Brazos G Regional
Water Planning Area

Regional Water Plan

Volume II
Evaluation of
Water Management
Strategies

January 2006

Prepared by:

Brazos G Regional Water Planning Group

With administration by:

Brazos River Authority

With technical assistance by:

HDR Engineering, Inc.

In association with:

Freese and Nichols, Inc.
R.W. Harden and Associates, Inc.
Hicks and Company, Inc.
Fletcher Communications

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Brazos G Regional Water Planning Area

2006 Brazos G Regional Water Plan

V*olume II – Evaluations of Water Management Strategies*

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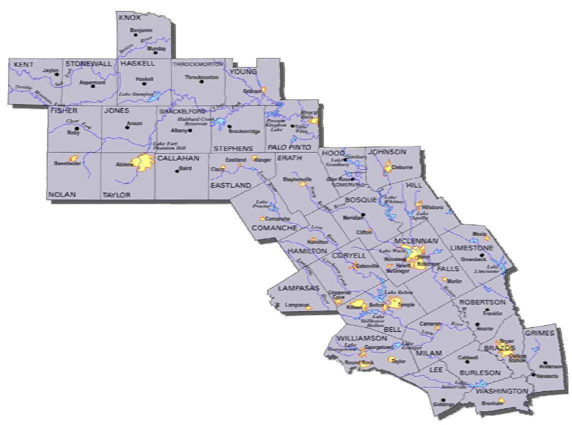

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Section 4B
Identification, Evaluation, and Selection of Water Management Strategies
[31 TAC §357.7(a)(5-7)]

4B.1 Water Management Strategies

Title 31 TAC 357.7(a)(7) requires that the regional water planning group evaluate all water management strategies determined to be potentially feasible. The guidelines list multiple types of strategies and numerous subtypes, including water conservation; drought management measures; reuse of wastewater; expanded use of existing facilities, including systems optimizations, conjunctive use, reallocation of storage to new uses, etc.; interbasin transfers; new supply development; and others. At the beginning of the 2006 planning cycle, the Brazos G Regional Water Planning Group (BGRWPG) identified approximately 25 water management strategies to be potentially feasible. Some of these were evaluated for the previous 2001 Brazos G Regional Water Plan. Several strategies were re-evaluated due to changed conditions such as new hydrologic information or requests for further information.

Potential water supply strategies evaluated during preparation of the 2006 Brazos G Regional Water Plan are listed in Table 4B.1-1. Within some of the 15 types of water management strategies listed in Table 4B.1-1 there are a number of sub-options. For instance, in the section on New Reservoirs (Section 4B.14), seven potential reservoir sites are evaluated.

Them remainder of this section describes methods and procedures utilized to evaluate water management strategies considered for inclusion in the water plan for the Brazos G Area.

4B.1.1 Evaluation of Strategies

The following chapters contain an evaluation of each of the potential water management strategies. Each section is typically divided into five subsections: (1) Description of Option; (2) Available Yield; (3) Environmental Issues; (4) Engineering and Costing; and (5) Implementation Issues. Information in these sections was presented to the BGRWPG at regularly scheduled public meetings and was used in evaluating strategies to meet water needs in the region.

Table 4B.1-1.
Water Management Strategies Evaluated
for the 2006 Brazos G Regional Water Plan

Section No. (Located in Volume II)	*Title*
4B.2	Water Conservation
4B.3	Wastewater Reuse
4B.4	System Operation of Brazos River Authority Reservoirs
4B.5	Groundwater/Surface Water Conjunctive Use (Lake Granger Augmentation)
4B.6	Desalination
4B.7	Millers Creek Reservoir Augmentation
4B.8	Aquifer Storage and Recovery
4B.9	Brush Control and Range Management
4B.10	Weather Modification
4B.11	Interregional Water Management
4B.12	New Reservoirs
4B.13	Off-Channel Reservoirs
4B.14	Interconnection of Regional and Community Systems
4B.15	Carrizo-Wilcox Aquifer Development
4B.16	Voluntary Redistribution

4B.1.2 Plan Development Criteria

It is the goal of the BGRWPG to develop a plan to meet projected water needs within the region. The BGRWPG has adopted a set of Plan Development Criteria that was used to evaluate whether a given strategy should be used to meet a projected shortage and ultimately be included in the Brazos G Regional Water Plan. The proposed strategies were developed by evaluating the water management strategies using the BGRWPG criteria and then matching strategies to meet projected shortages. This section discusses the evaluation criteria adopted by the planning group during plan development, and criteria to be met in formulation of the plan. The adopted plan elements will meet these criteria:

- Water Supply – Water supply must be evaluated with respect to quantity, reliability, and cost. The criteria for quantity are that the plan must be sufficient to meet all projected needs in the planning period. The criteria for reliability is that it meet municipal and industrial needs 100 percent of the time, and 75 percent of agricultural needs 75 percent of the time. The criteria for cost are that the projected cost be reasonable to meet the projected needs.

- Environmental Issues – Environmental considerations must be examined with respect to environmental water needs, wildlife habitat, cultural resources, and bays and estuaries. The criteria for environmental water flows and wildlife habitat are that stream conditions must meet permit requirements for diversions that currently have permits. For projects that require permit acquisition the project will provide adequate environmental instream flows for aquatic habitat. Projects should be sited to avoid known cultural resources, if possible. Flows to bays and estuaries should meet expected permit conditions. (It should be noted that the Brazos River does not have a well-defined estuary or bay system, so bay and estuary inflow requirements are expected to be low).
- Impacts on Other State Water Resources – The criteria recommends a follow-up study by the BGRWPG if any significant impacts are anticipated on other state water resources.
- Threats to Agriculture and Natural Resources – The criteria requires that the planning group identify any potential impact, compare the impact to the proposed benefit of the plan, and make recommendations.
- Equitable Comparison of Feasible Strategies – This is achieved by the equal application of criteria across different water development plans.
- Interbasin Transfers – The planning group may consider interbasin transfers as a supply option. The criteria require that the participating entities recognize and follow Texas Water Code requirements for expected permitting requirements.
- Impacts from Voluntary Redistribution – The criteria require that any potential third party social or economic impacts from voluntary redistribution of water rights be identified and described.
- Other Criteria – Texas Water Development Board (TWDB) allows the BGRWPG to adopt other criteria. The BGRWPG has not adopted any further criteria.

The following sections discuss the methods and procedures used to develop the information needed to evaluate the strategies and compare them to the criteria.

4B.1.3 Engineering

A procedure was developed to maintain equal and consistent consideration of various design and cost variables across differing management options. These were planning level estimates only, and did not reflect detailed site-specific design work, nor any extensive optimization and selection of design variables. These procedures standardized the consideration of the following design and costing issues as closely as possible, given the varying scope and magnitude of differing projects. For each option, major cost components were determined at the outset. Estimates of volume of water and rate of delivery needed were developed from the supply-demand comparisons presented in Section 3, if directly applicable. Volumes necessary to meet shortages were estimated, and both average annual and peak rates of projected delivery were calculated. Average annual rates were adjusted to reflect pump station downtime due to maintenance activities. Transmission and treatment facilities were generally sized based on peak rates of delivery. Water source and delivery locations were determined, considering source and destination elevations, surrounding land use, and other geographic considerations. Further details on engineering factors considered are presented in the discussions of the various water management strategies presented in Volume II, Sections 4B.2 through 4B.16.

4B.1.4 Cost Estimates

The cost estimates of this study are expressed in three major categories: (1) construction costs or capital (structural) costs, (2) other (non-structural) project costs, and (3) annual costs. Construction costs are the direct costs incurred in constructing facilities, such as those for materials, labor, and equipment. "Other" project costs include expenses not directly associated with construction activities of the project, such as costs for engineering, legal counsel, land acquisition, contingencies, environmental studies and mitigation, and interest during construction. Capital costs and other project costs comprise the total project cost. Operation and maintenance, energy costs, purchase of wholesale water and debt service payments are examples of annual costs. Major components that may be part of a preliminary cost estimate are listed in Table 4B.1-2. All costs represent second quarter 2002 prices.

Table 4B.1-2.
Major Project Cost Categories

<table>
<tr><th>Capital Costs
(Structural Costs)</th><th>Other Project Costs
(Non-Structural Costs)</th></tr>
<tr><td rowspan="3">1. Pump Stations
2. Pipelines
3. Water Treatment Plants
  a. Conventional
  b. Desalination
4. Water Storage Tanks
5. Off-Channel Reservoirs
6. Well Fields
  a. Injection
  b. Recovery
  c. ASR Wells
7. Dams and Reservoirs
8. Relocations
9. Other Items</td><td>1. Engineering (Design, Bidding and Construction Phase Services, Geotechnical, Legal, Financing, and Contingencies)
2. Land and Easements
3. Environmental - Studies and Mitigation
4. Interest During Construction</td></tr>
<tr><th>Annual Project Costs</th></tr>
<tr><td>1. Debt Service
2. Operation and Maintenance (excluding pumping energy)
3. Pumping Energy Costs
4. Purchase Water Cost (if applicable)</td></tr>
</table>

To estimate capital costs, tables of unit costs for each major component in the capital costs were developed through an internal review of bid documents and project cost audits of projects that HDR and Freese & Nichols (subconsultant) have implemented in the past. The cost tables report all-inclusive costs to construct, including the construction, infrastructure and control equipment, and all other materials, labor, and installation costs. Unit costs were developed for pump stations, intake structures, pipelines, wells, reservoir structures, channel dams and any other structural component called for in a water supply option.

As previously mentioned, “other” (non-structural) project costs are costs incurred in a project that are not directly associated with construction activities. These include costs for engineering, legal counsel, financing, contingencies, land, easements, surveying and legal fees for land acquisition, environmental and archaeology studies, permitting, mitigation, and interest during construction. These costs are added to the capital costs to obtain the total project cost. A standard percentage applied to the capital costs is used to calculate a combined cost that includes engineering, financial, legal services, and contingencies.

Annual costs are those that the project owner can expect to incur if the project is implemented. These costs include repayment of borrowed funds (debt service), operation and maintenance costs of the project facilities, pumping power costs, and water purchase costs, when applicable.

Debt service is the estimated annual payment that can be expected for repayment of borrowed funds based on the total project cost, an assumed finance rate, and the finance period in years. As specified in TWDB Exhibit B, Section 4.2.9, debt service for all projects was calculated assuming an annual interest rate of 6 percent and a repayment period of 40 years for large reservoir projects and 30 years for all other projects.

Operation and maintenance costs for dams, pump stations, pipelines, and well fields (excluding pumping power costs) include labor and materials required to operate the facilities and provide for regular repair and/or replacement of equipment. In accordance with TWDB guidelines, unless specific project data are available, operation and maintenance costs are calculated at 1 percent of the total estimated construction costs for pipelines, at 1.5 percent of the total estimated construction costs for dams and reservoirs, and at 2.5 percent for intake and pump stations. Water treatment plant operation and maintenance costs were based on treatment level and plant capacity. The operation and maintenance costs include labor, materials, replacement of equipment, process energy, building energy, chemicals, and pumping energy.

In accordance with TWDB guidelines, power costs are calculated on an annual basis using the appropriate calculated power load and a power rate of $0.06 per kWh. The amount of energy consumed is based upon the pumping horsepower required.

The raw water purchase cost, if applicable, is included if the water supply option involves purchase of raw or treated water from an entity. This cost varies by source.

A cost estimate summary for each individual option is presented with total capital costs, total project costs, and total annual costs. The level of detail is dependent upon the characteristics of each option. Additionally, the cost per unit of water involved in the option is reported as costs per acft and cost per 1,000 gallons of water developed. The individual option cost tables specify the point within the region at which the cost applies (e.g., raw water at the lake, treated water at the municipal and industrial demand center, or elsewhere as appropriate).

Numerous recommended water management strategies are included in plans for individual water user groups that are not specifically analyzed as separate water management strategies in Volume II. These generally involve small interconnections between two neighboring systems or purchases of additional supplies from a wholesale water provider or adjacent water user group. In these cases, the basis for the cost estimate is described briefly in the individual water user group plan.

4B.1.5 Methods Used to Investigate Environmental Effects of Proposed Regional Water Management Strategies

The Regional Water Planning Guidelines (31 TAC 357.7) require that each regional water management strategy includes an evaluation of environmental factors, specifically effects on environmental water needs, wildlife habitat, cultural resources, agricultural resources, upstream development on bays, estuaries, and arms of the Gulf of Mexico. These factors were evaluated for each of the proposed water management strategies according to the level of description and engineering design information provided. Details regarding the methodology to investigate environmental water needs, instream flow needs, impact on bays and estuaries, and fish and wildlife habitat are generally included in the analysis of each strategy.

4B.1.6 Agricultural Water Management Strategies

New firm water supplies cannot be developed for irrigated agriculture, because the cost of development far exceeds the value of the water in irrigated production. The assumption is made that the available groundwater resources are already fully exploited. Cloud seeding and brush control for water yield are the only potential new supplies of water for irrigated agriculture, but a firm yield cannot be assigned to these practices. Without any firm supply of water, agricultural producers will have to reduce the irrigation and confined livestock demands through a variety of conservation and other management practices. Conservation practices were evaluated, specifically related to irrigation conservation and the savings of water that can be expected. The evaluation is presented in Volume II, Section 4B.2.2.

4B.1.7 Water Conservation and Drought Preparation

Water conservation recommendations are included in the plans for individual Water User Groups. Water conservation as a water management strategy for individual municipal water user groups was evaluated as per the description in Volume II, Section 4B.2.1. Costs and savings to be expected from various Best Management Practices (BMPs) are described, and recommended target reductions in per capita water use (gpcd) are presented. For irrigation conservation, specific costs, expected savings and conservation target recommended by the Brazos G RWPG are described in Volume II, Section 4B.2.2. For conservation for other types of use (manufacturing, steam electric, mining, livestock) the Brazos G RWPG has recommended a target goal of seven percent reduction in overall water demands for entities with projected shortages, and has presented a list of recommended BMPs in Volume II, Section 4B.2.3. Little guidance exists for estimating water savings and costs for BMPs for non-municipal and non-irrigation uses, as water use under each of these categories is facility-specific.

While water conservation is a viable water management strategy that makes more efficient use of available supplies to meet projected water needs, drought management recommendations have not been made by the Brazos G RWPG as a water management strategy for specific WUG needs. The regional water plan is developed to meet projected water demands during a drought. The purpose of the planning is to ensure that sufficient supplies are available to meet future water demands. Reducing water demands during a drought as a defined water management strategy does not ensure that sufficient supplies will be available to meet the projected water demands; but simply eliminates the demands. While the Brazos G RWPG encourages entities in the Brazos G Area to promote demand management during a drought, it should not be identified as a "new source" of supply. Recommending demand reductions as a water management strategy is antithetical to the concept of planning to meet projected water demands. It does not make more efficient use of existing supplies as does conservation, but instead effectively turns the tap off when the water is needed most. It is planning to not meet future water demands. When considering the costs of demand reduction during drought, the costs for drought management could be considered as the economic costs of not meeting the projected water demands, as summarized in Appendix I.

4B.1.8 Funding and Permitting by State Agencies of Projects Not in the Regional Water Plan

Senate Bill 1 requires water supply projects to be consistent with approved regional water plans to be eligible for TWDB funding and to obtain TCEQ permits. Texas Water Code[1] provides that the TCEQ shall grant an application to appropriate surface water, including amendments to existing permits, only if the proposed action addresses a water supply need in a manner that is consistent with an approved regional water plan. TCEQ may waive this requirement if conditions warrant.

For TWDB funding, the Texas Water Code[2] states that the TWDB may provide financial assistance to a water supply project only after TWDB determines that the needs to be met by the project will be addressed in a manner that is consistent with the appropriate regional water plan. The TWDB may waive this provision if conditions warrant.

The Brazos G Regional Water Planning Group has considered the variety of actions and permit applications that may come before the TCEQ and the TWDB and does not want to unduly constrain projects or applications for small amounts of water that may not be specifically included in the adopted regional water plan. "Small amounts of water" is defined as involving no more than 1,000 acft/yr, regardless of whether the action is for a temporary or long term action. The Brazos G RWPG provides direction to TCEQ and TWDB regarding appropriations, permit amendments, and projects involving small amounts of water that will not have a

[1] Texas Water Code, Section 11.134
[2] Texas Water Code, Section 16.053(j)

significant impact on the region's water supply as follows: such projects are consistent with the regional water plan, even though not specifically recommended in the plan.

The Brazos G RWPG also provides direction to the TWDB regarding financial assistance for repair and replacement of existing facilities, or to develop small amounts of water (less than 1,000 acft/yr). Water supply projects not involving the development of or connection to a new water source, or involving development of a new supply less than 1,000 acft/yr, are consistent with the regional water plan, even though not specifically mentioned in the adopted plan.

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4B.2 Water Conservation

4B.2.1 Municipal Water Conservation

4B.2.1.1 Description of Option

Water conservation is defined as those methods and practices that either reduce the demand for water supply or increase the efficiency of the supply, or use facilities so that available supply is conserved and made available for future use. Water conservation is typically a non-capital intensive alternative that any water supply entity can and should pursue. All water supply entities and some major water right holders are required by Senate Bill 1 regulations to submit a Drought Contingency and Water Conservation Plan to the TCEQ for approval. These plans must detail the water supply entities' plans to reduce water demand at times when the demand threatens the total capacity of the water supply delivery system or overall supplies are low.

In 2001, the Texas Legislature amended the Texas Water Code, Texas Administrative Code 357.7(a)7(A), to require Regional Water Planning Groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). The Water Conservation Implementation Task Force was created by Senate Bill 1094 to identify and describe Water Conservation Best Management Practices (BMPs) and provide a BMP Guide for use by Regional Water Planning groups in the development of the 2006 Regional Water Plans. Two documents, GDS Associates Report[1] and Water Conservation Implementation Task Force Report,[2] provide guidance for municipal water conservation.

For regional water planning purposes, municipal water use is defined as residential and commercial water use. Municipal water is primarily for drinking, sanitation, cleaning, cooling, fire protection, and landscape watering for residential, commercial, and institutional establishments. A key parameter for assessing municipal water use within a typical city or water service area is the number of gallons used per person per day (per capita water use). The objective of water conservation is to decrease the amount of water – measured in gallons per person per day (gpcd) – that a typical person uses.

[1] "Quantifying the Effectiveness of Various Water Conservation Techniques in Texas," Texas Water Development Board, prepared by GDS Associates, Austin, Texas, July 2003.
[2] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

The Water Conservation Implementation Task Force recommends that a standardized methodology be used for determining per capita per day (gpcd) municipal water use so as to allow consistent evaluations of effectiveness of water conservation measures among Texas cities that are located in the different climates and parts of Texas. The Task force further recommends gpcd targets and goals that should be considered by retail public water suppliers when developing water conservation plans required by the state, as follows:

- All public water suppliers that are required to prepare and submit water conservation plans should establish targets for water conservation, including specific goals for per capita water use and for water loss programs using appropriate water conservation BMPs.
- Municipal Water Conservation Plans required by the state shall include per capita water-use goals, with targets and goals established by an entity giving consideration to a minimum annual reduction of 1 percent in total gpcd, based upon a 5-year moving average, until such time as the entity achieves a total gpcd of 140 gpcd or less, or
- Municipal water use (gpcd) goals approved by regional water planning groups.

The current Texas Water Development Board (TWDB) municipal water demand projections account for expected water savings due to implementation of the 1991 State Water-Efficient Plumbing Act. However, any projected water savings due to conservation programs over and above the savings associated with the 1991 Plumbing Act must be listed as a separate water management strategy. The savings projected by the TWDB include a 100 percent replacement of existing plumbing fixtures to water efficient fixtures by Year 2045 (assumed 2 percent per year replacement). The projections also assume that 100 percent of new construction includes water-efficient plumbing fixtures. Consequently, any water management strategy intended to replace inefficient plumbing fixtures installed prior to 1995 would constitute an acceleration of the effects of the 1991 Plumbing Act, but provide no additional long-term savings. Including a retrofit program as a water management strategy without first discounting the TWDB per capita water use reductions would double-count water savings, since those savings due to retrofits are already included in the base water demand projections.

Conservation is recommended for every municipal WUG with a projected need (shortage) and a per capita water use rate greater than 140 gallons per capita per day (gpcd) in 2060. The Brazos G Regional Water Planning Group (BGRWPG) recommends conservation for municipal WUGs with per capita rates greater than 140 gpcd based on the Water Conservation Task Force's statewide gpcd target. This conservation can be achieved in a variety of ways, including using these BMPs identified by the Water Conservation Implementation Task Force:

1. System Water Audit and Water Loss,
2. Water Conservation Pricing,
3. Prohibition on Wasting Water,
4. Showerhead, Aerator, and Toilet Flapper Retrofit,
5. Residential Toilet Replacement Programs with Ultra-Low-Flow toilets,
6. Residential Clothes Washer Incentive Program,
7. School Education,
8. Water Survey for Single-Family and Multi-Family Customers,
9. Landscape Irrigation Conservation and Incentives,
10. Water-Wise Landscape Design and Conversion Programs,
11. Athletic Field Conservation,
12. Golf Course Conservation,
13. Metering of all New Connections and Retrofitting of Existing Connections,
14. Wholesale Agency Assistance Programs,
15. Conservation Coordinator,
16. Reuse of Reclaimed Water,
17. Public Information,
18. Rainwater Harvesting and Condensate Reuse,
19. New Construction Graywater,
20. Park Conservation, and
21. Conservation Programs for Industrial, Commercial, and Institutional Accounts.

The BGRWPG does not recommend specific conservation BMPs for each municipal entity, as each entity should choose those conservation strategies that best fit their individual situation. The TWDB requires that costs and water supply estimates be developed for each recommended water management strategy. However, the Task Force Report does not present methods for computing water savings and costs for each of the above BMPs, reducing the list of specific BMPs that can be used to compute costs and savings. Estimated water savings for municipal water conservation are presented in Table 4B.2-1 for specific BMPs. The BMPs presented in Table 4B.2-1 were used to provide a basis for estimating costs and expected water savings. A city may choose other BMPs not included in Table 4B.2-1 to reduce their per capita water use.

If all of the programs listed in Table 4B.2-1 were implemented by a utility, an estimated total per capita water use reduction of 21 gpcd can be expected. This total reduction of 21 gpcd includes those reductions already incorporated into the TWDB demand projections. In order to meet both short and long-term needs, it is assumed that the 21 gpcd reductions will occur by Year 2020 for all municipal WUGs with needs, regardless of the timing of the needs. A portion of the 21 gpcd reduction is therefore an acceleration of the savings expected due to full implementation of the 1991 Plumbing Act. The savings shown in Table 4B.2-1 are average expected savings across the Brazos G Area. Actual expected savings are computed separately for each WUG based on locality (rural, urban, etc.) and expected population growth.

Table 4B.2-1.
Selected Water Conservation BMPs

Conservation BMP	*Savings*	*Source*
Advanced Conservation	7 gpcd*	GDS Associates, savings are for existing connections only
• Toilet retrofit		
• Showerheads and Aerators		
• Irrigation Audit – High User		
Landscape Irrigation	11 gpcd	Based upon 15% reduction referenced in Task Force report
Public Education Programs	3 gpcd	TCEQ
Total	**21 gpcd**	

* Note: This is an average for the WUGs analyzed, and represents 50 percent replacement of existing fixtures. In contrast, the TWDB maximum savings for a specific WUG in Region G (Brazos County-other) is about 13 gpcd, representing 100 percent replacement of existing fixtures for a WUG projected to have declining population and, consequently, minimal new construction.

4B.2.1.2 Available Supply

The available supply to any entity from this strategy would be the reduction in demand over and above that assumed in the TWDB water demand projections. All entities, in order to be in line with projections, will need to verify that their conservation planning measures are consistent with TCEQ standards and the TWDB projections. Beyond that, some communities with projected needs may be able to reduce or eliminate those needs with stronger conservation planning.

Table 4B.2-2 lists the 38 municipal entities in the Brazos G Area for which water conservation is recommended as a water management strategy. The table also lists the potential additional water conservation savings attributable to the BGRWPG conservation recommendations[3].

[3] Additional savings represents savings beyond the 1991 Plumbing Act savings.

Table 4B.2-2.
Water User Groups for which Conservation is a Recommended Water Management Strategy

ID	County Name	Water User Group	Water Savings-with Conservation (acft)*					
			2010	2020	2030	2040	2050	2060
1	JONES	ABILENE	977	2,042	1,636	1,196	1,026	994
2	STONEWALL	ASPERMONT	8	16	12	9	6	6
3	BELL	BARTLETT	12	30	25	19	18	18
4	WILLIAMSON	BRUSHY CREEK MUD	92	398	427	427	427	427
5	WILLIAMSON	CEDAR PARK	413	1,398	1,840	2,300	2,761	3,368
6	BELL	CHISHOLM TRAIL SUD	154	456	721	1,114	1,538	1,869
7	JOHNSON	CLEBURNE	229	515	454	413	416	473
8	BRAZOS	COLLEGE STATION	545	1,378	1,320	1,177	1,149	1,184
9	CORYELL	CORYELL COUNTY-OTHER	61	154	135	117	109	116
10	WILLIAMSON	FLORENCE	8	22	20	20	20	24
11	CORYELL	GATESVILLE	131	381	388	395	390	416
12	WILLIAMSON	GEORGETOWN	228	873	986	1,141	1,398	1,675
13	LEE	GIDDINGS	39	107	101	91	87	91
14	MCLENNAN	HALLSBURG	4	10	8	6	6	6
15	HASKELL	HASKELL	23	47	36	26	19	18
16	HILL	HILLSBORO	66	148	123	96	89	94
17	BELL	JARRELL-SCHWERTNER WSC	30	107	115	116	136	158
18	HILL	JOHNSON COUNTY RURAL WSC	423	1,307	1,883	2,761	3,941	4,792
19	JOHNSON	JOHNSON COUNTY-OTHER	87	208	190	171	166	175
20	BELL	KILLEEN	820	1,839	1,752	1,439	875	381
21	KNOX	KNOX CITY	9	21	17	13	11	11
22	LAMPASAS	LAMPASAS COUNTY-OTHER	55	134	126	114	107	110
23	WILLIAMSON	LEANDER	65	254	292	342	422	509
24	WILLIAMSON	LIBERTY HILL	17	62	87	107	134	163
25	FALLS	MARLIN	46	112	91	68	61	63
26	MCLENNAN	MCLENNAN COUNTY-OTHER	184	421	374	284	256	266
27	JOHNSON	MOUNTAIN PEAK WSC	10	37	44	46	57	71
28	KNOX	MUNDAY	10	25	20	15	11	10
29	MCLENNAN	NORTH BOSQUE WSC	10	33	36	38	37	42
30	WILLIAMSON	ROUND ROCK	586	1,872	2,120	2,455	3,014	3,612
31	BURLESON	SNOOK	3	11	8	7	6	7
32	STEPHENS	STEPHENS COUNTY-OTHER	11	22	18	13	10	10
33	PALO PINTO	STRAWN	7	14	11	9	9	9
34	NOLAN	SWEETWATER	94	195	156	113	95	91
35	BOSQUE	VALLEY MILLS	9	19	15	11	10	10
36	WILLIAMSON	WEIR	7	25	31	38	47	58
37	HILL	WHITE BLUFF COMMUNITY WS	11	29	31	33	40	45
38	HILL	WHITNEY	16	36	29	23	21	22

* Note: This conservation is in addition to savings attributed to the 1991 Water Efficient Plumbing Fixtures Act. Conservation beyond Year 2020 is based on Year 2020 gpcd being held constant through Year 2060.

4B.2.1.3 Environmental Issues

No substantial environmental impacts are anticipated, as water conservation is typically a non-capital intensive alternative that is not associated with direct physical impacts to the natural environment. A summary of the few environmental issues that might arise for this alternative are presented in Table 4B.2-3.

Table 4B.2-3.
Environmental Issues: Municipal Water Conservation

Water Management Option	Municipal Water Conservation
Implementation Measures	Voluntary reduction, reduced diversions, water pricing, mandatory restrictions (landscaping ordinances, watering days), reducing unaccounted for water
Environmental Water Needs / Instream Flows	No substantial impact identified, assuming relatively low reduction in diversions and return flows; substantial reductions in municipal and industrial diversions from water conservation would result in possibly low to moderate positive impacts as more stream flow would be available for environmental water needs and instream flows
Bays and Estuaries	No substantial impact identified, assuming relatively low reduction in diversions and return flows
Fish and Wildlife Habitat	No substantial impact identified, assuming relatively low reductions in diversions and return flows; possible low to moderate positive impact to aquatic and riparian habitats with substantial reductions as more stream flow would be available to these habitats; possible moderate positive benefits from implementation of site-specific xeriscape landscaping
Cultural Resources	No substantial impact anticipated
Threatened and Endangered Species	No substantial impact identified, assuming relatively low reduction in diversions and return flows; possible low to moderate positive impact to aquatic and riparian threatened and endangered species (where they occur) with substantial diversion reductions
Comments	Assumes no substantial change in infrastructure with attendant landscape impacts; further assumes that infrastructure improvements which do occur will largely be in urbanized settings

4B.2.1.4 Engineering and Costing

Since water conservation plans are required for each community by Senate Bill 1, regular costs for implementing and enforcing a general conservation program were not estimated. Only the efforts needed to enforce a more stringent conservation plan over and above that assumed in the projections were studied. These might include those BMPs included in Table 4B.2-1 or other conservation measures as deemed appropriate by each individual entity. Based upon the costs obtained for the selected BMPs from the GDS Associates report (Table 4B.2-4), the average cost per acft of water saved would be between $325 and $400. This is the cost associated with water savings above those already included in the TWDB water demand projections.

Table 4B.2-4.
Savings and Costs Associated with Municipal Water Conservation

Conservation BMP	Savings	Estimated Cost ($/acft of water saved)
Advanced Conservation	7 gpcd*	$325 to $385
• Toilet retrofit		
• Showerheads and Aerators		
• Irrigation Audit – High User		
Landscape Irrigation	11 gpcd	$400
Public Education Programs	3 gpcd	N/A
Total	**21 gpcd**	**$325 to $400**

* Note: This is an average for the WUGs analyzed, and represents 50 percent replacement of existing fixtures. In contrast, the TWDB maximum savings for a specific WUG in Region G (Brazos County-other) is about 13 gpcd, representing 100 percent replacement of existing fixtures for a WUG projected to have declining population and, consequently, minimal new construction.

4B.2.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.2-5, and the option meets each criterion.

Table 4B.2-5.
Comparison of Municipal Water Conservation Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Variable, dependent on current per capita rate
2. Reliability	2. Variable, dependent on public acceptance
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. None or low impact
2. Habitat	2. No apparent negative impact
3. Cultural Resources	3. None
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Not applicable

4B.2.2 Irrigation Water Conservation

4B.2.2.1 Description of Strategy

Irrigation water use is the use of freshwater that is pumped from aquifers and/or diverted from streams and reservoirs of the planning area and applied directly to grow crops, orchards, and hay and pasture in the study area. Irrigation water is typically applied to land by: (1) flowing or flooding water down furrows; and (2) the use of sprinklers. When groundwater is used, irrigation wells are usually located within the fields to be irrigated. For surface water supplies, typically water is diverted from the source and conveyed by canals and pipelines to the fields. For both groundwater and surface water, the conservation objective is to reduce the quantity of water that is lost to deep percolation and evaporation between the originating points (wells in the case of groundwater, and stream diversion points in the case of surface water), and the irrigated crops in the fields. Thus, the focus is upon investments in irrigation application equipment, instruments, and conveyance facility improvements (canal lining and pipelines) to reduce seepage losses, deep percolation, and evaporation of water, and management of the irrigation processes to improve efficiencies of irrigation water use and reduce the quantities of water needed to accomplish irrigation.

In the 37 counties of the Brazos G Area, irrigation varies from county to county along with the crops irrigated. In 1994, there were 214,096 acres of irrigated land in the Brazos G Area. In 2000, crops grown on irrigated acres in the Brazos G Area included alfalfa, corn, cotton, sorghum, hay-pasture, forage crops, peanuts, pecans, wheat and other grains, and vegetables. According to TWDB estimates, the entire Brazos G Area had 217,916 irrigated acres in 2000 with approximately 75 percent of the acreage planted to cotton, hay-pasture, peanuts, and wheat and other grains. Table 4B.2-6 summarizes the variety of crops grown in the Brazos G Area and number of irrigated acres for each crop in each county in 2000.

In 1994, irrigators in the Brazos G Area used 202,460 acft of water, of which nearly 80 percent was from groundwater sources. In 2000, the TWDB estimated that the irrigators used 233,686 acft (an increase of 15 percent over 1994). This increase is due to an increase in irrigated acreage of 1.8 percent and increased application rates, which changed from 0.95 acft/acre in 1994 to 1.07 acft/acre in 2000.

The TWDB irrigation water demand projections for the Brazos G Area predict significant decreases in irrigation usage in the future, declining to 218,691 acft/yr by 2030 and

204,386 acft/yr by 2060 (Volume I, Table 2-7). This decline in water use is attributable to expected reductions in irrigated land and partly to increased efficiencies.

In the Brazos G Area, six counties are projected to have irrigation needs (shortages) during the 2000 to 2060 planning period, as shown in Table 4B.2-7: Burleson, Eastland, Haskell, Knox, Nolan, and Shackelford. The predominant crops in these counties are cotton and wheat/other grains, constituting 45 percent and 25 percent of the irrigated acres, respectively (Table 4B.2-6).

Irrigation shortages range from less than 100 acft/yr in Shackelford County to greater than 28,000 acft in Haskell County (2010). Generally, the shortages decrease over time except for Eastland County, where minimal increases in shortages (less than 100 acft/yr) are anticipated from 2010 to 2060. Five of the six counties (Burleson, Eastland, Haskell, Knox, and Nolan) use both surface water and groundwater supplies to address irrigation water demands. Shackelford County irrigators receive surface water supplies.

TWDB rules for regional water planning require regional water planning groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). In addition, the rules direct water conservation "Best Management Practices," as identified by the Water Conservation Implementation Task Force (Task Force), be considered in the development of the water conservation water management strategy.

Table 4B.2-6.
Irrigated Acres by Crop (2000) in the Brazos G Area

County	alfalfa	corn	cotton	forage crops	grain sorghum	hay-pasture	other orchard	peanuts and other oil crops	pecans	soybeans	vegetables	wheat and other grains	all other crops	Total
Bell	0	520	80	0	0	1,141	61	0	0	0	35	110	0	1,947
Bosque	0	220	0	241	0	657	0	754	50	0	0	175	60	2,157
Brazos	0	2,147	5,437	0	381	0	25	0	0	263	0	0	0	8,253
Burleson	0	2,743	11,348	0	686	0	0	0	0	3,137	0	0	1,000	18,914
Callahan	0	0	0	0	0	1,135	0	125	0	0	0	0	0	1,260
Comanche	125	0	0	4,050	0	5,078	0	6,097	9,482	0	1,450	1,772	0	28,054
Coryell	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eastland	166	0	0	1,860	538	6,424	0	3,655	53	0	293	1,232	0	14,221
Erath	0	0	0	3,646	0	3,002	0	1,829	0	0	32	0	56	8,565
Falls	0	2,229	0	0	0	15	0	0	27	0	60	0	0	2,331
Fisher	136	0	2,081	125	0	575	0	0	0	0	0	160	0	3,077
Grimes	0	0	504	0	0	60	10	0	40	0	102	0	0	716
Hamilton	0	100	0	0	0	358	0	0	0	0	0	40	22	520
Haskell	146	4	18,699	560	291	1,909	0	7,599	11	0	367	10,117	0	39,703
Hill	0	0	0	0	0	0	0	0	0	0	0	0	26	26
Hood	0	0	0	0	0	190	0	0	1,560	0	0	0	840	2,590
Johnson	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jones	100	0	3,085	0	1,500	2,200	0	1,200	0	0	0	1,500	0	9,585
Kent	19	0	0	0	92	195	0	0	45	0	0	304	21	676
Knox	0	0	17,704	144	680	683	0	1,295	67	0	722	17,156	34	38,485
Lampasas	0	58	0	0	0	60	0	40	1	0	0	0	2	161
Lee	0	46	0	0	0	1,252	20	121	141	31	0	0	0	1,611
Limestone	0	0	0	0	0	0	0	0	0	0	0	0	0	0
McLennan	0	915	1,850	0	0	130	0	180	212	0	50	0	635	3,972
Milam	0	1,074	136	3,868	0	748	0	0	5	60	0	0	40	5,931
Nolan	0	0	2,345	0	0	250	0	0	38	0	20	203	35	2,891
Palo Pinto	0	0	0	0	0	735	0	0	0	0	0	0	252	987
Robertson	0	4,879	11,994	0	0	749	0	0	254	0	0	0	12	17,888
Shackelford	17	0	0	110	15	17	0	0	0	0	0	158	0	317
Somervell	0	0	0	0	0	160	0	0	0	0	0	0	210	370
Stephens	0	0	0	0	0	260	0	0	0	0	0	463	0	723
Stonewall	40	0	77	0	0	73	0	94	0	62	0	64	0	410
Taylor	0	0	150	0	200	330	0	0	0	0	0	190	0	870
Throckmorton	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Washington	0	0	0	0	0	85	40	0	265	0	0	0	173	563
Williamson	0	0	0	0	0	10	0	0	20	0	0	0	50	80
Young	0	0	0	0	0	60	0	0	2	0	0	0	0	62
Total	**749**	**14,935**	**75,490**	**14,604**	**4,383**	**28,541**	**156**	**22,989**	**12,273**	**3,553**	**3,131**	**33,644**	**3,468**	**217,916**
Percent	**0.3**	**6.9**	**34.6**	**6.7**	**2.0**	**13.1**	**0.1**	**10.5**	**5.6**	**1.6**	**1.4**	**15.4**	**1.6**	**100**

Table 4B.2-7.
Projected Irrigation Water Demands, Supplies, and Needs (Shortages) in Counties Having Projected Irrigation Shortages

County	Projections (acft/yr)						
	2000	***2010***	***2020***	***2030***	***2040***	***2050***	***2060***
Burleson							
Irrigation Demand	18,239	17,480	16,749	16,052	15,431	14,741	14,082
Irrigation Existing Supply							
Groundwater	8,955	8,583	8,224	7,882	7,577	7,238	6,914
Surface water	4,177	4,177	4,177	4,177	4,177	4,177	4,177
Total Irrigation Supply	13,132	12,760	12,401	12,059	11,754	11,415	11,091
Shortage	(5,107)	(4,720)	(4,348)	(3,993)	(3,677)	(3,326)	(2,991)
Eastland							
Irrigation Demand	16,274	16,302	16,327	16,352	16,370	16,377	16,385
Irrigation Existing Supply							
Groundwater	4,698	4,693	4,691	4,690	4,689	4,688	4,687
Surface water	2,436	2,437	2,438	2,439	2,439	2,440	2,441
Total Irrigation Supply	7,134	7,130	7,129	7,129	7,128	7,128	7,128
Shortage	(9,140)	(9,172)	(9,198)	(9,224)	(9,242)	(9,249)	(9,257)
Haskell							
Irrigation Demand	50,820	49,309	47,844	46,422	45,040	43,702	42,405
Irrigation Existing Supply							
Groundwater	19,684	19,677	19,668	19,659	19,649	19,639	19,628
Surface water	827	827	827	827	827	827	827
Total Irrigation Supply	20,511	20,504	20,495	20,486	20,476	20,466	20,455
Shortage	(30,309)	(28,805)	(27,349)	(25,936)	(24,564)	(23,236)	(21,950)
Knox							
Irrigation Demand	43,124	42,065	41,033	40,025	39,041	38,082	37,147
Irrigation Existing Supply							
Groundwater	23,778	23,775	23,771	23,768	23,764	23,761	23,757
Surface water	2,951	2,948	2,944	2,941	2,937	2,934	2,930
Total Irrigation Supply	26,729	26,723	26,715	26,709	26,701	26,695	26,687
Shortage	(16,395)	(15,343)	(14,318)	(13,317)	(12,340)	(11,388)	(10,460)
Nolan							
Irrigation Demand	5,276	5,138	5,003	4,871	4,741	4,618	4,497
Irrigation Existing Supply							
Groundwater	1,862	1,854	1,845	1,837	1,827	1,819	1,811
Surface water	120	120	120	120	120	120	120
Total Irrigation Supply	1,982	1,974	1,965	1,957	1,947	1,939	1,931
Shortage	(3,294)	(3,164)	(3,038)	(2,914)	(2,794)	(2,679)	(2,566)
Shackelford							
Irrigation Demand	195	189	183	178	173	168	163
Irrigation Existing Supply							
Groundwater	0	0	0	0	0	0	0
Surface water	77	78	79	80	80	81	82
Total Irrigation Supply	77	78	79	80	80	81	82
Shortage	(118)	(111)	(104)	(99)	(93)	(87)	(81)

Table 4B.2-8.
Projected Water Demands and Needs (Shortages) for Irrigation Users after Recommended Irrigation Water Conservation

Counties	***2010***	***2020***	***2030***	***2040***	***2050***	***2060***
Burleson						
New Demand (acft/yr)	16,956	15,912	14,928	14,351	13,709	13,096
Expected Savings (acft/yr)	*524*	*837*	*1,124*	*1,080*	*1,032*	*986*
New shortage (acft/yr)	(4,196)	(3,511)	(2,869)	(2,597)	(2,294)	(2,005)
Shortage Reduction (acft/yr)	11%	19%	28%	29%	31%	33%
Eastland						
New Demand (acft/yr)	15,813	15,511	15,207	15,224	15,231	15,238
Expected Savings (acft/yr)	*489*	*816*	*1,145*	*1,146*	*1,146*	*1,147*
New shortage (acft/yr)	(8,683)	(8,382)	(8,079)	(8,096)	(8,102)	(8,110)
Shortage Reduction (acft/yr)	5%	9%	12%	12%	12%	12%
Haskell						
New Demand (acft/yr)	47,830	45,452	43,172	41,887	40,643	39,437
Expected Savings (acft/yr)	*1,479*	*2,392*	*3,250*	*3,153*	*3,059*	*2,968*
New shortage (acft/yr)	(27,326)	(24,957)	(22,686)	(21,411)	(20,177)	(18,982)
Shortage Reduction (acft/yr)	5%	9%	13%	13%	13%	14%
Knox						
New Demand (acft/yr)	40,803	38,981	37,223	36,308	35,416	34,547
Expected Savings (acft/yr)	*1,262*	*2,052*	*2,802*	*2,733*	*2,666*	*2,600*
New shortage (acft/yr)	(14,081)	(12,266)	(10,515)	(9,607)	(8,722)	(7,860)
Shortage Reduction (acft/yr)	8%	14%	21%	22%	23%	25%
Nolan						
New Demand (acft/yr)	4,984	4,753	4,530	4,409	4,295	4,182
Expected Savings (acft/yr)	*154*	*250*	*341*	*332*	*323*	*315*
New shortage (acft/yr)	(3,010)	(2,788)	(2,573)	(2,462)	(2,356)	(2,251)
Shortage Reduction (acft/yr)	5%	8%	12%	12%	12%	12%
Shackelford						
New Demand (acft/yr)	183	174	166	161	156	152
Expected Savings (acft/yr)	*6*	*9*	*12*	*12*	*12*	*11*
New shortage (acft/yr)	(105)	(95)	(86)	(81)	(75)	(70)
Shortage Reduction (acft/yr)	5%	9%	13%	13%	14%	14%

4B.2.2.2 Available Yield

In February 2005, the Brazos G RWPG recommended that counties with projected irrigation needs (shortages) reduce their irrigation water demands by 3 percent by 2010, 5 percent by 2020, and 7 percent from 2030 to 2060 by using Best Management Practices (BMPs) identified by the Task Force. A reduction in irrigation water demand subsequently reduces shortages for each decade, if water supplies remain constant. In 2060, with conservation reductions, the shortages would range between 12 percent for Nolan County to 33 percent for Burleson County (Table 4B.2-8). The maximum water savings expected amongst the six counties is for Haskell County, with a recommended savings of 3,250 acft/yr in 2030.

The Task Force report[4] lists the following irrigation BMPs that may be used to achieve the recommended water savings:

1. Irrigation Scheduling;
2. Volumetric Measurement of Irrigation Water Use;
3. Crop Residue Management and Conservation Tillage;
4. On-Farm Irrigation Audit;
5. Furrow Dikes;
6. Land Leveling;
7. Contour Farming;
8. Conservation of Supplemental Irrigated Farmland to Dry-Land Farmland;
9. Brush Control/Management;
10. Lining of On-Farm Irrigation Ditches;
11. Replacement of On-Farm Irrigation Ditches with Pipelines;
12. Low-Pressure Center Pivot Sprinkler Irrigation Systems;
13. Drip/Micro-Irrigation Systems;
14. Gated and Flexible Pipe for Field Water Distribution Systems;
15. Surge Flow Irrigation for Field Water Distribution Systems;
16. Linear Move Sprinkler Irrigation Systems;
17. Lining of District Irrigation Canals;
18. Replacement of District Irrigation Canals and Lateral Canals with Pipelines;
19. Tailwater Recovery and Use Systems; and
20. Nursery Production Systems.

[4] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board, Special Report, Austin, Texas, November 2004.

The Task Force report describes the above BMP methods and how they reduce irrigation water use; however, information regarding specific water savings and costs to install irrigation water saving systems is generally unavailable. The Task Force report does include water savings and costs for three irrigation water conservation BMPs: (1) furrow dikes; (2) low-pressure sprinklers (LESA); and (3) low-energy precision application systems (LEPA). These major irrigation water conservation techniques applicable in the Brazos G Area are described briefly below.

Furrow dikes are small mounds of soil mechanically installed a few feet apart in the furrow. These mounds of soil create small reservoirs that capture precipitation and hold it until it soaks into the soil instead of running down the furrow and out the end of the field. This practice can conserve (capture) as much as 100 percent of rainfall runoff, and furrow dikes are used to prevent irrigation runoff under sprinkler systems. This maintains high irrigation uniformity and increases irrigation application efficiencies. Capturing and holding precipitation that would have drained from the fields replaces required irrigation water. Furrow dikes have been demonstrated to be useful management tools on both irrigated and non-irrigated cropland. Use of furrow dikes can have water savings up to 12 percent of the gross quantity of water applied using sprinkler irrigation. If all six counties with projected irrigation shortages in the Brazos G Area install furrow dikes, the expected water savings could be up to 12,359 acft/yr, assuming 100 percent participation of irrigated lands with sprinkler systems. Furrow dikes require special tillage equipment and cost $5 to $30 per acre to install.

Low-pressure sprinklers (LESA), with 90 percent application efficiency, improve irrigation application efficiency in comparison to conventional furrow irrigation by reducing water requirements per acre by between 10 and 25 percent. Low-pressure sprinklers spray water into the atmosphere above the crops as the sprinkler systems are moved across the fields. In the six Brazos G counties with projected water needs, conversion to LESA systems would save about 0.14 to 0.25 acft/acre converted and result in a total savings of 18,229 acft/yr.

LEPA systems involve a sprinkler system that has been modified to discharge water directly into furrows at low pressure, thus reducing evaporation losses. When used in conjunction with furrow dikes, LEPA systems can accomplish the irrigation objective with less water than is required for the furrow irrigation and pressurized sprinkler methods. When used with furrow dike systems, the expected water savings from LEPA would range from 0.25 acft/acre to 0.51 acft/acre (a total reduction in water use of 30 to 40 percent). Use of LEPA and furrow dikes allows irrigation farmers to produce equivalent yields per acre at lower energy and labor costs. It has been demonstrated that LEPA systems improve production and profitability of irrigation farming. The barriers to installation are high capital costs; with no assurance (at the present time) that the water saved would be available to the irrigator who incurred the costs.

A comparison of irrigation rates for furrow dikes, LESA, and LEPA systems to irrigation rates before irrigation water conservation are shown in Table 4B.2-9.

4B.2.2.3 Environmental Issues

The irrigation water conservation methods described above have been developed and tested through public and private sector research, and have been adopted and applied within the region. Hundreds of LEPA systems have been installed and are in operation today, and experience has shown that there are no significant environmental issues associated with this water management strategy. This method improves water use efficiency without making changes to wildlife habitat. This method of application, when coupled with furrow dikes, reduces runoff of both applied irrigation water and rainfall. The results are reduced transport of sediment and any fertilizers or other chemicals that have been applied to the crops. Thus, the proposed conservation practices do not have potential adverse effects, and may have potentially beneficial environmental effects.

4B.2.2.4 Engineering and Costing

The Brazos G RWPG recommended irrigation water conservation (7 percent reduction in demands) as a water management strategy for irrigation needs, resulting in a maximum water savings of 8,675 acft/yr. Furrow dikes could save up to 12,359 acft/yr at an average unit cost of $237 per acft (Table 4B.2-10). Installing LESA or LEPA systems would incur a greater capital cost, and therefore higher annual costs, however both achieve a substantially higher water savings potential and therefore have more economical unit cost ($/acft) when compared to furrow dikes. The maximum water conservation potential can be realized by using the LEPA system, as shown in Table 4B.2-10. The capital cost to install LEPA irrigation is approximately $400 per acre.[5] It is estimated that it would take a total investment of $33.4 million to equip the

[5] Ibid.

Table 4B.2-9.
Region G Irrigated Acreages and Effects of Water Conservation on Irrigation Water Use and Application Rates

County	Acreage Irrigated with Sprinklers (2000)	Without Conservation		With Conservation									
				Furrow Dikes[1]			LESA[2]			LEPA[3]			
		Irrigation Water Use (acft)	Irrigation Rate (acft per acre)	Irrigation Water Use (acft)	Irrigation Rate (acft per acre)	Estimated water savings (acft)	Irrigation Water Use (acft)	Irrigation Rate (acft per acre)	Estimated water savings (acft)	Irrigation Water Use (acft)	Irrigation Rate (acft per acre)	Estimated water savings (acft)
Burleson	6,903	7,480	1.08	6,583	0.95	898	5,818	0.84	1,662	5,512	0.80	1,968
Eastland	14,221	16,274	1.14	14,321	1.01	1,953	12,658	0.89	3,616	11,991	0.84	4,283
Haskell	31,107	44,584	1.43	39,234	1.26	5,350	37,153	1.19	7,431	35,198	1.13	9,386
Knox	28,647	29,846	1.04	26,264	0.92	3,581	24,871	0.87	4,974	23,562	0.82	6,283
Nolan	2,575	4,709	1.83	4,144	1.61	565	4,185	1.63	523	3,965	1.54	743
Shackelford	157	102	0.65	90	0.57	12	79	0.50	23	75	0.48	27
Total	83,610	102,994	1.23	90,635	1.08	12,359	84,765	1.01	18,229	80,304	0.96	22,691

[1] 12 percent savings of water applied using sprinkler irrigation.
[2] Assumes application efficiency of 90 percent.
[3] Assumes application efficiency of 95 percent.

estimated 83,610 irrigated acres currently served by sprinkler systems within the six counties with projected irrigation shortages. This investment, at an annual cost of $2.4 million (30 years at 6 percent), would save an estimated 22,691 acft/yr at an average unit cost of $107 per acft of water saved.

Each of the three irrigation water conservation strategies described (furrow dikes, LESA, and LEPA) have the potential to increase water savings beyond the minimum recommended by the Brazos G RWPG; however, none of the strategies can accomplish water savings sufficient to meet all of the projected needs. For example, the shortage for Burleson County is 2,991 acft/yr in Year 2060. If furrow dikes and LEPA systems were installed, only 2,866 acft/yr would be saved. Burleson County would need irrigation water conservation on 7,229 acres, while total irrigated acres in the county in year 2000 was only 6,903 acres (Table 4B.2-9). Further studies are needed to consider other irrigation water conservation BMPs that can be applied to surface applications to increase their application efficiencies.

It may not be economically feasible for agricultural producers to pay for additional water supplies to meet projected irrigation water needs (shortages), even if such supplies were available. For example, in 2004, the estimated income for irrigated cotton remaining after other production expenses had been paid was about $68 per acre, and the income for wheat with high input management was about $65 per acre. At an application rate of about 1 acft/acre, the cost of water from other sources far exceeds these values. For example, costs for water management strategies (new reservoirs) considered to meet projected municipal needs ranged between $210 per acft and $1,176 per acft for raw water supply at the reservoirs. The costs greatly exceed the income that would be realized from land irrigated with these water supplies.

Table 4B.2-10
Potential Water Savings and Costs (Total Project, Annual Average, and Unit Costs) to Implement Irrigation Water Conservation Best Management Practices

County	Maximum Desired Water Savings (acft)	Furrow Dikes			LESA (90% efficiency)				LEPA (95% efficiency)			
		Max. Amt. Saved (acft)	Annual Cost[1] (average)	Avg. Cost per acft	Max. Amt. Saved (acft)	Total Project Cost (average)	Annual Cost[1] (average)	Avg. Cost per acft	Max. Amt. Saved (acft)	Total Project Cost (average)	Annual Cost[1] (average)	Avg. Cost per acft
Burleson	1,124	**898**	$120,803	$269	**1,662**	$2,761,200	$200,598	$121	**1,968**	$2,761,200	$200,598	$102
Eastland	1,147	**1,953**	$248,868	$255	**3,616**	$5,688,400	$413,256	$114	**4,283**	$5,688,400	$413,256	$96
Haskell	3,250	**5,350**	$544,373	$204	**7,431**	$12,442,800	$903,956	$122	**9,386**	$12,442,800	$903,956	$96
Knox	2,802	**3,581**	$501,323	$280	**4,974**	$11,458,800	$832,469	$167	**6,283**	$11,458,800	$832,469	$132
Nolan	341	**565**	$45,063	$160	**523**	$1,030,000	$74,828	$143	**743**	$1,030,000	$74,828	$0
Shackelford	12	**12**	$2,748	$449	**23**	$62,800	$4,562	$202	**27**	$62,800	$4,562	$170
Total	**8,675**	**12,359**	**$1,463,175**	**$237**	**18,229**	**$33,444,000**	**$2,429,670**	**$133**	**22,691**	**$33,444,000**	**$2,429,670**	**$107**

[1] Annual costs calculated assuming debt service for 30 years at 6 percent interest.

4B.2.2.5 Implementation Issues

Demand reduction through water conservation is being implemented throughout the Brazos G Area and the State of Texas. The rate of adoption of efficient water-use practices is dependent upon public knowledge of the benefits, information about how to implement water conservation measures, and financing.

There is widespread public support for irrigation water conservation and it is being implemented at a steady pace, and as water markets for conserved water expand, this practice will likely reach its maximum potential. A major barrier to implementation of water conservation is financing. The TWDB has irrigation conservation programs that may provide funding to irrigators to implement irrigation BMPs that increase water use efficiency. Future planning efforts should consider the use of detailed studies to fully determine the maximum potential benefits of additional irrigation conservation.

This option is compared to the plan development criteria in Table 4B.2-11 and the options meets most criteria.

Table 4B.2-11.
Comparison of Irrigation Water Conservation Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Firm Yield: Variable according to BMP selected. Ranges from 12,359 acft/yr to 22,691 acft/yr
2. Reliability	2. High reliability
3. Cost	3. High for internal use: Ranges from $107 to $237 per acft water saved (based on BMP selected)
B. Environmental factors	
1. Environmental Water Needs	1. None or low impact
2. Habitat	2. None or low impact
3. Cultural Resources	3. No apparent negative impact
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. None
6. Wetlands	6. No cultural resources affected
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Standard analyses and methods used
F. Requirements for Interbasin Transfers	• None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.2.3 Water Conservation for Industrial Uses

4B.2.3.1 Description of Strategy

Water uses for industrial purposes (manufacturing, steam-electric power generation, and mining) are primarily associated with manufacturing products, cleaning and waste removal, waste heat removal, dust control, landscaping, and mine dewatering. In the Brazos G Area, industrial water demands amounted to 193,123 acft/yr in 2000 (24% total water demand) and are projected to increase to 294,044 acft/yr in 2060 (26% of total water demand) as shown in Table 4B.2-12.

Manufacturing is a significant part of the Brazos G Area's economy, and industries use water as a component of the final product, for cooling, and cleaning/wash-down of parts and/or products. Regional industries that are major water users include food and kindred products, apparel, fabricated metal, machinery, and stone and concrete production. Manufacturing water demand is projected at 19,787 acft/yr in 2010 and expected to increase to 31,942 acft/yr by 2060. There are eighteen counties in the Brazos G Area with projected manufacturing needs: Bell, Bosque, Brazos, Burleson, Erath, Fisher, Grimes, Hill, Hood, Johnson, Lampasas, Limestone, McLennan, Nolan, Robertson, Somervell, Washington, and Williamson. In 2060, the estimated water needs are 11,844 acft/yr, which is 37% of the manufacturing water demand for the Brazos G Area.

In the Brazos G Area, the trends for steam-electric water demands are projected to increase each decade with a maximum demand of 242,344 acft/yr by 2060. Grimes, Hood, Limestone, McLennan, Robertson, and Somervell Counties comprise nearly 80 percent of the projected regional steam-electric water use in 2060. The increase in water demand is due to projected increases in population and manufacturing growth and estimated increases in fresh water use based on projected power generation capacities. The Brazos G Area steam-electric users receive 93% of their water supplies from surface water sources. There are nine counties in the Brazos G Area with projected steam-electric needs: Bosque, Grimes, Johnson, Limestone, McLennan, Milam, Nolan, Palo Pinto, and Robertson. In 2060, the estimated water needs are 90,267 acft/yr, which is 37% of the steam-electric water demand for the Brazos G Area.

Table 4B.2-12. Projected Water Demands, Supplies, and Needs (Shortages) for Industrial Uses in the Brazos G Area

	Projections (acft/yr)						
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Manufacturing							
Demand	16,939	19,787	23,201	25,077	26,962	30,191	31,942
Existing Supply							
Groundwater	9,354	9,342	9,336	9,332	9,327	9,323	9,321
Surface water	11,068	11,645	12,019	12,357	12,700	12,990	13,311
Total Supply	20,422	20,987	21,355	21,689	22,027	22,313	22,632
Manufacturing Balance	3,483	1,200	(1,846)	(3,388)	(4,935)	(7,878)	(9,310)
Steam-Electric							
Demand	103,330	147,734	158,789	171,489	191,968	219,340	242,344
Existing Supply							
Groundwater	15,251	15,253	15,255	15,257	15,258	15,260	15,262
Surface water	199,774	206,439	206,382	206,326	205,946	205,440	204,891
Total Supply	215,025	221,692	221,637	221,583	221,204	220,700	220,153
Steam-Electric Balance	111,695	73,958	62,848	50,094	29,236	1,360	(22,191)
Mining							
Demand	72,854	32,229	33,156	33,602	23,816	19,259	19,758
Existing Supply							
Groundwater	64,289	21,985	22,130	22,220	12,087	7,189	7,275
Surface water	4,346	4,346	4,346	4,346	4,346	4,346	4,346
Total Supply	68,635	26,331	26,476	26,566	16,433	11,535	11,621
Mining Balance	(4,219)	(5,898)	(6,680)	(7,036)	(7,383)	(7,724)	(8,137)
Total Industrial							
Demand	193,123	199,750	215,146	230,168	242,746	268,790	294,044
Existing Supply							
Groundwater	88,894	46,580	46,721	46,809	36,672	31,772	31,858
Surface water	215,188	222,429	222,747	223,029	222,991	222,776	222,547
Total Supply	304,082	269,009	269,469	269,838	259,664	254,548	254,405
Total Industrial Balance	110,959	69,259	54,323	39,670	16,918	(14,242)	(39,639)

Gross state product data released from the U.S. Department of Commerce shows mining economic outputs of $37.6 billion for 1999 and $29.9 billion for 2000.[6] The TWDB water demand projections for mining users is generally based on projected economic output, assuming that past and current water use trends remain constant over time. In the Brazos G Area, the trends for mining water demands are projected to decrease each decade from 32,229 acft/yr in 2010 to 19,758 acft/yr by 2060, largely due to projected closure of the Sandow Mine in Milam County. In 2000, the Brazos G Area mining users received 94% of their water supplies from groundwater sources. Groundwater use is expected to decline to 63% of the regional mining water supply by 2060. There are ten counties in the Brazos G Area with projected mining needs: Haskell, Hood, Johnson, Knox, Lampasas, Nolan, Somervell, Stephens, Taylor, and Williamson. In 2060, the estimated water needs are 9,242 acft, which is 47% of the steam-electric water demand for the Brazos G Area.

TWDB Rules for regional water planning require Regional Water Planning Groups to consider water conservation and drought management measures for each water user group with a need (projected water shortage). In addition, the Rules direct that water conservation BMPs, as identified by the Water Conservation Implementation Task Force (Task Force), be considered in the development of the water conservation water management strategy.

4B.2.3.2 Available Yield

In February 2005, the Brazos G RWPG recommended that counties with projected needs (shortages) for industrial users (manufacturing, steam electric, or mining) reduce those water demands by 3 percent by 2010, 5 percent by 2020, and 7 percent from 2030 to 2060 by using Best Management Practices identified by the Water Conservation Implementation Task Force.

For the eighteen manufacturing users with projected needs, the total water savings after 7 percent water demand reduction in 2060 is 1,430 acft/yr (a 12% reduction in total regional manufacturing shortages) as shown in Table 4B.2-13.

For the nine steam-electric users with projected needs, the total water savings after 7 percent water demand reduction in 2060 is 13,281 acft/yr (a 15% reduction in total regional steam-electric shortages) as shown in Table 4B.2-14.

[6] TWDB, "Water Demand Methodology and Projections for Mining and Manufacturing," March 2003.

Table 4B.2-13.
Projected Water Demands and Needs (Shortages) for Manufacturing Users Considering up to a 7 Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	2020	2030	2040	2050	2060
Bell						
New Demand	951	1,031	1,097	1,184	1,260	1,361
Expected Savings	29	54	83	89	95	102
New Shortage	(934)	(1,014)	(1,080)	(1,167)	(1,243)	(1,344)
Shortage Reduction	3%	5%	7%	7%	7%	7%
Bosque						
New Demand	975	1,093	1,195	1,318	1,424	1,548
Expected Savings	30	58	90	99	107	116
New Shortage	(610)	(729)	(831)	(953)	(1,059)	(1,184)
Shortage Reduction	5%	7%	10%	9%	9%	9%
Brazos						
New Demand	307	347	384	430	471	511
Expected Savings	9	18	29	32	35	38
New Shortage	—	(30)	(67)	(113)	(154)	(194)
Shortage Reduction	—	38%	30%	22%	19%	17%
Burleson						
New Demand	190	221	251	286	316	344
Expected Savings	6	12	19	21	24	26
New Shortage	—	—	—	(13)	(44)	(72)
Shortage Reduction	—	—	—	62%	35%	27%
Erath						
New Demand	71	78	84	91	98	106
Expected Savings	2	4	6	7	7	8
New Shortage	—	(4)	(10)	(17)	(24)	(32)
Shortage Reduction	—	51%	39%	29%	24%	20%
Fisher						
New Demand	186	214	237	264	288	312
Expected Savings	6	11	18	20	22	24
New Shortage	(86)	(114)	(137)	(164)	(188)	(212)
Shortage Reduction	6%	9%	12%	11%	10%	10%
Grimes						
New Demand	249	282	312	349	381	414
Expected Savings	8	15	24	26	29	31
New Shortage	—	(26)	(56)	(93)	(125)	(158)
Shortage Reduction	100%	36%	29%	22%	19%	16%

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Table 4B.2-13.
Projected Water Demands and Needs (Shortages) for
Manufacturing Users Considering up to a 7 Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	***2020***	***2030***	***2040***	***2050***	***2060***
Hill						
New Demand	82	92	100	111	120	130
Expected Savings	3	5	8	8	9	10
New Shortage	—	(5)	(13)	(24)	(33)	(43)
Shortage Reduction	—	49%	38%	26%	22%	18%
Hood						
New Demand	24	27	28	30	32	34
Expected Savings	1	1	2	2	2	3
New Shortage	(2)	(5)	(6)	(8)	(10)	(12)
Shortage Reduction	25%	23%	26%	22%	20%	17%
Johnson						
New Demand	2,057	2,391	2,700	3,064	3,391	3,714
Expected Savings	64	126	203	231	255	280
New Shortage	(1,698)	(2,033)	(2,343)	(2,708)	(3,036)	(3,359)
Shortage Reduction	4%	6%	8%	8%	8%	8%
Lampasas						
New Demand	125	135	142	153	162	174
Expected Savings	4	7	11	11	12	13
New Shortage	(107)	(117)	(124)	(135)	(144)	(156)
Shortage Reduction	3%	6%	8%	8%	8%	8%
Limestone						
New Demand	47	50	54	59	62	67
Expected Savings	1	3	4	4	5	5
New Shortage	(24)	(32)	(40)	(48)	(55)	(64)
Shortage Reduction	6%	8%	9%	8%	8%	7%
McLennan						
New Demand	3,420	3,865	4,257	4,739	5,172	5,600
Expected Savings	106	203	320	357	389	422
New Shortage	(678)	(738)	(769)	(882)	(985)	(1,086)
Shortage Reduction	13%	22%	29%	29%	28%	28%
Nolan						
New Demand	756	869	965	1,078	1,177	1,276
Expected Savings	23	46	73	81	89	96
New Shortage	—	—	—	—	(43)	(143)
Shortage Reduction	—	—	—	—	67%	40%

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Table 4B.2-13.
Projected Water Demands and Needs (Shortages) for
Manufacturing Users Considering up to a 7 Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	*2020*	*2030*	*2040*	*2050*	*2060*
Robertson						
New Demand	82	96	109	125	140	152
Expected Savings	3	5	8	9	11	11
New Shortage	—	(10)	(23)	(39)	(54)	(66)
Shortage Reduction	—	34%	26%	20%	16%	15%
Somervell						
New Demand	6	7	7	8	9	10
Expected Savings	0	0	1	1	1	1
New Shortage	(2)	(3)	(3)	(4)	(5)	(6)
Shortage Reduction	9%	12%	14%	13%	12%	11%
Washington						
New Demand	402	438	469	509	544	589
Expected Savings	12	23	35	38	41	44
New Shortage	—	(4)	(35)	(75)	(110)	(155)
Shortage Reduction	—	85%	50%	34%	27%	22%
Williamson						
New Demand	1,539	1,761	1,972	2,221	2,446	2,656
Expected Savings	48	93	148	167	184	200
New Shortage	(994)	(1,221)	(1,435)	(1,687)	(1,915)	(2,128)
Shortage Reduction	5%	7%	9%	9%	9%	9%
Total Savings	**355**	**684**	**1,081**	**1,206**	**1,317**	**1,430**

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Table 4B.2-14.
Projected Water Demands and Needs (Shortages) for
Steam-Electric Users Considering up to a 7% Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	2020	2030	2040	2050	2060
Bosque						
New Demand	4,193	5,879	6,729	7,914	9,360	11,124
Expected Savings	130	309	506	596	705	837
New Shortage	(455)	(2,141)	(2,991)	(4,176)	(5,622)	(7,386)
Shortage Reduction	22%	13%	14%	12%	11%	10%
Grimes						
New Demand	9,023	11,180	12,795	15,051	17,801	21,154
Expected Savings	279	588	963	1,133	1,340	1,592
New Shortage	—	—	—	(2,020)	(4,770)	(8,123)
Shortage Reduction	—	—	100%	36%	22%	16%
Johnson						
New Demand	1,164	1,140	1,116	1,116	1,116	1,116
Expected Savings	36	60	84	84	84	84
New Shortage	(1,164)	(1,140)	(1,116)	(1,116)	(1,116)	(1,116)
Shortage Reduction	3%	5%	7%	7%	7%	7%
Limestone						
New Demand	21,662	21,468	24,571	28,903	34,185	40,623
Expected Savings	670	1,130	1,849	2,176	2,573	3,058
New Shortage	—	—	—	(1,036)	(6,318)	(12,756)
Shortage Reduction	—	—	—	68%	29%	19%
McLennan						
New Demand	35,985	31,334	33,220	36,322	40,104	44,715
Expected Savings	1,113	1,649	2,500	2,734	3,019	3,366
New Shortage	(21,874)	(17,232)	(19,127)	(22,239)	(26,030)	(30,650)
Shortage Reduction	5%	9%	12%	11%	10%	10%
Milam						
New Demand	8,420	11,875	11,625	11,625	14,880	14,880
Expected Savings	260	625	875	875	1,120	1,120
New Shortage	(620)	(4,075)	(3,825)	(3,825)	(7,080)	(7,080)
Shortage Reduction	30%	13%	19%	19%	14%	14%
Nolan						
New Demand	1,276	1,788	2,046	2,407	2,847	3,383
Expected Savings	39	94	154	181	214	255

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Table 4B.2-14.
Projected Water Demands and Needs (Shortages) for
Steam-Electric Users Considering up to a 7% Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
New Shortage	(452)	(965)	(1,223)	(1,585)	(2,026)	(2,562)
Shortage Reduction	8%	9%	11%	10%	10%	9%
Palo Pinto						
New Demand	1,324	1,188	1,359	1,599	1,891	2,247
Expected Savings	41	63	102	120	142	169
New Shortage	—	—	—	—	(640)	(1,489)
Shortage Reduction	—	—	—	100%	18%	10%
Robertson						
New Demand	27,160	28,500	27,900	32,550	37,200	37,200
Expected Savings	840	1,500	2,100	2,450	2,800	2,800
New Shortage	—	—	—	(784)	(5,459)	(5,484)
Shortage Reduction	—	—	—	76%	34%	34%
Total Savings	**3,408**	**6,018**	**9,135**	**10,349**	**11,997**	**13,281**

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For the ten mining users with projected needs, the total water savings after 7 percent water demand reduction in 2060 is 1,074 acft/yr (a 11% reduction in total regional mining shortages) as shown in Table 4B.2-15. With the recommended demand reduction, the projected shortages are eliminated for Taylor County (2010 to 2060).

The Task Force report lists the following industrial BMPs that may be used to achieve the recommended water savings:[7]

1. Industrial Water Audit
2. Industrial Water Waste Reduction
3. Industrial Submetering
4. Cooling Towers
5. Cooling Systems (other than Cooling Towers)
6. Industrial Alternative Sources and Reuse and Recirculation of Process Water
7. Rinsing/Cleaning
8. Water Treatment
9. Boiler and Steam Systems

[7] Water Conservation Implementation Task Force, Report to the 79th Legislature, Texas Water Development Board,

10. Refrigeration (including Chilled Water)
11. Once-Through Cooling
12. Management and Employee Programs
13. Industrial Landscape
14. Industrial Site Specific Conservation

The Task Force report describes the above BMP methods and how they reduce water use; however, information regarding specific water savings and costs to implement conservation programs is generally unavailable. Conservation savings and costs are by nature facility-specific. Since industrial entities are presented on a county basis and are not individually identified, identification of specific water management strategies is not a reasonable expectation.

4B.2.3.3 Environmental Issues

The Task Force BMPs have been developed and tested through public and private sector research, and have been applied within the region. Such programs have been installed, and are in operation today, and are not expected to have significant environmental issues associated with implementation. For example, most BMPs improve water use efficiency without making changes to wildlife habitat. Thus, the proposed conservation practices do not have anticipated potential adverse effects, and may have potentially beneficial environmental effects.

4B.2.3.4 Engineering and Costing

The Brazos G RWPG recommends implementing water conservation for industrial users (manufacturing, steam-electric, and mining) with projected needs amounting to a 3 percent water demand reduction by 2010, 5 percent by 2020, and 7 percent from 2030 to 2060. The eighteen counties in the Brazos G Area with projected manufacturing shortages can save up to 1,430 acft/yr in 2060. The nine counties in the Brazos G Area with projected steam-electric shortages can save up to 13,281 acft in 2060. The ten counties in the Brazos G Area with projected mining shortages can save up to 1,074 acft in 2060. Costs to implement BMPs vary from site to site and the Brazos G RWPG recognizes that industries will pursue conservation strategies that are economically feasible with water savings benefits. For this reason, it is impractical to evaluate the costs of implementing industrial water conservation strategies.

Table 4B.2-15.
Projected Water Demands and Needs (Shortages) for Mining Users Considering up to a 7% Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Haskell						
New Demand	90	86	84	83	82	81
Expected Savings	3	5	6	6	6	6
New Shortage	(53)	(48)	(46)	(44)	(42)	(41)
Shortage Reduction	5%	9%	12%	12%	13%	13%
Hood						
New Demand	157	153	149	148	147	146
Expected Savings	5	8	11	11	11	11
New Shortage	(20)	(17)	(14)	(14)	(13)	(13)
Shortage Reduction	19%	32%	45%	45%	46%	46%
Johnson						
New Demand	359	371	375	386	397	405
Expected Savings	11	20	28	29	30	31
New Shortage	(246)	(255)	(257)	(267)	(277)	(284)
Shortage Reduction	4%	7%	10%	10%	10%	10%
Knox						
New Demand	25	25	24	24	24	24
Expected Savings	1	1	2	2	2	2
New Shortage	(2)	(2)	(1)	(1)	(1)	(1)
Shortage Reduction	26%	43%	61%	61%	61%	61%
Lampasas						
New Demand	147	137	129	126	122	119
Expected Savings	5	7	10	9	9	9
New Shortage	(21)	(18)	(14)	(15)	(13)	(14)
Shortage Reduction	18%	29%	41%	39%	42%	39%
Nolan						
New Demand	270	264	259	259	259	259
Expected Savings	8	14	19	19	19	19
New Shortage	(192)	(185)	(180)	(178)	(178)	(178)
Shortage Reduction	4%	7%	10%	10%	10%	10%

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Table 4B.2-15.
Projected Water Demands and Needs (Shortages) for Mining Users Considering up to a 7% Percent Demand Reduction by 2030

	Projections (acft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Somervell						
New Demand	295	273	259	251	245	239
Expected Savings	9	14	19	19	18	18
New Shortage	(97)	(84)	(75)	(72)	(70)	(67)
Shortage Reduction	9%	15%	21%	21%	21%	21%
Stephens						
New Demand	8,454	8,862	8,897	9,112	9,322	9,623
Expected Savings	261	466	670	686	702	724
New Shortage	(4,773)	(5,180)	(5,214)	(5,429)	(5,638)	(5,938)
Shortage Reduction	5%	8%	11%	11%	11%	11%
Taylor						
New Demand	276	289	291	299	307	316
Expected Savings	9	15	22	23	23	24
New Shortage	—	—	—	—	—	—
Shortage Reduction	100%	100%	100%	100%	100%	100%
Williamson						
New Demand	2,283	2,484	2,599	2,764	2,929	3,050
Expected Savings	71	131	196	208	220	230
New Shortage	(1,234)	(1,334)	(1,380)	(1,478)	(1,577)	(1,652)
Shortage Reduction	5%	9%	12%	12%	12%	12%
Total Savings	**382**	**681**	**983**	**1,012**	**1,041**	**1,074**

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4B.2.3.5 Implementation Issues

Demand reduction through water conservation is being implemented throughout the Brazos G Area. The rate of adoption of efficient water-using practices is dependent upon public knowledge of the benefits, information about how to implement water conservation measures, and financing.

There is public support for industrial water conservation and it is being implemented at a steady pace, and as water markets for conserved water expand, this practice will likely reach greater potentials. The TWDB has industrial water conservation programs including presentations and workshops for utilities who wish to train staff to develop local programs including water use site surveys, publications on industrial water reuse potential, and information on tax incentives for industries that conserve or reuse water. Future planning efforts should consider the use of detailed studies to fully determine the maximum potential benefits of mining conservation.

This option is compared to the plan development criteria in Table 4B.2-16 and the option meets each criterion.

Table 4B.2-16. Comparison of Industrial Water Conservation Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1 Quantity	1. Manufacturing Firm Yield: up to 1,430 acft/yr Steam-Electric Firm Yield: up to 13,281 acft/yr Mining Firm Yield: up to 1,074 acft/yr
2. Reliability and Cost	2. Good reliability.
3. Cost	3. Cost: Highly variable based on BMP selected and facility specifics.
B. Environmental factors	
1. Instream flows	1. None or low impact.
2. Bay and Estuary Inflows	2. None or low impact.
3. Wildlife Habitat	3. None or low impact.
4. Wetlands	4. None or low impact.
5. Threatened and Endangered Species	5. None.
6. Cultural Resources	6. No cultural resources affected.
7. Water Quality	7. None or low impact.
C. Impacts to State water resources	• No apparent negative impacts on water resources
D. Threats to agriculture and natural resources in region	• None
E. Recreational impacts	• None
F. Equitable Comparison of Strategies	• Standard analyses and methods used
G. Interbasin transfers	• None
H. Third party social and economic impacts from voluntary redistribution of water	• None
I. Efficient use of existing water supplies and regional opportunities	• Improvement over current conditions by reducing the rate of decline of local groundwater levels.
J. Effect on navigation	• None
K. Consideration of water pipelines and other facilities used for water conveyance	• None

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4B.3 Wastewater Reuse

Wastewater reuse would be defined as the types of projects that utilize treated wastewater effluent as a replacement for potable water supply, reducing the overall demand for fresh water supply. Wastewater reuse typically involves a capital project connecting the treatment plant discharge facilities to an individual area that has a relatively high, localized use that can be met with non-potable water. Examples most frequently include the irrigation of golf courses and other public lands and specific industries or industrial use areas. Few entities, if any, would be capable of utilizing their entire effluent capacity for reuse at present; long term, it is likely that increased pressure on water supplies will result in increased emphasis on reuse, with reused water approaching the quantity of effluent available. Downstream needs, both water rights and environmental instream uses, would have to be met. Any remaining flows after these needs are met could potentially be utilized. Virtually any water supply entity with a wastewater treatment plant could pursue a reuse alternative, provided that downstream water rights do not have a claim for the entire return flow. Current examples of existing reuse systems in the Brazos G Area include those of the cities of Abilene, Cleburne, Georgetown, and Round Rock. Many other smaller communities make their effluent available for irrigation purposes.

Wastewater reuse can be classified into two forms, defined by how the reuse water is handled:

1. Direct Reuse – Pipe treated wastewater directly from wastewater plant to place of use (also called “flange-to-flange”).
2. Indirect Reuse – Discharge treated wastewater to river, stream, or lake for subsequent diversion downstream (also called “bed and banks”).

4B.3.1 Direct Reuse

All direct reuse water supply options assume that treated wastewater remains under the control (in pipelines or storage tanks) at all times from treatment to point of use by the entity treating the wastewater and/or supplying reuse water.

Wastewater reuse quality and system design requirements are regulated by TCEQ by 30 TAC §210. TCEQ allows two types of reuse as defined by the use of the water and the required water quality:

- Type 1 – Public or food crops generally can come in contact with reuse water.
- Type 2 – Public or food crops cannot come in contact with reuse water.

Current TCEQ criteria for reuse water are shown in Table 4B.3-1. Trends across the country indicate that criteria for unrestricted reuse water will likely tend to become more stringent over time. The water quality required for Type 1 reuse water is more stringent with lower requirements for oxygen demand (BOD_5 or $CBOD_5$), turbidity, and fecal coliform levels.

Table 4B.3-1.
TCEQ Quality Standards for Reuse Water

Parameter	***Allowable Level***
Type 1 Reuse	
BOD_5 or $CBOD_5$	5 mg/L
Turbidity	3 NTU
Fecal Coliform	20 CFU / 100 ml[1]
Fecal Coliform (not to exceed)	75 CFU / 100 ml[2]
Type 2 Reuse	
For a system other than a pond system	
BOD_5	20 mg/L
or $CBOD_5$	15 mg/L
Fecal Coliform	200 CFU / 100 ml[1]
Fecal Coliform (not to exceed)	800 CFU / 100 ml[2]
Type 2 Reuse	
For a pond system	
BOD_5	30 mg/L
Fecal Coliform	200 CFU / 100 ml[1]
Fecal Coliform (not to exceed)	800 CFU / 100 ml[2]

[1] geometric mean
[2] single grab sample

Two approaches were utilized to evaluate a broad range of potential reuse water supplies:

1. General evaluation of wastewater reuse for multiple water user groups with needs and potential wastewater sources.
2. Specific supply options for eight (8) water user groups with defined wastewater sources and identified needs.

The following nine potential wastewater reuse projects were evaluated as specific management strategies:

1. City of Sweetwater
2. City of College Station
3. City of Round Rock
4. City of Bryan
5. City of Cleburne
6. City of Godley
7. City of Joshua
8. Waco East – LS Power Station, Hallsburg, Mart, and Riesel
9. Waco North – Chalk Bluff WSC and Gholson

4B.3.1.1 General Evaluation of Direct Reuse Potential for Multiple Water User Groups

4B.3.1.1.1 Description of Option

Many water user groups with need have the potential to develop wastewater reuse projects, and a general evaluation of wastewater reuse potential was conducted for these entities. Figure 4B.3-1 shows the municipal county balances and the "Year 2060 Confirmed Discharge" for wastewater treatment plants with 1 MGD or greater treatment capacity. The "Year 2060 Confirmed Discharge" is the projected wastewater discharge into the receiving stream as reported by the entity responsible for the wastewater treatment plant. Some entities reported that they intended to utilize all 2060 wastewater effluent for reuse and therefore the confirmed discharge reported is zero. Figure 4B.3-2 shows the municipal balance of individual water user groups.

4B.3.1.1.2 Available Supply

The water supply from reuse that would be potentially available for any entity would be that portion of their wastewater effluent stream that is over and above any currently planned reuse and any commitments made to downstream water rights and environmental flows. Of this potential, the amount that can actually be recognized depends on the availability of suitable uses within an economical distance from the treatment plant. If individual high water use industrial plants or open land that benefits from irrigation, such as golf courses, are located relatively close to the plant, then reuse can provide a substantial benefit to water supplies.

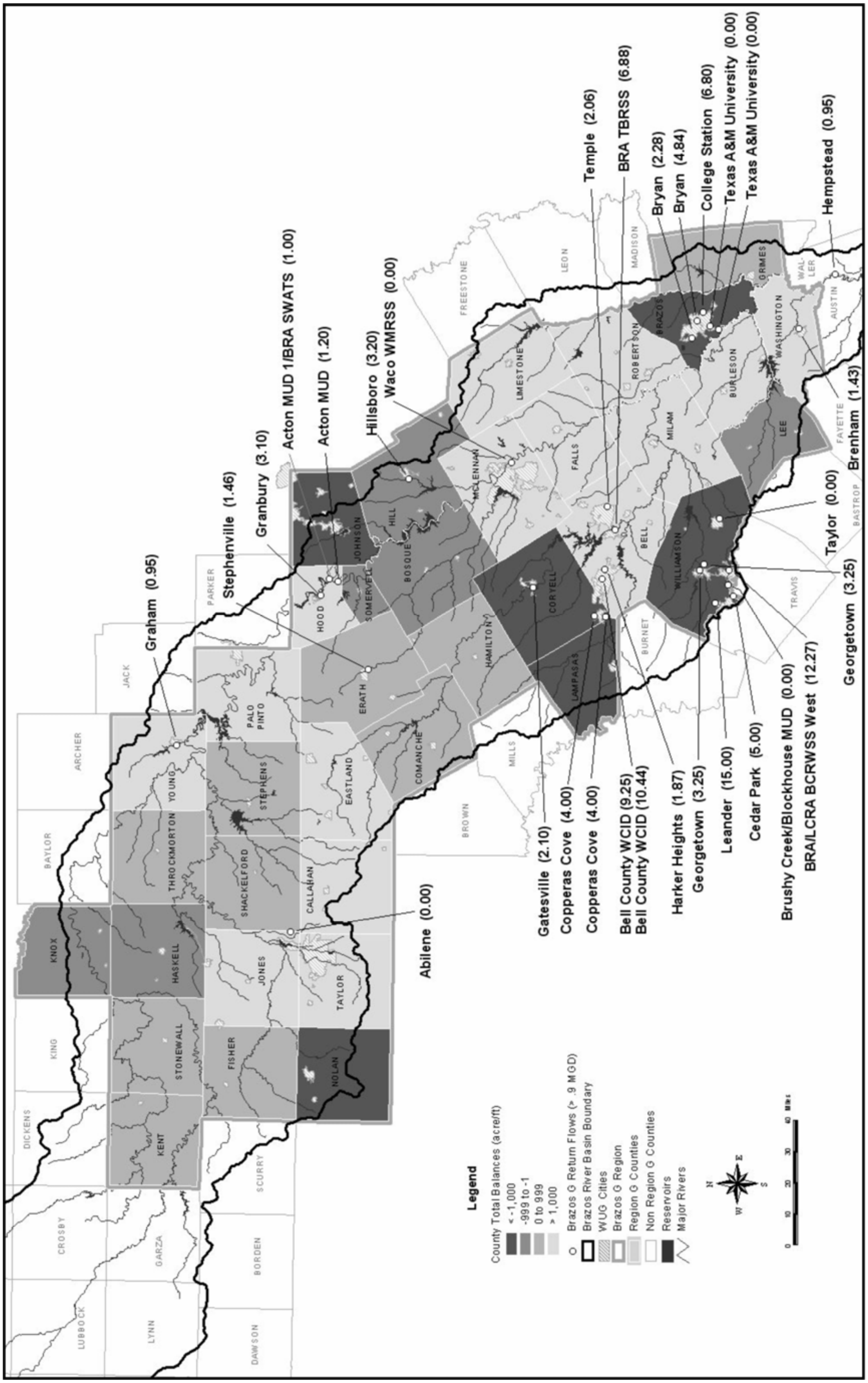

Figure 4B.3-1. Year 2060 Confirmed Discharges and County Balances

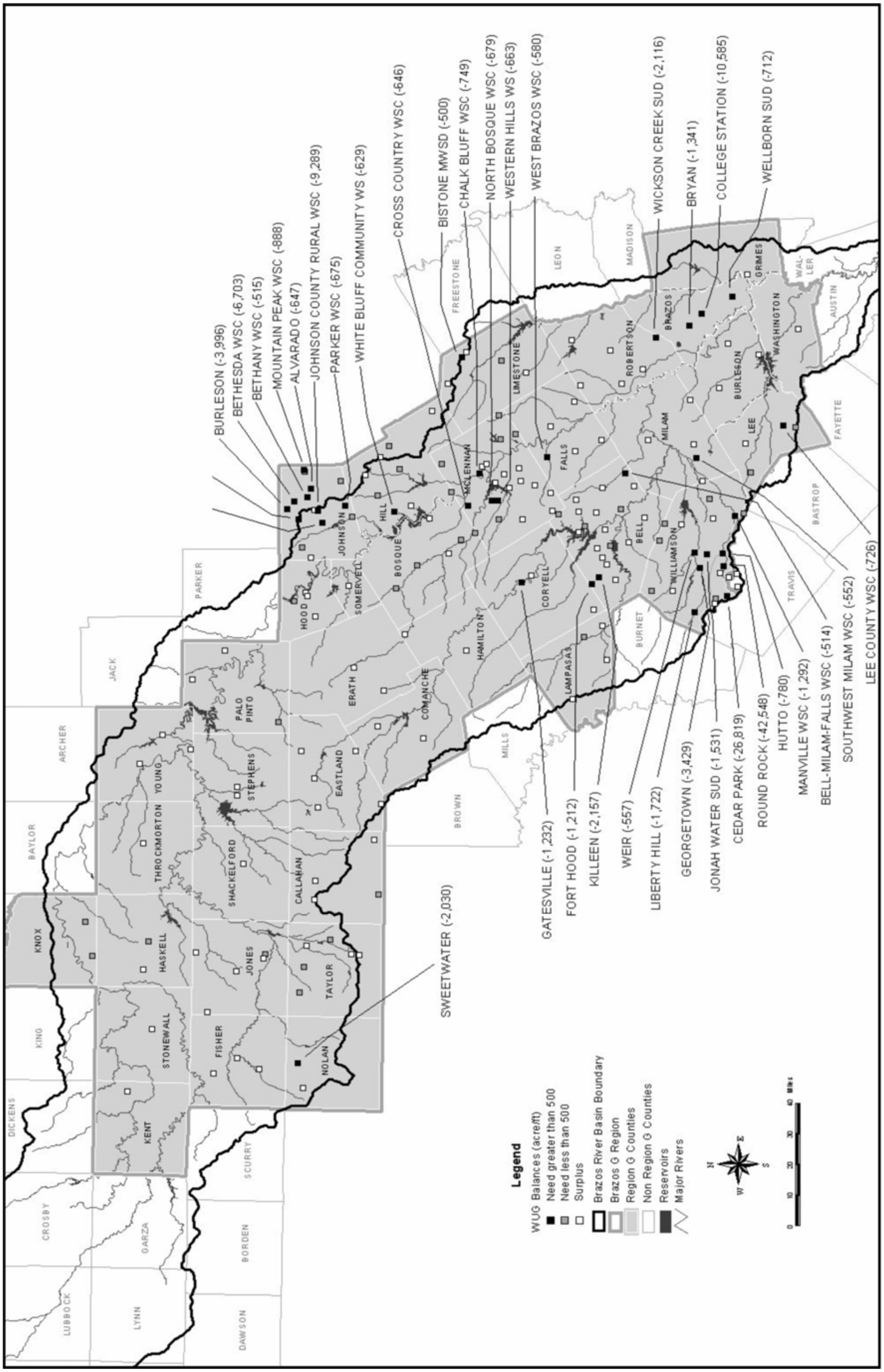

Figure 4B.3-2. Year 2060 Water User Group Balances

In order to isolate those communities that may potentially benefit from a reuse program, information regarding each of the communities with both a projected need for additional water supply and a wastewater treatment plant (WWTP) proximate to need was gathered. Table 4B.3-2 lists these water user groups, their projected need, approximate average effluent, and an assumed portion of the effluent that may be recoverable. If a WWTP with discharge over 1 MGD is proximate to the need it is listed in the table. Initially, the portion of effluent that may be recoverable was estimated as 25 percent of the current average effluent plus 50 percent of future effluent. A relatively low recoverable percentage was used because of the variability in effluent flows, variability in demand, and the large storage volumes that would likely be needed to match availability with demand. Entities were then contacted to verify this estimate and the assumed effluent recoverable adjusted based on feedback from entities. The difference between the potential supply and any existing reuse would be considered the amount available.

Several water user groups show a potential reuse amount greater than the projected need and could possibly meet their need in this manner. Utilization of this water source is contingent on whether a potential use for the wastewater effluent exists within an economical distance from the treatment plant.

4B.3.1.1.3 Environmental Issues

A summary of environmental issues is presented in Table 4B.3-3.

4B.3.1.1.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply would be expected to vary considerably between entities based on the upgrades required both in treatment and distribution. Therefore, general cost estimates were developed for varying wastewater reuse scenarios as described in Table 4B.3-4. To provide more flexibility in the types of wastewater reuse applications possible, the scenarios assume the use of a type 1 wastewater effluent.

Scenarios 1, 2, 3, and 5 include central storage at the wastewater plant with reuse water delivered to demand location on an as needed basis. An alternate delivery option not included here is a more decentralized reuse system with storage located at the point of use. Providing storage at the point of use may decrease required pipeline and pump station size because the water can be transported at a more uniform rate to fill storage tanks at the point of use. However, installation of storage tanks at the point of use may be problematic in highly urbanized areas or undesirable near high public use areas.

**Table 4B.3-2.
General Wastewater Reuse Potential**

Water User Group	County	Proximate WWTP Over 1 MGD	2060 Projected Need (acft/yr)	2060 Projected Need Percent of Demand	Current Reuse	2060 Estimated Available WWTP Effluent (acft/yr)	2060 Potential Reuse (acft/yr)
Dog Ridge WSC	Bell	BRA TBRSS	311	32%	N	14,090	5,560
Killeen	Bell	Bell County WCID #1-3	2,157	7%	N	19,000	7,297
Little River Academy	Bell	BRA TBRSS	29	10%	N	14,090	5,560
Morgan's Point Resort	Bell	BRA TBRSS	255	47%	Y	14,090	5,560
Meridian	Bosque		69	28%	N	NA	NA
Valley Mills	Bosque		102	41%	N	NA	NA
Walnut Springs	Bosque		59	59%	Y	NA	NA
Bryan	Brazos	City of Bryan	1,341	8%	Y	12,532	4,551
College Station	Brazos	College Station + A&M Univ.	3,436	11%	N	15,312	5,347
Gatesville	Coryell	City of Gatesville-2	1,232	20%	N	4,024	1,670
Kempner WSC	Coryell	City of Copperas Cove-2	2,462	62%	N	2,724	964
Haskell	Haskell		472	100%	N	NA	NA
Oak Trail Shores Sub.	Hood	City of Granbury	101	21%	N	3,475	2,197
Alvarado	Johnson		647	88%	N	NA	NA
Cleburne	Johnson	City of Cleburne	2,853	29%	N	2,623	1,625
Godley	Johnson	City of Godley	403	94%	N	336	336
Joshua	Johnson	Johnson County FWSD #1	1,163	91%	N	401	200
Hawley WSC	Jones	City of Abilene	197	59%	N	14,460	4,047
Aqua WSC	Lee		176	28%	N	NA	NA
Groesbeck	Limestone		87	7%	N	NA	NA
Hallsburg	McLennan	City of Waco WMRSS	172	95%	N	31,779	9,741
Mart	McLennan	City of Waco WMRSS	390	94%	N	31,779	9,741
Riesel	McLennan	City of Waco WMRSS	129	94%	N	31,779	9,741
Sweetwater	Nolan	City of Sweetwater	2,030	73%	N	1,681	841
Merkel	Taylor		52	12%	N	NA	NA
Cedar Park	Williamson	City of Cedar Park	26,819	71%	N	23,585	11,366
Florence	Williamson		232	49%	Y	NA	NA
Hutto	Williamson		780	96%	N	NA	NA
Georgetown	Williamson	City of Georgetown	3,429	12%	Y	13,138	5,952
Jonah Water SUD	Williamson	City of Georgetown-2	1,531	32%	N	6,793	3,251
Leander	Williamson	City of Leander	232	3%	N	16,814	15,010
Manville WSC	Williamson		1,292	35%	N	NA	NA
Round Rock	Williamson	BRA/LCRA BCRWSS West	42,548	68%	Y	19,079	7,443
Thrall	Williamson		239	90%	N	NA	NA
Weir	Williamson	City of Georgetown-1	557	96%	N	6,345	2,701

Table 4B.3-3.
Environmental Issues: General Wastewater Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations.
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows.
Bays and Estuaries	Possible low negative impact.
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Negligible impact.
Comments	Assumes needed infrastructure will be in urbanized areas.

Table 4B.3-4.
Wastewater Reuse Scenarios

Scenario #	*Treatment*	*Distribution*
1	Existing WWTP is achieving treatment that meets the Type 1 effluent requirements. Treatment upgrade includes only the addition of chlorine for distribution.	Treated wastewater is supplied to demand location(s) from central WWTP by addition of piping and pump station.
2	Existing WWTP is nearly achieving treatment that meets the Type 1 effluent requirements. Treatment upgrade includes tertiary treatment and chlorine.	Treated wastewater is supplied to demand location(s) from central WWTP by addition of piping and pump station.
3	Existing WWTP requires extensive upgrade to meet the Type 1 effluent requirements. Treatment upgrade includes additional secondary treatment, tertiary treatment, and chlorine.	Treated wastewater is supplied to demand location(s) from central WWTP by addition of piping and pump station.
4	New satellite WWTP to meet Type 1 effluent requirements. Does not include solids handling (solids are discharged to existing collection system	Demand location is adjacent to satellite WWTP. Minimal distribution piping and pumping required.
5	New reuse WWTP to meet type 1 effluent requirements. Includes solids handling and all ancillary facilities	Treated wastewater is supplied to demand location(s) from central WWTP by addition of piping and pump station.

Scenario 4 is a decentralized wastewater reuse option where the water is diverted from wastewater lines, treated, and stored near the point of use. A wastewater plant used in this application is commonly referred to as a satellite plant and generally consists of full wastewater treatment to produce effluent meeting reuse standards, but excluding facilities for solids handling. Solids from the wastewater satellite plant can be returned to the wastewater line for transport to a central wastewater plant with solids handling capabilities. This decentralized approach may be beneficial for circumstances where a high reuse water demand center is located far away from an existing WWTP.

The decreased wastewater flow to existing facilities (both treatment and collection systems) should be considered as a benefit of using a decentralized reuse option. The addition of a new satellite or full WWTP to provide reuse water may delay or eliminate the need to upgrade or expand existing centralized wastewater facilities.

Cost estimates were developed for each of these scenarios with required facilities for each scenario shown in Tables 4B.3-5 and 4B.3-6. The demand for reuse water used for irrigation of golf courses, parks, schools, crops, or other landscapes will vary seasonally. For planning purposes the application rates in Table 4B.6-7 are assumed to determine the available project yield for varying sizes of wastewater reuse facilities. Reuse facilities are sized for the peak usage periods, and consequently, the average annual rate of usage may be considerably lower than the peak usage. For a reuse system with typical application rates, as shown in Table 5A.6-7, the annual available project yield is 57 percent of the reuse system capacity. Available project yield may be higher than 57 percent of maximum capacity for systems supplying a large portion of the reuse water to industrial or other users that have a more uniform reuse water demand.

Irrigation water for landscapes such as golf courses and parks will generally be applied during periods when these areas are not being utilized, typically at night. Therefore, the distribution facilities are sized to deliver the total daily demand in a 6-hour period. Pumping facilities are sized to provide a residual pressure of 60 psi at the delivery point.

Table 4B.3-5.
Wastewater Reuse Scenarios 1, 2, 3, and 5 Required Distribution Facilities

Facility	Maximum Capacity (MGD)				Description
	0.5	1	5	10	
Pump Station, HP	127	248	1,209	2,332	Capacity to deliver maximum daily demand in 6 hours
Storage Tank, MG	0.5	1	5	10	Store one days treated reuse water at WWTP
Pipeline, Size in Inches (Length in Miles)	12 (2)	16 (2)	33 (3) 18 (2) 12 (1)	48 (4) 18 (3) 12 (2)	Capacity to deliver maximum daily demand in 6 hours
Available Project Yield, acft/yr (MGD)	319 (0.28)	638 (0.57)	3,193 (2.85)	6,385 (5.7)	Yield is 57 percent of maximum treatment capacity based on seasonal use shown in Table 4B.3-7

Table 4B.3-6.
Wastewater Reuse Scenario 4 Required Distribution Facilities

Facility	Maximum Capacity (MGD)				Description
	0.5	1	5	10	
Pump Station, HP	108	215	1,081	2,109	Capacity to deliver maximum daily demand in 6 hours
Storage Tank, MG	0.5	1	5	10	Store one days treated reuse water at WWTP near demand location
Pipeline, Size in Inches (Length in Miles)	12 (0.5)	16 (0.5)	33 (1) 18 (0.5) 12 (0.5)	48 (2) 18 (1) 12 (1)	Capacity to deliver maximum daily demand in 6 hours
Available Project Yield, acft/yr (MGD)	319 (0.28)	638 (0.57)	3,193 (2.85)	6,385 (5.7)	Yield is 57 percent of maximum treatment capacity based on seasonal use shown in Table 4B.3-7

Table 4B.3-7.
Wastewater Reuse Irrigation Application Rate

Use Level	*Application Rate*	*Duration*
Peak	1.25 in/week	4 months
Normal	0.75 in/week	3 months
Below Normal	0.25 in/week	5 months
Average	0.71 in/week	weighted
Average/Peak	0.71 / 1.25 = 0.57	

Table 4B.3-8 shows annual cost of reuse water per 1,000 gallons for a range of project scenarios and capacities. Figure 4B.3-3 expresses those costs graphically as an annual cost per acft. These costs are for general planning purposes and will vary significantly depending on the specific circumstances of an individual water user group. Tables 4B.3-9 and 4B.3-10 show the total project capital costs and total operations and maintenance costs for reuse water supplies, respectively.

Table 4B.3-8.
General Wastewater Reuse Annual Cost of Water
($ per 1,000 gal available project yield)
Second Quarter 2002 Prices

Scenario	*Capacity (MGD)*			
	0.5	*1*	*5*	*10*
1	$2.19	$1.61	$1.18	$1.05
2	$4.42	$3.01	$1.62	$1.32
3	$6.04	$4.41	$2.83	$2.48
4	$6.39	$4.88	$3.01	$2.61
5	$8.18	$6.91	$4.23	$3.82
Debt Service (6 percent for 30 years)				

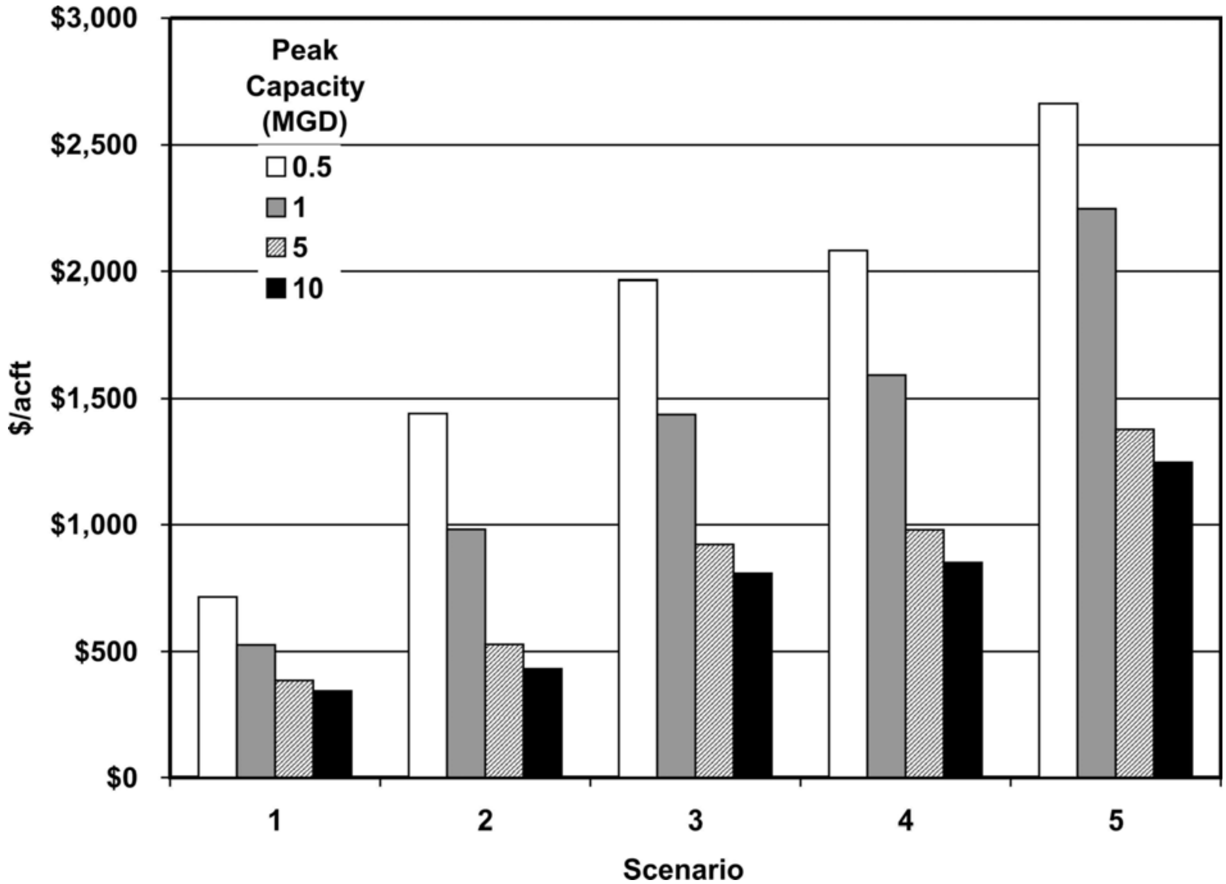

Figure 4B.3-3. General Wastewater Reuse Annual Cost of Water
($ per acft available project yield)
Second Quarter 2002 Prices

Table 4B.3-9.
General Wastewater Reuse Total Project Capital Cost
($ per gallon maximum capacity)
Second Quarter 2002 Prices

Scenario	*Maximum Capacity (MGD)*			
	0.5	*1*	*5*	*10*
1	$5.12	$3.66	$2.74	$2.44
2	$7.65	$5.35	$3.28	$2.78
3	$9.64	$6.90	$4.49	$3.88
4	$10.26	$7.93	$4.82	$4.07
5	$16.01	$13.06	$7.03	$6.10

Table 4B.3-10.
General Wastewater Reuse Total Operations and Maintenance Cost
($ per 1,000 gallons)
Second Quarter 2002 Prices

Scenario	Maximum Capacity (MGD)			
	0.5	1	5	10
1	$0.40	$0.34	$0.23	$0.20
2	$1.75	$1.14	$0.48	$0.35
3	$2.67	$2.00	$1.26	$1.13
4	$2.81	$2.12	$1.33	$1.19
5	$2.59	$2.35	$1.77	$1.69

The general wastewater reuse costs are utilized to develop the cost estimates for individual water user groups shown in Table 4B.3-11. The reuse project maximum capacity (MGD) for each water user group was developed based on the "2060 Projected Need" and "2060 Potential Reuse," as shown in Table 4B.3-3. A reuse scenario, as shown in Table 4B.3-4, was applied to each water user group based on available information about existing wastewater treatment facilities proximate to the need.

Information for individual water user groups that have specific reuse as water supply options are not included in Table 4B.3-11; the individual options should be referenced for information on reuse options for these water user groups.

4B.3.1.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-12, and the option meets each criterion. Each community that pursues wastewater reuse will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit restrictions.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Table 4B.3-11.
Cost Estimate Summaries
Reuse as a Water Management Strategy for Multiple Water User Groups
Second Quarter 2002 Prices

Water User Group	*County*	*Reuse Maximum Capacity (MGD)*	*Available Project Yield (MGD)*	*Scenario*	*Unit Cost ($/1000 gal)*	*Project Cost ($/gal)*	*Total Project Cost ($)*
Dog Ridge WSC	Bell	0.50	0.29	2	$4.42	$7.65	$3,826,000
Fort Hood	Bell	1.00	0.57	1	$1.61	$3.66	$3,655,000
Killeen	Bell	1.00	0.57	1	$1.61	$3.66	$3,655,000
Little River Academy	Bell	0.20	0.11	2	$4.42	$7.65	$1,530,400
Morgan's Point Resort	Bell	0.20	0.11	2	$4.42	$7.65	$1,530,400
Meridian	Bosque	0.20	0.11	2	$4.42	$7.65	$1,530,400
Valley Mills	Bosque	0.20	0.11	2	$4.42	$7.65	$1,530,400
Walnut Springs	Bosque	0.10	0.06	2	$4.42	$7.65	$765,200
Bryan	Brazos	See Individual Option					
College Station	Brazos	See Individual Option					
Gatesville	Coryell	1.00	0.57	2	$3.01	$5.35	$5,354,000
Kempner WSC	Coryell	1.00	0.57	2	$3.01	$5.35	$5,354,000
Haskell	Haskell	0.50	0.29	2	$4.42	$7.65	$3,826,000
Oak Trail Shores Sub.	Hood	0.20	0.11	2	$4.42	$7.65	$1,530,400
Alvarado	Johnson	0.20	0.11	2	$4.42	$7.65	$1,530,400
Cleburne	Johnson	See Individual Option					
Godley	Johnson	See Individual Option					
Joshua	Johnson	See Individual Option					
Hawley WSC	Jones	0.10	0.06	2	$4.42	$7.65	$765,200
Aqua WSC	Lee	0.10	0.06	2	$4.42	$7.65	$765,200
Groesbeck	Limestone	0.20	0.11	2	$4.42	$7.65	$1,530,400
Hallsburg	McLennan	See Individual Option					
Mart	McLennan	See Individual Option					
Riesel	McLennan	See Individual Option					
Sweetwater	Nolan	See Individual Option					
Merkel	Taylor	0.10	0.06	2	$4.42	$7.65	$765,200
Cedar Park	Williamson	5.00	2.85	2	$1.62	$3.28	$16,394,000
Florence	Williamson	0.20	0.11	2	$4.42	$7.65	$1,530,400
Hutto	Williamson	0.50	0.29	2	$4.42	$7.65	$3,826,000
Georgetown	Williamson	5.00	2.85	2	$1.62	$3.28	$16,394,000
Jonah Water SUD	Williamson	1.00	0.57	2	$3.01	$5.35	$5,354,000
Leander	Williamson	1.00	0.57	2	$3.01	$5.35	$5,354,000
Manville WSC	Williamson	1.00	0.57	2	$3.01	$5.35	$5,354,000
Round Rock	Williamson	See Individual Option					
Thrall	Williamson	0.10	0.06	2	$4.42	$7.65	$765,200
Weir	Williamson	0.10	0.06	2	$4.42	$7.65	$765,200

Reuse of reclaimed wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water customers may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Table 4B.3-12.
Comparison of General Wastewater Reuse Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

4B.3.1.2 City of Sweetwater Reuse

4B.3.1.2.1 Description of Option

The City of Sweetwater currently does not utilize wastewater reuse as a water supply. The City completed a new WWTP in 2002 with a treatment capacity of 8 MGD. Currently, Sweetwater's treated wastewater flow averages 1.5 MGD with a maximum of 2.2 MGD. The new WWTP produces high quality effluent that meets the Type 1 Reuse requirement for a 30-day average of BOD_5 less than 5 mg/L. There are no identified reuse water users currently located near the Sweetwater WWTP. This option anticipates future demand for reuse water by an industrial customer located within 2 miles of the Sweetwater WWTP supplied with reuse water quality meeting Type 1 reuse requirements.

4B.3.1.2.2 Available Supply

The water supply that would be potentially available for Sweetwater would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant.

4B.3.1.2.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows; and
- Possible low negative impact to fish and wildlife habitat with reduced stream flows.

A summary of environmental issues is presented in Table 4B.3-13.

4B.3.1.2.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Sweetwater are summarized in Table 4B.3-14.

Table 4B.3-13.
Environmental Issues: Sweetwater Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

Table 4B.3-14
Required Facilities – Sweetwater Reuse for Industrial Use

Facility	***Description***
1 Treatment Upgrade	0.5 MGD, Scenario 1; existing wastewater treatment plant built recently meets Type 1 reuse standards, requiring only the addition of chlorine for distribution
1 Pump Station	76 hp; 1 MGD capacity to deliver average daily demand of 0.5 MGD in 12 hours
1 Storage Tank	0.5 MG; Store one days treated reuse water at wastewater plant
Pipeline	10,560 ft of 8-inch pipe
Available Project Yield	0.5 MGD (560 acft/yr), industrial customer consistently takes full demand all year

Costs presented in Table 4B.3-15 provide the total option costs for developing a wastewater reuse supply for an industrial customer. Compared to a reuse water supply for seasonal irrigation use, there is a significant decrease in the annual cost of water for a reuse supply delivered at a uniform rate throughout the year to an industrial customer. These unit cost savings are due to greater utilization of the capital improvements because the facilities do not need to be sized for a large peak season with significantly decreased use during the rest of the year or oversized to deliver the daily demand during a short period of the day as is generally required for an irrigation use.

Table 4B.3-15
Cost Estimate Summary
Reuse as a Water Management Strategy for Sweetwater
Costs for a 0.5 MGD Industrial Use
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$337,000
Transmission Pipeline	993,000
Reuse Water Treatment	27,000
Total Capital Cost	**$1,357,000**
Engineering, Legal Costs and Contingencies	$442,000
Environmental & Archaeology Studies and Mitigation	69,000
Land Acquisition and Surveying (12 acres)	90,000
Interest During Construction (2 years)	157,000
Total Project Cost	**$2,115,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$154,000
Operation and Maintenance:	
Intake, Pipeline, Pump Station	18,000
Reuse Water Treatment	11,000
Pumping Energy Costs (70,522 kWh @ $0.06/kWh)	4,000
Total Annual Cost	**$187,000**
Available Project Yield (acft/yr)	**560**
Annual Cost of Water ($ per acft)	**$334**
Annual Cost of Water ($ per 1,000 gallons)	**$1.02**

4B.3.1.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-16, and the option meets each criterion. Before pursuing wastewater reuse, Sweetwater will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit restrictions.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Table 4B.3-16.
Comparison of Sweetwater Reuse Option
to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

4B.3.1.3 City of College Station Reuse

4B.3.1.3.1 Description of Option

The City of College Station currently does not utilize wastewater reuse as a water supply. The City has obtained TCEQ Reclaimed Water Type 1 permits to utilize treated wastewater from the Lick Creek and Carters Creek WWTPs in the future if desired. The City evaluated several wastewater reuse options in a report dated November 20, 2001 titled “Veterans Park Irrigation Water Supply Study”. The assumptions from the study are utilized in developing this wastewater reuse option for the City.

This option consists of a reuse project to deliver treated wastewater for irrigation of Veterans Park as shown in Figure 4B.3-4. The irrigation demand at Veterans Park provided by the City is 1,500,000 gallons per week during peak summer irrigation season. It is assumed that Veterans Park will be irrigated three times a week for a maximum daily demand of 500,000 gallons. Reuse water will be supplied from the Carters Creek WWTP. This WWTP plant currently produces an effluent that meets TCEQ Type 1 reclaimed water standards, and the only treatment upgrade is the addition of chlorine for distribution residual.

4B.3.1.3.2 Available Supply

The water supply that would be potentially available for College Station would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The average daily effluent flow from the Carters Creek WWTP for the summer months of the year 2000 was 3,540 gpm (5.10 MGD). The reported minimum hourly flow from the Carters Creek WWTP for the summer of the year 2000 was approximately 1,540 gpm (2.22 MGD).

Figure 4B.3-4. College Station Reuse

Wastewater treatment plants located within the College Station water user group include two College Station operated WWTPs (Carters Creek and Lick Creek) and two Texas A&M University operated WWTPs. The combined Year 2060 Estimated WWTP Effluent for these four WWTP plants is 15,312 acft/yr (13.67 MGD). Based on feedback from the WWTP operators the combined Year 2060 Confirmed WWTP Effluent for these four WWTP is 7,617 acft/yr (6.8 MGD), which includes zero available effluent from the Texas A&M WWTP. The 2060 Potential Reuse is the difference between the Estimated and 2060 Effluent and the Confirmed 2060 Discharge, which is 7,695 acft/yr (6.87 MGD).

4B.3.1.3.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows; and
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows.

A summary of environmental issues is presented in Table 4B.3-17.

Table 4B.3-17.
Environmental Issues: College Station Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

4B.3.1.3.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for College Station are summarized in Table 4B.3-18.

Table 4B.3-18
Required Facilities – College Station Reuse for Veterans Park Irrigation

Facility	***Description***
Treatment Upgrade	0.22 MGD, Scenario 1; existing WWTP meets type 1 reuse standards, requiring only the addition of chlorine for distribution
Pump Station	43 hp; 0.67 MGD capacity to deliver 3 times/week demand of 0.5 MGD in 18 hours
Storage Tank	0.5 MG; Store one days treated reuse water at Veterans Park
Pipeline	15,260 ft of 8-inch pipe
Available Project Yield	0.12 MGD (137 acft/yr), yield is 57 percent of peak demand for irrigation customer with seasonal use as shown in Table 4B.3-7.

Costs presented in Table 4B.3-19 provide the total option costs for developing a wastewater reuse supply for irrigation of Veterans Park. The unit cost of a reuse water supply could potentially be decreased by the addition of other users within an economical distance from the WWTP(s).

4B.3.1.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-20, and the option meets each criterion. Before pursuing wastewater reuse, College Station will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.
- Potential other users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Table 4B.3-19
Cost Estimate Summary
Reuse as a Water Management Strategy for College Station
Costs for Irrigation of Veterans Park
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$229,000
Transmission Pipeline and Storage Tank	1,251,000
Reuse Water Treatment	17,000
Total Capital Cost	**$1,497,000**
Engineering, Legal Costs and Contingencies	$478,000
Environmental & Archaeology Studies and Mitigation	89,000
Land Acquisition and Surveying (15 acres)	119,000
Interest During Construction (2 years)	175,000
Total Project Cost	**$2,358,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$171,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	18,000
Reuse Water Treatment Plant	6,000
Pumping Energy Costs (80,814 kWh @ $0.06/kWh)	5,000
Total Annual Cost	**$200,000**
Available Project Yield (acft/yr)	**137**
Annual Cost of Water ($ per acft)	**$1,462**
Annual Cost of Water ($ per 1,000 gallons)	**$4.49**

Table 4B.3-20.
Comparison of College Station Reuse Option
to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

4B.3.1.4 City of Round Rock Reuse

4B.3.1.4.1 Description of Option

The City of Round Rock currently irrigates the Forest Creek Golf Course with treated wastewater effluent from the Brushy Creek Regional WWTP that is owned by the Lower Colorado River Authority (LCRA) and Brazos River Authority (BRA) Alliance. The water supplied to Forest Creek Golf Course meets Type 2 effluent requirements. The City has evaluated additional wastewater reuse options utilizing Type 1 Effluent[1]. The assumptions from previous evaluations are utilized in developing a wastewater reuse option for the City.

This option consists of a reuse project to deliver Type 1 treated wastewater for irrigation of Old Settler's Park. The peak irrigation demand at Old Settler's Park is estimated as 2.4 MGD. Type 1 reuse water will be supplied from the Brushy Creek Regional WWTP. This WWTP currently produces an effluent that meets TCEQ Type 2 reclaimed water standards and will require treatment upgrades to meet Type 1 standards.

4B.3.1.4.2 Available Supply

The water supply reductions that would be potentially available for Round Rock would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The Brushy Creek Regional WWTP Year 2060 Estimated WWTP Effluent is 13,744 acft/yr (12.27 MGD).

4B.3.1.4.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows; and
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows.

A summary of environmental issues is presented in Table 4B.3-21.

[1] HDR Engineering, Inc., "Master Plan for the Development of the Brushy Creek Regional Reclaimed Water System", Prepared for the Lower Colorado River Authority, March 2001.

4B.3.1.4.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Round Rock are summarized in Table 4B.3-22.

Table 4B.3-21.
Environmental Issues: Round Rock Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

Table 4B.3-22.
Required Facilities – Round Rock Reuse for Old Settler's Park Irrigation

Facility	*Description*
Treatment Upgrade	2.4 MGD, Scenario 2; existing WWTP meets Type 2 reuse standards, requiring additional tertiary treatment and addition of chlorine for distribution
Pump Station	162 hp; 2.4 MGD capacity to deliver peak capacity at uniform rate
Storage Tank	2.4 MG; Store one days treated reuse water at Old Settler's Park
Pipeline	10,000 ft of 12-inch pipe
Available Project Yield	1.37 MGD (1,532 acft/yr), yield is 57 percent of peak demand for irrigation customer with seasonal use as shown in Table 4B.3-7.

Costs presented in Table 4B.3-23 provide the total option costs for developing a wastewater reuse supply for irrigation of Old Settler's Park.

Table 4B.3-23
Cost Estimate Summary
Reuse as a Water Management Strategy for Round Rock
Costs for Irrigation of Old Settler's Park
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$564,000
Transmission Pipeline and Tank	1,964,000
Reuse Water Treatment	1,729,000
Total Capital Cost	**$4,257,000**
Engineering, Legal Costs and Contingencies	$1,448,000
Environmental & Archaeology Studies and Mitigation	85,000
Land Acquisition and Surveying (14 acres)	107,000
Interest During Construction (2 years)	472,000
Total Project Cost	**$6,369,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$463,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	34,000
Reuse Water Treatment Plant	241,000
Pumping Energy Costs (572,207 kWh @ $0.06/kWh)	34,000
Total Annual Cost	**$772,000**
Available Project Yield (acft/yr)	**1,532**
Annual Cost of Water ($ per acft)	**$504**
Annual Cost of Water ($ per 1,000 gallons)	**$1.55**

4B.3.1.4.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-24, and the option meets each criterion. Before pursuing wastewater reuse, Round Rock will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit restrictions.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Table 4B.3-24.
Comparison of Round Rock Reuse Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

4B.3.1.5 City of Bryan Reuse

4B.3.1.5.1 Description of Option

The City of Bryan currently irrigates the Traditions Golf Course with Type 2 treated wastewater effluent from Turkey Creek WWTP, a small package treatment plant located near the golf course with a capacity of 0.35 MGD. The City has two other WWTPs, Burton Creek and Still Creek, that produce effluent requiring additional treatment to meet Type 1 or 2 reuse water requirements. There are several parks, ball fields, and other green spaces dispersed throughout the City that could be irrigated with reuse water if the wastewater could be treated and distributed economically. However, these green spaces do not individually have large irrigation water demands and are located a significant distance from the existing wastewater treatment plant. Therefore, irrigation reuse options were not evaluated.

This option consists of a reuse project to deliver Type 1 treated wastewater to Bryan Utilities Lake, a small lake associated with a power generation plant (Figure 4B.3-5). The City has periodically supplied potable water to this lake for extended periods at a rate of up to 3,000 gpm (4.32 MGD). This option will replace a portion of this potable water demand with a wastewater reuse supply having a peak capacity of 1,500 gpm (2.16 MGD). Since Bryan Utilities Lake is used for recreational purposes, this option includes additional treatment at Still Creek WWTP to supply Type 1 reuse water to the lake. The reuse water supply will be delivered at a continuous daily rate during periods of demand, so no storage is required. The project yield is based on an average demand of 2.16 MGD for three months during each year.

Figure 4B.3-5. Bryan Reuse

4B.3.1.5.2 Available Supply

The water supply that would be potentially available for Bryan would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The Still Creek WWTP Year 2060 Estimated WWTP Effluent is 4,178 acft/yr

(3.73 MGD). The Burton Creek WWTP Year 2060 Estimated WWTP Effluent is 8,345 acft/yr (7.45 MGD).

4B.3.1.5.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible impact to water quality in Bryan Utilities Lake and potential for release downstream of reuse water from Bryan Utilities Lake,
- Possible increased water quality to remaining stream flows; and
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows.

