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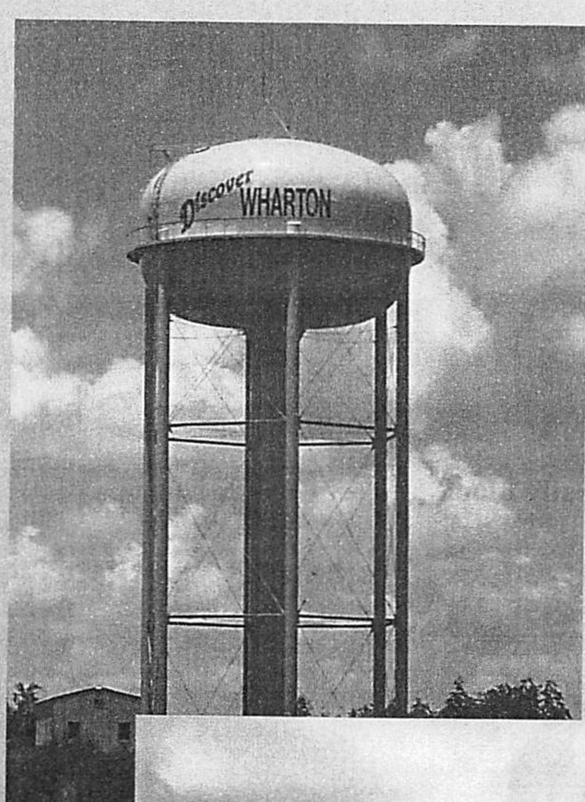
Texas Water Development Board

Research and Planning Fund

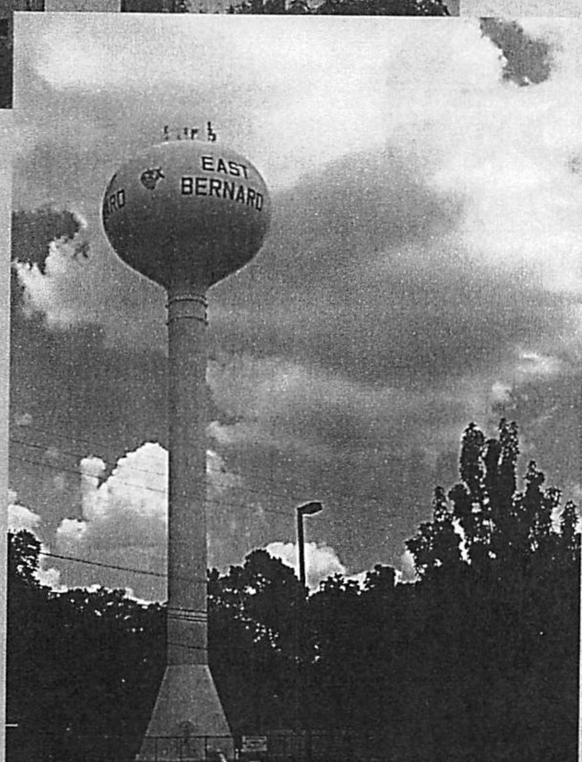
Regional Water Supply Study

For the City of

Wharton, Texas



East Bernard, Texas



In Wharton County, Texas

Prepared by

HALFF

Halff Project 30519C

April 2017

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1. Introduction

The Cities of Wharton and East Bernard in Wharton County currently use groundwater to meet municipal water demands. Wharton's wells have exhibited declining production in recent years and capital improvements projects will be needed in the coming years to repair, rehabilitate, or replace the wells to restore and maintain water production capabilities. An evaluation of water supply options and opportunities available to Wharton is appropriate and timely before the City commits resources to improve its existing water supply system.

Wharton County Water Control and Improvement District #2 (WCID #2) is the public water system that serves a portion of the City of East Bernard. East Bernard desires a water supply evaluation to identify the feasibility of expanding WCID #2's service area to cover all of the city as well as future growth.

Neither Wharton nor East Bernard has experienced significant growth in the last 30 years, but both cities are poised for considerable growth as the Harris County urban area expands. Fort Bend County is currently experiencing that growth, which will likely continue into Wharton County over time. Water supply is an important infrastructure component for both Wharton and East Bernard to ensure they can meet the demands of future growth.

Recognizing that their water supply evaluations could be considered together to develop a regional solution, Wharton and East Bernard teamed to pursue funding for a joint water supply study. In June 2015, the Texas Water Development Board (TWDB) approved a grant for Wharton and East Bernard to fund this Regional Facility Plan under its Research and Planning Fund.

1.1 Objectives and Scope

The primary objectives of this study are to project potential water demands for a minimum 50-year period and evaluate three different water supply options to meet those future demands. The three water supply options include surface water purchased from the Lower Colorado River Authority, continued groundwater production, and aquifer storage and recovery (ASR). This project included a hydrogeological assessment of the two water supply alternatives involving groundwater production. Intera performed this assessment, which includes numerical models of groundwater flow that predict drawdown and subsidence as a result of increased pumping to meet the future demands. The project scope also includes consideration of conservation as part of the water supply evaluation and an update to Wharton's water conservation plan.

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2. Planning Area

2.1 Study Area Boundaries

The cities of Wharton and East Bernard comprise the planning area for this study. Wharton is located on the Colorado River approximately 50 miles upstream from Matagorda Bay and 60 miles southwest of Houston along US Highway 59. Wharton is the county seat of Wharton County. East Bernard is located on the San Bernard River and US Highway 90 Alt, approximately 15 miles north of Wharton along Texas Highway 60. Figure 2-1 shows the boundaries of each city.

Wharton owns and operates its municipal utility system, which includes potable water supply and distribution, as well as wastewater collection and treatment. As mentioned previously, East Bernard does not operate a municipal utility; WCID #2 operates the public water system that serves the area within East Bernard's municipal boundaries shown in Figure 2-2. Residents and businesses outside of the Wharton County WCID #2 service area obtain water from private wells. No centralized wastewater collection or treatment is provided in WCID #2 or East Bernard.

The planning assumptions developed for this study recognize that East Bernard and WCID #2 are separate entities. Historical populations are from East Bernard, and historic water data has been provided by WCID #2. Future projections for growth, increased water demand and additional water supplies are discussed relative to East Bernard. All future growth is assumed to be served by the public water system in East Bernard, regardless of who owns and operates it.

Neither Wharton nor WCID #2 currently hold a Certificate of Convenience and Necessity (CCN) for their utilities. A CCN grants the exclusive right to provide retail water and/or sewer utility service to an identified geographic area. In turn, a CCN holder must provide continuous and adequate service to the area within its CCN boundary. Municipalities and districts are not required to have a CCN; however the certificate protects the interests of a utility from outside competition. An entity may not provide utility services within an area for which another utility holds a CCN.

2.2 Historical Populations

Historical population values for Wharton and East Bernard are shown in Table 2-1 and charted in Figure 2-3. Wharton's population has been relatively constant for 35 years, even showing slight declines since 2000. The East Bernard community was originally settled in the 1850's, but the City of East Bernard did not incorporate until about 2000. Therefore, historic population data is limited.

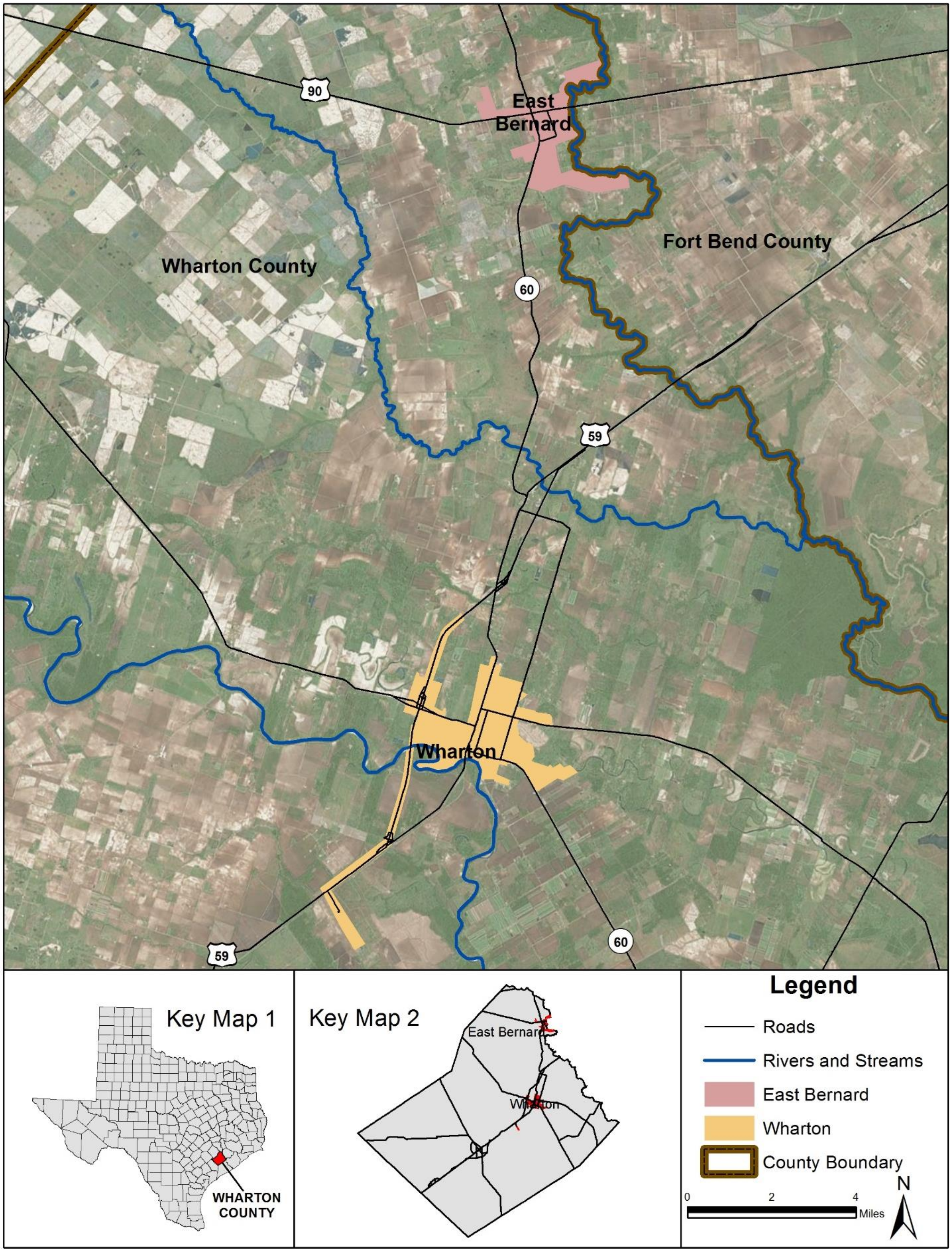

Figure 2-1 Study Area

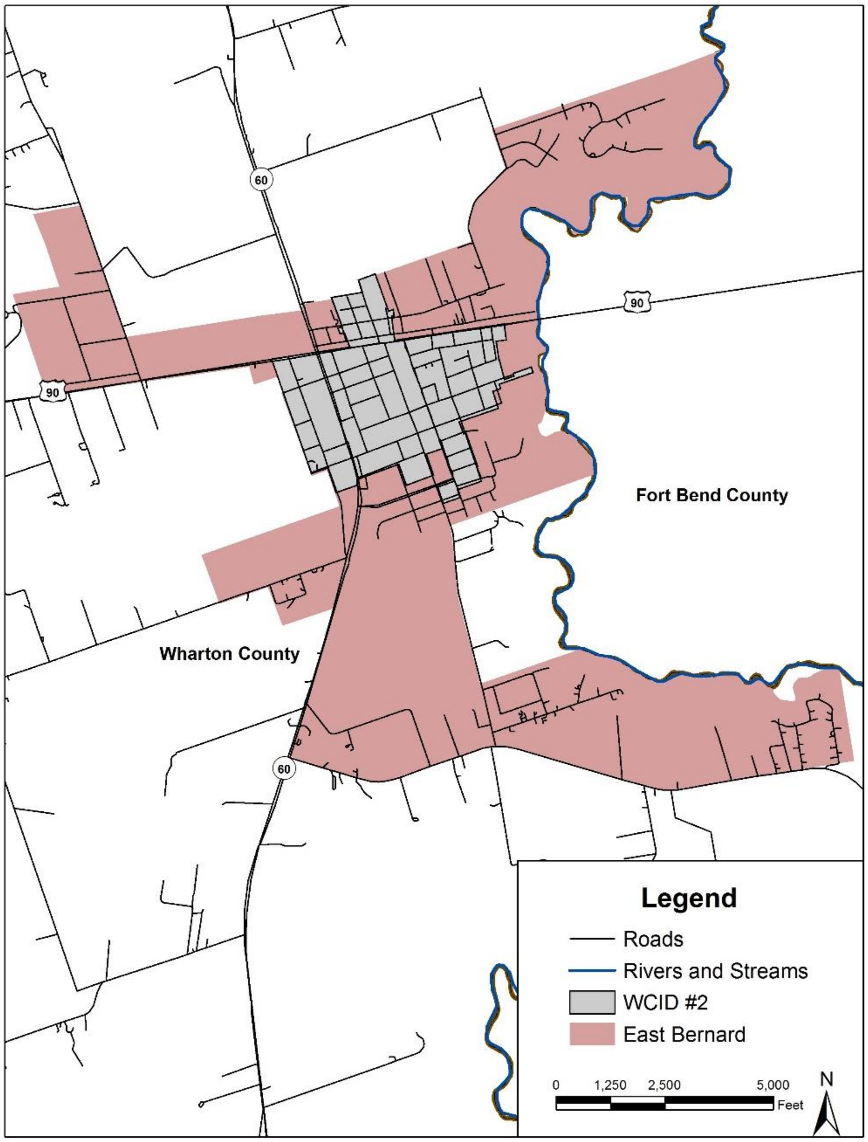

Figure 2-2 Wharton County WCID #2 Water Service Area

Table 2-1 Historical Population for Wharton and East Bernard

Year	Wharton	East Bernard
1960	5,734	-
1970	7,881	-
1980	9,033	-
1990	9,011	-
2000	9,237	-
2010	8,832	2,272
2015	8,726	2,304

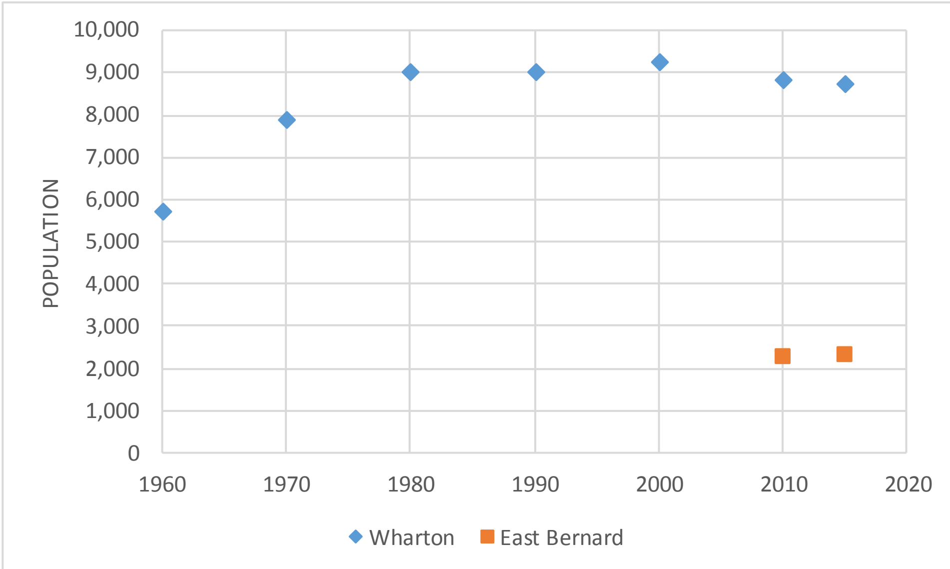

Figure 2-3 Historical Population for Wharton and East Bernard

2.3 Historic Water Demands

2.3.1 Historic Average Day Demands

Tables 2-2 and 2-3 show total annual water production for Wharton and East Bernard (served by WCID #2), respectively, for the previous five years. The total produced water is metered at the source and represents all water treated for distribution. Wharton's average annual demand since 2011 is 1.43 million gallons per day (mgd) and East Bernard's is 0.35 mgd.

Wharton and East Bernard's reported per capita demands are similar and both have exhibited a declining trend for the last five years (Figure 2-4). The average gallons per capita per day (gpcd) amounts are used as the baseline for water demand projections in the Section 3 of this study.

Table 2-2 Historic Water Demands for the City of Wharton

Year	Pop. Served	Well Prod.	MGD
2011	8,799	563,305,000	1.54
2012	8,758	522,367,000	1.43
2013	8,731	516,501,000	1.42
2014	8,659	503,843,000	1.38
2015	8,726	506,169,000	1.39
		Average	1.43

Table 2-3 Historic Water Demands for the City of East Bernard

Year	Pop. Served	Well Prod.	MGD
2011	2,494	164,700,000	0.45
2012	2,490	121,560,000	0.33
2013	1,990	129,360,000	0.35
2014	2,090	110,390,000	0.30
2015	2,100	108,110,000	0.30
		Average	0.35

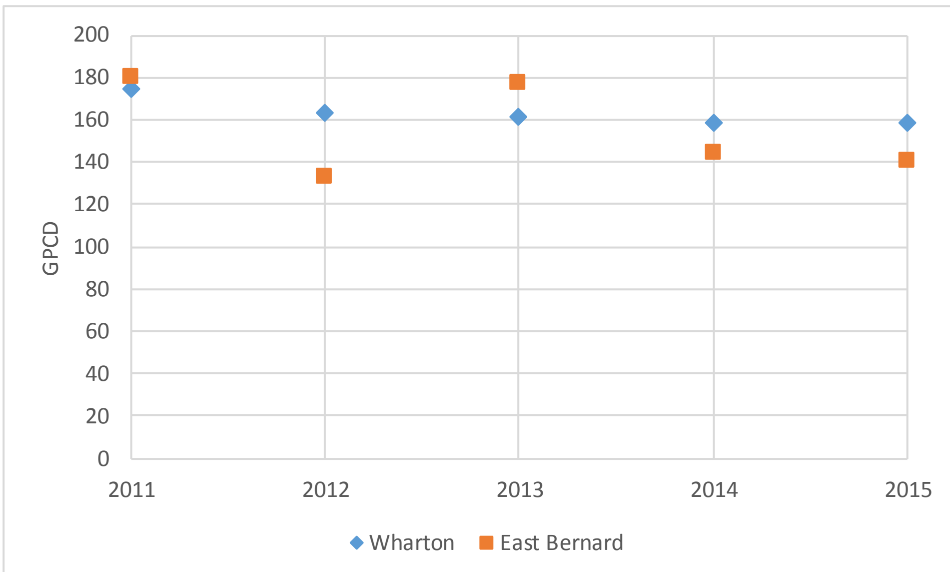

Figure 2-4 Historical Per Capita Water Demands

2.3.2 Historic Maximum Day Demand

Wharton's maximum day demand occurred on July 3, 2013, when 2.43 million gallons of water were pumped. Wharton's resulting ratio of maximum day:average annual daily demand is approximately 1.72. However, a ratio of 1.85 is used in this study for future projections to be consistent with Texas Commission on Environmental Quality (TCEQ) criteria and to provide a conservative planning basis.

2.4 Existing Water Supplies

Wharton and East Bernard both currently use groundwater as their sole source of potable water. Wharton operates four wells within the city, which are described in Table 2-4. Two additional small wells at the Wharton airport provide water to hangars, but are not discussed in this report, as they are not viable as a significant source of long-term water supply. Figure 2-5 shows the existing wells in Wharton. Wells #1 and #3 (which are on the same site) and well #4 all pump into a ground storage tank on their respective sites. Water is chlorinated and fluoride is added before entering the tanks, and then pumped out to distribution via a booster pump station. Well #2 pumps directly into the distribution system; water is chlorinated prior to the 20,000-gallon pressure tank on site.

Table 2-4 Existing Wharton Wells

Well #	Well Name (street)	Year Constructed	2016 Pumping Rate (gpm)	2015 Total Gallons Pumped
1	Alabama	1949	636	83,173,000
2	Cloud	1953	963	151,758,000
3	Alabama	1965	513	69,927,000
4	Valhalla	1985	613	201,311,000

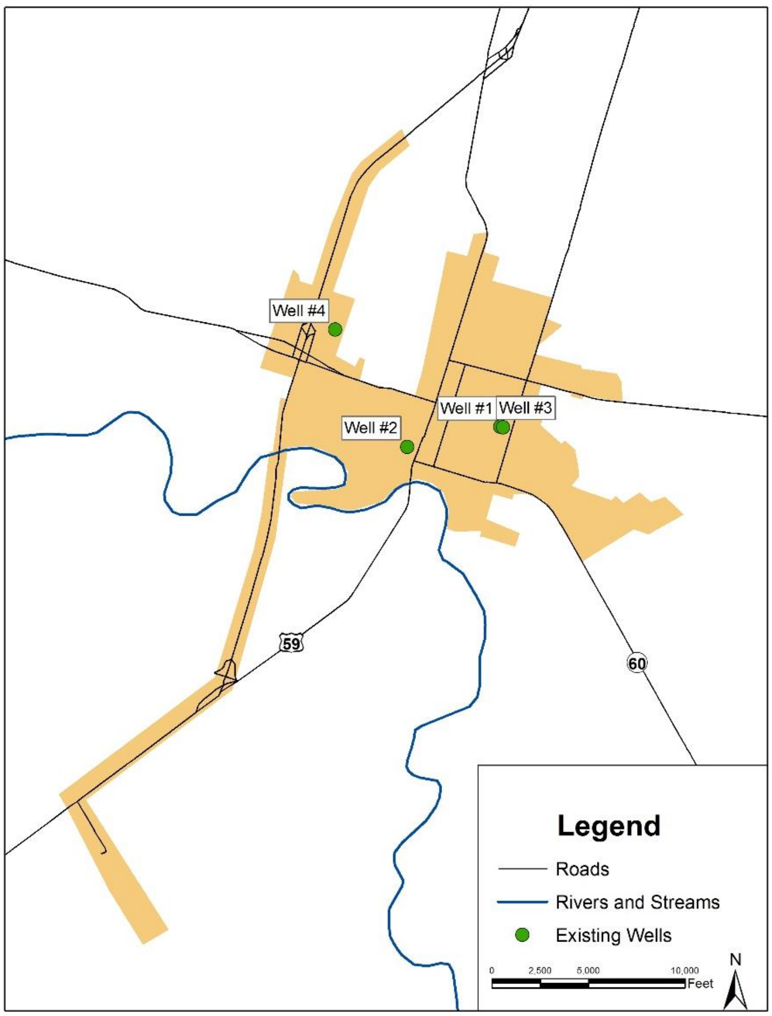

Figure 2-5 Existing Wharton Wells

The wells that WCID #2 operates are described in Table 2-5 and the location of each can be seen in Figure 2-6.

Table 2-5 Existing East Bernard Wells

Well #	Well Name (street)	Year Constructed	2016 Pumping Rate (gpm)	2015 Total Gallons Pumped
1	Leveridge/Shannon	1976	650	60,060,000
2	Bernard Timbers	1967	100	11,510,000
3	Leveridge	2014	750	N/A

East Bernard's Well #3 was constructed in 2014 but was not placed in service until 2016, thus the well produced no water in 2015.

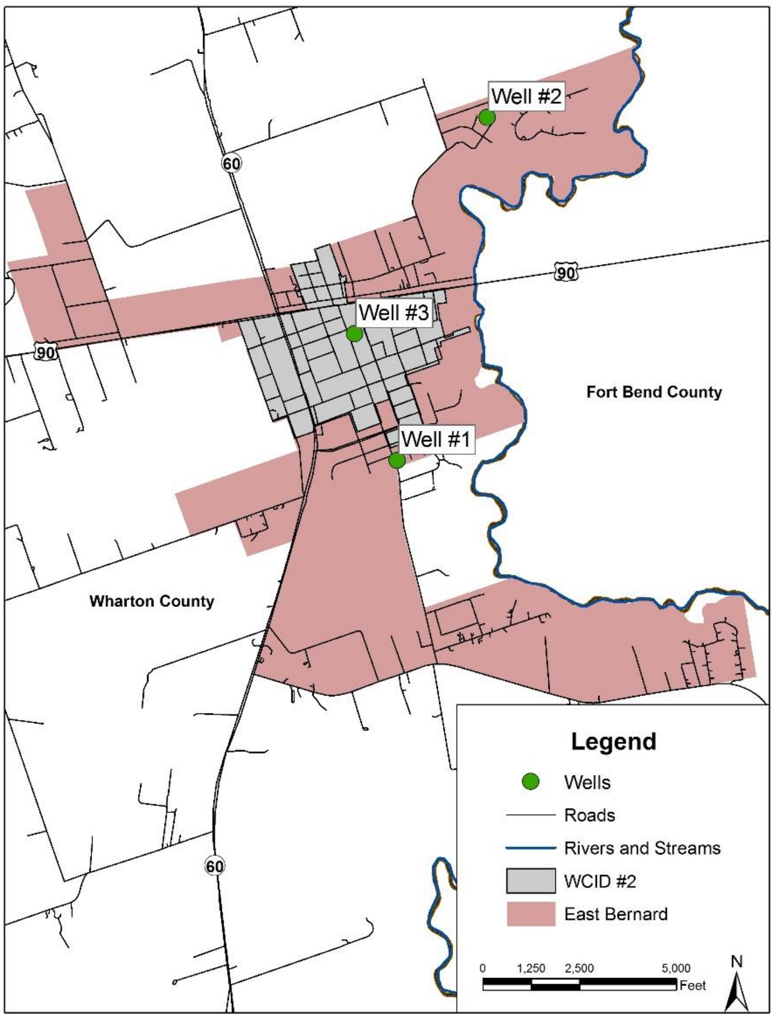

Figure 2-6 Existing WCID #2 Wells

2.4.1 Existing Permit Information

Both Wharton and East Bernard have existing well permits in place that expire in 2017 (Appendix A). Table 2-6 shows the number of wells covered by each permit and the three-year authorized withdrawal, as well as an average daily withdrawal amount. However, WCID #2's permit does not reflect its actual well conditions. One of the four wells covered by the permit has already been decommissioned and another is in the process of being decommissioned in favor of a new, larger well. The new well became fully operational in 2016.

Table 2-6 Current Permitted Groundwater Supply

City	Number of wells covered by permit	3-Year Authorized Withdrawal (ac-ft)	Authorized Withdrawal (MGD)
Wharton	4	5382.7	1.60
WCID #2	4	1500	0.45

2.4.2 Total Existing Water Supply Available

The total groundwater production capacity of Wharton's wells in their current state is approximately 3.92 mgd. Three of the four wells have seen a marked decline in production capacity in recent years; potential causes for the declining production are discussed further in Section 12.2. The cumulative original capacity of the four wells is 5.18 mgd. However, Wharton's three year permitted withdrawal amount is only 5382.57 ac-ft, which equals an average daily withdrawal of 1.6 mgd. Table 2-7 shows Wharton's historical percentage of annual demand relative to their authorized permitted withdrawal. The average daily withdrawal was closest to being exceeded in 2011, which was a year of significant drought. With an expected increase in population and the potential of future droughts, permitted withdrawal amounts should be increased whenever possible.

Table 2-7 Wharton's Historic Percentage of Authorized Withdrawal Used

Year	Average Authorized Withdrawal (MGD)	Average Annual Daily Demand (MGD)	Percentage of Authorized Withdrawal
2011	1.56	1.54	99%
2012	1.56	1.43	92%
2013	1.56	1.42	91%
2014	1.60	1.38	86%
2015	1.60	1.39	87%

East Bernard's pumping capacity is 2.16 mgd, and the existing wells have shown no significant decrease in pumping capacity.

3. Planning Area Projections and Assumptions

3.1 Limits of Study

The future service area for the purposes of this study include the cities of Wharton and East Bernard. These municipalities' corporate boundaries are expected to expand with increased population. Growth in other Wharton County communities in the study vicinity is also likely within the planning timeframe. The water supply alternatives considered in this study can be scaled to meet the needs of other local communities in the county if deemed beneficial in the future. However, the alternatives developed in this study are conceptually sized and compared based on the needs of only Wharton and East Bernard.

As described in Section 2.1, WCID #2 currently provides water to the developed portion of East Bernard. WCID #2 has expressed reluctance to expand its service boundaries to serve additional residents. For this reason, this study assumes that East Bernard will develop a public water system that will serve all future growth.

3.1.1 Planning Timeframe

The planning window for this study spans to 2070. Population and water demand projections presented in this section are developed incrementally over this period. Infrastructure for water supply alternatives are sized based on the demand projections at the end of this period.

3.1.2 Potential Partners/Wholesale Customers

This study assumes that neither Wharton nor East Bernard will provide wholesale or retail potable water to public water systems or utility districts other than their own. However, proactively planning for future water supply needs place both cities in a place where they could become a water supply alternative for other municipalities or utility districts in the region. If future partners or wholesale customers arise within the planning study, the water supply alternative can be scaled to meet the actual required demands.

3.2 Projected Populations

The population of The City of Wharton currently is slightly less than 9,000, while approximately 2,300 live in East Bernard. The TWDB has developed population projections through 2070 for Wharton and East Bernard that reflect roughly 0.6 percent annual growth. This modest growth rate reflects historic trends, but it does not account for the potential impacts of the likely eventual Houston urban area expansion into Wharton County. The modest growth rate reflected by the TWDB population projections also do not result in a need for additional water supply for Wharton or East Bernard. Alternate population projections have been developed for this study that deviate from the TWDB projections to provide a conservative target for future planning.

Harris County suburban cities have experienced the effects of the Houston urban area expansion to various extents over the previous 50 years. Table 3-1 shows populations and 50-year historic growth rates of cities in Harris County, as well as the countywide 50-year growth rate that excludes Houston itself. This data shows that the 50-year growth of suburban cities in Harris County has averaged approximately 5 percent annually.

Table 3-1 Historical Populations and Growth Rates for Cities in Harris County[1]

City	1960	1970	1980	1990	2000	2010	50 Year Growth Rate
Baytown	28,159	43,980	56,923	63,850	66,430	71,802	3.1%
Bellaire	19,872	19,009	14,950	13,842	15,642	16,855	-0.3%
Deer Park	4,865	12,773	22,648	27,652	28,520	32,010	11.2%
Friendswood	-	5,675	10,719	22,814	29,037	35,805	13.3%
Katy	1,569	2,923	5,660	8,005	11,775	14,102	16.0%
La Porte	4,512	7,149	14,062	27,910	31,880	33,800	13.0%
Missouri City	604	4,136	24,423	36,176	52,913	67,358	221.0%
Morgan's Point	560	593	428	341	336	339	-0.8%
Nassau Bay	-	-	4,526	4,320	4,170	4,002	-0.4%
Pasadena	58,737	89,957	112,560	119,363	141,674	149,043	3.1%
Seabrook	-	3,811	4,670	6,685	9,443	11,952	5.3%
South Houston	7,532	11,527	13,293	14,207	15,833	16,983	2.5%
Southside Place	-	1,466	1,366	1,392	1,546	1,715	0.4%
Spring Valley	3,004	3,170	3,353	3,392	3,611	3,715	0.5%
Tomball	1,713	2,734	3,996	6,370	9,089	10,753	10.6%
Waller	900	1,123	1,241	1,493	2,092	2,326	3.2%
Webster	329	2,231	2,405	4,678	9,083	10,400	61.2%
West University	14,628	13,317	12,010	12,920	14,211	14,787	0.0%
Harris County Pop.	146,984	225,574	309,233	375,410	447,285	497,747	**4.8%**

The Houston and Harris County urban area has started expanding into counties adjacent to Harris County, including Fort Bend County. This expansion is expected to continue, particularly along the Highway 59 corridor as it expands and is replaced by Interstate 69. Therefore, a five percent linear growth was used as the average annual growth rate for the Wharton and East Bernard population projections shown in Table 3-2. Recognizing that this growth rate will not be realized immediately, a 10-year continuation of TWDB's projected growth was built into the population projections for both cities. Even with this 10-year delay for the alternate growth rate, it is recognized that these projections do not correspond with population growth projected by the Region K planning group in previous state water plans. Further, the Region K planning group is not likely to adopt these population projections for state water plans in the near future.

[1] United States Census Bureau

Nevertheless, the projections suit the purpose of this study by providing a conservative, consistent target for evaluating future water supply alternatives.

Figure 3-1 shows the population projections graphically. Linear growth has been assumed since the primary goal of this study is to evaluate water supply needs for the possible demands in 2070. Accurately predicting the time of need for new water supplies and infrastructure capacity expansions is not a primary goal of this study, so non-linear growth assumptions were deemed unnecessary.

Table 3-2 Projected Populations for Wharton and East Bernard

Year	Wharton	East Bernard
2010	8,832	2,272
2015	8,726	2,304
2020	9,372	2,411
2025	9,673	2,489
2030	12,091	3,111
2035	14,510	3,734
2040	16,928	4,356
2045	19,346	4,978
2050	21,764	5,600
2055	24,183	6,223
2060	26,601	6,845
2065	29,019	7,467
2070	31,437	8,089

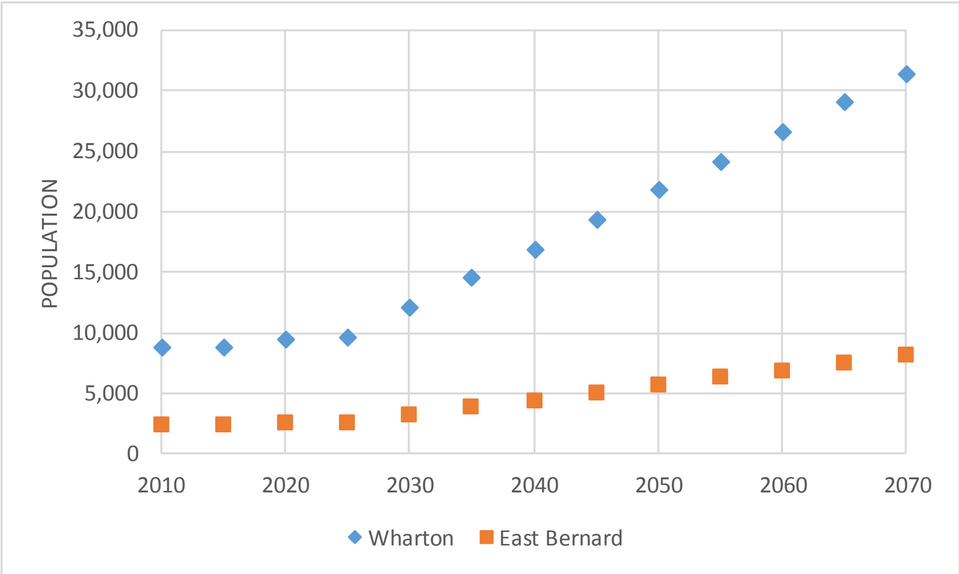

Figure 3-1 Study Area Population Projections

3.3 Projected Water Demands

Projected water demands for this study are based on historical per capita water demand rates. Wharton's historical water use has been approximately 164 gpcd, while East Bernard's has been approximately 156 gpcd (Table 3.3). These water usage amounts were multiplied by the assumed future populations to project average annual daily demands (Table 3-4 and Figure 3-2).

Table 3-3 Basis of Water Demand Projections

City	Historical GPCD	Max Day Factor
Wharton	164	1.85
WCID #2	156	1.85

Table 3-4 Projected Average Annual Daily Water Demands (mgd)

Year	Wharton	East Bernard	Combined
2010	1.45	0.30	1.75
2015	1.39	0.30	1.69
2020	1.54	0.38	1.91
2025	1.58	0.39	1.97
2030	1.98	0.48	2.47
2035	2.38	0.58	2.96
2040	2.77	0.68	3.45
2045	3.17	0.78	3.94
2050	3.57	0.87	4.44
2055	3.96	0.97	4.93
2060	4.36	1.07	5.42
2065	4.75	1.16	5.92
2070	5.15	1.26	6.41

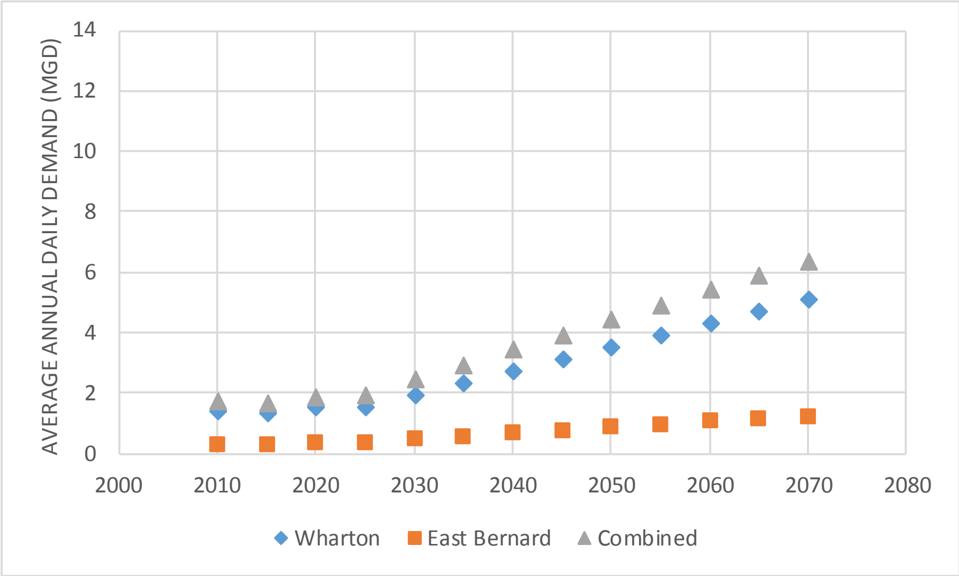

Figure 3-2 Average Annual Daily Demand Projections

Water supply infrastructure needs to be sized to meet the maximum daily demand in a given year. Future max day demands were projected for Wharton and East Bernard using a maximum day:average day demand ratio of 1.85. Table 3-5 and Figure 3-3 show the projected individual and total combined maximum demands. The combined maximum demand is the basis for sizing all future regional water supply options.

Table 3-5 Projected Max Day Water Demands (mgd)

Year	Wharton Max Day	East Bernard Max Day	Combined Max Day
2010	2.68	0.56	3.23
2015	2.57	0.56	3.13
2020	2.84	0.69	3.54
2025	2.93	0.72	3.65
2030	3.66	0.90	4.56
2035	4.40	1.08	5.47
2040	5.13	1.25	6.39
2045	5.86	1.43	7.30
2050	6.60	1.61	8.21
2055	7.33	1.79	9.12
2060	8.06	1.97	10.0
2065	8.80	2.15	10.9
2070	9.53	2.33	11.9

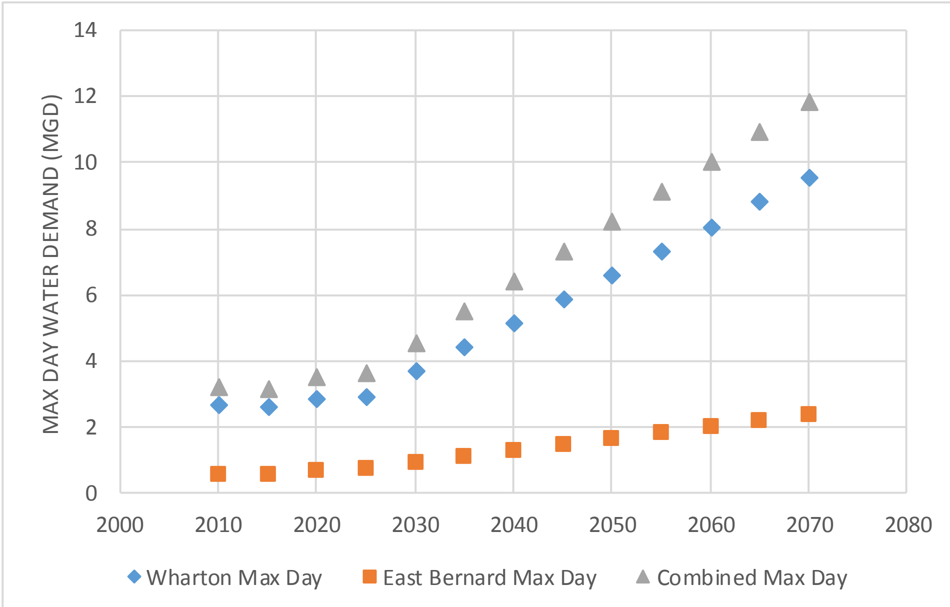

Figure 3-3 Max Day Demand Projections

4. Water Supply Alternatives – Overview

Three general alternatives have been identified as viable sources of additional water supply for Wharton and East Bernard. Each of the alternatives, as well as the options associated with each, are listed below.

1. Surface Water – Involves purchase of water from Lower Colorado River Authority (LCRA) and decommissioning existing wells
2. Groundwater
   a. Drill additional wells individually for each city
   b. Establish a location for a shared well field between Wharton and East Bernard
3. ASR

Each of these options is discussed at further length in subsequent sections.

4.1 Fate of Existing Water Supply Sources

In the groundwater and ASR water supply options, the existing wells in each city are assumed in this study to be replaced on the same site as they currently exist when they reach the end of their useful life. The existing wells or their replacements remain part of the groundwater supply system.

The existing wells could also remain in operation in the surface water alternative. One potential strategy would involve designing new surface water conveyance and treatment infrastructure to meet average annual projected demands and supplement this supply with groundwater to meet seasonal peak demands. Another strategy could be to continue to use existing groundwater sources to meet existing demands and develop a surface water alternative to meet future demands. Both strategies would result in less capacity needed for the surface water conveyance and treatment infrastructure compared to a strategy in which groundwater is no longer used at all.

While strategies exist to use both ground and surface water, existing wells are assumed to be decommissioned for the surface water supply alternative presented in this study. Blending ground and surface water causes concerns related to treatment methodologies and effectiveness. Additional study would be needed to understand potential water quality concerns, identify the best place to blend the two sources (pre- or post-treatment), and suitable treatment processes, including disinfection methods. The strategy of seasonal supplementation of surface water with groundwater makes this water quality analysis more complex and would place significantly more burden on water system operators; this strategy is not recommended.

More significantly, economies of scale will benefit raw surface water conveyance and treatment infrastructure that is constructed to meet the total water demands for the project period, not just new demand growth, which occurs in future years. The cost of water on a unit volume basis is expected to be higher if a combination of surface and groundwater sources are used to meet demands relative to a single source. For these reasons, existing wells are assumed to be decommissioned in the surface water supply options.

4.2 Water Supply Assumptions

Proposed new wells in this study are assumed to each produce 1,500 gpm, or 2.2 mgd. Actual capacity of individual wells is expected to be between 1,200 and 3,200 gpm (1.7 to 4.6 mgd), but will not be confirmed until yield tests are performed at proposed well sites. Pierce Ranch has drilled five new wells in the past few years capable of producing more than 3,000 gpm each, so Wharton and East Bernard may be able to construct new wells that produce more than the assumed 1,500 gpm.

The following additional assumptions are made in this study in the development and evaluation of water supply alternatives

- Each new well site includes a ground storage tank and a pump station.
- Pipeline alignments follow highways and county roads to minimize the amount of property acquisition required.
- Regional water supply alternatives are sized to serve new growth in East Bernard, but WCID#2 is assumed to continue to serve their existing customers.

4.2.1 Unified Costing Model

Texas Water Development Board's Unified Costing Model (UCM) for Regional Water Planning was utilized in development of the cost estimates. The UCM was developed for 16 regional water planning groups in Texas and assures consistent planning-level cost estimates for water supply projects statewide. The UCM allows the user to input the most recent values for Producer Price Index (PPI – used for pipelines) and Engineering News Record Construction Cost Index (CCI – used for all other facilities) in order to develop a present-day cost estimate. June 2016 PPI and August 2016 CCI index values were used in this study.

4.2.2 Capital Cost Analysis

A number of assumptions were made regarding capital cost, which are listed below.

1. Pipeline lengths are based on conceptual alignments that follow roads when possible, as mentioned previously.
2. Pipeline diameters are based on a conceptual level analysis of a hydraulic grade profile.
3. Intake structures and pump stations are sized to meet 2070 max day demands.
4. Total ground storage capacity is equal to the 2070 max day demand less existing capacity.
5. Cost of professional services (engineering, survey, permitting, financing, legal), land acquisitions, and contingencies is assumed to be 40 percent of total capital cost.
6. The cost shown for shared infrastructure is pro-rated based on the percentage of 2070 demand projected for each city.
7. The UCM does not reflect inflation, so all costs reflect 2016 values.

