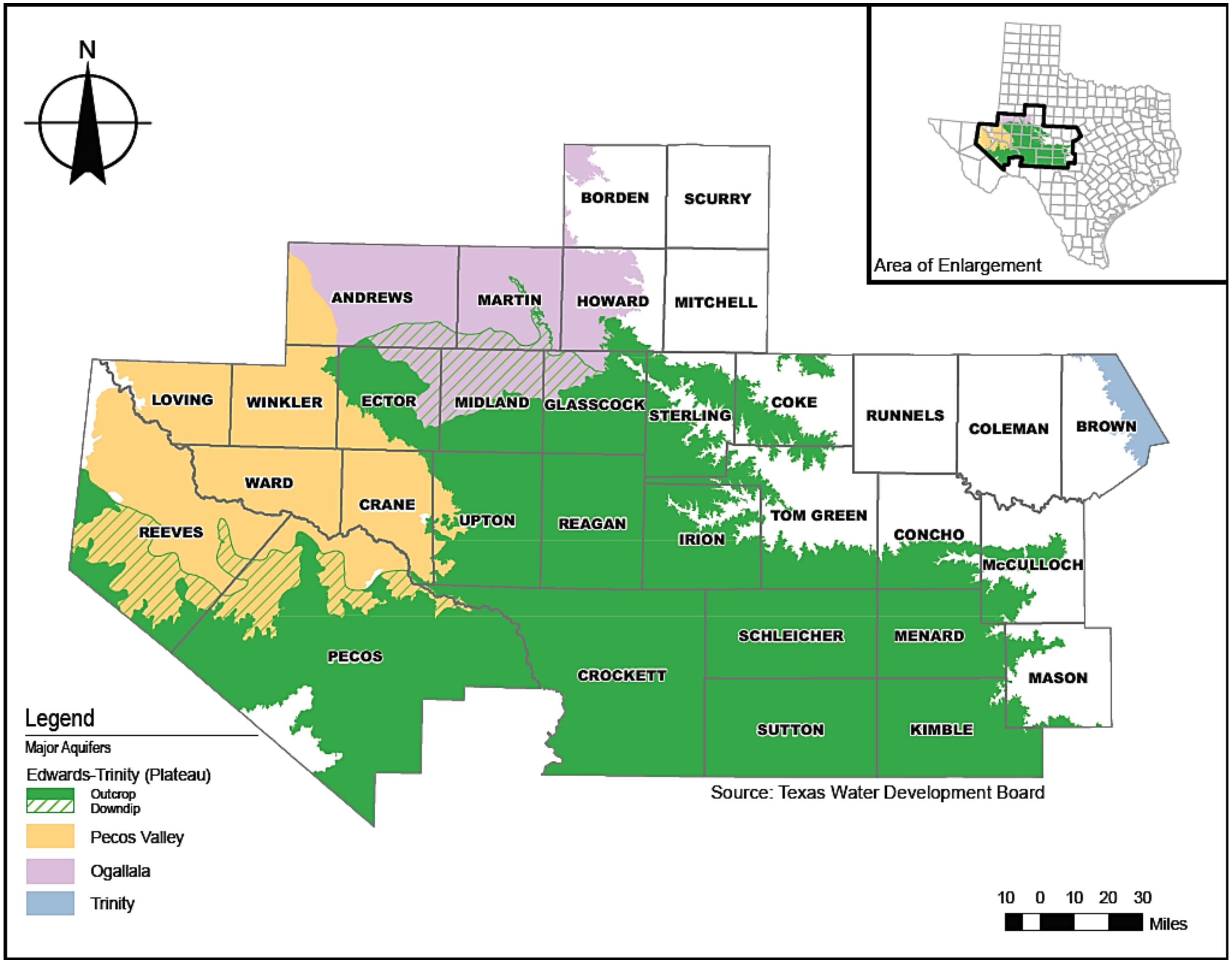
3.2.1 Groundwater

Groundwater is the primary water source for Region F. Groundwater resources supplied approximately 70% of the total water used in the region during the period from 2005 to 2010. An average of approximately 416,000 acre-feet per year (AF/yr) [370 million gallons per day (MGD)] was provided. It is projected that in 2040 29% of the water used in Ector County and 81% of the water used in Midland County will come from groundwater[1].

Three major aquifers supply groundwater to Ector and Midland Counties. The primary aquifer is the Edwards-Trinity Aquifer. Some water supplies are also obtained from the Ogallala Aquifer to the north, and the Pecos Valley Aquifer to the west. (see Figure 3.1). A minor aquifer in the region is the Dockum Aquifer. This aquifer underlies Ector County and the western margin of Midland County (see Figure 3.2) (Freese 2015).

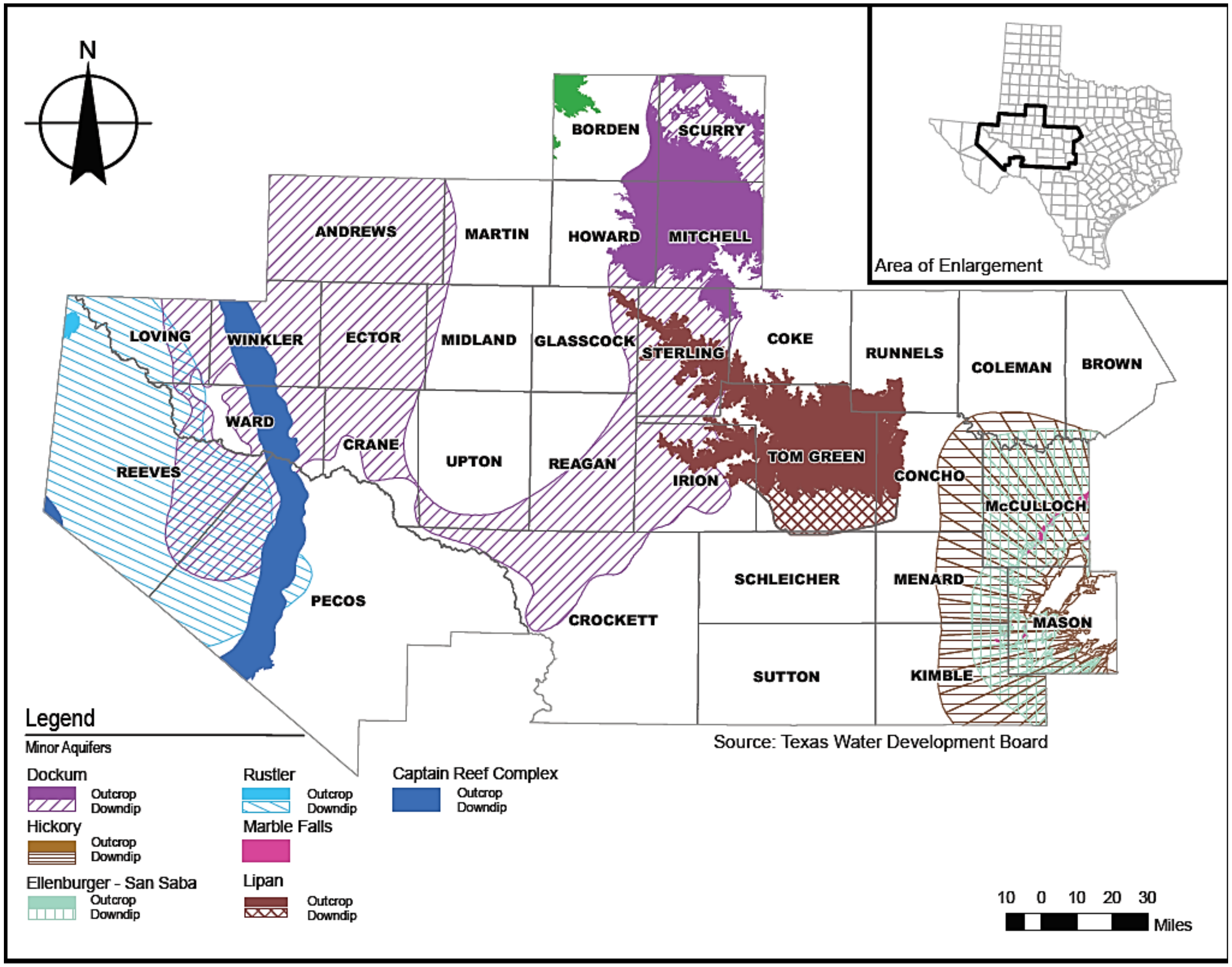
[1]These percentages are based on projections of future reuse, future conservation, and subordination. Subordination is a practice whereby downstream senior water rights holders in the Lower Colorado River Basin do not make priority calls for water in the Upper Colorado River Basin.

Figure 3.1 Major Aquifers



Source: Freese 2010

Figure 3 2 Minor Aquifers



Source: Freese 2010

3.2.1.1 Edwards-Trinity Aquifer

The Edwards-Trinity Aquifer system is one of the most extensive aquifers in Region F. Approximately 41% of groundwater produced in Region F is from the Edwards-Trinity Aquifer. Approximately 86% of the Edwards-Trinity water is used for irrigation and livestock watering. It is also commonly used for public drinking water supply; approximately 12% is used for municipal supply. Long-term water level declines have been observed in areas of heavy pumping, which includes both Ector and Midland Counties.

The aquifer is divided into the overlying Edwards Formation and the Trinity Formation below. These two formations vary in quality and productivity.

Waters from the Edwards generally have better water quality than waters from the Trinity. Average concentrations of TDS in the Edwards waters are usually less than 500 mg/L but can exceed 1,000 mg/L in some areas. In most of the region, the Edwards produces water at higher rates than the Trinity (Freese 2015).

Waters from the Trinity are used primarily in the northern third of Region F, including Midland County. The waters from the Trinity exhibit a TDS range of 500 mg/L to greater than 1000 mg/L. TDS concentrations generally increase towards the west. Trinity waters commonly contain high concentrations of calcium bicarbonate and sulfate (Freese 2015).

3.2.1.2 Ogallala Aquifer

The Ogallala Aquifer is one of the largest groundwater sources in the United States. It extends from South Dakota to Texas. The counties in the study area, Ector and Midland, are found at the southernmost extent of the Ogallala Aquifer. The Ogallala provides approximately 24% of the water used in Region F. Eighty-five percent of the groundwater withdrawn from this aquifer is used for agricultural irrigation and livestock watering. Approximately 12% of the Ogallala water is used for municipal purposes.

Water quality in the portion of the Ogallala that supplies Ector and Midland Counties tends to be brackish. However, there are wells in this portion of the Ogallala that produce water with TDS concentrations less than 1,000 mg/L. (LBG-Guyton 2003) The aquifer formation in the southernmost portion of the Ogallala is thin. Therefore, it may not support high capacity production wells. (LBG-Guyton 2003)

3.2.1.3 Pecos Valley Aquifer

In the study area, the Pecos Valley Aquifer occurs in only the southwestern extent of Ector County. Midland County is not underlain by the Pecos Valley Aquifer. Throughout Region F, 80% of the water from the Pecos Valley Aquifer is used for agricultural purposes. Lesser uses are municipal supply and power generation.

In general, the water in Pecos Valley tends to be brackish. However, there are extensive areas on the eastern edge of the aquifer where the Pecos Valley water contains less than 1,000 mg/L TDS (LBG-Guyton 2003).

3.2.1.4 Dockum Aquifer

The Dockum Aquifer underlies all of Ector County and the western margin of Midland County. Its water is used extensively for oil field operations. Although there is freshwater in outcrop areas located to the northeast of the study area, for most of its extent, the Dockum is brackish. The average concentration of TDS in water from the Dockum Aquifer is greater than 2,500 mg/L in Ector County (Freese 2015).

3.2.2 <u>Surface Water</u>

Surface water sources that supply Ector and Midland Counties are O.H. Ivie Reservoir, E.V. Spence Reservoir, and Lake J.B. Thomas. These lakes are managed by the CRMWD.

A recent drought in Texas impacted the availability of water from these surface water supplies. On February 5, 2015, O.H. Ivie Reservoir was at 14% capacity. E.V. Spence Reservoir was at 2.1% capacity, and Lake J.B. Thomas was at 45% capacity.

Water quality in Lake J.B. Thomas is such that the water can generally be used for all purposes. Waters in O.H. Ivie Reservoir and E.V. Spence Reservoir need to be managed when used for municipal purposes because concentrations of TDS, chloride, and sulfate can exceed secondary standards for drinking water at times.

3.2.3 <u>Wastewaters</u>

Wastewater from oil and gas production, including hydraulic fracturing (HF) flowback, oil and gas produced water, and treated wastewaters from industrial and/or municipal sources are present in Ector and Midland Counties. Wastewater constitutes another source that may be available to meet water needs. Descriptions of current water reclamation projects are presented in Chapter 5.

3.2.3.1 Oil and Gas Produced Water and Hydraulic Fracturing Flowback Water

Two of the types of wastewater produced from oil and gas wells during the production of hydrocarbons are produced water and HF flowback water. The two types vary in composition, when the water is generated during the production process, and in volume.

Produced Water

Produced water is formation water that is brought to the surface along with the production of hydrocarbons. This water is generated during both conventional and unconventional oil and gas production. The volume and quality of produced water varies based on the geochemistry of the producing formation, geographical location, production stage of the well, and type of hydrocarbon produced (oil, gas, or condensate).

In most oil and gas fields in North America, some amount of water is produced with hydrocarbons throughout the life of the well. Reclamation reports that, on average, approximately 7-10 bbls (290-420 gallons) of water are produced for every barrel of crude oil, with oil reservoirs commonly producing more water than gas reservoirs. Older wells and oil wells undergoing enhanced oil recovery (i.e., waterflooding) generate the most produced water. Produced water is the largest waste-stream associated with oil and gas production (Guerra and Dundorf 2011).

As a whole, Texas is the largest generator of produced water in the country. In 2010, Texas generated approximately 237 million AF [1.84 x 10^{12} bbls; 77.3 million gallons (MG)] of produced water (Guerra and Dundorf 2011).

Ector County produced approximately 28.4 million bbls of oil in 2013 (RRC 2014). Based on the Reclamation estimate of the average amount of water produced for every barrel of crude oil, approximately 26,000 AF (200 million bbls; 8500 MG) to 37,000 AF (290 million bbls; 12,000 MG) of produced water was generated in Ector County in 2013. Midland County produced approximately 23.6 million bbls oil in 2013 (RRC 2014), which would generate approximately 21,000 AF (160 million bbls;6800 MG) to 30,000 AF (230 million bbls; 9800 MG) of produced water.

The general water quality characteristics of produced water quality are provided in an extensive online database published by the USGS. However the data are not qualified with the type of well, age of well, sampling technique, or analytical methods. Constituents found in produced water may include suspended solids, salts, inorganic compounds, organic compounds, radioactive material, and chemical additives, as well as bacteria and iron.

Produced waters commonly have high concentrations of dissolved salts, especially in basins in the southwest and southern United States. Produced waters in the Permian Basin have a median TDS concentration of almost 100,000 mg/L (Guerra and Dundorf 2011).

The dominant salt in produced waters in the Permian Basin is sodium chloride. Potassium, magnesium, and calcium salts are also present. Bicarbonate, barium and strontium are common constituents in produced water, although in smaller amounts (Guerra and Dundorf 2011).

Heavy metals may be found in produced water. Although these metals make up less than 1% of the TDS in produced water, they are important due to their regulation in beneficial use standards and, potentially, can cause the water to be classified as a hazardous substance if concentrated during treatment. The most commonly occurring heavy metals in produced waters are arsenic (up to 151 mg/L) and lead (up to 10 mg/L), although beryllium, cadmium, and mercury may be present (Guerra and Dundorf 2011).

Organic constituents in produced water include insoluble and soluble organic compounds. Produced water from oil fields may contain low levels of volatile organic compounds such as benzene, toluene, ethylbenzene, and xylene (BTEX). Total organic carbon (TOC) can range from zero to up to 1,700 mg/L in produced water. Oil can also exist as discrete oil droplets suspended in water. The total oil content of produced water has been measured at up to 550 mg/L (Guerra and Dundorf 2011).

In some oil- and gas-bearing formations naturally occurring radioactive materials (NORM) are present. These materials dissolve into waters geologically present in the formation; and, subsequently, NORM is present in produced water. The primary radioactive material in produced water is radon. Uranium, thallium, and radium are present in some produced waters. In Ector and Midland Counties, NORM is at the background level or marginally detectable. Produced water occurring just to the southeast of Midland County has radioactive levels of up to 5 times the median background level (Guerra and Dundorf 2011).

In addition to naturally occurring organic and inorganic compounds, chemical additives associated with oil and gas production are present in produced water. Chemicals are added to the oil and gas reservoir to prevent or minimize a variety of problems, including corrosion, mineral deposition, hydrate formation, foaming, and paraffin formation. Chemicals used for these purposes include the following: amine inidazolines and salts; ammonium salts; nitrogen; bactericides; ethylene glycol; methanol; triethylene glycol; phosphate esters; acid polymers; oxyalklated resins; silicones; and polyglycol esters (Guerra and Dundorf 2011).

Hydraulic Fracturing Flowback Water

In the process of HF, water, frequently fresh or only slightly brackish, is mixed with a proppant (sand or ceramics that are used to keep the fractures open) and chemicals. The mixture is injected into an oil- or gas-bearing formation under high pressure in order to create fractures in the rock and allow hydrocarbons to be produced. A significant portion of the HF fluid that is injected into the formation is recovered along with the hydrocarbons; these reclaimed HF fluids are called "flowback water" (Guerra and Dundorf 2011).

HF flowback water differs from produced water in two primary ways. First, flowback water is only produced for a short time after a well is hydraulically fractured. Nicot et. al. (2012) found that wells in the Permian Basin usually recover 100% of HF flowback water within a year. Secondly, this water is fresher and requires less treatment than much of the produced water, if the water injected for HF is relatively fresh.

Both vertical and horizontal wells can be hydraulically fractured. Horizontal wells commonly require larger volumes of water, usually from 48,000 to 240,000 bbls (2 to10 MG; 0.65 to 3.3 AF) of water per well. The BEG estimates that, in 2011, the average horizontal well in the Permian Basin that had a productive interval of 6,000 ft. used 120,000 bbls (5 MG;15 AF) per well for hydraulic fracturing (Nicot et al. 2012). Longer wells would require more HF fluid and, therefore, produce more HF flowback fluid.

Midland County has recently been the location of very active HF operations. Wells in Midland County target the Wolfcamp, Sprayberry, and Cline formations. These are shale formations that are developed via horizontal wells that utilize high volumes of HF fluids. Midland County uses more HF fluids and produces more HF flowback water than Ector County at this time, as evidenced by the fact that four times more drilling permits were submitted for horizontal wells in Midland County than in Ector County in 2014.

3.2.3.2 Wastewaters from Industrial and Municipal Sources

Industrial and municipal wastewaters are additional sources of water for reuse. GCWDA treats a combination of municipal and industrial wastewaters from the City of Odessa. The City of Odessa, City of Midland, and City of Goldsmith treat municipal wastewater. Also, the Quail Run Energy Center (Quail Run) treats the industrial wastewaters generated by this combined-cycle power generating facility.

GCWDA owns and operates the Odessa South Regional Wastewater Treatment Plant (South WWTP), which is located in Ector County. The permitted discharge flow limit of treated wastewater for the South WWTP is 5.6 MGD. Treated wastewater quality requirements are designed to protect the aquatic life uses of the receiving stream. Very low levels of oxygen-demanding constituents, nutrients, some metals, and bacteria may be present in the treated wastewater.

The City of Odessa owns and operates the Bob Derrington Water Reclamation Plant (Derrington WRP), which is located in Midland County. The permitted annual average discharge flow limit of treated wastewater for the Derrington WRP is 11.0 MGD. However, the annual average treatment capacity of the Derrington WRP is 12.7 MGD. Treated wastewater quality requirements are designed to protect the aquatic life uses of the receiving waters. Very low levels of oxygen-demanding constituents, nutrients, some metals, and bacteria may be present in the treated wastewater.

The City of Midland owns and operates the City of Midland Wastewater Treatment Plant (Midland WWTP), which is located in Midland County. The Midland WWTP is authorized to dispose of treated wastewater at a daily average flow limit of 21 MGD via surface irrigation on pasture and cultivated land that has no public access. Treated wastewater quality requirements for the Midland WWTP are less stringent than the requirements for the South WWTP and the Derrington WRP. Higher levels of oxygen-demanding constituents, nutrients, some metals, and bacteria are expected to be present in the Midland WWTP treated wastewater than what may be present in the treated wastewater from the South WWTP and the Derrington WRP.

The City of Goldsmith owns and operates the City of Goldsmith Wastewater Treatment Facility (Goldsmith WWTP), which is located in Ector County. The Goldsmith WWTP is authorized to dispose of treated wastewater at a daily average flow limit of 0.031 MGD via surface irrigation on land that has no public access. Treated wastewater quality requirements for the Goldsmith

WWTP are less stringent than the requirements for the South WWTP and the Derrington WRP. Higher levels of oxygen-demanding constituents, nutrients, some metals, and bacteria are expected to be present in the Goldsmith WWTP treated wastewater than what may be present in the treated wastewater from the South WWTP and the Derrington WRP.

Quail Run is located in Ector County. Quail Run is authorized to dispose of wastewater that consists of cooling tower blowdown, low-volume wastewater (floor drains in maintenance areas, contact storm water from paved and machinery areas, and raw water treatment system backwash) and metal cleaning waste. The disposal method utilizes a system of evaporation ponds. The permitted maximum volume of wastewater that may be put into the evaporation ponds is 123 million gallons per year (MG/yr). The facility also has the ability to send wastewater to the South WWTP. The facility operates on a seasonal basis; therefore, the volume of discharge is intermittent and variable.

3.3 CONCLUSION

The availability of water from traditional sources, such as surface waterbodies and non-brackish aquifers, is limited in the Permian Basin. Surface water supplies are periodically impacted by drought conditions. Freshwater from aquifers is in short supply. Waters from non-traditional sources that could potentially meet industrial water supply needs, however, are available. The use of these waters for industrial needs would contribute toward the preservation of the freshwaters for potable supplies and the less brackish waters for agricultural supplies.

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4 WATER USE CATGORIES: DEMANDS, SOURCES, AND NEEDS

This chapter summarizes the current and projected water requirements for Ector and Midland Counties. Projected demands are compared with available sources of water supply to determine projected water surpluses or deficits. The primary sources for the information presented in this section are the *2016 Region F Water Plan* and the *Oil & Gas Water Use in Texas: Update to the 2011 Mining Water Use Report*, written in 2012 (Nicot et al. 2012).

The projected estimates of water demands, availability, and needs in the *2016 Region F Water Plan* are summarized for the following six water use categories:

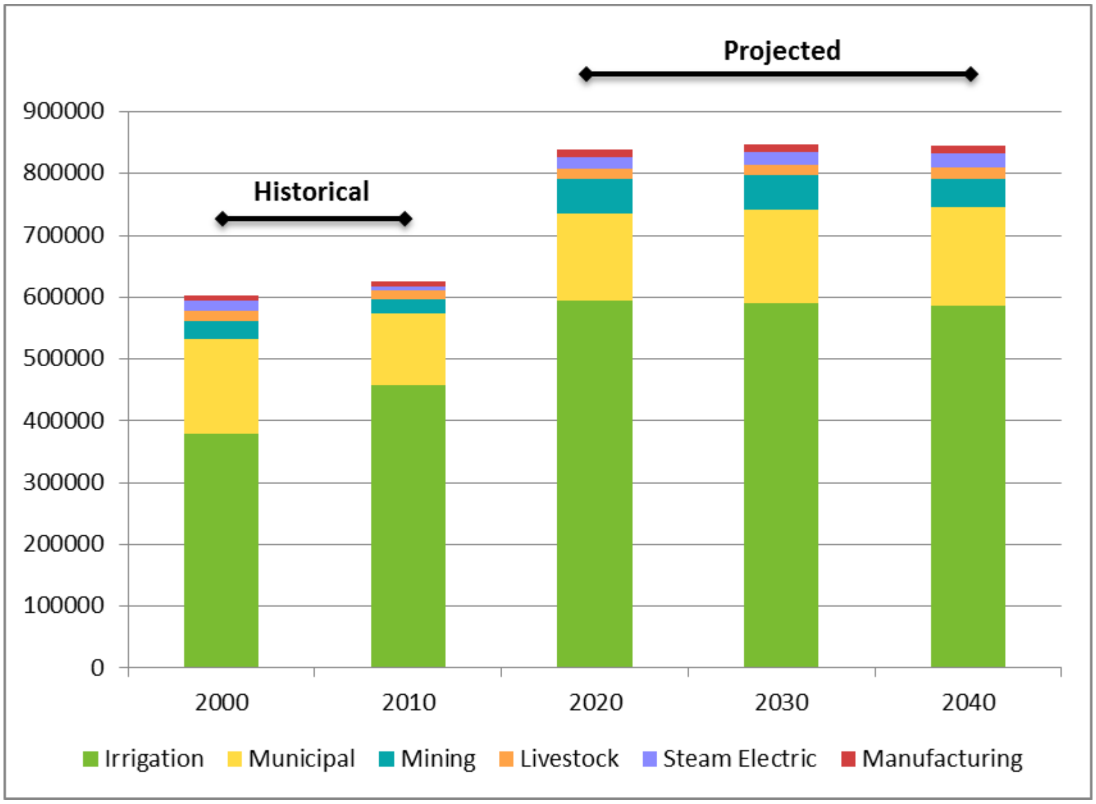
- Municipal – residential and commercial uses, including landscape irrigation,
- Irrigation - irrigated commercial agriculture,
- Manufacturing – various types of heavy industrial use,
- Steam-electric Power Generation – water consumed in the production of electricity,
- Livestock Watering – water used in commercial livestock production, and
- Mining – water used in the commercial production of various minerals, including water used in the production of oil and gas.

The projected water demands, water availability, and surplus or deficit in Ector and Midland Counties for each of these categories are discussed in this chapter. Water quality requirements of each use category are also discussed.

4.1 WATER DEMANDS

Figure 4.1 shows the historical and projected water demands for each of the water use categories for Region F. According to the *2016 Region F Water Plan*, Region F used 626,000 ace-feet (AF) water in 2010. Water use is projected to increase to nearly 850,000 AF in 2040. Historically and projected in the future, irrigation and municipal supply are the largest users of water in Region F.

Figure 4.1 Historical and Projected Water Demands in Region F by Category (in acre-feet per year)



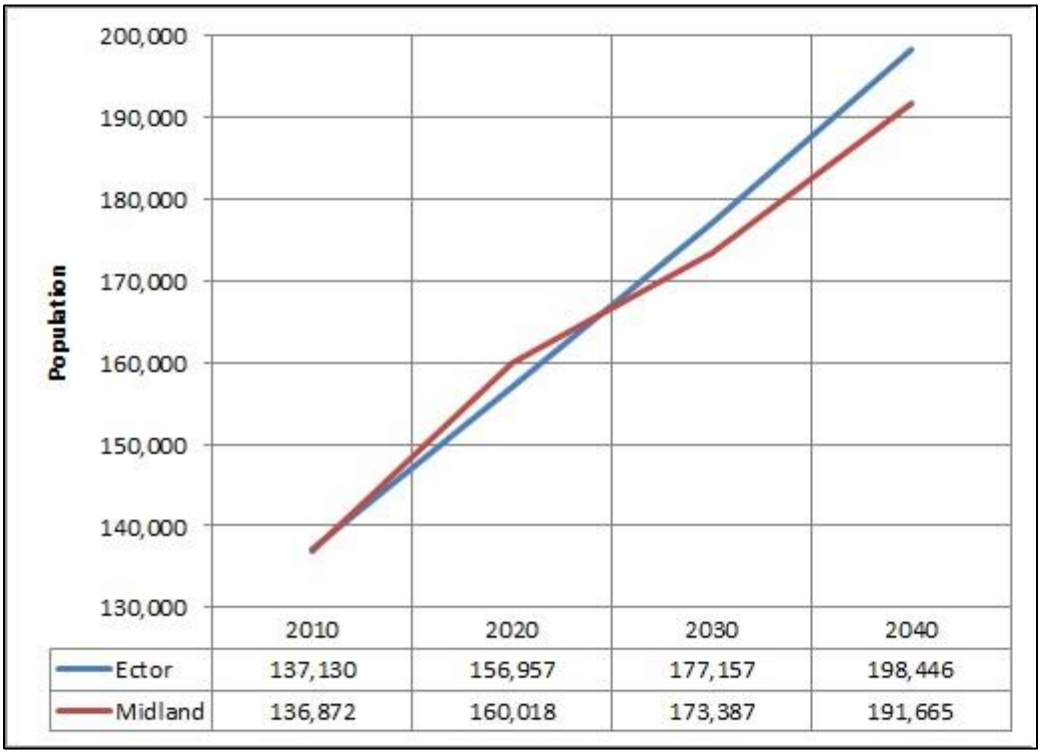
Data Sources: 2011 and 2016 Region F Water Plans

4.1.1 Municipal

As defined in the *2016 Region F Water Plan*, municipal water use consists of both residential and commercial use, including water used for landscape irrigation. Residential use is defined as use by single- and multi-family dwellings. Commercial use is use by businesses, public spaces, and institutions. Commercial use does not include industrial use, which is included in in the manufacturing category.

Quantity. Municipal use is closely related to population. The populations of Ector and Midland Counties are expected to increase from 274,000 in 2010 to over 390,000 in 2040. Figure 4.2 shows the projected populations, by county, for Ector and Midland Counties.

Figure 4.2 Historical (2010) and Projected Population of Ector and Midland Counties



	2010	2020	2030	2040
Ector	137,130	156,957	177,157	198,446
Midland	136,872	160,018	173,387	191,665

Data Source: 2016 Region F Water Plan

Municipal is the largest category of water use in Midland and Ector Counties. By 2040, Ector and Midland Counties are expected to use a combined 77,000 AF/yr (69 MGD; 600 million bbls/yr) of water for municipal use, accounting for 58% of total water use in the two counties.

Quality. Municipal water used for drinking water is governed under the 1996 Safe Drinking Water Act. Drinking water must meet the primary and secondary drinking water standards. The primary and secondary standards are presented in Appendix 1 (the pathogenic standards are not included). The primary quality challenge with respect to providing municipal supplies in the study area is the higher than desirable concentrations of TDS in many available water sources.

4.1.2 Irrigation

Projections of irrigation water demands are relatively uncertain. Changes in weather, crop prices, and government programs can have a large impact on the extent and type of crops grown in a region.

Quantity. Midland County is currently the eighth largest user of water for irrigation in Region F, when compared to the other counties. Over 16,000 AF/yr (14 MGD; 124 million bbls/yr) of water were used for irrigation in 2010 in Ector and Midland Counties. By 2020, this volume is expected to increase to over 34,000 AF/yr (30 MGD; 264 million bbls/yr) of water.

Quality. Waters can be grouped with respect to their suitability for irrigation based in the TDS concentration. A bulletin of the Texas A&M AgriLife Extension (Fipps Undated) recommends classifying waters as follows:

	Class	TDS (mg/L)
1.	Excellent	175
2.	Good	175 – 525
3.	Permissible*	525 – 1400
4.	Doubtful**	1400 – 2100
5.	Unsuitable	>2100

Note: *Leaching needed.
**Good drainage needed, and sensitive plants will have difficulty obtaining stands.

4.1.3 Manufacturing

Manufacturing use is the water used by industries in producing various products. In Region F, the most prevalent form of manufacturing is the sand and gravel operations that provide materials to the oil and gas industry. As defined by the North American Industry Classification System (NAICS), these operations differ from rock and mineral mining (aggregates and stone) covered in the "mining" category (OMB 1997) discussed in Section 4.1.6 of this report.

Quantity. Manufacturing water use accounts for a very small percentage, approximately 3%, of the total water demands in Ector and Midland counties. Most of the manufacturing demand is in Ector County. By 2040 manufacturing demand in Ector County is expected to be over 3,800 AF/yr (3.4 MGD; 29 million bbls/yr). Manufacturing water demands in Midland County are currently very small (less than 1% of the total demands) and are expected to remain insignificant in 2040, at only 269 AF/yr (0.24 MGD; 2.1 million bbls/yr).

Quality. The quality of the water needed for manufacturing uses is highly variable. Even for sand and gravel operations, different quality objectives exist depending on the use of the material produced. Sand that is to be used as proppant in HF requires a freshwater supply. The quality of the water is not as important for sand and gravel used to construct drilling pads.

4.1.4 Steam-Electric Power Generation

There are two power plants in Ector County: the Odessa -Ector Power Partners (OEPP) plant and the Quail Run power plant. There are no power plants in Midland County. Water is used at power plants for cooling towers and boilers.

The construction of a new steam-electric facility in Ector County is planned. However, a date for the initiation of construction has not been set.

Quantity. In 2010, water for OEPP and the Quail Run power plants was provided by Great Plains. The supply source for Great Plains is the Ogallala Aquifer in Andrews County. Because the water supply is outside of Ector County, the estimate in the *2016 Region F Water Plan* of water use for steam-electric power generation in Ector County in 2010 is zero.

However, based on the proposed construction of the additional steam-electric power plant in Ector County, this demand is projected to be almost 13,000 AF/yr (12 MGD; 101 million bbls/yr) by 2040. Steam-electric water demand is expected to account for 24% of the total water demand for Ector County by 2040.

Quality. Power plants require a water source that contains, or can be treated to produce, a TDS concentration of less than 1,000 mg/L. Therefore, to the extent practical, it is desirable to access freshwater resources for water supplies for power plants.

4.1.5 Livestock

The livestock water use category provides for water used for large-scale commercial livestock operations such as feedlots and dairies. Water uses for these operations include livestock drinking water, sanitation, and wash-down of facilities. The majority of livestock water use in Region F occurs in counties outside this study area.

Quantity. Ector and Midland Counties, combined, are expected to use less than 700 AF/yr (0.63 MGD; 5.4 million bbls/yr) of water for livestock purposes in 2040. This is less than 1% of the total water demand for the two counties.

Quality. Livestock can generally tolerate a higher level of salts and some bacteria than humans or crops. Different animals are able to tolerate different levels of water quality. Appendix 2 details common standards for many contaminants. The National Academy of Sciences recommends that sulfates not exceed 2,000 mg/L and TDS not exceed 10,000 mg/L for any type of livestock (Guerra and Dundorf 2011).

4.1.6 Mining

Mining water use includes water used in the production of minerals and the production of oil and gas. As defined by the NAICS, water used for processing of minerals and oil and gas into a finished product is classified as manufacturing water use (OMB 1997). Materials mined in the study area are oil, gas, and crushed stone.

4.1.6.1 Total Mining Water Requirements

The estimate in the *2016 Region F Water Plan* for total water use for mining in Ector and Midland Counties in 2010 is approximately 2,400 AF (2.1 MGD; 19 million bbls/yr). By 2040, the combined mining water demand for the two counties is projected to be approximately 4,500 AF/yr (4.0 MGD; 35 million bbls/yr). Midland County is projected to use nearly 50% more water for mining than Ector County.

4.1.6.2 Oil and Gas Mining Water Requirements

There are different water needs during the different phases of development and production of oil and gas. The primary types of uses of water in the oil and gas industry are as follows: drilling, completion (including HF), and enhanced oil recovery (waterflooding). The quality, quantity, and timing of water needs are different for each of these different uses.

In recent years there have been considerable operational changes in the oil and gas industry, both across the State of Texas and within the Permian Basin. Production capability has improved dramatically with the introduction and refinement of techniques for horizontal well design and HF.

As a result of these new technologies, drilling in the Permian Basin increased rapidly in recent years. The number of new vertical wells drilled per year increased from less than 500 wells in 2008 to more than 1500 wells in 2011.

The length of the productive vertical section also has increased during the period from 2008 to 2011. The typical productive vertical sections were 1,500 feet in 2008. By 2011 the vertical sections had increased to over 2,000 feet.

The use of horizontal drilling also increased during this period. The number of new horizontal wells drilled in 2008 was less than 50. In 2011, 160 horizontal wells were drilled.

Many of these new vertical and horizontal wells are completed using HF. All of these developments have resulted in increasing needs for water to support the development of oil and gas fields.

In the past year, there has been a dramatic decrease in the price of oil and gas. This has resulted in a substantial decrease in the development of new wells and a corresponding decrease in the demand for water. However, it is expected that prices will recover; and, as a long-term projection, the following projections for water use by the oil and gas industry should remain valid.

The following sections summarize water quantity demands and quality objectives for the following major oil and gas development and production activities: drilling, HF, and waterflooding. A summary of total water demands for oil and gas development and production is also presented.

Drilling Water Requirements

During the process of drilling a well, a fluid is required to lubricate the hole, maintain the pressure in the hole, dissipate heat, and remove cuttings from the hole. There are three primary types of fluids used in this process: air, water-based drilling muds, and oil-based drilling muds. Water-based mud (WBM) is by far the most common type. Drilling in some shale formations requires the use of oil-based mud (OBM) because clays are present that may react with water (Nicot et al. 2011). The majority of wells in the Permian Basin are drilled with WBM.

Quantity. Few regulations and requirements exist for reporting volumes of water used for drilling. Therefore, precise estimates of the amount of water used for drilling are not available.

In 2011, the University of Texas Bureau of Economic Geology (BEG) studied drilling water use for oil and gas wells in the Permian Basin (Nicot et al. 2011) and estimated the average total drilling water volume to be approximately 2 AF (0.65 MG; 16,000 bbls) per well. The study did not investigate the difference in the average volumes for vertical wells compared to horizontal wells.

Quality. Generally, operators prefer fresh water for drilling muds (Nicot et al. 2012). High concentrations of TDS in the water can cause thick deposits and clog up the hole.

Hydraulic Fracturing

Historically, more large-scale HF has occurred in Midland County than in Ector County. This is due to the more widespread presence of oil-bearing shale formations underlying that area. This trend is likely to continue.

HF technology is changing extremely rapidly. As drilling and completion technology improves, the trend is for companies to reduce their surface footprint, maximize subsurface productive intervals, and minimize drilling costs by drilling longer horizontal wells at each surface-hole location. If this trend continues, the HF water usage for an individual well is likely to increase.

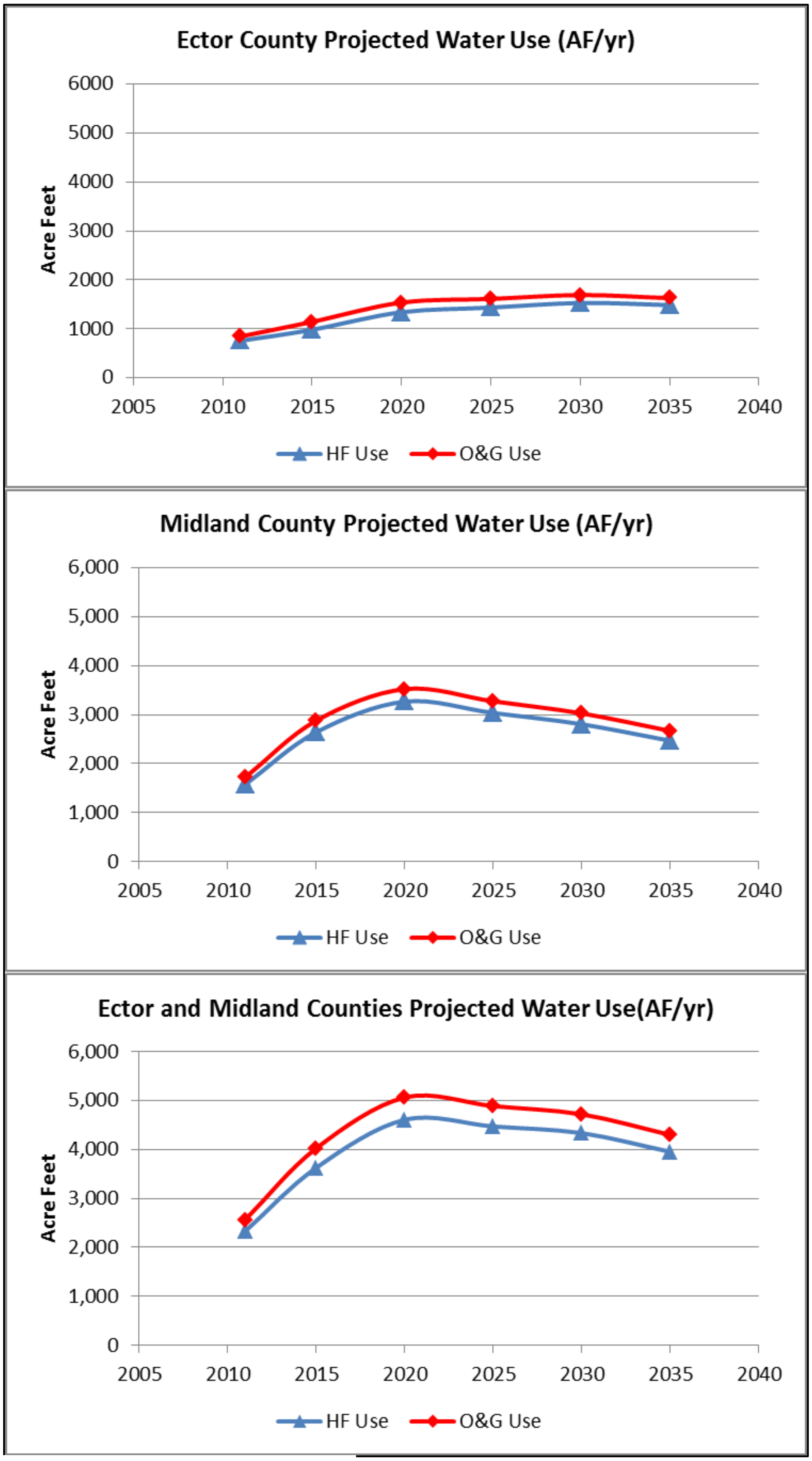
Quantity. The increase in HF operations is evidenced by the change of water volumes used in just three years. Across Texas, HF water use increased from 36,000 AF/yr (32 MGD; 279 million bbl/yr) in 2008 to 81,500 AF/yr (73 MGD; 632 bbls/yr) in 2011. Although the Barnett and Eagle Ford Formations accounted for most of the new horizontal and hydraulically fractured wells, HF also expanded in the Permian Basin (Nicot et al. 2012).

Productive intervals which are hydraulically fractured can range from less than 1,000 ft. to more than 10,000 ft. The volume of liquid used in a HF operation can also vary depending on the formation. This makes the volume of water needed per well highly variable.

The BEG estimates that in the Permian Basin in 2011 an average vertical well used approximately 3 AF (1 MG; 23,000 bbls) of water for HF. Horizontal wells use significantly more water for HF. The BEG estimates that the average horizontal well in the Permian Basin in 2011 used approximately 15 AF (5 MG; 116,000 bbls) of water for HF (Nicot et al. 2012). In 2011, the Permian Basin used 14,400 AF/yr (13 MGD; 112 million bbls/yr) for HF. (Nicot et al. 2011).

Nicot et al. (2012) also provides estimates of projected water use for HF and for total water use by the oil and gas industry in counties throughout Texas. The 2011 historical and projected volumes of total and HF water use for Ector and Midland Counties are summarized on Figure 4.3.

Figure 4.3 Ector and Midland County Projected Hydraulic Fracturing



Data Source: Nicot el al 2012

Both Ector and Midland Counties are projected to need increasing volumes of water for HF operations in the future. The rate of increase and total volumes needed are greater in Midland County than in Ector County.

Quality. The quality of water used for HF varies by operator, by service company, by producing formation, and by HF type (i.e., slickwater, foam, gel, etc.). A 2011 report by Reclamation states that water for HF needs to be low in soluble salts because these salts could precipitate in fractures and lower formation permeability (Guerra and Dundorf 2011). More recent technologies, however, have enabled the use of water for HF operations that contain up to 200,000 mg/L TDS (Lord and LeBas 2013). Further technological improvements may allow the use of waters with even higher TDS concentrations.

HF operations in the Permian Basin use the highest relative percentage of brackish water of any of the major oil producing areas in Texas. It has been estimated that in the Midland Basin region 2% of water used for HF is recycled from a previous HF operation, 30% is brackish groundwater, and 68% is fresh groundwater (Nicot et al. 2012).

Waterflooding

Waterflooding is a type of enhanced oil recovery (EOR) in which water is injected into the productive formation of an oil reservoir in order to increase the reservoir pressure and sweep residual hydrocarbons from the formation. As opposed to water used for drilling mud and HF (these operations only occur when a well is being developed) waterflooding may be conducted throughout the life of a well. This is an important distinction as water supply for a field or area undergoing waterflooding could use thousands of barrels a year for many years. EOR by waterflooding has been practiced in some areas of the Permian Basin since the 1920’s (Harris and Walker 1990).

Quantity. Nicot et al. (2011) found that in 2010, 77.2% of injected water in RRC District 8 was for waterflooding. However, waterflooding is less common in Ector and Midland Counties. In 2010 approximately 89 AF/yr and 169 AF/yr of water were used for waterflooding in Ector and Midland Counties, respectively (Nicot et al. 2011).

Quality. The quality of water needed for waterflooding is different than that needed for HF. In many oil and gas reservoirs, brackish or saline water is desirable because of its higher density. However, an incompatible TDS composition in waters with relatively high TDS concentrations may cause serious issues in some oil and gas reservoirs.

Precipitation of calcium (Ca), magnesium (Mg), barium (Ba), and/or strontium (Sr) can cause sludge or scale build-up in the injector well (Crabtree et al.1999). Oil-bearing formations in the Permian Basin are commonly high in carbonate, which makes the likelihood of Ca and Mg precipitation very high. Therefore, proper identification and mitigation of incompatible components in the water before downhole injection is important.

Oil and Gas Water Use Projections (Combining Drilling, Hydraulic Fracturing, and Waterflooding)

The 2012 update to the 2011 Report conducted by the BEG (Nicot et al. 2012) looks at projected water use by the oil and gas industry in Texas. As in any study of this nature, all projections have uncertainties related to unforeseen new drilling fields and drilling technologies. The developments in HF technology and the subsequent increase in oil and gas production from shale were taken into account in developing water use projections for the 2012 report. Of course, the recent fluctuations in oil prices were not considered.

County-specific water use projections were developed by Nicot et al. (2012). Figure 4.3 presents the projections for Ector and Midland Counties for HF and total oil and gas water use.

In the study area, water use for HF and for total oil and gas activities is projected by Nicot et al. (2012) to increase steadily until it peaks in 2020 and then slowly decline. Freese (2015) states that this decrease is predicated on the assumption that reuse and recycle methods and policies will be put in place in the area.

The peak around 2020, at just over 5,000 AF/yr (4.5 MGD; 39 million bbls/yr), is driven by activity in Midland County. Shale reserves are not currently as widespread in Ector County, making it less of a current target for large-scale HF. Water use in Ector County is more stable; it slowly increases to a peak use around 2030 and then declines slowly.

4.1.6.3 Water Requirements for Crushed Stone

The crushed stone industry in Texas is primarily focused on mining limestone and dolomite. Water is used in relatively small quantities in the production of crushed stone. Usually, no water is used during the extraction process except for roadway watering and dust suppression. Initial rock crushing and separation are, also, usually dry processes except, again, for dust suppression. The primary use of water is to wash and sort the different-sized products. Wash water is treated in sedimentation ponds to remove non-dissolved solids. After sedimentation, the water is reused. Most facilities report 70-to-80% of the water used in the process is recycled water (Nicot 2012). The primary losses are due to evaporation.

Quantity. Nicot et al. (2011) estimates water use projections by county. Ector and Midland Counties used 380 AF/yr (0.34 MGD; 2.9 million bbls/yr)and 325 AF/yr (0.29 MGD; 2.5 million bbls/yr), respectively, for crushed stone operations in 2008. These numbers are expected to grow to 491 AF/yr (0.44 MGD; 3.8 million bbls/yr) and 403 AF/yr (0.36 MGD; 3.1 million bbls/yr) for Ector and Midland Counties by 2040, respectively. These volumes are much smaller than the projected water use volumes for the oil and gas segment of mining in Ector and Midland Counties.

Quality. The 2011 BEG Report states that “brackish or saline water cannot be used for aggregate mining because the salt will adversely impact the quality of the concrete, asphalt, and other products manufactured from the materials” (Nicot et al. 2011, pg. 143). Therefore, freshwater is needed for this industrial sector.

4.1.7 Summary of Demands

A summary of demand, through 2040, for each water use category is presented on Table 4.1. These values are from the *2016 Region F Water Plan*.

Table 4. 1 Historical and Projected Water Demands by Use Category

	ECTOR COUNTY				MIDLAND COUNTY			
	Historical*	Projected*			Historical*	Projected*		
Use Cateogory	**2010**	**2020**	**2030**	**2040**	**2010**	**2020**	**2030**	**2040**
Municipal	24,669	27,520	30,350	33,482	25,446	37,470	39,725	43,294
Irrigation	1,050	1,432	1,415	1,397	14,969	33,276	33,016	32,756
Manufacturing	1,930	3,454	3,643	3,809	156	230	250	269
Steam Electric	0	9,436	11,031	12,976	0	0	0	0
Livestock	249	265	265	265	256	394	394	394
Mining	845	1,977	2,164	1,926	1,593	3,893	3,418	2,630
Total	28,743	44,084	48,868	53,855	42,420	75,263	76,803	79,343

*all values in AF/yr

4.2 WATER SUPPLY BY WATER USE CATEGORY

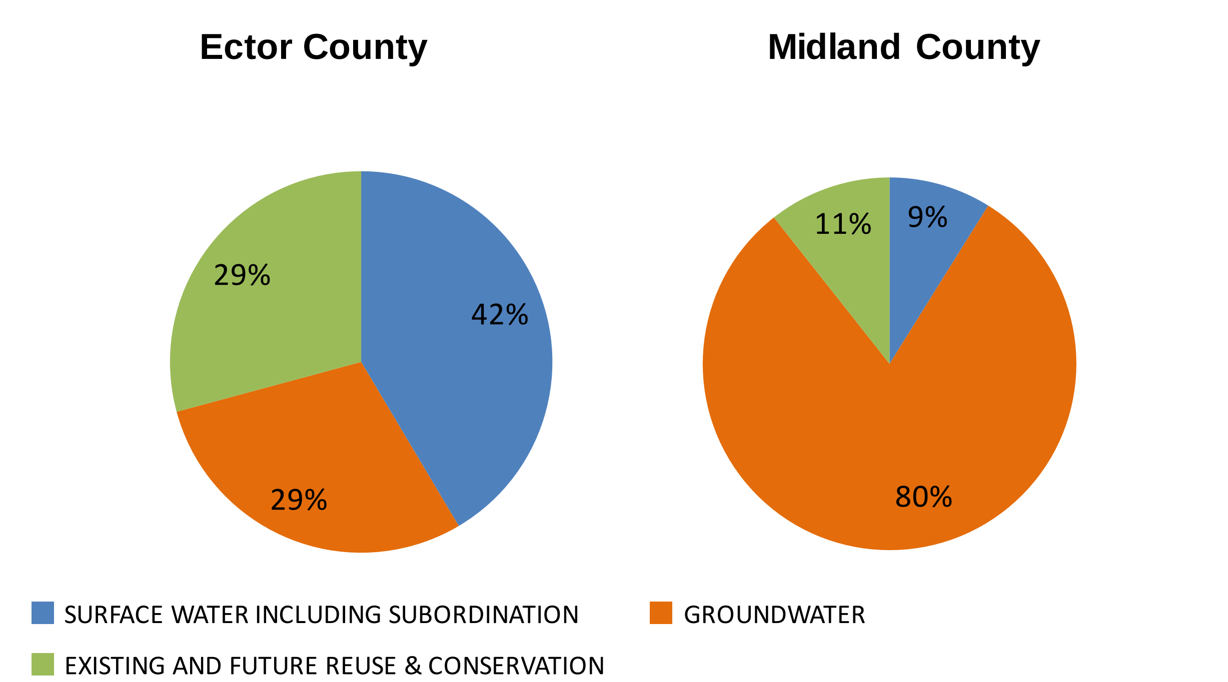
Supply volumes presented in this chapter include estimates of the effects of anticipated conservation measures, direct reuse activities, and a strategy unique to Region F identified as subordination. Pursuant to the practice of subordination, downstream senior water rights holders in the Lower Colorado River Basin would not make priority calls for water in the Upper Colorado River Basin. The water supply accessible to water users will be significantly less than projected if the implementation of reuse and conservation measures is delayed or if downstream senior water right holders exercise their priority rights.

The projected availability of water supply sources for each water use category were developed for Ector and Midland Counties. Water is classified as sourced from either surface waters, including subordination; groundwaters; or from direct reuse or conservation methods. Chapter 3 discusses the surface and groundwater sources that are available in detail. TWDB defines reuse as reclaimed water obtained directly from a water reclamation plant that is introduced back into the relevant use category (TWDB 2013). Conservation supply is water that is projected to be available due to the implementation of conservation methods (Freese 2015).

Figure 4.4 summarizes the projected water source availability by water use type for Ector and Midland Counties in 2040. Surface water is projected to be the major source used for Ector County in 2040, comprising 42% of the total supply. In Midland County, groundwater is projected to be the major source in 2040, at 80% of the total supply (TWDB 2015).

The following sections summarize the projected available water supply, by source, in Ector and Midland Counties in 2040 for each water use category. Appendix 3 presents a tabular summary of the specific volumes projected to be available from each water use strategy for each water use category. The volumetric measurements in Appendix 3 are provided in AF/yr, MGD, and bbls/yr.

Figure 4.4 2040 Water Source Type



Ector County: **53,400 AF/yr** **48 MGD** **415,000,000 bbls/yr**	**Midland County:** **64,800 AF/yr** **58 MGD** **503,000,000 bbls/yr**

Data Source: 2016 Region F Water Plan

4.2.1 Municipal

Municipal use in Ector and Midland Counties relies heavily on surface water supplies, subordination, and groundwater. Figure 4.5 shows the relative percentages of the water supply sources, by type, in each county for municipal use in 2040.

