10 Aquifer Storage and Recovery (ASR)

10.1 City of Bryan ASR

10.1.1 Description

The City of Bryan (Bryan) currently has 12 water supply wells in the Simsboro and Sparta Aquifers with a combined permitted supply of 33,540 acft/yr. Eleven of these wells are permitted under historical use with an annual permitted production amount of 28,702 acft/yr. The current capacity of these wells is limited to 20,167 acft/yr. According to the City of Bryan's engineering consultant, the total current annual water supply based on permitted amounts meets the City's annual supply needs until 2056; however, pumping capacity from these wells prevents them from meeting the maximum day demands beyond 2040. Additionally, the Brazos County Modeled Available Groundwater (MAG) developed for the City of Bryan only allows for a supply of 16,792 acft/yr in 2020. Although the MAG allowable supply increases over time (maxing out at the pumping capacity of 20,167 acft/yr by 2040), the supply is not enough to meet demands beyond 2030.

Using TWDB methodology, the calculated total water supply, total water demand and water balance (surplus and shortage) is presented in Table 10.1-1 by decade. This analysis shows Bryan will need an additional 24,435 acft/yr by 2070. A groundwater strategy that is described in Section 9.1 will provide 5,100 acft/yr from the Carrizo Aquifer in Brazos County beginning in 2050. Remaining supplies will be developed by the ASR strategy

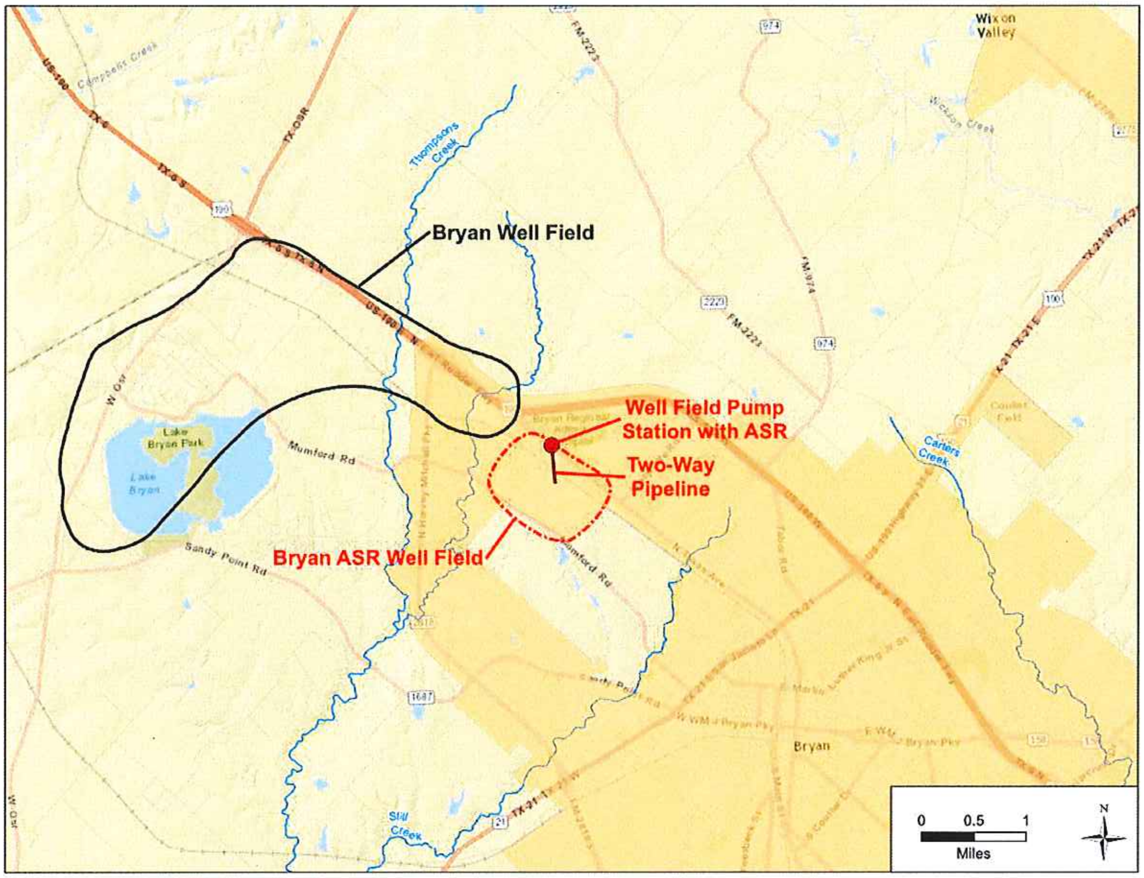
An ASR conjunctive use strategy was developed to meet demands out to 2070 that includes ASR and production wells. A spreadsheet model was developed that simulates the storage and use of ASR water to determine when ASR wells and additional productions wells are needed over time.