4.2.3 Annual Cost Analysis

Annual cost estimates were developed using the following inherent UCM assumptions:

1. Debt service is 30 years at 5.5 percent interest
2. Pumping energy cost is $0.09/kW-hr
3. Annual Operations and Maintenance Costs (by percent of capital):
    a. 1 percent for pipe, storage, and wells
    b. 2.5 percent for pump stations
    c. 10 percent for water treatment plant

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5. Water Supply Alternative 1 – Surface Water

Purchasing raw surface water is the first of three water supply options considered for Wharton and East Bernard. The LCRA controls the rights to more than 2.1 million acre-feet of water per year, which includes most of the available surface water rights in the project area. LCRA manages these rights in a water supply system serving municipalities and potable water utility systems, businesses, industries and other beneficial uses, while maintaining environmental flows and providing flood control.

Surface water purchased from LCRA falls into one of two primary categories. Firm water supply is water available during severe drought conditions, while the interruptible water supply is water available for irrigation and other non-firm uses that are subject to occasional disruptions in times of drought. LCRA is in the process of constructing a new off-channel reservoir near Lane City that is projected to provide an additional 90,000 acre-feet of firm water to the region's supply.

The surface water supply alternative considered in this study entails entering a firm water supply contract to purchase raw surface water from LCRA. The various infrastructure and permitting requirements and costs associated with this option are discussed in the following sections.

5.1 Infrastructure Needs

Figure 5-1 shows a schematic of Alternative 1, which includes the following basic infrastructure:

- intake pump station;
- raw water pipeline;
- water treatment plant;
- finished water pipeline; and
- ground storage and distribution pumping in each city.

LCRA controls the location of points of availability, which is where water is withdrawn. The point of availability for Wharton and East Bernard is assumed to be on the Colorado River, as shown in Figure 5-1, but could also be at a nearby canal or the off-channel reservoir that is being built in Lane City. The intake station will include multiple pumps to convey water to a treatment facility. The station will need an adequate source of electric power to drive the pumps and ancillary equipment. The pump motors and other powered equipment must be protected from flooding. The station also requires mechanically cleaned screens to protect the pumps from solid materials carried in the water.

Compared to groundwater, raw surface water often requires significantly more treatment to make it safe for potable consumption. A surface water treatment facility typically includes chemical addition, mixing and flocculation basins, sedimentation basins, filters and disinfection. Membrane filtration may also be used to replace or augment some of these conventional treatment units. After treatment, water will be stored in clear wells (ground storage tanks) and pumped from a pump station on the water plant site. The treatment plant is assumed to be located in or near Wharton,

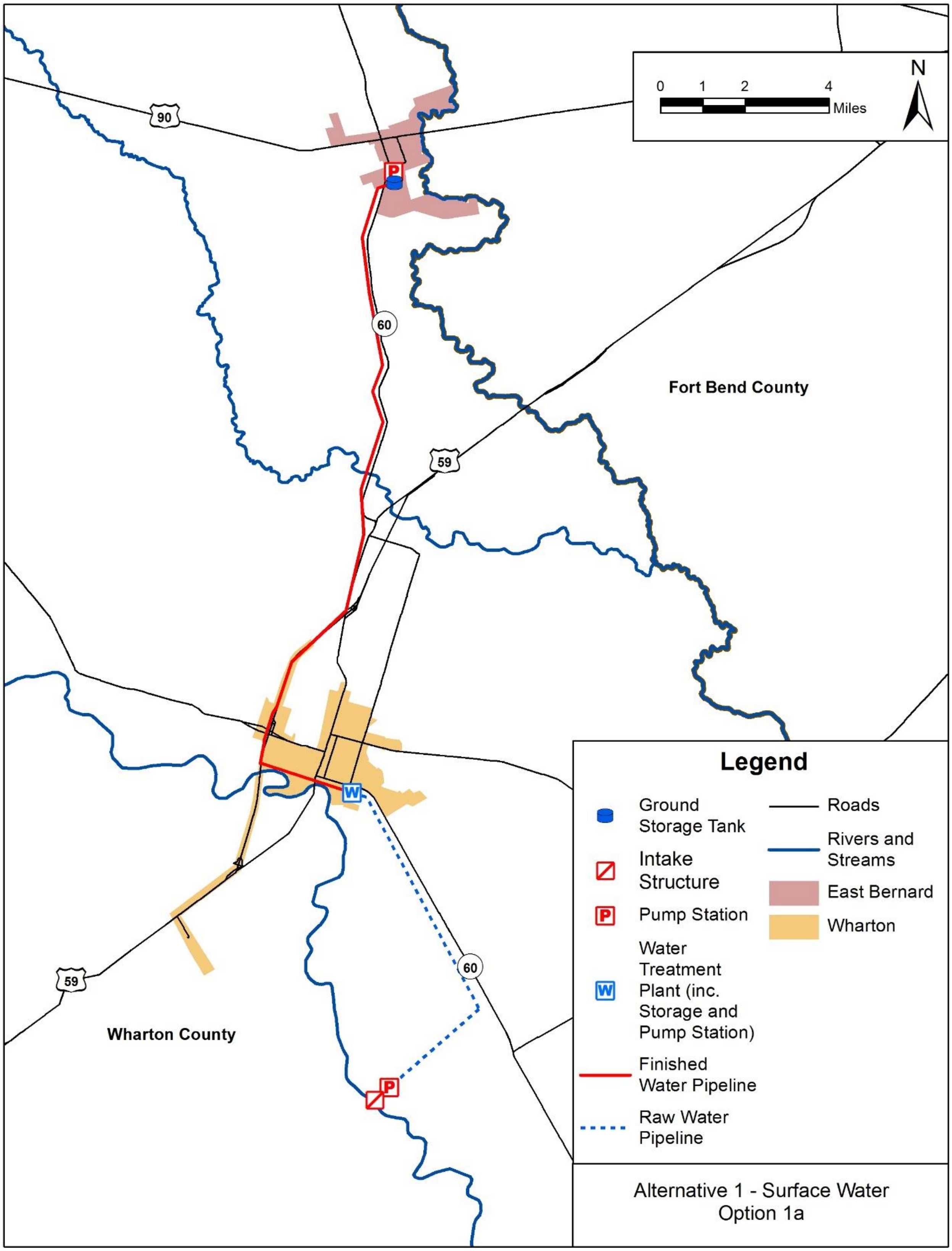

Figure 5-1 Alternative 1 - Surface Water Schematic

with water assumed to be pumped directly into Wharton's distribution system. Separate pumps in the same station will convey water to a ground storage tank in East Bernard via a finished water transmission main. This alternative includes the cost of a distribution pump station in East Bernard to pump from the ground storage tank into its distribution system.

The intake pump station and water treatment plant were sized based on total maximum day 2070 water demands, while the pipeline sizes and classes were based on total water conveyance and a conceptual level analysis of a hydraulic grade profile. Distribution pump stations are sized for water conveyance in each city. Each city will be provided with enough ground storage to meet 2070 average day demands, as mentioned in Section 4.2.2.

5.2 Program Cost Estimates

Table 5-1 breaks out the total capital cost, annual cost, and unit costs of water for both Wharton and East Bernard.

Table 5-1 Surface Water Alternative Projected Costs

Capital Costs			
Item	**Wharton**	**East Bernard**	**Total**
Pump Stations	$10.3 M	$3.5 M	$13.8 M
Pipeline	$8.4 M	$7.4 M	$15.8 M
Water Treatment Plant	$33.6 M	$5.9 M	$39.5 M
Ground Storage	$3.0 M	$1.0 M	$4.0 M
Professional Services and Contingencies	$22.5 M	$6.5 M	$29.0 M
Total Cost	**$78 M**	**$24 M**	**$102 M**
Annual Costs			
Item	**Wharton**	**East Bernard**	**Total**
Debt Service (30 yrs)	$5.40 M	$1.70 M	$7.10 M
O&M	$3.80 M	$0.70 M	$4.50 M
Pumping Energy	$0.20 M	$0.10 M	$0.30 M
Purchase of Water	$0.70 M	$0.10 M	$0.80 M
Total Cost	**$10.1 M**	**$2.6 M**	**$12.7 M**
Annual Water Cost	**Wharton**	**East Bernard**	**Total**
($/ac-ft/yr)	$1,749	$2,419	$1,852
($/1000 gal)	$5.37	$7.42	$5.68

The cost to purchase water from LCRA is currently $145/ac-ft of water used. This rate was assumed to remain constant throughout the study period, with only the demand changing. The average annual cost of water, excluding inflation, is included in Table 5-1 in the row labeled "Purchase of Water."

5.3 Permitting and Regulatory Requirements

The intake structure and pipelines for the surface water supply alternative will impact Waters of the United States and will therefore require a US Army Corps of Engineers permit for construction. The effort and time to obtain a permit will depend on the magnitude of impacts on waterways and wetlands.

The terms of LCRA's standard water supply contract establish the primary conditions governing this option. The following list summarizes a few of the key terms.

- The duration of an LCRA water supply contract for municipal water supply is a minimum of five years and a maximum of 40 years.
- As mentioned previously, the cost to purchase water from LCRA is currently $145/ac-ft.
    - A portion of this amount is due to LCRA in an annual payment, currently calculated as half of the $145/ac-ft water rate, or $72.50/ac-ft, multiplied by the volume of water reserved.
    - The other half of the water cost ($72.50/ac-ft) is billed on a monthly basis for the actual volume of water used in that month.
- LCRA requires municipal customers to develop, submit and implement Drought Contingency and Water Conservation Plans that are consistent with LCRA's rules and state laws.
- Municipal customers who divert but do not use water from LCRA must return the surplus water to the Colorado River or a tributary.
- LCRA does not allow interbasin transfers outside of its service area without special approval, which would be required for East Bernard if its future water service area expands east of the San Bernard River into Fort Bend County.
- LCRA requires its water purchasers to obtain necessary state approvals and permits for wastewater treatment and disposal facilities, including on-site sewage facilities within its service area. The standard water supply contract provides LCRA the right to access the wastewater treatment plants of its purchasers to collect samples for testing to determine permit compliance.

The LCRA manages its water supply obligations and flood control operations in accordance with its state-approved Water Management Plan. During drought conditions, LCRA customers are required to reduce water demands in accordance with the trigger provisions of their Drought Contingency plans. In times of severe drought, LCRA may curtail its firm water supply to its customers on a pro-rated basis. Therefore, this surface water supply option is vulnerable to climactic conditions and is not completely risk-free relative to the availability of water.

6. Water Supply Alternative 2 – Additional Groundwater

Two alternatives have been identified for Wharton and East Bernard to continue using groundwater as a water supply source:

1. Drill additional wells in each city as needed, referenced as Alternative 2a
2. Develop a shared regional well field for both cities, referenced as Alternative 2b.

The infrastructure and costs associated with each of these groundwater supply alternatives are discussed in this section.

6.1 Infrastructure Needs

The infrastructure required for Alternative 2a includes additional groundwater wells in each city, with ground storage and a booster pump station at each new site and a pipeline connecting each booster station to the existing water distribution system. A preliminary schematic of Alternative 2a is shown in Figure 6-1. Well locations shown are based on discussions with city officials and are subject to change following pump tests at each site.

The infrastructure required for Alternative 2b includes a shared well field between the two cities, ground storage and a transmission pump station at the well field, a transmission pipeline from the well field to Wharton and East Bernard, ground storage in each city, and distribution pump stations in each city. The pump station at the well site was sized for 2070 max day demands, while the ground storage at the same location was sized to meet one day of 2070 average day demands. The pipeline sizes and classes were based on total water conveyance and a conceptual level hydraulic grade profile. A preliminary schematic of Alternative 2b is shown in Figure 6-2.

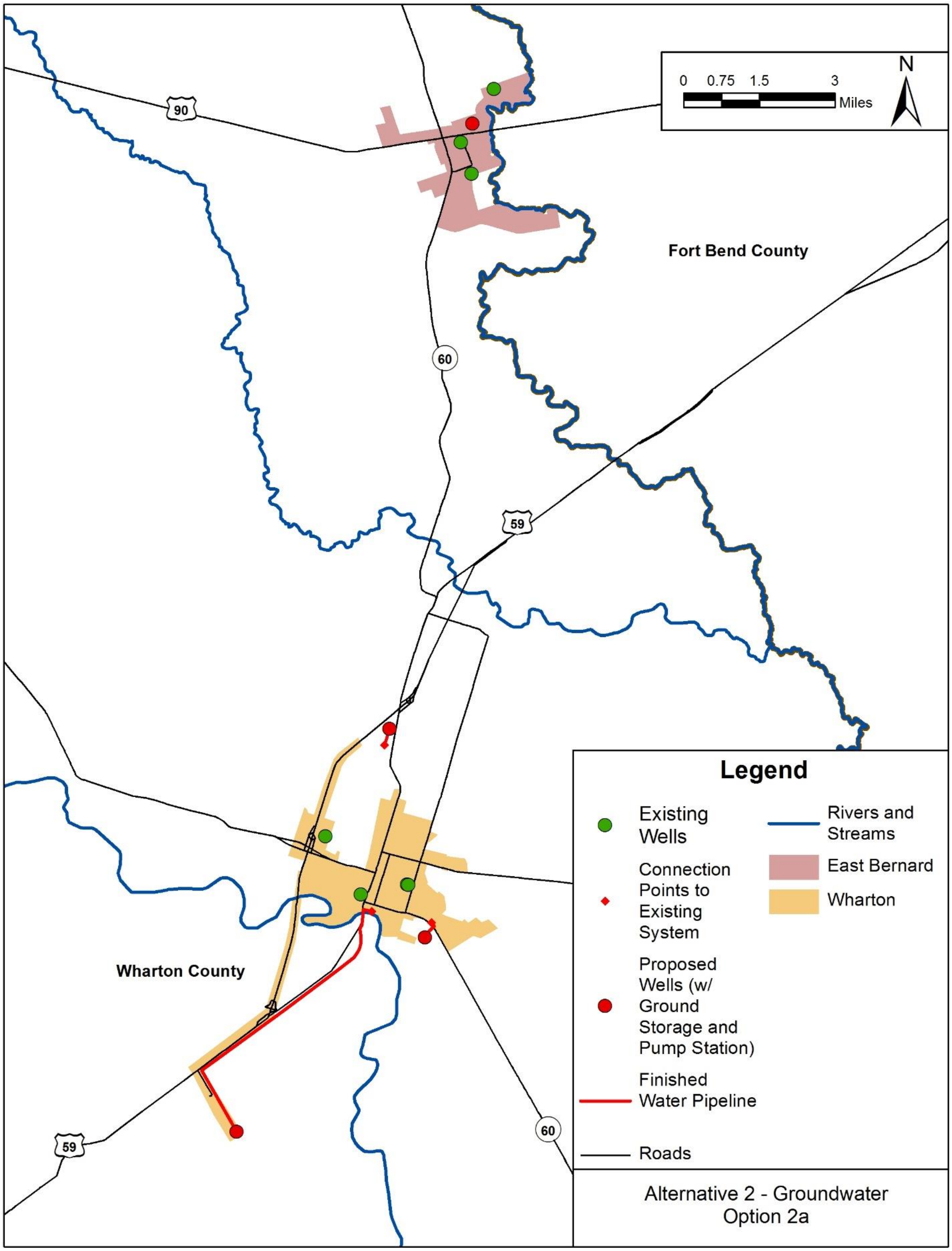

Figure 6-1 Alternative 2a – Individual Wells

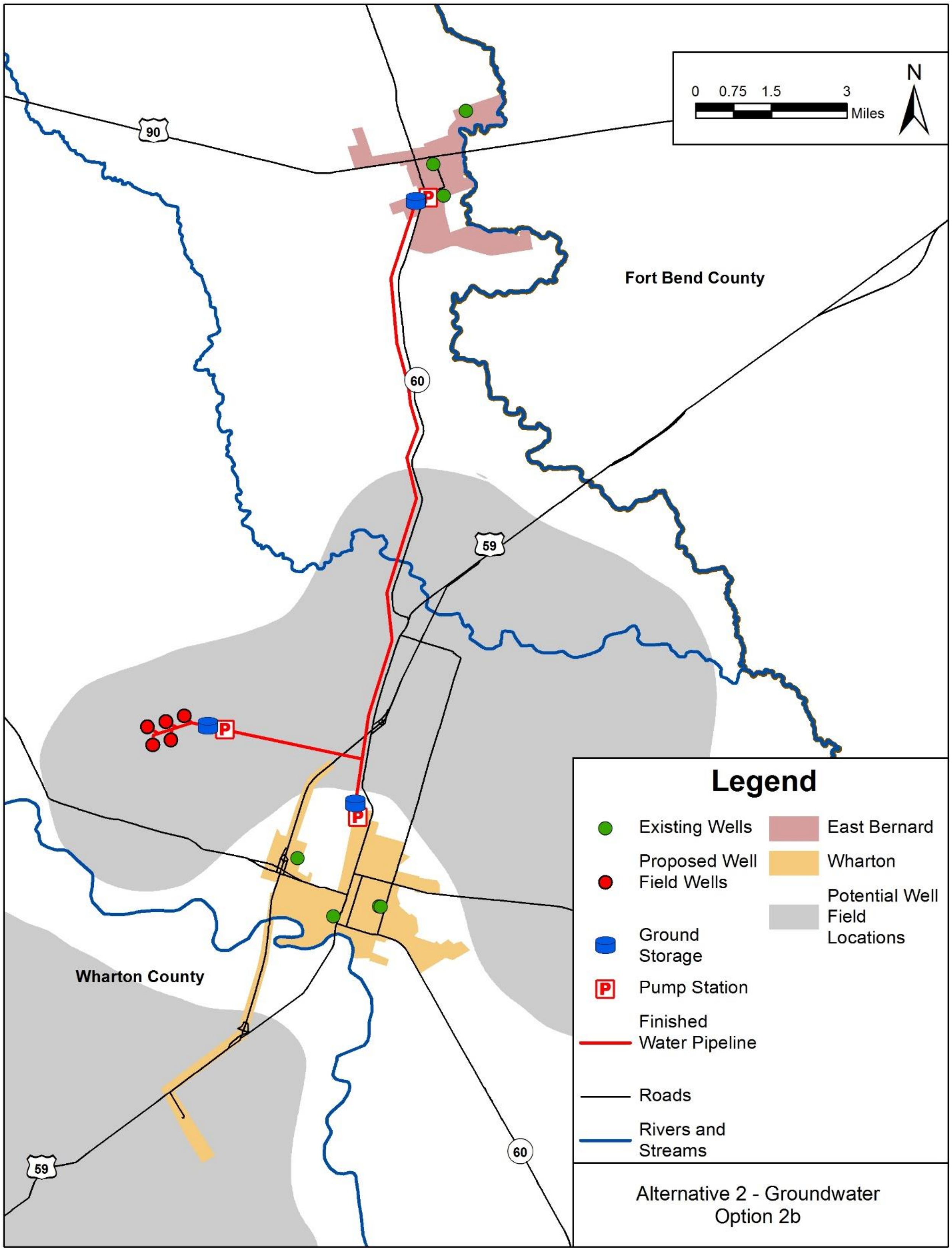

Figure 6-2 Alternative 2b – Shared Well Field

6.2 Program Cost Estimate

Tables 6-1 and 6-2 include the total capital cost, annual cost, and unit costs of water for the individual well and shared well field groundwater options, respectively.

Table 6-1 Groundwater Alternative 2a Projected Costs

Capital Costs			
Item	**Wharton**	**East Bernard**	**Total**
Pump Stations	$4.1 M	$1.3 M	$5.4 M
Pipeline	$1.6 M	$1.5 M	$3.1 M
Wells and Pumps	$6.5 M	$2.4 M	$8.9 M
Ground Storage	$3.0 M	$1.1 M	$4.1 M
Professional Services and Contingencies	$6.8 M	$1.9 M	$8.7 M
Total Cost	**$22 M**	**$8 M**	**$30 M**
Annual Costs			
Item	**Wharton**	**East Bernard**	**Total**
Debt Service (30 yrs)	$1.50 M	$0.55 M	$2.05 M
O&M	$0.25 M	$0.04 M	$0.29 M
Pumping Energy	$0.10 M	$0.02 M	$0.12 M
Purchase of Water	$0.00 M	$0.00 M	$0.00 M
Total Cost	**$1.9 M**	**$0.6 M**	**$2.5 M**
Annual Water Cost	**Wharton**	**East Bernard**	**Total**
($/ac-ft/yr)	$320	$567	$364
($/1000 gal)	$0.98	$1.74	$1.12

Table 6-2 Groundwater Alternative 2b Projected Costs

Capital Costs			
Item	**Wharton**	**East Bernard**	**Total**
Pump Stations	$10.8 M	$3.2 M	$14.0 M
Pipeline	$2.8 M	$4.8 M	$7.6 M
Well Field	$7.7 M	$1.9 M	$9.6 M
Ground Storage	$6.4 M	$1.7 M	$8.1 M
Professional Services and Contingencies	$11.3 M	$4.4 M	$15.7 M
Total Cost	**$39 M**	**$16 M**	**$55 M**
Annual Costs			
Item	**Wharton**	**East Bernard**	**Total**
Debt Service (30 yrs)	$2.70 M	$1.10 M	$3.80 M
O&M	$0.50 M	$0.10 M	$0.60 M
Pumping Energy	$0.40 M	$0.10 M	$0.50 M
Purchase of Water	$0.00 M	$0.00 M	$0.00 M
Total Cost	**$3.6 M**	**$1.3 M**	**$4.9 M**
Annual Water Cost	**Wharton**	**East Bernard**	**Total**
($/ac-ft/yr)	$657	$1,209	$710
($/1000 gal)	$2.02	$3.71	$2.18

The average annual cost to produce groundwater assumes there is no cost associated with the purchase of groundwater. Leasing water rights at some point in the future may become necessary if the Desired Future Condition (DFC) is reached at any point before 2070. The DFC and other risks associated with groundwater production are discussed further in section 9 – Feasibility of Groundwater Production.

6.3 Results of Hydrogeological Assessment

A hydrogeological assessment of the groundwater and ASR water supply options developed in this study was performed by Intera. The complete Intera Hydrogeological Assessment report is included in Appendix B. The focus of the hydrogeologic assessment was to predict impacts to countywide aquifer drawdown and potential subsidence in Wharton as a result of increased well pumping for the various alternatives.

6.3.1 Average Drawdown

A combination of two pumping scenarios and two well field locations were developed, generating a total of four model simulations for the groundwater supply alternative.

- Well Field Locations
    - Pierce Ranch, west of the Colorado River
    - North of the City of Wharton
- Pumping Scenarios
    - S1: Wharton's four existing wells continue to be used, minimizing the number of new wells needed in a future well field
    - S2: Wharton's four existing wells are decommissioned, requiring all water supply wells to be located in a future well field, but potentially minimizing the subsidence impacts in Wharton

The well field locations analyzed are conceptual and do not include consideration of property access and acquisition, well spacing relative to property boundaries, temporary construction access for drilling operations, proximity to power supply sources, or potential conflicts with underground utilities. Additional siting analysis is required for individual wells or a well field serving the project area.

A baseline model was also analyzed that simulated continued Wharton and East Bernard pumping from their existing wells at rates that do not increase through time to support future growth. This baseline was used to compare to the four pumping scenarios described previously. These four pumping scenarios were initially analyzed by Intera using maximum day pumping rates throughout a given year, which is overly conservative. The results of this analysis are described in Section 6 of their report. Intera performed a revised analysis, described in Section 8 of their report, using average day demands. The revised drawdowns were approximately 60 percent of the original estimates using maximum day demands. Table 6-3 shows the estimated difference in net drawdown countywide based on Intera's revised analysis.

Table 6-3 Average Change in Net County Drawdown Relative to Baseline Model for Groundwater Supply Option

Pumping Scenario	Well Field Location	Average County-Wide Change in Net Drawdown, 2020 - 2070
S1	Pierce Ranch	1.0 feet
S2	Pierce Ranch	1.1 feet
S1	North of Wharton	0.84 feet
S2	North of Wharton	0.78 feet

6.3.2 Subsidence

Some types of subsurface geological layers that make up aquifers experience compaction after a significant volume of the groundwater within the formation is pumped out. The land surface above the depleted aquifer lowers in elevation, or subsides, when this subsurface compaction occurs. Land subsidence can occur over large areas and result in extensive and costly damage to structures on the surface. The potential for subsidence in the project area was analyzed in the hydrogeological assessment performed for this study. In all modeled scenarios, the predicted subsidence after 50 years was negligible at less than 0.1 feet.

6.4 Permitting and Regulatory Requirements

Several regulatory agencies oversee components of a municipal groundwater production system. Construction plans for new wells and the associated treatment, storage and pumping facilities must be prepared in accordance with TCEQ requirements and submitted for TCEQ review and approval prior to construction. Municipal water wells must be spaced no closer than 150 feet from the nearest property boundary or sanitary control easements must be obtained on adjacent properties and submitted to TCEQ. Well drillers must be licensed by the Texas Department of Licensing and Regulation (TDLR), and well construction must be performed in accordance with TCEQ and TDLR requirements.

Groundwater conservation districts also regulate and permit the construction and operation of wells. The Coastal Bend Groundwater Conservation District (CBGCD) permits wells in Wharton County. The CBGCD rules and their potential impacts are discussed in more detail in Section 9.

7. Water Supply Alternative 3 – Aquifer Storage and Recovery

The third water supply alternative considered for Wharton and East Bernard involves the implementation of an ASR system. ASR systems introduce water into an underground aquifer for storage until the water is needed. While multiple methods can be used to introduce water into the subsurface, well injection is the most common, and is the method assumed to be used in this study. The source of injected water is assumed to be treated wastewater effluent from Wharton's wastewater treatment plant. This study also assumes that water withdrawn from the ASR occurs at separate wells from those used to inject water into the system. By some definitions, this type of system is referred to as a "hybrid ASR" or an aquifer storage transfer and recovery (ASTR) system. The term ASR is used in this report for simplicity.

ASR systems have several benefits compared to water storage in surface reservoirs, which make them generally more efficient. For instance, water loss from evaporation does not occur in ASR systems, whereas an estimated 21 percent of all water stored in Texas reservoirs is lost annually due to evaporation. Another problem that does not impact ASR systems is sedimentation, which results in a loss of storage capacity in surface reservoirs. Finally, surface water reservoirs have significant impacts to the regional topography and environment, often inundating hundreds or thousands of acres of land. Dams and reservoirs have become costly and difficult to permit. ASR systems by contrast take up little land at the surface and typically do not entail significant environmental impacts.

ASR systems also have benefits relative to conventional groundwater production systems. For many aquifers, the rate of natural recharge has been exceeded by the withdrawal rate for human use. Over time, this imbalance results in resource depletion with several possible consequences. Lowering aquifer water levels result in reduced well pump production rates and may require that well pumps be lowered periodically. For wells that are not constructed deep enough, complete well replacement may be needed. When significant drawdown occurs, diminished water quality and/or surface subsidence can result, potentially requiring wells to be completely abandoned and a new water source developed. All of these impacts can be costly for well owners. ASR systems create a more sustainable, "closed loop" water system in which injected water can be recovered, even in times of drought, without increasing the baseline demand on the native groundwater. Because of their sustainability characteristics, ASR systems are being considered more readily as regional and/or long-term water supply solutions.

A primary disadvantage of ASR systems is the requirement to significantly treat the water before injecting it into an aquifer. Injected water must currently meet primary drinking water standards, necessitating extensive and costly treatment facilities. However, similar to conventional groundwater production systems, water withdrawn from an ASR system does not typically require significant treatment other than disinfection prior to domestic use.

7.1 Infrastructure Needs

Multiple conceptual ASR alternatives were evaluated in this study. An originating concept leading to this study was an ASR system on Pierce Ranch, southwest of Wharton. This concept included infrastructure for Pierce Ranch to divert, store and distribute Colorado River water for agricultural irrigation uses on the ranch. Existing Pierce Ranch irrigation wells would be converted to ASR wells for Wharton and East Bernard. An initial cost model for this alternative using the UCM projected a total capital cost of nearly $200 million and a unit cost of water significantly higher than other proposed alternatives. This Pierce Ranch alternative was clearly not cost-effective for regional potable water supply and was not developed further. However, Pierce Ranch was one location evaluated in the Intera Hydrogeological Assessment as a potential site for an ASR.

The ASR concept developed for this study (Figure 7-1) is a regional system schematically the same as the water production infrastructure needed for Alternative 2b. However, the ASR system includes the need for additional infrastructure to convey and treat wastewater and inject the treated effluent. This alternative involves construction of a lift station in East Bernard and a force main to transmit wastewater from East Bernard to Wharton. The existing wastewater treatment plant on the northwest side of Wharton is assumed to expand to treat the wastewater from both cities. A new water treatment plant would need to be constructed to treat the wastewater effluent to drinking water standards. This treated water would be pumped to multiple injection wells.

7.2 Program Cost Estimates

Table 7-1 breaks out the total capital cost, annual cost, and unit costs of water for both Wharton and East Bernard.

Table 7-1 ASR Alternative Projected Capital Costs

Capital Costs			
Item	**Wharton**	**East Bernard**	**Total**
Pump Stations	$10.5 M	$6.2 M	$16.7 M
Pipeline	$6.5 M	$7.4 M	$13.9 M
Well Field	$16.3 M	$2.0 M	$18.3 M
Treatment	$16.5 M	$4.1 M	$20.6 M
Ground Storage	$6.4 M	$1.7 M	$8.1 M
Professional Services and Contingencies	$23.1 M	$8.2 M	$31.3 M
Total Cost	**$79 M**	**$30 M**	**$109 M**
Annual Costs			
Item	**Wharton**	**East Bernard**	**Total**
Debt Service (30 yrs)	$5.40 M	$2.10 M	$7.50 M
O&M	$2.30 M	$0.60 M	$2.90 M
Pumping Energy	$0.40 M	$0.10 M	$0.50 M
Purchase of Water	$0.00 M	$0.00 M	$0.00 M
Total Cost	**$8.1 M**	**$2.8 M**	**$10.9 M**
Annual Water Cost	**Wharton**	**East Bernard**	**Total**
($/ac-ft/yr)	$1,403	$2,605	$1,585
($/1000 gal)	$4.30	$7.99	$4.86

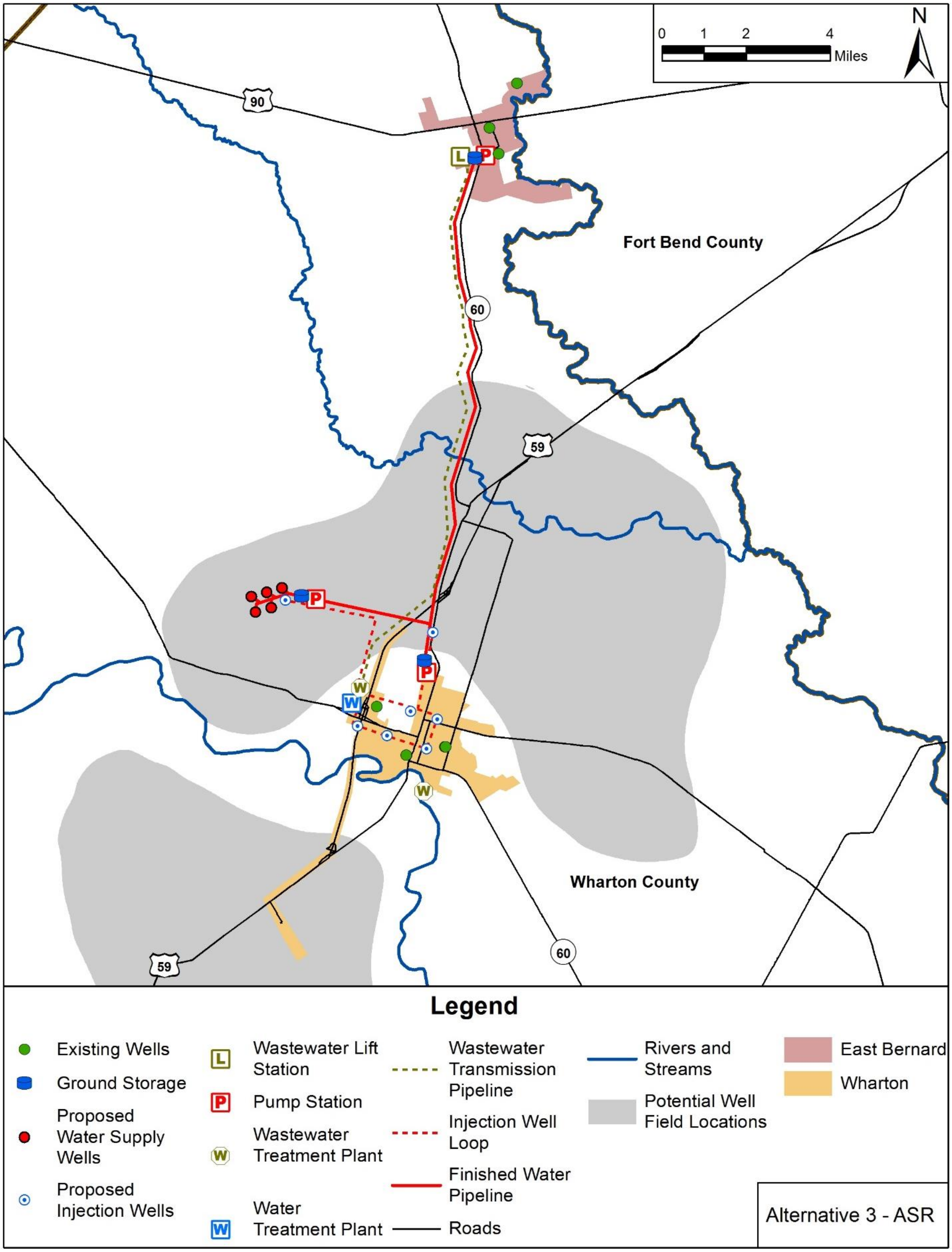

Figure 7-1 Alternative 3 - Basic ASR Schematic

A significant potential benefit of an ASR system is that there would be no cost associated with the right to produce water, even in times of drought or reduced average aquifer levels. An ASR operator can withdraw the water that has been injected for storage regardless of regional water restrictions under regulatory policies currently in place. Consequently, the average annual cost in Table 7-1 assumes there is no cost associated with the purchase of water.

7.3 Results of Hydrogeological Assessment

The hydrogeological assessment of the ASR water supply option predicts impacts to countywide aquifer drawdown and potential subsidence in Wharton. The change in net countywide drawdown was less than 0.3 feet for all modeled ASR scenarios, which is one to 1.5 feet less drawdown than estimated for the groundwater alternative. Less drawdown is expected in an ASR due to the aquifer recharge component. Like the groundwater alternative, the predicted subsidence after 50 years of ASR use was negligible at less than 0.1 feet. The complete Intera Hydrogeological Assessment report is included in Appendix B.

7.4 Permitting and Regulatory Requirements

According to a 2015 TWDB report[2], there are currently only three active ASR systems operating in Texas. The oldest systems serving El Paso and Kerrville were developed in the mid-1980's and early 1990's, respectively. The San Antonio Water System ASR became operational in 2004. The regulatory framework for ASR systems in Texas mirrors the use of the technology, which is to say that it is still growing and evolving. Groundwater conservation districts regulate and permit conventional groundwater wells, and they may also regulate ASR wells. Only 18 conservation or subsidence districts in Texas, out of 98 total, had rules relating to ASR as of 2015. The CBGCD does not currently have rules in place relating to ASR systems. TCEQ permits Class V injection wells used for ASR systems and enforces construction, operation and maintenance requirements for the injection wells.

The implementation of ASR requires detailed consideration of local hydrogeology and water quality within the proposed project area, as well as complex geochemical reactions that may occur between the native groundwater, recharge water, and the subsurface geological formations. Multiple study and testing phases are necessary to ensure the efficacy of a proposed ASR system.

[2] Aquifer Storage and Recovery in Texas: 2015, June 2015, Matthew Webb, TWDB Technical Note 15-04

8. Comparative Analysis of Alternatives

Table 8-1 compares the total capital costs, annual costs, and unit costs of water for each of the options discussed in Section 5 - 7.

Table 8-1 Comparative Cost Analysis of Alternatives

	Surface Water	Groundwater		ASR
Type	Decommission Wells	Individual Wells	Shared Well Field	Shared Well Field
Capital Cost	$102 M	$30 M	$55 M	$109 M
Annual Cost	$12.7 M	$2.5 M	$4.9 M	$10.9 M
$/ac-ft/yr	$1,852	$364	$710	$1,585
$/1000 gal	$5.68	$1.12	$2.18	$4.86

Groundwater appears to be the most economical water supply source available to the Cities of Wharton and East Bernard for the foreseeable future. The continued development of groundwater wells for water supply is expected to cost less than half of the cost required to develop a surface water supply source or a regional ASR system. Significant savings in annual operation and maintenance costs are also expected in the groundwater option relative to the surface water and ASR options.

A significant factor contributing to the higher cost for these alternate supplies is the requirement for more significant water treatment. Groundwater in the project area typically meets drinking water standards without any treatment. The water has to be disinfected prior to distribution, and Wharton currently adds Fluoride. Significantly more treatment of the water is required for the alternate water supply methods, contributing to the higher construction costs and operating expenses.

The comparison of alternatives in Table 8-1 also demonstrates that a regional, shared groundwater supply alternative is not currently favorable. The shared alternative includes infrastructure to store, pump and convey water from a well field to each city. An inherent benefit to the groundwater supply alternative in Wharton County is that costly conveyance infrastructure is unnecessary because production wells can be drilled in or near each city’s distribution system.

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9. Regulatory Impacts on Groundwater Production Feasibility

Every water supply alternative available to municipalities entails some risk. The reliability of water sources is a key consideration in the comparison of various alternatives. For instance, surface water systems are prone to shortages during times of drought. Groundwater resources can also be depleted if the production rate exceeds an aquifer's recharge rate.

The regulation of groundwater use is becoming more stringent with the growth of groundwater conservation districts and the maturation of their policies. The purpose of this increased regulation and oversight is to actively manage groundwater resources so they do not become depleted. While this management improves the likelihood that groundwater will be available for use, the regulation itself leads to a level of risk that a sufficient volume may be unavailable in the future to meet a municipality's demands. Based on current policies, a chance exists that permitted withdrawal amounts may even be curtailed.

The CBGCD has rules in place that may limit groundwater production based on aquifer conditions. This section summarizes those policies and evaluates the likelihood of production limits being placed on Wharton and East Bernard. This section also describes ways in which Wharton and East Bernard can mitigate the risks associated with future production limits.

9.1 Coastal Bend Groundwater Conservation District Rules Summary

The CBGCD is a political subdivision of the State of Texas. The District's boundaries are essentially the same as those of Wharton County, and it is one of 14 conservation districts in Groundwater Management Area (GMA) 15. The mission of the CBGCD is to manage and protect the groundwater resources of the District. The CBGCD is committed to maintaining a sustainable, adequate, reliable, cost effective, and high quality source of groundwater to promote the vitality, economy, and environment of the District.

This subsection summarizes the rules and policies currently in effect that impact permitted withdrawal amounts. The complete and current CBGCD rules (last revisions adopted April 2016) and the District's Groundwater Management Plan (last revisions adopted November 2014) can be viewed on the District's website at www.cbgcd.com.

9.1.1 Applicable Definitions and Current Values

Aggregate System – two or more wells permitted for a total aggregate withdrawal

Contiguous Acre – land within the District, which is either

- Abutting and touching properties, including corner-to-corner
- Properties that are non-abutting but connected by a water delivery system owned by the permittee
- The same person has the right to produce groundwater from the contiguous acreage through deed, easement, contract, lease, or other legally recognized agreement

Historic User – a permittee who owns a well that operated for beneficial used prior to December 31, 2014

Desired Future Condition (DFC) – the desired quantity of groundwater at a specified future time or in perpetuity, as defined by participating Groundwater Conservation Districts within GMA 15 as part of the joint planning process

Goal Level – the aquifer level at the maximum amount of drawdown as defined by the DFC

Modeled Available Groundwater (MAG) – the amount of water that TWDB determines may be produced annually to achieve the DFC

Minimum MAG-derived amount – groundwater withdrawal amount per acre equal to the MAG divided by the District's total acreage

The CBGCD Rules do not define quantities for critical conditions such as the DFC, MAG, and Minimum MAG-derived amount. The District's Groundwater Management Plan quantifies those conditions as follows:

- The MAG is 178,493 acre-ft/year.
- Minimum MAG-derived amount is 0.25 acre-ft/year/acre, or 3 acre-inches/year/acre.
- DFC is an average drawdown in the Gulf Coast Aquifer within the GMA boundary of 12 feet relative to year 1999 starting conditions.

9.1.2 Rules Regarding Production Limits

Chapter 6, Subchapter B in the CBGCD Rules addresses production limits, which is summarized below.

- The CBGCD Board determines permit allocation for individual permittees based on the amount of water needed for beneficial use by that permittee, as long as aquifer levels exceed the DFC.
- All permits are subject to production limits adopted by the District.
- When the goal level outlined by the DFC is reached, the District will consider the following prior to renewing any permits.
    - the MAG, as determined by the TWDB
    - estimates for the amount of current and projected water produced from exempt (non-permitted) wells
    - the amount of authorized withdrawal from all permits
    - estimates for the actual amount of water produced from permitted wells
    - yearly precipitation and production patterns
- The schedule in Table 9-1 will be implemented if the District determines that production limitations are needed to achieve the DFC.
- Under no circumstances will the amount of production be limited to an amount less than the Minimum-MAG derived amount for the permittee's property.

- Implemented production limits may be reduced or eliminated if aquifer levels improve

Table 9-1 Curtailment Amounts Based on Water Levels

	Amount Below Goal Level		
	1-2 ft	**2-4 ft**	**>4 ft**
Permit Curtailment	5%	10%	20%

9.2 Desired Future Condition Uncertainties

The Desired Future Condition is the key regulatory benchmark upon which production limits will be evaluated and implemented. However, several DFC-related issues exist that complicate predicting the reliability of permitted production limits.

- The DFC itself appears to be in flux as more data becomes available and the Groundwater Availability Model (GAM) is refined.
  - The current documented DFC in CBGCD's management plan is 12 feet below a 1999 baseline condition, which is based on a GAM performed in 2010.
  - Intera has indicated that the DFC was changed in 2016 to an average drawdown of 15 feet relative to year 2000 starting condition, although this revision has not been formally published by the CBGCD.
  - During the next joint planning cycle, the GAM, base year and the goal level are expected to change again.
- As indicated in Figures 2-1 and 2-2 in Intera's Hydrogeological Assessment Report (Appendix B), the Gulf Coast Aquifer is comprised of multiple hydrogeologic formations that vary significantly in thickness across the aquifer. Establishing the average water level in such a spatially complex system over the entire county is challenging, and to date has not been clearly defined.
- The CBGCD has not established an analysis methodology to evaluate compliance using monitoring data, nor has any other conservation district in GMA 15. For instance, the following components of a potential methodology are currently unclear in the regulatory framework:
  - The basis of calculation, i.e. volume or area
  - The points of measurement, i.e. monitoring well sample sets
  - Whether interpolation is needed between monitoring wells, and the appropriate interpolation method
- The baseline condition, currently referencing a 1999 aquifer level, is not clearly defined and documented, and it is also in flux.

The uncertainties associated with the current DFC policies cloud the reliability associated with groundwater permits. Similarly unclear in the regulatory framework are enforcement policies and procedures. The CBGCD Rules allow the District to seek injunctive relief and to assess civil penalties, up to $10,000 per day, when a rule violation occurs. However, no specific provisions exist that establish what constitutes a DFC-related violation requiring enforcement.

9.3 Potential for Permit Curtailments

According to the 2015 CBGCD Usage Summary, the 10-year average groundwater use in the District was 145,000-acre feet per year. This usage volume is approximately 80 percent of the District's MAG, which is the theoretical usage at which the average groundwater levels will remain relatively constant. Only once in the last 10 years, in 2011, has the reported usage exceeded the MAG. Based on these volumes, aquifer levels would not be expected to decline significantly.

Seven monitoring wells in Wharton County that are inspected monthly showed an average water level decline of 0.5 feet from March 2005 to March 2015. There are 32 monitoring wells inspected semi-annually in Wharton County. The average water level at these monitoring wells increased by two feet from March 2013 to March 2015. In summary, average reported annual usage volumes do not appear to be unsustainable, and available well monitoring data show average aquifer levels holding steady. The 50-year drawdown amounts shown in Table 6-3 do not indicate significant drawdown would be expected from increased groundwater production to meet the needs of growing populations in Wharton and East Bernard.

Permit curtailments do not appear likely based on historical data and the evaluations performed in this study. However, risk remains. The 2015 Usage Summary shows that the 10-year average of permitted water has been approximately 289,100 acre-feet per year, which is 162 percent of the MAG. The usage volume is approximately 50 percent of the total permitted volume in the District. The average water levels in the county would be expected to decline if all permit holders began to use more of their allotted amounts annually. The CBGCD would likely curtail permitted withdrawals in this event.

9.4 Mitigation Strategies for Production Limits

Curtailments of permitted withdrawal rates do not appear to be likely in the near future based on current regulations, recent aquifer trends, and the hydrogeological projections from this study. However, the GAMs and conservation district rules and policies are refined regularly. Future changes to those policies could increase the risk that Wharton and East Bernard's groundwater permits are modified with reduced withdrawal rates.