A summary of environmental issues is presented in Table 4B.3-25.

Table 4B.3-25.
Environmental Issues: Bryan Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

4B.3.1.5.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Bryan are summarized in Table 4B.3-26.

Table 4B.3-26
Required Facilities – Bryan Reuse for Bryan Utilities Lake

Facility	*Description*
Treatment Upgrade	2.16 MGD, Scenario 2; existing WWTP requires additional tertiary treatment to meet type 1 standards and addition of chlorine for distribution
Pump Station	249 hp; 2.16 MGD capacity to deliver peak capacity at uniform rate
Storage Tank	None
Pipeline	29,000 ft of 12-inch pipe
Available Project Yield	0.54 MGD (605 acft/yr), yield is 3 months per year of peak demand supplied to lake

Costs presented in Table 4B.3-27 provide the total option costs for developing a wastewater reuse supply to Bryan Utilities Lake.

4B.3.1.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-28, and the option meets each criterion. Before pursuing wastewater reuse, Bryan will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit restrictions.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Table 4B.3-27.
Cost Estimate Summary
Reuse as a Water Management Strategy for Bryan
Costs for Bryan Utilities Lake Supply
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$747,000
Transmission Pipeline	1,496,000
Reuse Water Treatment	1,653,000
Total Capital Cost	**$3,896,000**
Engineering, Legal Costs and Contingencies	$1,289,000
Environmental & Archaeology Studies and Mitigation	174,000
Land Acquisition and Surveying (25 acres)	231,000
Interest During Construction (4 years)	895,000
Total Project Cost	**$6,485,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$471,000
Operation and Maintenance:	
Pipeline, Pump Station	34,000
Reuse Water Treatment Plant	58,000
Pumping Energy Costs (881,032 kWh @ $0.06/kWh)	13,000
Total Annual Cost	**$576,000**
Available Project Yield (acft/yr)	**605**
Annual Cost of Water ($ per acft)	**$952**
Annual Cost of Water ($ per 1,000 gallons)	**$2.92**

Table 4B.3-28.
Comparison of Bryan Reuse Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

4B.3.1.6 City of Cleburne Reuse

4B.3.1.6.1 Description of Option

The City of Cleburne obtains its water supply from Lake Pat Cleburne, Lake Aquilla, and groundwater from the Trinity Aquifer. The city owns and operates Lake Pat Cleburne, which impounds runoff from Nolan Creek for storage and use. The city also has contracted with the Brazos River Authority (BRA) for water supply from Lake Aquilla (5,300 acft/yr) and from the BRA System (4,700 acft/yr). The city owns and operates six wells that produce water from the

Trinity Aquifer. Based on the existing water supply available to the city, no shortages are projected through the year 2040. However, the City of Cleburne is projected to have a long-term deficit of 2,853 acft/yr in the year 2060.

The City of Cleburne has embraced the beneficial use of reuse water as a viable water management strategy to meet anticipated future shortages. The city plans to reuse available wastewater supplies to help meet its projected deficit in the year 2060, and has recently filed a water rights application for 8,440 acre feet (7.5 MGD) with TCEQ to allow reuse of all authorized discharges, which would provide for the city's needs well beyond the current planning horizon.

4B.3.1.6.2 Available Supply

The city currently supplies 2.0 MGD (2,240 acft/yr) of reuse water directly to Ponderosa Pines Power Plant located north of the city for use as cooling water. The City of Cleburne owns and operates the existing reuse water treatment facility located on the city's wastewater treatment plant site. The facility is designed for 2.0 MGD and utilizes inclined plate clarification technology to produce a Type 1 effluent for use in unrestricted areas. A 16-inch diameter reuse water transmission line exists along the east side of the city to convey reuse water from the wastewater facility to the power plant.

The city intends to expand the reuse water treatment facilities in the near future to accommodate planned increases in reuse. Imminent plans for increased reuse include the supply of an average of 250,000 gallons per day to a sports complex currently designed east of the city. In this scenario, reuse water will be conveyed to the complex via a new 6-inch diameter branch line, approximately 3,170 feet in length, which would intersect the existing 16-inch diameter reuse water pipeline. The reuse water will be used for irrigation of the turf fields. Other potential future uses identified by the City of Cleburne and as indicated on Figure 4B.3-6 include the following:

- Supply of reuse water for irrigation of a new golf course planned northeast of the city;
- Irrigation of the existing city-owned golf course located east and adjacent to Lake Pat Cleburne;
- Supply of reuse water for irrigation of commercial facilities (hospital complex, college grounds, etc.);
- Supply to new commercial developments associated with the Highway 121 corridor to Fort Worth currently under design within the western portion of the city;

- Supply of reuse water for use in fracing gas wells;
- Additional cooling water for the Ponderosa Pines Power Plant; and
- Supply of reuse water to other industries.

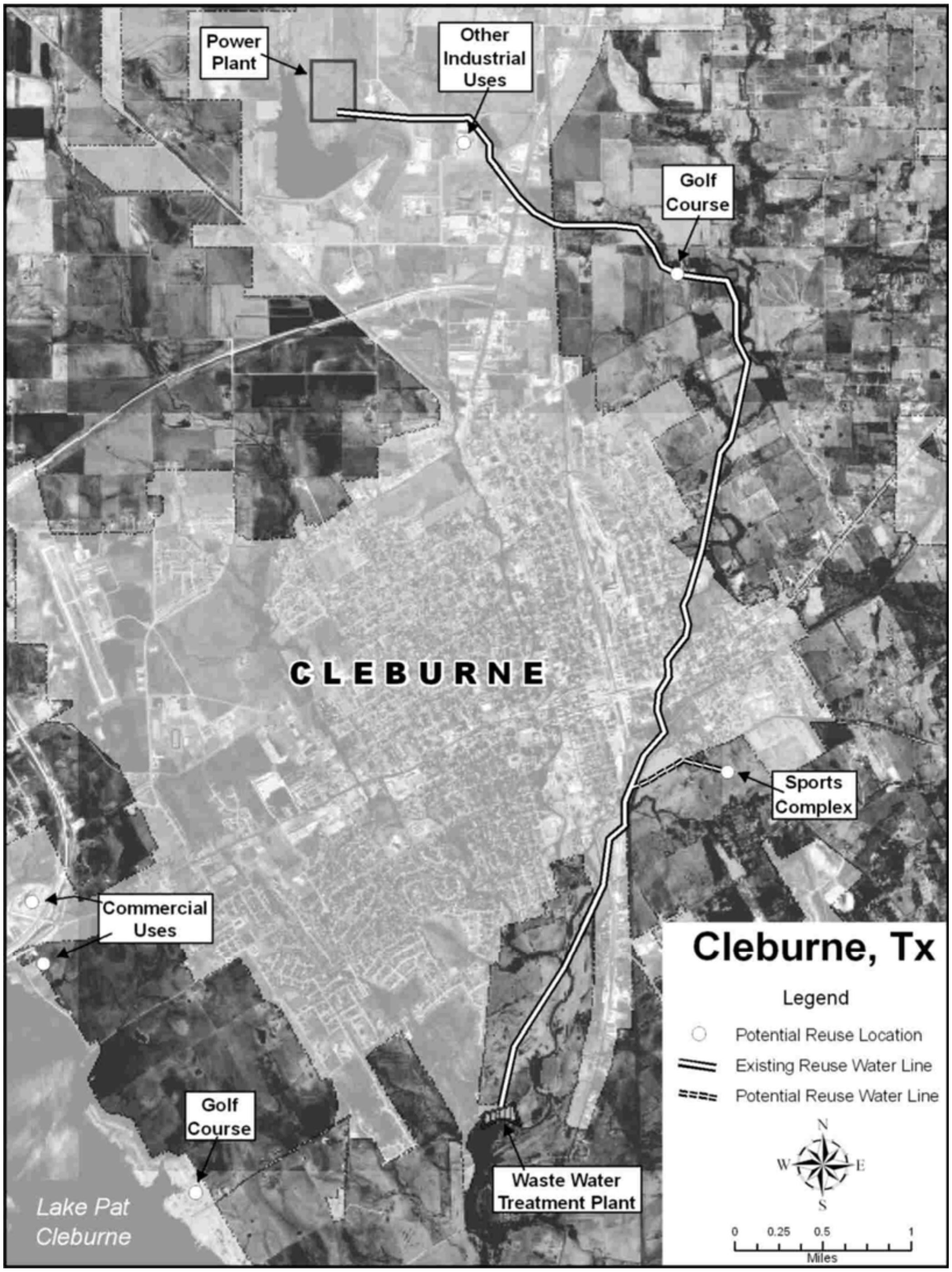

Figure 4B.3-6. Cleburne Reuse

For the purpose of estimating costs associated with meeting a portion of the 2060 planning horizon needs, supply of reuse water for irrigation to the new golf course planned northeast of the city and adjacent to the existing reuse water pipeline has been included as a second project. However, this project is not the only anticipated use of reuse water for the city. The reuse projects considered for estimating costs associated with this plan are included in Table 4B.3-29.

Table 4B.3-29.
Additional Reuse Project Summary
Reuse as a Water Management Strategy for Cleburne

Project	*Peak Demand*
Sports Complex Irrigation	280 acft/yr
Other Irrigation	336 acft/yr
Total Peak Demand from Additional Reuse Projects	**616 acft/yr**
Available Project Yield = 0.31 MGD (351 acft/yr), yield is 57 percent of peak demand for irrigation customers with seasonal use as shown in Table 4B.3-7	

4B.3.1.6.3 Environmental Issues

The City of Cleburne is currently in the process of filing a water rights application with TCEQ to reuse all effluent discharged pursuant to TPDES Permit No. 10006-001, currently authorized as 8,440 acre feet (7.5 MGD). The city is also in the process of amending its Chapter 210 Use of Reclaimed Water authorization to supply reuse water for irrigation to the sports complex facility planned east of the city, and to supplement industrial scenarios for fracing. Additional future reuse will require further amendment of the city's reuse authorization.

Expansion of the reuse water treatment facilities would involve relatively low environmental impacts:

- Reduced effluent discharges to the wastewater outfall could have a low impact on environmental water needs and instream flows.
- For potential future reuse within areas a reasonable distance from the existing reclaimed water pipeline, pipeline construction would be limited since available capacity in the existing 16-inch reclaimed water pipeline is currently underutilized.
- Reduced effluent discharges would reduce the BOD stream loading.

A summary of environmental issues is presented in Table 4B.3-30.

Table 4B.3-30.
Environmental Issues: Cleburne Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

4B.3.1.6.4 Engineering and Costing

The facilities needed to provide reuse water for the proposed expansion of the existing reuse water system are somewhat minimal. The capacity of the existing 16-inch reuse water transmission piping is sufficient to accommodate the proposed plans for reuse. The facilities needed include the following:

- Expanded reuse water treatment facility;
- Extension of reuse water lines from existing 16-inch mainline to the sports complex and new golf course; and
- Expanded reuse water pump station.

Estimated costs to expand the reuse water system as described above are summarized in Table 4B.3-31. Given that the existing treatment facility is designed for 2.0 MGD (2,240 acft/yr), an additional capacity of only 0.5 MGD (616 acft/yr) is needed. With the pipeline capacity available and the existing 16-inch reuse water line located within reasonable proximity to the sports complex to the east and new golf course northeast, the total estimated project cost is approximately $1,048,000.

In keeping with the city's goal to maximize its use of reuse water, the additional expansion of the reuse water facilities may cost more than other alternatives that could be used to meet additional portions of the projected water shortage of 2,853 acft/yr in year 2060. As uses of reuse water increase over time, booster pump stations may also be required along the existing 16-inch reuse water line to allow for increased conveyance capacity.

Table 4B.3-31.
Cost Estimate Summary
Reuse as a Water Management Strategy for Cleburne
Incremental Costs to Meet Year 2060 Projected Shortage
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Expansion of Reuse Treatment Facility	$437,000
Transmission Pipelines	156,000
Expansion of Pump Station	104,000
Total Cost	**$697,000**
Engineering, Legal and Contingencies	$237,000
Environmental Studies and Mitigation	15,000
Land Acquisition and Surveying	21,000
Interest During Construction	78,000
Total Project Cost	**$1,048,000**
Annual Costs (Incremental)	
Debt Service	$77,000
Operation and Maintenance:	
Reclaimed Water Treatment, Pump Station, Pipelines	80,000
Pumping Energy Costs (Additional)	29,000
Total Annual Cost	**$186,000**
Additional Reclaimed Water Delivery (acft)	**351**
Annual Cost of Additional Reclaimed Water ($ per acft)	**$530**
Annual Cost of Additional Reclaimed Water ($ per 1,000 gallons)	**$1.63**

4B.3.1.6.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-32, and the option meets each criterion. Implementation of this strategy is relatively straightforward and will include the required permit and reuse authorization amendments mentioned previously in addition to right-of-way and easement acquisition for reuse water piping, authorization for creek and river crossings, and financing.

Table 4B.3-32.
Comparison of Bryan Reuse Option
to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

4B.3.1.7 City of Godley Reuse

4B.3.1.7.1 Description of Option

The City of Godley currently does not utilize wastewater reuse as a water supply option. This option consists of a reuse project to deliver Type 1 treated wastewater for irrigation of the high school and other green spaces. The peak irrigation demand for Godley is estimated as 0.1 MGD. Type 1 reuse water will be supplied from the Godley WWTP.

4B.3.1.7.2 Available Supply

The water supply that would be potentially available for Godley would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The Godley WWTP Year 2060 Estimated WWTP Effluent is 280 acft/yr (0.25 MGD).

4B.3.1.7.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows; and
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows.

A summary of environmental issues is presented in Table 4B.3-33.

Table 4B.3-33.
Environmental Issues: Godley Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

4B.3.1.7.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Godley are summarized in Table 4B.3-34.

Table 4B.3-34
Required Facilities – Godley Reuse for Irrigation

Facility	Description
Treatment Upgrade	0.1 MGD, Scenario; existing WWTP meets type 1 reuse standards, requiring only addition of chlorine for distribution
Pump Station	26 hp; 0.4 MGD capacity to deliver peak daily capacity in 6 hours
Storage Tank	0.1 MG; Store one days treated reuse water at WWTP
Pipeline	7,920 ft of 6-inch pipe
Available Project Yield	0.06 MGD (64 acft/yr), yield is 57 percent of peak demand for irrigation customers with seasonal use as shown in Table 4B.3-7.

Costs presented in Table 4B.3-35 provide the total option costs for developing a wastewater reuse supply for irrigation.

4B.3.1.7.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-36, and the option meets each criterion. Before pursuing wastewater reuse, Godley will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.
- Johnson County SUD currently supplies water to the high school and other Godley green spaces. A service area variance agreement would be needed between the City of Godley and Johnson County SUD for the City to serve reuse water to the high school or other areas currently served by Johnson County SUD.

Table 4B.3-35
Cost Estimate Summary
Reuse as a Water Management Strategy for Godley
Costs for Irrigation
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$157,000
Transmission Pipeline and Tank	487,000
Reuse Water Treatment	12,000
Total Capital Cost	**$656,000**
Engineering, Legal Costs and Contingencies	$210,000
Environmental & Archaeology Studies and Mitigation	53,000
Land Acquisition and Surveying (10 acres)	70,000
Interest During Construction (2 years)	80,000
Total Project Cost	**$1,069,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$78,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	9,000
Reuse Water Treatment Plant	4,000
Pumping Energy Costs (91,669 kWh @ $0.06/kWh)	6,000
Total Annual Cost	**$97,000**
Available Project Yield (acft/yr)	**64**
Annual Cost of Water ($ per acft)	**$1,519**
Annual Cost of Water ($ per 1,000 gallons)	**$4.66**

Table 4B.3-36.
Comparison of Godley Reuse Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

4B.3.1.8 City of Joshua Reuse

4B.3.1.8.1 Description of Option

The City of Joshua water and wastewater service is provided by Johnson County Fresh Water Supply District No. 1 (JCFWSD1). The District currently supplies about 800 gallons/day of Type 2 effluent to Mountain Valley Golf Course. The District is interested in supplying other customers with reuse water as a water management strategy. This option consists of a reuse project to deliver Type 1 treated wastewater for irrigation of some existing green spaces and potential future parks and schools. The JCFWSD1 peak irrigation demand in Joshua is estimated as 0.1 MGD. Type 1 reuse water will be supplied from the JCFWSD1 WWTP in Joshua.

4B.3.1.8.2 Available Supply

The water supply that would be potentially available for Joshua would be that portion of their wastewater effluent stream that has suitable uses within an economical distance from the treatment plant. The JCFWSD1 WWTP in Joshua Year 2060 Estimated WWTP Effluent is 401 acft/yr (0.36 MGD).

4B.3.1.8.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows; and
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows.

A summary of environmental issues is presented in Table 4B.3-37.

4B.3.1.8.4 Engineering and Costing

The required improvements to implement a wastewater reuse supply for Joshua are summarized in Table 4B.3-38. The estimated required facilities for Joshua are identical to the facilities for Godley except for additional tertiary treatment at the Joshua WWTP to meet type 1 standards.

Table 4B.3-37.
Environmental Issues: Joshua Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

Table 4B.3-38
Required Facilities – Joshua Reuse for Irrigation

Facility	*Description*
Treatment Upgrade	0.1 MGD, Scenario 2; existing WWTP meets type 2 reuse standards, requiring additional tertiary treatment to meet type 1 standards and addition of chlorine for distribution
Pump Station	26 hp; 0.4 MGD capacity to deliver peak daily capacity in 6 hours
Storage Tank	0.1 MG; Store one days treated reuse water at WWTP
Pipeline	7,920 ft of 6-inch pipe
Available Project Yield	0.06 MGD (64 acft/yr), yield is 57 percent of peak demand for irrigation customers with seasonal use as shown in Table 4B.3-7.

Costs presented in Table 4B.3-39 provide the total option costs for developing a wastewater reuse supply for irrigation.

Table 4B.3-39.
Cost Estimate Summary
Reuse as a Water Management Strategy for Joshua
Costs for Irrigation
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$157,000
Transmission Pipeline and Tank	487,000
Reuse Water Treatment	450,000
Total Capital Cost	**$1,094,000**
Engineering, Legal Costs and Contingencies	$364,000
Environmental & Archaeology Studies and Mitigation	55,000
Land Acquisition and Surveying (10 acres)	72,000
Interest During Construction (2 years)	127,000
Total Project Cost	**$1,712,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$124,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	9,000
Reuse Water Treatment Plant	93,000
Pumping Energy Costs (91,669 kWh @ $0.06/kWh)	6,000
Total Annual Cost	**$232,000**
Available Project Yield (acft/yr)	**64**
Annual Cost of Water ($ per acft)	**$3,634**
Annual Cost of Water ($ per 1,000 gallons)	**$11.15**

4B.3.1.8.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-40, and the option meets each criterion, but unit costs for this water are high. Before pursuing wastewater reuse, Joshua will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.
- Unit costs compared to other alternatives, including additional uses of reuse water to reduce unit costs

Table 4B.3-40.
Comparison of Joshua Reuse Option to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. High
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

4B.3.1.9 Waco East – LS Power Station and Cities of Hallsburg, Mart, and Riesel Reuse

4B.3.1.9.1 Description of Option

The City of Waco is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco and potentially to other entities within the vicinity of Waco. Several water user groups in the vicinity of Waco showing a water supply need by the year 2060 may potentially be provided reuse water as part of this larger Waco reuse system. This option consists of an integrated reuse project to deliver Type 1 reuse water from the Waco Metropolitan Area Regional Sewerage System (WMARSS) wastewater treatment plant to a new power station planned southeast of Waco and to the Cities of Hallsburg, Mart, and Riesel. The new power station (LS Power Station) is to be located near Lake Creek Reservoir as shown in Figure 4B.3-7. The City of Waco has negotiated a contract to supply the LS Power Station with 16,000 acft/yr of water to be used for cooling tower and other non-potable purposes. This option assumes that the full 16,000 acft/yr of water supplied by Waco to LS Power Station will be Type 1 reuse water from WMARSS.

The potential reuse water demand for the Cities of Hallsburg, Mart, and Riesel is estimated at 30 percent of each city's 2060 water demand for purposes of this option. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers within these cities. For this option the transmission system to supply reuse water for these three cities also includes capacity to supply 900 acft/yr of reuse water for use by County-Other entities within the vicinity of the reuse transmission pipelines. The amount of reuse water supplied to each entity for this option is summarized in Table 4B.3-41. All estimated reuse demands are less than the total needs (shortages) projected for each WUG in 2060.

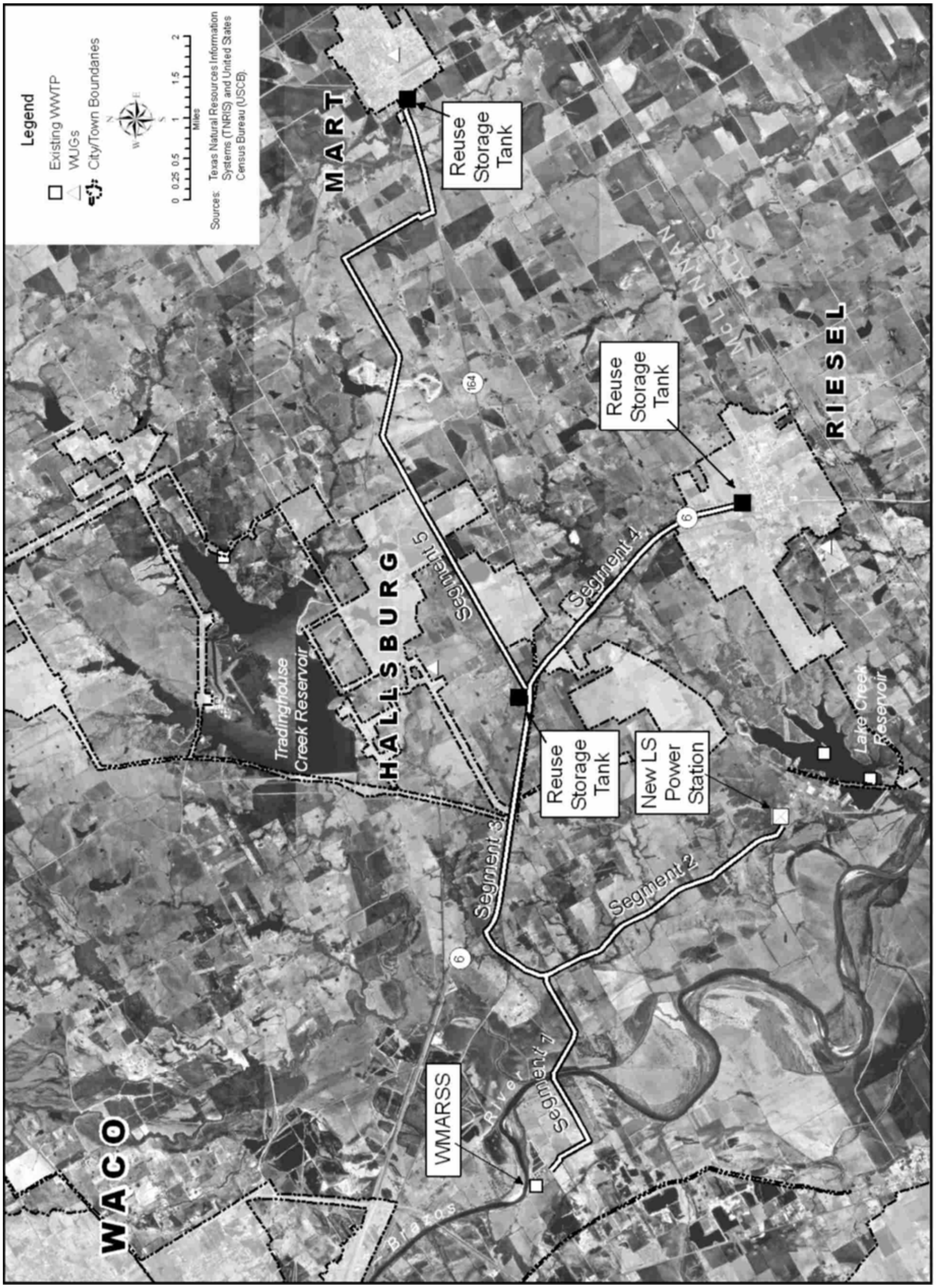

Figure 4B.3-7. Waco East Reuse

Table 4B.3-41.
Waco East Reuse Water Demand

Entity	2060 Demand (acft/yr)	Reuse Water Demand (acft/yr)	2060 Need (acft/yr)
Hallsburg	182	55	172
Mart	415	124	390
Riesel	137	41	129
LS Power Station	NA	16,000	NA
County-Other	7,881	900	6,786
Total		**17,120**	

4B.3.1.9.2 Available Supply

The Year 2060 Estimated WWTP Effluent for WMARSS is 31,779 acft/yr (28.37 MGD). Based on feedback from the City of Waco the combined Year 2060 Confirmed WWTP Effluent for this WWTP is 0 acft/yr (0 MGD). Therefore, the 2060 Potential Reuse is the difference between the Estimated and Confirmed WWTP Effluent which is 31,779 acft/yr (28.37 MGD).

4B.3.1.9.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows; and
- Possible negative impact to fish and wildlife habitat with reduced stream flows.

A summary of environmental issues is presented in Table 4B.3-42.

Table 4B.3-42.
Environmental Issues: Waco East Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

4B.3.1.9.4 Engineering and Costing

Many of the required improvements to implement a reuse supply for this option are shared between the multiple entities. These shared facilities include the upgraded treatment at the WMARSS treatment plant, pump stations, and transmission pipelines. The shared facilities are sized to supply the combined demand for the entities served by each improvement. To determine each entities share of the total improvement cost, the shared improvements are estimated separately and costs per acft of total supply are developed for each shared improvement. The total cost estimates for each entity include the cost of these shared improvements as annual costs based on the quantity supplied by the improvement to each entity. Due to the economy of scale, significant cost savings are realized by utilizing shared larger improvements for the treatment and delivery of reuse water to all entities supplied by the Waco East water supply option.

As an example of how shared improvements are handled for this option, consider the Segment 1 pump station and transmission pipeline shown in Figure 4B.3-7. Segment 1 is the initial pipeline segment that transmits reuse water from the WMARSS treatment plant to other pipelines supplying the LS Power Station, Hallsburg, Mart, Riesel, and County-Other. The segment 1 improvements are sized for the total demand for all these entities (17,120 acft/yr). The required facilities for Segment 1 are shown in Table 4B.3-43. The costs presented in Table 4B.3-44 provide the total cost for Segment 1 improvements to be shared between the entities supplied.

Table 4B.3-43.
Required Facilities – Waco East Segment 1

Facility	*Description*
Pump Station	887 hp; 15.3 MGD capacity to deliver at uniform rate to LS Power Station and storage tank at start of segment 3 pipeline with 25 psi residual pressure
Storage Tank	1.5 MG; balancing storage at WMARSS sized at 10 percent of daily flow
Pipeline	15,488 ft of 27-inch pipe; from WMARSS to intersection of segments 2 and 3
Available Project Yield	15.3 MGD (17,120 acft/yr); total yield for all projects supplied plus 900 acft/yr for County-Other

The cost to each entity for the use of Segment 1 is shown in table 4B.3-45. The great majority of the cost for Segment 1 is paid by LS Power Station because it is the largest user of the Segment 1 improvements. By comparison, the costs to the other smaller users of the Segment 1 improvements are much less on an annual basis.

The required facilities for the other shared improvements to implement a wastewater reuse supply for all Waco East entities are shown in Tables 4B.3-46 through 4B.3-48. The cost estimates for the other shared improvements are shown in Tables 4B.3-49 through 4B.3-52. The treatment upgrades at WMARSS to supply a Type 1 reuse effluent are additional tertiary treatment and chlorine addition to provide a residual for distribution. A separate cost estimate is not provided for Segment 2 because those improvements are solely utilized for LS Power Station, and therefore, the Segment 2 costs are included in the LS Power Station cost estimate.

The required improvements to implement wastewater reuse supplies for LS Power Station, Hallsburg, Mart, and Riesel are summarized in Tables 4B.3-53 through 4B.3-56. Storage and irrigation pumping are included for Hallsburg, Mart, and Riesel. The LS Power Station demand is to be supplied at a more uniform rate for industrial purposes, and therefore, no additional storage or pumping is included at the LS Power Station site.

Table 4B.3-44.
Cost Estimate Summary
Waco East - Segment 1
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$1,931,000
Transmission Pipeline and Tank	2,935,000
Total Capital Cost	**$4,866,000**
Engineering, Legal Costs and Contingencies	$1,596,000
Environmental & Archaeology Studies and Mitigation	87,000
Land Acquisition and Surveying (15 acres)	118,000
Interest During Construction (2 years)	534,000
Total Project Cost	**$7,201,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$523,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	78,000
Pumping Energy Costs (5,513,119 kWh @ $0.06/kWh)	331,000
Total Annual Cost	**$932,000**
Available Project Yield (acft/yr)	**17,120**
Annual Cost of Water ($ per acft)	**$54.44**
Annual Cost of Water ($ per 1,000 gallons)	**$0.17**

Table 4B.3-45.
Waco East - Segment 1 Cost to each Entity

Entity	*Reuse Water Demand (acft/yr)*	*Unit Cost for Segment 1 ($/acft)*	*Annual Cost for Segment 1 ($/yr)*
Hallsburg	55	54.44	$2,994
Mart	124	54.44	$6,750
Riesel	41	54.44	$2,232
LS Power Station	16,000	54.44	$871,028
County-Other	900	54.44	$48,995
Total	**17,120**		**$932,000**

Table 4B.3-46.
Required Facilities – Waco East Segment 3

Facility	*Description*
Pump Station	101 hp; 1.0 MGD capacity to deliver at uniform rate to storage tanks located at Hallsburg, Mart, or Riesel with 25 psi residual pressure
Storage Tank	1.0 MG; balancing storage at intersection of segment 1 and 3
Pipeline	20,583 ft of 10-inch pipe; from intersection of segments 1 and 3 to Hallsburg tank
Available Project Yield	1.0 MGD (1120 acft/yr); total yield for combined Hallsburg, Mart, and Riesel plus 900 acft/yr for County-Other

Table 4B.3-47.
Required Facilities – Waco East Segment 4

Facility	*Description*
Pump Station	No Pump Station; Segment 3 pump station pressure utilized
Storage Tank	No Storage Tank
Pipeline	19,832 ft of 6-inch pipe; from Hallsburg tank to Riesel tank
Available Project Yield	0.3 MGD (341 acft/yr); 41 acft/yr Riesel plus 300 acft/yr County-Other

Table 4B.3-48.
Required Facilities – Waco East Segment 5

Facility	*Description*
Pump Station	No Pump Station; Segment 3 pump station pressure utilized
Storage Tank	No Storage Tank
Pipeline	45,505 ft of 6-inch pipe; from Hallsburg tank to Mart tank
Available Project Yield	0.38 MGD (425 acft/yr); 125 acft/yr Riesel plus 300 acft/yr County-Other

Table 4B.3-49.
Cost Estimate Summary
Waco East - Segment 3
Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Transmission Pump Station	$416,000
Transmission Pipeline	1,542,000
Total Capital Cost	**$1,958,000**
Engineering, Legal Costs and Contingencies	$637,000
Environmental & Archaeology Studies and Mitigation	111,000
Land Acquisition and Surveying (15 acres)	151,000
Interest During Construction (2 years)	229,000
Total Project Cost	**$3,086,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$224,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	26,000
Pumping Energy Costs (627,037 kWh @ $0.06/kWh)	38,000
Total Annual Cost	**$288,000**
Available Project Yield (acft/yr)	**1,120**
Annual Cost of Water ($ per acft)	**$257.14**
Annual Cost of Water ($ per 1,000 gallons)	**$0.79**

***Table 4B.3-50.
Cost Estimate Summary
Waco East - Segment 4
Second Quarter 2002 Prices***

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pipeline	$586,000
Total Capital Cost	**$586,000**
Engineering, Legal Costs and Contingencies	$176,000
Environmental & Archaeology Studies and Mitigation	94,000
Land Acquisition and Surveying (15 acres)	131,000
Interest During Construction (2 years)	79,000
Total Project Cost	**$1,066,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$77,000
Operation and Maintenance:	
Pipeline	6,000
Total Annual Cost	**$83,000**
Available Project Yield (acft/yr)	**341**
Annual Cost of Water ($ per acft)	**$243.40**
Annual Cost of Water ($ per 1,000 gallons)	**$0.75**

Table 4B.3-51. Cost Estimate Summary Waco East - Segment 5 Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Transmission Pipeline	$1,345,000
Total Capital Cost	**$1,345,000**
Engineering, Legal Costs and Contingencies	$403,000
Environmental & Archaeology Studies and Mitigation	215,000
Land Acquisition and Surveying (15 acres)	300,000
Interest During Construction (2 years)	182,000
Total Project Cost	**$2,445,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$178,000
Operation and Maintenance:	
Pipeline	13,000
Total Annual Cost	**$191,000**
Available Project Yield (acft/yr)	**425**
Annual Cost of Water ($ per acft)	**$449.41**
Annual Cost of Water ($ per 1,000 gallons)	**$1.38**

Table 4B.3-52.
Cost Estimate Summary
Waco East - Treatment
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Reuse Water Treatment	$2,551,000
Total Capital Cost	**$2,551,000**
Engineering, Legal Costs and Contingencies	$893,000
Environmental & Archaeology Studies and Mitigation	72,000
Land Acquisition and Surveying (15 acres)	79,000
Interest During Construction (2 years)	288,000
Total Project Cost	**$3,883,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$282,000
Operation and Maintenance:	
Reuse Water Treatment Plant	425,000
Total Annual Cost	**$707,000**
Available Project Yield (acft/yr)	**17,120**
Annual Cost of Water ($ per acft)	**$41.30**
Annual Cost of Water ($ per 1,000 gallons)	**$0.13**

Table 4B.3-53.
Required Facilities – LS Power Station

Facility	***Description***
Treatment Upgrade	Purchase 14.3 MGD treated reuse water from Waco
Pump Station	Shared use of segment 1 pump station
Storage Tank	No storage tank; continuous use by power station or storage in reservoir
Pipeline	Segment 2 = 18,440 ft of 27-inch pipe; shared use of pipeline segment 1
Available Project Yield	14.3 MGD (16,000 acft/yr), yield provided by City of Waco for future power station

Table 4B.3-54.
Required Facilities – Hallsburg

Facility	***Description***
Treatment Upgrade	Purchase 0.05 MGD treated reuse water from Waco
Pump Station	8 hp; 0.2 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 and 3 pump stations
Storage Tank	0.05 MG; Store one days treated reuse water at tank in Hallsburg
Pipeline	Shared use of pipeline segments 1 and 3
Available Project Yield	0.05 MGD (55 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Table 4B.3-55.
Required Facilities – Mart

Facility	***Description***
Treatment Upgrade	Purchase 0.11 MGD treated reuse water from Waco
Pump Station	17 hp; 0.44 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 and 3 pump stations
Storage Tank	0.11 MG; Store one days treated reuse water at tank in Mart
Pipeline	Shared use of pipeline segments 1, 3, and 5
Available Project Yield	0.11 MGD (125 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Table 4B.3-56.
Required Facilities – Riesel

Facility	*Description*
Treatment Upgrade	Purchase 0.04 MGD treated reuse water from Waco
Pump Station	6 hp; 0.16 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 and 3 pump stations
Storage Tank	0.04 MG; Store one days treated reuse water at tank in Riesel
Pipeline	Shared use of pipeline segments 1, 3, and 5
Available Project Yield	0.04 MGD (41 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Costs presented in Table 4B.3-57 to 4B.3-60 provide the total option costs for developing a wastewater reuse supply for each of the entities supplied by the Waco East reuse project. The demand from County-Other is divided evenly between pipeline segments 3, 4, and 5 with each segment including 300 acft/yr of reuse water demand from County-Other. Inclusion of the County-Other shared use of these transmission facilities greatly decreases the unit cost for transmission of reuse water to Hallsburg, Mart, and Riesel. Without participation from County-Other in this reuse water supply option, supplying the relatively small quantity of reuse water demanded by Hallsburg, Mart, and Riesel would likely not be economical. The costs shown are those that would be required to develop the reuse projects, and are not the retail or wholesale costs of the water to the LS Power Station or the Cities of Hallsburg, Mart, and Riesel.

4B.3.1.9.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-61, and the option meets each criterion. Before pursuing wastewater reuse, the Waco East entities will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Table 4B.3-57.
Cost Estimate Summary
Reuse as a Water Management Strategy for LS Power Station
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pipeline	$1,972,000
Total Capital Cost	**$1,972,000**
Engineering, Legal Costs and Contingencies	$592,000
Environmental & Archaeology Studies and Mitigation	87,000
Land Acquisition and Surveying (15 acres)	122,000
Interest During Construction (2 years)	222,000
Total Project Cost	**$2,995,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$218,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	20,000
Shared Costs:	
Treatment (16,000 acft/yr @ $41.29/acft)	661,000
Segment 1 Pipeline and Pump Station (16,000 acft/yr @ $54.41/acft)	871,000
Total Annual Cost	**$1,770,000**
Available Project Yield (acft/yr)	**16,000**
Annual Cost of Water ($ per acft)	**$111**
Annual Cost of Water ($ per 1,000 gallons)	**$0.34**

Table 4B.3-58.
Cost Estimate Summary
Reuse as a Water Management Strategy for Hallsburg
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station for Distribution	$73,000
Storage Tank	59,000
Total Capital Cost	**$132,000**
Engineering, Legal Costs and Contingencies	$46,000
Environmental & Archaeology Studies and Mitigation	14,000
Land Acquisition and Surveying (15 acres)	15,000
Interest During Construction (2 years)	17,000
Total Project Cost	**$224,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$16,000
Operation and Maintenance:	
Pump Station, Tank	2,000
Pumping Energy Costs (11,933 kWh @ $0.06/kWh)	1,000
Shared Costs:	
Treatment (55 acft/yr @ $41.29/acft)	2,000
Segment 1 Pipeline and Pump Station (55 acft/yr @ $54.41/acft)	3,000
Segment 3 Pipeline and Pump Station (55 acft/yr @ $256.83/acft)	14,000
Total Annual Cost	**$38,000**
Available Project Yield (acft/yr)	**55**
Annual Cost of Water ($ per acft)	**$691**
Annual Cost of Water ($ per 1,000 gallons)	**$2.12**

Table 4B.3-59.
Cost Estimate Summary
Reuse as a Water Management Strategy for Mart
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station for Distribution	$120,000
Transmission Pipeline	106,000
Total Capital Cost	**$226,000**
Engineering, Legal Costs and Contingencies	$79,000
Environmental & Archaeology Studies and Mitigation	14,000
Land Acquisition and Surveying (15 acres)	15,000
Interest During Construction (2 years)	27,000
Total Project Cost	**$361,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$26,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	4,000
Pumping Energy Costs (26,362 kWh @ $0.06/kWh)	2,000
Shared Costs:	
Treatment (125 acft/yr @ $41.30/per acft)	5,000
Segment 1 Pipeline and Pump Station (125 acft/yr @ $54.44/acft)	7,000
Segment 3 Pipeline and Pump Station (125 acft/yr @ $257.14/acft)	32,000
Segment 5 Pipeline and Pump Station (125 acft/yr @ $449.41/acft)	56,000
Total Annual Cost	**$132,000**
Available Project Yield (acft/yr)	**124**
Annual Cost of Water ($ per acft)	**$1,065**
Annual Cost of Water ($ per 1,000 gallons)	**$3.27**

Table 4B.3-60.
Cost Estimate Summary
Reuse as a Water Management Strategy for Riesel
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station for Distribution	$55,000
Storage Tank	49,000
Total Capital Cost	**$104,000**
Engineering, Legal Costs and Contingencies	$36,000
Environmental & Archaeology Studies and Mitigation	14,000
Land Acquisition and Surveying (15 acres)	15,000
Interest During Construction (2 years)	14,000
Total Project Cost	**$183,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$13,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	2,000
Pumping Energy Costs (9,542 kWh @ $0.06/kWh)	1,000
Shared Costs:	
Treatment (41 acft/yr @ $41.30/acft)	2,000
Segment 1 Pipeline and Pump Station (41 acft/yr @ $54.44/acft)	2,000
Segment 3 Pipeline and Pump Station (41 acft/yr @ $257.14/acft)	11,000
Segment 4 Pipeline (41 acft/yr @ 243.4 $ per acft)	10,000
Total Annual Cost	**$41,000**
Available Project Yield (acft/yr)	**41**
Annual Cost of Water ($ per acft)	**$1,000**
Annual Cost of Water ($ per 1,000 gallons)	**$3.07**

Table 4B.3-61.
Comparison of Waco East Reuse Option
to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

4B.3.1.10 Waco North – Chalk Bluff WSC and Gholson Reuse

4B.3.1.10.1 Description of Option

The City of Waco is currently pursuing the development of a wastewater reuse system to supply reuse water to customers within the City of Waco and potentially to other entities within the vicinity of Waco. Several water user groups in the vicinity of Waco showing a water supply need by the year 2060 may potentially be provided reuse water as part of this larger Waco reuse system. This option consists of an integrated reuse project to deliver Type 1 reuse water from a new satellite wastewater reuse treatment plant located north of Waco and diverting wastewater from a collection main of the Waco Metropolitan Area Regional Sewerage System (WMARSS). Treated reuse water from this satellite plant is transported to Chalk Bluff WSC and the City of Gholson. The new satellite reuse treatment plant and transmission pipeline locations are shown in Figure 4B.3-8.

The potential reuse water demand for Chalk Bluff WSC and the City of Gholson is estimated at 30 percent of their 2060 water demand for purposes of this option. This Type 1 reuse water may be utilized for landscape irrigation at existing or future parks, schools, ball fields, and other green spaces. Reuse water may also potentially supply existing or future industrial customers. For this option the transmission system to supply reuse water for these entities also includes capacity to supply 811 acft/yr of reuse water for use by County-Other entities within the vicinity of the reuse transmission pipelines. The amount of reuse water supplied to each entity for this option is summarized in Table 4B.3-62. All estimated reuse demands are less than the total needs (shortages) projected for each WUG in 2060.

4B.3.1.10.2 Available Supply

The Year 2060 Estimated WWTP Effluent for WMARSS is 31,779 acft/yr (28.37 MGD). Based on feedback from the City of Waco the combined Year 2060 Confirmed WWTP Effluent Discharge for this WWTP is 0 acft/yr (0 MGD). Therefore, the 2060 Potential Reuse is the difference between the Estimated and Confirmed WWTP Effluent which is 31,779 acft/yr (28.37 MGD). The amount of reuse water available for Waco North reuse will be limited by the wastewater flow in the collector main feeding the new satellite reuse treatment plant.

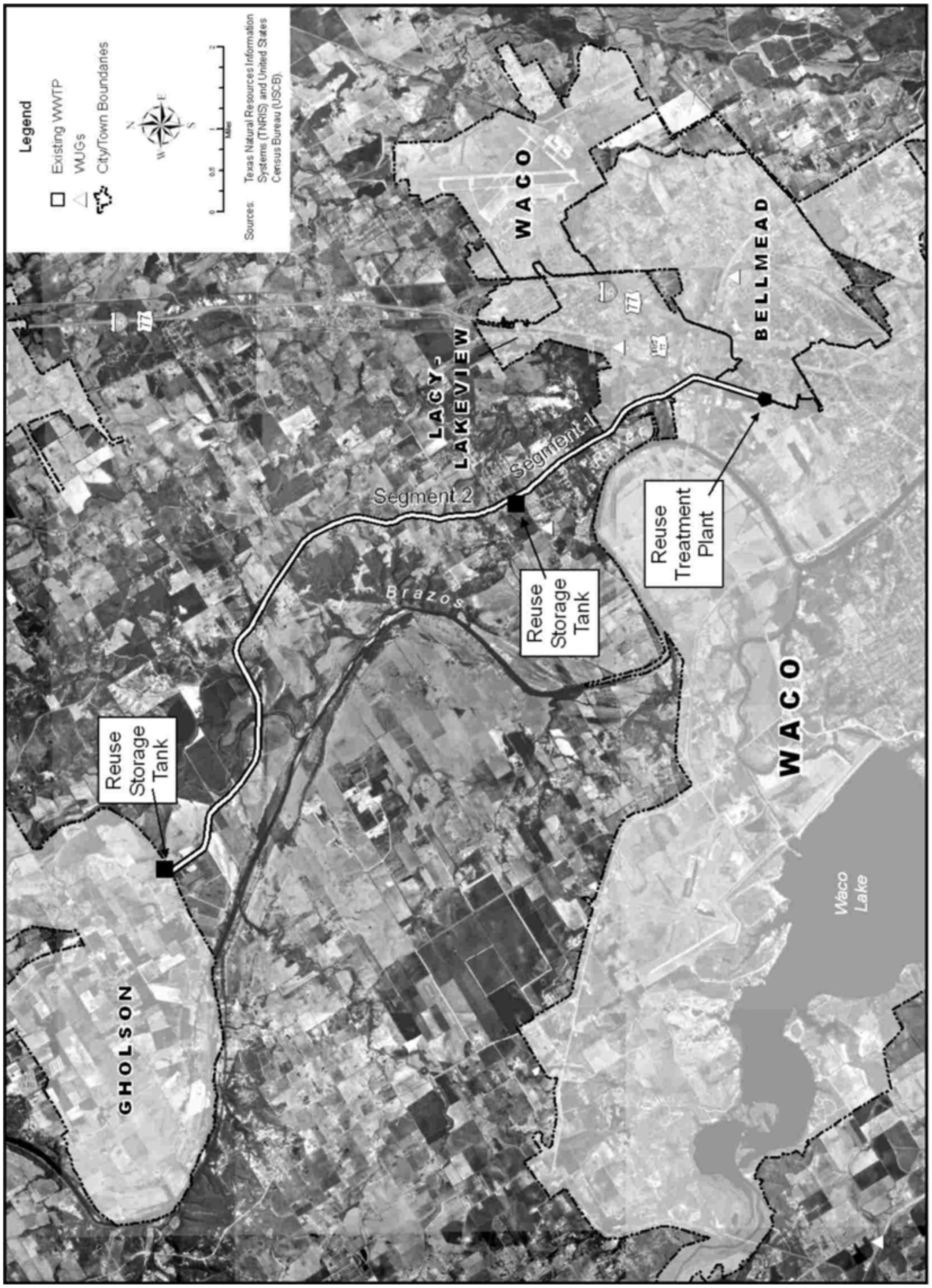

Figure 4B.3-8. Waco North Reuse

Table 4B.3-62.
Waco North Reuse Water Demand

Entity	***2060 Demand (acft/yr)***	***Reuse Water Demand (acft/yr)***	***2060 Need (acft/yr)***
Chalk Bluff WSC	798	240	749
Gholson	231	69	222
County-Other	7,881	811	6,786
Total		**1,120**	

4B.3.1.10.3 Environmental Issues

Environmental impacts could include:

- Possible low impact on instream flows below discharge points due to reduced effluent return flow rates;
- Possible increased water quality to remaining stream flows; and
- Possible high negative impact to fish and wildlife habitat with substantially reduced stream flows.

A summary of environmental issues is presented in Table 4B.3-63.

Table 4B.3-63.
Environmental Issues: Waco North Reuse

Implementation Measures	Development of additional wastewater treatment plant facilities, distribution pipelines, and pump stations
Environmental Water Needs / Instream Flows	Possible low impact on in-stream flows due to decreased effluent return flows; possible increased water quality to remaining stream flows
Bays and Estuaries	Possible low negative impact
Fish and Wildlife Habitat	Possible variable impacts depending on changes in volume of effluent return flows; possible high negative impact to fish and wildlife habitat with substantially reduced stream flows
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes needed infrastructure will be in urbanized areas

4B.3.1.10.4 Engineering and Costing

Many of the required improvements to implement a reuse supply for this option are shared between the multiple entities. These shared facilities include the satellite reuse treatment plant in north Waco, pump stations, and transmission pipelines. The shared facilities are sized to supply the combined demand for the entities served by each improvement. To determine each entities share of the total improvement cost, the shared improvements are estimated separately and costs per acft of total supply were developed for each shared improvement. The total cost estimates for each entity include the cost of these shared improvements as annual costs based on the quantity supplied by the improvement to each entity. Due to the economy of scale, significant cost savings are realized by utilizing shared larger improvements for the treatment and delivery of reuse water to all entities supplied by the Waco North water supply option.

As an example of how shared improvements are handled for this option, consider the Segment 1 pump station and transmission pipeline shown in Figure 4B.3-8. Segment 1 is the initial pipeline segment that transmits reuse water from the satellite reuse treatment plant to Chalk Bluff WSC, County-Other, and the Segment 2 pipeline supplying Gholson and County-Other. The segment 1 improvements are sized for the total demand for all these entities (1,120 acft/yr). The required facilities for Segment 1 are shown in Table 4B.3-64. The costs presented in Table 4B.3-65 provide the total cost for Segment 1 improvements to be shared between the entities supplied.

The cost to each entity for the use of Segment 1 is shown in Table 4B.3-66. The costs are divided between the supplied entities based on the quantity of water supplied to each.

The required facilities for Segment 2 improvements to implement a wastewater reuse supply for all Waco North entities are shown in Table 4B.3-67. The cost estimates for Segment 2 and shared reuse treatment improvements are shown in Tables 4B.3-68 and 4B.3-69. The treatment upgrades to supply a Type 1 reuse effluent are a new satellite reuse treatment plant with a treatment capacity of 3 MGD. The satellite treatment plant is oversized by 2 MGD for this option to allow for additional reuse water demand in the vicinity of the new plant [1 MGD (1,120 acft/yr) demand for Waco North; 2 MGD (2,240 acft/yr) demand for others in the vicinity of reuse plant].

Table 4B.3-64.
Required Facilities – Waco North Segment 1

Facility	***Description***
Pump Station	73 hp; 1.0 MGD capacity to deliver at uniform rate to storage tanks at Chalk Bluff WSC and Gholson with 25 psi residual pressure
Storage Tank	1 MG; balancing storage at new satellite reuse plant
Pipeline	18,434 ft of 10-inch pipe; from satellite reuse plant to Chalk Bluff WSC and start of segment 2
Available Project Yield	1.0 MGD (1,120 acft/yr); total yield for all Waco North projects supplied

Table 4B.3-65.
Cost Estimate Summary
Waco North - Segment 1
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station	$329,000
Transmission Pipeline and Tank	1,419,000
Total Capital Cost	**$1,748,000**
Engineering, Legal Costs and Contingencies	$570,000
Environmental & Archaeology Studies and Mitigation	101,000
Land Acquisition and Surveying (17 acres)	137,000
Interest During Construction (2 years)	205,000
Total Project Cost	**$2,761,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$201,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	22,000
Pumping Energy Costs (450,995 kWh @ $0.06/kWh)	27,000
Total Annual Cost	**$250,000**
Available Project Yield (acft/yr)	**1,120**
Annual Cost of Water ($ per acft)	**$223.21**
Annual Cost of Water ($ per 1,000 gallons)	**$0.68**

Table 4B.3-66.
Waco North - Segment 1 Cost to each Entity

Entity	***Reuse Water Demand (acft/yr)***	***Unit Cost for Segment 1 ($/acft)***	***Annual Cost for Segment 1 ($/yr)***
Chalk Bluff WSC	240	223.21	$53,571
Gholson	69	223.21	$15,402
County-Other	811	223.21	$181,027
Total	**1,120**		**$250,000**

Table 4B.3-67.
Required Facilities – Waco North Segment 2

Facility	***Description***
Pump Station	No pump station, pressure from segment 1 pump station utilized
Storage Tank	No storage tank
Pipeline	39,722 ft of 8-inch pipe; from end of segment 1 to Gholson tank
Available Project Yield	0.5 MGD (560 acft/yr); 69 acft/yr yield for Gholson and 491 acft/yr yield for County-Other

The required improvements to implement wastewater reuse supplies for Chalk Bluff WSC and Gholson are summarized in Tables 4B.3-70 and 4B.3-71. Storage and irrigation pumping are included for Chalk Bluff WSC and Gholson.

Costs presented in Tables 4B.3-72 and 4B.3-73 provide the total option costs for developing a wastewater reuse supply for Chalk Bluff WSC and Gholson. The demand from County-Other is divided between pipeline segments 1 and 2. Inclusion of the County-Other shared use of these transmission facilities greatly decreases the unit cost for transmission of reuse water to Chalk Bluff WSC and Gholson. Without participation from County-Other in this reuse water supply option, supplying the relatively small quantity of reuse water demanded by Chalk Bluff WSC and Gholson would likely not be economical.

Table 4B.3-68.
Cost Estimate Summary
Waco North - Segment 2
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pipeline and Tank	$1,463,000
Total Capital Cost	**$1,463,000**
Engineering, Legal Costs and Contingencies	$439,000
Environmental & Archaeology Studies and Mitigation	188,000
Land Acquisition and Surveying (27 acres)	262,000
Interest During Construction (2 years)	189,000
Total Project Cost	**$2,541,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$185,000
Operation and Maintenance	
Pipeline	15,000
Total Annual Cost	**$200,000**
Available Project Yield (acft/yr)	**560**
Annual Cost of Water ($ per acft)	**$357.14**
Annual Cost of Water ($ per 1,000 gallons)	**$1.10**

Table 4B.3-69.
Cost Estimate Summary
Waco North - Treatment
Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Reuse Water Treatment Plant	$7,612,000
Total Capital Cost	**$7,612,000**
Engineering, Legal Costs and Contingencies	$2,664,000
Environmental & Archaeology Studies and Mitigation	27,000
Land Acquisition and Surveying (17 acres)	30,000
Interest During Construction (2 years)	827,000
Total Project Cost	**$11,160,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$811,000
Operation and Maintenance:	
Reuse Water Treatment Plant	830,000
Total Annual Cost	**$1,641,000**
Available Project Yield (acft/yr)	**3,360**
Annual Cost of Water ($ per acft)	**$488.39**
Annual Cost of Water ($ per 1,000 gallons)	**$1.50**

Table 4B.3-70.
Required Facilities – Chalk Bluff WSC

Facility	*Description*
Treatment Upgrade	Purchase 0.22 MGD treated reuse water from Waco
Pump Station	52 hp; 0.88 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1pump station
Storage Tank	0.22 MG; Store one days treated reuse water at tank near Chalk Bluff WSC demand
Pipeline	Shared use of pipeline segment 1
Available Project Yield	0.22 MGD (240 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Table 4B.3-71.
Required Facilities – Gholson

Facility	***Description***
Treatment Upgrade	Purchase 0.06 MGD treated reuse water from Waco
Pump Station	14 hp; 0.24 MGD capacity to deliver peak daily capacity in 6 hours at 60 psi; shared use of segment 1 pump station
Storage Tank	0.06 MG; Store one days treated reuse water at tank in Gholson
Pipeline	Shared use of pipeline segments 1 and 2
Available Project Yield	0.06 MGD (69 acft/yr), yield is based on 30 percent of total year 2060 demand to be used for irrigation and/or industrial customers

Table 4B.3-72.
Cost Estimate Summary
Reuse as a Water Management Strategy for Chalk Bluff WSC
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station for Distribution	$263,000
Transmission Pipeline	172,000
Total Capital Cost	**$435,000**
Engineering, Legal Costs and Contingencies	$152,000
Environmental & Archaeology Studies and Mitigation	14,000
Land Acquisition and Surveying (17 acres)	15,000
Interest During Construction (2 years)	50,000
Total Project Cost	**$666,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$48,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	8,000
Pumping Energy Costs (80794 kWh @ $0.06/kWh)	5,000
Shared Costs:	
Treatment (240 acft/yr @ $488.39/acft)	117,000
Segment 1 Pipeline and Pump Station (240 acft/yr @ $223.21/acft)	54,000
Total Annual Cost	**$232,000**
Available Project Yield (acft/yr)	**240**
Annual Cost of Water ($ per acft)	**$967**
Annual Cost of Water ($ per 1,000 gallons)	**$2.97**

Table 4B.3-73.
Cost Estimate Summary
Reuse as a Water Management Strategy for Gholson
Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Pump Station for Distribution	$108,000
Transmission Pipeline	67,000
Total Capital Cost	**$175,000**
Engineering, Legal Costs and Contingencies	$61,000
Environmental & Archaeology Studies and Mitigation	14,000
Land Acquisition and Surveying (17 acres)	15,000
Interest During Construction (2 years)	22,000
Total Project Cost	**$287,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$21,000
Operation and Maintenance:	
Pipeline, Pump Station, Tank	3,000
Pumping Energy Costs (21,779 kWh @ $0.06/kWh)	1,000
Shared Costs:	
Treatment (69 acft/yr @ $488.39/acft)	34,000
Segment 1 Pipeline and Pump Station (69 acft/yr @ $223.21/acft)	15,000
Segment 2 Pipeline and Pump Station (69 acft/yr @ $357.14/acft)	25,000
Total Annual Cost	**$99,000**
Available Project Yield (acft/yr)	**69**
Annual Cost of Water ($ per acft)	**$1,435**
Annual Cost of Water ($ per 1,000 gallons)	**$4.40**

4B.3.1.10.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.3-74, and the option meets each criterion. Before pursuing wastewater reuse, the Waco North entities will need to investigate concerns that would include at a minimum:

- Amount of treated effluent available, taking into consideration downstream water commitments and discharge permit requirements.
- Potential users, primarily individual large-scale users that could utilize non-potable water (e.g., certain industries) and irrigated lands (e.g., golf courses and park areas).
- Capital costs of constructing needed distribution systems connecting the treatment facilities to the areas of reuse.

Table 4B.3-74.
Comparison of Waco North Reuse Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Potentially important source, up to 25 percent of demand
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Produces instream flows—low to moderate impact
2. Habitat	2. Possible low impact
3. Cultural Resources	3. None or low impact
4. Bays and Estuaries	4. None or low impact
5. Threatened and Endangered Species	5. None or low impact
6. Wetlands	6. None or low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; benefit accrues to demand centers by more efficient use of available water supplies; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Generally positive effect to agriculture and natural resources by avoiding need for new supplies
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Could offset the need for voluntary redistribution of other supplies

Supply of reuse wastewater requires a TCEQ permit. Requirements specific to pipelines needed to link wastewater treatment facilities to reuse water users may include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan; and
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

4B.3.2 Indirect Reuse

Indirect reuse is the discharge of treated wastewater to rivers, streams, or lakes for subsequent diversion downstream (also called "bed and banks"). Several water user groups within the Brazos G Area have applied for or have plans to apply for indirect reuse of municipal wastewater flows. For these entities, indirect reuse may be more economical than direct reuse options and/or enable a greater quantity of treated wastewater flows to be utilized as a replacement for potable water supplies.

Applications for indirect reuse are currently being evaluated on a case by case basis, and the requirements for indirect reuse are in the process of becoming better defined. Some relevant sections of the Texas Water Code are presented here in an effort to present the framework that is informing the current deliberations on indirect reuse. State water is defined in the Texas Water Code as:

> § 11.021. STATE WATER. (a) The water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the storm water, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state is the property of the state.
>
> (b) Water imported from any source outside the boundaries of the state for use in the state and which is transported through the beds and banks of any navigable stream within the state or by utilizing any facilities owned or operated by the state is the property of the state.

Indirect reuse or "bed and banks" delivery is addressed in the Texas Water Code as:

> § 11.042. DELIVERING WATER DOWN BANKS AND BEDS. (a) Under rules prescribed by the commission, a person, association of persons, corporation, water control and improvement district, water improvement district, or irrigation district supplying stored or conserved water under contract as provided in this chapter may use the bank and bed of any flowing natural stream in the state to convey the water from the place of storage to the place of use or to the diversion point of the appropriator.

(b) A person who wishes to discharge and then subsequently divert and reuse the person's existing return flows derived from privately owned groundwater must obtain prior authorization from the commission for the diversion and the reuse of these return flows. The authorization may allow for the diversion and reuse by the discharger of existing return flows, less carriage losses, and shall be subject to special conditions if necessary to protect an existing water right that was granted based on the use or availability of these return flows. Special conditions may also be provided to help maintain in stream uses and freshwater inflows to bays and estuaries. A person wishing to divert and reuse future increases of return flows derived from privately owned groundwater must obtain authorization to reuse increases in return flows before the increase.

(c) Except as otherwise provided in Subsection (a) of this section, a person who wishes to convey and subsequently divert water in a watercourse or stream must obtain the prior approval of the commission through a bed and banks authorization. The authorization shall allow to be diverted only the amount of water put into a watercourse or stream, less carriage losses and subject to any special conditions that may address the impact of the discharge, conveyance, and diversion on existing permits, certified filings, or certificates of adjudication, in stream uses, and freshwater inflows to bays and estuaries. Water discharged into a watercourse or stream under this chapter shall not cause a degradation of water quality to the extent that the stream segment's classification would be lowered. Authorizations under this section and water quality authorizations may be approved in a consolidated permit proceeding.

(d) Nothing in this section shall be construed to affect an existing project for which water rights and reuse authorizations have been granted by the commission before September 1, 1997.

Table 4B.3-75 shows the Brazos G entities with indirect reuse applications currently filed with TCEQ. For reference, all other indirect reuse applications for the state of Texas are shown in Table 4B.3-76.

Table 4B.3-75.
Current Indirect Reuse Applications Filed at the TCEQ in Region G as of June 2, 2005

Applicant/App No.	Basin	County	Amount
Brazos River Authority / 5851	Brazos River Basin and Coastal Basins	Multiple	current and future return flows
City of Abilene / 12-4161C	Brazos River Basin	Jones, Taylor, Shackelford, Haskell, Stephens	22 MGD (minus 4,330 acft)
City of Cleburne / 12-4106C	Brazos River Basin	Johnson	8,400 acft
City of Waco / 5840	Brazos River Basin	McLennan	42,344 acft

Table 4B.3-76.
Current Indirect Reuse Applications Filed at TCEQ (Not in Region G) as of June 2, 2005

Applicant/App No.	***Basin***	***County***	***Amount***
City of Austin / 5779	Colorado River Basin	Travis	93,350 acft
City of Dallas / 08-2456E	Trinity River Basin	Dallas, Denton	97,200 acft
City of Dallas / 08-2462G	Trinity River Basin	Collin, Dallas, Rockwall	150,000 acft
City of Houston / 5827	San Jacinto River Basin, the Trinity River Basin, San Jacinto- Brazos Coastal Basin, and Trinity-San Jacinto Coastal Basin	Harris, Fort Bend, Brazoria, Chambers, and Galveston	580,923 acft
City of Irving / 03-4799C	Sulphur River Basin, Trinity River Basin	Delta, Hopkins, Dallas	31,600 acft
City of Lubbock / 12-3985A	Brazos River Basin	Lubbock	10,080 acft
Lower Colorado River Authority / 14-5478D	Colorado River Basin	all counties below Buchanan Dam	all historical, current, and future return flows
Lower Colorado River Authority / 14-5482D	Colorado River Basin	all counties below Mansfield Dam	all historical, current, and future return flows
North Texas Municipal Water District / 08-2410E	Trinity River Basin	Collin	71,882 acft
North Texas Municipal Water District / 08-2410F	Trinity River Basin	Collin, Dallas, Kaufman, Rockwall	206,600 acft
North Texas Municipal Water District / 5003A	Red River Basin, Trinity River Basin, Sabine River Basin	multiple	return flows associated with the additional 113,000 acft from Lake Texoma
Trinity River Authority / 08-3404D	Trinity River Basin	Dallas, Tarrant, Ellis	4,368 acft
Trinity River Authority / 08-4248B	Trinity River Basin	Polk	historical and future return flows
Upper Trinity Regional Water District / 5778	Trinity River Basin	Denton	9,664 acft

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4B.4 System Operation of Brazos River Authority Reservoirs

The Brazos River Authority (BRA) has submitted to the Texas Commission on Environmental Quality (TCEQ) a water rights permit application requesting additional appropriation of water that could be made available through system operations of the BRA's existing water rights and reservoirs. The BRA has requested an appropriation of up to 421,449 acft/yr of firm supply. The BRA also requests authorization to use up to 90,000 acft/yr of its firm supply to produce, along with other unappropriated flows, an interruptible supply of up to 670,000 acft/yr for appropriation. By conventional definition, at least 75 percent of an interruptible supply is available at least 75 percent of the time.

At the request of the BRA, the Brazos G RWPG evaluated several aspects of the BRA System Operations as a potential water management strategy for the 2006 Brazos G Regional Water Plan (2006 Plan).

The evaluation was completed through three distinct tasks:

1. Incorporate the BRA System Operations into the Brazos G WAM and determine the maximum amount that could be made available under the constraints of existing contractual obligations and future reservoir sedimentation conditions.
2. Determine the additional water supply that would be made available by the BRA System Operations to Water User Groups (WUGs) with needs that could potentially utilize the additional supply.
3. Determine various effects of the proposed BRA System Operations:
    - on new water management strategies evaluated as being junior in priority to the proposed BRA appropriation;
    - on the increase in supply that could be made available by operating new water management strategies as part of the BRA System; and
    - on the increase in supply that could be made available from existing projects owned by other entities by operating those projects in conjunction with the BRA System.

4B.4.1 Availability of Water from the BRA System Operations

The water requested in the BRA water rights permit application is the maximum amount of water that might be developed by the BRA System if all of the water were utilized (diverted) near the Gulf of Mexico. Diverting all water supply from the BRA System (both existing and new appropriations) near the Gulf maximizes the supply available by (a) allowing all BRA reservoirs to contribute and make releases, and (b) maximizes the area contributing flows (uncontrolled runoff and wastewater return flows[1]) that originate downstream of the BRA reservoirs. Under this hypothetical operation (diverting all supply near the Gulf), uncontrolled flow originating downstream of the BRA reservoirs is diverted during wet times, and firmed up by releases from storage in the upstream BRA reservoir during dry times. In this fashion, a total "system" yield can be developed that is substantially greater than the sum of the individual reservoir yields.

The BRA currently holds multiple contracts to supply water to cities, districts, irrigators and industry throughout the Brazos River Basin. The total of the contracts held by the BRA to supply water total more than 80 percent of their currently authorized diversions from their existing water rights (including Allens Creek Reservoir, which is not constructed). Many of these contracts are supplied proximate to the BRA's reservoirs, or through lakeside diversions. This reduces the efficiency of the BRA System because (a) not every BRA reservoir can contribute releases to every contractual diversion location, and (b) diversion of the contracts from the basin upstream of the Gulf reduces the opportunity to utilize flows contributed by the basin downstream of the reservoir system. Because of this constraint, the total amount of water that the BRA could realize through system operations of its reservoirs is reduced substantially.

The Brazos G WAM was utilized to determine the availability of water from the BRA System. The Brazos G WAM, as developed by the Brazos G RWPG, includes 600,946 acft of existing BRA contracts simulated at their actual points of diversion in the basin. The BRA System operations concept was incorporated into the Brazos G WAM by specifying which contracts could receive releases from multiple reservoirs, and then allowing those reservoirs to make releases during model simulations. The remaining water available from the BRA System (after supplying current contractual commitments) was then evaluated at the Gulf of Mexico. The BRA application includes estimates of potential system diversions at three locations: Brazos River near Glen Rose, Brazos River near Highbank, and the Brazos River at the Gulf of Mexico. The analysis performed for the Brazos G RWPG evaluating the effects of the BRA System Operations includes only the Brazos River at the Gulf of Mexico system diversion location.

During the model simulations, the BRA contracts are met first from the BRA System, followed by the remaining amount that could be met at the Gulf of Mexico. This would be the

[1] This water management strategy shall not impair or prejudice the rights of an owner of groundwater based discharges to seek or obtain authorization to reuse such discharges either directly or indirectly pursuant to Texas Water Code Section §11.042 (b) consistent with state law.

maximum amount that could be realized by the BRA under the agency's current contractual commitments. All simulations assume Year 2060 reservoir sedimentation conditions.

Results of the water availability analysis are shown in Table 4B.4-1. The sum of the BRA's existing contractual obligations included in this analysis total 600,946 acft/year. When all remaining supply from the system is diverted at the Gulf after meeting upstream contractual commitments, an additional 395,000 acft/yr of firm supply could be developed by system operations of the BRA reservoirs. This total includes both currently permitted yield that is not utilized by existing contracts, and unpermitted yield that could be developed by the system operations.

Table 4B.4-1.
Water Availability from BRA System Operations

Total BRA Permitted Diversions (acft/yr)	*BRA Contractual Diversions (acft/yr)*	*Diversions at Gulf (acft/yr)*	*Total BRA System Diversions (acft/yr)*	*Permitted Unutilized Yield (acft/yr)*	*Unpermitted Yield (acft/yr)*
761,551	600,946	395,000	995,946	160,605	234,395

The availability of interruptible supply was not evaluated for this portion of the analysis, but was included in Task 3 to determine the overall effects of the proposed BRA appropriation on water management strategies considered for the 2006 Plan.

The Gulf of Mexico diversion scenario was utilized as the standard "base run" with which the remaining portion of the analysis was completed.

4B.4.2 Utilization of the BRA System Operations as a Water Management Strategy for Specific WUGs

Water available from BRA System Operations represents a new supply of water that could be utilized to meet future needs in the Brazos G Area without construction of new reservoirs. WUGs with projected needs were identified in counties adjacent to the main stem of the Brazos River. Demands equal to those needs were included as new contractual diversions in the system operations version of the Brazos G WAM. The model was then used to determine if sufficient water was available from system operations to meet the projected needs of each of the WUGs, as well as the facility and operational costs for diversion, transmission, and treatment.

4B.4.2.1 Selected WUG with Needs

In consultation with the BRA, eight potential diversion locations were identified along the main stem of the Brazos River that are proximate to the locations of one or more WUGs with projected needs. Some of the selected diversion locations can be utilized for multiple WUGs. Figure 4B.4-1 shows the eight diversion locations, and Table 4B.4-2 lists the ten WUGs or groups of WUGs selected for which water available from BRA System Operations might be a feasible water management strategy. WUGs with needs based on infrastructure constraints were not included as selected WUGs.

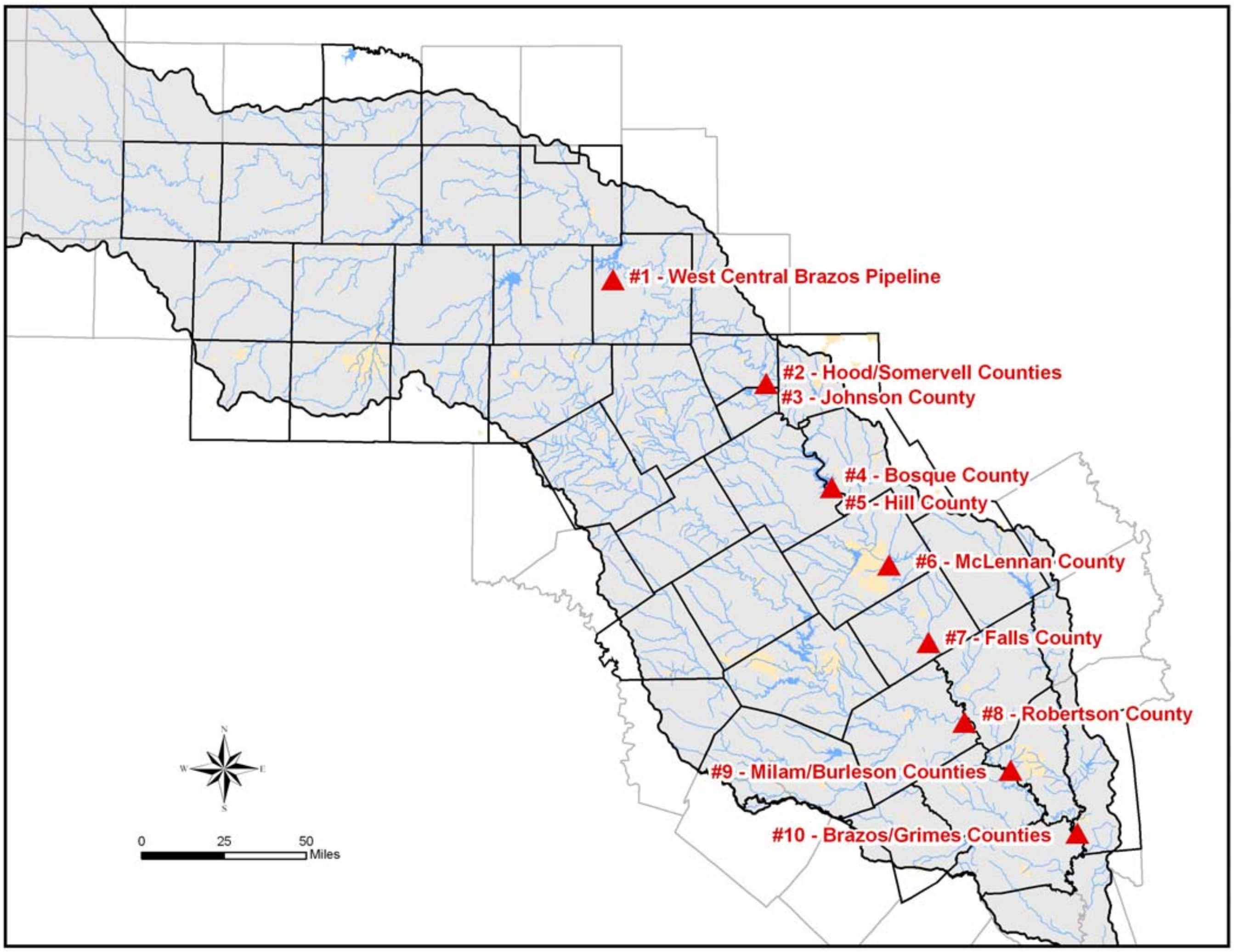


Figure 4B.4-1. WUG Diversion Locations

Table 4B.4-2.
Selected WUGs for Availability and Cost Analysis

Diversion Location #	WUG Location	Combined WUG Need (acft/yr)	Included WUGs
1	West Central Brazos Pipeline	10,689	Stephens County Other Stephens County Mining Shackleford County Mining
2	Hood / Somervell Counties	4,089	Oak Trail Shores Subdivision Hood County Other Hood County Manufacturing Hood County Mining Somervell County Other Somervell County Manufacturing Somervell County Mining
3	Johnson County	20,305	Alvarado Bethany WSC Godley Grandview Johnson County SUD Joshua Parker WSC Rio Vista Venus Johnson County Other Johnson County Manufacturing Johnson County Other
4	Bosque County	10,000	Bosque Steam Electric
5	Hill County	1,606	Brandon-Irene WSC Hillsboro Parker WSC White Bluff Community WSC Woodrow-Osceoal WSC
6	McLennan County	3,022	Chalk Bluff WSC Crawford Cross County WSC Gholson North Bosqu WSC West Western Hill WSC McLennan County Manufacturing
7	Falls County	1,211	Elm Creek WSC West Brazos WSC
8	Robertson County	8,244	Robertson County Steam Electric
9	Milam / Burleson Counties	1,164	Bell-Milam-Falls WSC Southwest Milam WSC Burleson County Manufacturing
10	Brazos / Grimes Counties	3,162	Bryan Wickson Creek SUD Brazos County Manufacturing Grimes County Manufacturing
Total WUG Needs		65,482	

4B.4.2.2 Water Availability to WUGs with Needs

The individual WUG diversions were incorporated into the model in upstream to downstream order, and assigned priority junior to BRA's existing water supply contracts. As additional WUG diversions are added in the downstream direction, additional BRA reservoirs are capable of making releases to meet the demands, and the remaining supply available at the Gulf of Mexico is reduced in response to the additional upstream demand.

All 10 WUG needs are able to be met exclusively by the BRA system without negatively impacting any existing BRA water supply obligations. However, in order to be able to meet the additional 65,482 acft of identified WUG demands, the remaining supply at the Gulf would be reduced by 129,000 acft. As supply is taken upstream it causes a reduction of available supply at the downstream location that is greater than a 1:1 proportion, caused by the system's reduced ability to "firm up" the downstream uncontrolled flows.

4B.4.2.3 Costs for Meeting WUG Needs with BRA System Supply

The following sections describe the estimated facilities and operational costs associated with diverting, transmitting, and treating the BRA system water if it was used to meet the identified WUG needs. Raw water costs were set equal to the current BRA system rate of $45.75 per acft. Facilities and operation costs for the 10 WUG supply scenarios were estimated using the cost estimating procedure used for other water management strategies evaluated for the 2006 Plan.

No facilities costs were computed for WUG Supply scenario #1 (West Central Brazos Pipeline); the only cost associated with this strategy is for raw water purchased from the BRA, which the BRA has indicated would be sufficient to cover costs of delivering water through system. Since the facilities exist and the end users are expected to be mining operations with proximate access to the existing pipeline, no other additional facilities or operational costs were estimated for this option.

Table 4B.4-3 presents a summary comparison of the costs for the individual WUGs. Unit costs vary considerably due to economies of scale and treatment considerations for the type of use contemplated. Desalination was considered necessary for all municipal and manufacturing uses, but not mining or steam electric uses. Large individual unit costs could be decreased by serving additional WUGs beyond those enumerated herein. Unit costs for supply from the West

Central Brazos Pipeline were provided by BRA. Detailed cost summaries for the other 9 WUG supply options are shown in Tables 4B.4-4 – 4B.4-12.

Table 4B.4-3.
Comparison of WUG Costs for Utilization of Supply Available from BRA System Operation

WUG #	WUG Location	Demand (acft/yr)	Capital Cost (Millions)	Annual Cost (Millions)	Unit Cost ($/acft)	Unit Cost ($/1,000 gal)
1	West Central Brazos Pipeline	10,689	n/a	na/	$45.75	$0.14
2	Hood / Somervell Counties	4,089	$40.68	$5.22	$1,277	$3.92
3	Johnson County	20,305	$140.70	$21.06	$1,037	$3.18
4	Bosque County	10,000	$25.49	$3.82	$382	$1.17
5	Hill County	1,606	$36.15	$3.78	$2,355	$7.23
6	McLennan County	3,022	$35.69	$4.35	$1,439	$4.42
7	Falls County	1,211	$23.12	$2.60	$2,145	$6.58
8	Robertson County	8,244	$16.60	$2.36	$286	$0.88
9	Milam / Burleson Counties	1,164	$33.47	$3.39	$2,909	$8.93
10	Brazos / Grimes Counties	3,162	$44.78	$5.27	$1,667	$5.12

Table 4B.4-4.
WUG #2 Facilities and Operation Cost Summary

Cost Estimate Summary Water Supply Project Option Second Quarter 2002 Prices WUG-2 Hood and Somerville Counties	
Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (5 MGD)	$1,926,000
Transmission Pipeline (18 in dia., 4 miles)	$1,245,000
Transmission Pipeline (16 in dia., 8 miles)	$2,574,000
Transmission Pipeline (12 in dia., 20 miles)	$5,898,000
Transmission Pump Station(s)	$1,062,000
Water Treatment Plants (4.84 MGD RO System)	$14,056,000
Total Capital Cost	**$26,761,000**
Engineering, Legal Costs and Contingencies	$8,880,000
Environmental & Archaeology Studies and Mitigation	$851,000
Land Acquisition and Surveying (126 acres)	$1,172,000
Interest During Construction (2 years)	$3,014,000
Total Project Cost	**$40,678,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,955,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$169,000
Water Treatment Plant	$1,588,000
Pumping Energy Costs (5,357,365 kW-hr @ 0.06 $/kW-hr)	$321,000
Purchase of Water (4,089 acft/yr @ 45.75 $/acft)	$187,000
Total Annual Cost	**$5,220,000**
Available Project Yield (acft/yr)	4,089
Annual Cost of Water ($ per acft)	$1,277
Annual Cost of Water ($ per 1,000 gallons)	$3.92

Table 4B.4-5.
WUG #3 Facilities and Operation Cost Summary

Cost Estimate Summary Water Supply Project Option Second Quarter 2002 Prices WUG-3 Johnson County	
Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (24.8 MGD)	$5,374,000
Transmission Pipeline (36 in dia., 24 miles)	$16,395,000
Transmission Pipeline (12 in dia., 47 miles)	$10,739,000
Transmission Pump Station(s)	$9,924,000
Water Treatment Plants (24.42 MGD RO System)	$48,325,000
Total Capital Cost	**$90,757,000**
Engineering, Legal Costs and Contingencies	$30,408,000
Environmental & Archaeology Studies and Mitigation	$1,876,000
Land Acquisition and Surveying (277 acres)	$2,580,000
Interest During Construction (3 years)	$15,075,000
Total Project Cost	**$140,696,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$10,221,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$632,000
Water Treatment Plant	$6,799,000
Pumping Energy Costs (41,355,382 kW-hr @ 0.06 $/kW-hr)	$2,481,000
Purchase of Water (20,305 acft/yr @ 45.75 $/acft)	$929,000
Total Annual Cost	**$21,062,000**
Available Project Yield (acft/yr)	20,305
Annual Cost of Water ($ per acft)	$1,037
Annual Cost of Water ($ per 1,000 gallons)	$3.18

Table 4B.4-6.
WUG #4 Facilities and Operation Cost Summary

Cost Estimate Summary Water Supply Project Option Second Quarter 2002 Prices WUG-4 Bosque County	
Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (12.2 MGD)	$2,562,000
Transmission Pipeline (24 in dia., 17 miles)	$8,704,000
Transmission Pump Station(s)	$5,780,000
Water Treatment Plant (none needed)	$0
Total Capital Cost	**$17,046,000**
Engineering, Legal Costs and Contingencies	$5,531,000
Environmental & Archaeology Studies and Mitigation	$430,000
Land Acquisition and Surveying (67 acres)	$596,000
Interest During Construction (2 years)	$1,889,000
Total Project Cost	**$25,492,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,852,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$284,000
Water Treatment Plant	$0
Pumping Energy Costs (20,417,920 kW-hr @ 0.06 $/kW-hr)	$1,225,000
Purchase of Water (10,000 acft/yr @ 45.75 $/acft)	$458,000
Total Annual Cost	**$3,819,000**
Available Project Yield (acft/yr)	10,000
Annual Cost of Water ($ per acft)	$382
Annual Cost of Water ($ per 1,000 gallons)	$1.17

Table 4B.4-7.
WUG #5 Facilities and Operation Cost Summary

Cost Estimate Summary Water Supply Project Option Second Quarter 2002 Prices WUG-5 Hill County	
Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (1.96 MGD)	$1,230,000
Transmission Pipeline (12 in dia., 56 miles)	$12,863,000
Transmission Pump Station(s)	$877,000
Water Treatment Plants (1.96 MGD RO System)	$7,786,000
Total Capital Cost	**$22,756,000**
Engineering, Legal Costs and Contingencies	$7,321,000
Environmental & Archaeology Studies and Mitigation	$1,420,000
Land Acquisition and Surveying (212 acres)	$1,976,000
Interest During Construction (2 years)	$2,678,000
Total Project Cost	**$36,151,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,626,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$180,000
Water Treatment Plant	$789,000
Pumping Energy Costs (1,895,643 kW-hr @ 0.06 $/kW-hr)	$114,000
Purchase of Water (1,606 acft/yr @ 45.75 $/acft)	$73,000
Total Annual Cost	**$3,782,000**
Available Project Yield (acft/yr)	1,606
Annual Cost of Water ($ per acft)	$2,355
Annual Cost of Water ($ per 1,000 gallons)	$7.23

Table 4B.4-8.
WUG #6 Facilities and Operation Cost Summary

Cost Estimate Summary Water Supply Project Option Second Quarter 2002 Prices WUG-6 McLennan County	
Item	***Estimated Costs for Facilities***
Capital Costs	
Intake 1 and Pump Station (1.19 MGD)	$1,209,000
Intake 2 and Pump Station (2.51 MGD)	$1,220,000
Transmission Pipelines (12 in dia., 33 miles)	$8,355,000
Transmission Pump Station(s)	$953,000
Water Treatment Plants (3.69 MGD RO System)	$11,552,000
Total Capital Cost	**$23,289,000**
Engineering, Legal Costs and Contingencies	$7,733,000
Environmental & Archaeology Studies and Mitigation	$849,000
Land Acquisition and Surveying (131 acres)	$1,178,000
Interest During Construction (2 years)	$2,644,000
Total Project Cost	**$35,693,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,593,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$166,000
Water Treatment Plant	$1,269,000
Pumping Energy Costs (3,047,084 kW-hr @ 0.06 $/kW-hr)	$183,000
Purchase of Water (3,022 acft/yr @ 45.75 $/acft)	$138,000
Total Annual Cost	**$4,349,000**
Available Project Yield (acft/yr)	3,022
Annual Cost of Water ($ per acft)	$1,439
Annual Cost of Water ($ per 1,000 gallons)	$4.42

Table 4B.4-9.
WUG #7 Facilities and Operation Cost Summary

Cost Estimate Summary Water Supply Project Option Second Quarter 2002 Prices WUG-7 Falls County	
Item	**Estimated Costs for Facilities**
Capital Costs	
Intake and Pump Station (1.48 MGD)	$1,215,000
Transmission Pipeline (12 in dia., 24 miles)	$5,233,000
Transmission Pump Station(s)	$1,773,000
Water Treatment Plants (1.48 MGD RO System	$6,741,000
Total Capital Cost	**$14,962,000**
Engineering, Legal Costs and Contingencies	$4,975,000
Environmental & Archaeology Studies and Mitigation	$615,000
Land Acquisition and Surveying (96 acres)	$853,000
Interest During Construction (2 years)	$1,713,000
Total Project Cost	**$23,118,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,679,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$125,000
Water Treatment Plant	$656,000
Pumping Energy Costs (1,383,144 kW-hr @ 0.06 $/kW-hr)	$83,000
Purchase of Water (1,211 acft/yr @ 45.75 $/acft)	$55,000
Total Annual Cost	**$2,598,000**
Available Project Yield (acft/yr)	1,211
Annual Cost of Water ($ per acft)	$2,145
Annual Cost of Water ($ per 1,000 gallons)	$6.58

Table 4B.4-10.
WUG #8 Facilities and Operation Cost Summary

Cost Estimate Summary Water Supply Project Option Second Quarter 2002 Prices WUG-8 Robertson County	
Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (10.1 MGD)	$2,566,000
Transmission Pipeline (24 in dia., 17 miles)	$6,182,000
Transmission Pump Station(s)	$2,154,000
Water Treatment Plant (none needed)	$0
Total Capital Cost	**$10,902,000**
Engineering, Legal Costs and Contingencies	$3,506,000
Environmental & Archaeology Studies and Mitigation	$426,000
Land Acquisition and Surveying (64 acres)	$591,000
Interest During Construction (2 years)	$1,234,000
Total Project Cost	**$16,659,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,210,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$175,000
Water Treatment Plant	$0
Pumping Energy Costs (9,969,192 kW-hr @ 0.06 $/kW-hr)	$598,000
Purchase of Water (8,244 acft/yr @ 45.75 $/acft)	$377,000
Total Annual Cost	**$2,360,000**
Available Project Yield (acft/yr)	8,244
Annual Cost of Water ($ per acft)	$286
Annual Cost of Water ($ per 1,000 gallons)	$0.88

Table 4B.4-11.
WUG #9 Facilities and Operation Cost Summary

Cost Estimate Summary *Water Supply Project Option* *Second Quarter 2002 Prices* *WUG-9 Milam/Burleson County*	
Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (1.42 MGD)	$1,214,000
Transmission Pipeline (12 in dia., 56 miles)	$12,168,000
Transmission Pump Station(s)	$895,000
Water Treatment Plants (1.42 MGD RO System)	$6,610,000
Total Capital Cost	**$20,887,000**
Engineering, Legal Costs and Contingencies	$6,702,000
Environmental & Archaeology Studies and Mitigation	$1,422,000
Land Acquisition and Surveying (211 acres)	$1,976,000
Interest During Construction (2 years)	$2,479,000
Total Project Cost	**$33,466,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$2,431,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$173,000
Water Treatment Plant	$639,000
Pumping Energy Costs (1,497,245 kW-hr @ 0.06 $/kW-hr)	$90,000
Purchase of Water (1,164 acft/yr @ 45.75 $/acft)	$53,000
Total Annual Cost	**$3,386,000**
Available Project Yield (acft/yr)	1,164
Annual Cost of Water ($ per acft)	$2,909
Annual Cost of Water ($ per 1,000 gallons)	$8.93

Table 4B.4-12.
WUG #10 Facilities and Operation Cost Summary

Cost Estimate Summary Water Supply Project Option Second Quarter 2002 Prices WUG-10 Brazos/Grimes County	
Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Station (3.86 MGD)	$1,512,000
Transmission Pipeline (14 in dia., 6 miles)	$1,736,829
Transmission Pipeline (12 in dia., 47 miles)	$11,568,524
Transmission Pump Station(s)	$2,098,000
Water Treatment Plants (3.86 MGD RO System)	$11,922,000
Total Capital Cost	**$28,837,353**
Engineering, Legal Costs and Contingencies	$9,428,000
Environmental & Archaeology Studies and Mitigation	$1,340,000
Land Acquisition and Surveying (201 acres)	$1,860,000
Interest During Construction (2 years)	$3,318,000
Total Project Cost	**$44,783,353**
Annual Costs	
Debt Service (6 percent, 30 years)	$3,253,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$219,000
Water Treatment Plant	$1,316,000
Pumping Energy Costs (5,648,603 kW-hr @ 0.06 $/kW-hr)	$339,000
Purchase of Water (3,162 acft/yr @ 45.75 $/acft)	$145,000
Total Annual Cost	**$5,272,000**
Available Project Yield (acft/yr)	3,162
Annual Cost of Water ($ per acft)	$1,667
Annual Cost of Water ($ per 1,000 gallons)	$5.12

4B.4.3 Effects of the Proposed BRA System Operations on Water Management Strategies Considered for the 2006 Plan

BRA System Operations would appropriate additional water in the Brazos River Basin with a priority date set in 2004. Under the Doctrine of Prior Appropriation, any water management strategy requiring a new TCEQ water rights permit (a new reservoir or run-of-the-river diversion) would be junior to this priority date, and would be required to pass flows to BRA System needs under the concept of "first in time, first in right." This would reduce the water available to any new appropriation, and would reduce the supply developed by any new water management strategy. In order to determine the efficacy of including the BRA System Operations as a recommended water management strategy in the 2006 Plan, the potential effects of the new appropriation on other water management strategies considered for the 2006 Plan were evaluated by the Brazos G RWPG.

Nine water management strategies (all new reservoirs) were evaluated with and without the proposed BRA System Operations in place. All nine were operated as if junior to the proposed BRA System appropriation and would be required to pass flows when called on by the proposed new BRA water rights. Two alternative analyses were completed for each reservoir: the first incorporated just the firm portion of the proposed BRA System Diversion at the Gulf of Mexico as a water right senior to the new reservoir; the second analysis added the interruptible portion of the proposed appropriation as a water right senior to the new reservoir.

Table 4B.4-13 presents the yields of each project operated as junior to the BRA System Operation (with and without interruptible water), and compares those yields to the yield if the reservoir were operated senior to the proposed BRA System appropriation. The yields of the projects senior to the BRA System appropriation are identical to those determined for the reservoirs as individual water management strategies in Sections 4B.12 and 4B.13. As shown by the table, operation of the potential new reservoirs at a priority junior to the proposed BRA System appropriation substantially reduces the available yield from each of the projects. The inclusion of the proposed interruptible water further reduces the yields from these projects. This reduction in the yields of these projects is expected, as any new appropriation of water will reduce availability to any other appropriation with a junior priority.

Figure 4B.4-2 presents this information graphically for the Millican-Bundic Reservoir. The last bar on this graph represents the increase in System yield if the reservoir were operated as part of the BRA System Operations. This is discussed later in the next section.

Table 4B.4-13.
Yields of Reservoir Water Management Strategies when Operated Junior to the BRA System Operations Appropriation

Water Management Strategy	Senior to BRA System Operations (acft/yr)	Junior to BRA System Operations (acft/yr): Gulf Diversion, No Interruptible Water[1]	Junior to BRA System Operations (acft/yr): Gulf Diversion, with Interruptible Water[2]
Double Mountain Fork - East Site	40,100	8,625	5,000
South Bend	44,940[3] (30,635)[4]	22,700 [4]	14,700 [4]
Millers Creek	-	-	-
Cedar Ridge	15,000 (32,570)[5]	13,900	12,050
Turkey Peak + Palo Pinto	19,130 [6]	15,580	15,580
Groesbeck	950	200	200
Little River Off-Channel (108" diversion pipeline)	32,110	26,900	22,500
Little River On-Channel	124,000	93,480	92,000
Millican-Bundic	38,080	31,800	30,750

[1] BRA System Diversion of 395,000 acft/yr at Gulf of Mexico, with 600,946 acft/yr contracts diverted at contractual locations.

[2] Interruptible supply of 670,000 acft/yr diverted at Gulf of Mexico, with firm supply of 395,000 acft/yr at Gulf and 600,946 acft/yr contracts diverted at contractual locations.

[3] Yield of South Bend reservoir when operated in conjunction with Possum Kingdom Reservoir.

[4] These yields are based on the stand alone firm yield of South Bend Reservoir for purposes of determining the impacts to the strategy.

[5] Includes subordination to Possum Kingdom Reservoir.

[6] Additional Yield due to Turkey Peak Reservoir is 8,648 acft/yr, keeping Palo Pinto Reservoir rights firm.

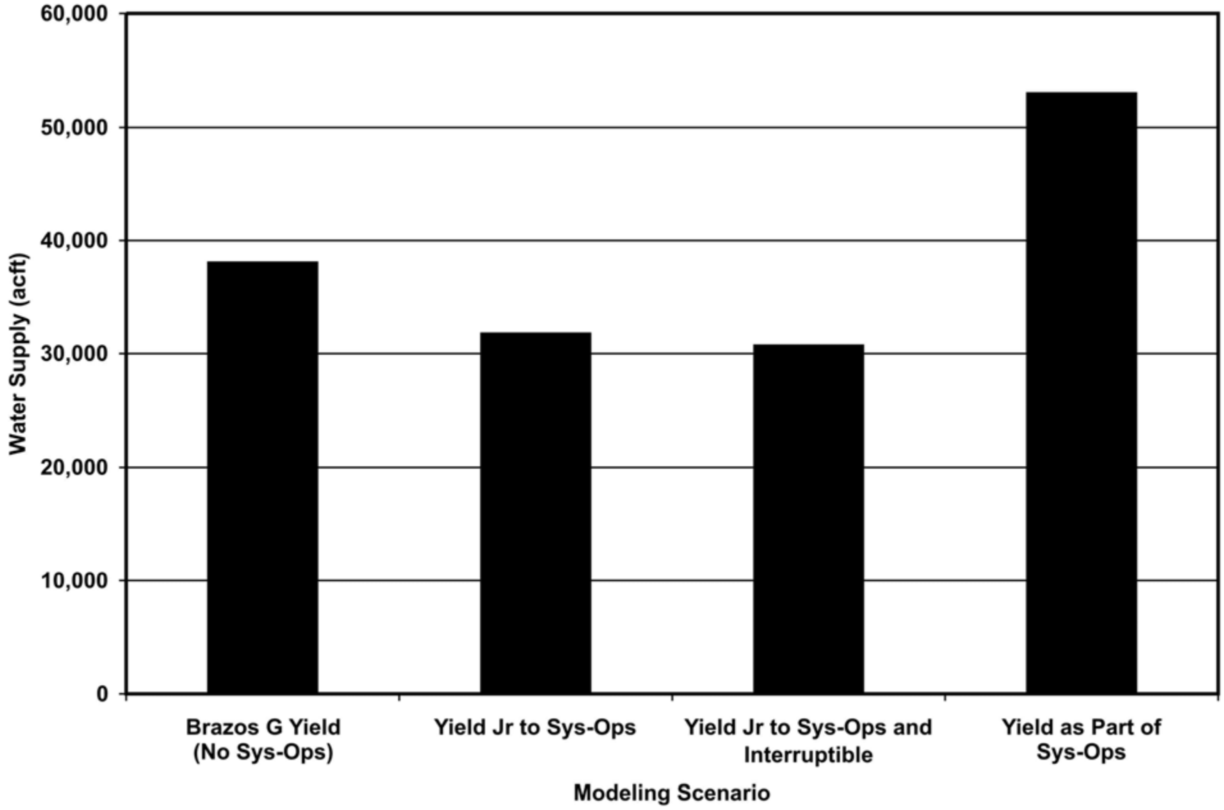


Figure 4B.4-2. Yields of the Millican-Bundic Reservoir Operated with Various Priority Relationships to the BRA System

4B.4.4 Effects of Incorporating Water Management Strategies into BRA System Operations

While the yields of the reservoir strategies evaluated previously are substantially reduced when operated junior in priority to the BRA System Operations appropriation, the projects can provide a substantial benefit to the overall yield of the BRA system if operated conjunctively as part of the system. Table 4B.4-14 presents the increase in overall system supply that would be realized if these projects were operated as part of the BRA System. In all cases, the reservoirs were operated to make releases to a BRA System diversion at the Gulf of Mexico. Figure 4B.4-2 illustrates the yield of the Millican-Bundic Reservoir senior to, junior to, and as part of the BRA System. Results for other potential reservoir projects are similar.

As shown in Table 4B.4-14, the system yield increases that could be realized by incorporating individual new reservoirs into the BRA System generally are greater than the

Table 4B.4-14.
BRA System Yield Results when Water Management Strategies are Operated with BRA System Operations
(all values in acre-feet per year)

Total BRA Authorization	761,551
BRA Contracts included in Model	600,946
Current Permitted Unutilized Authorization	160,605

Water Management Strategy	Brazos G System Diversion Yield at the Gulf	Contracts Included in Model	Permitted Unutilized Yield	Unpermitted Yield	Total Potential Firm Supply from the BRA System
Base Yield without any WMS	395,000	600,946	160,605	234,395	995,946
Double Mountain Fork East Site	435,000	600,946	160,605	274,395	1,035,946
Cedar Ridge	423,000	600,946	160,605	262,395	1,023,946
South Bend	441,000	600,946	160,605	280,395	1,041,946
Turkey Peak + Palo Pinto	420,000	600,946	160,605	259,395	1,020,946
Little River Off-Channel (108-inch pipe)	435,000	600,946	160,605	274,395	1,035,946
Little River On-Channel	420,000	600,946	160,605	259,395	1,020,946
Millican-Bundic	425,000	600,946	160,605	264,395	1,025,946

stand-alone yield of the projects themselves. This is primarily due to the reservoir storage being operated to “firm up” uncontrolled flows diverted at the Gulf that originate downstream of existing BRA reservoirs and downstream of the potential new reservoir.

Figure 4B.4-3 illustrates different components of supply in the Brazos River Basin, both current and potential. In this figure, the supply from the BRA System is shown in black, both as currently permitted and with the proposed BRA System appropriation. The combined yields of the other major reservoirs are shown in green. As shown by comparing these two bars, the BRA controls the majority of the reservoir firm yield in the basin. Shown in blue are the combined stand-alone yields of three water management strategies considered for the 2006 Plan: Breckenridge Reservoir (Cedar Ridge site), Little River Off-Channel Reservoir and the Millican-Bundic Reservoir. These are shown, alternatively, as stand-alone yields (dark blue) and as operated in conjunction with the BRA System. Finally, the interruptible portion of the proposed BRA System appropriation is shown in grey.

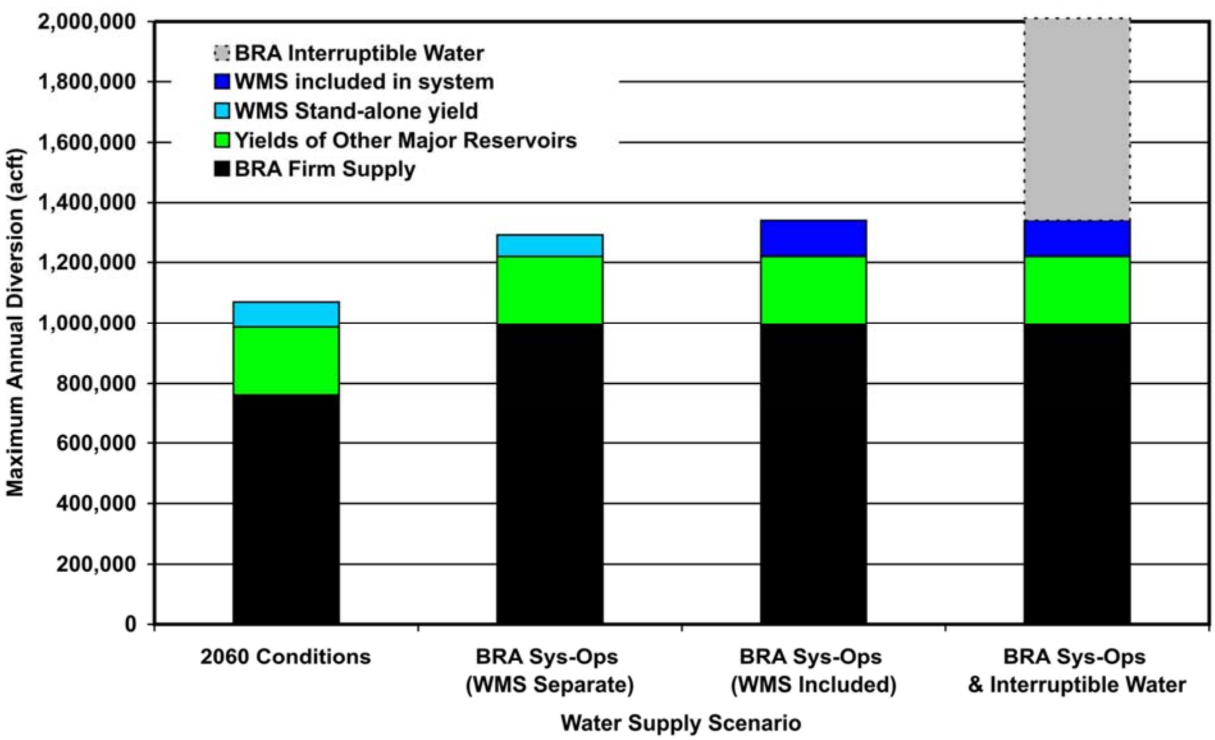


Figure 4B.4-3. Summary of BRA System Diversions When Combined with Three New Reservoir Projects: Cedar Ridge Reservoir, Little River Off-Chanel, and Millican-Bundic Reservoir

4B.4.5 Effects of Including Existing Water Supply Sources as Part of BRA System Operations

A final analysis was completed, wherein an existing water supply reservoir (Lake Waco) would be operated in conjunction with the proposed BRA System appropriation to determine the supply increase that such an operation would have on the BRA System.

For this analysis, Lake Waco's participation in the BRA System was constrained to give priority to local needs and to maintain lake levels for recreational purposes. The lakeside demand on the reservoir was set to the estimated Year 2060 demand on the reservoir plus 15%, or 67,935 acft/yr.[2] Lake Waco contributions to the BRA System were limited to times when the reservoir was at or above 455 feet elevation; approximately 71% of the reservoir storage would be kept in reserve for local use with the top 29% of the storage used jointly to meet local demands and augment the BRA System. The results of this analysis indicate that the inclusion of Lake Waco in the BRA System Operations under those operational constraints would add approximately 6,000 acft/yr to the firm yield of the BRA System, diverted at the Gulf.

4B.4.6 Summary of Hydrologic Findings Concerning the Proposed BRA System Operations

The proposed BRA System Operations appropriation would add a considerable amount of firm supply to the Brazos River Basin that could be used in the Brazos G Area, but also in adjacent regions where the BRA supplies water, most notably Region H (Houston area). New proposed water management strategies may be negatively impacted by the BRA System Operations, but only to the extent that priority limits availability to the new options.

Supply from the BRA System Operations can be utilized to meet WUG demands throughout the Brazos Basin. Several WUGs with needs were identified, and unit cost estimates for using BRA System Operations supply to meet these needs ranged from $286 to $2,909 per acft.

The BRA System Operations would negatively affect the yields of several proposed water management strategies that are considered for the 2006 Brazos G Regional Water Plan.

[2] At the time this analysis was completed, strategies involving the City of Waco providing additional supply to McLennan County entities had not been identified. Projected local demands on Lake Waco are now greater than 67,935 acft/yr if all water management strategies utilizing the City of Waco as a wholesale water provider are implemented.

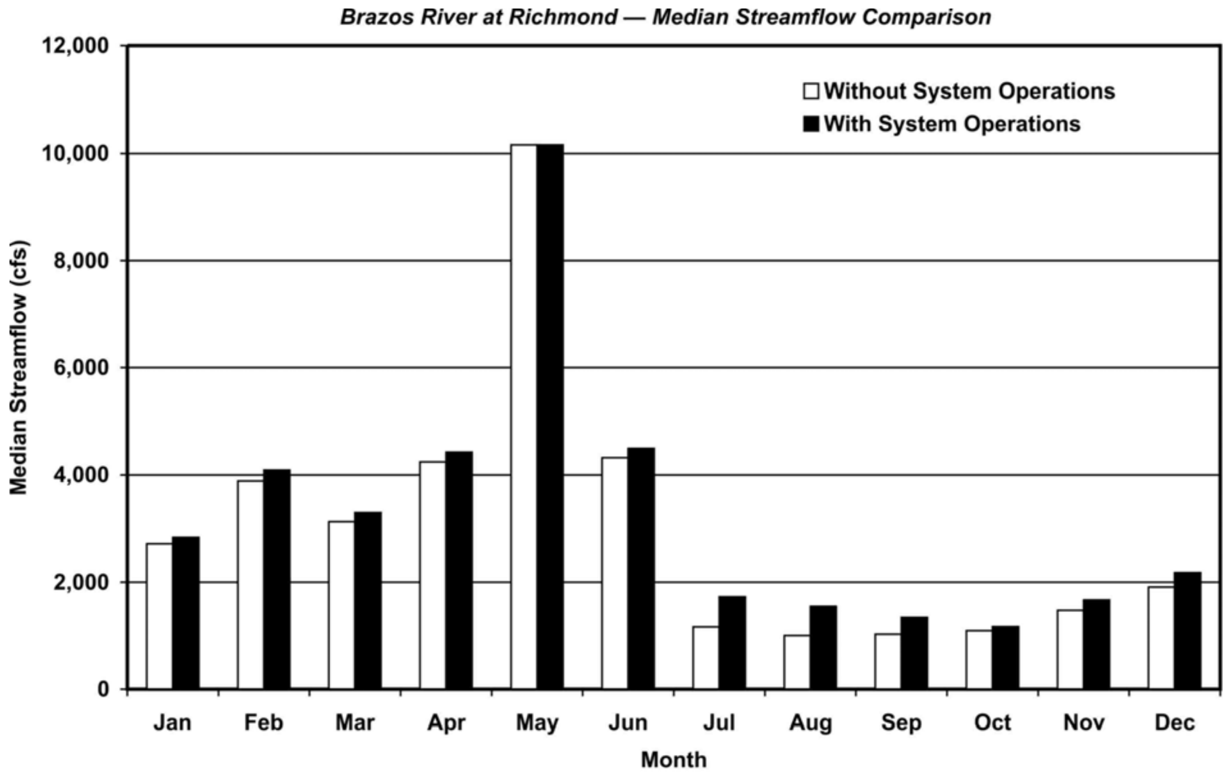
The proposed BRA System Operations appropriation would be granted with a priority date senior to any of these proposed reservoir projects, and would have a priority call on inflows. However, any of these proposed reservoirs could be operated in conjunction with the BRA System, and the resulting increase in supply to the Brazos River Basin would be greater than that obtained from the projects operated on a stand-alone basis with a priority senior to the proposed BRA appropriation.

The benefits of including an existing water supply project (Lake Waco) into the BRA System are limited by constraints designed to protect water supply for local needs. These types of constraints would likely be included in agreements with any local entity willing to include a local water supply reservoir in BRA System Operations.

4B.4.7 Environmental and Implementation Issues

Unlike the typical implementation of a large surface water reservoir, the proposed BRA System Operations appropriation requires no environmental permits because the reservoirs are existing. However, instream flow restrictions likely to be placed on the new appropriation could limit supplies that could be developed by the project. Figure 4B.4-4 illustrates streamflows in the Brazos River at the Richmond gage, both with and without the proposed BRA System appropriation. Figure 4B.4-5 illustrates the expected Brazos River flows downstream into the Gulf of Mexico. The figures indicate that with the proposed BRA appropriation, as modeled with the majority of the proposed appropriation diverted from the lower basin, streamflows would generally be greater up to the point of diversion. However, flows into the Gulf of Mexico would generally decrease.

A summary of environmental issues for the BRA System Operations is presented in Table 4B.4-15. This water supply option has been compared to the plan development criteria, as shown in Table 4B.4-16, and the option meets each criterion.



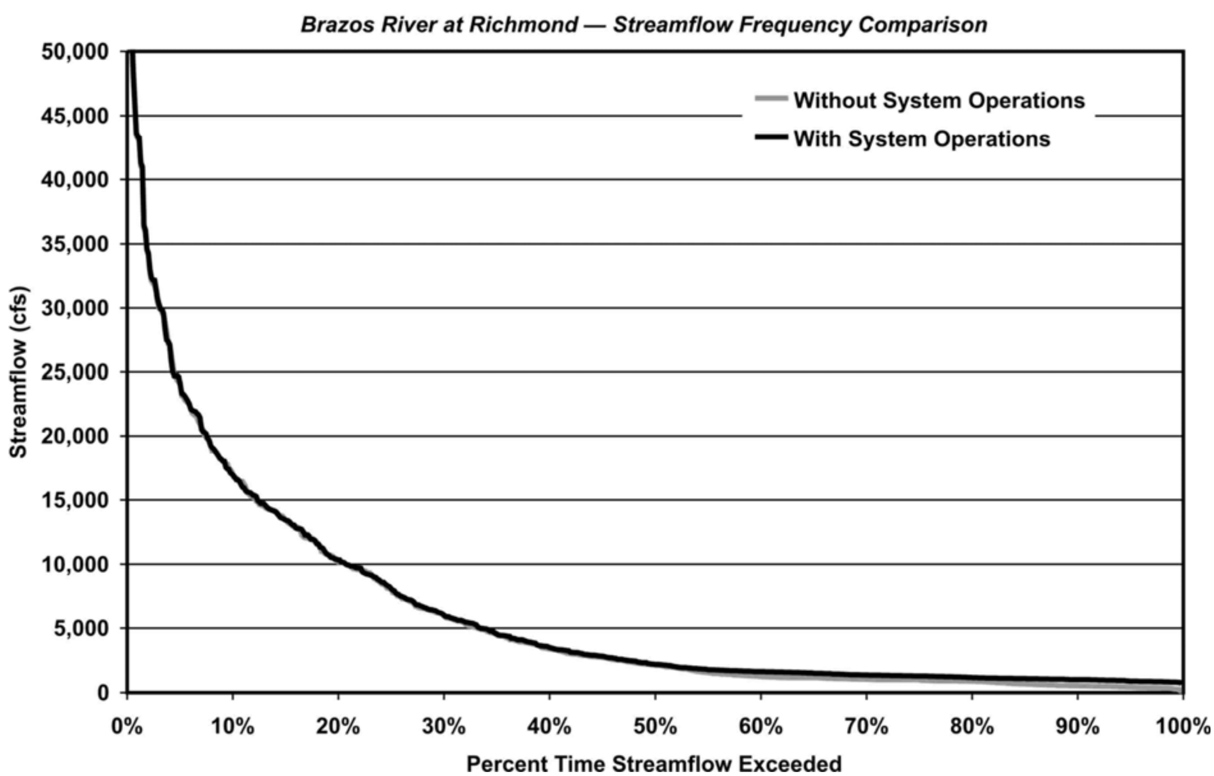
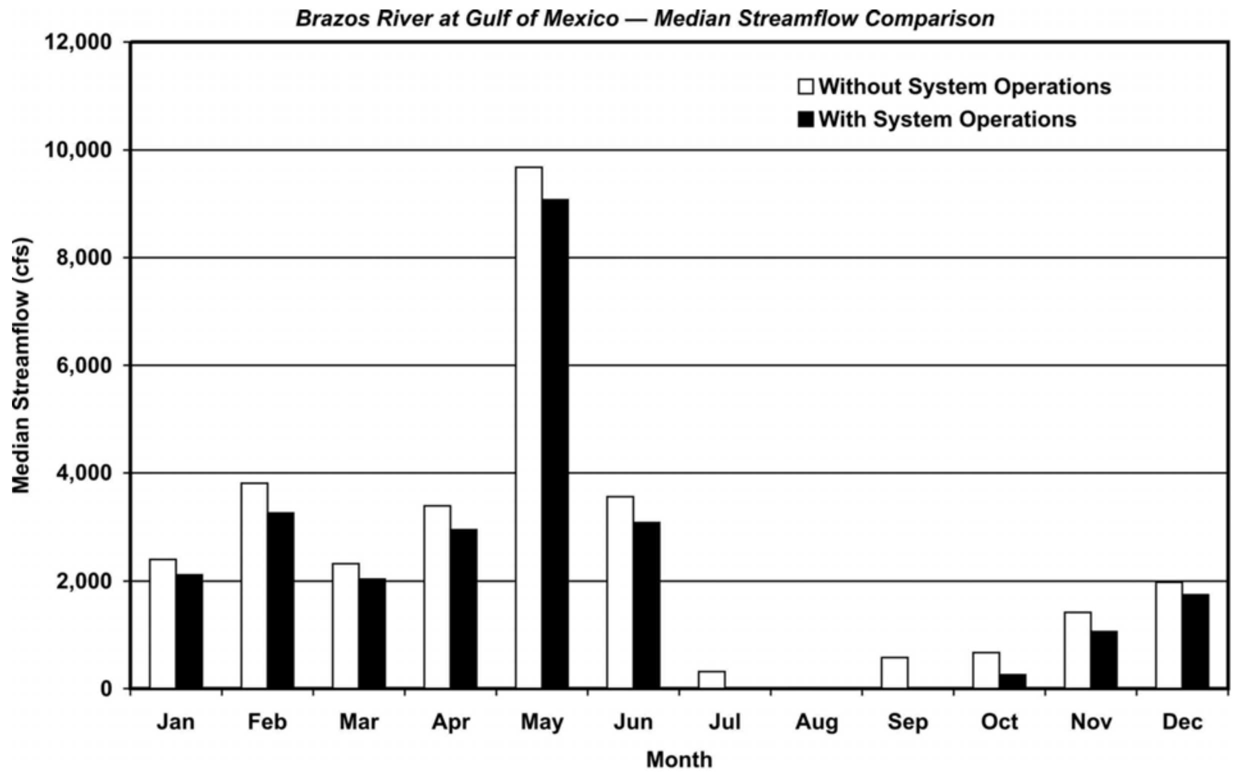


Figure 4B.4-4. BRA System Operations Streamflow Considerations at Brazos River at Richmond Control Point



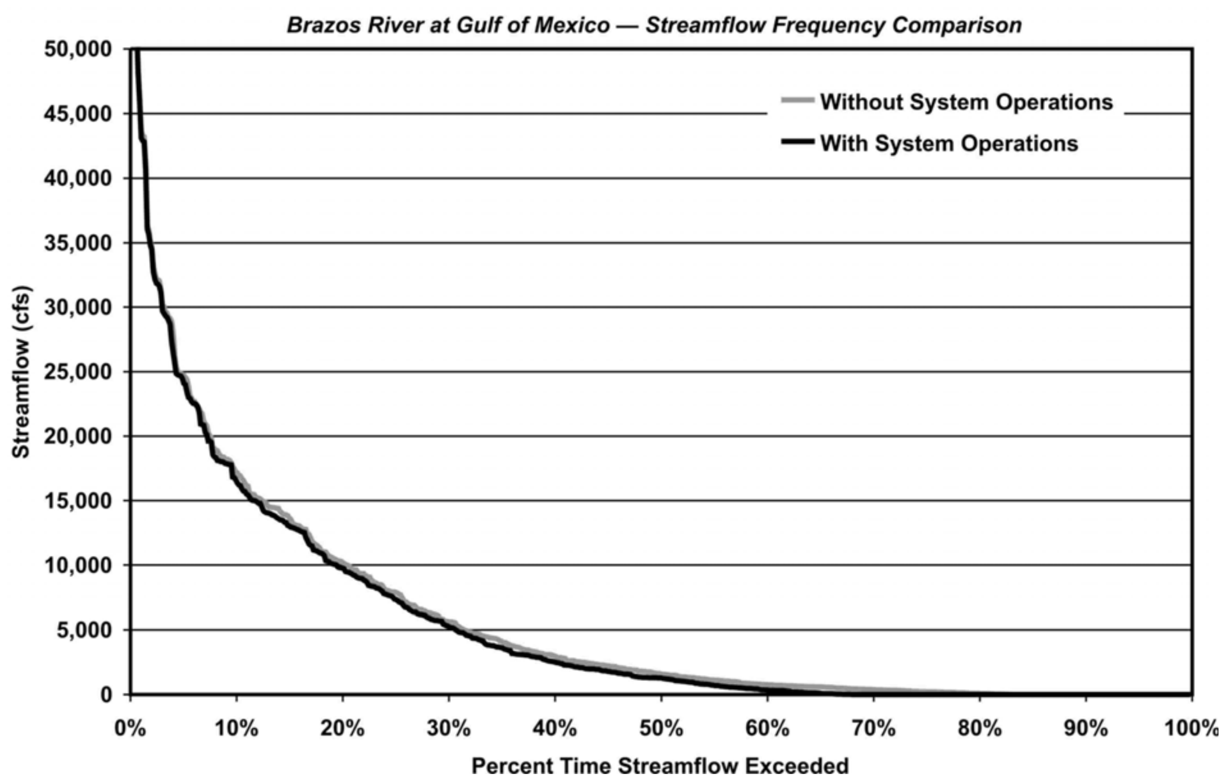


Figure 4B.4-5. BRA System Operations Streamflow Considerations at Brazos River at Gulf of Mexico Control Point

Table 4B.4-15.
Environmental Issues: BRA System Operations

Water Management Option	BRA System Operations
Implementation Measures	Each entity receiving the supply would have a water supply contract with the BRA.
Environmental Water Needs / Instream Flows	Possible low impacts. The primary sources of water are existing stored water and unappropriated flows diverted just upstream of the Gulf.
Bays and Estuaries	Possible low impact from reduced inflows to the Gulf.
Fish and Wildlife Habitat	Potential Impacts include constructing and maintaining easements for new pipelines or pump stations. Extent of impacts dependent on location and size of projects.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Potential Impacts include constructing and maintaining easements for new pipelines or pump stations. Extent of impacts dependent on location and size of projects.
Comments	Assumes infrastructure is needed to distribute purchased water to the entity in need.

Table 4B.4-16.
Comparison of BRA System Operations to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply: 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs[1] 2. High reliability 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Low impact 2. Low impact 3. Low impact 4. Low impact 5. Low impact 6. Low Impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• None
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

[1] Significant quantity for regional use and Region H

A summary of the implementation steps for the project is presented below.

1. It will be necessary to obtain these permits:
   a. TCEQ Water Right permit[3];
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for reservoirs and pipelines impacting wetlands or navigable waters of the U.S;
   c. TPWD Sand, Gravel, and Marl Permit for construction in state owned streambeds;
   d. NPDES Storm Water Pollution Prevention Plan;
   e. GLO easement for use of the state-owned streambed; and
   f. Section 404 certification from the TNRCC related to the Clean Water Act.
2. Permitting, at a minimum, will require these studies:
   a. Assessment of changes in instream flows in the Brazos River.
   b. Habitat mitigation plan.
   c. Environmental studies of potential impact on endangered species.
   d. Cultural resource studies and mitigation.
3. Land will need to be acquired through either negotiations or condemnation for pipeline and other facilities.

[3] Consideration of water rights permits, including the need for water for specific purposes, and conditions of the permits, is the responsibility of TCEQ, not the regional water planning process. However, the Brazos G RWPG assumes that any water appropriated by water right permits associated with this water management strategy will not impair the capability to impound and store water in surface water bodies such as sedimentation ponds, end lakes and other environmental features associated with mining and mining reclamation activities, when such are required by the Railroad Commission of Texas and other regulatory entities. This assumption is applicable only to runoff originating within the watershed that drains directly to each water body, and is not applicable to diversions from rivers or streams to maintain storage in the water bodies. Diversions of water from those water bodies for any reason are also specifically excluded from this assumption.

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4B.5 Groundwater/Surface Water Conjunctive Use (Lake Granger Augmentation)

4B.5.1 Description of Option

Rapid population growth and development in Williamson County cause continuing need for additional water supplies throughout the planning period. Total need for new supply in Williamson County is 24,470 acft/yr in the year 2030, increasing to 97,204 acft/yr by year 2060. Much of the increased demand is in the southwestern portion of the county in and adjoining the Cities of Cedar Park and Round Rock and extending along major highway corridors served by other potable water suppliers. This alternative will add 54,390 acft/yr by augmenting the long-term firm yield of Lake Granger with groundwater pumped from the Simsboro member of the Carrizo-Wilcox Aquifer in areas east of Williamson County, in Milam and Lee Counties. Groundwater would be pumped into Lake Granger, then diverted into a water treatment plant at the lake, with potable water supply delivered to terminal ground storage at a point between the Cities of Round Rock and Georgetown. Facilities are depicted in Figure 4B.5-1.

4B.5.2 Available Yield

Reservoir sedimentation in Lake Granger is depleting conservation storage from its original permitted volume of 65,500 acft to a projected volume at year 2060 of 22,597 acft. This sedimentation is projected to cause the yield of Lake Granger to decline to 10,564 acft/yr in the year 2060, which is slightly more than half its year 2000 yield of 19,840 acft/yr. This option envisions overdrafting Lake Granger, utilizing interruptible surface water from BRA System Operations, supplementing the surface water supply from well fields in the Simsboro Aquifer, and treating the commingled supplies to deliver potable water to Williamson County.