The ASR aspect of this conjunctive use strategy would fully utilize the MAG or well capacities by pumping at the allowable rate or capacities year round. During times when water demand is less than the amount of water being produced from the production wells, the excess water would be directed from the City's Well Field Pump Station to a new ASR well field for aquifer storage. This water would be recovered from the ASR wells when Bryan's demand exceeds the allowable use from the MAG. The recovered water would be delivered back to the Well Field pump station for cooling and disinfection and then into the distribution system. Additional production wells are added over time according to the modeling. The model was also used to determine when each of the ASR wells in the proposed ASR well field would need to come online.

This conjunctive use strategy requires four new ASR wells and four recovery wells.. The ASR strategy will produce 19,839 acft/yr The modeling of the strategy is discussed further in Section 10.1.2.

In addition to the wells required for this strategy, two-way pipelines between the ASR well field and the Well Field Pump Station, an ASR pump station at Well Field Pump Station, and an interconnect into the storage tanks are needed. A map showing the locations of the well fields is shown in Figure 10.1-1. For the purposes of this strategy, the target aquifer for storing the water is the brackish water zone of the Simsboro unit of the Wilcox Group.

Figure 10.1-1. Bryan's Existing Well Field and Proposed ASR Well Field



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Table 10.1-1. Bryan's Water Supply and Demand

Year	Total Supply	Total Demand	Balance
2020	16,792	19,634	-2,841
2030	19,294	18,990	304
2040	20,167	24,084	-3,917
2050	20,167	30,345	-10,178
2060	20,167	37,058	-16,891
2070	20,167	44,602	-24,435

Units are in acft/yr

10.1.2 Modeling and Available Supply

A probabilistic model was developed that simulates water demand over the available hydrologic record (1948 to 2014) to determine when ASR water may be stored or used. This model was used to determine how much water could be stored over time starting in 2020 and then adding production and ASR wells so as not to completely deplete the ASR supply out to 2070.

The first step in developing the model was to determine a relationship between current water demand and hydrologic conditions to simulate the monthly variations in demand. Water production data from 2000 to 2014 was converted to per capita demand and related to variables including precipitation, evaporation, and temperature. Evaporation was found to be the best indicator of water demand when considering each variable individually. The relationship was improved slightly by adding precipitation. Different relationships were then developed for each season or month to further improve the prediction.

Evaporation was the best indicator, but records from TWDB in the region are only available back to 1954. It was important to include the 1950's drought in the simulation; therefore, temperature data was used to extend the record. A relationship between evaporation and temperature was developed using all available data from 1954 to 2014. This relationship was used to extend the evaporation time series back to 1948.

Figure 10.1-2 shows a scatter plot of the production-based demand versus the final modeled demand based on the relationship developed between per capita demand and evaporation and precipitation for monthly values from 2000 to 2014.

Using the demand relationship that was developed, per capita water demand was predicted on a monthly time step from 1948 to 2014 using the available and extended evaporation and precipitation data. The Region G population projections were applied to the predicted monthly per capita water demands. Each decade was simulated over the entire period of record to determine the likelihood of ASR storage or use. It was found that water is likely to accumulate given 2020 and 2030 demands. By 2040, ASR water would likely be used at a greater rate than could be accumulated without adding additional supply. This agrees with the deficit predictions shown in Table 10.1-1.

To determine how much water is likely to be available through ASR over time as population increases, the median value of ASR storage or use on an annual basis was extracted for each of the simulated decades. These median storage/use values were applied to each decade from 2020 to 2070, and values between each decade were linearly interpolated. The cumulative volume was then calculated over time applying an unrecoverable (loss) factor of 10 percent. This analysis was used to determine how long the ASR supply would last given the MAG predicted supplies. Next, additional production wells and ASR wells were added to the strategy when needed to avoid depleting the supply and/or creating deficits. The resulting graph of cumulative supply is shown in Figure 10.1-3. The inflection points at 2030, 2040, and 2050 indicate when increases in the MAG allowed for additional pumping.