Multiple strategies should be considered before a strategy to develop an alternate water supply source if curtailments are implemented. The first such strategy should be reducing water demands through water conservation. Water conservation is discussed in detail in Section 10. The second available strategy is to reduce water demands in accordance with drought contingency policies in place. These self-imposed curtailments may not be sustainable for municipalities and their commercial customers over periods of multiple years. However, strategic drought contingency measures could be implemented for brief periods of time to meet withdrawal rates over a three-year permit term, depending on the volume of water that needs to be saved.

The following subsections describe two additional strategies to mitigate the impacts of reduced permitted volumes. The first strategy is a proactive one to promote and implement groundwater conservation district policies favorable to municipalities that reduce the likelihood and/or severity of permit curtailments. Such policies would require municipalities to share in the burden of demand reductions, but do so with a reduced risk of having to develop alternate water supplies. The second strategy is to purchase the rights to produce groundwater within current CBGCD rules. This strategy is a reactive one to be implemented in the event that groundwater curtailments become a reality.

9.4.1 Rulemaking Participation

Wharton and East Bernard, as well as other cities in the CBGCD, would benefit from collaborative efforts to develop a larger role in groundwater conservation district policy making. Municipal water demands in Wharton County are currently supplied entirely by groundwater but only account for 4 percent of the total groundwater volume used annually in the county[3]. As a result, groundwater withdrawals for municipal use have a minor effect on average aquifer levels across the county. Similarly, curtailments in municipal groundwater withdrawals will likely have an insignificant benefit on aquifer levels as long as the total municipal demands remain a small percentage of the overall Wharton County groundwater use.

Municipalities should be required to share part of the burden to reduce demands on the aquifers if curtailments are implemented. However, as this study indicates, the costs are substantial for Wharton County municipalities to develop alternate water supply sources. Wharton, East Bernard, El Campo and other cities would benefit from groundwater management policies that equitably balance the needs to use water wisely, but that are not so severe to require the development of costly alternate water supplies that will have minimal positive results on the groundwater resources.

The following brief list includes example policies, one or more of which could be equitably developed to benefit municipalities while allowing the CBGCD to continue successfully achieving its mission to manage and protect its groundwater resources. These policies should align with the CBGCD’s commitment of maintaining a reliable, cost effective source of groundwater that promotes the vitality, economy, and environment of the District.

- DFC-triggered reductions in permitted withdrawals that are less for municipalities than other larger-volume user groups.
- Minimum-MAG derived amounts which are higher for municipalities than other larger-volume user groups

[3] 2017 Texas State Water Plan, Texas Water Development Board

- Allow withdrawal curtailment rates to be offset by quantifiable, documented water conservation improvements achieved by municipalities.
- Defer withdrawal curtailment for municipalities that voluntarily implement their drought contingency plans
- Allow municipal corporate boundaries to count toward contiguous acreage "owned" by the municipalities.

Existing policies favorable to municipalities and the District may already be in use in other Texas conservation districts. An investigation of other districts' rules and policies could help identify examples already in place. Achieving these or similar policy revisions will require that cities work collaboratively with the CBGCD on an ongoing basis. Regular participation in District meetings by municipal representatives, or even municipal representation on the District Board, is recommended.

9.4.2 Contiguous Acreage Lease

A contiguous acreage purchase or lease is a strategy for a municipality to increase its groundwater production rights, particularly in the event that permit curtailments are implemented, without developing alternate water supplies. Contiguous acreage is a term defined in the current CBGCD rules. The definition states that the same person shall have the right to produce groundwater from contiguous acreage through deed, easement, contract, lease, or any other legally recognized agreement. Further details of a contiguous acreage agreement are not included in the rules currently, but the definition outlines the possibility for water users to increase their permitted withdrawal rates by purchasing or leasing groundwater production rights from contiguous properties. This process is similar to various forms of "banking," where a property owner receives compensation for providing a portion of his or her surplus capacity to someone with a capacity deficit.

A municipality considering a groundwater lease should hire a qualified attorney experienced in land rights and leasing issues. While groundwater leases may generally follow leases for mineral rights in form, each case is different and few guidelines exist. The price for groundwater rights is negotiable, and groundwater is different from other commodities in that there is not a "market rate" to inform those negotiations.

The amount of acreage required is dependent on multiple factors, including the magnitude of curtailments, the District rules in place at the time of curtailments, and the minimum-MAG derived amount. Three basic curtailment scenarios are considered in Table 9-2 to estimate the amount of acreage needed and the importance of conservation district rules related to permit curtailments. The following assumptions are made in this analysis:

- Minimum MAG-derived amount: 0.25 acre-feet/year/acre
- Wharton-Owned Land: 400 acres in 2016, increases over time proportional to population growth
- Land within Wharton's corporate boundaries: 4,600 acres in 2016, increases over time proportional to population growth

- Average annual daily demands in Wharton equal those shown in Table 3.4

Table 9-2 Contiguous Acreage Estimates

Permit Curtailment Scenario	Contiguous Acreage Required	
	2020	2070
20% of Average Annual Daily Demand	1,400	4,500
Minimum-MAG derived amount based on amount of Wharton-owned property	6,400	21,300
Minimum-MAG derived amount based on land within Wharton city limits	2,200	7,300

Consideration of these scenarios, particularly the worst-case curtailment possibilities, indicates the importance of the how contiguous acreage is defined. A CBGCD rule revision to allow municipal corporate boundaries to count toward contiguous acreage "owned" by the municipalities would reduce the amount of contiguous acreage rights Wharton needs by approximately one-third.

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10. Water Conservation

Water conservation is an important consideration in any water supply study. Conservation-based water management is a cost-effective strategy to reduce capital and operating expenses associated with water supply and distribution infrastructure. Conservation will be increasingly critical so that the demands associated with population growth and development can be supplied by the finite water resources available. This section describes the results of a survey that reflects how well Wharton performs in administering its water conservation program relative to similarly sized Texas municipalities. The importance of reducing water loss and lowering domestic use are explained in relation to potential cost savings on water supply infrastructure. Finally, Wharton's existing water conservation plan is summarized with recommendations for changes.

10.1 Texas Water Conservation Scorecard

The Texas Water Conservation Scorecard was released for the first time in 2016. Developed by the Texas Living Waters Project, which is a partnership of the Sierra Club-Lone Star Chapter, National Wildlife Federation, and Galveston Bay Foundation, the Scorecard assesses how much various utilities throughout Texas are doing to conserve water. The Scorecard is more of an evaluation of utilities' level of effort to advance water conservation rather than a direct evaluation or quantification of their actual water conservation achievements. More than 300 water utilities in Texas were evaluated, categorized by large and medium-size utilities (serving 25,000 customers or more) and small utilities (serving less than 25,000 customers). Wharton falls into the latter category. Utilities were evaluated on six different criteria:

1. Did the utility submit its most-recent required Water Conservation Plan to the State?
2. Did the utility submit its most-recent Annual Report (on implementation of its water conservation plan) to the State?
3. Did the utility submit its most-recent annual Water Audit Report to the State?
4. What was the most-recent reported total percent water loss as stated in its Water Audit Report?
5. How many of the municipal water conservation Best Management Practices (BMPs) presented in the State's BMP Guide did the utility report that it was using in its most recent Annual Report?
6. Does the utility's water rate structure send a strong "water conservation pricing signal" to the utility's single-family residential customers?

The utilities were scored on these six criteria with a total possible score of 55. Wharton scored a 22 out of the possible 55, which ranked 138 out of 180 small utilities surveyed. Figure 10-1 shows the distribution of scores for small utilities throughout the state.

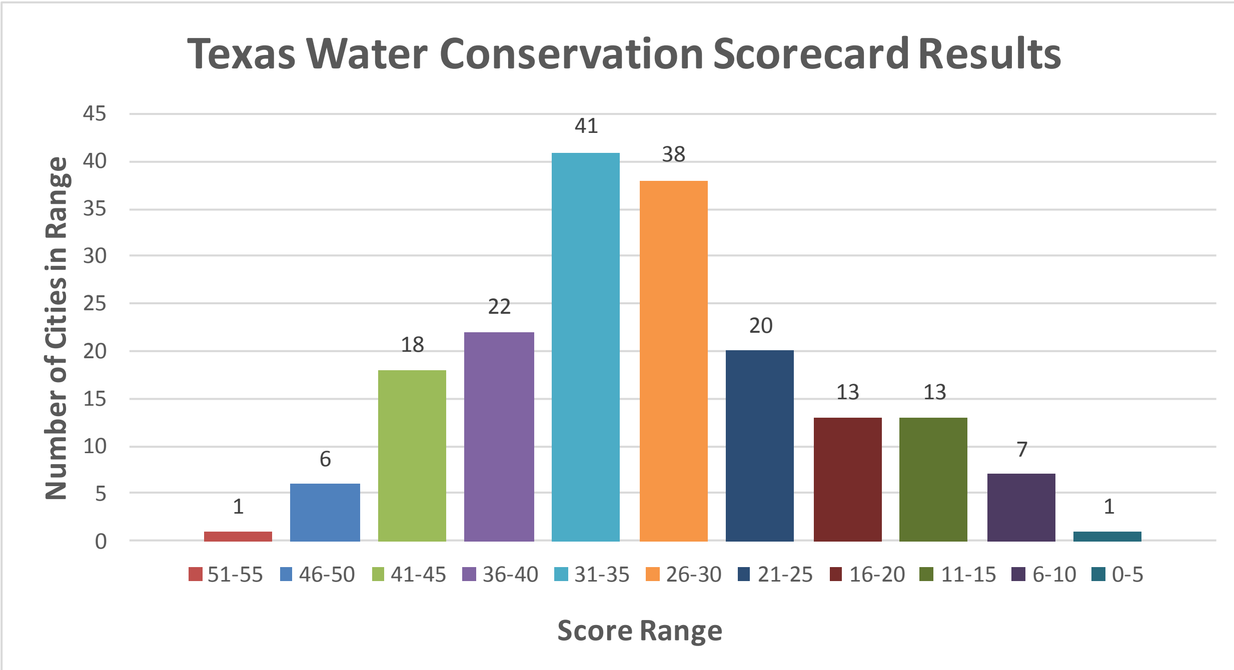

Figure 10-1 Distribution of Scores for Small Utilities (Population < 25,000)

Wharton is progressive and proactive with regards to planning for its future water supply needs and identifying effective water supply alternatives. However, Wharton is below the median with regards to administering and managing its water conservation plan, according to the Texas Water Conservation Scorecard. An increased emphasis on record keeping, reporting, proactive implementation of BMPs, and meeting its water reduction goals is recommended.

10.2 Reduction of Water Losses

A key to an improved water management plan for Wharton is reducing its non-revenue water, and lost water in particular. Figure 10-2 shows a classification system for water supply and consumption in a retail water system. In a water audit, the volume of water supplied in a year (total system input) should equal the volume consumed plus the water lost. Non-revenue water is water for which the utility is not reimbursed, even though the utility paid to produce, treat, and distribute that water to its customers. Non-revenue water, shaded blue in Figure 10-2, includes unbilled authorized consumption, apparent losses from unauthorized consumption and metering inaccuracies, and real losses from leaks in the system. Wharton's five-year average water loss in 2015 exceeded 25 percent.

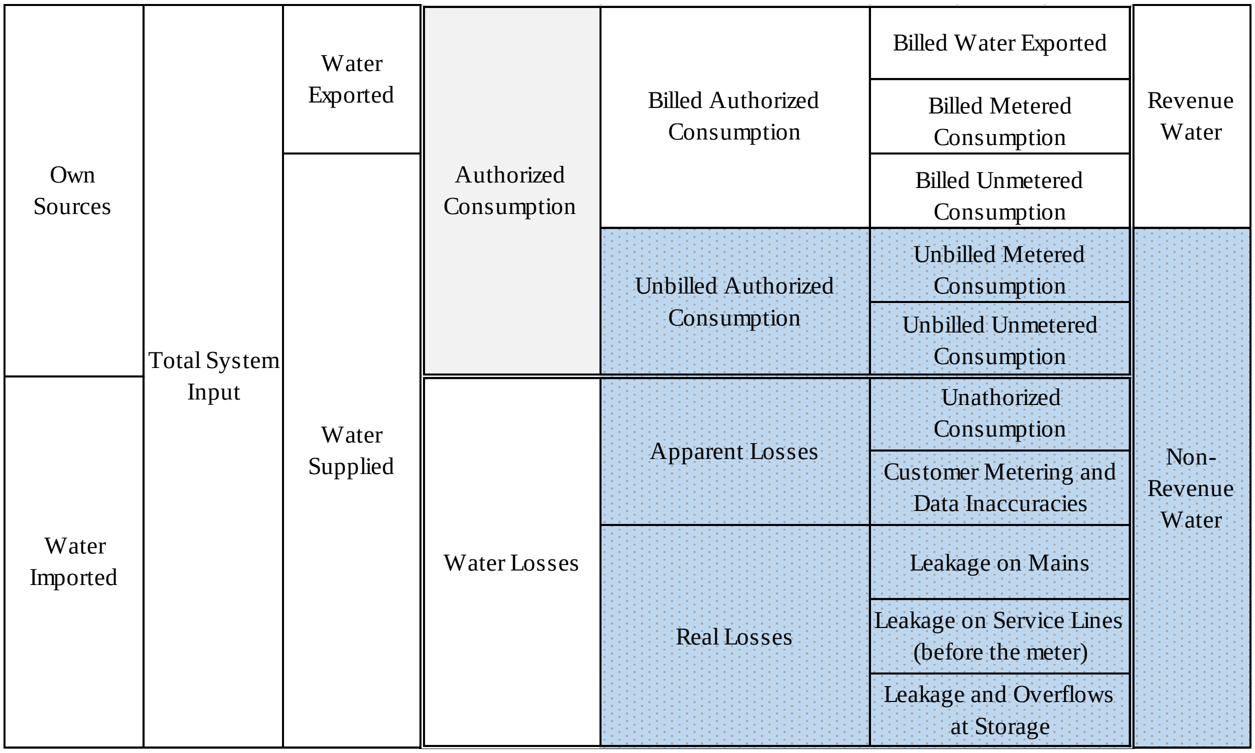

Figure 10-2 Water Accounting Categories

City staff have begun to actively reduce its non-revenue water by improving the accuracy of meters at its water plant sites and identifying unmetered connections. Continued effort to identify and reduce the water loses in its system will help Wharton meet its water conservation goals, as discussed in more detail in Section 10.3. The City's well permit also requires that lost water be maintained at 15 percent or less.

10.3 Water Conservation Plan Recommendations for Wharton

Wharton's water conservation plan was approved and adopted in 2013. The plan was reviewed for compliance with Texas Administrative Code (TAC) Rule 363.15, which establishes requirements for water conservation plans. These rules require the inclusion of ten elements. The following three elements were identified to be missing from Wharton's water conservation plan:

- A schedule for implementing the plan to achieve the applicant's targets and goals
- A method for tracking the implementation and effectiveness of the plan
- A master meter to measure and account for the amount of water diverted from the source of supply.

Wharton maintains master meters at each of its well sites, but a requirement to do so or description of those meters are not included in its conservation plan. The TAC rules also require a utility profile to be included in conservation plans. Wharton's plan references a utility profile, but it is out of date and not in the standard TWDB form. A proposed, revised water conservation plan for

Wharton that includes missing elements, an updated utility profile, and revised goals (described in the following section) is attached in Appendix C.

10.3.1 Wharton Conservation Goals

In 2003, the TWDB created the Water Conservation Implementation Task Force in an effort to realize water conservation's full potential. The Task Force developed a report on advancing water conservation and a BMPs guide with detailed descriptions of actions that could be taken to achieve conservation. In its 2004 report, the Task Force recommended that an entity required to prepare and submit a municipal water conservation plan should consider in setting its targets and goals "a minimum annual reduction of 1 percent in total per capita demand based on a five-year rolling average, until such time as the entity achieves a total daily per capita demand of 140 or less." The 2016 Water Plan for Region K reinforces the Task Force's recommended target of 140 gpcd.

Wharton's 2013 water conservation plan includes the following targets:

- Five-Year Goal: Reduce the average municipal use by 10 gpd *per connection* and keep unaccounted for water (i.e. lost water) below 10 percent annually
- Ten-Year Goal: Reduce the average municipal use by 40 gpd *per connection* and keep unaccounted for water below 10 percent annually

Two concerns with these goals may make it difficult for Wharton staff to track and report its progress. First, Wharton's conservation plan does not clearly state the starting or goal level demands. Revising these goals to include a specific target for per capita demands is recommended. Second, the goals are based on per connection water reductions. The TAC requires goals to be provided in terms of per capita demand. The TWDB requires per capita demands to be calculated as follows:

GPCD = Total System Input (TSI) / Permanent Population / 365

TSI = Produced Water + Imported Water – Exported Water (in terms of annual volumes)

Wharton's TSI equals the total volume of water produced from all of its wells in a calendar year since it does not currently import or export any water.

The 2013 Wharton Utility Profile submitted to TWDB indicates that the prior five-year average annual demand was approximately 164 gpcd and 387 gpd per connection. The population and connection counts in the Utility Profile indicate approximately 2.36 people per connection. The goals referenced in Wharton's conservation plan require achieving the following actual average annual demands:

- Five-year goal (by 2018)
  - 377 gpd per connection
  - 160 gpd per capita
  - Equals a per capita reduction of 0.5 percent annually for the first five years.

- Ten-year goal (by 2023)
  - 347 gpd per connection
  - 147 gpd per capita
  - Equals an average annual per capita reduction of 1.1 percent through 2023.

Wharton's 10-year goal results in an annual per capita reduction of more than 1 percent annually, which meets the TWDB's recommended reduction rate. At this rate, more than 10 years will be needed to reach the target of 140 gpcd.

As mentioned in Section 10.2, Wharton's lost water in 2015 exceeded 25 percent of total water produced, which equaled 44 gpcd. Table 10-1 shows the five-year averages for total water demand, water loss and per capita demands.

Table 10-1 Wharton's Five-Year Average Water Demands and Losses (through 2015)

	2015 5-year average
Retail Water (MGY)	374
Total Water (MGY)	513
Water Loss (MGY)	139
Water Loss (%)	27
Per Capita Demand (gpcd)	164

Because Wharton's lost water is so significant, reducing that volume will be extremely impactful to its per capita demands. Wharton will far surpass its goals for per capita demands if it meets its goals of reducing lost water. Table 10-2 shows the resulting per capita demands if Wharton achieves various water loss percentages and assuming the retail water per capita demand remains constant at 117 gpcd. The retail water volume reflects a population served of approximately 8,800, which is the projected five-year average in 2018.

Table 10-2 Impacts of Water Loss Reduction on Wharton's Per Capita Demands

	Annual Water Loss (%)		
	20	15	10
Retail Water (MGY)	377	377	377
Water Loss (MGY)	94.3	66.5	41.9
Reduction in Water Loss (%)	32	52	70
Resulting gpcd	147	138	130

Table 10-2 shows that if Wharton achieves its goal to keep unaccounted for water at 10 percent of its total water, its per capita demand will reach 130 gpd without any reductions in per capita retail water use. This will require Wharton to reduce its annual volume of lost water by 70 percent. Wharton's per capita demand will reach 147 gpcd, which is its current per capita target, with a 32 percent reduction in its lost water. However, this reduction only results in an annual water loss equal to 20 percent of its total demand, coming up short of the City's goal to achieve 10 percent annual loss.

The following revised targets are recommended for Wharton's water conservation plans so that its goals are consistent with each other and reflect TWDB targets.

- Five-Year Goal (2017 – 2021): Reduce the five-year average municipal use to 148 gpcd and reduce unaccounted for water to 15 percent
- Ten-Year Goal (2017 – 2026): Reduce the five-year average municipal use to 133 gpcd and reduce unaccounted for water to 10 percent

These revised per capita goals reflect the effects of five-year averaging and assume it takes five years for Wharton to reach its target reduction in lost water. Wharton will exceed these per capita demand goals if it achieves its water loss goals sooner, up to the per capita values shown in Table 10-2.

The revised goals provide a more incremental target for water loss reduction. Wharton should continue to strive to reduce its lost water to 10 percent of its total demand and further reduce its per capita demand. Specifically, the City should endeavor to reduce its retail per capita water demand. Effective BMPs tailored to this goal may include promoting residential consumption savings and efficient irrigation at parks, school fields, and the golf course in Wharton. These goals and procedures can be incorporated in subsequent five-year revisions to Wharton's water conservation plan once the revised goals are achieved.

10.4 Benefits of Water Conservation

Implementing an effective water conservation program and striving to achieve reductions in per capita water demands is sound resource management and fiscally prudent. If Wharton reduces its per capita water usage and meets its revised water conservation goals, the projected 2070 maximum day demand would reduce from 9.5 mgd to 7.3 mgd. Figure 10-3 shows both demand curves, with and without conservation, along with existing and future well production capacities (assuming no losses in well production). This chart demonstrates two significant benefits that water conservation can have in Wharton. The first benefit is the deferment of needed infrastructure. In this scenario, a well needed in 2047 without conservation could be delayed approximately eight years if water conservation goals are achieved. The second benefit is reducing the total amount of water supply infrastructure needed. At the end of the study period, a reduction of demand by 2.2 mgd could mean one fewer wells is needed. The elimination of a well site also results in no need for disinfection equipment, a storage tank and a distribution pump station at that site. The capital savings for property, infrastructure and debt service is estimated to be three to four million dollars per eliminated well.

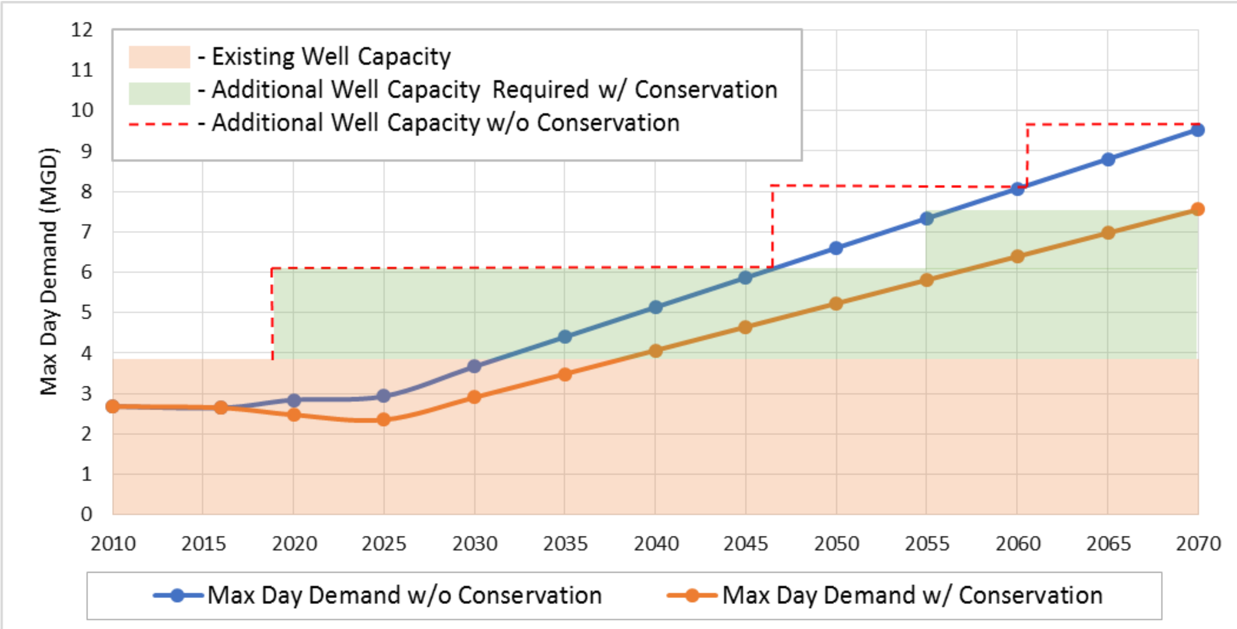

Figure 10-3 Water Demand Reduction

Water conservation reduces the annual operational expenses associated with producing groundwater, disinfecting it and pumping it into the distribution system. The estimated savings totals $150,000 to $200,000 per year. For groundwater supply systems, reduced demands also mean less impact on the local aquifer and potentially reduced drawdown over time. In all, a significant return on investment can be realized for a proactive and effective water management program that meets its conservation goals.

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11. East Bernard Recommendations

Groundwater production has been identified in previous sections of this study to be both viable and economical. This section includes more specific recommendations relating to permit needs in East Bernard. As previously mentioned, Wharton County WCID #2 provides domestic water service to East Bernard. However, the District has expressed reluctance in the past to expand to serve existing customers outside of its current service area or to serve future growth. Therefore, this section also compares water utility options for East Bernard to meet the needs of future growth.

11.1 Permitted Groundwater Withdrawal

Wharton County WCID #2 operates three wells with a current permitted capacity of 1,500 acre-feet over the three-year permit term, which equates to 0.45 mgd. Figure 11.1 shows East Bernard's average demand projections and the WCID #2 current permitted capacity. This capacity is expected to be sufficient until approximately 2027. Withdrawal increases of up to 10 percent can be granted by the CBGCD as minor amendments to well permits. Each of the permit increases shown in Figure 11.1 is less than a 10 percent increase from the previous amount, which will be sufficient for WCID #2 to maintain permitted capacity greater than projected demands.

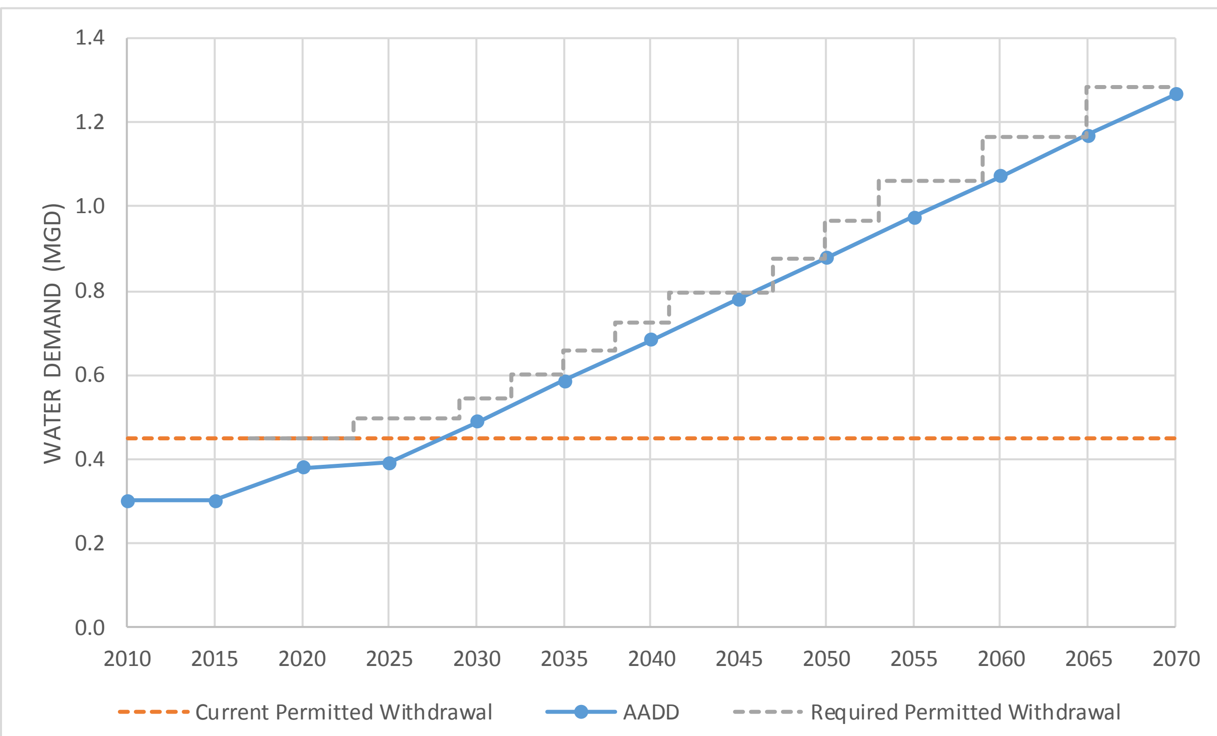

Figure 11-1 Average Annual Daily Demand with Permitted Withdrawal Increase

11.2 East Bernard Water Utility Options to Serve Future Growth

WCID #2's total pumping capacity is currently approximately 2.2 mgd, which if maintained is projected to be sufficient for East Bernard growth until 2065 (Figure 11-2). Well production can decline over time due to the effects of declining aquifer levels, pump and motor wear, and well screens that become clogged. Periodic well maintenance and cleaning is required to overcome these effects and sustain the production capacity. Successful water conservation efforts will prevent the need for a new well during the planning period and reduce annual operation costs.

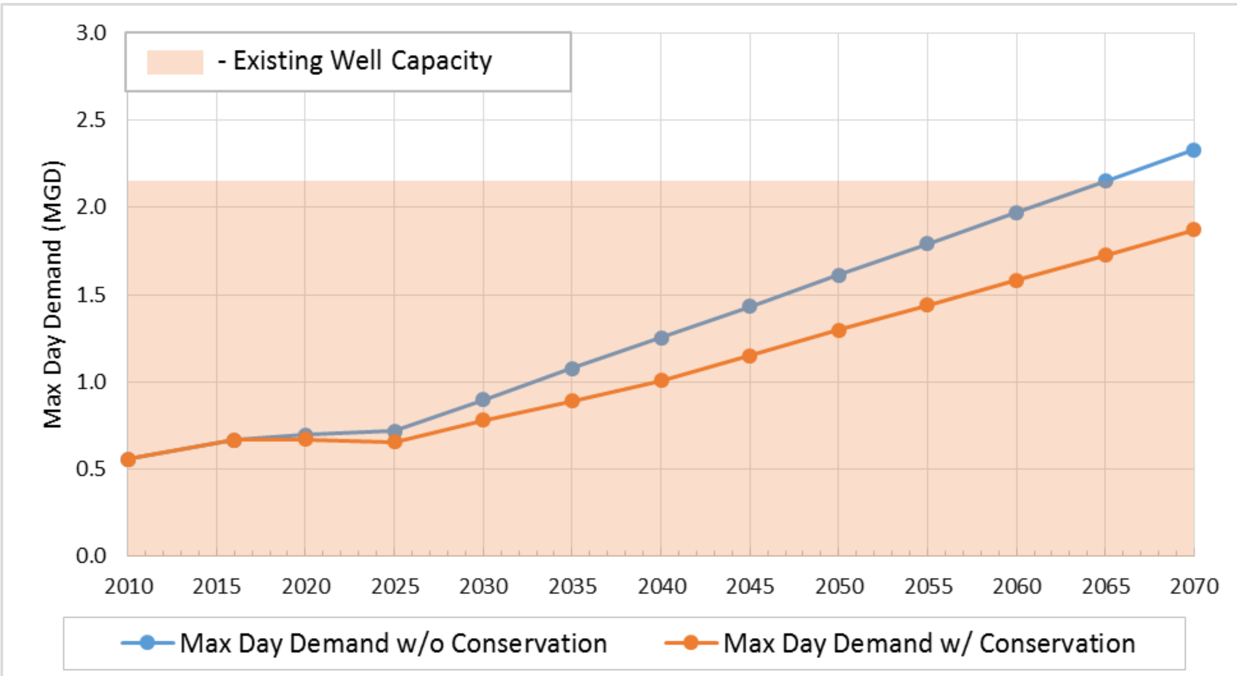

Figure 11-2 Max Day Demand vs. Existing Well Capacity

Even though they have ample water supply capacity to meet future needs in East Bernard, WCID #2's prior reluctance to expand means another utility may have to be created to serve future growth. Table 11-1 presents conceptual cost estimates for three alternatives to serve existing and future customers outside of WCID #2's current service area.

- Option 1: WCID #2 expands to serve all existing and future East Bernard customers.
- Option 2: East Bernard creates its own water utility, purchasing water from WCID #2
- Option 3: East Bernard creates its own water utility, developing its own groundwater wells

Table 11-1 Conceptual Capital Costs Associated with East Bernard Water Utility Alternatives

Item	Option 1	Option 2	Option 3
Pump Stations	N/A	$1.3 M	$1.3 M
Pipeline	$1.5 M	$1.5 M	$1.5 M
Wells and Pumps	N/A	N/A	$1.0 M
Ground Storage	N/A	$1.5 M	$1.5 M
Professional Services and Contingencies	N/A	$1.5 M	$1.9 M
Total Capital Cost	**$1.5 M**	**$5.8 M**	**$7.2 M**

In each of the three options, the existing distribution pipe network would have to expand to serve growth outside of the current service area. In Options 2 and 3, two separate water utilities would exist that operate independently. TCEQ specifies the minimum capacities of water distribution infrastructure that each utility must maintain, including water storage and booster pumping facilities. The East Bernard water utility would have to construct these facilities in Options 2 and 3, and it would have to construct its own wells in Option 3.

Creating a new water utility in East Bernard to serve customers outside of WCID #2's service area will be more costly due to infrastructure redundancies. Many of these redundant facilities would be unnecessary if WCID #2 instead expanded its existing service area. Further redundancy and cost inefficiencies would arise in the management and operation of a second utility. Residents and businesses in Options 2 and 3 could have significantly higher water costs compared to their neighbors. These higher costs could even have a negative impact on future growth in East Bernard. Rather than funding new facilities associated with an unneeded new water utility, generally the same amount of funding would be a significant start to creating wastewater collection and treatment services for East Bernard.

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12. Wharton Recommendations

This section includes more specific recommendations for Wharton to maintain its groundwater supply system so that it can continue to efficiently meet its needs.

12.1 Permitted Groundwater Withdrawal

Wharton's existing permitted withdrawal for groundwater is 5,382.7 acre-feet over its three-year permit term, or approximately 1.60 mgd. The average daily demand is projected to exceed this amount in approximately 2025. However, as Table 2-7 indicates, Wharton's average annual demand in 2011 was 1.54 mgd. Multiple dry years could lead to Wharton's demand exceeding 90 percent of its current permitted withdrawal prior to 2025, so consideration should be given to requesting additional permitted capacity in the 2017 permit renewal. The permit increase amounts shown in Figure 12-1 are all less than 10 percent from the previous permit term, meaning minor amendments to Wharton's operating permits will be sufficient to keep up with projected demands.

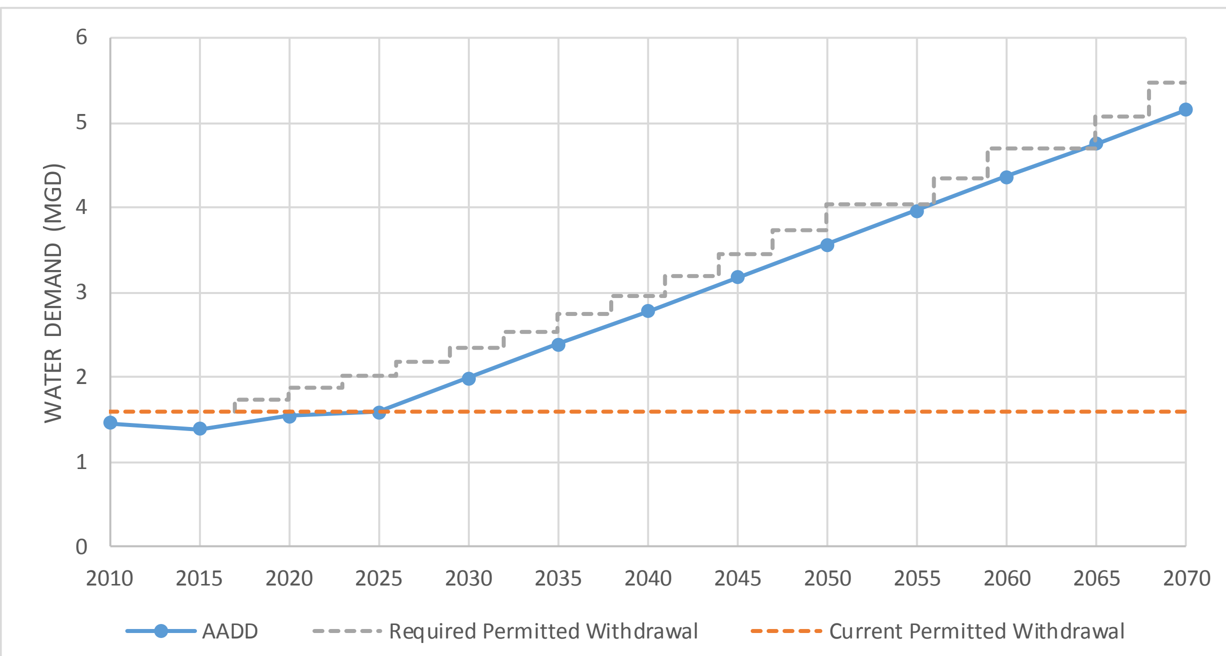

Figure 12-1 Average Annual Daily Demand with Permitted Withdrawal Increase

12.2 Maintaining Capacity in Existing Wells

Well production can decrease over time due to the effects of declining aquifer levels, pump and motor wear, and well screens that become clogged. When the aquifer levels at a well location decline, the well pump must overcome a higher head, which means the pump will not deliver as much flowrate. This change in operating head also likely results in the well pump operating at a lower efficiency and more electric power used, increasing operating costs. A significant decrease in pumping efficiency can also lead to excessive wear and more frequent required maintenance.

Two of Wharton's four existing wells are exhibiting declining production likely due to a combination of declining local water levels in the aquifer and declining well equipment performance. A third well is experiencing iron bacteria problems and requires rehabilitation. Wharton's total production capacity has declined approximately 20 percent since 2006. As Figure 12-2 shows, if the total well production continues to decline at a similar rate, Wharton's maximum day demand will exceed its total well capacity within 10 years. The figure shows a dramatic well capacity decline in 2023, which is when the pumping level in Well #3 is projected to become lower than the pump if the pump is not lowered.

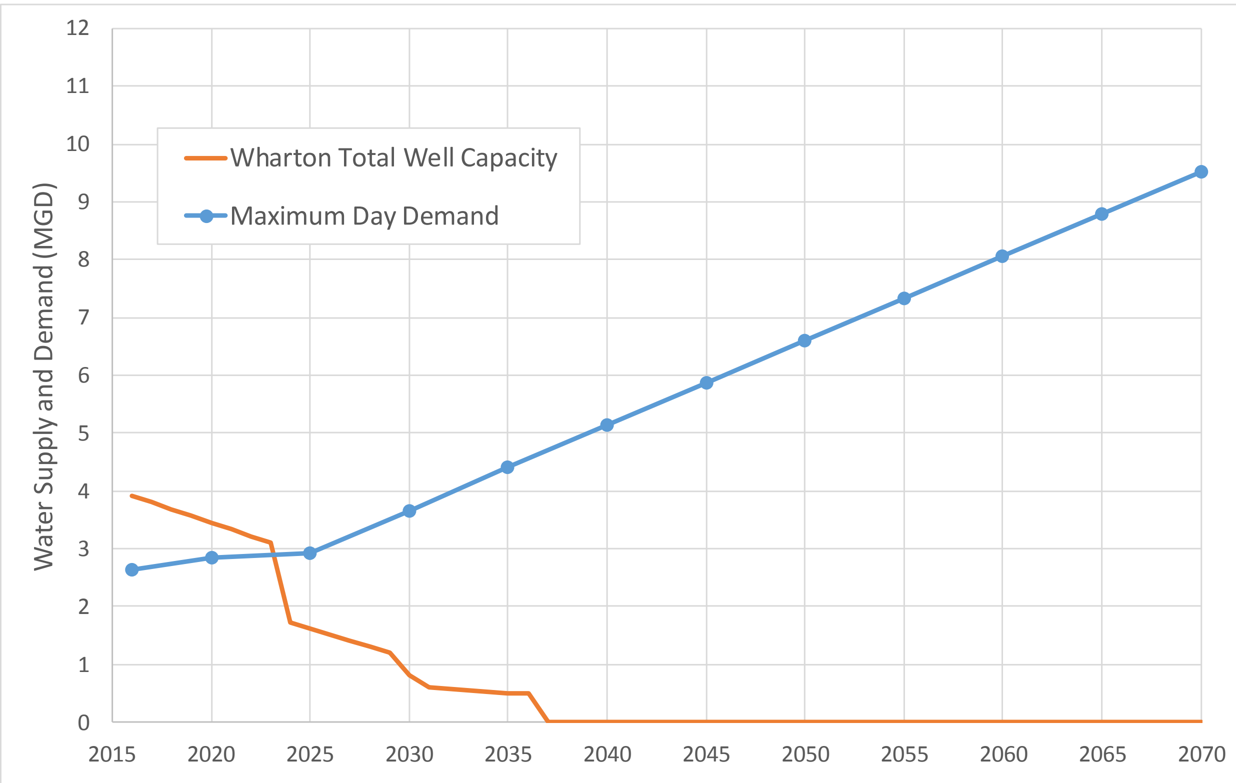

Figure 12-2 Declining Capacity of Existing Wells

Figure 12-2 underlines the importance of regular well cleaning and periodic rehabilitation so that Wharton maintains its groundwater production capacity. Cleaning and rehabilitation are considered to be periodic operation and maintenance activities required to preserve existing water supply capacity; cleaning and rehabilitation are not considered alternatives for added capacity for the purposes of this study. Well cleaning could include a combination of chemical treatment and physical screen cleaning, such as brushing, high pressure jetting, or other means. Cleaning may be needed as frequently as once per year, particularly for the wells that have experienced iron bacteria problems. Well cleaning requires that the pump and motor to be removed and reinstalled after completion. Well rehabilitation refers to more significant maintenance, and possible replacement, of the well pump and motor. Well pump lowering may be needed due to declining pumping levels so that the pump remains below the water with enough submergence to prevent cavitation. Pump lowering can be achieved by adding one or multiple segments of column pipe and drive shaft to vertical turbine pumps. The need for new pump bowls may not be a direct result of the lowering. However, the bowls may need to be replaced in well pumps that experience declining pumping levels, regardless of whether the pump setting needs to be lowered.

Figure 12-3 shows a comparison of Wharton water supply capacity to water demands based on a conceptual phasing plan for new wells and regular capacity renewal projects (i.e. cleaning and rehabilitation). The upper capacity line reflects the total production possible from all wells, while the lower line reflects the capacity available assuming the City's largest well is out of service. The following assumptions were made regarding well implementation:

- A new well will be operational by 2018. Wharton is currently seeking funding for this new well.
- Each new well adds approximately 2 mgd of additional production capacity.
- Well production declines at approximately 3 percent each year, but a well rehabilitation project is initiated when pumping capacity reaches 75 percent of design capacity
- Existing well capacity returns to design capacity after rehabilitation
- New wells become operational the year before max day demand exceeds total pumping capacity

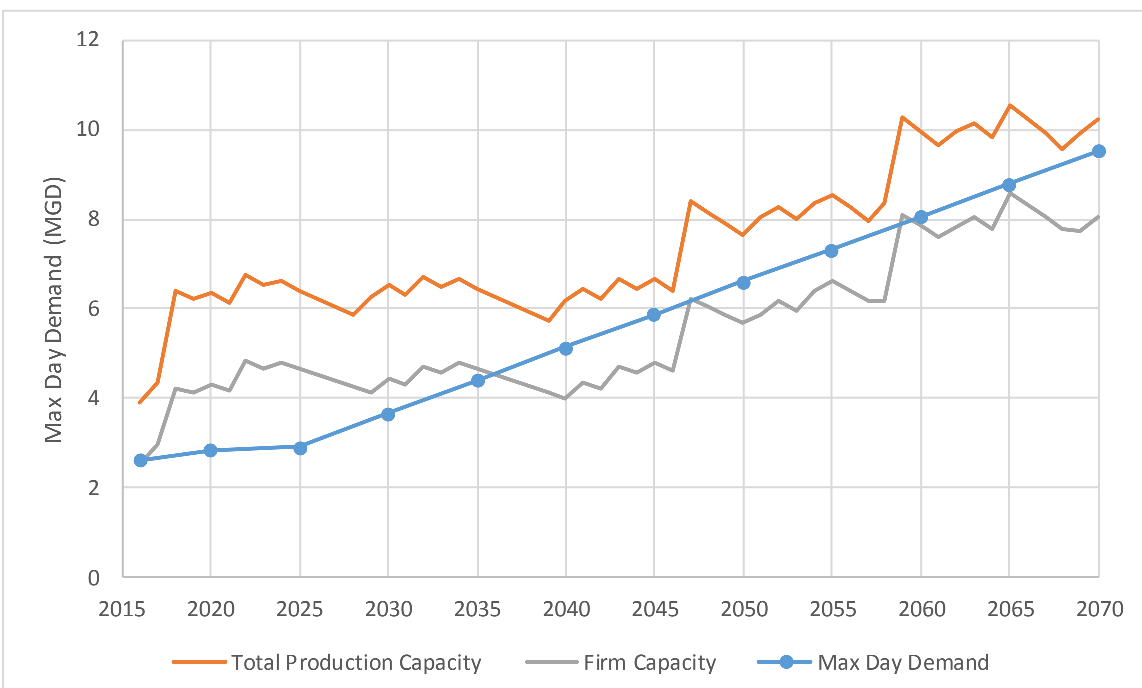

Figure 12-3 Conceptual Implementation Schedule

Wharton will not need an additional well until roughly 2045 if it completes the construction of a new well as currently planned and it periodically restores the production from all of its wells. A new well would be needed in 2035 if Wharton desires to maintain sufficient redundancy in its water supply system to be able to meet maximum day demands with its largest well out of service. A total of three new wells is needed within the study period to meet projected demands, and a fourth well is required to meet maximum day demands through the study period with its largest well out of service. If the city increases its conservation efforts, the timing of new wells for additional supply capacity can be deferred and the number of new wells required within the study period may be reduced.