The Brazos G WAM was utilized to simulate operations of Lake Granger supplemented with the groundwater pumpage. Pumpage from the Simsboro Aquifer (Figure 4B.5-2) would average 28,263 acft/yr with a peak monthly pumping rate of 6,250 acft/month. Figure 4B.5-3 illustrates the proportion of total water impounded each year in Lake Granger from groundwater pumpage and runoff from the Lake Granger watershed. The conjunctive use project would develop a firm supply of 67,930 acft/yr. The availability of this supply is reduced by quantities BRA currently has obligated to the Cities of Taylor and Georgetown, and Alcoa's Rockdale Operations, leaving a supply of 54,390 acft/yr to meet Williamson County needs. The Lake Granger simulations included specific operational constraints regarding groundwater pumpage to minimize chances of spilling groundwater supply stored in the reservoir, and a requirement that 30 percent of storage remain in the reservoir in the critical drought to protect local supplies. Figure 4B.5-4 illustrates simulated Lake Granger storage throughout the simulation.

4B.5.3 Environmental

Environmental impacts could include:

- Possible reduction in flood releases to the San Gabriel River downstream of Lake Granger;
- Possible moderate impacts on riparian corridors depending on specific locations of pipelines; and
- Possible low impacts on instream flows due to slight decrease in groundwater discharges from the Carrizo-Wilcox Aquifer.

A summary of environmental issues is presented in Table 4B.5-1.

4B5.4 Engineering and Costing

Facilities required to meet this option include a well field consisting of 109 wells along a 30-mile corridor as shown in Figure 4B.5-2. Pumpage will be gathered by a well field collection system and delivered to a ground storage tank and booster pump station for transmission in a 60-inch diameter, 22.5 mile pipeline to Lake Granger, which would discharge into a stilling basin in the lake. The treatment plant will take water from the lake, treat up to 97.13 MGD, and pump potable water in a 72-inch diameter, 18.4 mile pipeline to terminal ground storage sited between the Cities of Georgetown and Round Rock.

The total capital costs including wells, well field collection system, storage and booster pump station, groundwater transmission pipeline, treatment plant, potable water pipeline, and terminal ground storage is $192,826,000, as summarized in Table 4B.5-2. Additional costs for professional services, land acquisition, well mitigation, and interest during construction add $110,462,000 for a total project cost of $303,288,000. Annual debt service on this principal amount, calculated on the basis of 6 percent interest for 30-year debt is $22,034,000. Operation and maintenance costs for pumping, transmission, and treatment to deliver the new annual supply of 54,390 acft, as well as groundwater leasing, regulatory groundwater withdrawal fees, and surface water purchase contracts must be accounted for to arrive at a unit cost of produced

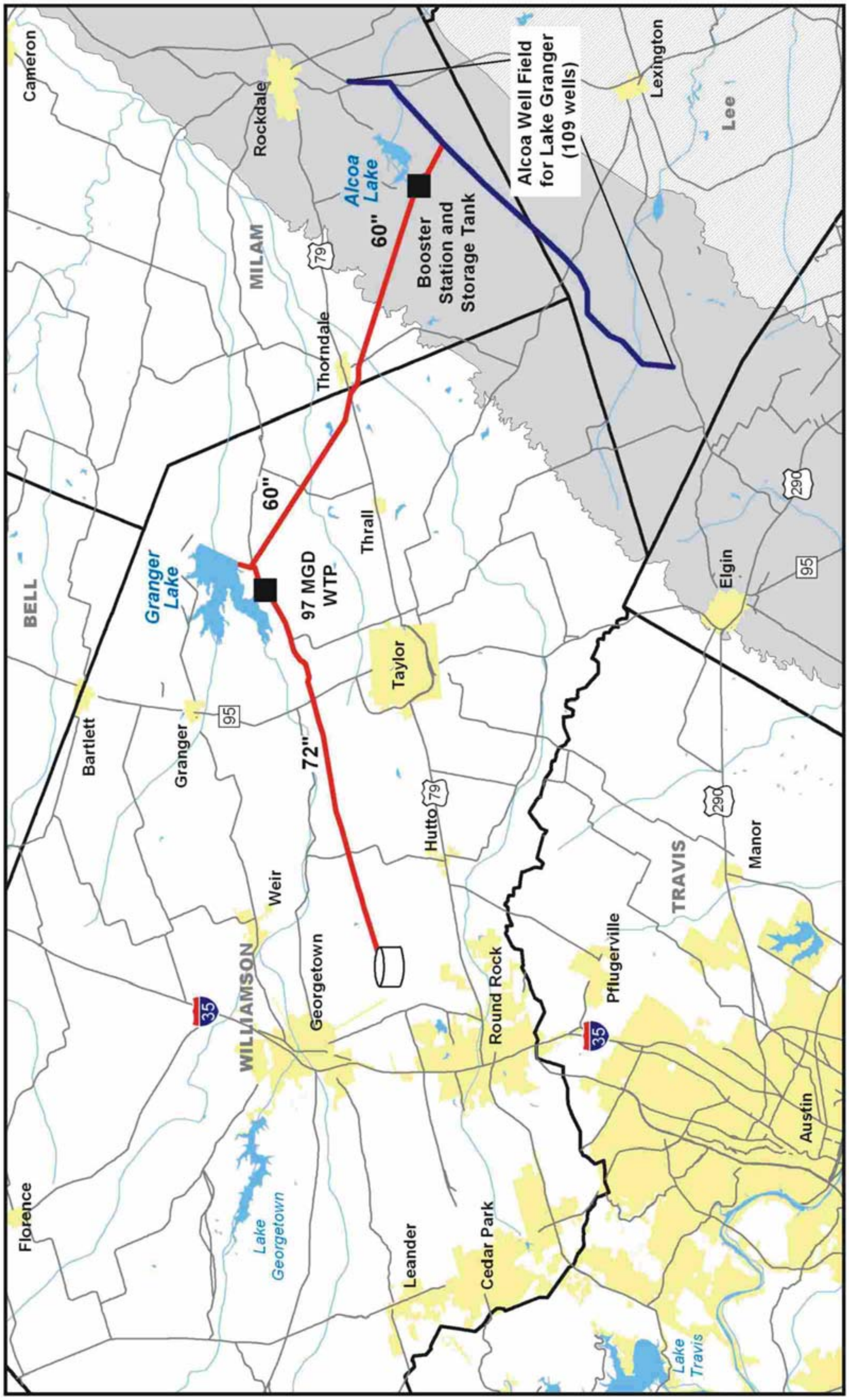

Figure 4B.5-1. Lake Granger Conjunctive Use System

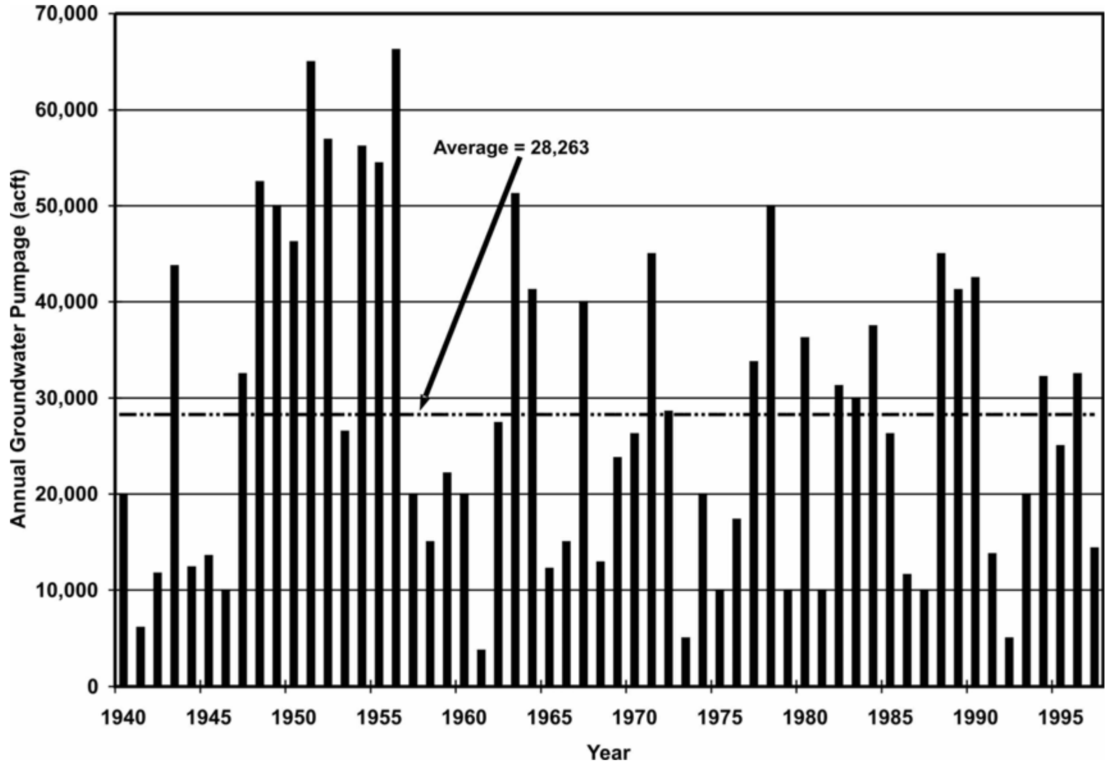

Figure 4B.5-2. Annual Simsboro Aquifer Pumpage into Lake Granger

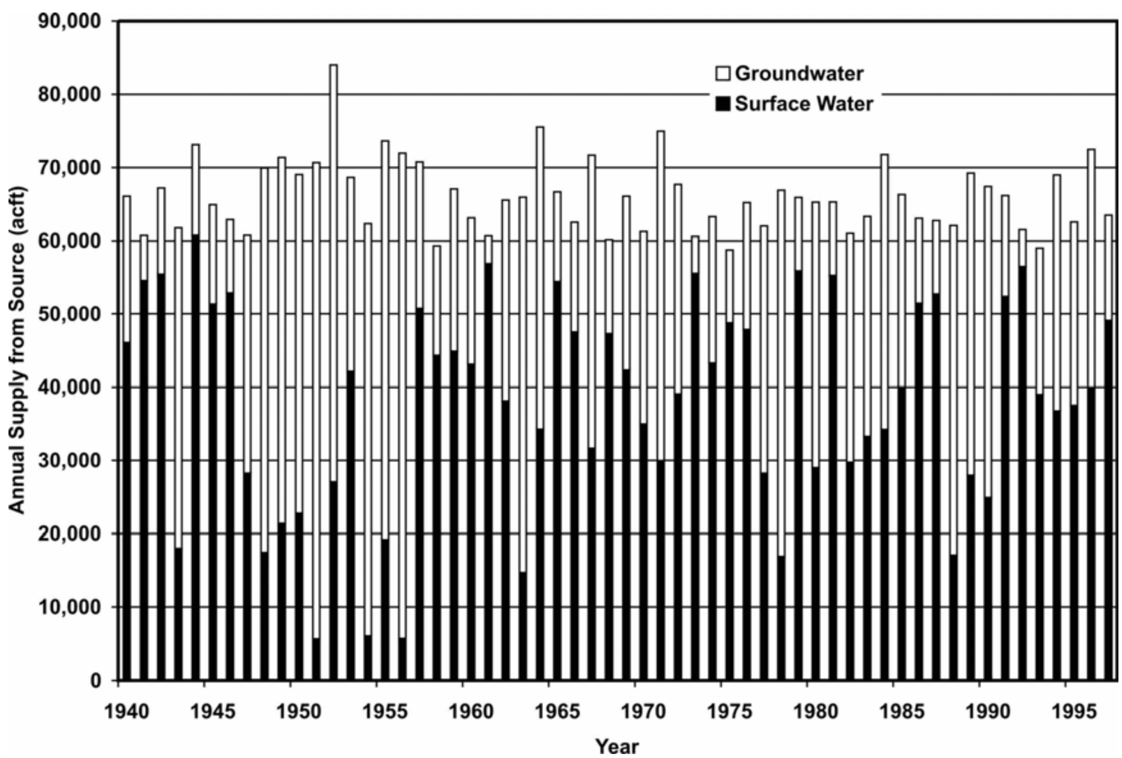

Figure 4B.5-3. Contributions to Lake Granger Supply

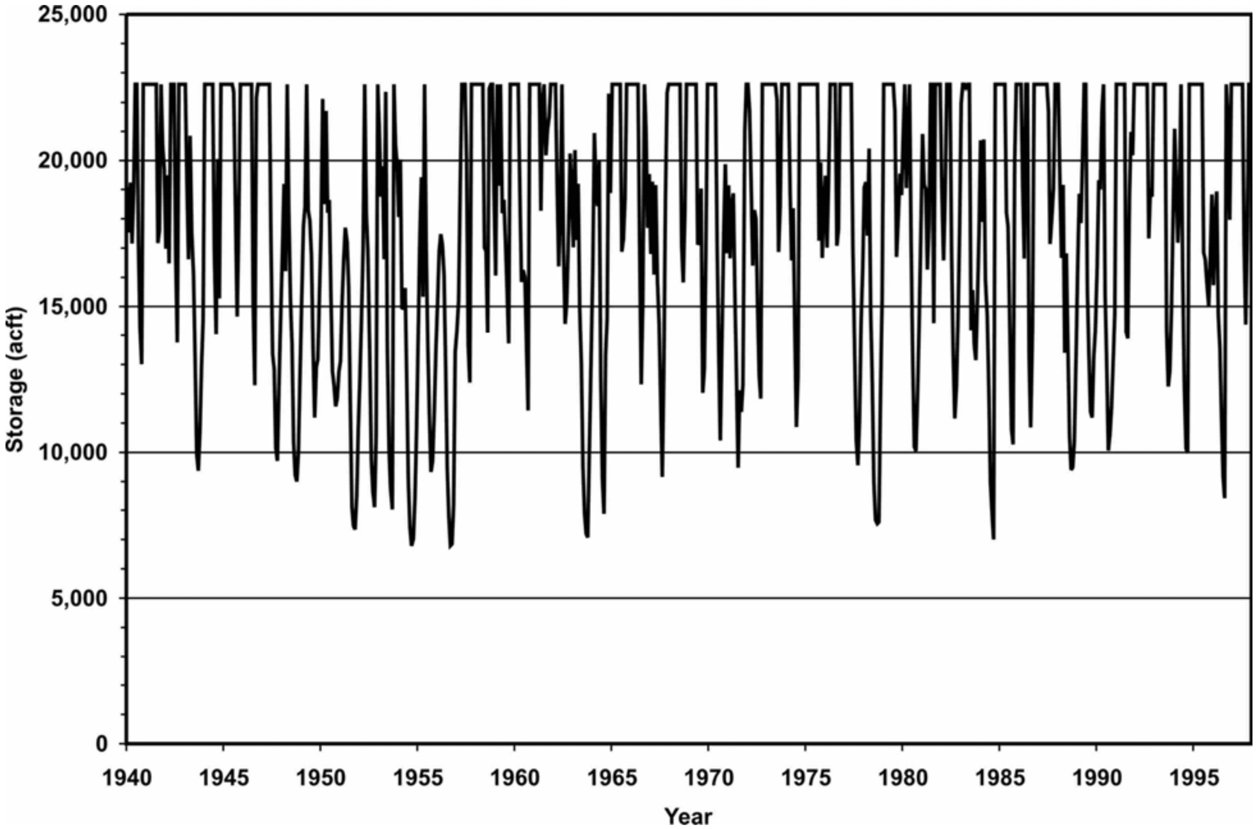

Figure 4B.5-4. Lake Granger Storage

Table 4B.5-1.
Environmental Issues:
Groundwater/Surface Water Conjunctive Use (Lake Granger Augmentation)

Water Management Option	Groundwater/Surface Water Conjunctive Use
Implementation Measures	Construction of well fields (109 wells), collection systems (30-mile corridor), pump stations, pipelines (37 miles) and a 97 MGD treatment plant
Environmental Water Needs/Instream Flows	Possible impacts on instream flows
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors and upland habitats depending on specific locations of pipelines
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible low impact
Comments	Assume institutional transfer agreements among water rights owners, suppliers, and users

Table 4B.5-2.
Cost Estimate Summary for
Lake Granger Augmentation
(Second Quarter 2002 Prices)

Item	Estimated Costs for Facilities
Capital Costs	
Discharge Structure in Lake Granger	$313,000
Transmission Pipeline (60 in dia., 37 miles)	$49,684,000
Transmission Pump Station(s)	$7,003,000
Well Fields	$58,934,000
Water Treatment Plant (97.13 MGD)	$76,892,000
Total Capital Cost	**$192,826,000**
Engineering, Legal Costs and Contingencies	$64,990,000
Environmental & Archaeology Studies and Mitigation	$1,727,000
Land Acquisition and Surveying (251 acres)	$1,955,000
Interest During Construction (4 years)	$41,790,000
Total Project Cost	**$303,288,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$22,034,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$1,243,000
Water Treatment Plant	$8,158,000
Pumping Energy Costs (50139720 kW-hr @ 0.06 $/kW-hr)	$3,008,000
Ground Water Purchase Cost ($75/acft)	$2,120,000
Management Costs ($25K/month)	$300,000
Ground Water Conservation District Fee ($44/acft)	$1,244,000
Mitigation Reserve for Possible Impacts to Local Wells (All Wells)	$116,000
Purchase of Water (54,390 acft/yr @ 45.75 $/acft)	$2,488,000
Total Annual Cost	**$40,711,000**
Available Project Yield (acft/yr)	54,390
Annual Cost of Water ($ per acft)	$749
Annual Cost of Water ($ per 1,000 gallons)	$2.30

water. These additional costs of $18,677,000 added to the annual debt service gives a total annual cost for the full project of $40,711,000. At full development and use, the unit cost of treated water is $748 per acft/yr or $2.30 per 1,000 gallons at the terminal ground storage site.

4B.5.5 Implementation Issues

Development of this option at the scale of this evaluation will require an institutional framework with a regional structure. Early significant activity toward implementation has been accomplished by the Brazos River Authority via its ownership of Lake Granger water supply, application for a systems operation permit, ownership of the existing water treatment plant on Lake Granger, and pursuit of nearby groundwater supplies. Developing a suitable approach to the evaluated level of groundwater pumping requires additional cooperative agreements with local groundwater districts and landowners.

This water supply option has been compared to the plan development criteria, as shown in Table 4B.5-3.

4B.5.5.1 Potential Regulatory Requirements

Requirements for permits to use surface water and groundwater, as well as for pipeline construction, will require permits as follow:

- TCEQ water rights permit (pending) for BRA System Operations
- Local groundwater district pumping permits outside areas exempted by surface mining permits.
- U.S. Army Corps of Engineers Section 404 permits for pipeline stream crossings, discharges of fill into wetlands and waters of the U.S. for construction, and other activities
- NPDES Stormwater Pollution Prevention Plans
- TP&WD Sand, Shell, Gravel, and Marl permit for construction in state-owned stream beds

Table 4B.5-3. Comparison of Lake Granger Augmentation to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient for local needs
2. Reliability	2. High
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low Impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and “County-Other” shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.6 Desalination

4B.6.1 Description of Options

Water demands in Johnson County are increasing at a very significant rate, while the existing supply from the Surface Water and Treatment System (SWATS) water treatment plant at Lake Granbury is at or near capacity, and withdrawals from the Trinity Aquifer are substantially exceeding its estimated long-term capacity. Two desalination options are being considered for Johnson County to meet part or all of these demands. These options are treating and delivering: (1) additional brackish surface water from Lake Granbury and (2) fresh to brackish groundwater from the Woodbine and Paluxy Aquifers in the northeastern part of the county. The surface water desalination project expands the potable water supply from Lake Granbury to most all major water utilities in the county. The groundwater desalination project is an option to treat and blend groundwater from the Paluxy and Woodbine Aquifers and is considered for the northeastern part of the county.

4B.6.2 Desalination of Lake Granbury Water for Johnson County Regional Plan

4B.6.2.1 Description of Option

In the mid-1980s, the population growth of Johnson County was projected to result in water demands that would exceed available supplies. One largely unused supply was Lake Granbury, which impounds slightly saline (brackish) water. A study of alternatives determined if it would be feasible to install a desalination plant on the lake, using either electrodialysis reversal (EDR) or reverse osmosis (RO) technology. The initial design and construction of the SWATS plant followed for a 3.5 MGD first phase of an ultimate 26 MGD system of a coupled conventional and desalination water treatment plant located on the shore of Lake Granbury. This capacity was increased to 15 MGD. Within the last few years, water demands have increased to the point that an expansion of this plant is being considered in the near future.

Currently, the BRA operates the SWATS plant near Lake Granbury to serve five wholesale customers. Johnson County Special Utility District, Johnson County Fresh Water Supply District, and City of Keene are in Johnson County, while Acton Municipal Utility District and the City of Granbury are in Hood County.

Most municipal water user groups in Johnson County are projected to be water short by 2060. The three greatest shortages are: Johnson County Special Utility District (13,259 acft/yr), County-Other (2,977 acft/yr), and City of Cleburne (2,853 acft/yr). The City of Burleson is not included because its water supply is expected to come from the Tarrant Regional Water District (TRWD). The combined shortage for Johnson County in 2060, excluding Burleson, is about 28,100 acft/yr. Using a peaking factor of 2.0, the additional system capacity needed is 50 MGD.

Recognizing the substantial future water shortage in Johnson and Parker Counties, the Brazos River Authority (BRA) and the TRWD conducted a cooperative study[1] to explore the feasibility of developing regional facilities to help meet the growing water supply needs. For purposes of this plan, their option to expand SWATS (Scenario #1) is adjusted for this Brazos G option. Scenario #1 considered an expansion (new facilities that largely parallel the existing facilities) of an average of 15 MGD in 2020 and an additional expansion of 30 MGD in 2060, for a total of 45 MGD. In other units, Scenario # 1 provides an average water supply at build-out of 50,400 acft/yr and a peaking capacity of 90 MGD. For purposes of this analysis, the surface water desalination project is intended to meet Johnson County's long-term shortage of about 28,000 acft/yr.

Figure 4B.6-1 shows the locations of the existing SWAT facilities and pipelines planned for this option.

4B.6.2.2 Available Yield

The BRA has uncommitted water available at Lake Granbury to be purchased for long-term supply. In addition to available BRA supply at Lake Granbury, the expanded SWATS regional system could utilize additional raw water supplies from one or more of several possible sources: purchase of water from an entity that has unused supply (such as Texas Utilities); enhancement of yield from an existing source, such as reallocation of storage at Lake Whitney; BRA System Operations; or negotiating a water trade among BRA customers to make additional water available in Lake Granbury.

[1] Freese and Nichols, Inc., "Regional Water Supply and Wastewater Service Study for Johnson and Parker Counties, Phase I," prepared for Brazos River Authority and Tarrant Regional Water District, April 2004.

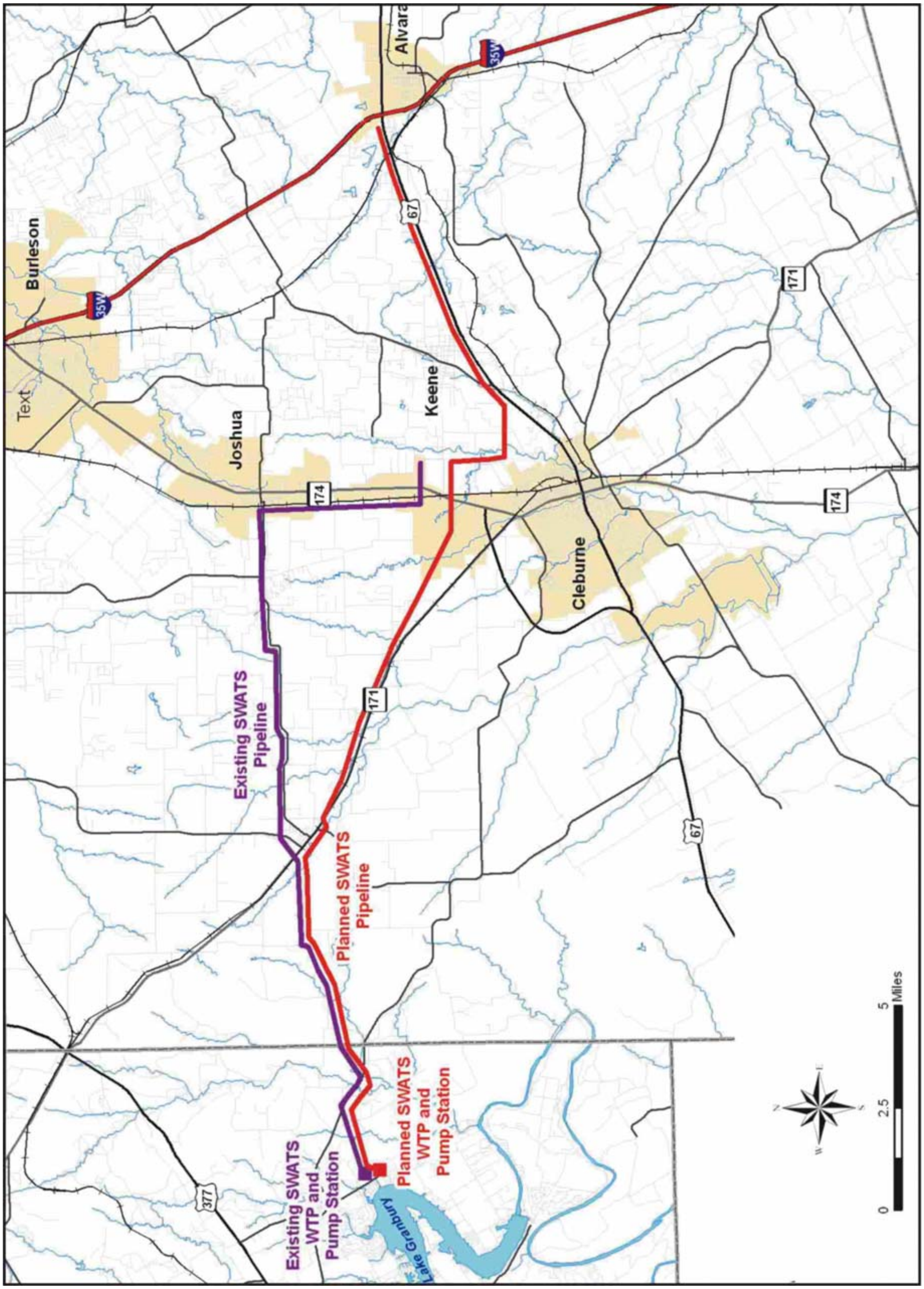

Figure 4B.6-1. Existing and Planned Facilities for SWATS Expansion in Johnson County

4B.6.2.3 Environmental Issues

The construction of a water supply project to supply water from Lake Granbury to Johnson County would involve relatively low environmental impacts:

- Reduced flows in the Brazos River below Lake Granbury could have a low impact on environmental water needs and instream flows.
- Pipeline construction effects on fish and wildlife habitat at creek and river crossings and on cultural resources would be low if inside existing highway right-of-way, possibly moderate if outside right-of-way.
- Brine disposal through blending of brine concentrate effluent would have possibly low impacts on Lake Granbury and other receiving streams.

4B.6.2.4 Engineering and Costing

The facilities needed to provide water for the long-term projected shortages in Johnson County by the Lake Granbury desalination project are:

- New raw water intake structure at Lake Granbury;
- Expanded SWATS water treatment plant (EDR or RO process preceded by a conventional water treatment plant);
- Treated water pump stations; and
- Water transmission pipelines to receiving entities.

The raw water intake, water treatment facilities, pump station, and transmission pipelines are all designed to be peaking facilities with a 50 MGD capacity and an average of delivery rate of 28,000 acft per year.

For purposes of this plan, the cooperative study's Scenario #1, which is an expansion of SWATS and delivery facilities, is adjusted for this Brazos G Lake Granbury desalination option. In developing the cost estimates for this option, the cost estimates for the Scenario #1 in the cooperative study were used as a basis and adjusted by reducing the capacity from 90 MGD to 50 MGD and reducing the costs from 2003 economic conditions to second quarter 2002 economic conditions, as per regional water planning guidelines. Table 4B.6-1 summarizes the cost estimates for this water supply option. As shown in the table, the total project cost for the Lake Granbury Supply to Johnson County project is estimated to be $74,192,000, resulting in a unit cost of $761 per acft or $2.34 per 1,000 gallons. These costs include the purchase of raw water at the current BRA system price. Of importance, these costs are based on full utilization of the facility which does not occur until 2060. In the interim, with year 2030 as an example, the

Johnson County shortage is estimated to be about 6,400 acft/yr. At this level of utilization, the unit cost of water from these customers would be about $3,330 acft/yr or $10.24 per 1,000 gallons.

4B.6.2.5 Implementation

The Lake Granbury water supply option has been compared to the plan development criteria, as shown in Table 4B.6-2, and the option meets each criterion.

Implementation will require these steps, in addition to development of the necessary supply from the BRA.

1. It will be necessary to obtain these permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings
   b. General Land Office Sand and Gravel Removal Permits
   c. Texas Parks and Wildlife Department Sand, Gravel and Marl permit for river crossings
2. Right-of-Way and easement acquisition.
3. Crossings
   a. Highways and Railroads
   b. Creeks and Rivers
   c. Other Utilities
4. Financing
   a. Sponsoring entity must be identified and be able to incur debt to finance project.
   b. Participating entities must negotiate water purchase contract with BRA and establish rate structure.

The regulatory permits that are expected to be requirements specific to pipelines include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the United States for pond construction; and other activities;
- National Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit for construction in state-owned streambed.

Table 4B.6-1.
Cost Estimate Summary
Lake Granbury Supply to Johnson County
Second Quarter 2002 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Intake and Pump Station (50 MGD)	$513,000
Transmission Pipeline (60-in dia.)	18,026,000
Transmission Pump Station(s)	3,947,000
Water Treatment Plant (50 MGD)	30,788,000
Total Capital Cost	**$53,274,000**
Engineering, Legal Costs and Contingencies	$14,246,000
Environmental & Archaeology Studies and Mitigation	853,000
Land Acquisition and Surveying	1,188,000
Interest During Construction	4,631,000
Total Project Cost	**$74,192,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$6,469,000
Operation and Maintenance:	
Intake, Pipeline, Pump Station	2,388,000
Water Treatment Plant	9,004,000
Pumping Energy Costs (36,133,333 kWh @ $0.06/kWh)	2,168,000
Purchase of Water (28,000 acft/yr @ $45.75/acft)	1,281,000
Total Annual Cost	**$21,310,000**
Available Project Yield (acft/yr)	**28,000**
Annual Cost of Water ($ per acft)	**$761**
Annual Cost of Water ($ per 1,000 gallons)	**$2.34**

Note: Base costs are from Regional Water Supply and Wastewater Service Study fro Johnson and Parker Counties, Phase I. Capacity was adjusted from 90 to 50 MGD, and dated from 2003 to 2002.

Table 4B.6-2.
Comparison of Lake Granbury Supply to Johnson County Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High
3. Cost	3. High in the short-term and moderate in the long-term
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low Impact
6. Wetlands	6. Low Impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.6.3 Brackish Groundwater Desalination for Northeast Johnson County

4B.6.3.1 Description of Option

This water supply option is targeted for the extreme northeastern part of Johnson County, as shown in Figure 4B.6-2. This option evaluates the use of groundwater from the Paluxy and Woodbine Aquifers[2,3,4,5] that ranges in salinity from fresh to brackish. In the target area, the Woodbine Aquifer is relatively shallow and confined. Wells are be about 200 to 400 ft deep and produce about 75 gallons per minute (gpm). TWDB water quality data on iron and manganese indicate that the water typically has very high concentrations of these constituents. Data on salinity indicate most wells have concentrations of total dissolved solids of 500 to 1,000 milligrams per Liter (mg/L). However, several wells have concentrations ranging up to 2,000 mg/L. Data from wells with multiple samples indicate the water quality appears to be quite variable over time. The underlying Paluxy Aquifer, which is the upper water-bearing zone of the Trinity Aquifer, is confined and well depths are expected to range from 800 to 900 ft. The capacity of high capacity wells is expected to be about 100 gpm. TWDB water quality data indicate that the water also has moderate iron and manganese concentrations. The concentrations of total dissolved solids typically range from 500 to 1,000 mg/L; however, some samples indicate concentrations up to 1,200 mg/L

4B.6.3.2 Available Yield

For Johnson County as a whole, the currently estimated groundwater availability from the Trinity Aquifer is substantially exceeded by withdrawals. However, most of this pumpage is from the deep, most productive water-bearing units (Hensell and Hosston) and in the central and eastern parts of the county. Of considerable importance, the Paluxy Aquifer in this area is seldom used because higher yielding wells can be obtained in the deeper Hensell and Hosston and shallower supplies are available in the overlying Woodbine. For the Woodbine Aquifer, current

[2] Thompson, G.L., 1969, Ground-water resources in Johnson County, Texas: Texas Water Development Board Report 94.
[3] Klemt, W.B. and others, Ground-water resources of Part of Central Texas with Emphasis on the Antlers and Travis Peak Formations: Texas Water Development Board Report 195, v. I and II.
[4] Nordstrom, P.L., Occurrence, Availability, and Chemical Quality of Ground Water in the Cretaceous Aquifers of North-Central Texas: Texas Water Development Board Report 269, v. I and II.
[5] R.W. Harden & Associates, Inc., 2004, Northern Trinity/Woodbine Aquifer Groundwater Availability Model: Texas Water Development Board Contract Report

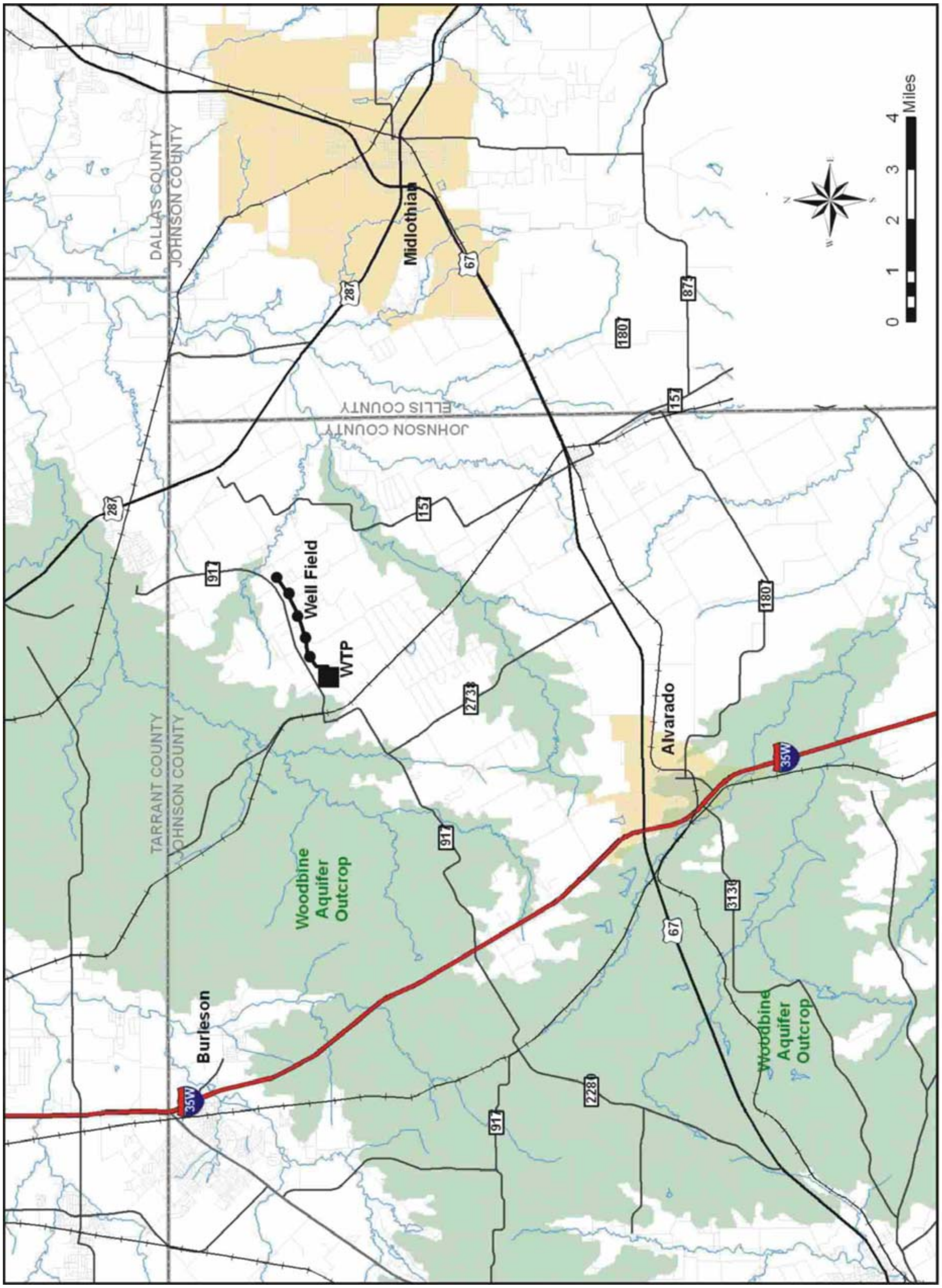

Figure 4B.6-2. Brackish Groundwater Desalination Option for Northeast Johnson County groundwater withdrawals are by local users and by water utilities at least several miles distant. The area is relatively close to the outcrop area, and drawdowns of water levels from these wells are not expected to significantly impact the other wells in the Woodbine.

4B.6.3.3 Environmental Issues

The development of wells in the Paluxy and Woodbine Aquifers and the construction of wells, collector pipelines, and water treatment facilities would involve relatively low environmental impacts:

- Drawdown from wells is expected to have little or no effect on discharge to Walnut Creek or Mountain Creek.
- Construction of pipelines, wells and water treatment facilities would have little or no effect on wildlife habitat and would be in existing right-of-ways or in disturbed areas. No streams or wetlands are expected to be encountered.
- No brine concentrated is expected to be produced.

4B.6.3.4 Engineering and Costing

For preliminary design, a Woodbine well and a Paluxy well would be constructed in a well yard and have a combined yield of 175 gpm. To provide a peak capacity of 1.0 MGD and an average yield of 560 acft/yr, five well yards are needed. The planned site of the well field and water treatment plant is along Farm Road 917 and between the town of Lillian and the Johnson-Ellis County line. Five well yards are required and would be spaced about a half mile apart. Well depths are estimated to be about 300 and 800 feet for the Woodbine and Paluxy, respectively. The water treatment facility will be designed to remove the high iron and manganese concentrations and to blend water from any wells producing brackish water with water from wells producing freshwater. Thus, no desalination treatment or disposal of brine concentration are expected to be required. The water treatment plant is planned to be located next to existing water mains and no additional water transmission facilities are required.

The major facilities required are:

- Water Collection and Conveyance System
  - Wells
  - Pipelines from well fields to treatment plant
  - Pump Station
  - Storage

- Water Treatment
  - Removal of iron and manganese concentrations
  - Blending of water from wells with relatively low and high concentrations of total dissolved solids.

Cost estimates are based on a peak capacity of 1.0 MGD with an average delivery of 560 acft/yr. These estimates were computed for capital costs, annual debt service, operation and maintenance, power, land, and environmental mitigation for peak day delivery and are summarized in Table 4B.6-3. Water treatment costs are for removal of iron and manganese, filtration, blending, and disinfection. As shown, the project cost is estimated to be $4,545,000; and the annual costs, including debt service, operation and maintenance, and power, are estimated to be $511,000. This option produces potable water at an estimated cost of $913 per acft ($2.80 per 1,000 gallons).

4B.6.3.5 Implementation

The brackish groundwater supply option for northeast Johnson County has been compared to the plan development criteria, as shown in Table 4B.6-4, and the option meets each criterion.

Implementation will require these steps:

1. Acquisition of groundwater rights;
2. Right-of-way and easement for wells, pipelines, and water treatment plant; and
3. Financing and operations by a sponsoring entity, who must be identified.

Table 4B.6-3.
Cost Estimate Summary
Brackish Groundwater Desalination Project for Northeast Johnson County
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station at Water Treatment Plant	$810,000
Well Fields (5 Well Yards, a Paluxy well and a Woodbine well in each yard)	1,643,000
Water Treatment Plant (Level 2)	602,000
Total Capital Cost	**$3,055,000**
Engineering, Legal Costs and Contingencies	$1,069,000
Environmental & Archaeology Studies and Mitigation	112,000
Land Acquisition and Surveying (14 acres)	134,000
Interest During Construction (1 years)	175,000
Total Project Cost	**$4,545,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$330,000
Operation and Maintenance:	
Intake, Pipeline, Pump Station	37,000
Water Treatment Plant	120,000
Pumping Energy Costs (395,967 kWh @ $0.06/kWh)	24,000
Total Annual Cost	**$511,000**
Available Project Yield (acft/yr)	**560**
Annual Cost of Water ($ per acft)	**$913**
Annual Cost of Water ($ per 1,000 gallons)	**$2.80**

Table 4B.6-4.
Comparison of Brackish Groundwater Option in
Northeast Johnson County to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient only for local needs
2. Reliability	2. High
3. Cost	3. Moderately expensive
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and "County-Other" shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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4B.7 Augmentation of Millers Creek Reservoir

4B.7.1 Description of Canal Option

Millers Creek Reservoir is located in Baylor and Throckmorton Counties approximately 14 miles southwest of the City of Seymour. Lake Creek flows parallel to Millers Creek and the Millers Creek Reservoir. In an effort to increase the yield of the reservoir, this strategy includes diverting water from Lake Creek through a grass-lined canal into Brushy Creek, which flows into Millers Creek and eventually into Millers Creek Reservoir, as shown in Figure 4B.7-1.

The maximum monthly depletion from Lake Creek, assuming the Lake Creek diversion is the most senior in the basin, is approximately 700 cfs. Therefore, the grass-lined canal was sized to accommodate a 700 cfs flow rate at a 0.05 percent slope. The canal bottom width would be 90 feet and the maximum top width would be 287 feet; the water level would be 2.8 feet. The proposed canal location and Lake Creek channel dam are shown on Figure 4B.7-2. The proposed canal length is 1.8 miles from Lake Creek to Brushy Creek. The topography in the area is such that there is a topographic 'high' between Lake Creek and Brushy Creek and therefore, a massive volume of earth cut will be needed to construct the grass-lined canal. It is anticipated that about 40 percent of the excess fill will be disposed of on-site, adjacent to the canal creating 5-feet high, 120-feet wide berms along the top of the canal.

The approximately 8-feet high channel dam would be an earthfill embankment to impound runoff from the Lake Creek watershed. The dam embankment would extend approximately 5,000 feet across Lake Creek at an elevation of 1,477 ft-msl. When full, the lake formed by the dam would periodically inundate approximately 360 acres.

4B.7.1.1 Available Yield

Water potentially available for impoundment into the Millers Creek Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from Lake Creek into the Millers Creek Reservoir without causing increased shortages to existing downstream rights. Safe yield was computed subject to the reservoir having to pass

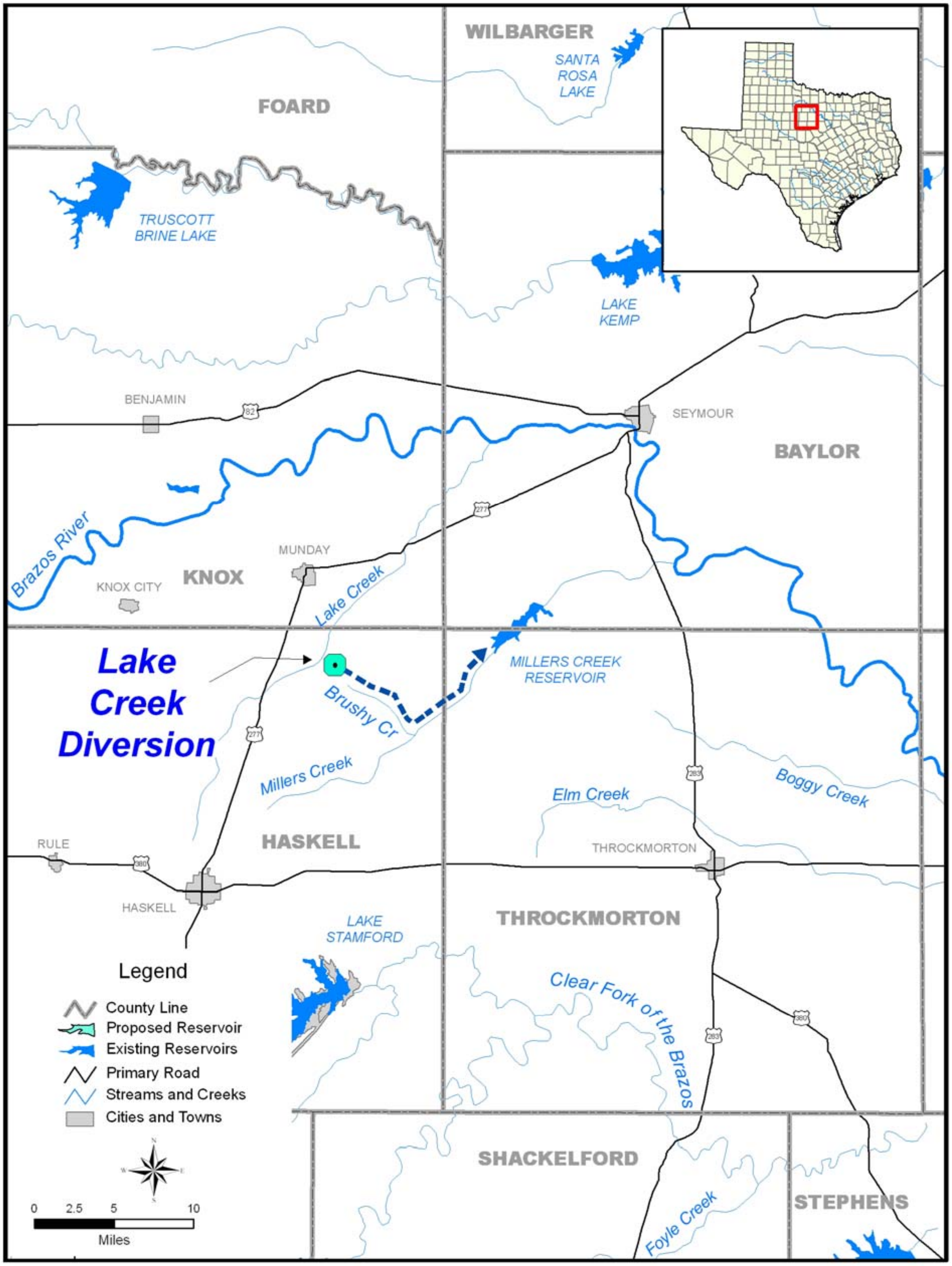


Figure 4B.7-1 Lake Creek Diversion to Millers Creek Reservoir

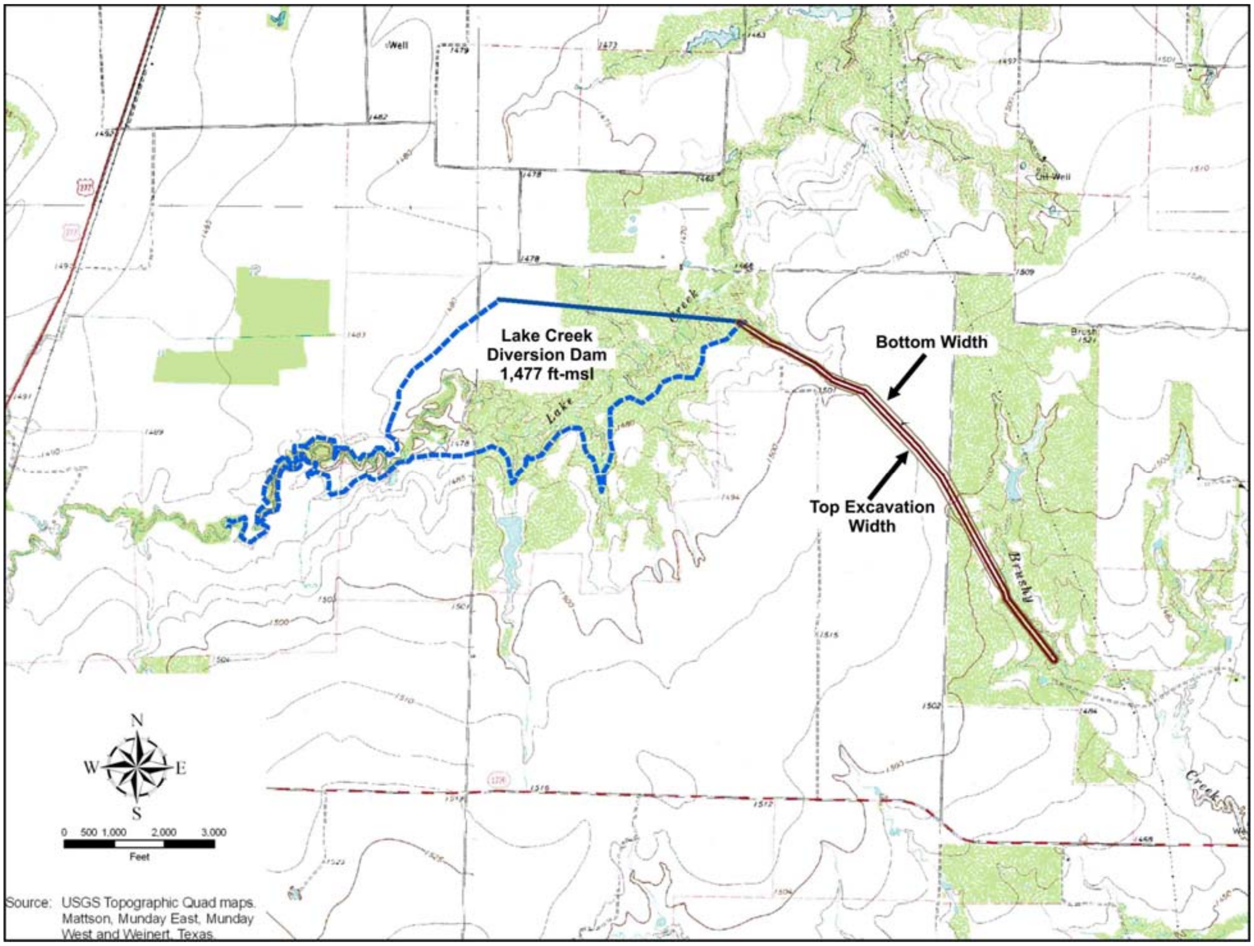


Figure 4B.7-2. Lake Creek Diversion Dam and Canal to Brushy Creek

inflows to meet Consensus Criteria for Environmental Flow Needs (CCEFN) instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass through requirements for the Lake Creek Diversion are shown in Table 4B.7-1.

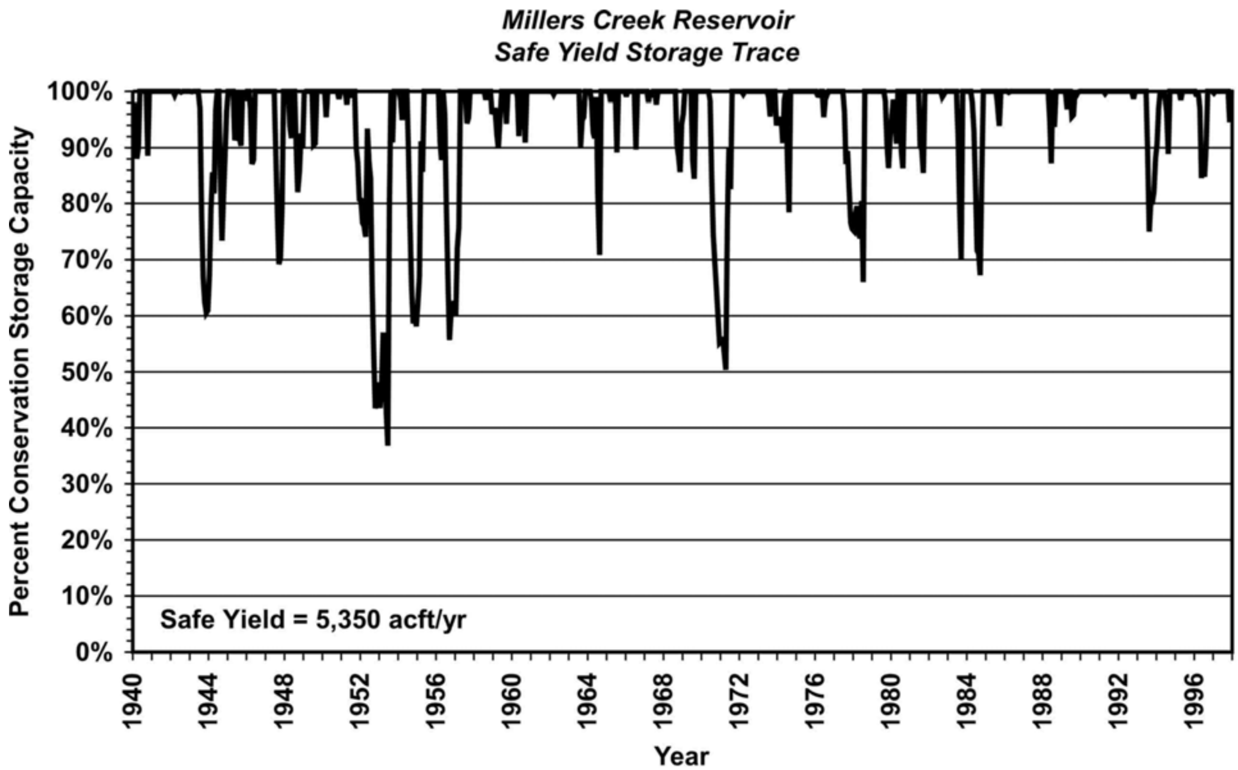
The calculated safe yield of the Millers Creek Reservoir with the Lake Creek diversion is 5,350 acft/yr, assuming subordination of Possum Kingdom Reservoir to the Millers Creek Reservoir and the Lake Creek diversion. The Lake Creek diversion increases the yield of the Millers Creek Reservoir by 4,870 acft/yr. The yield impact on Possum Kingdom due to the reservoir and the diversion was assumed to be 2,500 acft/yr for costing purposes. Additional analysis is required to refine this estimate.

Figure 4B.7-3 illustrates the simulated Millers Creek Reservoir storage levels for the 1940 to 1997 historical period, subject to the safe yield of 5,350 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 91 percent of the time and above the Zone 3 trigger level (50 percent capacity) nearly 100 percent of the time (all but 7 months of the simulation).

Table 4B.7-1.
Daily Natural Streamflow Statistics
for the Lake Creek Diversion

Month	***Median Flows - Zone 1 Pass Through Requirements (cfs)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (cfs)***
January	0.0	0.0
February	0.5	0.0
March	0.3	0.0
April	0.0	0.0
May	0.3	0.0
June	1.3	0.0
July	0.1	0.0
August	0.0	0.0
September	0.0	0.0
October	0.0	0.0
November	0.0	0.0
December	0.0	0.0
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0

Figure 4B.7-4 illustrates the changes in Lake Creek and Millers Creek streamflows caused by the project. The largest changes could be a decline in median streamflow in Lake Creek of 5.9 cfs during June and 3.9 cfs in May. During the months of January, February, August, and September there would be little change in Lake Creek streamflow. The largest change in Millers Creek streamflows due to the Lake Creek diversion could be an increase in median streamflow of 3.2 cfs during June and 1.6 cfs in May downstream from Millers Creek Reservoir. These increases are due to more frequent spills due to higher reservoir levels. During the months of January, July, September, and December there would be little change in the Millers Creek streamflow. Figure 4B.7-4 also illustrates the Lake Creek and Millers Creek streamflow frequency characteristics with the diversion in place. There is a very limited overall impact on flows due to the diversion.



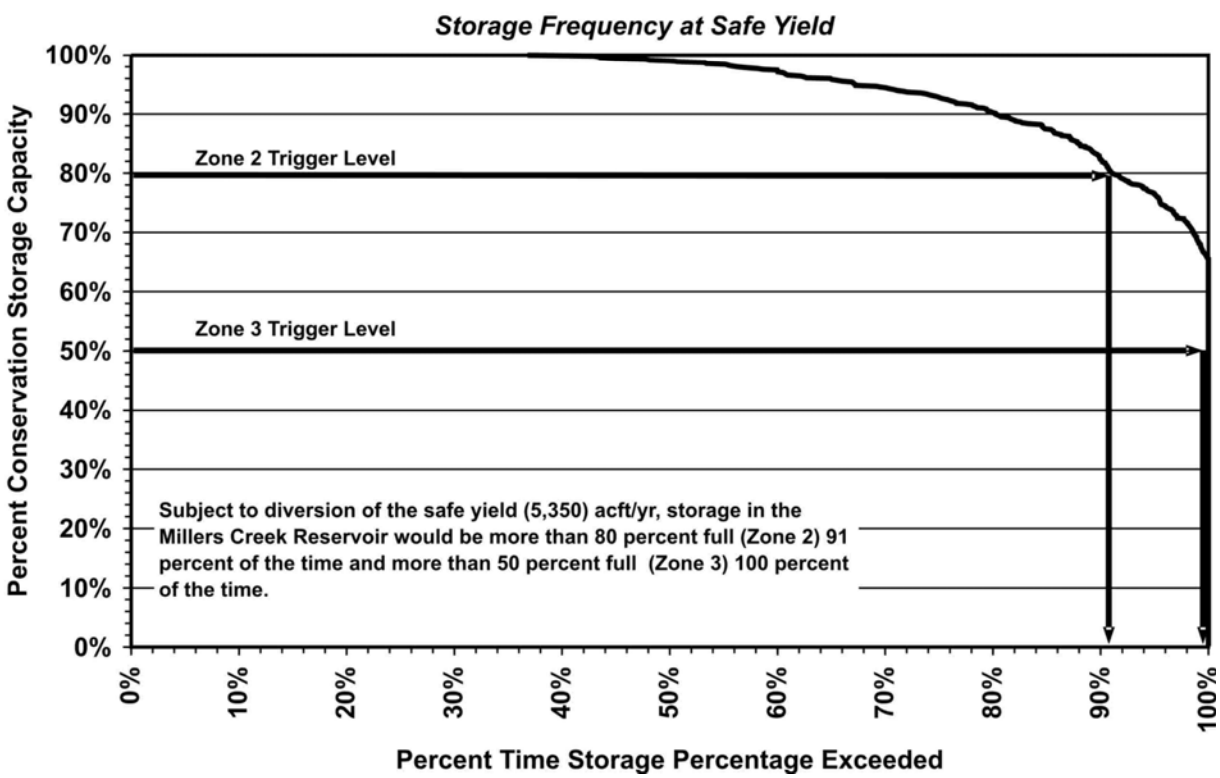


Figure 4B.7-3 Millers Creek Reservoir Storage Considerations

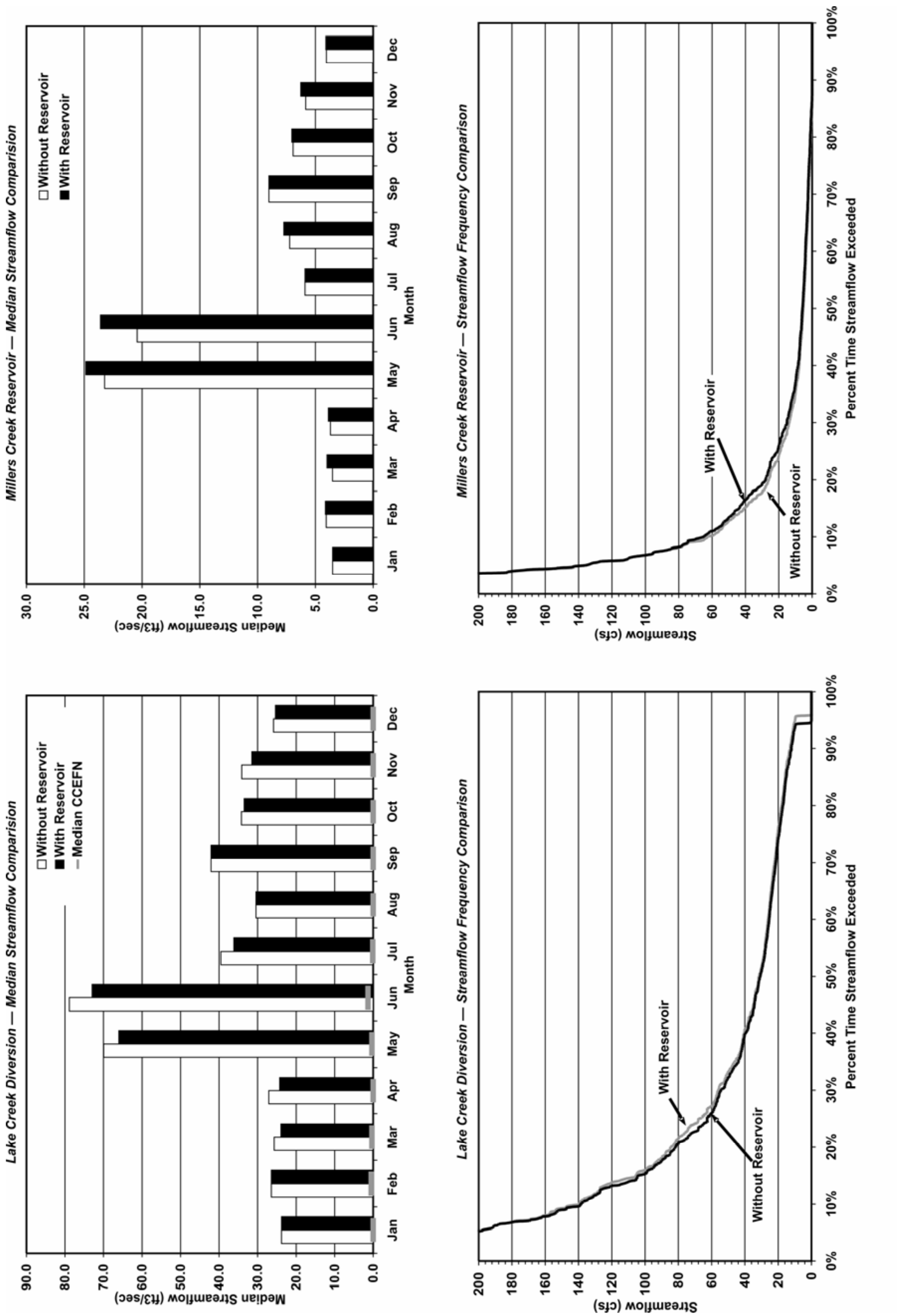


Figure 4B.7-4. Lake Creek Diversion and Millers Creek Reservoir Streamflow Comparisons

4B.7.1.2 Environmental Issues

The Millers Creek Reservoir Augmentation Site in Haskell County lies within the Rolling Plains Ecological Region (Gould et al. 1960). This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, juniper breaks, and midgrass prairie. The physiognomy of the region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive plant species and have decreased the value of the land for cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region (Telfair 1999). The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average precipitation ranges between 24 and 26 inches (Larkin and Bomar 1983).

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by alluvial deposits in 20 counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravel, that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs (USGS 2004).

The physiography of the region includes recharge sand, undissected red beds, loose surficial sand, flood prone areas, and severely eroded land (Kier et al. 1977). Three major vegetation types occur within the general vicinity of the project area: Mesquite (*Prosopis glandulosa*) - Lotebush Shrub, Mesquite-Saltcedar (*Tamarix*) Brush/Woods, and Crops (McMahan et al. 1984). Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Mesquite-Lotebush Shrub could include the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera angustifolia*), juniper, tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania peristena*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*). Commonly associated plants of Mesquite-Saltcedar Brush/Woods are creosotebush (*Larrea tridentata*), cottonwood (*Populus deltoides*), desert willow (*Chilopsis linearis*), giant reed (*Arundo donax*), seepwillow (*Baccharis* sp.), common buttonbush (*Cephalanthus occidentalis*), whitethorn acacia (*Acacia constricta*), Australian saltbush (*Atriplex semibaccata*), fourwing saltbush (*Atriplex canescens*), lotebush, wolfberry (*Lycium berlandieri*), tasajillo, guayacan (*Guaiacum angustifolium*), alkali sacaton (*Sporobolus airoides*), Johnsongrass (*Sorghum halepense*), saltgrass (*Distichlis spicata*), cattail (*Typha* spp.), bushy bluestem (*Andropogon glomeratus*), and chino grama (*Bouteloua ramosa*). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.7.1.2.1 Potential Impacts

4B.7.1.2.1.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated at the existing Millers Creek Reservoir, and at the Lake Creek diversion point. The diversion will occur at a small impoundment created by construction of a channel dam on Lake Creek. During periods of high flow, water will be diverted from the Lake Creek impoundment via a canal to Brushy Creek which feeds Millers Creek and Millers Creek Reservoir. There is a very limited anticipated impact associated with this project either in variability or quantity of monthly flow conditions. The difference in variability of median monthly flows at Millers Creek Reservoir would be negligible (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place; sample variance without project =3.07×10^7; sample variance with project =3.10×10^7). The difference in variability of monthly flows at the Lake Creek diversion site would also be negligible (sample variance without project =2.225×10^7; sample variance with project =2.221×10^7). There would be a slight increase in median monthly flows at Millers Creek Reservoir (Table 4B.7-2); the highest increases (>10 percent) would occur in March and June. Flows would decrease slightly in the Lake Creek diversion site with a maximum of 10 percent reduction in April (Table 4B.7-3). Low-flows would be less common downstream of Millers Creek Reservoir. With the proposed project, spills would occur 12 percent of the time compared to 15 percent without the project. Low flows would be slightly more common at the Lake Creek diversion site with an 85 percent exceedance value of 15.2 cfs with and 15.8 cfs without the proposed reservoir in place.

This project would have minimal influence on flow in the Brazos River or on freshwater inflows to the Brazos River estuary.

Table 4B.7-2.
Median Monthly Streamflow: Millers Creek Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	3.5	3.5	0.0	0%
February	4.1	4.1	-0.1*	-2%*
March	3.5	4.0	-0.5*	-13%*
April	3.7	3.9	-0.2*	-5%*
May	23.2	24.9	-1.6*	-7%*
June	20.4	23.6	-3.2*	-16%*
July	5.9	5.9	0.0	0%
August	7.2	7.7	-0.5*	-7%*
September	9.0	9.0	0.0	0%
October	6.9	7.0	-0.1*	-2%*
November	5.8	6.3	-0.4*	-7%*
December	4.0	4.1	0.0	-1%*

*Represents increase in flow under With Project conditions

Table 4B.7-3.
Median Monthly Streamflow: Diversion from Lake Creek to Brushy Creek

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	23.8	23.8	0.0	0%
February	26.4	26.4	0.0	0%
March	25.7	23.9	1.8	7%
April	27.1	24.3	2.8	10%
May	69.9	66.0	3.9	6%
June	78.9	73.0	5.9	8%
July	39.5	36.2	3.4	8%
August	30.4	30.4	0.0	0%
September	42.1	42.1	0.0	0%
October	34.2	33.5	0.7	2%
November	34.1	31.5	2.6	8%
December	25.9	25.4	0.5	2%

4B.7.1.2.1.2 Threatened and Endangered Species

A total of 21 animal species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes three reptiles, 12 birds, four mammals, and two fish species (Table 4B.7-4). Four bird species and one mammal species federally-listed as threatened or endangered could occur (or historically occurred) in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*). While the black-footed ferret (*Mustela nigripes*) historically occurred in the area, there have been no confirmed reports of this species in Texas since 1963 (Campbell 1995). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

A search of the Texas Wildlife Diversity Database (TPWD 2004c) revealed no documented occurrences of rare or listed species within the project vicinity (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This is based on the best information available to TPWD. However, this does not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.7.1.2.1.3 Wildlife Habitat

The ROW for the diversion canal connecting Lake Creek with Brushy Creek (that will transport diverted water to Millers Creek) is estimated to be approximately 1.8-miles long by with a minimum width of 131 feet and a maximum width of 289 feet.. This would result in approximately 48 acres of impact to wildlife habitat. Of this amount, approximately three acres would be comprised of Mesquite Brush, with the remaining acreage comprising Cropland.

Table 4B.7-4. Potentially Occurring Species that are Rare or Federal- and State-Listed at the Diversion Site for Augmentation of Millers Creek Reservoir, Haskell County

Scientific Name	Common Name	Federal/ State Status	Potential Occurrence
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant
Buteo regalis	Ferruginous Hawk	SOC	Migrant*
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Tympanuchus pallidicinctus	Lesser Prairie Chicken	C/SOC	Resident
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius melodus	Piping plover	FT w/CH	Migrant
Charadrius alexandrinus	Snowy Plover	SOC	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Fishes			
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Mustela nigripes	Black-footed Ferret	LE/E	Extirpated
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Vulpes velox	Swift Fox	SOC	X
Reptiles			
Nerodia harteri	Brazos Water Snake	SOC/T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X

(TPWD 2004a, b; USFWS 2003) * Nesting migrant; may nest in the county.

X = Occurs in county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas;

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

A number of vertebrate species would be expected to occur within the general vicinity of the project site as indicated by county occurrence records (TAMU 1998). These include one species of salamander, five species of frogs and toads, three species of turtles, five species of lizards and skinks, and 17 species of snakes. Additionally, 78 species of mammals could occur within the site or surrounding region (TTU 1997) in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.7.1.2.1.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that three archeological sites have been documented within the general vicinity of the proposed diversion canal. These sites, which lie outside the current project alignment, were recorded as prehistoric habitation sites. Two of these sites (41KX95 and 41HK1) were recommended for further testing in 1973. Prior to construction of the diversion canal, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the alignment. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.7.1.2.1.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would have very limited impact associated with lower stream flows or declining water quality. Millers Creek Reservoir would have a slight increase in median monthly inflow that would enhance water quality and offset a decline in water levels.

4B.7.1.3 Engineering and Costing

The total project is estimated to cost $18.2 million for construction of a channel dam and grass-lined canal. The annual project costs are estimated to be $1.35 million; this includes annual debt service, operation and maintenance, and annual payment to the Brazos River Authority for lost yield in Possum Kingdom Reservoir. A summary of the project costs is presented in Table 4B.7-5. The cost for the estimated safe yield of 4,870 acft/yr translates to an annual unit cost for raw water of $0.85 per 1,000 gallons, or $277/acft.

Table 4B.7-5.
Cost Estimate Summary for
Augmentation of Millers Creek Reservoir (Canal Option)
(Second Quarter 2002 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (1,477 ft. msl)	$11,213,000
Total Capital Cost	**$11,213,000**
Engineering, Legal Costs and Contingencies	$3,925,000
Environmental & Archaeology Studies and Mitigation	$273,000
Land Acquisition and Surveying (941 acres)	$297,000
Interest During Construction (2 years)	$2,514,000
Total Project Cost	**$18,222,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$1,211,000
Operation and Maintenance	
Dam and Reservoir	$25,000
Purchase of Water (2,500 acft/yr @ 45.75 $/acft)	$114,000
Total Annual Cost	**$1,350,000**
Available Project Yield (acft/yr)	4,870
Annual Cost of Water ($ per acft)	$277
Annual Cost of Water ($ per 1,000 gallons)	$0.85

4B.7.1.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.7-6, and the option meets each criterion.

Table 4B.7-6.
Comparison of Augmentation of Millers Creek Reservoir (Canal Option) to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);

- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

State and Federal Permits may Require the Following Studies and Plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

4B.7.2 Description of Pipeline Option

Another option previously studied[1] to increase the yield of Millers Creek Reservoir is to divert water from Lake Creek through a 24-inch pipeline into Brushy Creek, which flows into Millers Creek and eventually into Millers Creek Reservoir, as shown in Figure 4B.7-1.

4B.7.2.1 Available Yield

Water potentially available for impoundment into the Millers Creek Reservoir was estimated by the previous study. The pipeline option was evaluated for flows that are above 5 cfs and below 15.5 cfs via a 24-inch pipeline. The increase in Millers Creek Reservoir firm yield due to the Lake Creek diversion would be 800 acft/yr.

[1] Freese & Nichols, Inc, "West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan," August 2004.

4B.7.2.2 Environmental Issues

The Lake Creek diversion pipeline option is located near the canal option; therefore, the existing environment is similar to that described in Section 4B.7.2. However, the potential environmental impacts of the pipeline option are likely to be less than the impacts associated with the canal option because the pipeline option encompasses a smaller area and therefore critical sites can be avoided more easily.

4B.7.2.3 Engineering and Costing

The total project is estimated to cost $7.47 million for construction of a diversion weir, intake canal, pipeline, and pump station. The annual project costs are estimated to be $708,000, including annual debt service, operation and maintenance, and annual payment to the Brazos River Authority for lost yield in Possum Kingdom. A summary of the project costs is presented in Table 4B.7-7. The cost for the estimated safe yield of 800 acft/yr translates to an annual unit cost for raw water of $2.72 per 1,000 gallons, or $885 per acft.

4B.7.2.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.7-8, and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

Table 4B.7-7.
Cost Estimate Summary for
Augmentation to the Millers Creek Reservoir (Pipeline Option)
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Diversion Weir and Intake Canal)	$3,403,000
Intake and Pump Station	$1,312,000
Transmission Pipeline (24 in dia., 1.8 miles)	$584,000
Total Capital Cost	**$5,299,000**
Engineering, Legal Costs and Contingencies	$1,736,000
Environmental & Archaeology Studies and Mitigation	$265,000
Land Acquisition and Surveying	$10,000
Interest During Construction (2 years)	$158,000
Total Project Cost	**$7,468,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$542,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	$124,000
Pumping Energy Costs	$21,000
Purchase of Water (400 acft/yr @ $45.75/acft)	$18,300
Total Annual Cost	**$705,300**
Available Project Yield (acft/yr)	800
Annual Cost of Water ($ per acft)	$882
Annual Cost of Water ($ per 1,000 gallons)	$2.71

State and Federal Permitting Requirements:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;

- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4B.7-8.
Comparison of Augmentation to the Millers Creek Reservoir (Pipeline Option) to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.8 Aquifer Storage and Recovery (ASR)

In the development of Brazos G water management strategies, Aquifer Storage and Recovery (ASR) is considered for (1) the Seymour Aquifer in Knox and Haskell Counties where the aquifer is recharged with water from the Salt Fork Brazos River by infiltration and recovered with existing irrigation wells, and (2) the Trinity Aquifer in Johnson County where new, dual-purpose wells are used to inject potable water from the SWATS water treatment plant on Lake Granbury into the aquifer for storage and recovery by public supply wells.

The ASR management strategy is useful to water suppliers who periodically have surplus water and water shortages. For example, ASR can be used to inject and store water in aquifers during the fall, winter, and spring when demands are low and to recover the water during the summer when demands are high. This strategy better utilizes the available capacity of the water treatment plant and supply and transmission system, and commonly delays the need for expanding water treatment and distribution facilities. In most all cases, the water utility's operating plan would call for balancing injection and recovery or possibly recovering slightly less than the amount injected.

4B.8.1 Seymour Aquifer in Knox and Haskell Counties

4B.8.1.1 Description of Option

A proposed ASR water management option for irrigation water supplies in Knox and Haskell Counties is based on diverting a portion of runoff during relatively high flow conditions from the Salt Fork Brazos River to an off-channel reservoir for temporary storage, transporting the stored water to spreading basins in the target recharge area in the Seymour Aquifer, and recovering some or all the water with existing irrigation wells. The project area was selected on the basis of the local proximity of potentially suitable surface water reservoirs for temporary storage, the Salt Fork Brazos River, and areas of the Seymour where the aquifer is rather thick and productive, water level declines are significant, and there is extensive agricultural irrigation with groundwater. The selected ASR area of the Seymour Aquifer is in a region along the Haskell-Knox County line and between the towns of Munday and Knox City; the selected off-channel reservoir is Lake Davis, which is located about 5 miles north of the ASR area. The Salt Fork is between the off-channel reservoir and the target ASR area. The strategy is intended to supplement the natural recharge to the Seymour and benefit irrigated agriculture. This area is shown in Figure 4B.8.1-1.

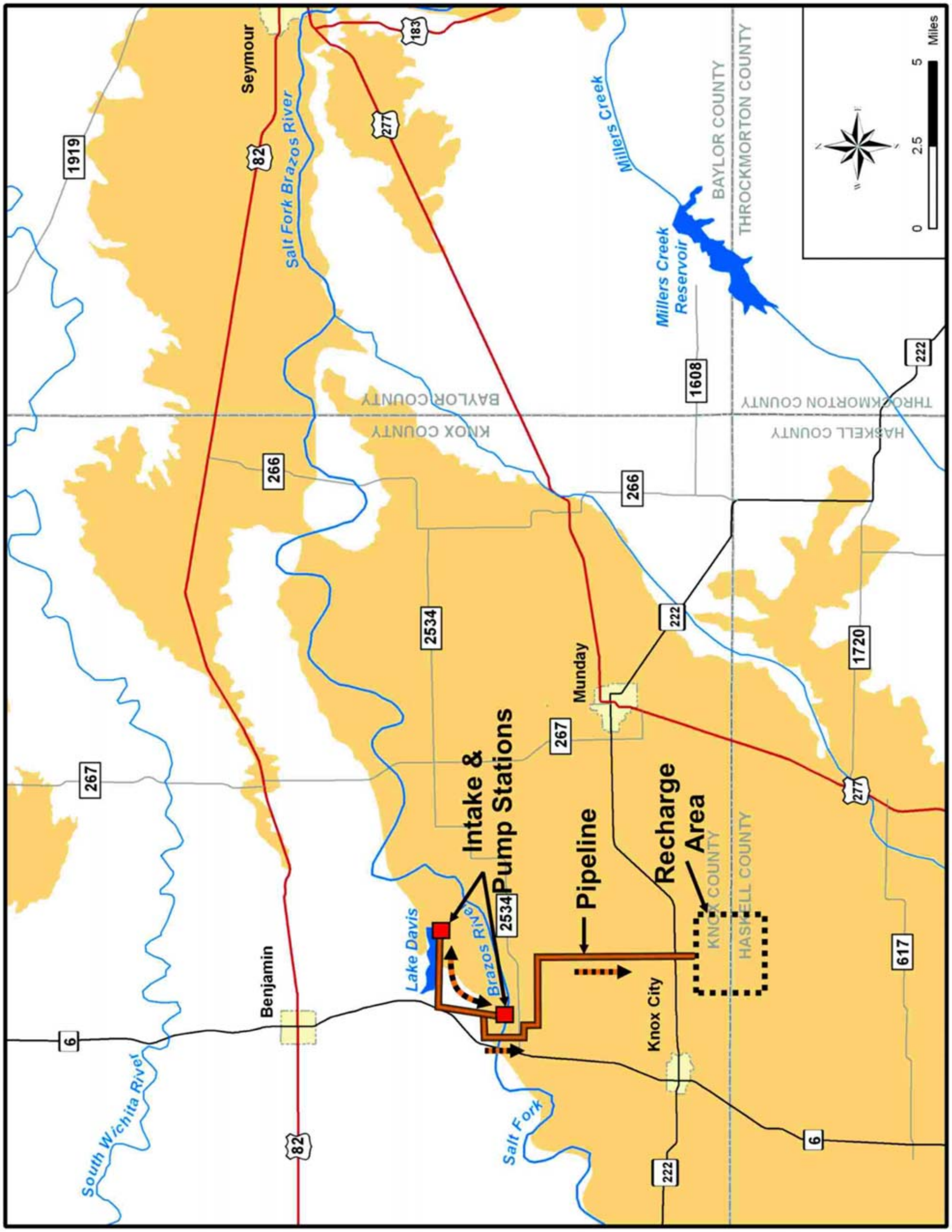


Figure 4B.8.1-1. Location and Features of Seymour ASR Project

4B.8.1.2 Available Yield

4B.8.1.2.1 Source and Supply of Surface Water

The source of water for the Seymour ASR project is the Salt Fork Brazos River. During seasons of high flow available water from the Salt Fork would be diverted to Lake Davis. Later, some or all the water would be delivered to the target area for recharging the Seymour Aquifer.

The Brazos G WAM was used to evaluate the availability of water in the Salt Fork and potential operation of Lake Davis. Operational settings to the Brazos G WAM included:

- No diversions to ASR unless at least 350 acft of storage remained in Lake Davis;
- Adjustment of the water diversion patterns from Lake Davis to allow existing irrigation water rights to continue from May through August and ASR diversions from September through April;
- When water in the Salt Fork is available and needed by the ASR project, the filling rate of Lake Davis is 2,100 acft/month (equivalent of a 36-in. pipe transporting water at a velocity of 5 cfs from the Salt Fork to Lake Davis); and
- ASR diversions are limited to 9,000 acft/yr.

In addition to these WAM settings, the project approach to operations assumes available water in Lake Davis is to be diverted to the recharge area over eight months. If a maximum of 9,000 acft/yr was available for diversion, 1,125 acft could be diverted each month to the recharge area.

Using the planned operations described above, the Brazos G WAM model shows that the yield of Lake Davis for irrigation increases from 125 acft/yr to 325 acft/yr. With subordination of Possum Kingdom to Lake Davis, the yield of Lake Davis for irrigation increases to 850 acft/yr. Figure 4B.8.1-2 shows the annual available flow from the Salt Fork to Lake Davis, and Figure 4B.8.1-3 shows the simulated annual diversions to the ASR recharge area from Lake Davis. The year with the most available flow in the South Fork is 1941, and the year with the most diversions to the ASR system is 1992. Several incidents of no water availability and, consequently, zero diversion to the ASR system, occur in 1944, 1952, 1956, 1964, 1983, and 1984. Based on these settings and assumptions, the long-term average diversion to Davis Lake is about 5,440 acft/yr and the diversion to ASR is about 3,750 acft/yr.

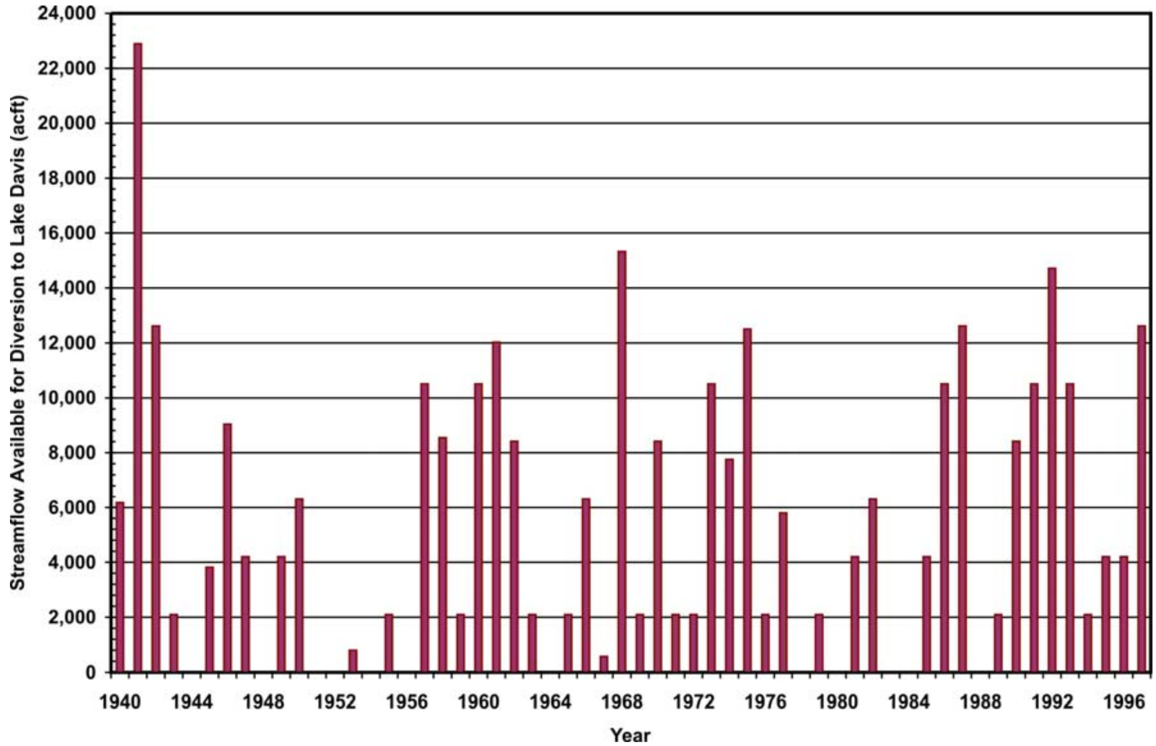


Figure 4B.8.1-2. Annual Availability of Water from the Salt Fork Brazos River for Storage in Lake Davis

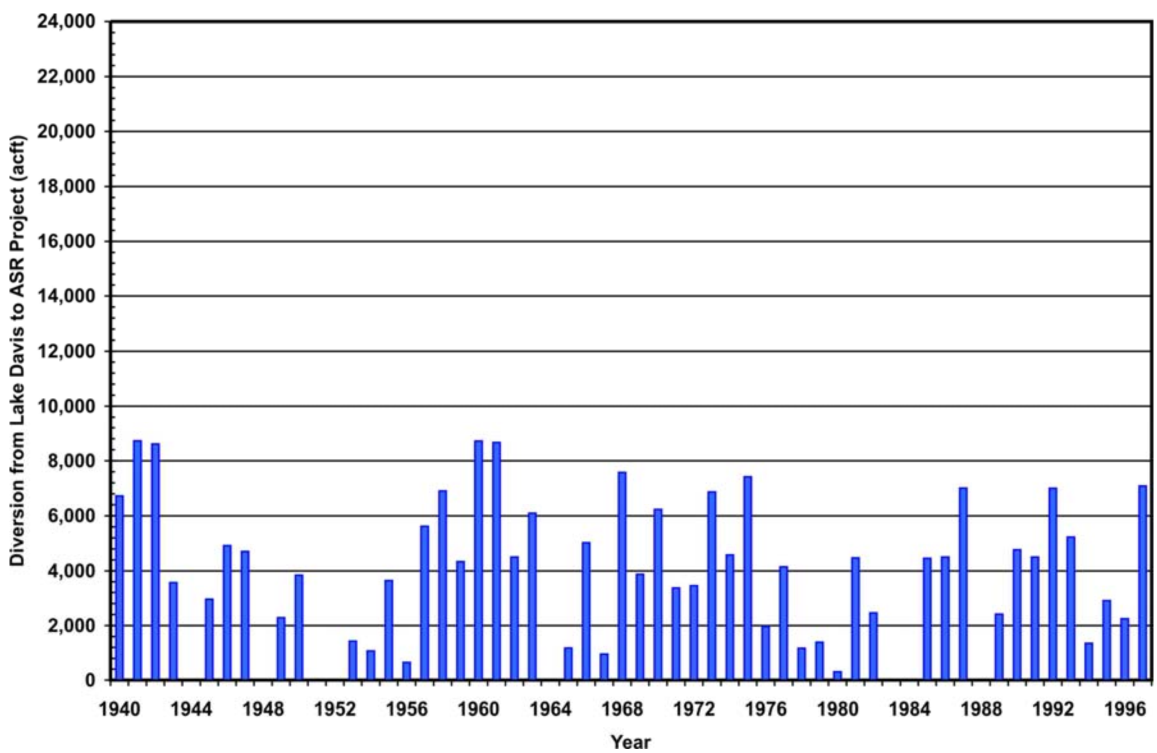


Figure 4B.8.1-3. Annual Availability of Water from the Lake Davis for ASR Recharge

Water quality in the Salt Fork was considered in the study of the ASR system. For this analysis, chloride concentrations and streamflow records at USGS gaging station 08082000 Salt Fork Brazos River near Aspermont, Texas, were analyzed. Figure 4B.8.1-4 shows the concentration of chloride versus streamflow. The shaded area indicates the range of discharges at which the most scalping of high flows in the Salt Fork would occur. The chart shows that chloride concentration decreases significantly as discharge increases.

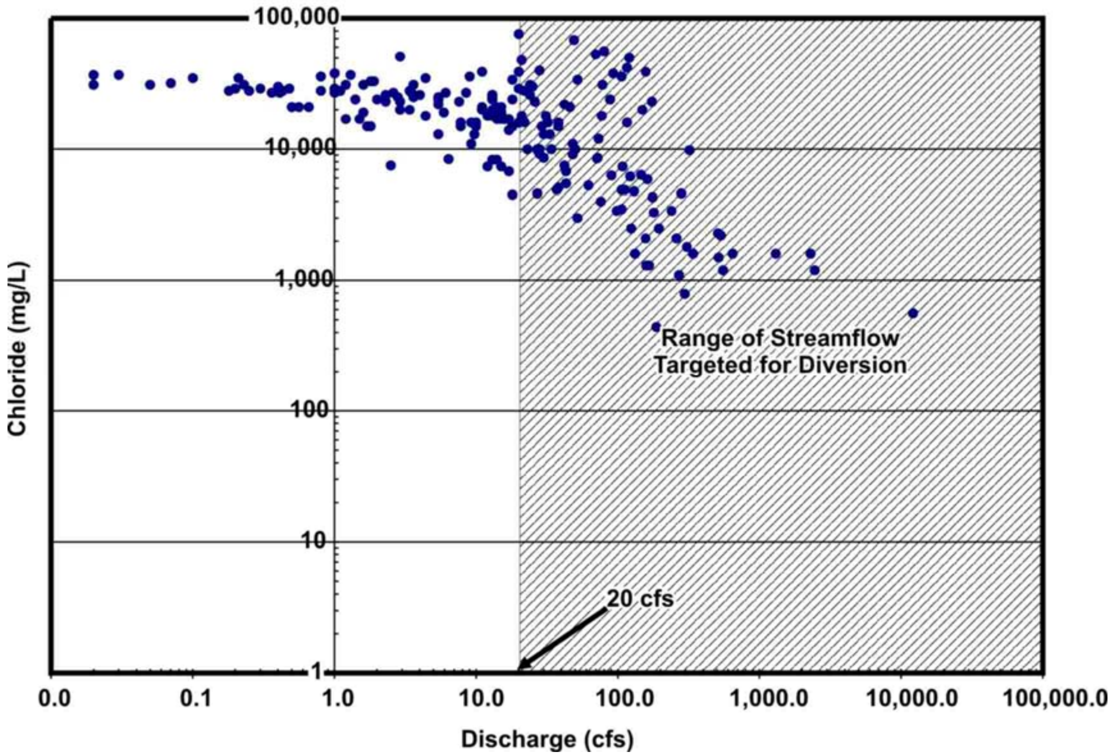


Figure 4B.8.1-4. Relation of Chloride Concentrations to Streamflow at 08082000 Salt Fork Brazos at Aspermont

4B.8.1.2.2 Seymour Aquifer

The Seymour Aquifer is composed of alluvial clay, silt, sand, and gravel deposited during the Pleistocene era and can be up to several tens of feet thick. Originally, the geologic material was laid down as a continuous unit; however, natural erosion has dissected the geologic material into several disconnected “pods.” The targeted ASR area is in a relatively large and hydraulically transmissive pod of the Seymour Aquifer and has been utilized for irrigation and local municipal supplies during the last several decades. Unconfined (water table) conditions exist throughout the aquifer. Infiltration of precipitation and excess irrigated water serve as the primary sources of recharge.

Historical water level data in the vicinity of the target recharge area show significant declines in saturated thickness during the last 20 years. For example, a decline of about 30 feet was recorded between 1987 and 2003 at TWDB's monitoring well 2134902, which is near Knox City. This is about a 70 percent reduction in saturated thickness. These declines suggest that well yields from this area have declined in the past and, if the historical trend in declining water levels persists, well yield declines will continue. The reductions in saturated thickness also indicate that storage space for ASR recharge exists within the aquifer. Because the Seymour is an unconfined aquifer, any surplus recharge added through ASR must be contained within the sediment pore spaces.

4B.8.1.2.3 ASR Modeling

To better evaluate the potential benefits of an ASR system in the region, a groundwater flow model was developed from the TWDB's Seymour Aquifer Groundwater Availability Model (SAGAM). The original SAGAM was modified for use in this study to better simulate the potential application of ASR. The modifications included:

- Clipping the Seymour GAM to cover only the Seymour in Haskell and Knox Counties;
- Refining the model grid by a factor of 5, this resulted in cells dimensions of 1,056 feet by 1,056 feet; the increase in cell density allowed for greater resolution of the smaller-scale effects produced by the simulated ASR well field;
- Assigning the elevation of the upper surface of the Seymour to land surface (as recorded in the National Elevation Dataset distributed by the USGS);
- Engaging MODFLOW's Evapotranspiration (ET) package;
- Disengaging regional pumpage; and
- Adjusting average recharge rates until the modeled saturated thickness closely matched the most recent values recorded by the TWDB for wells in the area of the proposed ASR site (these conditions are believed to represent quasi-steady-state conditions).

Assignment of ground level and subsequent engagement of the ET package was necessary to ensure that water table rises from recharge did not go above ground level throughout the simulations. The removal of regional pumpage allowed a straightforward assessment of the likely regional effects of the simulated ASR wells.

Two modeling scenarios were then conducted to assess the benefits of the ASR system. These scenarios are intended to represent the extremes of water availability for recharge which were selected during the period 1940 through 1997 and for continuous 10-year periods. The first scenario assumed the volume available for ASR injection corresponded to the 10-year period when the most surface water was available. This "wettest" period was from 1985 to 1994 and is expected to provide a supply of about 3,600 acft/yr and recovery of about 3,000 acft/yr. The second scenario assumed that the volume available for injection corresponded to 10-year period when the least amount of surface water is available. The "driest" period began in 1944 and provided approximately 1,360 acft/yr recharge and 1,000 acft/yr of pumpage. On the basis of water levels and changes in water levels, the estimated recovery is about 75 to 80 percent of the water injected.

Recharge to the Seymour was simulated utilizing a cyclic approach in order to illustrate the water level fluctuations that may occur during operation of the ASR system. For this study, it is assumed that injection of water takes place during a 4-month period each year. Similarly, recovery of groundwater from the Seymour is assumed to occur during an 8-month period each year. The model evaluations applied to each scenario extended through a 10-year period, simulating the magnitude, extent, and distribution of the water level increases that may occur following the implementation of an ASR system in the region.

4B.8.1.2.4 Simulated ASR Impacts on the Seymour Aquifer

The ASR project impact on water levels of interest include: (1) magnitude of water level fluctuations over the injection and recovery cycle, and (2) extent of water table mounding and drawdown. As shown in Figure 4B.8.1-5, water level fluctuations in the center of the ASR area are approximately 18 feet for the "wet" scenario. During the "dry" scenario when smaller amounts of water are stored and recovered from the aquifer, the graph shows the total water table fluctuations are about 8 feet.

The water table maps representing conditions at the end of the recharge and recovery cycles of the 10-year simulations are shown for the wettest scenario in Figure 4B.8.1-6. These maps indicate that the location of the well field and the layout of wells do not significantly impact the overall distribution of the simulated water level increases. This is primarily due to the relatively high transmissivity of the Seymour Aquifer in the vicinity of the selected recharge

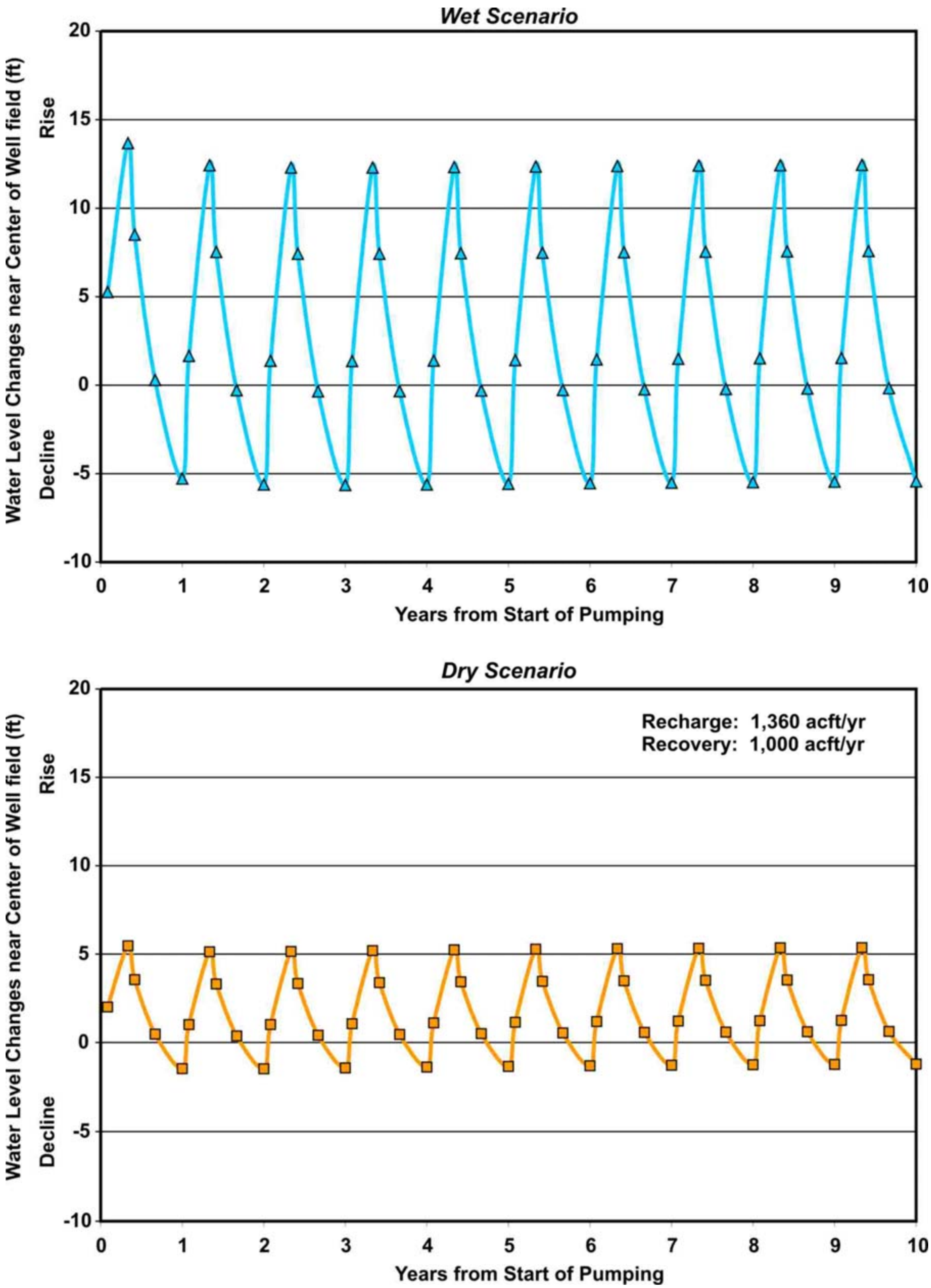
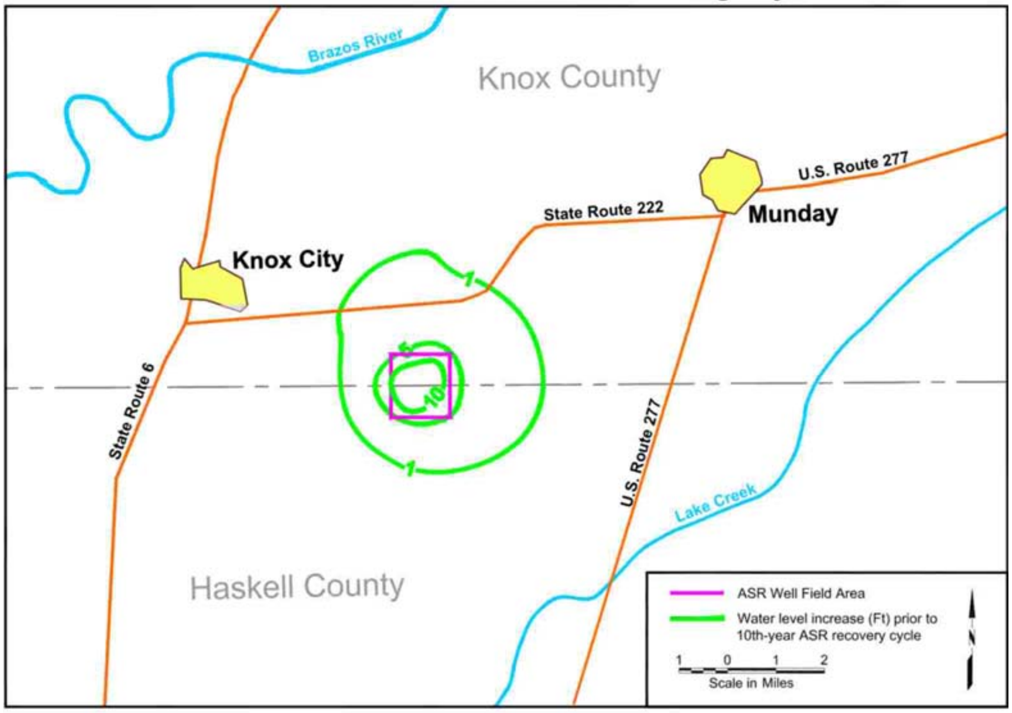


Figure 4B.8.1-5. Water Level Fluctuations at Center of ASR Recharge Area

Net Rise in Water Levels at End of Recharge Cycle



Net Decline in Water Levels at End of Recovery Cycle

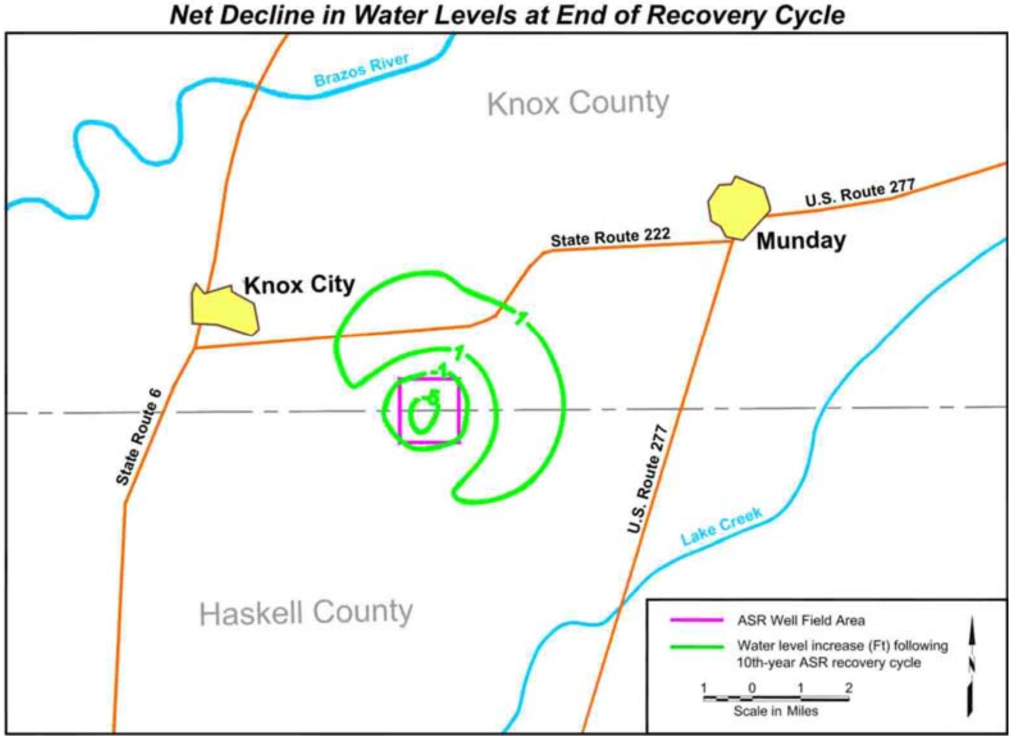


Figure 4B.8.1-6. Net Change of Water Level During 10th Year of Simulation for Wettest Scenario

area. When 3,600 acft/yr is recharged and 3,000 acft/yr is pumped for a period of 10 years during an extended “wet” scenario, the area exhibiting at least a 1-foot water level increase extends about 1.5 to 2 miles from the recharge area. When 1,360 acft/yr is recharged and 1,000 acft/yr is pumped for 10 years, the 1-foot water level increase extends only about 0.5 miles from the recharge area. In both scenarios, the simulation results indicate that the increases in water levels around the ASR well field are not entirely symmetrical; slightly greater increases are seen to the north and northwest of the well field. These results are consistent with the general north-northwest direction of groundwater flow reported in the region.

4B.8.1.2.5 Potential Seymour ASR Design

The proposed method of recharge is the use of spreading basins instead of wells. The spreading basins are expected to be shallow swales in the more permeable areas and along topographic contours. The spreading basins have the advantage of allowing the use of recharge water with some sediment concentrations, high application rates, and limited maintenance. It has the disadvantage of some water loss. This probably will be overcome with the retention of rainfall that may otherwise runoff. Site-specific information on soil infiltration characteristics and aquifer properties would be needed to design the recharge system and to identify the prime recovery wells.

4B.8.1.2.6 Important Seymour ASR Assumptions

Important issues relating to the applicability of a Seymour ASR project include annual recharge and recovery cycles and suitable quality and quantity of surface water for aquifer compatibility and local groundwater use.

The recovery cycle must soon follow the injection cycle, or the recharge may dissipate into the regional aquifer system. While benefiting the aquifer on a more regional basis, specific project benefits for participants may be minimal. Additional studies concerning water quality from the Salt Fork would need to be conducted if the project appears feasible from cost/benefit studies.

4B.8.1.3 Environmental Issues

Diversion facilities on the Salt Fork with a pump station and pipeline to Lake Davis and then to the recharge area, which would cover a relatively small surface area of 57 acres, would probably result in:

- Negligible impacts on environmental water needs, instream flows, and bays and estuaries;
- Improved fish and wildlife habitat conditions in Lake Davis;
- Low to moderate impacts to wildlife habitat along pipeline crossing of Salt Fork;
- Low to moderate impacts to fish and wildlife, including endangered species; and
- Low impacts on cultural resources.

4B.8.1.4 Engineering and Costing

The engineering facilities for the ASR project consist of an intake and pump station on the Salt Fork Brazos River, a 36-in pipeline to Lake Davis, an intake and pump station at Lake Davis, a 24-in pipeline from the river to the ASR recharge area, distribution pipelines to several delivery points, and swales in the fields. The pipeline from the Salt Fork to Lake Davis would be used for filling the lake and diverting water from the lake to the recharge area. The river intake and pump station would be located near State Hwy 6. The Lake Davis discharge, intake and pump station facilities would be located near the dam. These facilities were shown in Figure 4B.8.1-1. The major facilities required for this option is:

- River Diversion to Off-Channel Storage
  - River Intake;
  - Pump Station;
  - Pipeline; and
  - Outlet works.
- Lake Diversion to Recharge Area
  - Lake Intake;
  - Pump Station;
  - Pipeline;
  - Outlet works; and
  - Terraces or swales.

Estimates were prepared for capital costs, annual debt service, operation and maintenance, water purchases, power, land, and environmental mitigation. These costs are summarized in Table 4B.8.1-1. The project costs, including capital, are estimated to be $18,826,000. The annual costs, including debt service, operation and maintenance, and power are estimated to be $1,776,000. This water management option produces water at estimated costs of $474 per acft/yr for a long-term average delivery of 3,750 acft/yr. Because of relatively large fixed cost, unit rates would be less for relatively wet conditions and more for relatively dry conditions.

Table 4B.8.1-1.
Seymour Aquifer ASR Water Supply Project Option
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Intake and Pump Stations (23 MGD to Davis and 12 MGD to ASR)	$6,133,000
Transmission Pipeline (36-in to Davis and 24-in to ASR)	6,102,000
Recharge Facilities in Fields	250,000
Total Capital Cost	**$12,485,000**
Engineering, Legal Costs and Contingencies	$4,065,000
Environmental & Archaeology Studies and Mitigation	368,000
Land Acquisition and Surveying (57 acres)	513,000
Interest During Construction (30 years)	1,395,000
Total Project Cost	**$18,826,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$1,368,000
Operation and Maintenance:	
Intake, Pipeline, Pump Station	214,000
Pumping Energy Costs (3,226,476 kWh @ $0.06/kWh)	194,000
Total Annual Cost	**$1,776,000**
Available Project Yield (acft/yr)	**3,750**
Annual Cost of Water ($ per acft)	**$474**
Annual Cost of Water ($ per 1,000 gallons)	**$1.45**

4B.8.1.5 Implementation

Implementation of the described ASR water management strategy for the Seymour Aquifer includes the following issues:

- Availability of suitable water quantities and water quality from the Salt Fork Brazos River;
- Contractual arrangements can be made with owner of Lake Davis or another nearby reservoir for use of the unused storage capacity of the reservoir;
- Contractual arrangements with land owners where the infiltration basins are to be constructed;
- Pipeline right-of-way from Salt Fork diversion to Lake Davis, and from Lake Davis to ASR site;
- Entity who is willing and capable of funding and operating the facilities and capable of developing and administering a management plan to efficiently use the facilities and to balance injection and recovery cycles.
- Controlling the loss of the injected water by the participants in the project;
- Initial cost; and/or
- Experience in operating water facilities.

It will be necessary to obtain these permits:

- TCEQ water rights permit to divert from Salt Fork Brazos River
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings
- General Land Office Sand and Gravel Removal Permits
- Texas Parks and Wildlife Department Sand, Gravel and Marl permit for river crossings

The impacts of the ASR option for the Seymour Aquifer in Knox and Haskell Counties has been compared to the plan development criteria, as shown in Table 4B.8.1-2.

Table 4B.8.1-2.
Comparison of ASR –Seymour Option in Knox and Haskell Counties to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient in most years
2. Reliability	2. Low
3. Cost	3. Moderate to expensive for irrigation use
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• Potential negative impacts on water quality of Seymour; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is an attempt to meet agricultural irrigation needs
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.8.2 Trinity Aquifer in Johnson County

4B.8.2.1 Description of Option

For purposes of this option, the ASR project of the Trinity Aquifer in Johnson County is considered to be the use of dual-purpose wells to inject potable water into the aquifer for storage and recovery of the water at a later date. This management strategy is useful to water suppliers who periodically have surplus water and water shortages. For example, ASR can be used to inject and store water in aquifers during the fall, winter, and spring when demands are low, and to recover the water during the summer when demands are high. This strategy better utilizes the available capacity of the water treatment plant and supply and transmission system, and commonly delays the need for expanding water treatment and distribution facilities. In most cases, the water utility's operating plan would call for balancing injection and recovery or possibly recovering slightly less than the amount injected.

For Johnson County, the ASR option is considered to be a potential water management option on the basis of more fully utilizing the available water transmission capacity from the SWATS facility on Lake Granbury to Johnson County customers (Figure 4B.8.2-1). As shown in Figure 4B.8.2-2, the July and August demands are expected to exceed the pipeline capacity by year 2010. However, with a fully operational ASR system, the annual average demand does not exceed the capacity of the pipeline until nearly 2020. This surplus of available capacity occurs during the fall, winter, and spring; however, the surplus diminishes with time as water demands gradually increase. Facilities required for this option are the installation of ASR wells, well field, pipelines, and booster station.

The area selected for potential implementation of an ASR well field is located in the northeast part of the county between the towns of Godley and Joshua and covers about 16 square miles. For purposes of this study, it is assumed that SWATS water is chemically compatible with the Trinity Aquifer and native Trinity water.

4B.8.2.2 Available Yield

4B.8.2.2.1 Trinity Aquifer System

In Johnson County, the Trinity Aquifer system is composed of three sandy aquifer units that are confined and separated by relatively impermeable clay units. These aquifer units include, from youngest to oldest: the Paluxy, Hensell, and Hosston (Figure 4B.8.2-3). In the proposed ASR well field, the water-bearing units are confined with artesian pressures generally rising several hundred feet above the top of the aquifer(s). The geometry and hydraulic properties of the hydrogeologic units of the Trinity Aquifer units vary throughout Johnson County. In general, the most hydraulically transmissive (i.e., sand-rich) portions of the aquifers vary from 50 to 100 feet in thickness. High-capacity production wells typically yield from 150 to 250 gallons per minute (gpm).

Figure 4B.8.2-1. Location of Johnson County ASR Project

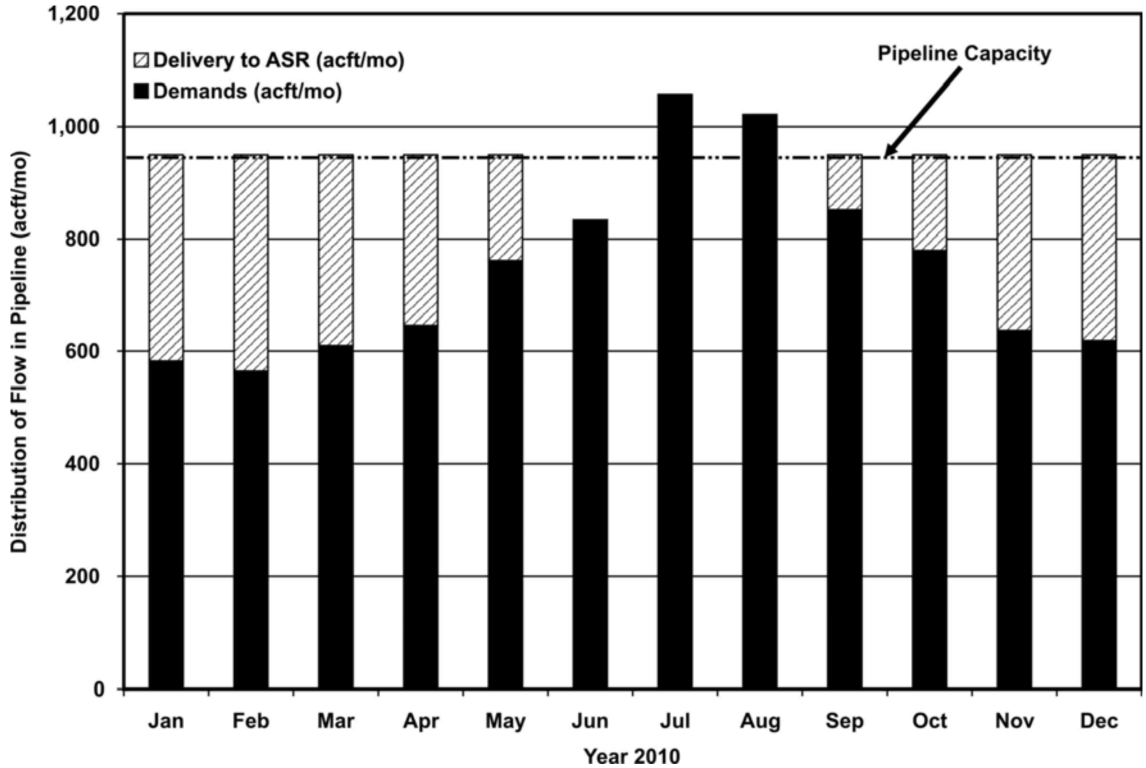


Figure 4B.8.2-2. Johnson County ASR Operations

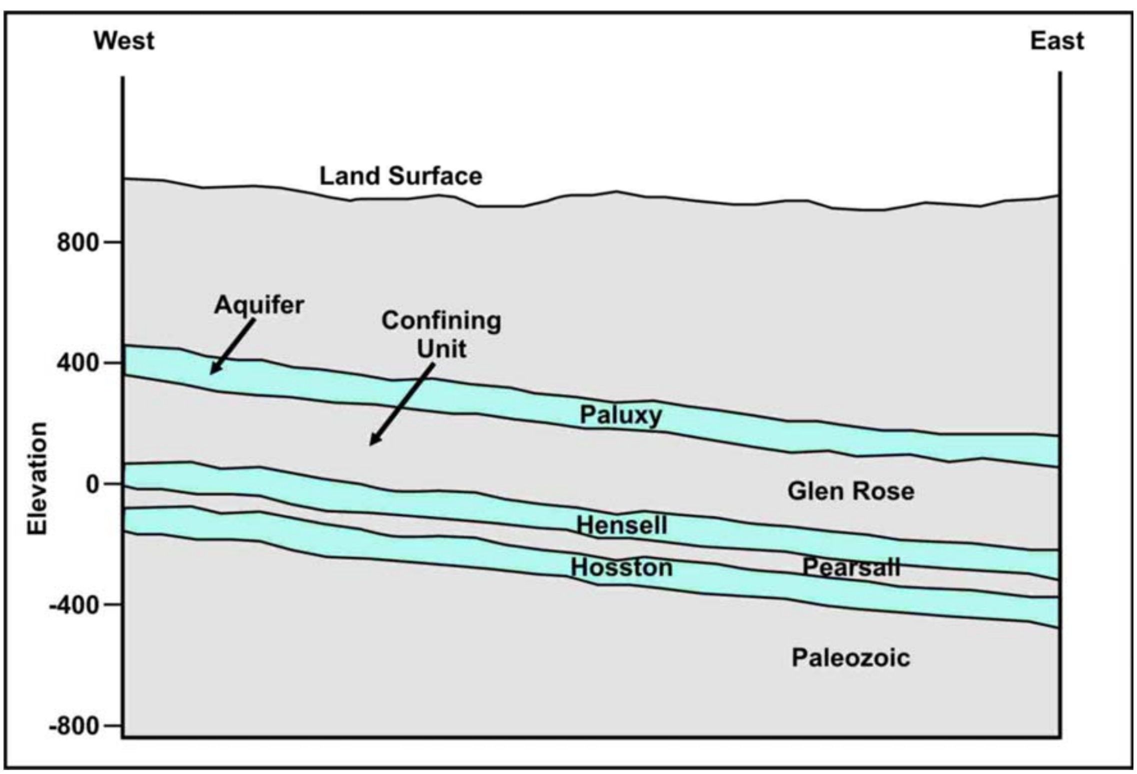


Figure 4B.8.2-3. Hydrogeologic Profile in ASR Well Field

4B.8.2.2.2 Modeling ASR Operations in the Trinity Aquifer

To estimate the likely impacts of ASR operations on the aquifer system, the TWDB's Northern Trinity/Woodbine Groundwater Availability Model (NTWGAM) was utilized. The GAM subdivides the Trinity Aquifer system in the study area into three discrete aquifer units: (1) Paluxy, (2) Hensell, and (3) Hosston. For this study, all ASR injection and recovery is simulated in wells that penetrate the Hosston, the deepest and generally the most transmissive aquifer in the local region. With the exception of predictive pumpage, original GAM input parameters were retained for all simulations. Recharge was held constant at a rate corresponding to the average estimated during 1980 to 2000.

Several entities have forecasted significant declines in the rate of withdrawal from the Trinity for the next half-century, and these rate reductions were included in the predictive pumpage set included with the NTWGAM. However, it is unclear whether reductions in pumpage will actually occur given the projected population growth within the region and the lack of alternative water supplies. Because of the uncertainty in future use of the Trinity, the regional pumpage estimated during the year 1999 was held constant throughout the simulations in an effort to minimize the underestimation of regional drawdown should a planned reduction in future pumpage not occur and to simplify the analysis.

Injection of water into the Hosston member of the Trinity Aquifer was simulated utilizing a cyclic approach in order to illustrate the water level fluctuations that may occur during operation of the ASR system. For this study, it is assumed that injection of about 2,600 acft/yr of water takes place during a 9-month interval within each 1-year period of the simulation. Following the injection cycle, recovery of groundwater is assumed to occur during a 3-month interval in the course of a 1-year simulation.

The test scenario was conducted on the basis of 2,600 acft/yr of ASR recharge followed by full recovery. To test for trends, the model simulations extended through a 10-year period, simulating the magnitude, extent, and distribution of the water level increases that may occur following the implementation of an ASR system in the region.

Figure 4B.8.2-4 shows the well field water level fluctuations caused by ASR operations for 10 years. Conceptually, the injection would begin in September and last through May, and the recovery would be from June through August. During these simulations, 2,600 acft/yr of annual ASR injection with full recovery will likely result in yearly water level (artesian pressure) oscillations of about 750 feet. As shown, the water levels slowly decline over time because the water levels for background pumping have not stabilized. As shown in Figure 4B.8.2-5, the model results also indicate that significant fluctuations in artesian pressure may be expected to extend several miles from the well field. At the end of the injection cycle in the 10th year, water level rises range from about 300 feet in the center of the well field to about 10 feet at a distance of 7 miles. At the end of the recovery cycle in the 10th year, the declines are more than 10 feet within about 6 miles of the well field.