Figure 10.1-2. Fit of Demand Model

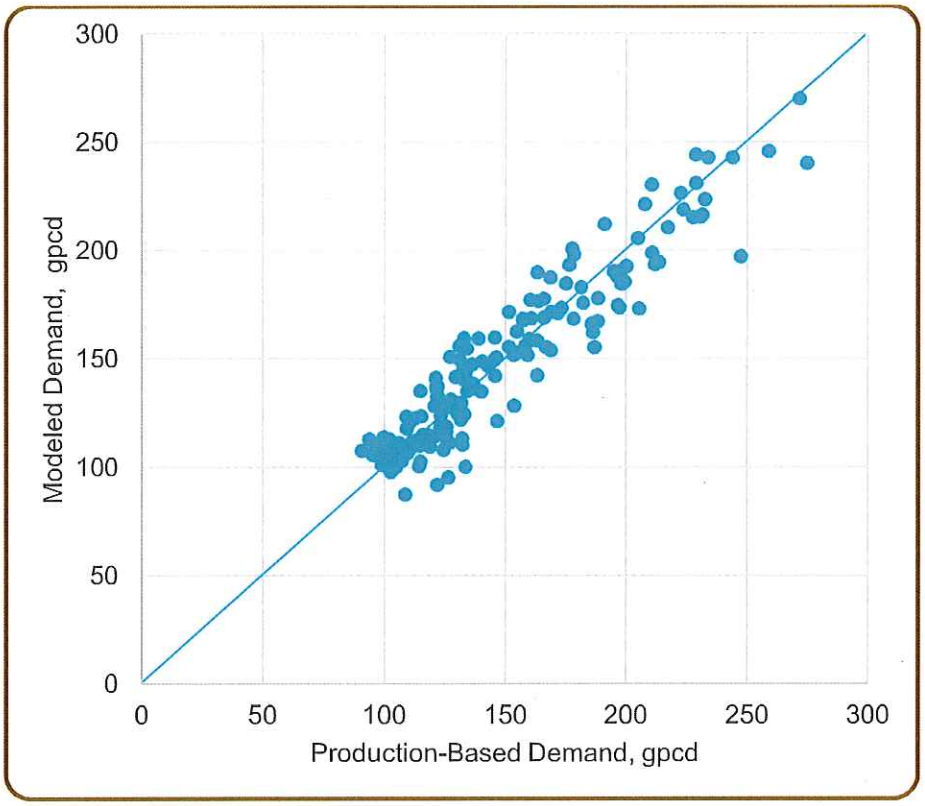
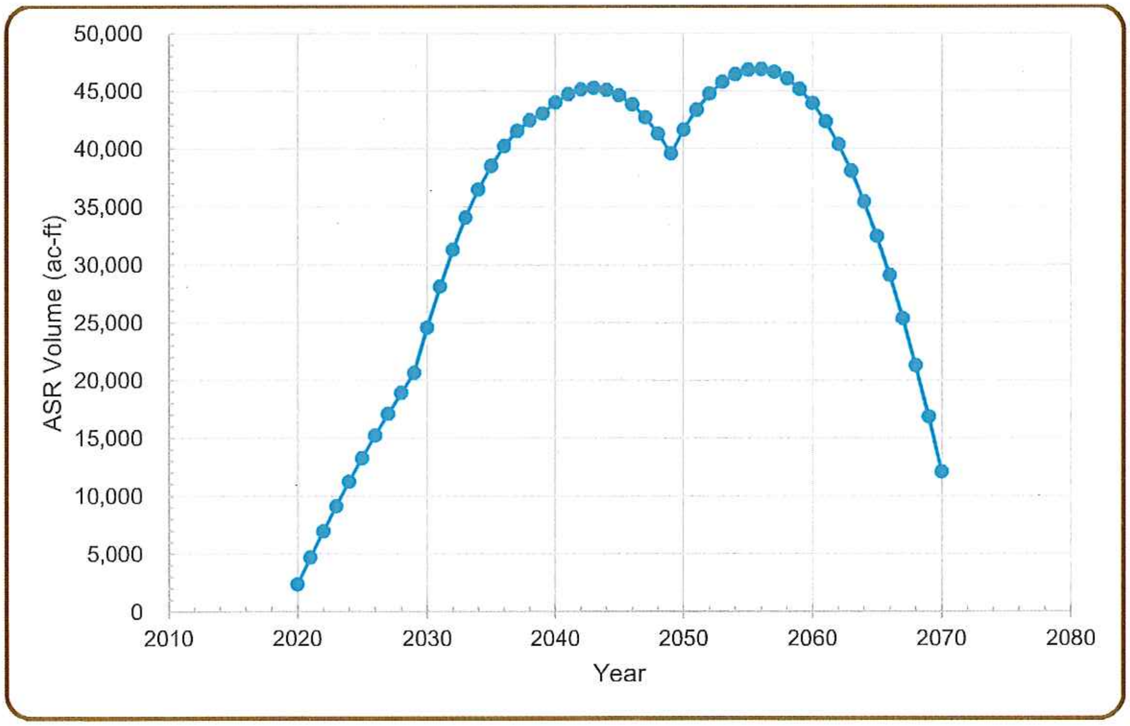