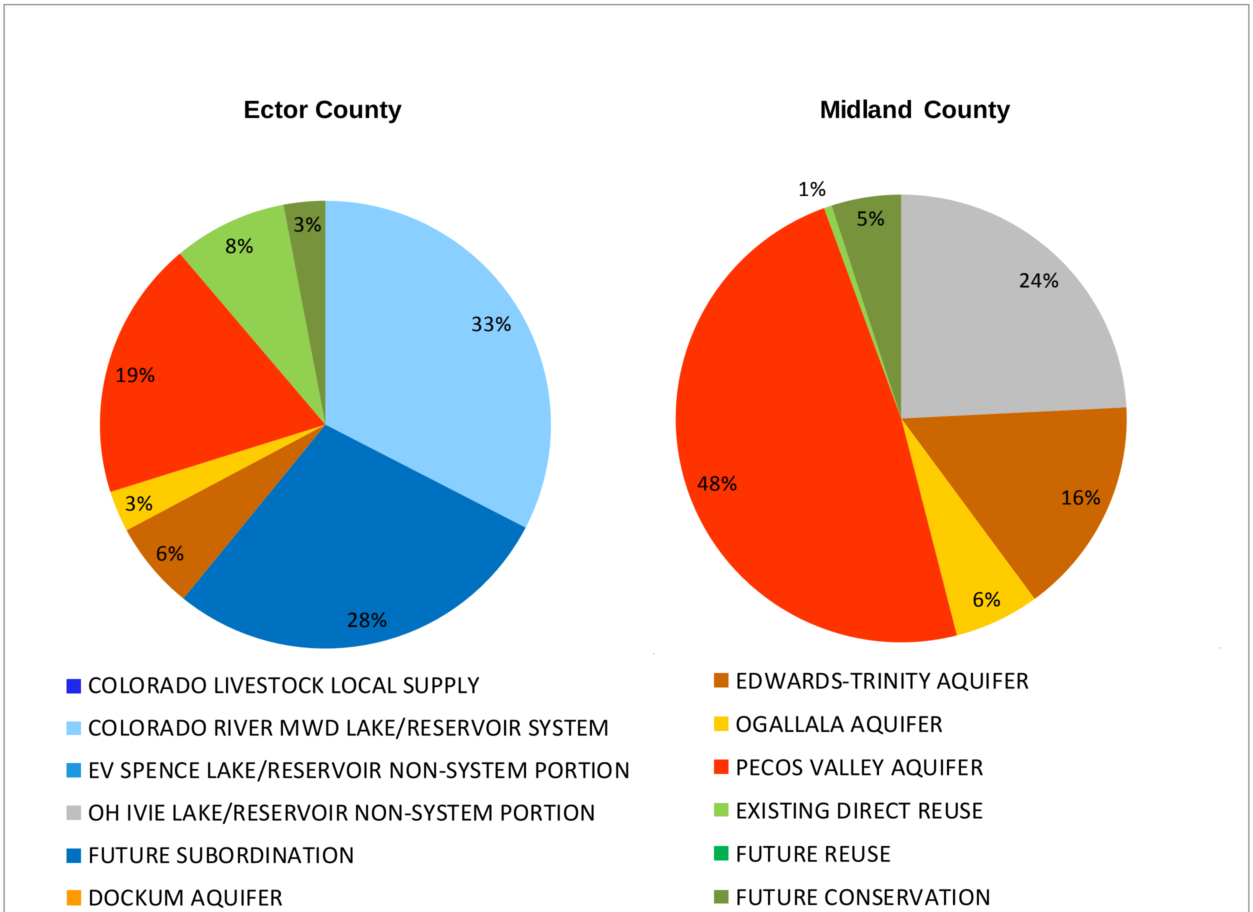
In Ector County, especially, subordination is expected to be a primary source for municipal water at over 10,000 AF/yr (9.1 MGD; 78 million bbls/yr). Surface water supplies sourced from lakes and reservoirs provide for 61% and 24% of the water for municipal use in Ector and Midland Counties, respectively. Ector County relies heavily on the CRMWD Lake/Reservoir System, while Midland County relies primarily on O.H. Ivie Lake/Reservoir System for its surface water.

In Ector and Midland Counties, groundwater is projected to provide 28% and 70%, respectively, of municipal water used in 2040. The groundwater sources are the Pecos Valley Aquifer in

Ward and Winkler Counties, the Edwards-Trinity, and the Ogallala. It is estimated that, in 2040, over two-thirds of the groundwater will come from the Pecos Valley; 22%, from the Edwards-Trinity; and 9%, from the Ogallala.

Direct reuse and conservation measures are expected to account for 11% and 6%, respectively, of the municipal water supply demands in 2040 for Ector and Midland Counties

Figure 4.5 2040 Municipal Supply Source



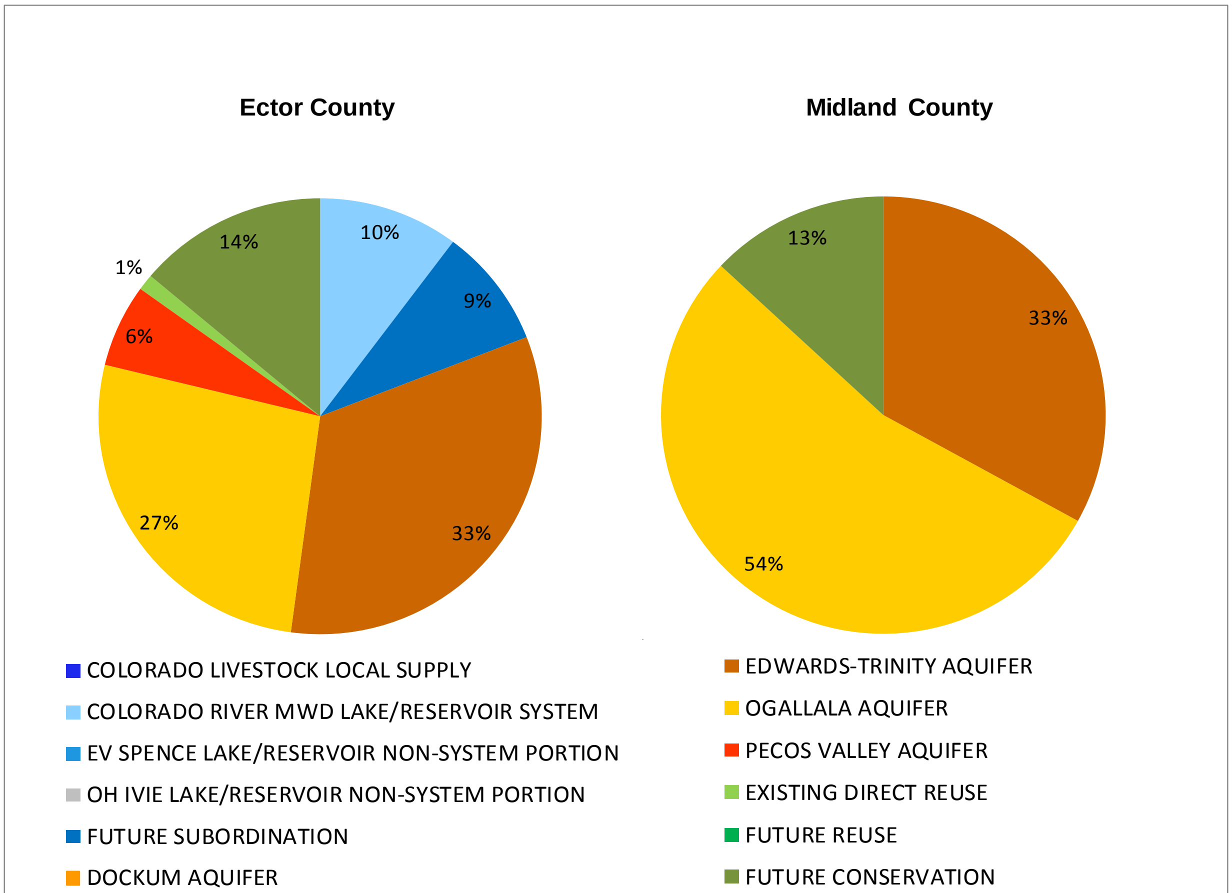
Ector County: **35,000 AF/yr** **31 MGD** **272,000,000 bbl/syr**	**Midland County:** **23,000 AF/yr** **21 MGD** **180,000,000 bbls/yr**

Data Source: 2016 Region F Water Plan

4.2.3 Irrigation

In 2040, irrigation use in Ector and Midland Counties is projected to rely on water from the CRMWD Lake/Reservoir System, future subordination, direct reuse, future conservation, and groundwater from the Dockum, Edwards-Trinity, and Pecos Valley Aquifers. The relative percentages provided by each of the water supply sources in 2040 in each county are shown on Figure 4.6.

Figure 4.6 2040 Irrigation Supply Source



Ector County:	Midland County:
1,500 AF/yr	38,000 AF/yr
1.4 MGD	34 MGD
12,000,000 bbl/syr	292,000,000 bbls/yr

Data Source: 2016 Region F Water Plan

Ector County is expected to use 1,500 AF/yr (1.4 MGD; 12 million bbls/yr) of water for irrigation in 2040. Midland County is projected to use much more water for irrigation: 38,000 AF/yr (34 MGD; 292 million bbls/yr).

Ector County is projected to rely on conservation and direct reuse to meet approximately 15% of the irrigation water needs in 2040. Two-thirds of the water for irrigation use is projected to come from groundwater. The Edwards-Trinity and the Ogallala are the primary groundwater sources for irrigation use in Ector County. Over 19% of the water allocated for Ector County's irrigation use in 2040 is surface waters, as increased by subordination.

In 2040, in Midland County, it is projected that almost all of the water used for irrigation will be groundwater. Over half of Midland County's irrigation water supply, over 20,000 AF/yr (18 MGD; 157 million bbls/yr), is projected to come from the Ogallala. A third of the irrigation water supply is projected to come from the Edwards-Trinity. Future conservation methods are expected to meet 13% of the water demand for irrigation use in Midland County in 2040.

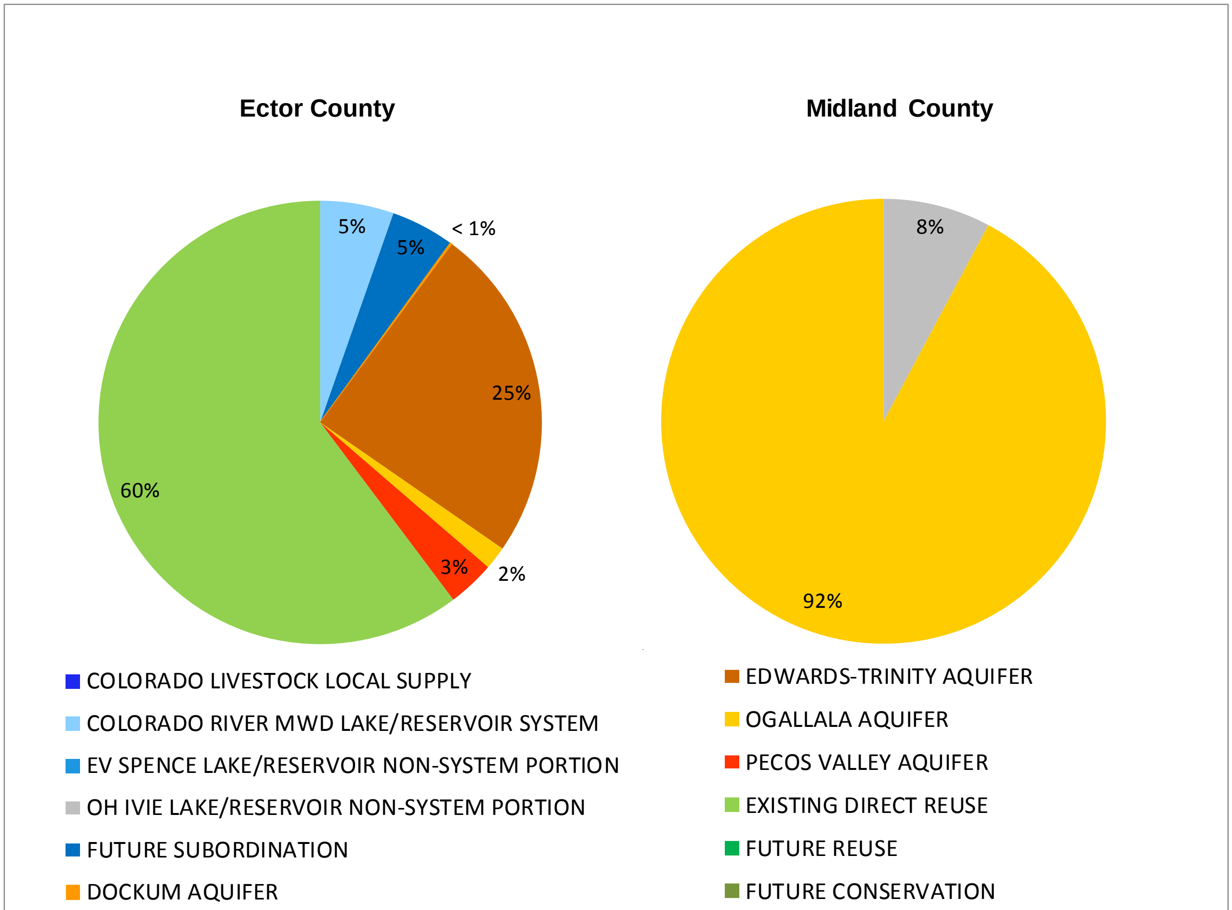
4.2.4 Manufacturing

Water for manufacturing use in Ector and Midland Counties is projected to come from surface water, direct reuse, and groundwater. Figure 4.7 shows the relative percentages provided by each water supply source for manufacturing use in 2040 in each county. Ector County is projected to use 5,200 AF/yr (4.6 MGD; 40 million bbls/yr) for manufacturing in 2040. Midland County is projected to use much less, only 270 AF/yr (0.2 MGD; 2.1 million bbls/yr) of water, for manufacturing use in 2040.

Two-thirds of the manufacturing water needs in Ector County in 2040 is projected to be met by direct reuse. Just under 30% of the water supply for manufacturing use is projected to come from groundwater. The Edwards-Trinity is the primary groundwater source, providing 24% of the manufacturing water supply. The Pecos Valley and Ogallala Aquifers account for a small amount, 3% and 2%, respectively, of the manufacturing water supply.

Midland County's supply for manufacturing use is projected to come almost entirely, 92%, from the Ogallala. The remaining supply is from the O.H. Ivie Lake/Reservoir System.

Figure 4.7 2040 Manufacturing Supply Source



Ector County: **5,200 AF/yr** **4.6 MGD** **40,000,000 bbl/syr**	**Midland County:** **270 AF/yr** **0.2 MGD** **2,100,000 bbls/yr**

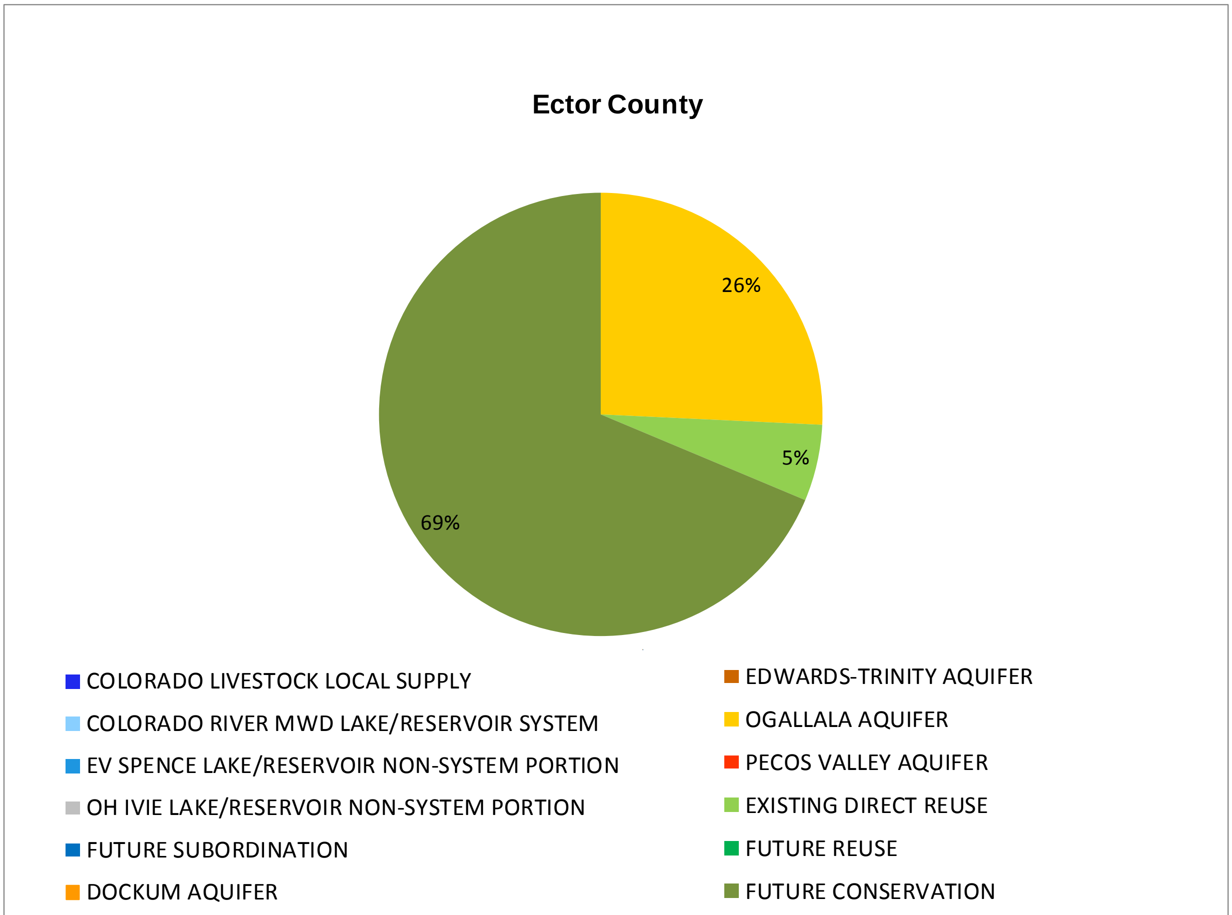
Data Source: 2016 Region F Water Plan

4.2.5 Steam-Electric Power Generation

The future water supply needs for steam-electric power generation in Ector County are projected to be met by conservation, the Ogallala, and direct reuse. Figure 4.8 shows the relative percentages of each of these measures that are proposed in order to meet the needs in Ector County for steam-electric power generation in 2040. Ector County is projected to use 9,000 AF/yr (8 MGD; 70 million bbls/yr) of water for steam-electric power generation in 2040.

Twenty-six percent of the water needed for steam-electric power generation, 2,300 AF/yr (2.1 MGD; 18 million bbls/yr), is projected to come from the Ogallala. Sixty-nine percent of water for steam-electric power generation is projected to result from the implementation of future conservation measures. The remainder of the supply, 6%, is projected to come from direct reuse.

Figure 4.8 2040 Steam-Electric Supply Source



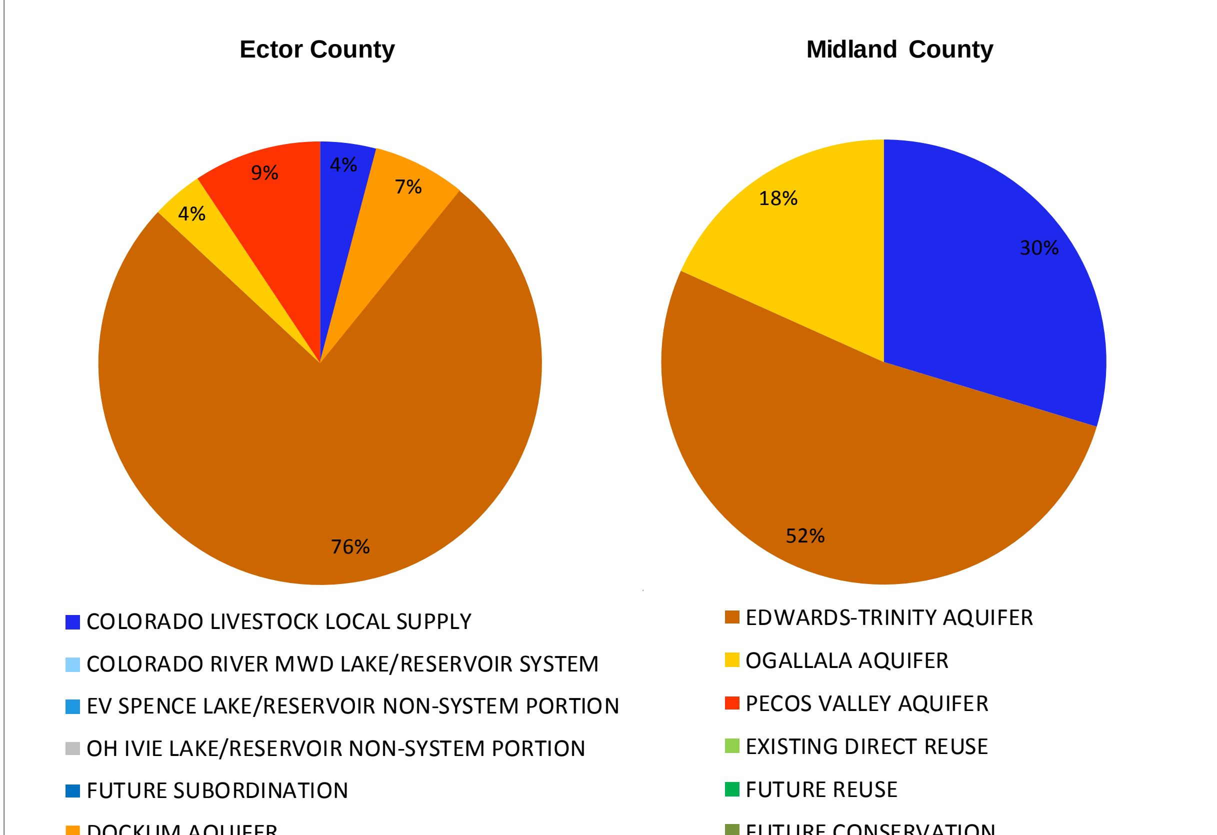
Ector County:
9,000 AF/yr
8.0 MGD
70,000,000 bbl/syr

Data Source: 2016 Region F Water Plan

4.2.6 Livestock

Water available for livestock use is projected to come primarily from groundwater from the Edwards-Trinity and local supplies. Livestock local supply is water provided by stock tanks, rain-gathering systems, and related methods on individual ranches and farms throughout the two counties. This volume is very small when compared to other water sources. Figure 4.9 shows the relative percentages of each of these sources, in each county, projected to be used to meet the needs for livestock in 2040. Ector County is projected to use 270 AF/yr (0.2 MGD; 2.1 million bbls/yr) of water for livestock in 2040. Midland County is projected to use 390 AF/yr (0.4 MGD; 3.1 million bbls/yr) of water for livestock in 2040

Figure 4.9 2040 Livestock Supply Source



Ector County:	Midland County:
270 AF/yr	**390 AF/yr**
0.2 MGD	**0.4 MGD**
2,100,000 bbl/syr	**3,100,000 bbls/yr**

Data Source: 2016 Region F Water Plan

In Ector County, more than three-quarters of the water supply for livestock use is projected to come from the Edwards-Trinity. The Pecos Valley, Dockum, and Ogallala Aquifers are projected to provide a combined 20% of supply for livestock use. The remainder of the projected water for livestock is livestock local supply.

In Midland County, 70% of the projected water for livestock use in 2040 is from groundwater. Just over half is from the Edwards-Trinity; 18% is from the Ogallala. Water from local livestock supply is projected to meet 30% of the projected use for livestock in Midland County by 2040.

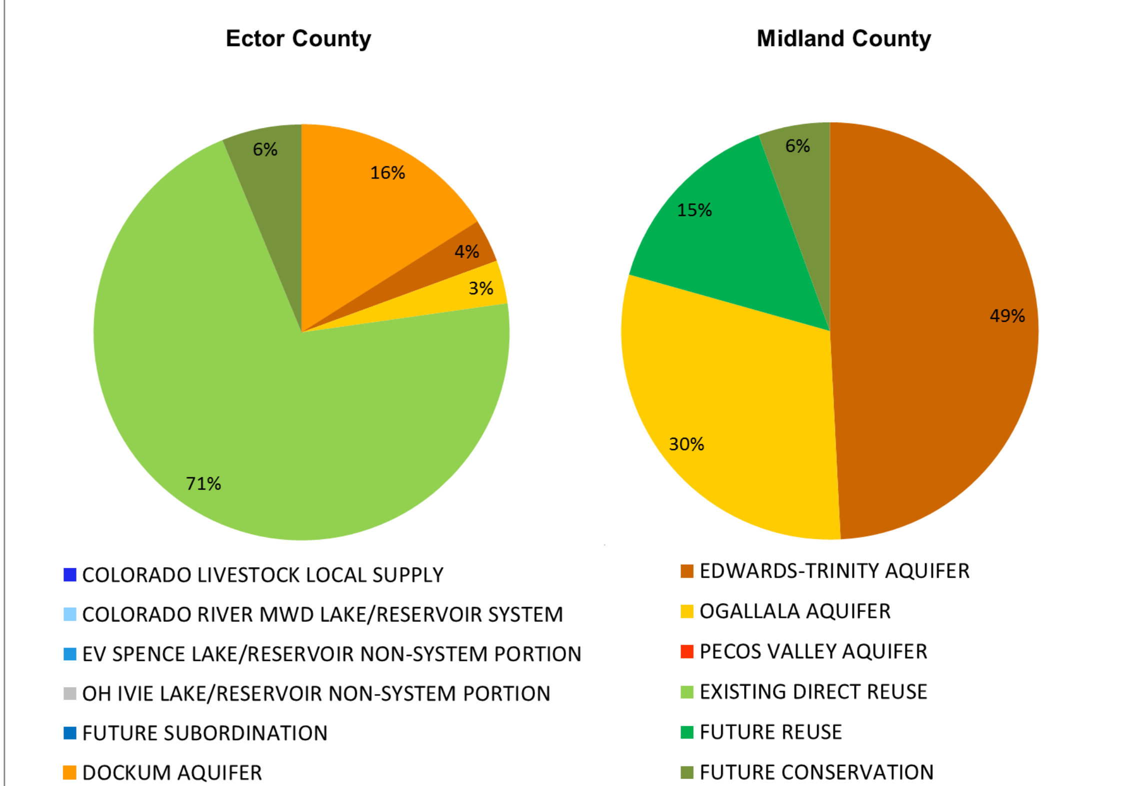
4.2.7 Mining

Water for mining use in Ector and Midland Counties in 2040 is projected to come primarily from reuse and groundwater from the Edwards-Trinity and Ogallala Aquifers. Figure 4.10 shows the relative percentage of each water supply source, in each county, projected to be available for mining use in 2040. Ector County is projected to use 2,200 AF/yr (1.9 MGD; 17 million bbls/yr) of water for mining in 2040. Midland County is projected to use 3,300 AF/yr (3.0 MGD; 26 million bbls/yr) of water for mining in 2040.

In Ector County, direct reuse and conservation are projected to be the primary means for meeting mining water needs. Three-quarters of the water used for mining, over 1,600 AF/yr (1.5 MGD; 13 million bbls/yr), is expected to result from these measures. The remaining water needed is projected to be supplied by groundwater, with the Dockum as the primary groundwater source for mining use in Ector County in 2040.

In Midland County, direct reuse is projected to supply 15% of the water for mining in 2040; and conservation is projected to meet 6% of the projected need. Most of the water for mining use in Midland County, 79%, is projected to come from groundwater. Over 1,600 AF/yr (1.5 MGD; 12 million bbls/yr) are projected to come from the Edwards-Trinity, an aquifer that is also used for municipal and irrigation purposes.

Figure 4.10 2040 Mining Supply Source



Ector County:	Midland County:
2,200 AF/yr	3,300 AF/yr
1.9 MGD	3.0 MGD
17,000,000 bbl/syr	26,000,000 bbls/yr

Data Source: 2016 Region F Water Plan

4.3 WATER SURPLUS OR DEFICIT BY CATEGORY

Table 4.2 summarizes whether there is a surplus or deficit of water available for each water use category. The calculation assumes the identified water strategies (additional development of wells in the Pecos Valley, increased reuse, etc.) have been successfully implemented. These data are from the *2016 Region F Water Plan*. Notable conclusions based on this table are as follows:

Table 4.2 Projected Water Surplus or Need by Use Category (All Values in AF/yr)

	ECTOR COUNTY								
	2020			2030			2040		
Use Category	Demand	Supply	Surplus (Need)	Demand	Supply	Surplus (Need)	Demand	Supply	Surplus (Need)
Municipal	28,037	27,824	1,149	30,974	30,445	1,265	34,211	33,398	1,118
Irrigation	1,432	2,562	(54)	1,415	2,867	33	1,397	3,084	117
Manufacturing	3,454	4,534	1,392	3,643	4,843	1,382	3,809	4,945	1,376
Steam Electric	9,436	2,817	(3,333)	11,031	2,768	(4,000)	12,976	2,811	(4,000)
Livestock	265	265	3	265	265	3	265	265	3
Mining	1,977	2,379	409	2,164	2,485	321	1,926	2,170	244
Total	44,601	40,381	(434)	49,492	43,673	(996)	54,584	46,673	(1,142)
	MIDLAND COUNTY								
	2020			2030			2040		
Use Category	Demand	Supply	Surplus (Need)	Demand	Supply	Surplus (Need)	Demand	Supply	Surplus (Need)
Municipal	36,953	43,842	6,887	39,101	25,484	(13,775)	42,565	23,333	(19,429)
Irrigation	33,276	34,940	1664	33,016	36,318	3,302	32,756	37,669	4,913
Manufacturing	230	230	0	250	250	0	269	269	0
Steam Electric	0	0	0	0	0	0	0	0	0
Livestock	394	394	0	394	394	0	394	394	0
Mining	3,893	4,166	773	3,418	3,657	739	2,630	2,814	684
Total	74,746	83,572	9,324	76,179	66,103	(9,734)	78,614	64,479	(13,832)

- In Midland County there is a projected deficit of municipal water supply in 2030 and beyond. The projected deficit is almost 20,000 AF/yr (18 MGD; 155 million bbls/yr) in 2040[2].
- With the exception of Ector County in 2020, a small surplus of water for irrigation in Ector and Midland Counties is projected to be available through 2040.
- A small surplus of water for manufacturing uses is projected in Ector County. Midland County is not projected to have either a surplus or a deficit of water for manufacturing.
- There is a projected deficit of water available to meet the demand for steam-electric power generation in Ector County. The deficit is projected to be approximately 4,000 AF/yr.

[2]The municipal demand shown in Table 4.2 and in Appendix 3 differs from the demand amount shown in Table 4.1 This is due to the fact that an area served by the City of Odessa is located in Midland County. The demand projections in Table 4.1 are based on the location of the user, whereas the demand projections in Table 4.2 are based on the location of the supplier. This is the convention used in the 2016 Region F Water Plan. Municipal use is the only category that describes supply and demand using this method.

- There is projected to be a slight surplus of water for mining use in Ector and Midland Counties beginning in 2020. The surplus volume declines each decade through 2040. The expected surplus is so small that even a slight increase in drilling activity or a decrease in supply could cause a deficit. In addition, it should be noted that 77% of the water projected to be available for mining in Ector County comes from either conservation or direct reuse.

4.4 CONCLUSIONS

Water is essential for the people of, and the industries that conduct business in, Ector and Midland Counties. The data developed for the *2016 Region F Water Plan* indicate that it would be prudent to reserve freshwater sources for those uses where they are essential, such as municipal supply, and to supplement water supplies for oil and gas production by recycling flowback and produced waters when feasible.

The water use categories where freshwater availability is most important are municipal supply and steam-electric power generation. Both need water low in TDS. Also, both are large-volume users. Together they represent 67% of the total projected water demand in 2040. It will be very difficult for users in these categories to use available brackish waters and provide treatment to reduce the TDS concentrations. The costs would be high. Also, currently available treatment methods generate a large-volume waste stream that is very high in TDS. Disposal of this waste stream would be very difficult.

The current assessment for Region F indicates that there is sufficient water of suitable quality available for municipal uses in Ector County. However, this assessment assumes a heavy reliance on the reservoirs operated by CRMWD and the availability of subordination if circumstances warrant. While these reservoirs are expected to provide sufficient supplies under most conditions, the possibility exists of periodic significant droughts, such as the one that was experienced in recent years. Therefore, it is prudent to maintain freshwater resources in reserve to meet municipal and steam-electric demands under extreme conditions.

Oil and gas development and production water demands in Ector and Midland Counties are shown as being met in the *Region F Water Plan* development documents. Around the year 2020, when the plan projects that demand will peak, this demand is estimated to be 5,870 AF/yr (5.2 MGD; 45.6 million bbls/yr). However, it should be noted that the assumptions under which the demands for water for mining are met are as follows:

- **Ector County**

  - 77% of the water supply needs are met by conservation and direct reuse. Quantification of current reuse volumes is not available, but in 2012 Nicot et al. estimated that, of the water used for HF (which is a high percentage of total water use for oil and gas), only 2% of the supply was derived from reuse.
  - 6% is from the Edwards-Trinity and Ogallala Aquifers, which frequently provide freshwater to users in this area.
  - 16% is from the Dockum, which is classified as having low productivity and is of unknown longevity.

- **Midland County**

  - 30% is from the Ogallala, which can be freshwater source in some areas.
  - 49% is from the Edwards-Trinity, which is, also, a freshwater resource for many in the area.

Therefore, substantially increasing the volumes of flowback and produced waters that are being recycled is an important step for the oil and gas industry. It will decrease the use of freshwater that is needed for other important purposes, and will reduce reliance on the Dockum, which may not be a reliable long-term source of water.

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5 DESCRIPTION OF CURRENT WATER REUSE

In this chapter, water recycling systems currently in use in the study area are summarized. A primary source of water for reuse in Ector and Midland Counties is the three publicly owned treatment works (POTWs) operating in these counties. However, reuse of wastewaters generated from the exploration and production of oil and gas is increasing, as well. Descriptions of the oil and gas wastewaters, including sources, volumes, quality, and disposal/discharge methods, can be found in Chapter 3, Section 3.2.3.

Water reuse in Ector and Midland Counties is rapidly evolving, particularly with respect to the reuse of wastewaters generated by the exploration and production of oil and gas. Water reuse is, therefore, subject to change as water supplies and demands change and as treatment requirements and technologies change.

5.1 PUBLICLY OWNED TREATMENT WORKS

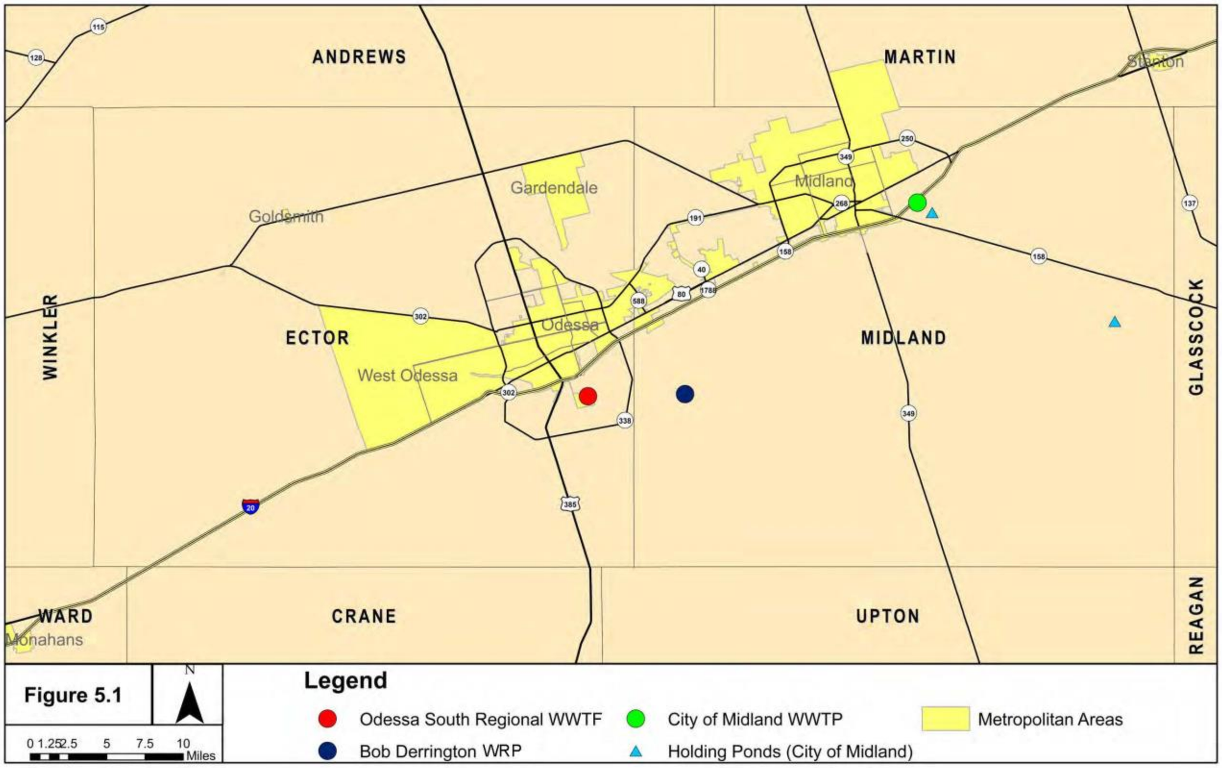
The three major POTWs in Ector and Midland Counties all have existing reuse programs. Figure 5.1 shows the locations of the South WWTP, Derrington WRP, and Midland WWTP. A discussion of the reuse programs associated with each plant follows.

5.1.1 Odessa South Regional Wastewater Treatment Plant

The South WWTP is authorized to provide recycled wastewater. The facility receives municipal wastewater, industrial wastewater and cooling tower blowdown from both the OEPP and Quail Run. Blowdown is discharged to the collection system, and it is processed through the plant's biological treatment process with all other wastewater.

The South WWTP is permitted to provide treated wastewater for a variety of uses, including power production, other industrial activities, and in-plant service water. In addition, the facility provides treated wastewater to COG Operating, LLC, an affiliate of Concho Resources, Inc., for oilfield operations. GCWDA has a three-year agreement, with renewal options, to provide 2 MGD (2,200 AF/yr; 17 million bbls/yr) of treated wastewater to COG Operating, LLC, for use in drilling and completion operations (Miller 2015).

Figure 5.1 Publicly Owned Treatment Works in Ector and Midland Counties



COG Operating, LLC, has developed a distribution system that is used to transport water, including the reclaimed water, to its operating sites. The distribution system is designed to allow for the reclaimed water to be used where needed based on drilling activity.

5.1.2 Bob Derrington Water Reclamation Plant

The Derrington WRP currently has contracts to provide effluent for reuse by a steam-electric power plant (for cooling water), manufacturers, and various irrigation users. It is not being used by the steam-electric plant at this time. Up to 3 MGD [3,400 AF/yr; 26 million bbls/yr] is used for landscape irrigation at several locations throughout Odessa, including golf courses, a cemetery, the campus of the University of Texas Permian Basin, city parks, and Texas Department of Transportation highway medians (Toledanes 2012). Effluent is delivered to these areas via pipeline.

In 2014, the City of Odessa entered into an agreement with Pioneer Natural Resources (Pioneer) to provide effluent for use in their oilfield operations (Pioneer 2013). Pioneer will commingle the effluent with wastewater from oil and gas development and production, and brackish groundwater, as part of a larger recycling system. A description of this recycling system is presented in Section 5.2.2.

5.1.3 City of Midland Wastewater Treatment Plant

The Midland WWTP is authorized to treat up to 21 MGD [23,500 AF/yr; 180 million bbls/yr] of wastewater. The Midland WWTP permit does not authorize the discharge of effluent to Waters of the United States; rather, disposal is entirely by irrigation. Because there is no discharge associated with the plant, the permit allows a less stringent treatment process and lower quality effluent than would be allowed in a typical discharge permit.

Plant effluent is stored in holding ponds located in eastern Midland County. The locations of the holding ponds are shown on Figure 5.1. Approximately 5,000 acres of non-public pasture and cultivated land are irrigated from these holding ponds (City of Midland 2014).

There is a potential for reuse of effluent from the Midland WWTP in nearby oilfields, as well. Pioneer is exploring the possibility of obtaining up to 10 MGD [11,000 AF/yr; 87 million bbls/yr] of effluent for nearby oil and gas operations (Pioneer 2013; Paul 2014). Such reuse will require significant upgrades to the existing treatment processes at the Midland WWTP.

5.2 OIL AND GAS

The wastewaters generated in the production of oil and gas are primarily produced water and HF flowback water. A description of the volumes and qualities of these waters is provided in Chapter 3, Section 3.2.3. These waters are managed primarily by disposal into salt water disposal (SWD) wells. However, recycling of these wastewaters in the oilfields is increasing.

Wastewater is typically transported from the oil or gas well-site to the SWD well by truck. In some cases, pipelines have been constructed to convey wastewater to the SWDs. In Ector and Midland Counties, there were approximately 290 wells permitted for water disposal as of early 2015. In December 2014, a combined 2,400 MG of wastewater [7,500 AF; 58 million bbls] were injected into disposal wells located in Ector and Midland Counties (Digital H2O 2015).

Although most of the wastewater from oil and gas activities is disposed via SWD well, some operators are implementing recycle programs. Most of these recycle programs focus on treating HF flowback and reusing the treated water as part of the HF water supply. These programs are generally located near HF well-sites.

Sections 5.2.1 and 5.2.2 provide an overview of two types of water recycling programs currently in operation, or in development, in the Permian Basin: the hub-and-spoke and inter-field pipeline systems. Section 5.2.3 provides an overview of mobile treatment systems for reusing oilfield wastewater.

This report is not intended to describe every approach currently used to recycle oil- and gas-field wastewaters. Rather, the purpose is to illustrate some of the different solutions that operators are developing to address the issue of providing water in this water-short area. The development of new approaches is rapidly evolving in this area. Decisions on how to implement reuse in oilfield applications are driven by operator preference, perceived risks, cost, and the type of HF being performed.

5.2.1 Hub-and-Spoke

In a “hub-and-spoke” system, wastewater is collected and treated at a centralized “hub” in the area of HF activity. The hub also provides necessary storage for treated wastewater. As it is needed, water is transported out to a well-site via a series of pipelines that act as the “spokes.” This process enables the operator to recycle water for a field-wide area without having to move the recycling machinery each time a well is completed. In addition, brackish groundwater or other suitable water may also be conveyed to the hub location for blending and distribution to well-sites via the spokes.

An example of a hub-and-spoke system is currently located in Irion County, southeast of Midland County. In this system, initially, brackish groundwater from the Dockum is pumped into a large, lined pit that is capable of holding approximately 21 MG [65 AF; 500,000 bbls] of water. The brackish groundwater is used primarily to initiate the HF(Apache 2015). Before use in the HF operation, the brackish groundwater is treated to remove sulfate, magnesium, iron, bacteria, and large solids (Seeley 2014).

As water flows back during the HF operation, it is conveyed to the “hub” via the same pipeline system (i.e., the spokes) and collected in modified grain bins used as holding tanks. Figure 5.2 shows the brackish groundwater pit and holding tanks for the hub-and-spoke system in Irion County. Tanks at each well-site have a capacity to store approximately 10 MG [31 AF; 240,000 bbls] of water. In the holding tanks, the flowback is treated to remove iron, blended with the brackish groundwater, and transported back to the well-site via the pipelines. This water is treated for bacteria and injected downhole for the HF operation. Once the HF operation is complete, the remaining HF flowback and produced water is treated and used in the next HF operation (Apache 2015).

Figure 5.2 Brackish Water Pit and Holding Tanks in Irion County, Texas

(Source: DeFosse and Cooper 2015)

5.2.2 Inter-Field Pipeline

Pioneer is an oil and gas E&P company in the Permian Basin that is implementing a large-scale, multi-sourced, water recycling and redistribution facility in the Permian Basin. Pioneer's plans are to reduce reliance on fresh water during HF operations using a combination of purchased treated municipal wastewater; directly recycled HF flowback and produced water; and brackish, non-potable groundwater. In 2014, Pioneer entered an agreement with the City of Odessa to purchase treated municipal wastewaters produced by the Derrington WWTP. In addition, Pioneer is currently in negotiation with the City of Midland to purchase treated wastewater from the Midland WWTP.

Treated water from the WWTPs will be conveyed to the well-site locations via an approximately 100-mile long pipeline. The system may consist of up to 20 water subsystems branching from the mainline. The subsystems will include a variable number of strategically placed, double-lined storage ponds designed to support HF operations in the nearby area. The number and location of storage ponds within each subsystem will be based on the number and type of HF operations anticipated for the area.

5.2.3 Mobile Treatment Unit

In some cases, a mobile treatment unit can be a viable option for recycling oil- and gas-field wastewaters at a well site. Mobile treatment units are storage tanks and treatment units that are transported to the HF well-site using trucks. Units can be set up quickly and relocated when needed elsewhere. One benefit of mobile units is that they reduce truck traffic by minimizing the amount of water that needs to be transported to, or from, the site.

Mobile treatment generally targets the removal of oil, solids, precipitants, scalants, and bacteria from oilfield wastewater. Treatment is tailored to the quality of the wastewater being treated and the specific water quality requirements of the well that is being hydraulically fractured. Treatment technologies used range from solids separation to evaporation/distillation (Bowman 2014; Halliburton 2015).

Mobile units may not always be able to provide the volume of water required for a large-scale HF operation. In addition, when HF operations are very active in the Permian Basin, it may be difficult to secure a mobile unit when needed.

5.3 SUMMARY

Water in the Permian Basin is a valuable resource, and some oil and gas operators are developing plans to ensure that water is recycled rather than disposed. But, even with the current and planned recycling options, the majority of HF flowback and produced water continues to be disposed in SWD wells. Decisions on whether to use recycled water are driven primarily by operator preference, risks to the well as perceived by the operator, reuse costs, and the type of HF being performed.

POTWs in Midland and Ector Counties are already maximizing their reuse of WWTP effluent. The major WWTPs provide, or have contracts to provide, all currently available effluent for irrigation, industrial reuse, and oilfield operations. Some of the larger oil and gas producers in the Permian Basin have been able to secure large volumes of POTW effluent for use in their company's HF operations. However, not all operators are able to implement a similar system independently. Many operators do not have enough contiguous acreage under development or production, or the capital investment required, to undertake a large-scale, operator-owned recycling system like the hub-and-spoke or inter-field pipelines. For smaller operators, mobile treatment is an option and can work well, if the units are available.

Additional reuse options for oilfield wastewater are needed to ensure that the use of water resources is maximized. The *2016 Region F Water Plan* estimates that by 2040 approximately 2,000 AF/yr [1.8 MGD; 16 million bbls/yr] of water used for mining in Ector and Midland Counties will come from reuse/recycle systems. The *2016 Region F Water Plan* does not identify any specific reuse and recycle methods to achieve these numbers.

A reuse/recycle system developed specifically to fit the needs of the oil and gas industry in Ector and Midland Counties could offer a viable option for water for many operators throughout the area. Oil and gas operators obtaining water from such a system may have the benefit of a smaller capital investment than that required to implement an independent reuse program. This system could provide a more consistent supply and larger volumes than a mobile unit.

Water resources of Ector and Midland County can be used in a manner that provides the best long-term solution for use by both residents in the area and the oil and gas industry. Although some operators are working to increase the amount of oilfield water that is reused, a need remains for further development of reuse programs in Ector and Midland Counties.

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6 MARKET FOR RECYCLED WATER

One critical component of the development of a project to utilize recycled water in the Permian Basin is identification of the market. This discussion of the market for recycled water focuses on potential industrial users within Ector and Midland Counties and impediments to market development for recycled water. The primary industrial water users in Ector and Midland Counties are power generators and oil and gas operators.

6.1 REUSE POTENTIAL FOR THE POWER GENERATION INDUSTRY

Power generation (which is typically steam-electric, and this is the term used in regional water planning) can have a particularly heavy demand on water resources of a region. As will be addressed following, the potential for reuse in the power industry is limited in arid regions such as Ector and Midland Counties. Water use in power generation is primarily for cooling tower make-up. The quality of water for cooling must be tightly controlled to prevent problems with scaling in the cooling tower. Make-up water quality may be managed by chemical addition. However, as source water quality decreases, chemical treatment costs typically increase. In addition, monitoring of water quality is necessary, especially where there is significant variability in quality. Cooling tower operators may opt to use more costly fresh water if the quality of fresh water varies less than the quality of recycled water.

Two steam-electric power generating facilities currently operate in Ector County: OEPP and Quail Run. Steam-electric power is not generated in Midland County.

The source of supply to meet the current water demand for the existing Ector County power generating facilities is groundwater from the Ogallala Aquifer. Reclaimed water from the Bob Derrington WWTP is under contract to be used in power generation in Ector County. However, at this time, power generating facilities in Ector County do not use treated effluent.

The cooling mechanism in each of the Ector County facilities is a system of cooling towers. Cooling water is evaporated as it is recirculated through the cooling towers with a resultant increase in dissolved salts (TDS) in the water with each cycle of recirculation. To properly manage the TDS levels in the cooling water, a portion of water in the sump is “blown down” or removed and “make-up” water is introduced to the system to replace cooling water that has either evaporated or been removed from the system as blowdown.

The number of times cooling water can be recirculated through the system (number of "cycles") depends, in part, on the TDS of the water. The lower the TDS of the water, the more efficient the cooling process is in terms of the amount of water needed for cooling. Ideally, water should have a sufficiently low TDS to allow 5 or more cycles of water through the cooling tower.

The use of recycled water from the oil and gas industry for cooling purposes appears to be infeasible due to the very high TDS concentrations of the wastewater and the potential variability of the wastewaters. Given the high TDS concentrations and the wide variations in the quality of oil and gas industry wastewaters, providing the treatment needed to make it useable for cooling water in the power industry is considered impractical.

6.2 REUSE POTENTIAL FOR THE OIL AND GAS INDUSTRY

The oil and gas industry is driven largely by fluctuations in the price of oil and gas in the market. Changes in the price per barrel for oil or price per cubic foot for natural gas can occur quickly (up or down). Such changes affect how the industry does business, including how the recycling of water is viewed in the exploration and production process.

To some extent, economic impediments are associated with supply and demand. If an adequate volume of non-recycled water (i.e., existing surface water or groundwater) exists in the region and can be purchased by operators at a reasonable price, there will be a strong tendency to continue to use these sources. It is only when such sources are depleted, or at risk of being depleted, and the cost to develop and utilize new sources increases, that alternative sources, such as recycled water, become attractive.

However, as noted in Chapter 5, there is a growing awareness of the value of reclaimed water. The recycled water industry for the oilfield is rapidly evolving as larger producers develop their own means of reusing wastewater, and smaller third-party wastewater treatment developers are entering the market. As new treatment technologies and systems are developed, the market for recycled water will increase.

6.2.1 Market Assessment

The assessment of the market for recycled water in the oil and gas industry has included consultation with various producers and stakeholders in the area. The procedures utilized in this study for assessing the market for recycled water in the oil and gas industry in Ector and Midland Counties are as follows:

- Industry representatives on the Advisory Committee, as well as some not on the Advisory Committee, were consulted.
- Information and data from organizations such as the Texas Water Recycling Association, which advocates for expanded reuse of water generated by the oil and gas industry, were evaluated to determine trends in the recycled water industry.

However, the volatility of the oil and gas industry, as a whole, makes the projection of future trends in the recycled water market somewhat speculative (see discussion in sub-section 6.3.1.3 Oil and Gas Price Impediments).

6.2.2 Potential Recycled Water Uses and Users In the Oil and Gas Industry

Oil and gas exploration and production require water for three primary processes: drilling; development, including HF; and waterflooding. Other minor uses for water include equipment and site clean-up.

Drilling requires relatively fresh water. The volume of water needed for drilling is relatively small compared to the volume of water used for HF and waterflooding. Quantity and quality requirements for HF have been discussed in detail in Chapter 4. As described, Ector and Midland Counties may require between 3,000 and 5,000 AF/yr (2.7 to 4.0 MGD; 23 million to 39 million bbls/yr) of water for oil and gas production for the next 25 years.

6.3 IMPEDIMENTS TO MARKET DEVELOPMENT

There are currently two potentially significant types of impediments to the development of a market for recycled water in the Permian Basin in the oil and gas industry: economic and regulatory. Each of these impediments could inhibit development of the recycled water market in its own unique way, but in some cases the impacts are related. Each type of impediment and potential solutions are presented in this section.

6.3.1 Economic Impediments

Economic impediments to the market for recycled water use come from two basic directions: recycled water project costs and the fluctuating condition of the oil and gas market itself. Managing the risks of a fluctuating market makes it unwise to invest in capital expenditures that require financing over several years.

6.3.1.1 Cost Impediments Related to Implementation

The cost to implement a wastewater recycling project can be a major impediment. Costs are associated with each of the following elements of a project:

- Treatment of the water to a level that allows its reuse.
- Storage requirements both before treatment and after treatment.
- Conveyance (i.e., pump stations and pipelines) to transport generated wastewater to a treatment location and treated water from where it is treated to where it is needed.

Treatment costs depend on the water quality requirements for the proposed use and the quality of the wastewater to be treated. Water quality requirements for use in the oil and gas industry are discussed in Chapter 7. Since techniques for using water of lesser quality (e.g., higher TDS) are developing rapidly, treatment costs are becoming less of a factor. This could help make recycling a more cost-effective alternative in the future.

6.3.1.2 Municipal Wastewater Cost Issues

Municipal wastewater effluent can be a significant source of reuse, but it is generated at specific locations (i.e., the WWTPs) and must be stored and conveyed to the user. This is typically accomplished by pump stations and pipelines that convey the effluent to the reuse destination. However, oil and gas industry users need the water at a large number of widely dispersed locations (i.e., well sites), making the development of a viable distribution system for the effluent a challenge from a cost standpoint in some cases. Chapter 5 describes some potential distribution scenarios that could be used to move effluent from its source to the users.

6.3.1.3 Oil and Gas Price Impediments

Economic impediments that are caused by fluctuations in the market for oil and gas are very difficult to predict or to manage. When oil and gas prices are high, drilling activity in a productive area, such as the Permian Basin, can be very intense. High levels of drilling and development put pressure on existing supplies of water and can help make a recycled water project viable from an economic standpoint. However, if the price of oil or gas in the market drops, drilling and development can quickly drop. When that happens, demand for water drops as well; and operators will quickly stop progress on planning or implementation of a recycled water project.

A significant drop of prices in the oil and gas industry is being experienced at this time. From a price of over $110 per barrel for oil in June 2014, the market price fell to less than $50 per barrel in January 2015 and was at, or below, $30/bbl in early 2016. This drop in price has produced a significant drop in exploration and development activity in the Permian Basin. For example, the rig count (a common indicator of exploration and development activity) for the Permian Basin between June 2014 and January 2015 dropped by approximately 25%. During 2015, the number of active rigs fell an additional 53%, and this trend is projected to continue into 2016 (Digital H_2O 2016).