As mentioned, Wharton is currently seeking funding for a new well to add water supply capacity to their system. This additional capacity will allow them to take existing wells out of service so that their capacity can be restored via cleaning and/or rehabilitation while continuing to meet system demands. The following additional infrastructure, with preliminary capacity estimates, are assumed to be constructed with a new 2.0 mgd well:

- 500,000 gallon ground storage tank
- 2.0 mgd pump station
- 12-inch diameter discharge pipeline connecting to the existing distribution system (pipeline length is dependent on the well site selected.

The following funding sources are available to the City for its next well.

- Various TWDB grant and loan programs, including
    - Drinking Water State Revolving Fund (DWSRF) Loan Program
    - Rural Water Assistance Fund (RWAF) Program
    - Texas Water Development Fund (DFund)
    - Water Infrastructure Fund
- United States Department of Agriculture (USDA) Rural Utilities Service loans and grants
- Texas Department of Agriculture grant programs
- Proceeds from the sale of municipal utility bonds

13. Summary, Conclusions and Recommendations

The Cities of Wharton and East Bernard in Wharton County currently use groundwater to meet municipal water demands. An evaluation of water supply options and opportunities available to Wharton is appropriate and timely before it commits resources to improve its aging water supply system. Wharton County WCID #2 serves a portion, but not all, of East Bernard. East Bernard desires a water supply evaluation to identify the feasibility of expanding WCID#2's service area. Water supply is important to both Wharton and East Bernard to ensure they can meet the demands of future growth. The cities teamed to pursue funding for a joint water supply study recognizing that their water supply evaluations could be considered together to develop a regional solution. TWDB partially funded this Regional Facility Plan under its Research and Planning Fund.

Projected water demands for this study are based on population projections and historical per capita water demand rates. Population projections developed for this study reflect the likelihood that the Houston and Harris County urban area will continue expanding, particularly along the Interstate 69 corridor, within the 50-year planning period for this study. These projections were multiplied by historical per capita water demands and a maximum day:average day demand ratio to develop maximum daily demands from which water supply options were sized and evaluated.

13.1 Water Supply Alternatives Evaluations

Three general alternatives were identified as viable sources of additional water supply for Wharton and East Bernard.

1. Purchase surface water from the LCRA and decommission existing wells
2. Groundwater
   a. Drill additional wells individually for each city
   b. Establish a location for a shared well field between Wharton and East Bernard
3. ASR

TWDB's UCM was utilized to develop conceptual level cost estimates for these alternatives. The UCM was developed for regional water planning and assures consistent planning-level cost estimates for water supply alternatives.

The continued development of groundwater wells to meet municipal demands is expected to cost 30 to 50 percent of the cost to develop a surface water supply source or a regional ASR system. Significant savings in annual operation and maintenance costs are also expected in the groundwater option relative to the surface water and ASR options. A significant factor contributing to the higher cost for alternate supplies is the requirement for more significant water treatment. Groundwater in the project area typically meets drinking water standards without any treatment, requiring only disinfection prior to distribution. Significantly more treatment is required for the alternate water supply methods, contributing to the higher construction costs and operating expenses. Another benefit of the groundwater supply alternative in Wharton County is that costly conveyance infrastructure is unnecessary because production wells can be drilled in or near each city's distribution system. The following conclusions have been drawn based on these findings:

- Groundwater appears to be the most economical water supply source available to the Cities of Wharton and East Bernard for the foreseeable future.
- A regional, shared groundwater supply alternative is not currently favorable.

13.2 Impacts and Risks

The reliability of water sources is a key consideration in the selection of a water supply alternative. Groundwater production can be reduced because of resource depletion or curtailed through regulatory restrictions. The hydrogeological assessment performed for this study predicts the following drawdown and subsidence resulting from the conservative water demand projections:

- average drawdown in the groundwater supply options are less than 1.5 feet for all simulations
- average drawdown for ASR alternatives are 0.3 feet or less for all simulations.
- no subsidence is expected to result from future Wharton and East Bernard groundwater production rates.

The CBGCD regulates groundwater production in Wharton County. Their rules include provisions to curtail permitted groundwater withdrawal amounts incrementally up to the Minimum-MAG derived amount for a permittee's property. This is the model-predicted maximum amount of available groundwater that can be withdrawn on a per-acre basis that sustains the average aquifer levels at or above a desired level. A municipal water system must reduce its demands or find supplemental or alternative water supplies if its permitted withdrawal amount is reduced to a level less than its demands.

Curtailments of permitted withdrawal rates do not appear to be likely in the near future based on current regulations, recent aquifer trends, and the hydrogeological projections from this study. However, the GAMs and conservation district rules and policies are refined regularly. Future changes to those policies could increase the risk that Wharton and East Bernard's groundwater permits include reduced withdrawal rates. If curtailments become more likely in the future, multiple strategies are available to these cities that may be more cost effective than the development of an alternate water supply source. One such strategy is to proactively promote the implementation of groundwater conservation district policies favorable to municipalities. Such policies would require municipalities to share in the burden of demand reductions, but do so with a reduced risk of having to develop alternate water supplies. Another strategy is to purchase the rights to produce more groundwater to supplement the volume defined in the permit through a contiguous acreage lease. This strategy is a reactive one to be implemented in the event that groundwater curtailments become a reality. An example of a conservation district rule that would reduce the costs associated with a contiguous acreage lease is one that allows municipal corporate boundaries to count toward contiguous acreage "owned" by the municipalities.

13.3 Importance of Water Conservation

An increased focus on water conservation will benefit both Wharton and East Bernard in several ways. Implementing an effective water conservation program and striving to achieve reductions in per capita water demands is sound resource management and fiscally prudent. Reducing water demands through conservation will reduce the likelihood that permit curtailments are required and reduce the costs associated with contiguous acreage leases should they become necessary. Conservation-based water management is also a cost-effective strategy to reduce capital and operating expenses associated with water supply and distribution infrastructure.

Wharton has an existing water conservation plan as required, but East Bernard does not yet meet the criteria that require them to have a conservation plan in place. Wharton's plan was reviewed and a few issues were noted that should be revised. First, Wharton's conservation plan does not clearly state the starting or goal level demands, making progress difficult to track and success difficult to determine. Second, the goals are based on per connection water reductions instead of per capita reductions as required by the state. Finally, Wharton's five-year average water loss in 2015 exceeded 25 percent. The City's existing goals for per connection water reduction and reduction of lost water do not correlate; the City can meet its per connection demand goals but be far short of meeting its lost water goals. The following revised targets are recommended for Wharton's water conservation plan so that its goals are consistent with each other and reflect regulatory targets.

- Five-Year Goal (2017 – 2021): Reduce the five-year average municipal use to 148 gpcd and reduce unaccounted for water to 15 percent
- Ten-Year Goal (2017 – 2026): Reduce the five-year average municipal use to 133 gpcd and reduce unaccounted for water to 10 percent

Wharton's projected 2070 maximum day demand would reduce from 9.5 mgd to 7.3 mgd if it meets its revised water conservation goals. Conservation allows Wharton to both defer demand-based capital improvements and reduce the total amount of water supply infrastructure needed. A reduction of demand by 2.2 mgd could mean the elimination of a well site, which also eliminates the need for disinfection equipment, a storage tank and a distribution pump station at that site. The capital savings for property, infrastructure and debt service is estimated to be three to four million dollars per eliminated well. Water conservation reduces the annual operational expenses associated with producing groundwater, disinfecting it and pumping it into the distribution system. The annual savings estimated in Wharton totals $150,000 to $200,000 per year for each well that becomes unnecessary due to water conservation. For groundwater supply systems, reduced demands also mean less impact on the local aquifer and potentially reduced drawdown over time. In all, a significant return on investment can be realized for a proactive and effective water management program that meets its conservation goals.

13.4 East Bernard Needs and Recommendations

Wharton County WCID #2 operates three wells with a current permitted capacity equal to 0.45 mgd. WCID #2's total well pumping capacity is currently approximately 2.2 mgd. These capacities are more than sufficient to serve current East Bernard residents outside of the existing WCID #2 service area and future growth. The following upgrade estimates are based on the water demand projections developed for this report and assume Wharton County WCID #2 expands to meet those future needs.

- Additional well permit withdrawal capacity needed: 2030.
- Additional well production capacity needed: 2065

WCID #2 has expressed reluctance to expand however, meaning another utility may have to be created to serve future demands. Creating a new water utility in East Bernard will require $4 to $5 million in water infrastructure that would be unnecessary if WCID #2 expands. Further redundancy and cost inefficiencies would arise in the management and operation of a second utility. A wastewater collection and treatment infrastructure system could be constructed to serve East Bernard for a comparable level of funding.

13.5 Wharton Needs and Recommendations

Wharton's existing permitted withdrawal for groundwater is 5,382.7 acre-feet over its three-year permit term, or approximately 1.60 mgd. The average daily demand is projected to exceed this amount in approximately 2025, requiring a permit withdrawal increase by the City's 2023 permit renewal. However, multiple dry years could lead to Wharton's demand exceeding 90 percent of its current permitted withdrawal, so consideration should be given to requesting additional permitted capacity in the 2017 permit renewal.

Wharton's total production capacity has declined approximately 20 percent since 2006. If the total well production continues to decline at a similar rate, Wharton's maximum day demand will exceed its total well capacity within 10 years. Regular well cleaning and periodic rehabilitation will be important for Wharton to maintain its groundwater production capacity.

Wharton is currently planning to design and construct a new well, which could be operational by 2018. With this new well and restored production from its existing wells, the next well will not be needed in Wharton until approximately 2045. A new well would be needed in 2035 if Wharton desires to maintain sufficient redundancy in its water supply system to be able to meet maximum day demands with its largest well out of service. Three new wells are needed within the study period to meet projected demands, and a fourth well is required to meet Wharton's maximum day demands through the study period with its largest well out of service. If the city increases its conservation efforts, the timing of new wells for additional supply capacity can be deferred and the number of new wells required within the study period will be reduced.

Appendix A

Existing Well Permits

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Coastal Bend Groundwater Conservation District
PO Box 341, 109 E. Milam
Wharton, Texas 77488
Phone: (979) 531-1412 Fax: (979) 531-1002
Email:thedistrict@cbgcd.com Web Site: www.cbgcd.com

OPERATING PERMIT
PERMIT NO.: OP-04120602

I. PERMITTEE:

City of Wharton c/o Andres Garza, Jr.
120 East Caney Street
Wharton, TX 77488-

II. REGISTRANT:

Andres Garza, Jr.
120 East Caney Street
Wharton 77488-

III. NUMBER OF WELLS COVERED BY PERMIT: 4

IV. WELL REGISTRATION NUMBER AND LOCATION

Well Reg #	Personal ID	Latitude	Longitude	Well Reg #	Personal ID	Latitude	Longitude
2004120642	Alabama Rd. Well #3	29.31639	-96.08833	2004120643	Alabama Well #1	29.31611	-96.08833
2005051201	Valhalla Dr. Well #4	29.33083	-96.11528	2005051202	Cloud Street #2	29.31389	-96.10389
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000

V. PERMIT TERM:

Commencement Date: 2/1/2014
Expiration Date: 2/28/2017

VI. PURPOSE OF USE:
Municipal

VII. AUTHORIZED WITHDRAWAL:
Only that which is required without being wasteful during the permit term, but not to exceed 5382.570 Acre Feet. Any pumpage and excess of the amount authorized in this permit is a violation of the District's Rules. Applications for an amendment to increase authorized withdrawal must be submitted prior to exceeding the permitted amount.

VIII. SPECIAL PROVISIONS:

SUBJECT TO CONDITIONS AND REQUIREMENTS ON ATTACHED PAGE.

DATED, ISSUED, AND EXECUTED THIS 2/1/2014; TO BE EFFECTIVE ON THE 2/1/2014.

BY: ______________________
Neil Hudgins, General Manager

Coastal Bend Groundwater Conservation District
PO Box 341, 109 E. Milam
Wharton, Texas 77488
Phone: (979) 531-1412 Fax: (979) 531-1002
Email:thedistrict@cbgcd.com Web Site: www.cbgcd.com

OPERATING PERMIT
PERMIT NO.: OP-04120608

I. PERMITTEE:

City of Wharton c/o Andres Garza, Jr.
120 East Caney Street
Wharton, TX 77488-

II. REGISTRANT:

Andres Garza, Jr.
120 East Caney Street
Wharton 77488-

III. NUMBER OF WELLS COVERED BY PERMIT: 2

IV. WELL REGISTRATION NUMBER AND LOCATION

Well Reg #	Personal ID	Latitude	Longitude	Well Reg #	Personal ID	Latitude	Longitude
2004120647	Wharton Regional Airport	29.25833	-96.15528	2004120648	Wharton Regional Airport	29.26111	-96.15750
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000

V. PERMIT TERM:

Commencement Date: 2/1/2014
Expiration Date: 2/28/2017

VI. PURPOSE OF USE:
Municipal

VII. AUTHORIZED WITHDRAWAL:
Only that which is required without being wasteful during the permit term, but not to exceed 2.520 Acre Feet. Any pumpage and excess of the amount authorized in this permit is a violation of the District's Rules. Applications for an amendment to increase authorized withdrawal must be submitted prior to exceeding the permitted amount.

VIII. SPECIAL PROVISIONS:

SUBJECT TO CONDITIONS AND REQUIREMENTS ON ATTACHED PAGE.

DATED, ISSUED, AND EXECUTED THIS 2/1/2014; TO BE EFFECTIVE ON THE 2/1/2014.

BY: ______________________
Neil Hudgins, General Manager

§3.17 PERMIT TERMS AND CONDITIONS

All permits are granted subject to these Rules, orders of the Board, and the laws of the State of Texas. In addition to any special provisions or other requirements incorporated into the permit, each permit issued shall be subject to the following terms and conditions:

(1) The permit is granted in accordance with the provisions of the Enabling Act in conjunction with Texas Water Code Chapter 36, and the Rules and orders of the District.

(2) The permit confers no vested rights in the holder. The permit may be revoked or suspended or its conditions may be modified or amended pursuant to the requirements of the Enabling Act and any applicable Rules and orders of the District.

(3) The drilling and operation of the well for the authorized use shall be conducted in such a manner as to avoid waste, pollution, or harm to the aquifer.

(4) The permittee shall maintain records estimating the amount of groundwater withdrawn each month, the purpose of the withdrawal, and the total amount of water exported, if any. The permittee shall describe the method or technique used to estimate water withdrawn. Such records shall be available for inspection by District representatives. Monthly use shall be reported to the District in the annual pumpage report on a form approved by the District. Immediate written notice shall be given to the District in the event a withdrawal exceeds the quantity authorized by the permit.

(5) The well site shall be reasonably accessible to District representatives for inspection. The permittee agrees to cooperate fully in any reasonable inspection of the well site and related monitoring or sampling by District representatives.

(6) The application pursuant to which a permit has been issued is incorporated in the permit, and the permit is granted on the basis of and contingent upon the accuracy of the information supplied in that application and in any amendments thereof. A finding that false information has been supplied shall be grounds for immediate revocation of the permit. In the event of conflict between the provisions of the permit and the contents of the application, the provisions of the permit shall control.

(7) Driller's logs must be submitted to the District within sixty (60) days of the drilling of a well. Failure to submit a driller's log will be grounds for revocation of a permit.

(8) Violation of the permit's conditions, requirements, or special provisions, including pumping amounts in excess of authorized withdrawal, is a violation of these Rules and shall be punishable by civil penalties as provided by the Enabling Act and these Rules. Each day a violation continues is a separate violation, and each day pumping continues after reaching the amount authorized to be withdrawn on the permit constitutes a separate violation.

(9) If special provisions on a permit are inconsistent with other provisions or regulations of the District, the special provisions shall prevail.

(10)Public water system permittees should maintain at least 85 percent accountability. If losses or unaccounted for water exceeds 15 percent, the District may require the public water system permittee to submit a report to the District outlining the steps the permittee will take to improve system accountability. Unaccounted for water is presumed to be waste unless the permittee can provide evidence the water was put to a beneficial use.

Additional Provision: This well may be aggregated with other existing wells owned and operated by the permittee and the groundwater withdrawn from this well may be considered part of the historical use claimed by the permittee only so long as the permittee owns and operates this well and limits its use to the quantity and type of use which has been historically used by existing wells. If this well or the land where this well is located is ever sold or transferred to any other party authorization to withdraw groundwater based upon historical user status is withdrawn, and the new owner must apply for a new operating permit prior to operating the well.

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Coastal Bend Groundwater Conservation District
PO Box 341, 109 E. Milam
Wharton, Texas 77488
Phone: (979) 531-1412 Fax: (979) 531-1002
Email:thedistrict@cbgcd.com Web Site: www.cbgcd.com

OPERATING PERMIT
PERMIT NO.: OP-05011157

I. PERMITTEE:

Wharton Co. W.C.I.D. #2 c/o Edward Vacek
P.o. Box 639
East Bernard, TX 774350639

II. REGISTRANT:

Edward Vacek
P.O. Box 639
East Bernard 77435

III. NUMBER OF WELLS COVERED BY PERMIT: 4

IV. WELL REGISTRATION NUMBER AND LOCATION

Well Reg #	Personal ID	Latitude	Longitude	Well Reg #	Personal ID	Latitude	Longitude
2005011159	Well #3	29.52056	-96.06194	2005011160	Well #1	29.52889	-96.06528
2005011161	Well #2	29.52889	-96.06472	2005010618	bt#1	29.54472	-96.05389
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000
		.00000	.00000			.00000	.00000

V. PERMIT TERM:

Commencement Date: 3/11/2014
Expiration Date: 2/28/2017

VI. PURPOSE OF USE:

Municipal

VII. AUTHORIZED WITHDRAWAL:

Only that which is required without being wasteful during the permit term, but not to exceed 1500.000 Acre Feet. Any pumpage and excess of the amount authorized in this permit is a violation of the District's Rules. Applications for an amendment to increase authorized withdrawal must be submitted prior to exceeding the permitted amount.

VIII. SPECIAL PROVISIONS:

SUBJECT TO CONDITIONS AND REQUIREMENTS ON ATTACHED PAGE.

DATED, ISSUED, AND EXECUTED THIS 3/11/2014; TO BE EFFECTIVE ON THE 3/11/2014.

BY: ______________________________
Neil Hudgins, General Manager

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Appendix B

Hydrogeological Assessment

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DRAFT HYDROGEOLOGICAL ASSESSMENT FOR GROUNDWATER WELL OPTIONS FOR THE CITY OF WHARTON, TEXAS

Prepared for:

HALFF Associates, Inc.
12225 Greenville Avenue
Suite 200
Dallas, TX 75243
214.572.2272

Prepared by:

Steve C Young, PhD, PE, PG
Joan Blainey, PhD, PG
Tingting Yan, EIT

INTERA Incorporated
1812 Centre Creek Drive
Suite 300
Austin, TX 78754
512.425.2000

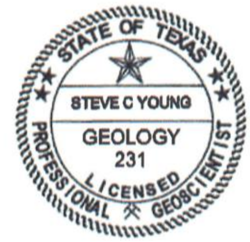
October, 2016

PROFESSIONAL GEOSCIENTIST SEAL(S)

This report documents work of the following Licensed Geoscientists:

Steven C. Young, PG, PE, PhD

Dr. Young was the Project Manager for the report and was responsible for assembling and interpreting the well test information.



Steven C Young — 8/5/2016

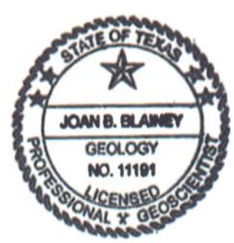
Signature Date

Joan Blainey, PG, PhD

Dr. Joan Blainey developed and applied analytical element models for predicting drawdown.

Joan B. Blainey — 8/5/2016

Signature Date



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ACROYNMS AND ABBREVIATIONS

ASR	Aquifer Storage and Recovery
GAM	Groundwater Availability Model
GCD	Groundwater Conservation District
GPM	Gallons Per Minute
IBS	Interbed-Storage package of MODFLOW
LCRB	Lower Colorado River Basin
MGD	Million Gallons per Day
NCOW	North of the City of Wharton
TCEQ	Texas Comission on Environmental Quality
TWDB	Texas Water Development Board
USGS	United States Geological Survey
WEL	Well package of MODFLOW

EXECUTIVE SUMMARY

This report documents the development of and results from numerical models of groundwater flow that predict drawdown and subsidence as a result of increased pumping of groundwater to meet future water supply demands. Modeling scenarios were based on the assumption that central Wharton County will need to expand the existing water supplies from 3 million gallons per day (MGD) in 2020 to 11 MGD in 2070 for the cities of Wharton and East Bernard. Two water sources were considered to meet the projected demand. The first water source is withdrawal from the Gulf Coast Aquifer System at additional wells. The second source of water is treated wastewater effluent that is injected into wells as part of aquifer storage and recovery (ASR). This report provides analyses for the two water supply options for the cities of Wharton and East Bernard based on seven simulations that consider variations in the locations of the additional wells, varied contributions of the water sources (additional wells or additional wells and ASR), and four different pumping scenarios (pumping rates and number of wells over time) in the two proposed well field areas (Pierce Ranch and North of the City of Wharton (NCOW)).

The Lower Colorado River Basin (LCRB) groundwater model (Young and others, 2009) was used to predict drawdown and subsidence impacts from additional pumping from 2020 through 2070 for seven simulations. These seven simulations consist of the two proposed well field areas, two water supply options with one including ASR, and four different pumping scenarios as indicated by S1, S2, S3, and S4. INTERA validated the application of the LCRB model in the vicinity of the city of Wharton by checking that the hydraulic properties in the model were consistent with those derived from a pumping test in the city of Wharton well field.

For each of the seven simulations, the maximum drawdown was calculated as: (1) an average drawdown over Wharton county and (2) a net change in drawdown over Wharton County relative to the drawdown calculated using the baseline LCRB model which includes a constant pumping rate of 3 MGD for the cities of Wharton and East Bernard. Key metrics to characterize the average drawdown from 2020 through 2070 are shown in the table below as the average net change in drawdown in Wharton County over all the aquifers in the LCRB model relative to the baseline simulation. Policies for groundwater management are often based on a county-wide average drawdown metric.

Water Supply Option(s)	Potential Well Field Area	New Wells	ASR	Pumping Scenario	Average Change in Net Drawdown over Wharton County (feet) 2020 to 2070
Add new wells	Pierce Ranch	X		S1	1.7
Add new wells	Pierce Ranch	X		S2	1.8
Add new wells	North of the City of Wharton	X		S1	1.4
Add new wells	North of the City of Wharton	X		S2	1.3
Add new wells and ASR	Pierce Ranch	X	X	S3	0.3
Add new wells and ASR	North of the City of Wharton	X	X	S3	<0.1
Add new wells	North of the City of Wharton	X		S4	0.6

In all of the seven simulations, the maximum simulated subsidence was less than 0.1 feet indicating that the predicted drawdown is not sufficient to create significant subsidence. From a subsidence perspective, there is no incentive to pursue ASR and incur the additional costs associated with the ASR wells and the pipeline infrastructure needed to connect the treated wastewater effluent with the ASR well field.

INTERA also considered the impact of the variation in hydraulic properties on the simulated drawdown using four different potential well field locations identified by the City of Wharton. The simulated maximum and minimum drawdowns are similar among all four well field locations in 2070 indicating that the variability in hydraulic properties in the LCRB model at these locations results in little variation in drawdown with time.

Pumping scenarios simulated with the LCRB model, summarized in the above table, indicate that increased pumping from 3 MGD in 2020 to 11 MGD in 2070 could result in an average drawdown of up to about 1.8 feet without ASR and 0.3 feet with ASR across Wharton County. Given the potentially high costs of implementing ASR to reduce the likelihood of violating a desired future condition (DFC) set by Groundwater Management Area (GMA) 15, the cities should discuss options with the Coastal Bend Groundwater Conservation District (GCD) regarding the development and adoption of groundwater management policies that would help municipalities in Wharton County meet future water demands with minimal infrastructure investments, while still providing long-term protection of the county's groundwater resources.

1.0 INTRODUCTION

The modeling scenarios created to predict drawdown and subsidence as a result of increased pumping of groundwater to meet future water supply demands were based on the assumption that central Wharton County will need to expand the existing water supplies from 3 million gallons per day in 2020 to 11 MGD in 2070 for the cities of Wharton and East Bernard. Two water sources were considered to meet the projected demand. The first water source is withdrawal from the Gulf Coast Aquifer System at additional wells. The second source of water is treated wastewater effluent that is injected into wells as part of ASR. This report provides analyses for the two water supply options for the cities of Wharton and East Bernard based on seven simulations that consider variations in the locations of the additional wells, different water sources (additional wells or additional wells and ASR), and four pumping scenarios (pumping rates and number of wells over time). The total pumping is identical for all of the pumping scenarios but the number of wells, pumping rates at individual wells, and the well locations vary among the four pumping scenarios. This report provides information to compare the analysis of the two water supply options for the cities of Wharton and East Bernard.

1.1 Report Objectives

The investigation had three main objectives. The first objective was to characterize local aquifer properties using the results of an existing pumping test performed in the City of Wharton well field. The aquifer properties obtained from the pumping test were compared to the aquifer properties contained in the LCRB model near the city of Wharton. The second objective was to perform a hydrogeologic assessment of well field options for additional groundwater wells and to predict groundwater impacts of additional pumping using the LCRB model. The third objective was to perform a hydrogeologic assessment of well field options that included ASR as a new water source and to predict groundwater impacts of the proposed injection and extraction wells using the LCRB model.

1.2 Report Outline

This report discusses the hydrogeology of central Wharton County and hydrogeologic assessments of expanding existing water supplies to meet projected demands for the cities of Wharton and East Bernard.

This report is organized into seven sections as follows:

- Section 1 introduces the objectives of the study.
- Section 2 provides a summary of the geology of Wharton County with an emphasis on the central portion of Wharton County.
- Section 3 provides a summary of the LCRB model which was used to conduct groundwater simulations and calculate drawdown and subsidence responses to additional pumping.
- Section 4 presents a hydrogeologic assessment of the aquifer properties near the city of Wharton.
- Section 5 presents the locations of the proposed well field sites and pumping schedule for the proposed extraction wells.
- Section 6 presents the drawdown for the simulations described in Section 5.
- Section 7 presents the locations of the proposed injection and extraction wells and pumping schedule for ASR wells and the simulated drawdown with ASR.

- Section 9 presents the pumping schedule and drawdown for a simulation with average annual daily demands
- Section 10 presents the references used in this report.

2.0 HYDROGEOLOGIC SETTING

2.1 Regional Geology

In Wharton County, groundwater is primarily pumped from the Gulf Coast Aquifer System. The Gulf Coast Aquifer System encompasses all geological units above the Vicksburg Formation (George and others, 2011; Young and others, 2010). **Figure 2-1** depicts the geological formations and the hydrogeological units that comprise the Gulf Coast Aquifer System.

The Gulf Coast sediments are comprised of sequences of interbedded sandstones and shales, which are grouped into geological formations and aquifers based on regional scale correlations of the lithologic units and the depositional environments responsible for the spatial variability in the patterns and thickness of these lithologic units. Among the factors that caused the depositional environments to change over time and across distance were: changes in sedimentary processes, sediment supply, climate, tectonics (earth movements), sea level changes, biological activity, water chemistry, and volcanic activity.

The most recent studies funded by the Texas Water Development Board (TWDB) that delineate the structure and stratigraphy of the Gulf Coast Aquifer are by Young and others (2010, 2012). These studies subdivided the aquifer units into geological formations based on chronostratigraphic correlations. **Figure 2-2** is a vertical cross-section through the Gulf Coast Aquifer that crosses through Wharton County that shows the relationships between geological formations and aquifers as defined by Young and others (2010, 2012) and the study of the Catahoula Aquifer (LBG Guyton and INTERA, 2012). Most of the registered wells in Wharton County are located in either the Chicot Aquifer or the Evangeline Aquifer. As shown in Figure 2-2, these two aquifers comprise the majority of the upper 2,000 feet (ft) of the Gulf Coast Aquifer System in Wharton County. These two aquifers are described below.

Chicot Aquifer – The Chicot Aquifer includes, from the shallowest to deepest, the Beaumont and Lissie formations of Pleistocene-age and the Pliocene-age Willis Formation. The Beaumont outcrop covers a large part of the lower coastal plain, except where cut by modern river valleys or covered by Holocene wind-blown sand in south Texas. The Beaumont Formation is often composed of clay-rich sediments transected by sandy fluvial and deltaic-distributary channels. At outcrop, the Lissie Formation is composed of fine-grained sand and sandy clay and unconformably overlies and onlaps the Willis Formation (Morton and Galloway, 1991). The Lissie Formation is dominated by non-marine depositional systems in the onshore part across most of the Texas Gulf Coast, although some shore-zone facies occur in Matagorda County as well as other coastal counties. At outcrop, the Willis Formation is composed of gravelly coarse sand in several upward-fining successions that are interpreted as incised valley fills overlain by transgressive deposits (Morton and Galloway, 1991). Near the modern shoreline and offshore, Willis deltaic and marine systems record four cyclic depositional episodes bounded by transgressive shales (Galloway and others, 2000). Willis fluvial systems include dip-oriented sand-rich channel-fill facies and sand-poor interchannel areas, which grade toward the coast into shore-parallel deltaic and shore-zone sands and interdeltaic muddy bay deposits. Individual Willis sands vary widely in thickness from about 20 to 200 ft and are separated by muds of similar thickness (Knox and others, 2006).

Evangeline Aquifer – The Evangeline Aquifer includes the Upper Goliad Formation of earliest Pliocene and late Miocene age, the Lower Goliad Formation of middle Miocene age, and the upper unit of the

Lagarto Formation (a member of the Fleming Group) of middle Miocene age. The Goliad Formation in Wharton County was formed as part of the Eagle Lake extrabasinal fluvial system. In this system, the Goliad fluvial depositional systems consist of channel-fill and interchannel deposits (Young and others, 2012). Channel belts are typically 10 to 30 miles wide with about 50 percent sands, and the interchannel deposits typically have less than 20 percent sand. The Upper Lagarto Formation is comprised of deposits from the Fleming Group. The Fleming Group comprises several large fluvial systems that grade downdip into equally large delta and shore-zone systems (Rainwater, 1964; Doyle, 1979; Spradlin, 1980; DuBar, 1983; Galloway and others, 1991). In Wharton County, the Fleming sands tend to align parallel to the shoreline and have sand contents between 10 and 40 percent (Young and others, 2012).

Burkeville – The Burkeville Confining Unit is represented by the middle unit of the Lagarto Formation of middle and early Miocene age, which is the chronostratigraphic layer with the most widespread clayey interval between the Evangeline and Jasper aquifers.

Jasper Aquifer – The Jasper Aquifer includes the lower Lagarto unit of early Miocene-age, the early Miocene Oakville sandstone member of the Fleming Group, and the sandy intervals of the Oligocene-age Catahoula Formation.

2.2 Groundwater Wells and Pumping

This section characterizes the permitted and exempt water wells near two potential well field areas based on the data from the Coastal Bend Groundwater Conservation District (GCD). The water wells are characterized as either a permitted well or an exempt well. Well depth was used to assign each well to the appropriate LCRB model layer based on the total depth of the well.

Figure 2-3 presents the central Wharton County study area and **Figure 2-4** shows the permitted wells within Wharton County by LCRB model layer. The majority of the permitted wells are in the Beaumont Formation (LCRB model layer 2) or the Lissie Formation (LCRB model layer 3). Shallow permitted wells, those pumping from the Unconfined Aquifer (LCRB model layer 1) are excluded from Figure 2-4. Figure 2-4 shows that wells on Pierce Ranch pump from the Willis Formation (LCRB model layer 4) while the city of Wharton wells pump from the Upper Goliad Formation (LCRB model layer 5) based on the total depth of the well.

The permitted groundwater volumes for 2014 through 2017 in acre-feet by the Coastal Bend GCD are also shown in Figure 2-4. The permitted groundwater volumes aided in the development of the potential well field areas. For example, the northwestern boundary of the north of the City of Wharton (NOCW) well field area coincides with transition between the 501 to 1,000 acre-feet and the 1,001 to 2,000 acre-feet values.

Figure 2-5 shows the exempt wells within Wharton County by LCRB model. Shallow exempt wells, those pumping from the Unconfined Aquifer (LCRB model layer 1) are excluded from Figure 2-5. Within Pierce Ranch the exempt wells are pumping from the Beaumont, Lissie, Willis, and Upper Goliad formations (LCRB model layers 2 through 5) based on the total depth of the well.

ERA	Epoch		Est. Age (M.Y)	Geologic Unit	Hydrogeologic Unit
Cenozoic	Pleistocene		0.7	Beaumont	CHICOT AQUIFER
			1.6	Lissie	
	Pliocene		3.8	Willis	
	Miocene	Late	11.2	Upper Goliad	EVANGELINE AQUIFER
			14.5	Lower Goliad	
			17.8	Upper Lagarto	
		Middle		Middle Lagarto	BURKEVILLE
		Early		Lower Lagarto	JASPER AQUIFER
			24.2	Oakville	
	Oligocene		32	Frio	CATAHOULA
			34	Vicksburg	

Figure 2-1 Geologic and hydrogeologic units of the Gulf Coast Aquifer in Wharton County, modified from Young and others (2010, 2012) and LBG Guyton and INTERA (2012)

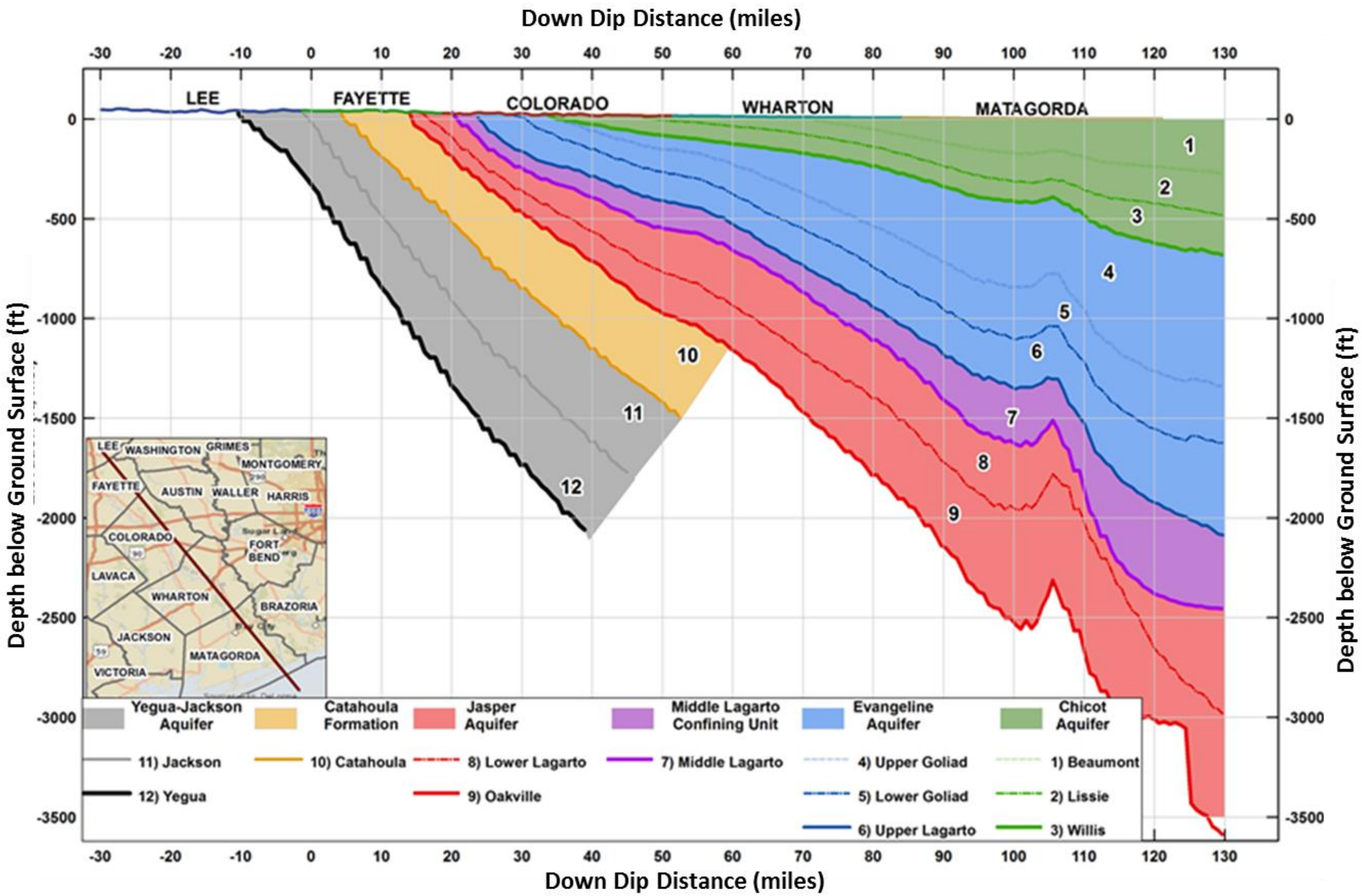


Figure 2-2 Cross-section along dip through the Gulf Coast Aquifer system showing the aquifers and geological formations in Colorado, Wharton, and Matagorda counties

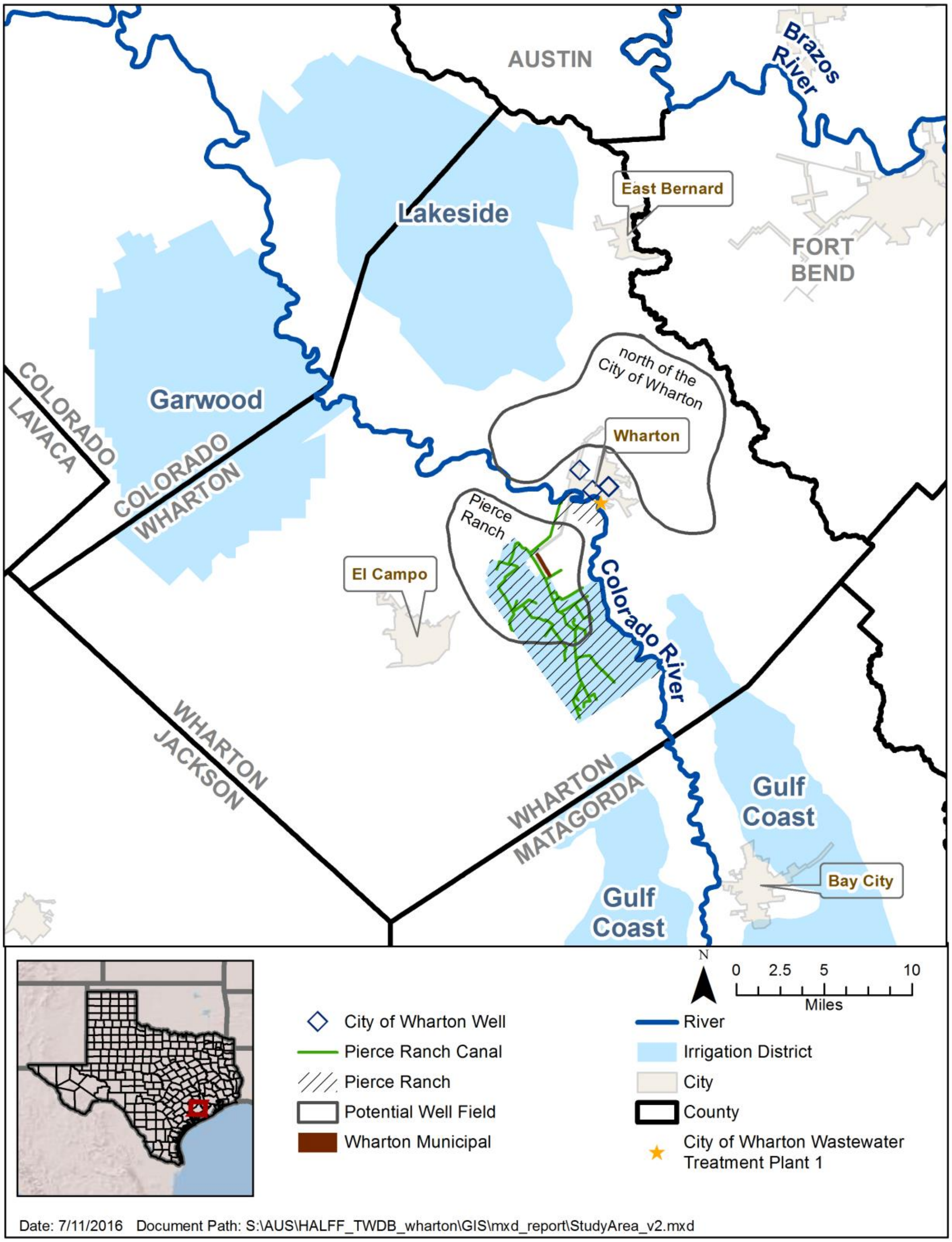


Figure 2-3 Study area in central Wharton County

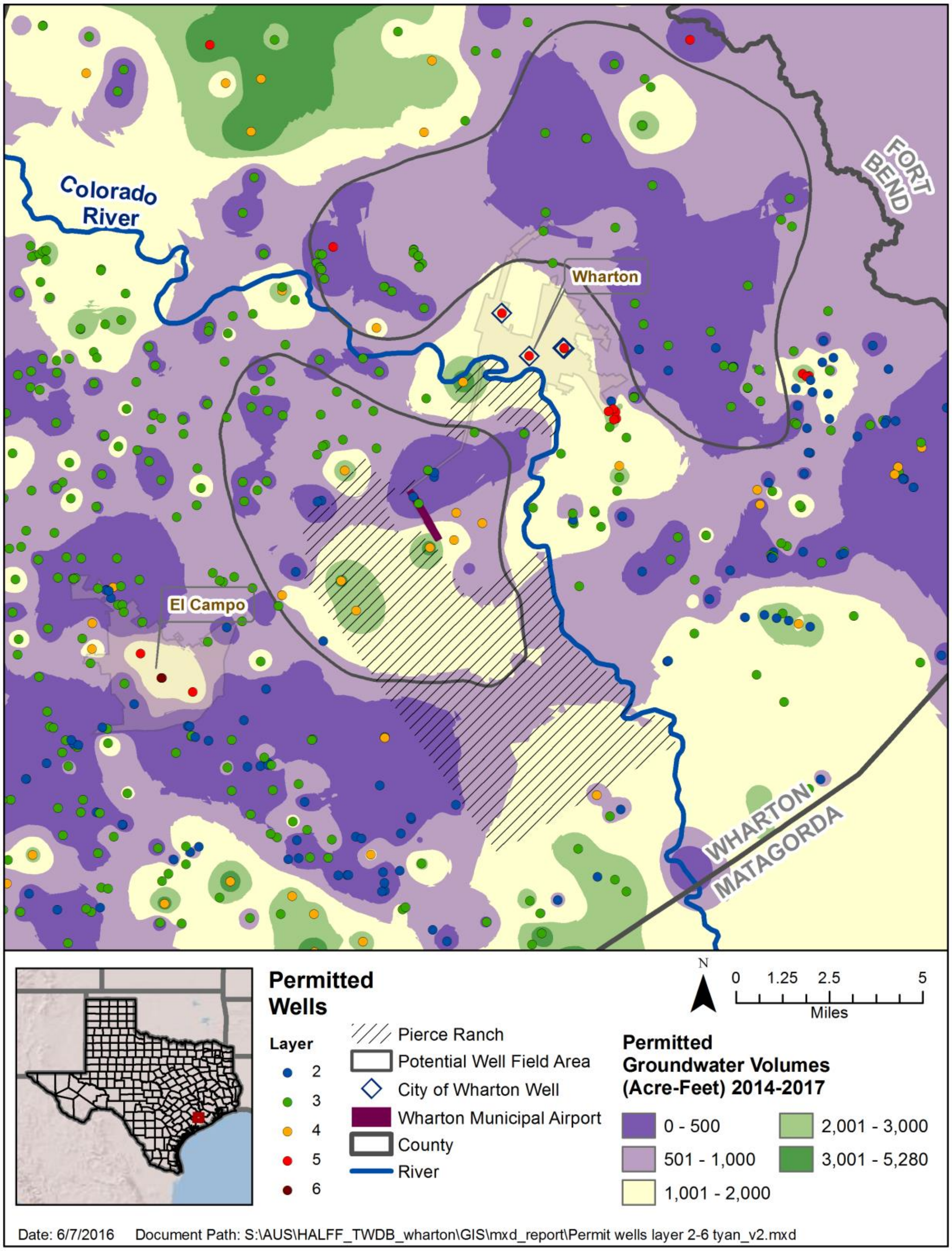


Figure 2-4 Permitted wells by LCRB model layer and permitted groundwater volumes in Wharton County

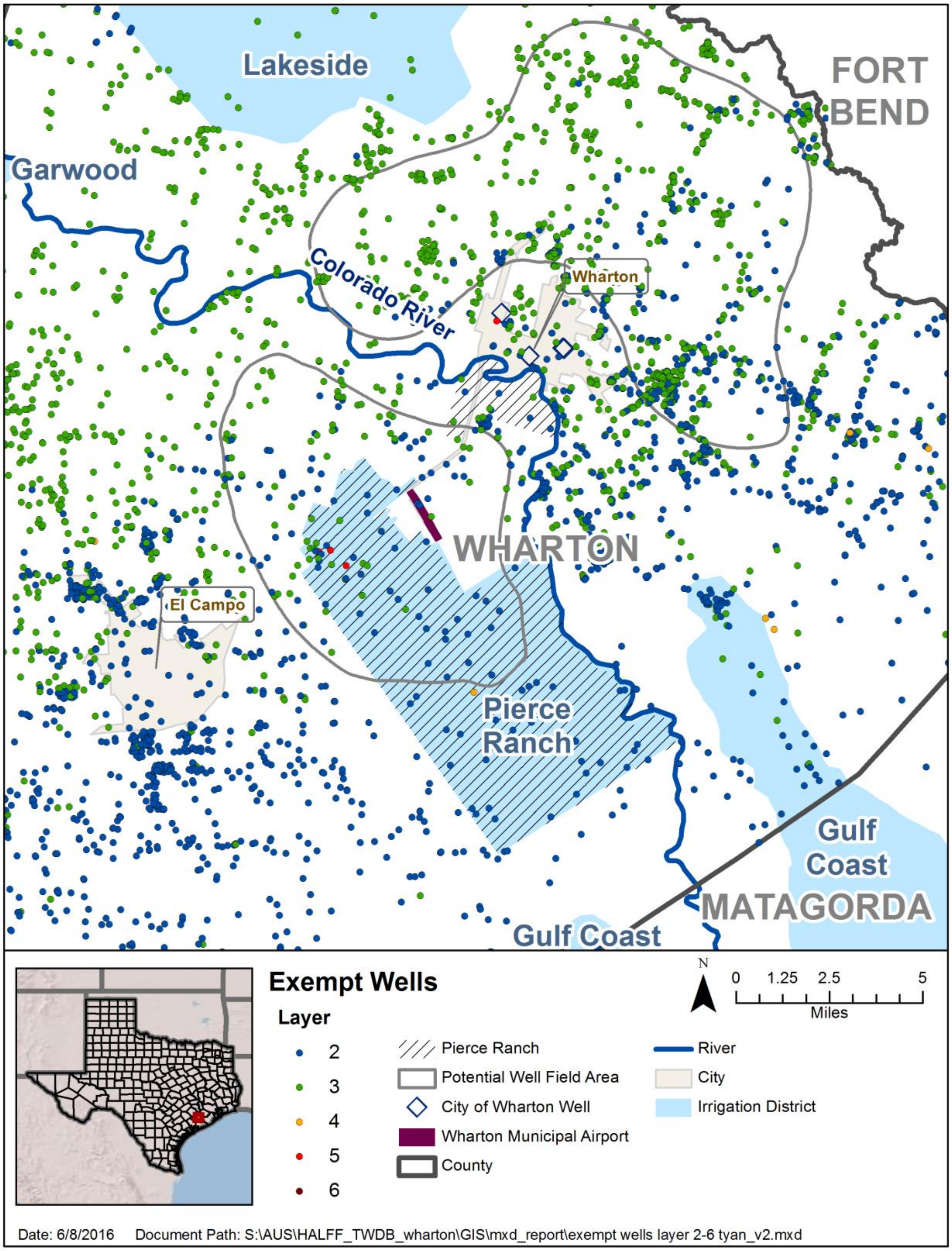


Figure 2-5 Exempt wells by LCRB model layer in Wharton County

3.0 LCRB Model

The LCRB groundwater model (Young and others, 2009) was developed from 2003 to 2009 as part of the Lower Colorado River Authority/San Antonio Water System Water Project (LSWP). **Figure 3-1** shows the areal extent of the LCRB model. The model covers 10,000 square miles and is centered on Wharton County. The purpose of the model was to apply state of the art modeling tools and approaches in order to provide a significantly better model for predicting impacts of pumping at the local scale of ten or fewer miles than the Central Gulf Coast Groundwater Availability Model (GAM) (Chowdhury and others, 2004). The process of developing the LCRB model involved regular stakeholder and public meetings, a scientific panel that continually reviewed the model assumptions and functionality, quarterly meetings with the groundwater conservation districts, and semiannual meetings with the TWDB.