Figure 10.1-3. Time series Plot of ASR Recoverable Volume

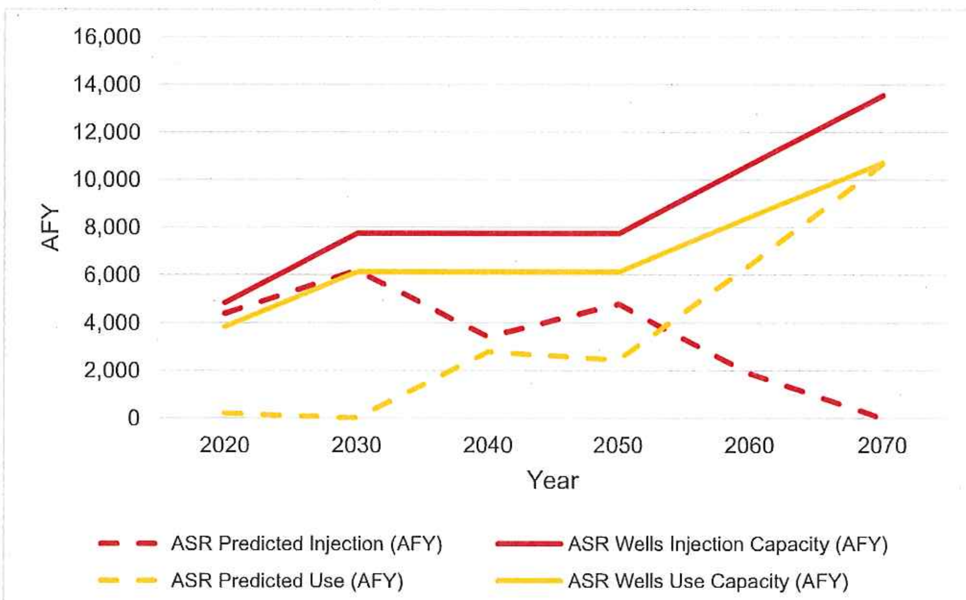


10.1.3 Infrastructure Timing

The modeling results show that by starting ASR in 2020, Bryan's current water production well infrastructure is sufficient until 2050. It is recommended that Bryan construct two new production wells in Brazos County by 2050. Each new well is assumed to have a rated capacity of 3,000 gpm. Actual production assumes that the wells need to meet a maximum day factor of 2 and that the wells are 95 percent reliable.

Results from the modeling were used to determine the timing of ASR wells. For each simulated decade, the maximum annual amount stored and used was compared to the total ASR injection and use capacities, respectively. The ASR injection capacity is assumed to be 60 percent of the rated production capacity of the well. The use capacity assumes the same factors as for the production wells. Figure 10.1-4shows the model predicted ASR injection and ASR use versus the ASR injection capacity and ASR use capacity. Predicted ASR use decreases each decade that additional production is recommended and increases in other decades. Predicted ASR injection follows opposite trends. To meet the predicted ASR injection and ASR use needs, Bryan should begin storing ASR water using Well #10 and one new ASR well by or before 2020. Then one new ASR well is needed each in 2030, 2060, and 2070. Additionally, piloting of Well #10 as an ASR well should begin as soon as possible.