During a period of downturn, producers or operators must focus on the immediate issue of reducing costs. Concerns related to water demand during periods of greater activity become a lower priority. Some producers may take a proactive view, choosing to prepare ahead of time for higher water demands that will occur when oil and gas prices again rise; but for these plans to be implemented, sale of oil must generate sufficient capital for new investments. This condition does not exist when oil sells at, or below, $30/bbl, which is less than the cost of producing oil for many operators in the Permian Basin.

6.3.2 Regulatory Impediments

Regulation of the oil and gas industry, in particular environmental regulation, could be an impediment to water reuse within the industry. Environmental regulation, and particularly that associated with water quality, is managed by a number of State and Federal agencies. In Texas, environmental regulation of the oil and gas industry is under the purview of the RRC. However, the primary source of recycled water other than wastewater from oil and gas activities is treated wastewater from municipal and industrial WWTPs, which is regulated by the TCEQ. At the federal level, the U.S. Environmental Protection Agency (USEPA) is responsible for carrying out the Clean Water Act. The USEPA, therefore, works closely with both the TCEQ and the RRC to manage activities that potentially affect the quality of groundwater and surface water in the State.

The RRC and TCEQ work together to coordinate environmental regulation of oil and gas activities in the State. A memorandum of understanding (MOU) between the agencies (Title 16 TAC, Part 1, Chapter 3) guides coordination activities. The MOU addresses a range of environmental programs associated with oil and gas activities, including solid waste, water quality, and injection wells. However, as reuse of wastewater from municipal or industrial sources for the oil and gas industry increases, the line of jurisdiction between the RRC and TCEQ may become less clear. Likewise, as recycling approaches that take oil and gas wastewaters off of the oilfield lease for treatment, storage, and redistribution become viable, additional interagency coordination to clarify the responsibilities between these agencies may be necessary.

Regulatory impediments to the water reuse market may occur in two specific ways. The existing rules and guidance have been developed for other types of systems and may need to be modified. This can present a hindrance to an operator who has other alternatives for meeting water demand. It is also possible that the rules and guidance from the various agencies may overlap and/or conflict with one another, thus creating confusion among potential participants in a project to reuse water.

These potential impediments can be managed. Chapter 10 will discuss the regulatory framework associated with reuse projects and approaches to minimizing impediments or barriers from the regulatory arena.

6.4 SUMMARY

Currently, the only wastewaters available for reuse in any significant quantity are flowback and produced water from oil and gas operations. It is impractical to reuse these waters for steam-electric power generation because of the high TDS concentration. However, they can be used for HF if suitably treated. The keys to success lie in (1) whether treatment costs can be competitive with existing water costs and viable at the current reduced price of oil and gas; and (2) whether regulatory processes can be adapted to these new concepts.

7 REUSE WATER QUALITY REQUIREMENTS

Based on a review of the potential viability of a regional water reuse system for industries in Ector and Midland Counties, it has been determined that the most viable reuse alternative is to use wastewaters from oil and gas fields, after suitable treatment, as a water supply for HF operations. Both produced water and flowback water can potentially be used for this purpose.

The use of oilfield wastewaters for waterflooding is being done by some operators, but waterflooding is not a widespread practice in Ector and Midland Counties. When waterflooding is practiced using recycled water, typically it is performed within the same oilfield. There is not a demand for a regional solution to facilitate this type of reuse.

The other industrial operations in the study area that use significant volumes of water, and are not already using recycled water, are the power plants. It has been concluded that oil- and gas-field wastewaters are not practical for reuse at a power plant. The principal water use at a power plant is for cooling. There are multiple constituents in oil- and gas-field wastewaters that would have to be removed before these waters could be used effectively for cooling water. The technologies that would have to be used to achieve an acceptable level of water quality are too expensive to be practical.

Water that is used in oilfield activities must meet certain quality requirements to ensure that it is functional for the intended use and does not violate any regulatory requirements. Wastewaters collected for reuse will contain some level of undesirable contaminants. These contaminants must be identified and treated to an appropriate level before the water is distributed back into the oilfield for further use in HF operations.

Contaminants in oilfield wastewaters are caused by one of two conditions: dissolution of the formation (produced water), and residual treatment chemicals left over from previous HF operations (flowback water). The contaminants present and the concentrations of those contaminants vary depending on the formation and depth from which oil and gas is being extracted; and the quality also varies, to some extent, between wells in the same formation.

The treatment quality objectives for HF reuse also vary. Different producers and different HF operators have different preferences on HF protocols, which results in different water quality requirements.

Therefore, this chapter provides a general summary of the types of constituents that may be present in oilfield wastewaters and which may need to be reduced in order to reuse the water for HF. In general, the constituents of concern can be classified as oils, solids, scalants and precipitants, interferences with HF chemicals, TDS, bacteria, and naturally occurring radioactive material (NORM). The primary source for this chapter is the 2011 report by Reclamation concerning produced water in the western United States (Guerra et al. 2011).

7.1 OIL

When oilfield wastewaters are collected, much of the free oil is separated from the water and retained as a resource. However, some oil typically remains in the water. It may be present as free oil, oil-wet solids, mechanically or chemically emulsified oil, or dissolved oil (Alther 2001).

- Free oil particles are 150 microns or greater in size.
- Oil-wet solids include oil that adheres to sediments or particulate matter in water.
- Oil can be either mechanically or chemically emulsified, which means it is dispersed in the water and resists separation. Smaller particles create a more stable emulsion.
    - Mechanically emulsified oil consists of suspended oil droplets that range in size from 20 to 150 microns. It is formed as larger particles of free oil are dispersed in water during high-shear processes such as traveling through a pump or sloshing in a tank.
    - Chemically emulsified oil is less than 20 microns in size. It may be formed when surfactants are used, which is common in slickwater HF operations.
- Dissolved oils are less than 5 microns in size. Common dissolved oils are benzene, toluene, ethylbenzene, and xylene, which are commonly grouped into the BTEX acronym (Alther 2001).

Water that contains oil is detrimental to HF operations. One potential problem is bacterial growth, because the oils are a food source for the bacteria. Also, if oil is present, the effectiveness of surfactants commonly used in HF operations may be reduced.

7.2 SOLIDS

Solids are one of the primary constituents of concern in water that is to be used in HF operations. Solids can be present as organic or inorganic particles in the water, or they can be the result of bacterial growths.

Solids in water are generally referred to, and measured as, total suspended solids (TSS). TSS particles can range in size from 0.001 microns to 1 millimeter (Murphy 2007).

If TSS are present in water used for HF operations, they can clog the formation and/or increase friction, which decreases the effectiveness of the HF fluid. Additional problems can be associated with the presence of bacterial growth. The issues associated with bacterial growths are summarized in Section 7.6.

7.3 SCALANTS AND PRECIPITANTS

Scalants and precipitants are ions in the wastewater that are initially dissolved but which, when mixed with waters containing other specific ions, react to produce solids that either coat surfaces (scalants) or form particulate matter in the form of TSS (precipitants). Both scalants and precipitants can clog formations and increase friction, which decreases the effectiveness of the HF fluid. In addition, they can adversely affect the functioning of pumps, pipelines, and tanks. Following is a description of the most common ions that, under specified conditions, produce scaling or precipitation.

7.3.1 Iron and Manganese

Iron is relatively common in produced waters in Ector and Midland Counties. If acid treatments were used during a previous HF operation, as is common, this acid can solubilize even more iron from the formation into the flowback water. Manganese can be present, also, in some waters.

Iron is most likely to form precipitates when exposed to sulfide or oxygen. In addition to the potential problems associated with the formation of scalants and precipitants, iron can produce the following problems:

- Chemical reactions that adversely affect the manipulation of pH that is required for HF operations.
- Formation of hydrogen sulfide gas (H_2S) when iron sulfide (FeS) is present in the recycled water, and strong acids (e.g., those sometimes used in HF operations) are used.
- Iron biofouling, caused by bacteria such as *Thiobacillus ferrooxidans* and *Leptospirillum ferrooxidans*, which feed on iron and produce a slime buildup. The seriousness of this problem can range from creating a nuisance to causing extreme damage to the treatment system and underground formations (Excel 2014).

Manganese can produce the following problems:

- Scaling.
- Formation of H_2S when manganese sulfide (MnS) is present in the recycled water, and strong acids (e.g., those sometimes used in HF operations) are used.
- Biofouling, which produces a slime buildup.

7.3.2 Sulfur Compounds

Sulfur can be present as sulfate (SO_4), sulfite (SO_3), or sulfide. SO_4 and SO_3 are combinations of sulfur and oxygen that are found in many naturally occurring rock and mineral formations. Produced water from formations targeted for the production of oil and gas may be rich in these forms of sulfur (Ozone 2013).

SO_4 and SO_3 can react with some elements and cause scale buildup in tanks and pipes. They can also precipitate in the formation and occlude porosity, depending on the quality of the formation water.

Additionally, in the presence of sulfur-reducing bacteria, SO_4 and SO_3 can be converted to H_2S. Sulfur-reducing bacteria are commonly found in anoxic (oxygen-deficient) environments such as deep wells.

7.3.3 Calcium and Magnesium

Calcium and magnesium are the primary cations that comprise water “hardness.” Under the proper conditions and in the appropriate ratios, they can react with bicarbonate and/or SO_4 anions to produce scaling and precipitation. The hardness of formation waters varies widely from formation to formation.

7.3.4 Barium and Strontium

Barium and strontium can form scale that is particularly difficult to remove. Both of these elements can react with SO_4 to form precipitates and produce scaling in pipes, tanks, equipment, and formations. The acids typically used to remove the more common scaling associated with calcium are less effective on barium and strontium scales. Most operators treat injected waters with special chemicals to inhibit barium and strontium scale formation.

7.4 INTERFERENCE WITH HYDRAULIC FRACTURING CHEMICALS

A number of chemicals are added to waters used for HF: acids, proppants, gels, etc. The chemicals added and the concentrations of the various chemicals in the flowback waters from a specific well vary depending on the formation, the producer, and the HF operator. The residuals of some of those chemicals have the potential to interfere with HF operations if present in reuse water. Constituents and characteristics that most commonly are present and may require management are boron, potassium, synthetic organic chemicals, and pH. These are discussed below.

7.4.1 Boron and Potassium

Boron in the form of tetrahydroxyborate [$B(OH)_4$] and potassium metaborate (KBO_2) are used in HF fluids as a crosslinker or viscosity increaser. Boron is the most common crosslinking agent added during guar-based HF. These types of constituents react with selected polymers and chemically link the polymer chains. This produces an increase in viscosity, which facilitates transport of the proppant into the formation. After the formation has been fractured, the pH is lowered, which breaks the chemical linkages. The resulting lowered viscosity allows the HF fluid to be flushed out of the formation and permeability restored (Hodge 2011).

The presence of unneeded boron and potassium in HF fluids, especially during the acid flush, can potentially have negative effects by impeding the breaking of the chemical linkages. This, in turn, can result in a failure to achieve the desired lower viscosities.

7.4.2 Synthetic Organic Chemicals

Synthetic organic chemicals are introduced into HF fluids during most HF operations. In slickwater HF operations, ethers, glycols, and celluloses are used in several stages of the process. In linear gel and cross-linked gel HF operations, many forms of guars and cellulose are used as viscosity increasers (Hodge 2011). HF flowback waters can, therefore, be laden with these organic components.

One concern with the presence of these organic chemicals is that they can be food for bacteria. The bacteria can, in turn, clog the formation, create H_2S gas, and cause slime or scaling in tanks or pipes. Also, because the type and amount of organics used vary by HF type, manufacturer, HF operator, targeted formation, etc., care must be taken to ensure that residual organic chemicals do not interfere with the addition of other synthetic organic chemicals during reuse.

7.4.3 pH

The preferred pH of water used in HF operations is generally between 6 and 8. During HF operations, pH is manipulated in order to change the viscosity of the HF fluid. Thus, reusing water that is too acidic would prevent the linking of bonds in the crosslink gel, and the desired increase in viscosity would not be achieved. Reusing water that is too basic could inhibit the pH lowering needed to break the polymer bonds and reduce viscosity during the final stages of HF operations (Godsey 2011).

Because pH is manipulated so frequently throughout the HF operation, most operators will have the ability to make adjustments of pH at the well site. Although not critical, many operators report a desire to have incoming water as close to neutral as possible to reduce the frequency of well-site pH adjustments.

7.5 TOTAL DISSOLVED SOLIDS

TDS is a measure of all organic and inorganic ions and compounds in water that are small enough to pass through a filter that has a pore size of two microns. TDS in oilfield wastewaters is predominantly comprised of inorganic ions. The dominant inorganic ions in formations in the Permian Basin are sodium and chloride (Guerra et al. 2011).

Hardness comprised of calcium and magnesium, which is discussed above, is a component of TDS. Calcium and magnesium are commonly found in waters in the formations underlying the Permian Basin.

Although a significant constraint in the past, maintaining low concentrations of TDS in HF waters is becoming less critical as technology improves. (Specific components of TDS, such as calcium and/or magnesium, may still require management.) Some companies perform HF operations using waters with TDS concentrations over 200,000 mg/L (Schlumberger 2015a; Halliburton 2015).

7.6 BACTERIA

Oils are organic and, therefore, provide food that can support bacterial growth during water storage, during water transport, or in the formation. Bacterial growths can create slime; corrode tank or pipe surfaces; and generate H_2S (Maugans 2013). Bacterial growth in a formation can clog the formation and slow the productivity of the well.

7.7 NATURALLY OCCURRING RADIOACTIVE MATERIAL

NORM can be present in produced waters. The types most commonly found are radium 226, radium 228, and radon gas. The levels present in the produced waters are not typically a concern during normal oilfield operations. However, when evaluating reuse systems, the potential exists for concentration of NORM.

NORM regulations are focused on conditions where NORM is concentrated such as in scaling, particularly barium sulfate scale, and in sludges. The regulations governing NORM are discussed in Chapter 10.

Unlike other constituents of concern, the focus with respect to NORM is not how to treat it for removal but, rather, how to guard against concentrating NORM to levels that trigger regulatory requirements. Therefore, the systems proposed for management of oilfield wastewaters for reuse will be reviewed to determine if concentration of NORM to regulatory levels can be expected to occur anywhere within the system.

7.8 SUMMARY

Table 7.1 identifies the seven categories of constituents of concern. The constituents most commonly encountered in flowback and produced waters in the Permian Basin in each of the categories are also identified.

Table 7.1 Primary Constituents of Concern
Hydraulic Fracturing Operations

Category	Principal Constituents	Potential Effects
Oil	Free, emulsified or dissolved oils; oil-wet solids	Bacterial growth, clogging, slimes, interference with surfactants
Solids	Inorganic precipitants, bacteria, formation particulates,	Clogging, increasing friction in formation, decreasing effectiveness of HF operations
Scalants and Precipitants	Iron, manganese, sulfur-related compounds, calcium, magnesium, barium, and strontium	Clogging; slimes; decreasing effectiveness of HF operations; functioning of pumps, pipelines and tanks; H_2S formation
Interference with Hydraulic Fracturing Chemicals	Boron, potassium, synthetic organic chemicals, pH	Impeding flushing of HF fluid at end of HF operation, bacterial growth, clogging, slimes, H_2S formation, scaling, increased difficulty in pH adjustments
Total Dissolved Solids	Dissolved inorganic and organic ions and compounds	Depending on inorganic elements present, scaling and precipitation may occur
Bacteria	Iron, manganese, sulfur, and general bacteria	Clogging, slimes, corrosion, H_2S formation
Naturally Occurring Radioactive Materials	Radium 226, radium 228, radon gas	Regulatory requirements for handling and disposal when concentrated

8 ALTERNATIVES FOR TREATMENT, TRANSPORT AND STORAGE

As discussed in previous chapters, it has been determined that, currently, the only viable option for industrial water reuse in Ector and Midland Counties is to reuse oilfield flowback and produced waters for HF operations. Any project that accomplishes this type of reuse will provide multiple major benefits in this water-short area.

It should be noted that this project is focused on systems that will allow wastewaters to be reused for oilfield operations. It is not an objective of this study to identify a system that will result in a discharge of treated oilfield wastewaters to surface waters.

Oilfield reuse systems will require facilities for treatment, transport, and storage. Each of these system components is discussed in this chapter.

The treatment system must be able to treat the wastewaters so that the quality is sufficient for the water to be used for its intended purpose of HF. The water quality needed for HF operations varies by producing formation, the particular HF technology being used, producer preference, and HF operator preference.

This chapter presents a general overview of proven treatment technologies that effectively reduce constituents of concern. These technologies are described in Section 8.1 below.

Transport systems will be needed to deliver the wastewaters to a facility for treatment and to return the treated water to locations where it can be reused. Transport systems are described below in Section 8.2.

Finally, storage facilities will be required. Storage may be needed at the point wastewaters are delivered to the treatment system to provide a more consistent rate of flow through the treatment system; at the end of the treatment system to provide a more consistent feed to distribution pumps; and along the distribution system to provide flexibility with respect to when and where the water is delivered for HF operations. Storage facilities are described in Section 8.3.

8.1 TREATMENT ALTERNATIVES

Treatment systems are developed to produce a specific quality of treated water. Treatment technologies are selected based on those quality objectives. The following section discusses the challenges inherent in identifying a suitable treatment system for an oilfield water reuse project and then summarizes proven candidate technologies.

8.1.1 Challenges to Treating Oilfield Wastewaters for Reuse

Variability of quality can be a significant challenge when developing a treatment system for the reuse of oilfield wastewaters. Both the wastewaters received and the quality needed for reuse vary greatly over time and location. Examples of this variability include the following:

- Wastewater quality
  - The quality of formation waters varies by formation, between wells in a given formation, and over time in a given well. This variation occurs with respect to both the types of constituents present and the concentrations of those constituents.
  - Flowback waters also vary in quality depending on the HF technology used.
- Quality required for reuse
  - Waters reinjected for HF need to have a mineral composition that is compatible with the formation waters. An incompatibility may result in the formation of solids that will clog or reduce production from the well. This is most likely to need to be addressed if the reuse system accepts wastewaters from different formations.
  - Quality requirements vary depending on the HF technology used. Formation conditions are one factor that can influence the HF technology selected.
  - Quality requirements vary based on the preferences of the producer and the HF operator.

Because of the significance of the HF technology used when defining treatment objectives, the following section describes the three major technologies and their respective general quality requirements.

8.1.2 Hydraulic Fracturing Technologies

There are three broad categories of HF operations that are routinely performed in the Permian Basin: slickwater, linear gel, and crosslinked gel. These operations can be applied singly or as hybrid combinations. Each HF category uses different chemicals and, therefore, has different requirements for the water quality needed to conduct that operation. In addition to water quality requirements based on the type of HF operation, the limit of each constituent tolerated for HF water can also vary by operator preference and target formation.

8.1.2.1 Slickwater Hydraulic Fracturing

Slickwater HF operations use friction reducers, in the form of polyacrylamide or petroleum distillate, to decrease the friction of the HF fluid so that it can be pumped rapidly into the formation. Surfactants, such as butanol or ethers, keep the proppant suspended during the process. If needed, oxidizers or enzyme breakers, such as ammonium or sodium salt, are injected between HF stages and after the final HF stage to reduce the fluid's viscosity and allow the fluids, water, and oil in the formation to flow back more freely.

Slickwater HF operations are generally able to tolerate the least stringent quality water. TDS and boron have very little impact on slickwater chemicals; almost any level can be tolerated. Slickwater operations can also tolerate higher levels of iron and oils in the water used than linear gel and crosslinked gel operations. TSS concentrations are the limiting factor for slickwater HF operations and should not be above 100 mg/l. Slickwater is not sensitive to changes in pH.

8.1.2.2 Linear Gel Hydraulic Fracturing

Linear gel HF operations use a viscosity increaser to thicken the HF fluid and facilitate the transport of the proppant into the formation. The viscosity of linear gels is usually between 10 and 30 centipoise (cP). Derivatives of guar are most often used in linear gel for this purpose. Therefore, linear gel HF fluids are often referred to as "guar gel" or "guar gum." Derivatives of cellulose may also be used in linear gels. The viscosity of linear gels is reduced after the last HF stage by oxidizers and enzyme breakers. The pH is also lowered at that time to destabilize the gel.

Linear gels are sensitive to the concentrations of TSS, iron, boron, and oils present. Linear gels are most stable in neutral to high pH environments; low pH is used to break down the gel. Therefore, water provided for linear gel operations should have an initial pH between 6 and 8.

8.1.2.3 Crosslinked Gel Hydraulic Fracturing

Crosslinked gels are very similar to linear gels but include an additional "crosslinker," almost exclusively boron, to increase the viscosity even further, up to 1,000 cP. Crosslinkers react with specific sites on the guar gels and chemically link the polymer chains to create three-dimensional structure. Crosslinked gels can be tailored for specific formation properties and offer operators a higher degree of flexibility than linear gels. Maintaining the viscosity of crosslinked gels requires a pH of 9 or above. The bonds are easily broken by reducing pH after the final HF stage; this enables easy clean-up and good flow back from the formation.

Like linear gels, crosslinked gels are sensitive to TSS, iron, boron, and oils in water. They are more sensitive to boron and pH than linear gels. Because crosslinked chemicals are designed for specific formation properties, the introduction of unplanned boron via the incoming water could interfere with the effectiveness of the formulation. The use of waters with a low pH could prevent the desired increase in viscosity or prematurely decrease viscosity, which would disrupt the HF operation.

8.1.3 <u>Treatment Processes</u>

This section presents treatment processes that have been utilized successfully to treat oilfield wastewater. While there are a number of experimental treatment technologies in development, to ensure consistent and reliable results, this study only reviewed proven technologies.

The following section groups treatment technologies by the constituent of concern that they are intended to reduce. Each treatment technology, its advantages and disadvantages, and approximate relative capital and operating costs are described.

The costs are derived from cost curves, and actual costs could vary substantially based on project-specific factors. However, the costs presented are internally consistent and are suitable for comparing the relative costs of the various technologies. The costs do not include pretreatment units for technologies where pretreatment may be required. Costs are based on units sized to treat an average flow of 100 gpm and a maximum flow of 200 gpm. A primary reference for this section is the 2012 *General Electric Handbook of Industrial Water Treatment* (GE 2012).

8.1.3.1 Oil and Solids Treatment

The following section describes six different techniques, with different levels of complexity, for removing oil and solids from flowback and produced waters. Some of these technologies require, or benefit from, pretreatment prior to application. Others benefit from the use of emulsion breakers. The various types of treatments that may precede these treatments are not discussed because they tend to be application-specific. Similarly, requirements and costs for residuals management are not addressed below but will be considered when evaluating alternative systems.

8.1.3.1.1 Parallel-Plate Oil-Water Separator

An oil-water separator uses gravity and the density difference between oil and water to separate oil from water. It is effective for removing free oil, oil-wet solids, some emulsified oil, and settleable solids. It is not effective in reducing or removing dissolved oil or unsettleable suspended solids.

Oil-water separators can be of conventional American Petroleum Institute (API) design or parallel-plate design. A parallel-plate separator has a much smaller footprint than a conventional gravity separator and provides equivalent or better oil removal, provided that the flow rates to the parallel-plate separator are within its hydraulic capacity.

A parallel-plate oil-water separator consists of a tank containing an inclined parallel plate assembly, a skimmer, and a basin or receptacle to receive the accumulated sludge. Influent wastewater is pumped into the tank; free oil floats to the top and is skimmed off. The remaining water, with suspended oil droplets, then passes through the inclined parallel plates, which cause oil droplets to coalesce into larger globules. Once emulsified oil coalesces into larger globules, it rises to the top of the tank and can be removed by skimming. The settleable solids present in the water slide down the topside of the plate and collect at the base of the tank to be removed as sludge (API 2010).

These separators are found in many industrial water treatment facilities. They do not require the use of any chemicals, and only minimal energy is required to pump the water through the system, skim off the oils, and remove the sludge. Depending on the quality of the wastewater being treated, a significant waste stream can be generated.

Advantages to using a parallel-plate oil-water separator include the small footprint, the simplicity of the system, low capital costs, and moderate operating costs. They are easy to obtain and operate.

A disadvantage of this system is that it removes a limited number of constituents. It is not effective for the removal of small solids, colloids, or dissolved material. It also has limited capability for removing emulsified oils; and, therefore, it is necessary to minimize upstream disturbances that tend to create emulsions (e.g., use of centrifugal pumps).

Capital costs are low, and operating costs are moderate: approximately $30 per barrel per day (/bbl/d) ($700 per thousand gallons per day [/kgal/d] and $0.062/bbl [$1.50/kgal]), respectively. The primary operational cost is associated with removal of the waste from the unit.

8.1.3.1.2 Settling/Sedimentation

Sedimentation of settleable solids is a physical process commonly in use in the oil and gas industry. The process is usually accomplished in a pond but may also be done in constructed tanks. Sedimentation ponds are the more economic means in use in the oil and gas industry.

In either case, suspended solids having sufficient mass settle by gravity to the bottom and are periodically removed for disposal. Tanks may have mechanical sweeps or other devices that remove settled solids intermittently or continuously. Sedimentation is not generally effective for removing very small solids, colloids (which may be associated with clays), lighter silts, dissolved constituents, or oils.

Advantages to sedimentation include the simplicity of the process and the low operating costs. Sedimentation ponds are simple to install and operate and require very little maintenance apart from eventual sludge removal.

The major disadvantage of the settling/sedimentation processes is the relatively limited types of constituents removed. Only settleable TSS is removed—small size particles and particles with densities near that of the wastewater being treated are not removed effectively. If free or emulsified oil is present in the water being treated, it will separate and float, which complicates the effective operation of the sedimentation pond/basin because it has to be removed by skimming. Also, high-volume sedimentation ponds require a large surface footprint.

Capital costs are moderate, around $88/bbl/d ($2,100/kgal/d). There are few costs associated with maintenance of sedimentation ponds or tanks other than liner maintenance and sludge removal. The average operating cost for a sedimentation basin is approximately $0.018/bbl ($0.43/kgal).

8.1.3.1.3 Dissolved Gas Flotation

Dissolved Gas Flotation (DGF) is used to remove small, suspended particles that do not settle out of solution in a gravity settling/sedimentation process. For DGF, gas is injected into pressurized wastewater to supersaturate the solution. The solution is then discharged into a tank at atmospheric pressure; and the dissolved gas comes out of solution and forms small-diameter air bubbles on the surface of the suspended solids. The bubbles carry the suspended solids to the surface, which results in foam on the surface of the water. The foam is removed by skimming.

The dissolved gas used in the process can be air, nitrogen, or any inert gas (Guerra et al. 2011). Although air has been regularly used in the past, nitrogen is frequently used today in DGF. When nitrogen gas is used, it is recycled.

DGF is effective in removing particles 25 microns or larger. It can be used in conjunction with coagulation; if coagulation is used prior to DGF treatment, particles as small as 3-4 microns can be removed. DGF is used to remove oil and TSS from wastewater (Guerra et al. 2011). Volatile organic compounds will also be stripped by the dissolved gas, and treatment of the off-gas may be required to comply with air quality regulations.

An advantage of DGF is its ability to remove very small particles. When used with coagulation, it is one of the best ways to remove small, suspended particles from water. The use of nitrogen gas also reduces the risk that an explosive atmosphere could be created in the tank. In some DGF applications, if air is used there is the potential to create an explosive atmosphere.

A disadvantage of DGF is the moderately high capital costs. Also, the DGF process works best in lower temperatures; in higher temperatures, a higher pressure is required to dissolve the gas into the water, which results in higher energy costs.

Capital costs of a DGF system are approximately $155/bbl/d ($3,700/kgal/d). Operating costs are low, however, and average approximately $0.043/bbl ($1.00/kgal). The most significant component of the operating cost of a DGF system is the energy required to dissolve the gas in the influent wastewater (i.e., the pressurization step). Other costs include the pumping costs and solids disposal.

8.1.3.1.4 <u>Coagulation</u>

Coagulation is an effective treatment strategy to enhance the removal of colloids and small solids from wastewater. Colloids are often present in an emulsion in oil and gas industrial wastewaters. Coagulation can be effective in breaking these emulsions and removing these colloids. Coagulation can remove some dissolved constituents (e.g., iron and phosphate) when the appropriate chemical is added as the coagulant.

Colloids possess electrical charges on their surface. These charges repel other, similarly-charged colloids, which prevents colloidal particles from combining. Coagulation results when appropriate ions of an opposite charge are added in the form of a chemical or an electrical current. This destabilizes the charges around the colloids and allows the process of flocculation, in which the colloids adhere to each other. The end result is the creation of larger-sized particles that can more easily be removed from solution by physical and mechanical methods. These larger particles are referred to as “floc” (GE 2012).

Chemical Coagulation: The coagulants commonly used in chemical coagulation to form a floc are aluminum sulfate, referred to as “alum;” ferric chloride; ferric sulfate; ferrous sulfate; or lime. Polymers may also be used as the coagulant, either alone or in combination with one of the aluminum or iron salts. Immediately following the addition of the coagulant(s), mixing is provided to increase the rate of particle collision.

Advantages associated with chemical coagulation include the number of constituents that can be removed. By changing the chemical used to induce coagulation, varying constituents can be removed from wastewater in addition to solids and colloids.

Disadvantages associated with chemical coagulation include the costs associated with management of the sludge produced and the need for a disposal site for the sludge. In some applications, chemical coagulation can generate large volumes of sludge with high bound-water content. Some sludges are difficult to dewater. In addition, some chemicals used for chemical coagulation are corrosive.

Capital costs of chemical coagulation are moderate, around $63/bbl/d ($1,500/kgal/d). Operational costs are relatively high, around $0.15/bbl ($3.60/kgal), due to the high chemical and disposal costs.

Electrocoagulation: Electrocoagulation (EC) is a water treatment technology that uses electrical current to neutralize the charge of colloids and produce floc. In this method, the coagulant is generated in-situ by electrolytic oxidation of an anode material. EC can remove oil, TSS, colloids, iron, aluminum, calcium, sodium, barium, strontium, heavy metals (i.e., cadmium, chromium, lead, nickel, and zinc), arsenic, bacteria, and dissolved silica. EC is not very effective in removing TDS and boron.

A standard EC system consists of a series of conductive metal plates, arranged in parallel. These plates can be made of any conductive material, such as iron, aluminum, copper, titanium, or steel. The plates are arranged in close succession in an alternating series of positive and negative plates. Direct current is introduced, which initiates electrolysis. The positive plates undergo anodic reactions; the negative plates undergo cathodic reactions. This releases charged ions into the water between the plates. The ions neutralize the charges of the particles and initiate coagulation, which produces the floc. Metal ions become new centers for larger, stable insoluble complexes that precipitate out of solution. EC also speeds up the oxidation process, which allows faster precipitation and removal of compounds that can be removed by oxidation. Additionally, as emulsified oils and organic colloidal particulates move through the electric field, they undergo ionization and hydrolysis, which allows the oils to be separated out of solution (Martin 2014; F&T 2015).

Advantages associated with EC include the number of constituents that are removed. Since chemicals are not used in EC, there are savings associated with chemical purchase as compared with chemical coagulation. Additionally, the floc generated by EC contains less bound water than floc generated by some chemical coagulants and is more easily dewatered, which results in lower waste disposal costs.

Disadvantages associated with EC include the complexity of the system and associated installation. The system requires a large amount of equipment and is relatively complex to install. A more skilled staff is required to operate the EC system than is required for many other treatment processes. EC is also fairly energy-intensive and could become costly if energy prices increase. Also, most EC installations to date treat relatively low volumes of water. It is not known how larger systems would function or how they may need to be adapted.

The capital costs of the EC system average approximately $57/bbl/d ($1,400/kgal/d). Operational costs of EC treatment are somewhat less than chemical coagulation, averaging $0.088/bbl ($2.10/kgal). The primary operating costs are associated with electric power, replacement of electrodes, pump maintenance, and waste disposal.

Filtration

Filtration removes constituents from water by means of a physical barrier with restricted pore size. Filters are made of a variety of media, including screens, sand, anthracite coal, diatomaceous earth, walnut shells, and membranes. Filters have a wide range of pore sizes.

Granular media filtration removes the larger particles, and some media are relatively effective in removing oil. Microfiltration (MF) and ultrafiltration (UF) use membranes for filtration. These processes remove smaller particles than those removed by granular media.

Nanofiltration (NF) and reverse osmosis (RO) processes use membranes and are effective for filtering extremely small particles, including some or most dissolved ions. NF removes some of the dissolved ions, while RO removes most of the dissolved ions comprising TDS. These processes are described in Section 8.1.3.2.

Granular Media: Granular media filtration is a relatively simple form of filtration in which water is passed through a media (e.g., walnut shells, sand, or anthracite). Granular media can typically remove particles 5 microns and larger in size. Different filter media are effective for different constituents. Walnut shells are especially good for removing free oil from produced water and can achieve 90% free oil removal (Guerra et al. 2011). As particles are removed from water and build up in the filter, the filter must be backwashed.

The advantages of granular media filtration include the simplicity of the system and low operating cost. A granular media filtration system requires very little maintenance in comparison to other types of filtration systems.

Disadvantages include the limited range of constituents removed using granular media filtration. Granular media filtration is not effective in removing dissolved materials.

Capital costs for installing a granular media filtration unit are moderately high, approximately $114/bbl/d ($2,700/kgal/d). Granular media filtration is commonly gravity-fed and requires minimal energy to operate. Energy is primarily required for backwashing the filter. Operating costs are low, approximately $0.032/bbl ($0.76/kgal). Operating costs include solid waste disposal for the solids in the backwash (Guerra et al. 2011).

Membrane Filtration — Microfiltration and Ultrafiltration: MF and UF are membrane filtration systems that remove smaller particles than those removed by granular media filtration. MF removes particles between 0.1 and 3 microns in size. UF removes particles between 0.01 and 1 micron in size.

These filtration systems need to be preceded by treatment to remove larger TSS particles and oil, or they will rapidly fail due to clogging. Commonly used pretreatment processes are gravity oil-solids separation (e.g., parallel-plate separators) and coarse media filtration (e.g., granular media filters or cartridge filters).

In addition to typical TSS, MF can remove the smaller clay-sized particles and the larger humic acid compounds. MF can also remove bacteria, algae, and microbiological cysts. UF can remove viruses, color, odor-causing compounds, and some colloidal organic materials. Neither process removes dissolved salts from the water. MF or UF may be used as a pretreatment process for RO or NF (Guerra et al. 2011).

In MF and UF systems, water is driven through the membrane filtration system using either pressure or vacuum. The membrane filters can be either ceramic or polymeric. Ceramic filters are more effective in cleaning oil-containing waters but have a higher capital cost.

Periodic backwashing is required to clean the membranes; the frequency and duration of backwashing depend on the application. The membranes are delicate and can become damaged or clogged easily. Frequent monitoring of the membrane filter is necessary to ensure that the membranes remain effective and are not damaged (Guerra et al. 2011).

The primary advantage to using MF and UF is their ability to remove very small particles. These processes remove particles that are difficult to remove with any other process.

Disadvantages include the high capital and operating costs associated with the processes. In addition, these filtration systems must be continuously monitored.

Capital cost of a MF or UF system is approximately $222/bbl/d ($5,300/kgal/d). Operating cost is approximately $0.30/bbl ($7.10/kgal).

Centrifugation

Centrifugation is used to separate solids from liquids and/or liquids of differing densities by applying a gravitational force of several thousand times that of gravity. The gravitational force is created by the rotational speed of the centrifuge. The separation rate in the centrifuge is influenced by the particle size of the solids, the relative densities of the solids and liquid(s), and the relative viscosities of the liquids. Coagulants are often added to the wastewater being treated because flocculation improves the separation of oil, water, and solids.

A centrifuge used to separate oil, water, and solids is commonly referred to as a tricanter centrifuge. Solids accumulate on the wall of the centrifuge bowl and are conveyed out of the centrifuge. The two liquid phases are separated using a dual discharge system where the lower density oil phase is separated over a ring dam by gravity; and water, which is usually the heavier liquid phase, is discharged using a stationary impeller under pressure. Each of the three wastewater components — solids, oil, and water — are discharged as separate streams that are subsequently separately managed based on their characteristics and volumes.

Because of their compact size and efficiency of oil/solids/water separation, centrifuges may be a practical option for oil field operations. The centrifuge can be designed and operated to produce a water stream with low solids and oil content that can be reused with little or no additional treatment. The oil and solids streams from the centrifuge are low volume wastes (or, in the case of oil, potentially a resource) and can be managed by the range of methods applicable to oil and solids.

The capital cost of a centrifuge is approximately $158/bbl/d ($3,800/kgal/d). The operating cost is approximately $0.27/bbl ($6.40/kgal).

8.1.3.2 Scalant and Precipitant Treatment

Some ions that are initially dissolved may react with other constituents that are introduced to the water and produce insoluble compounds that attach to surfaces in the form of scale or settle out as solid particles. Either of these processes, which may occur within a formation or in surface facilities such as pumps, pipes, and tanks, interferes with the efficient functioning of oil and gas well systems.

The reactions producing the scaling and precipitation may be the result of either oxidation or a reaction between cathodic and anodic salt ions. Common reactions are the oxidation of iron or manganese, reaction of iron or manganese with a sulfide ion, precipitation of calcium or magnesium in the presences of bicarbonate or SO_4, and precipitation of barium or strontium in the presence of SO_4.

Therefore, common treatment processes, which are described below, include oxidation in a controlled environment so that it does not occur in the formation, and auxiliary equipment and processes that remove the ions with potential to produce scaling or precipitation. Depending on the ion to be removed, the treatment process may be coagulation, adsorption using ion exchange or granular activated carbon, or membrane filtration using NF or RO.

Oxidation

Oxidation alters the chemical state of dissolved iron, manganese, sulfide, and some organics so that they form insoluble compounds. Once insoluble compounds are formed, they can be removed by sedimentation or filtration (Guerra et al. 2011).

The most common types of oxidants used for treatment include free chlorine, chlorine dioxide, potassium permanganate, and hydrogen peroxide. The oxidation reaction type and rate are controlled by the chemical dose and the contact time between the oxidant and the wastewater (Guerra et al. 2011).

There are many advantages to using chemical oxidation. Chemical oxidation is relatively simple and inexpensive, requires minimal equipment, and is a well-established process.

Disadvantages to chemical oxidation include the recurring costs for the chemicals used in the treatment. Also, depending on the chemical used, there may be on-site storage requirements for the chemicals; and some chemical oxidants, such as chlorine, are hazardous.

The primary capital costs are the chemical metering pump and the mixing equipment used to rapidly and thoroughly mix the oxidant with the water being treated. Because the oxidation reactions are almost instantaneous, in-line mixers are often used. Capital costs are low, approximately $11/bbl/d ($260/kgal/d) of water treatment capacity.

Operationally, the main costs are the purchase of the chemicals, energy used to distribute the chemicals, and calibration and maintenance of the chemical metering pump. If the oxidant is generated on-site, the costs may be lower. Average operational costs for chemical oxidation are low at approximately $0.013/bbl ($0.31/kgal) of water.

Coagulation

Coagulation is discussed in detail, previously, in Section 8.1.3.1 as a process that removes oil and solids. It is also effective for removing a number of substances that produce scaling and precipitation. Both chemical coagulation and EC can remove calcium, magnesium, and some synthetic organic chemicals. EC can also remove iron, manganese, barium, strontium, and some synthetic organic chemicals.

Adsorption

Adsorption is a surface-based process in which atoms, ions, or molecules adhere to a surface. Common adsorbents used in wastewater treatment are resins designed to adsorb specific materials by an ion exchange mechanism and activated carbon, which adsorbs a wider range of substances. Although powdered activated carbon is used in some applications, granular activated carbon (GAC) is a preferred form for treating oilfield wastewaters and is the form discussed below.

Ion Exchange: Ion exchange processes use a media, usually in the form of resin beads, to remove cations and anions from water by adsorption. Specific ions can be targeted for removal by using specialized resin beads manufactured for that purpose (GE 2012). Calcium, magnesium, boron and sulfate are among the ions that can be removed from water using ion exchange (Parsaei et al. 2011; MDH 2008).

The resin beads used in ion exchange are small plastic beads composed of organic polymer chains that have charged functional groups built into the resin bead. The functional group has either a positive or negative fixed charge. As water is passed through the beads, targeted cations or anions are attracted to the resin bead of the opposite charge and are removed from the water. Eventually all of the exchange sites on the beads are exhausted, and the beads require regeneration to be used again (GE 2012).

Ion exchange processes generally require pretreatment. Turbidity and TSS should be reduced before treatment. Additionally, iron, manganese, and chlorine should be removed before the ion exchange process. Although iron and manganese can be removed by ion exchange, the oxidized forms will precipitate and clog the ion exchange columns. If organic material is present in the incoming water, it should be reduced in order to prevent bacterial growth in the resin beads.

Advantages of ion exchange include the range of constituents that can be removed by the process. Ion exchange is generally used to remove dissolved inorganic constituents that are otherwise difficult to remove and/or when water that is essentially ion-free is desired. The process is versatile and can be tailored to suit the composition of the incoming water and the quality objectives of the product water.

Significant disadvantages of ion exchange are the cost associated with regeneration/replacement of the resin beads and the pretreatment processes needed for ion exchange. Depending on the quality of the incoming water and level of removal needed, ion exchange resin beads may have to be regenerated frequently and, in some cases, replaced frequently. With time, the effectiveness of regeneration deceases; and, eventually, the resin must be replaced. In addition, when used to treat flowback and produced waters, significant pretreatment will be required to remove solids and organic material

Capital costs for an ion exchange system are moderate, approximately $78/bbl/d ($1,900/kgal/d). Operating costs vary based on the constituent(s) targeted for removal. Operating costs for hardness (i.e., calcium and magnesium) and SO_4 removal are approximately $0.067/bbl ($1.60/kgal). Operating costs for boron removal are higher, approximately $0.14/bbl ($3.30/kgal). Operating costs are primarily associated with the regeneration and periodic replacement of the resin beads.

Granular Activated Carbon: GAC is made from raw organic materials that are high in carbon, such as coal, wood, peat, or coconut shells. Heat, in the absence of air, is used to “activate” the surface of the material. The resulting material has very high carbon content and an extremely large adsorption surface area. On average, the adsorption surface area for GAC is 73-112 acres per pound (Guerra et al. 2011).

GAC effectively removes a large number of substances, including mercury, cadmium, dissolved organic matter, BTEX compounds, and other adsorbable organic chemicals. Certain organic compounds (e.g., methanol and ethanol) are not effectively removed by activated carbon. If high levels of TSS or bacteria are present in the water being treated, filtration and disinfection may be required before GAC treatment in order to avoid clogging the carbon pores and to prevent unwanted bacterial growth (Guerra et al. 2011).

Typically, high-volume GAC units are gravity-fed and can be sequenced in parallel or in series. GAC units can also be combined with other media filters (Jurenka 2010).

Replacement of the media is necessary when the active sites on the adsorptive material have been occupied, i.e., the carbon is “spent.” The frequency with which the adsorptive capacity is exhausted is dependent on the rate of usage, contaminant type, contaminant concentration, and type of carbon used (Guerra et al. 2011). It is typical for smaller carbon systems to have a commercial agreement whereby the carbon supplier replaces spent carbon on an as-required basis.

Advantages of using GAC include its high effectiveness for removing organic constituents. GAC is also able to remove H_2S from wastewater.

The primary disadvantage of using GAC is the high cost, both capital and operational. Capital costs average approximately \$327/bbl/d (\$7,800/kgal/d). Operating costs are approximately \$0.19/bbl (\$4.50/kgal). Replacement of the spent carbon can be required frequently, which can be very costly. Also, GAC systems need to be backwashed periodically, which is an operational cost component.

<u>Membranes – Nanofiltration and Reverse Osmosis</u>

NF and RO processes use membranes and are effective for filtering extremely small particles, including some or most dissolved ions. NF membrane systems remove extremely small particles, particles in the range of 0.001 to 0.01 microns in size. Therefore, some ions in solution, including SO_4, can be removed by NF. However, NF is most commonly used as a pretreatment process for RO systems.

RO membrane systems remove very small particles, particles less than 0.001 micron in size, which includes most inorganic cations and anions. When applicable, this technology can reduce TDS concentrations to almost any desired level. RO is generally used as an end-stage treatment since substantial pretreatment is required (Guerra et al. 2011).

In RO systems, a pressure greater than the osmotic pressure of the water being treated is applied to force the water through a membrane while leaving the salt ions behind. The osmotic pressure of a solution increases with the increasing salinity of the solution. Therefore, the pressure needed to separate the salts from the water also increases with the salinity of the water. For this reason, RO is only practical for waters containing less than 40,000 mg/L TDS (Guerra et al. 2011). Since formation waters in Ector and Midland Counties are typically in the range of 100,000 mg/L to 150,000 mg/L—and may be substantially higher--RO is not expected to be a practical treatment technology for oilfield wastewaters.

8.1.3.3 Treatment of Interferences with Hydraulic Fracturing Chemicals

When reusing flowback waters, there are sometimes residuals of the HF chemicals used originally that remain in the flowback waters. In some cases, these substances, if the concentration is not reduced, can interfere when the water is reused for HF. The principal concerns are boron, potassium, synthetic organic chemicals, and pH. The pH is easily adjusted with an acid or base, as appropriate. Depending on which of the other constituents is a concern, treatment using oxidation, coagulation, or adsorption may be needed. The application of each of these treatment processes for the removal of interferences with HF chemicals is discussed below.

Oxidation

A detailed discussion of oxidation processes is provided in Section 8.1.3.2. Oxidation may be used, in some cases, to reduce certain synthetic organic chemicals. The applicability of oxidation and the choice of oxidant are dependent on the organic chemical to be treated.

Coagulation

Section 8.1.3.1 contains a detailed discussion of coagulation processes. Chemical coagulation and EC are both potentially applicable treatment processes for the removal of synthetic organic chemicals. The suitability of either process will be dependent on which organic chemical is to be treated. EC also may be a suitable process for the removal of barium and strontium.

Adsorption

A detailed discussion of the ion exchange and GAC adsorption processes has previously been provided (Section 8.1.3.2). Ion exchange is a suitable treatment process to remove barium. GAC can remove a number of synthetic organic chemicals. Bench scale and/or pilot testing would be required to determine whether the specific organic chemicals of concern are efficiently removed by GAC.

8.1.3.4 Total Dissolved Solids Treatment

No treatment technologies are identified in this report for reducing the concentration of TDS. HF technologies are now available that can use water with high TDS concentrations. The technologies that could potentially be used to reduce TDS are either very expensive, not practical, or in the experimental stage. Therefore, they are not considered applicable for the purposes of this study.

8.1.3.5 Microbiological Constituent Treatment

The presence of bacteria in waters used for HF is a concern for multiple reasons, as discussed in Chapter 7. Treatment to control biological growths can occur at multiple times during the HF process. A variety of biocides are used depending on the specific activity underway and the preferences of the producer and water manager. Whether additional biocide treatment is needed as part of the reuse treatment system is dependent on the specific structure of the reuse system.

8.1.4 Treatment Summary

Table 8.1 summarizes the treatment processes that could be considered for use in a treatment system to provide reclaimed oilfield wastewaters for HF operations. The relevant constituents that are removed by each process; whether pretreatment is required; and generalized capital and operating costs are summarized.

8.2 TRANSPORTATION ALTERNATIVES

Water must be conveyed to and from the well-site and the treatment facility. The primary methods used to transport water are trucks, buried pipelines, and above-ground pipelines. A combination of these methods may be used during the transport process. This section will outline the advantages and disadvantages, capital costs, and operating costs associated with each primary transport method.

8.2.1 Trucking

Trucking is the most common means of transporting water associated with oilfield operations. The water required for an HF operation is frequently delivered to the well-site in tanker trucks over a period of days or weeks. Each truck holds 100-160 bbls [4,200-6,700 gal] of water (Slutz et al. 2012). The volume required for an HF operation varies widely depending on factors such as whether it is a horizontal or a vertical well and the length. Total volumes needed can be in the range of 40,000 bbls (1.6 MG) to 500,000 bbls (21 MG). Thus, a large number of trucks are needed to deliver the water. Trucking costs are often the largest portion of the water management expense for an HF operation (API 2010).

8.1 Potential Treatment Technologies for Reuse Wastewater

Treatment Technology		Treated Constituents of Concern								Pre-treatment Required?	Capital Cost		Operating Cost	
		Oil	Total Suspended Solids	Iron & Manganese	Sulfates/ Sulfites	Sulfides	Boron	Selected Salts	Synthetic Organic Chemicals		$/bbl/d	$/kgal/d	$/bbl	$/kgal
Parallel-Plate Oil-Water Separator		X[1]	X[2]							No	$30	$700	$0.062	$1.50
Settling/Sedimentation			X							No	$88	$2,100	$0.018	$0.43
Dissolved Gas Flotation (DGF)		X	X							Possible	$155	$3,700	$0.043	$1.00
Coagulation	Chemical Coagulation	X	X					Ca, Mg	X	No	$63	$1,500	$0.15	$3.60
	Electrocoagulation	X	X	X				Ca, Mg, Ba, Sr	X	No	$57	$1,400	$0.088	$2.10
Filtration	Granular Media Filtration	X	X							Yes	$114	$2,700	$0.032	$0.76
	Microfiltration and Ultrafiltration	X	X							Yes	$222	$5,300	$0.30	$7.10
Centrifugation		X	X							No	$158	$3,800	$0.27	$6.40
Chemical Oxidation				X		X			X	No	$11	$260	$0.013	$0.31
Adsorption	Granular Activated Carbon					X			X	Yes	$327	$7,800	$0.19	$4.50
	Ion Exchange				X		X	Ca, Mg, Ba		Yes	$78	$1,900	$0.067-$0.14	$1.60 - $3.30

[1]Except emulsified and dissolved oils
[2]Except colloids and small solids
Note: The costs on this table have been derived from cost curves. Actual costs based on sites-specific requirements and conditions may vary by ± 50%. These costs are provided for comparison purposes only and, based on that objective, are internally consistent. Costs are for a system to treat approximately 100 gpm (3,500 bbl/d) average flow and 200 gpm (7,000 bbl/d) maximum flow.

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The advantage to using trucking as a means to transport water is that it requires little, or no, initial investment on the part of the production company. Since most trucks are not owned by the oil or gas producer, the capital cost to truck water is minimal. It also requires little, or no, infrastructure development on the part of the operator, unless roads need to be improved. In most areas it is easy to secure a water hauling contract.

The primary disadvantages to trucking water are the high operational costs and community impacts. The community impacts are a result of the heavy traffic volumes associated with water trucking. The heavy truck traffic increases noise, dust, traffic congestion, road damage, and vehicular accidents. In the oil and gas industry, 40% of fatal occupational injuries are related to transportation events (Slutz et al. 2012).

As previously noted, there is no significant capital cost to an oil or gas producer for transporting water by truck. An average operational cost for trucking water is approximately $0.017/bbl ($0.40/kgal) per mile. Mileage is typically calculated as the round–trip distance. The distances from the well-site to the water supply or wastewater disposal location can be very different. However, if the distances to both the water supply and the wastewater disposal location were 5 miles, trucking cost for each would be $0.17/bbl ($4.00/kgal). The per-barrel operating cost to truck water can vary by region, weather conditions, local fuel price, and ease of access to the well-site.

8.2.2 <u>Buried Pipeline System</u>

Buried pipelines for water transport use pipe made of fiberglass, high-density polyethylene (HDPE), or polyvinyl chloride (PVC) to transport water. Water is transported through the pipe via a series of pump stations. The relative advantages and disadvantages of each type of pipe are presented in Sections 8.2.2.1, 8.2.2.2, and 8.2.2.3, respectively.

One advantage of buried pipe compared to above-ground pipe is that it is more protected. Also, there are locations, such as road crossings, where it is not feasible to use above-ground pipe. When compared to transport by trucks, the use of pipeline systems rather than trucks reduces the community impacts.

The primary disadvantage to using a buried pipeline system is that it is not mobile. If HF activity moves to a new area, the capital cost for installing the pipeline is a sunk cost that cannot be recovered. As with all pipelines, there is a risk of a pipeline break and subsequent environmental damage. The relative risk associated with buried pipelines compared to above-ground pipelines is that leaks are more difficult to detect.

Capital costs associated with developing and implementing a pipeline include costs for securing right-of-way and/or easements, obtaining pipeline materials, and constructing the pipeline. A planning level estimate of the cost for 12” pipe installed in an area with minimal rock and sand is $70 LF ($370,000/mi).

Operating costs are low. The primary costs are inspection and maintenance of the pipeline to ensure it is sound and the energy for pumping. Over time, scale may accumulate in the pipeline, which would need to be removed at an additional cost. If NORM is included in the scale, handling and disposal costs increase.

8.2.2.1 Fiberglass Pipe

Fiberglass pipe is often used to transport natural gas and water in oilfield operations. Although costly, fiberglass pipe can withstand higher pressures than HDPE and PVC pipe. Also, fiberglass is lightweight, strong, resistant to chemicals, and durable (FPI 2015).

The primary disadvantage associated with using fiberglass pipe is that is has a somewhat longer wait time for delivery after purchase (6-8 weeks). Additionally, fiberglass pipe is more expensive than HDPE or PVC pipe.

8.2.2.2 High-Density Polyethylene Pipe

Many buried pipelines designed for water transport are made of HDPE. HDPE is commonly used to transport potable water, wastewater, slurries, chemicals, hazardous wastes, and some compressed gases. The HDPE pipe used must be rated for appropriate chemical exposure, internal pressure, mechanical impact or loading, and temperature range.

The primary advantages to using HDPE are that it is durable, flexible, and corrosion-resistant. Additionally, HDPE is very smooth, which results in low rates of friction and drag, as well as reduced turbulence at high flow rates, compared to other types of pipe material (PPI 2015). HDPE is easier to obtain than fiberglass pipe, and it is less expensive. It is also more durable than PVC pipe.

A disadvantage of using HDPE pipe for water transport is that it is more expensive than PVC pipe. Also, it is less able to handle high pressures than fiberglass pipe.

8.2.2.3 Polyvinyl Chloride Pipe

Buried PVC pipe is also used to transport water. PVC is corrosion-resistant, very lightweight, and inexpensive. It comes in a range of lengths and sizes.

The primary advantage to using PVC pipe to transport water is that it is very inexpensive. It is also much easier to obtain than fiberglass pipe.