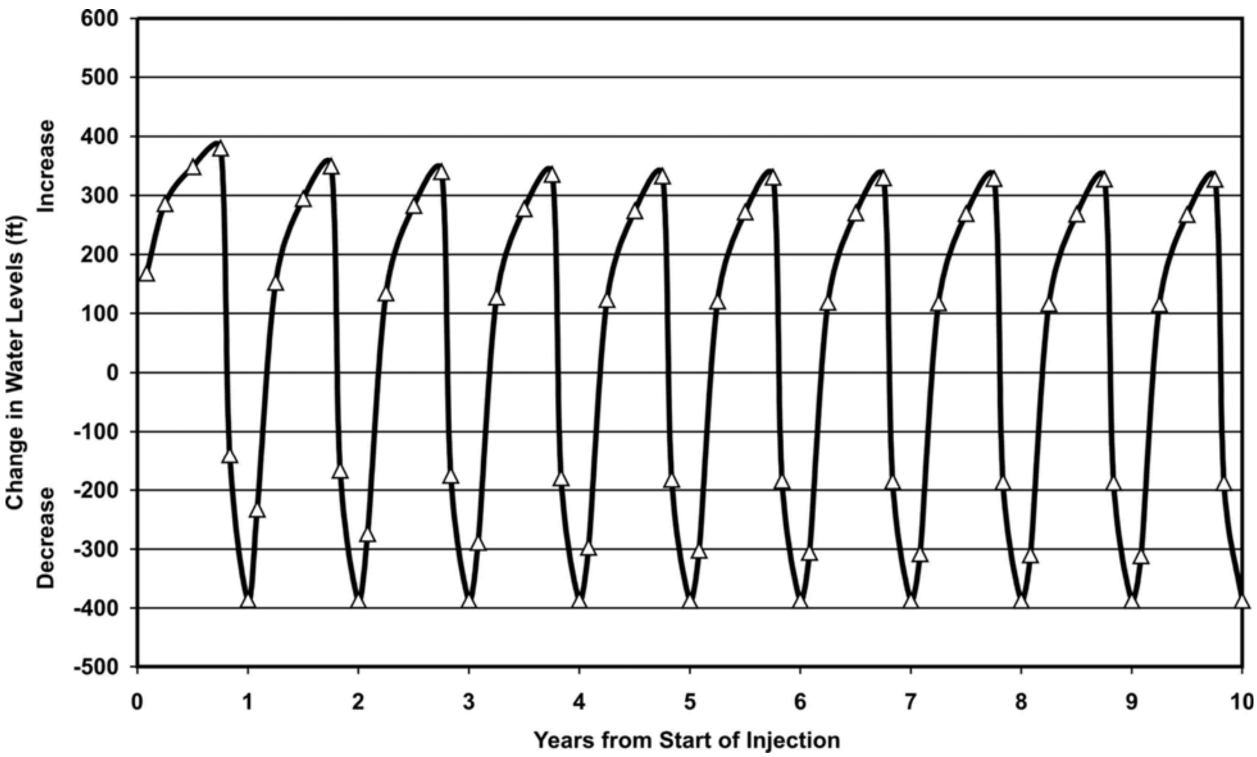
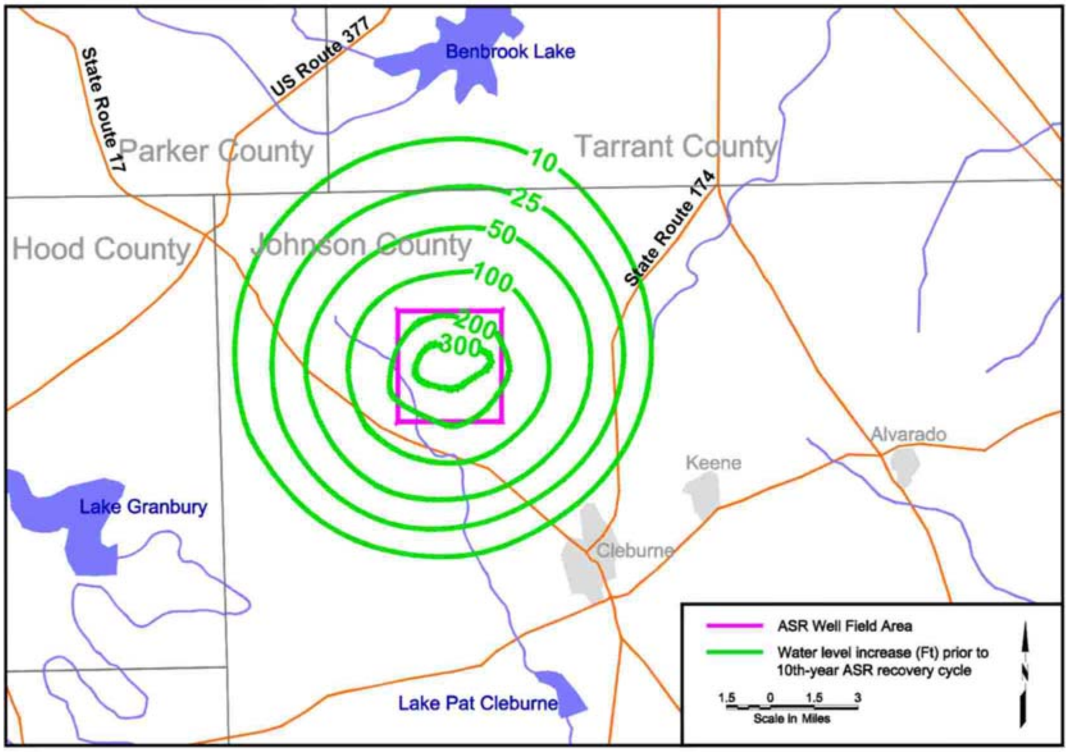


Figure 4B.8.2-4. Water Level Fluctuations in Center of ASR Well Field

It should be noted that the magnitude and extent of the modeled water level fluctuations are heavily dependent on the assumed hydraulic characteristics of the aquifer in the region, and that the actual water level changes will likely vary with the conditions found at specific well sites.

Water Level Rise



Water Level Decline

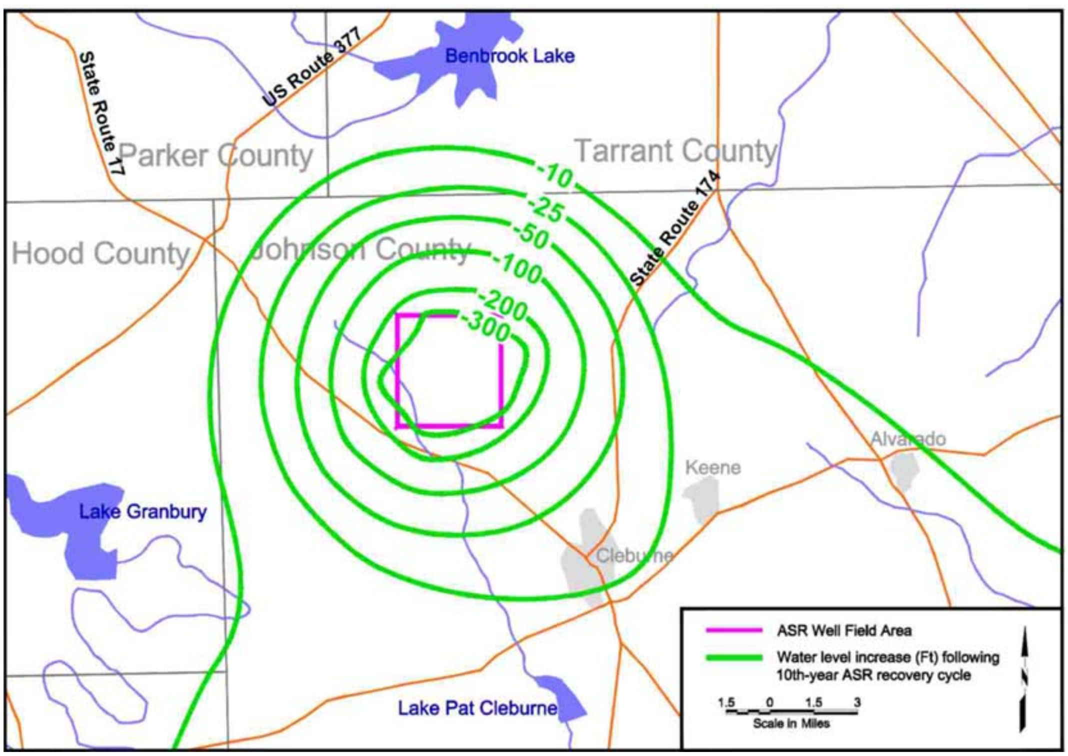


Figure 4B.8.2-5. Water Levels During 10th Year of Operations

4B.8.2.2.3 Potential Trinity ASR Well Field Design

The actual number of wells and land required for the well field is dependent upon local depth to water, and the thickness and character of sands present at each well field site. This site-specific information would need to be acquired through a test drilling and field testing program prior to implementation of an ASR system in the region.

Available records indicate that wells constructed in the area will average between 1,100 and 1,200 feet in depth. Based on existing wells in the area, the maximum injection and recovery rates per well is about 250 gpm. Given this restriction, it is estimated that about 26 wells would accommodate the recovery rate assumed for this study. A schematic of a potential well field design is shown in Figure 4B.8.2-6.

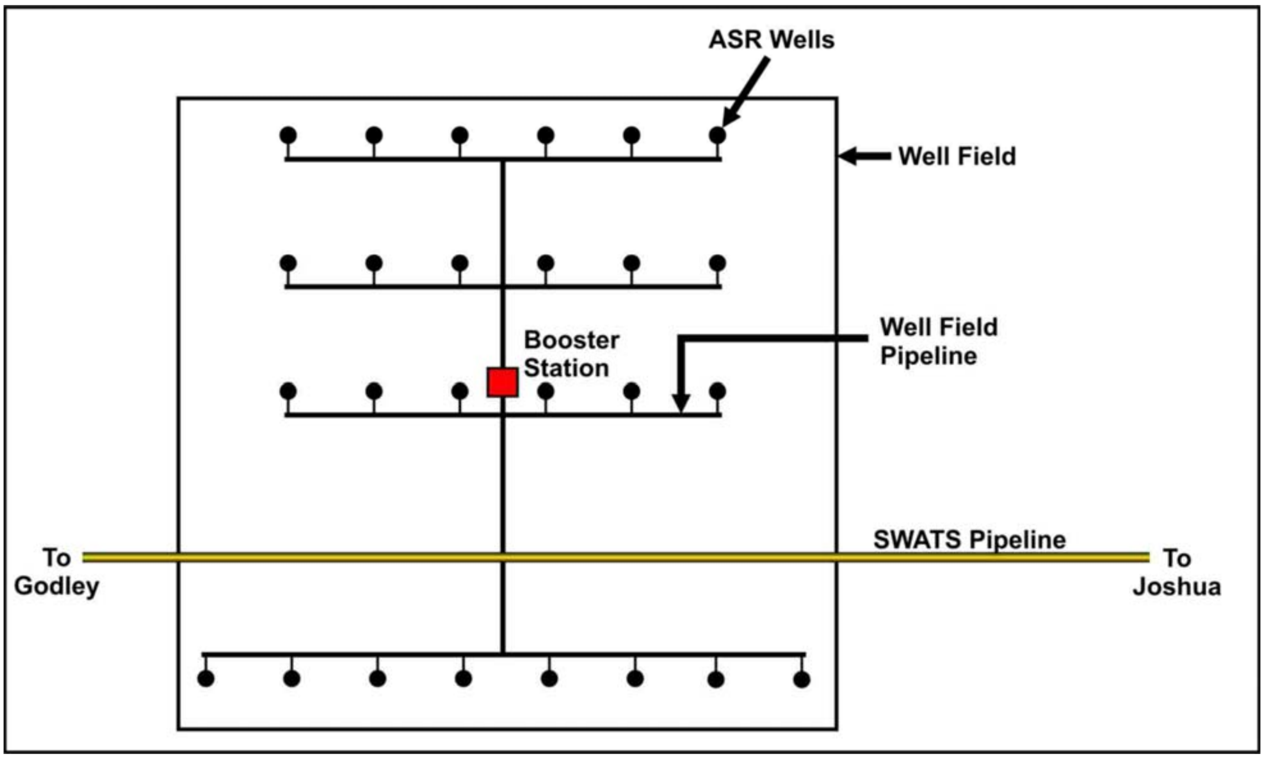


Figure 4B.8.2-6. Schematic of Potential ASR Well Field Design

4B.8.2.2.4 Important Assumptions

Important issues relating to the applicability of a Johnson County ASR project include: (1) annual injection and recovery cycles, (2) availability of suitable quality and quantity of water, (3) the aquifer and imported water are compatible, and (4) limited local groundwater use.

The recovery cycle must soon follow the injection cycle, or local artesian pressures generated during the injection phase will dissipate. While losing the annual pressure benefit, the project may provide water quality improvements even without a subsequent recovery cycle. As noted, it is assumed that injection water quality is compatible with the Trinity Aquifer. Additional studies concerning water quality would need to be conducted to determine if the project is feasible.

4B.8.2.3 Environmental Issues

The development of ASR facilities in the Johnson County includes the construction of wells, collector pipelines, and water treatment facilities would involve relatively low environmental impacts:

- Operation of ASR wells is expected to have no effect on streams in the area.
- Construction of wells, collector pipelines and pump station would have little or no effect on wildlife habitat or in disturbed areas. No streams or wetlands are expected to be encountered.

4B.8.2.4 Engineering and Costing

The ASR well field would be developed by constructing water wells capable of injection and recovery, well field pipelines for distribution and collection of water, a booster station for injection, and terminal storage. The well field is about midway between the towns of Godley and Joshua and will extend north and south of the SWATS pipeline, as shown in Figure 4B.8.2-1. During the injection cycle, a pump station and terminal storage is needed to provide sufficient pressure to the northern part of the ASR well field. In all, 26 dual-purpose wells constructed to public water supply standards are required. Eight would be south of the SWATS pipeline and 18 would be north, spaced at 5,000 feet. Well pumps will be large enough to produce sufficient head to force the recovered water directly into the SWATS pipeline. The major facilities required for these options are:

- Well Field and Collection and Conveyance System to the SWATS pipeline along State FM 917

- Wells;
- Pipelines;
- Booster Station; and
- Terminal Storage.

The approximate locations of the well fields, pipeline routes, and pump station were shown earlier in Figures 4B.8.2-1 and 4B.8.2-6.

Estimates were prepared for capital costs, annual debt service, operation and maintenance, water purchases, power, land, and environmental mitigation. These costs are summarized in Table 4B.8.2-1. The annual costs, including debt service, operation and maintenance, power, and purchase of treated water, are estimated to be $5,245,600. This water management option initially produces water at estimated costs of $2,025/acft/yr with about $1,140/acft/yr for the purchase of treated water. Later, as the SWATS pipeline has less and less capacity for recharge, the unit cost would increase.

4B.8.2.5 Implementation

The ASR water management strategy described above has been compared to the plan development criteria, as shown in Table 4B.8.2-2, and the option meets each criterion. Implementation of the ASR water management strategy for Johnson County includes the following issues:

- Contractual arrangements can be made with the Brazos River Authority for a supply of raw water and expanded use of the SWAT facility;
- Permits from TCEQ for ASR operations and for storage of surface water in the Trinity Aquifer can be obtained;
- Lack of experience to develop confidence in the ability to inject and recover water from an aquifer, which includes the uncertainty about the compatibility of the injected water with native groundwater and aquifer materials;
- Controlling the loss of the injected water by the funding agency;
- Initial cost;
- Experience in operating the facilities; and/or
- Development of a management plan to efficiently use the ASR wells with a balance of injection and recovery cycles.

Table 4B.8.2-1.
Johnson County ASR Water Supply Project Option
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Transmission Pump Station(s)	$1,400,000
Well Fields	14,397,000
Total Capital Cost	**$15,797,000**
Engineering, Legal Costs and Contingencies	$5,527,000
Environmental & Archaeology Studies and Mitigation	823,000
Land Acquisition and Surveying (107 acres)	1,006,000
Interest During Construction (2 years)	1,853,000
Total Project Cost	**$25,006,000**
Annual Costs	
Debt Service (6 percent, 30 years)	$1,817,000
Operation and Maintenance:	
Intake, Pipeline, Pump Station	170,000
Pumping Energy Costs (5,106,032 kWh @ $0.06/kWh)	306,000
Purchase of Treated Water (2,590 acft/yr @ $1,140/acft)	2,952,600
Total Annual Cost	**$5,245,600**
Available Project Yield (acft/yr)	**2,590**
Annual Cost of Water ($ per acft)	**$2,025**
Annual Cost of Water ($ per 1,000 gallons)	**$6.21**

Table 4B.8.2-2.
Comparison of Johnson County ASR-Trinity Water Supply Project to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Improves balance of winter and summer demands
2. Reliability	2. High
3. Cost	3. Moderately expensive
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. None
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and “County-Other” shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

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4B.9 Brush Control and Range Management

Brush control is a potential water management strategy that could possibly create additional water supply within the Brazos G Area. The Texas Brush Control Program, created in 1985 and operated by the Texas State Soil and Water Conservation Board (TSSWCB), serves to study and implement brush control programs in areas where brush is considered to be responsible for substantial water losses.

Brush control is a land management practice that converts land that is covered with brush, such as juniper and mesquite, to grasslands. The impact of these practices can increase water availability through reduced extraction of soil water for transpiration and increased recharge to shallow groundwater and emergent springs. To a lesser extent, there is the potential for increased runoff during rainfall and snowmelt events.

Research on brush control and water balance began in the 1920s, but the idea of brush control as a possible means of alleviating water scarcity in drought-prone western states started to take hold in the 1970s. Research and pilot studies have found that the control of brush species yields more water, but these increases are dependent upon rainfall variations and many other variables. To date, there has been mixed results regarding water production, but in general, the results indicate positive outcomes to carefully planned brush control.

One of the first studies on brush control was the federally sponsored Seco Creek Demonstration project in the Texas Hill Country. The findings from this study showed significant improvements in rangeland health and water quality and quantity of the underlying Edwards Aquifer. Following that study, significant state- support of brush control began with a feasibility study on the North Concho River Basin in 1998. Over the past 6 years, the State has authorized feasibility studies for the control of mesquite, juniper and mixed brush in 14 watersheds: North Concho, Main Concho, Twin Buttes/Lake Nasworthy, Upper Colorado, Canadian, Wichita, Pedernales, Edwards Aquifer, Nueces, Frio, Palo Pinto Lake, Lake Brownwood, Lake Phantom Hill and Lake Arrowhead. From these fourteen feasibility studies, three major state-supported brush control programs have been initiated in the North Concho, Upper Colorado and Pedernales River Basins. Each is administered by the TSSWCB.

In addition to State supported studies and programs, the Federal government, through the Corps of Engineers, is involved in brush control studies in the O.C. Fisher and Cibolo Creek watersheds. Both of these projects include brush control as part of environmental restoration and aquifer recharge enhancement efforts. Other efforts include salt cedar removal in the Colorado, Canadian and Pecos River Basins. Bio-control studies of salt cedar using Asian leaf beetles are also being conducted in these basins in conjunction with state and federal agencies.

Generally, brush control activities in Texas have been limited to feasibility studies with limited data collection from on-going brush programs. The results of the completed feasibility studies indicate increases in water production for all basins studied, with average annual water increases per acre treated ranging from 13,000 gallons in the Canadian Basin to 172,000 gallons in the Medina watershed (Edwards Aquifer). These calculations are based on comparisons of total water flow at the most downstream point of the watershed for conditions with and without brush. Estimates of long-term reliable supply from increased storage in reservoirs or aquifers are not reported in the studies.

The North Concho River Brush Control Project is one of the longer on-going brush programs in the state. From 1999 through 2003, over 207,000 acres of brush were cleared in the O.C. Fisher Reservoir watershed.[1] A total of 307,000 acres were targeted for removal by 2004. However, current drought conditions have limited removal efforts and basin-wide responses have been difficult to measure. In limited areas, the program is recording increased soil moisture after treatment and more frequent rainfall-runoff events, but it is difficult to assess the water supply benefits of brush control during drought. It appears that most of the water realized through brush removal is likely associated with increased soil moisture and/or contained in the shallow alluvial aquifer. There have been no significant increases in storage content in O.C. Fisher Reservoir since the program has been in place.

4B.9.1. Description of Brush Control Strategy

Virtually all of the renewable and sustainable water resources available for the Brazos G Area originate as precipitation within the boundaries of the region. The inflow from the upstream tributaries of the Brazos River is limited in amount and quality. The significant majority of this precipitation falls on agricultural lands, which includes crop land, improved pastures, improved range, native range, and other rural lands, such as rocky outcrops, heavy brush and trees, and other land that is not used for production. This water then infiltrates into the soil, runs off the land to nearby streams, or evaporates from localized ponding.

[1] Texas State Soil and Water Conservation Board, *Brush Control Program – 2003 Annual Report*, 2004.

Modification of the landscape has a significant impact on the partitioning of rainfall into runoff and infiltration, and ultimately the usability of this water. From a water yield standpoint, the ideal range (non-cropland) landscape has a good grass cover at all times of the year, whether the grass is alive or dormant. The grass retards surface runoff and allows more time for infiltration of the rainfall into the soil. The grass prevents sealing of the soil surface and the roots improve the soil structure, which also increases infiltration (water flow *into* the soil) and percolation (water flow *within* the soil). The active root zone of most grasses is easily within the top 3 feet of the soil, so the infiltrated soil water that is in excess to the storage capacity of the soil will percolate to the groundwater table. In aquifer outcrop areas, this percolation recharges the aquifer. If there is no aquifer, the shallow groundwater will emerge as springs and soil water movement into creek, stream, and river channels. This is the source of the highly desirable base flow of rivers that continuously recharge the reservoirs and provide wildlife habitat, livestock water, fish habitat, and recreational uses. Flash flood runoff does not contribute significantly to this base flow. The grass cover provides grazing for stock, which provides the economic incentive for the landowner to maintain the ranges in good condition.

The worst case from a water yield standpoint is a landscape that is covered with brush, such as juniper and mesquite. The grass cover is reduced under the brush (especially juniper) and, therefore, not fully effective in reducing runoff. The major impact of the brush, however, is the continuing extraction of soil water for transpiration long after the rainfall event has ended. Whereas most grasses have an effective rooting zone of 3 feet or less, mesquite can pull moisture from 10 to 20 feet and perhaps even more. Juniper is much shallower rooted, but will still extract moisture from below the grass root zone. Although each fair-sized shrub or small tree (10-foot diameter canopy) would only use 10 to 15 gallons of water a day, it would use the water every day and all of the water use for an area adds to a significant amount of groundwater consumed. Grass, with its much shallower root zone, is limited by the amount of soil water available for extraction.

Groundwater initially receives most of the additional water that is produced from brush removal, although surface water flows may be enhanced directly and indirectly following initial groundwater recharge. The rate of brush regrowth and brush control maintenance is important to maintaining stable, long-term water yield. Control methods that kill and remove the entire brush plant are more desirable than simply killing the brush. Water yield projections usually exceed actual results, and optimum results are achieved under optimum conditions.

There are three primary methods to remove upland brush: mechanical removal, chemical removal, and prescribed burning. Bio-control through Asian leaf beetles is limited to salt cedar removal, which generally occurs in riparian zones and lakes, and may be an option for some areas in the upper portion of the Brazos River. A brief description of each method is presented below.

4B.9.1.1 Mechanical Brush Control

A wide variety of mechanical brush control methods are available. The simplest is selective brush control with a hand axe and chain saw. Grubbing and piling is frequently done with a bulldozer. This may be either clear-cut or selective. Bulldozers and/or tractors may also be equipped with root plows, shears, or shredders. Two large bulldozers pulling large anchor chains stretched between them are capable of clearing low brush in swaths 100 foot or more in width at a time.

Moderate to heavy mesquite or cedar can be grubbed (bulldozer with a 3-foot-wide grubbing attachment) or root plowed for $100 to $165/acre. Two-way chaining can be effective on moderate to heavy cedar, but it often just breaks off mesquite and they re-sprout profusely from the bud zones below ground. Using hydraulic shears mounted on Bobcat loaders can be effective on blueberry juniper (a non-sprouting species) for a cost of $50 to $140/acre. If the shears are used on mesquite or redberry juniper one must spray the stump immediately with a herbicide, which will cost in the range of $0.10 to $0.30 per plant.

4B.9.1.2 Chemical Brush Control

Several herbicides are approved for brush control. The herbicides may be applied by applying a herbicide-water mixture from aircraft, from booms on tractor-pulled spray rigs, or from hand tanks. Some herbicides are also available in pellet form.

The herbicides Triclopyr (Remedy®) and Clopyralid methyl (Reclaim®) are approved herbicides for on-going TSSWCB brush programs. Arsenal is the herbicide typically used for removal of salt cedar. Chemical treatments with Remedy® and Reclaim® were shown to achieve about 70 percent root kill in studies around the state and in adjacent states. Commercial aerial applications in general are not as effective, which is most likely due to fewer controls. Timing is the key to successful chemical treatment. Soil temperature must be over 75°F at a depth of 12 to 18 inches, mesquite foliage must be dark green, and treatment is best conducted 42 to 63 days after bud break and 72 to 84 days after bud break. Other herbicide treatments are available, but many will achieve little root kill. Aerial spraying of brush such as mesquite costs about $25 per acre and is the same regardless of the plant density or canopy cover.

4B.9.1.3 Brush Control by Prescribed Burning

Prescribed burning is defined as the application of fire to a predetermined area. The burn is conducted under prescribed conditions of fine fuel load, weather, and season to specifically target desired effects. The purposes of prescribed burning include control or suppression of undesirable vegetation, to facilite distribution of grazing and browsing animals, to improve forage production and/or quality, and to improve wildlife habitat.

Prescribed burning is estimated at $15 per acre for the TSSWCB programs. Actual costs will depend on how rocky the soils are and the amount of large brush to remove from the fire guards (i.e., a once-over pass with a maintainer versus clearing heavy brush with a bulldozer, then smoothing up the fire guard). Prescribed burning will only be effective under the right environmental conditions, and with an adequate amount of fine fuel (dead or dormant grasses). For successful burns, a pasture deferment is essential for part or all of the growing season prior to burning, and burned pastures must be rested after the burn. On average, a 12-month deferment is necessary, which may increase costs if a rancher cannot utilize the land for livestock grazing.

Burning rarely affects moderate to heavy stands of mature mesquite. Burning only topkills the smooth-bark mesquite plants, and they re-sprout profusely. For mesquite, fire only gives short-term suppression, and stimulates the development of heavier canopy cover than was present pre-burn. Burning is not usually an applicable tool in moderate to heavy cedar (juniper) because these stands suppress production of an adequate amount of grass for fine fuel. Burning can be excellent for controlling junipers over 4 feet tall, if done correctly. Prescribed burning is often not recommended for initial clearing of heavy brush due to the concern that the fire could become too hot and sterilize the soil. Burning is often used for maintenance of brush removal.

4B.9.1.4 Bio-Control of Brush

Bio-control of salt cedar is a relatively new technique to be used in Texas. This control method has been studied for nearly 20 years and there have been pilot studies in the Lake

Meredith watershed and most recently in the Colorado River Basin[2]. Research has shown that the Asian leaf beetle can consume substantial quantities of salt cedar in a relatively short time period, and generally does not consume other plants. Different subspecies of the Asian beetle appear to be sensitive to varying climatic conditions, and there is on-going research on appropriate subspecies for Texas. It is recommended that this control method be integrated with chemical and mechanical removal to best control re-growth. The cost per acre is unknown.

4B.9.1.5 Range Management for Brush Control

Grazing management is very important following any type of upland brush control to allow the desirable forages to exert competition with the brush plants and to maintain good herbaceous groundcover, which hinders establishment of woody plant seedlings. Continued maintenance of brush is necessary to ensure the benefits of this potential strategy.

4B.9.2 Brush Control in the Brazos G Area

In 1985, the TSSWCB in conjunction with the Texas Water Development Board developed a list of water supply reservoirs where brush control could possibly enhance water supplies.[3] This list was updated in 2001; 27 existing reservoirs, one potential new reservoir site and two river segments in Region G were identified as potentially benefiting from brush control. The complete list as included in the State Brush Control Plan is shown in Table 4B.9-1.

Considering these potential sources, the TSSWCB has sponsored two brush removal feasibility studies in the Brazos G Area including the Lake Fort Phantom Hill watershed[4] and Lake Palo Pinto watershed.[5] In addition, an independent study is currently being conducted in the Leon River watershed. This project, which includes federal and state participation, focuses on brush removal in Hamilton and Coryell Counties, upstream of Belton Lake.[6,7]

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[2] Colorado River Municipal Water District, *Annual Report*, 2003.

[3] Texas State Soil and Water Conservation Board, *State Brush Control Program*, 2003 Annual Report. http://www.tsswcb.state.us/programs/brush.html

[4] Brazos River Authority, *Fort Phantom Hill Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003a.

[5] Brazos River Authority, *Palo Pinto Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003b.

[6] Kiel, Simone, of Freese and Nichols, Inc., Memorandum documenting telephone conversation with Steve Manning, Central Texas Cattleman's Association, regarding the Leon River Restoration Project, December 11, 2003.

[7] Kiel, Simone, of Freese and Nichols, Inc., Memorandum documenting telephone conversation with Wayne Hamilton, Texas A&M, regarding the Leon River Project, January 20, 2004.

Table 4B.9-1.
Brazos G Water Supply Sources Identified in the State Brush Control Plan that Could Benefit from Brush Control

County	Reservoir	Water Course	User	Comments
Baylor	Miller's Creek	Miller's Creek	N. Central Texas MWA	Not more than 20% canopy
Bell	Lake Belton	Leon River	Bell Co. WCID	
Bosque	Bosque River	Bosque River	Meridian	
Bosque	Bosque River	Bosque River	Clifton	Proposed reservoir
Callahan	Lake Baird	Mexia Creek	Baird	
Callahan	Lake Clyde	N. Prong Pecan Bayou	Clyde	Brownwood Study - 2002
Eastland	Lake Cisco	Sandy Creek	Cisco	
Erath	Bailey's Lake	Kickapoo Creek	Lipan	
Erath	Thurber Lake	Gibson Creek	Thurber	Palo Pinto Study - 2002
Falls	Lake Marlin	Big Sandy Creek	Marlin	
Falls	Lake Rosebud	Pond Creek Tributary	Rosebud	
Hamilton	Proctor	Leon River	Hamilton	
Haskell	Lake Stamford	Paint Creek	Stamford	
Johnson	Lake Pat Cleburne	Nolan River	Cleburne	
Jones	Ft. Phantom Hill	Elm Creek	Abilene	Ft. Phantom Hill Study - 2002
Nolan	Lake Trammel	Sweetwater Creek	Sweetwater	
Nolan	Lake Sweetwater	Bitter Creek	Sweetwater	
Palo Pinto	Palo Pinto	Palo Pinto Creek	Palo Pinto MWD	Palo Pinto Study - 2002
Palo Pinto	Lake Mingus	Gibson Creek	Mingus	Palo Pinto Study - 2002
Palo Pinto	Tucker Lake	Russell Creek	Strawn	Palo Pinto Study - 2002
Shackelford	McCarty Lake	Salt Prong Hubbard Creek	Albany	
Somerville	Paluxy River	Paluxy River		
Stephens	Lake Daniel	Gonzales Creek	Breckenridge	Base flow decline
Stephens	Hubbard Creek	Hubbard Creek	W. Central Texas MWD	
Taylor	Lake Abilene	Elm Creek	Abilene	Ft. Phantom Hill Study - 2002
Taylor	Lake Kirby	Cedar Creek	Abilene	Ft. Phantom Hill Study - 2002
Taylor	Lake Lytle	Lytle Creek	Abilene	Ft. Phantom Hill Study - 2002
Williamson	Lake Georgetown	N. Fork san Gabriel	Brazos RA	
Young	Lake Graham	Salt Creek	Graham	
Young	Lake Whiskey Creek	Whiskey Creek	Newcastle	

The feasibility studies sponsored by the TSSWCB are modeling studies, while the Leon River Project includes the collection of field data for pre- and post-brush removal conditions. The data from the Leon River Project will be used to help quantify the impacts of brush removal; however, the data are not yet available. At this time, the best predictive tools available for evaluating a potential brush removal project are modeling studies utilizing the Soil and Water Assessment Tool (SWAT) model developed by the USDA Agricultural Research Service. The model simulates the change of brush into native grass and calculates new water yields after brush is removed over the simulation period from 1960 to 1999. The term “water yield” in the study reports represents average annual increases in stream flow measured at the most downstream point in the model and average annual recharge to aquifers.

This is different from the term “yield” that is used to describe the reliable supply from a reservoir or a stream. Reservoir yields were not determined in the TSSWCB-sponsored studies. To clarify this difference, the term “water production” will be used in this memorandum to describe results from the TSSWCB studies and the term “yield” will be used in discussing supply from a reservoir.

4B.9.3 TSSWCB Brush Control Feasibility Studies

The studies for the Lake Fort Phantom Hill and Lake Palo Pinto watersheds were conducted during fiscal years 2001 and 2002. Hydrologic, climate, soils, and vegetation data were collected for each watershed. These data were used to develop and calibrate the SWAT model. While calibration of the hydrologic portion of the SWAT model showed long-term mean correlation with downstream gages over selected time periods, there were some significant differences in monthly flows. Monthly flows particularly during drought periods are critical when determining increases in reservoir yield. Other assumptions in parameter selection and interactions between surface and groundwater also impact the modeling results.

The SWAT model for each watershed assumed 100 percent removal of heavy and moderate categories of brush. The removal of light brush was not modeled. Results show that average water production within these watersheds will increase with the implementation of brush managements programs. Water production during drought conditions is expected to be less. For Lake Fort Phantom Hill, the drought of record in the 1950s was not included in the simulation.

According to the Feasibility Study Report, data from 1950 through 1957 were not included because the drought of record during this time period skewed the data.[8]

Costs were developed as part of the feasibility studies for different methods of brush removal, which include initial brush removal and maintenance for ten years. The most economical method as appropriate for the type of brush was used for cost estimating purposes. Costs were not developed for improved infrastructure to utilize the increased water production. The costs reported in this summary were obtained from the feasibility reports, and include landowner costs and State participation.

In the Lake Fort Phantom Hill study, 138,396 of the total 301,118 acres of the watershed were assumed to be treated during the simulation period. Model results showed implementing a brush control program could potentially increase the average annual water production by 111,000 gallons of water per acre treated.[7] This is equivalent to an additional average annual water production of 0.34 acre-feet per treated acre or an increase in water production in the entire watershed of 44,385 acre-feet per year. Treatment costs were estimated to range between $35.57 and $143.17 per acre depending on the brush type and treatment employed. Total costs for the program, with full implementation, were estimated at approximately $14.3 million with an assumed State participation cost share of $10.2 million. The cost per acre-foot of additional water production is estimated at $41.45. This includes both landowner and State participation costs. Landowner costs are estimated at an average of $30 per treated acre.[9] These costs, however, cannot be compared to costs for supply from additional reservoir yield.

For the Lake Palo Pinto watershed, there were similar findings. Calibration of the hydrologic portion of the SWAT model had varied results. There are no USGS monitoring stations historically or presently in operation upstream of Lake Palo Pinto, which provided little baseline data for model calibration. Considering these uncertainties, the study found that brush removal would generate an average annual water production of 0.55 acre-feet per treated acre. Assuming 139,425 of the total 296,400 acres of the Palo Pinto watershed were treated, the total increase in water production would be 76,330 acre-feet per year. Treatment costs for the Palo Pinto watershed were estimated at $35.57 to $173.17 per acre. The cost share portion for

[8] Brazos River Authority, *Fort Phantom Hill Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003a

[9] Brazos River Authority, *Fort Phantom Hill Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003a

landowners ranged from $17.09 per acre for treatment of moderate mesquite to $37.20 per acre for control of heavy Post/Shimmery Oak. The estimated total cost for the program is $18.2 million. This includes an assumed State participation cost of $14.3 million and landowner cost of $3.9 million. The total cost per acre-foot of additional water production is estimated at $30.65.[10]

4B.9.4 Potential Brush Control Project

Based on the findings of the feasibility studies and the high ranking by the TSSWCB, the Lake Fort Phantom Hill watershed was selected to evaluate the potential water supply benefits of a brush project in the watershed. This evaluation includes assumptions of landowner participation, brush removal percentages within each subbasin, and an assessment of increased monthly inflows to Lake Fort Phantom Hill.

While landowner support is assessed as high by the TSSWCB, the levels of participation assumed in the TSSWCB study (100 percent) will probably not be realized. Actual participation and removal percentages most likely will be less. For this project it was assumed that landowner participation would be approximately 50 percent of the total watershed. Subbasins with the highest amount of water generated from brush removal per acre were targeted for inclusion in the project. It was also assumed that 75 percent of the brush within the targeted subbasins would be removed. The subbasin data were obtained from the feasibility study and are shown in Table 4B.9-2.

To assess the potential water supply benefits, the SWAT model outputs for conditions with brush and without brush were obtained from the Blackland Research Center.[11] Monthly stream flows were extracted from the output files for both conditions. The differences in inflows between the brush and no brush simulations from SWAT were calculated. These increases in inflows were adjusted based on water production per acre treated to reflect a smaller project scope. The “with brush” and adjusted “no brush” inflows were then input into a reservoir operation model to assess the potential increase in reservoir yield. The reservoir operation model computes the available supply through a mass-balance evaluation, considering inflows, reservoir

[10] Brazos River Authority, *Palo Pinto Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003b.

[11] Rosenthal, Wesley, Blackland Research Center, Texas A&M University. Reach files for SWAT model for Lake Fort Phantom Hill, e-mail correspondence to Simone Kiel, January 15, 2004.

area-capacity data, reservoir surface evaporation, and diversions. A monthly time step was used for the simulation.

Table 4B.9-2. Subbasins Targeted for Potential Brush Control Project

Subbasin[1]	Total Area (acres)	Total Brush Area (acres)	Treated Brush (acres)	Increase in Water Yield (gal/ac/yr)
1	2,540	537	403	238,892
8	68	28	21	123,145
15	36,789	24,241	18,181	119,368
2	12,087	3,735	2,801	118,572
3	4,451	1,114	836	112,286
10	27,797	12,690	9,518	111,254
5	30,985	9,356	7,017	109,228
9	11,914	5,931	4,448	109,046
4	453	149	112	108,484
6	21,928	7,275	5,456	106,471
16	28,340	19,218	NI	104,404
14	23,069	12,073	NI	102,331
17	8,803	6,102	NI	97,874
7	12,483	4,431	NI	92,874
12	28,282	11,245	NI	91,332
11	38,084	14,597	NI	85,206
13	13,045	5,672	NI	82,080
Total - Watershed	**301,118**	**138,394**		**1,912,847**
Total - Project	**149,012**	**65,056**		**1,256,746**

[1]Listed in order of water production

NI – Not included in potential brush control project.

In this study, the "with brush" simulation is considered the baseline current condition. With these assumptions, the firm yield of Fort Phantom Hill with brush (using SWAT inflows) is 12,360 acre-feet per year. After implementing the brush control project, the firm yield of the reservoir is projected to be 15,000 acre-feet per year, an increase of 2,640 acre-feet per year. Diversions from the Clear Fork and Deadman Creek were not included in the study. The potential increase in reservoir yield that was computed is due solely to increases in watershed production.

Costs were assessed using the cost estimates developed for the feasibility study. These costs are based on the type of brush and removal methodology, and are unique to each subbasin. The total cost for the project as shown in Table 4B.9-3 was estimated at approximately $5 million. This includes costs typically attributed to the landowner, as well as State participation costs. To assess the cost per acre-foot of water generated from the brush control project, the total cost was amortized over a ten year period at an annual interest rate of 6 percent. Ten years were selected because the removal cost includes 10 years of maintenance activities and that is equivalent to the life of the project. With these assumptions, the cost per acre-foot of additional raw water in the lake is $257. Additional cost to maintain the level of brush removal will be needed after ten years. Cost per acre-foot of water may be less in subsequent decades if only maintenance activities are required.

Table 4B.9-3.
Costs for Potential Brush Control Project

Subbasin	*Treated Brush Area (acres)*	*State Cost per Treated Acre*	*State Cost*	*Estimated Rancher Cost*[1]	*Total Cost*
1	403	$59.38	$23,916	$11,277	$35,193
2	2,801	$59.62	$167,018	$78,435	$245,453
3	836	$62.71	$52,398	$23,394	$75,792
4	112	$72.68	$8,122	$3,129	$11,251
5	7,017	$64.36	$451,640	$196,476	$648,116
6	5,456	$78.62	$428,973	$152,775	$581,748
8	21	$82.71	$1,737	$588	$2,325
9	4,448	$82.50	$366,992	$124,551	$491,543
10	9,518	$73.43	$698,906	$266,490	$965,396
15	18,181	$78.78	$1,432,211	$509,061	$1,941,272
Totals	**48,792**		**$3,631,913**	**$1,366,176**	**$4,998,089**
Annual cost (amortized over 10 years)					$679,080
Increase in Safe Yield (acft/yr)					1,390
Cost/Ac-ft of water					$489
Cost/1,000 gal. of water					$1.50

[1]Rancher costs were estimated at $28 per acre. This corresponds to 20 to 30 percent of the total cost per acre. Recent changes to the brush control program rules limits State participation to 70 percent

The Brazos G RWPG has recommended that water supplies for reservoirs above Lake Possum Kingdom be evaluated on a safe yield basis. Using these guidelines, the increase in safe yield of Lake Fort Phantom Hill that is associated with a potential brush control program is 1,390 acre-feet per year. The total cost of the program remains the same, which results in a raw water cost of $489 per acre-foot or $1.50 per 1,000 gallons.

4B.9.5 Comparison of Findings to Other Studies

The SWAT model output under the "with brush" conditions should be similar to the inflows determined by the Brazos G WAM (Volume I, Section 3.2.1) under natural order analysis, i.e., not adhering to prior appropriation doctrine. Comparisons of the SWAT output to the WAM inflows found that the SWAT model underestimated the inflows into Lake Fort Phantom Hill in most years. The cumulative difference over time is about 339,000 acre-feet, which is shown on Figure 4B.9-1. Using the WAM inflows over the same period of record (1960-1997, with extended data for 1998 and 1999), the reservoir yield for Lake Fort Phantom Hill is 17,000 acre-feet per year. Recent data indicate that a new drought of record began in 1997 in the watershed. For the SWAT model inflows, the drought of record is in 1974, with other times of low content in 1981 and 1986. Application of the WAM through the drought of record period in the 1950s reduces the computed yield to 12,100 acre-feet per year.

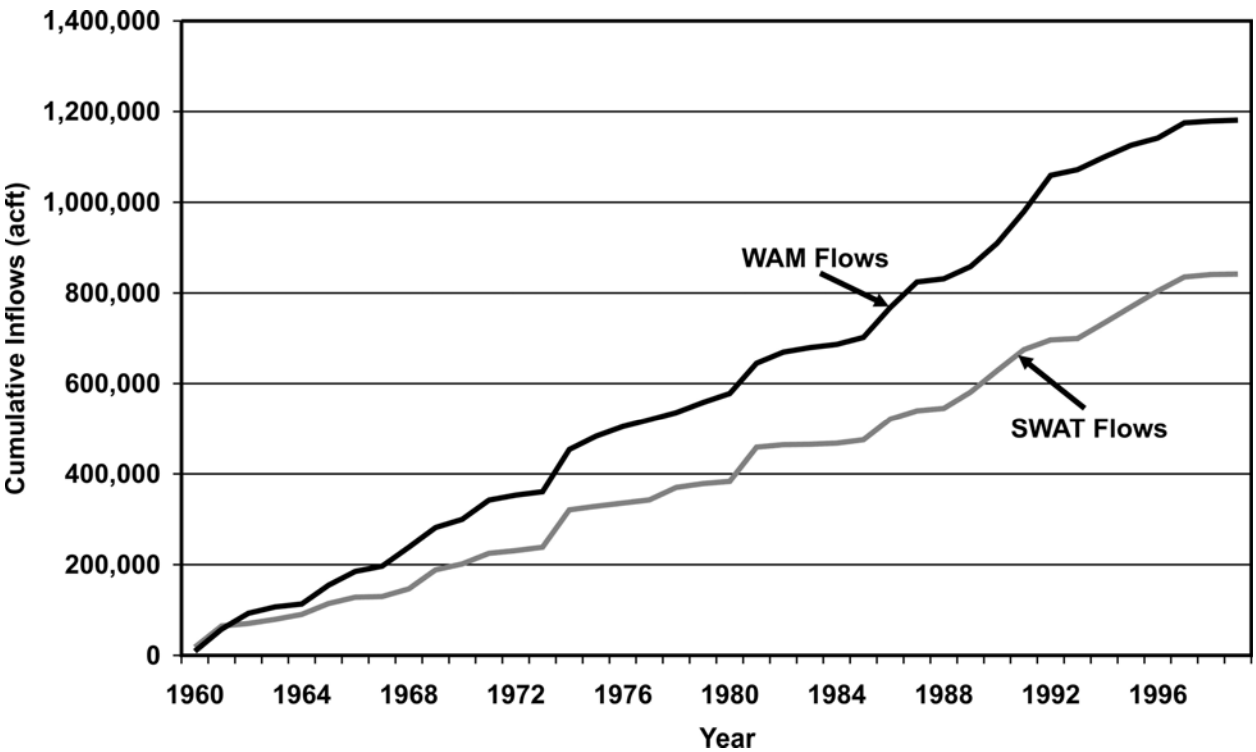

Figure 4B.9-1. Fort Phantom Hill Reservoir Cumulative Inflow Comparison

These factors indicate that the potential increase in reservoir yield would be less than indicated by the SWAT model because the SWAT model does not include the historical drought of record of the 1950s, or the potential new drought of record that started in the late 1990s.

Increased inflows from brush removal during drought may be minimal and have little to no impact on firm available water supplies, except the initiation of drought flows would be somewhat delayed to the extent that additional water would be temporarily stored in shallow soils and aquifers and subsequently discharged to streams. Not until brush control has been completed within a basin and data have been collected for a sufficient length of time can the water supply benefits be truly quantified.

4B.9.6 Environmental Impacts of the Potential Brush Control Project

The central and western portions of the Lake Fort Phantom Hill Watershed Brush Control Study Area are within the Edwards Plateau Ecological Region, while the northern and eastern portions of the study area are within the Rolling Plains Ecological Region.[12] The physiography of the study area includes recharge sands, massive limestone, caliche with some soil cover, severely eroded lands, and undissected red beds.[13] Topography varies from rough, rolling hills to nearly level terrain. Soil types are diverse. The Tarrant-Tobosa association comprises well-drained upland soils that are very shallow to steep. These soils include very shallow to deep calcareous, clays and cobbly clays. The Tillman-Vernon association consists of deep, nearly level to sloping, well-drained upland soils that include non-calcareous to calcareous clay loams and clays. The Sagerton-Rowena-Rotan association includes deep, nearly level to gently sloping, well-drained soils that are comprised of noncalcareous to calcareous clay loams.[14] Major aquifers that may be minimally represented in the study area include the Edwards-Trinity Aquifer in the western portion and the Trinity Aquifer in the eastern portion.[15] Climate is characterized as subtropical, sub humid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[16]

Vegetation and resulting wildlife habitats within these ecological regions have been greatly affected by anthropogenic factors over the last 200 years. The prairie grasslands once covering a large portion of the area have gradually changed to shrub and brush land communities

[12] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin. *Vegetational Areas of Texas*. Texas A&M University, Agricultural and Experiment Station Leaflet 492, 1960.
[13] Kier, R.S., L.E. Garner, and L.F. Brown, Jr. *Land Resources of Texas – A map of Texas Lands Classified According to Natural Suitability and Use Considerations*. University of Texas, Bureau of Economic Geology, Land Resources Laboratory Series, 1977.
[14] Soil Conservation Service. *Soil Survey of Taylor County, Texas*. U.S. Department of Agriculture Soil Conservation Service, 1976.
[15] Texas Water Development Board. *Major Aquifers of Texas, 1990*. A map.
[16] Larkin, T.J., and G.W. Bomar. *Climatic Atlas of Texas*. Texas Department of Water Resources LP-192, 1983.

from the suppression of wild fires and intensive livestock grazing. Three major vegetation types now occur in the study area,[17] these include: Mesquite (Prosopis glandulosa)-Lotebush (Ziziphus obtusifolia) Shrub, Mesquite-Juniper (Juniperus spp.) Shrub, and Mesquite-Juniper-Live Oak Quercus fusiformis) Brush. Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Other major cover types include crops and developed urban areas. Major land uses in the area include cattle ranches and farms, oil fields, hunting leases, and minerals. [18]

A number of vertebrate species would be expected to occur within the study area as indicated by county occurrence records.[19] These include 1 species of salamander, 14 species of frogs and toads, 7 species of turtles, 12 species of lizards, and 34 species of snakes. Additionally, 79 species of mammals could occur within the study area or surrounding region[20] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the study area but with distributions and population densities limited by the types and quality of habitats available.

A total of 26 species could potentially occur in the study area that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 4 reptiles, 14 birds, five mammals, 1 fish species, and 2 plants (Table 4B.9-4). Five bird species and one mammal are federally-listed as threatened or endangered that could occur (or historically occurred) in the study area. These include the bald eagle (*Haliaeetus leucocephalus*), black-capped vireo (*Vireo atricapillus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), whooping crane (*Grus americana*), and black-footed ferret (*Mustela nigripes*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the area, but would not likely be directly affected by brush control practices. The black-footed ferret historically

[17] McMahan, C.A., R.G. Frye, and K.L. Brown. *The Vegetation Types of Texas including Cropland*. Texas Parks and Wildlife Department Bulletin 7000-120, 1984.

[18] Telfair, R.C. II. *Ecological Regions of Texas: Description, Land Use, and Wildlife*. In Ray C. Telfair, Editor, *Texas Wildlife Resources and Land Uses*. University of Texas Press. Austin, Texas, 1999.

[19] Texas A&M University. *Texas Cooperative Wildlife Collection*. http://wfscnet.tamu.edu/tcwc/tcwc.htm Incorporates online checklists of amphibians and reptiles for counties based on information contained in: Dixon, J.R., and R.K. Vaughan. 1987. *Amphibians and Reptiles of Texas*. Texas A&M University Press. College Station Texas, 1998.

[20] Texas Tech University. *The Mammals of Texas – Online Edition*, 1997. http://www.nsrl.ttu.edu/tmot1/distribu.htm Incorporates information contained in: Davis, W.B., and D.J. Schmidly. 1994. *The Mammals of Texas*. Texas Parks and Wildlife Department. Austin, Texas.

occurred in prairie dog towns, but is thought to be extirpated throughout its historical range in Texas.

Impacts of brush control could directly affect the black-capped vireo that nests in brush communities about 6 feet in height with about 30 to 60 percent canopy coverage.[21]

Impacts of brush control can positively or negatively affect the environment depending on the type of control method used, location, and extent of application. If brush removal is planned and implemented as part of a comprehensive range management strategy and is consistent with Section 5.5.3, Wildlife Considerations, of the State Brush Control Plan,[22] very positive environmental benefits can result. Properly planned and applied brush control using mechanical, chemical, or prescribed fire can enhance soil conditions, increase water tables, provide greater streamflow thus improving water quantity and quality, provide higher energy and nutrient inputs, increase vegetation diversity, and enhance the quality of wildlife habitat with resulting higher abundance and diversity of wildlife species. However, removal of established of brush on uplands or removal of riparian woody vegetation along stream courses without consideration of a comprehensive long term management strategy can be detrimental to wildlife and associated habitats. Other adverse impacts could occur depending on the type of control method employed.

Mechanical treatment using mechanized equipment to root plow, brush mow, bulldoze or scrape the ground surface could result in moderate to high levels of soil disturbance that could result in erosion and sedimentation into adjacent streams and water bodies. There would also be a change in vegetation communities toward earlier succession species. Soil disturbance would favor both re-establishment of both grasses and forbs (herbaceous) in addition to re-invasion of woody brush and shrub species, prompting the need for re-treatment in future years. Soil disturbance would also have the potential of disturbing cultural or archeological artifacts, if present, within 12 inches of the ground surface. The probability of cultural and archeological artifacts being present is higher for sites along water courses, and old homesteads and settlements. However, cultural and archeological surveys are not required for private property included in the State Brush Program. Some federal cost sharing programs may require archeological surveys.

[21] Campbell, Linda. *Endangered and Threatened Animals of Texas*. Texas Parks and Wildlife Department, Endangered Resources Branch, Austin, Texas, 1995.

[22] Texas State Soil and Water Conservation Board. *State Brush Control Plan*, 2002. http://www.tsswcb.state.tx.us/reports/brushplan2001.pdf

Table 4B.9-4.
Federal and State-Listed Species, Candidate and Proposed Species for Listing, and Species of Concern for Counties in Fort Phantom Hill Brush Control Study Area

Scientific Name	Common Name	Federal/State Status	Callahan County	Jones County	Nolan County	Taylor County
Birds						
Falco peregrinus anatum	American Peregrine Falcon	DL/E	M	M	M	M
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	M	M	M	M
Ammodramus bairdii	Baird's Sparrow	SOC		M	M	M
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	M	M	M	M
Vireo atricapillus	Black-capped Vireo	LE/E	NM		NM	NM
Buteo regalis	Ferruginous Hawk	SOC		M	M	M
Sterna antillarum athalassos	Interior Least Tern	LE/E	M	M	M	M
Tympanuchus pallidicinctus	Lesser Prairie Chicken	C/SOC		R	R	
Charadrius montanus	Mountain Plover	PT/SOC	M	M	M	M
Charadrius melodus	Piping plover	FT w/CH	M	M	M	M
Charadrius aleMandrinus	Snowy Plover	SOC		M	M	
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	R	R	R	
Grus americana	Whooping Crane	LE/E	M	M	M	M
Buteo albonotatus	Zone-tailed Hawk	SOC/T				NM
Fishes						
Notropis buccula	Smalleye Shiner	C/SOC				R
Mammals						
Mustela nigripes	Black-footed Ferret	LE/E		R1	R1	
Cynomys ludovicianus	Black-tailed Prairie Dog	C/SOC		R	R	R
Myotis velifer	Cave Myotis Bat	SOC	R	R	R	R
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	R	R	R	R
Vulpes velox	Swift Fox	SOC		R	R	
Reptiles						
Nerodia harteri	Brazos Water Snake	SOC/T		R		
Holbrookia lacerata	Spot-tailed Earless Lizard	SOC				R
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	R	R	R	R
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	R	R	R	R
Plants						
Chamaesyce jejuna	Dwarf broomspurge	SOC			R	
Hexalectris warnockii	Warnock's coral root	SOC				R

Notes:
Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.)

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

Type of Occurrence: R - Resident; NM – Potential Nesting Migrant; M – Migrant, R1 – Historically occurred but now extirpated.

Source: Texas Parks and Wildlife Department, Texas Biological and Conservation Data System (TBCDS) 2004.

The State Brush Program requires all participants to follow recommended practices in the application of herbicides. The two most commonly used herbicides in the State Program are Triclopyr (Remedy®) and Clopyralid methyl (Reclaim®). Both of these chemicals are to be used only on upland areas and are not approved for use in or near water. If improperly applied, aerial or ground spraying could have possible biological impacts to wildlife through direct contact and/or potential pollution of surface water. Remedy® is toxic to aquatic organisms, while the toxicity of Reclaim® to birds, mammals and fish is low. A number of other herbicides are also toxic to aquatic life. There could also be effects to non-target plant species from broadcast applications.

The use of prescribed fire provides many ecological benefits. Historically, prairie wild fires were a major factor is suppressing invasion of woody vegetation among the prairie grassland communities. Other benefits include increased soil fertility through release of organic nutrients, stimulated growth of new plant material, and greater diversity of herbaceous plants tolerant to fire. Prescribed fire could adversely affect other vegetation such as damaging or killing established trees not intended for treatment, can be difficult to control if applied during the wrong season or during improper weather conditions, and could affect air quality regulated under federal and state laws. Environmental impacts are summarized in Table 4B.9-5.

4B.9.7 Implementation Issues

The extent of implementation of brush control will depend on the amount of funding available for state cost-sharing with landowners. State funding would be contingent upon following provisions of the State Brush Control Plan. Other funding may be available through federal and local agencies, which may have additional provisions. The extent of brush control that may be desired by landowners will depend on how they plan to manage their land for wildlife and how the brush control will affect the value of the land for wildlife recreation purposes. In recent years, the value of ranch lands which have sufficient brush cover to support wildlife populations, particularly white-tailed deer, wild turkey, bobwhite and scaled quail, has increased at a faster rate than the value of those lands which are void of brush or woody vegetation. Consequently, many landowners can be expected to support brush control to the extent that it does not exclude wildlife populations.

Other implementation issues for land owner participation include the perceived economic benefit of brush control. If the land is currently not actively managed for ranching or wildlife recreation the owner may chose not to participate. Decreased profitability of sheep, goat and cattle grazing systems will influence the economics of brush control by ranchers, and consequently their willingness to participate. Research by Thurow, et al.[23] found that only about 66 percent of ranchers surveyed were willing to enroll their land in a similarly characterized program. Also, the size of the land tracts can affect the total amount of brush removed and the effectiveness of a program. Watersheds that contain many small tracts are less likely to have contiguous land owner participation that is needed to realize the water supply benefits associated with brush control.

On specific tracts where brush control would incorporate state or federal funding, regulatory compliance with the Texas Antiquities Code and National Historic Preservation Act may be required that may involve cultural resource surveys and incorporation of preservation measures. The Texas Commission on Environmental Quality has established regulations governing prescribed burning.[24] There may also be local and county regulations associated with burning practices.

No land acquisition or relocations would be required for this water management strategy.

4B.9.8 Conclusions

Due to the uncertainties with the modeling calibration and other assumptions in the SWAT model, the amount of reliable supply generated by a brush control project in the Brazos G Area is uncertain. The yields reported in this case study do not include the historical drought of the 1950s, or the drought that began in the late 1990s. The amount of reliable water that is available through increased reservoir yields through brush control is relatively low as compared to the water production rates reported in published studies, yet brush control may be a feasible strategy for some watersheds. The success of such a program for providing increased water supplies is dependent on increased surface water runoff and significant landowner participation. The true benefits of brush control might not lie with increased surface water runoff, but increased deep soil percolation and improved land management. Significant landowner participation will

[23] Thurow, A., T. Thurow, and M. Garriga, "Modeling Texas Ranchers Willingness to Participate in a Brush Control Cost-Sharing Program to Improve Off-Site Water Yields," Journal of Agricultural and Resource Economics, (Manuscript submitted, Department of Rangeland Ecology and Management, Texas A&M University, College Station, TX), 1998.

[24] Texas Commission on Environmental Quality. Control of Air Emissions from Visible Emission and Particulate Matter. Chapter 11, Subchapter B, Outdoor Burning, Subsection 111.219, and 111.211. http://www.tnrcc.state.tx.us/oprd/rules/pdflib/111b.pdf , 2002.

require adequate external funding on a continuous basis because the benefits of brush control are lost if the maintenance activities are not continued. Securing these funds will depend upon the success of on-going pilot studies and brush programs. Support of the on-going brush programs with continued data collection is necessary to demonstrate the realized water benefits of brush control. This strategy should be re-evaluated once the results of these programs have been quantified.

Table 4B.9-5.
Environmental Impacts of Brush Control in Fort Phantom Hill Study Area

Type of Control [1]	Implementation Measures	Aquatic Environments	Bays, Estuaries, Arms of Gulf of Mexico	Wildlife Habitat	Threatened/ Endangered Species	Cultural Resources	Threats to Natural Resources
Mechanical	Removal of woody vegetation using mechanized equipment, e.g. root plowing, chaining, or brush mowing.	Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2].	No impact assuming any increase in streamflow is captured in downstream reservoirs.	High positive or negative impacts, depending on extent, timing, and location of removal; Positive impacts possible when properly planned & conducted according to Section 5.5.3 of the State Brush Control Plan.	Possible high positive or negative impacts to black-capped vireo nesting habitat, depending on extent, timing and location of removal.	Low adverse impacts from chaining & brush mowing; Moderate to high adverse impacts likely from root plowing, dozing or scraping.	Could mitigate declining water quantity & quality through increased streamflow, if properly applied.
Chemical	Removal of woody vegetation using application of herbicides.	Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2]. Variable impacts to aquatic organisms depending on toxicity of herbicide, and level of concentration to aquatic habitats[3].	No impact assuming any increase in streamflow is captured in downstream reservoirs.	High positive or negative impacts, depending on extent, timing, and location of applications and removal; Positive impacts possible when properly planned and conducted according to Section 5.5.3 of the State Brush Control Plan.	Possible high positive or negative impacts to black-capped vireo nesting habitat depending on extent, timing and location of removal.	Minimal or No Adverse Impacts.	Could mitigate declining water quantity & quality through increased streamflow, if properly applied.
Prescribed Fire	Removal of herbaceous and woody vegetation with managed, controlled fire.	Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2].	No impact assuming any increase in streamflow is captured in downstream reservoirs.	Generally moderate to high positive impacts to wildlife habitat.	Possible high positive or negative impacts to black-capped vireo nesting habitat depending on extent, timing and location of removal.	Minimal or No Adverse Impacts.	Could mitigate declining water quantity and quality through increased streamflow. Improved rangeland, if properly applied.

[1]Includes those practices eligible for cost-sharing under the State Brush Control Plan (2002).
[2]Studies show water yield maximized only through extensive control reducing brush coverage to less than 15 percent (Thurow, T.L., A.P. Thurow, and M.D. Garcia. "Policy prospects for brush control to increase off-site water yield." J. Range Manage. 53: 23-31, January 2000.)
[3]Many herbicides are toxic to fish and other aquatic organisms

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4B.10 Weather Modification

Weather modification is a water management strategy currently used in Texas to increase precipitation released from clouds over a specified area typically during the dry summer months. The most common form of weather modification or rainfall enhancement is cloud seeding. Cloud seeding is used to enhance the natural process for the formation of precipitation in a select group of convective clouds. Convective clouds, also known as cumulus clouds, are responsible for producing the bulk of rainfall during any given year in Texas[1]. The cloud seeding process increases the availability of ice crystals, which bond with moisture in the atmosphere to form raindrops, by injecting a target cloud with artificial crystals, such as silver iodide. Specially equipped aircraft release the seeding crystals into clouds that are rich in supercooled droplets. The silver iodide crystals form water droplets from available moisture in the air. Droplets then collide with droplets transforming the ice crystal into a raindrop.

While weather modification is most often utilized as a water management strategy during the dry summers in West Texas, the amount of additional rainfall produced by cloud seeding in a drought year is much less. The water that cloud seeding produces during non-drought periods augments existing surface and groundwater supplies. It also reduces the reliance on other supplies for irrigation during times of normal and slightly below normal rainfall. However, not all of this water is available for water demands. Some of this precipitation is lost to evaporation, evapotranspiration, and local ponds. The amount of water made available to a specific entity from this strategy is difficult to quantify, yet there are regional benefits. Three major benefits associated with weather modification include:

- Improved rangeland and agriculture due to increased precipitation
- Greater runoff to streams and rivers due to higher soil moisture
- Groundwater recharge

One ongoing weather modification program is partially located in the Brazos G Area, the Colorado River Municipal Water District rain enhancement project. A second weather modification program, conducted by the West Central Texas Weather Modification Association, was started in 2001, but due to budgetary issues, was stopped after the 2003 season.

[1] Texas Department of Licensing and Regulation's Website http://www.license.state.tx.us/weather/weathermod.htm. October 5, 2004.

The Colorado River Municipal Water District (CRMWD) rain enhancement project is based in Big Spring and has been active since 1971. It seeds clouds in a 2.6 million acre target area. Even though Big Spring is located in Region F, the target area of the project is the area between the cities of Big Spring, Lamesa, Snyder, and Sweetwater. The City of Sweetwater and a small portion of the target area are located in Region G.

Both increased rainfall and higher cotton yields within the target area have been attributed to the CRMWD rain enhancement project during the life of the project. According to the CRMWD website, the precipitation data indicate a 35 percent average increase in rainfall at rainfall stations within the target area. This can be compared to a 12 percent average increase in rainfall at weather stations outside of the target area. Precipitation and crop yield data from more recent years indicate that cotton yields have increased an average of 44 percent for counties in the cloud seeding area. In addition, a 37 percent increase in production was also reported for counties downwind of seeding activities, whereas only a 6 percent increase was reported for counties upwind of the program[2].

The West Central Texas Weather Modification Association's program, sponsored by an alliance of nine counties and the City of Abilene, performed cloud seeding activities over 4.9 million acres in nine counties during the 2001 -2003 seasons. Five of these counties, including Nolan, Taylor, Callahan, Eastland, and Comanche, are located in Region G. The program conducted seeding activities between May 1 and September 30 of the year. The 2003 operating budget was $496,000, of which a portion was provided by a grant from the State of Texas[3].

Since the West Central Texas Weather Modification program was active for only three seasons, documented data are limited. According to Tom Mann of the West Central Texas Council of Governments, during the three years of the program, there was a 62 percent average increase in normal precipitation recorded that generated an average of 40,550 acre-feet of additional rainwater. Even though 2002 was a drought year in the study area, there were more opportunities for cloud seeding, which resulted in a higher yield from the program.

Successful rainfall enhancement programs can improve dryland farming, reduce irrigation for irrigated acres, improve forage and potentially increase runoff to local streams and reservoirs. According to the Texas Agricultural Statistics Service, within the West Central Texas

[2] Colorado River Municipal Water District's Weather Modification Program Website: http://www.crmwd.org/wxprog.htm. October 12, 2004.
[3] Kiel, Simone of Freese and Nichols, Inc., Email with Tom Mann, West Central Council of Governments, July 22, 2003.

target area there are over 51,500 acres of irrigated agriculture, 632,400 acres of dryland farming, and 355,000 head of cattle. A study by Texas A&M University on the economic impacts of weather modification found that an additional one inch of rainfall distributed evenly over the target area would result in over $10 million in benefits per year[4]. The increases in rainfall recorded to date, if distributed uniformly over the target area, correspond to 0.0068 inches in 2001 and 0.011 inches in 2002. In 2003, seeded clouds produced 1.5 inches more rainfall than similar unseeded clouds. While the economic benefits cannot be proportioned directly, the benefits associated with these levels of increased rainfall would be substantially less than $10 million.

The cost of operating the weather modification program is approximately 10 cents per acre. Benefits of the program are widespread and are difficult to quantify for specific entities within Region G. As such, weather modification is not recommended to meet a specific need at this time. However, if the West Central Texas Weather Modification program is reinstated, it is recommended that the counties in Region G within the target area support the program. This would allow additional data to be collected to determine if weather modification could be used as a long-term water management strategy in the region.

[4] Kiel, Simone of Freese and Nichols, Inc., Email with Tom Mann, West Central Council of Governments, September 2, 2003.

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4B.11 Interregional Water Management Strategies

4B.11.1 Trinity River Authority Reuse Supply through Joe Pool Lake

4B.11.1.1 Description of Option

The Trinity River Authority (TRA) owns and operates several wastewater treatment plants, and has plans to develop a number of direct and indirect reuse projects in the Trinity River Basin. The TRA could develop a project to supply indirect reuse water through Joe Pool Lake for use in Johnson County (Johnson County SUD). The wastewater effluent would be delivered from the TRA Central Wastewater Treatment Plant in Grand Prairie to Joe Pool Lake. The reuse portion of the project is assumed to be developed by TRA by 2020 in conjunction with the Dallas County Reuse Project for steam electric power. The description and costs for the portion of the project developed by TRA are discussed in the 2006 *Initially Prepared Region C Water Plan*.[1] Johnson County SUD would develop the transmission and treatment facilities to use the water from Joe Pool Lake. A schematic of the proposed strategy is shown on Figure 4B.11.1-1. It is assumed that an existing intake structure on Joe Pool Lake can be utilized.

4B.11.1.2 Available Yield

Johnson County SUD would contract with the TRA for up to 20,000 acre-feet per year of indirect reuse water for use in Johnson County. The pipeline and components from Joe Pool Lake to Johnson County would be sized for 36 MGD peak design capacity.

4B.11.1.3 Environmental

Environmental impacts could include:

- Possible low to moderate impacts on in-stream flows due to increased diversions.
- Possible moderate impacts to water quality in Joe Pool Lake. This can be mitigated with advanced treatment of the wastewater effluent.
- Possible low impacts on riparian corridors depending on specific locations of pipelines. Generally, it is assumed that pipelines can be routed to avoid environmentally sensitive areas.

A summary of environmental issues is presented in Table 4B.11.1-1.

[1] Freese and Nichols, June 2005, Initially Prepared 2006 Region C Water Plan.

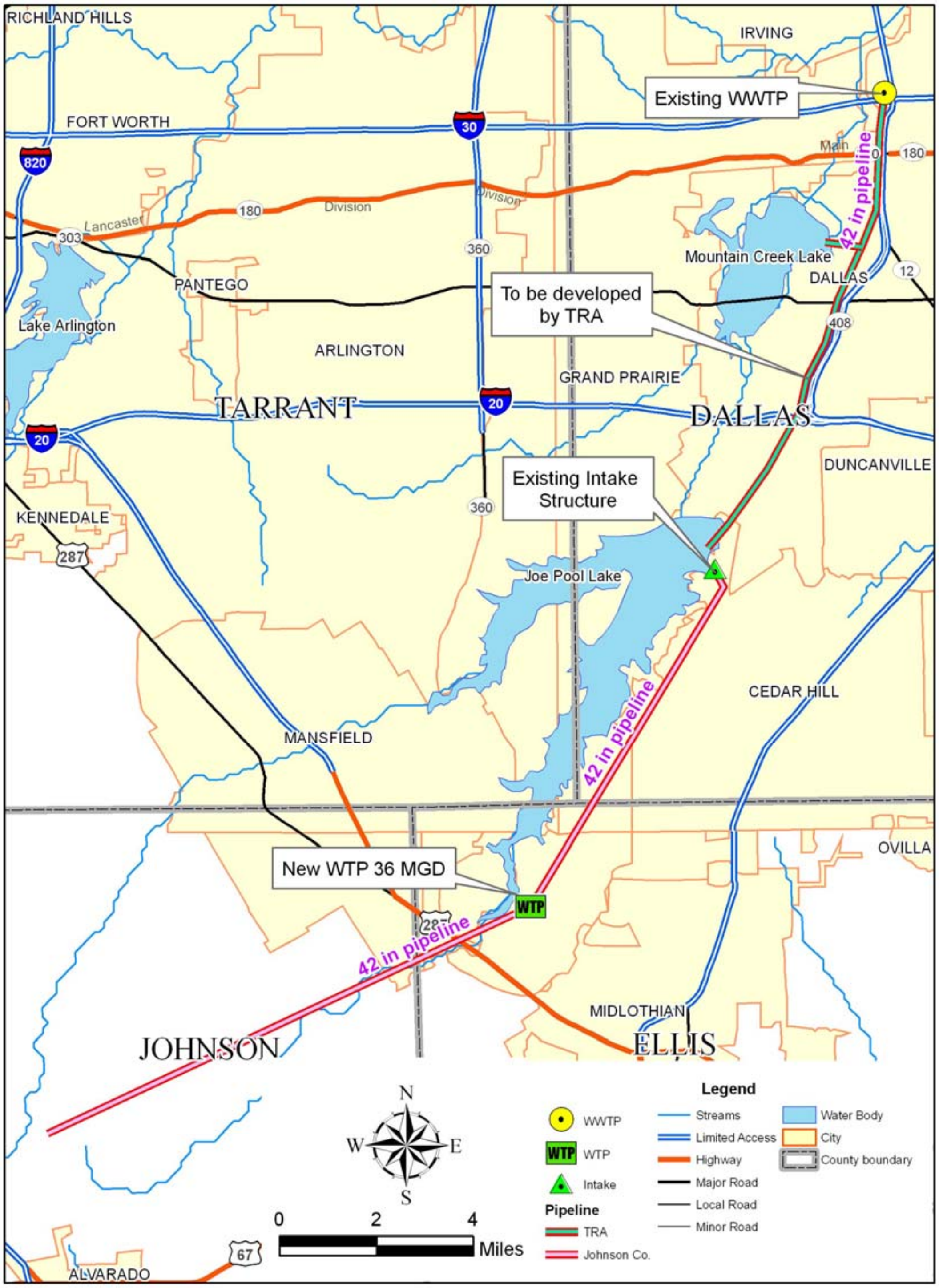

Figure 4B.11.1-1. TRA Reuse Project to Johnson County SUD

Table 4B.11.1-1.
Environmental Issues
TRA Reuse Supply to Johnson County SUD

Water Management Option	TRA Indirect reuse project to Johnson County SUD through Joe Pool Lake
Implementation Measures	Construction of pump stations, water treatment plant and approximately 20 miles of pipeline from Joe Pool Lake to Johnson County SUD. It is assumed that the infrastructure needed to move the wastewater effluent to Joe Pool Lake will be developed by TRA.
Environmental Water Needs / Instream Flows	Possible impacts on in-stream flows due to reuse of return flows. Cumulative impacts are expected to be minimal because as demands in the Dallas area increase, the net decrease in return flow due to reuse is negligible. Could impact water quality in Joe Pool Lake. This would be addressed during the reuse permitting process.
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible low to moderate impacts on riparian corridors and upland habitats depending on specific locations of pipelines.
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible to low impacts on endangered species depending on specific locations of pipelines
Comments	Will require indirect reuse permit and possible interbasin transfer permit from the Trinity to Brazos River Basin

4B.11.1.4 Engineering and Costing

Facilities required for Johnson County SUD to deliver treated water to its customers in Johnson County include:

- Water treatment plant
- Pump station; and
- Transmission pipeline.

Facilities required to move treated wastewater effluent to Joe Pool Lake are assumed to be developed by TRA and are not considered here. Costs associated with the TRA portion of the project are reflected in the water purchase price to Johnson County SUD.

This strategy assumes that the existing intake structure and pump station at Joe Pool Lake is sufficient to move raw water through a 42-inch pipeline to a water treatment plant located at the upstream end of the lake. The water would be treated at a new 36 MGD conventional surface water plant, and then transported approximately 12 miles to Johnson County SUD’s distribution system.

The total project costs including pump stations, pipeline, water treatment plant, and other project costs are $79,257,000. After taking into consideration debt service at 6 percent for 30 years, operation and maintenance, energy costs, and purchase of raw water on a wholesale basis at $166 per acft ($0.51 per 1,000 gallons), the total annual cost of the project is $12,003,200. This is a unit cost of $600 per acft ($1.84 per 1,000 gallons) for treated water. Table 4B.11.1-2 summarizes the cost estimate.

Table 4B.11.1-2.
Summary of Costs for TRA Reuse Supply to Johnson County SUD

Item	*Estimated Costs for Facilities*
Capital Costs	
Raw Water Pipeline	$8,747,000
Treated Water Pipeline	$12,807,000
Right of Way Easements (ROW)	$2,205,000
Engineering & Contingencies (30%)	$3,842,000
Total Pipeline Cost	**$18,854,000**
Intake and Pump station	$0
WTP Pump Station	$3,225,000
Engineering & Contingencies (35%)	$1,129,000
Total Pump Station Cost	**$4,354,000**
Water Treatment Plant	$37,900,000
Engineering & Contingencies (35%)	$13,265,000
Total Water Treatment Plant Cost	**$51,165,000**
Permitting and Mitigation	$297,000
Interest during Construction (18 months)	$4,587,000
Total Project Cost	**$79,257,000**
Annual Costs	
Debt Service (6% for 30 years)	$5,757,900
Electricity ($0.06 kWh)	$287,900
Operation & Maintenance - Conveyance System	$355,400
Purchase water ($166 per acft)	$3,320,000
Treatment Costs	$2,282,000
Total Annual Costs	**$12,003,200**
Total Project Yield (acft/yr)	**20,000**
Unit Costs (During Amortization)	
Per Acre-Foot	**$600**
Per 1,000 gallons	**$1.84**

Note: Cost to purchase reuse water is based on costs for TRA to develop the reuse project to Joe Pool Lake.

4B.11.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.11.1-3, and the option meets each criterion. To implement this option, TRA would need to obtain an indirect reuse permit to Joe Pool Lake. Currently this strategy is proposed to meet the needs of Johnson County SUD's customers in the Trinity River Basin. If this water is used for customers in the Brazos River Basin, an interbasin transfer permit will also be needed. Other permits that may be required as part of the construction are identified below.

4B.11.1.6 Regulatory Permits Required

Requirements specific to pipelines needed to link existing sources to users will include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the U.S. for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

4B.11.1.7 Mitigation Funding and Other

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 4B.11.1-3.
Comparison of TRA Reuse Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient quantities available
2. Reliability	2. High reliability
3. Cost	3. Low to moderate
B. Environmental factors	
1. Environmental Water Needs	1. Possible low to moderate impact. Possible water quality impacts in Joe Pool Lake from discharge of treated effluent. This can be mitigated through treatment.
2. Habitat	2. Low impact possible where new pipelines are constructed
3. Cultural Resources	3. Possible low impact
4. Bays and Estuaries	4. No substantial impact
5. Threatened and Endangered Species	5. No substantial impact
6. Wetlands	6. Low impact possible where new pipelines are constructed
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• No apparent negative impacts on agriculture or natural resources
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• May require interbasin transfer from the Trinity River Basin to supply customers in the Brazos River Basin. This would be an exempt IBT since Johnson County is partially located in the Trinity River Basin.
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.11.2 Regional Surface Water Supply to Williamson County from Lake Travis

4B.11.2.1 Description of Option

The Lower Colorado River Authority (LCRA) owns and operates five reservoirs, which along with Lake Austin, are known as the Highland Lakes. Two of the Highland Lakes, Lakes Buchanan and Travis, are water supply reservoirs and have dedicated conservation storage. The other four reservoirs in the Highland Lakes chain are constant level lakes and are not considered water supply reservoirs. The LCRA, which supplies water primarily in the Colorado River Basin (Region K), currently has contracts to supply water to two cities in Williamson County from Lake Travis, the largest of the Highland Lakes. The City of Cedar Park has a contract to purchase 18,000 acft/yr. Cedar Park owns and operates its own water treatment plant. The LCRA also has a contract with the City of Leander to provide 6,400 acft/yr of treated water.

This alternative evaluates the diversion of 51,200 acft/yr of raw water from Lake Travis for delivery to the City of Round Rock and the City of Cedar Park. Treated water would then be diverted from the water treatment plant in Cedar Park to Chisholm Trail SUD and the City of Liberty Hill. For this analysis, delivery and treatment capacity were sized to meet peak day demands at a peak factor of 2.0, creating a delivery capacity of 91.4 MGD.

Diversion facilities would be constructed in deep water on the main body of Lake Travis near the confluence of Sandy Creek with the main body of the lake. A raw water transmission pipeline would be constructed to either an expansion of the Round Rock treatment facility or to a new regional water treatment plant located near the Round Rock facility. This pipeline would split south of Cedar Park and divert water to either an expansion of the Cedar Park treatment facility or to a new regional water treatment plant. Treated water would then be diverted north to Chisholm Trail SUD and Liberty Hill. The general locations of the facilities are shown in Figure 4B.11.2-1.

4B.11.2.2 Available Yield

Under the provisions of HB 1437[2] and by agreement between the Brazos River Authority (BRA) and LCRA, 25,000 acft/yr of stored water in the Highland Lakes can be sold by LCRA (through the BRA) to entities in Williamson County in addition to the existing contracts with

[2] House Bill 1437, 76th Session, Texas Legislature.

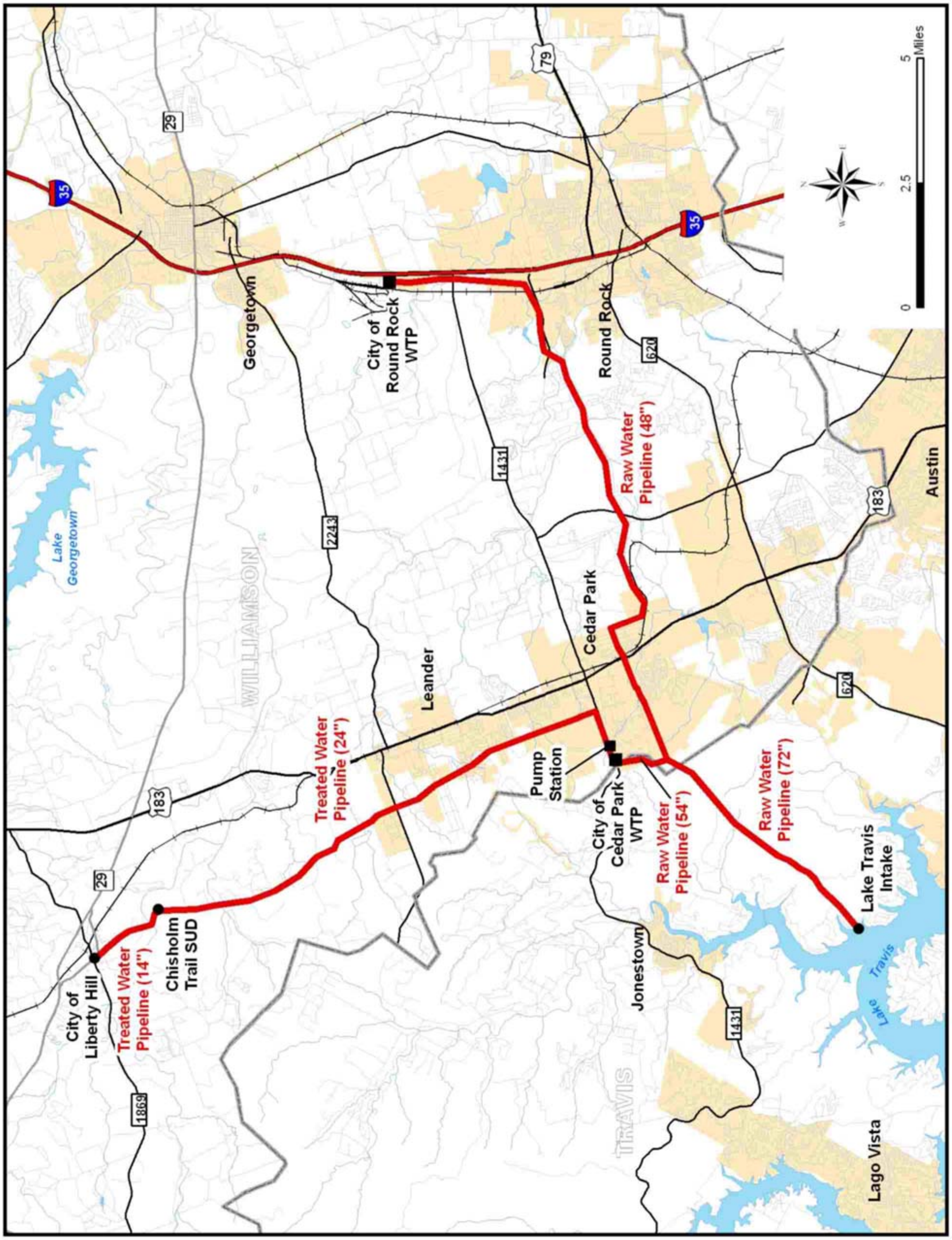

Figure 4B.11.2-1. Williamson County Supply from Lake Travis

Cedar Park and Leander. However, the 25,000 acft/yr allowed under HB 1437 does not meet the 2060 needs in Williamson County. Sufficient quantity of uncommitted stored water exists in the Highland Lakes to meet a large portion of Williamson County's projected 2060 shortages, and this supply option as conceptualized here is sized to meet 54 percent of the total 94,912 acft/yr of needs in the county. It requires that either HB 1437 be amended by the legislature to allow the sale of additional water, or other administrative measures such as a TCEQ interbasin transfer permit would be required to deliver the quantity above 25,000 acft/yr.

HB 1437 also provides that a 25 percent surcharge be added to the cost of water from the Colorado River basin delivered to Williamson County to pay for development of replacement supplies in the Colorado River Basin.

Several entities have already committed to purchase the original 25,000 acft/yr designated by HB 1437. Table 4B.11.2-1 presents the projected allocation of water under the original 25,000 acft/yr, and an additional allocation of water of 26,200 acft/yr. Currently, only 2,540 acft/yr of the HB 1437 water remains uncommitted. This plan assumes that the city of Round Rock will obtain the portion of the HB 1437 water currently allocated to Georgetown and the currently unallocated amount. Cedar Park and Liberty Hill would obtain additional supply above the original HB 1437 amount.

Table 4B.11.2-1.
Allocation of New Highland Lakes Supply in Williamson County

Entity	Current HB 1437 Allocation (acft/yr)	Projected HB 1437 Allocation (acft/yr)	Additional Highland Lakes Supply (acft/yr)	Total (acft/yr)
Cedar Park	0	0	25,000	25,000
Chisholm Trail SUD	3,472	3,472	0	3,472
Liberty Hill[1]	600	600	1,200	1,800
Round Rock	11,444	20,928	0	20,928
Georgetown	6,944	0	0	0
Unallocated	2,540	0	0	0
Total	25,000	25,000	26,200	51,200

[1] Note: In a comment letter following release of the Initially Prepared Plan, Liberty Hill informed the BGRWPG that the City has decided to pursue purchasing supply from BRA and has decided not to pursue water supply from Lake Travis. This notification was received too late to adjust the engineering and costing analysis for this option by removing the Liberty Hill portion. This would adjust some of the supplies and costs presented herein, but not substantially.

4B.11.2.3 Environmental

The construction of a new intake structure on Lake Travis and transmission pipeline to Williamson County would entail low to moderate environmental effects, depending on the quantity of water diverted, and the specific alignment of the pipelines.

- The diversion of up to 51,200 acft/yr or more could have a low impact below Lake Travis on environmental water needs, instream flows and Matagorda Bay, depending on the quantity and timing of diversions.
- The pipeline construction could have moderate to high impacts on karst invertebrates in Travis and Williamson Counties and other wildlife in the Travis County portion of route, where the pipeline would not follow existing highway rights-of-way.
- Low impacts could occur on three federally listed endangered bird species. Moderate to high impacts would be possible for seven federally listed endangered invertebrates.

4B.11.2.4 Engineering and Costing

A raw water intake and pump station would be needed at Lake Travis, and 33 miles of raw and treated water transmission pipelines would take the water to a water treatment plant near the existing Round Rock Water Treatment Plant, Cedar Park, Chisholm Trail SUD and Liberty Hill. All facilities were sized for a peaking factor of 2.0.

The major facilities needed to implement this project are:

- Raw water intake and pump station at Lake Travis;
- Raw water transmission pipeline from Lake Travis to Regional Water Treatment Plants near Round Rock and Cedar Park;
- Treated water transmission pipelines to Chisholm Trail SUD and Liberty Hill; and
- Water Treatment Plants.

Delivery of 51,200 acft/yr at a peaking rate of 2.0 would have a total project cost of approximately $211,821,000, an annual cost of $34,065,000, and an annual unit cost of $665 per acft, or $2.04 per 1,000 gallons of water. These costs are broken out for each entity below, and are summarized in Table 4B.11.2-2.

Delivery to the City of Round Rock of 20,928 acft/yr at a peaking rate of 2.0 would have a cost of approximately $101,336,000, an annual cost of $15,084,000, and an annual unit cost of $721 per acft, or $2.21 per 1,000 gallons of water.

Table 4B.11.2-2.
Cost Estimate Summary
Regional Surface Water Supply to Williamson County from Lake Travis
Second Quarter 1999 Prices

Item	Estimated Total Costs for Facilities	Round Rock	Cedar Park	Chisholm Trail SUD	Liberty Hill
Capital Costs					
Intake and Pump Station (96.2 MGD)	$16,498,000	$6,748,000	$8,051,000	$1,122,000	$577,000
Transmission Pipeline (33 miles)	39,591,000	26,234,000	6,310,000	4,374,000	2,672,000
Transmission Pump Stations	1,818,000	0	0	1,198,000	620,000
Two WTPs (56.9 and 39.3 MGD)	87,127,000	36,622,000	41,717,000	5,808,000	2,980,000
Total Capital Cost	**$145,034,000**	**$69,604,000**	**$56,078,000**	**$12,502,000**	**$6,849,000**
Engineering, Legal Costs and Contingencies	$48,782,000	$23,050,000	$19,312,000	$4,157,000	$2,264,000
Environmental & Archaeology Studies and Mitigation	878,000	418,000	113,000	202,000	144,000
Land Acquisition and Surveying (167 acres)	1,436,000	758,000	190,000	285,000	203,000
Interest During Construction (2 years)	15,691,000	7,506,000	6,055,000	1,372,000	757,000
Total Project Cost	**$211,821,000**	**$101,336,000**	**$81,748,000**	**$18,518,000**	**$10,217,000**
Annual Costs					
Debt Service (6 percent, 30 years)	$15,388,000	$7,362,000	$5,939,000	$1,345,000	$742,000
Operation and Maintenance:					
Intake, Pipeline, Pump Station	849,000	431,000	264,000	98,000	55,000
Water Treatment Plant	8,376,000	3,427,000	4,088,000	569,000	292,000
Pumping Energy Costs ($0.06 /kW-hr)	2,092,000	856,000	1,021,000	142,000	73,000
Purchase of Water - LCRA ($115 /acft)	3,594,000	0	3,594,000	0	0
Purchase of Water - LCRA/BRA Alliance ($61.53/acft)	3,766,000	3,008,000	0	499,000	259,000
Total Annual Cost	**$34,065,000**	**$15,084,000**	**$14,906,000**	**$2,653,000**	**$1,421,000**
Available Project Yield (acft/yr)	**51,197**	**20,928**	**25,000**	**3,472**	**1,800**
Annual Cost of Water ($ per acft)	**$665**	**$721**	**$596**	**$764**	**$789**
Annual Cost of Water ($ per 1,000 gallons)	**$2.04**	**$2.21**	**$1.83**	**$2.34**	**$2.42**

Delivery to the City of Cedar Park of 25,000 acft/yr at a peaking rate of 2.0 would have a cost of approximately $81,748,000, an annual cost of $14,906,000, and an annual unit cost of $596 per acft, or $1.83 per 1,000 gallons of water.

Delivery to the Chisholm Trail SUD of 3,472 acft/yr at a peaking rate of 2.0 would have a cost of approximately $18,518,000, an annual cost of $2,653,000, and an annual unit cost of $764 per acft, or $2.34 per 1,000 gallons of water.

Delivery to the City of Liberty Hill of 1,800 acft/yr at a peaking rate of 2.0 would have a cost of approximately $10,217,000, an annual cost of $1,369,000, and an annual unit cost of $761 per acft, or $2.34 per 1,000 gallons of water.

4B.11.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.11.2-3, and the option meets each criterion.

Table 4B.11.2-3.
Comparison of Lake Travis Supply to Williamson County Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Moderate to high impact along pipeline routes
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Moderate impact along pipeline routes
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Sales from LCRA to Cedar Park are exempted from interbasin transfer requirements
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

The transfer of water from Lake Travis to Williamson County in excess of the 25,000 acft/yr specified in HB 1437 would constitute an interbasin transfer, but would be exempted from interbasin transfer rules if supplied to Cedar Park. TCEQ permit amendments might be needed to add a point of diversion at Lake Travis.

Requirements Specific to Pipelines

1. Necessary permits:
   a. U.S. Army Corps of Engineers Section 404 dredge and fill permit for stream crossings and lake intake impacting wetlands or navigable water of the United States.
   b. GLO Sand and Gravel Removal permits.
   c. TPWD Sand, Gravel and Marl permit for construction in state-owned streambeds.
2. Right-of-way and easement acquisition.
3. Crossings:
   a. Highways and Railroads.
   b. Creeks and Rivers.
   c. Other Utilities.
4. Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

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4B.12 New Reservoirs

Over the majority of the last century, large on-stream reservoirs have been the backbone of the state's surface water supply resources as well as the planning for future supplies. Most of the sites in the state that are readily amenable to reservoir development have already been utilized. Many other sites that are amenable to reservoir development from a technical, or water supply, point of view have not been developed even though they have been studied for many years. These projects have regularly been mentioned in previous state water plans but have been unable to be developed due to permitting problems, environmental impacts, water quality, or cost considerations. Over the last 10 to 20 years, the development of major reservoirs has slowed considerably due to dramatically increased permitting requirements and increased environmental awareness. For these reasons any major reservoir should be considered only as a long-term solution, as the development time for the project, if it can be built at all, will probably be more than 10 years. Despite these recent impediments to development of on-stream reservoirs, these projects are an important option for development of water supplies to meet the state's needs.

Eight potential new reservoirs were reviewed and are shown in Figure 4B.12-1. The projects listed are feasible and can provide significant additional water supply; however, as with any major reservoir projects, development of any of them will be challenging. The proposed reservoirs are:

1. Breckenridge Reservoir (Cedar Ridge site) in Throckmorton County
2. South Bend Reservoir in Young County
3. Millican Reservoir (Bundic Dam Site) in Brazos, Madison, Leon, and Robertson Counties
4. Turkey Peak Reservoir in Palo Pinto County
5. Throckmorton Reservoir in Throckmorton County
6. Double Mountain Fork West Reservoir in Stonewall and Fisher Counties
7. Double Mountain Fork East Reservoir in Stonewall County
8. Little River Reservoir in Milam County

Each of the reservoirs is described briefly in the following sections. Except for updated hydrologic analyses, most of the information is updated from previous reports. A summary of all new reservoir yield and project costs are shown in Table 4B.12-1.

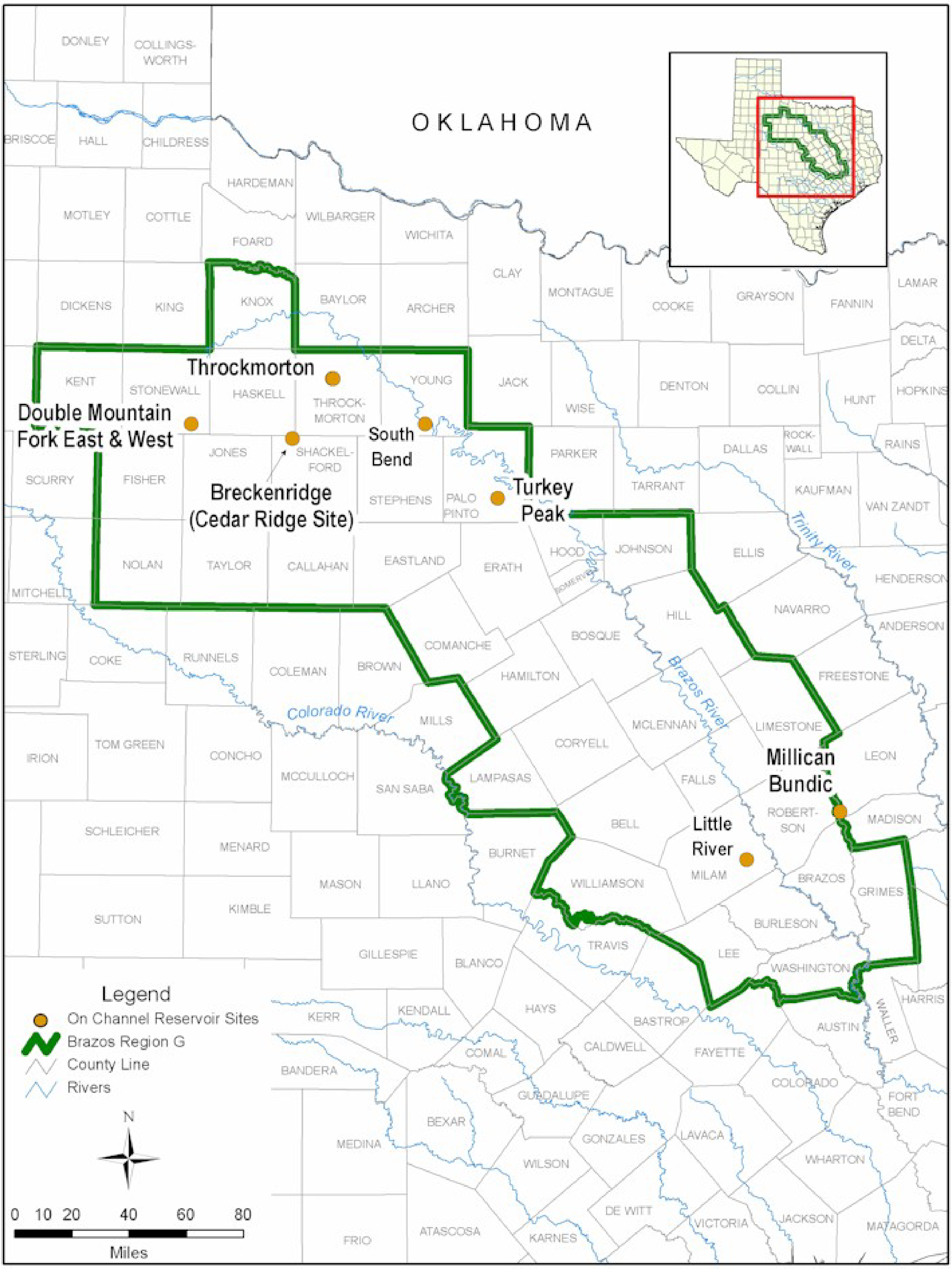

Figure 4B.12-1. New Reservoirs — Alternatives Reviewed

Table 4B.12 -1.
Summary of New Reservoir Yield and Costs[1]

Reservoir	Yield (acft/yr)	Total Project Cost	Total Annual Cost	Unit Cost per acft	Unit Cost per 1,000 gallons
Breckenridge (Cedar Ridge site)	28,920 (safe)	$82,755,000	$6,486,000	$224	$0.69
South Bend	44,940	$259,163,000	$18,826,000	$419	$1.29
Millican-Bundic	38,080	$464,764,000	$34,756,000	$913	$2.80
Turkey Peak	8,648	$46,150,000	$3,401,000	$393	$1.21
Throckmorton (sub Possum Kingdom)	3,100	$21,488,000	$1,672,500	$540	$1.66
Double Mtn. Fork (West)	30,250 (safe)	$115,189,000	$8,892,000	$293	$0.90
Double Mtn. Fork (East)	33,300 (safe)	$160,758,000	$12,443,000	$391	$1.20
Little River (310 ft-msl)	69,400	$252,277,000	$17,758,000	$256	$0.79
Little River (330 ft-msl)	129,000	$423,258,000	$29,885,000	$241	$0.74

[1] Costs shown are for raw water at the reservoir.

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4B.12.1 Breckenridge Reservoir (Cedar Ridge site)

4B.12.1.1 Description of Option

The proposed Breckenridge Reservoir, analyzed in the 2001 Plan at the Reynolds Bend site, and currently at the Cedar Ridge site, is located in Throckmorton County on the Clear Fork of the Brazos River, just shortly upstream from the mouth of Paint Creek about 50 miles north of the City of Abilene, as shown in Figure 4B.12.1-1. This project was studied in 1971 and most recently in 2004 by HDR Engineering.[1] The proposed reservoir will contain approximately 310,705 acft of conservation storage and inundate 6,190 acres at the full conservation storage level of 1,430 ft-msl.

The water supply from this reservoir could be used to meet the various municipal shortages in the area and is projected to be part of the West Central Brazos System Optimization Plan (see water supply plan for City of Abilene (Taylor County) Section 4C).

4B.12.1.2 Available Yield

Water potentially available for impoundment in the proposed Breckenridge-Cedar Ridge Reservoir was estimated using the Brazos G WAM. The model utilized an updated January 1940 through June 2004 hydrologic period of record to account for the recent drought in the Upper Brazos Basin. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Clear Fork of the Brazos River without causing increased shortages to existing downstream rights. Safe yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the reservoir are shown in Table 4B.12.1-1.

The calculated safe yield of the Breckenridge-Cedar Ridge Reservoir is 28,920 acft/yr, assuming subordination of Possum Kingdom Reservoir. The yield impact on Possum Kingdom due to the Breckenridge-Cedar Ridge Reservoir is estimated to be 5,000 acft/yr.

[1] HDR Engineering, "Evaluation of Breckenridge Reservoir (Cedar Ridge Site) and Other Water Supply Alternatives (Draft)," September 2004.

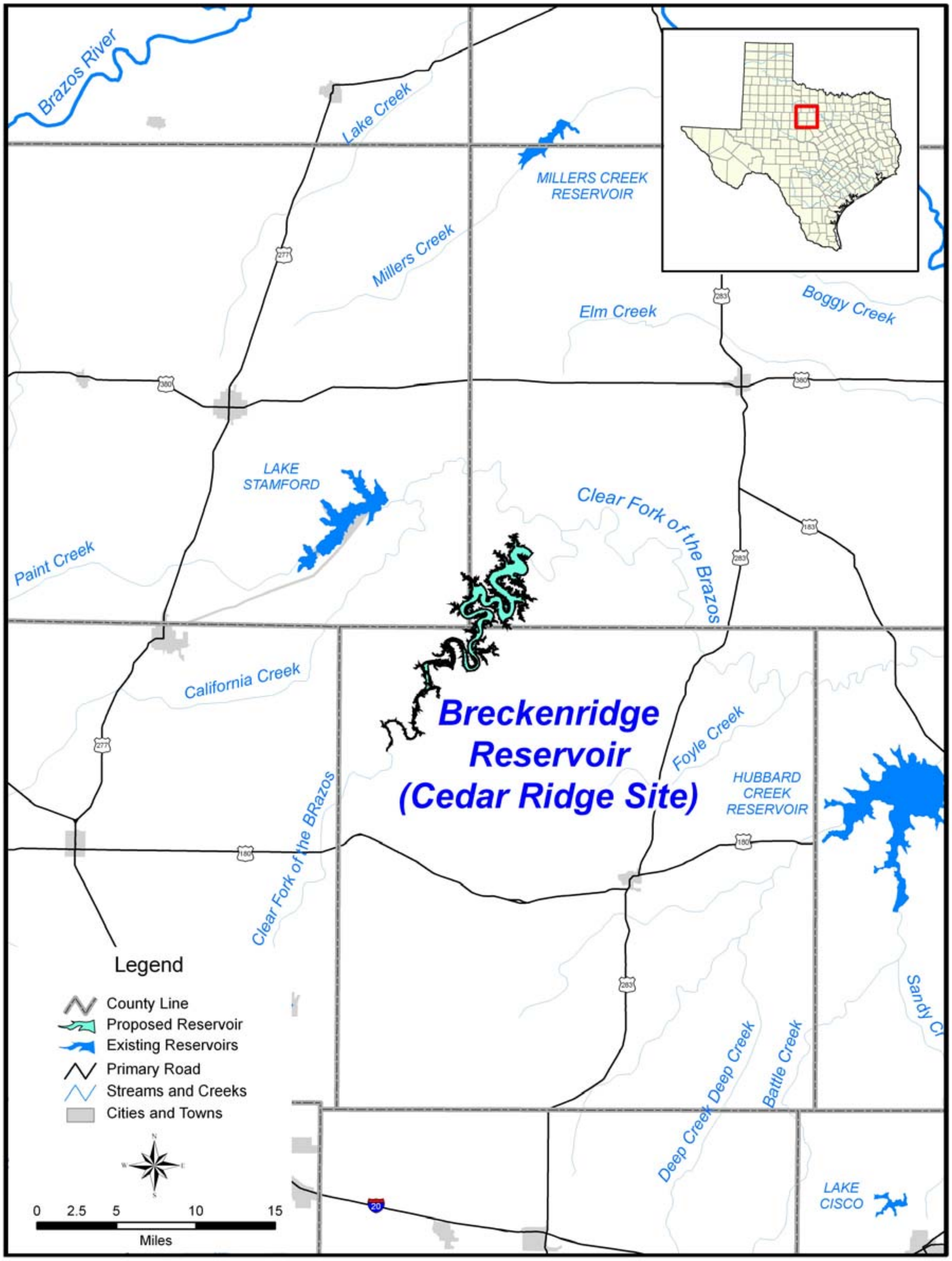


Figure 4B.12.1-1. Breckenridge Reservoir –(Cedar Ridge Site)

Table 4B.12.1-1.
Daily Natural Streamflow Statistics
for the Breckenridge-Cedar Ridge Reservoir

Month	***Median Flows – Zone 1 Pass-Through Requirements (cfs)***	***25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)***
January	24.6	13.5
February	33.2	16.3
March	34.6	17.3
April	38.4	13.2
May	54.0	12.6
June	55.4	17.4
July	22.0	2.8
August	13.0	1.2
September	22.0	1.0
October	24.1	3.8
November	19.1	4.3
December	16.7	7.0
Zone 3 (7Q2) Pass-Through Requirement (cfs):		1.5

Figure 4B.12.1-2 illustrates the simulated Breckenridge-Cedar Ridge Reservoir storage levels for the 1940 to 2004 historical period, subject to the safe yield of 28,920 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 30 percent of the time and above the Zone 3 trigger level (50 percent capacity) 78 percent of the time.

Figure 4B.12.1-3 illustrates the changes in Clear Fork streamflows caused by impounding the unappropriated waters of the Brazos River. The largest change would be a decline in median streamflow of 71 cfs during May. Other significant declines would occur in June through October. During the months of January through April and December, there would be little change in streamflow because the reservoir would only rarely be able to impound water in excess of that required for downstream senior water rights and environmental needs.

Figure 4B.12.1-3 also illustrates the Clear Fork streamflow frequency characteristics with the Breckenridge-Cedar Ridge Reservoir in place. At low flows, there is little difference with the project because the reservoir would typically be passing all, or nearly all, inflows in order to satisfy senior water rights and/or environmental constraints. There is a more pronounced difference at higher Brazos River flows, because in this range the reservoir would be able to impound water, since water rights and environmental needs would be satisfied more frequently.

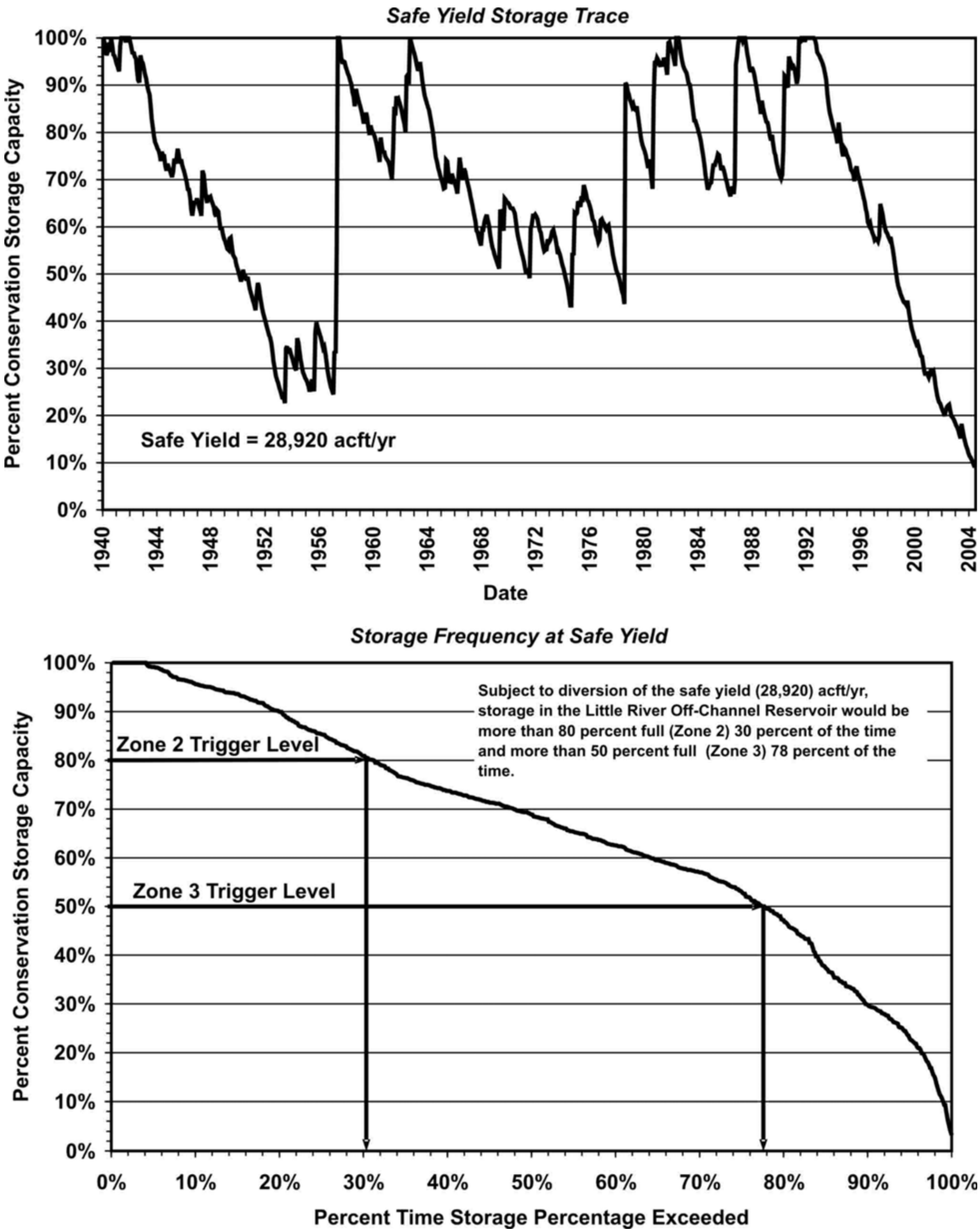
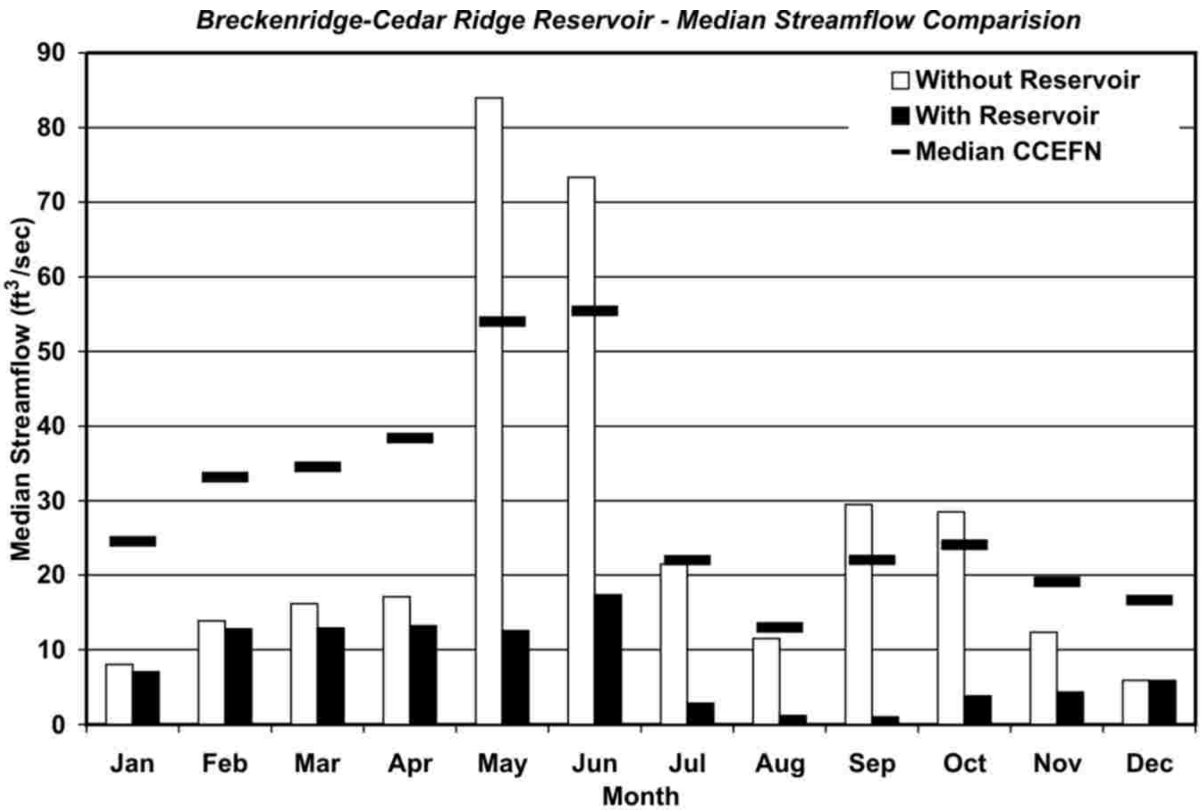


Figure 4B.12.1-2. Breckenridge – Cedar Ridge Reservoir Storage Considerations



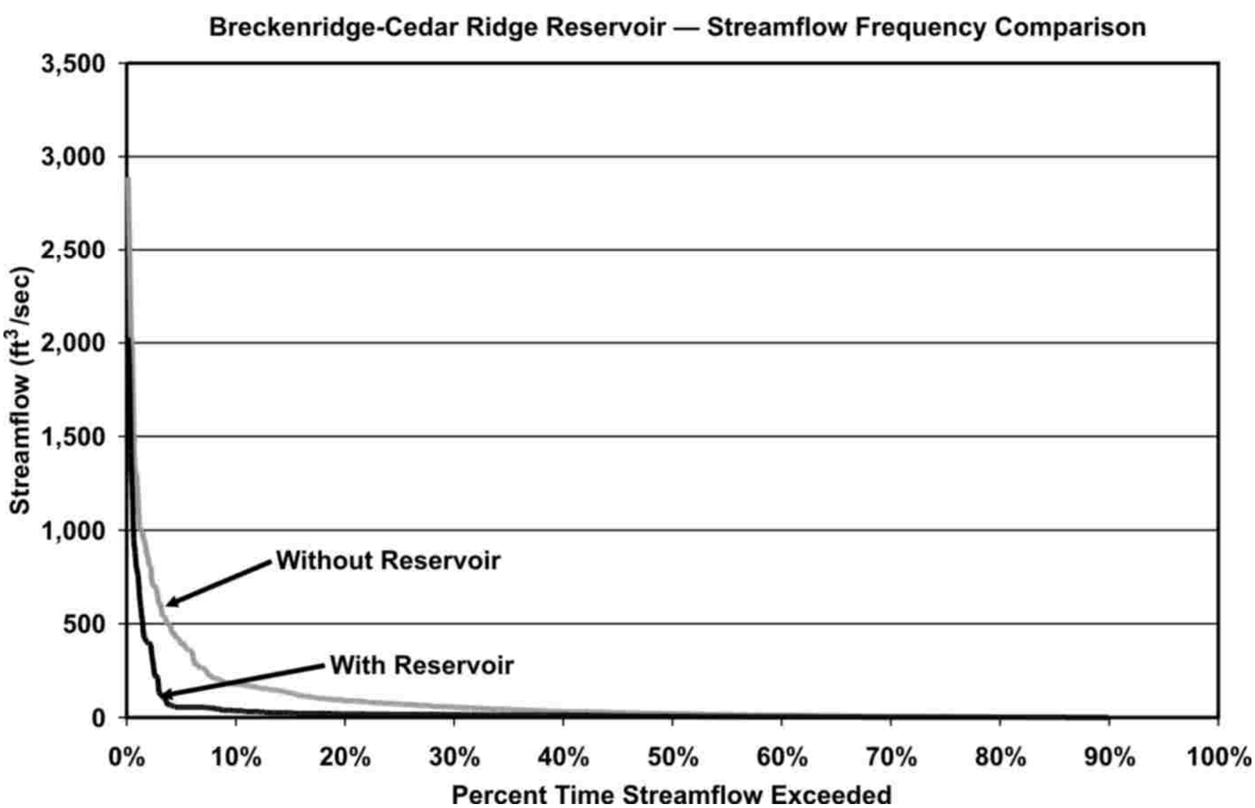


Figure 4B.12.1-3. Breckenridge-Cedar Ridge Streamflow Comparisons

4B.12.1.3 Environmental Issues

4B.12.1.3.1 Existing Environment

The Breckenridge-Cedar Ridge Reservoir site in Throckmorton, Haskell, and Shackelford Counties lies within the Rolling Plains Ecological Region.[2] This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, and juniper breaks and midgrass prairie. The physiognomy of the region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive plant species and have decreased the value of the land for cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[3] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[4]

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by isolated alluvial deposits in 20 counties in north central Texas. The Seymour Aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene Age, which consists of clay, silt, sand, and gravel, that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[5]

The physiography of the region includes flood-prone areas, terraces, stair step topography, thin-bedded limestone, and undissected red beds.[6] The predominant soil associations in the project area are Palopinto-Throck and Clairmont-Grandfiled-Clearfork (Rowena-Leeray-Nuvalde and Lueders-Throck-Nukrum are in the area but not predominant).

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[2] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[3] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[4] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[5] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.
[6] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., "Land Resources of Texas." Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

Three major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush (*Ziziphus obtusifolia*) Shrub, Mesquite Brush, and crops.[7] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Mesquite-Lotebush Shrub could include the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera pubescens*), juniper, tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania pinnatifida*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*). Commonly associated plants of Mesquite Brush are narrowleaf yucca (*Yucca angustissima*), grassland pricklypear (*Opuntia cymochila*), juniper, red grama, Texas grama, sideoats grama, hairy grama, purple three-awn, Roemer three-awn (*Aristida purpurea* var. *roemeriana*), buffalograss, red lovegrass (*Eragrostis secundiflora*), gummy lovegrass (*Eragrostis curtipedicellata*), sand dropseed, tobosa, western ragweed (*Ambrosia cumanensis*), James rushpea (*Caesalpinia jamesii*), scurfpea (*Psoralidium* sp.), and wild buckwheat (*Eriogonum* sp.). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.12.1.3.2 Potential Impacts

4B.12.1.3.2.1 Aquatic Environments including Bays and Estuaries

The anticipated impact of this project would be lower variability in and significant reductions in quantity of median monthly flows. The difference in variability of monthly flows would be a factor of approximately 2.7 (measured by comparing variances of monthly flows from 1940-2004 with and without the project in place; sample variance without project $=20.05 \times 10^7$; sample variance with project $=7.44 \times 10^7$). Variability in flow is important to the instream

[7] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

biological community as well as riparian species and this reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing habitat suitability for others. Reductions in the quantity of median monthly flow downstream of the project would range from 0.1 cfs (0.9 percent) in December to 71.4 cfs (85 percent) in May, as shown in Table 4B.12.1-2. The highest percent reductions (>85 percent) would be in July through October while December through February would have much lower reductions in median monthly streamflows (<15 percent). These lower flows would have substantial impacts on the instream biological community in areas downstream of the project site. Substantial reductions in July, August, and September would be particularly detrimental as a result of high temperatures and the high likelihood of impairment of other water quality parameters during that time of year. Despite these reductions, the frequency of low-flow conditions (>85 percent exceedance) would not be affected by this project. Streamflow would decrease to 0.73 cfs for 85 percent of the time and would cease for 6.6 percent of the time with or without the project.

Table 4B.12.1-2.
Median Monthly Streamflow: Breckenridge Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	8.0	7.1	1.0	12%
February	13.9	12.8	1.1	8%
March	16.2	12.9	3.2	20%
April	17.1	13.2	3.9	23%
May	84.0	12.6	71.4	85%
June	73.3	17.4	56.0	76%
July	21.5	2.8	18.6	87%
August	11.5	1.2	10.3	90%
September	29.5	1.0	28.5	97%
October	28.5	3.8	24.7	87%
November	12.4	4.3	8.0	65%
December	5.9	5.9	0.1	1%

Although there would be impacts on the biological community in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in the Brazos River or to freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows to the estuary. As a new reservoir without a current operating permit, the Breckenridge Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.12.1.3.2.2 Threatened and Endangered Species

A total of 24 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.1-3). This group includes three reptiles, 14 birds, five mammals, and two fish species. Five bird species federally-listed as threatened or endangered could occur in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), black-capped vireo (*Vireo atricapillus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

A search of the Texas Wildlife Diversity Database[8] revealed four documented occurrences of the Brazos water snake (*Nerodia harteri*) within the vicinity of the proposed Breckenridge-Cedar Ridge Reservoir (as noted on representative 7.5-minute quadrangle map(s) that include the project site). These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.1.3.2.3 Wildlife Habitat

Approximately 6,190 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 121 acres of Grasses/Forbs, 302 acres of Mesquite Brush, and 5,767 acres of Mesquite-Lotebush Shrub.

[8] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.

Table 4B.12.1-3. Potentially Occurring Species that are Rare or Federal- and State-Listed at the Breckenridge-Cedar Ridge Reservoir Site, Throckmorton, Haskell, and Shackelford Counties

Scientific Name	*Common Name*	*Federal/State Status*	*Throckmorton County*	*Haskell County*	*Shackelford County*
Birds					
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant	Migrant	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant	Migrant	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	—	Migrant	—
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant	Migrant	Migrant
Vireo atricapillus	Black-capped Vireo	LE/E	—	—	Migrant*
Buteo regalis	Ferruginous Hawk	SOC	—	Migrant	—
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant	—	—
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*	Migrant*	Migrant*
Tympanuchus pallidicinctus	Lesser Prairie Chicken	C/SOC	—	Resident	—
Charadrius montanus	Mountain Plover	SOC	Migrant*	Migrant*	Migrant*
Charadrius melodus	Piping Plover	LT w/CH	Migrant	Migrant	Migrant
Charadrius alexandrinus	Snowy Plover	SOC	—	Migrant	—
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*	Migrant*	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant	Migrant	Migrant
Fishes					
Notropis oxyrhyncus	Sharpnose Shiner	C/SOC	X	X	X
Notropis buccula	Smalleye Shiner	C/SOC	X	X	X
Mammals					
Mustela nigripes	Black-footed Ferret	LE/E	—	Extirpated	—
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X	X	X
Myotis velifer	Cave Myotis Bat	SOC	X	X	—
Canis lupus	Gray Wolf	LE/E	Extirpated	—	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X	X	X
Canis rufus	Red Wolf	LE/E	Extirpated	—	Extirpated
Vulpes velox	Swift Fox	SOC	—	X	—
Dipodomys elato	Texas Kangaroo Rat	SOC/T	X	—	—
Reptiles					
Nerodia harteri	Brazos Water Snake	SOC/T	X	X	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X	X	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X	X	X

X = Occurs in county; — = does not occur in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Throckmorton, Jones, Haskell, and Shackelford Counties (2004); TPWD Texas Wildlife Diversity Database (2004), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, September 12, 2003.

A number of vertebrate species would be expected to occur within the Cedar Ridge Reservoir site as indicated by county occurrence records.[9] These include 11 species of frogs and toads, six species of turtles, 10 species of lizards and skinks, and 31 species of snakes. Additionally, 78 species of mammals could occur within the site or surrounding region,[10] as well as an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.12.1.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 12 archeological sites have been documented within the general vicinity of the proposed reservoir. Ten of these sites were recorded in the 1930s, three of which (41SF15, 41SF16 and 41SF17) appear to lie within the currently proposed reservoir location. The present condition of these sites is unknown and the site files at the Texas Archeological Research Laboratory contain only location data for these sites. Further information regarding these sites is not available. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if these sites or any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.12.1.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower streamflows, declining water quality, and reduced inflows to reservoirs. This project would contribute to lower streamflow below the reservoir, particularly in the months of August and

[9] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.
[10] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

September. Lower flows could result in declining water quality with respect to lower dissolved oxygen, and higher concentration of any existing stream pollutants.