3.1 Model Development

The LCRB model was developed at a much greater resolution than previous groundwater models in the region. In Wharton County, the grid cells are a uniform 0.0625 square miles instead of the 1 square mile used in the Central Gulf Coast GAM. The LCRB model used six model layers as shown in **Figure 3-2** to represent the Chicot and Evangeline aquifers whereas as the Northern Gulf Coast GAM used two layers. The LCRB model was developed using a commercial version of MODFLOW called MODFLOW-SURFACT (HGL, 2005) because it provided significantly better solution techniques to simulate pumping from wells, recharge to the water table, and the rewetting and drying of the grid cells located in an aquifer outcrop. MODFLOW is a groundwater flow code that was developed by the United States Geological Survey (USGS) for modeling groundwater in three dimensions. The code has been continually enhanced and expanded by the USGS for more than two decades (McDonald and Harbaugh, 1988, Harbaugh and others, 2000). All of the GAMs developed by the TWDB have been built using the MODFLOW code.

The LCRB model has 426 rows and 264 columns of cells. The rows run perpendicular to the coastline or along the geologic dip of the Gulf Coast Aquifer. The columns run parallel to the coastline or along the geologic strike of the Gulf Coast Aquifer.

The model calibration consisted of simulating a pre-development steady-state period and a transient pumping period from 1900 to 1997. Results of the steady-state simulations were used for the initial conditions for the transient simulation. The model calibration was based on a systematic and objective approach implemented with PEST (Doherty, 2004). PEST is a parameter estimation and optimization code that is specifically tailored for application to groundwater codes. The primary calibration targets included 800 well hydrographs that contain approximately 35,000 water levels from wells and base flow estimates for five river basins. Secondary calibration targets included estimated averages of horizontal hydraulic conductivity for the geologic formations.

Young and Kelly (2006) document the conceptual model used to develop the LCRB model and Young and others (2009) document the construction and calibration of the model. Young and others (2009) compare the model to calibration results to previous regional groundwater models and the Central Gulf Coast GAM and demonstrate that the LCRB model has superior model calibration relative to the previous models with respect to simulating historical water levels, simulating base flow in rivers, and accurately representing historical pumping.

3.2 Comparison To Central Gulf Coast GAM

Two of the significant advancements provided by the LCRB model relative to the Central Gulf Coast GAM include a data-intensive stratigraphic and hydrogeologic framework for estimating aquifer hydraulic properties and a shallow flow system that provides a realistic interaction with the surface water bodies.

Young and Kelley (2006) provide a detailed explanation of the procedures and assumptions used to generate each hydraulic parameter from data generated by examining over 800 geophysical logs. Each of these algorithms has several adjustable variables or weights that can be changed during model calibration. Horizontal hydraulic conductivity values are generated by algorithms that calculate values based the sand percentage, the average thickness of the sand and clay beds, and the depositional setting (coastal or fluvial) associated with the grid cell. Vertical hydraulic conductivity values are generated by using algorithms that calculate values based on the harmonic mean of the vertical hydraulic conductivity values.

The LCRB model uses six model layers to simulate flow in the Chicot and Evangeline aquifers and has the capability to represent a hierarchy of groundwater flow. This hierarchy is based on the regional flow system originally proposed by Toth (1963) for large groundwater basins. The use of six model layers instead of the two layers used in the Central Gulf Coast GAM for these two aquifers provides enhanced capabilities in the following:

1. to more accurately simulate local flow paths critical for precisely simulating the interaction that occurs between surface water and groundwater;
2. to more accurately represent the location of well screens and thus pumping from subsurface and hydraulic gradients associated with local, intermediate, and regional groundwater flow regimes; and
3. to more accurately represent the spatial variability in the hydraulic properties of the Chicot and Evangeline aquifers.

3.3 Subsidence

Subsidence impacts were calculated using the Interbed-Storage (IBS) package of MODFLOW (Leake and Prudic, 1991). The IBS package uses Equation 3-1 to predict land-surface subsidence:

$$\Delta b = - \Delta h * S_{is} * b_o \qquad \text{Equation 3-1}$$

Δb= amount of compaction or expansion (ft)
Δh = change in hydraulic head (ft)
S_{is} = elastic or inelastic specific-unit compressibility (ft^{-1}); and
b_o = thickness of the interbed (ft).

The term interbed is used to denote a poorly permeable bed within a relatively permable aquifer. Interbeds consist primarily of highly compressible clay and silt beds from which water flows vertically to adjacent coarse-grained units.

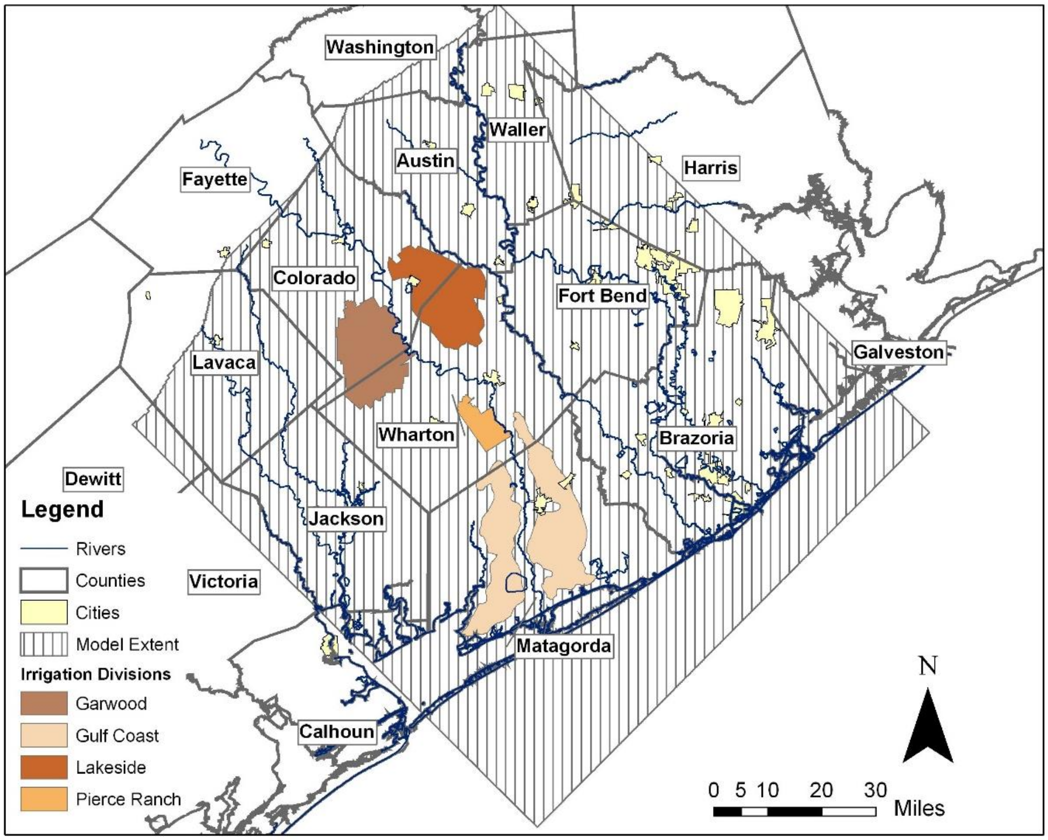
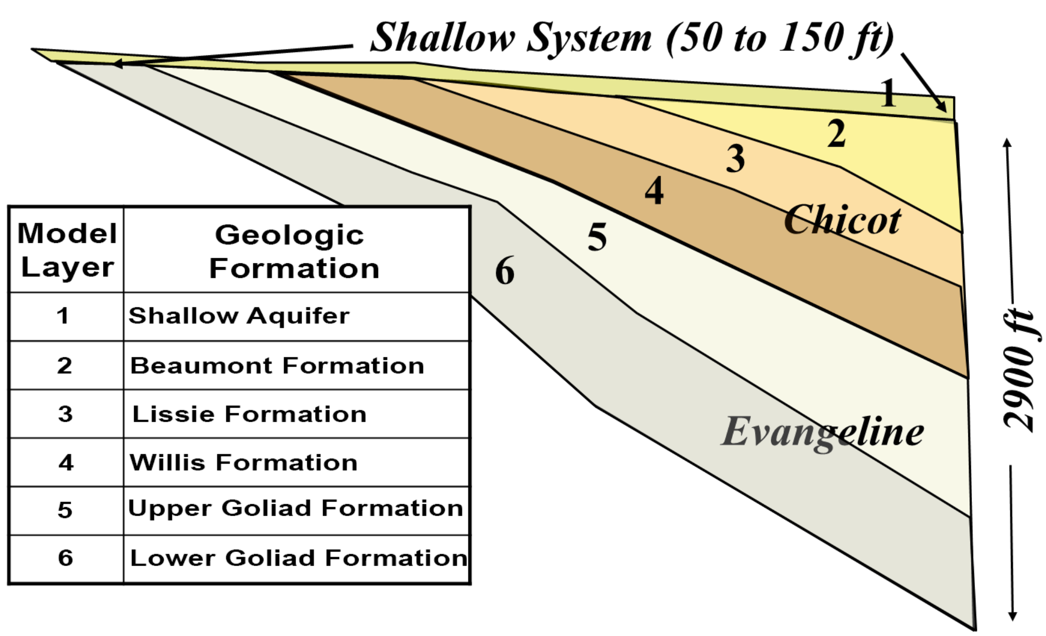


Figure 3-1 Areal extent of the Lower Colorado River Basin Model



Model Layer	Geologic Formation
1	Shallow Aquifer
2	Beaumont Formation
3	Lissie Formation
4	Willis Formation
5	Upper Goliad Formation
6	Lower Goliad Formation

Figure 3-2 Schematic of the model layers in the Lower Colorado River Basin Model

4.0 HYDROGEOLOGIC ASSESSMENT

4.1 Aquifer Properties Near the City of Wharton

Aquifers are typically characterized by considering the ease at which fluids can move through the aquifer matrix and by how much water is released from aquifer storage in response to pressure changes in the aquifer. Hydraulic conductivity, symbolically represented as "*K*", is a property of an aquifer that describes the ease with which a fluid (usually water) can move through pore spaces or fractures. It depends on the pore structure of the aquifer deposits and on the degree of saturation, and on the density and viscosity of the fluid. Hydraulic conductivity has dimensions of length per time (e.g., feet per day).

For many practical problems in water resources, transmissivity is a term often used by drillers and engineers to characterize groundwater production. Transmissivity is the aquifer parameter used to describe the transmissive properties of the aquifer at a given location. Transmissivity is calculated by multiplying the saturated thickness of the aquifer by the hydraulic conductivity (Freeze and Cherry, 1979):

$$T = K * b \qquad \text{Equation 4-1}$$

where:

T = transmissivity (volume of water per width per time)
K= hydraulic conductivity (volume of water per area per time)
b = thickness of the aquifer (length)

An indicator of the transmissivity of a hydrostratigraphic unit is the total thickness of the sands within the unit. Another factor related to transmissivity is the thickness of individual sand beds that comprise a hydrostratigraphic unit. In general, thicker sand beds have a higher hydraulic conductivity and greater lateral extents than thinner sand beds, equating to higher transmissivities. Correlations of the sand fraction and thickness, and transmissivity to spatial variation in the groundwater production characteristics of the Lissie and Willis Formations is provided in the following sections.

4.1.1 Sand Thickness Maps

Data regarding the occurrence of sands are presented in maps showing the fraction of sand and thickness of sands within the Lissie and Willis formations. Geophysical well logs provide the basis data for the sand maps. As part of the development of the structure of the LCRB model, the available geophysical logs were assembled and interpreted to identify sand fractions in individual geologic beds. Mr. Ernie Baker, a hydrologist with the Texas Water Science Center of the USGS, analyzed 322 geophysical wells logs and identified discrete sand intervals in each. The sand fraction identified in the geophysical logs was spatially interpolated using kriging to estimate sand fraction by model layer. Sand fraction data are key to identifying the most productive zones within a formation whereas the sand thickness maps integrate the occurrence of sand beds over the entire thickness of the formation.

Figure 4-1 shows the fraction of sand in the Lissie Formation in Wharton County. Along the county boundaries of Wharton and Fort Bend, the sand fraction in the Lissie Formation is greater than 80 percent. Within the Pierce Ranch potential well field area, the sand fraction in the Lissie Formation is as much as 76 percent. Within the NCOW potential well field area, the sand fraction in the Lissie Formation is as much as 92 percent.

Figure 4-2 shows the fraction of sand in the Willis Formation in Wharton County. Like the Lissie Formation, the sand fraction in the Willis Formation is higher in the northern portion of Wharton County. Within the Pierce Ranch well field area, the sand fraction in the Willis Formation is as much as 93 percent. Within the NCOW potential well field area, the sand fraction in the Willis Formation is as much as 92 percent.

The sand fraction was multiplied by the formation thickness in the LCRB model to calculate the sand thickness for both the Lissie and Willis formations as shown in **Figure 4-3** and **Figure 4-4**. Within the Pierce Ranch potential well field area, the sand thickness in the Lissie Formation ranges between 225 and 374 feet (ft). Within the NCOW potential well field area, the sand thickness in the Lissie Formation ranges between 240 and 435 ft. Within the Pierce Ranch well field area, the sand thickness in the Willis Formation ranges between 303 and 393 ft. Within the NCOW potential well field area, the sand thickness in the Willis Formation ranges between 253 and 324 ft.

4.1.2 Transmissivity Maps

Transmissivity data are typically available from two data sources: groundwater models and pumping tests at wells. **Figure 4-5** shows a map with the transmissivity from the LCRB model and the transmissivity data at wells obtained from pumping tests analyzed by Myers (1969) and pumping tests at public water supply wells. The majority of transmissivity values from Myers (1969) are considered very reliable because the pumping test data usually included the pumping rate,drawdown values, and the vertical interval over which the well is screened. The other data source is the records from the Public Water Supply Supervision program at the Texas Commission on Environmental Quality (TCEQ). As part of their mission, TCEQ maintains an electronic database and a set of paper records to manage information regarding public water supply (PWS) wells, which INTERA obtained.

Spatially distributed transmissivity was calculated by multiplying the horizontal hydraulic conductivity in the LCRB model by the thickness of the formation to compute a transmissivity for the entire thickness of the Lissie and Willis formations. Within the potential well field areas, the transmissivity is more than 31,000 ft^2/day in the northern portion of the Pierce Ranch potential well field area and in the western portion of the NCOW potential well field area. Within the boundaries of Pierce Ranch, the transmissivity varies from approximately 19,000 to 30,000 ft^2/day.

The transmissivity values estimated from pumping tests vary considerably, due in part to the quality of the analysis that is used to estimate transmissivity from measured drawdown values recorded during a pumping test. INTERA investigated the transmissivity interpreted from a pumping test in well G2410005C (a TCEQ well identifier), which is the city of Wharton well #2 near Alabama Road.

4.1.3 Pumping Test

In order for a groundwater model to serve as an accurate predictor of changes in water levels caused by pumping, the model needs to have reasonably accurate values of transmissivity. Despite the importance of transmissivity to the accuracy of groundwater models, most groundwater models are developed using relatively few transmissivity values.

The most common method for determining transmissivity values is from the analysis of pumping test data. An aquifer pumping test consists of pumping and observing the aquifer's "response" by measuring drawdown in the pumping well and/or nearby observation wells.

The transmissivity of a confined aquifer can be discerned by analyzing the time-drawdown relationship. If the pumping time is sufficiently long, a plot of the observed drawdown as a function of time will appear as a straight line. If the slope of the straight-line segment is expressed as the drawdown difference per log cycle of time, the transmissivity (T) can be calculated from Equation 4-2, which is a form of the Cooper-Jacob straight-line method (Cooper and Jacob, 1946):

$$T = \frac{2.3 * Q}{4\pi \Delta s}$$ Equation 4-2

T = transmissivity [L^2/T]

Q = pumping rate [L^3/T]

Δs = drawdown per log cycle of time [L]

An aquifer pumping test was performed at well G2410005C in August 1984 and the pumping test data were not used to develop the LCRB model. Transmissivity of the aquifer near the well G2410005C was estimated as 10,205 ft^2/day by applying Cooper-Jacob straight-line method (1946) to the drawdowns measured during the pumping test (**Figure 4-6**).

To test if the transmissivity in the LCRB model at the well location matches the pumping test results, INTERA performed an analytical simulation using the same pumping rate that was used during the pumping test to calculate drawdown over time. The simulated drawdown over time was used to estimate the transmissivity using the Cooper-Jacob method. The transmissivities estimated from the pumping test and from the simulated pumping test (**Figure 4-7**) differ by less than 10%, indicating that the transmissivity values in the LCRB model are a reasonable approximation to the hydraulic properties near the well. The changes in the hydraulic head responses as a result of pumping were compared to measured pumping test responses as described above. Figure 4-7 shows the straight line fit for the Cooper-Jacob method at well G2410005C. The transmissivity is estimated at 10,932 ft^2/day which is within 10 percent of the transmissivity calculated using the measured pumping test values. The TTim simulations did not account for well bore storage or well skin effects which are two factors that account for some of the difference between two transmissivity values. This verification of the LCRB model hydraulic properties with the available data provides confidence that the LCRB model is a reasonable approximation of transmissivity near the city of Wharton wells.

To simulate the aquifer response to pumping well G2410005C at the rate of 1,462 gallons per minute (GPM) as used in the pumping test, INTERA utilized a three-dimensional analytic element model called TTim (Bakker, 2006). INTERA has used TTim extensively for well spacing and well permits for seven GCDs, and it is well suited for simulating transient multi-aquifer flow. The advantage of using TTim over the existing models is that aquifer stratigraphy and hydraulic properties can easily be input to reflect aquifer conditions and accurate drawdown values can be calculated at the location of the well, because analytic element models utilize direct numerical solution and not a set of equations solved on a grid like MODFLOW.

All six of the model layers in the LCRB model were simulated with TTim. Because the well screen interval for well G2410005C was located in both the Lissie and Willis Formations, the TTim model layers for each of these formations were subdivided based on the elevation of the well screen at well G2410005C. The two TTim layers for the Lissie Formation correspond to the portion of the Lissie Formation above the well screen and the portion of the Lissie Formation intersecting the well screen. Similarly, the Willis Formation was subdivided into two TTim layers to represent the portion of the Willis Formation intersecting the well screen and the portion of the Willis Formation below the well screen interval. By creating layers that correspond to the well screen intervals in the Lissie and Willis formations, the hydraulic responses of the aquifer system can be more accurately represented.

Figure 4-8 shows the eight model layers used in TTim. From top to bottom the layers represent the shallow aquifer, the Beaumont Formation, the Lissie Formation above the well screen at well G2410005C, the screened portion of the LIssie Formation at the well, the screened portion of the Willis Formation at the well, the portion of the Willis below the well screen, the Upper Goliad Formation, and the Lower Goliad Formation. The TTim simulation was performed to assess the change in hydraulic head in response to pumping the well at a constant rate. Pumping was distributed between the screened portions of the Lissie and Willis Formations based on the transmissivity values in the LCRB model.

4.2 Selection of Potential Well Field Locations

As part of the process of identifying potential well field areas, INTERA investigated the impact of local hydraulic properties on the simulated drawdown as a pre-assessment tool to a more detailed investigation of potential well fields in two specific areas. As part of the pre-assessment, we simulated drawdown at four well field locations currently being considered by the city of Wharton as sites for new wells using the hydraulic properties from the LCRB model at each of the four well locations. We expanded the existing municipal well fields over a 50-year period from 2020 to 2070 by adding two additional pumping wells at each site and simulated the drawdown response using an analytical model. By simulating a range of hydraulic properties, the resulting drawdown can be expressed as a range of values that reflect the spatial variation inherent in the aquifer properties in the study area. This modeling approach and the results are described in more detail in **Appendix A**. The simulated maximum and minimum drawdowns are similar among all four sites in 2070 indicating that the variability in hydraulic properties from the LCRB model at these locations results in little variation in drawdown with time.

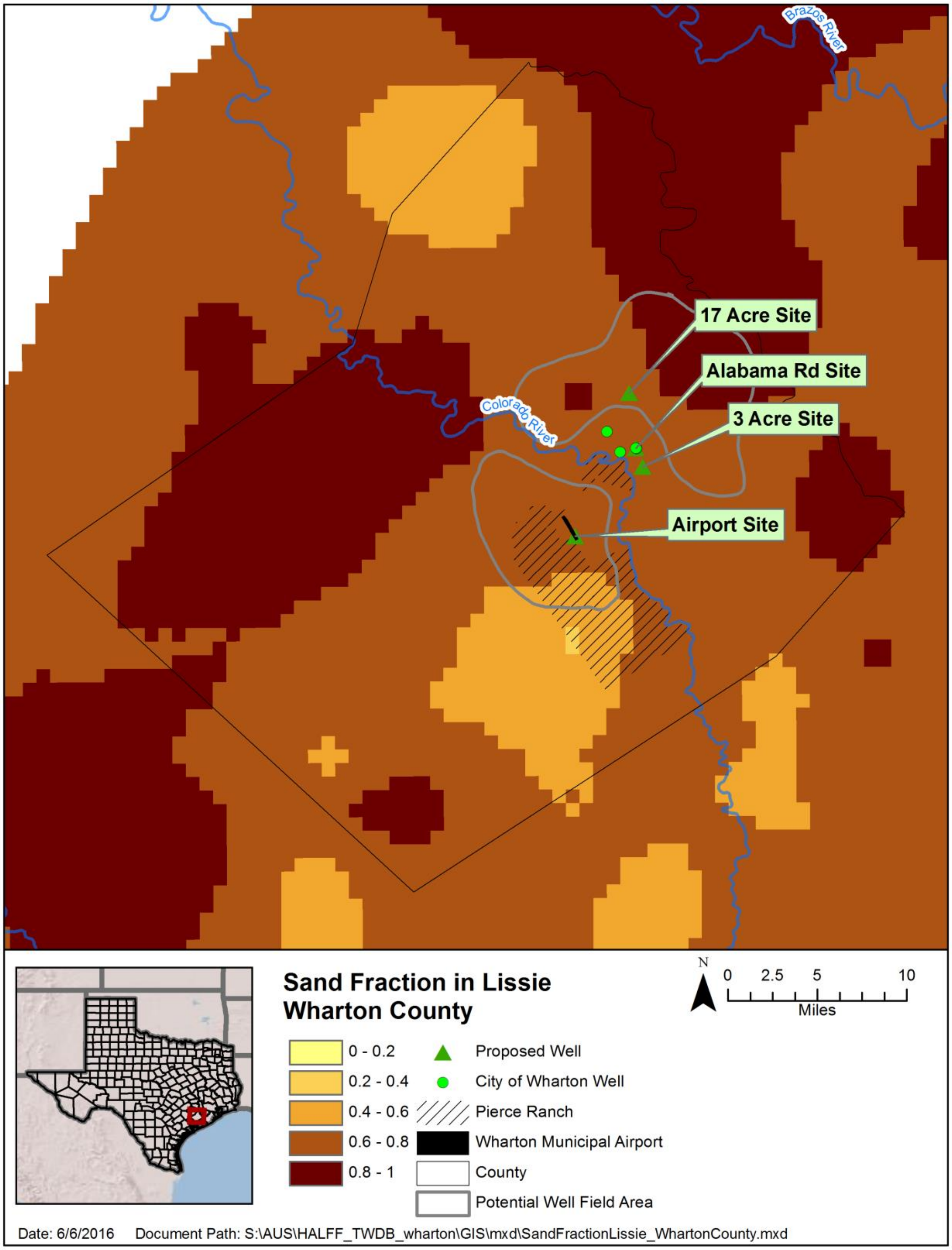


Figure 4-1 Sand fraction in the Lissie Formation in Wharton County

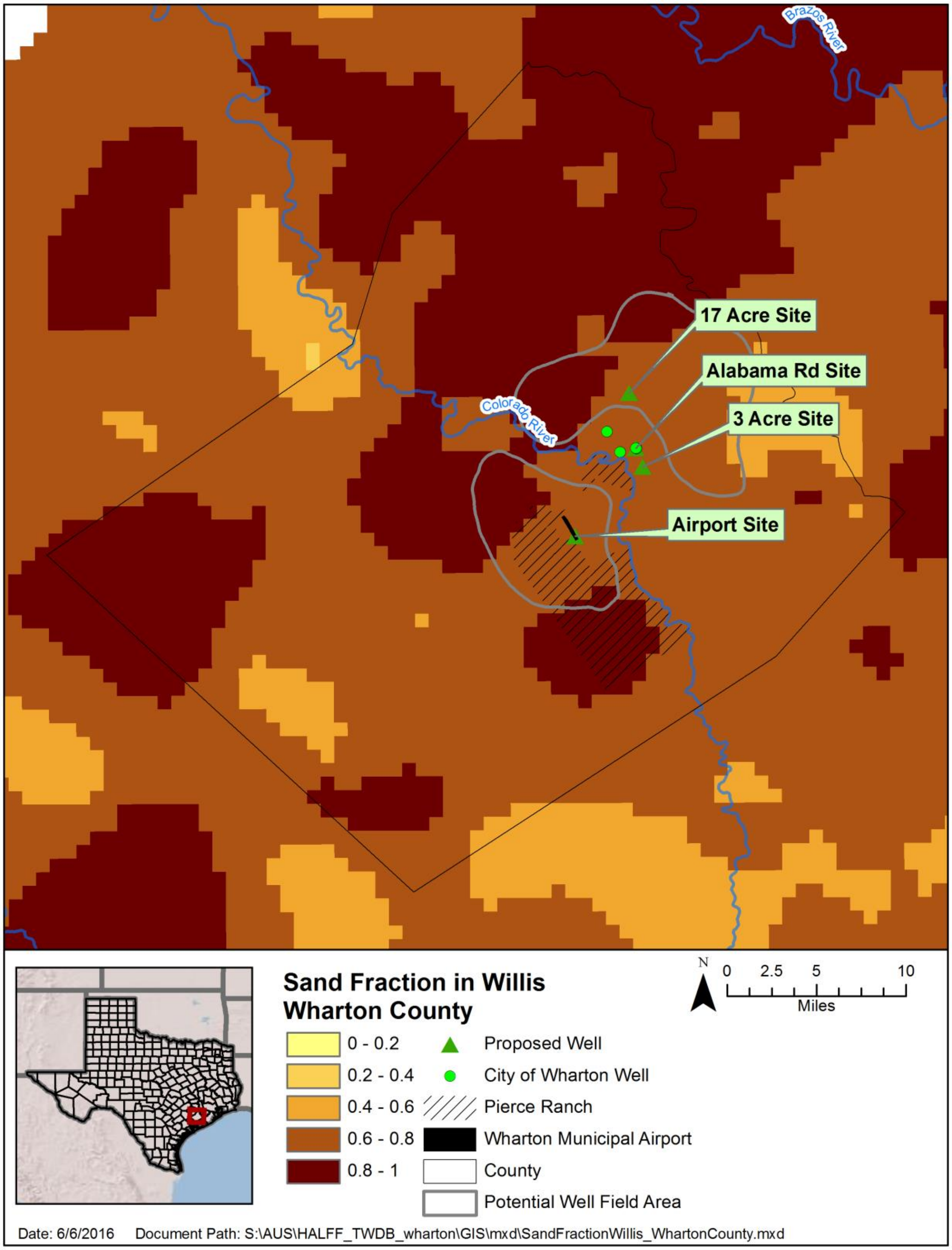


Figure 4-2 Sand fraction in the Willis Formation in Wharton County

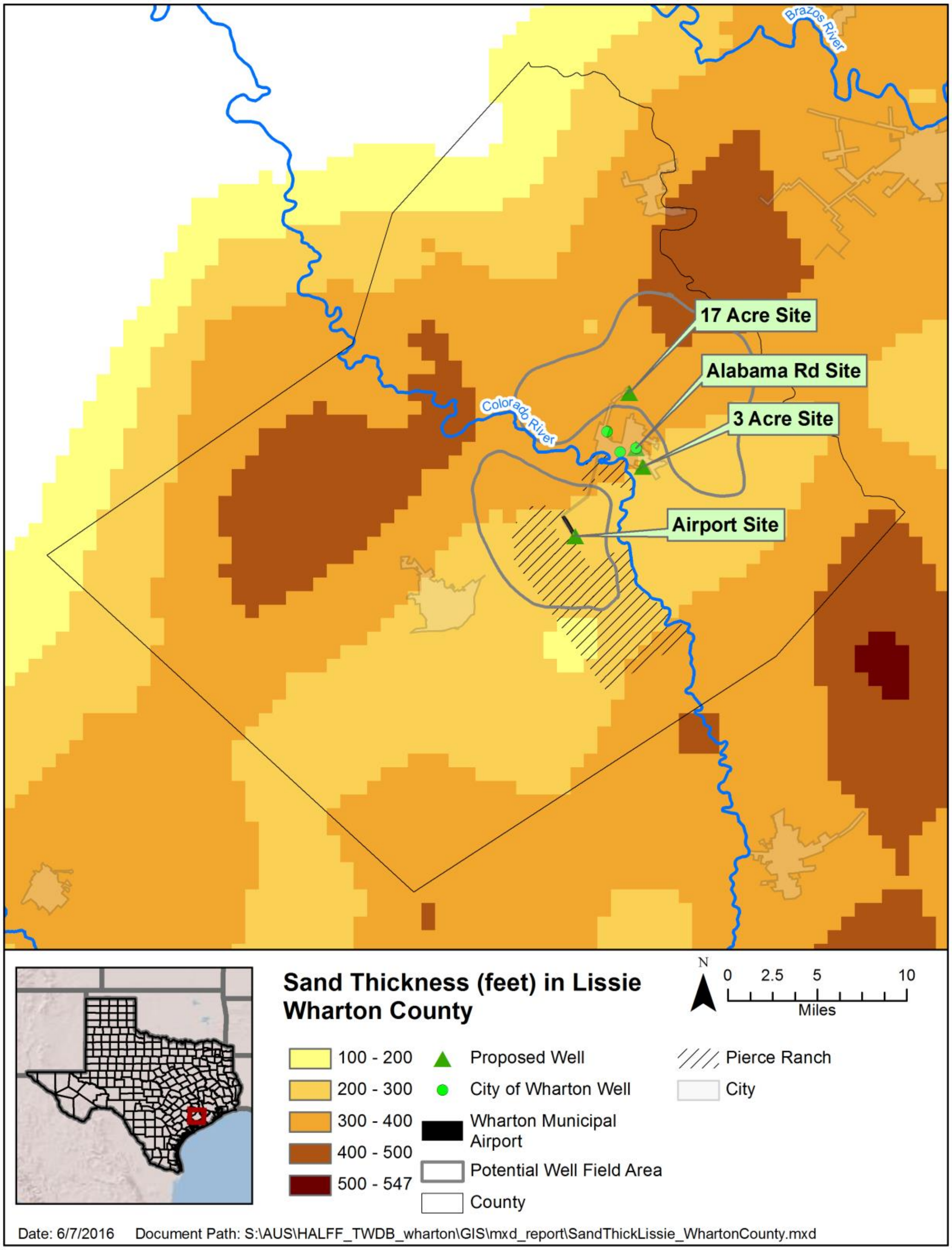


Figure 4-3 Sand thickness in feet in the Lissie Formation in Wharton County

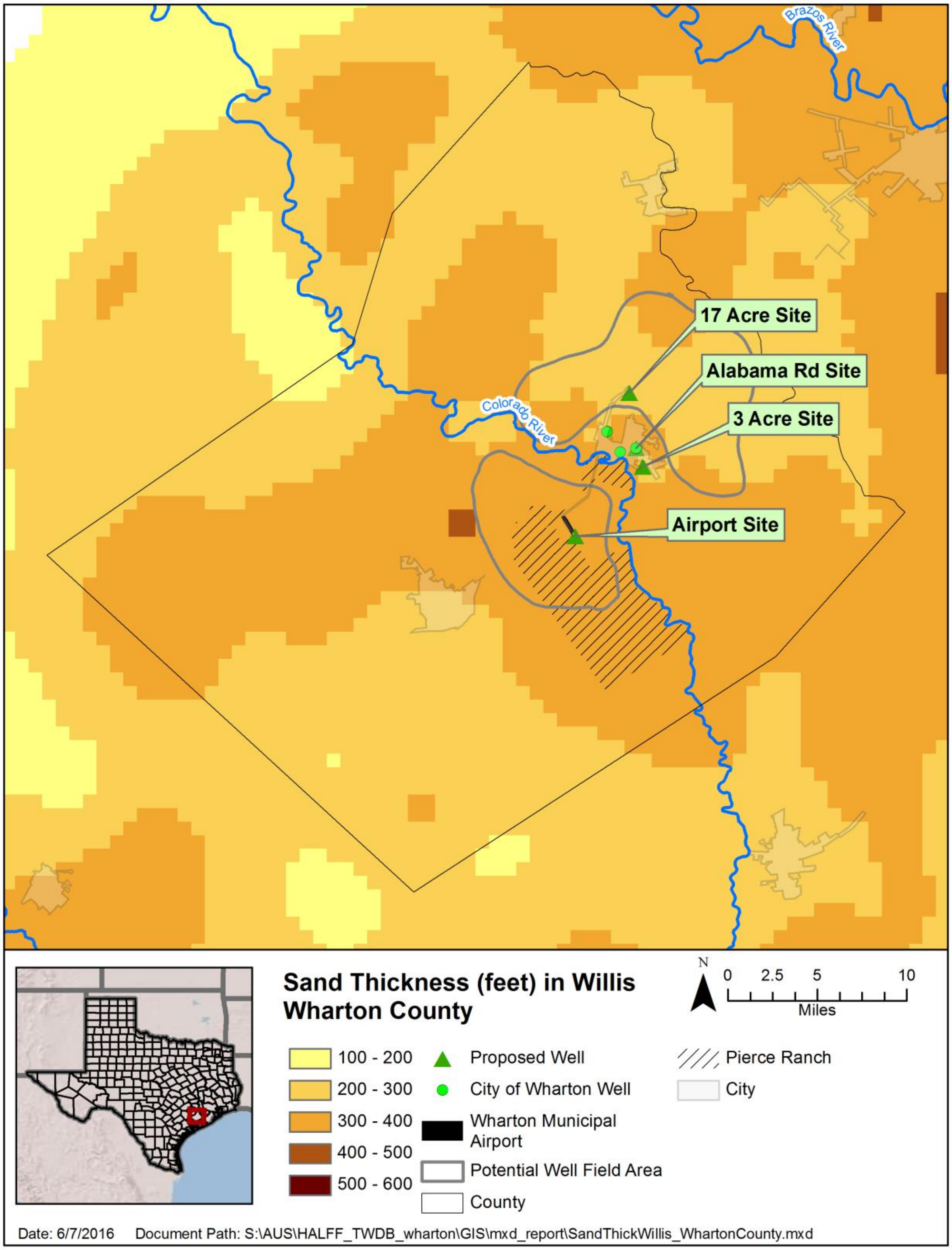


Figure 4-4 Sand thickness in feet in the Willis Formation in Wharton County

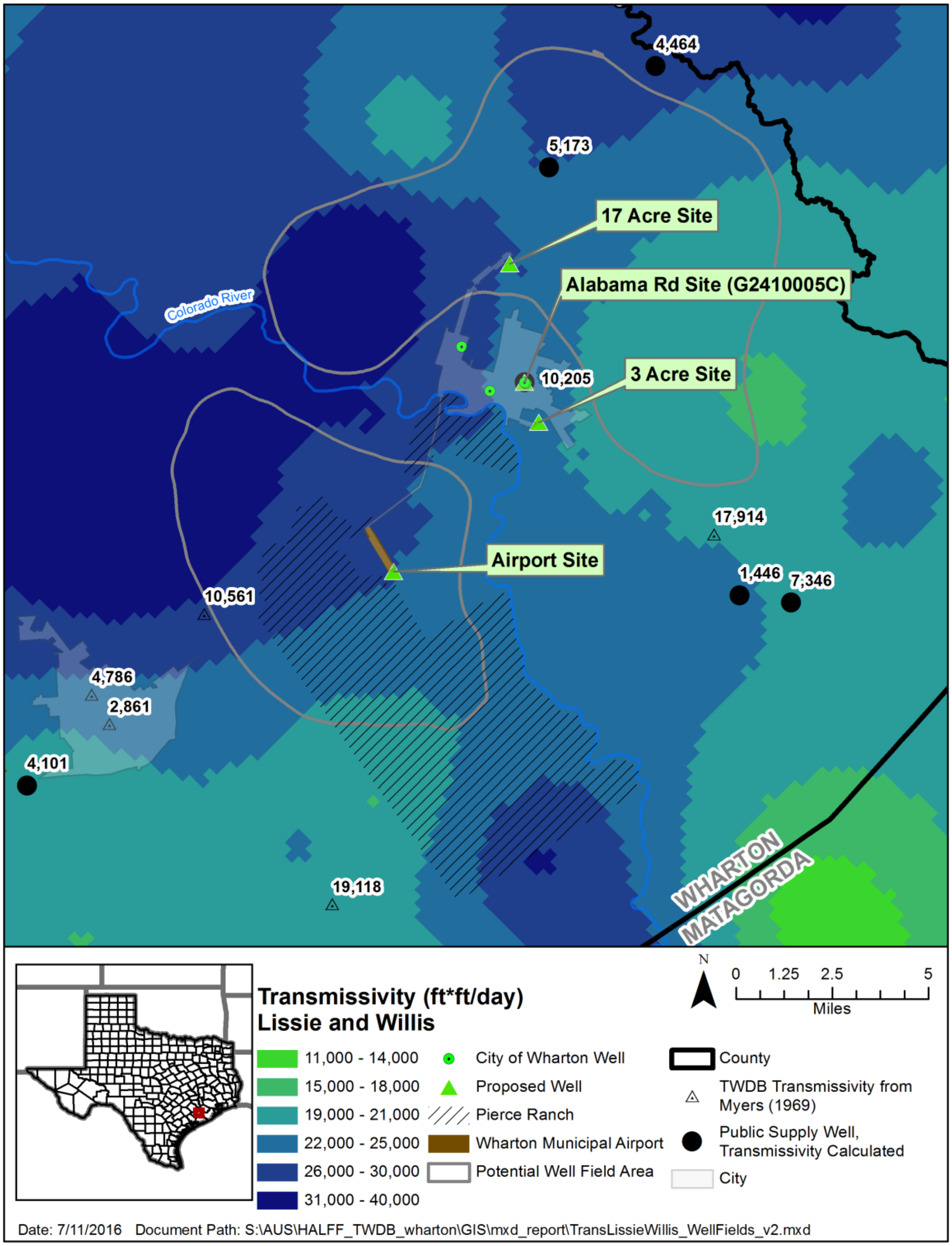


Figure 4-5 Transmissivity of the Lissie and Willis Formations in Wharton County

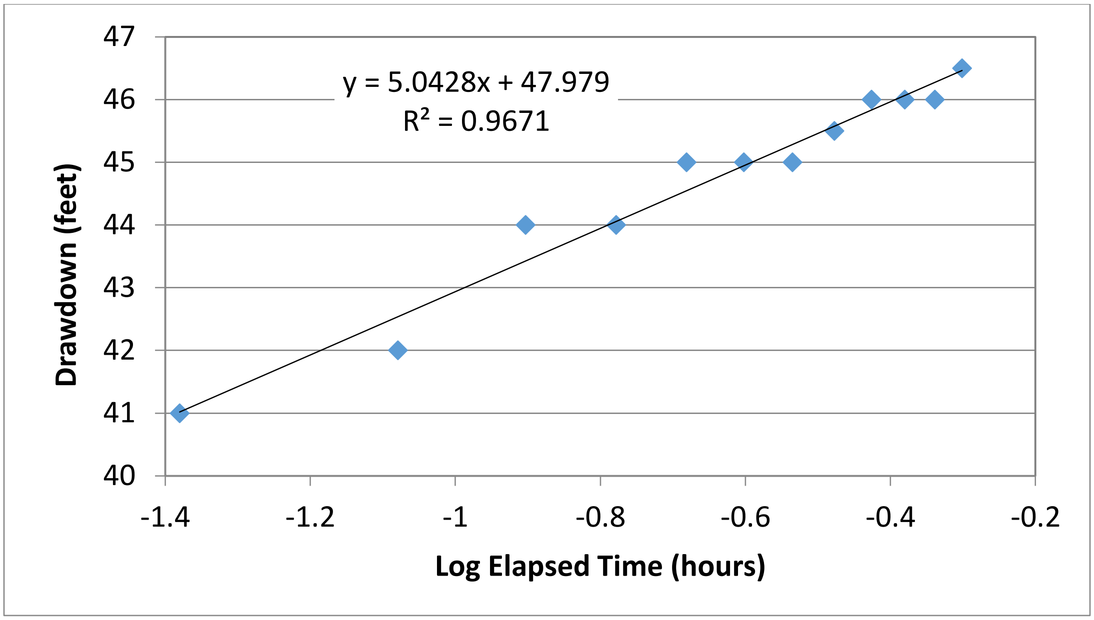


Figure 4-6 Semilog plot of times in hours versus drawdown in feet from an aquifer test perfored at public water supply well G2410005C in central Wharton County

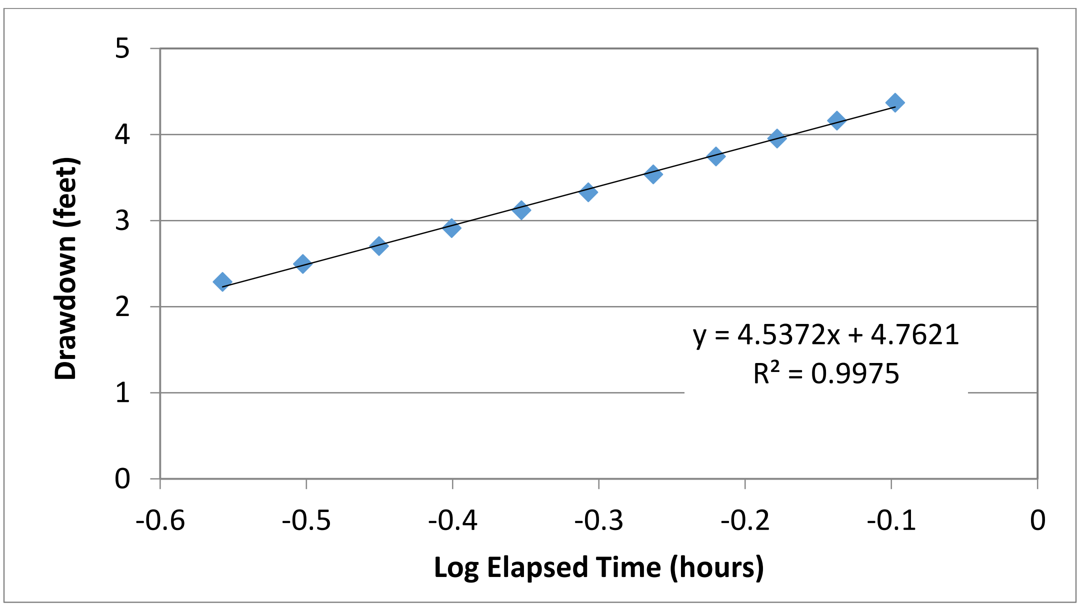


Figure 4-7 Semilog plot of the log of elapsed time in hours versus drawdown in feet as simulated in TTim

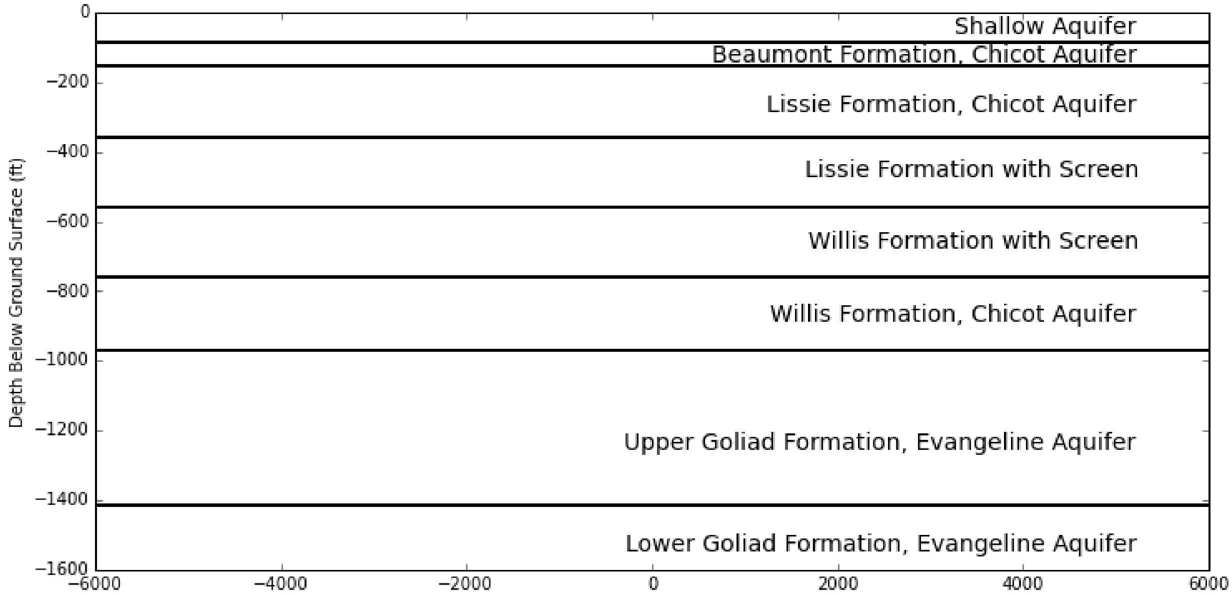


Figure 4-8 Cross-section for the analytic element simulation (TTim) at the Alabama Rd site

5.0 PROPOSED WELL FIELD SITES AND PUMPING RATES

HALFF Associates identified two potential locations as areas of interest for drilling additional wells for water supply for the city of Wharton and the city of East Bernard. The first potential well field area is located near Pierce Ranch and the second area is located north of the city of Wharton. The two potential well field areas are two alternative locations and only one of these well fields would be selected for additional water supply. Thus, responses to pumping stress are simulated at each well field independently.