The primary disadvantage to using PVC pipe is durability. It may become brittle over time and can weaken and deform when exposed to temperatures over 150 ^{o}F (Gur 2011). Generally, PVC is less durable than fiberglass and HDPE pipe.

8.2.3 Above-Ground Pipeline System

The advantages of an above-ground pipeline system include the following:

- It is mobile; the pipe can be moved from one area to another as HF operations shift from one field to another.
- It reduces the problems associated with heavy truck traffic.
- It is inexpensive to construct compared to buried pipelines.
- The operational costs are low compared to trucking.
- Above-ground pipes are able to be deployed in much less time than it takes to construct a buried pipeline.

The disadvantages of an above-ground pipeline system, compared to buried pipe, include the following:

- It cannot handle as much line pressure.
- Above-ground pipelines are less durable than buried pipelines and may need to be repaired or replaced more often. Because pipes are located above-ground, they are subject to more hazards, including temperature extremes, inadvertent damage by vehicles or machinery, vandalism, animal activity, or damage during deployment or retrieval.
- Surface features such as roads, fences, railroads, streams, and developed areas pose installation issues for above-ground pipelines.
- Securing right-of-way and surface use agreements may be more challenging for above-ground pipeline systems than for buried pipeline systems. In Texas, above-ground pipeline is not allowed in public rights-of-way, which include public roadways, highways,

streets, public sidewalks, waterways, and utility easements in which a municipality has an interest. Above-ground pipelines, therefore, have to be installed entirely on private property. Landowners may have concerns relating to placement of above-ground pipelines, especially if the pipeline is scheduled to be in place for an extended period of time.

Capital costs are dependent on the type of pipe material. A planning level estimate of the cost of installing above-ground HDPE is approximately $34/LF ($180,000/mi). The comparable cost of installing lay-flat pipe is approximately $22/LF ($120,000/mi).

Operating and maintenance costs are generally low, although they may be higher than for buried pipe because the pipe is more exposed to damage from a number of sources. Therefore, there may be more costs for monitoring the pipe to ensure it is in good condition and subsequent maintenance. As with buried pipe, the primary cost is the energy cost for pumping; this cost is variable because it is dependent on distance and grade.

Above-ground pipe may be either rigid, such as HDPE pipe, or flexible, such as “lay-flat” pipe. Both types are discussed below.

8.2.3.1 High-density Polyethylene Pipe

The same HDPE pipe that is used in buried pipeline systems can be placed above-ground and used to transport materials. Above-ground pipe may be suspended, cradled in support structures, or placed directly on the ground. The type of support structure and installation is determined based on the topography and surface conditions of the area serviced. As in buried pipeline systems, the HDPE pipe selected must be rated for appropriate chemical exposure, internal pressure, mechanical impact or loading, and temperature range.

External temperature is more of an issue in above-ground HDPE as compared to buried HDPE because of the lack of insulating ground around the pipe. Above-ground HDPE must also be rated for appropriate ultraviolet (uV) radiation, which can be damaging to the pipe.

8.2.3.2 Lay-flat Pipe

Flexible above-ground pipe is referred to as “lay-flat” pipe or hose. This pipe is made from circularly woven, high-tensile-strength polyester fiber, which is coated with a polyurethane, PVC, or nitrile-rubber layer. The polymer or rubber is extruded through the polyester.

Lay-flat pipe is strong, flexible, and durable. It can be flattened when not in use and easily transported. It is resistant to uV radiation (LTR 2013). Most manufacturers state that their pipes are suitable for a temperature range from very cold (down to -5^{o}F) to very hot (up to 150^{o}F).

8.2.4 Pumps

Both buried and above-ground pipeline systems use pumps to transport water to and from the well-site and the treatment or disposal site. Pumping stations are positioned at the beginning of the pipeline system and at strategically located intervals throughout the length of the pipeline. Pipelines transporting water long distances will need multiple pump stations along the route.

The number of pumps, type, capacity, and voltage will be operation-specific. Pump selection will vary according to the type of pipeline system, the distance traveled, elevation gain or loss, and the curvature of the pipeline.

The energy for pumps is supplied from a direct electrical line, if available, or diesel fuel in remote areas. The energy to operate the pump constitutes at least 50% of the total pipeline operating cost; so, determining the correct pump and operating it efficiently is important (Brennan 2000).

Pumps used with buried pipeline systems will be permanent and immobile. Depending on the configuration, above-ground pipeline systems may use a permanent pump at the beginning of the pipeline and mobile pumps along the pipeline route. Mobile pumps are much less common than permanent pump stations, although they do exist. Mobile pumps are skid-mounted or on wheels and can be delivered to the site using trucks (Precision 2010; FPI 2015; Stewart 2015).

The cost of the pumps and pumping stations are part of the capital cost of the pipeline system. A planning level operating cost for a pump, including energy and maintenance, is approximately ($1/MGD/PSI) ($0.042/kbbl/d/PSI) (Brennan 2000).

8.3 SUMMARY

The type of transportation used to convey water and wastewater is based on the needs of the project. Table 8.2 summarizes the types of water conveyance systems used for oilfield waters and wastewaters and the advantages, disadvantages, capital cost, and operating cost of each.

Table 8.2 Oilfield Water and Wastewater Transport Methods

Transport Method		Advantages	Disadvantages	Capital Cost[(1)] (per LF)	Operating Cost
Trucking		No capital cost; mobile; convenient	Increased road damage; increased traffic; vehicle accidents; high operating cost	Not Applicable	$17/kbbl/mi
Buried Pipeline (12")		Low operating cost; reduces road damage, traffic, and vehicular accident risk	High capital cost; not mobile	$70[(1)]	Low[(2)]
Above-Ground Pipeline (12")	Lay-Flat	Mobile; reduces road damage, traffic, and vehicular accident risk; lower capital cost than buried pipe	Challenging in areas with surface obstacles; may not be allowed in public right-of-way; less durable than buried pipe	$22	Low[(2)]
	HDPE			$34	Low[(2)]

[1]Installed, minimal rock and sand

[2]Primary costs are energy costs for pumping, which are dependent on distance and grade.

8.4 WATER STORAGE

Any system to provide recycled waters for use in the oilfield will require storage in conjunction with the collection, treatment, and distribution. There are three primary means of storing the wastewater and treated water:

- Earthen pits which are excavated from natural soils; bermed with the excavated soils; and, typically, lined with a synthetic liner.
- Above-ground storage tanks (ASTs), which can either be delivered to the well-site fully assembled or assembled from pre-constructed components on-site.
- Potentially, aquifer storage and recovery (ASR). ASR, while widely used to store potable water supplies, has not previously been used to store water supplies for oilfield operations.

This section will discuss the differing methods of water storage, offer advantages and disadvantages for each, and discuss costs.

Storage facilities can be permanent or temporary. Pits and pre-constructed ASTs are typically temporary, although their use in a given location may be relatively long-term. Modular ASTs can be temporary or permanent. An ASR system would be a permanent storage facility.

Pits and modular ASTs utilize liners to form a barrier between the stored liquid and the soil in order to prevent liquid loss and groundwater contamination. Liners can be made with varying types of material depending on the operator’s needs. Most commonly, a combination of several layers of low-density and high-density polyethylene is used. Liners can also be constructed from polypropylene, ethylene interpolymer alloy, and tri-polymer alloy. Liner thickness is measured in “mils”; a mil is 1,000th of an inch. Thicknesses can range between 12 and 80 mil. Liners must be chemically resistant, puncture- and tear-resistant, uV-resistant, and thermally stable. They must also have a high tensile strength. (RRC 2014).

8.4.1 <u>Lined Earthen Pits</u>

The advantages of earthen pits are as follows:

- Pits are relatively inexpensive.
- There are a large number of companies that construct pits in the Permian Basin, and scheduling pit construction is generally simple.

There are several disadvantages to utilizing earthen pits, however:

- If not properly designed and constructed, there may be an accidental discharge of pollutants to the environment. If possible, pits should be located in areas of low relief and in soils with high clay content. The RRC requires installation of a leak detection system for brine pits and recommends a leak detection system for other pit types (RRC 2014). If a leak does occur, the environmental impact could be significant and the cost of remediation, high.

- Uncovered earthen pits experience significant water loss due to evaporation. In the Permian Basin, the combination of high temperatures and high winds can lead to very high rates of evaporation. Placing a cover on a pit can help to control evaporation. Covers are expensive, (approximately $1.20/bbl [$29/kgal]) which reduces the capital cost savings otherwise associated with pit usage. However, operators generally report the cost of the cover is recovered quickly due to reduced water loss (Wilmouth 2014).

- Pits have a large surface footprint and disturb the natural surface conditions more than ASTs or ASR.

- In areas that are environmentally sensitive or have challenging topography, it may not be possible to construct a pit.

- In some cases, landowners may have concerns about the amount of surface disturbance that is required for construction of a pit, and obtaining a surface-use agreement could be challenging.

Pits are relatively inexpensive to construct. The average cost for an uncovered pit is approximately $3.40/bbl ($81/kgal). The primary cost components are the liner and the construction costs.

Operation and maintenance costs are very low. However, there is also the cost of reclaiming the land when the pit is no longer used.

8.4.2 Above-ground Storage Tanks

ASTs are available in a variety of shapes, sizes, and delivery methods. The most commonly used ASTs can be divided into two broad types: pre-constructed and modular. All ASTs are required to have associated containment systems to protect the environment in the event of spills. The advantages, disadvantages, capital costs, and operation and maintenance costs for these two types of ASTs are discussed below.

8.4.2.1 Pre-constructed Tanks

A common type of AST used for HF operations is a 500-barrel (21,000 gallon) fiberglass tank. (Kenter 2012). Operators generally use a number of these tanks to house the large amount of water needed for HF operations. The 500-barrel tank is 16.5 ft in diameter and 16 ft high.

Advantages of pre-constructed, 500-barrel tanks are as follows:

- Transport to the site is easy, and set-up is minimal.
- Spills and leaks are minimized.
- Surface footprint for individual tanks is small.
- Surface disturbance is less than for pits.
- Site is easily returned to its pervious condition, once the tanks are removed.
- Storing small volumes of waters of different quality is practical.
- Protection of environmentally sensitive areas may be enhanced. (Kenter 2013).

However, this may not be a practical alternative for storing large volumes of water. Since each tank stores a relatively small amount of water, storing a large volume of water would be costly and cover a large surface area. Also, a large number of trucks would also be necessary to deliver and remove the tanks.

The capital cost to purchase pre-constructed 500-barrel tanks and associated piping is approximately $26/bbl ($620/kgal). The operating cost of a 500-barrel pre-constructed tank is minimal.

8.4.2.2 Modular Tanks

Modular ASTs are assembled on-site. Typical modular ASTs have a capacity of 16,000 to 60,000 bbls (0.67 to 2.5 MG). The tanks are cylindrical and are approximately 100-180 ft in diameter and 12 ft high (Southern Frac 2013). The panels that form the sides of the tank when it is assembled are made of quarter-inch steel (Kenter 2013). Tank covers and heaters are available, if an operator wishes to use them (Southern Frac 2013).

Two advantages of modular ASTs are that they require fewer trucks for delivery and have a smaller surface footprint than 500-barrel pre-constructed ASTs. Also, the surface disturbance is less than when using earthen pits.

The primary disadvantage of using a modular AST, particularly for long-term or permanent use, is the risk of leakage. The modular tank does not include a base; pads and liners are used to protect the soil and subsurface from the stored water. The risk of a discharge due to liner malfunction is higher than with pre-constructed ASTs.

The capital cost to purchase a modular tank is approximately $6.60/bbl ($160/kgal). Operational costs associated with modular ASTs are minimal.

8.4.3 Aquifer Storage and Recovery

ASR is a storage method in which a porous underground formation is used to store water for future use. At the present time, ASR is used in a number of locations to store potable water resources. Using ASR to store waters for oilfield use would be the first application of this type. However, there is no immediately obvious reason why it could not be used for this purpose, and this possibility has been explored in this study.

Water must be adequately treated before injection into an ASR well. Injecting insufficiently treated water could result in deterioration in the quality of the stored water. It is also important that the injected water be compatible with the water in the receiving formation. If it is incompatible, precipitation may occur; this could reduce the transmissivity of the formation and reduce the ability to recover the water. However, in some areas, techniques are being developed whereby a buffer solution is being introduced between incompatible waters to mitigate this problem.

To store water using ASR, a suitable site for the injection well must be determined. Unlike the other storage methods discussed above, ASR is only viable when located at a disposal site, treatment facility, or in an otherwise centralized area. Since HF flowback and produced water will need treatment before injection, it would be logical to locate the ASR well-site in close proximity to the treatment facility.

8.4.3.1 Formation Proposed for Storage

A suitable formation is needed to provide the storage. The formation must be a non-underground source of drinking water (non-USDW). The non-USDW formation in Ector and Midland Counties that is believed to be best able to receive the treated recycle waters is the Rustler Aquifer.

The Rustler Aquifer is below the Dockum Aquifer, at a depth of about 1,900 to 2,300 ft in Ector and Midland Counties. In Ector and Midland Counties, the waters in the Rustler formation are estimated to have TDS concentrations of 40,000–80,000 mg/L. Because the Rustler is not an important formation for oil and gas recovery, little is known about it. However, because of its relative shallowness and the likelihood of it exhibiting higher permeability than deeper formations, the Rustler is a very strong candidate for the ASR receiving formation.

It is possible that one of the formations used by SWD facilities could be used. Formations used for SWDs in the two counties are the Queen Sand, the Grayburg, the San Andres, and the Clear Fork. Depths of these formations extend from about 3,400 ft to 5,000 ft. Although Class II disposal wells inject oilfield wastewaters into these formations, they are not considered highly permeable formations by water well standards. However, they may be able to accept reasonable quantities of water under pressure.

8.4.3.2 Implementation Requirements

The ASR well(s) will have to be permitted by the State. As previously noted, this will be the first use of an ASR system to store waters for oilfield use. Therefore, existing regulatory requirements might need to be modified by the agencies to address this new application.

Once the well is permitted, the injection well can be drilled and completed; and pumps can be installed. Pumping equipment and injection tubing can be installed in the same well bore. Another option is to drill two wells in close proximity: one for injection, and one for recovery. Drilling two wells increases the capital cost but provides more flexibility so that the most efficient equipment can be used for each task.

8.4.3.3 Advantages and Disadvantages

The primary advantages to ASR are that it has a small surface footprint, provides a large capacity, and protects water from the effects of evaporation. Once an ASR well is drilled, the operating costs of ASR are low. ASR offers a much greater storage capacity than any other storage method. Allowable injection volumes and pressures vary on a well-by-well basis; however, an individual well may be able to inject thousands of barrels of water a day. This enables an order of magnitude greater storage capacity than pits or ASTs.

Disadvantages associated with ASR include the following:

- High capital costs.
- Lack of mobility-The lack of mobility could result in increased operating costs over time if the areas of active HF move a substantial distance away from the ASR facility.
- Rate of retrieval of water-ASR water can be pumped into the formation faster than it can be removed from the formation. Operational protocols will need to be developed to ensure that sufficient water can be recovered in times of high demand.
- Time required for regulatory approvals-Because this is not a type of injection well for which there are established regulations, the time required to obtain a permit could be longer than typical.
- Control of ownership of the water-A means will be needed to insure that adjacent landowners with property overlying the aquifer containing the stored water do not drill wells and pump out the stored water.
- Protests to the permit-Because the water being stored is not potable quality, some landowners may be concerned that potable water resources will be adversely affected. This can be satisfactorily addressed at a hearing, if the well is properly designed and constructed; so, it should not result in denial of the permit but may delay permit issuance.

8.4.3.4 Conceptual Cost Estimates

Table 8.3 includes planning level cost estimates for capital and operation and maintenance costs for a conceptual ASR well completed in the Rustler Aquifer in Ector or Midland County. Because the characteristics of the Rustler Aquifer are not well documented in Ector and Midland Counties, and because the cost of installation of a complete ASR well is substantial, it is recommended that a test well be constructed to confirm the suitability of the Rustler Aquifer and to provide data for permitting and design of an ASR well.

Table 8.3 Conceptual Opinion of Capital and Operation and Maintenance Costs Aquifer Storage and Recovery Well

Capital Costs	**Cost Estimate**
Test Well Construction and Testing	$ 250,000
One ASR Well and Pumping/Injection Equipment Cost	$ 630,000
Subtotal	*$ 880,000*
Engineering fees for testing and permitting as Class V or Class II	$ 150,000
Legal contingency	$ 176,000
Total Estimated Capital Costs	**$1,206,000**
O&M Costs	
Injection Power Cost (none)	$
Pumping Power Cost (per 1,000 bbl)	$ 14
Annual Maintenance/Rehabilitation Cost	$ 20,000

These costs are based on a conceptual ASR well with the following characteristics:

- Depth of 2,000 ft
- Static water level of 500 ft below ground surface
- Production rate (injection and withdrawal) of 100 gpm
- Power costs of $0.11/kW-hr
- Casing size of 14 inches (sufficient to accommodate pumping equipment and injection tubing)

The estimated capital cost for an ASR well is $1.2 million. This capital cost does not include costs for land acquisition, roads, extensive site development, transmission pipelines, treatment facilities, or electrical infrastructure development. The operational cost for power is estimated to be $0.014/bbl ($0.33/kgal).

8.5 SUMMARY

The types of storage potentially available for use in a reclaimed water system are summarized in Table 8.4. Information is provided for each type of system regarding whether the storage is typically used on a permanent or temporary basis; advantages; disadvantages; capital cost; operating cost; relative surface impact; and relative storage capacity. The category of “temporary” use is loosely defined. These facilities may be used for a period ranging from months to years. However, there is an expectation, and frequently a requirement, that at some point in time they will be removed.

Table 8.4 Oilfield Water and Wastewater Storage Methods

Containment Method	Permanent or Temporary	Advantages	Disadvantages	Capital Cost	Capital Cost (per kbbl)	Operating Cost	Surface Impact	Storage Capacity
Pits	Temporary	Inexpensive to construct; commonplace	Risk of leaks or spill; high water losses from evaporation; not permitted for some waters; large surface disturbance; site remediation costs	Low	$3,400 (uncovered) to $4,600 (covered)	Low	Large	Moderate to Large
Pre-Constructed AST	Temporary	Easy to obtain; no site assembly needed; low risk of leaks/spills; minimizes evaporation losses; fits most surface conditions; can separate multiple types of water	High transportation cost; large surface footprint if using many	High	$26,000 [$13,319 per tank]	Low	Small to Large	Small to Moderate
Modular AST	Temporary	Smaller surface footprint and lower transport cost than pre-constructed AST; less surface disruption than pits	May be difficult to obtain; risk of leaks from liner malfunction; some surface disturbance	Moderate	$6,600	Low	Moderate	Moderate
Site-Built AST	Permanent	Can be developed for specific needs	High capital cost; not mobile	High	$31,500	Low	Small to Large	Moderate to Large
Aquifer Storage and Recovery	Permanent	Large capacity; no evaporation; small surface footprint	High capital investment; Not mobile; Risk of formation damage	Very High	$1,200,000[(1)]	Low	Small	Very Large

[(1)] Total cost to install typical well; storage capacity not known.

9 IDENTIFY AND RANK ALTERNATIVES

This chapter identifies and evaluates alternative reuse systems comprised of components selected from the range of potential components identified in Chapter 8. Collection, treatment, transport, and storage components of the systems are identified.

9.1 PROJECT OBJECTIVES

As discussed, the primary objective of this study is to identify a project that will provide a cost-effective reclaimed water supply for industrial use in the Permian Basin. The study is focused on water availability and use in Ector and Midland Counties. Based on evaluations described in previous chapters, it has been concluded that the most viable approach is to treat flowback and produced waters from oil and gas operations so that they can be reused for HF.

Using reclaimed water for HF will be a benefit to all sectors of the economy in this area, because it will reduce the volume of freshwater and brackish water used by the oil and gas industry. In this water-short area, providing adequate freshwater for municipal, agricultural, steam-electric power generation, and other industrial uses is a challenge.

The secondary benefit will be to reduce the volumes of flowback and produced waters disposed in SWDs. In some areas, concerns are developing that continued use of this practice at its current level will result in over-pressurization of the receiving formation, which will constrain the use of this disposal method.

9.2 DESCRIPTION OF ALTERNATIVE RECLAIMED WATER SYSTEMS

Following are descriptions of the selected components of three alternative reclaimed water systems. The collection, treatment, transport, and storage components that are common to all three alternatives are described first. Then, the individual features of the three system alternatives are described. There is also a “no action” alternative.

9.2.1 Wastewater Collection

All of the alternatives assume that the collection point for the wastewater to be treated will be at an SWD. The advantages of this concept include the following:

- SWDs are existing locations for aggregating wastewaters from oil- and gas-fields.
- SWDs provide storage capability that will equalize flows going to the treatment system.

- If wastewater flows exceed treatment capacity or demand for reclaimed water, the excess flow can be disposed in the SWD injection well.
- The SWD facilities will provide preliminary treatment to remove floating oil and heavy solids and, if needed, anti-scalant treatment.

9.2.2 Treatment

Major progress has been made recently with respect to the capability of producers to use a wide range of water quality for HF, especially with respect to TDS (salt) content. Therefore, it is proposed that this project only provide treatment to remove oils and TSS (suspended solids). No treatment is provided to reduce TDS. Some additional treatment will be required for down-hole use (e.g., disinfection for the control of bacteria or addition of anti-scalants). This type of treatment will be the responsibility of the producer receiving the water unless, on a project-specific basis, the participating E&P company(ies) requests that additional treatment be provided at the recycling treatment facility.

The treatment alternative that most cost-effectively provides the level of removal needed is a granular media filtration system, possibly using walnut-shell media. The basic components of this system are the filter; a pump, piping and containment for backwash waters; and associated peripheral components such as electrical, foundation, piping, etc. The costs of these peripheral items are included in the cost estimates in Chapter 8.

It is proposed to use modular treatment units. This will facilitate the construction of additional capacity, if needed. It will also allow operational flexibility with respect to changes in the volume of wastewater being treated.

9.2.3 Transport

Transport of wastewater and reclaimed water, for those components unique to this project, will be by buried pipeline. It is assumed the pipeline will be buried, 6- to 12-inch pipe; and no challenging installation conditions, such as extensive rock or sand, will be encountered. When a specific project location is identified, the pipeline costs, if part of this project, will be reassessed to account for actual conditions. As described, producers will deliver wastewater to a single point for reclamation, which will be an SWD. Transport to that point may be by pipeline or truck. Similarly, the reclaimed water will be available at a single distribution point, and the water users will be responsible for transporting the water to, and within, oil- and gas-fields for use.

No costs are included for transporting wastewater to the SWD or transporting reclaimed water back to an oil- or gas-field for use in HF. These costs are assumed to be a common cost for all alternatives, including the No Action Alternative.

The transportation costs will vary widely for different producers depending on the distance from the oilfield to the SWD and from the reclamation plant to the location where HF is being done. Also, depending on circumstances, transportation may be either by pipeline or by truck. However, for an individual producer, these costs are the same for all alternatives. Further, it is assumed that this cost will continue to be borne by the producer and is not a project-related cost.

Only two costs are assumed to be project-related costs associated with water transfer in the study:

- Very short pipelines to take water to be treated from SWD tanks to the O&G WWTP treatment units and/or to take reclaimed water to the delivery point – For Alternative 1, it is assumed that there would be 100 feet of pipeline to transport treated water to the delivery point. For Alternative 2, it is assumed there would be 100 feet of pipeline transporting produced water from the SWD to the O&G WWTP treatment units and 100 feet of pipeline transporting treated water to the delivery point. For Alternative 3, it is assumed there would be 100 feet of pipeline transporting produced water from the SWD to the O&G WWTP treatment units.

- The pipeline between the SWD site and the South WWTP site in Alternatives 1 and 3 – Since it is unknown which existing SWD site might be adapted to support the project, costs are determined for two pipeline distances: 1 mile and 5 miles.

9.2.4 <u>Storage</u>

With respect to storage, it is assumed that the location, function, and operation of large-volume storage facilities (e.g., pits) will be the responsibility of the producer. It is assumed that water for individual HF jobs will be stored at the well-site. There is not an anticipated need to accumulate large volumes of reclaimed water at the treatment site. Because the proposed treatment is a chemical-physical process, the treatment system can be started or stopped in response to the demand for reclaimed water. Also, because the volumes of produced water generated exceed the demand for HF waters, there is no need to accumulate large volumes of wastewater in long-term storage to avoid the risk of having an inadequate supply of water to be treated.

The only storage units needed as part of this project are relatively small in volume. The function of these units would be to regulate influent flow through the treatment system and provide cost-effective functioning of the effluent pumps that deliver reclaimed water to the distribution point. It is assumed 500-bbl ASTs will be used to provide any necessary storage.

9.2.5 Description of Alternative Reclaimed Water Systems

The alternative systems proposed are conceptual. Due to the dramatic decrease in the price of oil during the course of this project (from greater than $100/bbl to less than $40/bbl), there is very little HF activity at present and, hence, very little demand for water for HF). Producers currently are not in a position to make the capital investments required to implement the reclaimed water system.

Therefore, this report presents system alternatives that are not location-specific. Cost estimates are presented as ranges and could vary substantially when specific project locations and conditions are identified. The value of this study is to document a viable and cost-effective concept for recycling wastewaters from oil and gas development and production that can be refined and implemented when economic conditions are more favorable.

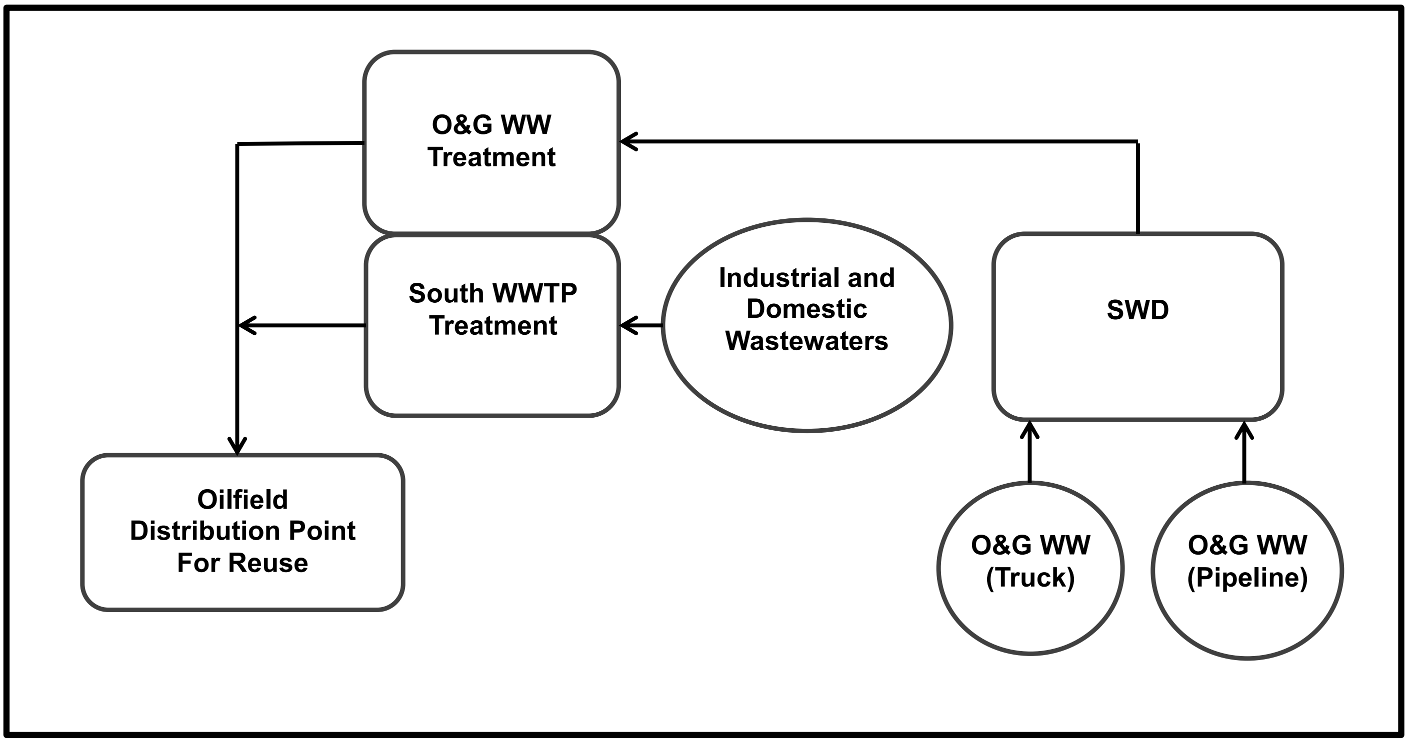
9.2.5.1 Alternative 1: Treat and Blend at Site of Odessa South Regional Wastewater Treatment Plant

This alternative is represented on Figure 9.1. The wastewater from oil and gas development and production will be diverted at an SWD after passing through the SWD tank battery. It will be transported by pipeline to the site of the South WWTP, operated by GCWDA. At that location, there will be a treatment train that has been constructed adjacent to the existing WWTP facilities. Treatment at the oil and gas WWTP (O&G WWTP) will consist of granular media filtration to remove solids and oil. After treatment, the reclaimed water produced by the O&G WWTP may be blended with the treated water produced by the South WWTP and delivered to a distribution point for an E&P company(ies). Alternatively, the O&G WWTP effluent may be delivered to the distribution point without blending.

Figure 9.1 Alternative 1: Treat and Blend at Odessa South Regional Wastewater Treatment Plant Site

The backwash from the granular media filter will be collected in tanks and transported by truck to an SWD for disposal. The distance to the SWD is assumed to be within a one-hour drive (two hours total for round trip).

The project components are as follows:



O&G WW = Oil and Gas Wastewater
South WWTP = Odessa South Regional Wastewater Treatment Plant
SWD = Saltwater Disposal Site

- O&G WWTP providing granular media filtration with a capacity to treat 6,000–24,000 bbl/d. A peaking factor of 1.25 is assumed.
- Buried pipeline (6-inch to 12-inch) from the SWD to the O&G WWTP adjacent to the South WWTP. A length of 1–5 miles is assumed, with associated pump stations.
- Storage tanks for O&G WWTP backwash and effluent (4–8, 500-bbl ASTs, depending on treatment capacity).
- Miscellaneous peripherals associated with site development, piping, and pumps.

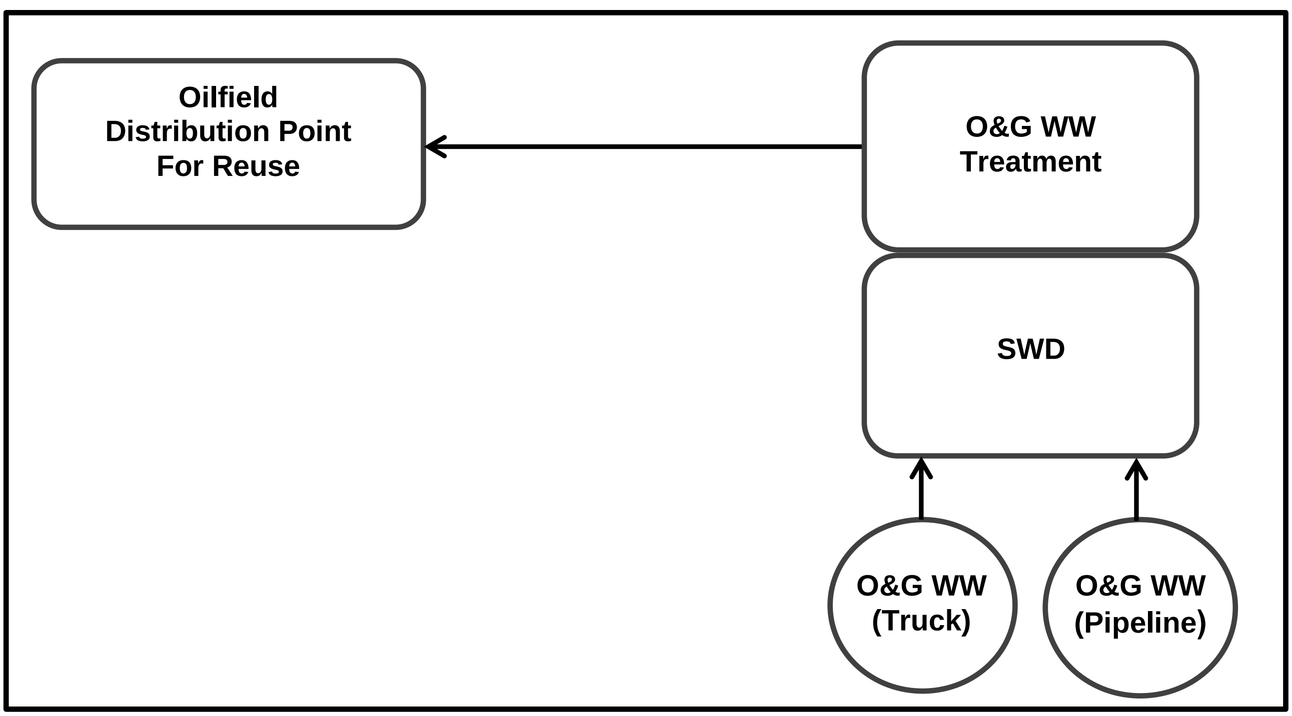
9.2.5.2 Alternative 2: Treat at a Site Adjacent to a Saltwater Disposal Well

This alternative is represented on Figure 9.2. The wastewater from oil and gas development and production will be picked up at an SWD after passing through the SWD tank battery. It will be transferred to a treatment facility adjacent to the SWD. Treatment will consist of granular media filtration with walnut-shell media or a similar media. The treated wastewater will be delivered to a distribution point in close proximity to the O&G WWTP, where it can be picked up by an E&P company(ies). Filter backwash will be disposed in the SWD well.

The project components are as follows:

- O&G WWTP providing granular media filtration with a capacity to treat 6,000–24,000 bbl/d.
- Storage tanks for O&G WWTP effluent (2–4, 500-bbl ASTs, depending on treatment capacity).
- Miscellaneous peripherals for site development, piping, and pumps.
- Sufficient automation for monitoring and controlling a remote facility that is not continually manned.

Figure 9.2 Alternative 2: Treat at a Site Adjacent to a Saltwater Disposal Well; No Effluent Blending

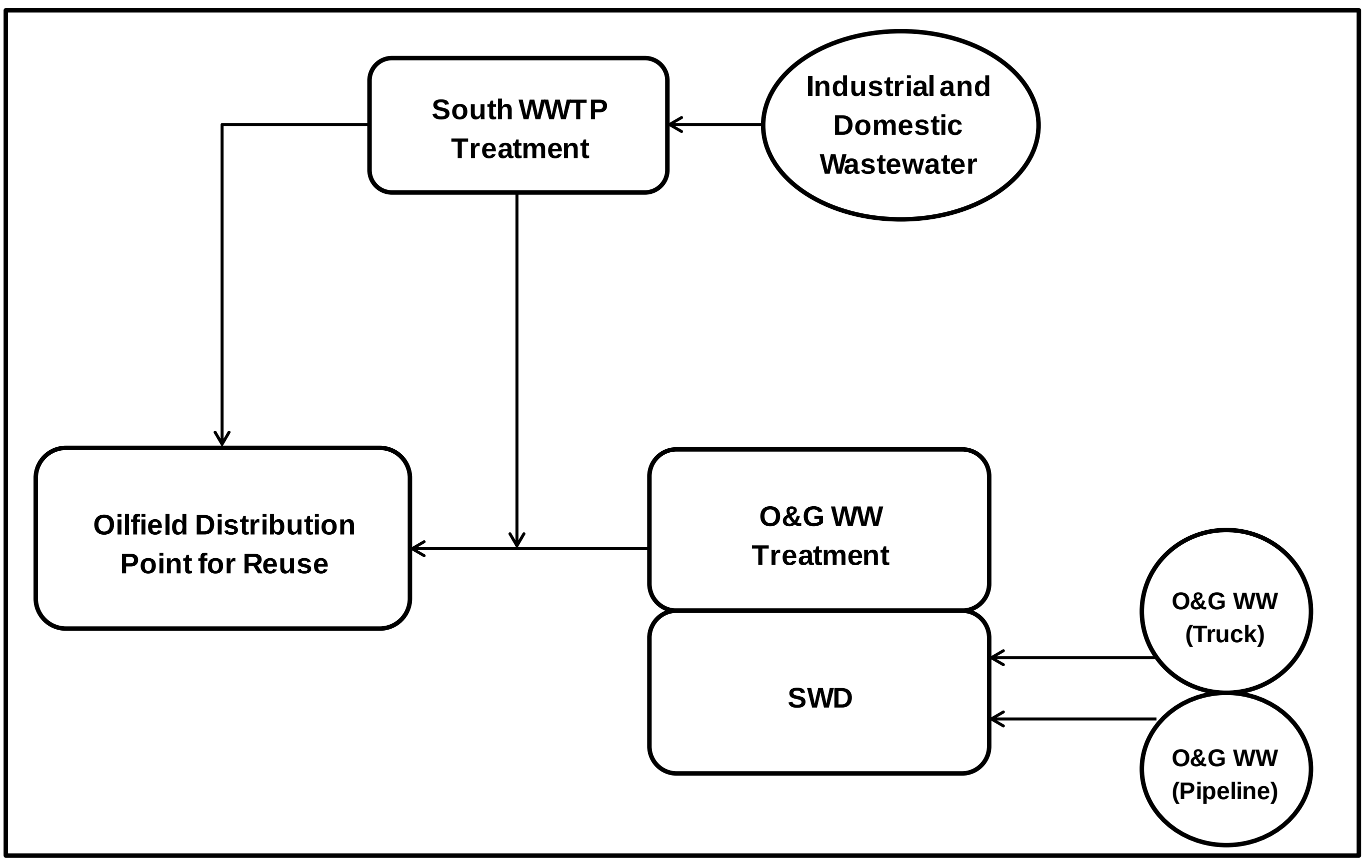


O&G WW = Oil and Gas Wastewater
SWD = Saltwater Disposal Site

9.2.5.3 Alternative 3: Treat at a Site Adjacent to a Saltwater Disposal Well and Blend with Effluent from Odessa South Regional Wastewater Treatment Plant

This alternative is represented on Figure 9.3. The wastewater from oil and gas development and production will be picked up at an SWD after passing through the SWD tank battery. It will be transferred to a treatment facility adjacent to the SWD. Treatment will consist of granular media filtration with walnut-shell media or a similar media. The treated wastewater will be delivered by pipeline to a distribution point, where it can be picked up by an E&P company(ies) for reuse. The distribution point will be in the vicinity of the South WWTP, and effluent from the South WWTP also may be delivered to the distribution point so it can be blended with the effluent from the O&G WWTP. Filter backwash will be disposed in the SWD well.

Figure 9.3 Alternative 3: Treat at a Site Adjacent to a Saltwater Disposal Well and Blend with Effluent from Odessa South Regional Wastewater Treatment Plant



O&G WW = Oil and Gas Wastewater
South WWTP = Odessa South Regional Wastewater Treatment Plant
SWD = Saltwater Disposal Site

The project components are as follows:

- O&G WWTP providing granular media filtration with a capacity to treat 6,000–24,000 bbl/d. A peaking factor of 1.25 is assumed.
- Storage tanks for O&G WWTP effluent (2–4, 500-bbl ASTs, depending on treatment capacity).
- Buried pipeline (6-inch to 12-inch) to bring O&G WWTP effluent back to a distribution point in the vicinity of the South WWTP. A total pipe length of 1–5 miles is assumed with associated pump stations.
- Miscellaneous peripherals associated with site development, piping, and pumps.
- Sufficient automation for monitoring and controlling a remote facility that is not continually manned.

9.2.5.4 Alternative 4: No Action

For this alternative, the water needs of the oil and gas industry in the Permian Basin continue to be met as they have been in the past; i.e., the primary source of water for HF is fresh or brackish groundwater delivered by existing pipelines or trucks. Therefore, there are no capital expenditures associated with this alternative.

Some E&P companies may choose to drill new wells for water supply, but this activity cannot be projected. Similarly, some of the larger E&P companies may invest in developing regional reuse options for their fields. This option will not be available to smaller companies or areas with multiple operators. This, too, is a type of capital expenditure that cannot be projected.

The primary O&M cost for this alternative is the trucking cost. However, this cost is borne by the trucking company and included in the sales price of the water.

9.3 EVALUATION OF ALTERNATIVES

Following is an evaluation of the four system alternatives that have been identified. The factors evaluated are cost, legal and regulatory considerations, suitability and reliability of treatment, adequacy of water supply produced, requirements for residuals management, and environmental considerations.

9.3.1 Costs

A program for preparing planning level opinions of cost that was developed for the State of Texas regional water planning process was the primary tool used to develop opinions of cost for this report. Where necessary, changes were made to customize the program to this specific project. The opinions of cost are based on the following assumptions:

- Transmission capital costs are based on costs for the transmission line and pump stations. Transmission O&M costs are 1% of the capital cost of the facilities. For this study, pipelines are sized using a peaking factor of 1.25.
- Treatment costs (capital and O&M) can be input to the program from external sources. For this study, the costs in Chapter 8 are used for capital and O&M costs for treatment.
- The capital cost of AST tanks used for on-site storage of effluent and backwash is included using the cost in Chapter 8.
- The combined costs for engineering and feasibility studies, legal assistance, financing, bond counsel, and contingencies are estimated as 25% of the total capital cost.
- Costs are provided in the program for environmental and archeological studies and mitigation, as well as surveying.
- Land acquisition costs are included at $5,445/acre. Costs are included for permanent right-of-way and the treatment site for those alternatives where treatment is located by an SWD. The acreage required for the O&G WWTP is assumed to be 7 acres.
- Interest during construction is 4% for the construction period with a 1% return on investment.
- Debt service is amortized at 5% per year over two years.
- Pumping energy costs are $0.09/kW-hr.

Preliminary cost opinion summary sheets, generated by the program, are provided in Appendix 4.

For Alternatives 1, 2, and 3, opinions of cost were prepared for O&G WWTPs with treatment capacities of 6,000 bbl/d (0.25 MGD), 12,000 bbl/d (0.5 MGD), and 24,000 bbl/d (1 MGD) average flow. These opinions of cost are approximate and based on cost curves.

Transmission costs were estimated for Alternatives 1 and 3 for distances of 1 mile and 5 miles. A distance of 100 feet was assumed for Alternatives 1 and 2 to transport reclaimed water from the effluent pump station to the delivery point. A distance of 100 feet was assumed for Alternatives 2 and 3 to transport wastewater from the SWD pump station to the filters.

Alternative 1 includes costs for 2–4 ASTs for storage of backwash residuals, as well as 2–4 ASTs for effluent storage. The number of ASTs is based on the treatment capacity. An annual hauling cost for transporting backwash to an SWD was computed based on the following assumptions:

- Backwash volume is 5% of treated water volume.
- Trucking cost is $0.67/bbl/hr.
- Round trip time is 2 hours.

Alternatives 2 and 3 include costs for 2–4 ASTs for effluent storage. The number of ASTs is based on the treatment capacity.

Alternatives 2 and 3 include capital costs for additional capability for remote monitoring and control. This cost is estimated to be $150,000 for remote operation using a radio system.

The current cost of water is used as the cost for Alternative 4. The current cost of fresh and brackish water in the Ector/Midland County area is $0.25–$0.75/bbl, depending on source and quality. This price does not include trucking costs.

No cost offset is provided for deferred disposal costs since all wastewaters will be processed through the tank batteries at an SWD. It is assumed that the SWD charge for accepting the wastewater will be the same for wastewater being reclaimed and wastewater being injected. The SWD will avoid the injection costs for wastewaters being reclaimed. The effective functioning of the system requires that flexibility be maintained to send wastewaters or treatment residuals to the deep well at any time. The benefit of the reduction in operational costs because of wastewaters that will not have to be injected can be an incentive for an SWD to participate in a reclaimed water system.

The cost data in Appendix 4 are disaggregated into fixed and variable costs. The contractual agreement between GCWDA and the E&P company(ies) is anticipated to incorporate a requirement to pay fixed costs on a regular basis regardless of water volume purchased and to pay for water purchased at a rate based on the variable costs.

Fixed costs consist of debt repayment cost and a portion of the total O&M costs. Fixed O&M costs range from 25% to 80% of total O&M costs. For the purposes of this report, the fixed O&M has been estimated at 40% of the total O&M costs. The estimate of the fixed O&M costs as 40% of the total O&M cost should be considered very preliminary and should be reassessed when the facility is designed. After the first two years, the fixed cost consists only of the fixed costs associated with O&M.

Table 9.1 presents the approximate costs for water during the first two years of operation of the project for each of the four alternatives. These cost estimates include both fixed and variable costs and assume the treatment facility is operating at capacity. The cost ranges represent the range of sizes (6,000–24,000 bbl/d) and pipeline distances (1 mi and 5 mi) evaluated.

Table 9.1 Evaluation of Alternatives; Range of Cost Opinions
Initial Costs: Includes Debt Repayment

Alternative	Cost of Water		
	$/AF	**$/kgal**	**$/bbl**
1. Treat and Blend at Odessa South Regional WWTP Site[(1)]	$3,600–$7,800	$11.00–$24.00	$0.46–$1.00
2. Treat at Site Adjacent to SWD; No Blending[(2)]	$2,500–$3,400	$7.70–$10.50	$0.32–$0.44
3. Treat at Site Adjacent to SWD; Blend with Effluent from Odessa South Regional WWTP[(3)]	$3,200–$7,800	$10.00–$24.00	$0.41–$1.00
4. No action[(4)]	$1,900–$5,800	$6.00–$18.00	$0.25–$0.75

[(1)]Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD) and pipeline distances of 1–5 miles.
[(2)]Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD).
[(3)]Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD) and pipeline distances of 1–5 miles.
[(4)]This cost is based on the current cost to purchase fresh or brackish groundwater; typical costs range between $0.25 and $0.75/bbl.

After the capital investment is repaid at the end of the second year, the costs decrease dramatically. Table 9.2 presents the ranges of costs after the first two years.

All alternatives provide reclaimed water for less than $0.75/bbl except (1) Alternative 1 for a treatment capacity of 12,000 bbls or less and a pipeline distance of 5 miles and (2) Alternative 3 when the treatment volume is 6,000 bbl/d, and the pipeline distance is 5 miles. The cost per bbl for Alternative 3 when treatment capacity is 12,000 bbls and the pipeline distance is 5 miles is very close to $0.75/bbl (it is $0.74/bbl.)

Table 9.2 Evaluation of Alternatives; Range of Cost Opinions After Debt Repayment is Completed

Alternative	Cost of Water		
	$/AF	$/kgal	$/bbl
1. Treat and Blend at Odessa South Regional WWTP Site (1)	$800–$900	$2.40–$2.60	$0.10–$0.11
2. Treat at Site Adjacent to SWD; No Blending(2)	$260–$270	$0.80–$0.82	±$0.03
3. Treat at Site Adjacent to SWD; Blend with Effluent from Odessa South Regional WWTP(3)	$280–$330	$0.84–$1.00	±$0.04
4. No action(4)	$1,900–5,800	$6.00–$18.00	$0.25–$0.75

(1)Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD) and pipeline distances of 1–5 miles.
(2)Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD).
(3)Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD) and pipeline distances of 1–5 miles.
(4)This cost is based on the current cost to purchase fresh or brackish groundwater; typical costs range between $0.25 and $0.75/bbl.

Figures 9.4 through 9.6 present, respectively, unit costs (in $/bbl of water produced) for Alternatives 1 through 3, compared to the unit cost range for Alternative 4 (the No Action Alternative). These costs are based on full utilization of the treatment facility. Unit costs would be higher at less than full utilization.

The treatment facility may not run at full capacity at all times. Table 9-3 identifies the fixed monthly costs, which are not based on volume treated, and the cost per bbl based on the volume of water produced.

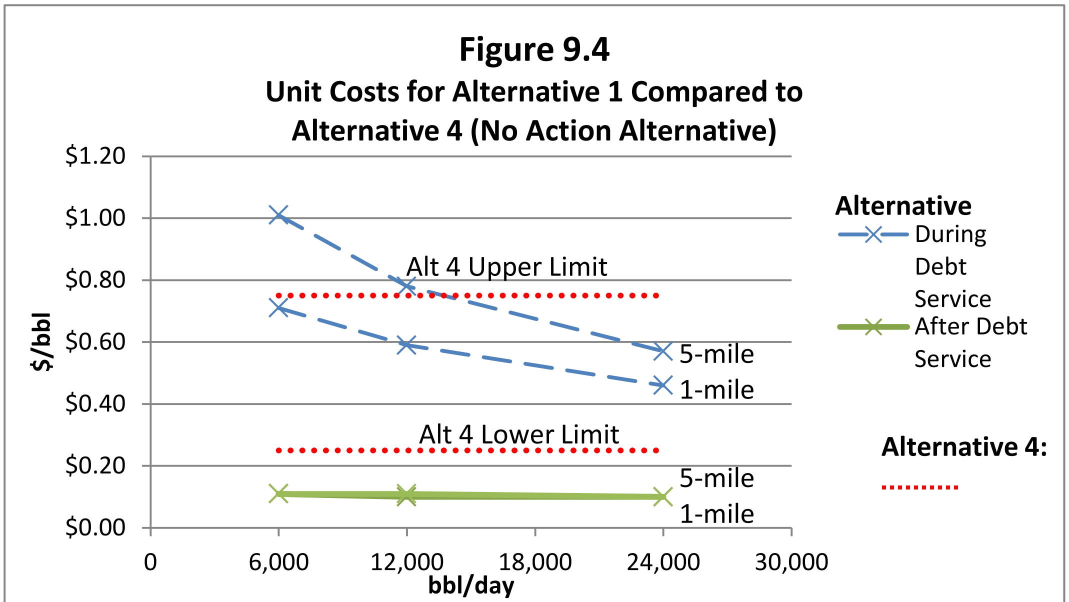


Figure 9.4
Unit Costs for Alternative 1 Compared to Alternative 4 (No Action Alternative)
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$0.00
$/bbl
Alt 4 Upper Limit
Alt 4 Lower Limit
5-mile
1-mile
5-mile
1-mile
0
6,000
12,000
18,000
24,000
30,000
bbl/day
Alternative
During Debt Service
After Debt Service
Alternative 4:

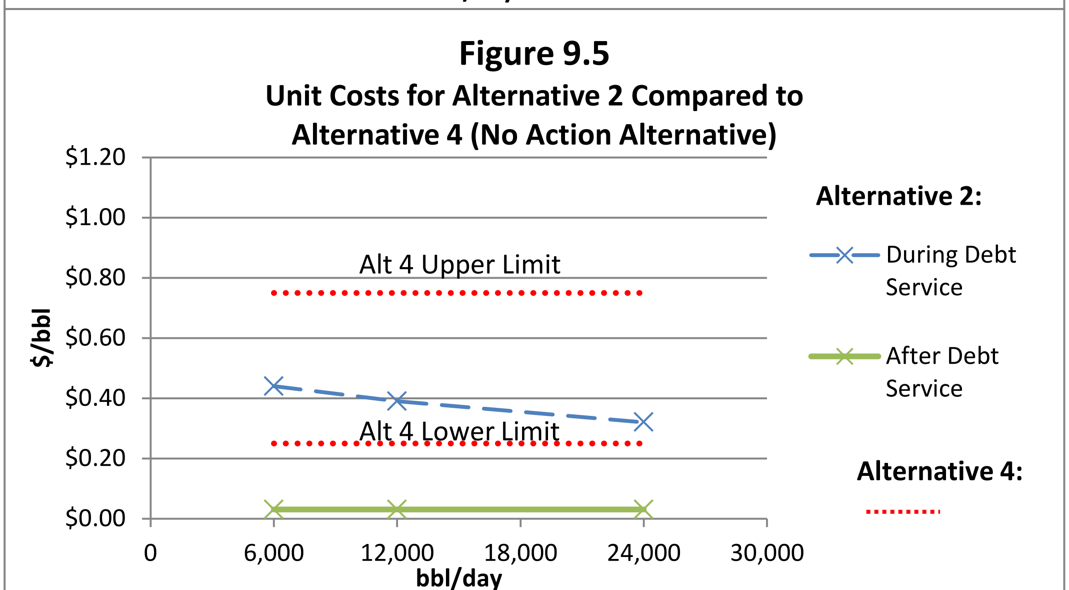


Figure 9.5
Unit Costs for Alternative 2 Compared to Alternative 4 (No Action Alternative)
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$0.00
$/bbl
Alt 4 Upper Limit
Alt 4 Lower Limit
0
6,000
12,000
18,000
24,000
30,000
bbl/day
Alternative 2:
During Debt Service
After Debt Service
Alternative 4:

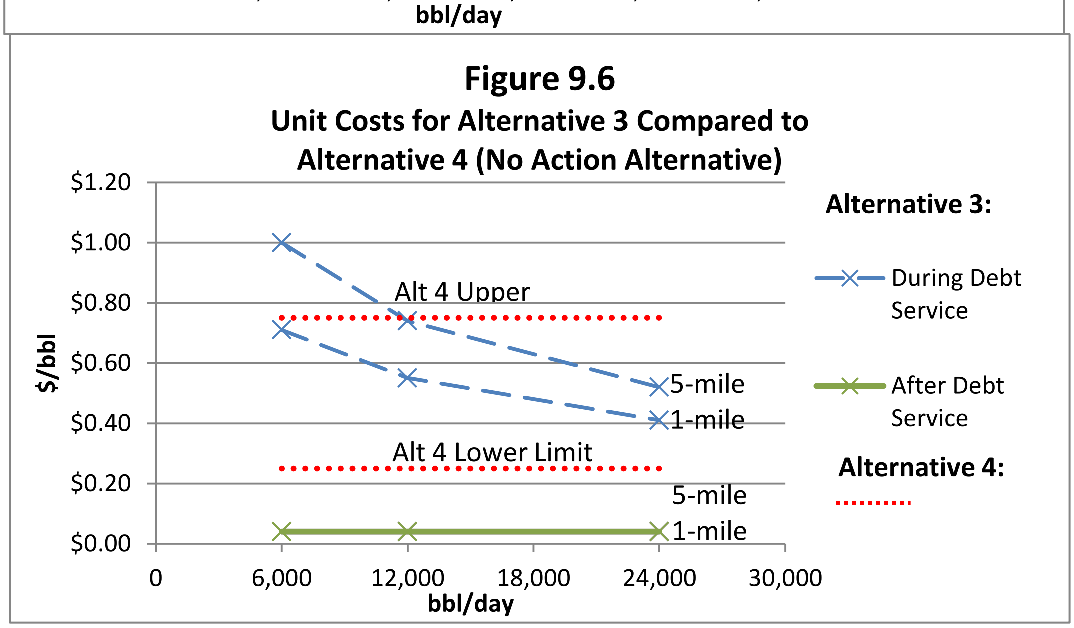


Figure 9.6
Unit Costs for Alternative 3 Compared to Alternative 4 (No Action Alternative)
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$0.00
$/bbl
Alt 4 Upper
Alt 4 Lower Limit
5-mile
1-mile
5-mile
1-mile
0
6,000
12,000
18,000
24,000
30,000
bbl/day
Alternative 3:
During Debt Service
After Debt Service
Alternative 4:

Table 9-3 Evaluation of Alternatives: Fixed and Variable Costs

Alt	Capacity (MGD)	Pipe Length(1) (miles)	Capacity (bbl/day)	Fixed Cost ($/mo) With Debt Service	Fixed Cost ($/mo) Excluding Debt Service	O&M Variable Cost(2) ($/mo)	Variable Cost ($/bbl)
1	0.25	1	6,000	$ 113,000	$ 2,700	$ 17,000	$0.09
1	0.50	1	12,000	$ 180,000	$ 5,200	$ 33,000	$0.09
1	1.00	1	24,000	$ 272,000	$ 9,900	$ 64,000	$0.09
1	0.25	5	6,000	$ 166,000	$ 2,900	$ 17,000	$0.09
1	0.50	5	12,000	$ 247,000	$ 5,500	$ 33,000	$0.09
1	1.00	5	24,000	$ 350,000	$ 10,300	$ 66,000	$0.09
2	0.25	na	6,000	$ 76,000	$ 2,500	$ 4,000	$0.02
2	0.50	na	12,000	$ 135,000	$ 4,900	$ 8,000	$0.02
2	1.00	na	24,000	$ 221,000	$ 9,600	$ 15,000	$0.02
3	0.25	1	6,000	$ 124,000	$ 2,700	$ 4,000	$0.02
3	0.50	1	12,000	$ 190,000	$ 5,200	$ 8,000	$0.02
3	1.00	1	24,000	$ 281,000	$ 9,900	$ 16,000	$0.02
3	0.25	5	6,000	$ 176,000	$ 2,900	$ 5,000	$0.03
3	0.50	5	12,000	$ 257,000	$ 5,500	$ 9,000	$0.02
3	1.00	5	24,000	$ 360,000	$ 10,300	$ 17,000	$0.02

(1)Length does not include short pipelines, estimated to be approximately 100 ft long, that transport wastewater from SWD to O&G WWTP or reclaimed water from O&G WWTP to the distribution point for reuse. These shorter lines are included in the cost estimate.
(2)Facility operating at full capacity.