4B.12.1.4 Engineering and Costing

The proposed Breckenridge Reservoir-Cedar Ridge Reservoir includes the construction of an earth dam principal spillway, emergency spillway, and appurtenant structures. HDR Engineering recently completed a study[11] of the proposed Breckenridge-Cedar Ridge Reservoir and estimated the project would cost approximately $82.7 million for raw water at the reservoir. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $6.5 million, which includes annual debt service, operation and maintenance, and an annual payment to the Brazos River Authority for lost yield in Possum Kingdom. A more detailed listing of the various components of the cost estimate is provided in Table 4B.12.1-4.

The cost for the estimated safe yield of 28,920 acft/yr translates to an annual unit cost of raw water of $0.69 per 1,000 gallons, or $224 per acft. Other project implementation costs would vary depending on whether water was diverted from the reservoir and transported directly to Abilene, or released downstream and diverted into Hubbard Creek Reservoir in order to utilize existing pipeline facilities.

4B.12.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.1-5, and the option meets each criterion.

A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;

[11] HDR Engineering, Op. Cit., September 2004.

Table 4B.12.1-4.
Cost Estimate Summary for
Breckenridge Reservoir (Cedar Ridge Site)
(Second Quarter 2002 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool: 310,705 acft, 6,190 acres, 1,430 ft-msl)	$48,112,000
Relocations & Other	3,800,000
Total Capital Cost	**$51,912,000**
Engineering, Legal Costs and Contingencies	$18,169,000
Environmental & Archaeology Studies and Mitigation	3,020,000
Land Acquisition and Surveying (10,066 acres)	3,523,000
Interest During Construction (2 years)	6,131,000
Total Project Cost	**$82,755,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$403,000
Reservoir Debt Service (6 percent for 40 years)	5,132,000
Operation and Maintenance	
Dam and Reservoir	722,000
Purchase of Water (5,000 acft/yr @ $45.75 per acft)	229,000
Total Annual Cost	**$6,486,000**
Available Project Yield (acft/yr)	**28,920**
Annual Cost of Water ($ per acft)	**$224**
Annual Cost of Water ($ per 1,000 gallons)	**$0.69**

Table 4B.12.1-5.
Comparison of Breckenridge Reservoir - Cedar Ridge Reservoir to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable to High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. High impact
3. Cultural Resources	3. High impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Possible moderate impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

- General Land Office Easement if State-owned land or water is involved; and
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and

- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions or other local landowner agreements;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

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4B.12.2 South Bend Reservoir

4B.12.2.1 Description of Option

The South Bend Reservoir is a very large proposed reservoir located in Young County immediately upstream from the confluence of the main stem Brazos River and the Clear Fork of the Brazos River, as shown in Figure 4B.12.2-1. The reservoir would capture flow from both channels, storing up to 771,604 acft from the 13,168-square mile drainage area. The dam would be an earthfill embankment that would extend approximately 2.8 miles across the Brazos River at an elevation of 1,090 ft-msl and inundate 29,877 surface acres.

There are a handful of water-short entities in the area that could benefit from the construction of the reservoir, but the majority of the water would have its greatest usefulness as part of the BRA System. Some of the water-short communities in the area would include Strawn, Oak Trail Shores Subdivision, and some smaller water supply corporations. Other non-municipal shortages identified in the area include manufacturing uses in Erath and Hood Counties and mining in Hood, Shackelford, and Stephens Counties.

4B.12.2.2 Available Yield

Water potentially available for impoundment in the proposed South Bend Reservoir was estimated using an updated version of the Brazos G WAM. The model utilized an updated January 1940 through June 2004 hydrologic period of record to account for the recent drought in the Upper Brazos Basin. Estimates of the water availability in the Brazos River Basin were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Brazos River without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the reservoir are shown in Table 4B.12.2-1.

Since the South Bend Reservoir is very large and geographically close to Possum Kingdom Reservoir, it was analyzed as a system with Possum Kingdom. The additional firm yield of the system that can be attributed to South Bend Reservoir is 44,940 acft/yr.

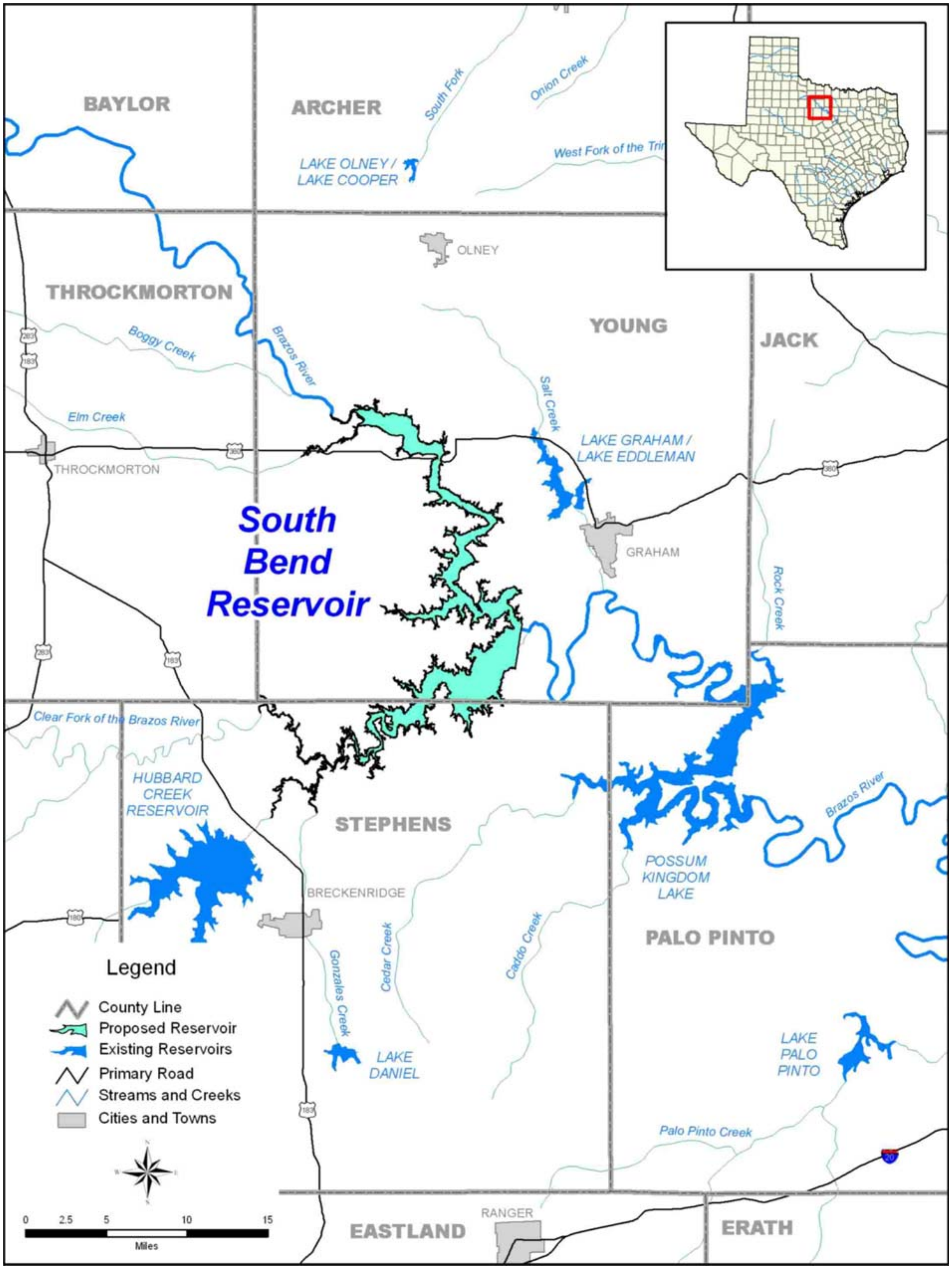


Figure 4B.12.2-1. South Bend Reservoir

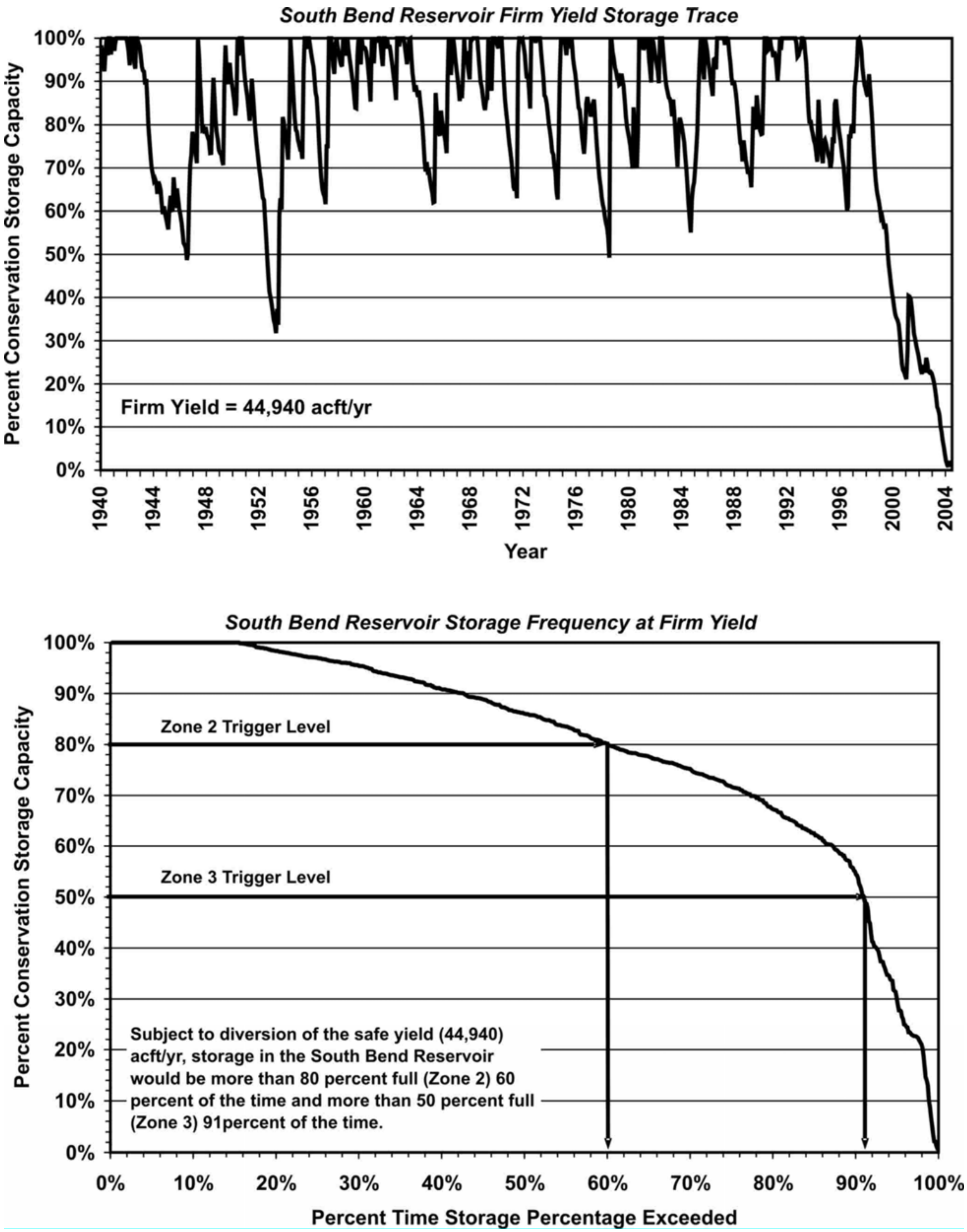
Table 4B.12.2-1.
Daily Natural Streamflow Statistics for the South Bend Reservoir

Month	Median Flows – Zone 1 Pass Through Requirements (cfs)	25th Percentile Flows – Zone 2 Pass Through Requirements (cfs)
January	122.2	40.8
February	149.5	52.9
March	161.4	51.3
April	126.5	49.3
May	163.0	51.3
June	54.8	18.0
July	10.9	2.9
August	3.0	0.4
September	7.2	1.2
October	9.3	1.5
November	32.9	10.7
December	63.7	21.1
Zone 3 (7Q2) Pass-Through Requirement (cfs):		1.56

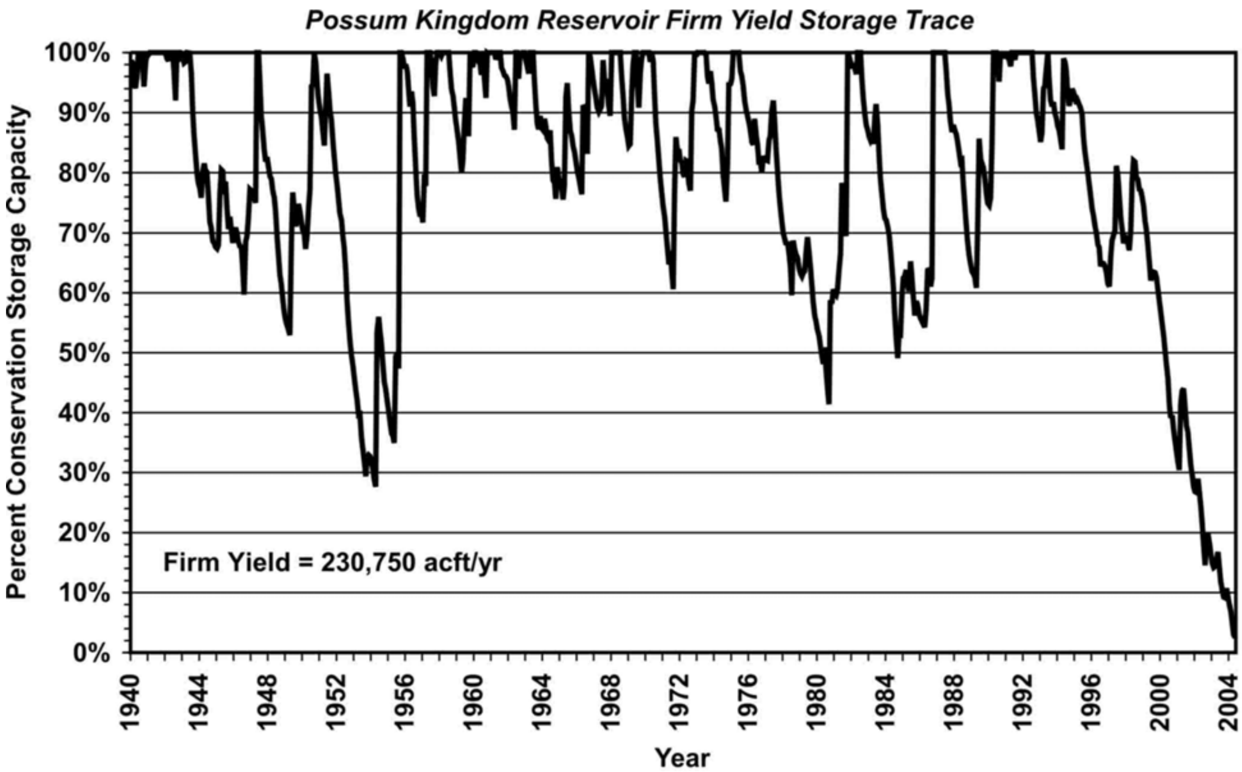
Figure 4B.12.2-2 illustrates simulated South Bend Reservoir storage levels for the 1940 to 2004 historical period, subject to the firm yield in South Bend Reservoir of 44,940 acft/yr and permitted diversion from Possum Kingdom of 230,750 acft. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 60 percent of the time and above the Zone 3 trigger level (50 percent capacity) 91 percent of the time.

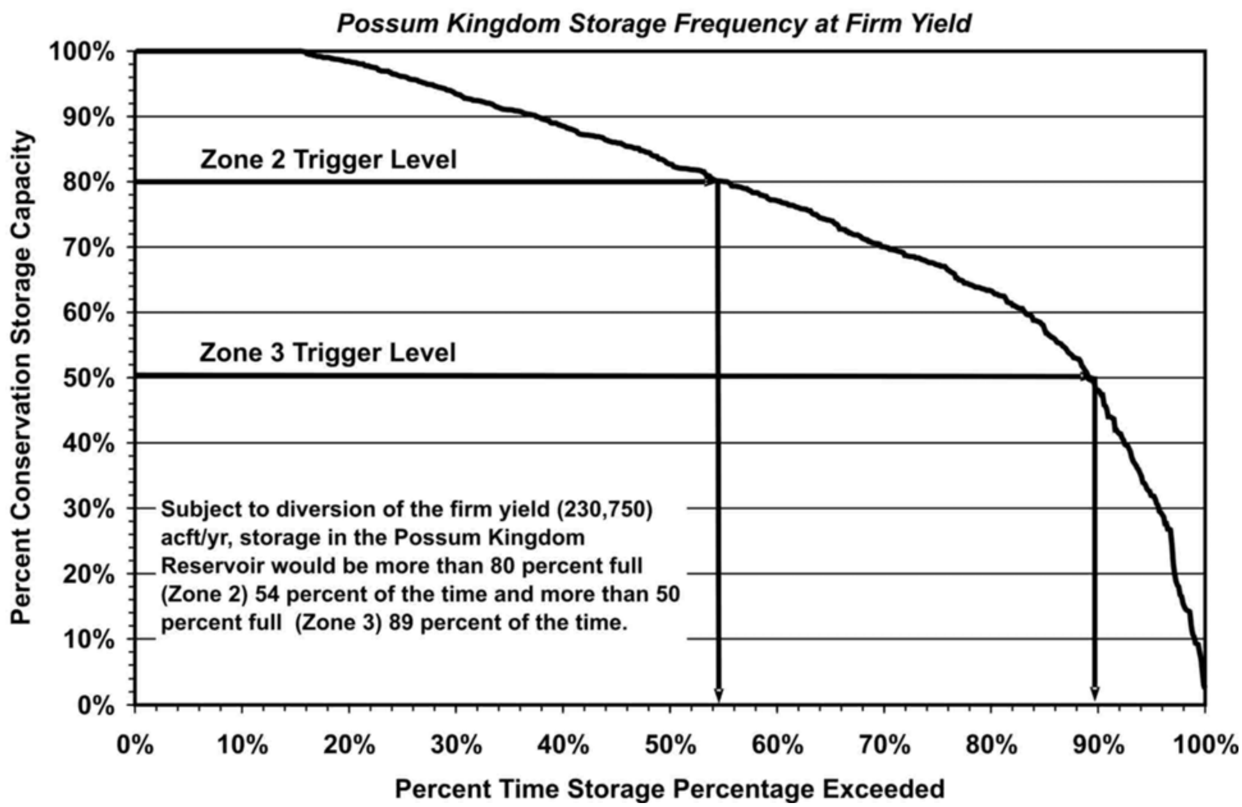
Figure 4B.12.2-3 illustrates simulated Possum Kingdom Reservoir storage levels for the same historical period, subject to a permitted diversion from Possum Kingdom of 230,750 acft. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 54 percent of the time and above the Zone 3 trigger level (50 percent capacity) 89 percent of the time. However, as a current permitted project, Possum Kingdom has not operated to meet CCEFN flow requirements.

Figure 4B.12.2-4 illustrates the changes in Brazos River streamflows caused by impounding the unappropriated waters of the Brazos and Clear Fork of the Brazos Rivers. The greatest change in flow would occur in the spring and summer months, April through September. The largest decline occurs in May, where the median streamflow is reduced by 407 cfs. During

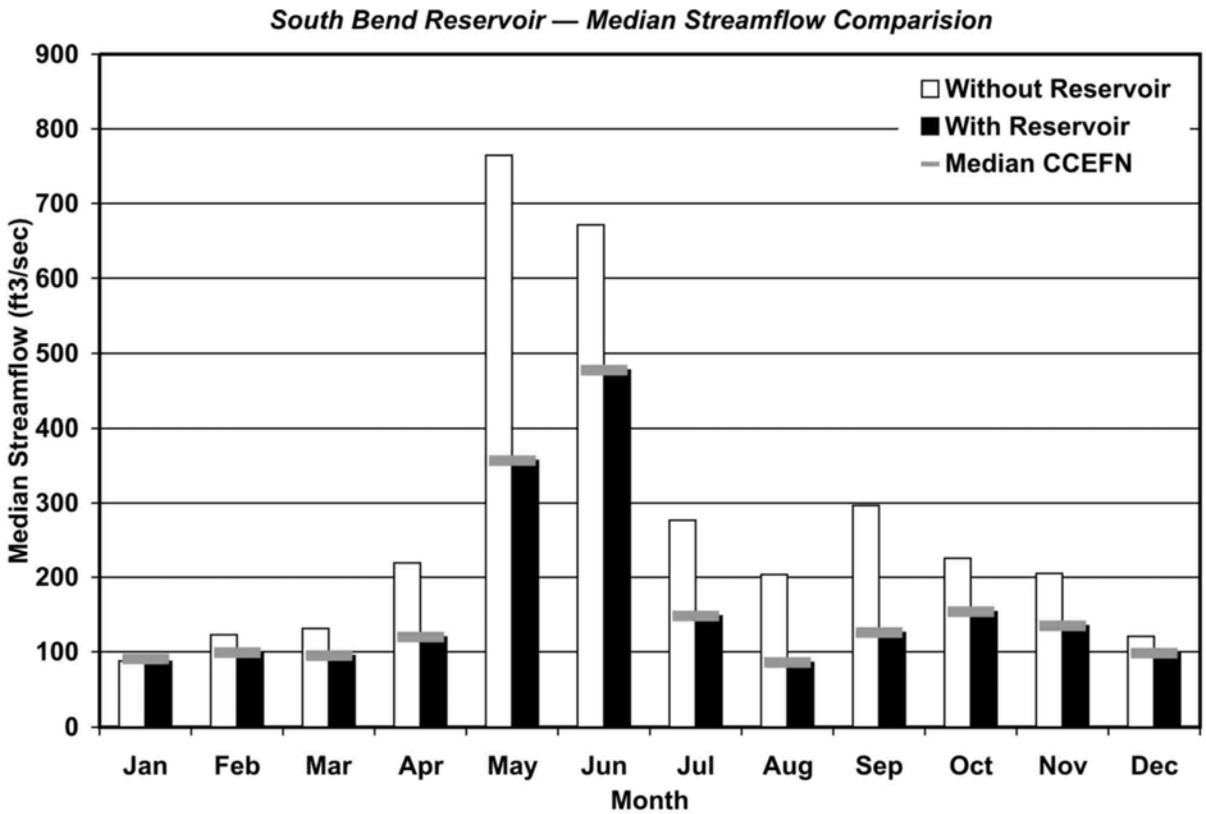


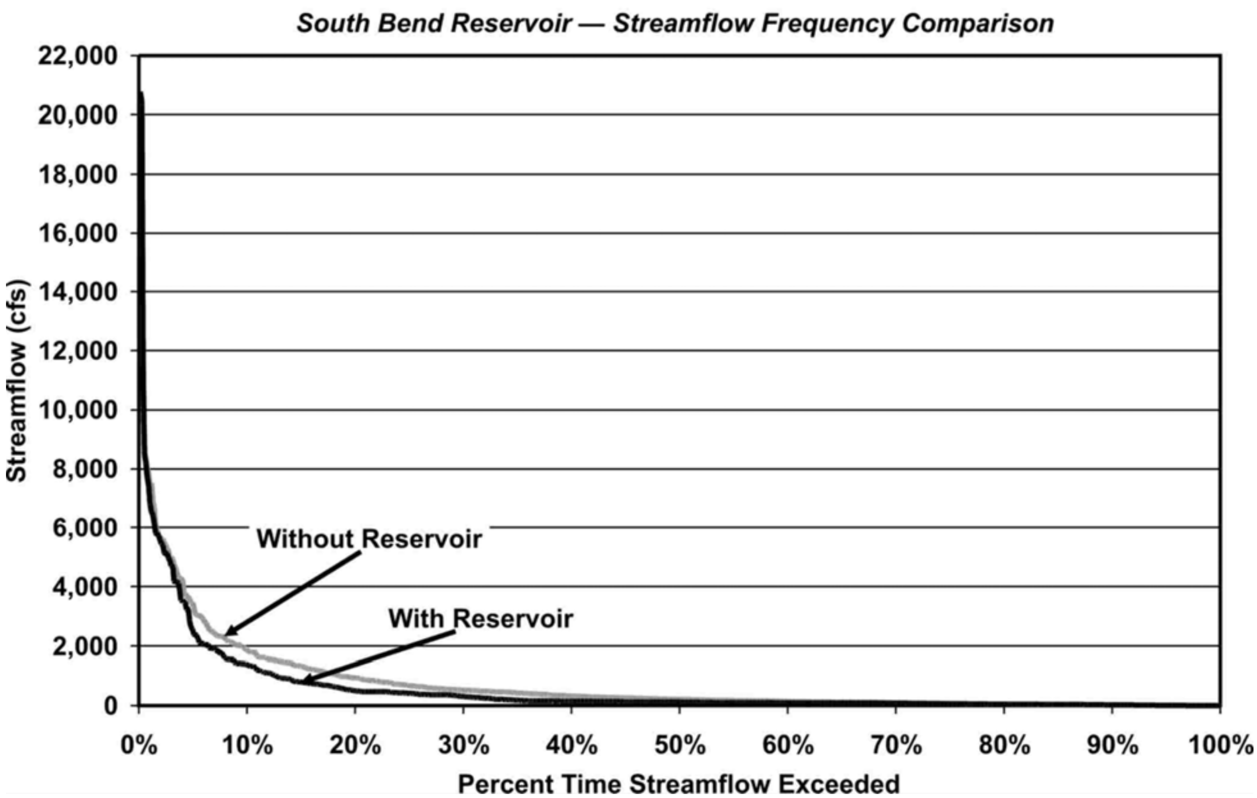
4B.12.2-2. South Bend Reservoir Storage Considerations





4B.12.2-3.Possum Kingdom Reservoir Storage Considerations





4B.12.2-4. South Bend Reservoir Streamflow Comparisons

the winter months, there would be little change in streamflow because the reservoir would only rarely be able to impound water in excess of that required for downstream senior water rights and environmental needs.

4B.12.2.3 Environmental Issues

4B.12.2.3.1 Existing Environment

The South Bend Reservoir Site in Stephens and Young Counties is within the Cross Timbers and Prairies Ecological Region, a complex transitional area of prairie dissected by two parallel timbered strips extending from north to south.[12] This region is located in north-central Texas west of the Blackland Prairies, east of the Rolling Plains, and north of the Edwards Plateau and Llano Uplift. The physiognomy of the region is oak and juniper woods and mixed grass prairie. Much of the native vegetation has been displaced by agriculture and development, and range management techniques—including fire suppression—have contributed to the spread of invasive woody species and grasses. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[13] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 28 and 32 inches.[14] The project area lies between the Seymour and Trinity major aquifers, but is underlain by no major or minor aquifers.[15]

The physiography of the region includes clay mud and sandstone, ceramic clay and lignite/coal, hard sandstone, mud, and mudstone (undifferentiated), hard sandstone and conglomerate (undifferentiated), terraces, and flood-prone areas. The topography ranges from rolling hills and prairie to steeply to moderate sloping hills and rugged hills and scarps. There are also flat areas and local shallow depressions in flood-prone areas along waterways.[16] The predominant soil associations in the project area are the Clearfork-Clairemont, Bastrop-Minwells, and Bonti-Truce-Bluegrove associations in Stephens County. The Clearfork-Clairemont association consists of very deep, nearly level and very gently sloping, loamy soils

[12] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[13] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[14] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[15] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.
[16] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., "Land Resources of Texas." Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

underlain by clayey and loamy alluvial sediments, on flood plains. The Bastrop-Minwells association consists of very deep, nearly level and very gently sloping, loamy soils underlain by loamy and gravelly alluvial sediments, on stream terraces. The Bonti-Truce-Bluegrove association consists of moderately deep and deep, gently sloping to hilly, loamy soils, most of which are flaggy or stony and underlain by sandstone or shale, on uplands.[17]

Three major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)-Lotebush (*Ziziphus obtusifolia*) Shrub, Post Oak (*Quercus stellata*) Parks/Woods, and Live Oak (*Q. virginiana*)-Mesquite-Ashe Juniper (*Juniperus ashei*) Parks.[18] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites.

Mesquite-Lotebush Brush/Shrub could include the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera pubescens*), juniper, tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania pinnatifida*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*).

Commonly associated plants of Post Oak Parks/Woods are blackjack oak (*Q. marilandica*), eastern redcedar (*J. virginiana*), mesquite, black hickory (*Carya texana*), live oak, sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* sp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem, silver bluestem, sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum*

[17] Cyprian, T.E., *Soil Survey of Stephens County, Texas*, United States Department of Agriculture Soil Conservation Service in cooperation with Texas Agricultural Experiment Station, 1994.
[18] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

anceps), three-awn (*Aristida* spp.), sprangle-grass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.).

Commonly associated plants of Live Oak-Mesquite-Ashe Juniper, found chiefly on level to gently rolling uplands and ridge tops of the Edwards Plateau, are Texas oak, shin oak (*Q. havardii*), cedar elm, netleaf hackberry (*Celtis laevigata*), flameleaf sumac (*Rhus lanceolata*), agarito, Mexican persimmon (*Diospyros texana*), Texas pricklypear (*Opuntia engelmannii*), kidneywood (*Eysenhardtia texana*), saw greenbrier (*Smilax bona-nox*), Texas wintergrass, little bluestem, curly mesquite (*Hilaria belangeri*), Texas grama, Hall's panicgrass (*Panicum hallii*), purple three-awn, hairy tridens (*Erioneuron pilusum*), cedar sedge (Carex *planostachys*), two-leaved senna (*Senna roemeriana*), mat euporbia (*Chamaesyce serpens*), and rabbit tobacco (*Evax prolifera*).

4B.12.2.3.1 Potential Impacts

4B.12.2.3.1.1 Aquatic Environments including Bays & Estuaries

The anticipated impact of this project would be minimal influence on the variability of monthly flows but substantial reductions in quantity of median monthly flows at the project site. The minimal reduction in variability of monthly flow values (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project =9.89 x 10^4; sample variance with project =9.45 x 10^4) would probably not have much impact on the instream biological community or riparian species. The decrease in monthly median flow values would range from 0.6 cfs (1 percent) in January to 407.5 cfs (53 percent) in May, as shown in Table 4B.12.2-2. The highest reductions (>40 percent) would occur in April, May and July through September, while the reductions would be 20 percent or less in December through February. Despite relatively large differences in median flow values, this project would have no effect on the frequency of low-flow conditions; the 85 percent exceedance value would be approximately 39 cfs both with and without the proposed reservoir in place. The reductions in flow that would occur with this project in place may have moderate impacts on the instream biological community since the highest reductions would occur in the summer when water temperatures are high.

Because this site is in the upper portion of the watershed, there would be a greater probability of impacts in the Brazos River than with a similar-sized project further downstream where flows are higher. However, additional downstream inflows would limit the extent of such impacts from this project. Alone, this project would not be expected to have a substantial influence on freshwater inflows to the Brazos River estuary, but the cumulative impact of multiple projects may reduce freshwater inflows to the estuary. As a new reservoir without a current operating permit, the South Bend Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4B.12.2-2.
Median Monthly Streamflow: South Bend Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	87.8	87.3	0.6	1%
February	123.0	98.9	24.1	20%
March	131.1	94.9	36.2	28%
April	219.0	119.9	99.1	45%
May	764.5	357.0	407.5	53%
June	671.3	477.5	193.8	29%
July	276.9	148.0	128.9	47%
August	203.4	85.8	117.5	58%
September	296.6	125.8	170.8	58%
October	225.2	153.6	71.6	32%
November	204.9	134.9	70.0	34%
December	120.8	98.3	22.5	19%

4B.12.2.3.1.2 Threatened & Endangered Species

A total of 20 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.2-3). This group includes three reptiles, 11 birds, four mammals, and two fish species. Six bird species federally-listed as threatened or endangered could occur in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), black-capped vireo (*Vireo atricapillus*), golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

A search of the Texas Wildlife Diversity Database[19] revealed the documented occurrence of two colonial water bird rookeries within the vicinity of the proposed South Bend Reservoir (as noted on representative 7.5-minute quadrangle maps that include the project site). These data arenot a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.2.3.1.3 Wildlife Habitat

Approximately 29,877 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 9,143 acres of Cropland, 2,788 acres of Grassland, 11,590 acres of Mesquite Shrub/Brush, 1,938 acres of Post Oak-Mesquite Woods, 3,434 acres of mixed Riparian Brush/Woods, and 984 acres of exposed streambed.

A number of vertebrate species would be expected to occur within the South Bend Reservoir site as indicated by county occurrence records.[20] These include 11 species of frogs and toads, seven species of turtles, 12 species of lizards and skinks, and 24 species of snakes. Additionally, 78 species of mammals could occur within the site or surrounding region[21] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.12.2.3.1.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that approximately 700 archeological sites have been documented within or in close proximity to the proposed reservoir. In 1987-88, Texas A&M University conducted a survey of South Bend Reservoir as it

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[19] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.
[20] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.
[21] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

Table 4B.12.2-3.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the South Bend Reservoir Site, Stephens and Young Counties

Scientific Name	Common Name	Federal/State Status	Stephens County	Young County
Birds				
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant	Migrant
Vireo atricapillus	Black-capped Vireo	LE/E	Migrant	—
Dendroica chrysoparia	Golden-cheeked Warbler	LE/E	Migrant	Migrant
Ammodramus henslowii	Henslow's Sparrow	SOC	—	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant	Migrant
Fishes				
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X	X
Notropis buccula	Smalleye Shiner	C/SOC	X	X
Mammals				
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X	X
Myotis velifer	Cave Myotis Bat	SOC	—	X
Canis lupus	Gray Wolf	LE/E	Extirpated	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X	X
Canis rufus	Red Wolf	LE/E	Extirpated	Extirpated
Dipodomys elato	Texas Kangaroo Rat	SOC/T	—	X
Reptiles				
Nerodia harteri	Brazos Water Snake	SOC/T	—	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X	X

X = Occurs in county; — = does not occur in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed)

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Brazos, Leon, Madison, and Robertson Counties (2004); TPWD Texas Wildlife Diversity Database (2004), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, September 12, 2003.

was then proposed, recording 673 archeological sites. The investigators recommended that 18 percent of the prehistoric sites and 21 percent of the historic sites warranted further testing to determine their eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Prior to reservoir inundation, these sites must be reassessed relative to their eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Additionally, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted for any areas within the proposed reservoir that were not included in the previous survey to determine if cultural resources are present. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.12.2.3.1.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower streamflows, declining water quality, and reduced inflows to reservoirs. This project would contribute to seasonally lower streamflows downstream of the reservoir site and potentially affect water quality through decreased flows.

4B.12.2.4 Engineering and Costing

A cost estimate for the proposed South Bend Reservoir was made in 1991. This estimate was updated for the 2001 Brazos G Regional Water Plan and now to Second Quarter 2002 prices for the current plan. The cost details are shown in Table 4B.12.2-4. The total project costs are estimated to be $259,163,000. The cost for the estimated increase in system yield of 44,940 acft/yr, translates to an annual unit cost of raw water at the reservoir of $1.29 per 1,000 gallons, or $419 per acft. The annual project costs are estimated to be $18.8 million; this includes annual debt service, and operation and maintenance costs.

Table 4B.12.2-4.
Cost Estimate Summary for
South Bend Reservoir
(Second Quarter 2002 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool: 771,604 acft, 29,877 acres, 1,090 ft-msl)	$82,795,000
Relocations & Other	37,185,000
Total Capital Cost	**$119,980,000**
Engineering, Legal Costs and Contingencies	$41,993,000
Environmental & Archaeology Studies and Mitigation	29,400,000
Land Acquisition and Surveying (52,877 acres)	32,043,000
Interest During Construction (4 years)	35,747,000
Total Project Cost	**$259,163,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$4,230,000
Reservoir Debt Service (6 percent for 40 years)	13,354,000
Operation and Maintenance	
Dam and Reservoir	1,242,000
Total Annual Cost	**$18,826,000**
Available Project Yield (acft/yr)	**44,940**
Annual Cost of Water ($ per acft)	**$419**
Annual Cost of Water ($ per 1,000 gallons)	**$1.29**

The total project cost reported in the 2001 Water plan was $205 million; the current plan costs are an estimated to be $259 million. In addition to inflation, cost differences are due to different methodology used in the 2001 and 2006 plans to calculate Engineering, Legal Costs and Contingencies and Environmental & Archaeology Studies and Mitigation.

The annual cost of water has increased from $141 per acft ($0.43 per 1,000 gallons) in the 2001 plan to $418 per acft ($1.28 per 1,000 gallons) in the current plan. The increase in cost is due to the decrease in projected project yield; projected yield was 106,700 acft/yr in the 2001 plan and is currently 44,940 acft/yr in the 2006 plan.

4B.12.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.2-5, and the option meets each criterion.

Implementation of the South Bend Reservoir would encounter difficult permitting constraints, as would be typical for any major reservoir. In addition, the water would likely require significant treatment due to water quality concerns. The level of dissolved solids, if used in the area, would require additional treatment similar to the SWATS plant for Lake Granbury water. The portion of the available supply used within the overall BRA system would not necessarily need demineralization treatment.

A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and
  - Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.
  - Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4B.12.2-5.
Comparison of South Bend Reservoir to Plan Development Criteria

Impact Category	Comment(s)
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. Moderate to High impact
2. Habitat	2. High impact
3. Cultural Resources	3. High impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Moderate impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
  - Wildlife habitat mitigation plan that may require acquisition and management of additional land;
  - Flow releases downstream to maintain aquatic ecosystems; and
  - Assessment of impacts on Federal- and State-listed endangered and threatened species.

4B.12.3 Throckmorton Reservoir

4B.12.3.1 Description of Option

A potential water management strategy for the City of Throckmorton is a new reservoir located approximately three miles northwest of the city as shown in Figure 4B.12.3-1. The proposed reservoir will be located on the North Elm Creek and will contain approximately 15,900 acft of conservation storage and inundate 1,161 acres at the full conservation storage level of 1,345 ft-msl. The contributing drainage area is approximately 82 square miles.

4B.12.3.2 Available Yield

Water potentially available for impoundment in the proposed Throckmorton Reservoir was estimated using an updated version of the Brazos G WAM. The model utilized an updated January 1940 through June 2004 hydrologic period of record to account for the recent drought in the Upper Brazos Basin. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from North Elm Creek without causing increased shortages to existing downstream rights. Safe yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the reservoir are shown in Table 4B.12.3-1.

The calculated safe yield of Throckmorton Reservoir is 3,100 acft/yr, assuming subordination of Possum Kingdom Reservoir. According to the Brazos GWAM, channel losses between Throckmorton Reservoir and Possum Kingdom Lake are about 18%. Therefore, the impact on the yield of Possum Kingdom is less than the gain of supply at Throckmorton. The firm yield of Possum Kingdom is reduced by an estimated 2,000 acft/yr.

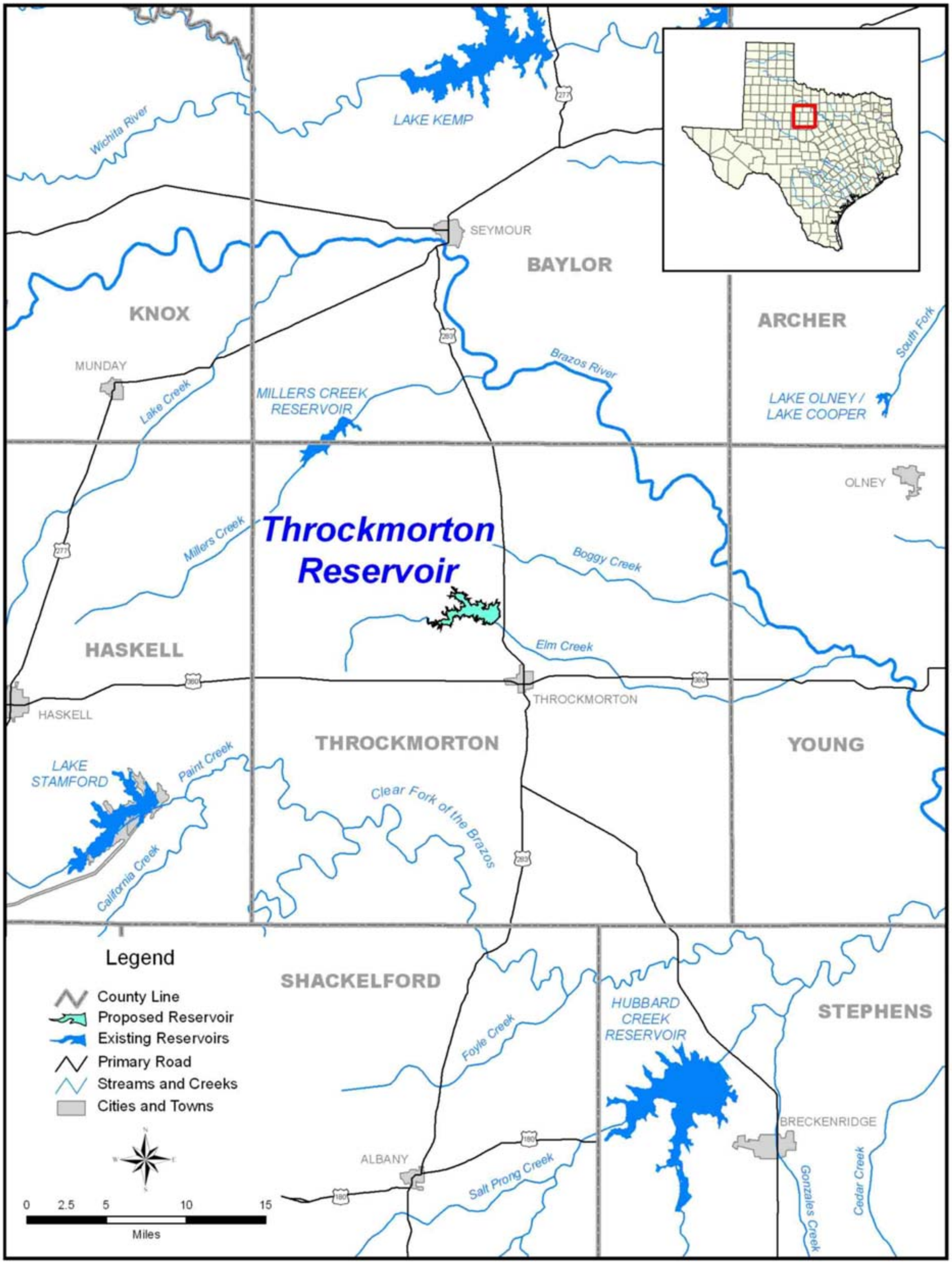


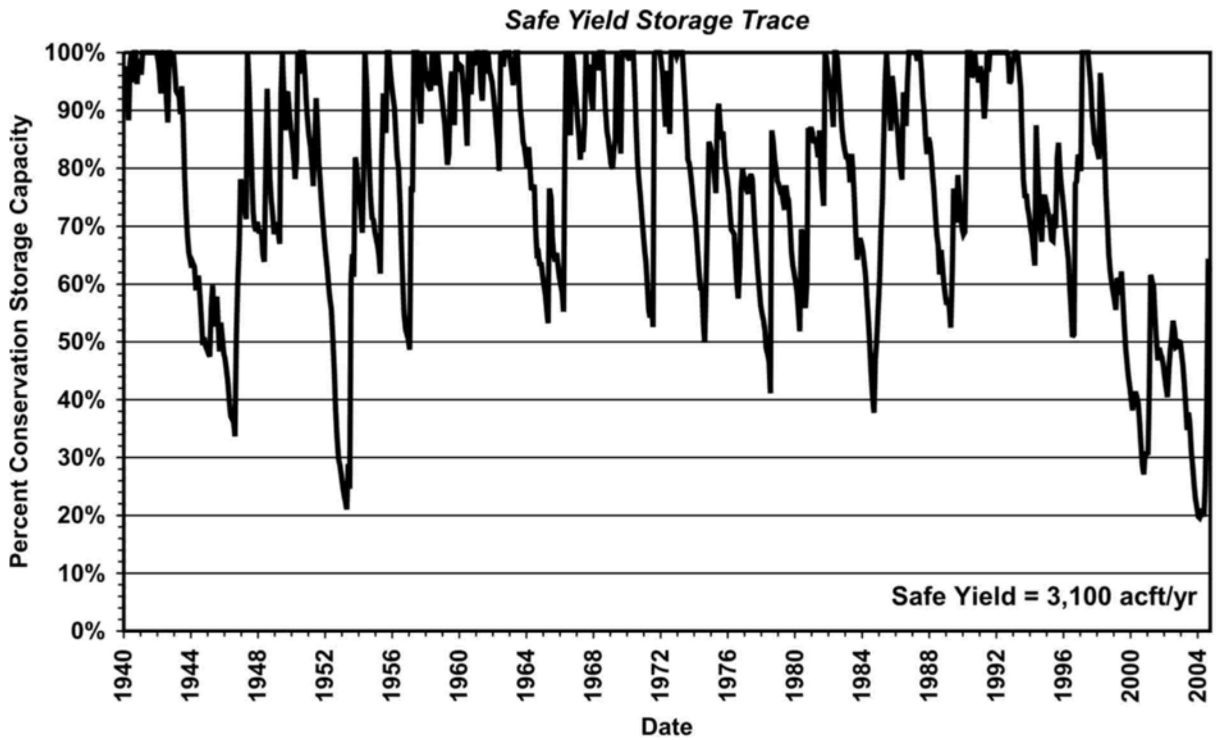
Figure 4B.12.3-1. Throckmorton Reservoir

Table 4B.12.3-1.
Daily Natural Streamflow Statistics
for Throckmorton Reservoir

Month	Median Flows - Zone 1 Pass Through Requirements (ft^3/sec)	25th Percentile Flows - Zone 2 Pass Through Requirements (ft^3/sec)
January	2.0	1.1
February	1.9	1.1
March	2.3	0.7
April	2.1	0.8
May	6.5	1.2
June	10.0	3.0
July	2.6	0.5
August	1.3	0.1
September	2.3	0.2
October	3.4	0.7
November	3.0	0.9
December	2.3	1.1
Zone 3 (7Q2) Pass-Through Requirement (ft^3/sec):		0

Figure 4B.12.3-2 illustrates the simulated Throckmorton Reservoir storage levels for the 1940 to 2004 historical period, subject to the safe yield of 3,100 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 50 percent of the time and above the Zone 3 trigger level (50 percent capacity) 88 percent of the time.

Figure 4B.12.1-3 illustrates the changes in North Elm Fork streamflows caused by impounding unappropriated water. The largest changes would be declines in median streamflow of 17.7 cfs during June (86 percent reduction) and 14.1 cfs during May (92 percent reduction). Streamflow is reduced greater than 50 percent in all months. Figure 4B.12.1-3 also illustrates the North Elm Creek streamflow frequency characteristics with the Throckmorton Reservoir in place.



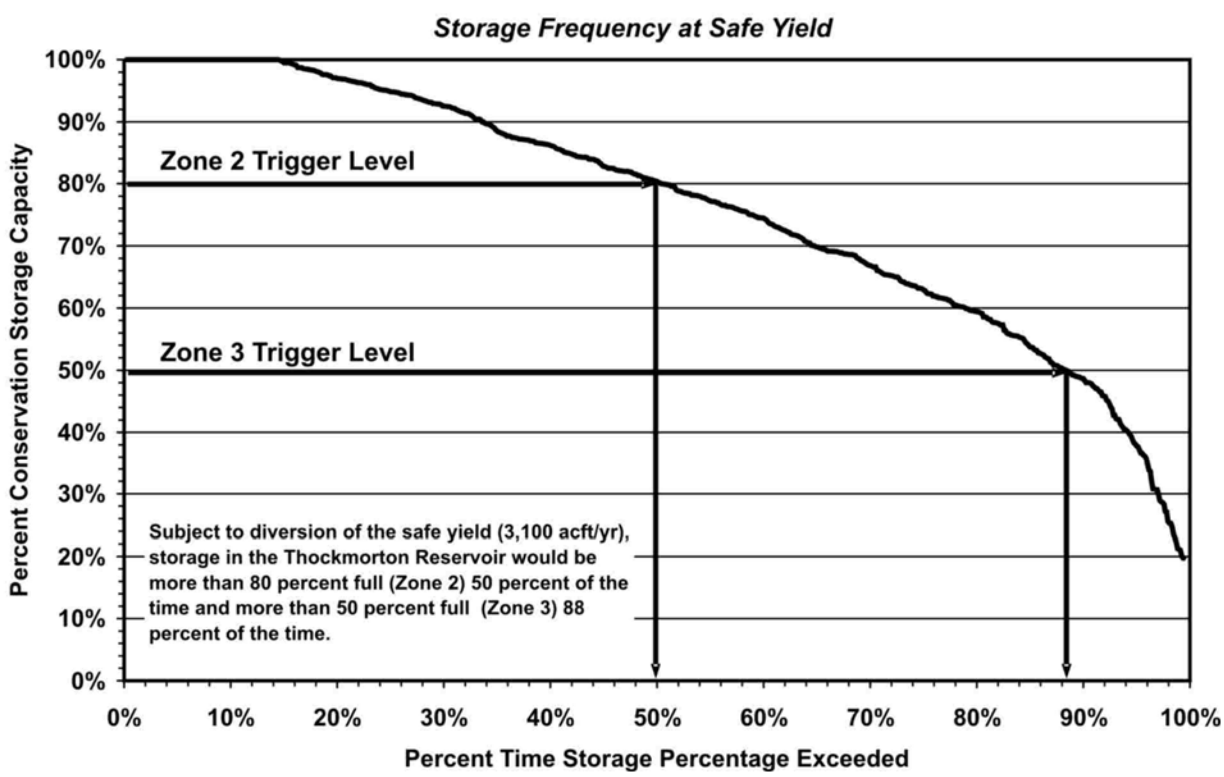
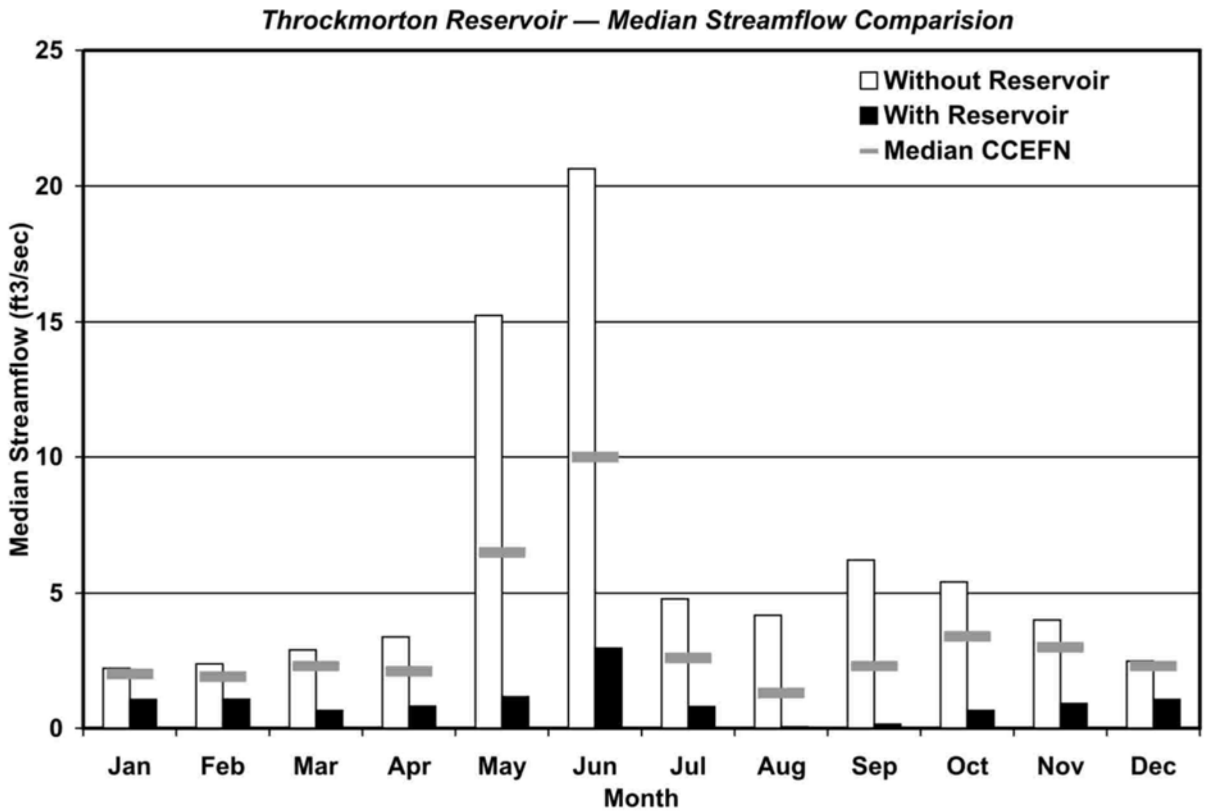


Figure 4B.12.3-2. Throckmorton Reservoir Storage Considerations



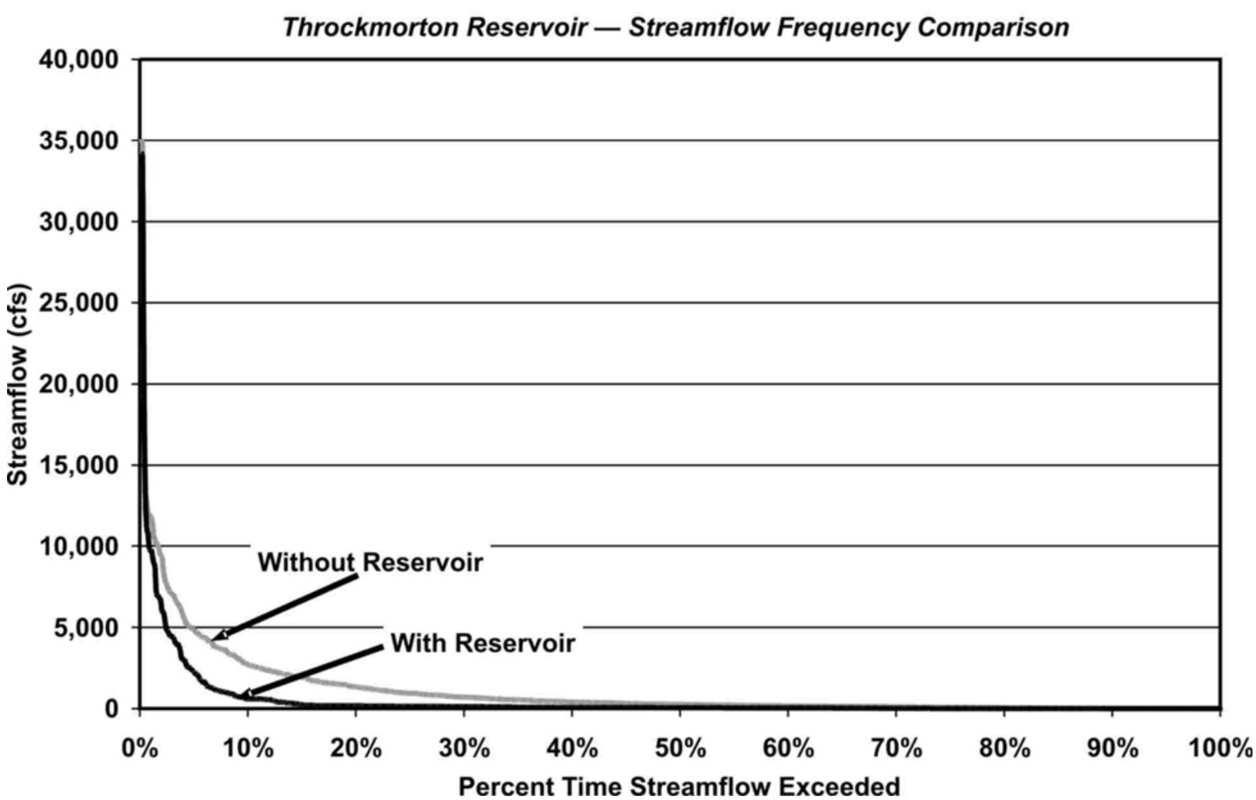


Figure 4B.12.3-3. Throckmorton Reservoir Streamflow Comparisons

4B.12.3.3 Environmental Issues

4B.12.3.3.1 Existing Environment

The Throckmorton Reservoir site in Throckmorton County is within the Rolling Plains Ecological Region[22]. This region is located east of the High Plains, west of the Cross Timbers and Prairies, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, and juniper breaks and midgrass prairie. The physiognomy of the region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive plant species and have decreased the value of the land for cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region[23]. The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[24]

The Seymour aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area.[25] It is formed by isolated alluvial deposits in 20 counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravels that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[26]

The physiography of the region includes clay mud and sandstone, terraces, stair step topography, and flood-prone areas. The topography ranges from flat to rolling to steeply sloped, with benches in some areas and local shallow depressions in flood zones along waterways.[27] The predominant soil associations in the project area are the Clearfork-Gageby and Lueders-Throck-Owens associations. Clearfork-Gageby soils are very deep, nearly level or very gently sloping,

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[22] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[23] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[24] Larkin, T.J., and G.W. Bomar, Climatic Atlas of Texas, Texas Department of Water Resources, Austin, Texas, 1983.
[25] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[26] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.
[27] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., *Land Resources of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

loamy soils on flood plains. Lueders-Throck-Owens soils are very shallow to deep, gently undulating or undulating, loamy and clayey upland soils.[28]

Two major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush Shrub and crops.[29] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Mesquite-Lotebush Shrub could include the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera angustifolia*), juniper, tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania peristena*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.12.3.3.2 Potential Impacts

4B.12.3.3.2.1 Aquatic Environments including Bays & Estuaries

The anticipated impact of this project would be minimal reduction in variability and substantial reductions in quantity of median monthly flows. The slight reduction in variability of monthly flow values (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project =6.94×10^6; sample variance with project =5.14×10^6) would probably not have much impact on the instream biological community or riparian species. However, there would be a reduction in the quantity of median monthly flows downstream of the project ranging from 1.1 cfs (52 percent) in January to 17.7 cfs (86 percent) in June, as shown in Table 4B.12.3-2. The

[28] Cyprian, T.E., *Soil Survey of Throckmorton County, Texas*, United States Department of Agriculture, Natural Resources Conservation Service, in cooperation with Texas Agricultural Experiment Station, 2004.
[29] McMahan, C.A., R.F. Frye, and K.L. Brown, *The Vegetation Types of Texas*, Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

highest reductions (>90 percent) would occur in May, August and September, and all months would be reduced by at least 50 percent. This project would also result in a higher frequency of low-flow conditions. Without the project, the monthly flow would be less than 0.53 cfs only 15 percent of the time (85 percent exceedance value), but the monthly flow would be 0 cfs for 20 percent of the time with the project in place. These reductions in flow would have substantial impacts on the instream biological community, especially since the greatest reductions are predicted for the summer months when flows are already historically low and water chemistry conditions are the most stressful for aquatic species (e.g., high temperatures and high nutrient growth).

Table 4B.12.3-2.
Median Monthly Streamflow for Throckmorton Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	2.2	1.1	1.1	52%
February	2.4	1.1	1.3	55%
March	2.9	0.7	2.2	77%
April	3.4	0.8	2.6	76%
May	15.2	1.2	14.1	92%
June	20.6	3.0	17.7	86%
July	4.8	0.8	4.0	83%
August	4.2	0.1	4.1	99%
September	6.2	0.2	6.1	98%
October	5.4	0.7	4.8	88%
November	4.0	0.9	3.1	77%
December	2.5	1.1	1.4	57%

Although there would be biological impacts in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in the Brazos River or to freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflow to the estuary. As a new reservoir without a current operating permit, the Throckmorton Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.12.3.3.2.2 Threatened & Endangered Species

A total of 18 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.3-3). This group includes three reptiles, nine birds, four mammals, and two fish species. Four bird species federally-listed as threatened or endangered could occur in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus Americana*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

A search of the Texas Wildlife Diversity Database[30] revealed the documented occurrence of one colonial water bird rookery within the vicinity of the proposed Throckmorton Reservoir (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This data is not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.3.3.2.3 Wildlife Habitat

Approximately 1,160 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 1,118 acres of Mesquite-Lotebush Shrub, and 42 acres of Mesquite-Saltcedar Brush.

A number of vertebrate species would be expected to occur within the Throckmorton Reservoir site as indicated by county occurrence records.[31] These include 11 species of frogs and toads, six species of turtles, 10 species of lizards and skinks, and 24 species of snakes.

[30] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.
[31] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.

Table 4B.12.3-3.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Throckmorton Reservoir Site, Throckmorton County

Scientific Name	Common Name	Federal/State Status	Potential Occurrence
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus Americana	Whooping Crane	LE/E	Migrant
Fishes			
Notropis oxyrhincus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X
Myotis velifer	Cave Myotis Bat	SOC	X
Canis lupus	Gray Wolf	LE/E (extirpated)	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E (extirpated)	X
Dipodomys elato	Texas Kangaroo Rat	SOC/T	X
Reptiles			
Nerodia harteri	Brazos Water Snake	SOC/T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X

X = Occurs in county. * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.)

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Brazos, Leon, Madison, and Robertson Counties (2004); TPWD Texas Wildlife Diversity Database (2004), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, September 12, 2003.

Additionally, 78 species of mammals could occur within the site or surrounding region [32] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.12.3.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that no archeological sites have been documented within the general vicinity of the proposed reservoir. However, the area has never been surveyed by a professional archeologist and the absence of documented sites may reflect the lack of investigation rather than the absence of archeological sites. Prior to reservoir inundation the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.12.3.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site as a reduction in the quantity of median monthly flow is projected downstream, but the reservoir would also trap sediment and/or dilute pollutants, providing some positive benefits to water quality immediately downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures during summer periods. The project is expected to have negligible impacts to total discharge downstream and overall water quality in the Brazos River.

[32] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

4B.12.3.4 Engineering and Costing

Construction of the Throckmorton Reservoir project will cost approximately $21.5 million. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $1.67 million; this includes annual debt service and operation and maintenance. The cost for the available project safe yield of 3,1000 acft/yr translates to an annual unit cost of raw water of $1.66 per 1,000 gallons, or $540/acft. A summary of the cost estimate is provided in Table 4B.12.3-4. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

4B.12.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.3-5, and the option meets each criterion.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Table 4B.12.3-4.
Cost Estimate Summary for
Throckmorton Reservoir
(Second Quarter 2002 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir	$10,200,000
Total Capital Cost	**$10,200,000**
Engineering, Legal Costs and Contingencies	$3,570,000
Environmental & Archaeology Studies and Mitigation	$3,080,000
Land Acquisition and Surveying	$3,080,000
Interest During Construction (2 years)	$1,558,000
Total Project Cost	**$21,488,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$1,428,000
Operation and Maintenance	$153,000
Purchase of Water (2,000 acft/yr @ $45.75 per acft)	91,500
Total Annual Cost	**$1,672,500**
Available Project Safe Yield (acft/yr)	3,100
Annual Cost of Water ($ per acft)	$540
Annual Cost of Water ($ per 1,000 gallons)	$1.66

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and,
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4B.12.3-5.
Comparison of Throckmorton Reservoir to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable to High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. High impact
3. Cultural Resources	3. High impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.12.4 Double Mountain Fork Reservoirs (East and West Sites)

4B.12.4.1 Description of Options

The Double Mountain Fork Reservoirs (East and West) are two alternative proposed new reservoirs on the Double Mountain Fork of the Brazos River. The two sites are less than 30 river miles apart from each other as shown on (Figure 4B.12.4-1). This project is a potential source of water for Stonewall County and other West Central Texas Counties.

The West Site will be located in Jones and Stonewall Counties, about 18 miles southwest of the City of Aspermont. The proposed west site has a storage capacity of 215,254 acft, covering 6,632 acres. The proposed conservation pool elevation is 1,790 feet. The drainage area at this location is 1,669 square miles.

The East Site is located about 30 river miles downstream of the west site, between Highway 83 and FM 1835, with a drainage area of 1,937 square miles. The storage capacity of the east site is 280,814 acft, with a surface area of 10,814 acres at the proposed conservation pool elevation of 1,667 feet. Preliminary studies have indicated that the east site may have some potential problems with land acquisition. If the east site needs to be relocated 5 to 10 miles downstream, it is expected that this change would have no significant impact on the firm yield.

The Stonewall County area has a great deal of gypsum in the soil. Gypsum is soluble in water and can make a reservoir site unsuitable to build a dam. The reservoir locations considered were chosen to avoid the presence of gypsum in the vicinity of the dam. However, more detailed soil investigations are required to ensure the foundation conditions are suitable for a dam. If necessary, the sites may be relocated to a suitable soil without having a significant impact on the yield.

4B.12.4.2 Available Yield

Water potentially available for impoundment in the proposed Double Mountain Fork Reservoirs (East and West) was estimated using the Brazos G WAM. The model utilized an updated January 1940 through June 2004 hydrologic period of record to account for the recent drought in the Upper Brazos Basin. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow

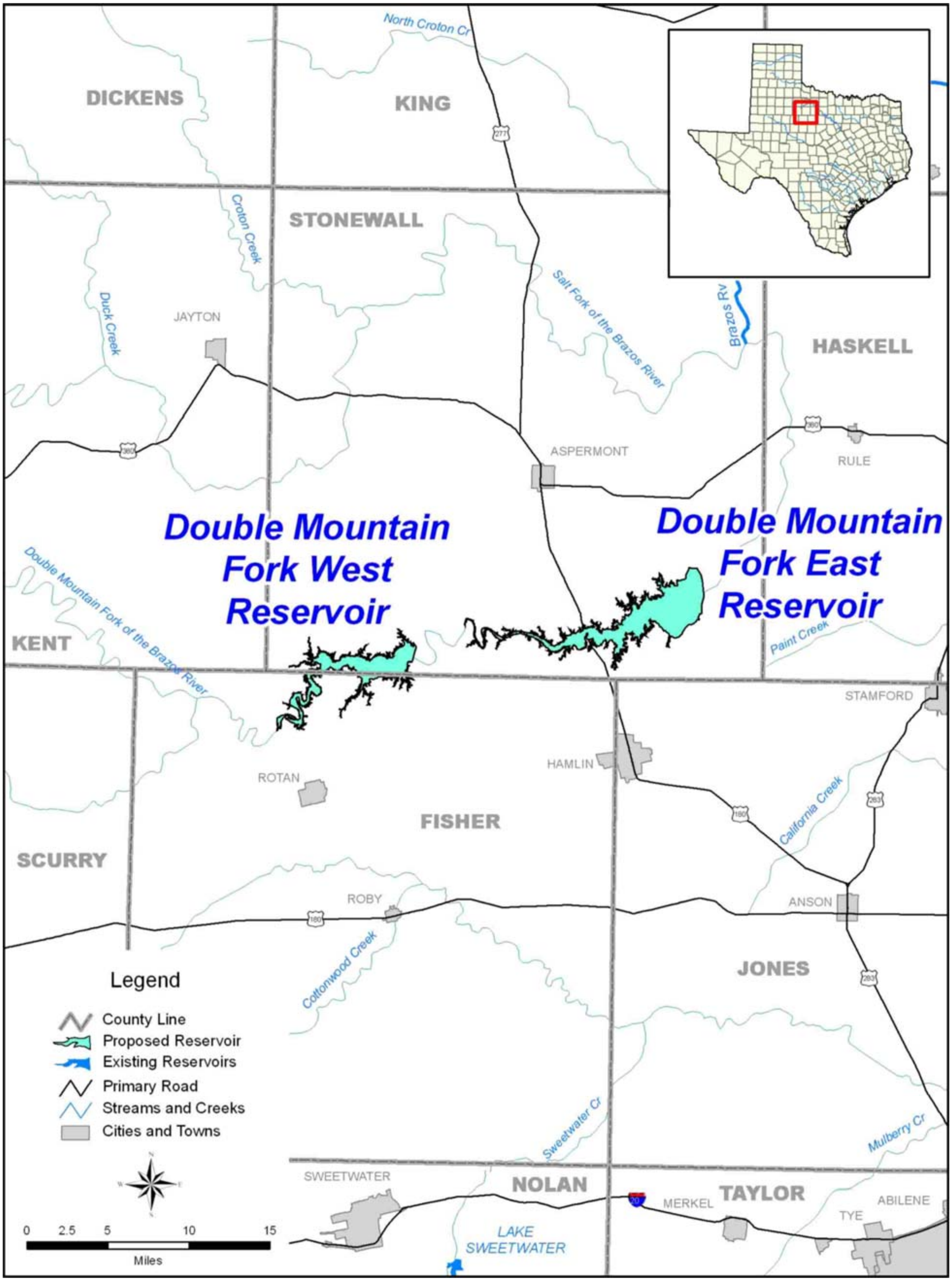

Figure 4B.12.4-1. Double Mountain Fork Reservoir (East and West Sites) available from the Double Mountain Fork of the Brazos River without causing increased shortages to existing downstream rights. Safe yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass through requirements for the east and west reservoirs, respectively, are shown in Tables 4B.12.4-2 and 4B.12.4-3.

Table 4B.12.4-2. Daily Natural Streamflow Statistics for the Double Mountain Fork Reservoir – East Site

Month	Median Flows - Zone 1 Pass Through Requirements (ft^3/sec)	25th Percentile Flows - Zone 2 Pass Through Requirements (ft^3/sec)
January	7.3	1.9
February	7.2	1.4
March	4.6	0.6
April	4.0	0.5
May	24.9	1.3
June	38.8	5.4
July	8.5	0.7
August	5.9	0.2
September	14.9	0.4
October	10.9	1.0
November	9.5	1.0
December	8.4	2.1
Zone 3 (7Q2) Pass-Through Requirement (ft^3/sec):		0

The calculated safe yield of the East Site is 33,300 acft/yr and the calculated safe yield of the West Site is 30,250 acft/yr; both safe yields assume subordination of Possum Kingdom Reservoir. The yield impact on Possum Kingdom due to the East Site is estimated to be 7,850 acft/yr and the yield impact on Possum Kingdom due to the West Site is estimated to be 4,300 acft/yr.

Table 4B.12.4-3.
Daily Natural Streamflow Statistics
for the Double Mountain Fork Reservoir – West Site

Month	*Median Flows - Zone 1 Pass Through Requirements (ft³/sec)*	*25th Percentile Flows - Zone 2 Pass Through Requirements (ft³/sec)*
January	6.4	1.3
February	6.5	0.8
March	3.8	0.3
April	3.9	0.3
May	23.6	1.0
June	39.4	5.3
July	8.7	0.6
August	5.7	0.2
September	14.4	0.4
October	10.6	0.7
November	8.1	0.5
December	7.8	1.4
Zone 3 (7Q2) Pass-Through Requirement (ft³/sec):		0

Figure 4B.12.4-2 illustrates the simulated Double Mountain Fork Reservoirs (East and West) storage levels for the 1940 to 2004 historical period, subject to the safe yield of 33,300 acft/yr for the East Site and 30,250 acft/yr for the West Site. For the East Site, simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 36 percent of the time and above the Zone 3 trigger level (50 percent capacity) 76 percent of the time. For the West Site, simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 49 percent of the time and above the Zone 3 trigger level (50 percent capacity) 83 percent of the time.

Figure 4B.12.4-3 illustrates the changes in Double Mountain Fork streamflows caused by impounding the unappropriated water. Median streamflows are reduced significantly due to the reservoir. Figure 4B.12.4-3 also illustrates the Double Mountain Fork streamflow frequency characteristics with the East Site and West Site reservoirs in place.

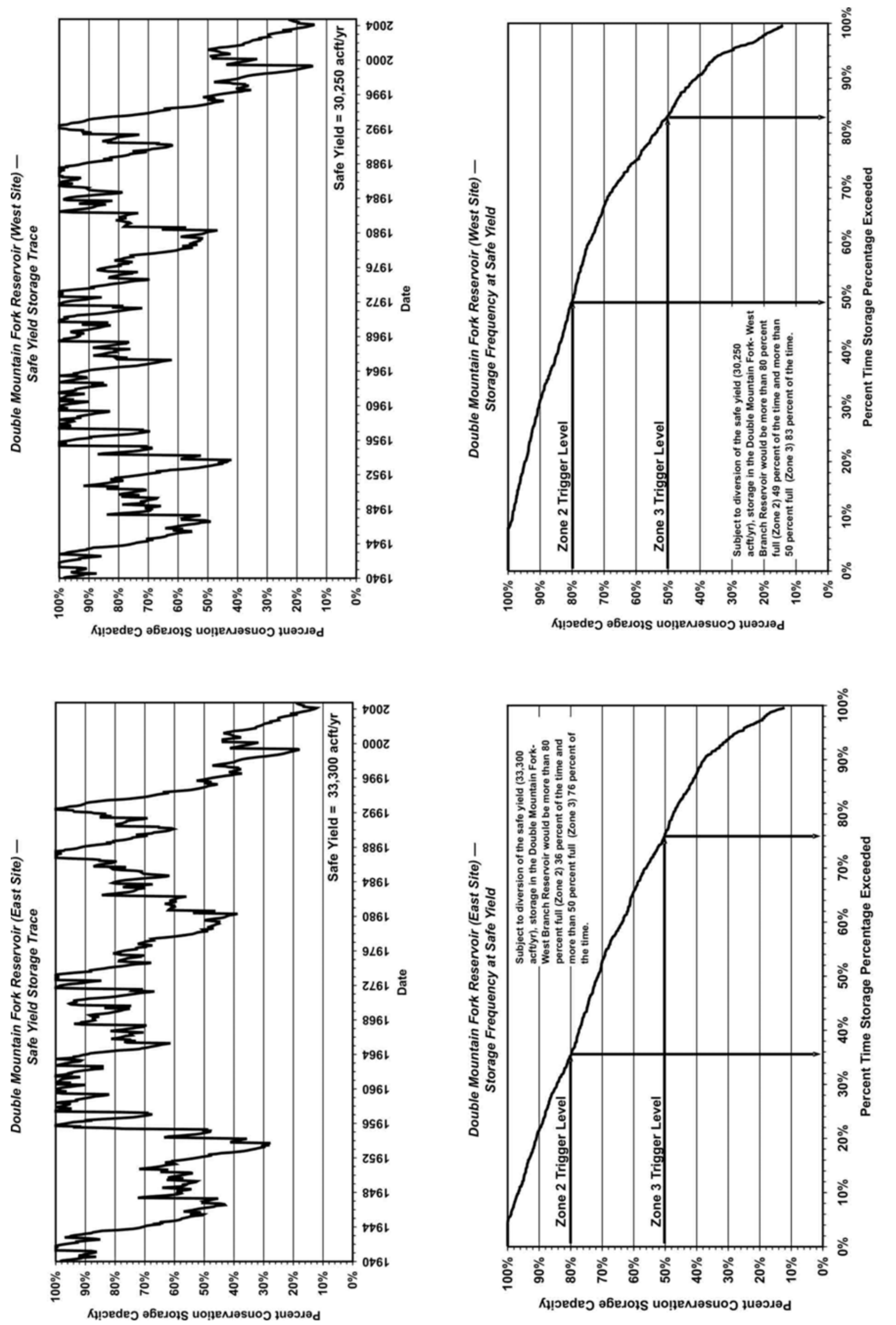

Figure 4B.12.4-2. Double Mountain Fork Reservoirs (East and West Sites) Streamflow Comparison

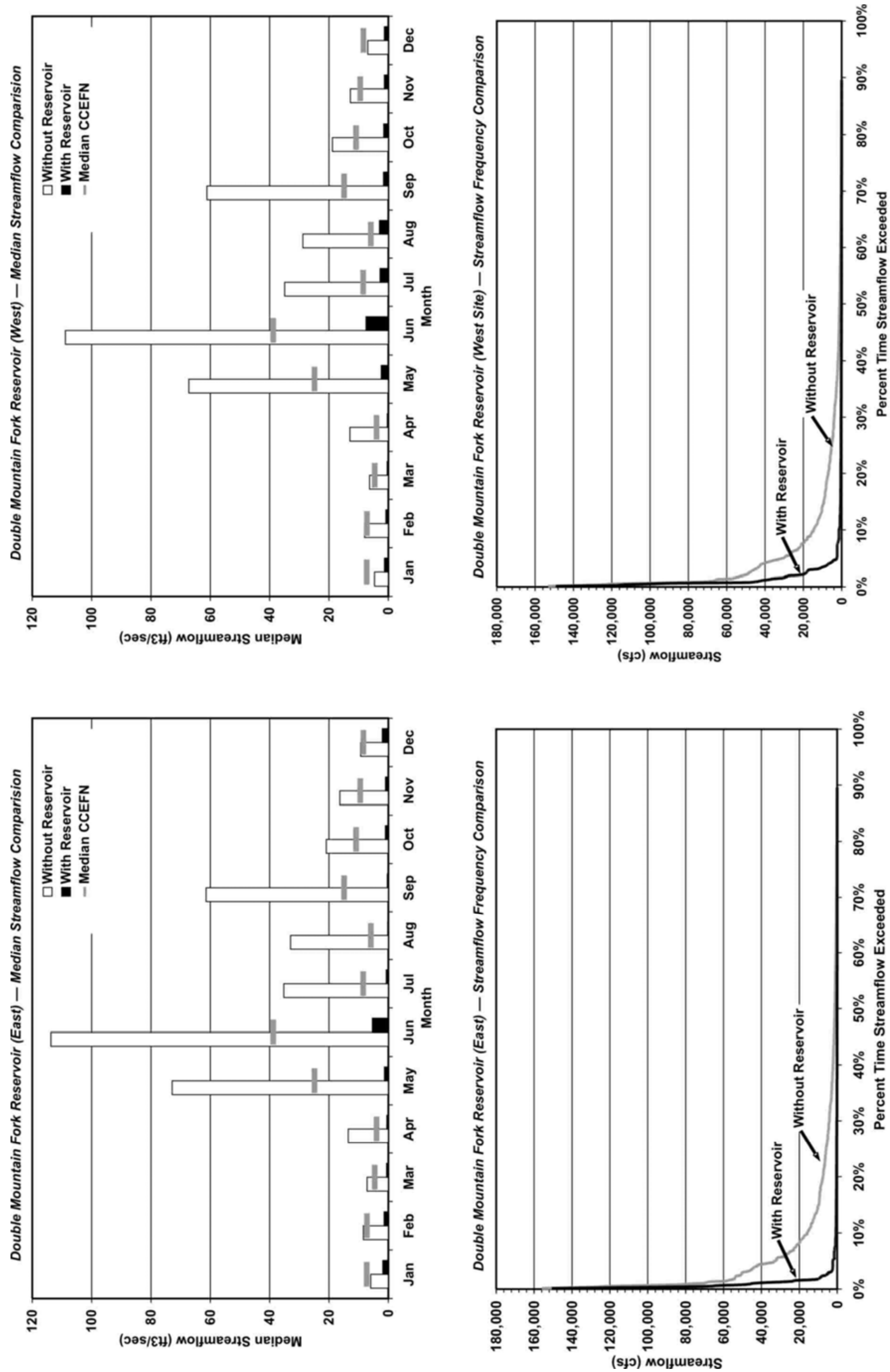

Figure 4B.12.4-3. Double Mountain Fork Reservoirs (East and West Sites) Streamflow Comparison

4B.12.4.3 Environmental Issues – East Site

4B.12.4.3.1 Existing Environment

The Double Mountain Fork East Reservoir site in Stonewall County is within the Rolling Plains Ecological Region.[33] This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, juniper breaks and midgrass prairie. The region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive plant species and have decreased the value of the land for cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[34] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[35]

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by isolated alluvial deposits in 20 counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravel that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[36]

The physiography of the region includes hard sandstone, mud, and mudstone (undifferentiated), gypsiferous red beds with dolomite, terraces, severely eroded land, undissected red beds, and flood-prone areas. In some areas, the topography is steeply sloped, with densely dissected gullies and low hills in severely eroded areas. There are also local shallow depressions in flood-prone areas along waterways.[37] The predominant soil associations in the project area are the Owens-Cottonwood and Rotan-Frankirk associations. The Owens-

[33] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, *Vegetational Areas of Texas*, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[34] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[35] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.
[36] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.
[37] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., *Land Resources of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

Cottonwood association consists of very shallow to shallow, gently to strongly sloping soils on uplands. These soils are very slowly to moderately permeable and well drained. Cottonwood soils are calcareous loam underlain by gypsum; and Owens soils are calcareous clay underlain by shaly clay. The Rotan-Frankirk association consists of deep, nearly level to gently sloping soils on uplands that formed in either ancient alluvial outwash (Rotan) or calcareous, loamy alluvium (Frankirk). These clay and clay loam soils are moderately slowly permeable and well drained.[38]

Four major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush Brush/Shrub, Mesquite-Juniper (*Juniperus*) Brush, Mesquite-Saltcedar (*Tamarix*) Brush/Woods, and crops.[39] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Mesquite-Lotebush Brush/Shrub could include the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis trifoliolata*), elbowbush (*Forestiera angustifolia*), juniper, tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania peristena*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*). Commonly associated plants of Mesquite-Juniper Brush are lotebush, shin oak (*Quercus havardii*), sumac (*Rhus* spp.), Texas pricklypear (*Opuntia engelmannii*), tasajillo, kidneywood (*Eysenhardtia texana*), agarito, yucca, Lindheimer silktassel (*Garrya ovata*), catclaw (*Acacia* sp.), Mexican persimmon (*Diospyros texana*), sideoats grama, three-awn (*Aristida* sp.), Texas grama, hairy grama, curly-mesquite (*Hilaria belangeria*), buffalograss, and hairy tridens (*Erioneuron pilusum*). Commonly associated plants of Mesquite-Saltcedar Brush/Woods are creosotebush (*Larrea tridentata*), cottonwood (*Populus deltoides*), desert willow (*Chilopsis linearis*), giant reed (*Arundo donax*), seepwillow (*Baccharis* sp.), common buttonbush (*Cephalanthus occidentalis*), whitethorn acacia (*Acacia constricta*),

[38] Goerdel, A.R., and L. Watson, *Soil Survey of Stonewall County, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1975.
[39] McMahan, C.A., R.F. Frye, and K.L. Brown, *The Vegetation Types of Texas*, Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

Australian saltbush (*Atriplex semibaccata*), fourwing saltbush (*Atriplex canescens*), lotebush, wolfberry (*Lycium berlandieri*), tasajillo, guayacan (*Guaiacum angustifolium*), alkali sacaton (*Sporobolus airoides*), Johnsongrass (*Sorghum halepense*), saltgrass (*Distichlis spicata*), cattail (*Typha* spp.), bushy bluestem (*Andropogon glomeratus*), and chino grama (*Bouteloua ramosa*). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.12.4.3.2 Potential Impacts

4B.12.4.3.2.1 Aquatic Environments including Bays & Estuaries

The anticipated impact of this project would be lower variability in and substantial reductions in quantity of median monthly flows. The difference in variability of monthly flows would be a factor of approximately 2.9 (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project=23.29 x 10^7; sample variance with project=8.05 x 10^7). Variability in flow is important to the instream biological community as well as riparian species and this reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing habitat suitability for others. In addition to reduced variability, there would be substantial reductions in the quantity of median monthly flow downstream of the project. These reductions would range from 4.1 cfs (69 percent) in January to 108.3 cfs (95 percent) in June, as shown in Table 4B.12.4-4. The decrease in monthly median flow values at the project site would be greater than 90 percent for nine consecutive months (March through November) and approximately 70 percent or greater in all months. This project would also result in a higher frequency of low-flow conditions. Without the project, the monthly flows would be less than 2.13 cfs only 15 percent of the time (85 percent exceedance value), but the monthly flows with the project in place would be 0 cfs for 26 percent of the time. These reductions in flow would have substantial impacts on the instream biological community, including reduced habitat available for spawning fish in the spring and an increased likelihood of high water temperatures and impairment of other water quality parameters in the summer.

Although there would be biological impacts in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in downstream locations on the Brazos River (this site is near the headwaters). It is also unlikely that this project would have an impact on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows to the estuary. As a new reservoir without a current operating permit, the Double Mountain Fork East Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4B.12.4-4.
Median Monthly Streamflow: Double Mountain Fork East Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	6.0	1.9	4.1	69%
February	8.4	1.4	7.0	83%
March	7.2	0.6	6.6	92%
April	13.5	0.5	13.0	96%
May	72.8	1.3	71.5	98%
June	113.7	5.4	108.3	95%
July	35.2	0.7	34.5	98%
August	33.0	0.2	32.8	99%
September	61.4	0.4	61.1	99%
October	20.9	1.0	19.9	95%
November	16.3	1.0	15.4	94%
December	9.3	2.0	7.3	78%

4B.12.4.3.2.2 Threatened & Endangered Species

A total of 19 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.4-5). This group includes one reptile, twelve birds, four mammals, and two fish species. Four bird species federally-listed as threatened or endangered could occur in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), whooping crane (*Grus americana*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

Table 4B.12.4-5.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Double Mountain Fork Reservoir East Site, Stonewall County

Scientific Name	Common Name	Federal/State Status	Potential Occurrence
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant
Buteo regalis	Ferruginous Hawk	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Tympanuchus pallidicinctus	Lesser Prairie Chicken	C/SOC	Resident
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant
Charadrius alexandrinus	Snowy Plover	SOC	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Fishes			
Notropis buccula	Smalleye Shiner	C/SOC	X
Notropis oxyrhincus	Sharpnose Shiner	C/SOC	X
Mammals			
Mustela nigripes	Black-footed Ferret	LE/E	Extirpated
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Vulpes velox	Swift Fox	SOC	X
Reptiles			
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X

(USFWS 2003; TPWD 2004a, b)
* Nesting migrant; may nest in the county.
X = Occurs in county.
Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).
State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas. SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

A search of the Texas Wildlife Diversity Database[40] revealed no documented occurrences of rare or listed species within the vicinity of the proposed Double Mountain Fork East Reservoir site (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This

[40] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.

is based on the best information available to TPWD. However, this does not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.4.3.2.3 Wildlife Habitat

Approximately 10,814 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 1,274 acres of crops, 2,623 acres of Mesquite-Juniper Brush, 5,541 acres of Mesquite-Lotebush Brush/Shrub, 711 acres of Mesquite-Salt Cedar Brush/Woods, and 665 acres of exposed streambed.

A number of vertebrate species could occur within the Double Mountain Fork Reservoir East site as indicated by county occurrence records.[41] These include 8 species of frogs and toads, 3 species of turtles, 7 species of lizards and skinks, and 15 species of snakes. Additionally, 64 species of mammals could occur within the site or surrounding region[42] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.12.4.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that no archeological sites have been documented within the general vicinity of the proposed reservoir. However, the area has never been surveyed by a professional archeologist and the absence of documented sites may reflect the lack of investigation rather than the absence of archeological sites. Prior to reservoir inundation the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas

[41] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.
[42] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

Antiquities Code (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).

4B.12.4.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site as a reduction in the quantity of median monthly flow is projected downstream, but the reservoir would trap and/or dilute pollutants, providing some positive benefits to water quality immediately downstream. These benefits could be offset, however, by declines in dissolved oxygen through decreased flows and higher temperatures during summer periods. The project is expected to have negligible impacts to total discharge downstream and overall water quality in the Brazos River.

4B.12.4.4 Environmental Issues – West Site

4B.12.4.4.1 Existing Environment

The Double Mountain Fork West Reservoir site in Fisher and Stonewall Counties is within the Rolling Plains Ecological Region.[43] This region is located east of the High Plains, west of the West Cross Timbers and North Central Prairie, and north of the Edwards Plateau. It is characterized by nearly level to rolling topography, soft prairie sands and clays, juniper breaks and midgrass prairie. The physiognomy of the region varies from open, short to tall, scattered to dense grasslands to savannahs with bunch grasses. Most of the plains are rangeland, but dryland and irrigated crops are increasingly important. Poor range management practices of the past have increased the density of invasive plant species and have decreased the value of the land for cattle production. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[44] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[45]

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[43] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, *Vegetational Areas of Texas*, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[44] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[45] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983

The Seymour Aquifer, an unconsolidated sand and gravel aquifer, is the only major aquifer in the project area. It is formed by isolated alluvial deposits in 20 counties in north central Texas. The Seymour aquifer consists mainly of the scattered erosional remnants of the Seymour Formation of Pleistocene age, which consists of clay, silt, sand, and gravel, that were deposited by eastward-flowing streams. The aquifer generally has less than 100 feet of saturated thickness, but it is an important source of water for domestic, municipal, and irrigation needs.[46]

The physiography of the region includes loose surficial sand, gypsiferous red beds with dolomite, dissected red beds, terraces, severely eroded land, and flood-prone areas. The topography ranges from flat to rolling and steeply sloped, with densely dissected gullies and low hills in severely eroded areas and local shallow depressions in flood-prone areas along waterways.[47] The predominant soil associations in the project area are the Quinlan-Woodward, Paducah-Obaro, Carey-Woodward, and Spur-Yahola associations. The Quinlan-Woodward association consists of shallow to deep, sloping to moderately steep, loamy soils over sandstone and packsand. These soils are moderately to moderately rapidly permeable and well drained. The Paducah-Obaro association consists of deep and moderately deep, nearly level to gently sloping, loamy upland soils over sandstone. These soils are moderately permeable and well drained. The Carey-Woodward association consists of gently sloping to moderately sloping, deep and moderately deep, loamy soils on uplands cut by many drainageways. Spur-Yahola soils are nearly level, deep, moderately fine- and medium-textured, moderately permeable soils of the bottomland. These soils are moderately permeable and well drained.[48,49]

Four major vegetation types occur within the general vicinity of the proposed project: Mesquite (*Prosopis glandulosa*)–Lotebush (*Ziziphus obtusifolia*) Brush, Mesquite-Lotebush Shrub, Mesquite-Saltcedar (*Tamarix*) Brush/Woods, and crops[50]. Both the Mesquite–Lotebush Brush and Mesquite–Lotebush Shrub vegetation types consist of the following commonly associated plants: yucca (*Yucca* spp.), skunkbush sumac (*Rhus trilobata*), agarito (*Berberis*

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[46] United States Geological Service (USGS), *Ground Water Atlas of the United States*, http://capp.water.usgs.gov/gwa/index.html, 2004.
[47] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., *Land Resources of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.
[48] Schwartz, R.L., *Soil Survey of Fisher County, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1992.
[49] Goerdel, A.R., and L. Watson, *Soil Survey of Stonewall County, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1975.
[50] McMahan, C.A., R.F. Frye, and K.L. Brown, *The Vegetation Types of Texas*, Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

trifoliolata), elbowbush (*Forestiera angustifolia*), juniper (*Juniperus* sp.), tasajillo (*Opuntia leptocaulis*), cane bluestem (*Bothriochloa barbinodis*), silver bluestem (*Bothriochloa saccharoides*), little bluestem (*Schizachyrium scoparium*), sand dropseed (*Sporobolus cryptandrus*), Texas grama (*Bouteloua rigidiseta*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), red grama (*Bouteloua trifida*), tobosagrass (*Pleuraphis mutica*), buffalograss (*Buchloe dactyloides*), Texas wintergrass (*Nasella leucotricha*), purple three-awn (*Aristida purpurea*), Engelmann daisy (*Engellmania peristena*), broom snakeweed (*Gutierrezia sarothrae*), and bitterweed (*Hymenoxys odorata*). Commonly associated plants of Mesquite-Saltcedar Brush/Woods are creosotebush (*Larrea tridentata*), cottonwood (*Populus deltoides*), desert willow (*Chilopsis linearis*), giant reed (*Arundo donax*), seepwillow (*Baccharis* sp.), common buttonbush (*Cephalanthus occidentalis*), whitethorn acacia (*Acacia constricta*), Australian saltbush (*Atriplex semibaccata*), fourwing saltbush (*Atriplex canescens*), lotebush, wolfberry (*Lycium berlandieri*), tasajillo, guayacan (*Guaiacum angustifolium*), alkali sacaton (*Sporobolus airoides*), Johnsongrass (*Sorghum halepense*), saltgrass (*Distichlis spicata*), cattail (*Typha* spp.), bushy bluestem (*Andropogon glomeratus*), and chino grama (*Bouteloua ramosa*). The crops cover type consists of cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations.

4B.12.4.4.2 Potential Impacts

4B.12.4.4.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and at a gage location on the Brazos River, near Aspermont. The anticipated impact of this project would be lower variability in and substantial reductions in quantity of median monthly flows in both locations. The difference in variability of monthly flows at the proposed project site would be a factor of approximately 2.0 (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project $=2.17 \times 10^8$; sample variance with project $=1.06 \times 10^8$). The difference in variability of monthly flow in the Brazos River would also be a factor of approximately 2.0 (sample variance without project $=2.55 \times 10^8$; sample variance with project $=1.31 \times 10^8$). Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

At the project site, reductions in median monthly flows would range from 3.3 cfs (72 percent) in January to 101.3 cfs (93 percent) in June, as shown in Table 4B.12.4-6. Median monthly flows would be reduced by at least 90 percent in nine consecutive months (February through October) and by at least 70 percent in the other months. In the Brazos River, reductions would range from 2.5 cfs (52 percent) in January to 74.1 cfs (62 percent) in June, with the greatest percentage reduction (80 percent) in September (Table 4B.12.4-7). Reductions in median monthly flow values would be greater than 60 percent in March through October and 50 percent in the remaining months. This project would also result in a higher frequency of low-flow conditions at the project site. Without the project, the 85 percent exceedance value would be 1.51 cfs, but would be only 0.07 cfs with the project in place. The 85 percent exceedance values would be 1.61 and 1.08 in the Brazos River without and with the project, respectively. These reductions in flow at the project site would have substantial impacts on the instream biological community, including reduced habitat available for spawning fish in the spring and an increased likelihood of high water temperatures and impairment of other water quality parameters in the summer. However, the potential impacts of the reservoir would be greatest at the project site and reduced in downstream locations where additional flow inputs would moderate the effects.

Table 4B.12.4-6.
Median Monthly Streamflow: Double Mountain Fork West Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	4.7	1.3	3.3	72%
February	8.0	0.8	7.2	90%
March	6.3	0.4	5.9	94%
April	12.9	0.4	12.6	97%
May	67.2	2.4	64.9	96%
June	108.8	7.5	101.3	93%
July	34.9	2.8	32.1	92%
August	28.8	3.0	25.8	90%
September	61.1	1.6	59.5	97%
October	18.9	1.6	17.3	92%
November	12.8	1.4	11.4	89%
December	6.9	1.4	5.6	80%

Table 4B.12.4-7.
Median Monthly Streamflow: Brazos River Gage Near Aspermont

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	4.8	2.3	2.5	52%
February	7.7	3.1	4.6	59%
March	6.9	2.0	4.9	70%
April	14.0	5.0	9.0	64%
May	72.1	25.4	46.8	65%
June	118.9	44.8	74.1	62%
July	36.5	12.9	23.5	65%
August	32.9	10.1	22.8	69%
September	66.4	13.5	53.0	80%
October	20.7	7.0	13.7	66%
November	13.6	6.1	7.5	55%
December	7.8	3.5	4.3	55%

Although there would be biological impacts in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in downstream locations the Brazos River (this site is near the headwaters). It is also unlikely that this project would have an impact on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows to the estuary. As a new reservoir without a current operating permit, the Double Mountain Fork West Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.12.4.4.2.2 Threatened & Endangered Species

A total of 20 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.4-8). This group includes two reptiles, twelve birds, four mammals, and two fish species. Four bird species federally-listed as threatened or endangered could occur in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius*

Table 4B.12.4-8.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Double Mountain Fork Reservoir West Site, Stonewall and Fisher Counties

Scientific Name	Common Name	Federal/ State Status	Fisher County	Stonewall County
Birds				
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant	Migrant
Buteo regalis	Ferruginous Hawk	SOC	Migrant	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*	Migrant*
Tympanuchus pallidicinctus	Lesser Prairie Chicken	C/SOC	Resident	Resident
Charadrius montanus	Mountain Plover	SOC	Migrant*	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant	Migrant
Charadrius alexandrinus	Snowy Plover	SOC	Migrant	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant	Migrant
Fishes				
Notropis buccula	Smalleye Shiner	C/SOC	X	X
Notropis oxyrhincus	Sharpnose Shiner	C/SOC	X	X
Mammals				
Mustela nigripes	Black-footed Ferret	LE/E	Extirpated	Extirpated
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X	X
Myotis velifer	Cave Myotis Bat	SOC	X	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X	X
Vulpes velox	Swift Fox	SOC	X	X
Reptiles				
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X	-
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	-	X

* Nesting migrant; may nest in the county.

X = Occurs in county; - Does not occur in county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed.)

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Brazos, Leon, Madison, and Robertson Counties (2004); TPWD Texas Wildlife Diversity Database (2004), United States Fish and Wildlife Service (USFWS), Federally-listed as Threatened and Endangered Species of Texas, September 12, 2003.

melodus), and whooping crane (*Grus americana*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

A search of the Texas Wildlife Diversity Database[51] revealed no documented occurrences of rare or listed species within the vicinity of the proposed Double Mountain Fork West Reservoir site (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This is based on the best information available to TPWD. However, this does not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.4.4.2.3 Wildlife Habitat

Approximately 6,632 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 1,175 acres of crops, 2,890 acres of Mesquite-Lotebush Brush, 1,046 acres of Mesquite-Lotebush Shrub, 1,089 acres of Mesquite-Salt Cedar Brush/Woods, and 432 acres of exposed streambed.

A number of vertebrate species could occur within the Double Mountain Fork Reservoir West site as indicated by county occurrence records.[52] These include 9 species of frogs and toads, 5 species of turtles, 10 species of lizards and skinks, and 17 species of snakes. Additionally, 64 species of mammals could occur within the site or surrounding region[53] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.12.4.4.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that one archeological site has been documented within the general vicinity of the proposed reservoir. This site lies

[51] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.

[52] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.

[53] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

outside the currently proposed reservoir location. The site (41SN1) was recorded as an historic occupation with associated graves in 1970 and was recommended for further testing and excavation. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.12.4.4.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site as a reduction in the quantity of median monthly flow is projected downstream, but the reservoir would trap and/or dilute pollutants, providing some positive benefits to water quality immediately downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures during summer periods. The project is expected to have negligible impacts to total discharge downstream and overall water quality in the Brazos River.

4B.12.4.5 Engineering and Costing

Construction of the Double Mountain Fork East Reservoir project will cost approximately $160.8 million. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $12.4 million; this includes annual debt service and operation and maintenance. The cost for the available project safe yield of 31,800 acft/yr translates to an annual unit cost of raw water of $1.20 per 1,000 gallons, or $391/acft. A summary of the cost estimate is provided in Table 4B.12.4-9. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

Construction of the Double Mountain Fork West Reservoir project will cost approximately $115.2 million. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $8.8 million; this includes annual debt service and operation and maintenance. The cost for the available project safe yield of 30,400 acft/yr translates to an annual unit cost of raw water of $0.90 per 1,000 gallons, or $293/acft. A summary of the cost estimate is provided in Table 4B.12.4-10. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

4B.12.4.6 Implementation Issues (East and West Sites)

Both sites have been compared to the plan development criteria as shown in Table 4B.12.4-11 and both sites meet each criteria.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems; and,
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Table 4B.12.4-9.
Cost Estimate Summary for
Double Mountain Fork Reservoir (East Site)
(Second Quarter 2002 Prices)

Item	Estimated Costs for Facilities
Capital Costs	
Dam and Reservoir	$93,331,000
Total Capital Cost	**$93,331,000**
Engineering, Legal Costs and Contingencies	$32,666,000
Environmental & Archaeology Studies and Mitigation	$7,613,000
Land Acquisition and Surveying	$7,613,000
Interest During Construction (3 years)	$19,535,000
Total Project Cost	**$160,758,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$10,684,000
Purchase of Water (7,850 acft/yr @ $45.75 per acft)	$359,000
Operation and Maintenance	$1,400,000
Total Annual Cost	**$12,443,000**
Available Project Safe Yield (acft/yr)	31,800
Annual Cost of Water ($ per acft)	$391
Annual Cost of Water ($ per 1,000 gallons)	$1.20

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4B.12.4-10.
Cost Estimate Summary for
Double Mountain Fork Reservoir (West Site)
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir	$69,361,000
Total Capital Cost	**$69,361,000**
Engineering, Legal Costs, and Contingencies	$24,276,000
Environmental & Archaeology Studies and Mitigation	$3,777,000
Land Acquisition and Surveying	$3,777,000
Interest During Construction (3 years)	$13,998,000
Total Project Cost	**$115,189,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$7,655,000
Purchase of Water (4,300 acft/yr @ $45.75 per acft)	$197,000
Operation and Maintenance	$1,040,000
Total Annual Cost	**$8,892,000**
Available Project Safe Yield (acft/yr)	30,400
Annual Cost of Water ($ per acft)	293
Annual Cost of Water ($ per 1,000 gallons)	$0.90

Table 4B.12.4-11.
Comparison of Double Mountain Fork Reservoir (East and West Sites) to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable to High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. High impact
3. Cultural Resources	3. High impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.12.5 Turkey Peak Reservoir

4B.12.5.1 Description of Option

The proposed Turkey Peak Reservoir is located on Palo Pinto Creek immediately downstream and adjacent to Lake Palo Pinto, as shown in Figure 4B.12.5-1. The Turkey Peak Reservoir is located approximately 2 miles northwest of the city of Santo, approximately 1,000 feet upstream from the bridge over Palo Pinto Creek on FM4. The storage capacity of Turkey Peak Reservoir is 24,208 acft and covers 647 acres at an elevation of 867 ft-msl.

Lake Palo Pinto is located immediately upstream of the proposed Turkey Peak Reservoir and was constructed in 1964. The current normal pool elevation is 867 ft-msl. The reservoir currently inundates 2,498 acres and the estimated conservation storage in 2060 is 21,426 acft.[54]

The normal pool elevation of the Turkey Peak Reservoir will be the same as Lake Palo Pinto, only the existing dam and spillway at Lake Palo Pinto will separate the two reservoirs. The reservoirs would operate as a single reservoir with a pipe connecting both pools, as shown in Figure 4B.12.5-2. The combined Turkey Peak/Palo Pinto Reservoir will contain approximately 45,634 acft of conservation storage and inundate 3,145 acres at the full conservation storage level of 867 ft-msl.

The Turkey Peak Reservoir will provide close to the same storage as Lake Palo Pinto at the normal pool elevation while inundating an additional land area that is about one-fourth the surface area of the existing Lake Palo Pinto.

4B.12.5.2 Available Yield

Water potentially available for impoundment in the proposed Turkey Peak/Palo Pinto Reservoir was estimated using the Brazos G WAM. The reservoir was modeled by combining the 2060 storage capacity of Lake Palo Pinto with the proposed storage capacity of Turkey Peak Reservoir. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Brazos River without causing increased shortages to existing downstream rights. Firm yield was

[54] HDR Engineering, "Yield Studies for Lake Palo Pinto and the Proposed Turkey Peak Reservoir," June 2001.

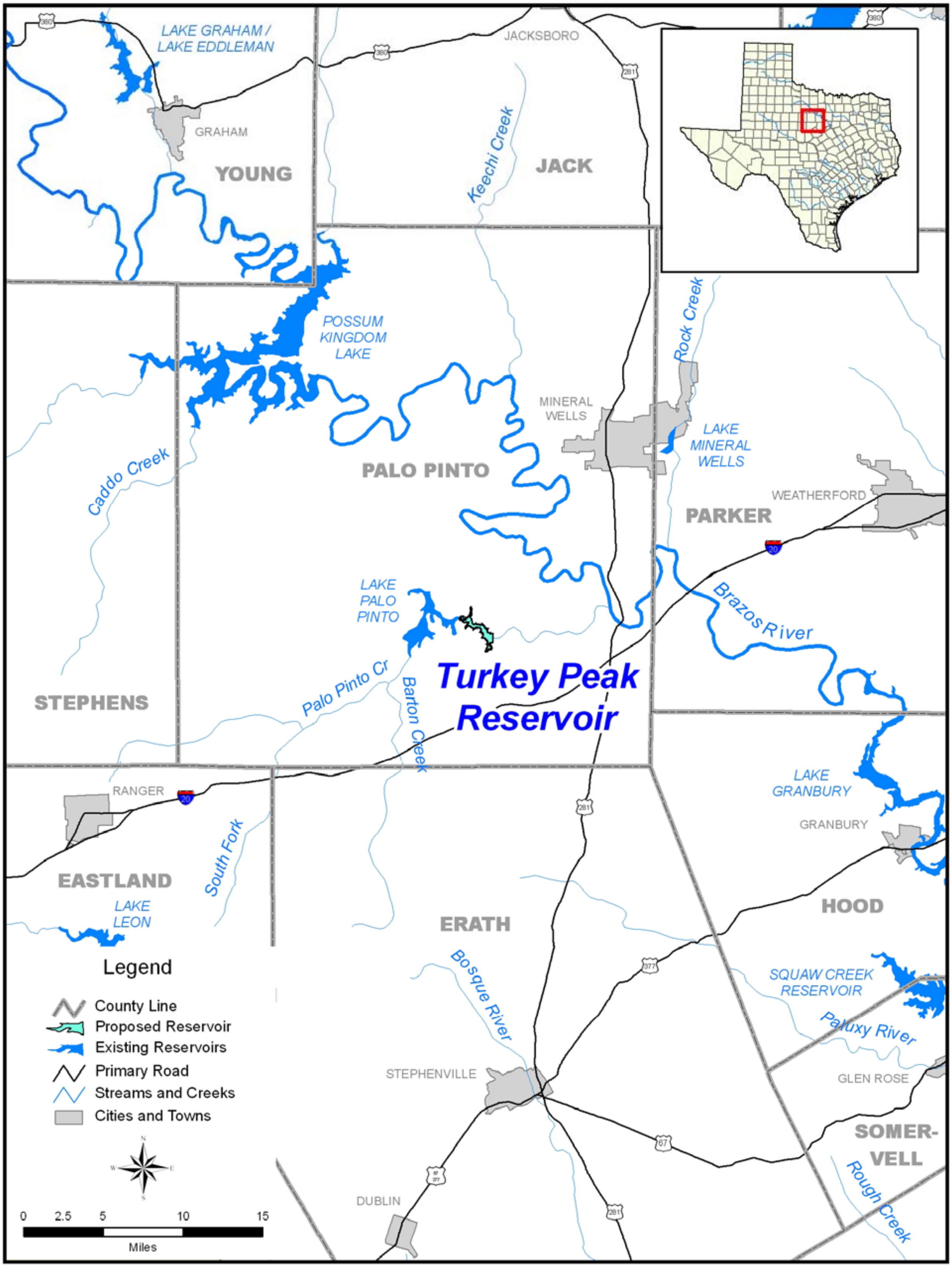


Figure 4B.12.5-1. Turkey Peak Reservoir

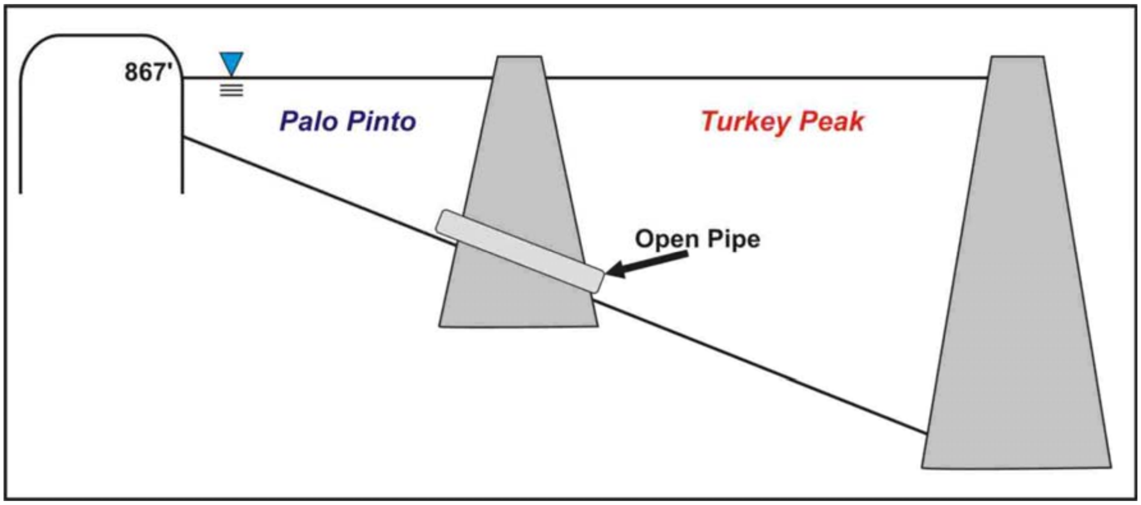


Figure 4B.12.5-2. Combined Turkey Peak/Palo Pinto Reservoir

computed subject to the Turkey Peak Reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass through requirements for Palo Pinto Creek are shown in Table 4B.12.5-1.

Table 4B.12.5-1.
Daily Natural Streamflow Statistics
for the Turkey Peak/Palo Pinto Reservoir

Month	***Median Flows – Zone 1 Pass-Through Requirements (cfs)***	***25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)***
January	5.5	0.1
February	8.0	0.3
March	9.1	0.0
April	9.4	0.5
May	16.1	1.2
June	12.9	3.3
July	2.5	0.0
August	1.0	0.0
September	0.8	0.0
October	3.0	0.0
November	4.0	0.0
December	4.0	0.0
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.0

The calculated firm yield of the Turkey Peak/Palo Pinto Reservoir is 19,130 acft/yr. The standalone firm yield of Lake Palo Pinto is 10,482 acft/yr. Therefore, the additional yield to the system attributed to Turkey Peak Reservoir is 8,648 acft/yr.

Figure 4B.12.5-3 illustrates the simulated Turkey Peak/Palo Pinto Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield of 19,130 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 40 percent of the time and above the Zone 3 trigger level (50 percent capacity) 73 percent of the time.

Figure 4B.12.5-4 illustrates the Palo Pinto Creek streamflow characteristics with the Turkey Peak Reservoir in place. The median streamflow in Palo Pinto Creek would be reduced 100 percent in all months except April, May, and June. The largest change would be a decline in median streamflow of 3.1 cfs during May. In June, the median streamflow with the Turkey Peak reservoir is greater than the median streamflow without the reservoir. When Palo Pinto Reservoir is modeled without Turkey Peak, the Palo Pinto storage is refilled from stream depletions. When Palo Pinto Reservoir is modeled with Turkey Peak, depletion from the stream is needed less often because the junior portion of Turkey Peak refills the Palo Pinto storage.

Figure 4B.12.1-4 also illustrates the Palo Pinto Creek streamflow frequency characteristics with the Palo Pinto/Turkey Peak Reservoir in place. While median monthly streamflows are reduced by the project, there is a minimal difference in streamflow frequencies in Palo Pinto Creek with the project

4B.12.5.3 Environmental Issues

4B.12.5.3.1 Existing Environment

The Turkey Peak Reservoir site in Palo Pinto County is within the Cross Timbers and Prairies Ecological Region.[55] This complex transitional area of prairie dissected by parallel timbered strips is located in north-central Texas west of the Blackland Prairies and east of the

[55] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.

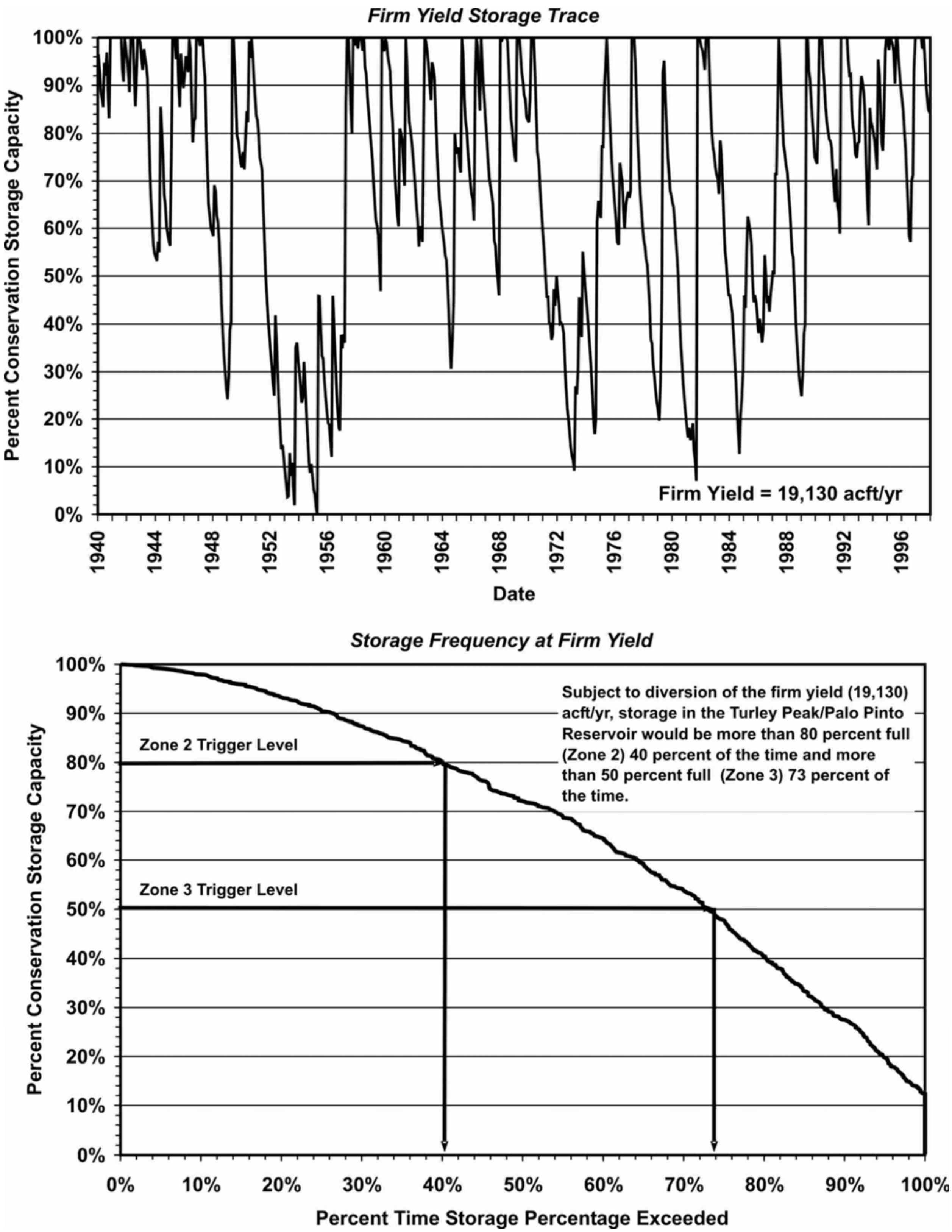
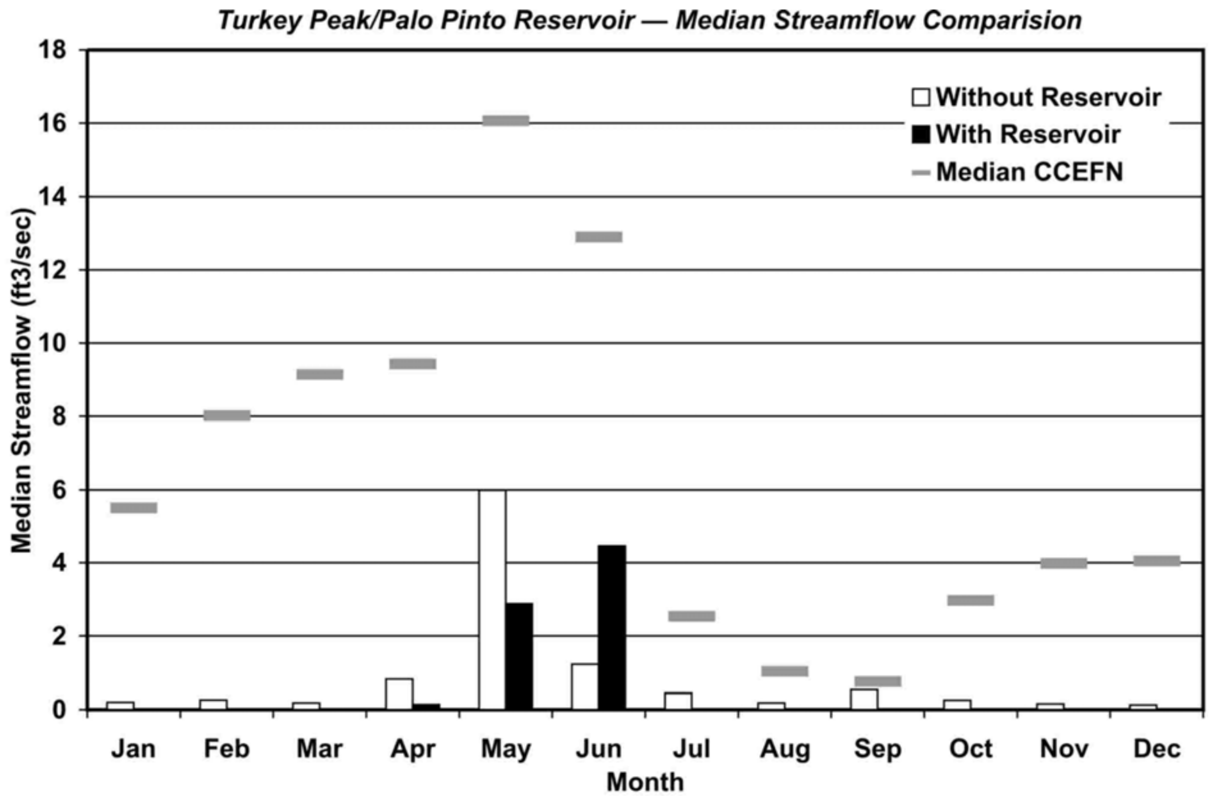


Figure 4B.12.5-3. Turkey Peak/Palo Pinto Reservoir Storage Considerations



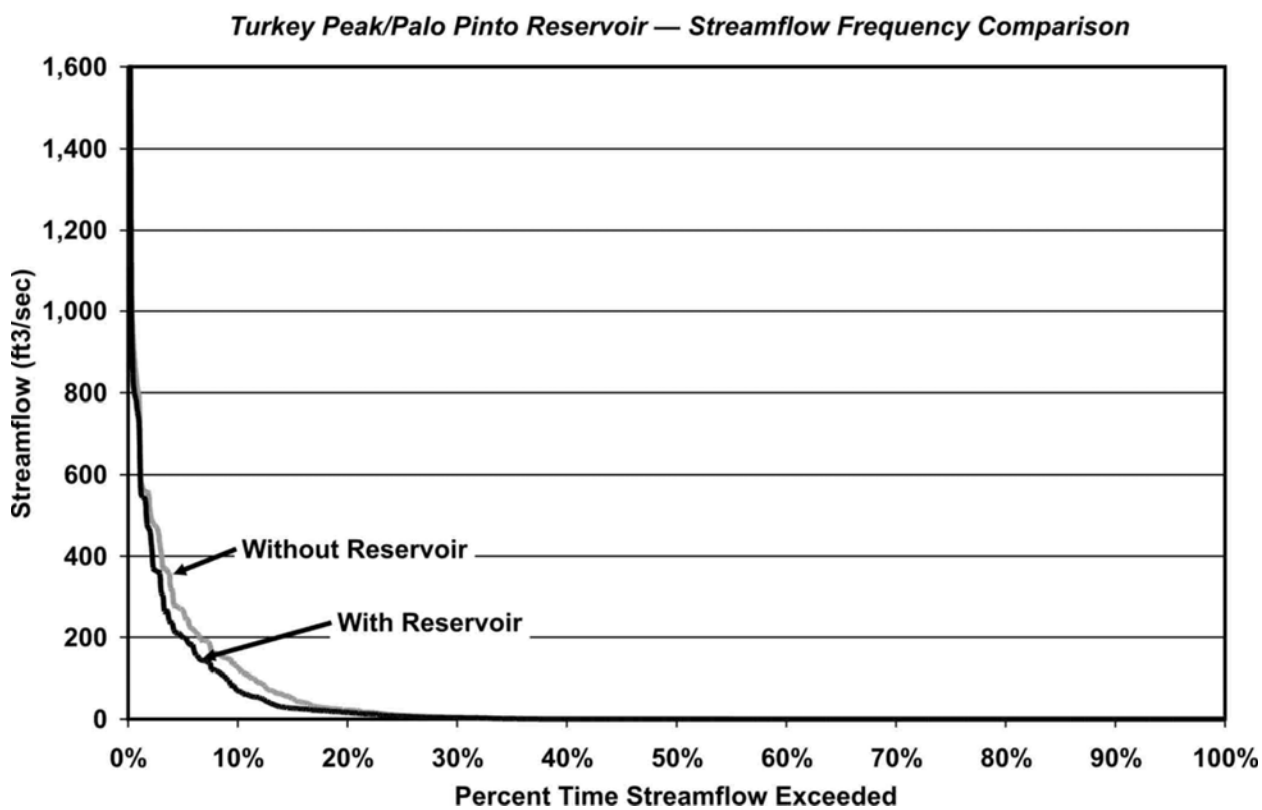


Figure 4B.12.5-4. Turkey Peak/Palo Pinto Reservoir Streamflow Comparisons

Rolling Plains Ecological regions, and north of the Edwards Plateau and Llano Uplift. The physiognomy of the region is oak and juniper woods and mixed grass prairie. Much of the native vegetation has been displaced by agriculture and development, and range management techniques, including fire suppression, have contributed to the spread of invasive woody species and grasses. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[56] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 28 and 32 inches.[57] No major or minor aquifers underlie the project area; the Trinity Aquifer, a major aquifer consisting of interbedded sandstone, sand, limestone, and shale of Cretaceous Age, lies east and south of the project area.[58]

The physiography of the region includes hard sandstone, mud, and mudstone (undifferentiated), ceramic clay and lignite/coal, terraces, and flood-prone areas. The topography ranges from flat to rolling, and from steeply to moderately sloped, with local shallow depressions in flood-prone areas along waterways.[59] The predominant soil associations in the project area are the Bosque-Santo and Bonti-Truce-Shatruce associations. Bosque-Santo soils are deep, nearly level to gently sloping, loamy soils, typically found on flood plains. Bonti-Truce-Shatruce soils are moderately deep and deep, gently sloping to steep, loamy, stony, and bouldery upland soils.[60]

Three major vegetation types occur within the general vicinity of the proposed project: Ashe Juniper (*Juniperus ashei*) Parks/Woods, Oak-Mesquite-Juniper (*Quercus-Prosopis-Juniperus*) Parks/Woods, and Live Oak (*Q. virginiana*)-Mesquite-Ashe Juniper Parks.[61] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Ashe Juniper Parks/Woods, which occurs principally on the slopes of hills in Stephens and Palo Pinto Counties, could include the following commonly associated plants: live oak, Texas oak (*Q. texana*), cedar elm (*Ulmus crassifolia*), mesquite (*Prosopis glandulosa*), agarito (*Mahonia*

[56] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[57] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[58] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[59] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., "Land Resources of Texas." Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.
[60] Moore, J.D., *Soil Survey of Palo Pinto County, Texas*, United States Department of Agriculture, Soil Conservation Service, in cooperation with Texas Agricultural Experiment Station, 1981.
[61] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

trifoliolata), tasajillo (*Opuntia leptocaulis*), western ragweed (*Ambrosia cumanensis*), scurfpea (*Psoralea* spp.), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Texas wintergrass (*Nasella leucotricha*), silver bluestem (*Bothriochloa saccharoides*), hairy tridens (*Erioneuron pilosum*), tumblegrass *(Schedonnardus paniculatus*), and red three-awn (*Aristida purpurea* var. *longiseta*). Oak-Mesquite-Juniper Parks/Woods, which occurs as associations or as a mixture of individual (woody) species stands on uplands, could include the following commonly associated plants: post oak (*Q. stellata*), Ashe juniper, shin oak (*Q. sinuata* var. *breviloba*), Texas oak, blackjack oak (*Q. marilandica*), live oak, cedar elm, agarito, soapberry (*Sapindus saponaria*), sumac (*Rhus* spp.), hackberry (*Celtis* spp.), Texas pricklypear (*Opuntia engelmannii* var. *lindheimeri*), Mexican persimmon (*Diospyros texana*), purple three-awn (*Aristida purpurea*), hairy grama (*Bouteloua hirsuta*), Texas grama (*B. texana*), sideoats grama, curly mesquite (*Hilaria belangeri*), and Texas wintergrass. Commonly associated plants of Live Oak-Mesquite-Ashe Juniper, found chiefly on level to gently rolling uplands and ridge tops of the Edwards Plateau, are Texas oak, shin oak, cedar elm, netleaf hackberry (*Celtis laevigata*), flameleaf sumac (*Rhus lanceolata*), agarito, Mexican persimmon, Texas pricklypear, kidneywood (*Eysenhardtia texana*), saw greenbrier (*Smilax bona-nox*), Texas wintergrass, little bluestem, curly mesquite, Texas grama, Hall's panicgrass (*Panicum hallii*), purple three-awn, hairy tridens, cedar sedge (*Carex planostachys*), two-leaved senna (*Senna roemeriana*), mat euporbia (*Chamaesyce serpens*), and rabbit tobacco (*Evax prolifera*)

4B.12.5.3.2 Potential Impacts

4B.12.5.3.2.1 Aquatic Environments including Bays & Estuaries

The anticipated impact of this project would be minimal influence on the variability of monthly flows but substantial reductions in the quantity of median monthly flows. The difference in variability of monthly flows would be a factor of about 1.2 (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place; sample variance without project=7.62 x 10^7; sample variance with project=6.18 x 10^7). This reduction in monthly flow variability would probably not have a substantial impact on the instream biological community or riparian species. The reduction in the quantity of median monthly flow in the project area would range from 0.1 cfs (100 percent) in December to 3.1 cfs (52 percent) in May, as shown in Table 4B.12.5-2. There would be a reduction in median monthly flow of 100 percent during nine months of the year, but there would be a substantial increase in flow (263%) during June. This project would also result in a higher frequency of low-flow conditions. Without the project, the monthly flow would be 0 cfs only 18% of the time, but with the project in place, the monthly flow would be 0 cfs for 53% of the time. These reductions in flow would likely have substantial impacts on the instream biological community near the project site.