We simulated additional pumping for a variety of scenarios (number of wells, pumping rates, and well locations) using the LCRB model and calculated the impacts on drawdown and subsidence due to the additional proposed pumping. The proposed injection and extraction wells were added to the WEL Package of MODFLOW by specifying the flow rate over time at each well.

The pumping scenarios include two water supply options: (1) add additional pumping wells over time or (2) inject treated wastewater and pump additional wells to meet projected water demands for the cities of Wharton and East Bernard. For the first water supply option, two different pumping scenarios were implemented in four simulations, one pumping scenario at each potential well field area. This section discusses the simulations for the first water supply option of additional pumping wells. Section 7 discusses the simulations for the second water supply option, which includes additional pumping wells and injection of treated wastewater into the aquifer.

5.1 Pumping Schedule

HALFF Associates provided an estimate of projected water demands over time, (aka a pumping schedule) for the cities of Wharton and East Bernard. The projected maximum daily demand is based on an aggressive population projection. The number of wells required is based on a pumping schedule with an aggressive population growth projection and well redundancy to provide more flexibility during well maintenance. The demand projections include demands for the city of East Bernard but do not include the city of East Bernard's existing wells. As some of the existing city of Wharton wells age and are decommissioned, the lost supply capacity in the city of Wharton wells will be made up by increased supply capacity in the city of East Bernard wells. The lost supply capacity in the city of Wharton wells are assumed to be equivalent to the increased supply capacity in the city of East Bernard wells resulting in no net change to the combined pumping demand for the cities of Wharton and East Bernard.

The pumping schedule, the demands from 2020 through 2070, was implemented in the model simulations based on two different pumping scenarios. The first pumping scenario (S1) assumes that all four of the existing city of Wharton wells are pumping in 2020 when the pumping schedule begins. The second pumping scenario (S2) is devised to minimize drawdown near the city of Wharton by turning off existing pumping wells in the city of Wharton in 2020 and replacing them with new wells located outside of the city of Wharton.

Table 5-1 summarizes the first and second pumping scenarios and lists the year, the projected maximum daily demand in MGD, the total number of extraction wells including the four existing city of Wharton wells, and the maximum pumping rate at any individual well in MGD and GPM. The total amount of pumping is identical for the first and second pumping scenarios, however, the number of wells, pumping rates at individual wells, and the locations of the wells vary.

Table 5-1 Pumping schedule for extraction of groundwater for pumping scenarios 1 and 2

		First Pumping Scenario (S1)[A]			Second Pumping Scenario (S2)[B]		
Year	Projected Maximum Daily Demand (MGD)	Number of Total Wells	Maximum Pumping Rate at a Well (MGD)	Maximum Pumping Rate at a Well (GPM)	Number of Total Wells	Maximum Pumping Rate at a Well (MGD)	Maximum Pumping Rate at a Well (GPM)
2020	3.17	4	0.79	549	2	1.59	1,104
2025	3.97	5	0.80	556	2	1.99	1,382
2030	4.76	5	1.59	1,104	3	1.59	1,104
2035	5.56	6	1.59	1,104	3	1.85	1,285
2040	6.35	6	1.59	1,104	3	2.12	1,472
2045	7.14	7	1.59	1,104	4	1.79	1,243
2050	7.94	7	1.59	1,104	4	1.99	1,382
2055	8.73	8	1.59	1,104	5	1.75	1,215
2060	9.52	8	1.59	1,104	5	1.90	1,319
2065	10.32	9	1.59	1,104	5	2.06	1,431
2070	11.11	9	1.59	1,104	6	1.85	1,285

[A]The well locations for pumping scenario S1 are shown on **Figure 5-1** for the Pierce Ranch proposed well field area and on **Figure 5-2** for the NCOW proposed well field area.

[B]The well locations for pumping scenario S2 are shown on **Figure 5-3** for the Pierce Ranch proposed well field area and on **Figure 5-4** for the NCOW proposed well field area.

Each pumping scenario was implemented by assigning well locations within each of the two potential well field areas. The next two sections discuss the rational for the selection of the proposed well sites and presents maps showing the locations of the proposed pumping wells identified in the pumping scenarios.

5.2 Pierce Ranch

Well placement within the proposed Pierce Ranch well field was based on consideration of the estimated transmissivity, proximity to existing wells, access to the canals on Pierce Ranch, proximity to the Colorado River, and the boundaries of the Pierce Ranch land parcels. In general, wells are concentrated in the northern portion of Pierce Ranch in the area of greatest transmissivity in the Lissie and Willis formations. Wells were sited away from existing pumping wells and a minimum spacing of 1,500 ft was maintained between all existing wells and proposed wells. To achieve cost efficiency, wells were sited near the Colorado River where the depth to water will be minimal resulting in lower drilling cost. Wells near the Colorado River were sited at least 50 ft from the river. Within the boundaries of the largest contiguous portion of Pierce Ranch, wells were sited along the canals for ease of access. These well locations are approximate locations. To finalize the proposed well sites, studies are needed to investigate the following: obtaining property rights, vetting for property access, and specifying appropriate well spacing relative to property boundaries. Vetting for property access includes evaluating access for drill rigs, proximity to power supplies, and verification that underground power, gas, and water lines are located away from the proposed sites. Additional considerations for well siting may include state regulations, which are applicable to well construction requirements within floodplains.

Figure 5-1 shows the proposed pumping locations for Pierce Ranch for the first pumping scenario (S1). The first pumping scenario consists of a total of nine wells in 2070 including four wells in the city of Wharton and five on Pierce Ranch. In this scenario, the existing four city of Wharton wells continue to pump in 2020. The fifth well begins pumping in 2030 at the Wharton Municipal Airport. This is a proposed well location currently being considered by the city of Wharton. The sixth and seventh wells begin pumping in 2035 and 2045, respectively, and are adjacent to the Colorado River. The eighth and ninth wells begin pumping in 2055 and 2065, respectively, and are located in the northern portion of Pierce Ranch along canals. These well sites were selected in part because they are far enough away from the well at the airport such that drawdown interference between these wells will be minimized.

Figure 5-2 shows the proposed pumping locations for Pierce Ranch for the second pumping scenario. The second pumping scenario consists of a total of six new wells all located within Pierce Ranch. In this scenario the existing four city of Wharton wells shut off in 2020 and are replaced with new wells away from the city of Wharton in order to minimize drawdown impacts and subsidence near the city of Wharton. The first well begins pumping in 2020 at the Wharton Municipal Airport. The second and third wells begin pumping in 2020 and 2030, respectively and are located west of the airport. The fourth well to begin pumping is located on the smaller of the two Pierce Ranch land parcels to minimize the drawdown interference near the existing wells within an area of higher transmissivity. The fifth and six wells begin pumping in 2055 and 2070, respectively, and are located north of the airport.

5.3 North of the City of Wharton

Well placement for the simulations of the NCOW potential well field was based on consideration of the estimated transmissivity in the Lissie and Willis formations and proximity to existing wells. The NCOW potential well field is a single well field located northwest of the city of Wharton with multiple wells in close proximity. This well field location was selected because it is near the northern portion of the city of Wharton, an area of higher projected population growth; it is near an area of higher transmissivity; and it is far away from the existing city of Wharton wells which will minimize drawdown and subsidence impacts near the city of Wharton. Wells were sited away from existing pumping wells and a minimum spacing of 1,500 ft was maintained between all existing wells and proposed wells. These well locations are approximate locations. To finalize the proposed well sites, studies are needed to investigate the following: obtaining property rights, vetting for property access, and specifying appropriate well spacing relative to property boundaries. Vetting for property access includes evaluating access for drill rigs, proximity to power supplies, and verification that underground power, gas, and water lines are located away from the proposed sites.

Figure 5-3 shows the proposed pumping locations northwest of the city of Wharton for the first pumping scenario. The first pumping scenario consists of a total of nine pumping wells in 2070 including four wells in the city of Wharton, one at a site of interest identified by the city of Wharton, and four wells concentrated in a small area northwest of the city of Wharton. In this scenario, the existing four city of Wharton wells continue to pump in 2020. The fifth well begins pumping in 2025 at the 17-acre site identified as a potential well location by the city of Wharton. This proposed well location is currently being considered by the city of Wharton. The sixth, seventh, eighth and ninth wells begin pumping in 2035, 2045, 2055, and 2065 respectively, and are located northwest of the city of Wharton.

Figure 5-4 shows the proposed pumping locations for the NCOW well field area for the second pumping scenario. The wells pumped in the second pumping scenario are identical to the set of wells in the first pumping scenario but the city of Wharton wells are shut off in 2020.

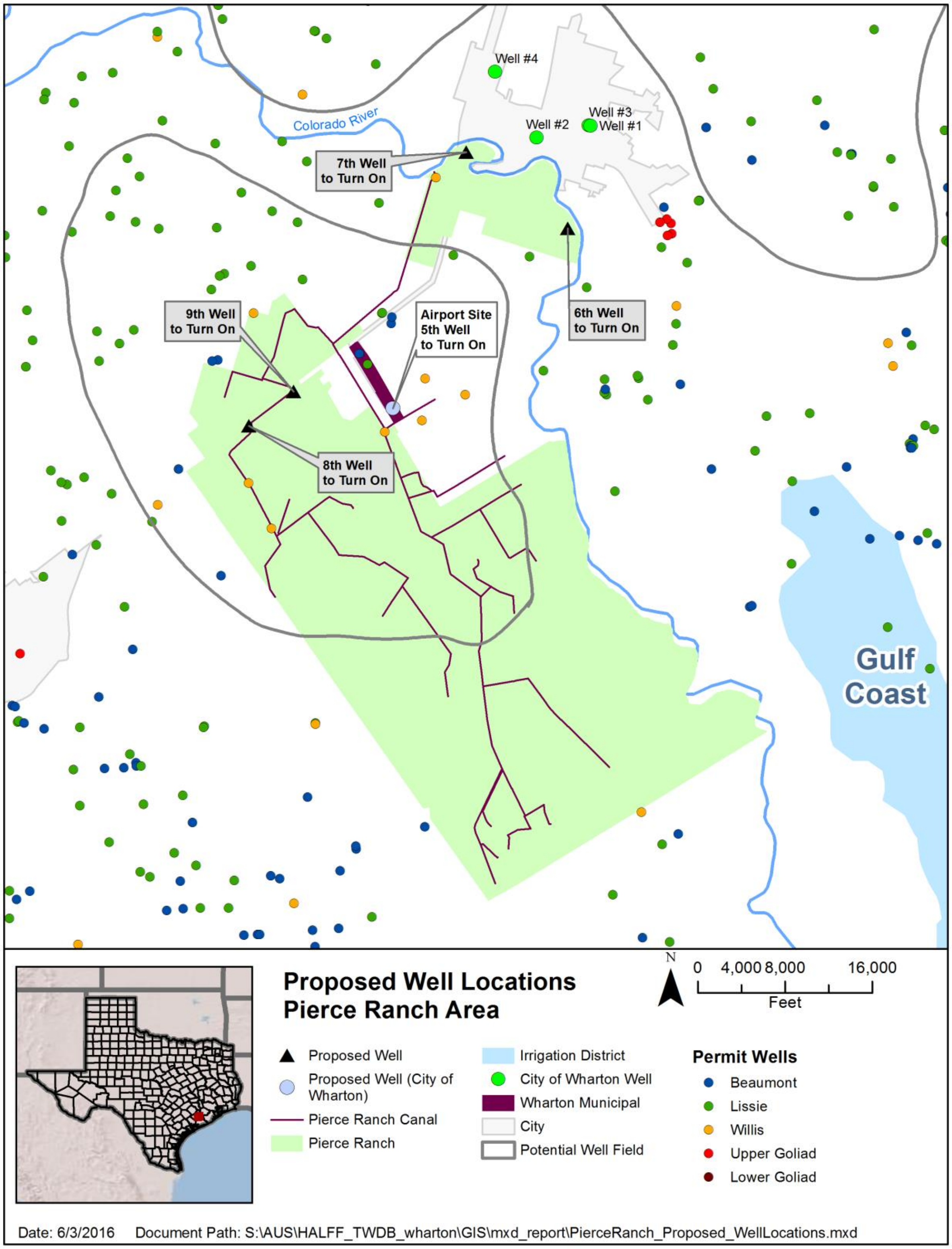


Figure 5-1 Proposed pumping well locations in the Pierce Ranch proposed well field area for simulation S1

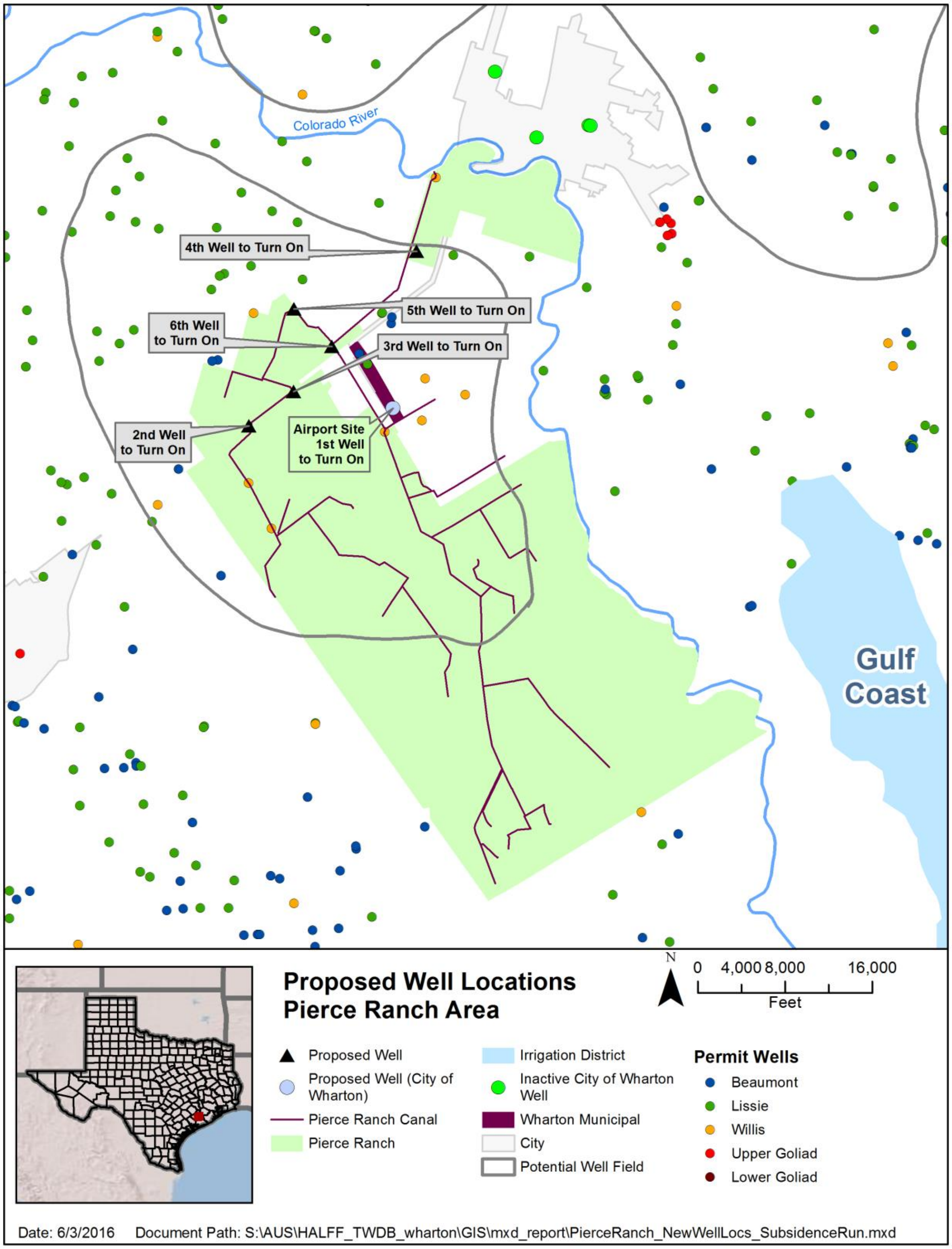


Figure 5-2 Proposed pumping well locations in the Pierce Ranch proposed well field area for simulation S2

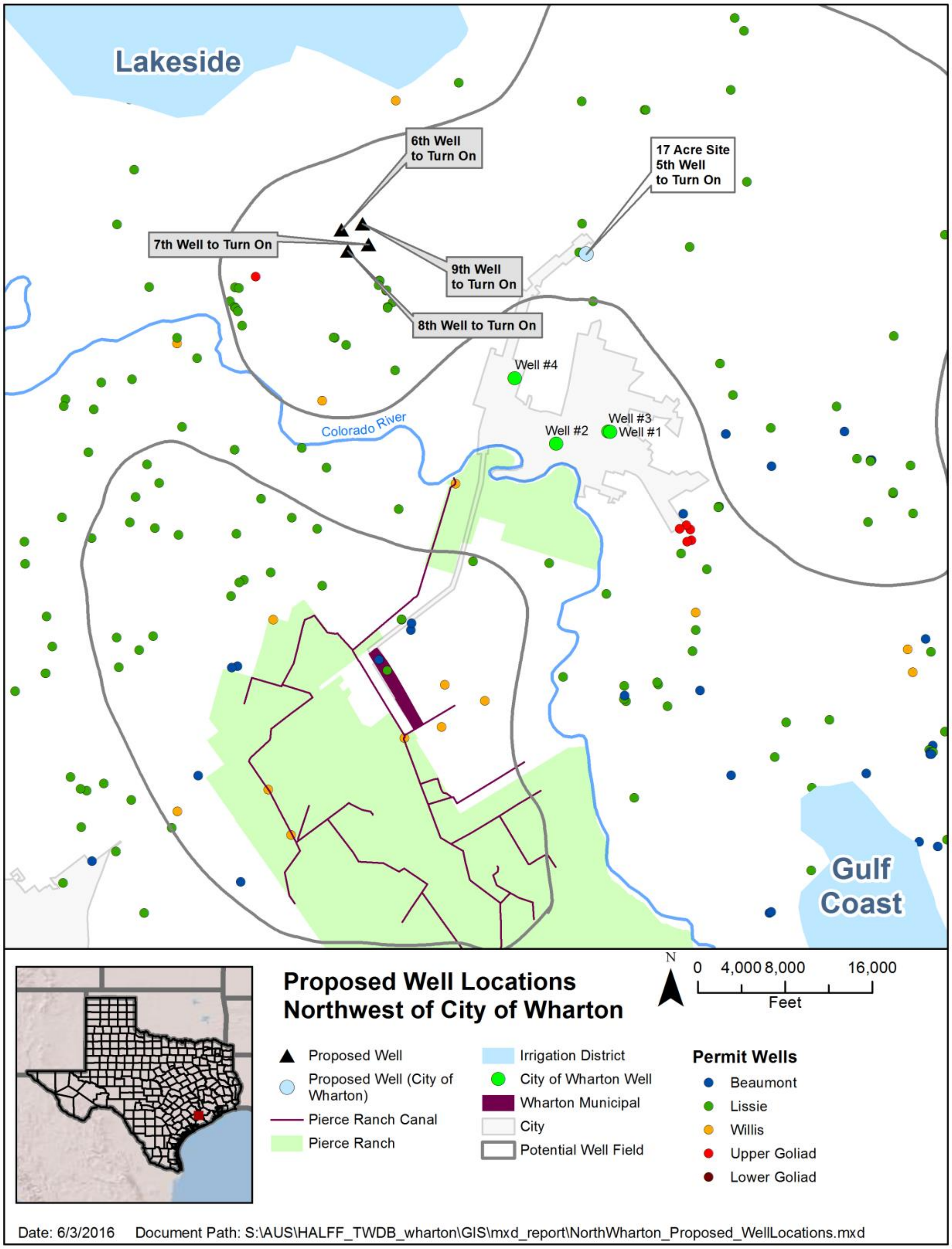


Figure 5-3 Proposed pumping well locations in the NCOW proposed well field area for simulation S1

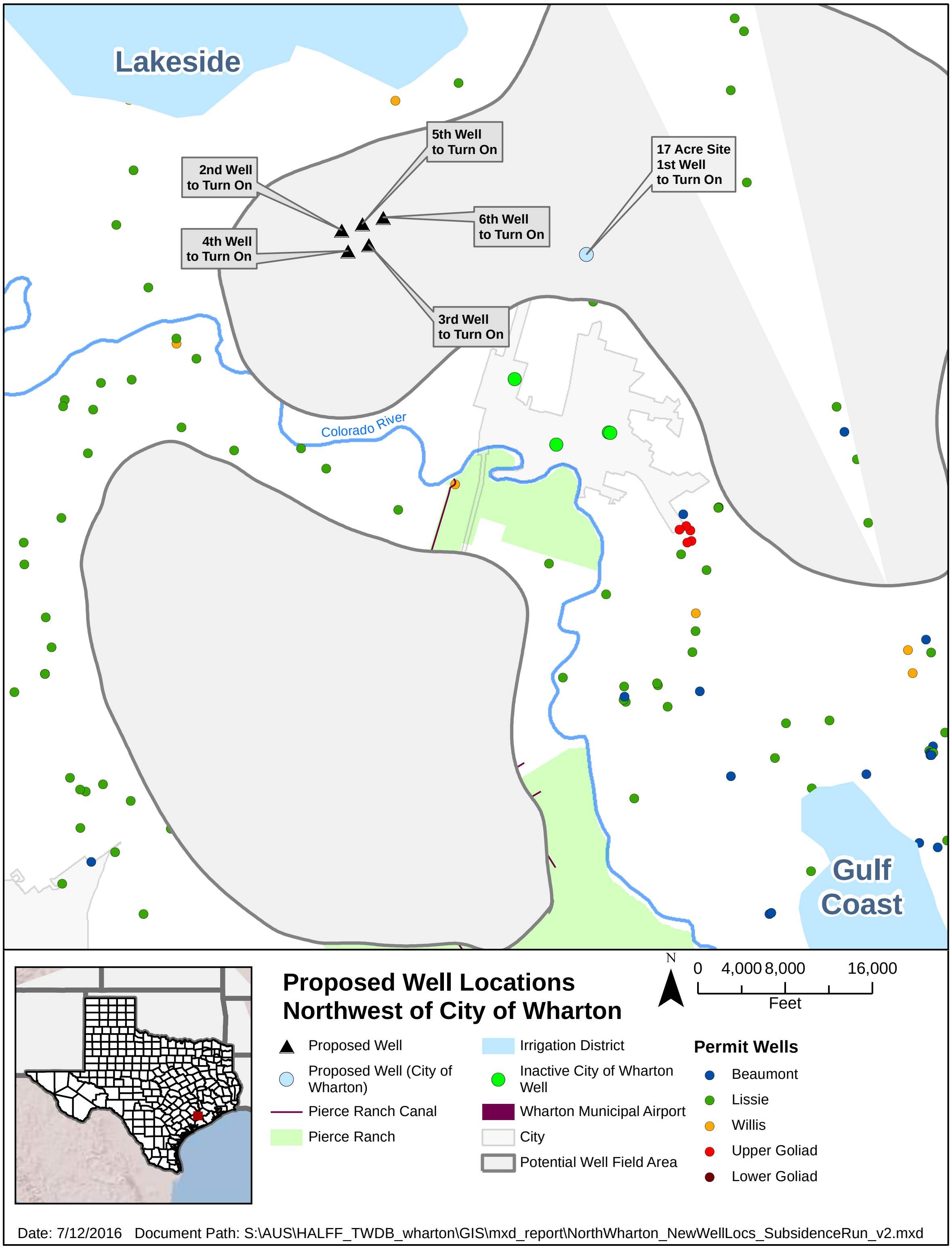


Figure 5-4 Proposed pumping well locations in the NCOW proposed well field area for simulation S2

6.0 SIMULATED DRAWDOWN

6.1 Model Set Up for Pumping Scenarios

The pumping scenarios were developed from a baseline run for the LCRB model. We developed the baseline LCRB model by taking the pumping at the end of the LCRB model, from 2000 and 2006, and applying the 2006 pumping for each year through 2070. Modification of the pumping was the only change in the model stresses. The hydraulic properties from the LCRB model were retained without modification. In order to accurately represent the pumping at the city of Wharton wells, we linearly interpolated pumping at these wells from 2006 to 2020 when the pumping schedule begins.

Table 6-1 summarizes of all of the simulations including the ASR simulations which are presented in section 7. The pumping scenario indicates the unique pumping schedule used. There are two simulations with identical pumping schedules – one that pumps from a proposed wellfield on Pierce Ranch and another simulation that pumps from a proposed well field north of the city of Wharton.

Table 6-1 Summary of pumping scenarios by water supply option and proposed well field area

Water Supply Option(s)	Proposed Well Field Area	Pumping	ASR	Pumping Scenario	Simulation Description	Report Section
Add new wells	Pierce Ranch	X		S1	Add new wells and continue pumping existing city of Wharton wells	5.2
Add new wells	Pierce Ranch	X		S2	Replace existing city of Wharton wells in 2020 with new wells outside of the city of Wharton	5.2
Add new wells	North of the city of Wharton	X		S1	Add new wells and continue pumping existing city of Wharton wells	5.2
Add new wells	North of the city of Wharton	X		S2	Replace existing city of Wharton wells in 2020 with new wells outside of the city of Wharton	5.3
Add new wells and ASR	Pierce Ranch	X	X	S3	Add new wells and continue pumping existing city of Wharton wells; inject wastewater near existing city of Wharton wells beginning in 2035	7.4
Add new wells and ASR	North of the city of Wharton	X	X	S3	Add new wells and continue pumping existing city of Wharton wells; inject wastewater near existing city of Wharton wells beginning in 2035	7.4

6.2 Drawdown Results

Drawdown results are presented as maps of drawdown in the Lissie and Willis formations for 1, 10, 20, and 30 years after the beginning of the proposed pumping in 2020. Each drawdown map illustrates drawdown in feet by model layer at specific points in time relative to the baseline LCRB model, which includes a constant pumping rate of 3 MGD for the cities of Wharton and East Bernard. In other words, the drawdown maps show the amount of drawdown that can be attributed to additional pumping above 3 MGD. For these time increments, many of the simulations had a maximum simulated drawdown of less than 0.10 ft and are not presented in the figures. The drawdown figures are detailed below and are presented in **Appendix B**:

- **Figure B-1** through **Figure B-6** show drawdown maps for pumping scenario S1 with proposed pumping from the Pierce Ranch potential well field area
- **Figure B-7** through **Figure B-16** show drawdown maps for pumping scenario S2 with proposed pumping from the Pierce Ranch potential well field area. Pumping scenario S2 has both positive values for drawdown and negative values for drawdown (or drawup) because simulated heads increased over time near the city of Wharton wells that stopped pumping in 2020
- **Figure B-17** through **Figure B-22** show drawdown maps for pumping scenario S1 with proposed pumping from the NCOW potential well field area
- **Figure B-23** through **Figure B-32** show drawdown maps for pumping scenario S2 with proposed pumping from the NCOW potential well field area. Simulation S2 has both positive values for drawdown and negative values for drawdown (or drawup) because simulated heads increased over time near the city of Wharton wells that stopped pumping in 2020

Table 6-2 presents drawdown results as the change in the average drawdown over Wharton County in feet since 2020 for 2020, 2030, 2040, 2050, 2060 and 2070. In 2050, the additional pumping in scenario S1 and S2 produced additional county-averaged drawdown changes of 1 ft or less relative to the baseline LCRB model. By 2070, the change in net drawdown is as much as 1.8 ft relative to the baseline LCRB model as presented in **Table 6-3**.

Table 6-2 Average change in drawdown over Wharton County in feet since 2020 by pumping scenario

		Change in Drawdown over Wharton County (Feet) Since 2020					
Pumping Scenario	**Potential Well Field Area**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
baseline	N/A	0	1.2	2.2	3.1	4.0	4.7
S1	Pierce Ranch	0	1.4	2.7	4.0	5.3	6.4
S2	Pierce Ranch	0	1.4	2.7	4.1	5.4	6.5
S1	NCOW	0	1.3	2.6	3.8	5.0	6.1
S2	NCOW	0	1.2	2.5	3.7	4.9	5.9

Table 6-3 Average change in net drawdown over Wharton County in feet from 2020 to 2070 by pumping scenario

Pumping Scenario	Potential Well Field Area	AvergeCounty Wide Change in Net Drawdown in Feet, 2020 to 2070
S1	Pierce Ranch	1.7
S2	Pierce Ranch	1.8
S1	NCOW	1.4
S2	NCOW	1.3

6.3 Land Subsidence Results

For all simulations, the simulated values of land subsidence were less than 0.1 foot after 30 years of pumping.

7.0 HYDROGEOLOGICAL ASSESSMENT OF ASR

Aquifer storage and recovery (ASR) is the storage of water in an aquifer, typically via injection wells, for later recovery and re-use. Often times the target storage zones for ASR are within aquifers that have experienced long-term declines in water levels due to pumping. If adequate water is recharged, groundwater levels can increase. Implementation of ASR requires detailed consideration of the hydrogeology, water quality, regulatory framework, and complex geochemical reactions that may occur between the native groundwater, recharge water, and rock matix. The hydrogeological assessment of ASR presented below only addresses the impact the injected water volumes have on the spatial distribution of drawdown.

7.1 New Water Sources with ASR

A conservative assumption was made that the source of water for ASR will be treated wastewater effluent from the city of Wharton, which would be a new source of water for the city of Wharton. The objective of the ASR simulation was to determine if this new source of water was sufficient to reduce local drawdown near the existing wells that supply water to the city of Wharton. The injection of wastewater effluent was assumed to occur beginning in 2035. In the simulations, wastewater is injected continuously over time at a rate equal to 60 percent of the total water produced from the wells supplying the city of Wharton.

7.2 Selection of Potential Well Field Locations for ASR

The proposed wells for ASR were sited in areas of maximum drawdown near the existing city of Wharton wells to minimize local drawdown impacts. The proposed injection wells are all located on the north side of the Colorado River near the city of Wharton's wastewater treatment plant for cost efficiency.

7.3 Pumping Schedule for ASR

The third pumping scenario (S3) utilizes treated wastewater as a new source of water that will be injected into wells beginning in 2035 in order to minimize drawdown near the city of Wharton. The extraction rates for the third pumping scenario are identical to those in the first pumping scenario (S1).

Table 7-1 summarizes the third pumping scenario and lists the year, the projected maximum daily demand in MGD, the number of wells for extraction and injection, and the maximum pumping rate at any individual well in MGD and GPM for both the injection and extraction wells. The extraction rate at each well was limited to 1,500 GPM which is consistent with extraction rates for nearby wells. Similarly, the injection rate at each well was limited to 700 GPM. These constraints were used to define the number of wells required to meet the specified total well field injection and extraction rates. Because a uniform pumping rate was assigned to all wells in any given year to meet the projected maximum daily demand, the maximum pumping and injection rates at a well is less than the upper limit of 1,500 GPM and 700 GPM for pumping and injection wells, respectively.

Table 7-1 Pumping schedule for extraction of groundwater and injection of treated wastewater

Pumping Scenario S3[A]	Extraction of Groundwater at Wells				Injection of Treated Wastewater at Wells			
Year	Projected Maximum Daily Demand (MGD)	Number of Wells	Maximum Pumping Rate at a Well (MGD)	Maximum Pumping Rate at a Well (GPM)	Projected Maximum Daily Treated Wastewater (MGD)	Number of Wells	Maximum Pumping Rate at a Well (MGD)	Maximum Pumping Rate at a Well (GPM)
2020	3.17	4	0.79	549	0	0	0	0
2025	3.97	5	0.80	556	0	0	0	0
2030	4.76	5	1.59	1,104	0	0	0	0
2035	5.56	6	1.59	1,104	3.34	4	0.83	576
2040	6.35	6	1.59	1,104	3.81	4	0.95	660
2045	7.14	7	1.59	1,104	4.28	5	0.95	660
2050	7.94	7	1.59	1104	4.76	5	0.95	660
2055	8.73	8	1.59	1,104	5.24	6	0.95	660
2060	9.52	8	1.59	1,104	5.71	6	0.95	660
2065	10.32	9	1.59	1,104	6.19	7	0.95	660
2070	11.11	9	1.59	1,104	6.67	7	0.95	660

[A]The well locations for pumping scenario S3 are shown on **Figure 7-1** for the Pierce Ranch proposed well field area and on **Figure 7-2** for the NCOW proposed well field area.

7.4 ASR Scenarios

Two ASRs simulations were conducted with the third pumping scnenario. The first simulation assumes that the proposed extraction wells are located on Pierce Ranch as shown in **Figure 7-1**. The second simulation assumes that the proposed extraction wells are located north of the city of Wharton as shown in **Figure 7-2**. Both ASR simulations use the same extraction well locations and pumping schedule as used in the first pumping scenario. In each ASR simulation, seven injection wells were added near the city of Wharton to minimize drawdown impacts.

7.4.1 Model Simulation of ASR

Model simulations for ASR were conducted by adding injection wells to the WEL Package of MODFLOW for each stress period of the simulation beginning in 2035. By convention, the extraction wells of MODFLOW have a negative flow rate while injection wells have positive flow rate. The well extraction and injection rates were apportioned between the Lissie and Willis formations, based on their transmissivities.

7.4.2 Drawdown Impacts of ASR

Drawdown results are presented as maps of drawdown in the Lissie and Willis formations for 1, 10, 20, and 30 years after the beginning of the proposed pumping in 2020. Each drawdown map illustrates drawdown in feet by model layer at specific points in time relative to the baseline LCRB model, which includes a constant pumping rate of 3 MGD for the cities of Wharton and East Bernard. In other words, the drawdown maps show the amount of drawdown that can be attributed to additional pumping above 3 MGD. The drawdown figures are summarized below and are presented in Appendix C:

- **Figure C-1** through **Figure C-6** show drawdown maps for pumping scenario S3 with proposed pumping from the Pierce Ranch potential well field area
- **Figure C-7** through **Figure C-12** show drawdown maps for pumping scenario S3 with proposed pumping from the NCOW potential well field area. Scenario S3 has both positive values for drawdown and negative values for drawdown (or drawup) because simulated heads increase near the the injection wells

Table 7-2 presents drawdown results as the change in the average drawdown over Wharton County in feet since 2020 for years 2020, 2030, 2040, 2050, 2060 and 2070 for the baseline simulation and the ASR simulation (S3). For the years 2020 and 2030, the county-wide average drawdown values in simulation S3 are identical to the county-wide average drawdown values in Table 6-1 for simulation S1 because simulations S1 and S3 have the same pumping and injection does not begin until 2035 in simulation S3.

Table 7-2 Average change in drawdown over Wharton County in feet since 2020 for the ASR simulations

		County Wide Change in Drawdown in Feet Since 2020					
Pumping Scenario	**Potential Well Field Area**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
baseline	N/A	0	1.2	2.2	3.1	4.0	4.7
S3	Pierce Ranch	0	1.4	2.1	3.1	4.1	5.0
S3	NCOW	0	1.3	2.0	2.9	3.9	4.7

By 2070, the change in net drawdown is as much as 0.3 ft relative to the baseline LCRB model as presented in **Table 7-3**.

Table 7-3 Average change in net drawdown over Wharton County in feet from 2020 to 2070 by pumping scenario for the ASR simulations

Simulation	Potential Well Field Area	Average County Wide Change in Net Drawdown in Feet, 2020 to 2070
S3	Pierce Ranch	0.3
S3	NCOW	<0.1

7.4.3 Land Subsidence Results

For all simulations, the simulated values of land subsidence were less than 0.1 foot after 30 years of pumping.