9.3.2 Legal and Regulatory Considerations

The primary aspects of this project that are subject to regulatory programs are as follows:

- Operation of the treatment facility
- Construction of the treatment facility and any associated pipelines

9.3.2.1 Operation of the Treatment Facility

The operation of the treatment facility will be under the jurisdiction of RRC for all three of the proposed alternatives. This is true even for Alternative 1, which puts the treatment facility on the same site as the South WWTP, as long as the following conditions are met:

- The O&G WWTP only accepts oil- and gas-field wastewaters.
- There is no discharge to surface waters in the State.
- The O&G WWTP is physically separated from the South WWTP, as by a fence.

The RRC rules authorizing recycling facilities are found in Title 16, Part I, Chapter 3 (Rule 3.8) and Title 16, Part I, Chapter 4, Subchapter B. Rule 3.8 applies to non-commercial fluid recycling and Subchapter B applies to commercial fluid recycling. In general, a commercial recycling facility is one that sells treated water to entities that may, or may not, be the source of the wastewaters being treated. A non-commercial recycling facility only provides treated wastewater to the E&P company(ies) that are the source of the wastewater being treated. The regulatory requirements of RRC are discussed in detail in Chapter 10.

9.3.2.2 Construction Requirements

Construction of the project could be required to meet some, or all, of the following regulatory requirements and approvals, depending on the location of the project and the entity responsible for implementation.

- U.S. Army Corps of Engineers (USACE) Section 404 Permit, if construction impacts streams, waterbodies, or wetlands.
- U.S. Fish and Wildlife Service (USFWS) and Texas Parks and Wildlife Department (TPDWD) programs to protect threatened and endangered species.
- TPWD Sand, Gravel, and Marl Permit for stream crossings.
- Texas Historical Commission (THC) survey of cultural and archeological resources.
- Approval from the appropriate entity (e.g., county, state, or municipality) for road crossings and the use of highway right-of-way for pipelines.
- Approval from the appropriate entity for railroad crossings.

- County drainage requirements.
- Applicable City ordinances, if in a City jurisdiction.

9.3.2.3 Other Requirements

It is recommended the Region F Regional Water Planning Group be advised of the project. This will enable consideration of the contribution of this project to meeting regional water supply needs as the regional water plan is periodically updated.

Water rights regulations are not applicable to any of the alternatives. The project does not reduce any surface or groundwater resources subject to regulation by the water rights program.

9.3.2.4 Contractual Considerations

GCWDA has the ability to own and/or operate the O&G WWTP. GCWDA can enter into a contract with the participating E&P company(ies) to provide treatment. Multiple approaches are feasible by which GCWDA could be reimbursed by the E&P company(ies) for the capital and operational costs of the treatment plant. Multiple approaches also exist for how the E&P company(ies) can interface with GCWDA when management decisions are made. The GCWDA currently operates several NPDES-permitted treatment systems that conform to this model. These systems operate under a range of reimbursement and management structures.

9.3.2.5 Summary

It is not possible to rank the alternatives based on legal and regulatory requirements. The nature and extent of regulatory requirements are dependent on the participants and the physical location of the components of the recycling system. It can be noted, however, that all alternatives are feasible, and none must meet regulatory requirements that are unduly burdensome.

9.3.3 Suitability of Treatment

Walnut-shell filtration has been widely used for treatment of oil- and gas-field wastewaters for many years. It is an established process. The media are resistant to attrition and effectively remove free (non-dissolved) oil and suspended solids. The technology typically produces effluent containing less than 5 mg/L free oil and suspended solids.

It is recommended that a pilot project be conducted to provide a proof-of-concept for the application of the treatment technology. The quality of water that may be treated varies widely between fields, and the treatment objectives with respect to the quality of water desired for HF varies between operators. The pilot study will investigate whether the proposed technology is suitable for the location and preferences of the participants. The study is summarized as follows:

> A small walnut-shell filter system would be constructed at an SWD and operated for 90 days. The effluent produced would be provided to a participating E&P company that would, in turn, provide the effluent to its HF contractor to be tested for suitability for HF.

Alternatives 1, 2, and 3 have the same ranking with respect to the suitability of the treatment process since all three have the same treatment process. For all three alternatives, the suitability needs to be confirmed by pilot testing.

Alternatives 1 and 3, which incorporate the optional step of blending with effluent from the South WWTP, may provide additional quality benefits. Blending will reduce the TDS concentration in the reclaimed water.

Alternative 4, no action, ranks highest with respect to the suitability of treatment. The treatment required to use existing groundwater has previously been confirmed.

9.3.4 Reliability of Treatment

Alternative 4, no action, also ranks highest with respect to reliability of treatment. To the extent treatment of groundwaters is required for use in HF, appropriate treatments have previously been developed and confirmed with respect to their reliability. Alternative 4 is also most reliable because the quality of the source water is typically known and relatively consistent.

The ability to control the quality of source waters for Alternatives 1, 2, and 3, and, thus, to achieve consistent effluent quality is less certain. In part it depends on the operational controls with respect to the wastewaters accepted by the SWD. The consistency of effluent quality may also be affected by whether the recycling facility is a commercial or a non-commercial facility. A non-commercial facility will accept wastewaters from an SWD operated for the benefit of one E&P company or an established consortium of E&P companies. The SWD will only receive wastewaters from these companies. Therefore, the wastewater will have a more consistent quality than wastewaters from an SWD accepting wastewaters from a wide and variable group of companies, which could be the case with a commercial recycling facility. The variation in source water quality at a commercial recycling facility could result in less consistent reclaimed water quality.

Among the other three alternatives, Alternative 1, treatment on the site of the South WWTP, is ranked as providing the most reliable treatment. Its location adjacent to the South WWTP treatment facilities provides consistent monitoring by operators, and rapid response should a problem arise.

Alternatives 2 and 3, which locate the O&G WWTP adjacent to an SWD, will rely more heavily on the use of remote monitoring and control. When problems arise that cannot be dealt with remotely, time will be required to mobilize and transport staff to address the problem.

9.3.5 Adequacy of Water Supply Produced

Alternatives 1, 2, and 3 offer the best assurance of maintaining a long-term supply of an adequate volume of water for HF. The volume of flowback and produced water that is generated in the Permian Basin exceeds the volume of water needed for HF. Therefore, an adequate supply of source water for treatment should always be available.

The adequacy of the volume of water provided by Alternative 4, no action, is less certain. It is uncertain how long the existing aquifers can sustain the current levels of production. Some aquifers are already experiencing a reduction in production.

9.3.6 Requirements for Residuals Management

Alternative 4, no action, does not require residuals management. To the extent that the source water is treated before being used for HF, residuals are not generated.

Alternatives 1, 2, and 3 will generate backwash water periodically as the filters are flushed to restore efficient functioning. The backwash water should be relatively easy to manage for Alternatives 2 and 3, where treatment is provided adjacent to an SWD. The backwash can be routed to the intake point of the SWD and disposed of by injection into the deep well.

Alternative 1, treatment in the South WWTP site, has additional requirements. Because of the TDS concentration, the backwash cannot be combined with other wastewaters treated at the South WWTP. Therefore, the backwater residuals will need to be accumulated in a storage tank and trucked to an SWD for disposal. The volume of backwash generated can be substantial. This will result in a significant operational cost and substantial resulting truck traffic. For example, treatment of 6,000 bbl/d (0.25 MGD) could result in 300 bbl/d (12,500 gal/d) of backwash water to be disposed. It may be possible to provide units that will reduce this volume. However, this assessment will need to be conducted on a project-specific basis.

9.3.7 Environmental Considerations

The environmental considerations are very similar for Alternatives 1, 2, and 3. In general, these three alternatives are environmentally superior to Alternative 4, no action.

Alternatives 1, 2, and 3 reduce the volume of wastewater sent to an SWD for deep-well injection compared to the no action alternative. Therefore, the useful life of the existing deep wells is extended, and the risk of overpressurization of the receiving geologic strata is reduced.

For Alternatives 1, 2, and 3, the reclaimed waters are redistributed for use via pipeline. This is preferable to the current heavy reliance on trucks to deliver water to HF sites. Reducing truck traffic will reduce greenhouse gas emissions, reduce energy use, improve safety on the roads, and reduce costs for road maintenance. As noted previously, Alternative 1 is less favorable in this respect than Alternatives 2 and 3, because of the need to truck backwash to an SWD.

Alternatives 1, 2, and 3 contribute to the preservation of fresh and brackish groundwater aquifers, which have limited production capability in this area. The freshwater aquifers are needed for municipal, household, and agricultural supplies. The less brackish groundwaters can be used for agricultural purposes.

Very little difference exists between the alternatives with respect to potential impacts in the following areas:

- Threatened and endangered species
- Waters of the United States
- Aesthetics
- Cultural and historic properties

When a specific project is identified, the environmental effects should be reassessed. There could be site-specific considerations with respect to threatened and endangered species and/or cultural and historic properties. Generally speaking, however, it is anticipated that the project will be located on areas already in use. In the case of Alternative 1, the treatment facility would be located on the site of the existing wastewater treatment plant. For alternatives 2 and 3, it would be located on the site of an existing SWD.

Pipeline construction impacts will vary depending on lengths, routes, etc. For Alternatives 1 and 3, it may be expected that a 5-mile pipeline could have a greater likelihood of environmental impacts than a 1-mile pipeline to the same location. Again, however, precise impacts will depend on the actual project conditions. Alternative 2, with only nominal pipe requirements within the SWD site itself, could ultimately be demonstrated to have the least environmental impact, in this regard.

9.3.8 Summary of System Alternatives

Table 9.4 presents a summary of the advantages and disadvantages of each alternative.

Table 9.4 Summary of Advantages and Disadvantages

Alternative	Initial Water Cost ($/bbl)	Legal and Regulatory Constraints	Residuals Management	Environmental Considerations	Suitability of Treatment	Reliability of Treatment	Adequacy of Supply
1. Oil and gas wastewater recycling facility at Odessa South Regional Wastewater Treatment Plant site.	$0.46 - $1.00	• Pipeline construction may require multiple permits and approvals. • No RRC permit required if same E&P companies that are sending wastewater are using reclaimed water. • Potential requirement for cultural survey.	• Filter backwash will be trucked to SWD for disposal. • Verification should be made that there is not unacceptable accumulation of NORM in backwash residuals.	• Reduces reliance on fresh and brackish water for HF and increases availability of fresh and brackish water for other uses. • Reduces reliance on use of trucks to deliver fresh or brackish water to well sites. • Value of reduction of trucks to transport water is partially offset by the trucks needed to transport backwash residuals. The volume of backwash waters is significant. • Extends life of existing SWD wells.	• Walnut-shell filters are an established treatment method for oil-field wastewaters. However, they have not been used previously to produce water suitable for HF. • Blending lowers TDS.	• Proximity to Odessa South WWTP with trained operators may enhance treatment reliability compared to remote operation of Alternatives 2 and 3. • Reliability may be affected by variations in source water quality.	• Provides a reliable supply indefinitely because in this area of the Permian Basin volume of produced water and flow back exceeds water demands for HF.
2. Oil and gas wastewater recycling facility at a saltwater disposal site	$0.32 - $0.44	• No RRC permit required if same E&P companies that are sending wastewater are using reclaimed water. • Site for O&G WWTP should be selected to avoid need for 404 Permit, threatened/endangered species habitat, and cultural resources.	• Filter backwash can be disposed in SWD • Verification should be made that there is not unacceptable accumulation of NORM in backwash residuals.	• Reduces reliance on fresh and brackish water for HF and increases availability of fresh and brackish water for other uses. • Reduces reliance on use of trucks to deliver fresh or brackish water to well sites. • Extends life of existing SWD wells.	• Walnut-shell filters are an established treatment method for oil-field wastewaters. However, they have not been used previously to produce water suitable for HF	• Because of distance from trained operational staff, more electronics for monitoring and control will be needed. • Response time will be greater than for Alternative 1 if a problem arises that needs an operator on-site. • Reliability may be affected by variations in source water quality.	• Provides a reliable supply indefinitely because in this area of the Permian Basin volume of produced water and flow back exceeds water demands for HF.
3. Oil and gas wastewater recycling facility at a saltwater disposal site; effluent piped to blend with Odessa South Regional Wastewater Treatment Plant effluent	$0.41 - $1.00	• Pipeline construction may require multiple permits and approvals. • No RRC permit required if same E&P companies that are sending wastewater are using reclaimed water. • Potential requirement for cultural survey. • Site for O&G WWTP should be selected to avoid need for 404 Permit, threatened/endangered species habitat, and cultural resources.	• Filter backwash can be disposed in SWD • Verification should be made that there is not unacceptable accumulation of NORM in backwash residuals.	• Reduces reliance on fresh and brackish water for HF and increases availability of fresh and brackish water for other uses. • Reduces reliance on use of trucks to deliver fresh or brackish water to well sites. • Extends life of existing SWD wells.	• Walnut-shell filters are an established treatment method for oil-field wastewaters. However, they have not been used previously to produce water suitable for HF. • Blending lowers TDS	• Because of distance from trained operational staff, more electronics for monitoring and control will be needed. • Response time will be greater than for Alternative 1 if a problem arises that needs an operator on-site. • Reliability may be affected by variations in source water quality.	• Provides a reliable supply indefinitely because in this area of the Permian Basin volume of produced water and flow back exceeds water demands for HF.
4. No action	$0.25 - $0.75	• Over pressurization of geologic strata could result in limitations on deep well disposal of wastewaters.	• No residuals	• Uses fresh and brackish water needed for other beneficial uses. • Continues reliance on trucks for water transfer with assorted traffic, safety, greenhouse gas emissions, energy use, and road maintenance concerns.	• All methods currently used to treat fresh and brackish water have been used extensively.	• Most reliable treatment because it is used extensively and applied at the well site. • Generally consistent source water quality.	• Availability in the future of water from existing aquifers is uncertain.

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9.4 FUNDING METHODS

Different funding methods are anticipated to be used for the different project components: treatment, transport, and storage. Following is a discussion of possible funding methods. There may be adjustments to the funding approach when a specific project is identified.

9.4.1 Treatment

The capital cost of the treatment facility is expected to be funded through financing obtained by GCWDA. Repayment will be guaranteed by payments from the E&P company(ies) participating in the project.

The GCWDA will operate the treatment facility. Operational costs will be reimbursed by the participating E&P company(ies).

9.4.2 Pipelines

It is anticipated that construction of the pipeline that takes wastewater from the SWD to the O&G WWTP on the site of the South WWTP (Alternative 1) would be funded by a third party. Similarly, construction of the pipeline needed to provide the blending option for Alternative 3 probably would be funded by a third party. There are companies that specialize in constructing pipelines to move water associated with oil- and gas-fields. Use of the lines owned by a third party is made available for a fee that covers capital and operational cost. The possibility also exists that the participating E&P company(ies) would finance these lines.

The pipelines that pick up the reclaimed water and transport it to HF sites for use will be funded by the participating E&P company(ies). This includes both capital and operating costs.

9.4.3 Storage

The only storage units directly associated with this project are ASTs on the site of the O&G WWTP. Therefore, the capital and operational costs of these storage units are funded as part of the treatment facility.

The larger storage systems in the field that are used to stage water for HF are funded by the participating E&P company(ies). In most cases, these storage systems are already in place.

9.5 MANAGEMENT APPROACHES

The participants in the project will be the E&P company(ies); the SWD owner/operator; GCWDA; and, for some alternatives, a pipeline owner/operator. Their respective roles are discussed below.

The E&P company(ies) will deliver wastewater to an SWD. The E&P company(ies) will pay the SWD its normal disposal cost. It will pay GCWDA for the cost of treating the water in accordance with a mutually agreed-to contract. If a pipeline owned by a third party is used to transfer wastewater from the SWD to the O&G WWTP, the E&P company(ies) will pay the owner/operator of the pipeline for use of the pipeline.

GCWDA will own and operate the O&G WWTP pursuant to a contract with the E&P company(ies). Initially, GCWDA will fund capital costs. The capital costs will be repaid within a short period of time; two years is proposed. Both capital and operational costs of the O&G WWTP will be reimbursed by the E&P company(ies) on a basis to be set out in the contract.

The SWD owner/operator will accept wastewater and process it through those components of its system that reduce settleable solids and free oil. When requested, the SWD will divert the processed wastewater to the O&G WWTP. It is anticipated there will be no charge to the E&P company(ies) or GCWDA for the diverted water since the SWD will have the cost savings of the deferred expense of deep-well injection.

Once the E&P company(ies) picks up the reclaimed water, all facilities associated with moving the water to, within, or between fields will be owned and operated by the respective E&P company. This includes pipelines, pump stations, and storage pits.

Effective communication will be very important to the successful operation of the recycling system. Depending on demand, water may, or may not, be transferred on a consistent basis and steady rate to the O&G WWTP. Therefore, it is important that the E&P company(ies) keep the SWD owner/operator, pipeline owner/operator, and GCWDA well informed as to the volume and rate at which water will be needed.

9.6 RANKING OF ALTERNATIVES

Table 9.5 presents rankings of each alternative in each of the evaluation categories. Alternatives are ranked from 1 to 4, with one being the best and four being the least favorable.

Table 9.5 Ranking of Alternatives

Alternative	Initial Water Cost* ($/bbl)	Water Cost After Debt Repayment ($/bbl)	Legal and Regulatory Constraints	Residuals Management	Environmental Considerations	Suitability of Treatment	Reliability of Treatment	Adequacy of Supply
1. Oil and gas wastewater recycling facility at Odessa South Regional Wastewater Treatment Plant site	3	3	2	3	2	2	2	1
2. Oil and gas wastewater recycling facility at a saltwater disposal site	1	1	3	2	1	2	3	1
3. Oil and gas wastewater recycling facility at a saltwater disposal site; effluent piped to blend with Odessa South Regional Wastewater Treatment Plant effluent	3	2	4	2	1	2	3	1
4. No action	2	4	1	1	3	1	1	2

*Cost of most expensive alternative with respect to O&G WWTP size and pipeline length.

Ranking: 1 is Most Favorable
4 is Least Favorable

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9.7 DESCRIPTION OF PREFERRED ALTERNATIVE

At this time, the preferred alternative is Alternative 2. However, depending on the location of the SWD, the location of the field to receive the reclaimed water, and the preference of the participating E&P company(ies) with respect to the quality of its HF water, either Alternative 1 or Alternative 3 is also viable. The only potentially negative consideration with respect to Alternatives 1 and 3 (due to cost) occurs if the O&G WWTP is small [around 6,000 bbl/d (0.25 MGD)] and the pipeline length is relatively long (around 5 miles).

Alternative 2, the currently preferred alternative, locates the O&G WWTP adjacent to the SWD. This is the least-cost alternative, and there are additional advantages.

- It will be convenient to transfer the partially treated wastewater from the SWD to the O&G WWTP.
- It will be convenient to dispose of the backwash residual in the SWD deep well.
- A third-party pipeline owner/operator will not be required.
- The permitting and approvals associated with constructing a pipeline will not be required.

Alternative 2 does require the E&P company(ies) to construct a pipeline to a location close to the O&G WWTP to pick up the reclaimed water. It also requires a treatment system with a heavy reliance on remote monitoring and operation.

GCWDA would own and operate the O&G WWTP pursuant to a contract with the E&P company(ies) that will use the reclaimed water. The E&P company(ies) will reimburse GCWDA for the capital and operational costs of the O&G WWTP.

It is probable that the reclaimed water system will be a system defined by RRC as a non-commercial fluid recycling facility. Thus, only the E&P company(ies) using the reclaimed water will deliver wastewater to the SWD. This should result in a more consistent and reliable treatment. It will also result in a more structured and reliable reimbursement agreement, whereby GCWDA can recover its capital investment and operational costs.

An agreement will also be required with the SWD. This agreement will set forth how, and under what provisions, the SWD provides partially treated wastewater to the O&G WWTP and accepts filter backwash residuals for disposal in the deep well.

The agreements between GCWDA, the E&P company(ies), and the SWD – or a separate, three-way agreement – should also establish communication protocols. All parties will need effective and timely notice regarding when, and what volume of, waters are to be transferred.

9.8 JUSTIFICATION FOR THE PROPOSED TITLE XVI PROJECT

The justification for the proposed Title XVI includes the following:

- Substantial water is used during the HF process. The current HF water sources are aquifers with limited capacity. As these aquifers are drawn down, it will be necessary to develop new sources of water. Since the proposed project enables the reuse of previously extracted waters as a water supply, it will postpone and/or reduce the need to develop new water supplies.
- The project will result in a reduction in existing withdrawals from aquifers since it will provide for the reuse of waters already withdrawn.
- Currently, wastewaters from oil and gas development and extraction are managed by disposal in deep wells. Over time, as these wells continue to be used, over-pressurization will occur, which will require the development of additional disposal wells. Since the proposed project will result in a reduction in the volume of wastewater that has to be disposed, it will reduce or postpone the need to develop additional disposal wells.

The project will not reduce the demand on existing federal water supply facilities since no federal facilities provide water to E&P operators in Ector and Midland Counties in the Permian Basin.

10 LEGAL AND REGULATORY CONSIDERATIONS

The following chapter summarizes legal and regulatory considerations associated with the proposed project. The following information is provided: legal capabilities of GCWDA and agencies potentially having regulatory requirements or applicable regulatory programs.

10.1 GULF COAST WASTE DISPOSAL AUTHORITY

GCWDA is a special district that was created by the Texas Legislature in 1969. The agency has authorization to provide regional facilities for the management of industrial and municipal wastewaters and industrial solid waste anywhere in the State of Texas. It can also provide non-potable water supplies. Finally, it can issue tax-exempt bonds for local governments and industries if the bonds are to be used to construct waste management facilities.

GCWDA currently operates wastewater treatment facilities that serve over 80 industrial customers and four municipal customers. One of these treatment facilities is the South WWTP. GCWDA assumed responsibility for this facility in 1997. The facility, which operates under TPDES Permit No. WQ0003776000, treats wastewaters from five industries, part of the City of Odessa, and trucked-in wastewaters.

10.2 AGENCIES AND ORGANIZATIONS WITH POTENTIAL INVOLVEMENT

There are various agencies and organizations that have potential jurisdiction or involvement with the project in the areas of wastewater management, water supply and water rights, solid waste management, or construction activities. The relevant entities in each area are as follows:

- Wastewater Management
  - RRC
  - TCEQ
  - EPA
- Water Supply and Water Rights
  - Region F Water Planning Group
- Management of NORM and Solid Waste
  - TCEQ
  - RRC
  - DSHS

- Construction Activities that Disrupt the Environment
  - USACE
  - RRC
  - USFWS
  - TPWD
  - THC

- Management of Drainage and Road Rights-of-Way
  - Ector County
  - Midland County
  - Texas Department of Transportation (TxDOT)

10.3 MANAGEMENT OF WASTEWATERS

The primary agencies that regulate wastewaters associated with the development and production of oil and gas in Texas are the RRC and TCEQ. The respective jurisdictions of the two agencies are set forth in a MOU. Summaries of the MOU and the applicable regulatory programs for wastewater follow.

The USEPA does not have a direct regulatory role with respect to wastewater associated with oil and gas activities in Texas, other than contaminated stormwater. Administration of the NPDES program in Texas for wastewater, stormwater that is not associated with oil and gas activities, and construction runoff that is not associated with oil and gas activities has been delegated to TCEQ. These programs are regulated through the TPDES program.

The regulation of wastewater discharges to surface waters and contaminated stormwater runoff associated with oil and gas activities is the responsibility of both RRC and USEPA. This aspect of the NPDES program has not been delegated.

Special provisions apply to stormwater runoff and construction-related runoff when associated with oil and gas operations. Section 402(l)(2) of the Federal CWA provides that permits will not be required "for discharges of stormwater runoff from … oil and gas exploration, production, processing, or treatment operations or transmission facilities composed entirely of flows …. which are not contaminated by contact with, or do not come into contact with, any overburden, raw material, intermediate products, finished product, byproduct, or waste products located on the site of such operations."

10.3.1 Memorandum of Understanding Between Railroad Commission of Texas and Texas Commission on Environmental Quality

In response to various legislative directives, RRC and TCEQ adopted, and have periodically revised, an MOU setting forth their respective jurisdictions in matters related to exploration, development, production, and refinery activities associated with the oil and gas industry. The most recent amendment was effective May 1, 2012.

The topics addressed in the MOU include, but are not limited to, the following: solid waste, water quality, injection wells, storage, transportation, recycling and reclamation, refining and manufacturing, spill response, and radioactive materials. Following is a summary of the provisions of the MOU related to wastewaters. Provisions related solid waste and radioactive materials are presented in later sections of this chapter.

The RRC is identified in the MOU as having responsibility for the following--in general, wastewaters associated with the development and production of oil and gas are regulated by RRC:

- Wastes resulting from activities associated with the exploration, development, or production of oil or gas resources.
- Wastewater discharges into, or adjacent to, waters of the State—these discharges must not violate water quality standards established by TCEQ.
- Stormwater runoff discharges other than uncontaminated runoff, which is exempt from permit requirements.
- Stormwater discharges associated with construction activity--reclamation plants are explicitly covered.
- Wastes from reclamation plants that process wastes from activities associated with the exploration, development, or production of oil and gas.

10.3.2 Wastewater Regulatory Programs of the Railroad Commission of Texas

The regulatory requirements applicable to the recycling facility being proposed vary depending on whether it is classified as a “commercial” or “non-commercial” recycling facility. Commercial facilities are regulated pursuant to Title 16 TAC Part 1, Chapter 4, Subchapter B (Subchapter B). Non-commercial facilities are regulated pursuant to Title 16 TAC Part 1, Chapter 3, Rule 3.8 (Rule 3.8).

In general, a non-commercial recycling facility is one where the E&P company(ies) sending production and/or flowback waters to the facility is also the E&P company(ies) using the reclaimed water. The reclaimed water has to be used in the well bore of an oil, gas, or service well. A commercial recycling facility is one where the company(ies) using the reclaimed water may, or may not, be the company(ies) sending production and/or flowback waters to the facility.

There are two categories of commercial fluid recycling facilities: off-lease and stationary. An off-lease commercial fluid recycling facility is capable of being moved and is generally in operation in a given location for a period greater than one year but less than two years. A stationary commercial fluid recycling facility is in a location for greater than two years.

The E&P company(ies) that would participate in the recycling facility envisioned by this study has not been confirmed. Therefore, it cannot be determined whether the proposed treatment facility will be categorized as a stationary commercial fluid recycling facility or a non-commercial fluid recycling facility. The regulatory requirements for each are summarized following.

10.3.2.1 Stationary Commercial Fluid Recycling Facility

Stationary commercial fluid recycling facilities are required to obtain a permit from the RRC. The permit application is submitted to the RRC headquarters office and the applicable RRC District Office. The information that must be submitted in the application is set forth in Rule 4.278 through Rule 4.285 and includes the following types of information:

- Contact information for the owner.
- Engineering and geological information demonstrating that issuance of the permit will not result in waste of a resource, pollution of surface or subsurface water, or a threat to public health or safety.
- Site description: location, groundwater strata, precipitation characteristics, soils, existing pipelines, and floodplains.
- Lease agreement if not owned by operator.
- Adjoining property owners.
- Sensitive receptors within 500 feet.
- Facility layout, unit sizing, and liners.
- Stormwater management plan.
- Monitoring well plan.

- Operating plan: storage, access control, wastewater acceptance plan, testing, recordkeeping, and inspections.
- Flow diagram of treatment process, including chemicals to be used.
- Closure plan.

Permit applicants are required to publish notice in a local newspaper and to provide notice to the owner of the tract on which the facility is located, the applicable city if within an incorporated area, adjoining landowners, and anyone else deemed to need to receive notice by RRC.

Permits are issued for a time period of up to five years. They can be renewed.

The permit will include the following:

- Financial security requirements as set forth in Texas Natural Resources Code §91.109. A bond is required.
- Provisions related to design and construction, as set forth in Rule 4.289.
- Provisions related to operations, as set forth in Rule 4.290.
- Monitoring requirements to demonstrate the recycled product is suitable for its intended use.
- Closure requirements.

In some cases, a demonstration project may be required prior to permit issuance. The purpose of the demonstration project is to confirm the adequacy of the proposed treatment process.

There is an exemption from the requirement to obtain a permit for a commercial recycling facility [Rule 4.202(d)] if the recycling is conducted on the site of an SWD operating pursuant to a permit issued under Section 3.9 or Section 3.46 of Title 16. The additional requirements associated with this exemption are as follows:

- The SWD operator contracts with the entity treating the wastewaters.
- The SWD operator is responsible for the recycling activities.
- The SWD operator has obtained financial security in accordance with Title 16 Section 3.78.

10.3.2.2 Non-commercial Fluid Recycling Facility

Non-commercial fluid recycling facilities are not required to have a permit if the reclaimed water is used for HF or any other purpose where it is used in the well bore [Rule 3.8(d)(7)(B)(i)].

10.3.2.3 Other Operational Requirements

There are regulatory requirements associated with stormwater runoff. Stormwater runoff management requirements are different for contact stormwater and non-contact stormwater. Contact stormwater is stormwater that has come into contact with oil and gas product or waste. Non-contact stormwater may be discharged from facilities under RRC jurisdiction without a permit. Contact stormwater must be managed to keep it separated from non-contact stormwater, and it must be disposed of in an authorized manner. Discharge of contact stormwater is prohibited.

No prohibition or specific regulatory requirement has been identified that would apply to the blending of treated wastewater from a facility operating under a TPDES permit, such as the South WWTP, and a recycling facility operating under RRC rules. It is necessary for the blending to occur after the final treatment unit and compliance monitoring point at both facilities.

Alternative 1 proposes to locate the recycling facility on GCWDA land adjacent to the South WWTP facilities. This recycling facility will be subject to RRC regulation rather than TCEQ regulation. However, this is conditioned on the two treatment facilities (the recycling facility and the South WWTP) being completely separated with respect to all fluid handling and treatment units. In addition, the two facility sites should be separately fenced.

Very few discharges to Waters of the State are authorized by RRC. Any such discharge would also require an NPDES permit, since permitting authority has not been delegated to RRC by USEPA. Any permitted discharge would have to comply with the surface water quality standards established by TCEQ.

10.4 WATER SUPPLY AND WATER RIGHTS CONSIDERATIONS

In general, there are no regulatory programs related to water supply or water rights that would apply to the proposed project. There are no surface water rights provisions associated with the waters used in oil- and gas-related operations that would limit the ability to reuse the reclaimed waters. Also, since there are no groundwater management districts with jurisdiction in Ector and Midland Counties, wastewaters that originate from the use of groundwater are similarly unregulated.

It is recommended that any relevant information on the development and implementation of the proposed project be regularly communicated to the Region F water planning group. This will improve the ability of the plan to forecast future water supply needs and sources. In addition, if

GCWDA should wish at some time in the future to seek loan funds from the State Water Implementation Fund for Texas (SWIFT) for this project, the project must be a recommended water management strategy in an adopted regional water plan.

10.5 MANAGEMENT OF NATURALLY OCCURRING RADIOACTIVE MATERIALS

NORM is widely distributed in the environment. It is typically present at levels that do not pose a health risk. NORM associated with oil and gas activities originates in subsurface formations. These formations may contain uranium, thorium, radium 226, or radium 228. Therefore, when waters from these formations are brought to the surface, some of these materials can be included. The concentrations present are typically not a concern. It is only when the concentration is increased by a treatment process, or as a result of scaling, that regulations apply.

Regulation of oil and gas NORM is split between RRC and DSHS. RRC regulates the disposal of NORM waste. DSHS regulates its possession, use, transfer, transport, and storage. Disposal of oil and gas NORM waste (other than when specific criteria are met, and it can be disposed on the site where the waste was generated) must be at a facility licensed by the United States Nuclear Regulatory Commission (USNRC), the State of Texas, or another state, which is authorized under its license to receive and dispose of such waste.

10.6 MANAGEMENT OF SOLID WASTE

Waste materials under the jurisdiction of RRC may be managed at solid waste facilities under the jurisdiction of TCEQ, including municipal solid waste (MSW) facilities, under certain conditions. Oil and gas wastes are designated “special wastes.” Some oil- and gas-related special wastes can be disposed at a MSW facility permitted by TCEQ without additional approvals; some require specific authorization by RRC; and some require specific authorization by TCEQ. Disposal at an MSW landfill of water treatment backwash solids from an oil and gas operation requires approval by both RRC and TCEQ. The solids must be tested for metals listed pursuant to the federal Resource Conservation and Recovery Act (RCRA) and NORM.

10.7 CONSTRUCTION ACTIVITIES THAT DISRUPT THE ENVIRONMENT

Virtually all construction activities, to some extent, disrupt the land surface. Construction of the treatment facility proposed for this project and pipelines, if included in the project, will affect the surface and near-surface environment. Therefore, the potential exists that habitat for threatened and endangered species, cultural or archeological resources, waterways, natural wetlands, or water quality could be affected. Information on the project should be submitted to a number of state and federal agencies to confirm either that no impacts are anticipated or that anticipated impacts can be sufficiently mitigated. The agencies that are potentially involved and their respective areas of influence and jurisdiction are presented below.

10.7.1 U.S. Army Corps of Engineers

Section 404 of the Federal CWA establishes a program that regulates the discharge of dredged or fill material into waters of the United States, including wetlands. Typically, any project that involves construction activities in a stream, wetlands, or other waterbody is subject to the permit requirements of Section 404.

The permit program is administered by USACE, with input at times from EPA. Projects that are expected to result in minimal adverse impacts can typically be covered by a nationwide general permit.

On February 21, 2012, USACE published final notice on the reissuance of nationwide permits. In this notice, 48 of the 49 existing nationwide permits were reissued, and two new nationwide permits were issued. Also included were modifications, three new general conditions, and three new definitions. It is probable that, if a 404 permit is required for the proposed project, a nationwide general permit will be sufficient. Until the specific project location is identified, it is not possible to determine precisely what will be required pursuant to Section 404.

10.7.2 Railroad Commission of Texas

Federally issued permits, including Section 404 permits, are subject to review and certification by the State that work proposed under the 404 permit will comply with applicable State water quality laws and regulations. RRC is the certifying agency for 404 permits for construction associated with oil and gas exploration, development, and production. In limited instances, RRC may waive certification.

10.7.3 U.S. Fish and Wildlife Service

The federal government has a program to protect endangered species. The program was originally authorized in the Endangered Species Act (ESA) of 1973. The USFWS implements the program.

An endangered species is a species that is in danger of extinction throughout all or a significant portion of its range. Threatened species are those species that are considered likely to become endangered within the foreseeable future. The ESA requires federal agencies to ensure that actions they authorize, fund, or a carry out are not likely to jeopardize the continued existence of a listed threatened or endangered species or result in the adverse modification of designated critical habitat of such species. The applicability of this program to the proposed project cannot be determined at this time. When the specific locations of the project components are determined, this should be evaluated.

10.7.4 Texas Parks and Wildlife Department

TPWD has two areas of jurisdiction: (1) protection of threatened and endangered species, and (2) issuance of Sand, Gravel and Marl permits for all stream crossings. Each of these programs is described below. Whether either is applicable to the proposed project can only be determined when the locations of project components are identified.

In addition to the requirements of the federal ESA, the Texas Legislature has authorized the protection of native plants and animals listed by the State. The state program is implemented by TPWD. TPWD prohibits the “taking” of any animal species listed by the state as endangered or threatened without a permit. “Taking” includes actions that have the potential to adversely impact individual members of a species. Listed plants are not protected from “taking.”

Chapter 86, Subtitle F of the Texas Parks and Wildlife Code directs TPWD to “manage, control, and protect marl and sand of commercial value and all gravel, shell, and mudshell located … within the freshwater areas of the state not embraced by a survey of private land.” TPWD requires that any disturbance of sand, gravel, or marl under the management and protection of the commission only be conducted in conformance with a permit issued by TPWD. There are both general and individual permits. This requirement applies to waterways that are navigable or otherwise public.

10.7.5 Texas Historical Commission

The National Historic Preservation Act of 1966, as amended, requires the federal government to consult with state and local parties to ensure that federally funded, licensed, or permitted projects avoid, minimize, or mitigate any negative impacts to cultural and historic resources. The Antiquities Code of Texas (1969) requires state agencies and political subdivisions of the state to notify THC of ground-disturbing activity on public land. The types of projects covered include construction of water and wastewater lines and treatment plants. In implementing these requirements, THC reviews projects and issues permits to conduct investigations.

10.7.6 Ector and Midland Counties

Counties have significant authority in the area of the construction and maintenance of roads. Therefore, any construction that crosses, or takes place in, the right-of-way of a county road will require approval from the county.

10.7.7 Texas Department of Transportation

If construction of any component of the project crosses, or takes place in, a state highway right-of-way, approval must be obtained from TxDOT. Whether this requirements applies to the proposed project can only be confirmed when the specific locations of project components are identified.

11 ENVIRONMENTAL CONSIDERATIONS AND POTENTIAL EFFECTS

The following chapter summarizes information relative to the measures that may be required to comply with state or federal environmental regulations, including the National Environmental Policy Act (NEPA), if necessary. A specific location for the project has not been selected. Therefore, it is not possible to make a firm finding with respect to specific actions that will be necessary to comply with environmental regulations. However, in general, the area is not environmentally sensitive. Therefore, the project is not expected to have potentially significant environmental effects or involve unique or undefined environmental risks. Also, there are no specified Federal, State, tribal, or local environmental compliance measures in Ector and Midland Counties that would apply to the proposed project.

The environmental review and approval process known as NEPA has been a major consideration for federally funded projects since the Act was first passed by the United States Congress in 1970. The purpose of NEPA is to establish national policy and goals to protect, maintain, and enhance the environment. At a federal level, NEPA accomplishes its goals by requiring federal agencies to use “all practicable means” to create and maintain conditions under which humans and nature can productively coexist. The NEPA process describes two primary levels of NEPA review:

- Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), which are required to establish that the project will either not materially affect the environmental (i.e., a FONSI is issued) or that full environmental impact statement is necessary.
- Environmental Impact Statement (EIS), which is a comprehensive environmental review of the project. The EIS describes impacts and mitigation procedures and identifies project alternatives. This is a very involved process, requiring a detailed assessment of numerous areas of environmental, socio-economic, and regulatory impacts of the project.

NEPA will come into play if federal funding is sought by GCWDA or other participants for the proposed project. If the NEPA process is required, anticipated project impacts are likely to be sufficiently small to allow the less involved EA process described above to be used. In other words, it is presumed that the EA process would result in a FONSI and the NEPA process could be concluded without implementation of the EIS process.

Whether the NEPA process must be followed or not, consideration of potential environmental impacts of the project is justified. Following is a preliminary evaluation of environmental considerations and effects possibly associated with the preferred alternative. Since a specific location for the project has not yet been selected, impacts that are site-specific can only be addressed as potentially present or probably absent.

Designated threatened and endangered species in Ector and Midland Counties are listed in Appendix 5, Table A5.1. A survey for these species should be conducted when the physical location of the project is determined; however, there is a very low probability that most of these species would be present in the project area. A species that could potentially be present is the Texas horned lizard, which is on the State list as threatened.

The project will have positive effects with respect to public health and safety. It will reduce the number of trucks hauling water to HF sites and the associated traffic hazards, roadway impacts, and greenhouse gas emissions.

No adverse impacts are anticipated with respect to natural resources. The potential project area consists mainly of semi-arid brushland.

There is a low probability of adverse impacts on Waters of the United States. However, appropriate measures need to be taken if the construction of pipelines associated with the project has a potential to affect Johnson Draw or its tributaries, Midland Draw, Salt Lake, or Pecks Lake in Midland County; or Monahans Draw or its tributaries in Ector or Midland Counties.

Any project-associated activities will need to avoid the site of the Odessa Meteor Crater and its associated museum. This site has been designated as a National Natural Landmark by the National Park Service.

Any proposed construction area should be surveyed for cultural or historic resources. The most likely locations where cultural resources may be found are along area waterways. Because of the arid and sparsely settled nature of the remainder of the counties, there's a low probability of encountering cultural resources in other areas. The Texas Historical Commission maintains information on known sites with cultural resources and/or historical properties. However, this information is not publically available. It is provided, on request, on a project-specific basis.

The area of disturbance that would be associated with the project is small, and there is flexibility with respect to where facilities are located. Once a site is tentatively identified, a preliminary evaluation of the proposed project site should be performed. If a potentially significant impact to endangered or threatened species, public health or safety, wetlands, historic properties, natural resources, or cultural resources is found to exist, consideration should be given to adjusting the project or project site in order to minimize or eliminate the impact. No impacts are anticipated to regulated Waters of the United States since no diversion from, or discharge to, these waters is proposed.

The Federal, State, and local environmental compliance measures that may be required for this project have been described previously in Chapter 10. No documents will be submitted pursuant to these requirements until the locations of the project components have been established, and it can be determined which regulatory requirements apply.

An allowance for costs associated with environmental and archaeological studies and mitigation is included in the cost estimates prepared for Chapter 9. These costs are identified for each alternative in Appendix 4.

The project will enhance water supply options in a semi-arid region with limited water supply sources. It will result in a reduction in the use of fresh and brackish groundwaters for oil and gas development and production. This will increase the availability of fresh and brackish waters for use by municipalities, agriculture, or other industrial users.

No impacts on water quality are anticipated. No discharges to surface or groundwaters are proposed other than the disposal of filter backwash waters by injection in deep wells. The quality of the filter backwash waters is comparable to, or better than, other waters being disposed by injection. Therefore, no adverse quality impacts to waters in the receiving strata are anticipated. The project is potentially beneficial because it will reduce the volume of O&G wastewater injected in SWDs. This will reduce the potential that the strata receiving the injected wastewater will become over-pressurized.

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12 JUSTIFICATION FOR THE PROPOSED TITLE XVI PROJECT

The proposed project is beneficial both to the oil and gas development and production industry and to the broader community in Ector and Midland Counties. These benefits are summarized below.

The project is beneficial to the oil and gas development and production industry in three respects:

- It provides a cost-effective, drought-proof water supply for HF that will be available for the foreseeable future.
- It reduces the need to develop additional water wells to access available groundwater sources.
- It reduces the volume of water being disposed in injection wells and, thus, prolongs the life of those wastewater management facilities.

In these ways, the project supports the continued availability of supplies of oil and gas at a reasonable cost, which is essential to the continued economic health of the nation.

The project is beneficial to the broader community in Ector and Midland Counties because it reduces demands by the oil and gas industry on fresh and brackish aquifers in the area. This makes more water of suitable quality available for domestic, municipal, and agricultural use and for use by other industrial sectors.

The project also reduces traffic in area roadways and the associated concerns with safety, energy use, greenhouse gas emissions, and expense for road maintenance.

The costs for supplying reclaimed water are very competitive with the costs of existing supply sources for fresh and brackish waters. Further, the capital costs associated with the project can be recovered in a period that is potentially as short as two years. A long-term repayment commitment is not required.

The successful implementation of proposed project could serve as a model for additional recycling facilities in the Permian Basin. Therefore, the potential future benefits of the project could be much greater than the direct effects of the project itself.

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13 ECONOMIC ANALYSIS

The following chapter provides an economic analysis of the proposed project. It includes a description of economic conditions in the area, how the proposed project is beneficial to the area economy, and how the proposed project is economically preferable to the most probable alternative, which is the “No Action” alternative.

13.1 DESCRIPTION OF AREA CONDITIONS

Two of the most significant factors influencing current and future economic conditions in Ector and Midland Counties are the health of the oil and gas industry and the availability of an adequate water supply. In fact, these two factors are inter-related.

A substantial percentage of the economic activity in Ector and Midland Counties is associated with the exploration for, development of, and production of oil and gas. This includes a wide range of sales, manufacturing, service, financial, and administrative companies that support the companies directly involved in exploration, development, and production.

The ability to provide consumers with reasonably priced oil and gas from the Permian Basin in the future is dependent on maintaining both an adequate supply of water for drilling and HF operations and the ability to dispose of wastewaters produced by oil and gas exploration, development, and production. The proposed project provides the benefits of both providing a secure source of water to support oil and gas operations that is reliable into the future and reducing the volumes of oil and gas wastewaters that are sent to deep wells, which will extend the life of those disposal facilities.

The project will be beneficial to future general economic conditions in the region by reducing demands on available water resources. Ector and Midland Counties are located in a semi-arid area of the country. Providing adequate supplies of water of suitable quality to support economic growth is a challenge. It would be beneficial to the region if the economy were diversified so that it is not as dependent on the price of oil and gas. The ability to diversify the economy is, to some extent, dependent on being able to demonstrate that there is an adequate water supply. The oil and gas industry currently relies heavily on groundwater supplies that are suitable for domestic and agricultural uses. The aquifers providing these groundwaters have limited production capacity. The proposed project will reduce reliance on the use of groundwater for oil and gas development activities and, thus, reduce the demand on the limited available groundwater.

13.2 COMPARISON OF COSTS WITH OTHER ALTERNATIVES

The most probable alternative to the proposed project is the “No Action” alternative. The current method of supplying water for exploration and development is the purchase of fresh or brackish groundwater at a cost of \$0.25 – \$0.75/bbl.

The cost for water provided by the proposed project is relatively cost competitive during the first two years when the financing for the capital costs is being repaid; It is much more positive after the repayment of the capital debt. The cost per barrel during the first two years ranges from approximately \$0.32/bbl to \$1.00/bbl, depending on the size of the treatment facility and the length of an associated pipeline—if one is required. The highest cost is associated with a small (6,000 bbl) plant when there is an associated 5-mile pipeline. After the debt is retired, the cost per barrel ranges from \$0.03–\$0.11/bbl. These are approximate costs derived from cost curves.

There are additional cost savings that are not readily quantified. Much of the water currently used is delivered by truck at a significant cost (\$0.67/bbl/hr, calculated based on round-trip travel time). Because the proposed project provides a permanent source of water, it is probable that users will install (perhaps, through third parties) pipelines to deliver water to their core water system. This will reduce the use of trucks. And, as with the capital cost of the treatment plant, after the initial capital cost of the pipeline is recovered, the operational cost will be much less than the cost of trucking.

Reducing the reliance on trucks will reduce costs associated with road maintenance and public safety. There are also environmental benefits from reducing reliance on trucks in the form of reductions in energy use and greenhouse emissions.

Implementation of the proposed project contributes to the long-term viability of an oil and gas industry in the Permian Basin that produces cost-competitive oil and gas. The current reliance on groundwater resources carries with it a measure of risk that those resources will be exhausted, either permanently or in times of drought. There is no such risk associated with the use of the reclaimed water provided by the proposed project. Furthermore, the success of the proposed project could serve as a model for much more extensive use of reclaimed waters throughout the Permian Basin.

14 PROPOSED TITLE XVI PROJECT SCHEDULE AND FUNDING PLAN

As previously noted, the start date for this project is dependent on an increase in the price of oil. Therefore, the schedule presented below is generic in that it identifies time periods rather than firm calendar dates.

14.1 PROJECT SCHEDULE

The next step in this project is to conduct a pilot study to provide a site-specific proof of the concept. The pilot study will be conducted on-site at the SWD that is the source of wastewaters to be reclaimed. The pilot unit will be operated for a minimum of 90 days. Depending on initial results, it may be determined to be desirable to repeat the 90-day testing more than once to test different pretreatment or chemical addition processes. A major objective of the pilot study is to confirm that the reclaimed water will be suitable for use in HF. Therefore, samples of effluent from the pilot facility will be provided to the E&P company(ies), which will provide them to its HF contractor for testing.

It is assumed the O&G WWTP will qualify as a non-commercial fluid recycling facility because it is anticipated that the SWD that provides the wastewater will be operated by the E&P company(ies) that will use the reclaimed water; and only flowback and production water from its wells will be accepted at the SWD. Therefore, a permit will not be required from the RRC.

The schedule for the pilot study is as follows:

Develop study protocol, design pilot unit, secure unit and install unit	6 months
Operate unit	2–4 months
Compile data and prepare report (requires coordination with HF contractor)	3 months

Information from the pilot study will be used to design the full-scale project and develop operational protocols. The schedule for implementation of the full-scale project is as follows:

Develop any required lease agreements and contracts between GCWDA, reclaimed water customers, and the SWD owner/operator. Secure financing.	This can proceed concurrently with the pilot study
Develop plans and specifications for the O&G WWTP	6 months
Obtain bids and award contract	4 months
Construct O&G WWTP	6–9 months
Start-up	1 month

Construction of any delivery pipelines, if required or desired, can proceed concurrently with the construction of the O&G WWTP.

14.2 FUNDING PLAN

Funding will be required in two phases. The first phase is the design, operation, and evaluation of the pilot system. The cost of the study is estimated to be as follows:

Lease and installation of pilot unit	$	25,000
Operation of pilot unit	$	35,000
Consulting engineering support	$	50,000
(design, sampling plan, system evaluation)		
Laboratory costs	$	10,000
Subtotal	**$**	**120,000**
Contingency (25%)	$	30,000
TOTAL	**$**	**150,000**

The costs of the pilot study will be funded through a contract between GCWDA and the E&P company(ies).

The second phase is the design and operation of the permanent O&G WWTP. It is anticipated that the first treatment facility that is constructed will be relatively small. It will be of modular construction so that it can be easily expanded as demand increases. The arrangements for funding of capital and operational costs of the O&G WWTP will be similar to those implemented by GCWDA for the other WWTPs it operates to serve industrial and municipal customers.

The capital cost of the initial O&G WWTP, if it is sized to treat 6,000 bbl/d and there are no associated pipeline costs, has been estimated to be approximately $1.6 million. The capital cost will be financed by GCWDA through a loan that is secured by a contract with the E&P company(ies) wherein the E&P company(ies) agrees to reimburse GCWDA for the loan repayments through a schedule of fixed monthly payments.

GCWDA will operate the O&G WWTP. The approximate O&M cost (derived from cost curves) of the 6,000 bbl/d O&G WWTP, assuming the plant is operated at full capacity, has been estimated to be $74,000/year. Of this total cost, between 25% and 80% of the O&M cost is fixed cost. For the purpose of this study, 40% ($2,500/mo) is estimated to be fixed cost, which the E&P company(ies) will pay to GCWDA at a fixed monthly rate that will be set forth in the contract between GCWDA and the E&P company(ies). In addition, the E&P company(ies) will pay a fee based on variable costs for the reclaimed water that it purchases. This fee has been estimated to be approximately $0.02/bbl. It should be noted that the fees for reclaimed water do not include the charge that the SWD will impose for accepting oil and gas wastewaters.

14.3 FUNDING SOURCES

At the present time, it is not anticipated that federal funding will be sought. The uncertainty of the timing when this project will proceed precludes filing an application for federal funding.

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15 PUBLIC PARTICIPATION

The public participation program for this project included two pre-study meetings, five meetings of the Advisory Committee for the study, three presentations to the Odessa Development Corporation (ODC) (which assisted with funding for the study), and a public meeting. These are described below.

15.1 PRE-STUDY MEETINGS

Meetings were held in the Ector-Midland County area to inform potential stakeholders about the study and to identify interested parties to serve on the Advisory Committee for the study. Invitations to these meetings were sent to 90 potential stakeholders. These meetings were held on April 30, 2014, and May 23, 2014. Appendices 6.1 and 6.2, respectively, have copies of the meeting summary, agenda, sign-in sheet, presentation, and handouts for each meeting.

15.2 ADVISORY COMMITTEE MEETINGS

Based on the response at the pre-study meetings, an Advisory Committee was established. The members of the committee and the entity each represents are shown in Table 15.1.

Table 15.1 Advisory Committee

Name	Affiliation
DeLynn Ano	RL Environmental, Inc.
Jim Breaux	Odessa Development Corporation
Dennis Danzik	RDX Technologies Corporation
Nick Fowler	Industry
John Grant	Colorado River Municipal Water District
Ian Kerr	Kerr Energy
Thomas Kerr	City of Odessa Utilities
Mike Robinson	Odessa-Ector Power Partners
Armando Rodriquez	Ector County
Ben Shepperd	Permian Basin Petroleum Assoc.
Heather Tash	Concho Resources, Inc.

