TRANS-TEXAS WATER PROGRAM

West Central Study Area Phase I Interim Report

Volume 2

San Antonio River Authority

San Antonio Water System

Edwards Underground Water District

Guadalupe-Blanco River Authority

Lower Colorado River Authority

Bexar Metropolitan Water District

Nueces River Authority

Texas Water Development Board

May, 1994

HDR

HDR Engineering, Inc.
in association with
Paul Price Associates, Inc.
LBG-Guyton Associates
Espey-Huston & Associates, Inc.

TRANS-TEXAS WATER PROGRAM
WEST CENTRAL STUDY AREA

PHASE I
INTERIM REPORT

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Prepared for

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TRANS-TEXAS WATER PROGRAM
WEST CENTRAL STUDY AREA

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3.0 WATER SUPPLY ALTERNATIVES AND EVALUATIONS

A total of 37 primary water supply alternatives with over 130 sub-alternative configurations were evaluated in this Phase I planning and screening level study. Each of these alternatives was evaluated for water supply potential, environmental effects, and cost. The names of the alternatives are listed in Table 3.0 and the locations of the water supply sources for each alternative are shown on Figures ES-6 in the Executive Summary as well as individual figures within this section of the report. The Environmental Overview (Section 3.0.1) contains a more detailed summary of the environmental assessment and study requirements of each alternative and Section 3.0.2 contains a summary of cost estimating procedures.

The water supply alternatives have all been studied on a stand-alone basis and many of the alternatives, if implemented, could affect water availability of other alternatives located in the same basin. Because of the inter-relationship among projects, implementation of one project may affect either the firm yield of another project, or the annual distribution of availability. For these reasons, the yields of projects listed in Table 3.0 within the same river basin, cannot necessarily be added together in their present form. An example of this would be a reuse alternative, such as L-12, Exchange of Reclaimed Water for BMA Medina Lake Water. The implementation of L-12 would significantly reduce the yield of the other reuse alternatives, such as L-11, L-13, and L-14. Further, the yield of downstream projects (Goliad Reservoir, S-16) could be affected. The yield available from implementation of various groups or scenarios of water supply alternative projects will require more detailed analysis in Phase II of the study in order to accurately determine the interaction between various alternatives.

Classification of Alternatives

Alternatives have been classified into four basic groups each of which considers alternative methods of supplying water to the study area. This grouping includes:

Natural Recharge: For purpose of this study natural recharge is considered to be recharge to the aquifer with water originating from the Edwards Plateau catchment, recharge zone, or from springs originating from the Edwards. Natural recharge to the aquifer can be accomplished through either an injection well or through the delivery of water to a stream or reservoir located in the recharge zone.

Table 3.0
Water Supply Alternatives[1]

Alternate No.	Description
	Conservation / Local Alternatives
L-10	Demand Reduction
L-11	Exchange Reclaimed Water for Edwards Irrigation Water
L-12	Exchange Reclaimed Water for BMA Medina Lake Water
L-13A	Recycling/Reuse Plans by SAWS
L-13B	Reclaimed Water to Edwards Aquifer
L-14	Transfer of Reclaimed Water to Corpus Christi Through Choke Canyon Reservoir
L-15	Purchase or Lease of Edwards Irrigation Water for Municipal and Industrial Use
L-16	Demineralization of Edwards "Bad Water"
L-17	Natural Recharge - Type 1 Projects
L-18	Natural Recharge - Type 2 Projects
L-19	Springflow Augmentation
3.11	Nueces River Basin Water Rights
L-20	Mayor's 2050 Committee Regional Plan[2]
	San Antonio River Basin
S-10	Unappropriated Streamflow near Elmendorf
S-11	Unappropriated Streamflow near Falls City
S-12	Unappropriated Streamflow near Goliad
S-13	Medina Lake
S-14	Applewhite Reservoir
S-15	Cibolo Reservoir
S-16	Goliad Reservoir
	Guadalupe River Basin
G-10	Unappropriated Streamflow near Gonzales
G-11	Unappropriated Streamflow near Cuero
G-12	Unappropriated Streamflow at Salt Water Barrier
G-13	San Marcos River Diversion
G-14	Guadalupe River at Lake Dunlap Diversion
G-15	Canyon Lake Released to Lake Dunlap
G-16	Cuero Reservoir
G-17	Lindenau Reservoir
G-18	McFaddin Reservoir
G-19	Guadalupe River Dam 7
G-20	Gonzales Reservoir
G-21	Lockhart Reservoir
G-22	Dilworth Reservoir
G-23	Canyon Lake/Mid-Cities Regional Plan[2]
	Colorado River Basin
C-10	Colorado River at Lake Austin with Purchase of Irrigation Rights
C-13	Lake Travis with Purchase of Irrigation Rights
C-17	Colorado River at Columbus with Purchase of Irrigation Rights
C-18	Shaws Bend Reservoir
C-19	Lake Mason[2]
	Brazos and Sabine River Basins
B-10	Allens Creek Reservoir
SB-10	Toledo Bend Reservoir
SBB-10	Allens Creek Reservoir and Toledo Bend Reservoir
	Carrizo Aquifer
CZ-10	Carrizo Aquifer