Figure 10.1-4. ASR Injection, Capacity and Use Curves over Time



10.1.4 ASR Aquifer

The target area for ASR wells near Bryan is over the Carrizo-Wilcox aquifer. Major water-bearing formations in the Carrizo-Wilcox consist of the Carrizo Sands and Simsboro Formation. The wells would be installed in the Simsboro, which is 450 ft thick. Bryan's current wells are in the Sparta and Simsboro and are about 600 and 2,800 ft deep, respectively. High capacity Simsboro wells typically yield up to 3,000 gallons per minute (gpm). The water temperature for Simsboro wells in this locale is about 115 deg F and requires cooling before discharging into the distribution system.

The groundwater supply for the ASR project is currently permitted with the Brazos Valley Groundwater Conservation District.

10.1.5 Environmental Issues

Environmental issues for the proposed City of Bryan ASR Project are described below. This project includes the pumping of existing production wells nearly year round and utilizing any excess water for aquifer storage. This water would be recovered, disinfected and distributed later when needed for public use. This project would include the development of an ASR well field, additional well field distribution and collection pipelines, a new two-way transmission pipeline, a water treatment plant for disinfection and an interconnect. Implementation of this project would require field surveys by qualified professionals to document vegetation/habitat types, waters of the U.S. including wetlands, and cultural resources that may be impacted. Where impacts to protected species habitat or significant cultural resources cannot be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. The project sponsor would also be required to coordinate with the U.S. Army Corps of Engineers regarding impacts to wetland areas and compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

The pipelines and wells needed for the ASR project's well field would occur in close proximity to Still Creek and a tributary of Still Creek which includes several small stock ponds/impoundment areas. Coordination with the U.S. Army Corps of Engineers would be required for construction within any waters of the U.S. Any impacts from this proposed project which would result in a loss of less than 0.5 acres of waters of the U.S. could be covered under Nationwide Permit #12 for Utility Line Activities.

The project occurs within the East Central Texas Plains Ecoregion[1] and lies within the Texan Biotic Province.[2] Vegetation types within the City of Bryan ASR well field area and transmission pipelines as described by the Texas Parks and Wildlife Department (TPWD)[3] include urban and other areas. These areas include portions of the city and wooded areas adjacent to cleared pasture areas. Avoidance of riparian areas near the creeks, impounded areas or heavily wooded areas would help minimize potential impacts to existing area species from project construction activities.

Table 10.1-2 lists state listed endangered or threatened species, and federally listed endangered or threatened species along with species of concern that may occur in Brazos County. This information comes from the county lists of rare species published online by the Texas Parks and Wildlife Department (TPWD). Inclusion in this table does not mean that a species will occur within the project area, but only acknowledges the

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[1] Griffith Glenn, Sandy Bryce, James Omernik, and Anne Rogers. 2007. Ecoregions of Texas. Texas Commission on Environmental Quality.

[2] Blair, W. Frank. 1950. The Biotic Provinces of Texas. Texas Journal of Science 2(1):93-117.

[3] McMahan, Craig A., Roy G. Frye and Kirby L. Brown. 1984. The Vegetation Types of Texas. Wildlife Division, Texas Parks and Wildlife Department, Austin, Texas.

potential for its occurrence in the project area county. Because the project will use previously allocated water from existing wells to inject into the aquifer no significant impacts to existing stream flows or aquatic species are anticipated. Potential impacts to listed species within the project area are anticipated to include disturbance of existing habitat resulting from the construction of well fields and their associated pipelines, transmission pipelines and a new water treatment plant. However most of these disturbances would be minimized by the small areas generally required for well field and pipeline construction. After construction is completed the majority of the disturbed areas will return to their previous habitat types excluding areas where maintenance activities are required.