All meetings were open meetings. As the study progressed, a distribution list was compiled of persons interested in the study, who were not on the committee. Everyone on the distribution list received notice of each meeting.

Five meetings of the Advisory Committee were held. Table 15.2 identifies the date of each meeting, the topic discussed, and the appendix referencing details of each meeting. Details of each meeting include summary, agenda, sign-in sheet, and presentation and are provided in Appendices 6.3 thru 6.7.

Table 15.2 Advisory Committee Meetings

Date	Topic(s) Discussed	Appendix
August 27, 2014	Present study objectives; identify data sources; and identify key success factors	6.3
February 11, 2015	Present data compiled on study area, water demands, and water availability; request sources of additional data. Chapters1 - 4 provided for review.	6.4
June 25, 2015	Present information on existing water reuse, additional opportunities for reuse, and alternatives for the treatment, transport and storage of oil field wastewaters to be reused for HF. Chapters 5 – 8 provided for review.	6.5
January 21, 2016	Present system alternatives.	6.6
June 30, 2016	Discuss Draft Final Report	6.7

15.3 ODESSA DEVELOPMENT CORPORATION MEETINGS

The ODC assisted with funding for the project. There have been three presentations and discussions of the project with ODC.

Two discussions were prior to initiation of the study and related to funding of the study:

- April 17, 2014--ODC committed $39,000 toward preparation of a grant application to Reclamation requesting funding support for the study.
- May 8, 2014--a representative of GCWDA made a presentation to ODC on the status of the grant.

Appendix 6.8 includes copies of the news coverage of these two events.

There was a presentation to ODC on February 11, 2016, that provided a status report on the project and described the three system alternatives being considered. Appendix 6.9 includes copies of a meeting summary, the public notice of the meeting agenda, and the presentation.

15.4 PUBLIC MEETING

A public meeting was held in conjunction with the Advisory Committee Meeting on June 30, 2016. The public was invited to attend through a Public Notice published in the Odessa American newspaper. A copy of the Public Notice is provided in Appendix 6.10.

The purpose of the meeting was to gather input from the public regarding the Industrial Water Management and Reclamation – Permian Basin Feasibility Study (draft report). The report was well received and no comments were made at the meeting that required revision of the draft report.

Because the meeting was also the final stakeholder meeting, a presentation was given by Dr. Peggy Glass summarizing the project and the identified alternatives for the use of reclaimed water for the oil and gas industry and analyses of those alternatives. Relevant tables from the engineering analyses were provided as handouts. Meeting notes for the combined public meeting and stakeholder meeting are provided in Appendix 6.7.

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Appendix 1

Primary and Secondary Drinking Water Standards

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Table A1.1

Natonal Primary Drinking Water Regulations
Inorganic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2] (mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass and electronicsproduction wastes
Asbestos (fiber > 10 micrometers)	7 million fibers per liter (MFL)	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints

Table A1.1

Natonal Primary Drinking Water Regulations
Inorganic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2] (mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	TT7; Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4	4	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories

Table A1.1

Natonal Primary Drinking Water Regulations
Inorganic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2](mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Lead	zero	TT7; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (measured as Nitrogen)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits

Table A1.1

Natonal Primary Drinking Water Regulations
Inorganic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2] (mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories

[1]Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

[2]Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

Note: Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water.

Table A1.2

Natonal Primary Drinking Water Regulations
Organic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2](mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Acrylamide	zero	TT8	Nervous system or blood problems; increased risk of cancer	Added to water during sewage/wastewater treatment
Alachlor	zero	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops
Atrazine	0.003	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops
Benzene	zero	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene (PAHs)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines
Carbofuran	0.04	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa
Carbon tetrachloride	zero	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities
Chlordane	zero	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide
Chlorobenzene	0.1	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories

Table A1.2

Natonal Primary Drinking Water Regulations
Organic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2](mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
2,4-D	0.07	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops
Dalapon	0.2	0.2	Minor kidney changes	Runoff from herbicide used on rights of way
1,2-Dibromo-3-chloropropane (DBCP)	zero	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards
o-Dichlorobenzene	0.6	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories
p-Dichlorobenzene	0.075	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories
1,2-Dichloroethane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories
1,1-Dichloroethylene	0.007	0.007	Liver problems	Discharge from industrial chemical factories
cis-1,2-Dichloroethylene	0.07	0.07	Liver problems	Discharge from industrial chemical factories
trans-1,2-Dichloroethylene	0.1	0.1	Liver problems	Discharge from industrial chemical factories
Dichloromethane	zero	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories
1,2-Dichloropropane	zero	0.005	Increased risk of cancer	Discharge from industrial chemical factories

Table A1.2

Natonal Primary Drinking Water Regulations
Organic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2](mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Di(2-ethylhexyl) adipate	0.4	0.4	Weight loss, liver problems, or possible reproductive difficulties.	Discharge from chemical factories
Di(2-ethylhexyl) phthalate	zero	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories
Dinoseb	0.007	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables
Dioxin (2,3,7,8-TCDD)	zero	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories
Diquat	0.02	0.02	Cataracts	Runoff from herbicide use
Endothall	0.1	0.1	Stomach and intestinal problems	Runoff from herbicide use
Endrin	0.002	0.002	Liver problems	Residue of banned insecticide
Epichlorohydrin	zero	TT8	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals
Ethylbenzene	0.7	0.7	Liver or kidneys problems	Discharge from petroleum refineries

Table A1.2

Natonal Primary Drinking Water Regulations
Organic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2] (mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Ethylene dibromide	zero	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries
Glyphosate	0.7	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use
Heptachlor	zero	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide
Heptachlor epoxide	zero	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor
Hexachlorobenzene	zero	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories
Hexachlorocyclopentadiene	0.05	0.05	Kidney or stomach problems	Discharge from chemical factories
Lindane	0.0002	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens
Methoxychlor	0.04	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Oxamyl (Vydate)	0.2	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes

Table A1.2

Natonal Primary Drinking Water Regulations
Organic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2](mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Polychlorinated biphenyls (PCBs)	zero	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals
Pentachlorophenol	zero	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories
Picloram	0.5	0.5	Liver problems	Herbicide runoff
Simazine	0.004	0.004	Problems with blood	Herbicide runoff
Styrene	0.1	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills
Tetrachloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners
Toluene	1	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories
Toxaphene	zero	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle
2,4,5-TP (Silvex)	0.05	0.05	Liver problems	Residue of banned herbicide
1,2,4-Trichlorobenzene	0.07	0.07	Changes in adrenal glands	Discharge from textile finishing factories
1,1,1-Trichloroethane	0.2	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories

Table A1.2

Natonal Primary Drinking Water Regulations
Organic Chemicals

Contaminant	MCLG[1] (mg/L)	MCL or TT[2] (mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
1,1,2-Trichloroethane	0.003	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories
Trichloroethylene	zero	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories
Vinyl chloride	zero	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories
Xylenes (total)	10	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories

[1]Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

[2]Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

Note: Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water.

Table A1.3

National Primary Drinking Water Regulations
Radionuclides

Contaminant	MCLG[1] (mg/L)	MCL or TT[2] (mg/L)	Potential Health Effects from Long-Term Exposure Above the MCL (unless specified as short-term)	Sources of Contaminant in Drinking Water
Alpha particles	none------- zero	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation
Beta particles and photon emitters	none------- zero	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation
Radium 226 and Radium 228 (combined)	none----- zero	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
Uranium	zero	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits

[1]Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.

[2]Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.

Note: Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water.

Table A1.4

Federal Secondary Drinking Water Standards

Contaminant	Secondary MCL	Noticeable Effects above the Secondary MCL
Aluminum	0.05 to 0.2 mg/L*	colored water
Chloride	250 mg/L	salty taste
Color	15 color units	visible tint
Copper	1.0 mg/L	metallic taste; blue-green staining
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	tooth discoloration
Foaming agents	0.5 mg/L	frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste
Odor	3 TON (threshold odor number)	"rotten-egg", musty or chemical smell
pH	6.5 - 8.5	low pH: bitter metallic taste; corrosion high pH: slippery feel; soda taste; deposits
Silver	0.1 mg/L	skin discoloration; graying of the white part of the eye
Sulfate	250 mg/L	salty taste
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	metallic taste

*mg/L is milligrams of substance per liter of water.

Table A1.5

State Secondary Drinking Water Standards

Contaminant	Noticeable Effects Above the Secondary MCL
Aluminum	0.05 to 0.2
Chloride	300
Color	15 color units
Copper	1
Corrosivity	Non-Corrosive
Fluoride	2
Foaming Agents	0.5
Iron	0.05
Manganese	0.3
Odor	3 Threshold Odor Number
pH	>7.0
Silver	0.1
Sulfate	300
Total Dissolved Solids (TDS)	1000
Zinc	5

Effective July 30, 2015

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Appendix 2

Recommended Water Quality for Livestock

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Table A2.1

Recommended Concentrations of Total Dissolved Solids for Livestock

Total Soluble Salts Content of Waters (mg/L)	Comments
Less than 1,000	These waters have a relatively low level of salinity and should present no serious burden.
1,000 to 2,999	These waters should be satisfactory. They may cause temporary and mild diarrhea in livestock unaccustomed to them, but they should not affect their health or performance.
3,000 to 4,999	These waters should be satisfactory, although they may cause temporary diarrhea or be refused at first by animals unaccustomed to them.
Discharge 5,000	
5,000 to 6,999	These waters can be used with reasonable safety. It may be well to avoid using those approaching the higher levels for pregnant or lactating animals.
7,000 to 10,000	Considerable risk may exist in using these waters for pregnant or lactating livestock, the young of these species, or for any animals subjected to heavy heat stress or water loss. In general, their use should be avoided, although older livestock may subsist on them for long periods under conditions of low stress.
More than 10,000	The risks with these highly saline waters are so great that they cannot be recommended for use under any condition.

(Fairies et al 1998)

Table A2.2
Recommended Concentrations of
Water Quality for Livestock

Toxic Substances
(All concentrations in milligrams per liter)

Substance	NAS[1]	CAST[2]
Arsenic	0.2	0.2
Boron	Not Established	Not Established
Cadmium	0.05	0.05
Chromium	1	1
Cobalt	1	1
Copper	0.5	0.5
Fluoride	2	2
Lead	0.1	0.1
Mercury	0.01	0.01
Nickel	1	1
Nitrate-N	100	100
Nitrite-N	10	10
Vanadium	Not Established	Not Established
Zinc	Not Established	Not Established

[1]National Academy of Science - 1974

[2] Council for Agricultural Science and Technology - 1974

Appendix 3

Projected Water Supply Sources for Each Water User Group in 2020, 2030, and 2040

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Table A3.1

Ector County Projected Supply Sources by Water User Group

Ector County		2020			2030			2040		
	SOURCE	AF/yr	MGD	Bbl/yr	AF/yr	MGD	Bbl/yr	AF/yr	MGD	Bbl/yr
Municipal	COLORADO RIVER MWD LAKE/RESERVOIR SYSTEM	7,582	6.76	58,821,156	11,241	10.03	87,207,678	11,210	10.00	86,967,180
	DIRECT REUSE	799	0.71	6,198,642	1,238	1.10	9,604,404	1,268	1.13	9,837,144
	OGALLALA AQUIFER	636	0.57	4,934,088	977	0.87	7,579,566	1,032	0.92	8,006,256
	PECOS VALLEY AQUIFER	4,064	3.63	31,528,512	6,269	5.59	48,634,902	6,429	5.74	49,876,182
	EDWARDS-TRINITY-PLATEAU AQUIFER	2,340	2.09	18,153,720	2,353	2.10	18,254,574	2,368	2.11	18,370,944
	CONSERVATION*	732	0.65	5,678,856	844	0.75	6,547,752	945	0.84	7,331,310
	SUBORDINATION*	11,671	10.41	90,543,618	7,523	6.71	58,363,434	10,146	9.05	78,712,668
Manufacturing	COLORADO RIVER MWD LAKE/RESERVOIR SYSTEM	212	0.19	1,644,696	284	0.25	2,203,272	278	0.25	2,156,724
	DIRECT REUSE	2,906	2.59	22,544,748	3,097	2.76	24,026,526	3,204	2.86	24,856,632
	OGALLALA AQUIFER	5	0.00	38,790	7	0.01	54,306	7	0.01	54,306
	PECOS VALLEY AQUIFER	133	0.12	1,031,814	177	0.16	1,373,166	178	0.16	1,380,924
	EDWARDS-TRINITY-PLATEAU AQUIFER	1,270	1.13	9,852,660	1,270	1.13	9,852,660	1,270	1.13	9,852,660
	DOCKUM AQUIFER	8	0.01	62,064	8	0.01	62,064	8	0.01	62,064
Mining	DIRECT REUSE	1,582	1.41	12,273,156	1,731	1.54	13,429,098	1,541	1.37	11,955,078
	OGALLALA AQUIFER	218	0.19	1,691,244	155	0.14	1,202,490	73	0.07	566,334
	EDWARDS-TRINITY-PLATEAU AQUIFER	100	0.09	775,800	100	0.09	775,800	73	0.07	566,334
	DOCKUM AQUIFER	348	0.31	2,699,784	348	0.31	2,699,784	348	0.31	2,699,784
	CONSERVATION*	131	0.12	1,016,298	151	0.13	1,171,458	135	0.12	1,047,330
Steam Electric	DIRECT REUSE	500	0.45	3,879,000	500	0.45	3,879,000	500	0.45	3,879,000
	OGALLALA AQUIFER	2,317	2.07	17,975,286	2,268	2.02	17,595,144	2,311	2.06	17,928,738
Livestock	OGALLALA AQUIFER	10	0.01	77,580	10	0.01	77,580	10	0.01	77,580
	PECOS VALLEY AQUIFER	25	0.02	193,950	25	0.02	193,950	25	0.02	193,950
	EDWARDS-TRINITY-PLATEAU AQUIFER	201	0.18	1,559,358	201	0.18	1,559,358	201	0.18	1,559,358
	DOCKUM AQUIFER	18	0.02	139,644	18	0.02	139,644	18	0.02	139,644
	COLORADO LIVESTOCK	11	0.01	85,338	11	0.01	85,338	11	0.01	85,338
Irrigation	COLORADO RIVER MWD LAKE/RESERVOIR SYSTEM	127	0.11	985,266	171	0.15	1,326,618	155	0.14	1,202,490
	DIRECT REUSE	1,303	1.16	10,108,674	1,444	1.29	11,202,552	1,592	1.42	12,350,736
	OGALLALA AQUIFER	403	0.36	3,126,474	404	0.36	3,134,232	404	0.36	3,134,232
	PECOS VALLEY AQUIFER	68	0.06	527,544	96	0.09	744,768	89	0.08	690,462
	EDWARDS-TRINITY-PLATEAU AQUIFER	500	0.45	3,879,000	500	0.45	3,879,000	500	0.45	3,879,000
	CONSERVATION*	72	0.06	558,576	142	0.13	1,101,636	210	0.19	1,629,180
	SUBORDINATION*	89	0.08	690,462	110	0.10	853,380	134	0.12	1,039,572
	Ector County Total Supply	**40,381**	**36**	**313,275,798**	**43,673**	**39**	**338,815,134**	**46,673**	**42**	**362,089,134**

1 AF = 0.326 MG
1AF = 7,758 Bbl
1 MG = 23,810 Bbl

Source: TWDB 2015

** Source: Freese 2015*

Data Source: TWDB 2015 Regional Water Planning DB17 Report

Table A3.2
Midland County Projected Supply Sources by Water User Group

Midland County	SOURCE	2020 AF/yr	2020 MGD	2020 Bbl/yr	2030 AF/yr	2030 MGD	2030 Bbl/yr	2040 AF/yr	2040 MGD	2040 Bbl/yr
Municipal	COLORADO RIVER MWD LAKE/RESERVOIR SYSTEM	6,121	5.46	47,486,718	215	0.19	1,667,970	229	0.20	1,776,582
	DIRECT REUSE	777	0.69	6,027,966	154	0.14	1,194,732	156	0.14	1,210,248
	OGALLALA AQUIFER	3,376	3.01	26,191,008	3,298	2.94	25,585,884	1,420	1.27	11,016,360
	PECOS VALLEY AQUIFER	14,482	12.92	112,351,356	11,320	10.10	87,820,560	11,331	10.11	87,905,898
	EDWARDS-TRINITY-PLATEAU AQUIFER	3,677	3.28	28,526,166	3,986	3.56	30,923,388	3,738	3.33	28,999,404
	OH IVIE LAKE/RESERVOIR NON-	5,924	5.29	45,958,392	5,767	5.15	44,740,386	5,601	5.00	43,452,558
	CONSERVATION*	958	0.85	7,432,164	1,043	0.93	8,091,594	1,156	1.03	8,968,248
	SUBORDINATION*	8,527	7.61	66,152,466	(299)	(0.27)	(2,319,642)	(298)	(0.27)	(2,311,884)
Manufacturing	OGALLALA AQUIFER	195	0.17	1,512,810	226	0.20	1,753,308	248	0.22	1,923,984
	OH IVIE LAKE/RESERVOIR NON-	35	0.03	271,530	24	0.02	186,192	21	0.02	162,918
Mining	OGALLALA AQUIFER	1,200	1.07	9,309,600	1,200	1.07	9,309,600	1,000	0.89	7,758,000
	EDWARDS-TRINITY-PLATEAU AQUIFER	2,693	2.40	20,892,294	2,218	1.98	17,207,244	1,630	1.45	12,645,540
	CONSERVATION*	273	0.24	2,117,934	239	0.21	1,854,162	184	0.16	1,427,472
Livestock	OGALLALA AQUIFER	72	0.06	558,576	72	0.06	558,576	72	0.06	558,576
	EDWARDS-TRINITY-PLATEAU AQUIFER	205	0.18	1,590,390	205	0.18	1,590,390	205	0.18	1,590,390
	COLORADO LIVESTOCK	117	0.10	907,686	117	0.10	907,686	117	0.10	907,686
Irrigation	OGALLALA AQUIFER	20,631	18.41	160,055,298	20,470	18.26	158,806,260	20,309	18.12	157,557,222
	PECOS VALLEY AQUIFER	12,645	11.28	98,099,910	12,546	11.19	97,331,868	12,447	11.10	96,563,826
	CONSERVATION*	1,664	1.48	12,909,312	3,302	2.95	25,616,916	4,913	4.38	38,115,054
	Midland County Total Supply	**83,572**	**75**	**648,351,576**	**66,103**	**59**	**512,827,074**	**64,479**	**58**	**500,228,082**

1 AF = 0.326 MG
1AF = 7,758 Bbl
1 MG = 23,810 Bbl

Source: TWDB 2015

** Source: Freese 2015*

Data Source: TWDB 2015 Regional Water Planning DB17 Report

Appendix 4

Cost Estimates of Alternatives

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Appendix 4

Alternative 1

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Table A4.1

Industrial Reclamation Permian Basin Facility

Preliminary Opinion of Cost Summary

Alternative 1

Treat at Odessa South Regional Wastewater Treatment Plant Site and Blend

Treat 0.25 MGD Average Flow; Transport 1 mile

Project Yield (bbl/day)	**6,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$1,005,000
Transmission Pipeline	$122,000
Storage Tanks	$52,000
Treatment Plant	$675,000
TOTAL COST OF FACILITIES	**$1,854,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$464,000
Environmental & Archaeology Studies and Mitigation	$25,000
Land Acquisition and Surveying	$73,000
Interest During Construction	$43,000
TOTAL COST OF PROJECT	**$2,459,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$81,000
FIXED COSTS (ANNUAL)	
Debt Service	$1,322,000
Fixed Operation and Maintenance	$32,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	$146,000
Variable Operations and Maintenance	$49,000
Pumping Energy Costs	$4,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$1,354,000
Total Variable Annual Cost	$199,000
Total Annual Cost During Debt Service	**$1,553,000**
After Debt Service	
Total Fixed Annual Cost	$32,000
Total Variable Annual Cost	$199,000
Total Annual Cost After Debt Service	**$231,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$5,546
Cost of Water ($ per k-gallons)	$17.00
Cost of Water ($ per barrel)	$0.71
After Debt Service	
Cost of Water ($ per AF)	$825
Cost of Water ($ per k-gallons)	$2.53
Cost of Water ($ per barrel)	$0.11

Table A4.2

Industrial Reclamation Permian Basin Facility

Preliminary Opinion of Cost Summary

Alternative 1

Treat at Odessa South Regional Wastewater Treatment Plant Site and Blend
Treat 0.25 MGD Average Flow; Transport 5 miles

Project Yield (bbl/day)	**6,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$1,106,000
Transmission Pipeline	$611,000
Storage Tanks	$52,000
Treatment Plant	$675,000
TOTAL COST OF FACILITIES	**$2,444,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$611,000
Environmental & Archaeology Studies and Mitigation	$125,000
Land Acquisition and Surveying	$363,000
Interest During Construction	$84,000
TOTAL COST OF PROJECT	**$3,627,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$87,000
FIXED COSTS (ANNUAL)	
Debt Service	$1,951,000
Fixed Operation and Maintenance	$35,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	$146,000
Variable Operations and Maintenance	$52,000
Pumping Energy Costs	$7,000
TOTAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$1,986,000
Total Variable Annual Cost	$205,000
Total Annual Cost During Debt Service	**$2,191,000**
After Debt Service	
Total Fixed Annual Cost	$35,000
Total Variable Annual Cost	$205,000
Total Annual Cost After Debt Service	**$240,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$7,825
Cost of Water ($ per k-gallons)	$24.00
Cost of Water ($ per barrel)	$1.01
After Debt Service	
Cost of Water ($ per AF)	$857
Cost of Water ($ per k-gallons)	$2.63
Cost of Water ($ per barrel)	$0.11

AL *6/13/2016*

Table A4.3

Industrial Reclamation Permian Basin Facility

Preliminary Opinon of Cost Summary

Alternative 1

Treat at Odessa South Regional Wastewater Treatment Plant Site and Blend

Treat 0.5 MGD Average Flow; Transport 1 mile

Project Yield (bbl/day)	**12,000**
Item	***Opinion of Costs***
CAPITAL COSTS	
Influent and Effluent Pump Stations	$1,380,000
Transmission Pipeline	$186,000
Storage Tanks	$78,000
Treatment Plant	$1,350,000
TOTAL COST OF FACILITIES	**$2,994,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$749,000
Environmental & Archaeology Studies and Mitigation	$25,000
Land Acquisition and Surveying	$73,000
Interest During Construction	$68,000
TOTAL COST OF PROJECT	**$3,909,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$156,000
FIXED COSTS (ANNUAL)	
Debt Service	$2,102,000
Fixed Operation and Maintenance	$62,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	$292,000
Variable Operation and Maintenance	$94,000
Pumping Energy Costs	$6,000
TOTAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$2,164,000
Total Variable Annual Cost	$392,000
Total Annual Cost During Debt Service	**$2,556,000**
After Debt Service	
Total Fixed Annual Cost	$62,000
Total Variable Annual Cost	$392,000
Total Annual Cost After Debt Service	**$454,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$4,564
Cost of Water ($ per k-gallons)	$14.00
Cost of Water ($ per barrel)	$0.59
After Debt Service	
Cost of Water ($ per AF)	$811
Cost of Water ($ per k-gallons)	$2.49
Cost of Water ($ per barrel)	$0.10

Table A4.4
Industrial Reclamation Permian Basin Facility
Preliminary Opinion of Cost Summary
Alternative 1
Treat at Odessa South Regional Wastewater Treatment Plant Site and Blend
Treat 0.5 MGD Average Flow; Transport 5 miles

Project Yield (bbl/day)	**12,000**
Item	***Opinion of Costs***
CAPITAL COSTS	
Influent and Effluent Pump Stations	$1,469,000
Transmission Pipeline	$930,000
Storage Tanks	$78,000
Treatment Plant	$1,350,000
TOTAL COST OF FACILITIES	**$3,827,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$957,000
Environmental & Archaeology Studies and Mitigation	$125,000
Land Acquisition and Surveying	$363,000
Interest During Construction	$124,000
TOTAL COST OF PROJECT	**$5,396,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$164,000
FIXED COSTS (ANNUAL)	
Debt Service	$2,902,000
Fixed Operation and Maintenance	$66,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	$292,000
Variable Operation and Maintenance	$98,000
Pumping Energy Costs	$11,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$2,968,000
Total Variable Annual Cost	$401,000
Total Annual Cost During Debt Service	**$3,369,000**
After Debt Service	
Total Fixed Annual Cost	$66,000
Total Variable Annual Cost	$401,000
Total Annual Cost After Debt Service	**$467,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$6,016
Cost of Water ($ per k-gallons)	$18.46
Cost of Water ($ per barrel)	$0.78
After Debt Service	
Cost of Water ($ per AF)	$834
Cost of Water ($ per k-gallons)	$2.56
Cost of Water ($ per barrel)	$0.11

Table A4.5

Industrial Reclamation Permian Basin Facility

Preliminary Opinion of Cost Summary

Alternative 1

Treat at Odessa South Regional Wastewater Treatment Plant Site and Blend
Treat 1.0 MGD Average Flow; Transport 1 mile

	Project Yield (bbl/day)	**24,000**
Item		***Opinion of Costs***
CAPITAL COSTS		
Influent and Effluent Pump Stations		$1,470,000
Transmission Pipeline		$239,000
Storage Tanks		$104,000
Treatment Plant		$2,700,000
	TOTAL COST OF FACILITIES	**$4,513,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies		$1,128,000
Environmental & Archaeology Studies and Mitigation		$25,000
Land Acquisition and Surveying		$73,000
Interest During Construction		$101,000
	TOTAL COST OF PROJECT	**$5,840,000**
ANNUAL COSTS		
Annual Operations and Maintenance Costs		$297,000
FIXED COSTS (ANNUAL)		
Debt Service		$3,140,000
Fixed Operation and Maintenance		$119,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)		
Trucking Backwash Reject		$584,000
Variable Operation and Maintenance		$178,000
Pumping Energy Costs		$11,000
TOTAL ANNUAL COST AT FULL UTILIZATION		
During Debt Service		
Total Fixed Annual Cost		$3,259,000
Total Variable Annual Cost		$773,000
	Total Annual Cost During Debt Service	**$4,032,000**
After Debt Service		
Total Fixed Annual Cost		$119,000
Total Variable Annual Cost		$773,000
	Total Annual Cost After Debt Service	**$892,000**
UNIT COSTS		
During Debt Service		
Cost of Water ($ per AF)		$3,600
Cost of Water ($ per k-gallons)		$11.05
Cost of Water ($ per barrel)		$0.46
After Debt Service		
Cost of Water ($ per AF)		$796
Cost of Water ($ per k-gallons)		$2.44
Cost of Water ($ per barrel)		$0.10
AL		*6/13/2016*

Table A4.6

Industrial Reclamation Permian Basin Facility

Preliminary Opinion of Cost Summary

Alternative 1

Treat at Odessa South Regional Wastewater Treatment Plant Site and Blend

Treat 1.0 MGD Average Flow; Transport 5 miles

Project Yield (bbl/day)	**24,000**
Item	***Opinion of Costs***
CAPITAL COSTS	
Influent and Effluent Pump Stations	$1,542,000
Transmission Pipeline	$1,193,000
Storage Tanks	$104,000
Treatment Plant	$2,700,000
TOTAL COST OF FACILITIES	**$5,539,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$1,385,000
Environmental & Archaeology Studies and Mitigation	$125,000
Land Acquisition and Surveying	$363,000
Interest During Construction	$174,000
TOTAL COST OF PROJECT	**$7,586,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$308,000
FIXED COSTS (ANNUAL)	
Debt Service	$4,080,000
Fixed Operation and Maintenance	$123,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	$584,000
Variable Operation and Maintenance	$185,000
Pumping Energy Costs	$17,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$4,203,000
Total Variable Annual Cost	$786,000
Total Annual Cost During Debt Service	**$4,989,000**
After Debt Service	
Total Fixed Annual Cost	$123,000
Total Variable Annual Cost	$786,000
Total Annual Cost After Debt Service	**$909,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$4,454
Cost of Water ($ per k-gallons)	$13.67
Cost of Water ($ per barrel)	$0.57
After Debt Service	
Cost of Water ($ per AF)	$812
Cost of Water ($ per k-gallons)	$2.49
Cost of Water ($ per barrel)	$0.10

AL *6/13/2016*

Appendix 4

Alternative 2

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Table A4.7

Industrial Reclamation Permian Basin Facility

Preliminary Opinion of Cost Summary

Alternative 2

Treat at Saltwater Disposal Site

Treat 0.25 MGD Average Flow; No Transmission

	Project Yield (bbl/day)	**6,000**
Item		***Opinion of Costs***
Influent and Effluent Pump Stations		$366,000
Transmission Pipeline		$4,000
Storage Tanks		$26,000
Treatment Plant		$825,000
	TOTAL COST OF FACILITIES	**$1,221,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies		$305,000
Environmental & Archaeology Studies and Mitigation		$39,000
Land Acquisition and Surveying		$42,000
Interest During Construction		$29,000
	TOTAL COST OF PROJECT	**$1,636,000**
ANNUAL COSTS		
Annual Operations and Maintenance Costs		$74,000
FIXED COSTS (ANNUAL)		
Debt Service		$880,000
Fixed Operation and Maintenance		$30,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)		
Trucking Backwash Reject		---
Variable Operation and Maintenance		$44,000
Pumping Energy Costs		$1,000
TOTAL ANNUAL COST AT FULL UTILIZATION		
During Debt Service		
Total Fixed Annual Cost		$910,000
Total Variable Annual Cost		$45,000
	Total Annual Cost During Debt Service	**$955,000**
After Debt Service		
Total Fixed Annual Cost		$30,000
Total Variable Annual Cost		$45,000
	Total Annual Cost After Debt Service	**$75,000**
UNIT COSTS		
During Debt Service		
Cost of Water ($ per AF)		$3,411
Cost of Water ($ per k-gallons)		$10.47
Cost of Water ($ per barrel)		$0.44
After Debt Service		
Cost of Water ($ per AF)		$268
Cost of Water ($ per k-gallons)		$0.82
Cost of Water ($ per barrel)		$0.03
AL		*6/13/2016*

Table A4.8

Industrial Reclamation Permian Basin Facility

Preliminary Opinion of Cost Summary

Alternative 2

Treat at Saltwater Disposal Site

Treat 0.5 MGD Average Flow; No Transmission

Project Yield (bbl/day)	**12,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$666,000
Transmission Pipeline	$6,000
Storage Tanks	$39,000
Treatment Plant	$1,500,000
TOTAL COST OF FACILITIES	**$2,211,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$553,000
Environmental & Archaeology Studies and Mitigation	$38,000
Land Acquisition and Surveying	$42,000
Interest During Construction	$50,000
TOTAL COST OF PROJECT	**$2,894,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$147,000
FIXED COSTS (ANNUAL)	
Debt Service	$1,556,000
Fixed Operation and Maintenance	$59,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	---
Variable Operation and Maintenance	$88,000
Pumping Energy Costs	$2,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$1,615,000
Total Variable Annual Cost	$90,000
Total Annual Cost During Debt Service	**$1,705,000**
After Debt Service	
Total Fixed Annual Cost	$59,000
Total Variable Annual Cost	$90,000
Total Annual Cost After Debt Service	**$149,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$3,045
Cost of Water ($ per k-gallons)	$9.34
Cost of Water ($ per barrel)	$0.39
After Debt Service	
Cost of Water ($ per AF)	$266
Cost of Water ($ per k-gallons)	$0.82
Cost of Water ($ per barrel)	$0.03

AL *6/13/2016*

Table A4.9
Industrial Reclamation Permian Basin Facility
Preliminary Opinion of Cost Summary
Alternative 2
Treat at Saltwater Disposal Site
Treat 1.0 MGD Average Flow; No Transmission

Project Yield (bbl/day)	**24,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$727,000
Transmission Pipeline	$8,000
Storage Tanks	$52,000
Treatment Plant	$2,850,000
TOTAL COST OF FACILITIES	**$3,637,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$909,000
Environmental & Archaeology Studies and Mitigation	$38,000
Land Acquisition and Surveying	$42,000
Interest During Construction	$81,000
TOTAL COST OF PROJECT	**$4,707,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$288,000
FIXED COSTS (ANNUAL)	
Debt Service	$2,531,000
Fixed Operation and Maintenance	$115,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	---
Variable Operation and Maintenance	$173,000
Pumping Energy Costs	$5,000
TOTAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$2,646,000
Total Variable Annual Cost	$178,000
Total Annual Cost During Debt Service	$2,824,000
After Debt Service	
Total Fixed Annual Cost	$115,000
Total Variable Annual Cost	$178,000
Total Annual Cost After Debt Service	$293,000
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$2,521
Cost of Water ($ per k-gallons)	$7.74
Cost of Water ($ per barrel)	$0.32
After Debt Service	
Cost of Water ($ per AF)	$262
Cost of Water ($ per k-gallons)	$0.80
Cost of Water ($ per barrel)	$0.03
AL	*6/13/2016*

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Appendix 4

Alternative 3

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Table A4.10
Industrial Reclamation Permian Basin Facility
Preliminary Opinion of Cost Summary
Alternative 3
Treat at Saltwater Disposal Site and Blend with
Odessa South Regional Wastewater Treatment Plant Effluent
Treat 0.25 MGD Average Flow; Transport 1 miles

Project Yield (bbl/day)	**6,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$1,005,000
Transmission Pipeline	$122,000
Storage Tanks	$26,000
Treatment Plant	$825,000
TOTAL COST OF FACILITIES	**$1,978,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$495,000
Environmental & Archaeology Studies and Mitigation	$63,000
Land Acquisition and Surveying	$115,000
Interest During Construction	$47,000
TOTAL COST OF PROJECT	**$2,698,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$81,000
FIXED COSTS (ANNUAL)	
Debt Service	$1,451,000
Fixed Operation and Maintenance	$32,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	
Variable Operation and Maintenance	$49,000
Pumping Energy Costs	$3,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$1,483,000
Total Variable Annual Cost	$52,000
Total Annual Cost During Debt Service	**$1,535,000**
After Debt Service	
Total Fixed Annual Cost	$32,000
Total Variable Annual Cost	$52,000
Total Annual Cost After Debt Service	**$84,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$5,482
Cost of Water ($ per k-gallons)	$16.82
Cost of Water ($ per barrel)	$0.71
After Debt Service	
Cost of Water ($ per AF)	$300
Cost of Water ($ per k-gallons)	$0.92
Cost of Water ($ per barrel)	$0.04
AL	*6/13/2016*

Table A4.11
Industrial Reclamation Permian Basin Facility
Preliminary Opinion of Cost Summary
Alternative 3
Treat at Saltwater Disposal Site and Blend with
Odessa South Regional Wastewater Treatment Plant Effluent
Treat 0.25 MGD Average Flow; Transport 5 miles

Project Yield (bbl/day)	**6,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$1,106,000
Transmission Pipeline	$611,000
Storage Tanks	$26,000
Treatment Plant	$825,000
TOTAL COST OF FACILITIES	**$2,568,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$642,000
Environmental & Archaeology Studies and Mitigation	$163,000
Land Acquisition and Surveying	$405,000
Interest During Construction	$89,000
TOTAL COST OF PROJECT	**$3,867,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$87,000
FIXED COSTS (ANNUAL)	
Debt Service	$2,080,000
Fixed Operation and Maintenance	$35,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	---
Variable Operation and Maintenance	$52,000
Pumping Energy Costs	$6,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$2,115,000
Total Variable Annual Cost	$58,000
Total Annual Cost During Debt Service	**$2,173,000**
After Debt Service	
Total Fixed Annual Cost	$35,000
Total Variable Annual Cost	$58,000
Total Annual Cost After Debt Service	**$93,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$7,761
Cost of Water ($ per k-gallons)	$23.81
Cost of Water ($ per barrel)	$1.00
After Debt Service	
Cost of Water ($ per AF)	$332
Cost of Water ($ per k-gallons)	$1.02
Cost of Water ($ per barrel)	$0.04
AL	*6/13/2016*

Table A4.12
Industrial Reclamation Permian Basin Facility
Preliminary Opinion of Cost Summary
Alternative 3
Treat at Saltwater Disposal Site and Blend with
Odessa South Regional Wastewater Treatment Plant Effluent
Treat 0.5 MGD Average Flow; Transport 1 mile

Item	Opinion of Costs
Project Yield (bbl/day)	**12,000**
Influent and Effluent Pump Stations	$1,381,000
Transmission Pipeline	$186,000
Storage Tanks	$39,000
Treatment Plant	$1,500,000
TOTAL COST OF FACILITIES	**$3,106,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$777,000
Environmental & Archaeology Studies and Mitigation	$63,000
Land Acquisition and Surveying	$115,000
Interest During Construction	$72,000
TOTAL COST OF PROJECT	**$4,133,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$156,000
FIXED COSTS (ANNUAL)	
Debt Service	$2,222,000
Fixed Operation and Maintenance	$62,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	---
Variable Operation and Maintenance	$94,000
Pumping Energy Costs	$6,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$2,284,000
Total Variable Annual Cost	$100,000
Total Annual Cost During Debt Service	**$2,384,000**
After Debt Service	
Total Fixed Annual Cost	$62,000
Total Variable Annual Cost	$100,000
Total Annual Cost After Debt Service	**$162,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$4,257
Cost of Water ($ per k-gallons)	$13.06
Cost of Water ($ per barrel)	$0.55
After Debt Service	
Cost of Water ($ per AF)	$289
Cost of Water ($ per k-gallons)	$0.89
Cost of Water ($ per barrel)	$0.04

AL *6/13/2016*

Table A4.13
Industrial Reclamation Permian Basin Facility
Preliminary Opinion of Cost Summary
Alternative 3
Treat at Saltwater Disposal Site and Blend with
Odessa South Regional Wastewater Treatment Plant Effluent
Treat 0.5 MGD Average Flow; Transport 5 mile

Project Yield (bbl/day)	**12,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$1,469,000
Transmission Pipeline	$930,000
Storage Tanks	$39,000
Treatment Plant	$1,500,000
TOTAL COST OF FACILITIES	**$3,938,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$985,000
Environmental & Archaeology Studies and Mitigation	$163,000
Land Acquisition and Surveying	$405,000
Interest During Construction	$129,000
TOTAL COST OF PROJECT	**$5,620,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$164,000
FIXED COSTS (ANNUAL)	
Debt Service	$3,022,000
Fixed Operation and Maintenance	$66,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	---
Variable Operation and Maintenance	$98,000
Pumping Energy Costs	$11,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$3,088,000
Total Variable Annual Cost	$109,000
Total Annual Cost During Debt Service	**$3,197,000**
After Debt Service	
Total Fixed Annual Cost	$66,000
Total Variable Annual Cost	$109,000
Total Annual Cost After Debt Service	**$175,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$5,709
Cost of Water ($ per k-gallons)	$17.52
Cost of Water ($ per barrel)	$0.74
After Debt Service	
Cost of Water ($ per AF)	$313
Cost of Water ($ per k-gallons)	$0.96
Cost of Water ($ per barrel)	$0.04

AL *6/13/2016*

Table A4.14 *Industrial Reclamation Permian Basin Facility* *Preliminary Opinion of Cost Summary* *Alternative 3* *Treat at Saltwater Disposal Site and Blend with* *Odessa South Regional Wastewater Treatment Plant Effluent* *Treat 1.0 MGD Average Flow; Transport 1 mile*	
Project Yield (bbl/day)	**24,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$1,470,000
Transmission Pipeline	$239,000
Storage Tanks	$52,000
Treatment Plant	$2,850,000
TOTAL COST OF FACILITIES	**$4,611,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$1,153,000
Environmental & Archaeology Studies and Mitigation	$63,000
Land Acquisition and Surveying	$115,000
Interest During Construction	$104,000
TOTAL COST OF PROJECT	**$6,046,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$297,000
FIXED COSTS (ANNUAL)	
Debt Service	$3,251,000
Fixed Operation and Maintenance	$119,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	---
Variable Operation and Maintenance	$178,000
Pumping Energy Costs	$11,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$3,370,000
Total Variable Annual Cost	$189,000
Total Annual Cost During Debt Service	**$3,559,000**
After Debt Service	
Total Fixed Annual Cost	$119,000
Total Variable Annual Cost	$189,000
Total Annual Cost After Debt Service	**$308,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$3,178
Cost of Water ($ per k-gallons)	$9.75
Cost of Water ($ per barrel)	$0.41
After Debt Service	
Cost of Water ($ per AF)	$275
Cost of Water ($ per k-gallons)	$0.84
Cost of Water ($ per barrel)	$0.04
AL	*6/14/2016*

Table A4.15
Industrial Reclamation Permian Basin Facility
Preliminary Opinion of Cost Summary
Alternative 3
Treat at Saltwater Disposal Site and Blend with
Odessa South Regional Wastewater Treatment Plant Effluent
Treat 1.0 MGD Average Flow; Transport 5 miles

Project Yield (bbl/day)	**24,000**
Item	***Opinion of Costs***
Influent and Effluent Pump Stations	$1,542,000
Transmission Pipeline	$1,193,000
Storage Tanks	$52,000
Treatment Plant	$2,850,000
TOTAL COST OF FACILITIES	**$5,637,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies	$1,409,000
Environmental & Archaeology Studies and Mitigation	$163,000
Land Acquisition and Surveying	$405,000
Interest During Construction	$179,000
TOTAL COST OF PROJECT	**$7,793,000**
ANNUAL COSTS	
Annual Operations and Maintenance Costs	$308,000
FIXED COSTS (ANNUAL)	
Debt Service	$4,191,000
Fixed Operation and Maintenance	$123,000
VARIABLE COSTS (ANNUAL AT FULL UTILIZATION)	
Trucking Backwash Reject	---
Variable Operation and Maintenance	$185,000
Pumping Energy Costs	$17,000
TOTAL ANNUAL COST AT FULL UTILIZATION	
During Debt Service	
Total Fixed Annual Cost	$4,314,000
Total Variable Annual Cost	$202,000
Total Annual Cost During Debt Service	**$4,516,000**
After Debt Service	
Total Fixed Annual Cost	$123,000
Total Variable Annual Cost	$202,000
Total Annual Cost After Debt Service	**$325,000**
UNIT COSTS	
During Debt Service	
Cost of Water ($ per AF)	$4,032.14
Cost of Water ($ per k-gallons)	$12.37
Cost of Water ($ per barrel)	$0.52
After Debt Service	
Cost of Water ($ per AF)	$290
Cost of Water ($ per k-gallons)	$0.89
Cost of Water ($ per barrel)	$0.04

AL *6/13/2016*

Appendix 5

Texas Parks & Wildlife Department Annotated County Lists of Rare Species for Ector and Midland Counties

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Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

ECTOR COUNTY

Species		Federal Status	State Status
BIRDS			
American Peregrine Falcon	*Falco peregrinus anatum*	DL	T
year-round residents and local breeder in West Texas, nests in tall cliff eyries; also, migrant across state from more northern breeding areas in US and Canada, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.			
Artic Peregrine Falcon	*Falco peregrinus tundrius*	DL	
migrant throughout state from subspecies' far northern breeding range, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.			
Baird's Sparrow	*Ammodramus bairdii*		
shortgrass prairie with scattered low bushes and matted vegetation; mostly migratory in western half of State, though winters in Mexico and just across Rio Grande into Texas from Brewster through Hudspeth counties			
Bald Eagle	*Haliaeetus leucocephalus*	DL	T
found primarily near rivers and large lakes; nests in tall trees or on cliffs near water; communally roosts, especially in winter; hunts live prey; scavenges, and pirates food from other birds.			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Ector County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

ECTOR COUNTY

Species		Federal Status	State Status
BIRDS			
Ferruginous Hawk	*Buteo regalis*		
open country, primarily prairies, plains, and badlands; nests in tall trees along streams or on steep slopes, cliff ledges, river-cut banks, hillsides, power line towers; year-round resident in northwestern high plains, wintering elsewhere throughout western two-thirds of Texas.			
Mountain Plover	*Charadrius montanus*		
breeding: nests on high plains or shortgrass prairie, on ground in shallow depression; nonbreeding: shortgrass plains and bare, dirt (plowed) fields; primarily insectivorous.			
Peregrine Falcon	*Falco peregrinus*	DL	T
both subspecies migrate across the state from more northern breeding areas in US and Canada to winter along coast and farther south; subspecies (F.p. anatum) is also a resident breeder in west Texas; the two subspecies listing statuses differ, F.p. tundrius is no longer listed in Texas; but because the subspecies are not easily distinguishable at a distance, reference is generally made only to the species level; see subspecies for habitat.			
Prairie Falcon	*Falco mexicanus*		
open, mountainous areas, plains, and prairie; nests on cliffs			
Snowy Plover	*Charadrius alexandrinus*		
formerly an uncommon breeder in the Panhandle; potential migrant; winter along coast			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Ector County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

ECTOR COUNTY

Species		Federal Status	State Status
BIRDS			
Sprague's Pipit	*Anthus spragueii*		
only in Texas during migration and winter, mid-September to early in April; short to medium distance, diurnal migrant; strongly tied to native upland prairie, can be locally common in coastal grasslands, uncommon to rare further west; sensitive to patch size and avoids edges.			
Western Burrowing Owl	*Athene cunicularia hypugaea*		
open grasslands, especially prairie, plains, and savanna, sometimes in open areas such as vacant lots near human habitation or airports; nests and roosts in abandoned burrows.			
Western Snowy Plover	*Charadrius alexandrinus nivosus*		
uncommon breeder in the Panhandle; potential migrant; winter along coast.			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Ector County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

ECTOR COUNTY

Species		Federal Status	State Status
MAMMALS			
Black-footed ferret	*Mustela nigripes*	LE	
extirpated; inhabited prairie dog towns in the general area			
Black-tailed prairie dog	*Cynomys ludovicianus*		
dry, flat, short grasslands with low, relatively sparse vegetation, including areas overgrazed by cattle; live in large family groups			
Gray wolf	*Canis lupus*	LE	E
extirpated; formlery known throughout the western two-thirds of the state in forests, brushlands, or grasslands			
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*		
roosts in caves, abandoned mine tunnels, and occasionally old buildings; hibernates in groups during winter; in summer months, males and females separate into solitary roosts and maternity colonies, respectively; single offspring born May-June; opportunistic insectivore			
Swift fox	*Vulpes velox*		
restricted to current and historic shortgrass prairie; western and northern portions of Panhandle			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Ector County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

ECTOR COUNTY

Species		Federal Status	State Status
REPTILES			
Spot-tailed earless lizard	*Holbrookia lacerata*		
central and southern Texas and adjacent Mexico; moderately open prairie-brushland; fairly flat areas free of vegetation or other obstructions, including disturbed areas; eats small invertebrates; eggs laid underground			
Texas horned lizard	*Phrynosoma cornutum*		T
open, arid and semi-arid regions with sparse vegetation, including grass, cactus, scattered brush or scrubby trees; soil may very in texture from sandy to rocky; burrows into soil, enters rodent burrows, or hides under rock when inactive; breeds March-September			

Species		Federal Status	State Status
PLANTS			
Cory's ephedra	*Ephedra coryi*		
GLOBAL RANK: G3; Dune areas and dry grasslands in the southern Plains County; Perennial; Flowering April-Sept; Fruiting May-Sept			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Ector County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

MIDLAND COUNTY

Species		Federal Status	State Status
BIRDS			
American Peregrine Falcon	*Falco peregrinus anatum*	DL	T
year-round residents and local breeder in West Texas, nests in tall cliff eyries; also, migrant across state from more northern breeding areas in US and Canada, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.			
Artic Peregrine Falcon	*Falco peregrinus tundrius*	DL	
migrant throughout state from subspecies' far northern breeding range, winters along coast and farther south; occupies wide range of habitats during migration, including urban, concentrations along coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.			
Baird's Sparrow	*Ammodramus bairdii*		
shortgrass prairie with scattered low bushes and matted vegetation; mostly migratory in western half of State, though winters in Mexico and just across Rio Grande into Texas from Brewster through Hudspeth counties			
Bald Eagle	*Haliaeetus leucocephalus*	DL	T
found primarily near rivers and large lakes; nests in tall trees or on cliffs near water; communally roosts, especially in winter; hunts live prey; scavenges, and pirates food from other birds.			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Midland County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

MIDLAND COUNTY

Species		Federal Status	State Status
BIRDS			
Ferruginous Hawk	*Buteo regalis*		
open country, primarily prairies, plains, and badlands; nests in tall trees along streams or on steep slopes, cliff ledges, river-cut banks, hillsides, power line towers; year-round resident in northwestern high plains, wintering elsewhere throught western two-thirds of Texas.			
Mountain Plover	*Charadrius montanus*		
breeding: nests on high plains or shortgrass prairie, on ground in shallow depression; nonbreeding: shortgrass plains and bare, dirt (plowed) fields; primarily insectivorous.			
Peregrine Falcon	*Falco peregrinus*	DL	T
both subspecies migrate across the state from more northern breeding areas in US and Canada to winter along coast and farther south; subspecies (F.p. anatum) is also a resident breeder in west Texas; the two subspecies listing statuses differe, F.p. tundrius is no longer listed in Texas; but because the subspecies are not easily distinguishable at a distance, reference is generally made only to the species level; see subspecies for habitat.			
Prairie Falcon	*Falco mexicanus*		
open, mountainous areas, plains, and prairie; nests on cliffs			
Snowy Plover	*Charadrius alexandrinus*		
formerly an uncommon breeder in the Panhandle; potential migrant; winter along coast			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Midland County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

MIDLAND COUNTY

Species		Federal Status	State Status
BIRDS			
Sprague's Pipit	*Anthus spragueii*		
only in Texas during migration and winter, mid-September to early in April; short to medium distance, diurnal migrant; strongly tied to native upland prairie, can be locally common in coastal grasslands, uncommon to rare further west; sensitive to patch size and avoids edges.			
Western Burrowing Owl	*Athene cunicularia hypugaea*		
open grasslands, especially prairie, plains, and savanna, sometimes in open areas such as vacant lots near human habitation or airports; nests and roosts in abandoned burrows.			
Western Snowy Plover	*Charadrius alexandrinus nivosus*		
uncommon breeder in the Panhandle; potential migrant; winter along coast.			
Whooping Crane	*Grus americana*	LE	E
potential migrant via plains throughout most of state to coast; winters in coastal marshes of Aransas, Calhoun, and Refugio counties			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Midland County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

MIDLAND COUNTY

Species		Federal Status	State Status
MAMMALS			
Black-footed ferret	*Mustela nigripes*	LE	
extirpated; inhabited prairie dog towns in the general area			
Black-tailed prairie dog	*Cynomys ludovicianus*		
dry, flat, short grasslands with low, relatively sparse vegetation, including areas overgrazed by cattle; live in large family groups			
Gray wolf	*Canis lupus*	LE	E
extirpated; formlery known throughout the western two-thirds of the state in forests, brushlands, or grasslands			
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*		
roosts in caves, abandoned mine tunnels, and occasionally old buildings; hibernates in groups during winter; in summer months, males and females separate into solitary roosts and maternity colonies, respectively; single offspring born May-June; opportunistic insectivore			
Swift fox	*Vulpes velox*		
restricted to current and historic shortgrass prairie; western and northern portions of Panhandle roosts in caves, abandoned mine tunnels, and occasionally old buildings; hibernates in groups during			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Midland County. Last revised 5/16/2016.

Table A5.1 State and Federally Listed Threatened and Endangered Species
Ector and Midland Counties

MIDLAND COUNTY

Species		Federal Status	State Status
REPTILES			
Spot-tailed earless lizard	*Holbrookia lacerata*		
central and southern Texas and adjacent Mexico; moderately open prairie-brushland; fairly flat areas free of vegetation or other obstructions, including disturbed areas; eats small invertebrates; eggs laid underground			
Texas horned lizard	*Phrynosoma cornutum*		T
open, arid and semi-arid regions with sparse vegetation, including grass, cactus, scattered brush or scrubby trees; soil may very in texture from sandy to rocky; burrows into soil, enters rodent burrows, or hides under rock when inactive; breeds March-September			

Source: Texas Parks and Wildlife Department, Wildlife Division, Diversity and Habitat Assessment Programs.
TPWD County Lists of Protected Species and Species of Greatest Conservation Need. Midland County. Last revised 5/16/2016.

Appendix 6

Public Participation

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Appendix 6
Public Participation

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Appendix 6.1

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ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

MEETING NOTES

DATE:	April 30, 2014
TIME:	10:00
APAI PROJECT NO.:	2014-031-00
LOCATION:	Atmos Energy, Midland TX
ROOM / CONF. CALL #	Fischer Community Room

MEETING TITLE:	Stakeholder Meeting		
MEETING CALLED BY:	Gordon Pederson	MEETING PURPOSE:	Introduction of Project to Potential Stakeholders
FACILITATOR:	Gordon Pederson	RECORDER:	James Naylor
ATTENDEES:	See attached Meeting Sign In sheet.		

NOTES

Sign-in Sheet:

I & II. Welcome & Introductions – Charles Harris (Gulf Coast Waste Disposal Authority, GCWDA)

- Introduction by Harris.

III. Meeting Purpose – Gordon Pederson (Gulf Coast Waste Disposal Authority, GCWDA)

- Gordon Pederson provided an introduction of GCWDA.
- GCWDA is a political subdivision of the State of Texas, similar to other river and water authorities. GCWDA started 2 years before the Clean Water Act in the efforts to clean wastes being discharged to the Houston Ship Channel. Part of the CWA stated that industry could not discharge to POTW without pretreatment. GCWDA received an exemption through Congress that allows them to treat industrial waste directly as a POTW. In 1995, State of Texas asked GCWDA to look at providing services throughout Texas. GCWDA started treating in Odessa in 1997.
- March 26, 2014 APAI identified a Bureau of Reclamation grant program and discussed the grant application with GCWDA. Odessa Development Corporation provided seed money for the grant application. The grant is for $150,000 but it is a matching grant and requires stakeholders to provide at least an equivalent amount. The purpose of this meeting is to introduce the grant, the project, and the need for stakeholders to assist in funding the project.

IV. Presentation of Proposed Project – Peggy Glass (Alan Plummer Associates, Inc, APAI)

- Glass presented a PowerPoint presentation. A copy of the presentation is attached.
- The scope in the grant application will be written around a program developed for Ector and Midland Counties. The actual project area will be dictated by the actual stakeholders' geographical region.

Questions and Answers Session

Q: Who is determining the water quality?