[1]Refer to Figure ES-11 in Executive Summary for location of Water Supply Alternatives.
[2]Amended scope items to be published in a supplemental report. West Central PMC Action 5/24/94.

Imported
Recharge: Imported recharge is recharge to the aquifer with all or a portion of the water originating from sources other than those listed under Natural Recharge, regardless of the delivery system into the aquifer.

Treatment
and Distribution: This classification considers alternatives which would include conventional water treatment (or just disinfection in the case of Carrizo water) and delivery to a municipal water distribution system at a point near the water treatment plant. (Note: Distribution costs are based on costs as estimated in previous studies for delivery to the SAWS system. This is a simplifying assumption for the Phase I study and does not preclude other entities receiving treated water from a regional water treatment plant or from an interconnection with the SAWS system.)

Other: This classification includes all other alternatives including: demand reduction by conservation, reclaimed water reuse, transfer of water through purchase or lease, and treatment of brackish water by demineralization.

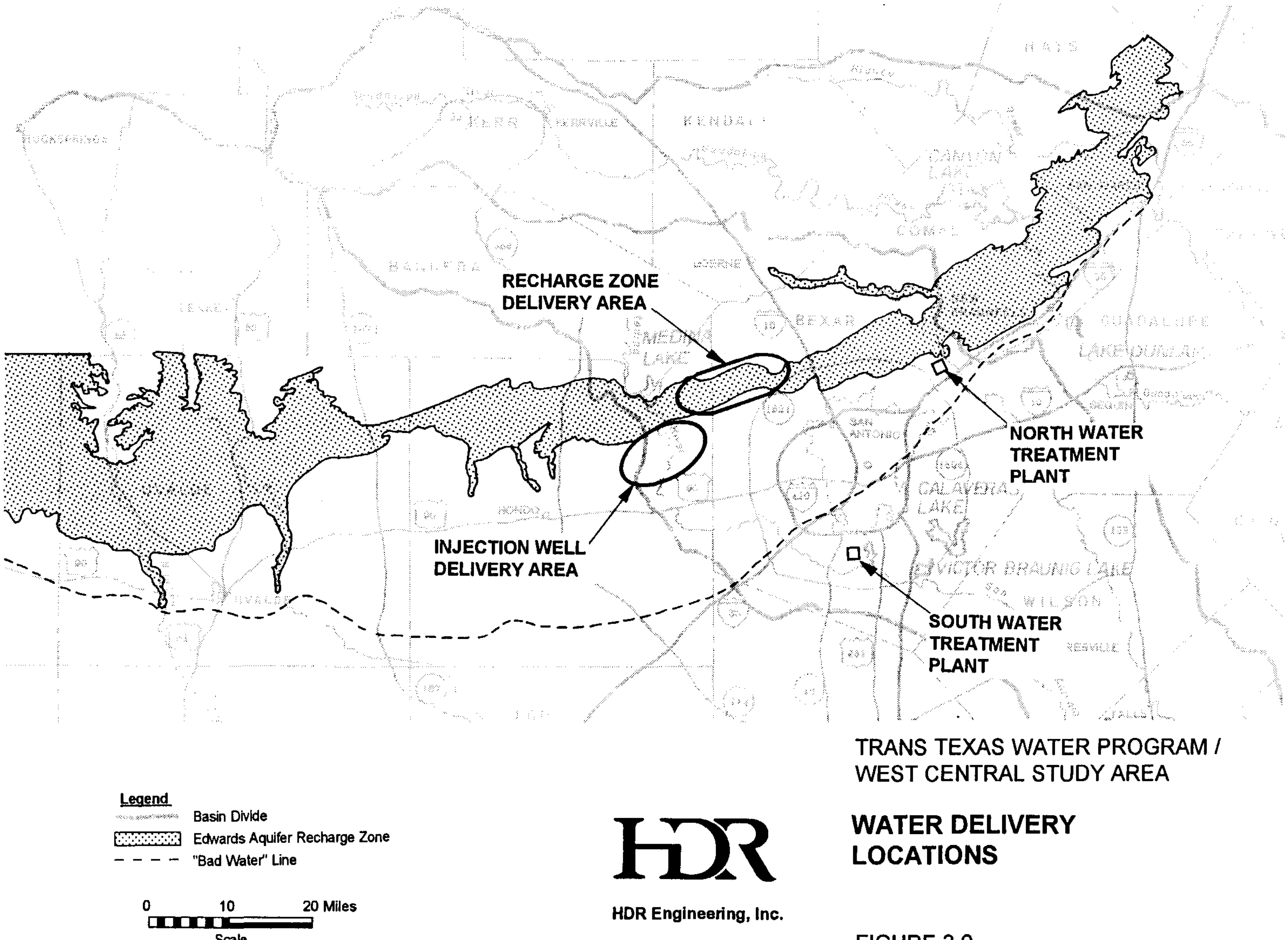
Water Delivery Locations

The water supply from many of the alternatives could be delivered into the study area in one or more of the following three ways: (1) to the recharge zone by discharge into a stream or a recharge structure; (2) to an injection well placed into the Edwards formation; or, (3) to a water treatment plant.

For delivery to the recharge zone, the Edwards formation outcrop between Leon Creek and Medina Lake (see Figure 3.0) was identified as the representative terminal point area with the existing San Geronimo Creek recharge site included as one of the terminal locations. Other potential recharge sites on Culebra, Government, Limekiln, and Deep creeks were selected as potential delivery locations. For recharge into the aquifer through injection wells, a possible recharge area is along the BMA canal in Medina County as identified in previous studies[1] (see Figure 3.0). For the treatment and distribution alternatives, two delivery points have been identified. For alternative sources located north or northeast of San Antonio, water would be delivered to a treatment facility to be located

[1]W. E. Simpson Co. and William F. Guyton Assoc. Inc., "Medina Lake Study, Recharge Evaluation," Edwards Underground Water District, no date.