Table 10.1-2. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
		AMPHIBIANS			
Houston toad	Anaxyrus houstonensis	Endemic species found in sandy substrate, water in pools.	LE	E	Resident
Southern crawfish frog	Lithobates areolatus areolatus	A species found in abandoned crawfish holes and small mammal burrows in moist meadows and river flood plains.	--	--	Resident
		BIRDS			
American peregrine falcon	Falco peregrinus anatum	Resident and local breeder in West Texas. Migrant across the state.	DL	T	Possible Migrant
Arctic peregrine falcon	Falco peregrinus tundrius	Migrant throughout the state.	DL	--	Possible Migrant
Bald eagle	Haliaeetus leucocephalus	Found primarily near rivers and large lakes, migrant.	DL	T	Possible Migrant
Henslow's sparrow	Ammodramus henslowii	Wintering individuals found in weedy or cut-over areas.	--	--	Possible Migrant
Interior least tern	Sterna antillarum athalassos	Nests along sand and gravel bars in braided streams	LE	E	Resident
Sprague's pipit	Anthus spragueii	Migrant in Texas in winter. Strongly tied to native upland prairie.	C	--	Migrant
Whooping crane	Grus americana	Potential migrant	LE	E	Potential Migrant
		FISH			

Table 10.1-2. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Blue sucker	Cycleptus elongatus	Found in larger portions of major rivers usually in channels and flowing pools with a moderate current.	--	T	Resident
Sharpnose shiner	Notropis oxyrhynchus	Endemic to Brazos River Drainage. Found in large rivers with a bottom of sand, gravel, and clay-mud.	LE	--	Resident
Smalleye shiner	Notropis buccula	Endemic to upper Brazos River system and its tributaries.	LE	--	Resident
		INSECTS			
Gulf coast clubtail	Gomphus modestus	Found in medium rivers in streams with silty sand or rocky bottoms.	--	--	Resident
Smoky shadowfly	Neurocordulia molesta	Found in rivers and sometimes large streams. Larvae cling to rocks or logs.	--	--	Resident
		MAMMALS			
Louisiana black bear	Ursus americanus luteolus	Possible as transient, found in bottomland hardwoods and large tracts of inaccessible forested areas.	LT	T	Potential Resident
Plains spotted skunk	Spilogale putorius interrupta	Prefers wooded, brushy areas.	--	--	Resident
Red wolf	Canis rufus	Extirpated.	LE	E	Historic Resident
		MOLLUSKS			
False spike mussel	Quadrula mitchelli	Possibly extirpated in Texas, probably found in medium to large rivers.	--	T	Historic Resident
Smooth pimpleback	Quadrula houstonensis	Found in small to moderate streams and rivers and moderate size reservoirs.	--	--	Resident
Texas fawnsfoot	Truncilla macrodon	Possibly occurs in rivers and larger streams and is intolerant of impoundment. Brazos and Colorado River basins.	C	T	Resident
		PLANTS			

Table 10.1-2. Endangered, Threatened, and Species of Concern for Brazos County

Common Name	Scientific Name	Summary of Habitat Preference	Listing Entity		Potential Occurrence in County
			USFWS	TPWD	
Branched gay-feather	Liatris cymosa	Texas endemic found in somewhat barren grassland openings in post oak woodlands on tight soils.	--	--	Resident
Bristle nailwort	Paronychia setacea	Endemic to eastern southcentral Texas, occurring in sandy soils.	--	--	Resident
Navasota ladies'-tresses	Spiranthes parksii	Texas endemic found in openings in post oak woodlands in sandy loams.	LE	E	Resident
Small-headed pipewort	Eriocaulon koenickianum	In East Texas in post-oak woodlands and xeric sandhill openings on permanently wet acid sands of upland seeps and hillside seepage bogs.	--	--	Resident
Texas meadow-rue	Thalicrum texanum	Texas endemic mostly found in woodlands and woodland margins on sandy loam.	--	--	Resident
Texas windmill-grass	Chloris texensis	Texas endemic found in sandy to sandy loam soils in relatively bare areas in coastl prairie grassland remnants.	--	--	Resident
		REPTILES			
Alligator snapping turtle	Macrochelys temminckii	A species found in perennial water bodies in deep water of rivers, canals, lakes and oxbows.		T	Resident
Texas horned lizard	Phrynosoma cornutum	Varied, sparsely vegetated uplands.	--	T	Resident
Timber rattlesnake	Crotalus horridus	Floodplains, upland pine, deciduous woodlands, riparian zones.	--	T	Resident

LE/LT=Federally Listed Endangered/Threatened
DL, PDL=Federally Delisted/Proposed for Delisting
T/SA=Listed as Threatened by Similarity of Appearance
E, T=State Listed Endangered/Threatened
Blank= Species of concern, but no regulatory listing status
Source: TPWD, 2014. Annotated County List of Rare Species – Brazos County revised 12/11/2014.