A: Pederson – GCWDA will not be making decisions on the study. They will provide the conduit for management and money. APAI will develop the study. The stakeholders will provide input and guidance on what the study addresses and their quality/quantity requirements. Odessa Development Corporation made it possible to do the grant, but not the entire study. If no financial commitments are made by stakeholders by June 1st, there will be no study.
Tucker – Treatment will be dependent on water source qualities and quality goals for the end use.

Q: Would you be looking at different treatment techniques to cover slickwater frac, gel frac, etc.? There would be a big range of water qualities that would be needed depending on how they do their frac.

A. Glass and Tucker – We are thinking that there will be different treatment trains or take points to satisfy the varying quality needs. There may be satellite plants needed with different trains.

Pederson – There are other industries that may need water as well, so there may be opportunities for them as well.

Q: Have the large oil producers/suppliers (i.e., Chevron) been contacted?

A. Yes, 90 invitations were sent out; however, several had scheduling conflicts.

Statement – Pederson – This type of study has not been done in Texas. The State of Texas has a water plan. If this program/project can be accepted by the Regional Water Planning Group, it may open up other possibilities for funding mechanisms (TWDB revolving fund, etc.).

Q: What kinds of financial interest are you looking for, private, public, etc.?

A. Both. Odessa Development Corporation put up money for the grant application. This will be a public study, so it will be publicly available; however, private financial support allows the stakeholders to provide input and guide the study. The public will benefit from this study and the stakeholders will drive the direction of the study.

Q: Funding from private interest does not preclude non-funding entities from gaining benefits?

A. It will not be beneficial outside of the geographic regional. Peggy is hoping that by working as a group more can be done to provide resources than just one corporation.

Q: Who would own and operate the treatment facilities, pipeline, and storage?

A: Pederson – That will depend on the stakeholders. Peggy – Mostly dependent on the study, but the initial thoughts would be that GCWDA would own and operate the treatment facility(s).

Q: What happens with chain of custody?

A: GCDWA takes custody of the waste stream as soon as it enters their system.

Several attendees commented that boron is a contaminant of concern for reuse.

V. Next Steps – Gordon Pederson (GCWDA)

- Pederson – We would like to get $20,000 from each stakeholder.
- The number of stakeholders could increase increase if the counties are expanded. Reeves, Glasscock, and Upton, etc. The deadline for stakeholders to signup is May 22, 2014.
- Time frame is of concern to Pioneer as they have immediate needs.

ACTION ITEMS	WHO	WHEN
Submit Bureau of Reclamation grant application	Peggy Glass – APAI	May 2, 2014
Prepare meeting notes for internal review	James Naylor – APAI	May 2, 2014
Send out meeting notes	James Naylor – APAI	May 7, 2014
Meet with additional potential stakeholders	Charles Harris	
Stakeholder signup and commitment	Stakeholders	May 22, 2014

AGENDA ITEMS FOR NEXT MEETING
To be determined

ADDITIONAL INFORMATION	
NEXT MEETING DATE:	To be determined

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FEASIBILITY STUDY OF INDUSTRIAL WATER MANAGEMENT AND RECLAMATION FOR PERMIAN BASIN

STAKEHOLDER MEETING

AGENDA
April 30, 2014

I WELCOME—CHARLES HARRIS

II. INTRODUCTIONS—GORDON PEDERSON

II. MEETING PURPOSE—GORDON PEDERSON

III. PRESENTATION OF PROPOSED PROJECT—PEGGY GLASS

- A. Need for Regional Approach
- B. Technical Studies Proposed
- C. Funding
- D. Schedule

IV. ORGANIZATION AND FUNCTION OF STAKEHOLDER COMMITTEE—GORDON PEDERSON

V. NEXT STEPS-GORDON PEDERSON

INDUSTRIAL WASTE WATER STUDY
APRIL 30, 2014

NAME	TITLE	COMPANY	ADDRESS	PHONE	EMAIL
MIKE ROBINSON	ENGINEER	ODESSA ECTOR POWER PARTNERS	2200 EAST I-20 ODESSA, TX	432-620-5752	[illegible]
Bud Cagle	PLANT MGR	REXtac	2501 S. Grandview ODESSA, TX	432-638-4415	Budc@rextac...
KYLE KRUEGER	ENGINEER	CRMWD	400 E 24TH ST BIG SPRING TX	432-267-6341	kkrueger@crmwd...
Andy Adams		Layne	Midland	817676 8227	Andy.adams@layne...
Darrell Peckham	Hydrogeologist	Water Quest	700 N. GRANT, ODESSA	432 580 5722	dpeckham@waterques...
JOHNNY LASITER	SITE MGR	FHR	2495 S. GRANDVIEW AVE	432-296-1001	[illegible]
THOMAS G. KERR	DIR. UTIL.	CITY OF ODESSA	P.O. Box 4398 Odessa 79760	432-335-4631	tkerr@odessa-tx.g...
Mike Eaton	Proj coord	TreyTrucks/Fluido	PO Box 366 Crane Tx 79763	432-557-2985	meaton1956@Yahoo.c...
Curtis Flug	Super	Pioneer	Hwy 80	432-212-2573	curtis.flug@pxd...
RUSTY BRANCH	VP	Collier Consulting	4009 ALTAVA, FT. WORTH, TX 76133	817-915-6174	rusty@collierconsulting...
ALAN TUCKER	President	APAI	1320 S. University #30 Ft. Worth TX 76107	817-806-1700	ATucker@APAIENV.com
Mark Malony	Venture Support	Shell E&P	200 N. Dairy Ashford, Houston 77079	281-506-1607	Mark.e.malony@shell.com
MARK HESSEL	LOGISTICS	SHELL E&P	2010 RANKIN HWY, MIDLAND, TX 79701	432-230-2418	mark.hessel@shell.com
JAMES NAYLOR	ENGINEER	ALAN PLUMMER ASSOCIATES, INC	1320 S UNIVERSITY DR 300 FORT WORTH, TX	817806 1700	JNAYLOR@APAIENV...
ALAN DAVIS	ENGINEER	ALAN PLUMMER	"	"	adavis@apaienv.com
Bill Dykes	VP Bus Dev	RL Group			bdykes@rlenc.us
DEAYNNE AND	VP Bus Dev	RL Group			dand@rleinc.us
Greg Mabee	CEO	Wasser	203 W. Wall, Suite 304, Midland 79707	432-693-6235	gmabee28@gmail.co...
David Fitz	VP	Wasser			

INDUSTRIAL WASTE WATER STUDY
APRIL 30, 2014

NAME	TITLE	COMPANY	ADDRESS	PHONE	EMAIL
John Cherry	OP manager	Wasser			
Joel Roberts	Attorney	city of Odessa			
Virginia Belew	Regional Services Dir	PBRPC			Virginia.Belew@PBRPC

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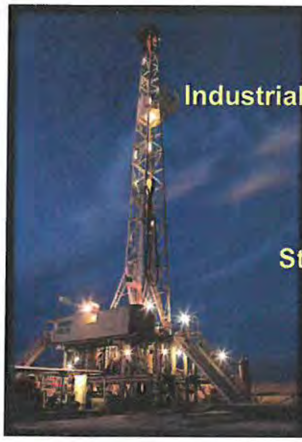

Feasibility Study Industrial Water Management and Reclamation

Permian Basin

Stakeholders Meeting
Project Description

April 30, 2014

Need for Regional Approach

- Water Shortage
- Wastewater Disposal Challenges
- Availability of Waters of Varying Quality

Project Focus

- Ector and Midland Counties
- Oil and Gas Exploration and Production
- Industrial Water Supply
- Power Plant Supply

Benefits of Regional Approach

- Higher quality waters preserved for potable use.
- Water supply based on reclamation more drought-proof.
- Improved ability to supplement with brackish groundwater.
- Centralized treatment may provide economies of scale.
- Movement of water by other than trucks will results in increase safety and decreased maintenance costs for roads.

Technical Study

- Water Resources (current, 5, 10 and 20 years)
  - Produced water
  - Flowback water
  - Brackish groundwater
  - Wastewater treatment effluent
  - Water recovered from disposal wells
  - Rig washdown water

Technical Study

- Water Needs (current, 5, 10 and 20 years)
  - Total
  - Oil and gas exploration and development
  - Power plants
  - Other industrial uses
- Water Needs Not Met by Available Sources

Technical Study
Reuse Treatment Alternatives
- Cost
- Current Availability and Proven Effectiveness
- Time Required for Implementation
- General Feasibility

Technical Study
Reuse Transportation Alternatives
- Construction Requirements
- Cost
- Ownership
- Time Required for Implementation

Technical Study
Reuse Storage Alternatives
- Construction Requirements
- Cost
- Location

Technical Study
Legal and Institutional Requirements
- Regulatory
  - TCEQ wastewater treatment or discharge, air, hazardous waste, solid waste, water rights
  - Texas Railroad Commission
  - Texas Parks and Wildlife Department
  - U.S. Fish and Wildlife Service
  - U.S. Environmental Protection Agency

Technical Study
Legal and Institutional Requirements
  - Texas Historical Commission
  - Region F Water Plan
  - Cities
  - Counties
  - Special Districts
- Contractual or Interagency Agreements

Technical Study
Alternative Regional Systems: Identify Then Evaluate and Rank
- Cost
- Adequacy of Water Provided
- Time Required for Implementation
- Availability of Proven Technology
- Residual Wastes
- Regulatory Requirements
- Other Benefits

Technical Study

Costs and Benefits Based on Reclamation Compared to the Alternatives

- Alternatives Identification
- Cost
- Benefits

Technical Study

Recommended Alternatives

- Components implemented in near-term
- Components needing more investigation
- Components potentially eligible for Title XVI funding from Bureau of Reclamation

Technical Study

Title XVI Project

- Environmental Considerations
- Justification
  - Meeting water needs
  - Cost-effectiveness
  - Timeliness
  - Benefits to non-industrial users
- Economic Analysis

Technical Study

Potential Research Needs

- Groundwater Quantity or Quality
- Flowback or Produced Water Quantity or Quality
- Treatment Technology
- Waste Disposal Technology

Funding

Bureau of Reclamation Grant	$ 150,000
GCWDA In-kind Contribution	$ 41,721
Local Contribution	$ 242,100
TOTAL	**$ 433,821**

Schedule

Grant application submittal	May 6, 2014
Notification of grant award	July 2014
Grant execution	October 2014
Near-term alternatives identification	July 2015
Final draft report submittal to Bureau of Reclamation	Nov 2015

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FEASIBILITY STUDY
INDUSTRIAL WATER MANAGEMENT AND RECLAMATION
PERMIAN BASIN

Objective: Explore the feasibility of a regional system using non-potable water sources (wastewaters and brackish groundwaters) to meet industrial water needs, including oil and gas exploration and production, by establishing centralized collection, treatment, and distribution systems.

Scope:

- Evaluate feasibility for Ector and Midland Counties;
- Consider 20-year projection;
- Identify quantity and quality requirements of water needs;
- Identify quantity and quality of available water sources;
- Identify alternatives for treatment, transport, and storage; and
- Estimate cost and feasibility of specific alternatives.

Facilitating Agency: Gulf Coast Waste Disposal Authority (GCWDA)

Contact:
Gordon Pederson
gpeders@gcwda.com
281.488.4115

Funding:

Bureau of Reclamation	$150,000*
Gulf Coast Waste Disposal Authority	$ 41,700**
Local Participants	$242,100
Total	**$433,800**

*Grant Application
**In-kind Contribution

Study Structure:
Managed by Gulf Coast Waste Disposal Authority
Participation by Stakeholders
Technical Support by Consultants (Alan Plummer Associates, Inc., Tischler/Kocurek, LBG Guyton)

Schedule:

Grant Submitted	May 6, 2014
Notification of Grant Awards	July 2014
Grant Execution	October 2014
Initial Recommendations	July 2015
Final Draft Report Submitted to Bureau of Reclamation	November 2015

DRAFT LETTER OF COMMITMENT

[Date]

Mr. Gordon Pederson
Manager, Facility Services
Gulf Coast Waste Disposal Authority
910 Bay Area Boulevard
Houston, Texas 77058

Re: WaterSMART Feasibility Study Grant Application — Gulf Coast Waste Disposal Authority

Dear Mr. Pederson:

The [organization name] supports the Gulf Coast Waste Disposal Authority application for a WaterSMART Feasibility Study Grant to evaluate opportunities to manage wastewater and provide reclaimed water for industrial uses, included oil and gas production, in areas of the Permian Basin, Texas.

The Permian Basin is a major source of oil and gas for the United States. The development and production of these resources require significant volumes of water. Providing this water is a challenge in this semi-arid region of West Texas. [Organization name] supports this effort by Gulf Coast Waste Disposal Authority to investigate ways to meet these water needs without impacting potable water supplies.

[Organization name] offers to contribute [$______] to assist in funding this important study.

Sincerely,

[Name]
[Title]

Appendix 6.2

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ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

MEETING NOTES

DATE:	May 23, 2014
TIME:	10:00
APAI PROJECT NO.:	2014-031-00
LOCATION:	Atmos Energy, Midland TX
ROOM / CONF. CALL #	Fischer Community Room

MEETING TITLE:	Stakeholder Meeting		
MEETING CALLED BY:	Gordon Pederson	MEETING PURPOSE:	Introduction of Project to Potential Stakeholders
FACILITATOR:	Gordon Pederson	RECORDER:	James Naylor
ATTENDEES:	See attached Meeting Sign In sheet.		

NOTES

Sign-in Sheet:

Welcome & Introductions – Charles Harris (Gulf Coast Waste Disposal Authority, GCWDA)

- Welcome and Introductions by Pederson.

Meeting Purpose – Gordon Pederson (Gulf Coast Waste Disposal Authority, GCWDA)

- Gordon Pederson provided an introduction of GCWDA.
- GCWDA is a political subdivision of the State of Texas, similar to other river and water authorities. GCWDA started 2 years before the Clean Water Act in the efforts to clean wastes being discharged to the Houston Ship Channel. Part of the CWA stated that industry could not discharge to POTW without pretreatment. GCWDA received an exemption through Congress that allows them to treat industrial waste directly as a POTW. In 1995, State of Texas asked GCWDA to look at providing services throughout Texas. GCWDA started treating in Odessa in 1997.
- March 26, 2014 APAI identified a Bureau of Reclamation grant program and discussed the grant application with GCWDA. Odessa Development Corporation provided seed money for the grant application. The grant is for $150,000 but it is a matching grant and requires stakeholders to provide at least an equivalent amount. The purpose of this meeting is to introduce the grant, the project, and the need for stakeholders to assist in funding the project.

Presentation of Proposed Project – Peggy Glass (Alan Plummer Associates, Inc, APAI)

- Glass presented a PowerPoint presentation. A copy of the presentation is attached.
- The scope in the grant application will be written around a program developed for Ector and Midland Counties. The actual project area will be dictated by the actual stakeholders' geographical region.

Questions and Answers Session

Pederson – The previous meeting on April 30, 2014 brought up a concern on the speed of the project if the project funding mechanism was by the Bureau of Reclamation grant. If they project was not funded by this grant, the scope would be modified to remove/reduce the components required for the Bureau or Reclamation.

Q: What else is required by the stakeholders outside of financial commitments?

A: Pederson – The financial commitments are needed by the end of the month. Data from each stakeholder would also be required. All data would be handled by APAI and would remain confidential. All other commitments would be determined by the stakeholders through the project.

V. Next Steps – Gordon Pederson (GCWDA)

- Financial commitments from stakeholders.

ACTION ITEMS	WHO	WHEN
Submit Bureau of Reclamation grant application	Peggy Glass – APAI	May 2, 2014 (completed)
Send out meeting notes	James Naylor – APAI	May 30, 2014
Stakeholder signup and commitment	Stakeholders	May 22, 2014

AGENDA ITEMS FOR NEXT MEETING
None.

ADDITIONAL INFORMATION	
NEXT MEETING DATE:	To be determined

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

MEETING AGENDA

DATE:	May 23, 2014
TIME:	10:00
APAI PROJECT NO.:	2014-031-00
LOCATION:	Atmos Energy, Midland, TX
ROOM / CONF. CALL #	Fischer Community Room

MEETING TITLE:	Feasibility Study of Industrial Water Management and Reclamation for Permian Basin Stakeholder Meeting and Project Description		
MEETING CALLED BY:	Gordon Pederson	MEETING PURPOSE:	Project Introduction
FACILITATOR:	Gordon Pederson	RECORDER:	James Naylor
INVITEES:			
PLEASE READ:	N/A		
PLEASE BRING:	N/A		

AGENDA ITEM	**WHO**
WELCOME	Charles Harris
INTRODUCTIONS	Gordon Pederson
MEETING PURPOSE	Gordon Pederson
PRESENTATION OF PROPOSED PROJECT	Peggy Glass
ORGANIZATION AND FUNCTION OF STAKEHOLDER COMMITTEE	Gordon Pederson
PARTICIPANT INTEREST	Gordon Pederson
REVIEW ACTION ITEMS (IF ANY)	
CONFIRM NEXT MEETING DATE	

ADDITIONAL INFORMATION	
NEXT MEETING DATE	

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

MEETING SIGN IN

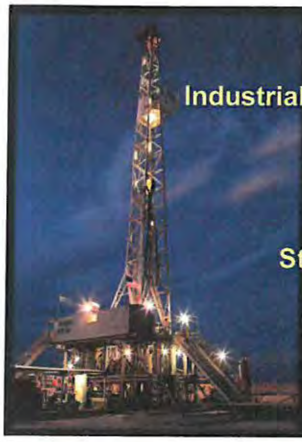
DATE:	May 23, 2014
TIME:	10:00 am
APAI PROJECT NO.:	2014-031-00
LOCATION:	Atmos Energy, Midland, TX
ROOM / CONF. CALL #:	Fischer Community Room

CLIENT: Gulf Coast Waste Disposal Authority

PROJECT NAME: Feasibility Study of Industrial Water Management and Reclamation for Permian Basin

MEETING TITLE: Stakeholder Meeting and Project Description

NAME	COMPANY	TITLE	ADDRESS	PHONE NUMBER	E-MAIL ADDRESS
James Narcon	Alan Plummer Associates, Inc.	Project Manager	1320 S. University Dr. 300 Ft. Worth TX	817 806 1700	JNarcon@apaienv.com
Peggy Glass	Alan Plummer Assoc. Inc	Principal	6300 La Calma, Suite 400 Austin TX 78752	512-452-5905	pglass@apaienv.com
Alan Davis	Alan Plummer	Project Manager			adavis@apaienv.com
James Beach	LBG-Guyton	Principal	1101 S. Capital of TX 78746	512 327 9640	jbeach@lbg-guyton.com
Stephanie Cavallo	WCTCOG	Rural Recycling Coord.	3702 loop 322 Abilene, TX 79602	325-672-8544	scavallo@wctcog.org
Debrah Gann	ConocoPhillips	Environmental Coord.	3300 N. A Street Midland TX 79705	432-688-9172	debrah.s.gann@contractor.conocophillips.com
Heather Tash	Concho	Facilities Eng.	600 W. Illinois Midland, TX 79701	432-250-1232	htash@concho.com
Kyle Kruebel	CRMWD	Engineering Coordinator	400 E. 24th St Big Spring, TX 79720	432-267-6341	KKruebel@crmwd.org
Rusty Branch	Collier Consulting	VP	4009 Alaska Dr., Fort Worth TX 76133	817.915.6174	rusty@collierconsulting.com
Mike Robinson	Odessa-Ector Power Partners	Plant Engineer	2200 East I-20 Odessa, Texas 79765	432-620-5752	MRobinson@OdessaPower.com



Feasibility Study
Industrial Water Management and Reclamation

Permian Basin

Stakeholders Meeting
Project Description

May 23, 2014

Need for Regional Approach

- Water Shortage
- Wastewater Disposal Challenges
- Availability of Waters of Varying Quality

Project Focus

- Ector and Midland Counties
- Oil and Gas Exploration and Production
- Industrial Water Supply
- Power Plant Supply

Benefits of Regional Approach

- Higher quality waters preserved for potable use.
- Water supply based on reclamation more drought-proof.
- Improved ability to supplement with brackish groundwater.
- Centralized treatment may provide economies of scale.
- Movement of water by other than trucks will results in increase safety and decreased maintenance costs for roads.

Technical Study

- Water Resources (current, 5, 10 and 20 years)
  - Produced water
  - Flowback water
  - Brackish groundwater
  - Wastewater treatment effluent
  - Water recovered from disposal wells
  - Rig washdown water

Technical Study

- Water Needs (current, 5, 10 and 20 years)
  - Total
  - Oil and gas exploration and development
  - Power plants
  - Other industrial uses
- Water Needs Not Met by Available Sources

Technical Study

Reuse Treatment Alternatives

- Cost
- Current Availability and Proven Effectiveness
- Time Required for Implementation
- General Feasibility

Technical Study

Reuse Transportation Alternatives

- Construction Requirements
- Cost
- Ownership
- Time Required for Implementation

Technical Study

Reuse Storage Alternatives

- Construction Requirements
- Cost
- Location

Technical Study

Legal and Institutional Requirements

- Regulatory
  - TCEQ wastewater treatment or discharge, air, hazardous waste, solid waste, water rights
  - Texas Railroad Commission
  - Texas Parks and Wildlife Department
  - U.S. Fish and Wildlife Service
  - U.S. Environmental Protection Agency

Technical Study

Legal and Institutional Requirements

  - Texas Historical Commission
  - Region F Water Plan
  - Cities
  - Counties
  - Special Districts
- Contractual or Interagency Agreements

Technical Study

Alternative Regional Systems: Identify Then Evaluate and Rank

- Cost
- Adequacy of Water Provided
- Time Required for Implementation
- Availability of Proven Technology
- Residual Wastes
- Regulatory Requirements
- Other Benefits

Technical Study

Costs and Benefits Based on Reclamation Compared to the Alternatives

- Alternatives Identification
- Cost
- Benefits

Technical Study

Recommended Alternatives

- Components implemented in near-term
- Components needing more investigation
- Components potentially eligible for Title XVI funding from Bureau of Reclamation

Technical Study

Title XVI Project

- Environmental Considerations
- Justification
  - Meeting water needs
  - Cost-effectiveness
  - Timeliness
  - Benefits to non-industrial users
- Economic Analysis

Technical Study

Potential Research Needs

- Groundwater Quantity or Quality
- Flowback or Produced Water Quantity or Quality
- Treatment Technology
- Waste Disposal Technology

Funding

Bureau of Reclamation Grant	$ 150,000
GCWDA In-kind Contribution	$ 41,721
Local Contribution	$ 242,100
TOTAL	**$ 433,821**

Schedule

Grant application submittal	May 6, 2014
Notification of grant award	July 2014
Grant execution	October 2014
Near-term alternatives identification	July 2015
Final draft report submittal to Bureau of Reclamation	Nov 2015

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FEASIBILITY STUDY
INDUSTRIAL WATER MANAGEMENT AND RECLAMATION
PERMIAN BASIN

Objective: Explore the feasibility of a regional system using non-potable water sources (wastewaters and brackish groundwaters) to meet industrial water needs, including oil and gas exploration and production, by establishing centralized collection, treatment, and distribution systems.

Scope:

- Evaluate feasibility for Ector and Midland Counties;
- Consider 20-year projection;
- Identify quantity and quality requirements of water needs;
- Identify quantity and quality of available water sources;
- Identify alternatives for treatment, transport, and storage; and
- Estimate cost and feasibility of specific alternatives.

Facilitating Agency: Gulf Coast Waste Disposal Authority (GCWDA)

Contact: Gordon Pederson
gpeders@gcwda.com
281.488.4115

Funding:

	Bureau of Reclamation	$150,000*
	Gulf Coast Waste Disposal Authority	$ 41,700**
	Local Participants	$242,100
	Total	**$433,800**

*Grant Application
**In-kind Contribution

Study Structure: Managed by Gulf Coast Waste Disposal Authority
Participation by Stakeholders
Technical Support by Consultants (Alan Plummer Associates, Inc., Tischler/Kocurek, LBG Guyton)

Schedule:

	Grant Submitted	May 6, 2014
	Notification of Grant Awards	July 2014
	Grant Execution	October 2014
	Initial Recommendations	July 2015
	Final Draft Report Submitted to Bureau of Reclamation	November 2015

DRAFT LETTER OF COMMITMENT

[Date]

Mr. Gordon Pederson
Manager, Facility Services
Gulf Coast Waste Disposal Authority
910 Bay Area Boulevard
Houston, Texas 77058

Re: WaterSMART Feasibility Study Grant Application — Gulf Coast Waste Disposal Authority

Dear Mr. Pederson:

The [organization name] supports the Gulf Coast Waste Disposal Authority application for a WaterSMART Feasibility Study Grant to evaluate opportunities to manage wastewater and provide reclaimed water for industrial uses, included oil and gas production, in areas of the Permian Basin, Texas.

The Permian Basin is a major source of oil and gas for the United States. The development and production of these resources require significant volumes of water. Providing this water is a challenge in this semi-arid region of West Texas. [Organization name] supports this effort by Gulf Coast Waste Disposal Authority to investigate ways to meet these water needs without impacting potable water supplies.

[Organization name] offers to contribute [$______] to assist in funding this important study.

Sincerely,

[Name]
[Title]

Appendix 6.3

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ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

MEETING NOTES

DATE:	August 27, 2014
TIME:	1:00 pm
APAI PROJECT NO.:	2014-031-00
LOCATION:	Odessa, TX
ROOM / CONF. CALL #	GCA – South Plant

MEETING TITLE: FIRST ADVISORY COMMITTEE MEETING			
MEETING CALLED BY:	Gulf Coast Waste Disposal Authority	MEETING PURPOSE:	Project Kickoff Meeting
FACILITATOR:	Gordon Pederson	RECORDER:	Janet Sims
ATTENDEES:	See attached Meeting Sign In sheet.		

NOTES

I. Welcome & Introductions – Gordon Pederson (Gulf Coast Waste Disposal Authority, GCWDA)

II. Meeting Purpose – To present the objectives of the study, discuss potential sources of data, and identify key success factors (See attached Meeting Agenda.)

III. Peggy Glass (Alan Plummer Associates, Inc.) presented a PowerPoint presentation, which discussed the objectives and elements of the study. The planned schedule for meetings was presented. (A copy of the presentation is attached.)

IV. Questions related to the information needed for the study were presented to the group with the agenda. The meeting was opened for discussion of the questions. A summary of the information shared among the group is as follows:

a. Mr. Danzik discussed projects that his company is currently working on. The data obtained in his projects would be very beneficial for this study. He will ask participants of his projects if they would be willing to share the data with us.

b. Mr. Harris will continue to try to connect with representatives with the Permian Basin Petroleum Association and Concho to obtain data related to quality and quantity of water needed for E&P operations.

c. Mike Robinson with OEPP/Power Plant indicated that consent from upper level management would be required before he can provide quality and quantity of waters that the OEPP would need. The uses of waters at the OEPP/Power Plant are for cooling towers and boilers which would require demineralized water.

d. Gordon Pederson reminded the group that the treated water would be strictly for industrial uses.

e. Mr. Haner suggested that it will be challenging to identify costs associated with alternatives due to the different processes required to treat the varying qualities of the initial waters received and the quality for potential uses.
Peggy acknowledged the project will involve identifying potential customers, available waters for reuse, the quality of available waters, and then tailoring the treatment to meet the needs of the specific waters available and individual customer needs.

f. Mr. Harris suggested identifying potential new customers by contacting the Economic Development Council and Chamber of Commerce to identify companies that are interested in coming to the area.

g. Mr. Danzik indicated that centralized treatment can be cost-competitive with on-site/mobile recycling units if the transportation of water is by pipe.

h. Mr. Haner indicated that achieving a good balance of inflow and outflow from the treatment plant will depend on the number of participants – the more the better.

i. Mr. Robinson encouraged us to investigate the regulatory aspects of who is ultimately responsible for the waters after custody of the water is given to GCWDA. Mr. Robinson's environmental manager does not agree that ultimate liability of the water passes to the entity that accepts custody of the wastewater.

j. Mr. Danzik indicated that the trucking companies may have issues with a project that changes current trucking operations to piping systems.
Mr. Pederson stated that the project will more than likely involve a combination of piping and trucking.

k. With respect to question about the term of payback companies would be willing to accept, it was mentioned that Pioneer had entered a 10-year agreement. Therefore, the oil activities based on Pioneer's activities are expected to continue for quite some time.

ACTION ITEMS	WHO	WHEN
1. Identify contacts with the Permian Basin Petroleum Association and Concho who can identify the water quality and quantity requirements associated with E&P operations.	Choc Harris	
2. Investigate the regulations related to liability of wastewater as the custody of the water changes.	Janet Sims	
3. Identify way to conduct a video conference for future meetings	Choc Harris	
4. Contact Economic Development Board to determine how to identify new/potential industries in the area.	Choc Harris	

AGENDA ITEMS FOR NEXT MEETING

ADDITIONAL INFORMATION

NEXT MEETING DATE:

INDUSTRIAL WATER MANAGEMENT AND RECLAMATION FOR THE PERMIAN BASIN FEASIBILITY STUDY ADVISORY COMMITTEE MEETING AUGUST 27, 2014

I. **WELCOME**

II. **INTRODUCTION OF COMMITTEE MEMBERS**

III. **INTRODUCTION OF PROJECT PARTICIPANTS**

IV. **OVERVIEW OF PROJECT**

   A. **Scope**

   B. **Schedule**

V. **IDENTIFICATION OF DATA SOURCES**

   A. **Quality and quantity of flow-back and produced water**

   B. **Quality of water in salt water disposal wells**

VI. **IDENTIFICATION OF KEY SUCCESS FACTORS**

   A. **Treatment**

   - Are there different water uses for different treatment levels?
   - Can centralized treatment be cost-competitive with on-site recycling?
   - Is generation of flow back and produced water consistent enough to support a continuous treatment process or should intermittent, non-biological processes be used?
   - Is there an intangible value in transferring responsibility for wastewater management to GCWDA?

   B. **Supplementation with brackish groundwater**

   - How common is the use of brackish groundwater for fracking and flooding?
   - What are the impediments to the use of brackish groundwater?

   C. **Transport**

   - What are the impediments to transport of water for treatment or reuse by pipeline (in-ground or flat pipe)?
   - What would be the point at which pipelines become cost-competitive with trucking (density or distance?)?

D. Recovery from salt water disposal wells

- What are the technical issues with recovery?
- Are there unique treatment issues?
- What are the regulatory or ownership issues?

E. Financial

- Is there a value in having long-term bond financing of the facilities?
- Are exploration and production companies will to commit to a multiple-year contract?
- What term should financing be spread over to manage risk: 5, 10, or 20 years?

F. Overall

- What would the greatest benefits of centralized management be?
- What are the greatest hurdles to be overcome?

Industrial Waste Water Study Committee

August 27, 2014

Representing	Name	Email
City of Odessa Utilities	Thomas Kerr	tkerr@odessa-tx.gov
Odessa Economic Board	Jim Breaux	jbreaux@pemcoequip.com
Ector County	[signature]	armando.Rodriguez@ectorcounty.tx.gov
OEPP/ Power Plants	MIKE ROBINSON	MROBINSON@ODESSAPOWER.COM
Industry		
Water Treatment		
Oil/gas Concho		
Colorado Municipal Water Dist.	JOHN GRAY	JGRAY@CRMWD.ORG
SWD		
PBPA		
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EPS	[signature]	haner@engpsi.com
ODC		
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Alan Plummer Asso.	Alan Tucker	atucker@apaienv.com
Alan Plummer Asso.	Peggy Glass	pglass@apaienv.com
GCA	Gordon Pederson	gpeders@gcwda.com
GCA	Charles Harris	charris@gcwda.com
LBG-Guyton	BRAD CROSS	BCROSS@LBG-GUYTON.COM

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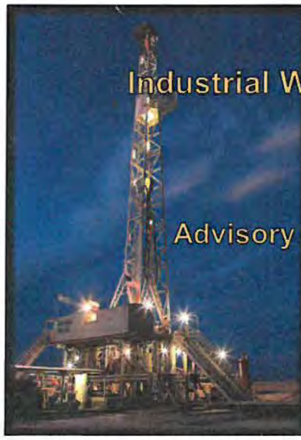


Feasibility Study Industrial Water Management and Reclamation Permian Basin

Advisory Committee Meeting

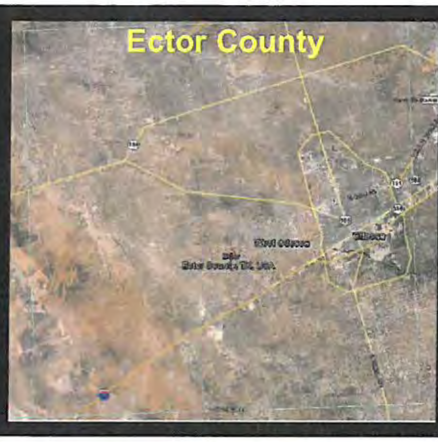
August 27, 2014

Need for Regional Approach

- Water Shortage
- Wastewater Disposal Challenges
- Availability of Waters of Varying Quality

Project Focus

- Ector County
- Oil and Gas Exploration and Production
- Industrial Water Supply
- Power Plant Supply

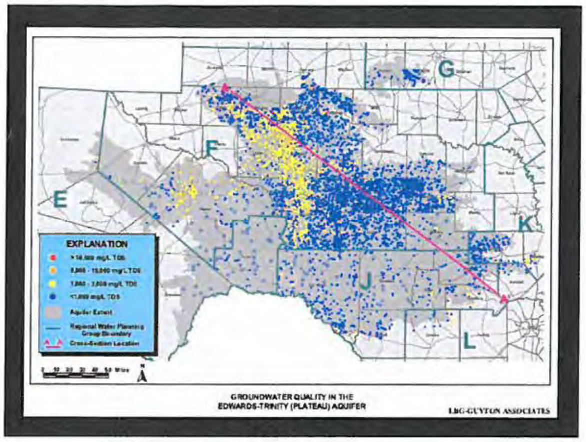


Benefits of Regional Approach

- Higher quality waters preserved for potable use.
- Water supply based on reclamation more drought-proof.
- Improved ability to supplement with brackish groundwater.
- Centralized treatment may provide economies of scale.
- Movement of water by other than trucks will results in increase safety and decreased maintenance costs for roads.

Technical Study

- Water Resources (current, 5, 10 and 20 years)
  - Produced water
  - Flowback water
  - Brackish groundwater
  - Wastewater treatment effluent
  - Water recovered from disposal wells
  - Rig washdown water



Technical Study

- Water Needs (current, 5, 10 and 20 years)
  - Total
  - Oil and gas exploration and development
  - Power plants
  - Other industrial uses
- Water Needs Not Met by Available Sources

Technical Study

Reuse Treatment Alternatives

- Cost
- Current Availability and Proven Effectiveness
- Time Required for Implementation
- General Feasibility

Technical Study

Reuse Transportation Alternatives

- Construction Requirements
- Cost
- Ownership
- Time Required for Implementation

Technical Study

Reuse Storage Alternatives

- Construction Requirements
- Cost
- Location

Technical Study

Legal and Institutional Requirements

- Regulatory
  - TCEQ wastewater treatment or discharge, air, hazardous waste, solid waste, water rights
  - Texas Railroad Commission
  - Texas Parks and Wildlife Department
  - U.S. Fish and Wildlife Service
  - U.S. Environmental Protection Agency

Technical Study

Legal and Institutional Requirements

- Texas Historical Commission
- Region F Water Plan
- Cities
- Counties
- Special Districts

- Contractual or Interagency Agreements

Technical Study

Alternative Regional Systems: Identify Then Evaluate and Rank

- Cost
- Adequacy of Water Provided
- Time Required for Implementation
- Availability of Proven Technology
- Residual Wastes
- Regulatory Requirements
- Other Benefits

Technical Study

Costs and Benefits Based on Reclamation Compared to the Alternatives

- Alternatives Identification
- Cost
- Benefits

Technical Study

Recommended Alternatives

- Components implemented in near-term
- Components needing more investigation
- Components potentially eligible for Title XVI funding from Bureau of Reclamation

Technical Study

Title XVI Project

- Environmental Considerations
- Justification
  - Meeting water needs
  - Cost-effectiveness
  - Timeliness
  - Benefits to non-industrial users
- Economic Analysis

Technical Study

Potential Research Needs

- Groundwater Quantity or Quality
- Flowback or Produced Water Quantity or Quality
- Treatment Technology
- Waste Disposal Technology

Appendix 6.4

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ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

MEETING NOTES

DATE:	February 11, 2015
TIME:	1:00
APAI PROJECT NO.:	1536-003-01
LOCATION:	TTHSC, Odessa, TX
ROOM / CONF. CALL #	

MEETING TITLE:	Stakeholder Meeting		
MEETING CALLED BY:	Gordon Pederson	MEETING PURPOSE:	Review Chapter 1 – 4
FACILITATOR:	Gordon Pederson	RECORDER:	Janet Sims
ATTENDEES:	See attached Meeting Sign In sheet.		

NOTES

Sign-in Sheet:

Welcome & Introductions – Gordon Pederson (Gulf Coast Waste Disposal Authority, GCWDA)

Meeting Purpose – Peggy Glass (Alan Plummer Associates, Inc, APAI) to present summary of information presented in Chapters 1 – 4 of the draft report.

Dr. Glass presented a PowerPoint presentation. A copy of the presentation is attached.

Dr. Glass asked if the information presented in the chapters was accurate.

- With respect to the number of barrels of water produced per barrels of oil produced (7 to 10 produced water/barrel of oil) does this seem reasonable? – No one disagreed. However, Heather Tash later said that some wells will produce a 1:1 ratio of water to oil. It all depends on the age of well and formation.
- John Grant [Colorado River Municipal Water District (CRMWD)] added that there is a written agreement for the subordination activities presented in the draft report. The agreement is between the Lower Colorado River Authority and CRMWD.
- Tim Reed (Concho) provided two comments.
  - The primary radioactive material in produced water is radium, not radon.
  - The number of gallons for produced water on page 3-7 is not correct.
- Choc Harris (GCA) said the reason the water used in Midland County for irrigation was high is that farmers in Glasscock County are using Midland County wells.

Next Steps – The information needed to complete the next phase of the project was presented.
The minimum quality objectives for hydraulic fracturing water have been difficult to obtain.
Jim Breaux suggested that a survey to be sent to oil and gas companies through the Permian Basin Petroleum Association. The surveys could be submitted anonymously.

ACTION ITEMS	**WHO**	**WHEN**

AGENDA ITEMS FOR NEXT MEETING

None.

ADDITIONAL INFORMATION

NEXT MEETING DATE: To be determined

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

DATE	February 11, 2015
TIME:	1:00 p.m.
APAI PROJECT NO.:	1536-003-01
LOCATION:	Texas Tech Health Science Center, Odessa

MEETING TITLE:	Industrial Water Management and Reclamation for the Permian Basin Feasibility Study, Advisory Committee Meeting		
MEETING CALLED BY:	GCWDA	**MEETING PURPOSE:**	Review Chapters 1 – 4
FACILITATOR:	Gordon Pederson	**RECORDER:**	Janet Sims

INVITEES:	DeLynn Ano	RL Environmental, Inc.	Thomas Kerr	City of Odessa Utilities
	James Beach	LBG-Guyton	Leonard Levine	GCWDA
	Jim Breaux	Odessa Dev. Corp.	Gordon Pederson	GCWDA
	Dennis Danzik	RDX	Mike Robinson	Odessa-Ector Power Partners
	Nick Fowler	Industry	Armando Rodriguez	Ector County
	John Grant	CRMWD	Ben Shepperd	Permian Basin Petroleum Association
	Gary Haner	EPS	Heather Tash	Concho
	Charles Harris	GCWDA	Mike Thornhill	Thornhill Group, Inc.
	Ian Kerr	Kerr Energy	Lial Tischler	Tischler/Kocurek

AGENDA

I. Welcome

II. Introduction

III. Project Objective

IV. Review and Discussion of Report

A. Study Area
B. Participants
C. Water Supply Sources
D. Water Availability
E. Water Surplus/Deficits

V. Data Needs for Next Phase

- Quality Objectives for Hydraulic Fracturing Water
- Current Industrial Reuse Activities

NEXT MEETING:

April 2015 – Discussion of Alternatives

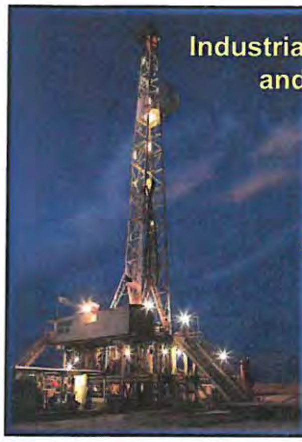
15-08-005-01
general

Industrial Water Management and Reclamation Feasibility Study

Advisory Committee

Feb 11, 2015

Name	Organization	e-mail
Peggy Glass	Alan Plummer Assoc., Inc.	pglass@apaienv.com
Janet Sims	Alan Plummer Assoc., Inc	jsims@apaienv.com
Gary Hanler	EPS, INC	hanler@engpsi.com
Tim Reed	Concho	treed@concho.com
JOHN GRANT	CRMWD	JGRANT@CRMWD.ORG
MIKE ROBINSON	OEPP	MROBINSON@ODESSAPOWER.co
DeLynne Ano	RL Environmental	dano@rleinc.us
LEONARD LEVINE	GCA	LLEVINE@GCWDA.COM
Gordon Pederson	GCA	gpeders@gcwda.com
James Beach	LBG-Guyton	jbeach@lbg-guyton.c
Michael Shores	Kerr Energy	mshores@kerrenergy.net
Charles Choc Harris	GCA	Charris@gcwda.com
Jim Breaux	Odessa Dev. Corp.	
THOMAS KERR	City of Odessa	tkerr@odessa-txgo
Heather Tash	Concho	htash@concho.com
Armando Rodriguez	Ector Co. Comm.	Armando.Rodriguez@Ectorcountytx.gov



Industrial Water Management and Reclamation for the Permian Basin

Feasibility Study

Advisory Committee Meeting

February 11, 2015

Overview of Presentation

- Project Objective
- Review and Discussion of Report
  - Study Area
  - Participants
  - Water Supply Sources
  - Water Demands
  - Water Availability
  - Water Surplus/Deficits
- Data Needs

Project Objective

Identify Regional System project(s) using non-potable water sources to meet industrial water needs.

Study Area

Participants

- Project Participants
  - Gulf Coast Waste Disposal Authority
  - Odessa Development Corporation
  - Advisory Committee

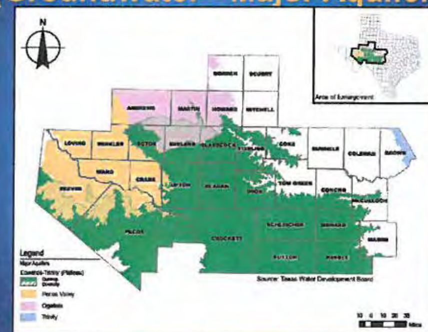
Advisory Committee

Name	Affiliation
DeLynn Ano	RL Environmental, Inc.
Jim Breaux	Odessa Development Corporation
Dennis Danzik	RDX Technologies Corporation
Nick Fowler	Industry
John Grant	Colorado River Municipal Water District
Ian Kerr	Kerr Energy
Thomas Kerr	City of Odessa Utilities
Mike Robinson	Odessa-Ector Power Partners
Armando Rodriquez	Ector County
Ben Shepperd	Permian Basin Petroleum Assoc.
Heather Tash	Concho Resources, Inc.

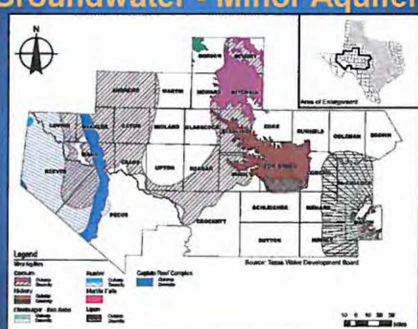
Water Supply Sources

- Groundwater
- Surface Water
- Wastewater

Water Supply Sources (Groundwater - Major Aquifers)



Water Supply Sources (Groundwater - Minor Aquifers)



Water Supply Sources (Surface Water)

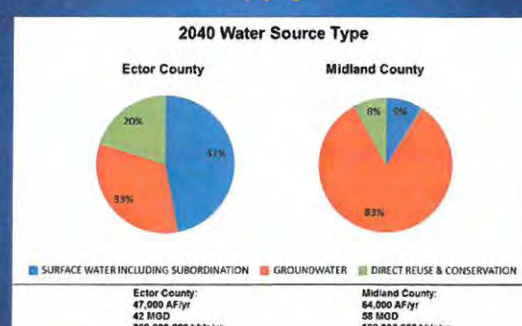
Significantly impacted by drought conditions.

- O.H. Ivie Reservoir
- E.V. Spence Reservoir
- Lake J.B. Thomas

Water Supply Sources (Wastewaters)

- Oil and Gas Produced Water and Hydraulic Fracturing Flowback Water
- Wastewaters from Industrial and Municipal Sources

Water Supply Sources



Water Demands (Use Categories)

- Municipal
- Irrigation
- Manufacturing
- Steam-electric Power Generation
- Livestock Watering
- Mining

Water Demands (in acre-feet per year)

	ECTOR COUNTY		MIDLAND COUNTY	
	Historical*	Projected*	Historical*	Projected*
Use Cateogory	2010	2040	2010	2040
Municipal	24,669	33,482	25,446	43,294
Irrigation	1,050	1,397	14,969	32,756
Manufacturing	1,930	3,809	156	269
Steam Electric	0	12,976	0	0
Livestock	249	265	256	394
Mining	845	1,926	1,593	2,630
Total	28,743	53,855	42,420	79,343

* all values in acre-feet per year (AF/yr)

Water Demands (Types of Water Quality)

- Freshwater – less than 1,000 milligram per liter (mg/L) total dissolved solids (TDS)
- Brackish – 1,000 mg/L TDS – 35,000 mg/L TDS
- Saline – greater than 35,000 mg/L TDS

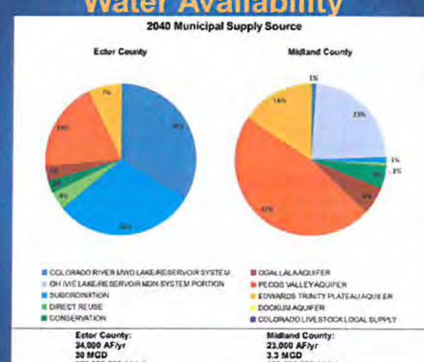
Water Demands (Use and Water Quality)

- Preferred Freshwater
  - Municipal
  - Steam-electric Power Generation
  - Manufacturing
- Accept Low Brackish
  - Irrigation
  - Livestock Watering
- Varies Freshwater to Saline

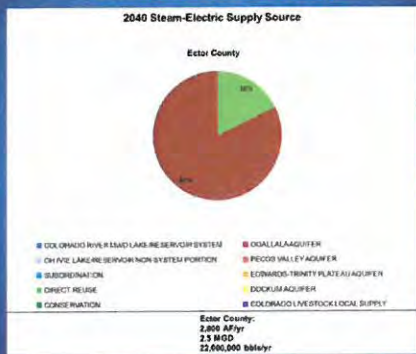
Water Demands

Water Quality	Use Category
Prefer Freshwater	Municipal Steam-electric Power Generation Manufacturing
Accepts Low Brackish	Irrigation Livestock Watering
Varies Freshwater to Saline	Mining

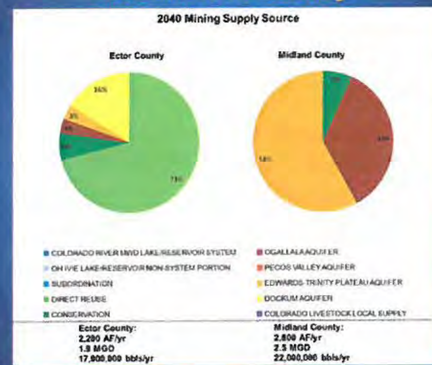
Water Availability



Water Availability



Water Availability



Projected Water Surplus/Deficit (Ector County)

	Ector County		
	2040		
Use Cateogory	Demand*	Supply*	Surplus (Need)*
Municipal	40,061	41,078	1,017
Irrigation	1,397	3,084	1,687
Manufacturing	3,809	4,946	1,137
Steam Electric	12,976	2,811	(10,165)
Livestock	265	265	0
Mining	1,926	2,170	244
Total	60,434	54,354	(6,080)

* all values in acre-feet per year (AF/yr)

Projected Water Surplus/Deficit (Midland County)

	Midland County		
	2040		
Use Cateogory	Demand*	Supply*	Surplus (Need)*
Municipal	42,623	22,729	(19,894)
Irrigation	32,756	37,669	4,913
Manufacturing	269	269	0
Steam Electric	0	0	0
Livestock	394	394	0
Mining	2,630	2,814	184
Total	78,672	63,875	(14,797)

* all values in acre-feet per year (AF/yr)

Conclusion

- Prudent to reserve freshwater source for those uses where they are essential, such as municipal supply
- Suitable quality available for municipal uses in Ector County
  - Dependent on subordination
  - Rely on surface water
- Oil and Gas demands are met with reliance on groundwater and reuse

Data Needs

- Quality objections for hydraulic fracturing
- Current industrial reuse activities

Appendix 6.5

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ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

MEETING NOTES

DATE:	June 25, 2015
TIME:	1:00
APAI PROJECT NO.:	1536-003-01
LOCATION:	TTHSC, Odessa, TX
ROOM / CONF. CALL #	

MEETING TITLE:	Advisory Committee Meeting—Industrial Water Mgmt and Reclamation-Permian Basin		
MEETING CALLED BY:	Gordon Pederson	MEETING PURPOSE:	Review Chapters 5 – 8
FACILITATOR:	Gordon Pederson	RECORDER:	Rex Hunt
ATTENDEES:	See attached Meeting Sign In sheet.		

NOTES

Sign-in Sheet: Attached

Welcome & Introductions: Gordon Pederson (Gulf Coast Waste Disposal Authority, GCWDA)

Meeting Purpose: Peggy Glass (Alan Plummer Associates, Inc, APAI) to present summary of information presented in Chapters 5 through 8 of the draft report.

Handouts: .Copies of the presentation and a revised Table 8.1 from the report were provided. A copy of Table 8.1, as revised, is attached.

Dr. Glass presented a PowerPoint summary of Chapters 5 through 8. Members of the committee, and others that have expressed interest in the project, had previously received an electronic copy of the report. A copy of the presentation is attached. A general discussion followed. There were no suggested changes to the report.

ACTION ITEMS	WHO	WHEN
Preparation of Interim Report on Alternatives	APAI	Fall 2015

AGENDA ITEMS FOR NEXT MEETING

Review Interim Report on Alternatives.

ADDITIONAL INFORMATION

NEXT MEETING DATE:	To be determined

ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS • DESIGNERS • SCIENTISTS

JOB NAME
JOB NO. PAGE OF
CALCULATED BY DATE
VERIFIED BY DATE

Industrial Water Management and Reclamation for the Permian Basin Feasibility Study

Advisory Committee Meeting
June 25, 2015

Name	Affiliation	e-mail
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LEONARD LEVINE	GCWDA	LLEVINE@GCWDA.COM
Rex Hunt	APAI	rhunt@apaienv.com
JOHN GRAF	CRMWD	
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ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS • DESIGNERS • SCIENTISTS

JOB NAME
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Industrial Water Management
and Reclamation
for the Permian Basin
Feasibility Study

Advisory Committee Meeting
June 25, 2015

Name	Affiliation	e-mail
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MIKE ROBINSON	ODESSA-ECTOR POWER PARTNERS, L.P.	—
CHOC HARRIS GCA		

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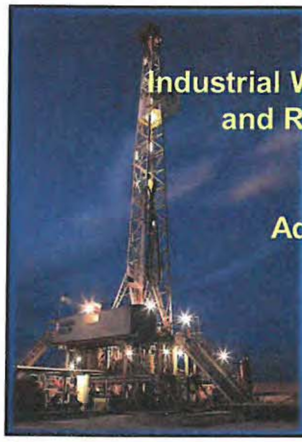

Feasibility Study
Industrial Water Management and Reclamation for the Permian Basin

Advisory Committee Meeting

June 25, 2015

Previous Interim Report – February 2015

- Existing Water Sources
- Water Demands
- Water Surplus or Deficit by Water Use Category

Previous Interim Report – February 2015 Conclusions – *Based on draft Region F Water Plan*

- Freshwater resources should be reserved for uses where freshwater is most needed
  - Midland Co. municipal supply has projected deficit in 2030.
  - Ector Co. has sufficient municipal supply if reservoirs not impacted by drought.
  - Ector Co. has stream-electric supply deficit in 2020.

Previous Interim Report – February 2015 Conclusions – *Based on draft Region F Water Plan*

- Sufficient water for oil and gas production, if 77% of water supply comes from conservation and reuse.
- 2012 report by Bureau of Economic Geology estimated 2% of water used for fracking is recycled water.

Existing Reuse
Gulf Coast Waste Disposal Authority
Odessa South Regional Wastewater Treatment Plant

- Accepts cooling tower blowdown from two power plants
- Permit allows effluent to be used for
  - Oilfield activities
  - Power production
  - Other industrial activities

Current discharge volume:	2 – 2.5 MGD
Contracted for use in oilfield operations:	2 MGD

Existing Reuse
City of Odessa
Bob Derrington Wastewater Treatment Plant

- Currently provides effluent for landscape irrigation
- Under contract to provide effluent for steam-electric power production and industrial manufacturing, but not used for these purposes currently.
- Has an agreement to provide effluent for oilfield operations.

Existing Reuse
City of Midland
Midland Wastewater Treatment Plant

- Effluent used for irrigation of non-public pasture and cultivated lands.
- Exploring providing effluent for oilfield operations.

Oil and Gas Operations Reuse

- Approximately 58 million barrels of wastewater (79 MGD) were injected into 290 SWDs in December 2014.
- Minimal demand for waterflooding in Ector and Midland Counties.
- Some water reused for fracking; may be mixed with brackish groundwater.