in the vicinity of FM 1604 and Nacogdoches Road; and, for sources east or southeast, delivery would be to the previously proposed water treatment plant site located in the vicinity of Highway 16 and FM 1604 as shown on Figure 3.0. Generally, each alternative considered in this study is described in a figure which shows potential water sources and the various delivery options considered.



TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

HDR

HDR Engineering, Inc.

WATER DELIVERY LOCATIONS

FIGURE 3.0

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3.0.1 Environmental Overview

3.0.1.1 Introduction

This section presents the methods used to perform the environmental evaluations, a broad overview of the environmental characteristics and concerns of the geographical area encompassed by the West Central region of the Trans-Texas Water Program, and a comparative discussion of the potential environmental consequences and mitigation liabilities that would accompany implementation of the various water supply alternatives.

3.0.1.2 Methods

The Phase I analyses reported in this document are not exhaustive environmental assessments, but have been developed by reference to existing information in published reports, maps, aerial photography, unpublished documents and communications from government agencies, individuals, and private organizations. These have been assembled to provide a preliminary assessment of the potential environmental consequences of each alternative in sufficient detail to compare the alternatives relative to one another, and to provide a general overview of the level of environmental disturbance that would be associated with the production of new water supplies. In general, this report addresses individual water supply alternatives. Assessments of system operations, or multiple combinations of sources will be the subject of future phases of the Trans-Texas Water Program.

The need for environmental studies and mitigation activities as part of a proposed project generally results from the need to obtain state and federal permits that allow necessary project activities to go forward. With respect to most of the West Central Study Area water supply alternatives, the regulations that will drive environmental compliance standards include the Clean Water Act (33 USC 1344), The River and Harbors Act of 1899 (33 USC 403), the Endangered Species Act (16 USC 1531 *et seq*), and portions of the Texas Water Code involving water rights permits (TAC chapters 281, 287, 295, 297, 299). Cultural resource protection on public lands, or lands affected by projects regulated under the federal permits mentioned above, is afforded by the National Historic Preservation Act (PL 96-515), the Archaeological and Historic Preservation Act (PL 93-291) and the Antiquities Code of

Texas (Title 9, Chapter 191, Texas Natural Resources Code of 1977).