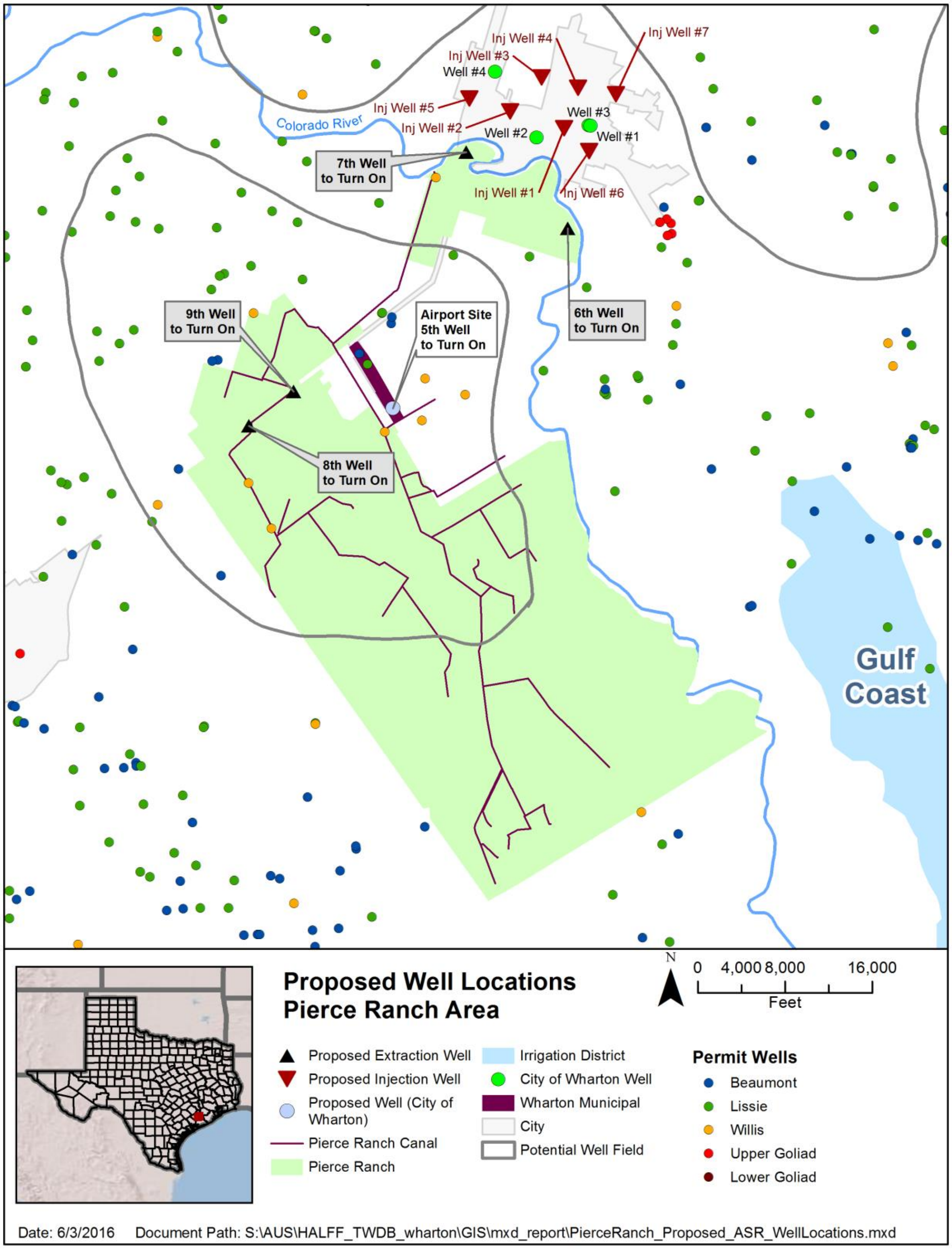


Figure 7-1 Proposed pumping and injection well locations in the Pierce Ranch proposed well field area for the ASR simulation (S3)

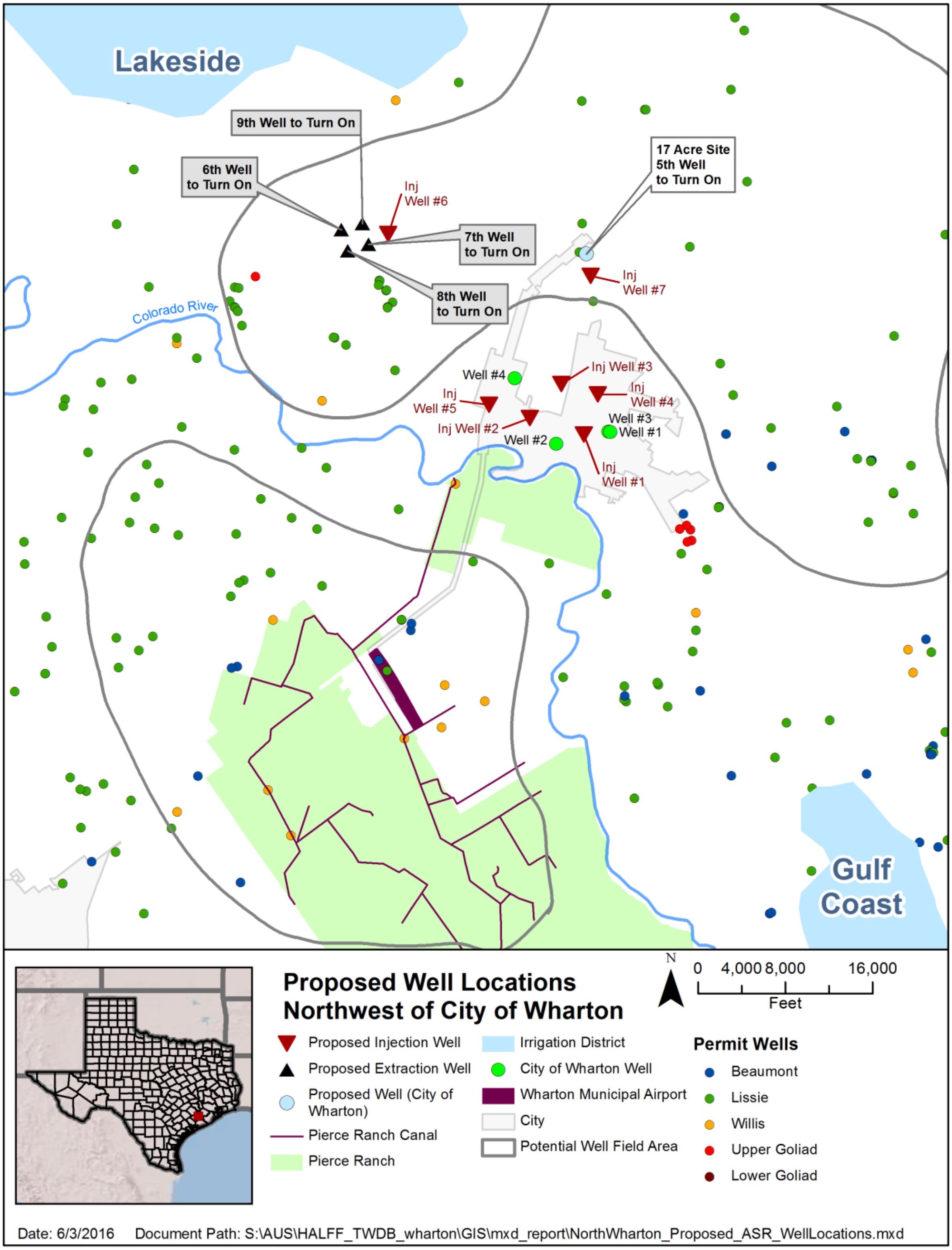


Figure 7-2 Proposed pumping and injection well locations in the NCOW proposed well field area for the ASR simulation (S3)

8.0 ADDITIONAL SIMULATION WITH AVERAGE ANNUAL DAILY DEMANDS

In response to feedback from stakeholders to the modeling results discussed in Section 6 , INTERA performed additional groundwater model simulation based on average annual daily demands provided by HALFF Associates for the cities of Wharton and East Bernard as listed in **Table 8-1**. The projected daily demands for the fourth pumping scenario (S4) are supplied by additional wells located in the NCOW potential well field. The locations of the wells and year in which each well begins pumping is identical to that of the first pumping scenario (S1) which is illustrated in Figure 5-2.

The average change in drawdown over the county simulated with pumping scenario S4 is shown in **Table 8-2** along with previously presented drawdown results for pumping scenarios S1 and S2. Pumping scenarios S1 and S4 use the same number of wells and the same well locations but different pumping rates. On average, the annual pumping in S4 is 56 percent of the pumping in scenario S1. The average county wide change in net drawdown from 2020 to 2070 is 1.4 feet for pumping scenario S1, and is 0.6 feet for pumping scenario S4 as shown in **Table 8-3**.

Table 8-1 Pumping schedule for extraction of groundwater for pumping scenario 4

		Fouth Pumping Scenario (S4)[A]		
Year	Projected Average Daily Demand (MGD)	Number of Total Wells	Maximum Pumping Rate at a Well (MGD)	Maximum Pumping Rate at a Well (GPM)
2020	1.91	4	0.30	331.6
2025	1.97	5	0.48	273.6
2030	2.47	5	0.39	343.1
2035	2.96	6	0.49	342.6
2040	3.45	6	0.49	399.3
2045	3.94	7	0.58	390.9
2050	4.44	7	0.56	440.5
2055	4.93	8	0.63	428.0
2060	5.42	8	0.62	470.5
2065	5.92	9	0.68	456.8
2070	6.41	9	0.66	494.6

[A]The well locations for pumping scenario S4 are shown on **Figure 5-2** for the NCOW proposed well field area.

Table 8-2 Average change in drawdown over Wharton County in feet since 2020 for pumping scenarios S1, S2, and S4 which simulate pumping at the proposed NCOW well field

		Change in Drawdown over Wharton County (Feet) Since 2020					
Pumping Scenario	Potential Well Field Area	2020	2030	2040	2050	2060	2070
baseline	N/A	0	1.2	2.2	3.1	4.0	4.7
S1	NCOW	0	1.3	2.6	3.8	5.0	6.1
S2	NCOW	0	1.2	2.5	3.7	4.9	5.9
S4	NCOW	0	1.0	2.2	3.3	4.3	5.2

Table 8-3 Average change in net drawdown over Wharton County in feet from 2020 to 2070 for pumping scenarios S1, S2, and S4 which simulate pumping at the proposed NCOW well field

Pumping Scenario	Potential Well Field Area	Averge County Wide Change in Net Drawdown in Feet, 2020 to 2070
S1	NCOW	1.4
S2	NCOW	1.3
S4	NCOW	0.6

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APPENDIX A:
EXPANSION OF EXISTING WELL FIELDS

Modeling Approach

To simulate the aquifer responses to well field pumping, INTERA used a three-dimensional analytic element model called TTim (Bakker, 2006) previously described in Section 4.1.3. The advantage of using TTim is that aquifer stratigraphy and hydraulic properties can easily be input to reflect local aquifer conditions and accurate drawdown values are calculated at the location of the well. TTim simulates changes in drawdown from an initial condition of a horizontal water table. This simplifying assumption is appropriate for the investigation of the variation in transmissivity and drawdown at different potential well field locations. Because the initial condition in the TTim simulations is a static water level, regional gradients formed from historical pumping are not considered. The impact of regional gradients is considered in the detailed investigation of the two potential well field areas based on simulations with the LCRB model as presented in Sections 5, 6, and 7.

The modeling approach was to assign the hydraulic properties (horizontal hydraulic conductivity, vertical hydraulic conductivity, and the storativity) from the LCRB model at the four potential well field areas identified by the city of Wharton in a TTim simulation of each of the four potential well field areas. The pumping schedule and well spacings are described below and followed by a summary of the simulated drawdowns for these simulations.

Well Fields

The four well field areas simulated in the TTim simulations, presented from north to south, are the 17-acre site in the northern portion of the city of Wharton, the Alabama Rd. site within the city of Wharton, the 3-acre site in the southern portion of the city of Wharton, and the Wharton Municipal Airport site southwest of the city of Wharton. **Figure A-1** shows the locations of potential well fields sites and the extent of each TTim model domain. The 17-acre site, the Alabama Rd site, and the 3-acre site are all located northeast of the Colorado River while the Airport site is located southwest of the Colorado River.

The thickness and elevation of the Lissie and Willis formations varies among the well fields as shown in **Figure A-2, Figure A-5, and Figure A-7** in cross-sections of the elevations used in the TTim simulations. In the TTIm simulation, the vertical layering was subdivided from that used in the LCRB model by defining a model layer for the screened portion of the Lissie and Willis formations. The screened interval was assumed to be 200 ft thick in both the Lissie and Willis formations resulting in eight model layers in TTim. From top to bottom, the layers represent the shallow aquifer, the Beaumont Formation, the Lissie Formation above the well screen, the screened portion of the LIssie Formation at the well, the screened portion of the Willis Formation at the well, the portion of the Willis below the well screen, the Upper Goliad Formation, and the Lower Goliad Formation.

The 50-year pumping schedule begins in 2020 and ends in 2070 as listed in **Table A-1**. In each of the four TTim simulations, three pumping wells were placed 3,000 ft apart in a triangular spacing pattern and each well was pumped at a rate of 1,000 GPM during the simulation period once it began pumping. In 2020 there is one pumping well, the second well starts pumping in 2035, and the third well begins pumping in 2050. Pumping was simulated from the Lissie and Willis formations as apportioned by the transmissivity of each formation and the resulting drawdown response was calculated.

Table A-4 Fifty-year expansion plan for the potential well fields

50 Year Expansion Plan			
Year	**Time Elapsed (years)**	**Discharge From Well Field (GPM)**	**Number of New Wells**
2020	0	1,000	1
2025	5	1,000	1
2030	10	1,000	1
2035	15	2,000	2
2040	20	2,000	2
2045	25	2,000	2
2050	30	3,000	3
2055	35	3,000	3
2060	40	3,000	3
2065	45	3,000	3
2070	50	3,000	3

Simulated Drawdown

The simulated drawdown in the Lissie Formation is shown in **Figure A-3, Figure A-4, Figure A-6, and Figure A-8** for the years 2025, 2040, 2055, and 2070 at the four protentional well field sites. The easting and northing coordinates are relative such that the wells are centered around the origin in each figure to simplify comparisons among the figures. Each figure shows drawdown at a radial distance of 1.14 miles (6,000 ft). The figures show little change in drawdown between 2055 and 2070 as the cone of depression has expanded and is larger in volume. The simulated maximum and minimum drawdowns are similar among all four sites in 2070 indicating that the variability in hydraulic properties from the LCRB model at these locations results in little variation in drawdown with time.

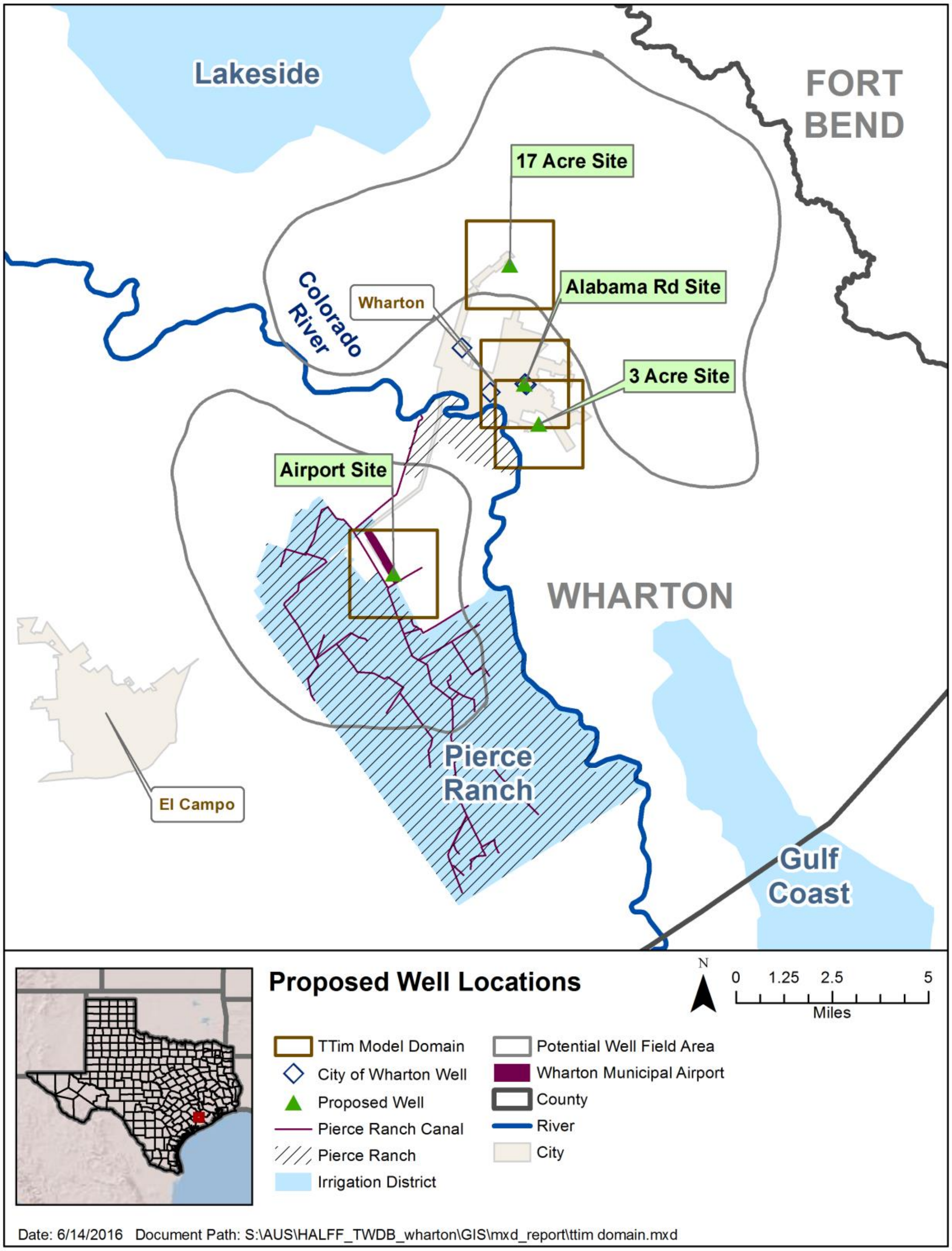

Figure A-1 Model domains for analytic element models at the 17-acre site, the Alabama Rd site, the 3-acre site, and the Airport Site

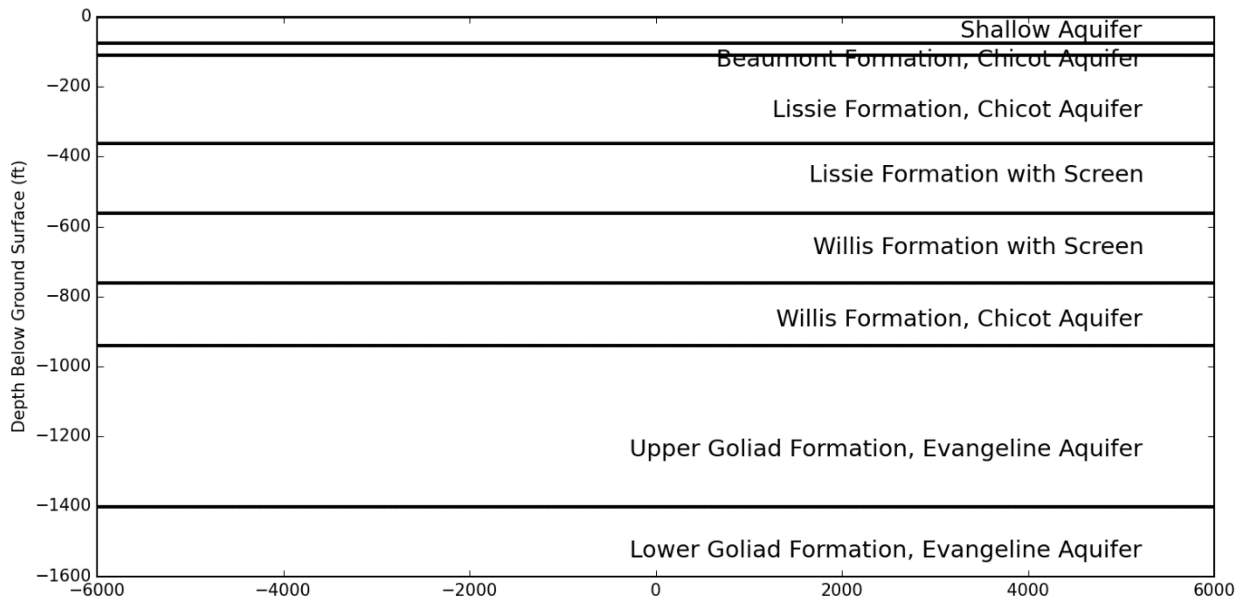

Figure A-2 Cross-section for the analytic element simulation (TTim) at the 17-acre site

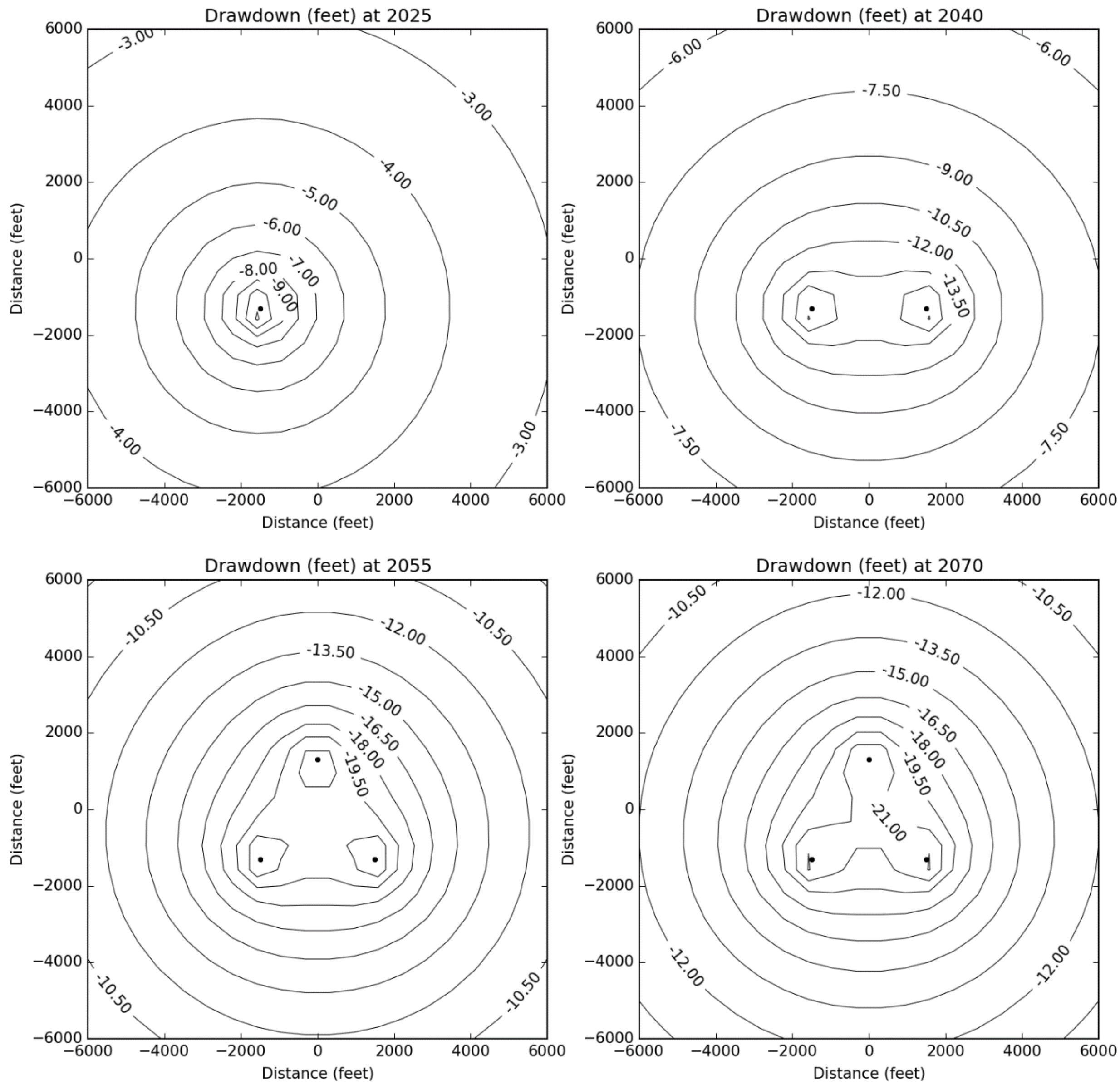

Figure A-3 Simulated drawdown in feet in the Lissie Formation at the 17-acre site in 2025, 2040, 2055, and 2070.

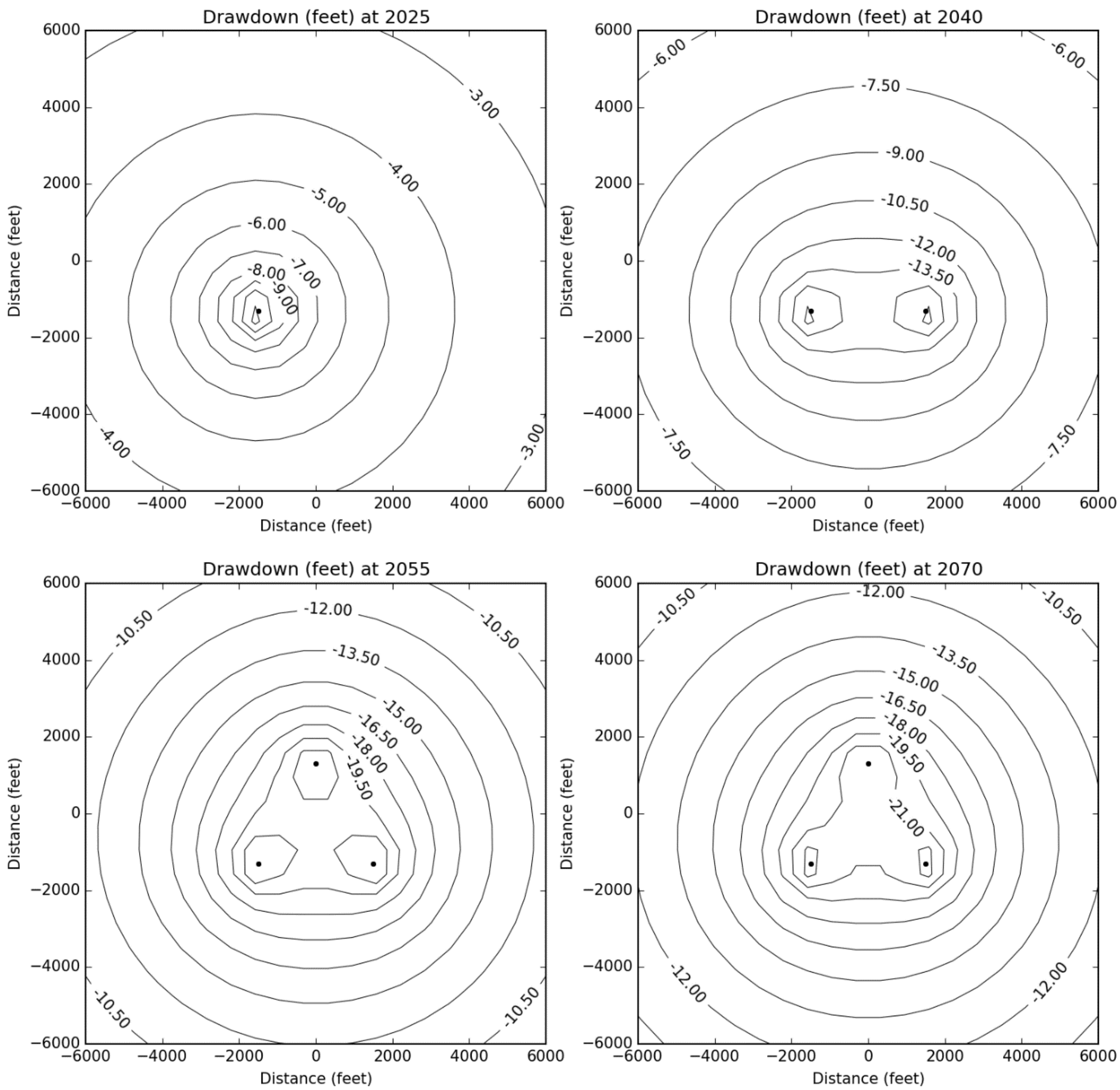

Figure A-4 Simulated drawdown in feet in the Lissie Formation at the Alabama Rd site in 2025, 2040, 2055, and 2070.

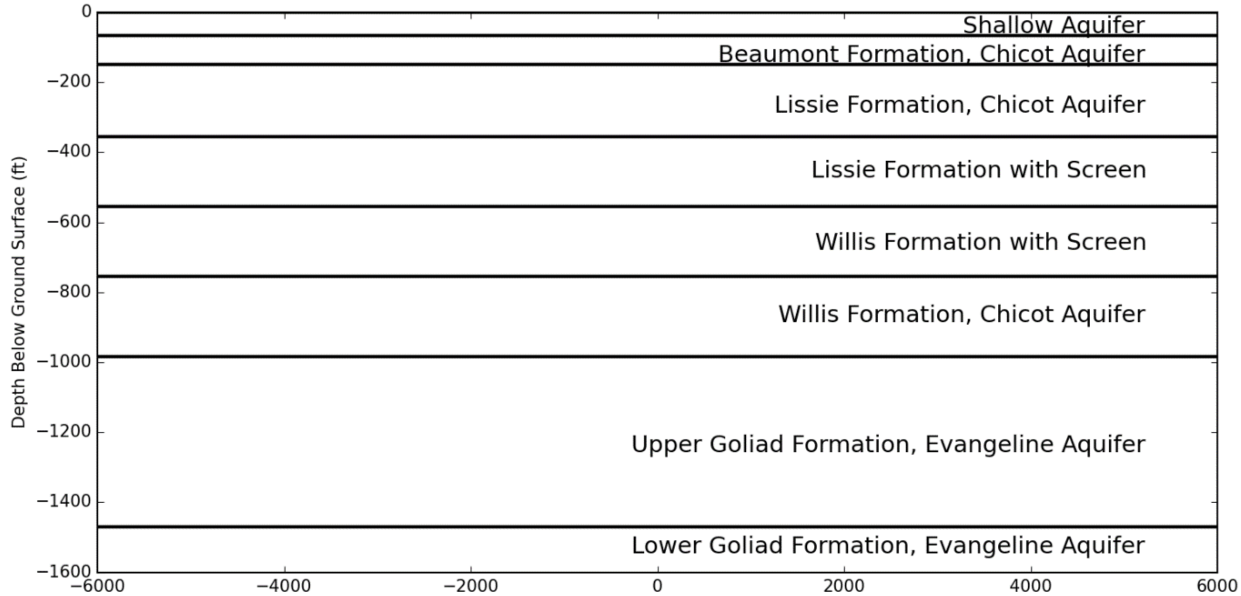

Figure A-5 Cross-section for the analytic element simulation (TTim) at the Airport site

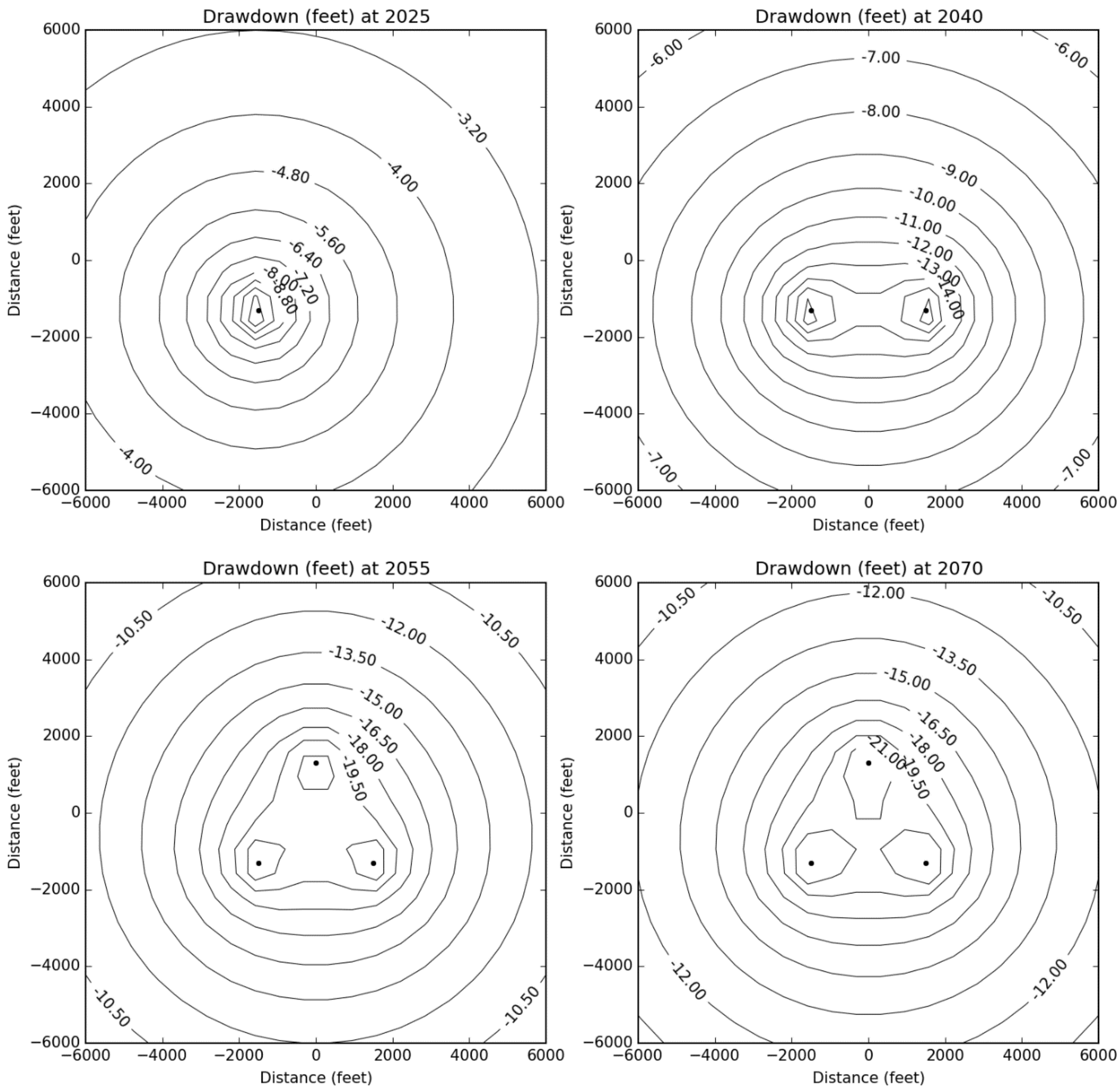

Figure A-6 Simulated drawdown in feet in the Lissie Formation at the Airport site in 2025, 2040, 2055, and 2070.

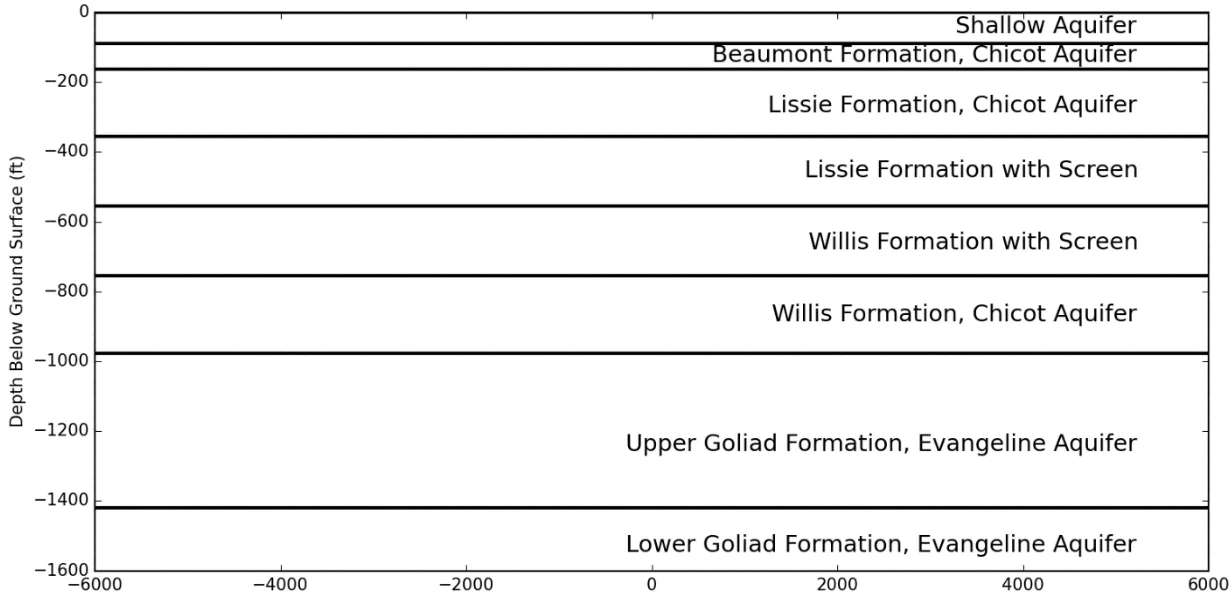

Figure A-7 Cross-section for the analytic element simulation (TTim) at the 3-acre site

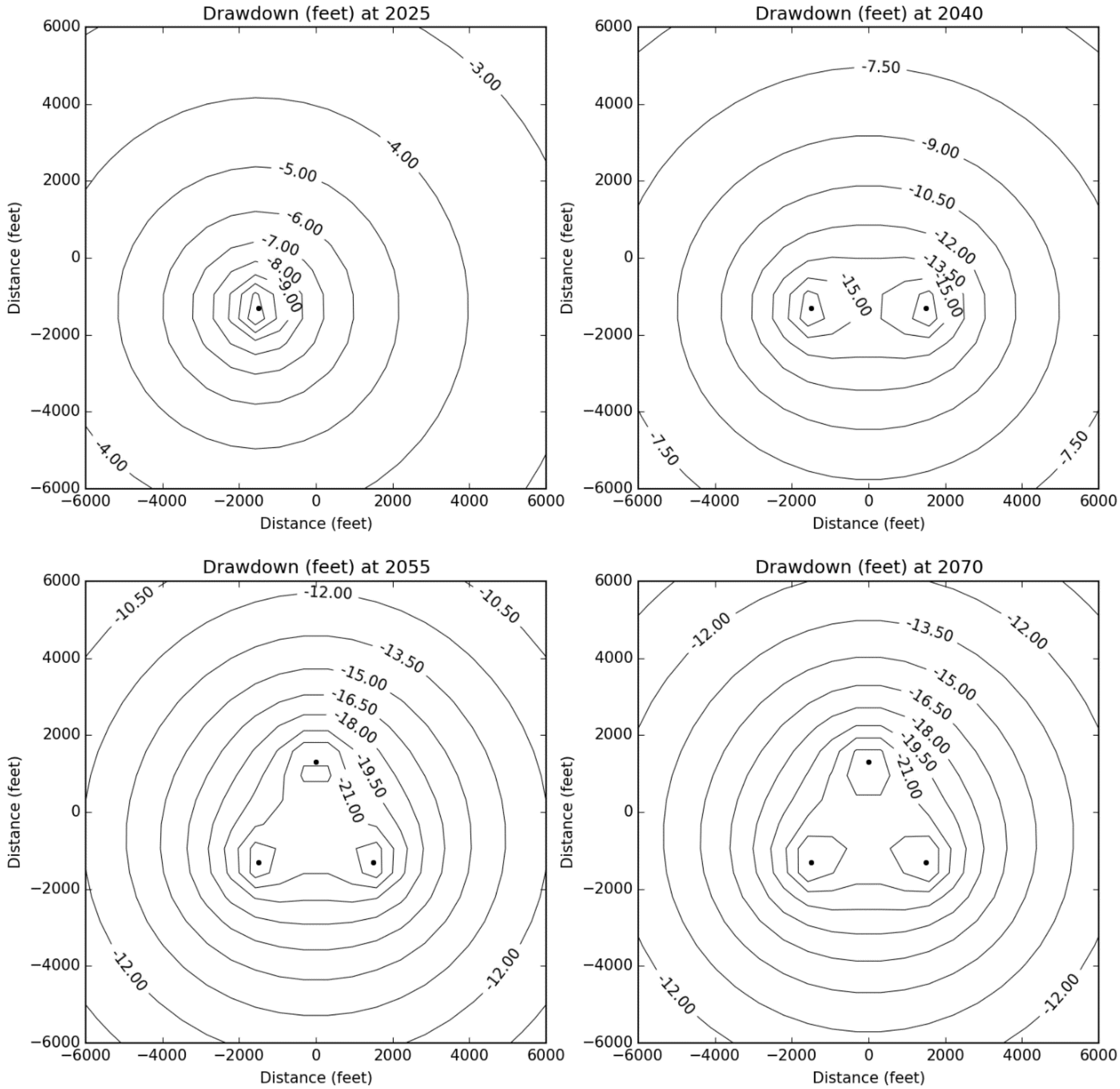

Figure A-8 Simulated drawdown in feet in the Lissie Formation at the 3-acre site in 2025, 2040, 2055, and 2070.

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Appendix C

Revised Wharton Water Conservation Plan

I. INTRODUCTION & OBJECTIVES

The City of Wharton is located in the central and eastern portion of Wharton County, approximately 26 miles southwest of the City of Rosenberg, Fort Bend County, Texas. The City of Wharton is located wholly within Wharton County, Texas.

The City of Wharton is responsible for providing, operating and maintaining adequate water supply and distribution systems, sanitary sewage treatment and collection systems, storm water drainage systems, and related services. The general laws of the State of Texas pertaining to municipalities establishes the rights, powers, privileges, authority and functions of the City and the City is subject to the continuing supervision of the Texas Commission on Environmental Quality ("Commission").

The City establishes and collects fees from water and sewer customers, based on an official rate, for the purpose of paying operational and maintenance costs of the City's facilities.

At the time of the adoption of this water conservation plan, all of the City's groundwater is obtained from the City's water plant facilities which provides groundwater pumped from the City's water wells. The City's water plant also serves a small portion of the city's extraterritorial jurisdiction.

The City's Utility Department, a division of the City's Public Works Department, is the current operator. The term "City Operator" shall mean the Utility Department or such other qualified entity engaged from time to time by the City as its operator.

Conservation plan goals are as follows:

(a) To reduce water consumption from the levels that would prevail without conservation efforts
(b) To reduce the loss and waste of water
(c) To improve the efficiency in the use of water
(d) To increase the reuse of water

II. UTILITY PROFILE

See Attached Utility Profile

Population and customer data
The City's Water Services Department manages a water distribution service area of 8 square miles and serves a population of 8,726 residents. The City provides drinking water to its customers through a network of 3,741 service connections.

Water use data
Maximum Daily consumption (MDC) and Dates
2.432 Million Gallons on July 3, 2013
2.661 Million Gallons on August 13, 2011
2.193 Million Gallons on September 15, 2010
3.030 Million Gallons on August 7, 2009

Average Daily Consumption (ADC)
From 2011 to 2015 the ADC was 1.43 MGD

III. FIVE-YEAR AND TEN-YEAR TARGETS

See attached Utility Profile for Current Treatment and distribution information.

Wharton shall use reasonable efforts to reduce water loss and municipal use of water. Such efforts shall include the following:

1. Continuing efforts to account for at least 90% of the water pumped from the City's water wells.
2. Continuing the testing, repair and replacement of water meters as well as leak detection efforts.
3. Distributing water conservation information to the City's water customers.

Five-Year Target: Within five (5) years of the date hereof, the City of Wharton shall attempt to reduce the five-year running average municipal water use within the City's service area to 148 gallons per capita per day and reduce the unaccounted for water to 15 %.

Ten-Year Target: Within ten (10) years of the date hereof, the City of Wharton shall attempt to reduce the five-year running average municipal water use within the City's service area to 133 gallons per capita per day and reduce the unaccounted for water in the system below 10% annually.

Notwithstanding the targets identified above, the City shall not be obligated to achieve any water savings in its service area, and the City's failure to do so shall not subject the City to any liability whatsoever.

IV. SCHEDULE FOR IMPLEMENTATION

In discussions with City officials, it was determined that further measures could be taken to increase water conservation. Best Management Practices, or BMP's, provide methods for the city to improve upon their water conservation efforts. The following table outlines a schedule for BMP's that the City has already implemented and ones that the City plans to implement in the future.

Implementation Schedule		
BMP Description	**Currently Implemented**	**Implemented Within 5-Years**
Conservation Coordinator		X
Water Conservation Pricing	X	
Metering of All New Connections and Retrofit of Existing Connections	X	
System Water Audit and Water Loss	X	
Public Information		X
School Education		X

1. Once a year, the City of Wharton will review consumption patterns and its income and expense levels and evaluate whether or not the current water rates are effective and appropriate. A progressive water rate structure may be considered by the City and adjustments will be made as needed.
2. The City of Wharton will provide information regarding the water rate structure to each of its customers once a year. The City will also provide customers with historical water use for the previous 12 months upon request.
3. Replacement of water lines found to be leaking or are in generally poor condition will be completed as quickly as practical to ensure minimal water loss.

V. METHOD FOR TRACKING EFFECTIVENESS

In order to track the progress of the Water Conservation and Drought Contingency Plan, the City of Wharton will need to collect a variety of information with regards to each program. The following information will be useful in tracking the progress of the Water Conservation Plan.

1. For information programs, the City will collect information about its programs and the population to evaluate the effectiveness of the program. For literature pieces, the number of such pieces and topics covered will be documented. The number of news programs or advertisements will also be documented and the total population of the service area will be tracked.
2. The billing structure will be evaluated annually. Several pieces of information are required to evaluate this structure effectively. A copy of the rate ordinance will be documented. Billing and customer records will be kept and water consumption by each customer class at the beginning and end of the reporting period will be recorded.
3. In order to evaluate the meter installation program, guidelines of meter installation based upon customer usage will be written and available, a meter repair and replacement policy will be documented, and meter number, size, make, and model will be recorded for each meter repair and replacement. In addition, a report will be written on method used to determine meter replacement and testing for each meter size.

VI. WATER LOSS CONTROL MEASURES

The goal of the City's water loss control program is to maintain unaccounted-for water (unbilled authorized and unbilled unauthorized usage) water at or below 10% if water produced, on a monthly basis. In order to meet this goal, the City of Wharton has several programs in place, including: meter testing and accuracy, meter repair, and tracking unaccounted-for water use.

METERING DEVICES

The City's policy calls for the installation and inspection of meters on all new service connections. The Commission requires that all metering devices be 95% accurate.

UNIVERSAL METERING

The City's policy calls for the installation and inspection of meters on all new service connections. At present, all active water service connections are metered.

METER REPAIR

Meters that are repairable shall be repaired by the City Operator or sent to a meter repair shop. Generally, all residential meters shall be replaced when they become defective or reach a total usage of one million gallons. In some cases where larger meters are used (generally by commercial customers), it is possible that these meters can be repaired. When a faulty meter is discovered, a new meter shall be immediately installed and the old meter will be repaired if practical and reused.

UNACCOUNTED- FOR WATER USE
The City Operator will routinely look for leaks, illegal connections and abandoned services, etc., during its periodic inspections of the City's Service Area.

VII. CONTINUING PUBLIC EDUCATION & INFORMATION

The City of Wharton will promote water conservation by informing the public of ways to conserve water. The following methods will be used to inform water users:

1. Distribution of educational materials to all customers. Educational materials utilized will include those prepared by the Texas Water Development Board;
2. Working with any future builders and developers co encourage use of water conserving plumbing fixtures and irrigation systems;
3. Inclusion of water conservation tips in monthly billing statements to the City's customers;
4. Distribution of general conservation information to new customers applying for service;
5. Participation in informational school programs in schools attended by students within the City's Service Area; and
6. As the need for future revenue becomes necessary, water rates rather than sewer rates will be raised to encourage conservation.

VIII. WATER RATE STRUCTURE

A water conservation pricing signal is a rate structure designed and priced in a way that significantly increases a consumer's water bill when he or she uses more water. Wharton has developed a strong water conservation pricing signal that dissuades consumers from wasting water.