Table 4B.12.5-2.
Median Monthly Streamflow: Turkey Peak Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	0.2	0.0	0.2	100%
February	0.3	0.0	0.3	100%
March	0.2	0.0	0.2	100%
April	0.8	0.1	0.7	83%
May	6.0	2.9	3.1	52%
June	1.2	4.5	-3.2*	-263%*
July	0.4	0.0	0.4	100%
August	0.2	0.0	0.2	100%
September	0.5	0.0	0.5	100%
October	0.3	0.0	0.3	100%
November	0.2	0.0	0.2	100%
December	0.1	0.0	0.1	100%
*Represents increase in flow under With Project conditions				

Although there would be biological impacts in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in downstream locations on the Brazos River. It is also unlikely that this project would have an impact on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows to the estuary. As a new reservoir without a current operating permit, the Turkey Peak Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.12.5.3.2.2 Threatened & Endangered Species

A total of 20 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.5-3). This group includes 4 reptiles, 12 birds, 2 mammals, and 2 fish species. Six bird species federally-listed as threatened or endangered could occur in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), black-capped vireo (*Vireo atricapillus*), golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

A search of the Texas Wildlife Diversity Database[62] revealed the documented occurrence of two colonial water bird rookeries within the vicinity of the proposed Turkey Peak Reservoir (as noted on representative 7.5-minute quadrangle maps that include the project site). These data arenot a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.5.3.2.3 Wildlife Habitat

Approximately 647 additional acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 327 acres of Juniper Woodland, 160 acres of Oak Mesquite-Juniper Parks, 88 acres of Grassland, and 72 acres of Riparian Woods.

A number of vertebrate species would be expected to occur within the Turkey Peak Reservoir site as indicated by county occurrence records.[63] These include 8 species of frogs and toads, 6 species of turtles, 11 species of lizards and skinks, and 17 species of snakes.

[62] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.
[63] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.

Table 4B.12.5-3.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Turkey Peak Reservoir Site, Palo Pinto County

Scientific Name	*Common Name*	*Federal/State Status*	*Potential Occurrence*
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant
Vireo atricapillus	Black-capped Vireo	LE/E	Migrant*
Dendroica chrysoparia	Golden-cheeked Warbler	LE/E	Migrant*
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Fishes			
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X
Canis lupus	Gray Wolf	LE/E	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Reptiles			
Nerodia harteri	Brazos Water Snake	SOC/T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, Annotated County List of Rare Species for Palo Pinto County, (Nov. 6, 2003); TPWD Texas Wildlife Diversity Database (2004); USFWS, Federally-listed as Threatened and Endangered Species of Texas, Sept. 12, 2003.

Additionally, 79 species of mammals could occur within the site or surrounding region[64] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.12.5.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 99 archeological sites have been documented within the general vicinity of the proposed reservoir. Researchers from the University of Texas recorded 49 of these sites as part of the Village Bend archeological survey in 1980. These sites, which lie outside the currently proposed reservoir, represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.12.5.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site as a reduction in the quantity of median monthly flow is projected downstream, but the reservoir would trap and/or dilute pollutants, providing some positive benefits to water quality immediately downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures during summer periods. The project is expected to have negligible impacts to total discharge downstream and overall water quality in the Brazos River.

[64] Davis, W.B., and D.J. Schmidly, “The Mammals of Texas – Online Edition,” Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

4B.12.5.4 Engineering and Costing

Cost estimates for the Turkey Peak/Palo Pinto Reservoir were originally prepared by HDR Engineering in 2001[65] and those costs were updated for this study to reflect current costs. Construction of the Turkey Peak/Palo Pinto Reservoir project will cost approximately $46.1 million (Table 4B.12.5-4). This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services.

Table 4B.12.5-4. Cost Estimate Summary for Turkey Peak/Lake Palo Pinto Reservoir (Second Quarter 2002 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool 24,208 acft, 647 acres, 867 ft-msl)	$18,298,000
Relocations & Other	6,142,000
Total Capital Cost	**$24,440,000**
Engineering, Legal Costs and Contingencies	$8,554,000
Environmental & Archaeology Studies and Mitigation	3,395,000
Land Acquisition and Surveying (0 acres)	3,395,000
Interest During Construction (4 years)	6,366,000
Total Project Cost	**$46,150,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$699,000
Reservoir Debt Service (6 percent for 40 years)	2,428,000
Operation and Maintenance	
Dam and Reservoir	274,000
Total Annual Cost	**$3,401,000**
Available Project Yield (acft/yr)	**8,648**
Annual Cost of Water ($ per acft)	**$393**
Annual Cost of Water ($ per 1,000 gallons)	**$1.21**

[65] HDR Engineering, "Yield Studies for Lake Palo Pinto and the Proposed Turkey Peak Reservoir", June 2001.

The annual project costs are estimated to be $3.4 million; this includes annual debt service, operation and maintenance, and pumping energy costs. The cost for the estimated increase in system yield of 8,648 acft/yr translates to an annual unit cost of raw water of $1.21 per 1,000 gallons, or $393/acft. A summary of the cost estimate is provided in Table 4B.12.5-4. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

4B.12.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria as shown in Table 4B.12.5-5, and the options meets each criterion. A summary of the implementation steps for the project is presented below.

Table 4B.12.5-5.
Comparison of Turkey Peak Reservoir
to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable to High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. Moderate impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if State-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and,
- Possible relocations or removal of residences, utilities, roads, or other structures.

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4B.12.6 Little River Reservoir

4B.12.6.1 Description of Option

The proposed new reservoir on the Little River would be located on the main stem of the Little River just upstream from its confluence with the Brazos River near the City of Cameron, as shown in Figure 4B.12.6-1. The smaller, at elevation 310 ft-msl, would provide a surface area of 20,690 acres and a storage volume of about 321,000 acft (Appendix N). The larger, full development of the site would represent a surface elevation of 330 ft-msl, with a surface area of 35,590 acres and a storage volume of about 877,770 acft.

The project would have its greatest usefulness as part of the BRA system, meeting water needs in Williamson County or downstream in Region H.

4B.12.6.2 Available Yield

Water potentially available for impoundment in the proposed Littler River Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Little River without causing increased shortages to existing downstream rights. Firm yield was computed subject to the Little River Reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the Little River are shown in Table 4B.12.6-1.

The available firm yield of the proposed reservoir is relatively large, since about a quarter of the approximately 7,584 square mile drainage area is uncontrolled. For the smaller size reservoir (310’ elevation), the estimated yield is about 69,400 acft/yr. The fully developed site (330’ elevation) would have a yield of about 129,000 acft/yr (Appendix N).

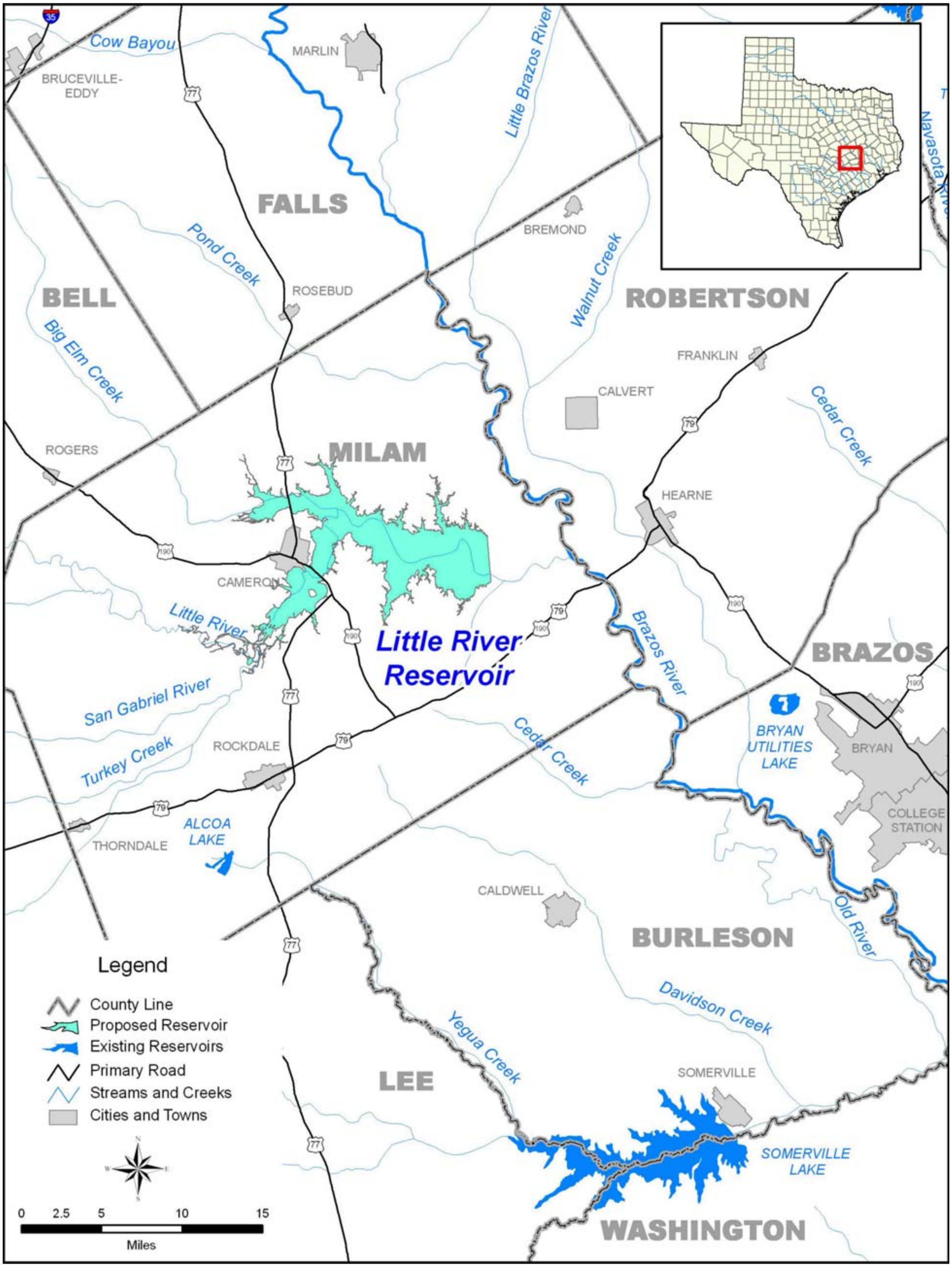


Figure 4B.12.6-1. Little River Reservoir

Table 4B.12.6-1.
Daily Natural Streamflow Statistics
for the Little River Reservoir

Month	***Median Flows - Zone 1 Pass Through Requirements (ft^3/sec)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (ft^3/sec)***
January	519	195
February	738	245
March	752	280
April	1,034	308
May	2,128	556
June	1,404	445
July	511	184
August	258	101
September	245	101
October	275	89
November	383	143
December	450	180
Zone 3 (7Q2) Pass-Through Requirement (ft^3/sec):		72

Figure 4B.12.6-2 illustrates the simulated Little River Reservoir storage levels at both elevations (310’ and 330’) for the 1940 to 1997 historical period, subject to the firm yields of 69,400 acft/yr and 129,000 acft/yr, respectively. For the 310’ elevation reservoir, the simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 72 percent of the time and above the Zone 3 trigger level (50 percent capacity) 93 percent of the time. For the 330’ elevation reservoir, the simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 76 percent of the time and above the Zone 3 trigger level (50 percent capacity) 91 percent of the time.

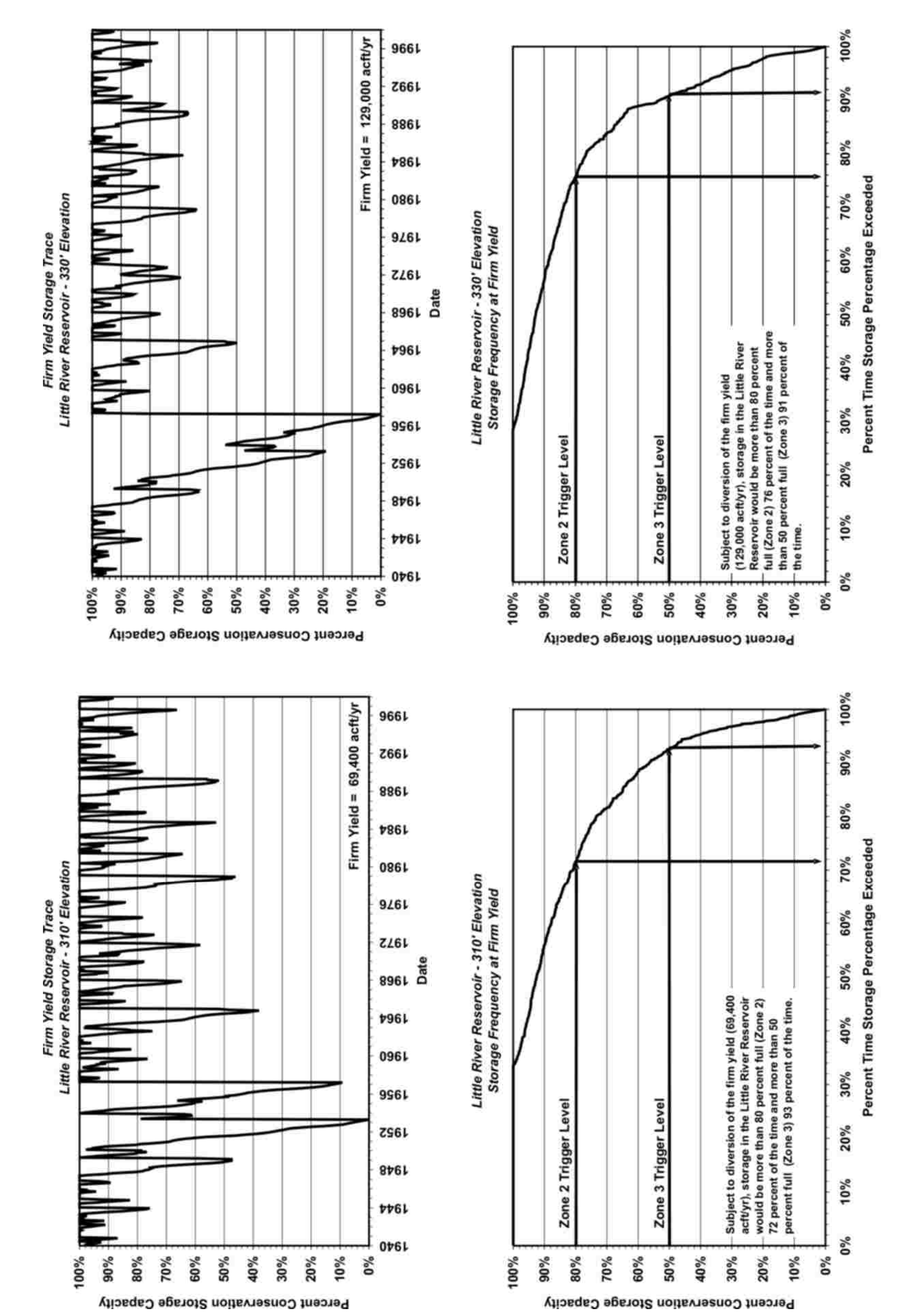


Figure 4B.12.6-2. Little River Reservoir Storage Considerations at 310' & 330' Elevation

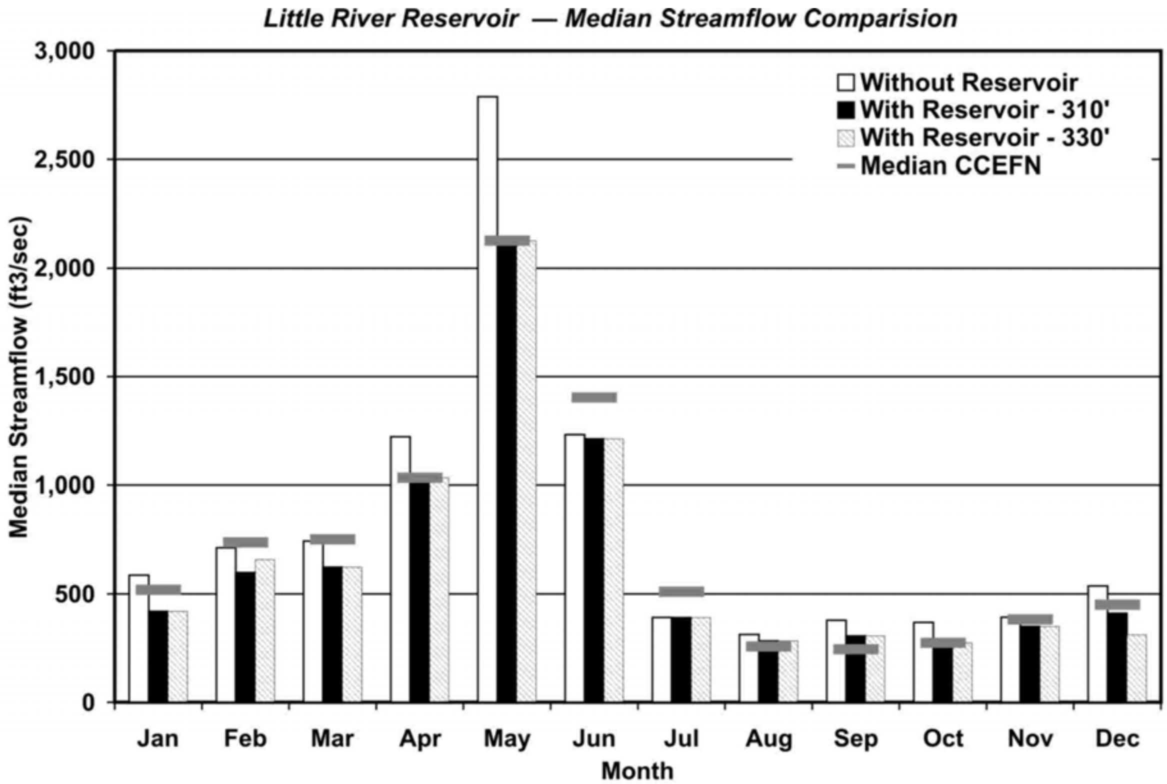
Figure 4B.12.6-3 illustrates the Little River streamflow characteristics and streamflow frequency characteristics at both elevations (310' and 330') with the Little River Reservoir in place. The proposed project at either conservation pool will have only a moderate impact on the streamflow since most the inflows will have to be passed to satisfy downstream senior water rights and/or environmental flows. Firm yield was computed subject to the Little River Reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass through requirements for the Little River are shown in Table 4B.12.6-1.

The available firm yield of the proposed reservoir is relatively large, since about a quarter of the approximately 7,584 square mile drainage area is uncontrolled. For the smaller size reservoir (310' elevation), the estimated yield is about 69,400 acft/yr. The fully developed site (330' elevation) would have a yield of about 129,000 acft/yr (Appendix N).

The effect of sedimentation on the firm yield for the both conservation pool elevations (310' and 330') was determined over a 60-year period. The rate of sediment production for the proposed Little River Reservoir was estimated based on available data from the Soil Conservation Service and from volumetric surveys in surrounding reservoirs (Appendix N). It was determined that the firm yield of the 330 ft-msl elevation reservoir would be reduced by 3,800 acre-feet/year (3% of the initial value) over 60 years. The firm yield of the 310 ft-msl elevation reservoir would reduced by 16,800 acre-feet or by 24% of the initial value. The critical drought period for the 330 ft-msl elevation option is April 1947 to March 1957. This period is 5-years longer than the critical period for the 310 ft-msl elevation option. Therefore, the 310 ft-msl reservoir is impacted to a larger degree than the 330 ft-msl elevation reservoir. Table 4B.12.6-2 summarizes the impact of sedimentation on the firm yield of the reservoir.

Table 4B.12.6-2.
Impact of Sedimentation on Firm Yields of the Little River Reservoir

Conservation Pool	Initial Firm Yield (acft/yr)	Firm Yield after 60 Years (acft/yr)	Loss of Yield (acft/yr)
330 ft-msl	124,000	120,200	3,800
310 ft-msl	69,400	52,600	16,800



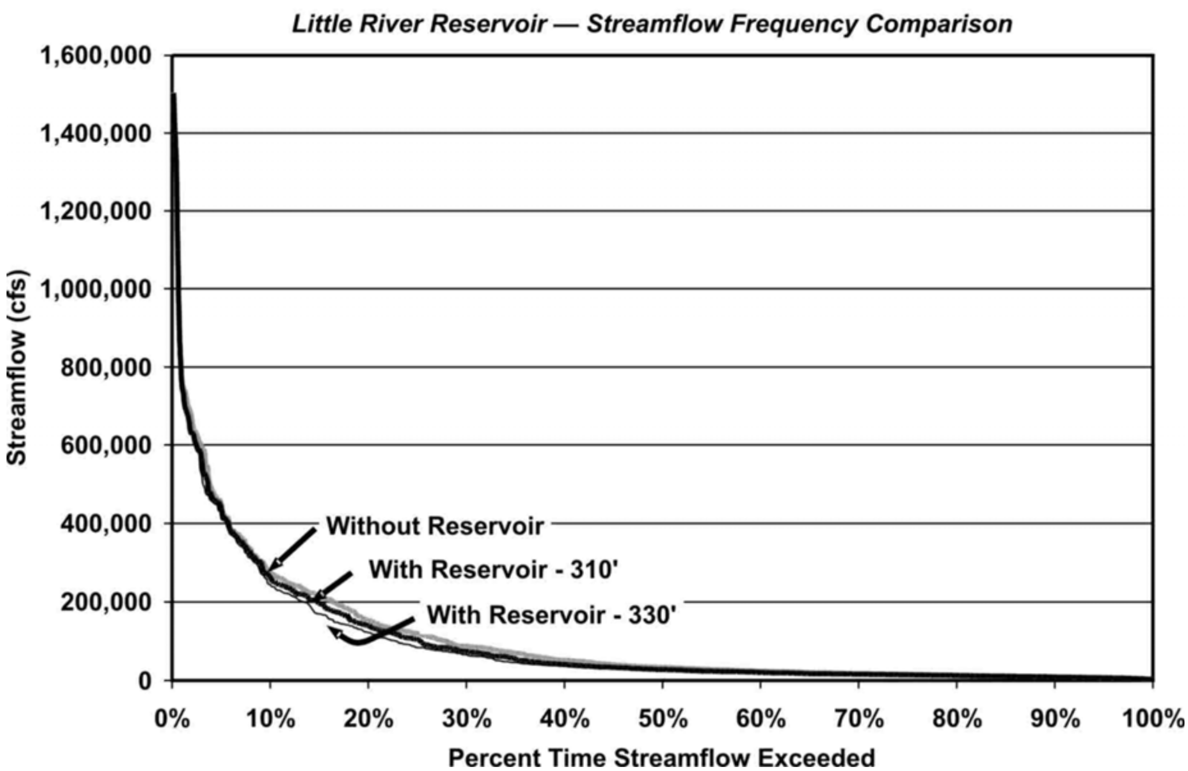


Figure 4B.12.6-3. Little River Streamflow Comparison

4B.12.6.3 Environmental Issues (Normal Pool Elevation = 310 ft-msl)

4B.12.6.3.1 Existing Environment

The proposed Little River Reservoir site (normal pool at 310 ft-msl) in Milam County is in a transitional zone with the Blackland Prairies Ecological Region to the west and the Post Oak Savannah Ecological Region to the east.[66] This region is characterized by level to rolling topography, with interspersed grassland and woodland, with soils ranging from the deep, fertile, black soils of the Blackland Prairies region to the shallow, nearly impervious clay pan of the Post Oak Savannah region. The original physiognomy of the region varied from medium to tall broad-leaved deciduous and some needle-leaved evergreen trees to medium-tall dense grasslands with scattered open groves of deciduous trees in minor prairies.[67] The climate is characterized as subtropical humid with warm summers. Average annual precipitation ranges between 36 and 40 inches.[68] The Carrizo-Wilcox Aquifer is the only major aquifer underlying in the project area, though the downdip portion of the Trinity Aquifer lies nearby to the west.[69] The Queen City and Brazos River Alluvium minor aquifers are to the south and east of the project area, respectively.

The physiography of the region includes ceramic clay and lignite/coal, recharge sands, limestone sand and gravel, expansive clay mud, terraces, and flood-prone areas. The topography is flat to rolling with local escarpments, with local shallow depressions in flood-prone areas along waterways.[70] The predominant soil types in the project area are primarily sandy loams and loamy sands, with a small amount of silty clay.[71]

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak Woods/Forest, Post Oak Woods, Forest, and Grassland Mosaic, and crops.[72] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites.

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[66] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, *Vegetational Areas of Texas*, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960

[67] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.

[68] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.

[69] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

[70] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., *Land Resources of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

[71] Soil Conservation Service (NRCS), *Soil Survey for Milam County, Texas*, Soil Conservation Service, United States Department of Agriculture, 1979.

[72] McMahan, C.A., R.F. Frye, and K.L. Brown, *The Vegetation Types of Texas*, Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

Post Oak Woods/Forest and the Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry *(Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.12.6.3.2 Potential Impacts

4B.12.6.3.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated with the proposed reservoir maintained at 310 feet (ft) above sea level and a diversion of 69,400 acre-feet of water per year. Overall, this alternative would have little influence on variability of monthly flows and result in a moderate reduction in quantity of median monthly flows in the Little River. The minimal reduction in variability of monthly flow values (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with each alternative in place; sample variance without project =2.95×10^{10}; sample variance with project at 310-ft elevation =2.82×10^{10}) would probably not have much impact on the instream biological community or riparian species.

The reduction in the quantity of median monthly flow in the area of the project would range from 0 cfs in June and July to 530.3 cfs (19 percent) in May, as shown in Table 4B.12.6-3. The highest reduction (26 percent) would occur in October, while the lowest (<10 percent) would occur during the summer months of June, July and August. The change in low-flow conditions (85% exceedance values) would also be minimal. Without the project, the 85% exceedance value for monthly flow would be 185 cfs while under this alternative the value would be 176 cfs. Overall, these reductions in flow should not have substantial impacts on the biological community since the highest reductions are anticipated in fall and winter. Reductions during these months are less critical than during spring and summer when flows are naturally lower and many aquatic species spawn.

Any reduction in discharge associated with this reservoir alternative in the Little River would have minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Little River Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4B.12.6-3.
Median Monthly Streamflow: Little River Reservoir at 310-ft elevation

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	586.6	469.8	116.8	20%
February	713.2	609.9	103.3	14%
March	744.1	623.8	120.3	16%
April	1,222.1	1,073.2	148.9	12%
May	2,788.2	2,257.9	530.3	19%
June	1,231.9	1,231.9	0.0	0%
July	392.1	392.1	0.0	0%
August	313.2	285.9	27.2	9%
September	379.4	307.3	72.1	19%
October	369.2	274.5	94.7	26%
November	393.1	355.2	37.9	10%
December	537.5	411.0	126.5	24%

4B.12.6.3.2.2 Threatened & Endangered Species

According to county occurrence records,[73] a total of 23 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 1 amphibian, 3 reptiles, 10 birds, 2 mammals, 5 fish species, and 2 plant species (Table 4B.12.6-4). One amphibian, two bird species, one fish species, and one plant

[73] Texas Parks and Wildlife Department (TPWD), Annotated County List of Rare Species for Stonewall County, 2004a.

Table 4B.12.6-4.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Little River Reservoir Site (Normal Pool Elevation = 310 ft-msl)

Scientific Name	Common Name	Federal/State Status	Potential Occurrence
Amphibians			
Bufo houstonensis	Houston Toad	LE/E	X
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant
Buteo albonotatus	Zone-tailed Hawk	SOC/T	Migrant*
Fishes			
Anguilla rostrata	American Eel	SOC	X
Cycleptus elongatus	Blue Sucker	SOC/T	X
Micropterus treculi	Guadalupe Bass	SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Mammals			
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Reptiles			
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Spiranthes parksii	Navasota ladies'-tresses	LE/ E	X
Polygonella parksii	Parks' jointweed	SOC	X

X = Occurs in county, - does not occur in county, * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Milam County (25 September 2004); TPWD Texas Wildlife Diversity Database (2004); USFWS (2004).

species federally-listed as threatened or endangered could occur in the project area. These include the Houston toad (*Bufo houstonensis*), interior least tern (*Sterna antillarum athalassos*), whooping crane (*Grus americana*), sharpnose shiner (*Notropis oxyrhynchus*), and Navasota ladies'-tresses (*Spiranthes parksii*). Habitat for the Houston toad includes pine and/or oak woodlands underlain by pockets of deep sandy soils with temporary pools of water available for breeding.[74] The Houston toad inhabits pools and stock tanks in area with a sandy substrate. The interior least tern and whooping crane are seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. The sharpnose shiner inhabits turbid sections of the Brazos and Colorado River drainages, in areas with a sand, gravel, and clay-mud bottom. Navasota Ladies'-tresses occurs on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon.

A search of the Texas Wildlife Diversity Database[75] revealed two documented occurrences of rookeries within the vicinity of the proposed Little River Reservoir (as noted on representative 7.5 minute quadrangle map(s) that include the project site). Both rookeries are described by TPWD as nesting colonies of the great egret, little blue heron, and cattle egret; one of the rookeries also has had nesting snowy egrets. These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.6.3.2.3 Wildlife Habitat

Approximately 20,687 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 16,493 acres of cropland, 549 acres of Post Oak Woods, and 3,645 acres of mixed Riparian Forest. Some new shoreline and wetland habitat would be created that would be associated with the land-water interface. Vegetation would change from streamside plant species adapted to short-term inundation and over bank

[74] U.S. Fish and Wildlife Service, *The Endangered Houston Toad*, http://ifw2es.fws.gov/HoustonToad/, 2004.

[75] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, Annotated County Lists of Rare Species for Throckmorton, Jones, Haskell, and Shackelford Counties, 2004.

flooding, to aquatic or semi-aquatic species adapted to hydric or semi-hydric conditions along the shoreline.

A number of vertebrate species could occur within the vicinity of the Little River Reservoir site as indicated by county occurrence records.[76] These include 4 species of salamanders and newts, 16 species of frogs and toads, 9 species of turtles, the American alligator, 10 species of lizards and skinks, and 21 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[77] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

The habitat value of occurring cover types has been estimated based on methodology developed by the Texas Parks and Wildlife Department[78] and other previous information.[79] Based on these estimates, preliminary mitigation requirements to compensate or offset the loss of inundated habitats are summarized in Table 4B.12.6-5.

4B.12.6.3.2.4 Cultural Resources

A search of the Texas Historical Commission's online database indicates that one Official State Historical Marker is located within the proposed reservoir footprint. This marker, erected in 1936, commemorates the landing of the steamboat Washington in the winter of 1850-1851. The Washington was the "first, last and only" steamboat to navigate the Little River. At least five cemeteries are mapped within the proposed reservoir. These include: Turnham-McCown Cemetery, Old City Cemetery, Milam Grove Cemetery, Pebble Grove Cemetery, and Oxsheer-Smith Cemetery. No properties listed in the National Register of Historic Places (NRHP) or State Archeological Landmarks (SALs) occur within the proposed reservoir footprint.

[76] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.

[77] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

[78] Texas Parks and Wildlife Departement (TPWD), *Wildlife Habitat Appraisal Procedure*. PWD RP N7100-145, http://www.tpwd.state.tx.us/conserve/whap/mainwhap.html, 1995.

[79] Texas Parks and Wildlife Department (TPWD), *Texas Water and Wildlife*, PWD-BK-7100-147, 1990

Table 4B.12.6-5.
Estimated Mitigation Requirements for Cover Types Inundated by the Proposed Little River Reservoir (Normal Pool Elevation = 310 ft-msl)

Cover Type	*Acres Lost*	*Habitat Quality Rating*[1]	*Habitat Units Lost*[2]	*Potential HQ Gain*[3]	*Compensation Acreage Requirements*[4]
Mixed Riparian Forest	3,645	0.75	2, 733.8	0.25	10,935
Post Oak Woods	549	0.58	318.4	0.42	758
Crops	16,493	0.20	3,298.6	0.80	4,123
Total	**20,687**		**6,350.8**		**15,816**

[1]Habitat Quality Ratings extrapolated from ratings of similar habitats within the same general region conducted by TPWD (1990).

[2]Values represent the product of Acres Lost multiplied by Habitat Quality Rating.

[3]Represents future maximum gain in habitat value (1.0 - Habitat Quality Rating Value) through intensive management of a mitigation area with similar baseline habitat value.

[4]Represents compensation required to fully offset loss of the cover type (Habitat Units lost ÷ Potential HQ gain); calculations derived from TPWD (1995); federal/state permits historically have required compensation only for jurisdictional waters of the U.S., including wetlands.

A total of 102 archeological sites have been documented within the general vicinity of the proposed reservoir. These sites represent a variety of historic and prehistoric site types. Five of these sites (41MM12, 41MM13, 41MM14, 41MM130, and 41MM292) occur within the proposed reservoir's normal pool at elevation 310 ft-msl. Four of the five sites within the normal pool are recorded as prehistoric artifact scatters and/or prehistoric occupation sites. The remaining site (41MM13) is recorded as a prehistoric occupation site and historic artifact scatter. Espey Huston & Associates recommended site 41MM13 for further testing in 1979. A total 22 prehistoric archeological sites have been documented along Cannonsnap Creek in the immediate vicinity of the proposed reservoir site. While these sites do not appear to occur within the normal pool, it is considered likely that similar sites (or undocumented components of these previously recorded sites) may exist within the proposed reservoir.

Prior to reservoir inundation, a cultural resources survey must be conducted to determine if any other cultural resources are present within the normal pool. Any cultural resources identified during survey will need to be formally assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect (APE) of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.12.6.3.2.5 Threats to Natural Resources

Identified threats to natural resources were identified in Section 1.7.3.2 as lower stream flows, declining water quality, and reduced inflows to reservoirs. This project is expected to have slight effects on the variability of median monthly flows, and not substantially change low flow conditions (flows exceeded 85% of the time). It is unlikely this project would have any substantial influence on total discharge in the Brazos River, freshwater inflows to the Brazos River estuary, or water quality downstream.

4B.12.6.3.3 Mineral Rights

Without researching courthouse deeds, the ownership of minerals contained within the footprint of the proposed Little River Reservoir normal pool elevation of 310 ft above sea level is unknown. However, according to known oil, gas, and other mineral recovery sites mapped from databases maintained by the Texas Railroad Commission[80], there is one gas well, one shut-in (not producing) oil well, one oil/gas well, and six dry holes located within the 310 ft-msl elevation footprint of the reservoir. (Table 4B.12.6-6).

Table 4B.12.6-6.
Oil and Gas Wells in the Little River Reservoir Footprint
(310 ft-msl Pool Elevation)

Type of Well	*Total Number*
Gas Well	1
Shut-In Oil Well	1
Oil/Gas Well	1
Dry Hole	6

Source: Railroad Commission of Texas, 2005.

[80] Texas Railroad Commission (TRC), Mineral Recovery Databases, 2005

4B.12.6.3.3.1 Mitigation Costs for Minerals

Plugging Existing Wells

As noted in Table 4B.12.6-6 the Texas Railroad Commission reports one gas well, one shut-in oil well, one oil/gas well, and six dry holes located within the 310 ft-msl elevation footprint of the proposed Little River Reservoir. Assuming the dry holes are properly plugged, the development of the proposed reservoir would require the plugging of three existing wells.

Estimated costs for plugging these wells is available from the Railroad Commission's state-funded well plugging program. This program was established to locate, prioritize, and plug wells that have been abandoned by non-compliant oil and gas operators that may pose a risk to the environment or public safety. The program has, as of March 2003, plugged a total of 162 abandoned wells in Milam County, Texas at a cost of $317,069.11 or an average of $1,957 per well (TRC, 2003). At an estimated cost of $1,957 per well, plugging the three wells in the reservoir footprint would cost about $5,871.

Raising Existing Wells and Relocating Storage Tanks

Another mitigation option would be to raise existing wells and relocate storage tanks out of the reservoir footprint. Although costs for this option have not been explicitly estimated, this option would result in oil and gas production facilities remaining on the surface of the reservoir – an outcome most project sponsors would probably seek to avoid.

Acquisition of Mineral Rights

Reservoir project sponsors could acquire the mineral rights for the property to be inundated. Texas law holds that the mineral estate is dominant over the surface estate.[81] This rule has serious implications for surface owners who are not mineral owners. Texas courts have held that mineral leases are not mere rental agreements as the name implies. Instead, they are actually deeds granting limited ownership rights to mineral lessees for as long as the lease continues. Thus, during the tenure of a lease, the mineral lessee enjoys the same rights to use the surface as any other mineral owner.

These property rights can be stated in the following way: mineral lessees can use as much of the surface as is *reasonably necessary* for mineral exploration and production. This privilege

[81] Fambrough, J., *Subdivision Drill Sites, A Reprint from the Real Estate Center Journal,* Texas A&M University, Publication 690, November 1997.

springs from the executed mineral lease. Independent permission from the surface owner is not necessary. No responsibility exists for restoring the surface or for paying surface damages. Liability arises only when the lessee goes beyond what is reasonably necessary or negligently injures the surface. The oil company or other entity leasing the minerals is the *lessee* and the mineral owner is the *lessor*.[82] The cost of mineral right acquisition would have to be estimated from a detailed examination of the Milam County Tax Office appraisals for the affected properties. This appraisal project would be undertaken at a latter stage of the project development, but the costs to acquire mineral rights in an actively producing region could be substantial.

Lignite Resources

Approximately 6,400 acres of the proposed reservoir at the 310 ft-msl pool elevation are underlain by lignite resources,[83] about 31% of the 20,687-acre footprint. This would imply acquisition of the mineral rights for the 6,400 acres affected. The cost of mineral right acquisition would require an appraisal study that, as in the case of oil and gas resources, would be undertaken at a latter stage of the project development. The presence of lignite resources in addition to oil and gas resources would, however, increase the cost of mineral rights substantially.

Sand and Gravel Resources

A search of the TxDOT Aggregate Quarry and Pit Safety Program Inventory File (TxDOT 2005) for pits and quarries in Milam County indicated two active aggregate quarries. This data were not sufficient to confirm whether these quarries were located within the reservoir footprint.

4B.12.6.3.4 Socioeconomic Effects

This section characterizes the potential socioeconomic effects of the proposed Little River Reservoir at a 310 ft-msl pool elevation on the local economy in terms of: (1) impact on the tax

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[82] Fambrough, J., *Minerals, Surface Rights and Royalty Payments. A Reprint from the Real Estate Center Journal*, Texas A&M University, Technical Report 840, November 1996.

[83] Henry, C.D. and J.M. Basciano, *Environmental Geology of the Wilcox Group Lignite Belt: East Texas. Report of Investigation* No. 98, Bureau of Economic Geology, University of Texas at Austin. 1979

base; (2) impacts to the local county economy from changes in the tax base; (3) revenue and employment effects from potential recreational businesses; and (4) loss of crop value.

Impact on the Tax Base of Milam County

At an elevation of 310 ft-msl the proposed Little River Reservoir would inundate an area of 20,685 acres in east-central Milam County between the City of Cameron and the confluence of the Little River and the Brazos River. The area proposed for inundation includes 16,493 acres of cropland, 3,645 acres of mixed riparian forests, and 549 acres of Post Oak woods. The impact on the Milam County tax base can, in principle, be estimated as the net effect of: (1) the loss of property tax revenue to local jurisdictions from the conversion of the reservoir footprint to public (tax exempt) ownership, assuming that the project sponsors will be public entities; and (2) the increase in value of property along the shoreline of the proposed reservoir, assuming that the shoreline will remain largely in private ownership. An estimate of increased values around the proposed reservoir would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

Estimates of total market value (land and improvements) and total appraised value by county are available from the Texas Association of Counties' County Information Project.[84] For Milam County, the average market value of land and improvements was $2,491 per acre and the average appraised value was $1,711 per acre in 2003. If this average can be taken as an upper limit to the per acre appraised value of the 20,685 acres that would be required for the proposed Little River Reservoir at a 310 ft-msl pool elevation, then the total appraised value that would be lost in Milam County for taxation is $35,392,035 in 2003 dollars.

Impacts to the Local Economy from Changes in the Tax Base

A total loss of $35,392,035 of tax base in Milam County represents a reduction of about 3% from the 2003 total appraised value of $1,119,106,754. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Milam County tax base of 3% would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy.

[84] Texas Association of Counties, County Information Project. http://www.county.org/resources/countydata/, 2004.

In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the proposed reservoir on the Milam County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

Revenue and Employment Effects from Potential Recreational Businesses

Potential sales, income, and jobs effects in Milam County arising from recreational benefits associated with the development of the proposed reservoir are estimated by comparing the proposed reservoir to estimated impacts in 1996 for similar reservoirs in the Brazos G Area that were documented in a study contracted by the Corps of Engineers.[85] Seven reservoirs in the Brazos G Area were analyzed as potentially representative of the proposed reservoir: (1) Belton Lake; (2) Somerville Lake; (3) Stillhouse Hollow Reservoir; (4) Waco Lake; (5) Whitney Lake; (6) Granger Lake; and (7) Lake Georgetown. Granger Lake is the closest to the proposed site in Milam County, but at 4,400 surface acres it is much smaller than the proposed Little River Reservoir at a normal pool elevation of 310 ft-msl. Whitney Lake, at normal pool elevation, covers 23,500 surface acres, relatively close to the size (20,687 acres) of the Little River Reservoir at the normal pool elevation of 310 ft-msl. Table 4B.12.6-7 presents estimates of total annual recreational spending, direct and total sales (output) effects, direct and total income effects, and direct and total job effects for the surrounding regions.

Size, proximity to urban areas and available facilities are variables that certainly affect the visitation, spending and resulting economic effects at these reservoirs. At a 310 ft-msl pool elevation, the effects of the proposed Little River Reservoir are estimated as the average of those for Whitney Lake (closest in size) and Granger Lake (closest in location). This estimate assumes that the proposed Little River Reservoir will be characterized by approximately the same level of recreational facilities as the average of Whitney and Granger Lakes. Table 4B.12.6-8 presents these estimates for the proposed Little River Reservoir.

[85] Propst, D. B., D. J. Stynes, W. Chang, and R. Jackson, *Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996.* U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. Technical Report R-98-1, September 1998.

Table 4B.12.6-7
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for Selected U.S. Corps of Engineers Projects in the Brazos G Area, 1996

Project	Total Spending (1996 $)	Direct Sales Effects (1996 $)	Total Sales Effects (1996 $)	Direct Income Effects (1996 $)	Total Income Effects (1996 $)	Direct Jobs Effects (Number of Jobs)	Total Jobs Effects (Number of Jobs)
Belton Lake	22,760,000	14,050,000	22,210,000	7,420,000	12,010,000	510	655
Somerville Lake	18,850,000	12,180,000	19,410,000	6,290,000	10,220,000	416	538
Stillhouse Hollow Reservoir	5,550,000	3,640,000	6,030,000	1,890,000	3,180,000	121	163
Waco Lake	19,540,000	13,010,000	23,140,000	7,010,000	12,600,000	442	616
Whitney Lake	19,780,000	12,860,000	23,650,000	6,790,000	12,660,000	442	629
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Lake Georgetown	10,550,000	6,920,000	11,460,000	3,590,000	6,050,000	230	309
Source: Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998.							

Table 4B.12.6-8.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for the Proposed Little River Reservoir (310 ft-msl) in Milam County

Project	Total Spending (1996 $)	Direct Sales Effects (1996 $)	Total Sales Effects (1996 $)	Direct Income Effects (1996 $)	Total Income Effects (1996 $)	Direct Jobs Effects (Number of Jobs)	Total Jobs Effects (Number of Jobs)
Whitney Lake	19,780,000	12,860,000	23,650,000	6,790,000	12,660,000	442	629
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Proposed Little River 310' (Average of Whitney and Granger Lakes)	12,995,000	8,465,000	15,200,000	4,450,000	8,110,000	289	406
Sources: HDR Engineering, Inc. and Hicks & Company, 2004; Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998; Texas Parks and Wildlife Department, http://www.tpwd.state.tx.us/fish/infish/lakes/granger/lake_id.htm; U.S. Army Corps of Engineers, Fort Worth District, http://www.swf-wc.usace.army.mil/whitney/pages/							

These estimates suggest that recreational activity at the proposed reservoir would have substantial positive economic effects on the surrounding region in Milam County. Total annual spending is estimated at $12,995,000, total sales effects at $15,200,000, total income effects at $8,110,000, and total jobs created at 406.

Loss of Crop Value

The proposed Little River Reservoir at pool elevation of 310 ft-msl would inundate a total of 20,687 acres in eastern Milam County. Approximately 16,493 acres of Cropland, 549 acres of Post Oak Woods, and 3,645 acres of mixed Riparian Forest would be included in the inundated area. The 1997 Census of Agriculture[86] reports harvested cropland and market value of crops sold in Milam County. The majority of harvested acreage (almost entirely dryland) included hay, sorghum, cotton, and corn. The value per acre for harvested cropland (all crops) for Milam County in 1997 was $139. Using this value per acre of cropland and the expected loss of 16,493 acres of cropland to the proposed reservoir yields a rough estimate for total annual loss of crop value of $2,292,527.

4B.12.6.4 Little River On-Channel Reservoir (Normal Pool Elevation = 330 ft-msl)

4B.12.6.4.1 Description of Existing Environment

The proposed Little River Reservoir site (normal pool at 330 ft above mean sea level) in Milam County is in a transitional zone with the Blackland Prairies Ecological Region to the west and the Post Oak Savannah Ecological Region to the east.[87] This region is characterized by level to rolling topography, with interspersed grassland and woodland, with soils ranging from the deep, fertile, black soils of the Blackland Prairies region to the shallow, nearly impervious clay pan of the Post Oak Savannah region. The original physiognomy of the region varied from medium to tall broad-leaved deciduous and some needle-leaved evergreen trees to medium-tall dense grasslands with scattered open groves of deciduous trees in minor prairies.[88] The climate is characterized as subtropical humid with warm summers. Average annual precipitation ranges

[86] U. S. Department of Agriculture, *Census of Agriculture, Highlights of Agriculture: 1997 and 1992, Milam County, Texas*; http://www.nass.usda.gov/census/census97/highlights/tx/txc166.txt, 1997.
[87] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, *Vegetational Areas of Texas*, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[88] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.

between 36 and 40 inches.[89] The Carrizo-Wilcox Aquifer is the only major aquifer underlying in the project area, though the downdip portion of the Trinity Aquifer lies nearby to the west.[90] The Queen City and Brazos River Alluvium minor aquifers are to the south and east of the project area, respectively.

The physiography of the region includes ceramic clay and lignite/coal, recharge sands, limestone sand and gravel, expansive clay mud, terraces, and flood-prone areas. The topography is flat to rolling with local escarpments, with local shallow depressions in flood-prone areas along waterways.[91] The predominant soil types in the project area are primarily sandy loams and loamy sands, with a small amount of silty clay.[92]

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak Woods/Forest, Post Oak Woods, Forest, and Grassland Mosaic, and crops.[93] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Post Oak Woods/Forest and the Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry *(Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Crops include cultivated cover crops or row crops providing food

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[89] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.
[90] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[91] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., *Land Resources of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.
[92] Soil Conservation Service (SCS), *Soil Survey of Milam County*, United States Department of Agriculture Soil Conservation Service in Cooperation with Texas Agricultural Experiment Station, 1925.
[93] McMahan, C.A., R.F. Frye, and K.L. Brown, *The Vegetation Types of Texas*, Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.12.6.4.2 Potential Impacts

4B.12.6.4.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated with the proposed reservoir maintained at 330 feet (ft) above sea level and a diversion of 124,000 acre-feet of water per year. Overall, this alternative would have little influence on variability of median monthly flows, similar to the 310-ft elevation alternative, but would result in a greater reduction in quantity of monthly flows in the Little River compared with that alternative. The minimal reduction in variability of monthly flow values (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with each alternative in place; sample variance without project =2.95 x 10^{10}; sample variance with 330-ft elevation =2.65 x 10^{10}) would probably not have much impact on the instream biological community or riparian species.

The reduction in the quantity of median monthly flow in the area of the project would range from 0 cfs in June and July to 660.6 cfs (24 percent) in May, as shown in Table 4B.12.6-9. The highest reduction (40 percent) would occur in December, while the lowest (<10 percent) would occur during the summer months of June, July and August. The change in low-flow conditions (85% exceedance values) would also be minimal. Without the project, the 85% exceedance value for monthly flow would be 185 cfs while under this alternative the value would be 176 cfs. The highest reductions are anticipated in fall and winter, which is less critical than reductions in spring and summer since many species spawn in the spring and summer flows are naturally lower and more susceptible to deterioration of water quality. Overall, the reductions in flow would be greater under this alternative than under the 310-ft elevation alternative, but should not have substantial impacts on the biological community.

Any reduction in discharge associated with this alternative for this project in the Little River would have minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Little River Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.12.6.4.2.2 Wildlife Habitat

Approximately 35,586 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 25,344 acres of Cropland, 1,390 acres of Post Oak Woods, and 8,852 acres of mixed Riparian Forest. Some new shoreline and wetland habitat would be created that would be associated with the land-water interface. Vegetation would change from streamside plant species adapted to short-term inundation and over bank flooding, to aquatic or semi-aquatic species adapted to hydric or semi-hydric conditions along the shoreline.

Table 4B.12.6-9.
Median Monthly Streamflow: Little River Reservoir at 330-ft Elevation

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	586.6	469.8	116.8	20%
February	713.2	662.1	51.1	7%
March	744.1	623.8	120.3	16%
April	1,222.1	1,033.6	188.5	15%
May	2,788.2	2,127.6	660.6	24%
June	1,231.9	1,231.9	0.0	0%
July	392.1	392.1	0.0	0%
August	313.2	285.9	27.2	9%
September	379.4	307.1	72.3	19%
October	369.2	274.5	94.7	26%
November	393.1	355.2	37.9	10%
December	537.5	320.5	217.0	40%

A number of vertebrate species could occur within the vicinity of the Little River Reservoir site as indicated by county occurrence records.[94] These include four species of salamanders and newts, 16 species of frogs and toads, nine species of turtles, the American alligator, 10 species of lizards and skinks, and 21 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[95] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds

[94] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.
[95] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

within the site, but with distributions and population densities limited by the types and quality of habitats available.

The habitat value of occurring cover types has been estimated based on methodology developed by the Texas Parks and Wildlife Department[96] and other previous information.[97] Based on these estimates, preliminary mitigation requirements to compensate or offset the loss of inundated habitats are summarized in Table 4B.12.6-10.

Table 4B.12.6-10. Estimated Mitigation Requirements for Cover Types Inundated by the Proposed Little River Reservoir (Pool level at 330 ft-msl)

Cover Type	Acres Lost	Habitat Quality Rating[1]	Habitat Units Lost[2]	Potential HQ Gain[3]	Compensation Acreage Requirements[4]
Mixed Riparian Forest	8,852	0.75	6,639	0.25	26,556
Post Oak Woods	1,390	0.58	806.2	0.42	1,920
Crops	25,344	0.2	5,068.8	0.8	6,336
Total	**35,586**		**12,514**		**34,812**

[1]Habitat Quality Ratings extrapolated from ratings of similar habitats within the same general region conducted by TPWD (1990).

[2]Values represent the product of Acres Lost multiplied by Habitat Quality Rating.

[3]Represents future maximum gain in habitat value (1.0 - Habitat Quality Rating Value) through intensive management of a mitigation area with similar baseline habitat value.

[4]Represents compensation required to fully offset loss of the cover type (Habitat Units lost ÷ Potential HQ gain); calculations derived from TPWD (1995); federal/state permits historically have required compensation only for jurisdictional waters of the U.S., including wetlands.

4B.12.6.4.2.3 Threatened and Endangered Species

According to county occurrence records,[98] a total of 23 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 1 amphibian, 3 reptiles, 10 birds, 2 mammals, 5 fish species, and 2 plant species (Table 4B.12.6-11). One amphibian, two bird species, one fish species, and one plant species federally-

[96] Texas Parks and Wildlife Department (TPWD), "Wildlife Habitat Appraisal Procedure," PWD RP N7100-145 (2/95), <http://www.tpwd.state.tx.us/conserve/whap/mainwhap.html>, 1995.
[97] TPWD, "Texas Water and Wildlife," PWD-BK-7100-147-5/90, 1990.
[98] Texas Parks and Wildlife Department (TPWD), Annotated County List of Rare Species for Stonewall County, 2004.

Table 4B.12.6-11.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Little River Reservoir Site (Pool Elevation = 330 ft-msl), Milam County

Scientific Name	Common Name	Federal/State Status	Potential Occurrence
Amphibians			
Bufo houstonensis	Houston Toad	LE/E	X
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant
Buteo albonotatus	Zone-tailed Hawk	SOC/T	Migrant*
Fishes			
Anguilla rostrata	American Eel	SOC	X
Cycleptus elongatus	Blue Sucker	SOC/T	X
Micropterus treculi	Guadalupe Bass	SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Mammals			
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Reptiles			
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Spiranthes parksii	Navasota ladies'-tresses	LE/ E	X
Polygonella parksii	Parks' jointweed	SOC	X

X = Occurs in county, - = does not occur in county; * Nesting migrant; may nest in the county.
Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).
State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.
SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).
Sources: Texas Parks and Wildlife Department (TPWD), Annotated County List of Rare Species for Milam County (25 September 2004a); TPWD Texas Wildlife Diversity Database (2004b); USFWS (2004).

listed as threatened or endangered could occur in the project area. These include the Houston toad (*Bufo houstonensis*), interior least tern (*Sterna antillarum athalassos*), whooping crane (*Grus americana*), sharpnose shiner (*Notropis oxyrhynchus*), and Navasota ladies'-tresses (*Spiranthes parksii*). Habitat for the Houston toad includes pine and/or oak woodlands underlain by pockets of deep, sandy soils with temporary pools of water available for breeding.[99] The interior least tern and whooping crane are seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. The sharpnose shiner inhabits turbid sections of the Brazos and Colorado River drainages, in areas with a sand, gravel, and clay-mud bottom. Navasota Ladies'-tresses occurs on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon.

A search of the Texas Wildlife Diversity Database[100] revealed two documented occurrences of rookeries within the vicinity of the proposed Little River Reservoir (as noted on representative 7.5 minute quadrangle map(s) that include the project site). Both rookeries are described by TPWD as nesting colonies of the great egret, little blue heron, and cattle egret; one of the rookeries also has had nesting snowy egrets. These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.12.6.4.2.4 Cultural Resources

The potential cultural resources constraints for the Little River Reservoir at the 330 ft-msl normal pool elevation are essentially identical to those of the reservoir alternative at the 310 ft-msl normal pool elevation. A search of the Texas Archeological Sites Atlas database indicates that 102 archeological sites have been documented within the general vicinity of the proposed reservoir. These sites represent a variety of historic and prehistoric site types. Five of these sites

[99] United States Fish and Wildlife Service (USFWS), *Federally-listed as Threatened and Endangered Species of Texas*, September 12, 2003.

[100] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, Annotated County Lists of Rare Species for Throckmorton, Jones, Haskell, and Shackelford Counties, 2004.

(41MM12, 41MM13, 41MM14, 41MM130, and 41MM292) occur within the proposed reservoir's conservation pool. Four of the five sites within the conservation pool are recorded as prehistoric artifact scatters and/or prehistoric occupation sites. The remaining site (41MM13) is recorded as a prehistoric occupation site and historic artifact scatter. Espey Huston & Associates recommended site 41MM13 for further testing in 1979. A total of 22 archeological sites have been documented along Cannonsnap Creek in the immediate vicinity of the proposed reservoir. These sites do not appear to be within the proposed conservation pool; however, it is considered likely that similar sites (or undocumented components of these previously recorded sites) may exist within the proposed reservoir.

One Official State Historical Marker is located within the footprint of the proposed reservoir. This marker, erected in 1936, commemorates the landing of the steamboat Washington in the winter of 1850-1851. The Washington was the "first, last and only" steamboat to navigate the Little River. At least five cemeteries are mapped within the proposed reservoir. These include: Burns Cemetery, Anderson Cemetery, Turnham-McCown Cemetery, Old City Cemetery, Milam Grove Cemetery, Pebble Grove Cemetery, and Oxsheer-Smith Cemetery. No properties listed in the National Register of Historic Places (NRHP) or State Archeological Landmarks (SALs) occur within the proposed reservoir footprint.

Prior to reservoir inundation, a cultural resources survey must be conducted to determine if any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be formally assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.12.6.4.2.5 Threats to Natural Resources

Identified threats to natural resources were identified in Section 1.7.3.2 as lower stream flows, declining water quality, and reduced inflows to reservoirs. This project is expected to have slight effects on the variability of median monthly flows, and not substantially change low flow conditions (flows exceeded 85% of the time). It is unlikely this project would have any substantial influence on total discharge in the Brazos River, freshwater inflows to the Brazos River estuary, or water quality downstream.

4B.12.6.4.3 Mineral Rights and Oil and Gas Wells

Without researching courthouse deeds, the ownership of minerals contained within the proposed normal pool elevation of 330 ft-msl is unknown. However, according to known oil, gas, and other mineral recovery sites mapped from databases maintained by the Texas Railroad Commission,[101] there is one gas well, two shut-in oil wells, two oil/gas wells, 12 permitted locations, 44 oil wells, six plugged oil wells, and 14 dry holes located within the reservoir footprint (Table 4B.12.6-12).

Table 4B.12.6-12.
Oil and Gas Wells in the Little River Reservoir Footprint
(330 ft-msl Pool Elevation)

Type of Well	*Total Number*
Gas Well	1
Shut-In Oil Well	2
Oil/Gas Well	2
Pemitted Location	12
Oil Well	44
Plugged Oil Well	6
Dry Hole	14
Source: Texas Railroad Commission, 2005.	

4B.12.6.4.3.1 Mitigation Costs for Minerals

Plugging Existing Wells

As noted in Table 4B.12.6-12, the Texas Railroad Commission reports 44 oil wells, 2 oil/gas wells, one gas well, 2 shut-in oil wells, 6 plugged oil wells, 14 dry holes and 12 permitted locations in the Little River footprint at a normal pool elevation of 330 ft-msl. Assuming the dry holes are properly plugged, the development of the proposed reservoir would require the plugging of 49 existing wells.

[101] Texas Railroad Commission (TRC), Mineral Recovery Databases, 2005.

Estimated costs for plugging these wells is available from the Railroad Commission's state-funded well plugging program. This program was established to locate, prioritize, and plug wells that have been abandoned by non-compliant oil and gas operators that may pose a risk to the environment or public safety. The program has, as of March 2003, plugged a total of 162 abandoned wells in Milam County, Texas at a cost of $317,069 or an average of $1,957 per well.[102] At an estimated cost of $1,957 per well, plugging the 49 wells in the 330 ft-msl reservoir footprint would cost about $95,893.

Raising Existing Wells and Relocating Storage Tanks

Another mitigation option to resolve the conflict would be to raise existing wells and relocate storage tanks out of the reservoir footprint. Although costs for this option have not been explicitly estimated, this option would result in oil and gas production facilities remaining on the surface of the reservoir – an outcome most project sponsors would probably seek to avoid.

Acquisition of Mineral Rights

Reservoir project sponsors could acquire the mineral rights for the property to be inundated. Texas law holds that the mineral estate is dominant over the surface estate.[103] This rule has serious implications for surface owners who are not mineral owners. Texas courts have held that mineral leases are not mere rental agreements as the name implies. Instead, they are actually deeds granting limited ownership rights to mineral lessees for as long as the lease continues. Thus, during the tenure of a lease, the mineral lessee enjoys the same rights to use the surface as any other mineral owner.

These property rights can be stated in the following way: mineral lessees can use as much of the surface as is *reasonably necessary* for mineral exploration and production. This privilege springs from the executed mineral lease. Independent permission from the surface owner is not necessary. No responsibility exists for restoring the surface or for paying surface damages. Liability arises only when the lessee goes beyond what is reasonably necessary or negligently injures the surface. The oil company or other entity leasing the minerals is the *lessee* and the

[102] Texas Railroad Commission (TRC), http://www.rrc.state.tx.us/news-releases/2003/030328a.html, 2003.

[103] Fambrough, J., *Subdivision Drill Sites, A Reprint from the Real Estate Center Journal,* Texas A&M University, Publication 690, November 1997.

mineral owner is the *lessor*.[104] The cost of mineral right acquisition would have to be estimated from a detailed examination of the Milam County Tax Office appraisals for the affected properties. This appraisal project would be undertaken at a latter stage of project development, but it is safe to say that costs to acquire mineral rights in an actively producing region could be substantial.

Lignite Resources

Approximately 7,680 acres of the proposed reservoir at the 330 ft-msl normal pool elevation are underlain by lignite resources,[105] about 22 % of the 35,586 acre footprint. The only practical resolution of this conflict would be the acquisition of the mineral rights for the 7,680 acres affected. The cost of mineral right acquisition would require an appraisal project that, as in the case of oil and gas resources, would be undertaken at a latter stage of the project development. The presence of lignite resources in addition to oil and gas resources would, however, increase the cost of mineral rights acquisition.

Sand and Gravel Resources

A search of the TxDOT Aggregate Quarry and Pit Safety Program Inventory File[106] for pits and quarries in Milam County indicated two active quarries. This data were not sufficient to confirm whether these quarries were located within the reservoir footprint.

4B.12.6.4.4 Socioeconomic Effects

This section characterizes the potential socioeconomic effects of the proposed Little River Reservoir at a 330 ft-msl normal pool elevation in terms of: (1) impact on the tax base; (2) impacts to the local county economy from changes in the tax base; (3) revenue and employment effects from potential recreational businesses; and (4) loss of crop value.

Impact on the Tax Base of Milam County

At an elevation of 330 ft-msl, the proposed Little River reservoir would inundate an area of 35,586 acres in east-central Milam County between the City of Cameron and the confluence

[104] Fambrough, J., *Minerals, Surface Rights and Royalty Payments. A Reprint from the Real Estate Center Journal,* Texas A&M University, Technical Report 840, November 1996
[105] Henry, C.D. and J.M. Basciano, *Environmental Geology of the Wilcox Group Lignite Belt: East Texas*. Report of Investigation No. 98, Bureau of Economic Geology, University of Texas at Austin. 1979.
[106] Texas Department of Transportation (TxDOT), Aggregate Quarry and Pit Safety Program Inventory File, 2005

of the Little River and the Brazos River. The area proposed for inundation includes 25,344 acres of cropland, 8,852 acres of mixed riparian forests, and 1,390 acres of Post Oak woods.

The impact on the local Milam County tax base can, in principle, be estimated as the net effect of: (1) the loss of property tax revenue to local jurisdictions from the conversion of the reservoir footprint to public (tax exempt) ownership, assuming that the project sponsors will be public entities; and (2) the increase in value of property along the shoreline of the proposed reservoir, assuming that the shoreline will remain largely in private ownership. This estimate would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

Estimates of total market value (land and improvements) and total appraised value by county are available from the Texas Association of Counties' County Information Project.[107] For Milam County, the average market value of land and improvements was $2,491 per acre and the average appraised value was $1,711 per acre in 2003. If this average can be taken as an upper limit to the per acre appraised value of the 35,586 acres that will be required for the proposed reservoir at the 330 ft-msl normal pool elevation, then the total appraised value that would be lost in Milam County for taxation is $60,887,646 in 2003 dollars.

Impacts to Local Economy from Changes in the Tax Base

A total loss of $60,887,646 of tax base in Milam County represents a reduction of about 5.4 % from the 2003 total appraised value of $1,119,106,754. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Milam County tax base of 5.4 % would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would therefore not, in itself, create a substantial negative impact on the local or regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Milam County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

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[107] Texas Association of Counties, County Information Project. http://www.county.org/resources/countydata/, 2004.

Revenue and Employment Effects from Potential Recreational Businesses

Potential sales, income, and jobs effects in Milam County arising from recreational benefits associated with the development of the proposed reservoir are estimated by comparing the proposed reservoir to estimated impacts in 1996 for similar reservoirs in the Brazos G Area that were documented in a study contracted by the Corps of Engineers.[108] Seven reservoirs in the Brazos G Area were analyzed as potentially representative of the proposed reservoir: (1) Belton Lake; (2) Somerville Lake; (3) Stillhouse Hollow Reservoir; (4) Waco Lake; (5) Whitney Lake; (6) Granger Lake; and (7) Lake Georgetown. Granger Lake is the closest to the proposed site in Milam County, but at 4,400 surface acres, it is much smaller than the proposed Little River Reservoir at the 330 ft-msl normal pool elevation. Table 4B.12.6-13 presents estimates of annual total spending, direct and total sales (output) effects, direct and total income effects and direct and total job effects for the surrounding regions.

Table 4B.12.6-13. Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for Selected U.S. Corps of Engineers Projects in the Brazos G Area, 1996

Project	Total Spending (1996 $)	Direct Sales Effects (1996 $)	Total Sales Effects (1996 $)	Direct Income Effects (1996 $)	Total Income Effects (1996 $)	Direct Jobs Effects (Number of Jobs)	Total Jobs Effects (Number of Jobs)
Belton Lake	22,760,000	14,050,000	22,210,000	7,420,000	12,010,000	510	655
Somerville Lake	18,850,000	12,180,000	19,410,000	6,290,000	10,220,000	416	538
Stillhouse Hollow Reservoir	5,550,000	3,640,000	6,030,000	1,890,000	3,180,000	121	163
Waco Lake	19,540,000	13,010,000	23,140,000	7,010,000	12,600,000	442	616
Whitney Lake	19,780,000	12,860,000	23,650,000	6,790,000	12,660,000	442	629
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Lake Georgetown	10,550,000	6,920,000	11,460,000	3,590,000	6,050,000	230	309

Source: Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, “Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996”, U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998.

[108] Propst, D. B., D. J. Stynes, W. Chang, and R. Jackson, Estimating *the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996.* U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. Technical Report R-98-1, September 1998.

Size, proximity to urban areas, and available facilities are variables that certainly affect the visitation, spending and resulting economic effects at these reservoirs. At a normal pool elevation of 330 ft-msl the proposed Little River Reservoir would have a surface area of 35,586 acres, about 75% more than at a pool elevation of 310 ft-msl. A larger reservoir would logically have correspondingly larger economic effects. To estimate the higher economic effects of the larger reservoir alternative, Corps of Engineers estimates for recreational effects at a larger lake in the Fort Worth District, Lake Lewisville (29,592 acres), were averaged with Granger Lake and results shown in Table 4B.12.6-14**.**

These estimates suggest that recreational activity at the 330 ft-msl normal pool elevation for the proposed reservoir would have substantially larger positive economic effects on the surrounding region in Milam County than at the 310 ft-msl normal pool elevation. Total annual spending at the higher elevation is estimated at $21,315,000, total sales effects at $26,405,000, total income effects at $15,080,000 and total jobs created at 541.

Table 4B.12.6-14.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for the Proposed Little River Reservoir (330 ft-msl) in Milam County

Project	***Total Spending (1996 $)***	***Direct Sales Effects (1996 $)***	***Total Sales Effects (1996 $)***	***Direct Income Effects (1996 $)***	***Total Income Effects (1996 $)***	***Direct Jobs Effects (Number of Jobs)***	***Total Jobs Effects (Number of Jobs)***
Lewisville Lake	36,420,000	27,830,000	46,060,000	16,020,000	26,600,000	653	900
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Proposed Little River 330' (Average of Lewisville and Granger Lakes)	21,315,000	15,950,000	26,405,000	9,065,000	15,080,000	395	541

Sources: HDR Engineering, Inc. and Hicks & Company, 2004; Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998; Texas Parks and Wildlife Department, http://www.tpwd.state.tx.us/fish/infish/lakes/granger/lake_id.htm; Texas Parks and Wildlife, Freshwater Fishing, http://www.tpwd.state.tx.us/fish/infish/lakes/lewisvll/lake_id.htm

Loss of Crop Value

The proposed Little River Reservoir at the 330 ft-msl normal pool elevation would inundate a total of 35,586 acres in eastern Milam County. Approximately 25,344 acres of Cropland, 1,390 acres of Post Oak Woods, and 8,852 acres of mixed Riparian Forest would be included in the inundated area. The 1997 Census of Agriculture[109] reports harvested cropland and market value of crops sold in Milam County. The majority of harvested acreage (almost entirely dryland) included hay, sorghum, cotton, and corn. The value per acre for harvested cropland (all crops) in 1997 was $139. Using this value per acre of cropland and the expected loss of 25,344 acres of cropland within the normal pool elevation of 330 ft-msl yields an estimate for total annual loss of crop value of $3,522,816, substantially higher than for the 310 ft-msl pool elevation alternative.

4B.12.6.5 Engineering and Costing

Construction of the Little River Reservoir at a normal pool elevation of 310 ft-msl will cost approximately $252.3 million. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $17.8 million; this includes annual debt service and operation and maintenance. The cost for the available project yield of 69,400 acft/yr translates to an annual unit cost of raw water of $0.79 per 1,000 gallons, or $256/acft. A summary of the cost estimate is provided in Table 4B.12.6-15. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs

[109] U. S. Department of Agriculture, *Census of Agriculture, Highlights of Agriculture: 1997 and 1992, Milam County, Texas*; http://www.nass.usda.gov/census/census97/highlights/tx/txc166.txt, 1997.

Table 4B.12.6-15
Cost Estimate Summary for
Little River Reservoir (Normal Pool Elevation = 310 ft-msl)
(Second Quarter 2002 Prices)

Item	***Estimated Costs***
Capital Costs	
Dam and Reservoir (Conservation Pool 321,000 acft, 20687 acres, 310 ft-msl)	$66,132,000
Total Capital Cost	**$66,132,000**
Engineering, Legal Costs and Contingencies	$23,146,000
Environmental & Archaeology Studies and Mitigation	$64,258,000
Land Acquisition and Surveying (31,000 acres)	$64,258,000
Interest During Construction (4 years)	$34,483,000
Total Project Cost	**$252,277,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$16,766,000
Operation and Maintenance	$992,000
Total Annual Cost	**$17,758,000**
Available Project Yield (acft/yr)	69,400
Annual Cost of Water ($ per acft)	$256
Annual Cost of Water ($ per 1,000 gallons)	$0.79

Construction of the Little River Reservoir at a normal pool elevation of 330 ft-msl will cost approximately $423.3 million. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $29.9 million; this includes annual debt service and operation and maintenance. The cost for the available project yield of 124,000 acft/yr translates to an annual unit cost of raw water of $0.74 per 1,000 gallons, or $241/acft. A summary of the cost estimate is provided in Table 4B.12.6-16. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

Table 4B.12.6-16.
Cost Estimate Summary for
Little River Reservoir (Normal Pool Elevation = 330 ft-msl)
(Second Quarter 2002 Prices)

Item	***Estimated Costs***
Capital Costs	
Dam and Reservoir (Conservation Pool 930,460 acft, 35,463.5 acres, 330 ft-msl)	$116,981,000
Total Capital Cost	**$116,981,000**
Engineering, Legal Costs and Contingencies	$40,943,000
Environmental & Archaeology Studies and Mitigation	$103,740,000
Land Acquisition and Surveying (53,200 acres)	$103,740,000
Interest During Construction (4 years)	$57,854,000
Total Project Cost	**$423,258,000**
Annual Costs	
Reservoir Debt Service (6 percent, 40 years)	$28,130,000
Operation and Maintenance	$1,755,000
Total Annual Cost	**$29,885,000**
Available Project Yield (acft/yr)	124,000
Annual Cost of Water ($ per acft)	$241
Annual Cost of Water ($ per 1,000 gallons)	$0.74

4B.12.6.6 Implementation Issues (Normal Pool Elevations 310 ft-msl and 330 ft-msl)

This option has been compared to the plan development criteria as shown in Table 4B.12.6-17.

Table 4B.12.6-17.
Comparison of Little River Reservoir (310 ft and 330 ft elevations) to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable to High
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. High impact
3. Cultural Resources	3. High impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);

- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits will require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required;
- Possible relocations of residences, utilities, roads, oil and gas production and storage facilities, or other structures; and
- Possible acquisition of mineral rights.

4B.12.7 Millican Reservoir (Bundic Site)

4B.12.7.1 Description of Option

Studies for development of a new reservoir on the Navasota River have been conducted by the U.S. Army Corps of Engineers (USCOE) since the mid-1940s. The proposed Millican Reservoir has been evaluated by the USCOE for the purposes of flood control, water supply, hydropower generation, and recreation. Many different sites have been studied along the Navasota River at various sizes and configurations.

Following completion of studies in the 1960s, the U.S. Congress authorized Millican Reservoir in 1968 as the first unit of a two-stage reservoir development. A second reservoir, Navasota Reservoir, located upstream of Millican Reservoir, was also authorized. Since the original authorization in 1968, concerns have evolved regarding the loss of large lignite and oil and gas resources that would occur by construction of Millican Reservoir. In addition, conditions in the Brazos River Basin changed including the construction of Lake Limestone and two power generation plants, Gibbons Creek and Twin Oaks. In 1980, the USCOE restudied the Millican Reservoir Project. As part of the study, detailed plans of alternative reservoir sites were evaluated including:

- Authorized Dam Site (Conservation Storage = 754,000 acft)
- Panther Creek Dam Site (Conservation Storage = 1,973,000 acft)
- Panther Creek Dam Site (Conservation Storage = 587,000 acft)
- Bundic Dam Site (Conservation Storage = 228,000 acft)

The results of the 1980 study found that the Bundic Site provided the maximum benefits and the plan for the Millican Reservoir was reformulated to be the Bundic Site. However, a Reevaluation Study was performed by the USCOE in 1985, which recommended the Panther Creek Dam Site instead of the Bundic Site. The results of the 1980 and 1985 studies on Millican Reservoir by the USCOE show that both the Panther Creek and Bundic Dam Sites are the two sites that are most feasible for reservoir development. However, only the Bundic Dam Site (Millican-Bundic Reservoir) is discussed in this current Regional Water Plan.

The Millican-Bundic Reservoir is on the Navasota River located between SH 21 and US 79, approximately 19 miles northeast of the City of Bryan, as shown in Figure 4B.12.7-1.

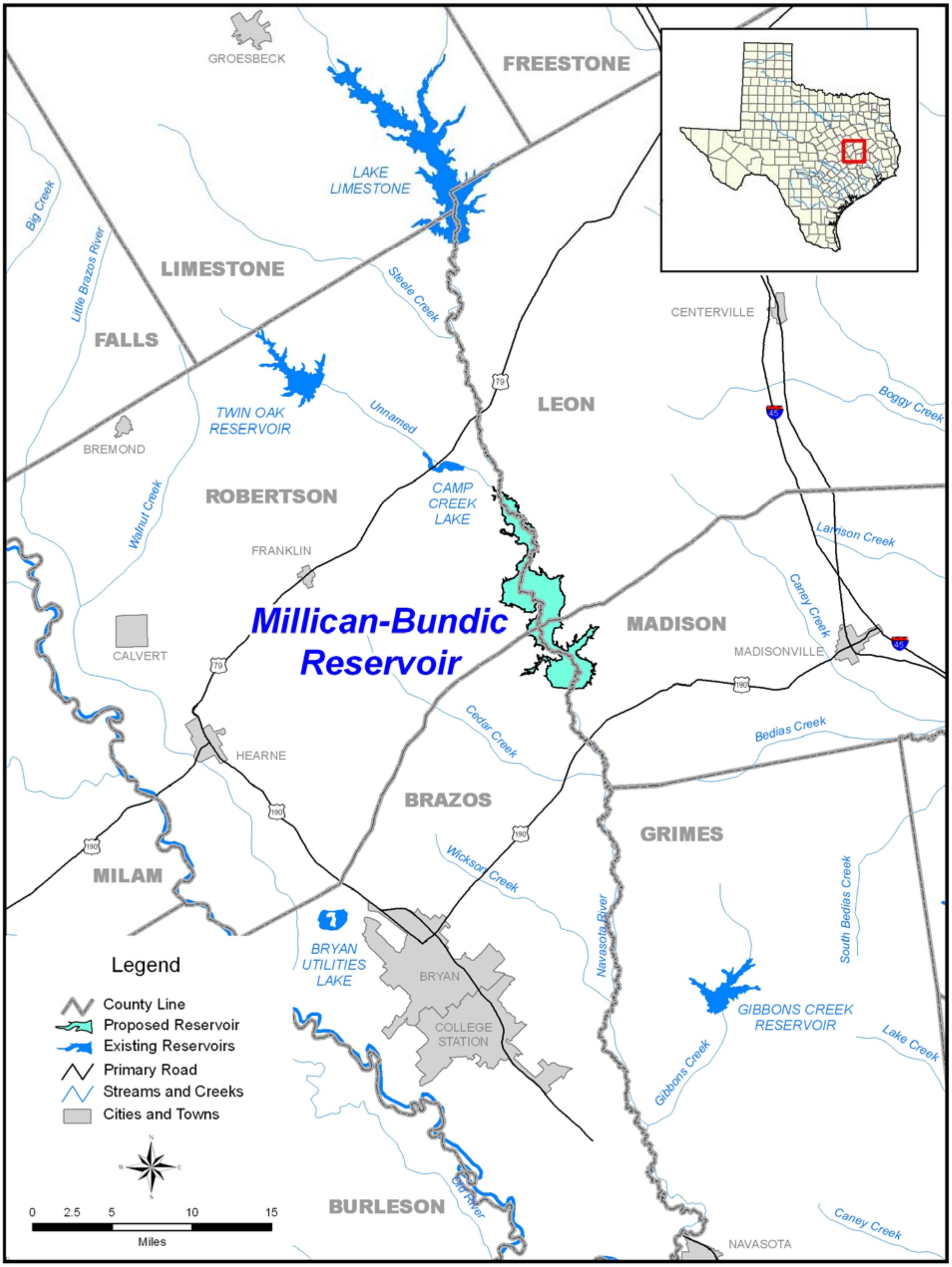


Figure 4B.12.7-1. Millican-Bundic Reservoir

Based on the USCOE study results, this reservoir would be constructed for the purposes of water supply and recreation. Flood control storage and hydropower generation were not found to be economically justified. The proposed reservoir will contain approximately 205,760 acft of conservation storage and inundate 14,630 acres at the full conservation storage level of 277 ft-msl. It would be formed by a dam about 2 miles long (10,400 feet).

The Millican-Bundic Reservoir could potentially provide surface water to the Brazos County and Grimes County area as well as meet downstream water supply needs in Region H.

4B.12.7.2 Available Yield

Water potentially available for impoundment in the proposed Millican-Bundic Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available from the Navasota River without causing increased shortages to existing downstream rights. Firm yield was computed subject to the reservoir having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the reservoir are shown in Table 4B.12.7-1.

Table 4B.12.7-1. Daily Natural Streamflow Statistics for the Millican-Bundic Reservoir

Month	Median Flows – Zone 1 Pass-Through Requirements (cfs)	25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)
January	122.2	40.8
February	149.5	52.9
March	161.4	51.3
April	126.5	49.3
May	163.0	51.3
June	54.8	18.0
July	10.9	2.9
August	3.0	0.4
September	7.2	1.2
October	9.3	1.5
November	32.9	10.7
December	63.7	21.1
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.82

Figure 4B.12.7-2 illustrates the simulated Millican-Bundic Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield in the reservoir of 38,080 acft/yr. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 64 percent of the time and above the Zone 3 trigger level (50 percent capacity) 88 percent of the time.

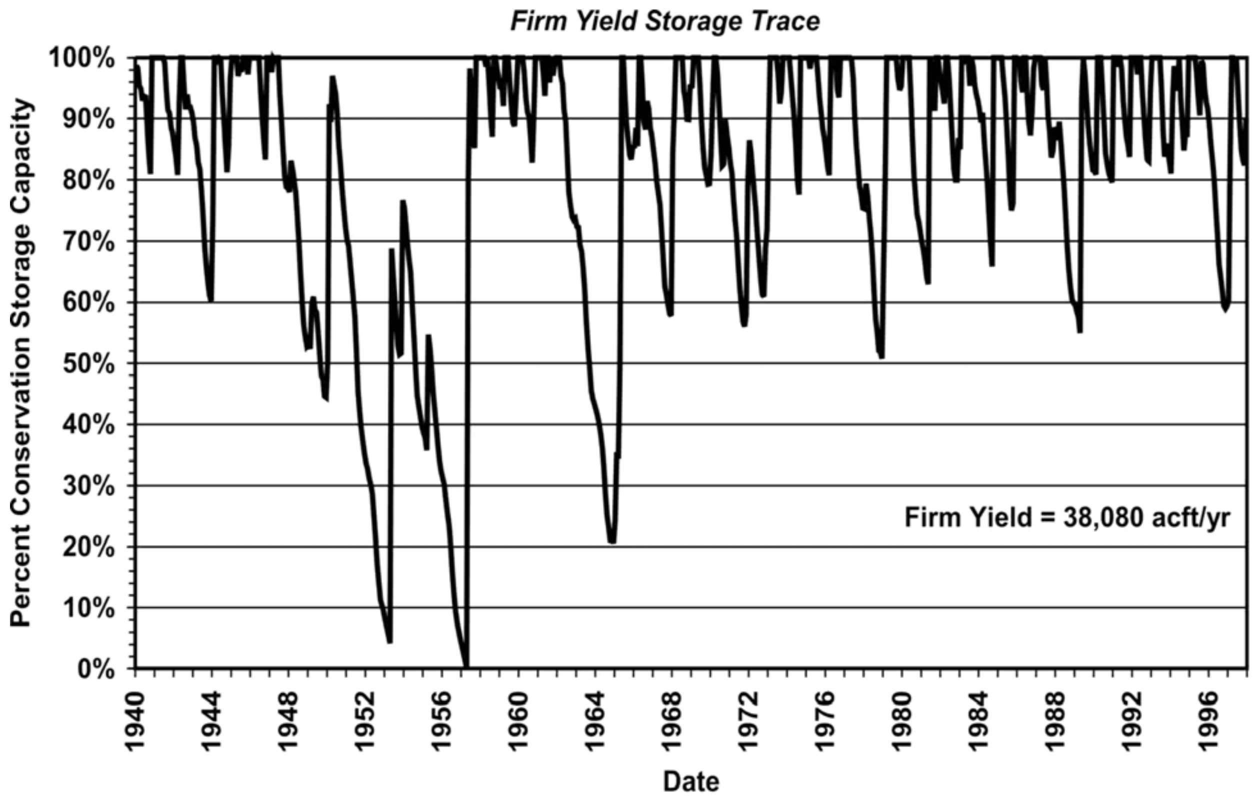
Figure 4B.12.7-3 illustrates the changes in streamflows caused by impounding the unappropriated waters of the Navasota River. The largest change would be a decline in median streamflow of 177 cfs during February. Other significant declines would occur in January, March, and May. During the months of August-October, there would be little change in streamflow because the reservoir would only rarely be able to impound water in excess of that required for downstream senior water rights and environmental needs.

4B.12.7.3 Environmental Issues

4B.12.7.3.1 Description of Existing Environment

The Bundic Site of the proposed Millican Reservoir lies within the Post Oak Savannah Ecological Region[110] in Brazos, Leon, Madison, and Robertson Counties. This region is characterized as a narrow, highly irregular oak belt that consists of intermingled forest, woodland, and savannah. It is located between the East Texas Pine-Hardwood Forest to the east, Blackland Prairies to the west, and the Coastal Prairie and South Texas Brushlands to the south. The original physiognomy of the region was medium to tall broad-leaved deciduous and some needle-leaved evergreen trees. The shallow, nearly impervious clay pan of the Post Oak Savannah region causes the soil to be arid.[111] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation ranges between 36 and 40 inches.[112] The Queen City and Sparta minor aquifers underlie the study area, and the Gulf Coast major aquifer lies south of the study area but does not underlie it.[113]

[110] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[111] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[112] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[113] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.



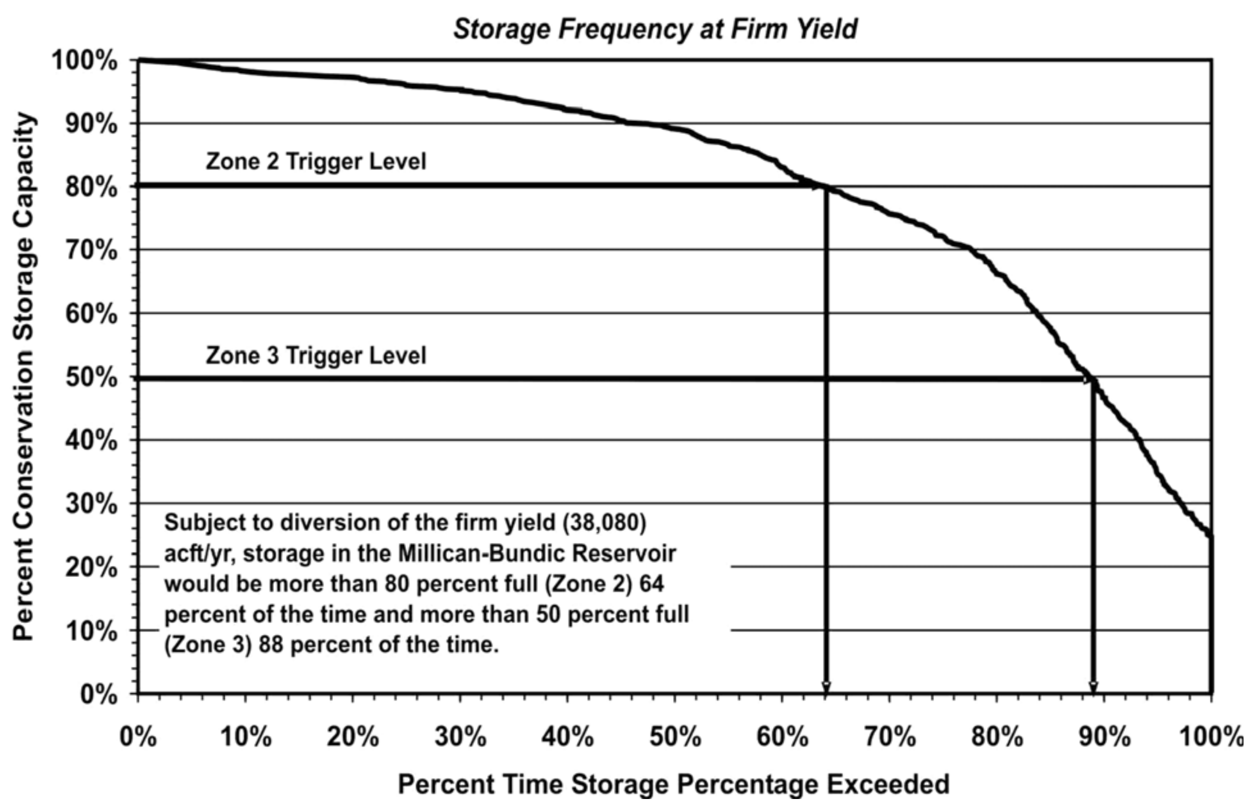
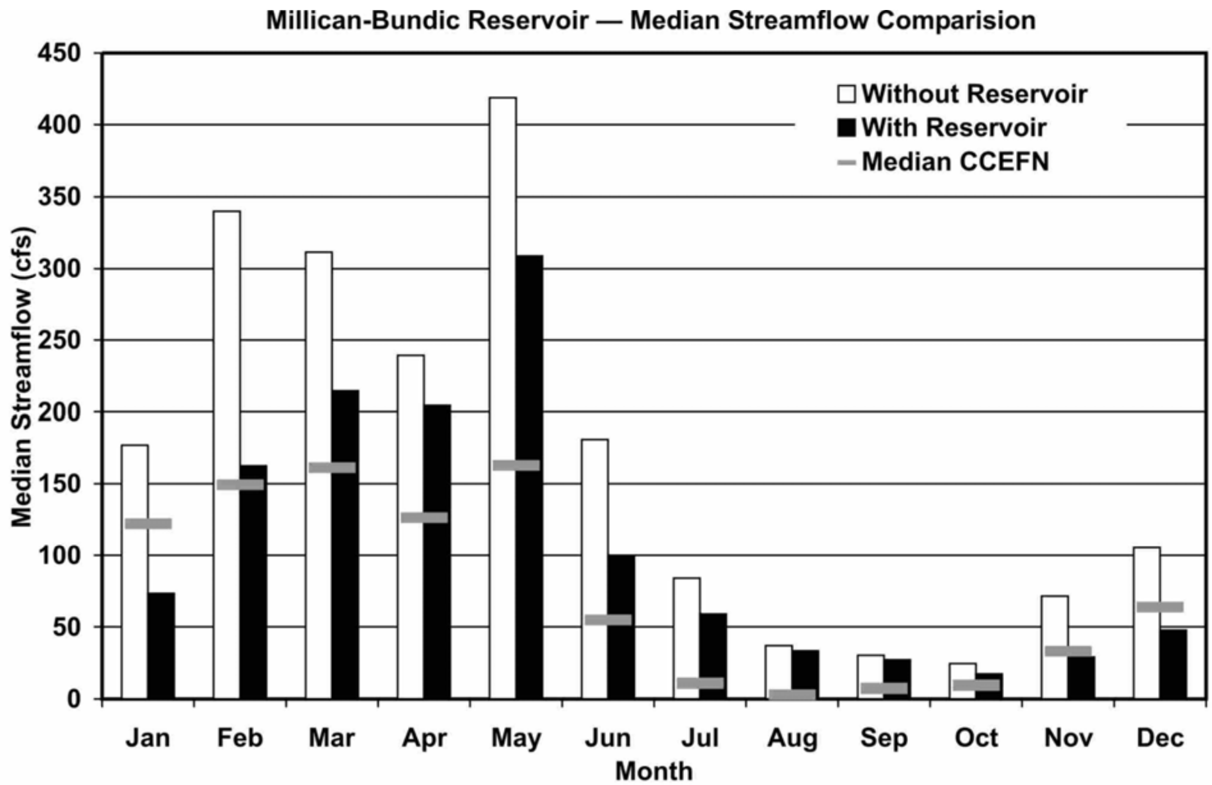


Figure 4B.12.7-2. Millican-Bundic Reservoir Storage Considerations



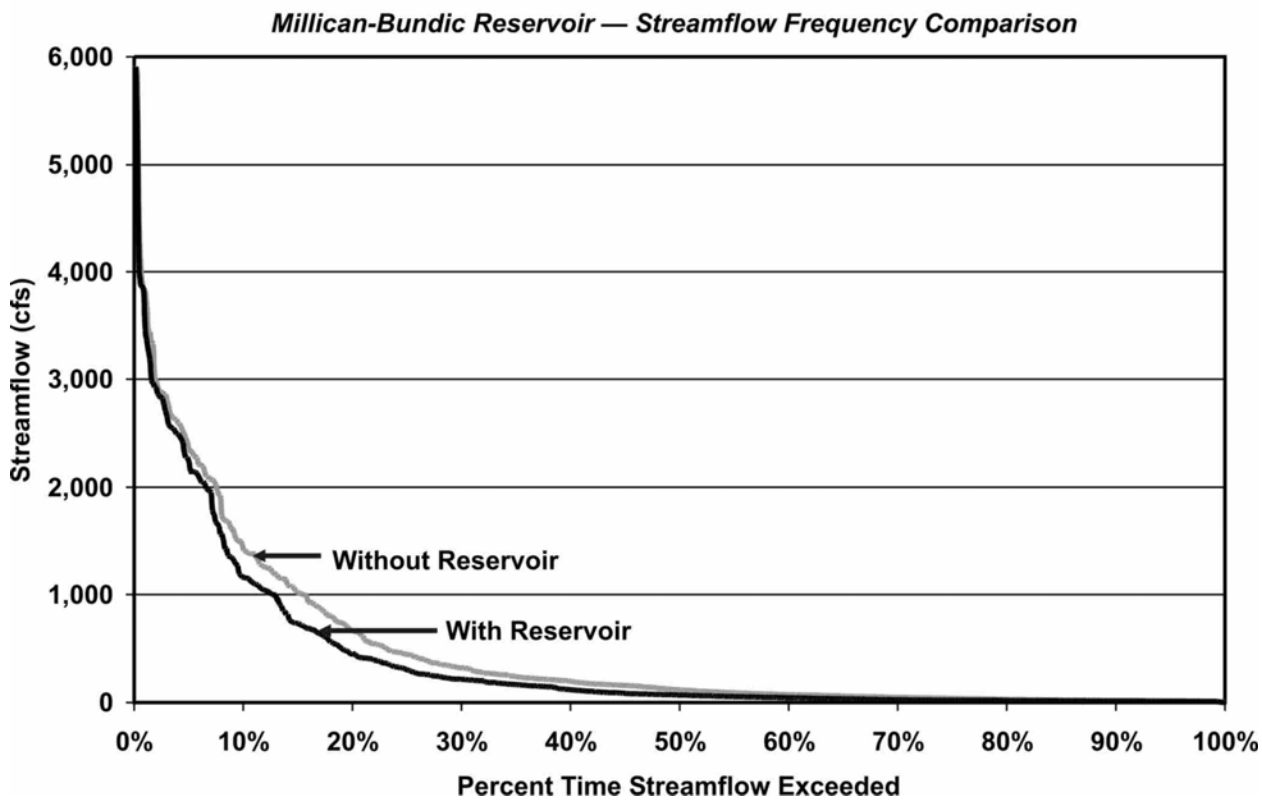


Figure 4B.12.7-3. Millican-Bundic Reservoir Storage Considerations

The physiography of the study area includes recharge sand, secondary aquifers, greensand-ironstone, siliceous sand and gravel, terraces, and flood-prone areas. The topography ranges from flat to rolling, with local escarpments in recharge sands and shallow depressions in flood-prone areas along waterways, to steeply sloped greensand-ironstone areas.[114] The predominant soil associations in the study area are the Tabor-Gredge-Rader and Sandow (Brazos County), Gladewater-Kaufman and Hatliff-Nahatche (Leon County), and Gladewater and Gowker-Nahatche (Madison and Robertson Counties). The Tabor-Gredge-Rader association consists of nearly level to moderately sloping, very deep, loamy soils that are well drained or moderately well drained, in areas of oak savannahs. Sandow soils are nearly level, very deep, loamy soils that are moderately well drained and occur in frequently flooded areas on bottomland.[115] Gladewater-Kaufman soils are nearly level, deep, clayey soils that are very poorly drained to somewhat poorly drained. Hatliff-Nahatche soils are nearly level, deep, loamy soils that are moderately well drained and somewhat poorly drained.[116] Gladewater soils are nearly level, clayey soils that are poorly drained and occur primarily on floodplains. Gowker-Nahatche soils are nearly level, loamy soils that are moderately well drained and somewhat poorly drained and occur primarily on floodplains.[117]

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak (*Quercus stellata*) Woods, Forest, and Grassland Mosaic, Post Oak Woods/Forest, and Water Oak (*Q. nigra*)-Elm (*Ulmus*)-Hackberry (*Celtis*) Forest.[118] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Post Oak Woods/Forest and Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (Q. incana), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis* spp.), yaupon (*Ilex*

[114] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., "Land Resources of Texas." Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.
[115] Natural Resources Conservation Service (NRCS), "Soil Survey of Brazos County, Texas," United States Department of Agriculture in cooperation with Texas Agricultural Experiment Station, 2002.
[116] Neitsch, C.L., J.J. Castille, and M.R. Jurena, "Soil Survey of Leon County, Texas," United States Department of Agriculture in cooperation with Texas Agricultural Experiment Station, 1989.
[117] Neitsch, C.L., "Soil Survey of Madison County, Texas," United States Department of Agriculture in cooperation with Texas Agricultural Experiment Station, 1994.
[118] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

vomitoria), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Water Oak-Elm-Hackberry Forest could include the following commonly associated plants: cedar elm, American elm (*Ulmus americana*), willow oak (*Q. phellos*), southern red oak (*Q. falcata*), white oak (*Q. alba*), black willow (*Salix nigra*), cottonwood (*Populus deltoides*), red ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), pecan (*Carya illinoinensis*), bois d'arc (*Maclura pomifera*), flowering dogwood (*Cornus florida*), dewberry, coralberry, dallisgrass (*Paspalum dilatatum*), switchgrass (*Panicum virgatum*), rescuegrass (*Bromus catharticus*), bermudagrass (*Cynodon dactylon*), eastern gamagrass (*Tripsacum dactyloides*), Virginia wildrye (*Elymus virginicus*), Johnsongrass (*Sorghum halepense*), giant ragweed (*Ambrosia trifida*), and Leavenworth eryngo (*Eryngium leavenworthii*).

4B.12.7.3.2 Potential Impacts

4B.12.7.3.2.1 Aquatic Environments including Bays & Estuaries

The anticipated impact of this project would be minimal influence on the variability of monthly flows but moderate reductions in the quantity of median monthly flows. The minimal reduction in variability of monthly flow values (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place; sample variance without project =2.39 x 10^9; sample variance with project =2.06 x 10^9) would probably not have much impact on the instream biological community or riparian species. The reduction in the quantity of median monthly flow in the area of the project would range from 3.2 cfs (11 percent) in September to 177.5 cfs (52 percent) in February, as shown in Table 4B.12.7-2. The highest reductions (>50 percent) would occur between December and February and in October, while the lowest (<12 percent) would occur in the summer months of August and September. This project would also result in a slightly higher frequency of low-flow conditions. Without the project, the 85 percent exceedance value would be 24 cfs, but it would only be 15 cfs with the project in place. These reductions in flow could have moderate impacts on the instream biological community. However, minimal reductions in the spring and summer will lessen impacts during critical times when many species spawn and when water quality conditions are highly susceptible to streamflow reductions.

Although there may be moderate biological impacts in the Navasota River in the immediate vicinity of the project site and downstream, it is unlikely that this project, alone, would have a substantial influence on total discharge in the Brazos River or to freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may have impacts on freshwater inflows to the estuary. As a new reservoir without a current operating permit, the Millican Lake Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4B.12.7-2.
Median Monthly Streamflow: Millican-Bundic Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	177.0	73.4	103.6	59%
February	340.0	162.5	177.5	52%
March	311.6	214.6	96.9	31%
April	239.3	204.5	34.8	15%
May	418.8	308.8	109.9	26%
June	180.9	99.2	81.7	45%
July	84.0	58.9	25.1	30%
August	36.8	33.2	3.6	10%
September	30.1	27.0	3.2	11%
October	24.3	17.1	42.6	60%
November	71.4	28.8	7.2	30%
December	105.4	47.6	57.9	55%

4B.12.7.3.2.2 Wildlife Habitat

Approximately 14,630 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 4,086 acres of Grasses/Forbs, 1,334 acres of Post Oak Woods, and 9,210 acres of mixed Bottomland Hardwood Forest. Some new shoreline and wetland habitat would be created that would be associated with the land-water interface. Vegetation would change from streamside plant species adapted to short-term inundation and over bank flooding, to aquatic or semi-aquatic species adapted to hydric or semi-hydric conditions along the shoreline.

A number of vertebrate species could occur within the Millican-Bundic Reservoir Site as indicated by county occurrence records.[119] These include 6 species of salamanders, 22 species of frogs and toads, 14 species of turtles, 1 alligator species, 11 species of lizards and skinks, and 33 species of snakes. Additionally, 60 species of mammals could occur within the site or surrounding region[120] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

The habitat value of occurring cover types has been estimated based on methodology developed by the Texas Parks and Wildlife Department (TPWD)[121] and other previous information.[122] Based on these estimates, preliminary mitigation requirements to compensate or offset the loss of inundated habitats are summarized in Table 4B.12.7-3.

Table 4B.12.7-3.
Estimated Mitigation Requirements for Cover Types
Inundated by the Proposed Millican Reservoir (Bundic Site)

Cover Type	*Acres Lost*	*Habitat Quality Rating* [1]	*Habitat Units Lost* [2]	*Potential HQ Gain* [3]	*Compensation Acreage Requirements* [4]
Mixed Bottomland Hardwood Forest	9,210	0.63	5,802.3	0.37	15,682
Grasses/Forbs	4,086	0.33	1,348.4	0.67	2,013
Post Oak Woods	1,334	0.39	520.3	0.61	853
Total	14,630		7,670.9		18,548

[1] Habitat Quality Rating values from TPWD (1990).
[2] Values represent the product of Acres Lost multiplied by Habitat Quality Rating.
[3] Represents future maximum gain in habitat value (1.0 – Habitat Quality Rating Value) through intensive management of a mitigation area with similar baseline habitat value.
[4] Represents compensation required to fully offset loss of the cover type (Habitat Units Lost ÷ Potential HQ Gain); calculations derived form TPWD (1995); federal/state permits historically have required compensation only for jurisdictional waters of the U.S., including wetlands.

[119] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.
[120] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.
[121] Texas Parks and Wildlife Department (TPWD), "Wildlife Habitat Appraisal Procedure," PWD RP N7100-145 (2/95), <http://www.tpwd.state.tx.us/conserve/whap/mainwhap.html>, 1995.
[122] TPWD, "Texas Water and Wildlife," PWD-BK-7100-147-5/90, 1990.

4B.12.7.3.2.3 Threatened & Endangered Species

According to county occurrence records[123] a total of 33 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.12.7-4). This group includes one amphibian, five reptiles, ten birds, four mammals, four fish species, and nine plant species. One amphibian species, four bird species, and two plant species federally-listed as threatened or endangered could occur in the study area. These include the Houston toad (*Bufo houstonensis*), bald eagle (*Haliaeetus leucocephalus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), whooping crane (*Grus americana*), large-fruited sand verbena (*Abronia macrocarpa*), and Navasota ladies'-tresses (*Spiranthes parksii*). The interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the study area but would not likely be directly affected by the proposed reservoir. The bald eagle is known to nest in Robertson County, but there are no known nesting sites in or near the project area.

Table 4B.12.7-4.
Potentially Occurring Federal-and State-Listed Species (Including Species of Concern) at the Millican-Bundic Reservoir (Brazos, Leon, Madison, and Robertson Counties)

Scientific Name	Common Name	Federal/ State Status	Brazos County	Leon County	Madison County	Robertson County
Amphibians						
Bufo houstonensis	Houston Toad	LE/E	X	w/CH	X	X
Birds						
Falco peregrinus anatum	American Peregrine Falcon	DL/E	—	—	—	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant	Migrant	Migrant	Migrant
Aimophila aestivalis	Bachman's Sparrow	SOC/T	—	Migrant*	Migrant*	—
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant*	Migrant*	Migrant*	Migrant*
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant	Migrant	Migrant	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*	Migrant*	Migrant*	Migrant*
Charadrius montanus	Mountain Plover	PT/SOC	Migrant*	Migrant*	Migrant*	Migrant*
Charadrius melodus	Piping plover	LT	Migrant	Migrant	Migrant	Migrant
Grus americana	Whooping Crane	LE/E	Migrant	Migrant	Migrant	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant	Migrant	Migrant	Migrant
Fishes						
Anguilla rostrata	American Eel	SOC	X	—	—	X
Cycleptus elongatus	Blue sucker	SOC/T	X	—	—	X
Notropis buccula	Smalleye Shiner	C/SOC	X	—	—	—
Notropis oxyrhincus	Sharpnose Shiner	C/SOC	X	—	—	X

Concluded on next page

[123] TPWD, "Annotated County List of Rare Species for Brazos, Leon, Madison, and Robertson Counties," 2004.

Table 4B.12.7-4 Concluded

Scientific Name	*Common Name*	*Federal/ State Status*	*Brazos County*	*Leon County*	*Madison County*	*Robertson County*
Mammals						
Myotis velifer	Cave Myotis Bat	SOC	—	—	—	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X	X	X	X
Corynorhinus rafinesquii	Rafinesque's Big-eared Bat	SOC/T	X	X	X	—
Canis rufus	Red Wolf	LE/E	—	—	—	Extirpated
Myotis austroriparius	Southeastern Myotis Bat	SOC	X	X	X	—
Reptiles						
Macrochelys temminckii	Alligator Snapping Turtle	SOC/T	X	—	X	—
Pituophis ruthveni	Louisiana Pine Snake	SOC/T	X	—	X	—
Thamnophis sirtalis annectens	Texas Garter Snake	SOC/T	X	X	X	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X	X	X	X
Crotalus horridus	Timber/Canebrake Rattlesnake	SOC/T	X	X	X	X
Vascular Plants						
Liatris cymosa	Branched Gay-feather	SOC	X	—	X	—
Xyris chapmanii	Chapman's Yellow-eyed Grass	SOC	—	X	X	X
Abronia macrocarpa	Large-fruited Sand Verbena	LE/E	—	X	—	X
Spiranthes parksii	Navasota Ladies'-tresses	LE/E	X	X	X	X
Polygonella parksii	Parks' jointweed	SOC	—	X	—	X
Hymenopappus carrizoanus	Sandhill woolywhite	SOC	—	X	—	X
Eriocaulon körnickianum	Small-headed pipewort	SOC	X	—	—	—
Thalictrum texanum	Texas meadow-rue	SOC	X	—	—	—
Chloris texensis	Texas windmill-grass	SOC	X	—	—	—

X = Occurs in county; — = does not occur in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD) Annotated County List of Rare Species for Brazos, Leon, Madison, and Robertson Counties (2004a); TPWD Texas Wildlife Diversity Database (2004b), USFWS (2004).

A search of the Texas Wildlife Diversity Database[124] revealed the documented occurrence of the federally-endangered Houston toad, large-fruited sand verbena, and Navasota Ladies'-tresses within the vicinity of the site (as noted on representative 7.5-minute quadrangle map(s) that include the project site). Although not federal- or state-listed as endangered or threatened, species of concern documented within the vicinity of the site include the sandhill woolywhite (*Hymenopappus carrizoanus*), and Parks' Jointweed (*Polygonella parksii*). Other documented sensitive species include the Centerville Brazos-mint (*Brazoria pulcherrima*), Mohlenbrock's umbrella-sedge (*Cyperus grayioides*), and the crawfish frog (*Rana areolata*). Additionally, two colonial water bird nesting rookeries were also documented near the vicinity of the site. These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

Habitat for the Houston toad includes pine and/or oak woodlands underlain by pockets of deep sandy soils, with temporary pools of water available for breeding.[125] Large-fruited sand verbena, which flowers from April through June and sometimes as late as October, is typically found in deep, somewhat excessively drained sandy soils in openings in post oak woodlands, sometimes in active sand blowouts. Navasota ladies'-tresses, which flowers in late October through early November, is typically found in the margins and openings of post oak woodlands in sandy loams along intermittent tributaries of rivers and streams.[126]

4B.12.7.3.2.4 Cultural Resources

A search of the Texas Historical Commission's online database indicates that no properties listed on the National Register of Historic Places, State Archeological Landmarks, Recorded Texas Historic Landmarks, or Official State Historical Markers occur within the proposed reservoir site. At least two cemeteries, the Burns Cemetery and the Anderson Cemetery, are mapped within the proposed reservoir site.

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[124] TPWD, "Texas Wildlife Diversity Database," Wildlife Division, Wildlife Diversity Branch, 2004.
[125] U.S. Fish and Wildlife Service, "The Endangered Houston Toad," http://ifw2es.fws.gov/HoustonToad/, 2004.
[126] Op. Cit.

A total of 56 archeological sites have been documented within the general vicinity of the proposed reservoir. Prewitt and Associates, Inc. recorded 53 of these sites in 1981 as part of an archeological survey of proposed reservoir alternatives. These sites, which represent a variety of historic and prehistoric site types, may be impacted by reservoir inundation. These sites must be reassessed in coordination with the Texas Historical Commission relative to their eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Additionally, a cultural resources survey must be conducted for any areas within the proposed reservoir that were not included in the previous survey efforts to determine if cultural resources are present. Any cultural resources identified during survey will need to be formally assessed for eligibility for inclusion in the National Register of Historic Places or as State Archeological Landmarks. Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.12.7.3.2.5 Threats to Natural Resources

Identified threats to natural resources were identified in Section 1.7.3.2 as lower streamflows, declining water quality, and reduced inflows to reservoirs. This project is expected to have slight effects on the variability of median monthly flows, but median monthly low flows (flows exceeded 85 percent of the time) would decline by about 39 percent. However, it is unlikely this project would have any substantial influence on total discharge in the Brazos River, freshwater inflows to the Brazos River estuary, or water quality downstream.

4B.12.7.3.4 Mineral Rights and Oil and Gas Wells

Without researching courthouse deeds, the ownership of minerals contained within the footprint of the proposed Millican-Bundic Reservoir is unknown. However, according to known oil, gas, and other mineral recovery sites mapped from databases maintained by the Texas Railroad Commission,[127] there is one oil well, two plugged oil wells, and four dry holes within the reservoir footprint (Table 4B.12.7-5).

[127] Texas Railroad Commission (TRC), Mineral Recovery Databases, 2005.

Table 4B.12.7-5.
Oil and Gas Wells in the Footprint of the Millican-Bundic Reservoir

Type of Well	*Total Number*
Oil Well (Bottom)	1
Plugged Oil Well	2
Dry Hole	4

Source: Railroad Commission of Texas, 2005.

4B.12.7.3.5 Mitigation Costs for Minerals

4B.12.7.3.5.1 Plugging Existing Wells

As noted in Table 4B.12.7-5, the Texas Railroad Commission[128] reports that within the footprint of the Millican-Bundic Reservoir, there are two plugged oil wells, one oil-producing well and four dry holes. Assuming that the dry holes are properly plugged, the development of the proposed Millican-Bundic Reservoir would require the plugging of one existing well.

Estimated costs for plugging these wells are available from the Railroad Commission's state-funded well plugging program. This program was established to locate, prioritize, and plug wells that have been abandoned by non-compliant oil and gas operators that may pose a risk to the environment or public safety. Based on data obtained from a nearby county (Milam County), the average cost to plug an abandoned well in 2003 was about $1,957.00[129]

4B.12.7.3.5.2 Raising Existing Wells and Relocating Storage Tanks

Another mitigation option would be to raise existing wells and relocate storage tanks out of the reservoir footprint. Although costs for this option have not been explicitly estimated, this option would result in oil and gas production facilities remaining on the surface of the reservoir – an outcome most project sponsors would probably seek to avoid.

4B.12.7.3.5.3 Acquisition of Mineral Rights

Reservoir project sponsors could acquire the mineral rights for the property to be inundated. Texas law holds that the mineral estate is dominant over the surface estate.[130] This

[128] Ibid.
[129] TRC, http://www.rrc.state.tx.us/news-releases/2003/030328a.html, 2003.
[130] Fambrough, J., "Minerals, Surface Rights and Royalty Payments," A Reprint from the Real Estate Center Journal, Texas A&M University, November 1996 Technical Report 840, 1996.

rule has serious implications for surface owners who are not mineral owners. Texas courts have held that mineral leases are not mere rental agreements as the name implies. Instead, they are actually deeds granting limited ownership rights to mineral lessees for as long as the lease continues. Thus, during the tenure of a lease, the mineral lessee enjoys the same rights to use the surface as any other mineral owner.

These property rights can be stated in the following way: mineral owners or lessees can use as much of the surface as is reasonably necessary for mineral exploration and production. This privilege springs from the executed mineral lease. Independent permission from the surface owner is not necessary although surface use agreements to minimize impacts of mineral recovery may be executed between the owner of the surface and the owner or lessee of the mineral rights. In the absence of a surface use agreement, or regulations established by the Texas Railroad Commission, no responsibility exists for restoring the surface or for paying surface damages. Liability arises only when the lessee goes beyond what is reasonably necessary or negligently injures the surface. The oil company or other entity leasing the minerals is the lessee and the mineral owner is the lessor.[131] The cost of mineral right acquisition would have to be estimated from a detailed examination of the Brazos, Leon, Madison and Robertson County Tax Offices appraisals for the affected properties. Although this appraisal project would be undertaken at a latter stage of project development, costs to acquire mineral rights in an actively producing region could be substantial.

4B.12.7.3.5.4 Lignite Resources

Kaiser[132] has identified lignite resources of the Yegua Formation occurring in Madison County. These resources are indicated to be east and south of the proposed Millican-Bundic Reservoir footprint, but are close enough to warrant a site-specific investigation of potential occurrence to be undertaken at a latter stage of the project development.

[131] Fambrough, J., "Subdivision Drill Sites," A Reprint from the Real Estate Center Journal, Texas A&M University, November 1997, Publication 690, 1997.
[132] Kaiser, W.R. 1974. Texas Lignite: Near-Surface and Deep-Basin Resources, Report of Investigation No. 79, Bureau of Economic Geology, University of Texas at Austin.

4B.12.7.3.5.5 Sand and Gravel Resources

A search of the TxDOT Aggregate Quarry and Pit Safety Program Inventory File[133] for pits and quarries in the counties of Leon, Robertson, Madison, and Brazos indicated six active quarries. The data were not sufficient to confirm whether any of these quarries were located within the reservoir footprint.

4B.12.7.3.5.6 Socio-economic Effects

This section characterizes the potential socioeconomic effects of the proposed reservoir in terms of: (1) impact on the tax base; (2) impacts to the local county economy from changes in the tax base; (3) revenue and employment effects from potential recreational businesses; and (4) loss of crop value.

4B.12.7.3.6 Impact on the Tax Base in Leon, Robertson, Madison, and Brazos Counties

The proposed Millican-Bundic Reservoir would inundate an area of 14,630 acres along the Navasota River in Leon (4,453 acres), Robertson (3,469 acres), Madison (3,295 acres) and Brazos (3,414 acres) Counties. The area proposed for inundation includes 9,210 acres of mixed bottomland hardwood forest, 4,086 acres of grasses and forbs, and 1,334 acres of Post Oak woods.

The impact on the local tax base can, in principle, be estimated as the net effect of: (1) the loss of property tax revenue to local jurisdictions from the conversion of the reservoir footprint to public (tax exempt) ownership, assuming that the project sponsors will be public entities; and (2) the increase in value of property along the shoreline of the proposed reservoir, assuming that the shoreline will remain largely in private ownership. An estimate of increased property values around the proposed reservoir would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

Estimates of total market value (land and improvements) and total appraised value by county are available from the Texas Association of Counties' County Information Project.[134] These estimates are used below to derive potential reductions to the affected counties' appraised

[133] Texas Department of Transportation (TxDOT), Aggregate Quarry and Pit Safety Program Inventory File, 2005.
[134] Texas Association of Counties, County Information Project, http://www.county.org/resources/countydata/, 2004.

values that would result from the acquisition of land for the proposed reservoirs by a public (tax exempt) sponsor.

4B.12.7.3.6.1 Leon County

For Leon County, the average market value of land and improvements was $2,128/acre and the average appraised value was $1,271/acre in 2003. Taking this as representative of the appraised value of land at the proposed reservoir site in the southern part of the county, then for the 4,453 acres of land proposed for the Millican-Bundic Reservoir in Leon County, the estimated loss of appraised value of land in Leon County available for taxation is $5,659,763 in 2003 dollars.

4B.12.7.3.6.2 Brazos County

For Brazos County, the average market value of land and improvements was $18,925/acre and the average appraised value was $16,396/acre in 2003. This average, however, includes urban land in Bryan and College Station and would not be representative of the value of land at the proposed reservoir site in the northern part of the county. Therefore, the average appraised value per acre from Leon County ($1,271) in 2003 was used as a more appropriate upper limit to the per-acre appraised value of the 3,414 acres in Brazos County that will be required for the proposed Millican-Bundic Reservoir[135] indicates $1,271/acre would be a reasonable upper limit for the appraised value of most land in northern Brazos County). This per-acre value would imply that the total appraised value that will be lost in Brazos County for taxation is $4,339,194 in 2003 dollars.

4B.12.7.3.6.3 Madison County

For Madison County, the average market value of land and improvements was $2,083/acre and the average appraised value was $1,219/acre in 2003. Taking this as representative of the appraised value of land at the proposed reservoir site in the western part of the county, then for the 3,295 acres of land proposed for the Millican-Bundic Reservoir in Madison County, the estimated loss of appraised value available for taxation is $4,016,605 in 2003 dollars.

[135] Personal communication with G.L Winn, Chief Appraiser, Brazos County Appraisal District, 2005.

4B.12.7.3.6.4 Robertson County

For Robertson County, the average market value of land and improvements was $2,513/acre and the average appraised value was $1,805/acre in 2003. Taking this as representative of the appraised value of land at the proposed reservoir site in the eastern part of the county, then for the 3,469 acres of land proposed for the Millican-Bundic Reservoir in Robertson County, the estimated loss of appraised value available for taxation is $6,261,545 in 2003 dollars.