Section 404 of the Clean Water Act prohibits the discharge of dredged or fill material into the waters of the United States, including adjacent wetlands, while Section 10 of the Rivers and Harbors Act regulates structural alterations in the navigable waters of the United States. Both regulations are administered by the U.S. Army Corps of Engineers, although the U.S. Environmental Protection Agency can exercise a veto over Section 404 permits.

The Texas Water Code requires a permit to store, or divert and use, publicly owned surface water. The Code also provides for a formal process for the evaluation of water rights applications, which is open to participation by affected members of the public and other branches of government. An assessment of environmental effects, specifically with respect to habitat mitigation, water quality effects, estuarine considerations and instream uses (TAC 297.49-52), is conducted as part of the application process.

The Texas Water Development Board has adopted guidelines, developed cooperatively with Texas Parks and Wildlife Department, that outline major environmental concerns that must be addressed in evaluating the various water supply alternatives (Appendix C). For purposes of this study, it has been assumed that this outline is not meant to be exhaustive or exclusive, but that the listed concerns are those considered to have some generality and importance in the context of water resources development in southern Texas.

Of particular concern, where water resources are to be developed, are potential impacts to the amount and timing of streamflows following impoundment or diversion for water supplies, and reductions in freshwater input to the brackish wetlands and shallow, muddy bays that comprise Texas estuaries. Since the Phase I analyses reported here are intended to provide a rapid screening of alternatives using existing information, and instream flow requirements have not been established for most Texas waters, a uniform set of streamflow criteria is being applied to all new (unpermitted) projects so that they can be evaluated on a uniform basis. Site-specific studies in later phases will establish the actual requirements.

The instream flow criteria in Appendix C specify that **new reservoirs** (those not operating under an existing permit) will pass through streamflows up to the average monthly discharges (flow) during April-June and August-October, and up to the median monthly discharges during remaining months as long as the reservoir contains more than 60% of its conservation capacity. When reservoir contents are less than 60% of capacity, streamflows will be passed through up to the median daily streamflow observed during the local drought of record. For purposes of this Phase 1 Study, the drought of record flows are based on the period from January 1, 1954 through December 31, 1956. Run-of-the-river **diversions,** which do not involve reservoir construction will be stopped when streamflows fall below 60 percent of the monthly median flow during March through September, or 40 percent of the monthly median flow during the remaining months. Under the existing criteria, there would be no drought relief from those requirements.

Land uses, habitat types and values, and wetland occurrences within the study area have been identified and evaluated using available literature and a variety of other sources, including the Texas Natural Resources Information System's aerial photography and map data base; Texas Highway Department aerial photography; U.S. Geological Survey (USGS) EROS Data Center aerial photography; Texas Parks and Wildlife Department (TPWD), Resource Protection Division's data and mapping files for endangered, protected and sensitive resources; the U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) maps; information available from the Edwards Aquifer Research and Data Center; the Nature Conservancy; USGS library resources; the Texas Natural Resource Conservation Commission (TNRCC) publications and library; consultant reports; and the general biological literature, particularly descriptions of the habitat requirements of species listed as Endangered or Threatened by either the U.S. Department of the Interior, or the State of Texas. References to specific data sources are given throughout this document wherever they are used. This data base, including archaeological sites, significant environmental features, state natural areas, protected species, and potential wetland areas, are mapped on USGS 7.5 minute quadrangles maintained at Paul Price Associates, Inc. in Austin, Texas. In order to protect species and archaeological sites, specific location information is not included in this document.

The general procedure used to evaluate each alternative was as follows:

1) Map each alternative selected for consideration on 7.5 minute topographic maps;