(a) The monthly charges for water service, which can be found on the City's website, are as follows:

Volume	**Charges**
First 2,000 gallons (minimum)	$18.35
Next 2,000 gal1ons, per 1,000	$3.48
Next 3,000 gallons, per 1,000	$3.60
Next 4,000 gallons, per 1,000	$3.74
Next 4,000 gallons, per 1,000	$3.98
Next 35,000 gallons, per 1,000	$4.22
Next 50,000 gallons, per 1,000	$4.38
Next 50,000 gallons, per 1,000	$4.70
Next 50,000 gallons, per 1,00	$4.99

(b) Customers requesting temporary water services (seven-day increments) can apply for a temporary water rate based on the following:

Volume	Charges
First 8,000 gallons for seven days	$42.41
Over 8,000 gallons, per 1,000	$3.87

IX. VARIANCES

The City Manager, or his/her designee, may, in writing, grant temporary variance for existing water uses otherwise prohibited under this Plan if it is determined that failure to grant such variance would cause an emergency condition adversely affecting the health, sanitation, or fire protection for the public or the person requesting such variance and if one or more of the following conditions are met:

(a) Compliance with this Plan cannot be technically accomplished during the duration of the water supply shortage or other condition for which the Plan is in effect.
(b) Alternative methods can be implemented which will achieve the same level of reduction in water use.

Persons requesting an exemption from the provisions of this Ordinance shall file a petition for variance with the City of Wharton within five (5) days after the Plan or a particular drought response stage has been invoked. All petitions for variances shall be reviewed by the City Manager, or his/her designee, and shall include the following:

(a) Name and address of the petitioner(s).
(b) Purpose of water use.
(c) Specific provision(s) of the Plan from which the petitioner is requesting relief.
(d) Detailed statement as to how the specific provision of the Plan adversely affects the petitioner or what damage or harm will occur to the petitioner or others if petitioner complies with this Ordinance.
(e) Description of the relief requested.
(f) Period of time for which the variance is sought.
(g) Alternative water use restrictions or other measures the petitioner is taking or proposes to take to meet the intent of this Plan and the compliance date.
(h) Other pertinent information.

Variances granted by the City of Wharton shall be subject to the following conditions, unless waived or modified by the City Manager or his/her designee:

(a) Variances granted shall include a timetable for compliance.
(b) Variances granted shall expire when the Plan is no longer in effect, unless the petitioner has failed to meet specified requirements.

No variance shall be retroactive or otherwise justify any violation of this Plan occurring prior to the issuance of the variance.

X. ENFORCEMENT PROCEDURE & PLAN ADOPTION

The city Operator is authorized and directed to implement applicable provisions of this water conservation plan. A copy of the City's Resolution adopting the Water Conservation Plan is attached.

ARTICLE V. - DROUGHT CONTINGENCY PLAN

Sec. 86-201. - Declaration of policy, purpose, and intent.

(a) In order to conserve the available water supply and protect the integrity of water supply facilities, with particular regard for domestic water use, sanitation, and fire protection, and to protect and preserve public health, welfare, and safety and minimize the adverse impacts of water supply shortage or other water supply emergency conditions, the City of Wharton hereby adopts the following regulations and restrictions on the delivery and consumption of water.

(b) Water uses regulated or prohibited under this drought contingency plan (the plan) are considered to be non-essential and continuation of such uses during times of water shortage or other emergency water supply condition are deemed to constitute a waste of water which subjects the offender(s) to penalties as defined in section 86-211 of this article.

(Ord. No. 2000-08, Exh. A(§ I), 3-13-00)

Sec. 86-202. - Public involvement.

Opportunity for the public to provide input into the preparation of the plan was provided by the city by means of scheduling and providing public notice of a public meeting to accept input on the plan.

(Ord. No. 2000-08, Exh. A(§ II), 3-13-00)

Sec. 86-203. - Public education.

The city will periodically provide the public with information about the plan, including information about the conditions under which each stage of the plan is to be initiated or terminated and the drought response measures to be implemented in each stage. This information will be provided by means of public events, press releases or utility bill inserts.

(Ord. No. 2000-08, Exh. A(§ III), 3-13-00)

Sec. 86-204. - Coordination with regional water planning groups.

The service area of the City of Wharton is located within the LCRA Planning Group and city has provided a copy of this plan to the Lower Colorado Regional Water Planning Group.

(Ord. No. 2000-08, Exh. A(§ IV), 3-13-00)

Sec. 86-205. - Authorization.

The city manager or his/her designee is hereby authorized and directed to implement the applicable provisions of this plan upon determination that such implementation is necessary to protect public health, safety, and welfare. The city manager, or his/her designee, shall have the authority to initiate or terminate drought or other water supply emergency response measures as described in this plan.

(Ord. No. 2000-08, Exh. A(§ V), 3-13-00)

Sec. 86-206. - Application.

The provisions of this plan shall apply to all persons, customers, and property utilizing water provided by the city. The term's "person" and "customer" as used in the plan include individuals, corporations, partnerships, associations, and all other legal entities.

(Ord. No. 2000-08, Exh. A(§ VI), 3-13-00)

Sec. 86-207. - Definitions.

For the purposes of this plan, the following definitions shall apply:

Aesthetic water use: Water use for ornamental or decorative purposes such as fountains, reflecting pools, and water gardens.

Commercial and institutional water use: Water use which is integral to the operations of commercial and non-profit establishments and governmental entities such as retail establishments, hotels and motels, restaurants, and office buildings.

Conservation: Those practices, techniques, and technologies that reduce the consumption of water, reduce the loss or waste of water, improve the efficiency in the use of water or increase the recycling and reuse of water so that a supply is conserved and made available for future or alternative uses.

Customer: Any person, company, or organization using water supplied by City of Wharton.

Domestic water use: Water use for personal needs or for household or sanitary purposes such as drinking, bathing, heating, cooking, sanitation, or for cleaning a residence, business, industry, or institution.

Even number address: Street addresses, box numbers, or rural postal route numbers ending in 0, 2, 4, 6, or 8 and locations without addresses.

Industrial water use: The use of water in processes designed to convert materials of lower value into forms having greater usability and value.

Landscape irrigation use: Water used for the irrigation and maintenance of landscaped areas, whether publicly or privately owned, including residential and commercial lawns, gardens, golf courses, parks, and rights-of-way and medians.

Non-essential water use: Water uses that are not essential nor required for the protection of public, health, safety, and welfare, including:

(1) Irrigation of landscape areas, including parks, athletic fields, and golf courses, except otherwise provided under this plan;

(2) Use of water to wash any motor vehicle, motorbike, boat, trailer, airplane or other vehicle;

(3) Use of water to wash down any sidewalks, walkways, driveways, parking lots, tennis courts, or other hard-surfaced areas;

(4) Use of water to wash down buildings or structures for purposes other than immediate fire protection;

(5) Flushing gutters or permitting water to run or accumulate in any gutter or street;

(6) Use of water to fill, refill, or add to any indoor or outdoor swimming pools or Jacuzzi-type pools;

(7) Use of water in a fountain or pond for aesthetic or scenic purposes except where necessary to support aquatic life;

(8) Failure to repair a controllable leak(s) within a reasonable period after having been given notice directing the repair of such leak(s); and

(9) Use of water from hydrants for construction purposes or any other purposes other than fire fighting.

Odd numbered address: Street addresses, box numbers, or rural postal route numbers ending in 1, 3, 5, 7, or 9.

(Ord. No. 2000-08, Exh. A(§ VII), 3-13-00)

Sec. 86-208. - Criteria for initiation and termination of drought response stages.

(a) The city manager or his/her designee shall monitor water supply and/or demand conditions on a daily basis and shall determine when conditions warrant initiation or termination of each stage of the Plan, that is, when the specified "triggers" are reached.

(b) The triggering criteria described below are based on the amount of water the city is able to pump in a day.

(1) *Stage 1 triggers—Mild water shortage conditions.*

a. *Requirements for initiation.* Customers shall be requested to voluntarily conserve water and adhere to the prescribed restrictions on certain water uses, defined in section 86-207, Definitions, when total daily water demand equals or exceeds three million gallons for three consecutive days or 3.25 million gallons on a single day (e.g,, based on the "safe" operating capacity of water supply facilities.

b. *Requirements for termination.* Stage 1 of the plan may be rescinded when all of the conditions listed as triggering events have ceased to exist for a period of three consecutive days.

(2) *Stage 2 Triggers—Moderate water shortage conditions.*

a. *Requirements for initiation.* Customers shall be required to comply with the requirements and restrictions on certain nonessential water uses provided in section 86-209 of this plan when total daily for three consecutive days 3.25 MGD or 3.5 MGD on a single day.

b. *Requirements for termination.* Stage 2 of the plan may be rescinded when all of the conditions listed as triggering events have ceased to exist for a period of three consecutive days. Upon termination of Stage 2, Stage 1 becomes operative.

(3) *Stage 3 triggers—Severe water shortage conditions.*

a. *Requirements for initiation.* Customers shall be required to comply with the requirements and restrictions on certain non-essential water uses for Stage 3 of this plan when total daily for three consecutive days 3.5 MGD or 3.75 MGD on a single day.

b. *Requirements for termination.* Stage 3 of the plan may be rescinded when all of the conditions listed as triggering events have ceased to exist for a period of three consecutive days. Upon termination of Stage 3, Stage 2 becomes operative.

(4) *Stage 4 triggers—Critical water shortage conditions.*

a. *Requirements for initiation.* Customers shall be required to comply with the requirements and restrictions on certain non-essential water uses for Stage 4 of this plan when total daily for three (3) consecutive days 3.75 MGD for 4.0 MGD on a single day.

b. *Requirements for termination.* Stage 4 of the plan may be rescinded when all of the conditions listed as triggering events have ceased to exist for a period of three (3) consecutive days. Upon termination of Stage 4, Stage 3 becomes operative.

(5) *Stage 5 triggers—Emergency water shortage conditions.*

a. *Requirements for initiation.* Customers shall be required to comply with the requirements and restrictions for Stage 5 of this plan when the city manager or his/her designee, determines that a water supply emergency exists based on:

1. Major water line breaks, or pump or system failures occur, which cause unprecedented loss of capability to provide water service; or

2. Natural or manmade contamination of the water supply source(s).

b. *Requirements for termination.* Stage 5 of the plan may be rescinded when all of the conditions listed as triggering events have ceased to exist for a period of three consecutive days.

(6) *Stage 6 Triggers—Water allocation.*

a. *Requirements for initiation.* Customers shall be required to comply with the water allocation plan prescribed in section 86-209 of this plan and comply with the requirements and restrictions for Stage 5 of this plan when total daily water demand equals of exceeds 90 percent of water system production capability for three consecutive days.

b. *Requirements for termination.* Water allocation may be rescinded when all of the conditions listed as triggering events have ceased to exist for a period of three consecutive days.

(Ord. No. 2000-08, Exh. A(§ VIII), 3-13-00)

Sec. 86-209. - Drought response stages.

(a) The city manager, or his/her designee, shall monitor water supply and/or demand conditions on a daily basis and, in accordance with the triggering criteria set forth in section viii of this plan, shall determine that a mild, moderate, severe, critical, emergency or water shortage condition exists and shall implement the following notification procedures:

(1) *Notification.*

a. *Notification of the public:* The city manager or his/her designee shall notify the public by means of publication in a newspaper of general circulation, and cable TV.

b. *Additional notification:* The city manager or his/her designee shall notify directly, or cause to be notified directly, the following individuals and entities:

Examples:

Mayor/and members of the city council fire chief

City and/or county emergency management coordinator(s)

County judge and commissioner(s)

State disaster district/department of public safety

TNRCC (required when mandatory restrictions are imposed)

Major water users

Critical water users, i.e. hospitals

Parks/street superintendents and public facilities managers

Emergency medical director

(b) *Response stages.*

(1) *Stage 1 response—Mild water shortage conditions.*

a. Goal: Achieve a voluntary five-percent reduction in daily water demand (e.g., total water use, daily water demand, etc.).

b. Supply management measures:

    1. Reduced or discontinued flushing of water mains.

c. Voluntary water use restrictions:

    1. Water customers are requested to voluntarily limit the irrigation of landscaped areas to Sundays and Thursdays for customers with a street address ending in an even number (0, 2, 4, 6 or 8), and Saturdays and Wednesdays for water customers with a street address ending in an odd number (1, 3, 5, 7 or 9), and to irrigate landscapes only between the hours of midnight and 10:00 a.m. and 8:00 p.m to midnight on designated watering days.

    2. All operations of the city shall adhere to water use restrictions prescribed for Stage 2 of the plan.

    3. Water customers are requested to practice water conservation and to minimize or discontinue water use for non-essential purposes.

(2) *Stage 2 response—Moderate water shortage conditions.*

a. Goal: Achieve a ten percent reduction in daily water demand (e.g., total water use, daily water demand, etc.).

b. Supply management measures:

    1. Reduced or discontinued flushing of water mains.

    2. Reduced or discontinued irrigation of public landscaped areas.

c. Water use restrictions. Under threat of penalty for violation, the following water use restrictions shall apply to all persons:

    1. Irrigation of landscaped areas with hose-end sprinklers or automatic irrigation systems shall be limited to Sundays and Thursdays for customers with a street address ending in an even number (0, 2, 4, 6 or 8), and Saturdays and Wednesdays for water customers with a street address ending in an odd number (1, 3, 5, 7 or 9), and irrigation of landscaped areas is further limited to the hours of 12:00 midnight until 10:00 a.m. and between 8:00 p.m. and 12:00 midnight on designated watering days. However, irrigation of landscaped areas is permitted at anytime if it is by means of a hand-held hose, a faucet filled bucket or watering can of five (5) gallons or less, or drip irrigation system.

    2. Use of water to wash any motor vehicle, motorbike, boat, trailer, airplane or other vehicle is prohibited except on designated watering days between the hours of 12:00 midnight and 10:00 a.m. and between 8:00 p.m. and 12:00 midnight. Such washing, when allowed, shall be done with a hand-held bucket or a hand-held hose equipped with a positive shutoff nozzle for quick rinses. Vehicle washing may be done at any time on the immediate premises of a commercial car wash or commercial service station. Further, such washing may be exempted from these regulations if the health, safety, and welfare of the public are contingent upon frequent vehicle cleansing, such as garbage trucks and vehicles used to transport food and perishables.

    3. Use of water to fill, refill, or add to any indoor or outdoor swimming pools, wading pools, or Jacuzzi-type pools is prohibited except on designated watering days between the hours of 12:00 midnight and 10:00 a.m. and between 8 p.m. and 12:00 midnight.

    4. Operation of any ornamental fountain or pond for aesthetic or scenic purposes is prohibited except where necessary to support aquatic life or where such fountains or ponds are equipped with a recirculation system.

    5. Use of water from hydrants shall be limited to fire fighting, related activities, or other activities necessary to maintain public health, safety, and welfare, except that use of water from designated fire hydrants for construction purposes may be allowed under special permit from the city.

6. Use of water for the irrigation of golf course greens, tees, and fairways is prohibited except on designated watering days between the hours of 12:00 midnight and 10:00 a.m. and between 8:00 p.m. and 12:00 midnight. However, if the golf course utilizes a water source other than that provided by the city, the facility shall not be subject to these regulations.

7. All restaurants are prohibited from serving water to patrons except upon request of the patron.

8. The following uses of water are defined as non-essential and are prohibited:

   (i) Wash down of any sidewalks, walkways, driveways, parking lots, tennis courts, or other hard-surfaced areas;

   (ii) Use of water to wash down buildings or structures for purposes other than immediate fire protection;

   (iii) Use of water for dust control;

   (iv) Flushing gutters or permitting water to run or accumulate in any gutter or street; and

   (v) Failure to repair a controllable leak(s) within a reasonable period after having been given notice directing the repair of such leak(s).

(3) *Stage 3 response—Severe water shortage conditions.*

a. Goal: Achieve a fifteen percent reduction in daily water demand.

b. Supply management measures:

   1. Reduced or discontinued flushing of water mains.

   2. Reduced or discontinued irrigation of public landscaped areas.

c. Water use restrictions. All requirements of Stage 2 shall remain in effect during Stage 3 except:

   1. Irrigation of landscaped areas shall be limited to designated watering days between the hours of 12:00 midnight and 10:00 a.m. and between 8 p.m. and 12:00 midnight and shall be by means of hand-held hoses, hand-held buckets, drip irrigation, or permanently installed automatic sprinkler system only. The use of hose-end sprinklers is prohibited at all times.

   2. The watering of golf course tees is prohibited unless the golf course utilizes a water source other than that provided by the City of Wharton.

   3. The use of water for construction purposes from designated fire hydrants under special permit is to be discontinued.

(4) *Stage 4 response—Critical water shortage conditions.*

a. Goal: Achieve a 20 percent reduction in daily water demand.

b. Supply management measures:

   1. Reduced or discontinued flushing of water mains.

   2. Reduced or discontinued irrigation of public landscaped areas.

c. Water use restrictions. All requirements of Stages 2 and 3 shall remain in effect during Stage 4 except:

   1. Irrigation of landscaped areas shall be limited to designated watering days between the hours of 6:00 a.m. and 10:00 a.m. and between 8:00 p.m. and 12:00 midnight and shall be by means of hand-held hoses, hand-held buckets, or drip irrigation only. The use of

hose-end sprinklers or permanently installed automatic sprinkler systems are prohibited at all times.

2. Use of water to wash any motor vehicle, motorbike, boat, trailer, airplane or other vehicle not occurring on the premises of a commercial car wash and commercial service stations and not in the immediate interest of public health, safety, and welfare is prohibited. Further, such vehicle washing at commercial car washes and commercial service stations shall occur only between the hours of 6:00 a.m. and 10:00 a.m. and between 6:00 p.m. and 10 p.m.

3. The filling, refilling, or adding of water to swimming pools, wading pools, and Jacuzzi-type pools is prohibited.

4. Operation of any ornamental fountain or pond for aesthetic or scenic purposes is prohibited except where necessary to support aquatic life or where such fountains or ponds are equipped with a recirculation system.

5. No application for new, additional, expanded, or increased-in-size water service connections, meters, service lines, pipeline extensions, mains, or water service facilities of any kind shall be approved, and time limits for approval of such applications are hereby suspended for such time as this drought response stage or a higher-numbered stage shall be in effect.

(5) *Stage 5 response—Emergency water shortage conditions.*

a. Goal: Achieve a 25-percent reduction in daily water demand.

b. Supply management measures:

1. Reduced or discontinued flushing of water mains.

2. Reduced or discontinued irrigation of public landscaped areas.

c. Water use restrictions. All requirements of Stages 2, 3, and 4 shall remain in effect during Stage 5 except:

1. Irrigation of landscaped areas is absolutely prohibited.

2. Use of water to wash any motor vehicle, motorbike, boat, trailer, airplane or other vehicle is absolutely prohibited.

(6) *Stage 6 response—Water allocation.* In the event that water shortage conditions threaten public health, safety, and welfare, the City Manager is hereby authorized to allocate water according to the following water allocation plan:

a. Single-family residential customers.

1. The allocation to residential water customers residing in a single-family dwelling shall be as follows:

Persons per Household	Gallons per Month
1 or 2	6,000
3 or 4	7,000
5 or 6	8,000
7 or 8	9,000
9 or 10	10,000
11 or more	12,000

3. "Household" means the residential premises served by the customer's meter. "Persons per household" includes only those persons currently physically residing at the premises and expected to reside there for the entire billing period. It shall be assumed that a particular customer's household is comprised of two (2) persons unless the customer notifies the City of a greater number of persons per household on a form prescribed by the city manager. The city manager shall give his/her best effort to see that such forms are mailed, otherwise provided, or made available to every residential customer. If, however, a customer does not receive such a form, it shall be the customer's responsibility to go to the city offices to complete and sign the form claiming more than two persons per household. New customers may claim more persons per household at the time of applying for water service on the form prescribed by the city manager. When the number of persons per household increases so as to place the customer in a different allocation category, the customer may notify the city on such form and the change will be implemented in the next practicable billing period. If the number of persons in a household is reduced, the customer shall notify the city in writing within two days. In prescribing the method for claiming more than two persons per household, the city manager shall adopt methods to insure the accuracy of the claim. Any person who knowingly, recklessly, or with criminal negligence falsely reports the number of persons in a household or fails to timely notify the city of a reduction in the number of person in a household shall be fined not less than $500.00.

3. Residential water customers shall pay the following surcharges:

   (1) $10.00 for the first 1,000 gallons over allocation.

   (ii) $20.00 for the second 1,000 gallons over allocation.

   (iii) $30.00 for the third 1,000 gallons over allocation.

   (iv) $40.00 for each additional 1,000 gallons over allocation.

4. Surcharges shall be cumulative.

b. Master-metered multi-family residential customers.

1. The allocation to a customer billed from a master meter which jointly measures water to multiple permanent residential dwelling units (e.g., apartments, mobile homes) shall be allocated 6,000 gallons per month for each dwelling unit. It shall be assumed that such a customer's meter serves two dwelling units unless the customer notifies the city of a greater number on a form prescribed by the city manager. The city manager shall give his/her best effort to see that such forms are mailed, otherwise provided, or made available to every such customer. If, however, a customer does not receive such a form, it shall be the customer's responsibility to go to the city offices to complete and sign the form claiming more than two dwellings. A dwelling unit may be claimed under this provision whether it is occupied or not. New customers may claim more dwelling units at the time of applying for water service on the form prescribed by the city manager. If the number of dwelling units served by a master meter is reduced, the customer shall notify the city in writing within two days. In prescribing the method for claiming more than two dwelling units, the city manager shall adopt methods to insure the accuracy of the claim. Any person who knowingly, recklessly, or with criminal negligence falsely reports the number of dwelling units served by a master meter or fails to timely notify the city of a reduction in the number of person in a household shall be fined not less than $500.00. Customers billed from a master meter under this provision shall pay the following monthly surcharges:

   (i) $10.00, for 1,000 gallons over allocation up through 1,000 gallons for each dwelling unit.

   (ii) $20.00, thereafter, for each additional 1,000 gallons over allocation up through a second 1,000 gallons for each dwelling unit.

(iii) $30.00, thereafter, for each additional 1,000 gallons over allocation up through a third 1,000 gallons for each dwelling unit. $40.00, thereafter for each additional 1,000 gallons over allocation.

(iv) $40.00, thereafter for each additional 1,000 gallons over allocation.

2. Surcharges shall be cumulative.

c. Commercial customers.

1. A monthly water allocation shall be established by the City of Wharton or his/her designee, for each nonresidential commercial customer other than an industrial customer who uses water for processing purposes. The non-residential customer's allocation shall be approximately 75 percent of the customer's usage for corresponding month's billing period for the previous 12 months. If the customer's billing history is shorter than 12 months, the monthly average for the period for which there is a record shall be used for any monthly period for which no history exists. Provided, however, a customer, 75 percent of whose monthly usage is less than 6,000 gallons, shall be allocated 5,000 gallons. The city manager shall give his/her best effort to see that notice of each non-residential customer's allocation is mailed to such customer. If, however, a customer does not receive such notice, it shall be the customer's responsibility to contact the city to determine the allocation. Upon request of the customer or at the initiative of the city manager, the allocation may be reduced or increased if, (1) the designated period does not accurately reflect the customer's normal water usage, (2) one nonresidential customer agrees to transfer part of its allocation to another nonresidential customer, or (3) other objective evidence demonstrates that the designated allocation is inaccurate under present conditions. A customer may appeal an allocation established hereunder to the City Council. Nonresidential commercial customers shall pay the following surcharges:

(i) Customers whose allocation is 6,000 gallons through 10,000 gallons per month:

(A) $10.00 per thousand gallons for the first 1,000 gallons over allocation.

(B) $20.00 per thousand gallons for the second 1,000 gallons over allocation.

(C) $30.00 per thousand gallons for the third 1,000 gallons over allocation.

(D) $40.00 per thousand gallons for each additional 1,000 gallons over allocation.

(ii) Customers whose allocation is 10,000 gallons per month or more:

(A) Two times the block rate for each 1,000 gallons in excess of the allocation up through five percent above allocation.

(B) Three times the block rate for each 1,000 gallons from five percent through ten percent above allocation.

(C) Four times the block rate for each 1,000 gallons from ten percent through 15 percent above allocation.

(D) Five times the block rate for each 1,000 gallons more than 15 percent above allocation.

3. The surcharges shall be cumulative. As used herein, "block rate" means the charge to the customer per 1,000 gallons at the regular water rate schedule at the level of the customer's allocation.

d. Industrial customers.

1. A monthly water allocation shall be established by the city manager, or his/her designee, for each industrial customer, which uses water for processing purposes. The industrial customer's allocation shall be approximately 90 percent of the customer's water usage baseline. Ninety days after the initial imposition of the allocation for

industrial customers, the industrial customer's allocation shall be further reduced to 85 percent of the customer's water usage baseline. The industrial customer's water use baseline will be computed on the average water use for the 12-month period ending prior to the date of implementation of Stage 2 of the plan. If the industrial water customer's billing history is shorter than 12 months, the monthly average for the period for which there is a record shall be used for any monthly period for which no billing history exists. The city manager shall give his/her best effort to see that notice of each industrial customer's allocation is mailed to such customer. If, however, a customer does not receive such notice, it shall be the customer's responsibility to contact the city to determine the allocation, and the allocation shall be fully effective notwithstanding the lack of receipt of written notice. Upon request of the customer or at the initiative of the city manager the allocation may be reduced or increased, (1) if the designated period does not accurately reflect the customer's normal water use because the customer had shutdown a major processing unit for repair or overhaul during the period, (2) the customer has added or is in the process of adding significant additional processing capacity, (3) the customer has shutdown or significantly reduced the production of a major processing unit, (4) the customer has previously implemented significant permanent water conservation measures such that the ability to further reduce water use is limited, (5) the customer agrees to transfer part of its allocation to another industrial customer, or (6) if other objective evidence demonstrates that the designated allocation is inaccurate under present conditions. A customer may appeal an allocation established hereunder to the city council. Industrial customers shall pay the following surcharges:

(i) Customers whose allocation is 10,000 gallons through 10,000 gallons per month:

(A) $10.00 per thousand gallons for the first 1,000 gallons over allocation.

(B) $20.00 per thousand gallons for the second 1,000 gallons over allocation.

(C) $30.00 per thousand gallons for the third 1,000 gallons over allocation.

(D) $40.00 per thousand gallons for each additional 1,000 gallons over allocation.

(ii) Customers whose allocation is 100,000 gallons per month or more:

(A) Two times the block rate for each 1,000 gallons in excess of the allocation up through five percent above allocation.

(B) Three times the block rate for each 1,000 gallons from five percent through ten percent above allocation.

(C) Four times the block rate for each 1,000 gallons from ten percent through 15 percent above allocation.

(D) Five times the block rate for each 1,000 gallons more than 15 percent above allocation.

2. The surcharges shall be cumulative. As used herein, "block rate" means the charge to the customer per 1,000 gallons at the regular water rate schedule at the level of the customer's allocation.

(Ord. No. 2000-08, Exh. A(§ IX), 3-13-00)

Sec. 86-210. - Enforcement.

(a) No person shall knowingly or intentionally allow the use of water from the city for residential, commercial, industrial, agricultural, governmental, or any other purpose in a manner contrary to any provision of this plan, or in an amount in excess of that permitted by the drought response stage in effect at the time pursuant to action taken by city manager, or his/her designee, in accordance with provisions of this plan.

(b) Any person who violates this plan is guilty of a misdemeanor and, upon conviction shall be punished by a fine of not less than $100.00 and not more than $1,000.00. Each day that one or more of the provisions in this Plan is violated shall constitute a separate offense. If a person is convicted of three or more distinct violations of this plan, the city manager shall, upon due notice to the customer, be authorized to discontinue water service to the premises where such violations occur. Services discontinued under such circumstances shall be restored only upon payment of a reconnection charge, hereby established at $20.00, and any other costs incurred by the City of Wharton in discontinuing service. In addition, suitable assurance must be given to the city manager that the same action shall not be repeated while the plan is in effect. Compliance with this plan may also be sought through injunctive relief in the district court.

(c) Any person, including a person classified as a water customer of the city in apparent control of the property where a violation occurs or originates shall be presumed to be the violator, and proof that the violation occurred on the person's property shall constitute a rebuttable presumption that the person in apparent control of the property committed the violation, but any such person shall have the right to show that he/she did not commit the violation. Parents shall be presumed to be responsible for violations of their minor children and proof that a violation, committed by a child, occurred on property within the parents' control shall constitute a rebuttable presumption that the parent committed the violation, but any such parent may be excused if he/she proves that he/she had previously directed the child not to use the water as it was used in violation of this plan and that the parent could not have reasonably known of the violation.

(d) Any employee of the city police department, or other city employee designated by the city manager, may issue a citation to a person he/she reasonably believes to be in violation of this article. The citation shall be prepared in duplicate and shall contain the name and address of the alleged violator, if known, the offense charged, and shall direct him/her to appear in the Municipal Court on the date shown on the citation for which the date shall not be less than three days nor more than five days from the date the citation was issued. The alleged violator shall be served a copy of the citation. Service of the citation shall be complete upon delivery of the citation to the alleged violator, to an agent or employee of a violator, or to a person over 14 years of age who is a member of the violator's immediate family or is a resident of the violator's residence. The alleged violator shall appear in municipal court to enter a plea of guilty or not guilty for the violation of this plan. If the alleged violator fails to appear in municipal court, a warrant for his/her arrest may be issued. A summons to appear may be issued in lieu of an arrest warrant. These cases shall be expedited and given preferential setting in municipal court before all other cases.

(Ord. No. 2000-08, Exh. A(§ X), 3-13-00)

Sec. 86-211. - Variances.

(a) The city manager, or his/her designee, may, in writing, grant temporary variance for existing water uses otherwise prohibited under this plan if it is determined that failure to grant such variance would cause an emergency condition adversely affecting the health, sanitation, or fire protection for the public or the person requesting such variance and if one or more of the following conditions are met:

  (1) Compliance with this plan cannot be technically accomplished during the duration of the water supply shortage or other condition for which the plan is in effect.

  (2) Alternative methods can be implemented which will achieve the same level of reduction in water use.

(b) Persons requesting an exemption from the provisions of this article shall file a petition for variance with the city within five days after the plan or a particular drought response stage has been invoked. All petitions for variances shall be reviewed by the City Manager, or his/her designee, and shall include the following:

(1) Name and address of the petitioner(s).

(2) Purpose of water use.

(3) Specific provision(s) of the plan from which the petitioner is requesting relief.

(4) Detailed statement as to how the specific provision of the plan adversely affects the petitioner or what damage or harm will occur to the petitioner or others if petitioner complies with this article.

(5) Description of the relief requested.

(6) Period of time for which the variance is sought.

(7) Alternative water use restrictions or other measures the petitioner is taking or proposes to take to meet the intent of this Plan and the compliance date.

(8) Other pertinent information.

(c) Variances granted by the city shall be subject to the following conditions, unless waived or modified by the city manager or his/her designee:

(1) Variances granted shall include a timetable for compliance.

(2) Variances granted shall expire when the plan is no longer in effect, unless the petitioner has failed to meet specified requirements.

(d) No variance shall be retroactive or otherwise justify any violation of this plan occurring prior to the issuance of the variance.

(Ord. No. 2000-08, Exh. A(§ XI), 3-13-00)

Appendix D

TWDB Review Comments on Draft Study with Responses and Report Revisions

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Texas Water Development Board
P.O. Box 13231, 1700 N. Congress Ave.
Austin, TX 78711-3231, www.twdb.texas.gov
Phone (512) 463-7847, Fax (512) 475-2053

January 23, 2017

Mr. Andres Garza
City of Wharton
120 E Caney St
Wharton, Texas 77488

RE: Regional Water Supply and Wastewater Facility Planning Study Contract with the City of Wharton, Contract No. 1548321873, Draft Report Comments Entitled "Draft Regional Water Supply Study"

Dear Mr. Garza:

Staff members of the TWDB have completed a review of the draft report prepared under the above-referenced contract. ATTACHMENT 1 provides the comments resulting from this review. As stated in the TWDB contract, the City of Wharton will consider revising the final report in response to comments from the Executive Administrator and other reviewers. In addition, the City of Wharton will include a copy of the Executive Administrator's draft report comments in the Final Report.

The TWDB looks forward to receiving one (1) electronic copy of the entire Final Report in Portable Document Format (PDF) and six (6) bound double-sided copies. **Please further note, that in compliance with Texas Administrative Code Chapters 206 and 213 (related to Accessibility and Usability of State Web Sites), the digital copy of the final report must comply with the requirements and standards specified in statute. For more information, visit http://www.sos.state.tx.us/tac/index.shtml.** If you have any questions on accessibility, please contact David Carter with the Contract Administration Division at (512) 936-6079 or David.Carter@twdb.texas.gov.

The City of Wharton shall also submit one (1) electronic copy of any computer programs or models, and, if applicable, an operations manual developed under the terms of this Contract.

Please feel free to contact Ms. Jo Dawn Bomar of our Program Administration and Reporting staff at 512-463-7912 or jodawn.bomar@twdb.texas.gov if you have any questions or need any further information.

Sincerely,

Jessica Zuba
Deputy Executive Administrator
Water Supply and Infrastructure

Attachment

c w/o att.: Ms. Jo Dawn Bomar, Program Administration and Reporting

Attachment 1
TWDB Comments on "Draft Regional Water Supply Study"
TWDB Contract No. 1548321873

General Comments on the Report

- Scope of work (3. A) required a clear comparison of the existing and projected conditions. Although existing and projected conditions were discussed in the report it was not a clear comparison of those conditions.
- Since the focus of the report was on new wells, there was no discussion of rehabilitation of existing wells except for a reference to restoring production (there was mention of declining well production as well as restored production for existing wells). Please provide a brief clarification of this issue.
- A list of proposed funding sources was not included in the Report.
- Sections 11, 10, and 12 do not contain preliminary design calculations for the chosen alternative. All proposed components should be listed, along with their sizing and quantities required. The sizing calculations should be shown in an appendix.
- Although there is a revised Wharton Conservation Plan there is no Drought Contingency Plan for Wharton. If one exists it could be included in Appendix C for a more complete picture of Wharton's intended conservation and drought responses.

Section 2

- Section 2.4, existing system description, Table 2-5: the 2015 pumping data for East Bernard's Well #3 should be given, or an explanation for why it is not available or included in the Report.
- Section 2.4.2, the reasons for the decline of production in Wharton's existing wells should be given. Later Report data in Appendix B, Hydrological Assessment indicates that this is not due to draw-down in the aquifer.
- The draft study states a new well for WCID #2 should be fully operational by 2016. Please update this statement to indicate whether the well has been completed.

Section 3

- In Section 3.2, a growth rate of 5% per annum is used by the consultant, verses TWDB projections of 0.6% per year. Per Tables 2-2 and 2-3 in the Report, actual population has been declining since 2011. The Report projects populations for the Cities of Wharton and East Bernard increasing 250%

through the year 2070. The 2012 TWDB State Water Plan projects a growth of 24%, about 10 times less for Wharton County (the portion in Region K). It should be noted that this assumption may or may not be acceptable to the Region K Regional Planning Group or the TWDB as a basis for determining needs for the project. Please provide further explanation for the population decline and how it is anticipated to be reversed in future decades.

- Section 3.3 Projected Water Demands, Table 3-3, shows average daily water demands per capita of 164 gallons per capita day (GPCD) for Wharton and 156 GPCD. Figure 2-4 shows historical water demands of 160 and 140, respectively. The 2012 SWP shows average GPCD demand at 133. The usage figures in the Report seem high. Table 3-3 also indicates that these GPCD demands are multiplied by 1.85, the multiplier to obtain maximum day usage from average usage. This is an incorrect way of determining water demand; average GPCD usage should be used. The excessive population projections, coupled with the high per capita daily usage lead to inflated demand. It is suggested that lower amount be used and that Table 3-4 show all the population and usage figures used to determine water demand. A sample calculation should also be shown in the Report, or Appendices.

Section 10

- Please provide more information for Figure 10-2. It is difficult to interpret without color definitions and explanation of the box sizes.

Section 11

- No implementation schedule for improvements is given. The chosen alternative (Fig 6-1) shows one new well for East Bernard. Please go into more detail on the proposed project schedule for the alternative chosen.

Section 12

- Figure 12-3 shows a proposed schedule for needed well replacement. Figure 6-1 shows three new wells are needed. Figure 12-3 incorrectly uses maximum daily demand to show when new wells will be needed, rather than average daily demand. The need and timing for additional wells should be based on average daily demand.

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Responses and Report Revisions
to TWDB Comments on "Draft Regional Water Supply Study"
Received January 23, 2017
TWDB Contract No. 1548321873

GENERAL COMMENTS

1) Comment: *Scope of work (3. A) required a clear comparison of the existing and projected conditions. Although existing and projected conditions were discussed in the report it was not a clear comparison of those conditions.*

Response: These comparisons are provided graphically in Sections 11 and 12.

- Figure 11-1 shows East Bernard's historical (2010-2015) average annual daily demand (AADD), projected future AADD, existing permitted withdrawal amount, and projected permit amount.
- Figure 11-2 shows East Bernard's historical (2010-2015) maximum daily demand (MDD), projected future MDD with and without water conservation, and existing water supply capacity. Additional water supply capacity is not projected to be needed in East Bernard.
- Figure 12-1 shows Wharton's historical (2010-2015) AADD, projected future AADD, existing permitted withdrawal amount, and projected permit amount.
- Figure 12-3 shows Wharton's historical (2010-2015) MDD, projected future MDD, historical water supply capacity, and projected future water supply capacity based on the construction of new wells.

2) Comment: *Since the focus of the report was on new wells, there was no discussion of rehabilitation of existing wells except for a reference to restoring production (there was mention of declining well production as well as restored production for existing wells). Please provide a brief clarification of this issue.*

Response: Pages 58-59 include descriptions of recommended regular cleaning and well rehabilitation. A statement has been added on page 58 to clarify that for the purposes of this report, cleaning and rehabilitation were only considered as regular O&M activities to maintain capacity and not options to add water supply capacity.

3) Comment: *A list of proposed funding sources was not included in the Report.*

Response: A list of funding sources for water supply infrastructure has been added at the end of Section 12.

4) Comment: *Sections 11, 10, and 12 do not contain preliminary design calculations for the chosen alternative. All proposed components should be listed, along with their sizing and quantities required. The sizing calculations should be shown in an appendix.*

Response: A paragraph has been added to the end of Section 12 estimating the capacities for Wharton's next well, storage and pump station. Section 10 discusses water conservation; there are no infrastructure alternatives in this section for which to develop preliminary design calculations. Section 11

HALFF

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notes that East Bernard does not need additional water supply infrastructure in the foreseeable future, so there is no infrastructure for which to develop preliminary design calculations.

5) Comment: *Although there is a revised Wharton Conservation Plan there is no Drought Contingency Plan for Wharton. If one exists it could be included in Appendix C for a more complete picture of Wharton's intended conservation and drought responses.*

Response: Wharton's Drought Contingency Plan has been added to Appendix C.

SECTION 2

1) Comment: *Section 2.4, existing system description, Table 2-5: the 2015 pumping data for East Bernard's Well #3 should be given, or an explanation for why it is not available or included in the Report.*

Response: A brief explanation was added after Table 2-5 as requested

2) Comment: *Section 2.4.2, the reasons for the decline of production in Wharton's existing wells should be given. Later Report data in Appendix B, Hydrological Assessment indicates that this is not due to draw-down in the aquifer.*

Response: Section 12.2 discusses possible causes of declining production. A reference to Section 12.2 has been added to this section. Wharton has biannual test data from each of its wells for over 10 years that show seasonally variable static aquifer levels with a slight declining trend at some of the wells. The analysis performed in the Hydrological Assessment predicts changes to average aquifer levels across the county.

3) Comment: *The draft study states a new well for WCID #2 should be fully operational by 2016. Please update this statement to indicate whether the well has been completed.*

Response: The statement was updated as requested.

SECTION 3

1) Comment: *In Section 3.2, a growth rate of 5% per annum is used by the consultant, verses TWDB projections of 0.6% per year. Per Tables 2-2 and 2-3 in the Report, actual population has been declining since 2011. The Report projects populations for the Cities of Wharton and East Bernard increasing 250% through the year 2070. The 2012 TWDB State Water Plan projects a growth of 24%, about 10 times less for Wharton County (the portion in Region K). It should be noted that this assumption may or may not be acceptable to the Region K Regional Planning Group or the TWDB as a basis for determining needs for the project. Please provide further explanation for the population decline and how it is anticipated to be reversed in future decades.*

Response: A note that the population projections in this study deviate from TWDB is included at the end of page 11. An additional acknowledgement that these projections will likely not be adopted by the Region K planning group has been added on pages 12 -13.

This conflict between our projections with Region K's was expected, but using historical growth rates to project future populations did not result in sufficient water demands that justify additional infrastructure.

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(The study found that East Bernard even has sufficient existing water supply capacity to meet these aggressive future demands).

Page 12 describes how the continued expansion of the Harris County urban area could result in Wharton County population growth resembling that of Harris County in the latter half of the 20th century. Recognizing this growth won't occur overnight, we used the TWDB projections for 10 years before applying the more aggressive assumptions. We have no additional explanation to supplement these assumptions.

The major findings of the study are not sensitive to the water demands. Those finding are:
- groundwater production is significantly more economical for Wharton and East Bernard than the water supply alternatives considered.
- East Bernard does not need additional water supply capacity for the foreseeable future
- Wharton will not need additional water supply infrastructure until after 2045 once it completes the construction of its new well and rehabilitates/restores existing wells.

2) Comment: *Section 3.3 Projected Water Demands, Table 3-3, shows average daily water demands per capita of 164 gallons per capita day (GPCD) for Wharton and 156 GPCD. Figure 2-4 shows historical water demands of 160 and 140, respectively. The 2012 SWP shows average GPCD demand at 133. The usage figures in the Report seem high. Table 3-3 also indicates that these GPCD demands are multiplied by 1.85, the multiplier to obtain maximum day usage from average usage. This is an incorrect way of determining water demand; average GPCD usage should be used. The excessive population projections, coupled with the high per capita daily usage lead to inflated demand. It is suggested that lower amount be used and that Table 3-4 show all the population and usage figures used to determine water demand. A sample calculation should also be shown in the Report, or Appendices.*

Response: The 160 gpcd for Wharton and 140 gpcd for East Bernard shown in Figure 2-4 are 2015 values. The per capita values in Table 3-3 are 5-year averages for per capita demands. Per capita demands can change widely year-to-year based on the amount of rainfall received and the resulting change in residential irrigation. Thus the 5-year average per capita values are used as a more realistic projection of future demands that aren't overly impacted by short-term weather patterns.

Water supply infrastructure must be planned to meet maximum day demands as required by the Texas Commission on Environmental Quality. Title 30 of the Texas Administrative Code, Chapter 290.41.(b) pertaining to water sources states:

> "Sources of supply, both ground and surface, shall have a safe yield capable of supplying the <u>*maximum daily demands*</u> of the distribution system during extended periods of peak usage and critical hydrologic conditions."

30 TAC 290.45(b)(1)(D) requires that community water systems served by groundwater have two or more wells with a total capacity of 0.6 gpm/connection. This equates to 864 gallons per day per connection, or approximately 288 gpcd (assuming 3 persons per connection). These required rates are commensurate with maximum daily demands, not average day demands.

No changes have been made to the report relating to these comments.

SECTION 10

1) Comment: *Please provide more information for Figure 10-2. It is difficult to interpret without color definitions and explanation of the box sizes.*

HALFF

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Response: Figure 10-2 has been revised and clarification language added

SECTION 11

1) Comment: *No implementation schedule for improvements is given. The chosen alternative (Fig 6-1) shows one new well for East Bernard. Please go into more detail on the proposed project schedule for the alternative chosen.*

Response: The study recognizes that East Bernard has sufficient well capacity to meet even the aggressive water demands assumed, thus no water supply improvements are necessary.

SECTION 12

1) Comment: *Figure 12-3 shows a proposed schedule for needed well replacement. Figure 6-1 shows three new wells are needed. Figure 12-3 incorrectly uses maximum daily demand to show when new wells will be needed, rather than average daily demand. The need and timing for additional wells should be based on average daily demand.*

Response: See response to Comment #2 in Section 3. No changes will be made to the report relating to this comment.

Revisions Made Since TWDB Review

One revision has been made to the study since TWDB's review that impacts a study finding. The initial drawdown analysis performed by Intera assumed maximum day pumping rates throughout a given year, the results of which are described in Section 6 of their report. During review, this assumption was deemed overly conservative. At Halff's request, Intera performed a revised analysis, the results of which were not yet available when the draft study was submitted to TWDB for review. The revised analysis uses average day demands and is described in Section 8 of Intera's final report in Appendix C. This change has been described briefly in Section 6, and Table 6-3 reflects the results of Intera's revised analysis. The summary in Section 13 has also been revised accordingly. The revised predictions for future drawdowns in the groundwater supply option are less than originally estimated in the draft study, and therefore the recommendations made in the study are not impacted.

A few minor revisions have been made since the draft report was submitted to provide minor clarifications, correct typographical errors, and to update the Table of Contents, none of which impact the context of the report.