4B.12.7.3.7 Impacts to the Local County Economies from Changes in the Tax Base

4B.12.7.3.7.1 Leon County

A total loss of $5,659,763 of tax base in Leon County represents a reduction of less than 1 percent from the 2003 total appraised value of $878,480,040. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Leon County tax base of less than 1 percent would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Leon County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.7.3.7.2 Brazos County

A total loss of $4,339,194 of tax base in Brazos County represents a reduction of less than one-tenth of 1 percent from the 2003 total appraised value of $6,190,931,875. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Brazos County tax base of less than one-tenth of 1 percent would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Brazos County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.7.3.7.3 Madison County

A total loss of $4,016,605 of tax base in Madison County represents a reduction of about 1 percent from the 2003 total appraised value of $369,105,924. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Madison County tax base of 1 percent would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Madison County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.7.3.7.4 Robertson County

A total loss of $6,261,545 of tax base in Robertson County represents a reduction of less than 1 percent from the 2003 total appraised value of $1,000,124,980. Neglecting the possibility of increased appraised value from the lake front property created by the reservoir, a reduction of the Robertson County tax base of less than 1 percent would not imply the need for a substantial increase in local taxes or decrease in the provision of public services and would not therefore, in itself, create a substantial negative impact on the regional economy. In addition, if the possibility of increased value arising from the creation of water front property were considered, depending upon assumptions, the net effect of the reservoir on the Robertson County tax base could even be positive. But, as noted above, an estimate of increased values would require a professional property appraisal for the land surrounding the proposed reservoir, an analysis that would be undertaken at a later stage of project development.

4B.12.7.3.8 Revenue and Employment Effects from Potential Recreational Businesses

Potential sales, income, and jobs effects arising from recreational benefits associated with the development of the proposed Millican-Bundic Reservoir are estimated by comparing the proposed reservoir to estimated impacts for similar reservoirs in the Brazos G Region presented in the Corps of Engineers study cited above.[136] Seven reservoirs in the Brazos G Region were analyzed as potentially representative of the proposed reservoir: (1) Belton Lake; (2) Somerville Lake; (3) Stillhouse Hollow Reservoir; (4) Waco Lake; (5) Whitney Lake; (6) Granger Lake; and (7) Lake Georgetown.

Table 4B.12.7-6 presents estimates of annual total spending, direct and total sales (output) effects, direct and total income effects and direct and total job effects for the surrounding regions.

Size, proximity to urban areas and available facilities are variables that certainly affect the visitation, spending and resulting economic effects at these reservoirs. As a rough approximation, economic effects for the proposed Millican-Bundic Reservoir are estimated as the average of those for Belton Lake (closest in size) and Somerville Lake (closest in location). This estimate assumes that the proposed Millican-Bundic Reservoir will be characterized by approximately the same level of recreational facilities as the average of Belton and Somerville Lakes.

Table 4B.12.7-6.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for Selected U.S. Corps of Engineers Projects in the Brazos G Area, 1996

Project	*Total Spending (1996 $)*	*Direct Sales Effects (1996 $)*	*Total Sales Effects (1996 $)*	*Direct Income Effects (1996 $)*	*Total Income Effects (1996 $)*	*Direct Jobs Effects (Number of Jobs)*	*Total Jobs Effects (Number of Jobs)*
Belton Lake	22,760,000	14,050,000	22,210,000	7,420,000	12,010,000	510	655
Somerville Lake	18,850,000	12,180,000	19,410,000	6,290,000	10,220,000	416	538
Stillhouse Hollow Reservoir	5,550,000	3,640,000	6,030,000	1,890,000	3,180,000	121	163
Waco Lake	19,540,000	13,010,000	23,140,000	7,010,000	12,600,000	442	616
Whitney Lake	19,780,000	12,860,000	23,650,000	6,790,000	12,660,000	442	629
Granger Lake	6,210,000	4,070,000	6,750,000	2,110,000	3,560,000	136	182
Lake Georgetown	10,550,000	6,920,000	11,460,000	3,590,000	6,050,000	230	309
Source: Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, “Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996”, U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998.							

[136] Propst, D. B., D. J. Stynes, W. Chang, and R. Jackson. 1998. Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996. U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998.

Table 4B.12.7-7 presents these estimates for the proposed Millican-Bundic Reservoir. The proposed Millican-Bundic Reservoir would have a surface area of 14,630 acres, comparable to both Somerville and Belton Lakes.

Table 4B.12.7-7.
Estimates of Annual Recreational Spending, Sales, Income and Job Effects on Surrounding Region for the Proposed Millican-Bundic Reservoir in Brazos, Leon, Robertson and Madison Counties

Project	*Total Spending (1996 $)*	*Direct Sales Effects (1996 $)*	*Total Sales Effects (1996 $)*	*Direct Income Effects (1996 $)*	*Total Income Effects (1996 $)*	*Direct Jobs Effects (Number of Jobs)*	*Total Jobs Effects (Number of Jobs)*
Belton Lake	22,760,000	14,050,000	22,210,000	7,420,000	12,010,000	510	655
Somerville Lake	18,850,000	12,180,000	19,410,000	6,290,000	10,220,000	416	538
Proposed Millican-Bundic Reservoir (average of Belton and Somerville Lakes)	20,805,000	13,115,000	20,810,000	6,855,000	11,115,000	463	597

Sources: HDR Engineering, Inc. and Hicks & Company, 2004; Propst, D. B., D. J. Stynes, W. Chang, R. Jackson, "Estimating the Local Economic Impacts of Recreation at Corps of Engineers Projects – 1996", U.S. Army Corps of Engineers, Waterways Experiment Station, Technical Report R-98-1, September 1998; U.S. Army Corps of Engineers, http://www.swf-wc.usace.army.mil/belton/Lkmap.htm; U.S. Army Corps of Engineers, http://swf67.swf-wc.usace.army.mil/SOMERVILLE/lakeinfo.htm

These estimates suggest that economic effects from recreational activity at the proposed reservoir would have positive economic effects on the surrounding region in Brazos, Leon, Robertson, and Madison Counties. These effects are comparable in magnitude to those expected for the proposed Little River 330' Reservoir. Total annual spending is estimated at $20,805,000, total sales effects at $20,810,000, total income effects at $11,115,000 and total jobs created at 597.

4B.12.7.3.9 Loss of Crop Value

Based on evaluation of existing aerial photography, no substantial acreage of intensively managed row crops occurs with the reservoir footprint. Therefore, no substantial loss of value of agricultural row crops or intensively managed agricultural land is expected. Among the 14,630 acres potentially inundated by the reservoir, approximately 4,086 acres or 28 percent includes grasslands that comprise of a mixture of non-native and native grassland species, a portion of which is used for livestock grazing and/or hay production. However, the value of these grasslands could not be determined because they could not be differentiated from other nonagricultural grasslands at this level of photographic analysis. Forested lands would also have value for timber production, but this would be highly variable depending on species composition and size. Estimates of the value of timber resources would be determined from site evaluations in later studies.

4B.12.7.4 Engineering and Costing

The proposed Millican-Bundic Reservoir project includes the construction of an earth dam, principal spillway, emergency spillway, and appurtenant structures. Project cost estimates were prepared by the USCOE in 1982. These project cost estimates were updated to Second Quarter 2002 prices. The total project cost for the Bundic Dam Site is estimated to be $464.7 million. This cost is based on a federal project and some federal participation in the project would be anticipated. The cost details are shown in Table 4B.12.7-8. The annual project costs are estimated to be $34.8 million; this includes annual debt service, and operation and maintenance. The cost for the estimated increase in system yield of 38,080 acft/yr, translates to an annual unit cost of raw water at the reservoir of $2.80 per 1,000 gallons, or $913 per acft.

Table 4B.12.7-8.
Cost Estimate Summary for
Millican-Bundic Reservoir
(Second Quarter 2002 Prices)

Item	*Estimated Costs for Facilities*
Capital Costs	
Dam and Reservoir (Conservation Pool 205,760 acft, 14,630 acres, 277 ft-msl)	$257,770,000
Total Capital Cost	**$257,770,000**
Engineering, Legal Costs and Contingencies	$90,220,000
Environmental & Archaeology Studies and Mitigation	25,968,000
Land Acquisition and Surveying (14,630 acres)	26,700,000
Interest During Construction (4 years)	64,106,000
Total Project Cost	**$464,764,000**
Annual Costs	
Reservoir Debt Service (6 percent for 40 years)	$30,889,000
Operation and Maintenance	
Dam and Reservoir	3,867,000
Total Annual Cost	**$34,756,000**
Available Project Yield (acft/yr)	**38,080**
Annual Cost of Water ($ per acft)	**$913**
Annual Cost of Water ($ per 1,000 gallons)	**$2.80**

The total project cost reported in the 2001 Water Plan was $552 million and the current plan costs have decreased to an estimated $464.7 million. The reductions in project costs are due largely to an updated methodology used to calculate Land Acquisition and Surveying.

The annual unit cost of water has increased from $541 per acft ($1.66 per 1,000 gallons) in the 2001 Plan to $913 per acft ($2.80 per 1,000 gallons) in the current plan. The increase in unit cost is due to the decrease in projected project yield; projected yield was 76,800 acft/yr in the 2001 Plan and is currently 38,080 acft/yr in the current Plan.

4B.12.7.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.12.7-9, and the option meets each criterion.

Table 4B.12.7-9.
Comparison of Millican-Bundic Reservoir
to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient quantity[1]
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Moderate impact
2. Habitat	2. Moderate impact
3. Cultural Resources	3. Moderate to High impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Moderate impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Potential impact on bottomland farms and habitat in reservoir area
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

[1] Significant quantity available for regional use and Region H.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for structures placed in navigable waters of the U.S. (Section 10 of Rivers and Harbors Act) or discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits will require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required;
- Possible relocations of residences, utilities, roads, oil and gas production and storage facilities, or other structures; and
- Possible acquisition of mineral rights.

4B.13 Off-Channel Reservoirs

4B.13.1 Introduction

Implementation of off-channel reservoirs is becoming more common as increasing environmental constraints limit the development of major on-channel reservoirs. The concept of an off-channel reservoir is to divert water from a primary stream during high flows to storage in a reservoir constructed on a smaller tributary stream. Stored water in the off-channel reservoir is used to provide a firm supply of water when flow is not available from the primary stream during drought periods. Off-channel reservoirs have been implemented in Texas in the past, primarily for industrial and steam electric purposes. Examples of existing off-channel reservoirs in the Brazos G Area include Lake Alcoa, Tradinghouse Creek Reservoir (Texas Utilities), Lake Creek Reservoir (Texas Utilities), City of Robinson, and the City of Clifton. A summary of each of these projects is presented in Table 4B.13.1-1.

Table 4B.13.1-1.
Summary of Existing Off-Channel Reservoirs in Brazos G Area

Owner	*Off-Channel Reservoir*	*Authorized Storage (acft)*	*Primary Stream for Diversion*
Alcoa	Lake Alcoa	15,650	Little River
Texas Utilities	Tradinghouse Creek Reservoir	37,800	Brazos River
Texas Utilities	Lake Creek Reservoir	8,500	Brazos River
City of Robinson	Robinson Off-Channel Reservoir	8,037	Brazos River
City of Clifton	Clifton Off-Channel Reservoir	2,000	North Bosque River

While providing a firm supply during drought times when run-of-the-river diversions are not available, off-channel reservoirs also provide other advantages, including:

- Less environmental impact than an on-channel reservoir as the site of the off-channel reservoir can be located to minimize environmental impacts;
- Off-channel reservoirs also generally offer a lower cost for storage because the reservoir is typically sited on a small tributary which reduces the size of the dam and spillway facilities;
- Opportunities to phase construction of the facilities as water demands increase in order to lower the initial cost of the supply system; and
- A pumping schedule can be developed to produce the optimal water quality from the primary stream.

The primary disadvantage of an off-channel reservoir is the requirement for a pump station and pipeline system to divert water from the primary stream to the off-channel reservoir site, which causes operation and maintenance costs to be generally higher than operation and maintenance of an on-channel reservoir.

Several locations in the Brazos G Region offer the potential for development of an off-channel reservoir as a source of water supply (Figure 4B.13.1-1). These locations include:

1. City of Groesbeck in Limestone County;
2. Wheeler Branch Off-Channel Reservoir in Somervell County,
3. Peach Creek Lake in Brazos County,
4. Little River Off-Channel Reservoir in Milam County, and
5. Lake Palo Pinto Off-Channel Reservoir in Palo Pinto County

Each of the reservoirs is described briefly in the following sections. A summary of all the proposed off-channel reservoir yields and project costs is shown in Table 4B.13.1-2.

Table 4B.13.1-2.
Summary of Off-Channel Reservoir Yields and Costs

Reservoir	***Yield (acft/yr)***	***Total Project Cost***	***Total Annual Cost***	***Unit Cost per acft***	***Unit Cost per 1,000 gallons***
Groesbeck (w/ Navasota River Diversion)	950	$9,623,000	$866,000	$912	$2.80
Little River (108”) (w/ Little River Diversion)	32,110	$96,512,000	$8,028,000	$250	$0.77
Peach Creek (w/ Navasota River Diversion)	3,980	$30,910,000	$2,834,000	$712	$2.19
Wheeler Branch (w/ Paluxy River Diversion)	1,800	$27,195,000	$2,117,000	$1,176	$3.61
Lake Palo Pinto (w/ Lake Palo Pinto Diversion)	3,110	$19,314,000	$1,621,000	$521	$1.60

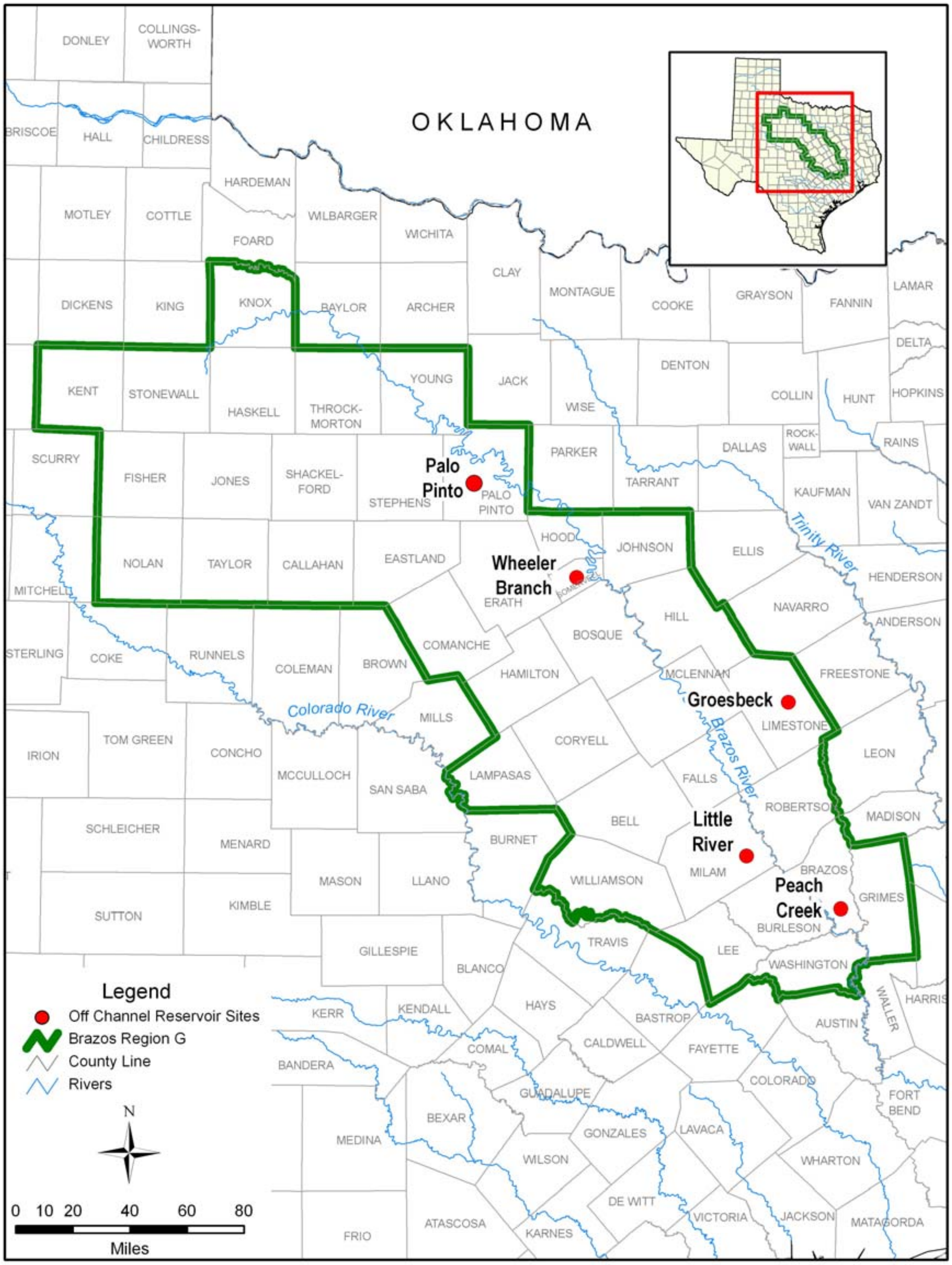

Figure 4B.13.1-1. Off-Channel Reservoir Location Map

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4B.13.2 City of Groesbeck Off-Channel Reservoir

4B.13.2.1 Description of Option

The Groesbeck Off-Channel Reservoir is a proposed new reservoir adjacent to the Navasota River, northeast of the City of Groesbeck in Limestone County, as shown in Figures 4B.13.2-1 and 4B.13.2-2. The City of Groesbeck uses surface water directly from the Navasota River and has water rights on the Navasota River that authorize diversion of 2,500 acft/yr and storage of 500 acft with a priority of June 1921. This water right is one of the more senior water rights in the Brazos River Basin.

The diversion point for the City of Groesbeck is just north (upstream) of the City and downstream (south) of Springfield Lake at Fort Parker. A natural spring occurs just below Springfield Lake that provides a base flow to the river just upstream of the City's diversion point during most years. However, during past drought periods the springflow has not been able to supply the City's water demand and the City has diverted stored water from Springfield Lake. Springfield Lake is owned by the TPWD for recreation purposes; however, Groesbeck's 500 acft storage right extends into the lake. During drought periods, when the flow in the Navasota River is not adequate to meet the City's water needs, the City siphons water from storage in Springfield Lake over the dam and into the downstream river channel. The City diverts the normal river flow and the water diverted from storage in Springfield Lake.

Springfield Lake was built in 1939 for the primary purpose of recreation. The lake is very shallow, originally storing about 3,100 acft over a surface area of 750 acres, making the average depth of the lake about 4 feet. Over the years, the lake has lost significant storage due to sedimentation. In 1991, the City of Groesbeck and the TPWD jointly participated in a project[1] to dredge the lake making the average lake depth approximately 4 feet over 500 acres. Groesbeck has relied on this storage during recent drought periods to meet their needs and has implemented water rationing in the City as recently as 1998.

A yield analysis of Springfield Lake was performed to determine what the reliable supply to Groesbeck would be with its diversion rights from the Navasota River and storage in Springfield Lake. The shallow depth of about four feet and effective surface area of 500 acres of Springfield Lake results in the reservoir being very inefficient. In comparison, net evaporation

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[1] Hunter & Associates, Inc., "A Plan for Dredging and Rehabilitation of Springfield Lake at Fort Parker, Limestone County, Texas," prepared for the City of Groesbeck and the Texas Parks and Wildlife Department, January 1991.

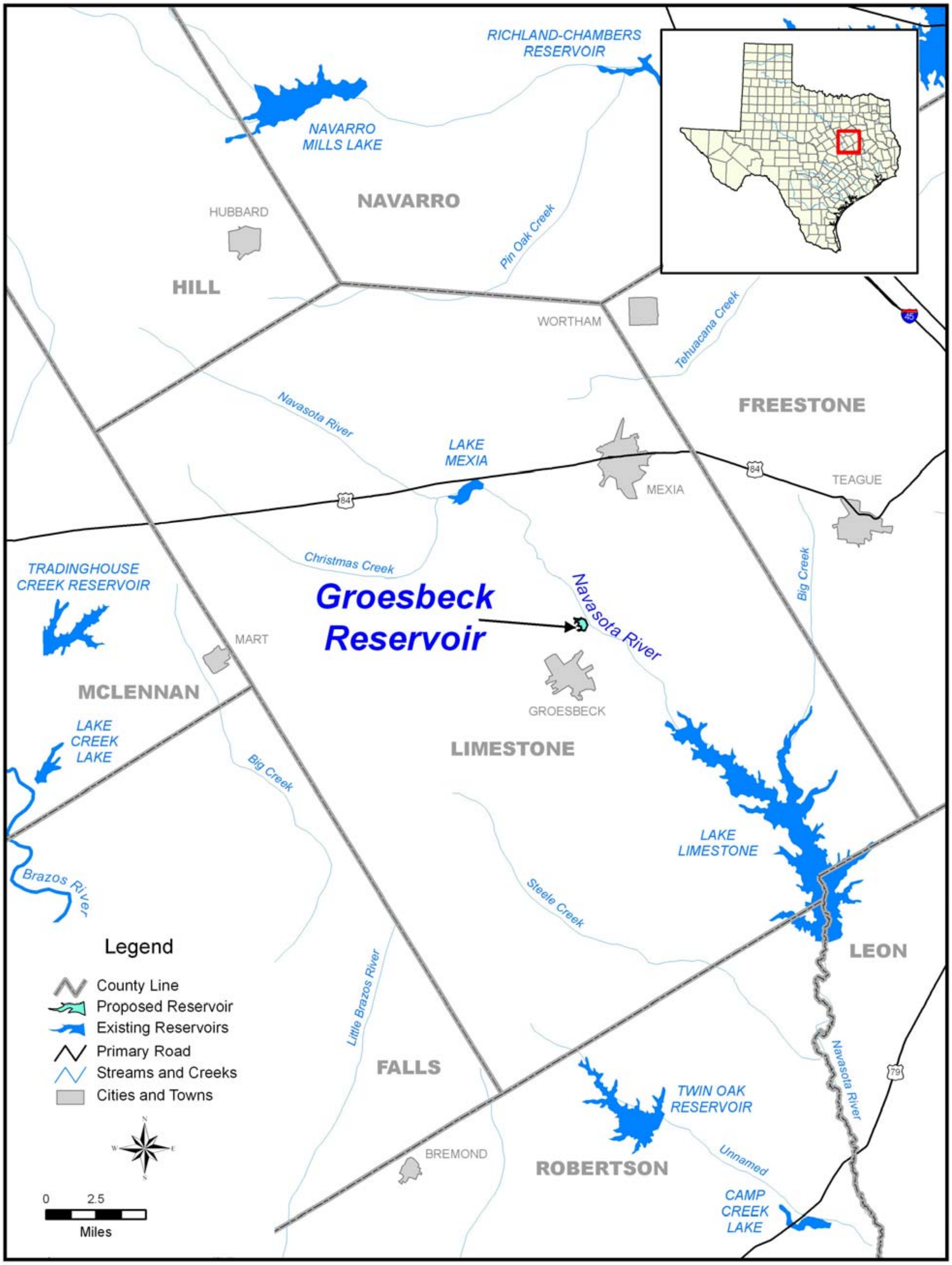


Figure 4B.13.2-1. Groesbeck Off-Channel Reservoir

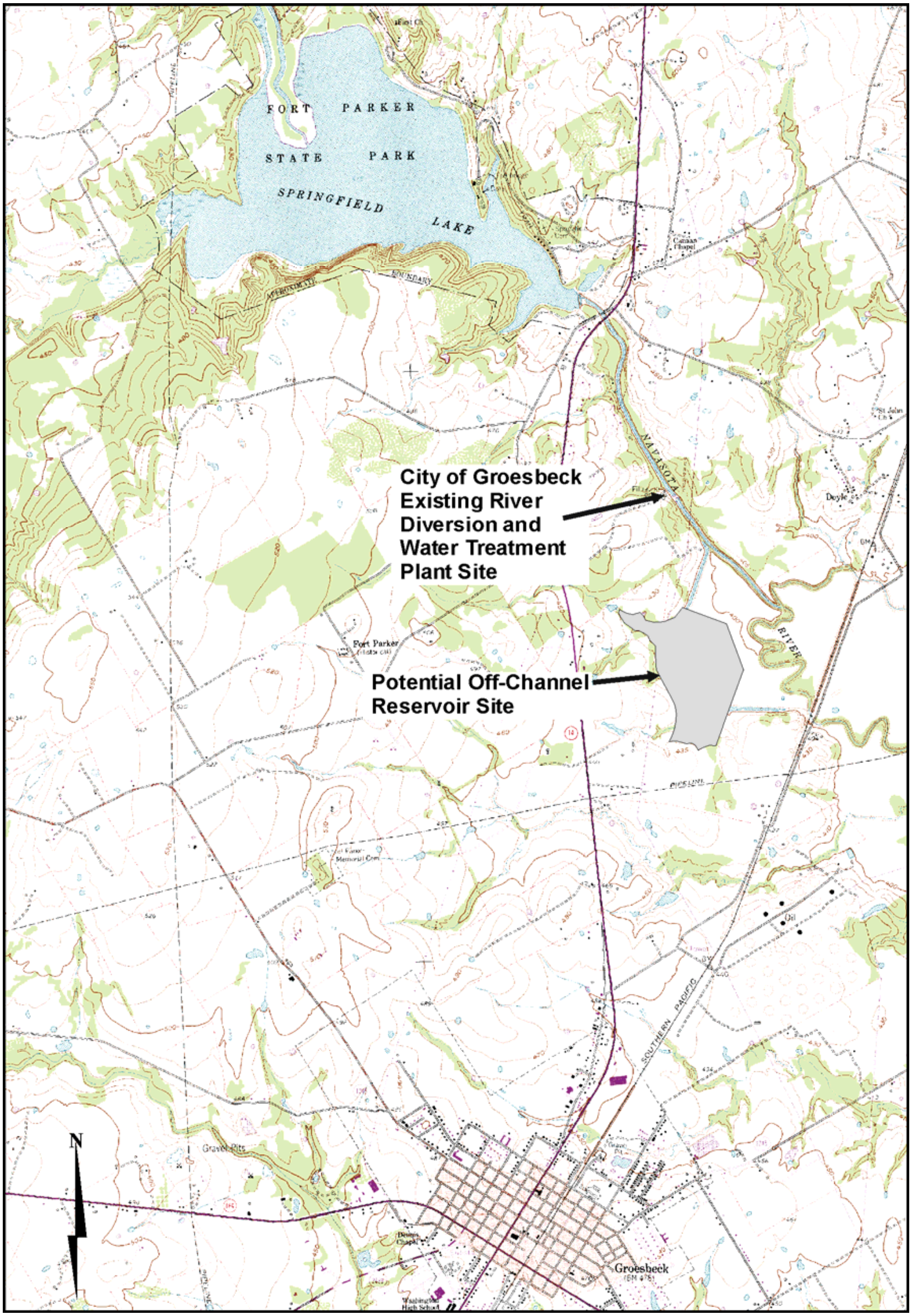


Figure 4B.13.2-2. Groesbeck Off-Channel Reservoir

rates during the extended drought periods of the 1950s were as high as 4.2 feet annually, which would severely deplete the reservoir storage without any diversions by the City. The yield analysis showed that the firm yield of the City's water right, supplemented with storage from Springfield Lake, was less than 200 acft/yr. The City of Groesbeck's water use in 2000 was 782 acft.

Various alternatives to supplement the City's supply are available. These alternatives include construction of an off-channel reservoir along the Navasota River to store water for use during drought periods, development of groundwater in the Carrizo-Wilcox Aquifer east of the City, and purchase of water from Lake Limestone, located downstream of the City. The off-channel reservoir alternative appears to be an economical solution to providing the City with a firm water supply, as the storage can be developed near the City's existing river diversion and water treatment facilities. A potential off-channel storage site along the Navasota River is shown in Figure 4B.13.2-2. The dam would be an earthfill embankment that would extend approximately 1,500 feet and provide a conservation storage capacity of 2,317 acft at an elevation 420 ft-msl; the reservoir would inundate 146 surface acres. The reservoir would impound flows from the watershed of a small, unnamed tributary, as well as flows diverted from the Navasota River.

4B.13.2.2 Available Yield

Water potentially available for impoundment in the proposed Groesbeck Off-Channel Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from the Navasota River into the Groesbeck Off-Channel Reservoir without causing increased shortages to existing downstream rights. Firm yield was computed subject to the reservoir and Navasota River diversion having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H). The streamflow statistics used to determine the Consensus Criteria pass through requirements for the off-channel reservoir and the Navasota River diversion are shown in Tables 4B.13.2-1 and 4B.13.2-2.

Table 4B.13.2-1.
Daily Natural Streamflow Statistics for the Groesbeck Off-Channel Reservoir

Month	Median Flows – Zone 1 Pass-Through Requirements (cfs)	25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)
January	0.11	0.03
February	0.15	0.05
March	0.16	0.05
April	0.14	0.05
May	0.20	0.05
June	0.06	0.01
July	0.01	0.00
August	0.00	0.00
September	0.00	0.00
October	0.01	0.00
November	0.03	0.01
December	0.07	0.01
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.00

Table 4B.13.2-2.
Daily Natural Streamflow Statistics
for the Navasota River Diversion

Month	Median Flows – Zone 1 Pass-Through Requirements (cfs)	25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)
January	12.6	3.8
February	21.1	6.4
March	18.2	6.1
April	14.0	4.6
May	23.0	6.5
June	5.3	1.5
July	1.0	0.1
August	0.6	0.0
September	0.7	0.0
October	0.9	0.2
November	3.1	0.8
December	7.5	1.8
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.02

The calculated firm yield of the Groesbeck Off-Channel Reservoir is 950 acft/yr with a maximum diversion capacity of 38 cfs (42-inch diameter pipeline) from the Navasota River and assuming an agreement would be obtained with the Brazos River Authority for subordination of Lake Limestone. The yield impact on Lake Limestone due to the Groesbeck Off-Channel Reservoir is estimated to be 844 acft/yr.

Figure 4B.13.2-3 illustrates the simulated Groesbeck Off-Channel Reservoir storage levels for the 1940 to 1997 historical period, subject to the firm yield of 950 acft/yr and based on delivery of Navasota River diversions via a 42-inch pipeline. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 74 percent of the time and above the Zone 3 trigger level (50 percent capacity) 96 percent of the time.

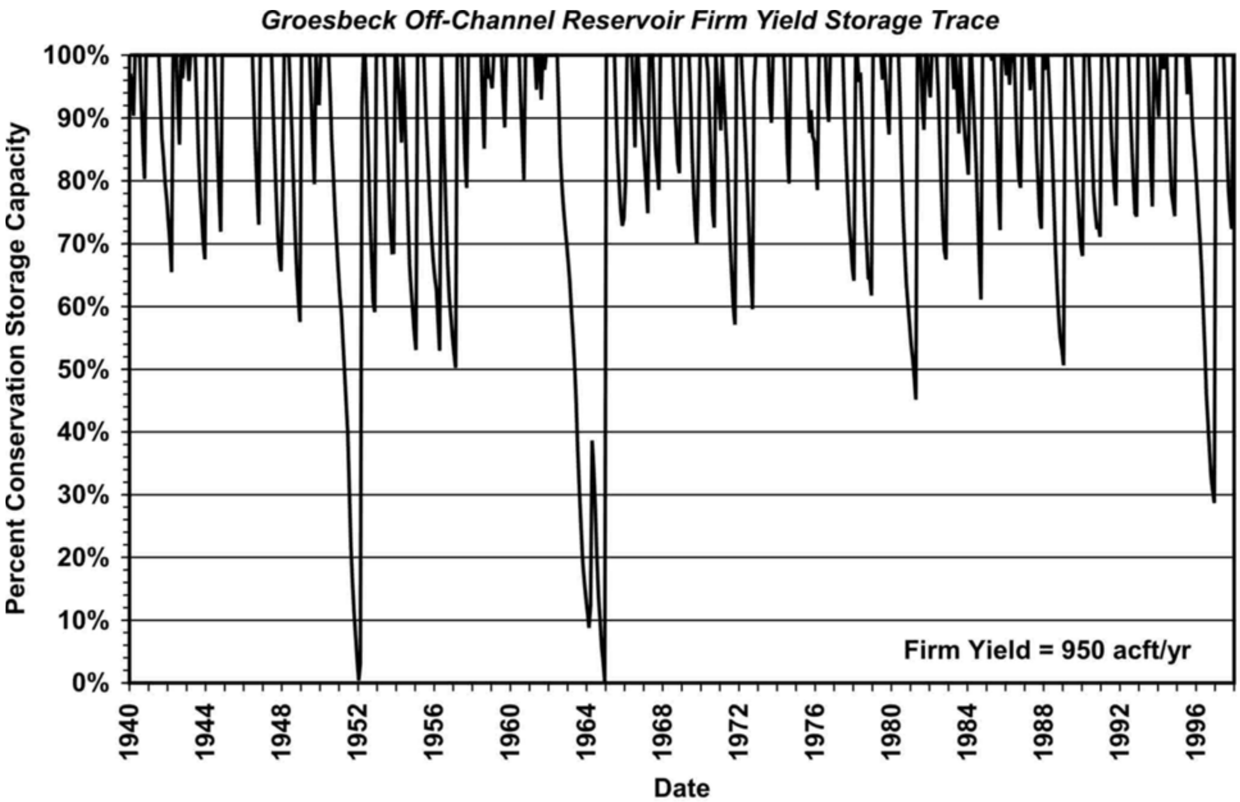
Figure 4B.13.2-4 illustrates the change in streamflows near the reservoir and in the Navasota River caused by the project. The largest change in the Navasota River would be a decline in median streamflow of 9.4 cfs during January. During the summer months, there is little or no water available in the stream. In the winter and spring months there would be a minimal change in streamflow. Figure 4B.13.2-4 also illustrates the Navasota River streamflow frequency characteristics with the Groesbeck Off-Channel Reservoir in place. There is little impact on flows due to the reservoir.

4B.13.2.3 Environmental Issues

4B.13.2.3.1 Existing Environment

The City of Groesbeck Off-Channel Reservoir site in Limestone County lies in a transitional zone with the Blackland Prairies Ecological Region to the west and the Post Oak Savannah Ecological Region to the east.[2] This region is characterized by level to rolling topography, with interspersed grassland and woodland, with soils ranging from the deep, fertile, black soils of the Blackland Prairies region to the shallow, nearly impervious clay pan of the Post Oak Savannah region. The original physiognomy of the region varied from medium to tall broad-leaved deciduous and some needle-leaved evergreen trees to medium-tall dense grasslands with

[2] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.



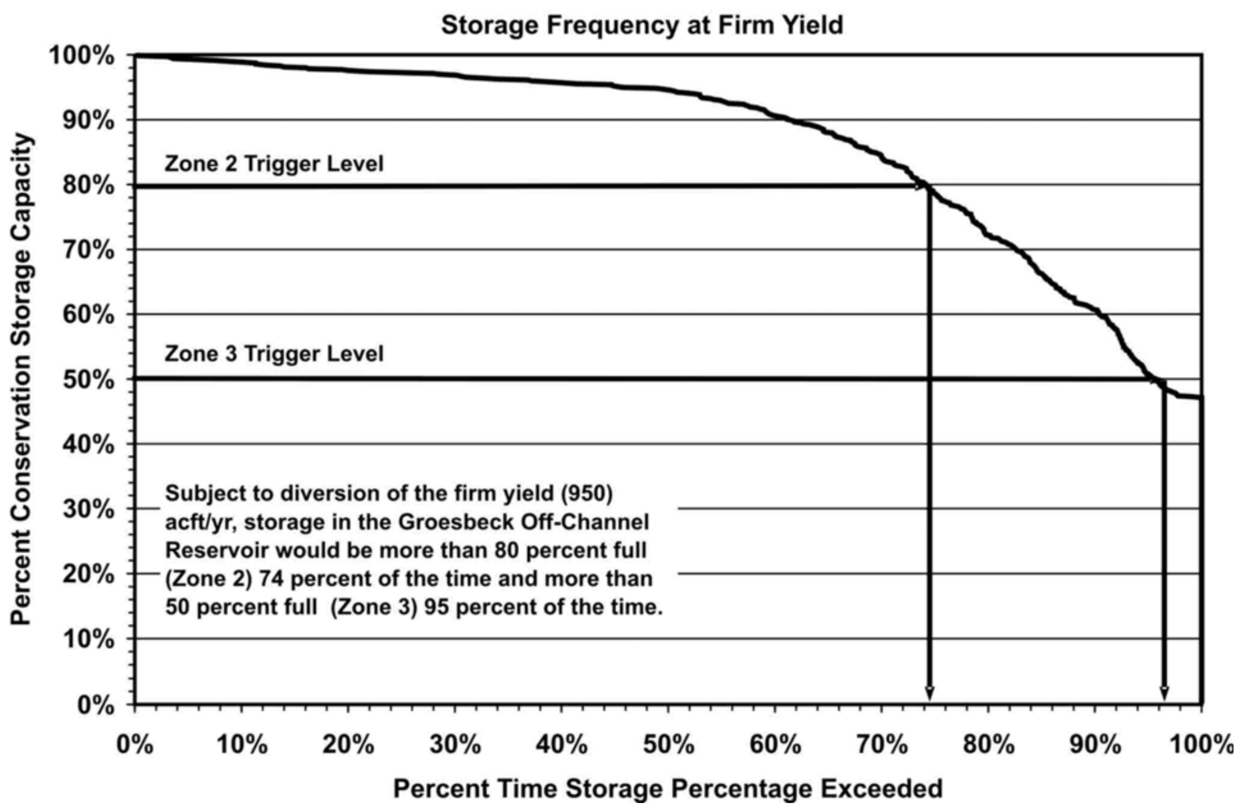


Figure 4B.13.2-3. Groesbeck Off-Channel Reservoir Storage Considerations

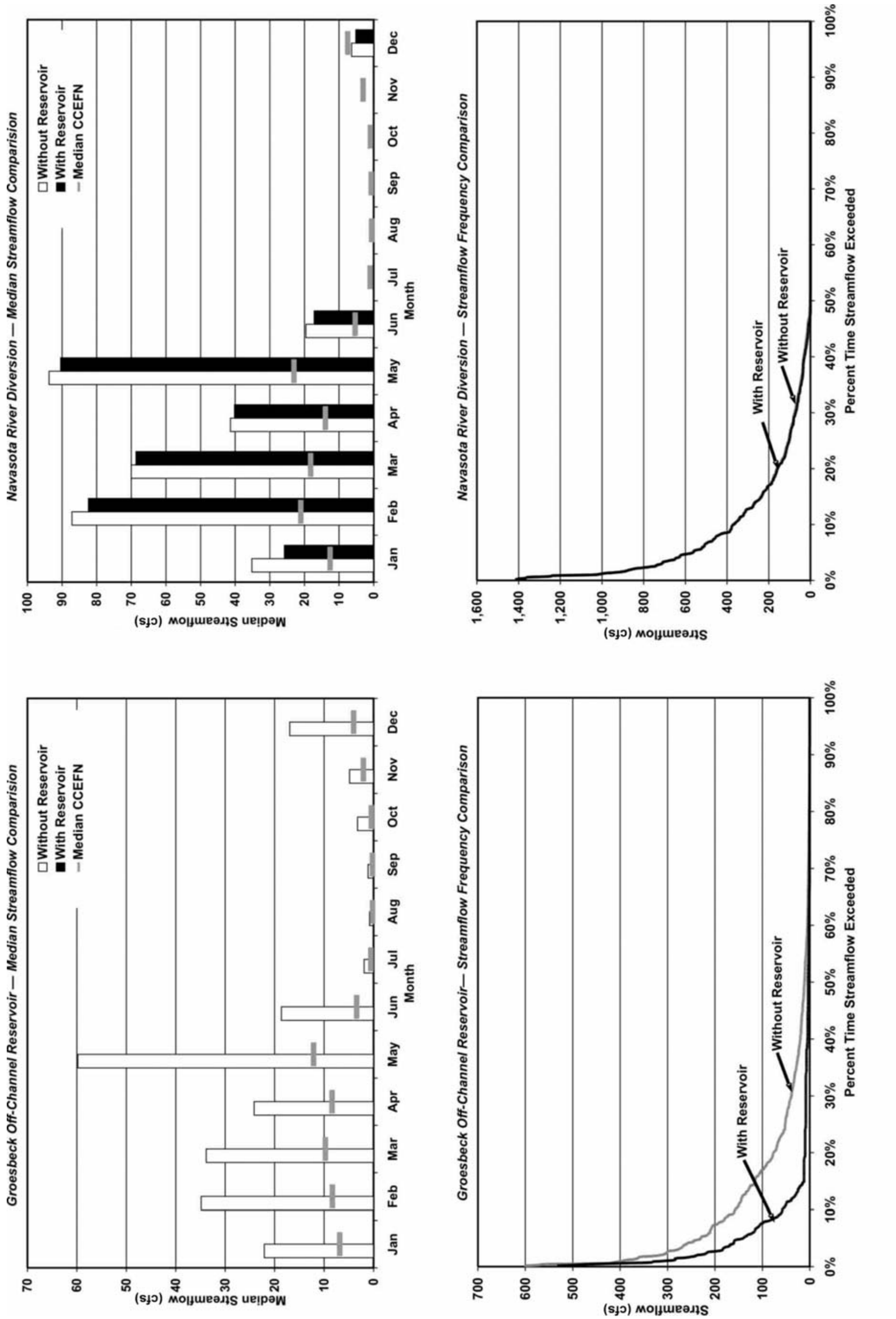


Figure 4B.13.2-4. Groesbeck Off-Channel Reservoir and Navasota River Diversion Streamflow Comparisons

scattered open groves of deciduous trees in minor prairies.[3] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation ranges between 36 and 40 inches.[4] The Carrizo-Wilcox Aquifer is the only major aquifer underlying the project area.[5]

The physiography of the region includes greensand-ironstone, undifferentiated sand and mud, terraces, and flood-prone areas. The topography ranges from steep slopes to low rolling hills and prairies, with some flat areas and local shallow depressions in flood-prone areas along waterways.[6] The predominant soil associations in the project area are Axtell-Rader and Whitesboro. The Axtell series consists of very deep, moderately well drained, very slowly permeable soils on Pleistocene terraces. The soil formed in slightly acid to alkaline clayey sediments. Slopes are dominantly 0 to 5 percent, but range up to 12 percent.[7,8]

Three major vegetation types occur within the general vicinity of the project: Elm-Hackberry (*Ulmus-Celtis*) Woods, Other Native and/or Introduced Grasses, and crops.[9] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Elm-Hackberry Parks/Woods could include the following commonly associated plants: mesquite (*Prosopis glandulosa*), post oak (*Quercus stellata*), woollybucket bumelia (*Sideroxylon lanuginosum*), honey locust (*Gleditsia triacanthos)*, coralberry (*Symphoricarpos orbiculatus*), pasture haw (*Crataegus spathulata*), elbowbush (*Forestiera pubescens*), Texas pricklypear (*Opuntia engelmannii* var. *lindheimeri*), tasajillo (*Opuntia leptocaulis*), dewberry (*Rubus* spp.), silver bluestem (*Bothriochloa saccharoides*), buffalograss (*Buchloe dactyloides*), western ragweed (*Ambrosia cumanensis*), giant ragweed (*A. trifida*), goldenrod (*Solidago* spp.), frostweed (*Verbesina virginica*), ironweed (*Vernonia* spp.), prairie parsley (*Polytaenia nuttallii*), and broom snakeweed (*Gutierrezia sarothrae*). Commonly associated plants of Other Native and/or Introduced Grasses are mixed native or introduced grasses and forbs on grassland sites or

[3] Telfair, R.C., "Texas Wildlife Resources and Land Uses," University of Texas Press, Austin, Texas, 1999.
[4] Larkin, T.J., and G.W. Bomar, "Climatic Atlas of Texas," Texas Department of Water Resources, Austin, Texas, 1983.
[5] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[6] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., "Land Resources of Texas." Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.
[7] Schappert, Phil., *The Stengl-Lost Pines Biological Station Soil Profiles*, http://www.sbs.utexas.edu/philjs/Stengl/soil/axtell.html, 1998.
[8] Baker, F.E., *Soil Survey of Bastrop County, Texas*, Soil Conservation Service, United States Department of Agriculture, Washington, D.C., 1979.
[9] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

mixed herbaceous communities resulting from the clearing of woody vegetation, which are subject to change due to brushy re-growth. Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.13.2.3.2 Potential Impacts

4B.13.2.3.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and in the Navasota River where water will be pumped and diverted to the project site. The potential impacts of this project are very different in the two locations. In the diversion site on the Navasota River, minimal impacts are anticipated in terms of a reduction in variability or quantity of median monthly flows. But in the proposed project site, there would be a moderate reduction in variability and dramatic reductions in the quantity of median monthly flows. The difference in variability of monthly flow conditions at the proposed project site would be a factor of approximately 2.0 (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place; sample variance without project =7,159; sample variance with project =3,536). The difference in variability of monthly flow values in the Navasota River diversion site would be negligible (sample variance without project =1.69 x 10^8; sample variance with project =1.70 x 10^8). Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

The reduction in the median monthly flow at the project site would be 100 percent in all months at the proposed reservoir site, as shown in Table 4B.13.2-3. In the Navasota River, reductions would range from zero in July through September to 9.4 cfs (27 percent) in January, as shown in Table 4B.13.2-4. The reduction in median monthly flow at the diversion site would be less than 10 percent during 7 months of the year. Because low-flows occur frequently without the project in place, the addition of this project would have minimal impact on these low-flow conditions. Without the project, the 85 percent exceedance value would be 0.007 cfs and with the project it would be 0.003 cfs at the project site. The 85 percent exceedance values would be the same with and without the project in the Navasota River diversion site.

Table 4B.13.2-3.
Median Monthly Streamflow: Groesbeck Off-Channel Reservoir

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	0.36	0.0	0.36	100%
February	0.63	0.0	0.63	100%
March	0.55	0.0	0.55	100%
April	0.41	0.0	0.41	100%
May	0.97	0.0	0.97	100%
June	0.31	0.0	0.31	100%
July	0.03	0.0	0.03	100%
August	0.01	0.0	0.01	100%
September	0.02	0.0	0.02	100%
October	0.05	0.0	0.05	100%
November	0.08	0.0	0.08	100%
December	0.28	0.0	0.28	100%

Table 4B.13.2-4.
Median Monthly Streamflow: Navasota River Diversion Site

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	35.2	25.8	9.4	27%
February	87.2	82.4	4.8	5%
March	70.0	68.6	1.4	2%
April	41.4	40.2	1.2	3%
May	93.7	90.4	3.3	4%
June	19.6	17.2	2.4	12%
July	0.01	0.01	0.0	0%
August	0.005	0.005	0.0	0%
September	0.008	0.008	0.0	0%
October	0.021	0.015	0.006	31%
November	0.044	0.015	0.029	65%
December	6.4	5.1	1.2	19%

Although there would be impacts in the immediate vicinity of the project site and downstream, it appears that this project, alone, would have minimal influence on total discharge in the Navasota or Brazos Rivers, in which case there would be minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Groesbeck Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.13.2.3.2.2 Threatened & Endangered Species

A total of 17 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 3 reptiles, 10 birds, 2 mammals, 1 fish species and 1 plant species (Table 4B.13.2-4). Four bird species federally-listed as threatened or endangered could occur in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

A search of the Texas Wildlife Diversity Database10 revealed the documented occurrence of the bald eagle and a rare plant, the golden wave tickseed (*Coreopsis intermedia*) within the vicinity of the proposed Groesbeck Off-Channel Reservoir (as noted on representative 7.5-minute quadrangle map(s) that include the project site). These data are not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

[10] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.

Table 4B.13.2-4.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the City of Groesbeck Off-Channel Reservoir Site, Limestone County

Scientific Name	*Common Name*	*Federal/State Status*	*Potential Occurrence*
Birds			
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Lanius ludovicianus migrans	Migrant Loggerhead Shrike	SOC	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Plegadis chihi	White-faced Ibis	SOC/T	Migrant
Grus Americana	Whooping Crane	LE/E	Migrant
Fishes			
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Reptiles			
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Eriocaulon koernickianum	Small-headed pipewort	SOC	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, *Annotated County List of Rare Species for Limestone County,* 2003. TPWD Texas Wildlife Diversity Database (2004), United States Fish and Wildlife Service (USFWS), *Federally-listed as Threatened and Endangered Species of Texas*, September 12, 2003.

4B.13.2.3.2.3 Wildlife Habitat

Approximately 146 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 107 acres of Grasses/Forbs, and 39 acres of Elm/Hackberry Woods.

A number of vertebrate species could occur within the City of Groesbeck Reservoir site as indicated by county occurrence records.[11] These include 3 species of salamanders, 14 species of frogs and toads, 10 species of turtles, the American alligator, 11 species of lizards and skinks, and 19 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[12] as well as an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.13.2.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 27 archeological sites have been documented within the general vicinity of the proposed reservoir. Fifteen of these sites were recorded by the Texas Parks and Wildlife Department as part of a survey of Fort Parker in 1994. While all of these sites lie outside the limits of the proposed reservoir, it is possible that similar unrecorded sites could occur within the project's Area of Potential Effect. These sites represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

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[11] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.

[12] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

4B.13.2.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely increase adverse effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures during summer periods. The project is expected to have negligible impacts to the stream flow and water quality in the Navasota and Brazos Rivers.

4B.13.2.4 Engineering and Costing

The potential off-channel reservoir project for the City of Groesbeck would require additional facilities to divert water from the Navasota River to the off-channel reservoir site. The facilities required for implementation of the project included:

- Raw water intake and pump station with a capacity of 38 cfs;
- 3,500 feet of raw water pipeline (42-inch diameter) from the pump station to the off-channel reservoir; and
- Off-channel dam including spillway, intake tower, and 146 acres of land for the reservoir.

A summary of the total project cost is presented in Table 4B.13.2-5. The proposed Groesbeck Off-Channel Reservoir project would cost approximately $9.6 million for surface water supply facilities. This includes the construction of the dam, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The project cost also includes the cost for the raw water facilities to convey surface water from the Navasota River to the off-channel reservoir and back to the City’s existing water treatment plant. The annual project costs are estimated to be $866,000. This includes annual debt service, operation and maintenance, pumping energy costs, and an annual payment to the Brazos River Authority for yield impacts to Lake Limestone.

The total project cost reported in the 2001 Water Plan was $4.17 million; the current plan costs are significantly higher at an estimated $9.6 million. Cost differences are due in part to higher capacity raw water pumping facilities. The 2001 plan included costs for a 12 cfs (8 MGD) raw water intake and pump station; the current plan estimates costs for a 38 cfs (25 MGD) facility. In addition to differing raw water pumping facilities, cost differences between the 2001 and 2006 Plans are also due to land costs. Land acquisition costs were most likely underestimated in the 2001 Water Plan.

Table 4B.13.2-5.
Cost Estimate Summary for
Groesbeck Off-Channel Reservoir
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Conservation Pool 2,317 acft, 146 acres, 420 ft-msl)	$2,427,000
Intake and Pump Station (24 MGD)	2,288,000
Transmission Pipeline (42 in-dia., 1 mile)	720,000
Transmission Pump Station(s)	809,000
Total Capital Cost	**$6,244,000**
Engineering, Legal Costs and Contingencies	$2,150,000
Environmental & Archaeology Studies and Mitigation	243,000
Land Acquisition and Surveying (156 acres)	272,000
Interest During Construction (2 years)	714,000
Total Project Cost	**$9,623,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$409,000
Reservoir Debt Service (6 percent for 40 years)	265,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	85,000
Dam and Reservoir	36,000
Pumping Energy Costs (540,550 kWh @ 0.06 $/kWh)	32,000
Purchase of Water (844 acft/yr @ $45.75/acft)	39,000
Total Annual Cost	**$866,000**
Available Project Yield (acft/yr)	**950**
Annual Cost of Water ($ per acft)	**$912**
Annual Cost of Water ($ per 1,000 gallons)	**$2.80**

[1] Raw water pumping facilities include a raw water intake and pump station (38 cfs), 3,500 feet raw water pipeline (42-inch diameter) from the river to the off-channel reservoir, and 3,500 feet raw water pipeline (12-inch diameter) from the off-channel reservoir to the existing water treatment plant.

[2] Includes the dam, intake, and spillway tower.

[3] Includes the power cost for pumping water from the Navasota River to the off-channel reservoir.

The total annual cost reported in the 2001 Water plan was $362,000; the current plan costs are estimated at $866,000. The increase in 2006 estimated costs are due to the higher power requirements needed by the higher capacity raw water facilities.

The annual cost of water has increased significantly from $214 per acft ($0.74 per 1,000 gallons) in the 2001 plan to $912 per acft ($2.80 per 1,000 gallons) in the current plan. The increase in cost is due to the decrease in projected project yield and an increase in total annual costs. The project yield and annual costs were 1,500 acft/yr and $362,000, respectively in the 2001 plan and are currently 950 acft/yr and $866,000, respectively in the 2006 plan.

4B.13.2.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.13.2-6, and the option meets each criterion.

Table 4B.13.2-6.
Evaluations of Groesbeck Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Negligible impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

Implementation of the off-channel reservoir project for the City of Groesbeck will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. The project may also have an impact on the firm yield of Lake Limestone, which may require mitigation with the Brazos River Authority in terms of a water supply contract in the amount of the firm yield impact. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

4B.13.3 Wheeler Branch Off-Channel Reservoir

4B.13.3.1 Description of Option

The Wheeler Branch Off-Channel Reservoir is a proposed new reservoir on the Wheeler Branch, a tributary of the Paluxy River, about two miles north of the City of Glen Rose in Somervell County (Figure 4B.13.3-1). The project would impound water from the Wheeler Branch watershed as well as divert water from the Paluxy River during periods of flow in excess of downstream needs. The reservoir will have conservation storage capacity of 4,118 acft and a drainage area of 1.6 square miles. Waters from the Paluxy River will be transported into the reservoir through a 36-inch pipeline and pump station system that has a capacity of 50 cfs. The diversion point on the Paluxy River has a drainage area of 428 square miles. The owner of the project is Somervell County Water District (SCWD), which will provide water from this project primarily to the City of Glen Rose.

The water right for this reservoir (Permit 5744) was approved by the TCEQ on September 11, 2002 with a priority date of June 17, 2001.[13] This water right authorizes an annual diversion of up to 5,000 acft from the Paluxy River at a maximum rate of 50 cfs and a diversion of 2,000 acft/yr from the reservoir for municipal use. SCWD has an agreement with the Brazos River Authority that subordinates the Authority's water right in Lake Whitney to the Wheeler Branch Off-Channel Reservoir. This project is currently under design and is expected to be built by 2010.

4B.13.3.2 Available Yield

Water potentially available for impoundment in the proposed Wheeler Branch Off-Channel Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from the Paluxy River into the Wheeler Branch Off-Channel Reservoir without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir and Paluxy River diversion having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H).

[13] TCEQ Database of Water Rights as of September 24, 2004.

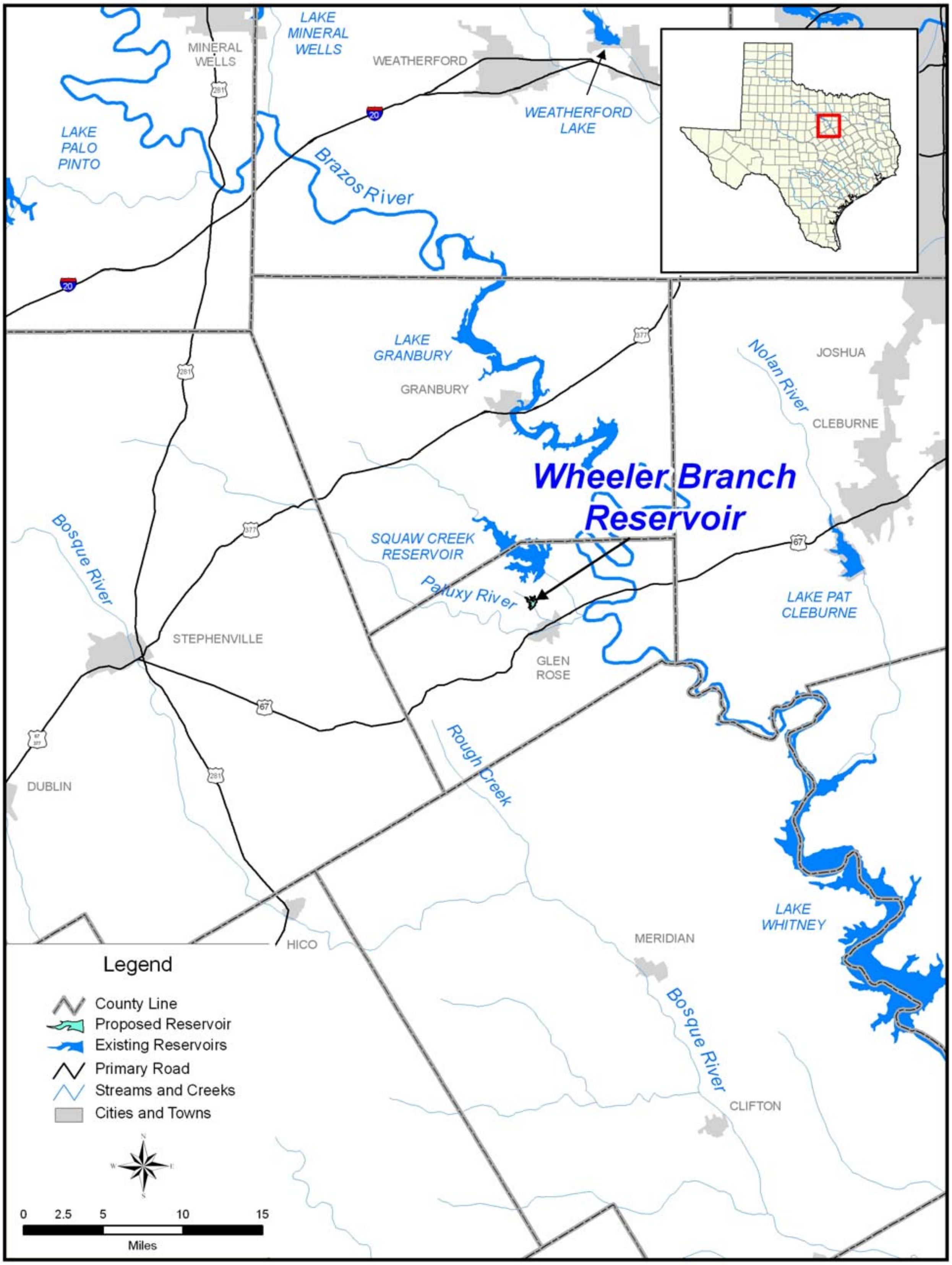


Figure 4B.13.3-1. Wheeler Branch Off-Channel Reservoir

The calculated firm yield of the Wheeler Branch Off-Channel Reservoir is 1,800 acft/yr. The yield is constrained by the capacity of a 36-inch diameter pipeline. The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the off-channel reservoir and the Paluxy River diversion are shown in Tables 4B.13.3-1 and 4B.13.3-2.

Table 4B.13.3-1.
Daily Natural Streamflow Statistics
for the Wheeler Branch Reservoir

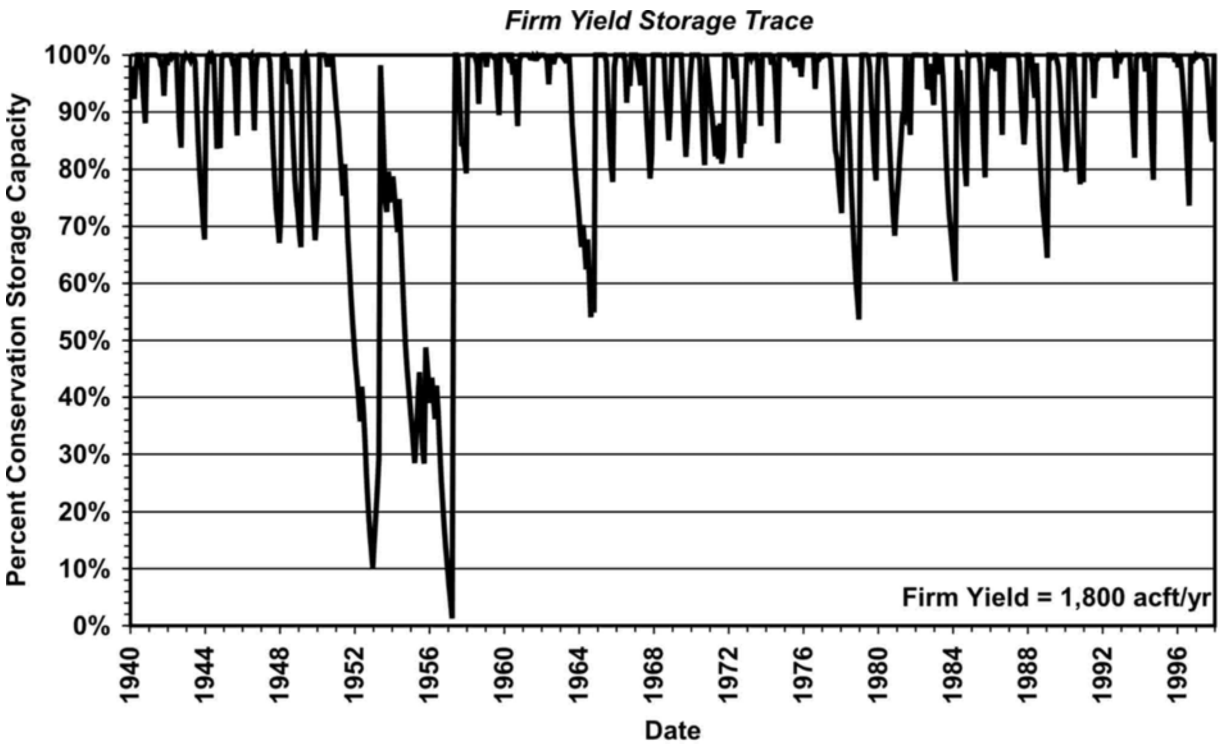
Month	*Median Flows - Zone 1 Pass Through Requirements (cfs)*	*25th Percentile Flows - Zone 2 Pass Through Requirements (cfs)*
January	0.14	0.05
February	0.21	0.10
March	0.25	0.09
April	0.29	0.11
May	0.26	0.06
June	0.22	0.05
July	0.10	0
August	0.10	0
September	0.10	0
October	0.10	0
November	0.10	0
December	0.13	0
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0

Figure 4B.13.3-2 illustrates the simulated Wheeler Branch Off-Channel Reservoir storage contents for the 1940 to 1997 historical period, subject to the firm yield of 1,800 acft/yr and based on delivery of Paluxy River diversions via a 36-inch pipeline. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 72 percent of the time and above the Zone 3 trigger level (50 percent capacity) 83 percent of the time.

Table 4B.13.3-2.
Daily Natural Streamflow Statistics
for the Paluxy River Diversion

Month	***Median Flows - Zone 1 Pass Through Requirements (cfs)***	***25th Percentile Flows - Zone 2 Pass Through Requirements (cfs)***
January	16.1	8.7
February	20.0	10.5
March	22.8	9.8
April	27.5	11.4
May	46.9	15.2
June	29.8	11.3
July	10.8	3.5
August	5.5	1.3
September	6.6	1.8
October	9.5	2.3
November	13.4	5.7
December	13.3	7.6
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.9

Figure 4B.13.3-3 illustrates the changes in Wheeler Branch and Paluxy River streamflows caused by the project. There are minimal changes in Paluxy River streamflow due to the project. The largest streamflow decline of 3.5 cfs (10 percent) occurs in May. Figure 4B.13.3-3 also illustrates the Paluxy River streamflow frequency characteristics with the Wheeler Branch Off-Channel Reservoir in place. There is little difference with the project because the Paluxy River diversion would be required to pass nearly all inflows in order to satisfy senior water rights and/or environmental flows.



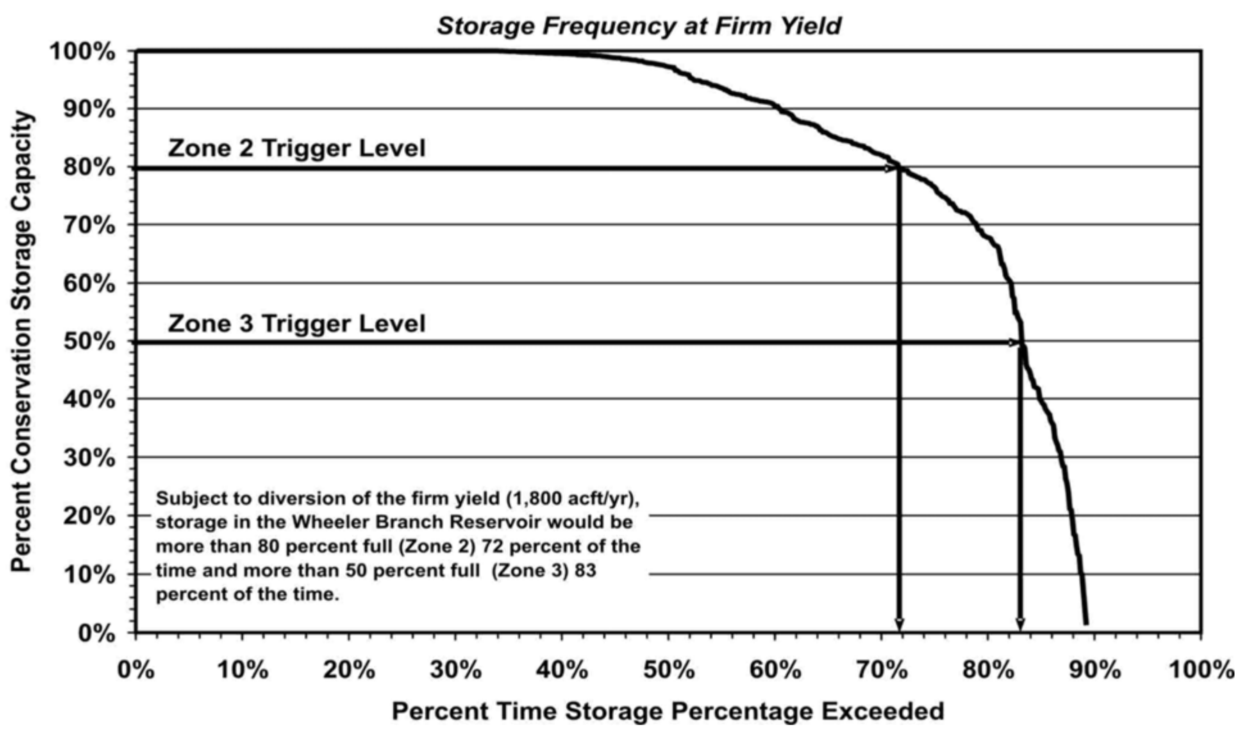


Figure 4B.13.3-2. Wheeler Branch Off-Channel Reservoir Storage Consideration

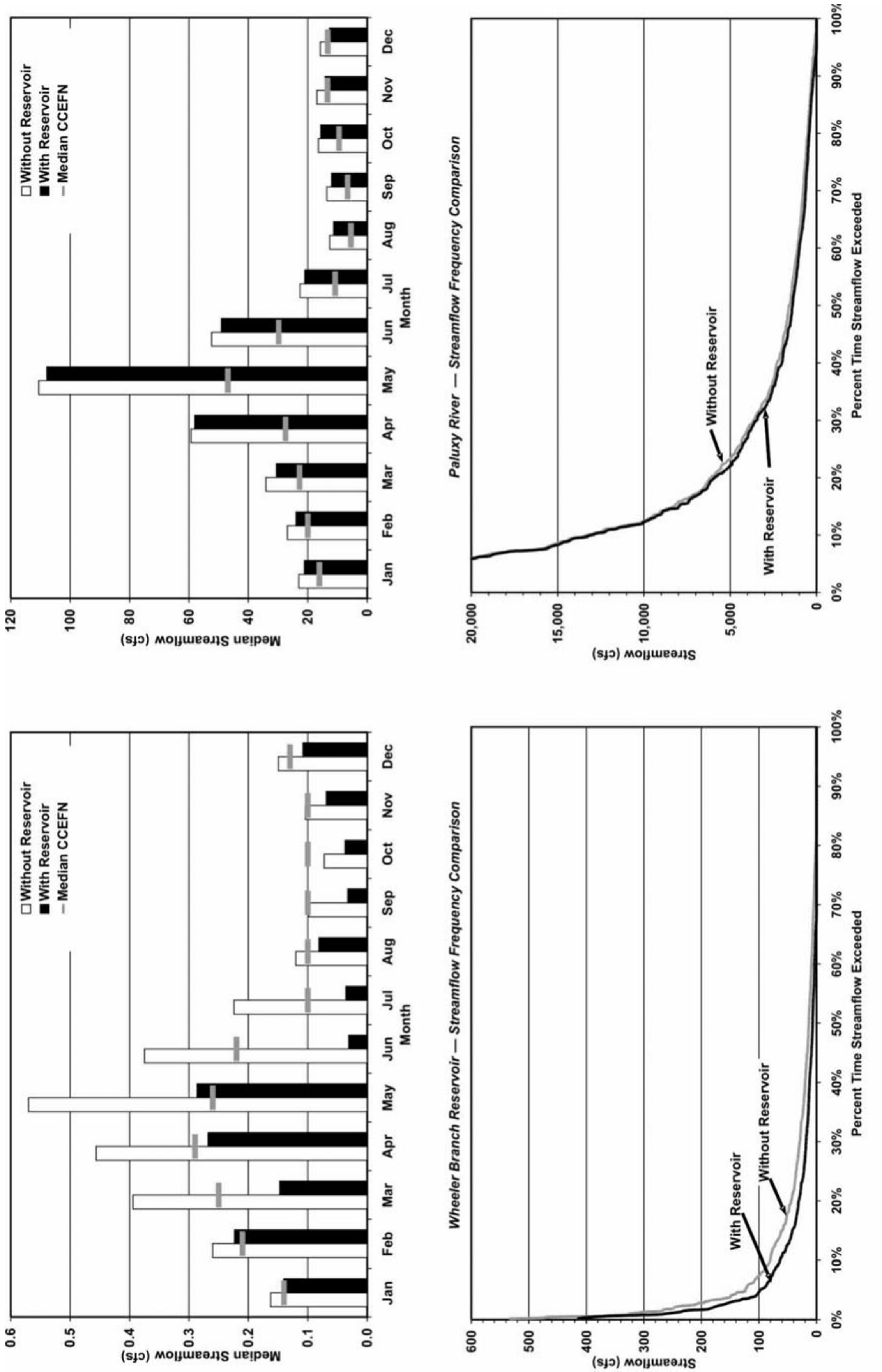


Figure 4B.13.1-3. Wheeler Branch Off-Channel Reservoir and Diversion Streamflow Comparisons

4B.13.3.3 Environmental Issues

4B.13.3.3.1 Existing Environment

The Wheeler Branch Off-Channel Reservoir site in Somervell County lies within the Cross Timbers and Prairies Ecological Region.[14] This complex transitional area of prairie dissected by parallel timbered strips is located in north-central Texas west of the Blackland Prairies and east of the Rolling Plains Ecological regions, and north of the Edwards Plateau and Llano Uplift. The physiognomy of the region is oak and juniper woods and mixed grass prairie. Much of the native vegetation has been displaced by agriculture and development, and range management techniques, including fire suppression, have contributed to the spread of invasive woody species and grasses. Farming and grazing practices have also reduced the abundance and diversity of wildlife in the region.[15] The climate is characterized as subtropical subhumid, with hot summers and dry winters. Average annual precipitation ranges between 28 and 32 inches.[16] The Trinity Aquifer, a major aquifer consisting of interbedded sandstone, sand, limestone, and shale of Cretaceous age, underlies the project area. The Trinity Aquifer extends in a band through the central part of the State from the Red River to the eastern edge of Bandera and Medina Counties. It is the primary water source for much of the Hill Country and has been intensively developed in northeast and central Texas.[17]

The physiography of the region includes stair step topography, terraces, recharge sand, and flood-prone areas. The topography is flat to rolling, with steep slopes and benches in some areas and local shallow depressions in flood-prone areas along waterways.[18]

Two major vegetation types occur within the general vicinity of the proposed project: Oak (*Quercus*) – Mesquite (*Prosopis*) – Juniper (*Juniperus*) Parks/Woods and Silver Bluestem (*Bothriochloa saccharoides*) – Texas Wintergrass (*Nassella leucotricha*) Grassland (McMahan et al. 1984). Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific

[14] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, *Vegetational Areas of Texas*, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[15] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.
[16] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.
[17] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

[18] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., *Land Resources of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.

range sites. Oak–Mesquite–Juniper Parks/Woods could include the following commonly associated plants: post oak (*Quercus stellata*), Ashe juniper (*Juniperus ashei*), shin oak (*Q. sinuata* var. *breviloba*), Texas oak (*Q. texana*), blackjack oak (*Q. marilandica*), live oak (*Q. virginiana*), cedar elm (*Ulmus crassifolia*), agarito (*Mahonia trifoliolata*), soapberry (*Sapindus saponaria*), sumac (*Rhus* spp.), hackberry (*Celtis* spp.), Texas pricklypear (*Opuntia engelmannii* var. *lindheimeri*), Mexican persimmon (*Diospyros texana*), purple three-awn (*Aristida purpurea*), hairy grama (*Bouteloua hirsuta*), Texas grama (*B. texana*), sideoats grama (*B. curtipendula*), curly mesquite (*Hilaria belangeri*), and Texas wintergrass. Commonly associated plants of Silver Bluestem–Texas Wintergrass Grassland are bushy bluestem (*Andropogon glomeratus*), slender bluestem (*Schizachyrium tenerum*), little bluestem (*Schizachyrium scoparium*), silver bluestem, three-awn (*Aristida* spp.), buffalograss (*Buchloe dactyloides*), bermudagrass (*Cynodon dactylon*), brownseed paspalum (*Paspalum plicatulum*), single-spike paspalum (*P. monostachyum*), smutgrass (*Sporobolus indicus*), sacahuista (*Spartina spartinae*), windmillgrass (*Chloris* spp.), southern dewberry (*Rubus trivialis*), live oak, mesquite, huisache (*Acacia farnesiana*), baccharis (*Baccharis* spp.), and Macartney rose (*Rosa bracteata*).

4B.13.3.3.2 Potential Impacts

4B.13.3.3.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and in the Paluxy River where water will be pumped and diverted to the project site. The potential impacts of this project differed in the two locations. In the diversion site on the Paluxy River, there would be very little impact on variability and minor changes in quantity of median monthly flows. In the proposed project site, there would also be relatively little effect on variability but substantial reductions in quantity of median monthly flows. The difference in variability of monthly flows at the proposed project site would be a factor of approximately 1.5 (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place sample variance without project =3,473; sample variance with project =2,288). The difference in variability of monthly flows in the Paluxy River diversion site would be negligible (sample variance without project =9.89 x 10^7; sample variance with project =9.81 x 10^7). These small differences in variability of flow conditions would probably not have much impact on the instream biological community or riparian species in the proposed reservoir site or in the Paluxy River.

The reduction in the quantity of median monthly flows at the reservoir site would range from 0.02 cfs (14 percent) in January to 0.34 cfs (92 percent) in June, as shown in Table 4B.13.3-3. The greatest reductions (>60 percent) would occur in March, June, July, and

Table 4B.13.3-3.
Median Monthly Streamflow: Wheeler Branch Reservoir

Month	***Without Project (cfs)***	***With Project (cfs)***	***Difference (cfs)***	***Percent Reduction***
January	0.16	0.14	0.02	14%
February	0.26	0.22	0.04	14%
March	0.39	0.15	0.25	63%
April	0.46	0.27	0.19	41%
May	0.57	0.29	0.28	50%
June	0.37	0.03	0.34	92%
July	0.22	0.04	0.19	84%
August	0.12	0.08	0.04	32%
September	0.10	0.03	0.07	67%
October	0.07	0.04	0.03	48%
November	0.10	0.07	0.04	34%
December	0.15	0.11	0.04	28%

September. The reductions would be less than 35 percent in November through February and in August. In the Paluxy River, median monthly flow would be reduced by a maximum of 3.5 cfs (10 percent) in March while the highest percent reduction (19 percent) would occur in December, as shown in Table 4B.13.3-4. The reduction in median monthly flows in the Paluxy River would be 10 percent or less during 8 months of the year. Low-flows would also be more common at the reservoir site with the proposed reservoir in place; flow would cease 32 percent of the time compared to 18 percent without the proposed reservoir in place. The 85 percent exceedance value in the Paluxy River would be 5.2 cfs with and 6.5 cfs without the proposed reservoir in place. The reductions in flow at the reservoir site would have moderate impacts on the instream biological community. Reductions in the Paluxy River may also have some influence on the instream biological community, but the highest reductions would occur during less critical months.

Table 4B.13.3-4. Median Monthly Streamflow: Paluxy River Diversion

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	23.0	21.2	1.8	8%
February	26.8	23.9	2.9	11%
March	34.1	30.6	3.5	10%
April	59.3	58.1	1.2	2%
May	110.6	107.9	2.7	2%
June	52.4	49.2	3.2	6%
July	22.6	21.0	1.6	7%
August	12.7	11.3	1.3	10%
September	13.6	12.0	1.5	11%
October	16.5	15.7	0.8	5%
November	16.9	14.2	2.7	16%
December	15.8	12.8	3.1	19%

Despite the potential biological impacts in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in the Paluxy or Brazos Rivers, in which case there would be minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary.

4B.13.3.3.2.2 Threatened & Endangered Species

A total of 22 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 4 reptiles, 12 birds, 2 mammals, 2 fish species, 1 insect, and 1 plant species (Table 4B.13.3-5). Six bird species federally-

Table 4B.13.3-5.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the City of Wheeler Branch Off-Channel Reservoir Site, Somervell County

Scientific Name	***Common Name***	***Federal/State Status***	***Potential Occurrence***
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Ammodramus bairdii	Baird's Sparrow	SOC	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Migrant
Vireo atricapillus	Black-capped Vireo	LE/E	Migrant*
Dendroica chrysoparia	Golden-cheeked Warbler	LE/E	Migrant*
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant
Athene cunicularia hypugaea	Western Burrowing Owl	SOC	Migrant*
Grus americana	Whooping Crane	LE/E	Migrant
Fishes			
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Insects			
Taeniopteryx starki	Leon River Winter Stonefly	SOC	X
Mammals			
Cynomys ludovicianus	Black-tailed Prairie Dog	SOC	X
Canis lupus	Gray Wolf	LE/E	Extirpated
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Reptiles			
Nerodia harteri	Brazos Water Snake	SOC/T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Yucca necopina	Glen Rose Yucca	SOC	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be Delisted (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-Delisted Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

listed as threatened or endangered could occur in the project area. These include the black-capped vireo (*Vireo atricapillus*), bald eagle (*Haliaeetus leucocephalus*), golden-cheeked warbler (*Dendroica chrysoparia*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir.

A search of the Texas Wildlife Diversity Database[19] revealed seven documented occurrences of the black-capped vireo, six occurrences of the golden-cheeked warbler, two occurrences of the Brazos water snake, one occurrence of a colonial water bird rookery, three occurrences of the Glen Rose Yucca, and two occurrences of the Glass Mountains coral-root (*Hexalectris nitida)* within the vicinity of the Wheeler Branch Off-Channel Reservoir site (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This data is not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.13.3.3.2.3 Wildlife Habitat

Approximately 169 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 15 acres of Oak-Mesquite-Juniper Parks and 154 acres of Oak-Mesquite-Juniper Woods.

A number of vertebrate species would be expected to occur within the Wheeler Branch Off-Channel Reservoir site as indicated by county occurrence records.[20] These include one species of salamander, 15 species of frogs and toads, seven species of turtles, 12 species of lizards and skinks, and 24 species of snakes. Additionally, 78 species of mammals could occur within the site or surrounding region[21] in addition to an undetermined number of bird species. A

[19] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.
[20] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.
[21] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.13.3.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 148 archeological sites have been documented within the general vicinity of the proposed reservoir. Researchers from Southern Methodist University recorded 49 of these sites in 1972-74. These sites represent a variety of historic and prehistoric site types. Thirty archeological sites have been recorded by the Texas Parks and Wildlife Department during various surveys of Dinosaur Valley State Park in 1991-97. While all of these sites lie outside the limits of the proposed reservoir, it is possible that similar unrecorded sites could occur within the project's area of potential effect. Similarly, several sites in the area have been recorded on privately held land by members of the Texas Historical Commission's Archeological Stewards Network. The sites in the area represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.13.3.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and potentially higher temperatures during summer periods. The project is expected to have low impacts to the stream flow and water quality in the Paluxy River, with negligible effects to Brazos River.

4B.13.3.4 Engineering and Costing

Construction of the Wheeler Branch Off-Channel Reservoir project will cost approximately $27.2 million. This includes the construction of the dam, pumping facilities, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $2.1 million; this includes annual debt service and operation and maintenance. The cost for the available project yield of 1,800 acft/yr translates to an annual unit cost of raw water of $3.61 per 1,000 gallons, or $1,176/acft. A summary of the cost estimate is provided in Table 4B.13.3-6. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

4B.13.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria as shown in Table 4B.13.3-7.

Potential Regulatory Requirements:

- A TCEQ water right permit has been acquired (Permit 5744)
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (TPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Table 4B.13.3-6.
Cost Estimate Summary for
Wheeler Branch Off-Channel Reservoir
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Raw Water Pumping Facilities[1]	$5,632,000
Dam and Reservoir	9,910,000
Total Capital Cost	**$15,542,000**
Engineering, Legal Costs and Contingencies	$5,158,000
Environmental & Archaeology Studies and Mitigation	1,812,000
Land Acquisition and Surveying	1,795,000
Interest During Construction (3 years)	2,888,000
Total Project Cost	**$27,195,000**
Annual Costs	
Debt Service (6 percent for 20 years)	$723,000
Reservoir Debt Service (6 percent for 40 years)	1,178,000
Operation and Maintenance	205,000
Energy Costs[2]	11,000
Total Annual Cost	**$2,117,000**
Available Project Yield (acft/yr)	**1,800**
Annual Cost of Water ($ per acft)	**$1,176**
Annual Cost of Water ($ per 1,000 gallons)	**$3.61**

[1] Raw water pumping facilities include a raw water intake and pump station (50 cfs), 11,250 feet raw water pipeline (36-inch diameter) from the river to the off-channel reservoir.
[2] Includes the power cost for pumping water from the Paluxy River to the off-channel reservoir.

Table 4B.13.3-7.
Evaluations of Wheeler Branch Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Negligible impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and
- Possible relocations or removal of residences, utilities, roads, or other structures.

4B.13.4 Peach Creek Off-Channel Reservoir

4B.13.4.1 Description of Option

The proposed Peach Creek Off-Channel Reservoir is located on Peach Creek, a tributary of the Navasota River in the Brazos County, about 10 miles southeast of the Bryan-College Station area (Figure 4B.13.4-1). The total reservoir storage capacity at a normal pool elevation of 240 feet-msl is 14,641 acft and the reservoir will inundate approximately 1,045 acres of land. The contributing drainage area is approximately 17 square miles. The project is proposed with a diversion from the Navasota River through a 60-inch pipeline and 1,400 HP pump station with a 100 cfs capacity to supplement local runoff from the Peach Creek watershed. The Navasota River diversion has a drainage area of 1,933 square miles. The reservoir is a potential source of water supply for Brazos County.

4B.13.4.2 Available Yield

Water potentially available for impoundment in the proposed Peach Creek Off-Channel Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from the Navasota River into the Peach Creek Off-Channel Reservoir without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir and Navasota River diversion having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H).

The calculated firm yield of the Peach Creek Off-Channel Reservoir is 3,980 acft/yr. This yield is obtained by assuming that only unappropriated flows in the Navasota River are available for pumping at a maximum rate of 100 cfs through a 60-inch diameter pipeline. The firm yield of the reservoir may increase if water is purchased from Lake Limestone to supplement local runoff with a larger pumping capacity. The 2001 Region G plan reported a firm yield of 16,500 acre-feet/year, which was based on a 1992 study completed by Global Natural Resources Corporation and Alan V. Thompson Engineering Consultants, Inc. The assumption for this previous evaluation did not consider requirement for senior downstream rights or environmental flows.

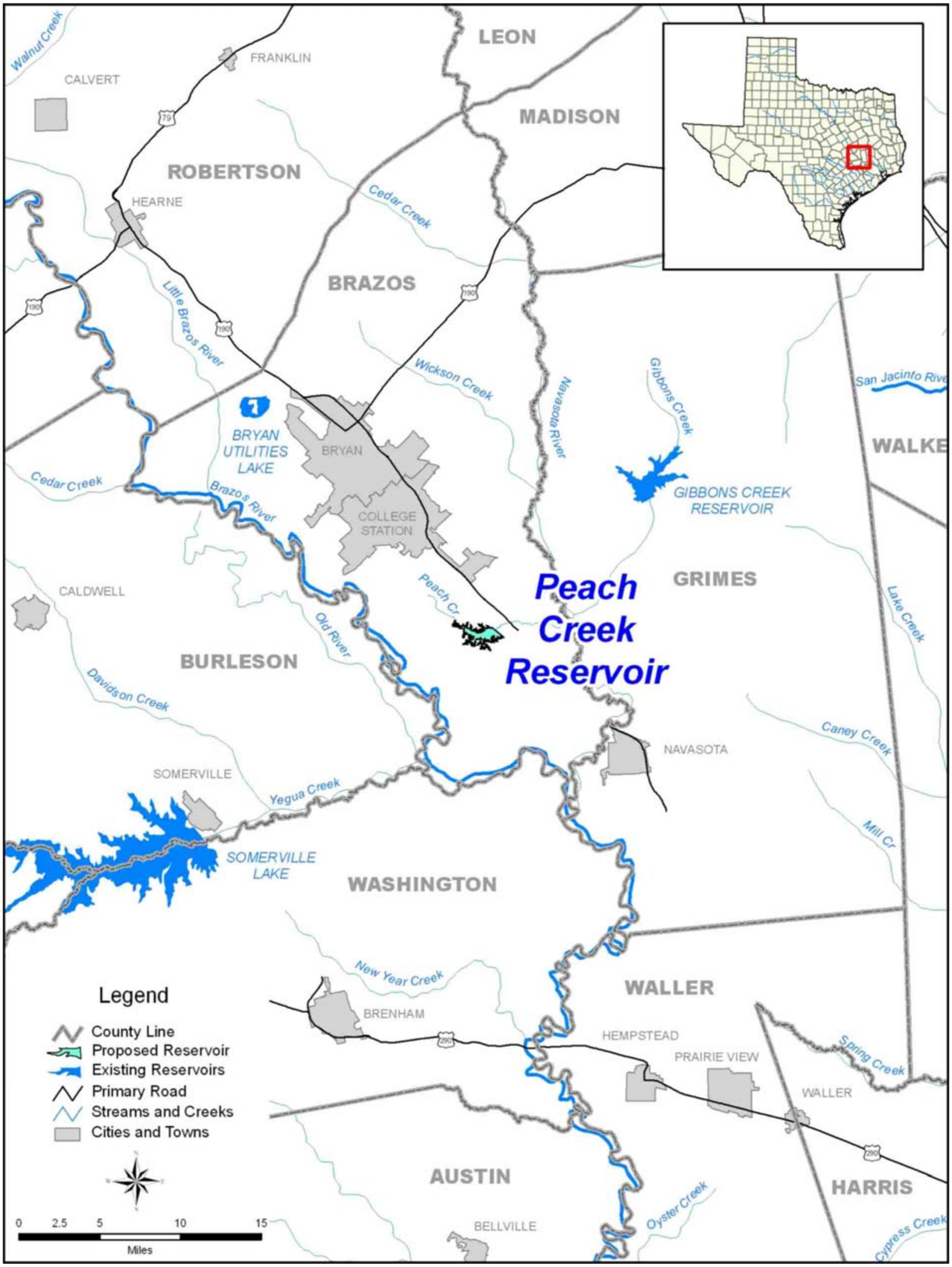


Figure 4B.13.4-1. Peach Creek Reservoir

The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the off-channel reservoir and the Navasota River diversion are shown in Tables 4B.13.4-1 and 4B.13.4-2.

Table 4B.13.4-1.
Daily Natural Streamflow Statistics
for the Peach Creek Off-Channel Reservoir

Month	*Median Flows - Zone 1 Pass Through Requirements (cfs)*	*25th Percentile Flows - Zone 2 Pass Through Requirements (cfs)*
January	6.4	2.4
February	7.0	2.8
March	6.7	2.3
April	5.2	1.9
May	7.6	0.9
June	6.5	1.8
July	3.8	1.6
August	1.8	0.7
September	1.9	0.7
October	1.4	0.4
November	3.4	1.2
December	4.1	1.6
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.5

Table 4B.13.4-2.
Daily Natural Streamflow Statistics
for the Navasota River Diversion

Month	*Median Flows - Zone 1 Pass Through Requirements (cfs)*	*25th Percentile Flows - Zone 2 Pass Through Requirements (cfs)*
January	294	132
February	390	163
March	351	124
April	320	126
May	422	115
June	216	69
July	127	53
August	60	21
September	69	18
October	61	21
November	132	55
December	226	89
Zone 3 (7Q2) Pass-Through Requirement (cfs):		8

Figure 4B.13.4-2 illustrates the simulated Peach Creek Off-Channel Reservoir storage contents for the 1940 to 1997 historical period, subject to the firm yield of 3,980 acft/yr and based on delivery of Navasota River diversions via a 60-inch pipeline. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 79 percent of the time and above the Zone 3 trigger level (50 percent capacity) 96 percent of the time.

Figure 4B.13.4-3 illustrates the changes in Peach Creek and Navasota River streamflows caused by the project. There is about a 50 percent reduction in median streamflows in Peach Creek and minimal changes in the Navasota River streamflow due to the project. Figure 4B.13.4-3 also illustrates the streamflow frequency characteristics with the Peach Creek Reservoir in place.

4B.13.4.3 Environmental Issues

4B.13.4.3.1 Existing Environment

The Peach Creek Off-Channel Reservoir site in Brazos County is within the Post Oak Savannah Ecological Region.[22] This region is characterized as a narrow, highly irregular oak belt that consists of intermingled forest, woodland, and savannah. It is located between the East Texas Pine-Hardwood Forest to the east, Blackland Prairies to the west, and the Coastal Prairie and South Texas Brushlands to the south. The original physiognomy of the region was medium to tall broad-leaved deciduous and some needle-leaved evergreen trees. In the northern and eastern areas, the trees are interspersed with open areas of grasses and forbs, but in the southern and western areas, trees are clumped or in solid stands. The shallow, nearly impervious clay pan of the Post Oak Savannah region causes the soil to be arid.[23] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation ranges between 36 and 40 inches.[24] The Queen City, Sparta, and Yegua Jackson minor aquifers underlie the project area, and the Gulf Coast major aquifer lies south of the project area but does not underlie it.[25]

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[22] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, *Vegetational Areas of Texas*, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960

[23] Telfair, R.C., *Texas Wildlife Resources and Land Uses*, University of Texas Press, Austin, Texas, 1999.

[24] Larkin, T.J., and G.W. Bomar, *Climatic Atlas of Texas*, Texas Department of Water Resources, Austin, Texas, 1983.

[25] Texas Water Development Board (TWDB), *Major and Minor Aquifers of Texas*, Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.

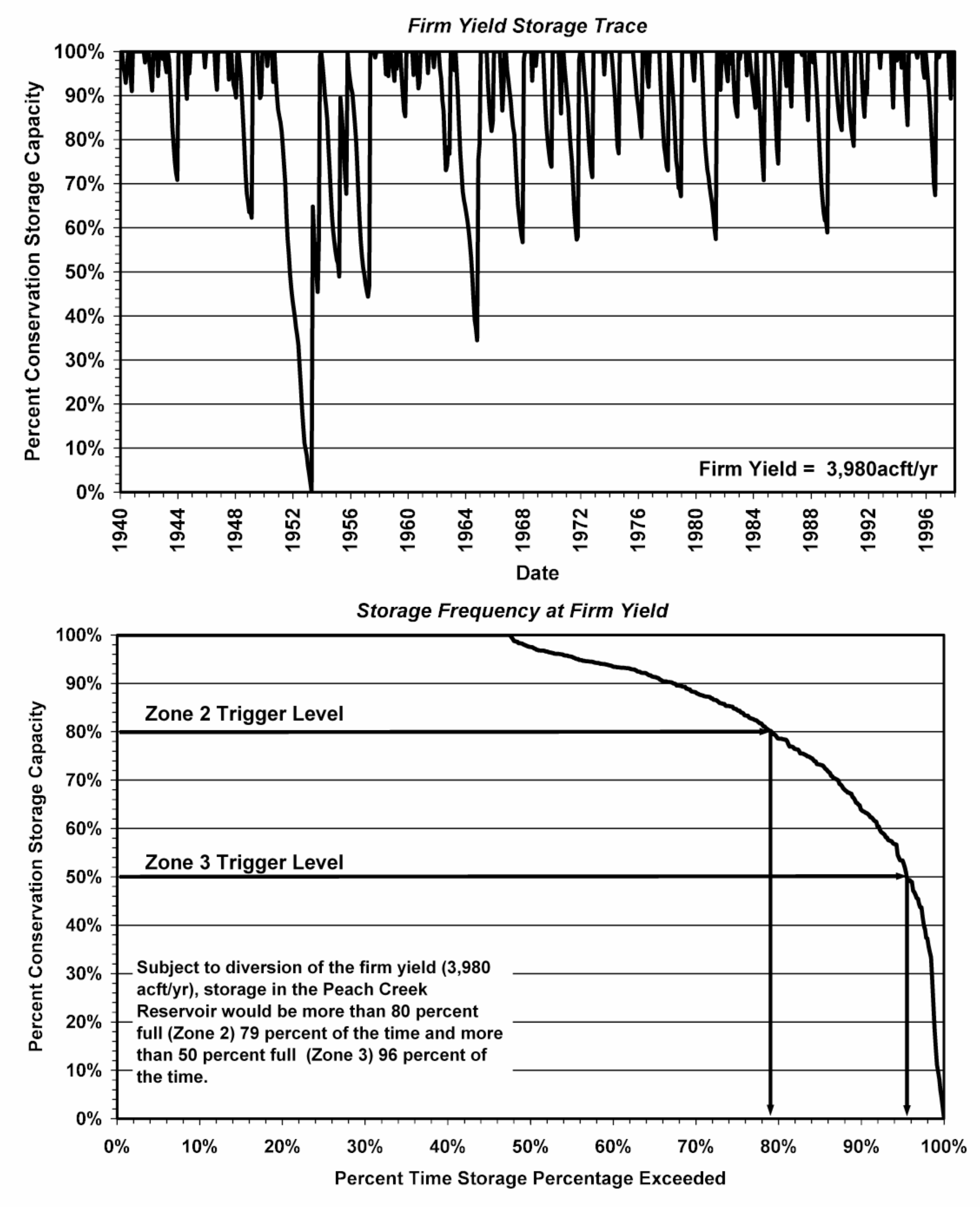

Figure 4B.13.4-2. Peach Creek Off-Channel Reservoir Storage Considerations

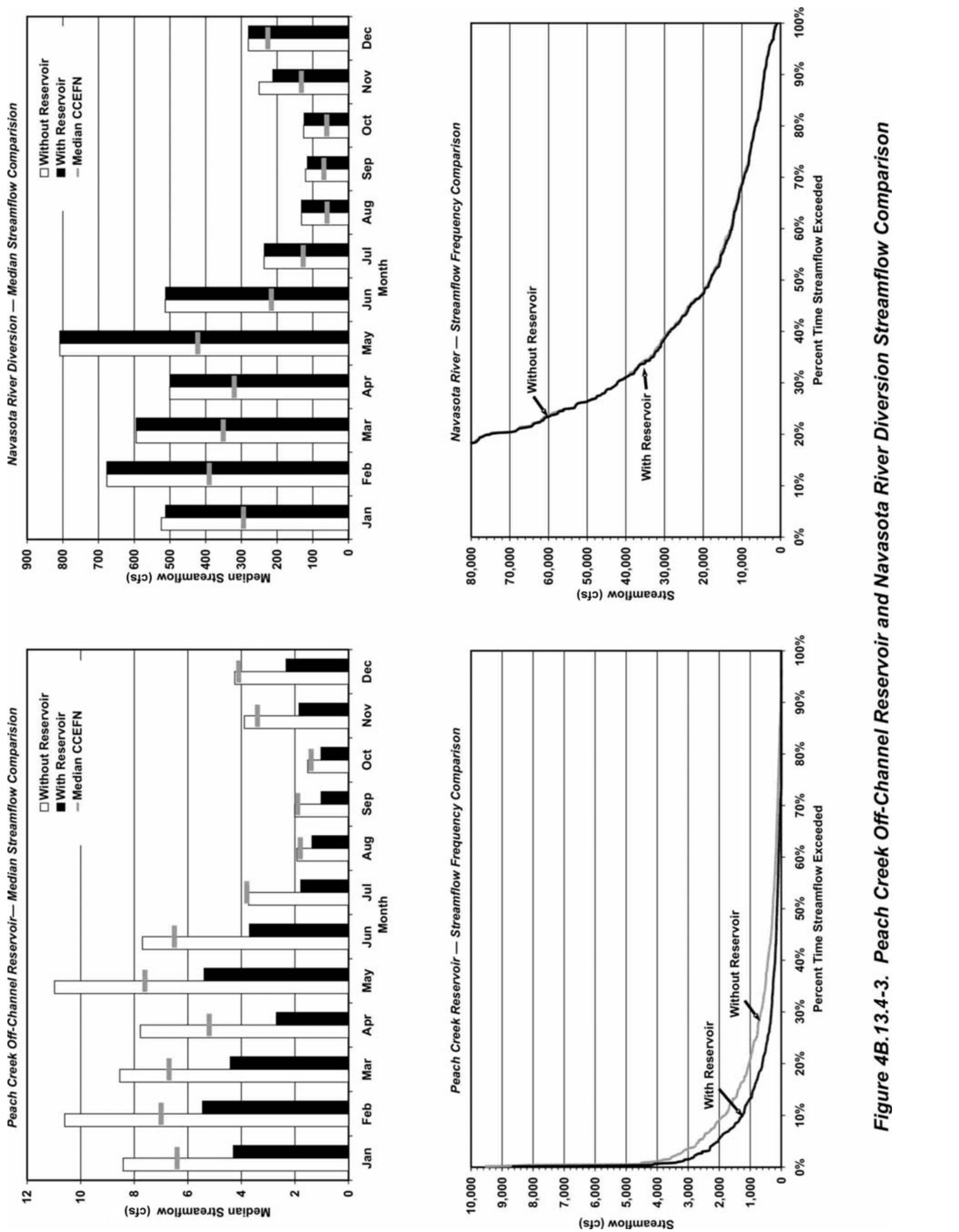

Figure 4B.13.4-3. Peach Creek Off-Channel Reservoir and Navasota River Diversion Streamflow Comparison

The physiography of the region includes sand and mud with lignite and bentonite, and flood-prone areas. The topography is low to moderately rolling with local shallow depressions in flood-prone areas along waterways.[26] The predominant soil associations in the project area are the Burlewash-Singleton and Sandow associations. Burlewash-Singleton soils are gently sloping to moderately sloping, moderately deep, loamy soils that are well drained or moderately well drained and occur in oak savannahs. Sandow soils are nearly level, very deep, loamy soils that are moderately well drained and occur in frequently flooded areas on bottom land.[27]

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak (*Quercus stellata*) Woods/Forest, Water Oak (*Q. nigra*)–Elm (*Ulmus*) –Hackberry (*Celtis*) Forest, and crops[28]. Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Post Oak Woods/Forest could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry *(Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Water Oak-Elm-Hackberry Forest could include the following commonly associated plants: cedar elm, American elm (*Ulmus americana*), willow oak (*Quercus phellos*), southern red oak (*Q. falcata*), white oak (*Q. alba*), black willow (*Salix nigra*), cottonwood (*Populus deltoides*), red ash (*Fraxinus pennsylvanica*), sycamore (*Platanus occidentalis*), pecan (*Carya illinoinensis*), bois d'arc (*Maclura pomifera*), flowering dogwood (*Cornus florida*), dewberry,

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[26] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., *Land Resources of Texas*, Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.
[27] Natural Resources Conservation Service (NRCS), *Soil Survey of Brazos County, Texas*, United States Department of Agriculture, in cooperation with Texas Agricultural Experiment Station, 2002.
[28] McMahan, C.A., R.F. Frye, and K.L. Brown, *The Vegetation Types of Texas*, Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

coralberry, dallisgrass (*Paspalum dilatatum*), switchgrass (*Panicum virgatum*), rescuegrass (*Bromus catharticus*), bermudagrass (*Cynodon dactylon*), eastern gamagrass (*Tripsacum dactyloides*), Virginia wildrye (*Elymus virginicus*), Johnsongrass (*Sorghum halepense*), giant ragweed (*Ambrosia trifida*), and Leavenworth eryngo (*Eryngium leavenworthii*). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.13.4.3.2 Potential Impacts

4B.13.4.3.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and in the Navasota River where water will be pumped and diverted to the project site. The potential impacts of this project would differ in the two locations. In the diversion site on the Navasota River, very little impact is predicted in terms of a reduction in flow variability or reduction in the quantity of median monthly flows. At the proposed reservoir site, there would be lower flow variability and substantial reductions in quantity of median monthly flows. The difference in variability of monthly flow conditions at the proposed project site would be a factor of approximately 1.7 (measured by comparing sample variances of all monthly flows from 1940-2004 and predicted flows over that same time period with the project in place; sample variance without project =9.85×10^5; sample variance with project =5.90×10^5) while the difference in variability of monthly flow values in the Navosota River diversion site would be negligible (sample variance without project =4.413×10^9; sample variance with project =4.412×10^9). Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

The reductions in median monthly flows at the project site would range from 0.5 cfs (32 percent) in October to 5.6 cfs (51 percent) in May, as shown in Table 4B.13.4-4. The greatest reductions (>50 percent) would occur from April through July and November. October is the only month in which the reduction in median monthly flow would be less than 40 percent at the proposed reservoir site. In the Navasota River, the reduction in median monthly flows would range from 0 cfs in February, March, May and August to 38.5 cfs (15 percent) in November, as shown in Table 4B.13.4-5. There would be virtually no reduction in eight months of the year and November is the only month that would have a consequential decrease in median monthly flow. This project would also result in a higher frequency of low-flow conditions at the project site. Without the project, the monthly flows would be less than 0.71 cfs only 15 percent of the time (85 percent exceedance value), but the monthly flows would be 0 cfs for 26 percent of the time with the project in place. The 85 percent exceedance value would be 84 and 83 cfs in the Navasota River without and with the project, respectively. These reductions in flow at the project site would have substantial impacts on the instream biological community, particularly during the summer months when streams are more susceptible to a reduction in water quality conditions (e.g., high temperatures and high nutrient growth).

Table 4B.13.4-4.
Median Monthly Streamflow: Peach Creek Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	8.4	4.3	4.1	49%
February	10.6	5.5	5.1	49%
March	8.5	4.4	4.1	48%
April	7.8	2.7	5.1	65%
May	11.0	5.4	5.6	51%
June	7.7	3.7	4.0	52%
July	3.7	1.8	1.9	52%
August	1.9	1.4	0.6	29%
September	2.0	1.0	1.0	49%
October	1.5	1.0	0.5	32%
November	3.9	1.8	2.0	52%
December	4.2	2.3	1.9	45%

Although there would be biological impacts in the immediate vicinity of the project site and downstream, this project, alone, would have little impact on total discharge in the Navasota and Brazos Rivers and minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Peach Creek Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

Table 4B.13.4-5.
Median Monthly Streamflow: Diversion Site in Navasota River

Month	Without Project (cfs)	With Project (cfs)	Difference (cfs)	Percent Reduction
January	524.4	512.4	12.0	2%
February	676.8	676.8	0.0	0%
March	594.6	594.6	0.0	0%
April	500.6	499.6	1.0	0%
May	808.4	808.4	0.0	0%
June	513.4	512.3	1.0	0%
July	236.5	236.0	0.6	0%
August	131.8	131.8	0.0	0%
September	120.5	115.2	5.3	4%
October	125.9	124.3	1.7	1%
November	250.5	212.0	38.5	15%
December	280.7	279.9	0.8	0%

4B.13.4.3.2.2 Threatened & Endangered Species

A total of 28 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern (Table 4B.13.4-6). This group includes one amphibian, five reptiles, eight birds, five mammals, four fish species, and five plant species. Four bird species, one amphibian, one mammal species, and one plant species federally-listed as threatened or endangered could occur (or historically occurred) in the project area. These include the bald eagle (*Haliaeetus leucocephalus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), whooping crane (*Grus americana*), Houston toad (*Bufo houstonensis*), Louisiana black bear (*Mustela nigripes*), and Navasota ladies'-tresses (*Spiranthes parksii*). The interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area, but would not likely be directly affected by the project. The bald eagle is known to nest in the Navasota River Basin, but there are no known nesting sites in or near the project area. The Houston toad prefers deep sands for burrowing and upland ponds and depressions for breeding. Navasota Ladies'-tresses occur on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon. Although historically occurring, populations of black bear no longer occur in the region.

Table 4B.13.4-6.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Peach Creek Off-Channel Reservoir Site, Brazos County

Scientific Name	Common Name	Federal/State Status	Potential Occurrence
Amphibians			
Bufo houstonensis	Houston Toad	LE/E	X
Birds			
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant
Grus americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant
Fishes			
Anguilla rostrata	American Eel	SOC	X
Cycleptus elongatus	Blue Sucker	SOC/T	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Mammals			
Ursus americanus	Black Bear	T-SA/T	X
Ursus americanus luteolus	Louisiana Black Bear	LT/T	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Corynorhinus rafinesquii	Rafinesque's Big-eared Bat	SOC/T	X
Myotis austroriparius	Southeastern Myotis Bat	SOC	X
Reptiles			
Macroclemys temminckii	Alligator Snapping Turtle	SOC/T	X
Pituophis melanoleucus ruthveni	Louisiana Pine Snake	C/T	X
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Liatris cymosa	Branched gay-feather	SOC	X
Spiranthes parksii	Navasota ladies'-tresses	LE/ E	X
Eriocaulon koernickianum	Small-headed pipewort	SOC	X
Thalictrum texanum	Texas meadow rue	SOC	X
Chloris texensis	Texas windmill-grass	SOC	X

* Nesting migrant; may nest in the county.

X= Occurs in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.) SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: Texas Parks and Wildlife Department (TPWD), Annotated County List of Rare Species for Brazos County (25 September 2004). TPWD, Texas Conservation and Biological Data System (TCBDS) 2004.

A search of the Texas Wildlife Diversity Database[29] revealed one documented occurrence of the Houston toad, one occurrence of the timber rattlesnake *(Crotalus horridus)*, one colonial water bird rookery, 39 occurrences of the Navasota ladies'-tresses, 21 occurrences of the branched gay-feather (*Liatris cymosa*), five occurrences of the Texas Meadow-rue (*Thalictrum texanum*), and one occurrence of the small-headed pipewort *(Eriocaulon koernickianum)* within the project vicinity (as noted on representative 7.5 minute quadrangle map(s) that include the project site). This data is not a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.13.4.3.2.3 Wildlife Habitat

Approximately 1,045 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 178 acres of Grasses/Forbs, 756 acres of Post Oak Woods, and 111 acres of Riparian Woods.

A number of vertebrate species could occur within the Peach Creek off-channel reservoir site as indicated by county occurrence records.[30] These include five species of salamanders and newts, 18 species of frogs and toads, 14 species of turtles, the American alligator, 11 species of lizards and skinks, and 31 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[31] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

4B.13.4.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 126 archeological sites have been documented within the general vicinity of the proposed reservoir. Prewitt and

[29] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004c.
[30] Texas A&M University (TAMU), *County Records for Amphibians and Reptiles*, Texas Cooperative Wildlife Collection, 1998.
[31] Davis, W.B., and D.J. Schmidly, *The Mammals of Texas – Online Edition*, Texas Tech University, http://www.nsrl.ttu.edu/tmot1/Default.htm, 1997.

Associates, Inc. recorded 23 of these sites in 1981 as part of an archeological survey of proposed reservoir alternatives. Researchers from the University of Texas documented 26 of these sites as part of a preliminary investigation of the area proposed for Millican Lake in 1973. An additional 22 sites have been recorded during surveys on behalf of the Texas Municipal Power Agency in advance of various electrical transmission lines and proposed lignite mines. Thirteen sites have been recorded during surveys of proposed facilities for Texas A&M University. The sites recorded on behalf of the Texas Municipal Power Agency and Texas A&M University lie outside the currently proposed reservoir location. The sites documented in the area represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if these sites or any other cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.13.4.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures immediately downstream during summer periods. The project is expected to have negligible impacts to stream flow and water quality in the Navasota and Brazos Rivers.

4B.13.4.4 Engineering and Costing

Construction of the Peach Creek Reservoir project will cost approximately $30.9 million. This includes the construction of the dam, pumping facilities, land acquisition, resolution of conflicts, environmental permitting and mitigation, and technical services. The annual project costs are estimated to be $2.8 million; this includes annual debt service and operation and maintenance. The cost for the available project yield of 3,980 acft/yr translates to an annual unit cost of raw water of $2.19 per 1,000 gallons, or $712/acft. A summary of the cost estimate is provided in Table 4B.13.4-7. Costs shown herein are for raw water supply at the reservoir and include no transmission, local distribution, or treatment costs.

Table 4B.13.4-7.
Cost Estimate Summary for
Peach Creek Reservoir
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Raw Water Pumping Facilities	$14,142,000
Dam and Reservoir	$5,016,000
Total Capital Cost	**$19,158,000**
Engineering, Legal Costs and Contingencies	$5,998,000
Environmental & Archaeology Studies and Mitigation	$1,756,000
Land Acquisition and Surveying	$1,756,000
Interest During Construction (2 years)	$2,242,000
Total Project Cost	**$30,910,000**
Annual Costs	
Debt Service (6% for 20 years)	$1,691,000
Reservoir Debt Service (6 percent, 40 years)	$765,000
Operation and Maintenance	$378,000
Total Annual Cost	**$2,834,000**
Available Project Yield (acft/yr)	3,980
Annual Cost of Water ($ per acft)	$712
Annual Cost of Water ($ per 1,000 gallons)	$2.19

Note

- Raw water pumping facilities include a raw water intake and pump station (100 cfs, 1,400 HP), 22,000 feet raw water pipeline (60-inch diameter) from the river to the off-channel reservoir.
- Includes the power cost for pumping water from the Navasota River to the off-channel reservoir.

4B.13.4.5 Implementation Issues

This option has been compared to the plan development criteria as shown in Table 4B.13.4-8.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (NPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

Environmental impact or assessment studies;

- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;

- Additional acquisition of rights-of-way and/or easements may be required; and,
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4B.13.4-8.
Evaluations of Peach Creek Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	***Comment(s)***
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. Reasonable (moderate to high)
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Negligible impact 2. Negligible impact 3. Low impact 4. Negligible impact 5. Low impact 6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.13.5 Little River Off-Channel Reservoir

4B.13.5.1 Description of Option

The Little River Off-Channel Reservoir is a proposed new reservoir on Beaver Creek, a tributary to the Little River. The reservoir site is located in Milam County, east of the City of Cameron, as shown in Figure 4B.13.5-1. The project would impound water from the Beaver Creek watershed as well as divert water from the Little River during periods of flow in excess of downstream needs. The dam would be an earthfill embankment that would extend approximately 1-mile across the Beaver Creek valley and provide a conservation storage capacity of 155,812 acft at an elevation 400 ft-msl; the reservoir would inundate 4,343 surface acres.

4B.13.5.2 Available Yield

Water potentially available for impoundment in the proposed Little River Off-Channel Reservoir was estimated using the Brazos G WAM. The model utilized a January 1940 through December 1997 hydrologic period of record. Estimates of water availability were derived subject to general assumptions for application of hydrologic models as adopted by the Brazos G Regional Water Planning Group and summarized previously. The model computed the streamflow available for diversion from the Little River into the Little River Off-Channel Reservoir without causing increased shortages to downstream rights. Firm yield was computed subject to the reservoir and Little River diversion having to pass inflows to meet Consensus Criteria for Environmental Flow Needs instream flow requirements (Appendix H).

Various maximum diversion capacities associated with potential pipeline sizes (64-inch, 72-inch, 90-inch, 108-inch, and 120-inch diameter pipelines) were considered. Figure 4B.13.5-2 illustrates the Little River Off-Channel Reservoir yield for each of the pipeline diameters considered. The greatest incremental benefit in yield occurs with the 90-inch and 108-inch pipeline sizes.

The calculated firm yield of the Little River Off-Channel Reservoir is 32,110 acft/yr. The yield is constrained by the capacity of a 108-inch diameter pipeline. The available firm yield is significant since there is a substantial watershed for the Little River (7,500 square miles) that is uncontrolled. The streamflow statistics used to determine the Consensus Criteria pass-through requirements for the off-channel reservoir and the Little River diversion are shown in Tables 4B.13.5-1 and 4B.13.5-2.

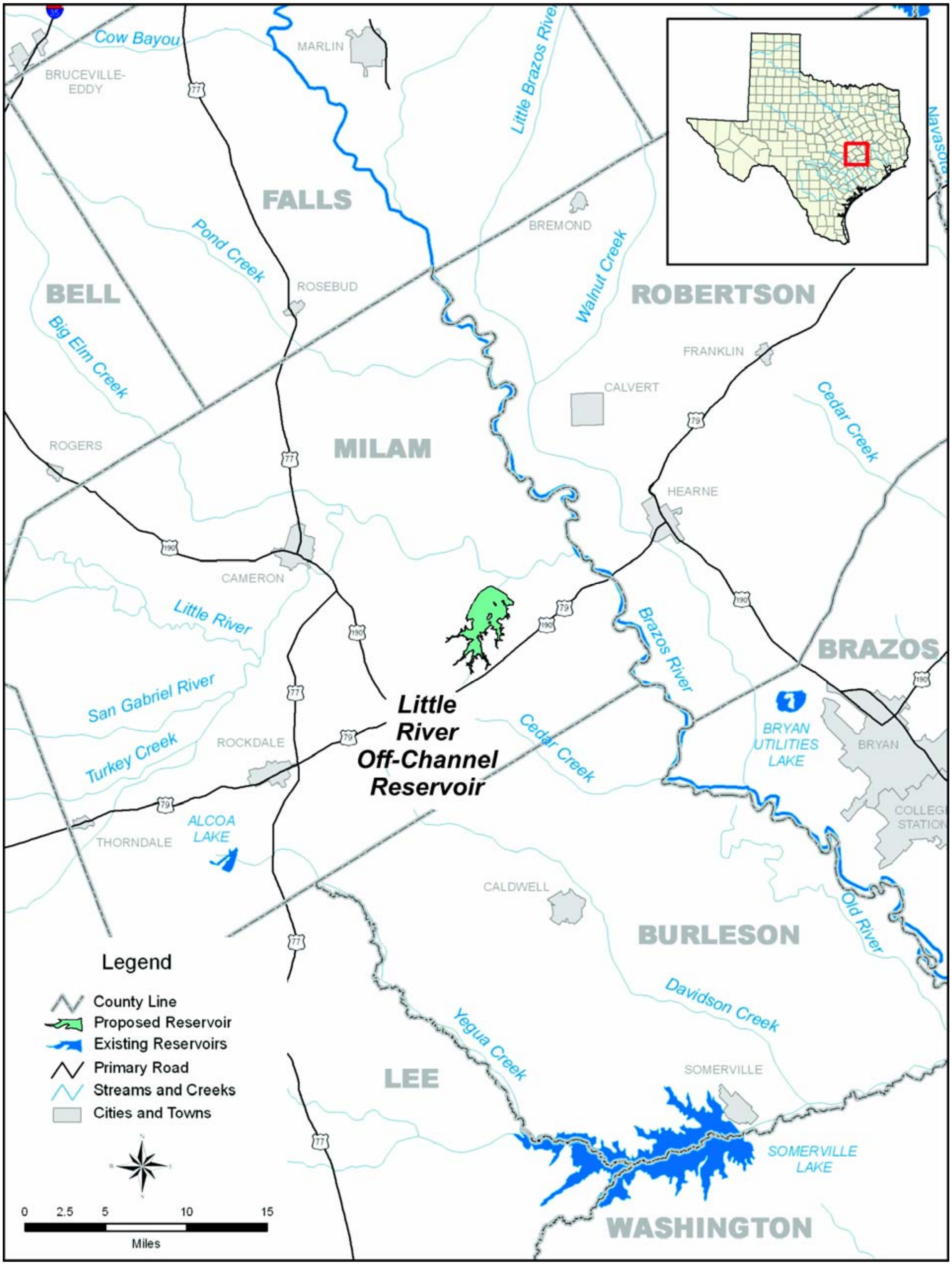

Figure 4B.13.5-1. Little River Off-Channel Reservoir

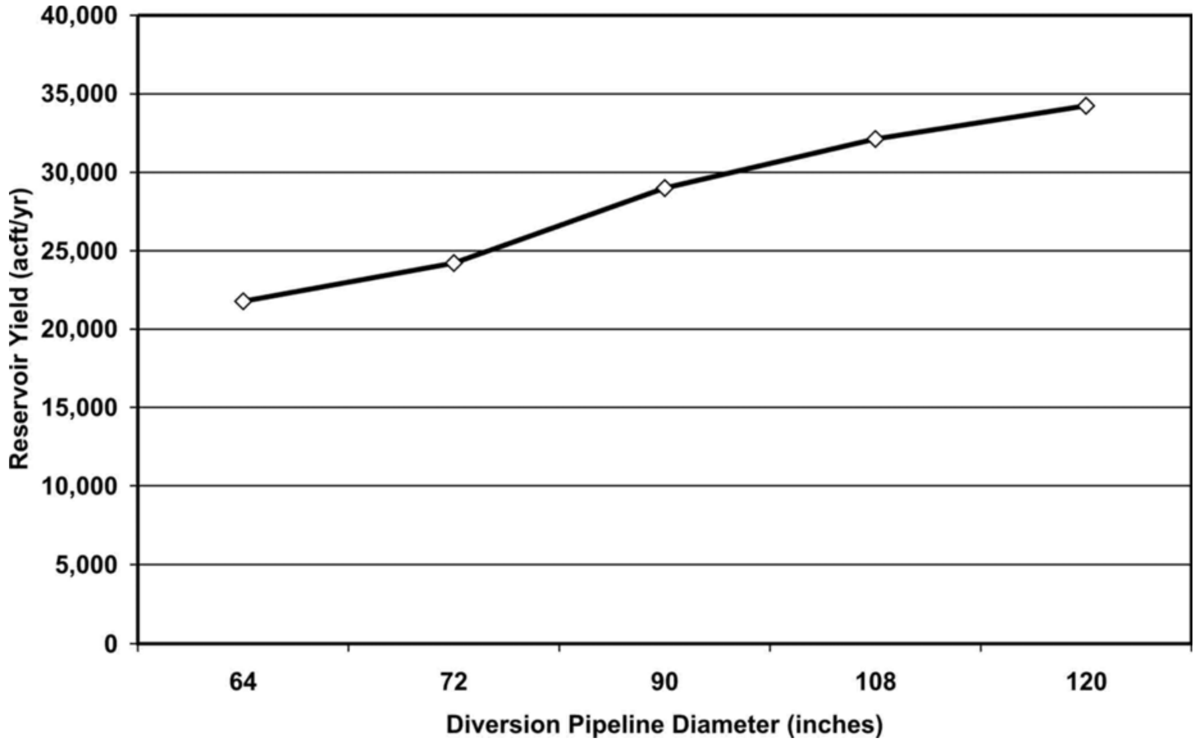

Figure 4B.13.5-2. Water Available from Little River Diversion into the Little River Off-Channel Reservoir

Table 4B.13.5-1. Daily Natural Streamflow Statistics for the Little River Off-Channel Reservoir

Month	***Median Flows – Zone 1 Pass-Through Requirements (cfs)***	***25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)***
January	2.7	0.6
February	2.8	1.0
March	3.0	0.9
April	2.4	0.4
May	4.5	1.2
June	3.1	0.5
July	1.7	0.3
August	1.1	0.3
September	0.8	0.1
October	0.7	0.0
November	1.5	0.6
December	2.2	0.7
Zone 3 (7Q2) Pass-Through Requirement (cfs):		0.0

Table 4B.13.5-2.
Daily Natural Streamflow Statistics
for the Little River Diversion

Month	*Median Flows – Zone 1 Pass-Through Requirements (cfs)*	*25th Percentile Flows – Zone 2 Pass-Through Requirements (cfs)*
January	466.9	190.9
February	787.9	257.1
March	761.7	269.5
April	925.0	263.2
May	1547.1	514.2
June	1022.5	317.8
July	441.0	154.5
August	244.0	92.2
September	250.9	66.9
October	268.8	76.5
November	405.3	142.5
December	494.1	165.3
Zone 3 (7Q2) Pass-Through Requirement (cfs):		54.6

Figure 4B.13.5-3 illustrates the simulated Little River Off-Channel Reservoir storage contents for the 1940 to 1997 historical period, subject to the firm yield of 32,110 acft/yr and based on delivery of Little River diversions via a 108-inch pipeline. Simulated reservoir contents remain above the Zone 2 trigger level (80 percent capacity) 82 percent of the time and above the Zone 3 trigger level (50 percent capacity) 96 percent of the time.

Figure 4B.13.5-4 illustrates the changes in streamflows at the reservoir location and the Little River caused by the project. There are significant changes in streamflow at the reservoir location due to the project; however, there are minimal changes in Little River streamflow due to the project. The largest decline in monthly median streamflow on the Little River (91 cfs) occurs in October. Figure 4B.13.5-4 also illustrates the streamflow frequency characteristics at the reservoir location and the Little River with the project in place. There is little difference in streamflow on the Little River with the project because the Little River diversion would be required to pass substantial inflows in order to satisfy senior water rights and/or environmental flow requirements.