A survey of the project area would be required prior to project construction to determine whether populations of or potential habitats used by listed species occur in the area to be affected. Coordination with TPWD and USFWS regarding threatened and endangered species with potential to occur in the project area should be initiated early in project planning.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (Pl96-515), and the Archeological and Historic Preservation Act (PL93-291).

Based on the review of publically available Geographic Information System (GIS) records obtained from the Texas Historical Commission, there are no State Historic Sites, National Register Properties or Districts, or cemeteries within the project area. However five historical markers occur near the proposed pipeline route from the ASR well field to the Tabor Road pump station. A review of archaeological resources in the proposed project area should be conducted during the project planning phase. Because the owner or controller of the project will likely be a political subdivision of the State of Texas (i.e., river authority, municipality, county, etc.), they will be required to coordinate with the Texas Historical Commission prior to project construction.

10.1.6 Engineering and Costing

This ASR conjunctive use strategy recommends a total of four recovery wells and four storage and recovery (ASR) wells. The timing of the recovery and ASR wells is summarized in Table 10.1-3.

Table 10.1-3. Timing of ASR Wellfield Infrastructure

Year	Recovery Wells	ASR Wells
2020		1
2030		1
2040		
2050	1	
2060	1	1
2070	2	1

Available records indicate that the ASR wells in the Simsboro, where proposed, would average about 3,200 ft deep. A typical injection and recovery rate is estimated to be 1,800 gpm and 3,000 gpm, respectively. The well field design has the wells spaced about 1,320 ft apart.

The major facilities required for these projects include:

- Pump station,
- Pipeline,
- ASR and Recovery wells,

- Collector pipelines, and
- Cooling and Disinfection water treatment, and
- Interconnect.

Estimates were prepared for capital and project costs, annual debt service, operation and maintenance, power, land, and environmental mitigation. These costs are summarized in Table 10.1-4. The annual costs, including debt service, operation and maintenance, and power, is estimated to be $385 per acft.

Table 10.1-4. Cost Estimate Summary: City of Bryan ASR Project Option

Item	Estimated Costs for Facilities
Pump Station	$2,425,000
Transmission Pipelines	$4,032,000
Well Fields (Wells, Pumps, and Piping)	$29,516,000
Water Treatment Plant (Cooling & Disinfection)	$5,123,000
TOTAL COST OF FACILITIES	**$41,096,000**
Engineering and Feasibility Studies, Legal Assistance, Financing, Bond Counsel, and Contingencies (30% for pipes & 35% for all other facilities)	$14,182,000
Environmental & Archaeology Studies and Mitigation	$111,000
Interest During Construction (4% for 1 yrs with a 1% ROI)	$1,9239,000
TOTAL COST OF PROJECT	**$57,328,000**
ANNUAL COST	
Debt Service (5.5 percent, 20 yrs)	$4,797,000
Operation and Maintenance	
Intake, Pipeline, Pump Station (1% of Cost of Facilities)	$396,000
Water Treatment Plant	$1,691,000
Pumping Energy Costs	$761,000
TOTAL ANNUAL COST	**$7,645,000**
Available Project Yield (acft/yr), based on a Peaking Factor of 1.94	**19,839**
Annual Cost of Water ($ per acft)	**$385**
Annual Cost of Water ($ per 1,000 gallons)	**$1.18**

10.1.7 Implementation

Implementation of the ASR conjunctive use water management strategy for Bryan includes the following issues:

- Acquiring permits from TCEQ for ASR construction and operations;
- Initial cost; and
- Development of a management and implementation of plan to efficiently balance utilization of production and ASR wells.

This water supply option has been compared to the plan development criteria, as shown in Table 10.1-5, and the option meets each criterion.

Table 10.1-5. Comparison of Bryan ASR Conjunctive Use Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Adequate supply with other strategies to meet needs
2. Reliability	2. High reliability
3. Cost	3. Low
B. Environmental factors	
1. Environmental Water Needs	1. None
2. Habitat	2. None
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. None
C. Impact on Other State Water Resources	None
D. Threats to Agriculture and Natural Resources	None
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered in an attempt to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	None