Opportunities for Industrial Reuse

Source – Oil and gas development and production wastewaters

Demands – Steam-electric
Oil and gas development and production

Opportunities for Industrial Reuse
Steam-electric power generation
Not a preferred option

- Primary use is cooling water
- Control of scaling is essential
- Low quality water means high chemical cost
- Consistent quality needed

Opportunities for Industrial Reuse
Oil and Gas Development – Fracking
Challenges

- Cost: treatment, transport, storage
- Balancing wastewater production and reuse demand
- Wide geographic area with changing area of demand
- Pay-back structure
- Lack of regulatory clarity

Potential Constituents of Concern for Reuse Water Used for Fracking

- Oil
- Solids
- Iron and manganese
- Sulfur compounds
- Barium and strontium
- Calcium and magnesium
- Boron and potassium
- Synthetic organic chemicals

Assume no treatment to reduce total dissolved solids

Treatment Approach

- Treat flowback and produced water for use in fracking
- Rely on proven technologies

Treatment Challenges

- System needs to be cost-competitive
- Quality of water treated is variable
  - Between formations
  - Between wells in same formation
  - Over time in a given well
  - Based on fracking technology used previously

Treatment Challenges (Continued)

- Treatment quality objectives are dependent on following:
  - Producing formation
  - Fracking technology used
  - Producer preference
  - Fracking operator preference

Treatment Technology Costs

- Costs do not include auxiliary equipment, pretreatment, or residuals management
- Costs are from cost curves and project-specific cost could vary ± 50%
- Costs are for comparison purposes and are internally consistent

Treatment Technologies Being Evaluated

- Parallel-plate oil-water separation
- Settling/sedimentation
- Centrifugation
- Chemical Oxidation
- Chemical Coagulation
- Electrocoagulation
- Dissolved Gas Flotation
- Granular Media Filtration
- Microfiltration and ultrafiltration
- Granular activated carbon adsorption
- Ion exchange

Transportation Alternatives

- Trucking
- Buried pipeline/permanent pump stations
  - Fiberglass
  - High-density polyethylene
  - Polyvinyl chloride
- Above-ground pipeline
  - High-density polyethylene
  - Lay-flat

Storage Alternatives –
In Conjunction with Collection, Treatment, Distribution

- Lined earthen pits
- Above-ground storage tanks
  - Preassembled
  - Pre-constructed components
- Aquifer Storage and Recovery

Table 8.1 Potential Treatment Technologies for Reuse of Wastewater (Revised 6/23/2015)

Treatment Technology		Treated Constituents of Concern								Pre-treatment Required?	Capital Cost		Operating Cost	
		Oil	Total Suspended Solids	Iron & Manganese	Sulfates/ Sulfites	Sulfides	Boron	Selected Salts	Synthetic Organic Chemicals		($/bbl/d)	($/MGD)	$/bbl	($/kgal)
Parallel Plate Oil-Water Separator		X[1]	X[2]							No	$30	$800,000	$0.062	$1.48
Centrifuge		X	X							No	$158	$3,800,000	$0.266	$6.34
Chemical Oxidation				X		X			X	No	$11	$300,000	$0.013	$0.31
Settling/Sedimentation			X							No	$88	$2,100,000	$0.018	$0.42
Coagulation	Chemical Coagulation	X	X					Ca, Mg	X	No	$64	$1,600,000	$0.146	$3.48
Coagulation	Electrocoagulation	X	X	X				Ca, Mg, Ba, Sr	X	No	$57	$1,400,000	$0.088	$2.10
Dissolved Gas Flotation (DGF)		X	X							Possible	$155	$3,700,000	$0.043	$1.02
Filtration	Granular Media Filtration	X	X							Yes	$114	$2,800,000	$0.032	$0.76
Filtration	Microfiltration	X	X							Yes	$222	$5,300,000	$0.298	$7.10
Filtration	Ultrafiltration	X	X							Yes	$222	$5,300,000	$0.298	$7.10
Granular Activated Carbon						X			X	Yes	$327	$7,800,000	$0.193	$4.59
Ion Exchange					X		X	Ca, Mg, SO_4, B		Yes	$78	$1,900,000	$0.07-0.15	$1.60-3.48

[1]Except emulsified and dissolved oils

[2]Except colloids and small solids

Note: The costs on this table have been derived from cost curves. Actual costs based on site-specific requirements and conditions may vary by ± 50%. These costs are provided for comparison purposes only and, based on that objective, are internally consistent. Costs are for a system to treat approximately 100 gpm (3500 bbl/day) average flow and 200 gpm (7,000 bbl/day) maximum flow.

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Appendix 6.6

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MEETING NOTES

DATE:	January 21, 2016
TIME:	1:00 pm
APAI PROJECT NO.:	1536-003-01
LOCATION:	TTHSC, Odessa, TX
ROOM / CONF. CALL #	

MEETING TITLE:	Advisory Committee Meeting—Industrial Water Mgmt and Reclamation-Permian Basin		
MEETING CALLED BY:	Gordon Pederson	MEETING PURPOSE:	Review selected conceptual project alternatives
FACILITATOR:	Gordon Pederson	RECORDER:	Rex Hunt
ATTENDEES:	See attached sheet.		

NOTES

Attendance Sheet: Attached

Welcome & Introductions: Gordon Pederson (Gulf Coast Waste Disposal Authority, GCWDA)

Meeting Purpose: Peggy Glass (Alan Plummer Associates, Inc., APAI) to present summary identified alternatives for the use of reclaimed water for the oil and gas industry.

Handouts: .Copies of the presentation.

Dr. Glass presented a PowerPoint summary of three identified alternatives for the use of reclaimed water, including:

- Treat at the site of the Odessa South plant and blend with treated municipal wastewater, then convey to users.
- Treat at salt water disposal site and provide to users.
- Treat at salt water disposal site and convey to Odessa South plant to blend with treated municipal wastewater; then convey to users.

A general discussion followed.

ACTION ITEMS	WHO	WHEN
Preparation of final draft Report for the project	APAI	Spring 2016

AGENDA ITEMS FOR NEXT MEETING

Review final draft Report on Alternatives.

ADDITIONAL INFORMATION

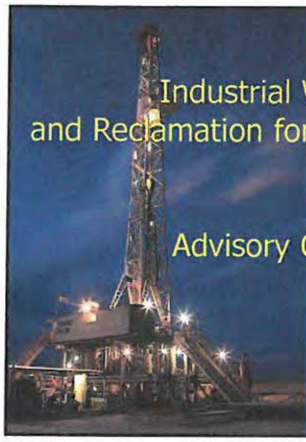
NEXT MEETING DATE:	To be determined

Industrial Water Management and Reclamation for the Permian Basin
Feasibility Study

Advisory Committee Meeting
January 21, 2016

Attendees

Gordon Pederson	Gulf Coast Waste Disposal Authority
Leonard Levine	Gulf Coast Waste Disposal Authority
Tom Kerr	City of Odessa
Ben Jordan	City of Odessa
John Grant	Colorado River Municipal Water District



Feasibility Study
Industrial Water Management and Reclamation for the Permian Basin

Advisory Committee Meeting
January 21, 2016

Interim Report 1
Major Conclusions Based on Region F Water Plan

- Freshwater resources should be reserved for uses where freshwater is most needed.
  - Midland Co. municipal supply has projected deficit beginning in 2030.
  - Ector Co. has sufficient municipal supply if reservoirs not impacted by drought and subordination is achieved.
  - Ector Co. steam-electric supply has projected deficit beginning in 2020.

Interim Report 1 – February 2015
Major Conclusions Based on Region F Water Plan (cont).

- Ector Co. has sufficient water for oil and gas production, if 77% of water supply comes from conservation and reuse.
- 2012 report by Bureau of Economic Geology estimated 2% of water used for fracking is recycled water.
- Midland Co. has sufficient water for oil and gas production based on 79% coming from Ogallala and Edwards-Trinity Aquifers. (When oil was $100/barrel).

Interim Report 2 –June 2015
Current Reuse of Treated Municipal Wastewater

Odessa South Regional WWTP and Bob Derrington WWTP

- Virtually all effluent used, or contracted for use, for landscape irrigation, oilfield use, or steam-electric power plant cooling water.

Midland WWTP

- Currently used for irrigation; discussion underway to provide for oilfield use.

Interim Report 2 –June 2015
Current and Proposed Reuse of Oil and Gas Wastewater

- Inter-field Pipeline - Proposed
  - Would service multiple fields.
  - Would use a blend of flowback, produced water, treated municipal wastewater, and brackish groundwater.

Interim Report 2 –June 2015
Current and Proposed Reuse of Oil and Gas Wastewater (cont).

- Hub and Spoke
  - System services a field with active well development.
  - Flowback and produced water are mixed with brackish groundwater and reused for hydraulic fracturing.
  - Treatment consists of iron removal and disinfection.

Interim Report 2 –June 2015 Current and Proposed Reuse of Oil and Gas Wastewater (cont).

- Mobile Treatment
  - Used to treat flowback and produced water for reuse in hydraulic fracturing.
  - Treatment technology used and treatment capacity vary widely.

Interim Report 2 –June 2015

- Identified treatment requirements and alternatives, including costs
- Identified transport and storage alternatives, including costs

Current Evaluation Three System Alternatives Reuse of Flowback and Produced Water

1. Treat at site of Odessa South Regional WWTP; blend with treated municipal wastewater.

2A. Treat at SWD site.

2B. Treat at SWD site; transport to Odessa South Regional WWTP, and blend with treated municipal wastewater.

Assumptions Common to All Alternatives

- Aggregation
  - Oilfield wastewater is aggregated at an SWD.

Assumptions Common to All Alternatives

- Treatment
  - Only treatment provided is removal of oil and suspended solids.
    - SWD operator will provide preliminary treatment to reduce oil and suspended solids.
    - Additional treatment by this project will further remove oil and suspended solids. Estimated costs will be based on walnut-shell filters, which are representative of the technology to be used.
  - Additional treatment, as needed for down-hole use, will be the responsibility of the E&P operator.

Assumptions Common to All Alternatives (cont.)

- Additional treatment by this project will further remove oil and suspended solids. Estimated costs will be based on walnut-shell filters, which are representative of the technology to be used.
- Additional treatment, as needed for down-hole use, will be the responsibility of the E&P operator.

Assumptions Common to All Alternatives (cont.)

- Storage
  - Storage will be provided for 2,000 barrels of treated oilfield wastewater in 500-barrel tanks.
- Transport
  - All transport will be by buried high density polyethylene (HDPE) or fiberglass pipe.
  - Only the pipeline required to reach an initial delivery point for treated water is part of this project.
  - Transport within and/or between fields is cost of E&P operator.

Preliminary Considerations; Advantages and Disadvantages

Alternative 1 – Treat at Odessa South Regional WWTP

Advantages:

- Sufficient land available for treatment units.
- Blending with Odessa South Regional WWTP effluent provides lower total dissolved solids (TDS) content.
- Trained staff already exist and are on-site.

Preliminary Consideration; Advantages and Disadvantages

Alternative 1 – Treat at Odessa South Regional WWTP

Disadvantages:

- Disposal of treatment residuals may be difficult.
- E&P operator may have additional cost for algae control in pits.
- Storage of influent for flow equalization is required (two 500-barrel tanks).

Preliminary Consideration; Advantages and Disadvantages

Alternative 2A – Treat at SWD Site

Advantage:

- Treatment residuals can be disposed in injection well.

Disadvantages:

- Requires operator staffing at a remote site.
- May require more remote monitoring.

Preliminary Consideration; Advantages and Disadvantages

Alternative 2B – Treat at SWD Site, Transport to Odessa South Regional WWTP for Blending

Advantages:

- Treatment residuals can be disposed in injection wells.
- Blending with Odessa South Regional WWTP effluent provides lower TDS content.

Preliminary Consideration; Advantages and Disadvantages

Alternative 2B – Treat at SWD Site, Transport to Odessa South Regional WWTP for Blending

Disadvantages:

- Requires operator staffing at a remote site.
- May require more remote monitoring.
- E&P operator may have additional costs for algae control in pits.
- Requires transport of treated wastewater to Odessa South Regional WWTP for blending.

Other Features to Be Assessed

- Cost: Capital, and Operation and Maintenance
- Environmental Impacts
- Legal and Regulatory Requirements
- Adequacy of Water Supply Produced
- Management Alternatives

Appendix 6.7

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MEETING NOTES

DATE:	June 30, 2016
TIME:	1:00 pm
APAI PROJECT NO.:	1536-003-01
LOCATION:	Atmos Energy Permian Basin
ROOM #	Robert Earl and Sally Fischer Community Room

MEETING TITLE:	Advisory Committee and Public Meeting Industrial Water Management and Reclamation—Permian Basin		
MEETING CALLED BY:	Gordon Pederson	MEETING PURPOSE:	Review final draft report and selected alternative for reuse
FACILITATOR:	Gordon Pederson	RECORDER:	Rex Hunt
ATTENDEES:	See attached meeting sign-in sheet.		

NOTES

Sign-in Sheet: Attached

Welcome & Introductions: Gordon Pederson (Gulf Coast Waste Disposal Authority, GCWDA). Four stakeholder meetings and this is a public meeting. There are no further planned meetings.

Meeting Purpose: Purpose of the meeting is to get input from the public regarding the report.

Handouts: Relevant tables from the engineering analyses of the alternatives

Peggy Glass (Alan Plummer Associates, Inc., APAI) presented a summary of identified alternatives for the use of reclaimed water for the oil and gas industry and the analyses of the alternatives; and addressed the next steps in the project. (Copy of presentation attached)

Dr. Glass presented a Powerpoint summary of the project, particularly the three identified alternatives for the use of reclaimed water, including:

- Region F Regional Water Plan projects deficits in water.
  - Ector County has enough water for O&G if significant portion of the water comes from reuse.
  - Need to preserve fresh water supplies for human consumption where possible.
- Preferred option for reuse
  - The most feasible reclamation option is to treat flowback and produced water so it can be used for fracking. E&P companies responsible for transport and storage and some treatment and GCA treats at SWD
- Three options considered in all
  - Option 1: At South Plant, blend with effluent
  - Option 2: At SWD, no blending (became selected option)
  - Option 3: At SWD, blend with effluent elsewhere
- With a no-action alternative
- Costs Analysis
  - 5% payback over 2 years for debt service
  - 40/60 split on fixed and variable cost
  - Contractual arrangement between GCA and user
- Next Steps:
  - Pilot project at SWD
    - $150,000+-
    - 12+- months
  - Full-scale project

A general discussion, with questions, followed.

- Will pipelines be regulated by RRC? It will have oil in it; but most all of it will have been stripped out. This could change the outcome if pipelines are regulated by RRC. The RRC has indicated that they do not intend to regulate these pipelines because they do not believe they would have a significant fraction of oil in the water carried in the pipelines.
- 5% backwash disposal from filters
- What happens with the walnut shells. How do you dispose of them? They last for a long time. This is a proven technology for many applications.
- Why not reverse flow on the pipelines to get water back out to wells? It's an issue of the small volume.
- Pilot plant funding. Where would it come from? Could come from US Burec; but becomes public information. Having done this report, GCA is eligible for such funding. If clients do not want the information made public, the funding would have to come from industry.
- No accounting for cost of transport of water away from the SWD? Correct.
- Were there any surprises? That it was so cost effective; which is a function of the shift in treatment requirements changing (e.g., TDS need not be removed to be used).
- What size would the pilot study be? Still evaluating what it might need to be.
- Still taking comments after this for a few weeks until the official copy is submitted to Burec
- Could the pilot study look at combinations of alternatives? Yes.

ACTION ITEMS

Get comments to APAI as soon as possible

AGENDA ITEMS FOR NEXT MEETING

No additional meetings anticipated

ADDITIONAL INFORMATION

NEXT MEETING DATE: NA

MEETING SIGN IN

DATE:	June 30, 2015
TIME:	1:00 p.m.
LOCATION:	Atmos Energy Permian Basin Operations Center

Meeting Title
Advisory Committee and Public Meeting – Industrial Water Management and Reclamation Permian Basin

NAME	AFFILIATION	E-MAIL
James Beach	LBG-Guyton	
Chas. HARRIS	~~Charris@gcwda.~~ CCP@gcwda.Gi	
Gordon Pederson	GCWDA	gpedens@gcwda.com
Leonard Levine	GCWDA	
Peggy Glass	APAI	pglass@apaienv.com
Monty Trimble	Odessa Ector Power Partners	monty.Trimble@kochind.com
Armando Rodriguez	Ector County	Armando.Rodriguez@Ectorcounty.tx.gov
Tim Reed	COG	
MARK HOLLY	COG	mHolly@concho.com
MIKE ROBINSON	OEPP	MROBINSON@ODESSAPOWER.COM
JIM BREAUX	ODC	JBREAUX@pemcoequip.com

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Feasibility Study
Industrial Water Management and Reclamation for the Permian Basin

Advisory Committee & Public Meeting

June 30, 2016

Water Availability
2016 Region F Water Plan

- Midland Co. municipal supply has projected deficit beginning in 2030.
- Ector Co. has sufficient municipal supply if reservoirs not impacted by drought and subordination is achieved.
- Ector Co. steam-electric supply has projected deficit beginning in 2020.

Water Availability 2016 Region F Water Plan (Cont.)

- Ector Co. has sufficient water for oil and gas production, if 77% of water supply comes from conservation and reuse.
- Midland Co. has sufficient water for oil and gas production based on 79% coming from Ogallala and Edwards-Trinity Aquifers.

Water Availability – Conclusions

- Freshwater needs to be saved for uses where it is most needed.
- Reclamation and reuse are needed to provide adequate supplies for oil and gas production.

Most Feasible Reclamation Option

Treat Flowback and Produced Water so it Can be Used for Fracking

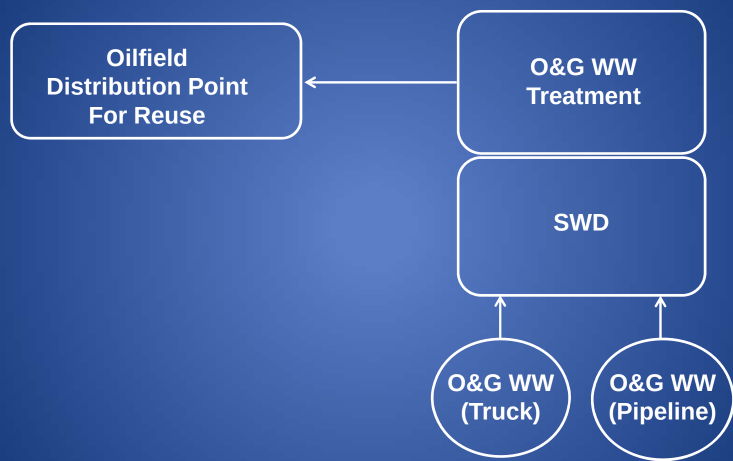
- Divert from saltwater disposal (SWD) site
  - Provides flow equalization
  - Wastewater can be diverted for treatment as needed
  - Preliminary treatment provided

Most Feasible Reclamation Option

Treat Flowback and Produced Water so it Can be Used for Fracking

- GCA treats to remove suspended solids, and oil with walnut-shell filters, or equivalent.
- Exploration and production (E&P) company(ies) responsible for transport and storage after delivery point and treatment for downhole use.

Most Feasible Option – Treat at SWD Site



O&G WW = Oil and Gas Wastewater
SWD = Saltwater Disposal Site

Treat at SWD Site
Advantages and Disadvantages

Advantage:

- Treatment residuals can be disposed in injection wells

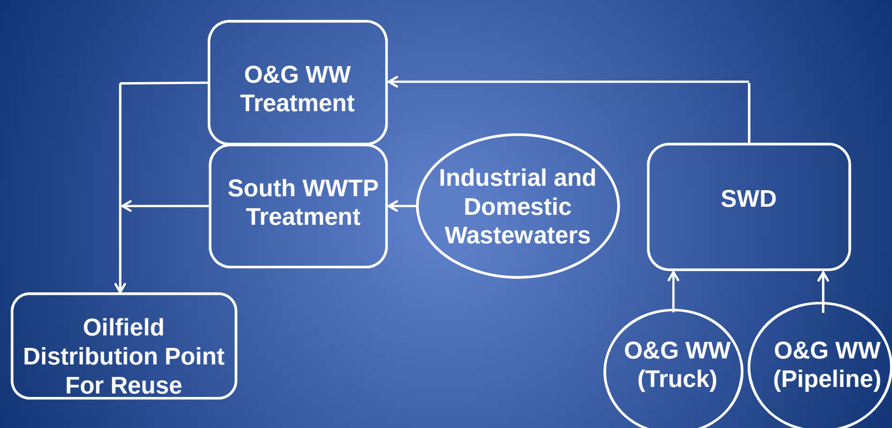
Disadvantages:

- Requires operator staffing at a remote site
- Requires more remote monitoring

Optional Systems – Provide Ability to Blend with Effluent from Odessa South Regional WWTP

- Reduces concentration of dissolved solids (salt)
- Requires pipeline to transport either wastewater or reclaimed water to Odessa South Regional WWTP
- Two alternative configurations

Option 1 – Treat at Odessa South Regional WWTP



O&G WW = Oil and Gas Wastewater
South WWTP = South Odessa Regional Wastewater Treatment Plant
SWD = Saltwater Disposal Site

Option 1 – Treat at Odessa South Regional WWTP Advantages and Disadvantages

Advantages:

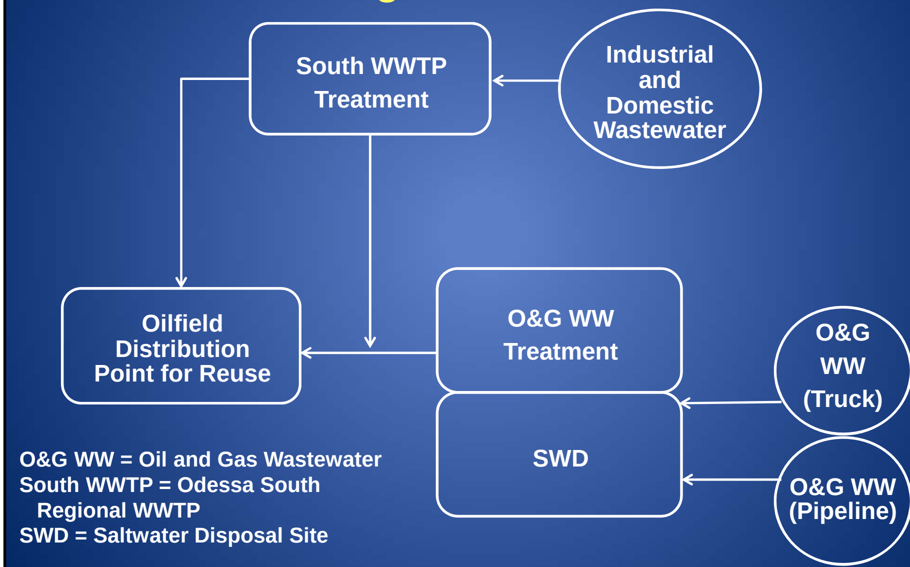
- Sufficient land available for treatment units
- Trained staff already exist and are on-site

Option 1 – Treat at Odessa South Regional WWTP Advantages and Disadvantages (Cont.)

Disadvantages:

- Treatment residuals disposal challenging
  - For 6,000 bbl/d (0.25 MGD) treatment system, truck 300 bbl/d (12,500 gal/d) of backwash
  - For 24,000 bbl/d (1.0 MGD) treatment system, truck 1,200 bbl/d (50,000 gal/d) of backwash

Option 2 – Treat at SWD and Blend at Odessa South Regional WWTP



Option 2 – Treat at SWD and Blend at Odessa South Regional WWTP Advantages and Disadvantages

Advantage:

- Treatment backwash can be disposed in injection wells

Option 2 – Treat at SWD and Blend at Odessa South Regional WWTP Advantages and Disadvantages (Cont.)

Disadvantages:

- Requires operator staffing at a remote site
- Requires more remote monitoring
- Requires transport of treated wastewater to Odessa South Regional WWTP

No Action Alternative

- Continues use of fresh and brackish groundwater reserves
- Continues deep well disposal, which could result in over pressurization of formations and limitations on disposal
- Continues reliance on trucking of water and associated impacts on traffic safety, roadway maintenance, and greenhouse gas emissions

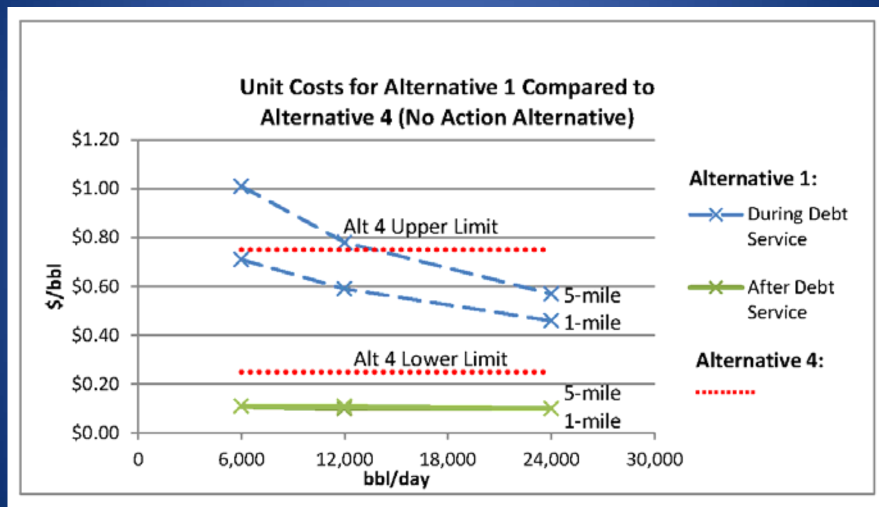
Cost Analyses

- Treatment Systems: 6,000 bbl/d (0.25 MGD), 12,000 bbl/d (0.50 MGD), and 24,000 bbl/d (1.0 MGD)
- Pipeline distances for Alternatives 2 and 3: 1 mile and 5 miles

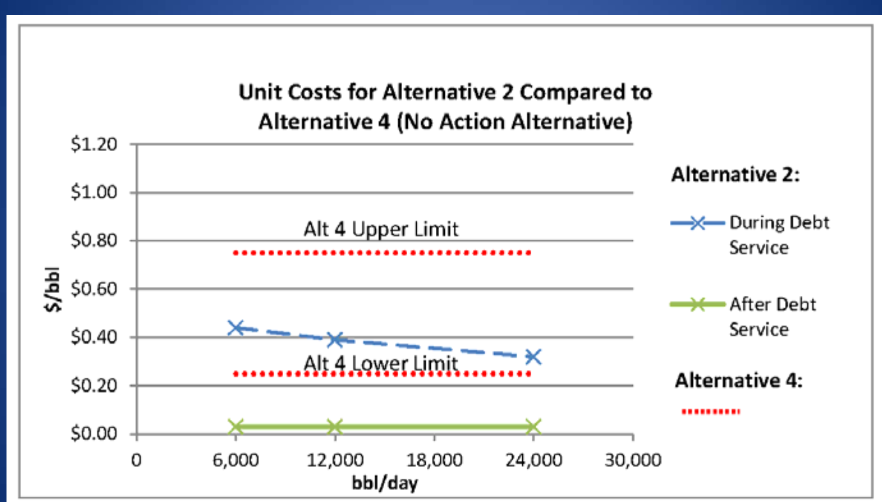
Cost Analyses

- Payback of capital cost in two years at 5%
- Operational Costs split 40% fixed cost and 60% variable cost – subject to adjustment based on project-specific analyses
- Contractual arrangement would consist of fixed monthly cost plus variable cost based on amount of water treated

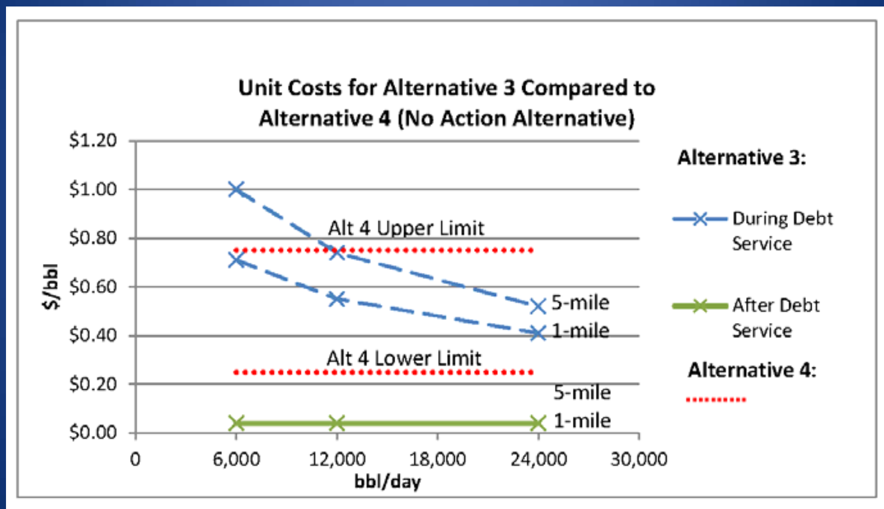
Cost Analysis – Treat at Odessa South Regional WWTP



Cost Analysis – Treat at SWD



Cost Analysis – Treat at SWD and Blend at Odessa South WWTP



Preferred Alternative – Treat at SWD

- Least cost
  - For 6,000 bbl/d, initial fixed cost 76,000/mo; after 2 years, fixed cost $2,500/mo
  - For 6,000 bbl/d, variable cost $0.02/bbl
- Least environmental impact
- Residuals management less problematic
- Less regulatory requirements

Next Step – Pilot Project

- Construct pilot treatment unit at SWD
- Operate 2 to 4 months
- Provide reclaimed water to hydraulic fracturing company for testing
- Estimated cost - $150,000

Pilot Project Schedule

Develop study protocol, design pilot unit, secure unit, and install unit.	6 months
Operate unit	2 to 4 months
Compile data and prepare report (requires coordination with HF contractor)	3 months

Full-Scale Project Schedule

Develop agreements and secure financing	During pilot study
Develop plans and specifications	6 months
Bid and award contract	4 months
Construction	6 to 9 months
Start-up	1 month

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Table 9.1: Evaluation of Alternatives; Range of Cost Opinions
Initial Costs: Includes Debt Repayment

Alternative	Cost of Water		
	$/AF	$/kgal	$/bbl
1. Treat and Blend at Odessa South Regional WWTP Site[(1)]	$3,600–$7,800	$11.00–$24.00	$0.46–$1.00
2. Treat at Site Adjacent to SWD; No Blending[(2)]	$2,500–$3,400	$7.70–$10.50	$0.32–$0.44
3. Treat at Site Adjacent to SWD; Blend with Effluent from Odessa South Regional WWTP[(3)]	$3,200–$7,800	$10.00–$24.00	$0.41–$1.00
4. No action	$1,900–$5,800	$6.00–$18.00	$0.25–$0.75

[(1)]Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD) and pipeline distances of 1–5 miles.
[(2)]Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD).
[(3)]Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD) and pipeline distances of 1–5 miles.

Table 9.2: Evaluation of Alternatives; Range of Cost Opinions After Debt Repayment is Completed

Alternative	Cost of Water		
	$/AF	$/kgal	$/bbl
1. Treat and Blend at Odessa South Regional WWTP Site (1)	$800–$900	$2.40–$2.60	$0.10–$0.11
2. Treat at Site Adjacent to SWD; No Blending(2)	$260–$270	$0.80–$0.82	±$0.03
3. Treat at Site Adjacent to SWD; Blend with Effluent from Odessa South Regional WWTP(3)	$280–$330	$0.84–$1.00	±$0.04
4. No action	$1,900–5,800	$6.00–$18.00	$0.25–$0.75

(1)Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD) and pipeline distances of 1–5 miles.

(2)Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD).

(3)Range of costs represents treatment capacities of 6,000–24,000 bbl/d (0.25–1.0 MGD) and pipeline distances of 1–5 miles.

Table 9-3 Evaluation of Alternatives: Fixed and Variable Costs

Alt	Capacity (MGD)	Pipe Length (miles)	Capacity (bbl/day)	Fixed Cost		O&M Variable Cost* ($/mo)	Variable Cost ($/bbl)
				With Debt Service	Excluding Debt Service		
1	0.25	1	6,000	$ 113,000	$ 2,700	$ 17,000	$0.09
1	0.50	1	12,000	$ 180,000	$ 5,200	$ 33,000	$0.09
1	1.00	1	24,000	$ 272,000	$ 9,900	$ 64,000	$0.09
1	0.25	5	6,000	$ 166,000	$ 2,900	$ 17,000	$0.09
1	0.50	5	12,000	$ 247,000	$ 5,500	$ 33,000	$0.09
1	1.00	5	24,000	$ 350,000	$ 10,300	$ 66,000	$0.09
2	0.25	na	6,000	$ 76,000	$ 2,500	$ 4,000	$0.02
2	0.50	na	12,000	$ 135,000	$ 4,900	$ 8,000	$0.02
2	1.00	na	24,000	$ 221,000	$ 9,600	$ 15,000	$0.02
3	0.25	1	6,000	$ 124,000	$ 2,700	$ 4,000	$0.02
3	0.50	1	12,000	$ 190,000	$ 5,200	$ 8,000	$0.02
3	1.00	1	24,000	$ 281,000	$ 9,900	$ 16,000	$0.02
3	0.25	5	6,000	$ 176,000	$ 2,900	$ 5,000	$0.03
3	0.50	5	12,000	$ 257,000	$ 5,500	$ 9,000	$0.02
3	1.00	5	24,000	$ 360,000	$ 10,300	$ 17,000	$0.02

* Facility operating at full capacity.

Table 9.4 Summary of Advantages and Disadvantages

Alternative	Initial Water Cost ($/bbl)	Legal and Regulatory Constraints	Residuals Management	Environmental Considerations	Suitability of Treatment	Reliability of Treatment	Adequacy of Supply
1. Oil and gas wastewater recycling facility at Odessa South Regional Wastewater Treatment Plant site.	$0.46 - $1.00	• Pipeline construction may require multiple permits and approvals. • No RRC permit required if same E&P companies that are sending wastewater are using reclaimed water. • Potential requirement for cultural survey.	• Filter backwash will be trucked to SWD for disposal. • Verification should be made that there is not unacceptable accumulation of NORM in backwash residuals.	• Reduces reliance on fresh and brackish water for HF and increases availability of fresh and brackish water for other uses. • Reduces reliance on use of trucks to deliver fresh or brackish water to well sites. • Value of reduction of trucks to transport water is partially offset by the trucks needed to transport backwash residuals. The volume of backwash waters is significant. • Extends life of existing SWD wells.	• Walnut-shell filters are an established treatment method for oil-field wastewaters. However, they have not been used previously to produce water suitable for HF. • Blending lowers TDS.	• Proximity to Odessa South WWTP with trained operators may enhance treatment reliability compared to remote operation of Alternatives 2 and 3. • Reliability may be affected by variations in source water quality.	• Provides a reliable supply indefinitely because in this area of the Permian Basin volume of produced water and flow back exceeds water demands for HF.
2. Oil and gas wastewater recycling facility at a saltwater disposal site	$0.32 - $0.44	• No RRC permit required if same E&P companies that are sending wastewater are using reclaimed water. • Site for O&G WWTP should be selected to avoid need for 404 Permit, threatened/endangered species habitat, and cultural resources.	• Filter backwash can be disposed in SWD • Verification should be made that there is not unacceptable accumulation of NORM in backwash residuals.	• Reduces reliance on fresh and brackish water for HF and increases availability of fresh and brackish water for other uses. • Reduces reliance on use of trucks to deliver fresh or brackish water to well sites. • Extends life of existing SWD wells.	• Walnut-shell filters are an established treatment method for oil-field wastewaters. However, they have not been used previously to produce water suitable for HF	• Because of distance from trained operational staff, more electronics for monitoring and control will be needed. • Response time will be greater than for Alternative 1 if a problem arises that needs an operator on-site. • Reliability may be affected by variations in source water quality.	• Provides a reliable supply indefinitely because in this area of the Permian Basin volume of produced water and flow back exceeds water demands for HF.
3. Oil and gas wastewater recycling facility at a saltwater disposal site; effluent piped to blend with Odessa South Regional Wastewater Treatment Plant effluent	$0.41 - $1.00	• Pipeline construction may require multiple permits and approvals. • No RRC permit required if same E&P companies that are sending wastewater are using reclaimed water. • Potential requirement for cultural survey. • Site for O&G WWTP should be selected to avoid need for 404 Permit, threatened/endangered species habitat, and cultural resources.	• Filter backwash can be disposed in SWD • Verification should be made that there is not unacceptable accumulation of NORM in backwash residuals.	• Reduces reliance on fresh and brackish water for HF and increases availability of fresh and brackish water for other uses. • Reduces reliance on use of trucks to deliver fresh or brackish water to well sites. • Extends life of existing SWD wells.	• Walnut-shell filters are an established treatment method for oil-field wastewaters. However, they have not been used previously to produce water suitable for HF. • Blending lowers TDS	• Because of distance from trained operational staff, more electronics for monitoring and control will be needed. • Response time will be greater than for Alternative 1 if a problem arises that needs an operator on-site. • Reliability may be affected by variations in source water quality.	• Provides a reliable supply indefinitely because in this area of the Permian Basin volume of produced water and flow back exceeds water demands for HF.
4. No action	$0.25 - $0.75	• Over pressurization of geologic strata could result in limitations on deep well disposal of wastewaters.	• No residuals	• Uses fresh and brackish water needed for other beneficial uses. • Continues reliance on trucks for water transfer with assorted traffic, safety, greenhouse gas emissions, energy use, and road maintenance concerns.	• All methods currently used to treat fresh and brackish water have been used extensively.	• Most reliable treatment because it is used extensively and applied at the well site. • Generally consistent source water quality.	• Availability in the future of water from existing aquifers is uncertain.

Appendix 6.8

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ODC supports study of large-scale water recycling

BY COREY PAUL cpaul@oaoa.com | Posted: Thursday, April 17, 2014 4:09 pm

Gulf Coast Waste Disposal Authority wants to apply for a federal grant to pay for an 18-month study examining the feasibility of establishing large-scale industrial water recycling infrastructure for the Permian Basin amid ongoing water scarcity.

The Odessa Development Corporation board on Thursday approved up to $39,000 for GCWDA to put together an application for the U.S. Department of Interior Bureau of Reclamation. The application, due next month, would defines the scope of the study.

The City Council must approve that award and is scheduled to vote whether to do so on Tuesday.

Gulf Coast Waste Disposal Authority is a state-created water treatment facility at 2760 S. Grandview Ave. Facility Superintendent Charles "Choc" Harris presented to the board at a sparsely attended, brief meeting on Thursday.

"If we are going to grow the industry in West Texas, we have to identify the water sources and we have to move to reuse," Harris said in an interview. "The big target is oilfield, but we are also targeting for other industries."

Establishing such reuse infrastructure could lessen competition for fresh drinking water, and City Manager Richard Morton said the city supports the project.

"The facility out there is designed to handle industrial water and if we can enhance its ability and better our status with regards for water, I think it's good for our community," Morton said.

The grant application would be put together Alan Plummer Associates, a Fort Worth-based environmental consulting firm, along with a sub-consultant and the GWCDA. The firm would also do the study, Harris said.

"What type of water is available? What is it, where is it, and where can we get it?" Harris said in an interview. " . . . Water is a very precious commodity, and what we find out here we have to look at the infrastructure too. We have to look at trucking. We have to look at pipelines. Nobody has addressed this. How can you move this?"

The study, if the federal grant is approved, would identify participants, industrial water sources, infrastructure demands and regulations, among other factors. It would not look solely at GWCDA to recycle the industrial water.

"Good luck," said Buz Browning, president of the ODC board. "I hope that turns into a very good thing for the area."

Harris said there will be a stakeholders meeting later this month to discuss the project, attended by industry, including oil and gas companies, and other groups such as economic development boards.

GWCDA would not be able to profit from recycling the water, Harris said. And part of the review would look at whether taking on water recycling work would require the facility to expand.

Harris said GCWDA handles about 8 million gallons a day from groups including the REXtac plant, Flint Hills Resources, Odessa-Electric Power Partners and the City of Odessa, which sends some waste water.

The treatment facility does not treat oilfield water, such as produced water returning from the wellbore during drilling operations or flowback water emerging from the well after hydraulic fracturing.

But GCWDA is working to supply water to the industry. GCWDA officials in October reached an agreement with Kerr Energy to send up to 2 million gallons of treated affluent water a day to the company for oil and gas production.

A February study found that 87 percent of oil wells in the Permian Basin are in "high or extremely high water stress areas" but use an average of about 1.1 million gallons of water per well. The duty, by the sustainable investing consultancy Ceres, projected water use for fracking to grow from 6.6 billion gallons in 2012 to 13 billion gallons of water in 2020.

But higher flowback water rates and lower salinity of the produced water also make many areas of the Permian Basin promising to water recycling, the report found.

The state regulator, the Railroad Commission, does not require oil and gas companies to report where the water they use for production comes from.

Several private water recycling companies operate in West Texas, but the practice has been slow to take hold, according to industry officials, because of the abundance of disposal wells, which are cheaper. But Harris and others say water regulations could someday force the practice.

"What we are trying to do is get this in a place where everybody is looking at it," Harris said in an interview. "If it is us doing it, fine. If it is somebody else, OK."

ODC hears update on water recycling grant

BY NATHANIEL MILLER nmiller@oaoa.com | Posted: Thursday, May 8, 2014 7:44 pm

Board members with the Odessa Development Corporation heard a presentation about the status of a federal grant that would allow a state agency to explore establishing a large-scale industrial water recycling infrastructure for oilfield use.

Charles Harris, the superintendent for the Gulf Coast Waste Disposal Authority's Odessa plant, said the application —which ODC members approved giving $39,000 for the study — was still being reviewed by the U.S. Department of Interior Bureau of Reclamation.

The Odessa City Council approved the $39,000 during their April 22 meeting.

The purpose of the study is to see if Gulf Coast Authority can take used oilfield wastewater and clean it again for oilfield use; something city officials said could save them fresh water in the future. Currently, the Odessa location treats municipal wastewater.

Gulf Coast Waste Disposal Authority was originally formed in 1969 by the Texas Legislature as a non-taxing entity to help clean up the Galveston Bay. The Odessa plant has been in operation since 1997, and the other three facilities are located in the Houston and Galveston area.

During Thursday's meeting, Harris said they had meet with potential partners — Pioneer Natural Resources, Shell and ConocoPhillips — who have expressed interest in the project if the company gets the grant.

ODC Board President Buz Browning said the potential partners could possibly help pay for a plant and use the recycled wastewater it produces.

"It's going to be a good investment," Browning said.

During the meeting, ODC board member Kris Crow also expressed an interest in seeing the project succeed, saying by recycling water for hydraulic fracturing use, it would ultimately cut back use on water sources for municipal purposes.

"If we can take that water and use it for fracking … it would significantly cut down on fresh water use," Crow said.

No action was taken on the presentation.

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ALAN PLUMMER ASSOCIATES, INC.
ENVIRONMENTAL ENGINEERS AND SCIENTISTS

MEETING NOTES

DATE:	February 11, 2016
TIME:	2:00 P.M.
APAI PROJECT NO.:	1536-003-02
LOCATION:	Odessa, TX
ROOM / CONF. CALL #	

MEETING TITLE:	Presentation to Odessa Development Corporation (ODC)		
MEETING CALLED BY:	ODC	MEETING PURPOSE:	Regular meeting of ODC
FACILITATOR:	Chair of ODC	RECORDER:	P Glass
ATTENDEES:	Board of ODC and observers		

NOTES

The ODC provided part of the funding for the Feasibility Study for Industrial Water Management and Reclamation for the Permian Basin. They requested a status report on the project. P. Glass presented a brief status report and provided copies of the attached presentation. The only question from the board was a question about the potential size of the facility. Glass responded that there had been discussions of a system up to 2 MGD; but, currently, the project was evaluating a 250,000 gpd system with the potential to construct multiple trains where needed.

Attachments:

ODC agenda

Power Point Presentation

Odessa Development Corporation

PUBLIC NOTICE

In accordance with the Open Meetings Act, Chapter 551 of the Government Code of Texas, notice is hereby given to all interested persons that the Odessa Development Corporation will meet on **Thursday, February 11, 2016**, at **2:00 p.m.**, at 411 West 8th Street, City Hall, in the Council Chambers, 5th Floor, Odessa, Texas, to consider the following items:

1. Minutes of January 14, 2016.
2. City grant for parking garage and certain infrastructure. (Richard Morton, Melanie Hollmann) (Resolution)
3. Downtown Infrastructure Improvement Program. (Melanie Hollmann, Gloria O. Hernandez) (Resolution)
4. Downtown Building Façade Improvement Program. (Melanie Hollmann, Gloria O. Hernandez) (Resolution)
5. Amended ODC Bylaws. (Joel Roberts) (Resolution)
6. Financial and Investment Report. (Terri Gayhart)
7. Economic Agency Reports. (MOTRAN, Chamber of Commerce, Odessa Hispanic Chamber of Commerce, OHCC Mexico Initiatives, UTPB-SBDC and Gulf Coast Waste Disposal-Charles Harris, Peggy Glass)
8. Board Projects and Committee and Officer Reports, including: Advertising, City of Odessa, Tax Incentive Committee and Odessa Partnership. (CVA has been asked to do a PowerPoint presentation on economic impact of Summit on the community and the economic impact of Mexico Initiative)
9. Adjourn.

If, during the course of the meeting covered by this notice, the Board needs to meet in executive session, then such closed or executive meeting or session, pursuant to Chapter 551, Government Code of Texas, will be held by the Board on the date, hour, and place given in this notice or as soon after the commencement of the meeting covered by this notice as the Board may conveniently meet in such closed or executive meeting or session concerning any and all subjects and for any and all purposes permitted by Section 551 of said Government Code including, but not limited to:

551.071 For the purpose of a private consultation with the Board's attorney.
551.072 For the purpose of discussing the purchase, exchange, lease, or value of real property.
551.073 For the purpose of discussing negotiated contracts for prospective gifts, or donations.
551.074 For the purpose of considering the appointment, employment, evaluation, reassignment, duties, discipline, or dismissal of a public officer or employee.
551.087 For the purpose of deliberation regarding economic development negotiations.

(1) to discuss or deliberate regarding commercial or financial information that the governmental body has received from a business prospect that the governmental body seeks to have locate, stay, or expand in or near the territory of the governmental body and with which the governmental body is conducting economic development negotiations; or

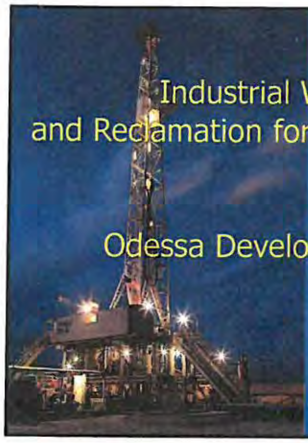
(2) to deliberate the offer of a financial or other incentive to a business prospect described by Subdivision (1).

Should any final action, final decision, or final vote be required in the opinion of the Board with regard to any matter considered in such closed or executive meeting or session, then such final action, final decision, or final vote shall be taken at either:

a. the open meeting covered by the notice upon the reconvening of this public meeting; or
b. at a subsequent public meeting of the council upon notice thereof; as the Board shall determine.

This notice is being posted on the south door of City Hall and on the bulletin board of the first floor of City Hall, Odessa, Texas, this the _____ day of ________________, 2016, at ___________ ___.m., said time being more than seventy-two hours (72) prior to the time at which the subject meeting will be convened and called to order.

Norma Aguilar-Grimaldo, TRMC CMC
City Secretary



Feasibility Study
Industrial Water Management and Reclamation for the Permian Basin

Odessa Development Corporation
February 11, 2016

Interim Report 1
Major Conclusions Based on Region F Water Plan

- Freshwater resources should be reserved for uses where freshwater is most needed.
  - Midland Co. municipal supply has projected deficit beginning in 2030.
  - Ector Co. has sufficient municipal supply if reservoirs not impacted by drought and subordination is achieved.
  - Ector Co. steam-electric supply has projected deficit beginning in 2020.

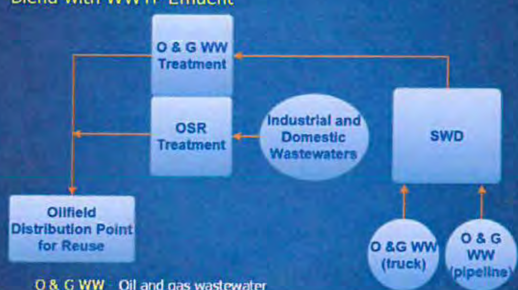
Interim Report 1
Major Conclusions Based on Region F Water Plan (cont).

- Ector Co. has sufficient water for oil and gas production, if 77% of water supply comes from conservation and reuse.
- Midland Co. has sufficient water for oil and gas production based on 79% coming from Ogallala and Edwards-Trinity Aquifers. Both have wells with suitable water quality for domestic use.

Interim Report 2
Reuse Alternatives

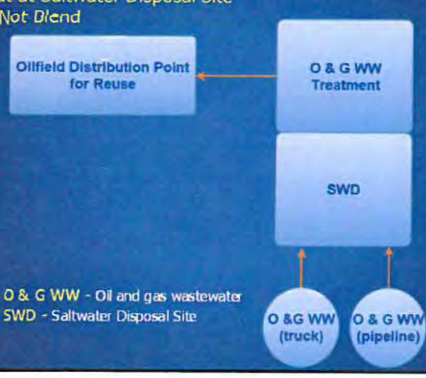
- Identified existing reuse.
- Identified treatment requirements and alternatives for flowback and produced water reuse.
- Identified transport and storage alternatives for flowback and produced water reuse.

Reuse Alternative 1:
Treat at Odessa South Regional WWTP
Blend with WWTP Effluent



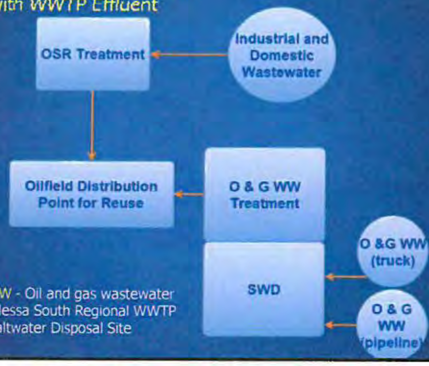
O & G WW - Oil and gas wastewater
OSR - Odessa South Regional WWTP
SWD - Saltwater Disposal Site

Reuse Alternative 2:
Treat at Saltwater Disposal Site
Do Not Blend



O & G WW - Oil and gas wastewater
SWD - Saltwater Disposal Site

Reuse Alternative 3:
Treat at Saltwater Disposal Site
Blend with *WWTP Effluent*



O & G WW - Oil and gas wastewater
OSR - Odessa South Regional WWTP
SWD - Saltwater Disposal Site

Assumptions Common to All Alternatives

- Aggregation
  - Oilfield wastewater is aggregated at an SWD.

Assumptions Common to All Alternatives (cont.)

- Treatment
  - Only treatment provided is removal of oil and suspended solids.
    - *SWD operator will provide preliminary treatment to reduce oil and suspended solids.*
    - *Additional treatment by this project will further remove oil and suspended solids. Estimated costs will be based on walnut-shell filters, which are representative of the technology to be used.*
  - Additional treatment, as needed for down-hole use, will be the responsibility of the E&P operator.

Assumptions Common to All Alternatives (cont.)

- Storage
  - Storage will be provided in 500-barrel tanks.
- Transport
  - All transport will be by buried pipeline.
  - Only the pipeline required to reach an initial delivery point for treated water is part of this project.
  - Transport within and/or between fields is cost of E&P operator.

Preliminary Considerations; Advantages and Disadvantages

Alternative 1 – Treat at OSR Site; Blend with OSR Effluent

Advantages:

- Sufficient land available for treatment units.
- Blending with Odessa South Regional WWTP effluent provides lower total dissolved solids (TDS) content.
- Trained staff already exist and are on-site.

Preliminary Consideration; Advantages and Disadvantages

Alternative 1 – Treat at OSR Site; Blend with OSR Effluent

Disadvantages:

- Disposal of treatment residuals may be difficult.
- E&P operator may have additional cost for algae control in pits.
- Requires transport of wastewater from SWD to OSR

Preliminary Consideration; Advantages and Disadvantages

Alternative 2 – Treat at SWD Site; Don't Blend

Advantage:

- Treatment residuals can be disposed in injection well.

Disadvantages:

- Requires operator staffing at a remote site.
- May require more remote monitoring.

Preliminary Consideration; Advantages and Disadvantages

Alternative 3 – Treat at SWD Site; Blend with OSR Effluent

Advantages:

- Treatment residuals can be disposed in injection wells.
- Blending with OSR effluent provides lower TDS content.

Preliminary Consideration; Advantages and Disadvantages

Alternative 3 – Treat at SWD Site; Blend with OSR Effluent

Disadvantages:

- Requires operator staffing at a remote site.
- May require more remote monitoring.
- E&P operator may have additional costs for algae control in pits.
- Requires transport of treated wastewater to OSR for blending.

Regulatory Considerations

- Concepts Reviewed with Railroad Commission of Texas.
  - Supportive
  - No Major Regulatory Hurdles
- Meeting Planned with Texas Commission on Environmental Quality

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PUBLIC NOTICE

To be published in the Odessa American on Thursday, June 30, 2016.

Public Invited to Meeting to Discuss Industrial Water Management Program

The Gulf Coast Waste Disposal Authority is in the process of completing a two-year study to identify opportunities for reclaiming industrial wastewaters for reuse in the Permian Basin. The study is being funded by the Authority, the Odessa Development Council, and the U.S. Department of Interior Bureau of Reclamation. A draft final report is now available. The public is invited to review the draft final report and to attend a meeting to discuss the report findings.

The report has been developed with input from an Advisory Committee representing key entities in the Odessa-Midland area. The Advisory Committee will meet at 1:00 P.M. on Thursday, June 30 to discuss the draft report. The public is invited to attend this meeting, which will be at the Atmos Energy Permian Basin Operations Center at 2304 Loop 40, Midland, Texas, in the Robert Earl and Sally Fischer Community Room. The building is near the Midland International Airport.

The report concludes that it would be cost-effective to treat flowback and produced water for use in hydraulic fracturing. This could be accomplished at a permanent treatment site. The Authority would own and operate the treatment facility. Implementation of this program could have multiple benefits to the region. It will reduced the demand imposed on fresh and brackish groundwater supplies by hydraulic fracturing operations, allowing those resources to remain available for domestic and agricultural use. It will alleviate some of the traffic on area roadways associated with trucks hauling water for hydraulic fracturing. It will also extend the life of the saltwater disposal wells.

A copy of the report can be obtained at the administration building at the GCA Odessa South Regional Wastewater Treatment Plant located at 2760 Grandview Avenue, Odessa, 79766. For additional information, contact Charles Harris at CHarris@gcwda.com or (432) 580-3866.

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