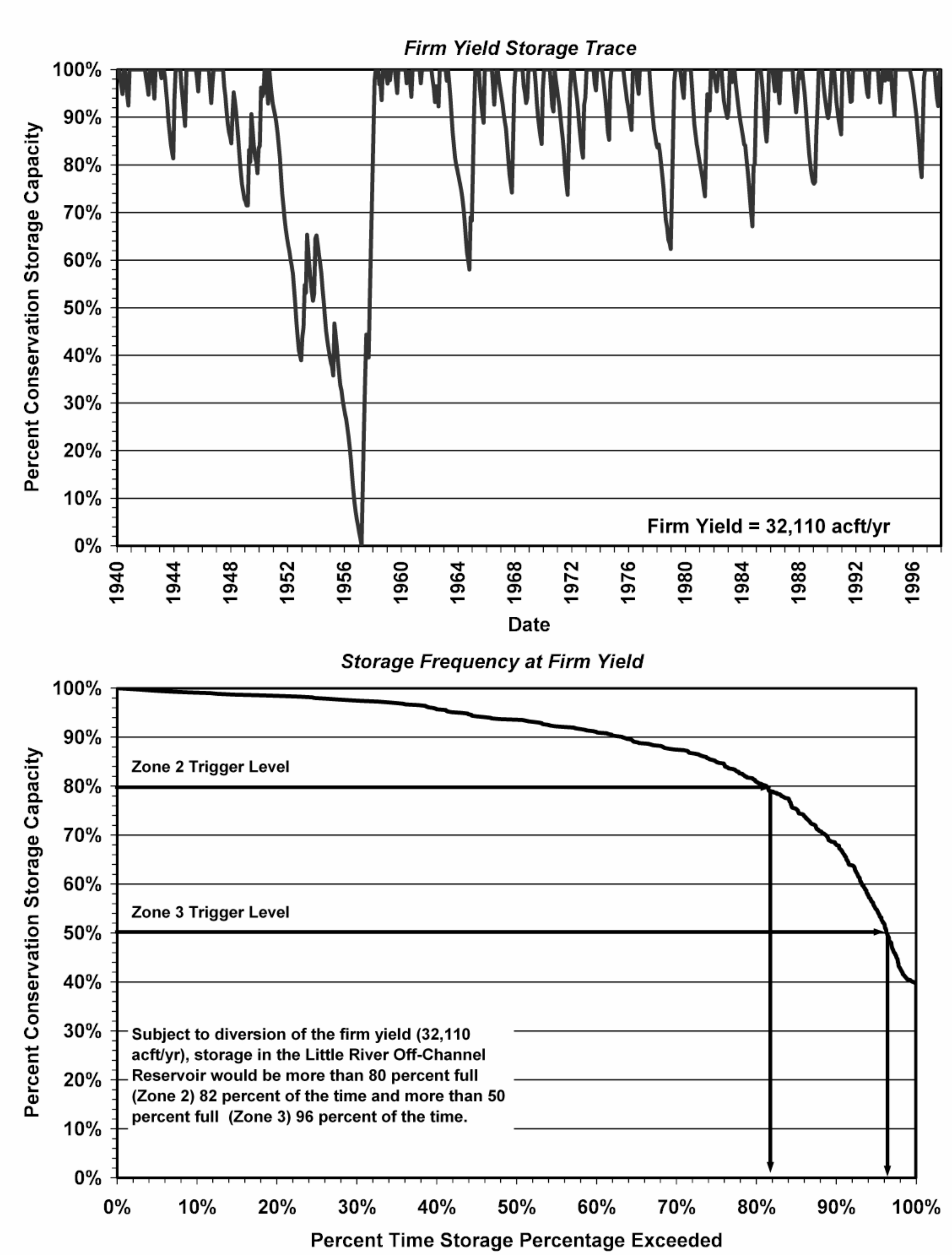

Figure 4B.13.5-3. Little River Off-Channel Reservoir Storage Considerations

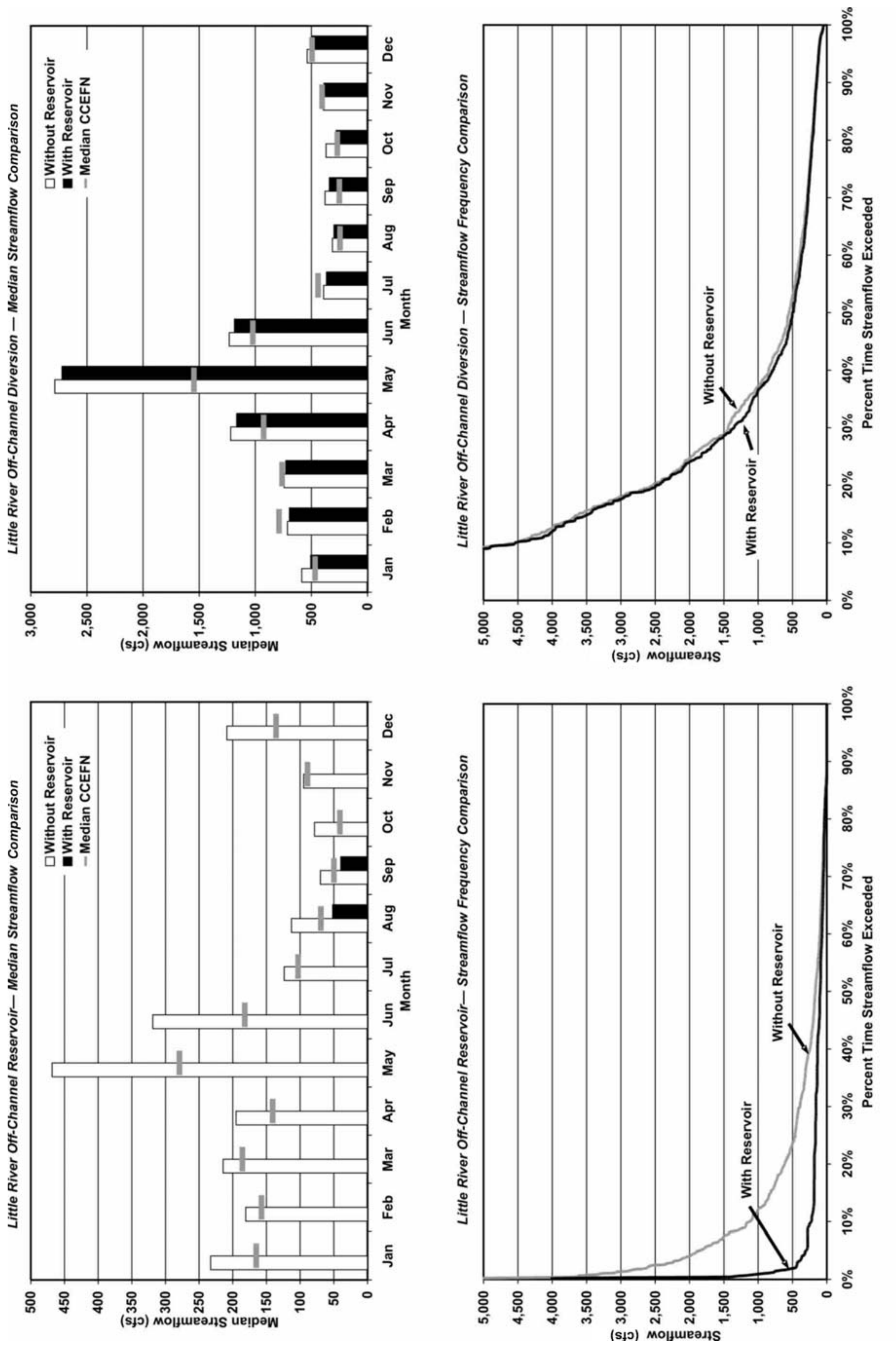

Figure 4B.13.5-4. Little River Diversion and Reservoir Streamflow Comparison

4B.13.5.3 Environmental Issues

4B.13.5.3.1 Existing Environment

The Little River Off-Channel Reservoir site in Milam County is within the Post Oak Savannah Ecological Region.[32] This region is characterized as a narrow, highly irregular oak belt that consists of intermingled forest, woodland, and savannah. It is located between the Pine-Hardwood Forest to the east, Blackland Prairies to the west, and the Coastal Prairie and South Texas Brushlands to the south. The original physiognomy of the region was medium to tall broad-leaved deciduous and some needle-leaved evergreen trees. In the northern and eastern areas, the trees are interspersed with open areas of grasses and forbs, but in the southern and western areas, trees are clumped or in solid stands. The shallow, nearly impervious clay pan of the Post Oak Savannah region causes the soil to be arid.[33] The climate is characterized as subtropical humid, with warm summers. Average annual precipitation ranges between 36 and 40 inches.[34] The Carrizo-Wilcox Aquifer is the only major aquifer underlying the project area.[35] The Queen City and Brazos River Alluvium minor aquifers are to the south and east of the project area, respectively.

The physiography of the region includes ceramic clay and lignite/coal, recharge sands, expansive clay mud, and flood-prone areas. The topography is flat to rolling with local escarpments, with local shallow depressions in flood-prone areas along waterways.[36] The predominant soil types in the project area are primarily sandy loams and loamy sands, with a small amount of silty clay.[37]

[32] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin, Vegetational Areas of Texas, Texas A&M University, Texas Agriculture Experiment Station Leaflet No. 492, 1960.
[33] Telfair, R.C., “Texas Wildlife Resources and Land Uses,” University of Texas Press, Austin, Texas, 1999.
[34] Larkin, T.J., and G.W. Bomar, “Climatic Atlas of Texas,” Texas Department of Water Resources, Austin, Texas, 1983.
[35] Texas Water Development Board (TWDB), Major and Minor Aquifers of Texas; Maps online at http://www.twdb.state.tx.us/mapping/index.asp, 2004.
[36] Kier, R.S., L.E. Garner, and L.F. Brown, Jr., “Land Resources of Texas.” Bureau of Economic Geology, University of Texas, Austin, Texas, 1977.
[37] Soil Conservation Service (NRCS), *Soil Survey for Milam County, Texas*, Soil Conservation Service, United States Department of Agriculture, 1979.

Three major vegetation types occur within the general vicinity of the proposed project: Post Oak Woods/Forest, Post Oak Woods, Forest, and Grassland Mosaic, and crops.[38] Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Post Oak Woods/Forest and the Post Oak Woods, Forest, and Grassland Mosaic could include the following commonly associated plants: blackjack oak (*Quercus marilandica*), eastern redcedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), black hickory (*Carya texana*), live oak (*Q. virginiana*), sandjack oak (*Q. incana*), cedar elm (*Ulmus crassifolia*), hackberry *(Celtis* spp.), yaupon (*Ilex vomitoria*), poison oak (*Toxicodendron pubescens*), American beautyberry (*Callicarpa americana*), hawthorn (*Crataegus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubus* spp.), coralberry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium* var. *scoparium*), silver bluestem (*Bothriochloa saccharoides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), spranglegrass (*Chasmanthium sessiliflorum*), and tickclover (*Desmodium* spp.). Crops include cultivated cover crops or row crops providing food and/or fiber for either man or domestic animals and may also include grassland associated with crop rotations and hay production.

4B.13.5.3.2 Potential Impacts

4B.13.5.3.2.1 Aquatic Environments including Bays & Estuaries

The potential impacts of this project were evaluated in two locations, at the proposed reservoir site and in the Little River where water will be pumped and diverted to the project site. The potential impacts of this project are very different in the two locations. In the diversion site on the Little River, very little impact is predicted in terms of a reduction in flow variability or quantity of median monthly flows. But in the proposed project site, there would be dramatic reductions in both flow variability and the quantity of median monthly flows. The difference in variability of monthly flow conditions at the proposed project site would be a factor of approximately 7.5 (measured by comparing sample variances of all monthly flows from 1940-1997 and predicted flows over that same time period with the project in place; sample variance without project =43.25 x 10^4; sample variance with project =5.54 x 10^4). The difference in

[38] McMahan, C.A., R.F. Frye, and K.L. Brown, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Wildlife Division, Austin, Texas, 1984.

variability of monthly flow values in the Little River diversion site would be negligible (sample variance without project =2.95 x 10^{10}; sample variance with project =2.93 x 10^{10}). Variability in flow is important to the instream biological community as well as riparian species and a reduction could influence the timing and success of reproduction as well as modify the current composition of species by favoring some and reducing suitability for others.

The reduction in the median monthly flow at the reservoir site would range from 0.5 cfs (43 percent) in September to 7.6 cfs (100 percent) in May, as shown in Table 4B.13.5-3. Median monthly flow would be reduced to zero (100 percent reduction) during 10 months of the year at the proposed reservoir site. At the diversion site, reductions in median monthly flow would range from 5.5 cfs (1 percent) in November to 89.7 cfs (24 percent) in October, as shown in Table 4B.13.5-4. Reductions would be 10 percent or less during 10 months of the year. This project would have minimal effects on the frequency of low-flow conditions at the proposed reservoir site. Without the project, 85 percent exceedance value of monthly flows would be 0.33 cfs; with the project in place, this value would be 0.19 cfs. At the diversion site, the 85 percent exceedance values would be 185 cfs without and 177 cfs with the project in place. Because of the number of months with zero flow values, this project is anticipated to have substantial impacts on the instream biological community at the proposed reservoir site; however, there would be minimal impacts in the Little River diversion site.

Although there would be biological impacts in the immediate vicinity of the project site and downstream, it is not likely that this project, alone, would have a substantial influence on total discharge in the Brazos River, in which case there would be minimal influence on freshwater inflows to the Brazos River estuary. However, the cumulative impact of multiple projects may reduce freshwater inflows into the estuary. As a new reservoir without a current operating permit, the Little River Off-Channel Reservoir would likely be required to meet environmental flow requirements determined by site-specific studies.

4B.13.5.3.2.2 Threatened & Endangered Species

A total of 23 species could potentially occur within the vicinity of the site that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 1 amphibian, 3 reptiles, 10 birds, 2 mammals, 5 fish species and 2 plant species (Table 4B.13.5-5). One amphibian, four bird

Table 4B.13.5-3.
Median Monthly Streamflow: Little River Off-Channel Reservoir

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	3.8	0.0	3.8	100%
February	3.3	0.0	3.3	100%
March	3.5	0.0	3.5	100%
April	3.3	0.0	3.3	100%
May	7.6	0.0	7.6	100%
June	5.4	0.0	5.4	100%
July	2.1	0.0	2.1	100%
August	1.8	0.8	1.0	54%
September	1.2	0.7	0.5	43%
October	1.3	0.0	1.3	100%
November	1.6	0.0	1.6	100%
December	3.4	0.0	3.4	100%

Table 4B.13.5-4.
Median Monthly Streamflow: Little River Diversion Site

Month	*Without Project (cfs)*	*With Project (cfs)*	*Difference (cfs)*	*Percent Reduction*
January	585.6	506.1	79.5	14%
February	713.0	695.5	17.6	2%
March	742.9	728.1	14.7	2%
April	1,219.5	1,165.9	53.6	4%
May	2,785.8	2,721.5	64.3	2%
June	1,231.9	1,185.9	46.0	4%
July	391.3	366.2	25.1	6%
August	313.0	298.7	14.3	5%
September	379.2	339.8	39.5	10%
October	369.0	279.3	89.7	24%
November	393.2	387.7	5.5	1%
December	537.5	494.1	43.4	8%

Table 4B.13.5-5.
Potentially Occurring Species that are Rare or Federal- and State-Listed at the Little River Off-Channel Reservoir Site, Milam County

Scientific Name	Common Name	Federal/State Status	Potential Occurrence
Amphibians			
Bufo houstonensis	Houston Toad	LE/E	X
Birds			
Falco peregrinus anatum	American Peregrine Falcon	DL/E	Migrant
Falco peregrinus tundrius	Arctic Peregrine Falcon	DL/T	Migrant
Haliaeetus leucocephalus	Bald Eagle	LT-PDL/T	Resident
Ammodramus henslowii	Henslow's Sparrow	SOC	Migrant
Sterna antillarum athalassos	Interior Least Tern	LE/E	Migrant*
Charadrius montanus	Mountain Plover	SOC	Migrant*
Charadrius melodus	Piping plover	LT w/CH	Migrant
Grus americana	Whooping Crane	LE/E	Migrant
Mycteria americana	Wood Stork	SOC/T	Migrant
Buteo albonotatus	Zone-tailed Hawk	SOC/T	Migrant*
Fishes			
Anguilla rostrata	American Eel	SOC	X
Cycleptus elongatus	Blue Sucker	SOC/T	X
Micropterus treculi	Guadalupe Bass	SOC	X
Notropis buccula	Smalleye Shiner	C/SOC	X
Notropis oxyrhynchus	Sharpnose Shiner	C/SOC	X
Mammals			
Myotis velifer	Cave Myotis Bat	SOC	X
Spilogale putorius interrupta	Plains Spotted Skunk	SOC	X
Canis rufus	Red Wolf	LE/E	Extirpated
Reptiles			
Thamnophis sirtalis annectens	Texas Garter Snake	SOC	X
Phrynosoma cornutum	Texas Horned Lizard	SOC/T	X
Crotalus horridus	Timber/ Canebrake Rattlesnake	SOC/T	X
Plants			
Spiranthes parksii	Navasota ladies'-tresses	LE/ E	X
Polygonella parksii	Parks' jointweed	SOC	X

X = Occurs in county; * Nesting migrant; may nest in the county.

Federal Status: LE-Listed Endangered; LT-Listed Threatened; w/CH-with critical habitat in the state of Texas; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations); SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas; SOC-Species of Concern (some information exists showing evidence of vulnerability, but is not listed).

Sources: TPWD, Annotated County List of Rare Species for Milam County (25 September 2004); TPWD, Texas Conservation and Biological Data System (TCBDS), 2004 species, and one plant species federally-listed as threatened or endangered could occur in the project area. These include the Houston toad (*Bufo houstonensis)*, bald eagle (*Haliaeetus leucocephalus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), and whooping crane (*Grus americana*), and Navasota ladies'-tresses (*Spiranthes parksii*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the project area but would not likely be directly affected by the proposed reservoir. The Navasota Ladies'-tresses occurs on upland margins of intermittent, minor tributaries in association with post oak, blackjack oak, and yaupon.

A search of the Texas Wildlife Diversity Database[39] revealed two documented occurrences of Navasota ladies'-tresses within the vicinity of the proposed Little River Off-Channel Reservoir (as noted on representative 7.5-minute quadrangle map(s) that include the project site). These data arenot a representative inventory of rare resources or sensitive sites. Although based on the best information available to TPWD, these data do not provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in the project area. On-site evaluations will be required by qualified biologists to confirm the occurrence of sensitive species or habitats.

4B.13.5.3.2.3 Wildlife Habitat

Approximately 4,343 acres are estimated to be inundated by the reservoir. Projected wildlife habitat that will be impacted includes approximately 2,215 acres of Mixed Grassland, 1,839 acres of Post Oak Woods, and 289 acres of Mixed Riparian Woods/Forest.

A number of vertebrate species could occur within the Little River Off-Channel Reservoir site as indicated by county occurrence records.[40] These include four species of salamanders and newts, 16 species of frogs and toads, nine species of turtles, the American alligator, 10 species of lizards and skinks, and 21 species of snakes. Additionally, 54 species of mammals could occur within the site or surrounding region[41] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the site, but with distributions and population densities limited by the types and quality of habitats available.

[39] Texas Parks and Wildlife Department (TPWD), Texas Wildlife Diversity Database, 2004.
[40] Texas A&M University (TAMU), "County Records for Amphibians and Reptiles," Texas Cooperative Wildlife Collection, 1998.
[41] Davis, W.B., and D.J. Schmidly, "The Mammals of Texas – Online Edition," Texas Tech University,

4B.13.5.3.2.4 Cultural Resources

A search of the Texas Archeological Sites Atlas database indicates that 31 archeological sites have been documented within the general vicinity of the proposed reservoir. Nineteen of these sites were recorded by private individuals or by university research programs for academic purposes. All of these sites lie outside the currently proposed reservoir location. These sites represent a variety of historic and prehistoric site types. Prior to reservoir inundation, the project must be coordinated with the Texas Historical Commission and a cultural resources survey must be conducted to determine if any cultural resources are present within the conservation pool. Any cultural resources identified during survey will need to be assessed for eligibility for inclusion in the National Register of Historic Places (NRHP) or as State Archeological Landmarks (SAL). Cultural resources that occur on public lands or within the Area of Potential Effect of publicly funded or permitted projects are governed by the Texas Antiquities Code (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).

4B.13.5.3.2.5 Threats to Natural Resources

Threats to natural resources were identified in Section 1.7.3.2 and include lower stream flows, declining water quality, and reduced inflows to reservoirs. This project would likely have increased adverse effects on stream flow below the reservoir site, but the reservoir would trap sediment and/or dilute pollutants, providing some positive benefits to water quality downstream. These benefits could be offset by declines in dissolved oxygen through decreased flows and higher temperatures immediately downstream of the reservoir during summer periods. The project is expected to have negligible impacts to the stream flow and water quality in the Little River and Brazos River.

4B.13.5.4 Engineering and Costing

A cost estimate for the proposed Little River Off-Channel Reservoir was made utilizing available mapping and information. The total project is estimated to cost $96.5 million for construction of the dam, reservoir, river intake and pump station, and raw water pipeline from the Little River to the reservoir site. The annual project costs are estimated to be $8 million; this includes annual debt service, operation and maintenance, and pumping energy costs. A summary of the project costs is presented in Table 4B.13.5-6. The cost for the estimated firm yield of

32,110 acft/yr translates to an annual unit cost for raw water of $0.77 per 1,000 gallons, or $250/acft.

The total project cost reported in the 2001 Water Plan was $78 million; the current plan costs are estimated to be $96 million. In addition to inflation, some of the cost differences are due to increased land costs and different methodology used to calculate Environmental & Archaeology Studies and Mitigation.

The annual cost of water has increased from $128/acft ($0.39 per 1,000 gallons) in the 2001 Plan to $250/acft ($0.77 per 1,000 gallons) in the current plan. The increase in annual cost is due largely to the decrease in projected project yield; project yield was 47,000 acft/yr in the 2001 plan and is currently 32,110 acft/yr in the 2006 plan.

4B.13.5.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.13.5-6, and the option meets each criterion.

This Implementation of the Little River Off-Channel Reservoir will require permits from various state and federal agencies, land acquisition, and design and construction of the facilities. A summary of the implementation steps for the project is presented below.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality Water Right and Storage permits;
- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- Texas Commission on Environmental Quality administered Texas Pollutant Discharge Elimination System Storm Water Pollution Prevention Plan;
- General Land Office Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

- Environmental impact or assessment studies;
- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,

Table 4B.13.5-6.
Cost Estimate Summary for
Little River Off-Channel Reservoir
(Second Quarter 2002 Prices)

Item	Estimated Costs for Facilities
Capital Costs	
Dam and Reservoir (Conservation Pool: 155,812 acft, 4,343 acres, 400 ft-msl)	$27,396,000
Intake and Pump Station (205.5 MGD)	16,231,000
Transmission Pipeline (108-in dia., 1 mile)	2,504,000
Relocations & Other	107,000
Total Capital Cost	**$46,238,000**
Engineering, Legal Costs and Contingencies	$16,058,000
Environmental & Archaeology Studies and Mitigation	11,429,000
Land Acquisition and Surveying (4,348 acres)	11,662,000
Interest During Construction (4 years)	11,125,000
Total Project Cost	**$96,512,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$1,954,000
Reservoir Debt Service (6 percent for 40 years)	4,627,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	431,000
Dam and Reservoir	411,000
Pumping Energy Costs (10,087,646 kWh @ 0.06 $/kWh)	605,000
Total Annual Cost	**$8,028,000**
Available Project Yield (acft/yr)	**32,110**
Annual Cost of Water ($ per acft)	**$250**
Annual Cost of Water ($ per 1,000 gallons)	**$0.77**

Table 4B.13.5-6.
Comparison of Little River Off-Channel Reservoir Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet some needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low to moderate impact
3. Cultural Resources	3. Low to moderate impact
4. Bays and Estuaries	4. Low impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Low to none
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

- Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;
- Additional acquisition of rights-of-way and/or easements may be required; and,
- Possible relocations or removal of residences, utilities, roads, or other structures.

4B.13.6 Lake Palo Pinto Off-Channel Reservoir

4B.13.6.1 Description of Option

In 1986 a volumetric survey was performed by HDR Engineering, Inc. to determine the capacity of Lake Palo Pinto. The survey indicated the capacity of the lake to be 27,650 acft or about 16,450 acft less than the authorized capacity of 44,100 acft.

In order to help restore the capacity of Lake Palo Pinto and increase its yield, an off-channel reservoir site was investigated.[42] The proposed off-channel reservoir is located approximately 1.6 miles north of Lake Palo Pinto at Wilson Hollow, as shown in Figures 4B.13.6-1 and 4B.13.6-2. The proposed dam would be an earthfill embankment that would extend approximately 1,550 feet and provide a conservation storage capacity of 10,000 acft at an elevation 1,088 ft-msl; the reservoir would inundate 182 surface acres. It is possible to upsize or downsize the storage capacity at this site depending on the anticipated municipal growth requirements of the Palo Pinto County Municipal Water District No. 1 (District) and the future needs of the Brazos Electric Power Cooperative (BEPC).

The proposed off-channel reservoir would be filled by natural drainage and by pumping water from Lake Palo Pinto when it is spilling or nearly full. As shown in Figure 4B.13.6-2, water would be pumped 1.9 miles via a 36-inch pipeline to the off-channel reservoir from Lake Palo Pinto at a new 27 MGD intake site located at the northeast corner of the lake. When the level of Lake Palo Pinto is lowered due to drought conditions, water would be released by gravity from the off-channel reservoir to Lake Palo Pinto to increase its supply capability. When both the off-channel reservoir and Lake Palo Pinto are at their conservation elevations, 1,088 ft-msl and 867 ft-msl respectively, the combined storage capacity in 2060 would be approximately 31,426 acft. This is less than the District's authorized storage capacity of Lake Palo Pinto of 44,100 acft.

[42] HDR Engineering, Inc. "Reconnaissance Report for Off-Channel Reservoir Project for Palo Pinto County Municipal Water District No. 1", April 2005.

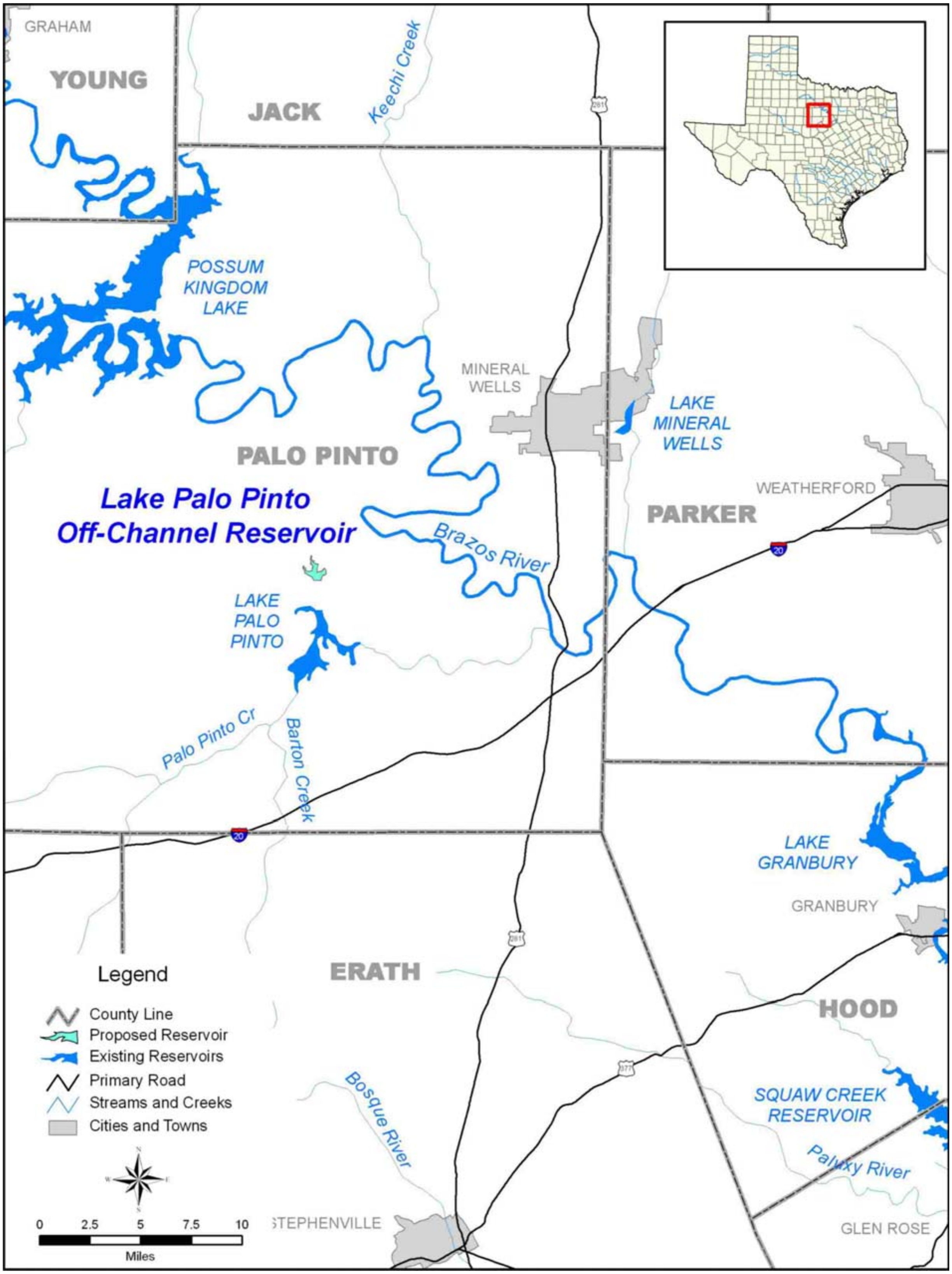

Figure 4B.13.6-1. Lake Palo Pinto Off-Channel Reservoir

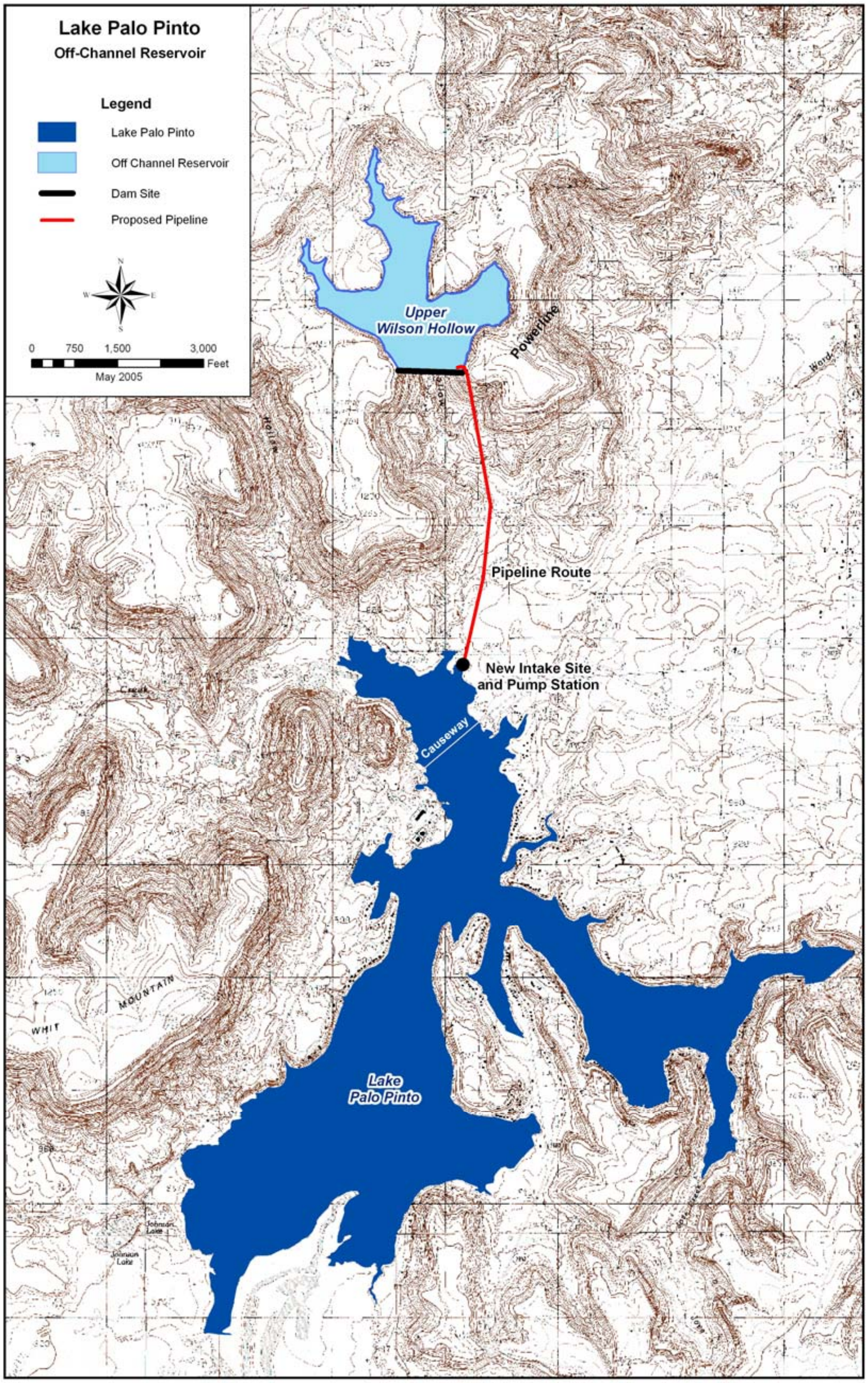

Figure 4B.13.6-2. Lake Palo Pinto Off-Channel Reservoir

4B.13.6.2 Available Yield

Water potentially available for impoundment in the proposed Lake Palo Pinto Off-Channel Reservoir was estimated using the Texas Water Development Board's (TWDB) reservoir operation model, SIMYLD-II. Using this model, Lake Palo Pinto and the proposed off-channel reservoir were evaluated as a reservoir system subject to a set of operational rules. These operational rules attempted to maintain Lake Palo Pinto above elevation 864 ft-msl for as long as possible while still meeting the municipal diversions of the District at the diversion dam located downstream of Lake Palo Pinto. The model utilized a January 1948 through December 2001 hydrologic period of record.[43,44]

The calculated 2060 safe yield (with a six month storage reserve) for the Lake Palo Pinto and off-channel reservoir system is 9,770 acft/yr. The 2060 stand alone safe yield of Lake Palo Pinto is 6,660 acft/yr. Therefore, the additional yield to the system attributed to the Lake Palo Pinto Off-Channel Reservoir is 3,110 acft/yr. Figure 4B.13.6-3 illustrates the Lake Palo Pinto and Off-Channel Reservoir storage levels for the 1948-2001 historical period, subject to the safe yield demand of 9,770 acft/yr. Figure 4B.13.6-4 compares the storage in Lake Palo Pinto at existing conditions (stand alone) with the storage when the lake is operated with the Off-Channel Reservoir. The figure shows that when operated with the proposed Off-channel Reservoir, the lake levels in Lake Palo Pinto are stabilized and more water is available in the drier years compared to Lake Palo Pinto operated independently.

Since both the combined storage and diversion amounts for the Lake Palo Pinto and off-channel reservoir are within the limits of the District's existing water rights, and the off-channel reservoir is proximate to Lake Palo Pinto, this proposed project would be within the existing water rights held by the District (storage capacity and diversion) and will have little or no change to streamflow beyond those already caused by the District's water rights when fully utilized.

[43] HDR Infrastructure, Inc. "Yield Studies of Lake Palo Pinto and Turkey Peak Reservoir," Palo Pinto County Municipal Water District Number One, March 1986.
[44] HDR Engineering, Inc. "Yield Studies for Lake Palo Pinto and the Proposed Turkey Peak Reservoir," Palo Pinto County Municipal Water District Number One, June 2001.

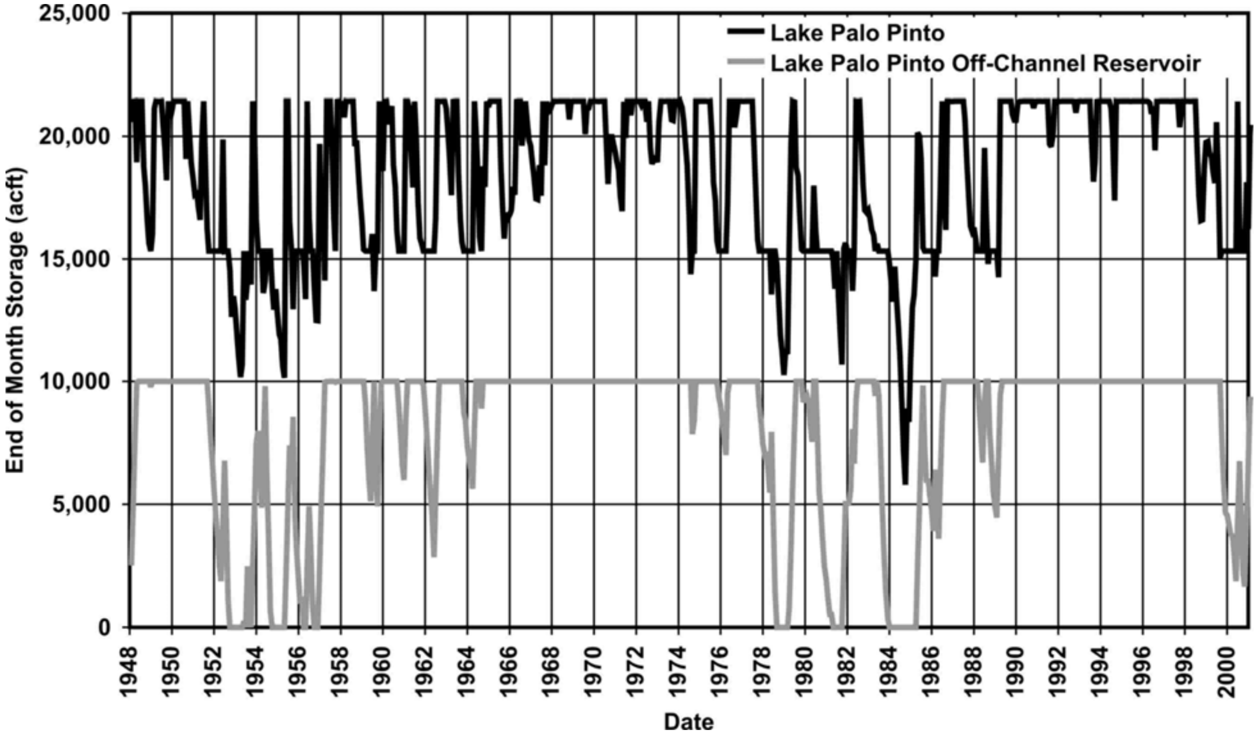

Figure 4B.13.6-3. Monthly Lake Palo Pinto and Lake Palo Pinto Off-Channel Reservoir Storage for 1948-2001 Period of Record

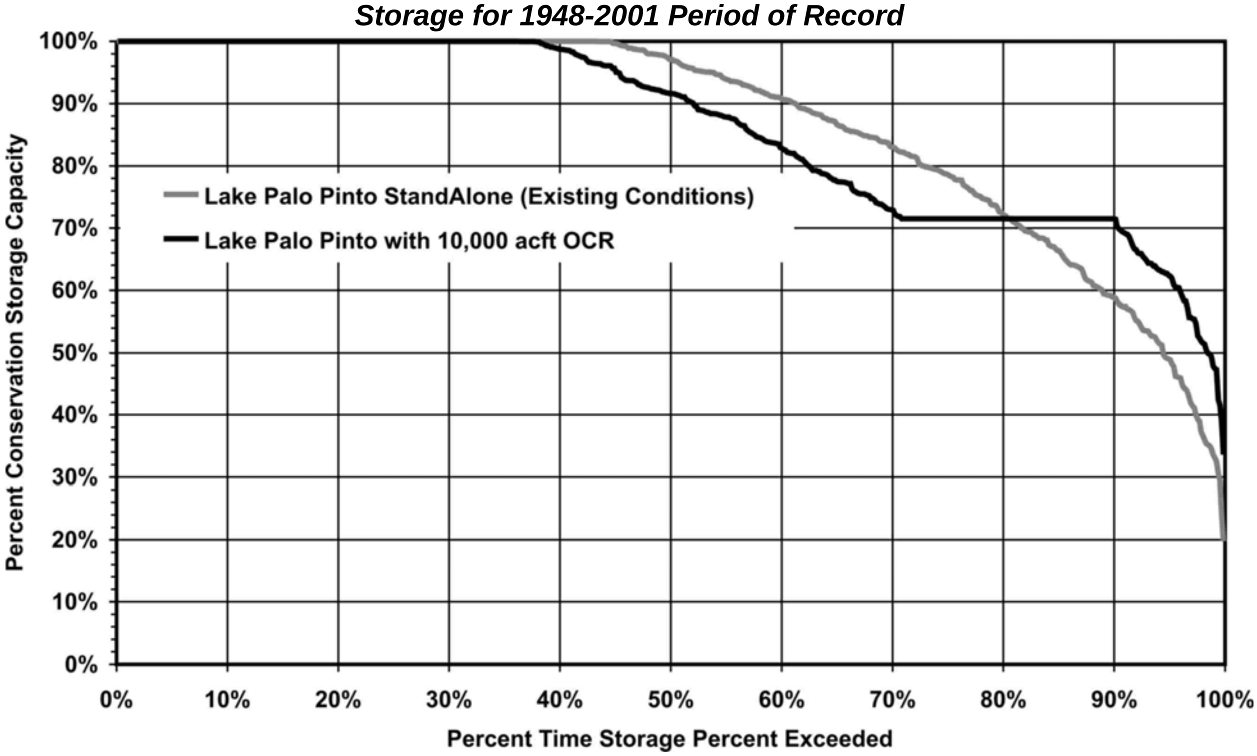

Figure 4B.13.6-4. Comparison of Lake Palo Pinto Storage when Operated With and Without Lake Palo Pinto Off-Channel Reservoir

4B.13.6.3 Environmental Issues

The Lake Palo Pinto Off-Channel Reservoir site is located less than four miles from the Turkey Peak Reservoir project site, therefore the existing environment is similar to that described for the Turkey Peak Reservoir in Section 4B.12.5. Nevertheless, the potential environmental impacts of the off-channel reservoir are likely to be less than the impacts associated with the Turkey Peak project for a variety of reasons. The off-channel reservoir inundation area is less than 30% of the area of the Turkey Peak Reservoir. Unlike the Turkey Peak site, the off-channel reservoir site also does not contain any bottom land areas. In addition, no major roadways or bridges will have to be relocated as a result of the off-channel project.

4B.13.6.4 Engineering and Costing

Cost estimates for the Lake Palo Pinto Off-Channel Reservoir were originally prepared by HDR Engineering Inc. in April, 2005 for the District.[45] For consistency with the regional water planning guidelines, these costs were adjusted to 2002 Second Quarter prices using a ratio derived from Engineering News Record Construction Cost Indexes. The estimated construction cost of the Lake Palo Pinto Off-Channel Reservoir is approximately $19.3 million. This includes the construction of the dam, land acquisition, resolution of conflicts, geotechnical investigation, environmental permitting and mitigation, and technical services.

The annual project costs are estimated to be $1.6 million; this includes annual debt service, operation and maintenance, and pumping energy costs. The cost for the estimated increase in system yield of 3,110 acft/yr translates to an annual unit cost of raw water of $1.60 per 1,000 gallons, or $521/acft. A summary of the cost estimate is provided in Table 4B.13.6-1.

4B.13.6.5 Implementation Issues

This option has been compared to the plan development criteria as shown in Table 4B.13.6-1.

Potential Regulatory Requirements:

- Texas Commission on Environmental Quality (TCEQ) Water Right and Storage permits;

[45] HDR Engineering, Inc. “Reconnaissance Report for Off-Channel Reservoir Project for Palo Pinto County Municipal Water District No. 1”, April 2005.

- U.S. Army Corps of Engineers Permits will be required for discharges of dredge or fill into wetlands and waters of the U.S. for dam construction, and other activities (Section 404 of the Clean Water Act);
- TCEQ administered Texas Pollutant Discharge Elimination System (NPDES) Storm Water Pollution Prevention Plan;
- General Land Office (GLO) Easement if State-owned land or water is involved; and,
- Texas Parks and Wildlife Department (TPWD) Sand, Shell, Gravel and Marl permit if state-owned streambed is involved.

State and Federal Permits may require the following studies and plans:

Environmental impact or assessment studies;

- Wildlife habitat mitigation plan that may require acquisition and management of additional land;
- Flow releases downstream to maintain aquatic ecosystems;
- Assessment of impacts on Federal- and State-listed endangered and threatened species; and,
- Cultural resources studies to determine resources impacts and appropriate mitigation plan that may include cultural resource recovery and cataloging; requires coordination with the Texas Historical Commission.

Land Acquisition Issues:

Land acquired for reservoir and/or mitigation plans could include market transactions and/or eminent domain;

- Additional acquisition of rights-of-way and/or easements may be required; and,
- Possible relocations or removal of residences, utilities, roads, or other structures.

Table 4B.13.6-1.
Evaluations of Lake Palo Pinto Off-Channel Reservoir Option to Enhance Water Supplies

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate)
B. Environmental factors	
1. Environmental Water Needs	1. Negligible impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

Table 4B.13.6-2.
Cost Estimate Summary for
Lake Palo Pinto Off-Channel Reservoir
(Second Quarter 2002 Prices)

Item	***Estimated Costs for Facilities***
Capital Costs	
Dam and Reservoir (Conservation Pool 10,000 acft, 182 acres, 1,088 ft-msl)	$7,145,000
Outlet Works/Intake Tower	$400,000
Pump Station & Pipeline (27 MGD, 36-inch, 1.9 miles)	$4,445,000
Relocations and Other	$290,000
Total Capital Cost	**$12,280,000**
Mobilization (5%)	$599,000
Construction Contingencies (12%)	$1,545,000
Land and Easements	$708,000
Engineering, Geotechnical, Legal, & Financing	$2,164,000
Environmental and Archaeological	$690,000
Interest During Construction (18 months)	$1,079,000
Pumping Costs to Fill Initial Reservoir	$249,000
Total Project Cost	**$19,314,000**
Annual Costs	
Debt Service (6%, 30 years)	$1,403,000
Operation and Maintenance	$138,000
Pumping Energy Cost (Avg. Annual)	$80,000
Total Annual Cost	**$1,621,000**
Available Project Yield (acft/yr)	3,110
Annual Cost of Water ($ per acft)	$521
Annual Cost of Water ($ per 1,000 gallons)	$1.60

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4B.14 Interconnection of Regional and Community Systems

4B.14.1 Bosque County Regional Project

4B.14.1.1 Description of Option

Several entities in Bosque County are projected to have water shortages in the year 2060. The cities of Meridian, Walnut Springs, and Valley Mills and the County-Other entities are projected to have a total combined shortage of 1,387 acft/yr by the year 2060. In an attempt to address this shortage, the Brazos River Authority, Texas Water Development Board, and the Cities of Clifton and Meridian have jointly sponsored a study[1] to determine the regional water needs and to evaluate existing and proposed water facilities. According to the study, water shortages in 2030 are: Childress WSC, 0.19 MGD; Meridian, 0.12 MGD; Valley Mills, 0.17 MGD; and Walnut Springs, 0.06 MGD. These quantities are approximately equal to the 2060 shortages determined by the BGRWPG. The study evaluated four alternatives, which are described below:

Alternative	*Description*
No. 1	The Clifton WTP provides water solely to the Meridian
No. 2	Meridian build WTP to serve its own users.
No. 3	Subregional water systems are built at Meridian (Northern) and Clifton (Southern) for all participants.
No. 4	Clifton WTP is expanded and becomes a regional facility for all participants.

The study recommended Alternative 4 on the basis of construction costs and unit water costs. For purposes of this water management strategy, the participating water utilities include: Clifton, Childress WSC, Meridian, Valley Mills, and Walnut Springs.

Clifton has recently implemented a surface water supply project to meet its water supply needs. The fourth alternative expands the city's system into a regional facility. This expansion would include a pump station and pipelines to the four participants. Figure 4B.14-1 shows the planned interconnection of the four water utilities with the regional facility at Clifton.

[1] Carter-Burgess, "Bosque County Regional Water Treatment and Distribution Facilities Plan," Final Report to the Brazos River Authority, March 2004.

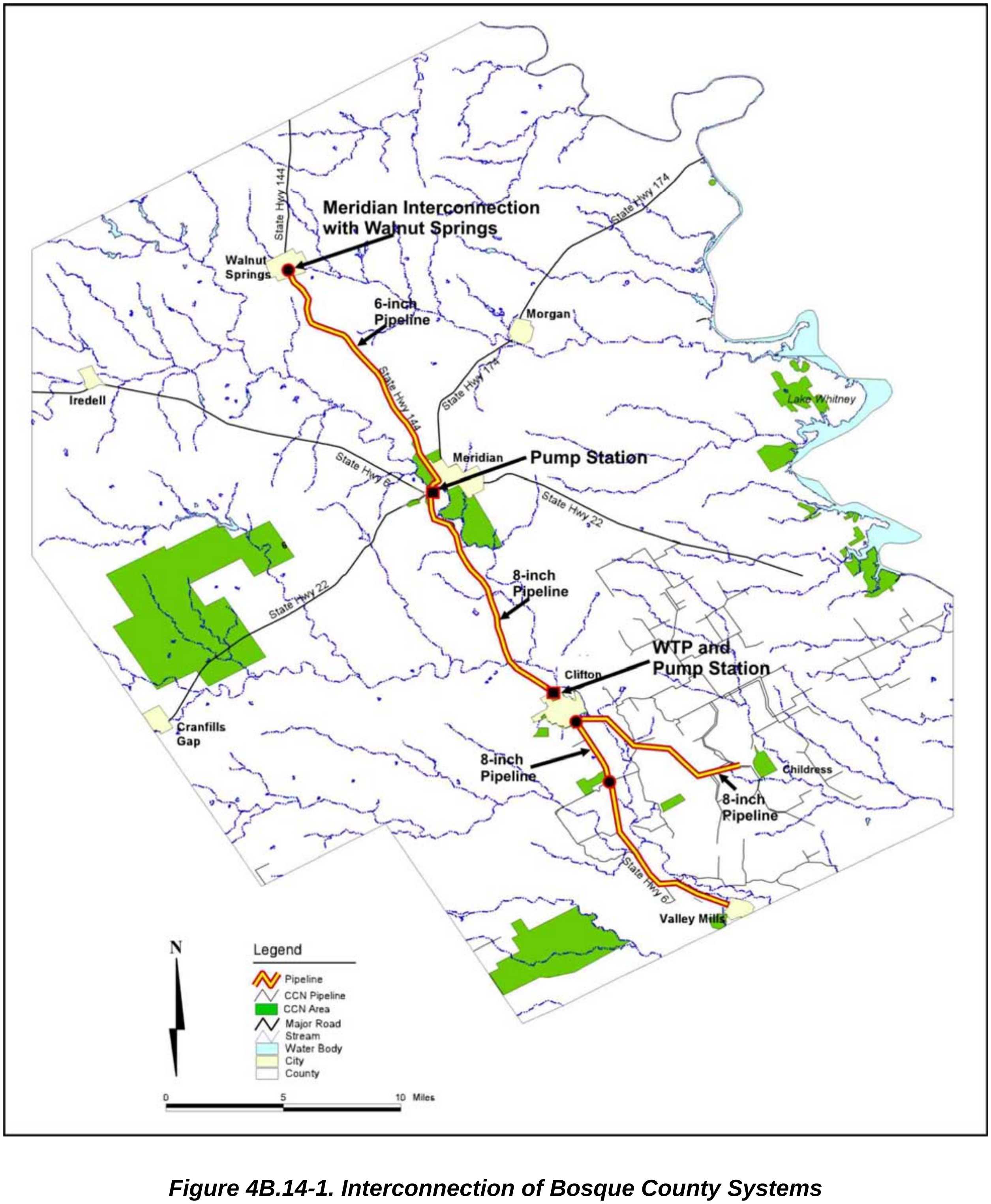

Figure 4B.14-1. Interconnection of Bosque County Systems

4B.14.1.2 Available Yield

The yield of the City of Clifton's surface water system (Bosque River diversion into an off-channel reservoir) is currently 1,133 acft/yr, but future enlargement of the reservoir could increase the yield to 1,777 acft/yr. Based on projected demands, Clifton would have up to 570 acft/yr of supply available to sell in 2060 if its current water treatment plant were expanded. This strategy, as formulated, would provide a total of 604 acft/yr to the four WUGS (213 acft/yr to Childress WSC; 134 acft/yr to Meridian; 190 acft/yr to Valley Mills; and 67 acft/yr to Walnut Springs). However, the combined shortage for the four WUGs is only 436 acft/yr and there is therefore sufficient supply from Clifton to meet these needs. If needs develop more rapidly than projected for Clifton or the four utilities, the Clifton off-channel reservoir could be enlarged if necessary.

4B.14.1.3 Environmental

Environmental impacts could include:

- Possible low to moderate impacts on in-stream flows due to increased diversions.
- Possible moderate impacts on endangered species depending on specific locations of pipelines.
- Possible moderate impacts on riparian corridors depending on specific locations of pipelines.

A summary of environmental issues is presented in Table 4B.14-1.

Table 4B.14-1
Environmental Issues
Interconnection of City of Clifton System to Surrounding Communities

Water Management Option	Interconnection of City of Clifton System to Surrounding Communities
Implementation Measures	Construction of pump stations, storage tanks and approximately 45 miles of pipelines between City of Clifton and surrounding communities
Environmental Water Needs / Instream Flows	Possible impacts on in-stream flows but within existing flow regimes allowed by current permits
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors and upland habitats depending on specific locations of pipelines
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible moderate impacts on endangered species, including Black-capped vireo and Golden-cheeked warbler, depending on specific locations of pipelines
Comments	Assumes institutional transfer agreements with 45 miles of pipeline and construction of associated facilities

4B.14.1.4 Engineering and Costing

The City of Clifton, which has developed a new surface water supply, is used as an example of expanding and interconnecting its system into a regional and community system. The following facilities would be needed to connect the City of Clifton to Childress WSC, Meridian, Valley Mills, and Walnut Springs:

- Expansion Clifton's Water Treatment Plant and Ground Storage;
- Treated Water Pump Station at Clifton and Meridian;
- Treated Water Storage Tank for Pump Station;
- Treated Water Transmission Pipelines; and
- Possible enlargement of off-channel storage if total needs develop more rapidly than projected.

The channel dam, off-channel reservoir, and water treatment facilities would form the hub of the regional water system. At Clifton, a central pump station would be built. From here separate pipelines would connect to a distribution point in the Childress WSC and Valley Mills, and to a pump station at Meridian. From the Meridian pump station, treated water would be pumped to a distribution point in the Meridian and Walnut Springs systems.

The costs for four participating communities in Bosque County to connect to the City of Clifton's water system are summarized in Table 4B.14-2. The capital and other project costs are derived from the Carter-Burgess study. For consistency with other water management strategies, the annual costs are based on HDR's cost guide for regional planning studies. The total project cost, including capital, engineering, legal costs, contingencies, environmental studies, land acquisition and surveying, for the regional interconnections are: Childress, $2,299,000; Meridian, $2,261,000; Valley Mills, $3,916,000; and Walnut Springs, $3,991,000.

Taking into consideration debt service on a 30-year loan, operation and maintenance costs, and pumping energy costs, the annual costs are: Childress, $235,000; Meridian, $212,000; Valley Mills, $357,295; and Walnut Springs, $346,000. On the basis water shortages listed above, the unit costs per 1,000 gallons of treated water are: Childress, $3.39; Meridian, $4.85; Valley Mills, $5.77; and Walnut Springs, $15.85. These costs reflect full development and use of the regional system, assuming enlargement of Clifton's off-channel reservoir is unnecessary.

Table 4B.14-2.
Cost Estimate Summary
Bosque County Interconnection of Clifton, Childress WSC, Meridian, Valley Mills and Walnut Springs
Second Quarter 2002 Prices

Item	Cost of Supply to Childress WSC	Cost of Supply to Meridian	Cost of Supply to Valley Mills	Cost of Supply to Walnut Springs
Capital Costs				
Transmission Pipeline	$1,131,000	$1,255,000	$2,226,000	$1,967,000
Transmission Pump Station(s)	$186,000	$131,000	$208,000	$768,000
Water Treatment Plant (Clifton Regional)	$325,000	$229,000	$363,000	$115,000
Total Capital Cost	**$1,642,000**	**$1,615,000**	**$2,797,000**	**$2,850,000**
Engineering (15%)	$246,000	$242,000	$420,000	$428,000
Contingency (25%) (Environmental, Archaeology, Mitigation, Land and Interest)	$411,000	$404,000	$699,000	$713,000
Total Project Cost	**$2,299,000**	**$2,261,000**	**$3,916,000**	**$3,991,000**
Annual Costs				
Debt Service (6 percent for 30 years)	$167,000	$164,000	$284,000	$290,000
Operation and Maintenance				
Pipeline and Pump Station	$16,000	$16,000	$27,000	$39,000
Water Treatment Plant	$47,000	$30,000	$42,295	$15,000
Pumping Energy Costs(@ $0.06/kWh)	$5,000	$2,000	$4,000	$2,000
Total Annual Cost	**$235,000**	**$212,000**	**$357,295**	**$346,000**
Available Project Yield (acft/yr)	**213**	**134**	**190**	**67**
Annual Cost of Water ($ per acft)	**$1,103**	**$1,582**	**$1,881**	**$5,164**
Annual Cost of Water ($ per 1,000 gallons)	**$3.39**	**$4.85**	**$5.77**	**$15.85**

4B.14.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14-3, and the option meets each criterion.

Table 4B.14-3
Comparison of Bosque County Interconnections Option
to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Low impact 2. Low impact 3. Low impact 4. Negligible impact 5. Low impact 6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

The participating entities must negotiate a regional water service contract to build and operated the system and to equitably share costs. This would probably include the need for a cost of service study.

Requirements specific to pipelines needed to link existing sources to users will include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the U.S. for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.14.2 West Central Brazos Water Distribution System

4B.14.2.1 Description of Option

The West Central Brazos Water Distribution System (WCBWDS) is a relatively unused system that could potentially provide raw water to a large portion of the upper Brazos River Basin area. The WCBWDS pipeline facilities, which are owned by the Brazos River Authority (BRA), consist of an intake and pump station on Possum Kingdom Reservoir, several miles of 8-inch through 36-inch pipeline and an intermediate pump station east of Breckenridge. The facilities currently provide raw water for industrial use to the area west of Possum Kingdom.

The Authority has received requests from numerous area water suppliers interested in purchasing raw water from Possum Kingdom Reservoir that could be conveyed through the WCBWDS facilities. Abilene, Albany, Breckenridge, Eastland County WSD, Graham, Shackelford WSC, Stephens County Rural WSC and West Central Texas MWD have all expressed interest in obtaining water from the BRA. As part of the West Central Brazos Study[2], a hydraulic analysis of the WCBWDS was conducted and improvements were identified to move water to different participants. Three scenarios were evaluated: 1) near-term requests, 2) long-term requests and 3) long-term requests with a potential request from Abilene. These amounts are shown in Table 4B.14-4.

Table 4B.14-4.
Demands for WCBWDS Hydraulic Analyses

Scenario	Water User	Demand (MGD)	Total Demand (MGD)
	Existing Industrial Demands	2.11	
1	Near-Term Requests	6.43	8.54
	Shackelford		
	Breckenridge		
	Stephens County RWSC		
	Throckmorton		
	Mining		
2	Long-Term Requests	18.96	27.51
	Albany		
	WCTMWD		
	Eastland County WSD		
	Graham		
	Stephens County Rural WSC		
3	Abilene	26.78	54.29

[2] Freese and Nichols, *West Central Brazos River Basin Regional Water Treatment and Distribution Facility Plan,* August 2004.

The hydraulic study found that with only pump station improvements and some additional pipeline capacity, the WCBWDS facilities have sufficient capacity to serve the existing customers and the near-term requests for water. With the addition of a booster station and a 27-inch parallel pipeline, the facilities could serve additional supply to West Central Texas MWD, Eastland County WSD, the City of Graham, and the City of Albany. Extensive improvements would be necessary to provide supply to the City of Abilene, although facilities are in place from the WCBWDS intake all the way to Abilene. Without considering Abilene, the WCBWDS pipeline could provide water to 20 or more entities.

For this plan, the transport of water from Possum Kingdom Lake using the WCBWDS is being considered for the Midway Group participants. The group currently consists of Shackelford Water Supply Corporation (WSC), Stephens County Rural Water Supply Corporation (RWSC), the City of Throckmorton and the City of Breckenridge.

4B.14.2.2 Description of Midway Group Option using the WCBWDS

The Midway Group provides much of the water in Shackelford, Stephens and Throckmorton Counties. Primary water sources for the group include Hubbard Creek Reservoir, Lake Daniel, Lake Throckmorton and a contract with the City of Albany, which receives water from Hubbard Creek Lake and Lake McCarty. Shackelford WSC and Stephens County RWSC do not have sufficient supplies to meet projected demands under current contract conditions, and the City of Throckmorton's supply is unreliable. The City of Breckenridge has sufficient supplies for the short term, but Lake Daniel is currently very low and the amount of reliable supply from this source is uncertain.

To meet the needs of the Midway Group, this strategy proposes to transport water from Possum Kingdom Reservoir to a regional water treatment facility near Breckenridge via the WCBWDS, and distributed using existing facilities, upgraded proposed facilities and new facilities. Figure 4B.14-2 presents a general schematic of the proposed improvements required for this strategy.

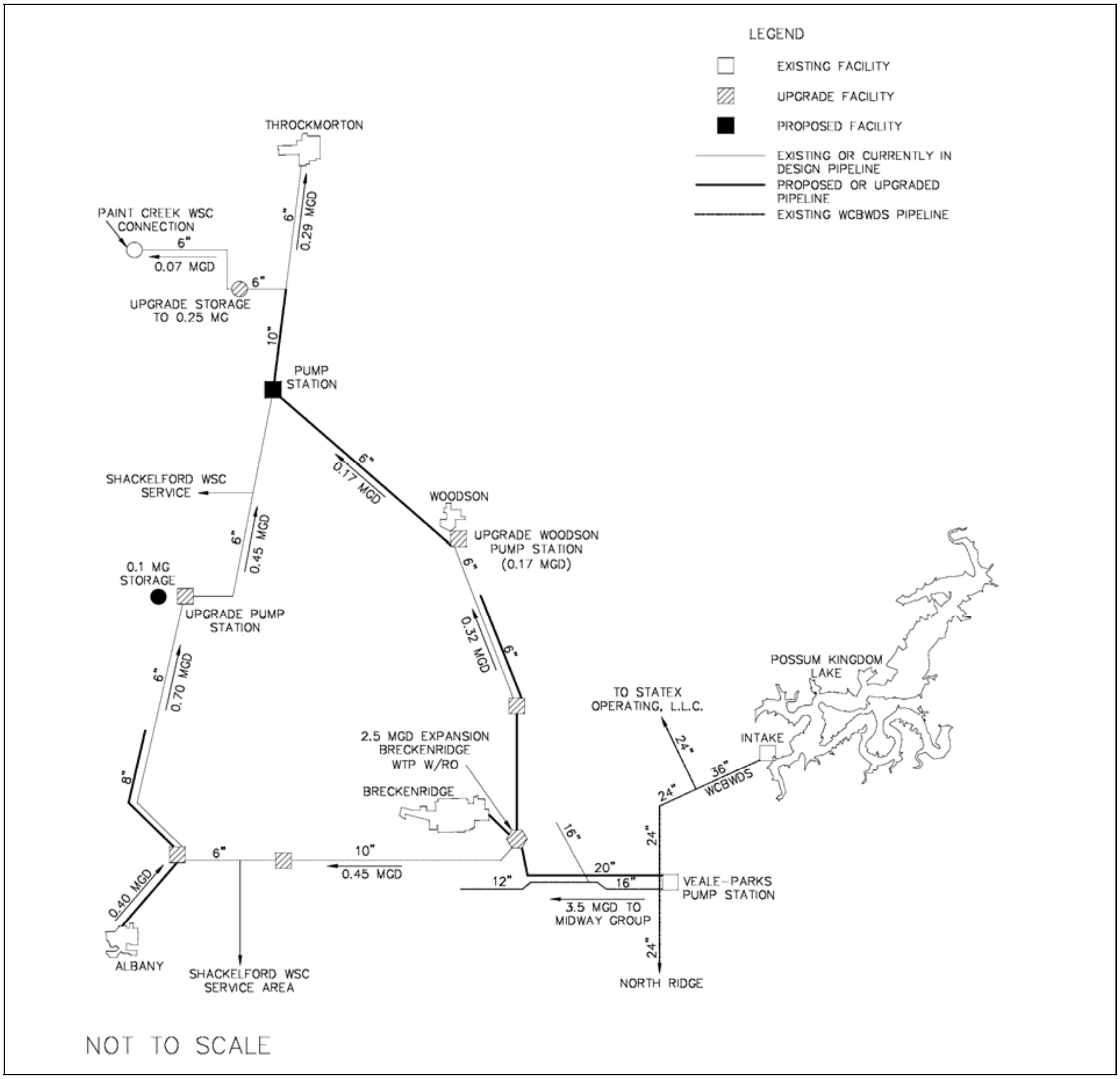

Figure 4B.14-2. Schematic of Midway Group Interconnections Using the WCBWDS Facilities

4B.14.2.3 Available Yield

This strategy assumes that the Midway Group participants would contract with the BRA for a total raw water supply of 2,000 acft/yr. Assuming 30 percent of this supply is lost as reject water during treatment (desalination), the available treated supply is approximately 1,400 acft/yr. The total projected demand for the group is over 2,000 acft/yr in 2010, reducing to about 1,800 acft/yr by 2060 due to declining populations and conservation in the water demands.

The WCBWSD would be used to move the 2,000 acft/yr of water from Possum Kingdom Reservoir to the regional water treatment plant. Hydraulic analyses of this pipeline found that a new 20-inch pipeline and some pump station improvements were needed to meet the peak demands of the Authority's current customers and the Midway Group. To treat the water, the existing water treatment plant at Breckenridge would be expanded with a 2.5 MGD microfiltration and reverse osmosis facility. Alternatively, a new water treatment plant could be built solely for treating water from Possum Kingdom Reservoir. The reject water could possibly be discharged to evaporation beds, brine disposal well, to the WCBWDS pipeline for delivery to on-going oil field water flood operations, or other means. Details of the proposed upgrades are shown on Figure 4B.14-2 and available supplies to each participant are discussed below.

Throckmorton County. This strategy proposes to supply the city of Throckmorton with 193 acft/yr (200 gpm) through upgrading Shackelford WSC's planned expansion into Throckmorton County and utilizing existing and new water lines in Stephens County RWSC system. To meet the City's full demands (232 acft/yr), a new water line from the water treatment plant to Throckmorton would be needed. This scenario assumes that Throckmorton will continue to use some water from Lake Throckmorton and/or extend its contract with Fort Belknap.

Shackelford County. Of the remaining supply, approximately 250 acft/yr of treated water would be provided to Shackelford WSC, 400 acft/yr to Stephens County RWSC and 550 acft/yr to Breckenridge to supplement current contracted supplies. The water for Shackelford WSC would be taken south of Breckenridge and transported through the WSC's system to a proposed in-line pump station on Highway 180. The water would then be conveyed to the WSC's office pump station where it could be blended with water from the city of Albany and transported to an existing booster pump station near Ft. Griffin. From there, water would be distributed to Shackelford 's customers and the City of Throckmorton. This scenario requires approximately 11.5 miles of upgrades to existing or planned water lines, upgrades of 5 pump stations and several new facilities. Some of these improvements are already proposed to serve retail customers of Shackelford WSC.

Stephens County. Stephens County RWSC and Breckenridge would take treated water directly from the water treatment plant. New connections to their existing distribution facilities would be needed. Some upgrades to Stephens County RWSC system as shown on Figure 4B.14-2 are also necessary to move water to Throckmorton and expand service to retail customers. These improvements include nearly 13 miles of new 6-inch pipeline and upgrades to Stephens County RWSC's two existing pump stations. No additional improvements are proposed for Breckenridge.

4B.14.2.4 Environmental

The environmental impacts are expected to be low for the transmission improvements and system upgrades. Most of the upgrades are to existing or proposed pipelines. It is assumed that new pipelines can be routed around environmentally sensitive areas, if needed.

Environmental impacts for the reject water from the treatment facility could be low to moderate, depending on the selected disposal method. Further study is needed on the disposal options and potential impacts. There should be minimal impacts to Possum Kingdom Reservoir from this strategy. The quantity of water represents a small amount of the total yield of lake, and would have little impact on water levels.

A summary of environmental issues is presented in Table 4B.14-5.

Table 4B.14-5.
Environmental Issues
Midway Group Option using the WCBWDS

Water Management Option	Infrastructure improvements to supply water from Possum Kingdom Lake to entities in Stephens, Shackelford and Throckmorton Counties (Midway Group)
Implementation Measures	Upgrading of existing pipelines and pump stations to move water from a regional water treatment plant near Breckenridge to users in a 3-county area. Includes 2.5 MGD expansion of water treatment plant with microfiltration to treat brackish water from Possum Kingdom Lake.
Environmental Water Needs / Instream Flows	Negligible impacts to Possum Kingdom Lake. Possible impacts to water quality if brine effluent is discharged to surface water streams.
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Negligible impact from upgrade of infrastructure since most of the infrastructure is in place. Possible low to moderate impacts if brine effluent is discharged to surface water streams
Cultural Resources	Negligible impact
Threatened and Endangered Species	Negligible to moderate impacts on threatened or endangered species depending on specific locations of pipelines and disposal option of brine effluent
Comments	Impacts from brine discharge will be evaluated and mitigated during the permitting process.

4B.14.2.5 Engineering and Costing

Facilities required for the Midway Option using the WCBWDS to deliver treated water to its customers in Stephens, Shackelford, and Throckmorton Counties include:

- Water treatment plant expansion (with microfiltration)
- Pump station upgrades; and
- Transmission pipeline
- Elevated storage tank upgrades.

The total capital costs for this strategy are estimated at $17 million, which includes upgrades to the WCBWDS pipeline and a 2.5 MGD water treatment facility. The cost for treated water would be $4.08 per 1,000 gallons. This does not include power costs to move the water to Throckmorton or other water suppliers' customers. The capital and annual costs are shown in Table 4B.14-6.

Table 4B.14-6.
Estimated Cost for the Midway Group Interconnections
(Second Quarter 2002 Dollars)

Item	*Estimated Costs for Facilities*
Capital Costs	
20" Pipeline (PK to Breckenridge)	$1,949,400
Upsize 8" to 10" Pipeline	$45,000
Upsize 6" to 8" Pipeline	$165,000
Upsize 3" to 6" Pipeline	$65,000
6" PVC pipe	$1,020,000
Bore & encasement	$250,000
Pump station improvements	$900,000
Upsize elevated tank	$75,000
In-line pump station	$150,000
SCADA system and meters	$320,000
2.5 MGD expansion of water treatment plant	$7,000,000
Total Capital Cost	**$11,939,400**
Engineering and Contingencies	$3,931,820
Mitigation and Permitting	$119,400
Interest During Construction	$986,100
Total Project Costs	**$16,976,720**
Annual Costs	
Debt Service - Total Capital	$1,233,340
Water Purchase	$79,500
Operation and Maintenance	
Pipelines	$32,440
Pump stations	$34,250
Surface Water Treatment ($0.75/1,000 gallons)	$342,140
RO Reject water disposal	$48,880
Pumping Costs	$90,000
Total Annual Costs	**$1,860,550**
Annual Cost ($ per acre-foot)	**$1,329**
Annual Cost ($ per 1000 gallons)	**$4.08**

4B.14.2.6 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14-7, and the option meets each criterion. A major issue facing this option is that full participation of the identified entities may be critical to having an economically feasible project. Utilization of the WCBWDS will require infrastructure improvements that will need to be financed by the water users. Significant increases in cost of water associated with the infrastructure improvements and water purchase can impede implementation, especially for smaller entities with limited financial resources.

The other major implementation issue is the possible water quality concerns associated with the treatment and disposal of the elevated salts in the water from Possum Kingdom Reservoir. The Midway Group Regional WTP is proposed to treat Possum Kingdom water using reverse osmosis (or other comparable method). This will generate a brine reject stream that will require disposal. Options considered include discharge to the Brazos River, deep well injection, oil field flooding, or evaporation ponds. Depending on the disposal option, the cost of disposal and the time needed to obtain necessary permits will vary. For any discharge to state waters, a Texas Pollutant Discharge Elimination Permit would be needed. This permit is issued by the TCEQ and requires demonstration of no to low impacts to the water quality of the receiving stream. Permits for deep well injection are granted by the TCEQ for municipal and manufacturing wastes or by the Railroad Commission for oil and gas operations. The permitting process through TCEQ for deep well injection can be costly and take several years. Options for salt water disposal through the oil and gas industry either by injection or oil field flood are likely to be easier to implement, but these options require willing oil/gas participates with appropriate facilities. One implementation issue associated with evaporation ponds or drying beds is available space. For small-scale projects, this may be an option, but large scale projects will generate considerable amounts of brine.

Mitigation requirements would vary depending on impacts. Mitigation is expected to be negligible for the infrastructure improvements. Mitigation requirements associated with the disposal of the brine effluent are unknown.

Table 4B.14-7.
Comparison of Midway Group Interconnections
to Plan Development Criteria

Impact Category	***Comments***
A. Water Supply	
1. Quantity	1. Sufficient quantities available
2. Reliability	2. High reliability
3. Cost	3. Moderate
B. Environmental factors	
1. Environmental Water Needs	1. Possible low to moderate impact, depending on disposal method for brine effluent
2. Habitat	2. Low impact possible where new pipelines are constructed
3. Cultural Resources	3. Possible low impact
4. Bays and Estuaries	4. No substantial impact
5. Threatened and Endangered Species	5. Possible low to moderate impact, depending on disposal method for brine effluent
6. Wetlands	6. Low impact possible where new pipelines are constructed
C. Impact on Other State Water Resources	No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	No apparent negative impacts on agriculture or natural resources
E. Equitable Comparison of Strategies Deemed Feasible	Option is considered to meet municipal shortages
F. Requirements for Interbasin Transfers	No interbasin transfer required.
G. Third Party Social and Economic Impacts from Voluntary Redistribution	No anticipated third party impacts

4B.14.3 Interconnection of City of Abilene System with City of Sweetwater

4B.14.3.1 Description of Option

The City of Sweetwater would purchase treated water from the City of Abilene through a 16-inch diameter pipeline from Abilene's Northeast Water Treatment Plant. Figure 4B.14-3 shows the major components of the system as well as the pipeline alignment.

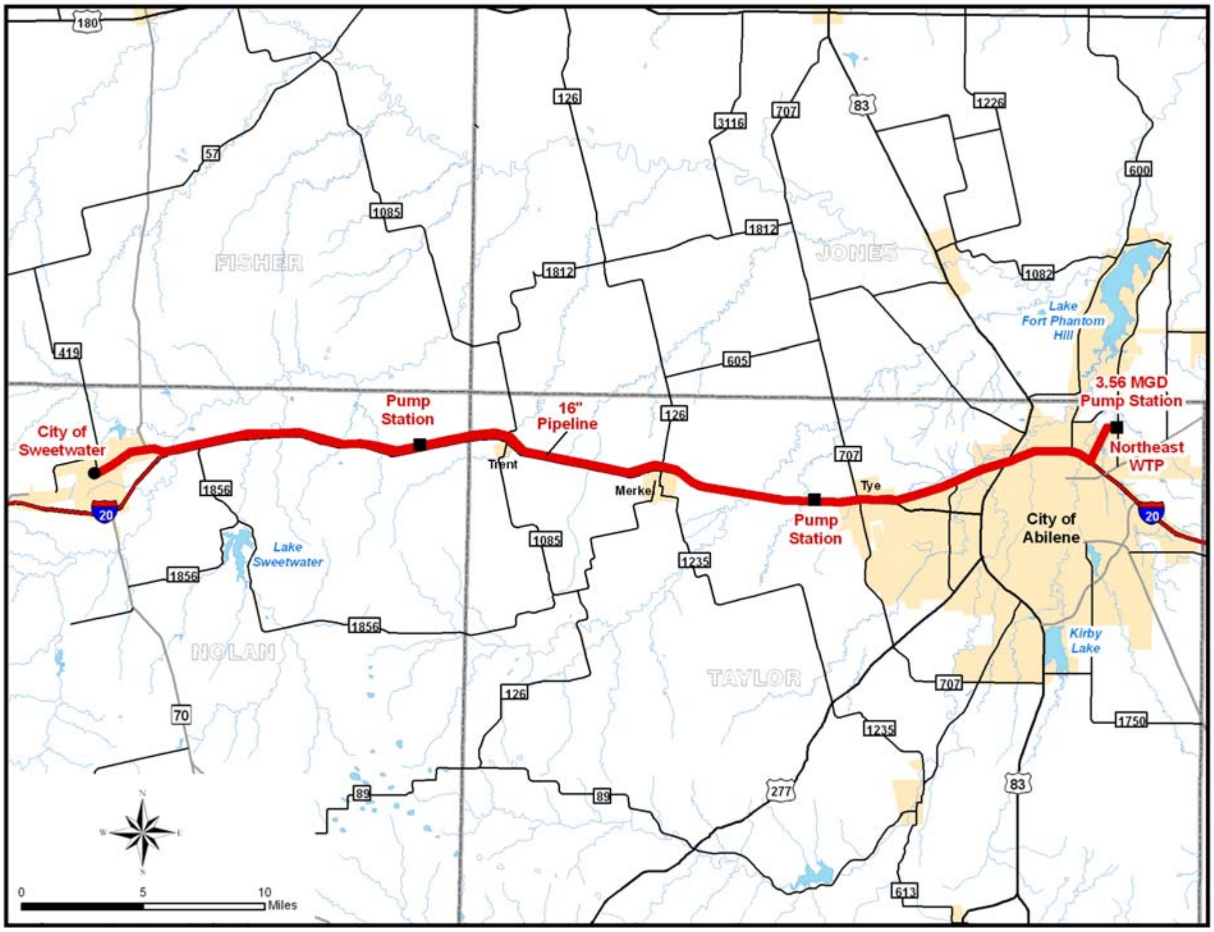

Figure 4B.14-3. Treated Water Pipeline from Abilene to Sweetwater

4B.14.3.2 Available Yield

The City of Sweetwater would contract with Abilene for delivery of up to 2,000 acft/yr of treated water. The pipeline and components would be sized to deliver up to 3.56 MGD for peaking requirements.

4B.14.3.3 Environmental

Environmental impacts could include:

- Possible low impacts on instream flows due to increased diversions;
- Possible low to moderate impacts on riparian corridors depending on specific locations of the pipeline.

A summary of environmental issues is presented in Table 4B.14-8.

Table 4B.14-8.
Environmental Issues
Interconnection of City of Abilene System with City of Sweetwater

Water Management Option	Interconnection of City of Abilene System with City of Sweetwater
Implementation Measures	Construction of a 45-mile pipeline between City of Abilene System and City of Sweetwater
Environmental Water Needs / Instream Flows	Possible low impacts on in-stream flows but within existing flow regimes allowed by current permits
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors if pipeline does not occur within existing rights-of-way
Cultural Resources	Possible low impact
Threatened and Endangered Species	Negligible impact
Comments	Assumes institutional transfer agreements for sale of water

4B.14.3.4 Engineering and Costing

Facilities required for the City of Sweetwater to receive treated water from Abilene include:

- Pump stations; and
- Transmission pipeline.

The system facilities include a 3.56-MGD pump station located nearby Abilene’s Northeast Water Treatment Plant. From this pump station, a 16-inch, approximately 45-mile pipeline transports water to the vicinity of Sweetwater’s existing water treatment plant via two booster stations.

The total capital costs including pump stations, pipeline, valves, and encasements are $20,862,000. Including the project costs of engineering, legal costs, contingencies, environmental studies, land acquisition, surveying, and interest during construction, the total project cost comes to $31,827,000. After taking into consideration annual costs including debt service at 6 percent for 30 years, operation and maintenance, energy costs, and purchase of treated water on a wholesale basis at $521 per acft ($1.60 per 1,000 gallons), the total annual cost of the project is $3,805,000. This is a unit cost of $1,903 per acft ($5.84 per 1,000 gallons) for treated water. Table 4B.14-9 summarizes more completely the cost estimate.

4B.14.3.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14-10, and the option meets each criterion.

Regulatory Permits Required

Requirements specific to pipelines needed to link existing sources to users will include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the U.S. for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Mitigation Funding and Other

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 4B.14-9.
Cost Estimate Summary
Interconnection of Abilene and Sweetwater Systems
Second Quarter 2002 Prices

Item	***Estimated Costs for Facilities***
Capital Costs	
Pump Station (3.75 MGD)	$1,228,000
Transmission Pipeline (16-in dia., 45 miles)	16,209,000
Transmission Pump Station(s)	2,844,000
Total Capital Cost	**$20,281,000**
Engineering, Legal Costs and Contingencies	$6,288,000
Environmental & Archaeology Studies and Mitigation	1,116,000
Land Acquisition and Surveying (168 acres)	1,556,000
Interest During Construction (1.5 years)	1,755,000
Total Project Cost	**$30,996,000**
Annual Costs	
Debt Service (6 percent for 30 years)	$2,252,000
Operation and Maintenance	
Intake, Pipeline, Pump Station	259,000
Pumping Energy Costs (2,935,927 kWh @ $0.06/kWh)	176,000
Purchase of Water (2000 acft/yr @ 521.36 $/acft[1])	1,043,000
Total Annual Cost	**$3,730,000**
Available Project Yield (acft/yr)	**2,000**
Annual Cost of Water ($ per acft)	**$1,865**
Annual Cost of Water ($ per 1,000 gallons)	**$5.72**

[1] Based upon a wholesale rate of $1.60 per 1,000 gallons of treated water. The actual rate would be negotiated.

Table 4B.14-10.
Comparison of Interconnecting Abilene System
with Sweetwater Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable (moderate to high)
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Water supply being redistributed is not need by seller; no third party impact

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4B.14.4 Interconnection of City of Waco System with Neighboring Communities

4B.14.4.1 Description of Option

Many entities in the Waco area of McLennan County have historically relied on groundwater from the Trinity Aquifer for municipal and other types of supply. Continued growth in the Waco area is projected to cause water demands to exceed the available supply from the Trinity Aquifer. The City of Waco has been pursuing plans to supply many of the entities surrounding Waco with water from the City of Waco system (Lake Waco) in order to alleviate demands on the Trinity Aquifer. The City of Waco's plans call for 36,447 acft/yr to be served to surrounding communities by 2030, as shown in Table 4B.14-11. In addition, the Brazos G RWPG has identified an additional 12,613 acft/yr that could be supplied to other water user groups with shortages in McLennan County, if both parties are agreeable.

4B.14.4.2 Available Yield

This water management strategy does not increase supply in the Brazos G Area, but increases utilization of existing Lake Waco and Brazos River supplies. These demands exceed current supply prior to the year 2050 for the City of Waco as a wholesale water provider. Future supplies could be supplemented with reuse water (direct or indirect) as per the City's wholesale water provider plan (Volume I, Section 4C.38.18).

4B.14.4.3 Environmental

Environmental impacts could include:

- Possible low to moderate impacts on in-stream flows due to increased diversions.
- Probable low impacts on endangered species depending on specific locations of facilities used to interconnect with the City of Waco.
- Probable low impacts on riparian corridors depending on specific locations of pipelines.

A summary of environmental issues is presented in Table 4B.14-12.

Table 4B.14-11
Supplies to McLennan County WUGs from the City of Waco (WWP)

Water User Group	Projected Supply from City of Waco[1] (acft/yr)	
	2030	2060
City of Waco Municipal Demands	27,781	31,304
City of Waco Current or Contemplated Contracts		
City of Bellmead	2,873	3,202
Chalk Bluff WSC	2,846	2,955
City of Gholson	2,539	2,647
City of Hewitt	6,106	6,389
City of Lacy-Lakeview	2,070	2,166
City of West	2,789	2,897
City of Woodway	2,903	2,874
McLennan County-Other	14,321	14,700
Additional Brazos G Recommendations		
City of Northcrest	183	178
City of Beverly Hills	416	424
West Brazos WSC	450	600
City of Crawford	65	70
Cross County WSC	550	700
City of Hallsburg	150	180
City of Mart	350	400
North Bosque WSC	500	700
City of Riesel	150	150
Western Hills WS	550	700
McLennan County Steam-Electric	6,000	19,000
McLennan County Manufacturing	3,249	4,275
Total City of Waco (WWP) Demands	76,841	96,511

[1] From Table 4A-20 (Volume I)

Table 4B.14-12
Environmental Issues
Interconnection of City of Waco System with Neighboring Communities

Water Management Option	Interconnection of City of Waco System to Surrounding Communities
Implementation Measures	Construction of pump stations, storage tanks and pipelines between City of Waco and surrounding communities
Environmental Water Needs / Instream Flows	Possible impacts on in-stream flows but within existing flow regimes allowed by current permits
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors and upland habitats depending on specific locations of pipelines
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible low impacts on endangered species, depending on specific locations of pipelines
Comments	Assumes institutional transfer agreements and construction of associated facilities

4B.14.4.4 Engineering and Costing

No detailed interconnection plan has been completed to assess the infrastructure costs associated with interconnecting the City of Waco with neighboring water systems. Individual costs for specific water user groups are shown in the individual county plan for McLennan County (Volume I, Section 4C.24). Costs for each water user group are based upon an assumed wholesale water rate of $815/acft ($2.60/1,000 gallons), which is expected to compensate for expected infrastructure requirements.

4B.14.4.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14-13, and the option meets each criterion.

The participating entities must negotiate individual water service contracts, likely based on individual cost of service studies.

Requirements specific to pipelines needed to link existing sources to users will include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the U.S. for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Table 4B.14-13
Comparison of City of Waco Interconnections Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Reasonable
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Negligible impact
6. Wetlands	6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.14.5 Interconnection of Central Texas WSC with Salado WSC

4B.14.5.1 Description of Option and Costing

Salado WSC is projected to have a water shortage starting in 2020 (100 acft/yr) through 2060 (400 acft/yr). A potential solution to meet the supply shortage is a purchase of wholesale treated water from Central Texas WSC. Specific information from Central Texas WSC regarding future interconnection plans is pending. The Central Texas WSC wholesale treated water cost for new customers is $2.10 per 1,000 gallons. For costing purposes, facility and operational costs are assumed to be included in this rate. The annual cost per decade is shown in Table 4B.14-14 below.

Table 4B.14-14.
Cost Estimate Summary
Interconnection of Central Texas WSC with Salado WSC

Year:	*2000*	*2010*	*2020*	*2030*	*2040*	*2050*	*2060*
Demand (acft/yr):	0	0	100	250	300	350	400
Cost:	$0	$0	$68,424	$171,062	$205,273	$239,486	$273,697

4B.14.5.2 Available Yield

This water management strategy does not increase supply in the Brazos G Area, but increases utilization of existing reservoir (Lake Stillhouse Hollow) supplies.

4B.14.5.3 Environmental

Environmental impacts could include:

- Possible low to moderate impacts on in-stream flows due to increased diversions.
- Probable low impacts on endangered species depending on specific locations of facilities used to interconnect the systems.
- Probable low impacts on riparian corridors depending on specific locations of pipelines.

A summary of environmental issues is presented in Table 4B.14-15.

4B.14.5.4 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.14-16, and the option meets each criterion.

Table 4B.14-15
Environmental Issues
Interconnection of Central Texas WSC with Salado WSC

Water Management Option	***Interconnection of Central Texas WSC with Salado WSC***
Implementation Measures	Construction of pump stations, storage tanks and pipelines
Environmental Water Needs / Instream Flows	Possible impacts on in-stream flows but within existing flow regimes allowed by current permits
Bays and Estuaries	Negligible impact
Fish and Wildlife Habitat	Possible moderate impacts on riparian corridors and upland habitats depending on specific locations of facilities
Cultural Resources	Possible low impact
Threatened and Endangered Species	Possible low impacts on endangered species, depending on specific locations of facilities
Comments	Assumes institutional transfer agreements and construction of associated facilities

Table 4B.14-16
Interconnection of Central Texas WSC with Salado WSC
to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply 1. Quantity 2. Reliability 3. Cost	 1. Sufficient to meet needs 2. High reliability 3. Reasonable
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries 5. Threatened and Endangered Species 6. Wetlands	 1. Low impact 2. Low impact 3. Low impact 4. Negligible impact 5. Negligible impact 6. Negligible impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

The Central Texas WSC and Salado WSC must negotiate a water service contract, likely based on an individual cost of service study.

Requirements specific to pipelines needed to link existing sources to users will include:

- U.S. Army Corps of Engineers Section 404 permit(s) for pipeline stream crossings; discharges of fill into wetlands and waters of the U.S. for construction; and other activities;
- NPDES Storm Water Pollution Prevention Plan;
- TPWD Sand, Shell, Gravel and Marl permit for construction in state-owned streambeds.

Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

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4B.15 Carrizo-Wilcox Aquifer Development

The development of the Carrizo-Wilcox Aquifer option involves pumping the aquifer and transporting the water to municipal and industrial users in Williamson and Brazos Counties (Bryan, College Station, and Texas A&M University areas). The required facilities for each of the two areas are a well field, pipelines, pump stations, and storage facilities. Water treatment to remove possible iron and manganese constituents would be required for the Williamson County option, while only disinfection and cooling would be required for Brazos County.

The Carrizo-Wilcox Aquifer System in Central Texas is capable of producing large quantities of fresh water from the Simsboro and Carrizo Formations.[1,2,3] On a sustained yield basis for the planning period, the estimates in the counties near Williamson County are 45,000 acft/yr. In Brazos County, the estimate is 52,000 acft/yr.

The aquifer is primarily used for domestic, livestock, public supplies, and some industrial purposes (mining and power plants). The largest municipal pumpage to date is from the Simsboro for public supply in the Bryan-College Station area, which began over 50 years ago. Other significant pumping is in Milam and Robertson Counties for mining and steam electric purposes and is also from the Simsboro. Water level changes experienced to date are mainly limited to artesian pressure declines in the vicinity of pumping centers. Little or no change in water tables in outcrop (recharge) areas has been observed.

Regulations on the development of groundwater and the export of groundwater have been established for Lee County by the Lost Pines, Milam and Burleson Counties by the Post Oak Savannah, and Brazos and Robertson Counties by the Brazos Valley Groundwater Conservation Districts. Well spacing and export requirements are to be addressed in the permitting process.

4B.15.1 Williamson County

4B.15.1.1 Description of Option

This option is an alternative to the Lake Granger Conjunctive Use Project, which is part of the BRA Systems Operations option and is planned to meet Williamson County's shortfall

[1] Thorkildsen, D. and Price, R. D., "Groundwater Resources of the Carrizo-Wilcox Aquifer in the Central Texas Region," Texas Water Development Board (TWDB) Report 332, 1991.
[2] Muller, D.A., and Price, R.D., "Groundwater Availability in Texas – Estimates and Projections through 2030," TWDB Report 238, 1979.
[3] Espey, Huston & Associates, Inc., "Brazos Valley Long-Range Regional Water Supply Planning Study," consulting report to City of Bryan and City of College Station, 1990.

from 2050 to 2060. This maximum shortfall is estimated to be 35,000 acft/yr. Groundwater from the Carrizo-Wilcox Aquifer from a well field crossing the Lee-Burleson County line would be supplied to Williamson County, including the cities of Georgetown, Hutto, Round Rock, and Weir, the utility districts of Chisholm Trail, Jerrell-Schwertner, and Jonah, and county-other and manufacturing (Figure 4B.15-1).

The option is presented at uniform delivery of 31.2 MGD and at a peak delivery of 62.4 MGD. For purposes of this assessment, peak day demand is 2.0 times the average day demand.

4B.15.1.2 Available Yield

The proposed well field is southeast of the Mexia-Talco Fault Zone and about midway between the outcrops of the Carrizo Aquifer and the downdip extent of freshwater. At this location, large capacity wells can be developed in both the Simsboro and Carrizo Aquifers. Simsboro wells would be about 2,500 feet deep and are expected to yield 2,100 gpm. Carrizo wells would be about 900 feet deep and are expected to yield about 1,000 gpm. For a uniform delivery rate at 35,000 acft/yr (31.2 MGD), eight (8) well yards producing at 4.4 MGD are required for the design capacity and a 10 percent contingency. For a well field to meet the peak day demand of 62.4 MGD, sixteen (16) well yards would be required. The well yards would be spaced at about 3,000-foot intervals. About a third of the well field would be in Lee County and the remaining two-thirds would be in Burleson County, as shown in Figure 4B.15-1.

4B.15.1.3 Environmental Issues

New and/or expanded well fields in the Carrizo-Wilcox Aquifer in Lee and Burleson Counties, including storage facilities, pump stations and a 60-mile pipeline to Williamson County, and about 25 miles of delivery treated water pipelines could possibly involve the following impacts:

- Impact on environmental water needs and instream flows over the Carrizo-Wilcox would possibly be low, if quantity withdrawn is relatively small. Potential increase in return flows to Brazos River. Base flows would decrease by less than 50 cfs across the outcrop in the Brazos River Basin from pumping of the full availability estimate.
- Possible low beneficial impact on bays and estuaries from increased return flows to Brazos River.
- Probable low impact on fish and wildlife habitat in general, including one amphibian and two plant species, all federally listed.
- Possible low impact on cultural resources.

- Unknown impacts of proposed well field on Houston toad habitat.
- Water level declines would be less than those estimated for pumping of full availability, as shown in Appendix B (Volume I).

4B.15.1.4 Engineering and Costing

The planned site of the well field is along a northeast-southwest line between US 77 and TX 36 and straddling the Lee-Burleson County line. A raw water pipeline would deliver the Carrizo and Simsboro water to a water treatment plant in Williamson County. From there, treated water pipelines would deliver water to individual water utilities.

The major facilities required are:

- Water Collection and Conveyance System
  - Wells
  - Pipelines
  - Pump Station
  - Storage
- Transmission System
  - Storage
  - Pipeline
  - Pump Station
- Water Treatment
  - Removal of iron and manganese concentrations may be required.

Two facility options are designed, one for a uniform delivery rate of 31.2 MGD and the other for a peak delivery rate of 62.4 MGD.

Cost estimates were computed for capital costs, annual debt service, operation and maintenance, power, land, and environmental mitigation for uniform and peak day delivery. These costs are summarized in Table 4B.15-1. Treatment costs are for removal of iron, manganese, and possibly hydrogen sulfide by aeration and/or oxidation and filtration. The project costs, including capital, are estimated to be $141,792,000 and $238,641,000 for the uniform and peak delivery options, respectively. As shown, the annual costs, including debt service, operation and maintenance, and power, are estimated to be $18,878,000 and $27,466,000 for the uniform and peak day options, respectively. This option produces potable water at an estimated cost of $539 per acft ($1.66 per 1,000 gallons) and $785 per acft ($2.41 per 1,000 gallons), respectively.

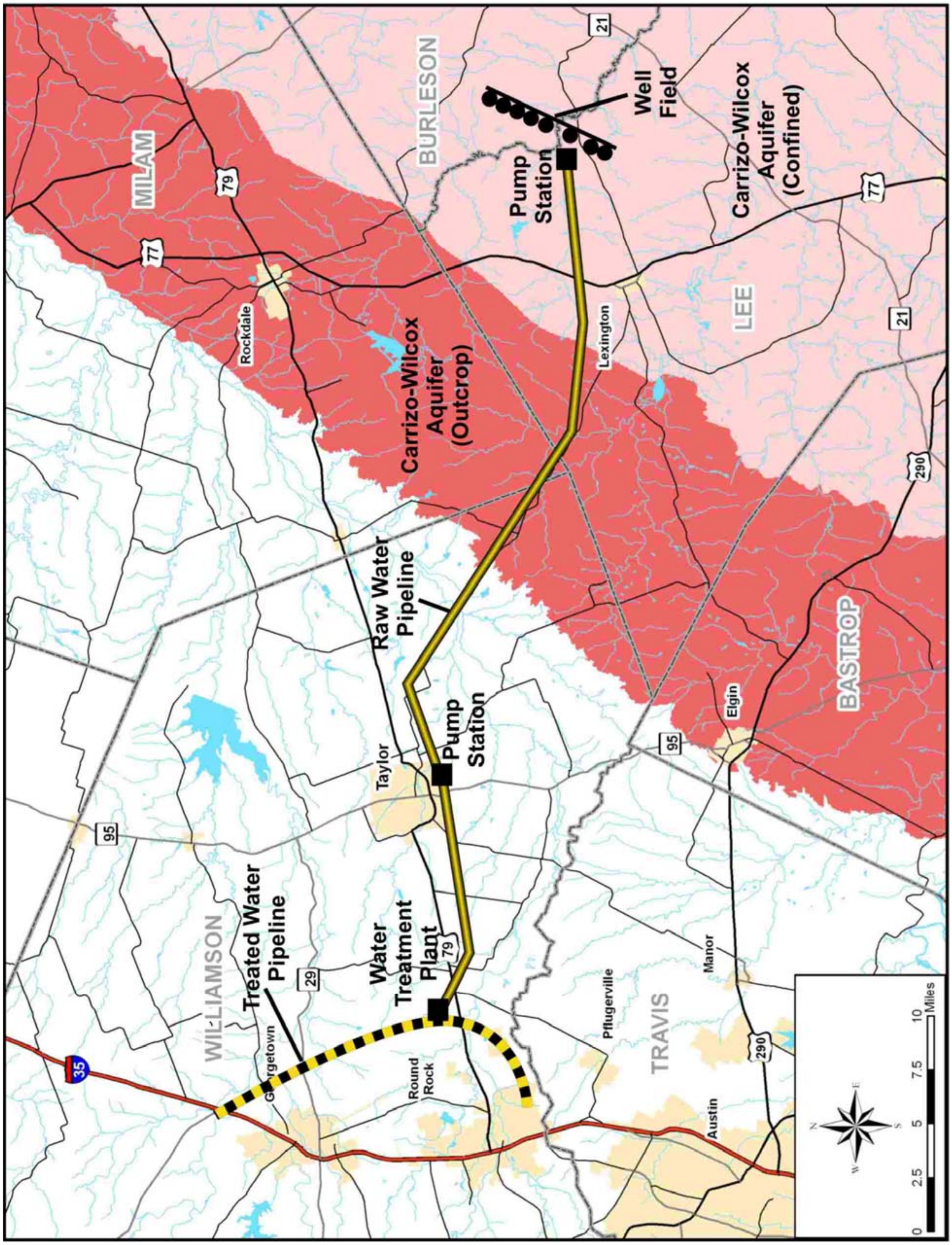

Figure 4B.15-1. Location of Carrizo-Wilcox Water Supply for Williamson County

Table 4B.15-1.
Cost Estimate Summary
Carrizo-Wilcox: Williamson County Option
Second Quarter 2002 Prices

Item	Uniform Annual Delivery Rate 31.2 MGD	Peak Delivery Rate 62.4 MGD
Capital Costs		
Transmission Pipeline	$53,696,000	$83,143,000
Transmission Pump Stations	16,710,000	26,364,000
Well Fields	19,751,000	44,113,000
Water Treatment Plant (Level 1)	5,129,000	8,874,000
Total Capital Cost	**$95,286,000**	**$162,494,000**
Engineering, Legal Costs and Contingencies	$30,665,000	$52,716,000
Environmental & Archaeology Studies and Mitigation	2,050,000	2,175,000
Land Acquisition and Surveying	3,287,000	3,578,000
Interest During Construction (2 years)	10,504,000	17,678,000
Total Project Cost	**$141,792,000**	**$238,641,000**
Annual Costs		
Debt Service (6 percent for 30 years)	$10,301,000	$17,337,000
Operation and Maintenance:		
Intake, Pipeline, Pump Station	1,114,000	1,866,000
Water Treatment Plant	1,678,000	3,156,000
Pumping Energy Costs ($0.06/kWh)	3,510,000	2,832,000
Purchase of Water (35,000 acft/yr @ $65/acft)[1]	2,275,000	2,275,000
Total Annual Cost	**$18,878,000**	**$27,466,000**
Available Project Yield (acft/yr)	**35,000**	**35,000**
Annual Cost of Water ($ per acft)	**$539**	**$785**
Annual Cost of Water ($ per 1,000 gallons)	**$1.66**	**$2.41**

[1] It is anticipated that acquisition of groundwater for export to areas outside of the aquifer will require payment to landowners for the water. Other entities have marketed groundwater for $65 per acft and that cost is used here.

4B.15.1.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.15-2, and the option meets each criterion.

Table 4B.15-2.
Comparison of Carrizo-Wilcox:
Williamson County Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High
3. Cost	3. Low to moderate
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact; possible affect on several species
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

The development of additional groundwater in the Carrizo and Simsboro Aquifers in Lee and Burleson Counties must address several issues. Major issues include:

- Competition with others for groundwater in the area.
- Purchase of groundwater rights.
- Impact on water levels in the aquifer. Anticipated pumping in combination with current supplies is less than the water availability estimates presented in Section 3.4

and Appendix B, and water level declines would be less than those projected under a full availability analysis.

The regulatory permits that are expected to be requirements specific to wells and pipelines include:

- Regulations and permits by the groundwater conservation districts (Lost Pines and Post Oak Savannah).
- U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the pipelines impacting wetlands or navigable waters of the United States.
- General Land Office easement for use of state-owned land.
- Texas Parks and Wildlife Department Sand, Gravel, and Marl permit for construction in state-owned streambeds.
- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

4B.15.2 Brazos County

4B.15.2.1 Description of Option

This Carrizo-Wilcox development option for Bryan and College Station is planned to meet their need for additional water by expanding their Simsboro Aquifer well fields. This shortfall totals about 11,200 acft/yr by 2060. Groundwater from the Simsboro Aquifer, which is the main water-bearing zone of the Wilcox Formation, would come from a well field in the extreme western part of the county (Figure 4B.15-2).

The option is presented at two delivery capacities. One is for a uniform delivery of water and the other is sized to meet peak day demands. For purposes of this assessment, peak day demand is 2.0 times the average day demand.

4B.15.2.2 Available Yield

Previous studies[4,5,6] and the ones conducted for Brazos G indicate that this quantity of water from the Simsboro part of the Carrizo-Wilcox Aquifer is available for development. In this area, Simsboro wells average 2,800 feet in depth and commonly yield 3 MGD—or 2,100 gpm.

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[4] Thorkildsen, D. and R.D. Price, Op. Cit., 1991.
[5] Muller, D.A. and R.D. Price, Op. Cit., 1979.
[6] Espey, Huston & Associates, Inc., Op. Cit., 1990.

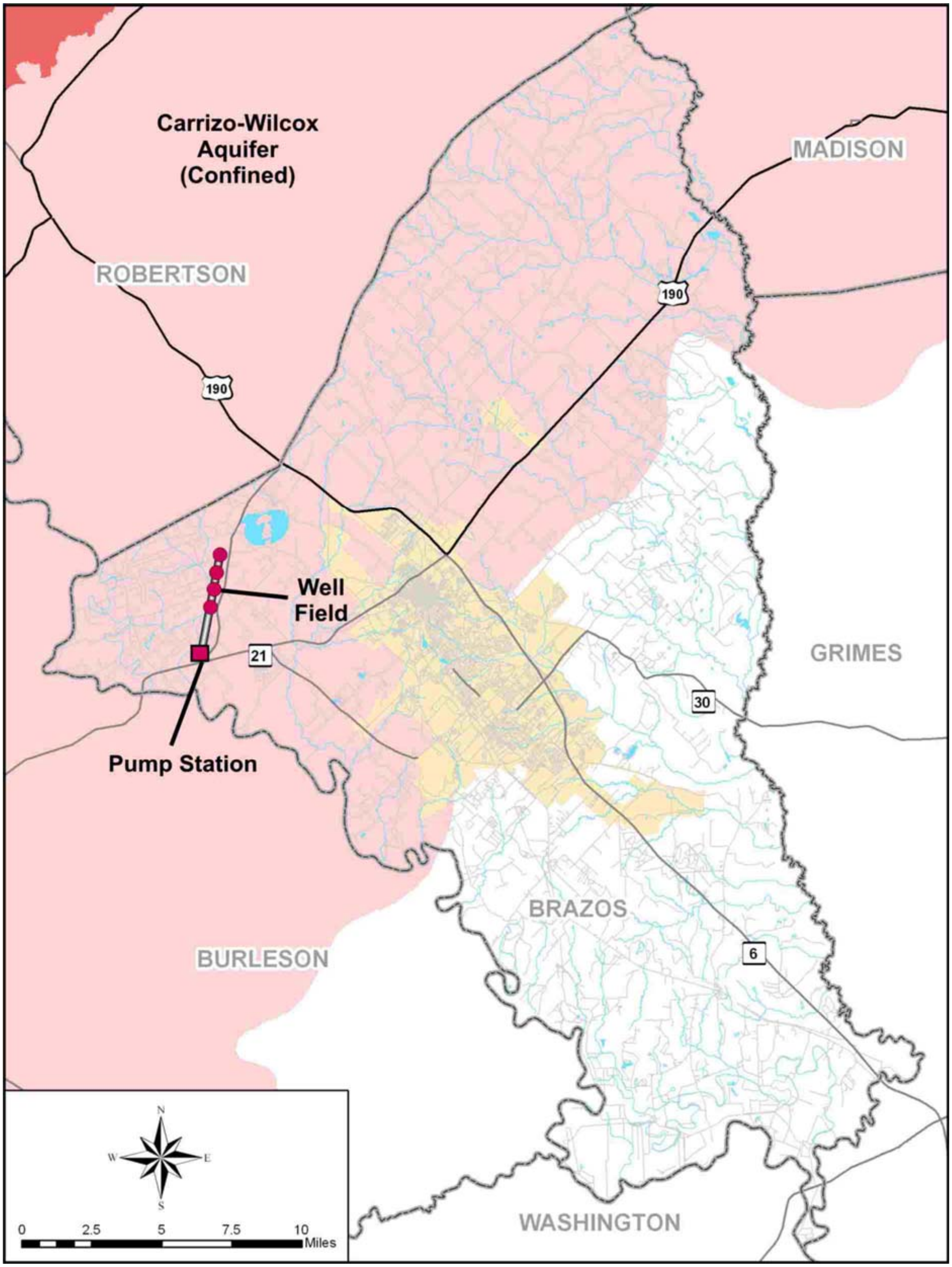

Figure 4B.15-2. Location of Carrizo-Wilcox Water Supply for Brazos County

For planning purposes, the maximum annual production of water from the Brazos County well field is 11,200 acft/yr. For the uniform water delivery option, five wells would be required when considering a contingency of one well. A well field sized to provide a peak day delivery rate would require a peak production rate of 20.0 MGD. This demand would require eight wells. The estimated well spacing would be similar to existing wells in the area (i.e., 2,000 to 2,500 feet). The location of the proposed well field is in Brazos County and is shown in Figure 4B.15-2.

4B.15.2.3 Environmental Issues

New and/or expanded well fields in the Carrizo-Wilcox Aquifer in Brazos Counties, include wells, storage facilities, pump stations and a 3-mile pipeline to existing or planned pipelines. This development is expected to have the following environmental impacts:

- Impact on environmental water needs and instream flows over the Carrizo-Wilcox would possibly be low. Potential increase in return flows to Brazos River downstream of Bryan-College Station. Base flows would decrease by less than 50 cfs across the outcrop in the Brazos Basin from pumping at the full estimated availability.
- Possible low beneficial impact on bays and estuaries from increased return flows to Brazos River.
- Probable low impact on fish and wildlife habitat in general, including one amphibian and two plant species, all federally listed.
- Possible low impact on cultural resources.
- Water level declines would be less than those estimated for pumping of full availability, as shown in Appendix B (Volume I).

4B.15.2.4 Engineering and Costing

For the Brazos County option, groundwater would be developed from a well field along a north-south line about 5 miles west of Bryan. Water treatment would require cooling and disinfection. The location is subject to adjustment, due to future expansions of adjoining well fields.

The major facilities required for these options are:

- Wells;
- Pipelines;
- Storage;
- Booster Station; and
- Water Treatment Plant.

These facilities are designed for a uniform delivery rate of 10.0 MGD and a peak delivery rate of 20.0 MGD. The approximate location of these facilities is shown in Figure 4B.15-2.

Estimates were prepared for capital costs, annual debt service, operation and maintenance, water purchases, power, land, and environmental mitigation. These costs are summarized in Table 4B.15-3. The project costs, including capital, are estimated to be $20,951,000 and $33,380,000 for the uniform and peak delivery options, respectively. The annual costs, including debt service, operation and maintenance, and power, are estimated to be $2,881,000 and $4,335,000 for base and peak options, respectively. This water management option produces water at estimated costs of $257 and $387 per acft for base and peak options, respectively.

4B.15.2.5 Implementation Issues

The development of additional groundwater in the Carrizo and Simsboro Aquifers in Brazos County must address several issues, including:

- Impact on water levels in the aquifer. Anticipated pumping in combination with current supplies is less than the water availability estimates presented in Section 3.4 and Appendix B, and water level declines would be less than those projected under a full availability analysis.
- Possibly Purchase of groundwater rights.
- Competition with others for groundwater in the area.
- Regulations and permits by Brazos Valley Groundwater Conservation District.
- Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

This water supply option has been compared to the plan development criteria, as shown in Table 4B.15.2-4, and the option meets each criterion.

Table 4B.15-3.
Cost Estimate Summary
Carrizo-Wilcox Well Field: Brazos County Option
Second Quarter 2002 Prices

Item	***Uniform Annual Delivery Rate 4.5 MGD***	***Peak Delivery Rate 20.0 MGD***
Capital Costs		
Transmission Pipeline	$1,117,000	$1,685,000
Transmission Pump Stations	1,929,000	3,282,000
Well Fields	9,091,000	14,728,000
Water Treatment Plant (Cooling)	2,505,000	3,698,000
Total Capital Cost	**$14,642,000**	**$23,393,000**
Engineering, Legal Costs and Contingencies	$5,069,000	$8,103,000
Environmental & Archaeology Studies and Mitigation	179,000	245,000
Land Acquisition and Surveying (367 acres)	255,000	355,000
Interest During Construction (1 year)	806,000	1,284,000
Total Project Cost	**$20,951,000**	**$33,380,000**
Annual Costs		
Debt Service (6 percent for 30 years)	$1,522,000	$2,425,000
Operation and Maintenance:		
Intake, Pipeline, Pump Station	145,000	237,000
Water Treatment Plant	668,000	1,127,000
Pumping Energy Costs (9,103,577kWh @ $0.06/kWh)	546,000	546,000
Total Annual Cost	**$2,881,000**	**$4,335,000**
Available Project Yield (acft/yr)	**11,200**	**11,200**
Annual Cost of Water ($ per acft)	**$257**	**$387**
Annual Cost of Water ($ per 1,000 gallons)	**$0.79**	**$1.19**

Table 4B.15-4.
Comparison of Carrizo-Wilcox:
Brazos County Option to Plan Development Criteria

Impact Category	***Comment(s)***
A. Water Supply	
1. Quantity	1. Sufficient to meet needs
2. Reliability	2. High reliability
3. Cost	3. Low to moderate
B. Environmental factors	
1. Environmental Water Needs	1. Low impact
2. Habitat	2. Low impact; possible affect on one endangered species
3. Cultural Resources	3. Low impact
4. Bays and Estuaries	4. Negligible impact
5. Threatened and Endangered Species	5. Low impact
6. Wetlands	6. Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• None
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

4B.16 Voluntary Redistribution

4B.16.1 Description of Option

For the purposes of this discussion, “voluntary redistribution” is defined as an entity in possession of water rights or water purchase contracts freely selling, leasing, giving, or otherwise providing water to another entity. Typically, the entity providing the water has determined that it does not need the water for the duration of the transfer. The water could be transferred for a set period of years or permanently.

Voluntary redistribution is nothing new to Texas or to the Brazos G Area, and is essentially a water purchase. Typical examples of voluntary redistribution occurring in the region are the sale of water by entities such as the BRA, City of Waco, LCRA, and the City of Abilene through purchase contracts. The most common water sales occur when cities such as Waco or Abilene sell water to their surrounding communities.

Voluntary redistribution has many benefits over other supply options because it avoids implementation issues associated with new reservoir projects such as environmental, local impacts, and large capital costs. Most importantly, redistribution of water makes use of existing resources and provides a more immediate source of water.

4B.16.2 Available Supply and Shortages

The first step towards voluntary distribution is determining where water supplies are available and are projected to be available for some future period. Water available for the voluntary redistribution option was identified for municipal and industrial uses only.

As potential sources of water for voluntary redistribution are identified, it is important to remember that the redistribution of water is voluntary. No entity is required to participate. For this reason, entities with available water will not be specifically identified in this analysis, and the quantity of unused water is aggregated on a county-wide basis.

The amount of water available for municipal use was determined from the projected demands and supplies. Each municipal water user group was examined for water that is projected to be in excess of projected demands.

4B.16.2.1 Available Municipal Supplies

The municipal water supplies available as a potential source for voluntary redistribution are approximately 167,000 acft/yr and 119,000 acft/yr, in 2030 and 2060, respectively. The total municipal need for the region in 2030 and 2060 is 76,220 acft/yr and 185,099 acft/yr, respectively. It is important to note that municipal voluntary redistribution is typically only feasible when an entity with a projected shortage is located in close proximity to an entity with a projected surplus. The projected municipal shortages and the amount of water available for transfer within each county are shown for 2030 and 2060 in Table 4B.16-1.

Table 4B.16-1.
Municipal Needs/Available Supplies for Voluntary Redistribution

County	Shortages		Available Supplies	
	2030 (acft/yr)	2060 (acft/yr)	2030 (acft/yr)	2060 (acft/yr)
Bell	732	3,134	30,686	19,205
Bosque	1,295	1,387	589	571
Brazos	6,077	13,581	5,013	3,876
Burleson	21	34	1,893	1,639
Callahan	1	0	960	1,068
Comanche	0	0	393	481
Coryell	2,172	4,342	6,017	4,135
Eastland	215	99	1,775	2,012
Erath	0	0	4,052	2,268
Falls	484	604	3,484	3,171
Fisher	0	0	224	275
Grimes	665	1,017	1,486	1,391
Hamilton	0	0	794	848
Haskell	383	472	80	109
Hill	506	936	2,412	520
Hood	1,309	3,644	7,262	3,792
Johnson	13,297	34,737	4,293	1,961
Jones	589	507	4,968	4,988
Kent	16	3	167	205
Knox	364	488	0	0
Lampasas	703	845	1,994	1,692
Lee	699	1,279	562	508
Limestone	0	87	2,035	1,374
McLennan	9,726	11,456	46,997	41,091
Milam	74	182	3,214	3,286
Nolan	2,095	1,714	7	20
Palo Pinto	7	181	3,587	3,244
Robertson	21	25	3,050	3,065
Shackelford	0	0	1,347	1,651
Somervell	231	260	38	37
Stephens	216	193	2,203	2,338
Stonewall	0	0	46	89
Taylor	13,748	12,649	1,173	1,237
Throckmorton	0	0	175	238
Washington	0	0	466	255
Williamson	20,574	91,243	22,039	4,581
Young	0	0	1,954	1,951

4B.16.2.2 Available Industrial Supply

Industrial uses include manufacturing, steam-electric, and mining. The industrial water supplies available as a potential source for voluntary redistribution are approximately 89,000 acft/yr and 71,000 acft/yr, in 2030 and 2060, respectively. The total industrial need for the region in 2030 and 2060 is 49,238 acft/yr and 111,013 acft/yr, respectively. The projected industrial shortages and the amount of water available for transfer are shown by county for 2030 and 2060 in Table 4B.16-2.

4B.16.3 Environmental Issues

No substantial environmental impacts are anticipated, as available water resources identified for this option are from existing supplies. A summary of the few environmental issues that might arise for this alternative are presented in Table 4B.16-3.

4B.16.4 Engineering and Costing

A cost estimate to this option cannot be fully assessed. Many unknowns exist including the price of the water, potential costs of new pipelines or water treatment facilities, and the proximity of the water needs to the water supply.

Potential costs of purchasing and using water available from voluntary redistribution are listed below:

- Cost of raw water;
- Treatment costs;
- Conveyance costs;
- Engineering costs of designing and constructing treatment and conveyance systems; and
- Additional costs required by water supplier. Many times when the water supplier is a city, water will be sold for 1.5 times the price of water sold within the city limits.

Table 4B.16-4 lists estimates of costs of voluntary redistribution. The raw water purchase price is estimated to be between $45 and $115 per acft. The price of raw water from the BRA (System Rate) and LCRA is $45.75/acft and $115/acft, respectively. The total potential cost of water from voluntary redistribution is $371 to $1,215 per acft, or $1.14 to $3.73 per 1,000 gallons.

Table 4B.16-2.
Industrial Needs/Available Supplies for Voluntary Redistribution

County	Shortages		Available Supplies	
	2030 (acft/yr)	2060 (acft/yr)	2030 (acft/yr)	2060 (acft/yr)
Bell	1,163	1,446	4,469	1,663
Bosque	4,418	9,523	0	0
Brazos	96	232	276	0
Burleson	0	98	2	0
Callahan	0	0	0	0
Comanche	0	0	7	0
Coryell	0	0	3	0
Eastland	0	0	1,085	1,070
Erath	16	40	0	0
Falls	0	0	1,465	1,427
Fisher	155	236	0	0
Grimes	807	9,904	16	16
Hamilton	0	0	3	0
Haskell	52	47	1,807	1,550
Hill	21	53	0	0
Hood	33	39	33,980	27,794
Johnson	4,031	5,154	0	0
Jones	0	0	1,330	565
Kent	0	0	0	0
Knox	3	3	0	0
Lampasas	159	192	0	0
Lee	0	0	3	0
Limestone	44	15,883	1,447	0
McLennan	22,717	35,524	0	0
Milam	4,700	8,200	2,071	494
Nolan	1,576	3,253	100	0
Palo Pinto	0	1,658	1,087	514
Robertson	31	8,361	1,800	9
Shackelford	0	0	50	50
Somervell	98	92	25,570	25,510
Stephens	5,884	6,662	53	50
Stonewall	0	0	0	0
Taylor	5	4	16	1
Throckmorton	0	0	0	0
Washington	70	199	0	0
Williamson	3,159	4,210	0	0
Young	0	0	12,268	10,663

Table 4B.16-3.
Environmental Issues: Voluntary Redistribution

Water Management Option	Voluntary Redistribution
Implementation Measures	Voluntary Redistribution or water purchase from an entity with available water supply to entities in need of water. Terms of the contract would be drawn up on a case by case basis.
Environmental Water Needs / Instream Flows	Possible low impacts. The primary source of water identified as available to this option is stored in existing reservoirs.
Bays and Estuaries	No substantial impact identified.
Fish and Wildlife Habitat	Potential impacts include constructing and maintaining easements for new pipelines or pump stations. Extent of impacts dependent on location and size of projects.
Cultural Resources	Possible low impact.
Threatened and Endangered Species	Potential impacts include impacts of constructing and maintaining easements for new pipelines or pump stations. Extent of impacts dependent on location and size of projects.
Comments	Assumes infrastructure is needed to distribute purchased water to the entity in need.

Table 4B.16-4.
Potential Annual Costs of Water from Voluntary Redistribution (i.e. Water Purchase)

Raw Water Purchase[1] ($/acft)	***Treatment ($/acft)***	***Conveyance ($/acft)***	***Potential Total Cost ($/acft)***
$45.75 to $115	$325 to $800	$0 to $300	$371 to $1,215 ($1.14 to $3.73/1,000 gallons)

[1] Based on raw water costs from BRA (System Rate) and LCRA of $45.75 and $115 per acft, respectively.

4B.16.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 4B.16-5, and the option meets each criterion.

An issue facing redistribution is appropriate compensation for the entity or individual that owns the water right or contract for water. If an entity has arranged through contracts to have more water than they currently need or may need in the study period, they should be compensated for the expense and upkeep of any facilities and purchase contracts already in place.

The following issues should be considered when negotiating a voluntary redistribution agreement:

- Quantity of water to be redistributed;
- Location of excess water supply in relation to buyer with need;
- Necessary water treatment and distribution facilities;
- Determination of fair market value;
- Consideration of how existing contracts will effect the sale or lease;
- Length of agreement;
- Drought contingencies;
- Protections needed by entity providing water;
- Protections needed by entity needing water;
- Enforcement of protections; and
- Other conditions specific to buyer and seller.

Table 4B.16-5.
Comparison of Voluntary Redistribution Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply	
1. Quantity	1. Significant quantities available in parts of the region
2. Reliability	2. High reliability
3. Cost	3. Low to moderate
B. Environmental factors	
1. Environmental Water Needs	1. Possible low impact
2. Habitat	2. Low impact possible where new pipelines are constructed
3. Cultural Resources	3. Possible low impact
4. Bays and Estuaries	4. No substantial impact
5. Threatened and Endangered Species	5. None or Low impact
6. Wetlands	6. None or Low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Could affect agriculture if supplies converted to M&I; beneficial effect on natural resources by avoiding need for new projects
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• Supplies considered are excess to 30-year needs; no anticipated third party effects