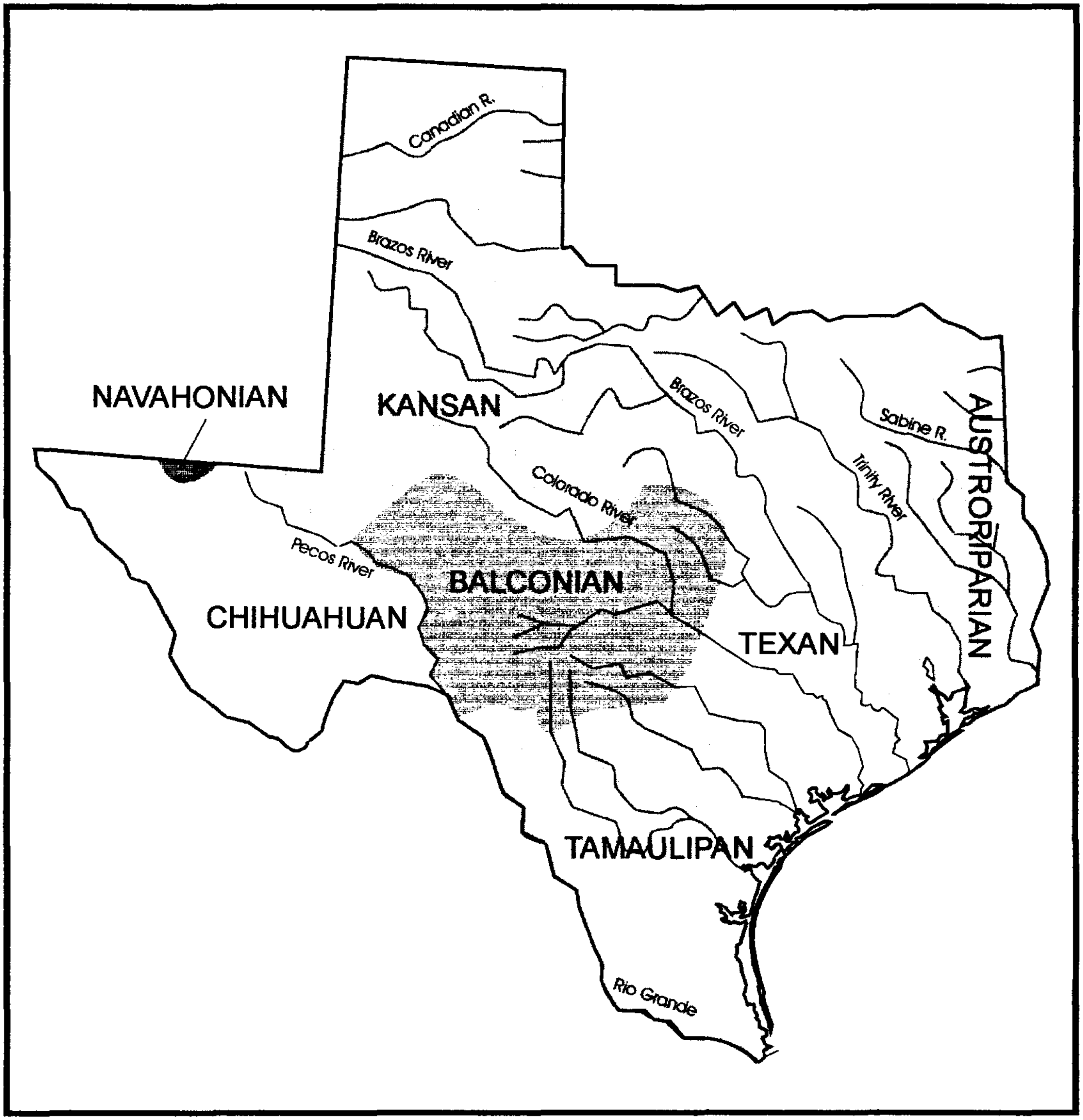
2) Obtain descriptions of construction methods and operational characteristics of each alternative from HDR Engineering;

3) Identify the general environmental effects of project components, for example:
   - Clearing or construction activities that may disturb soils and vegetation;
   - Stream crossing methods and other potential wetland disturbances;
   - Potential changes in historical streamflows, circulation patterns, or water quality;
   - Long term activities (e.g., continuing ROW vegetation maintenance, permanent structures, inundation, land use changes); and
   - Associated waste production or discharges.

4) For each alternative and an appropriate buffer zone, compile and map available information on:
   - Protected species (include federal candidate species);
   - Rare or sensitive communities or environmental features;
   - Wetlands;
   - Cultural resources (archaeological and historical);
   - Public properties;
   - Vegetation, terrestrial habitats, and important species;
   - Land use;
   - Aquatic habitats and important species;
   - Existing environmental problems; and
   - Regulatory constraints.

5) Compare the location of specific project activities, from (1) and (2), and the general modes of environmental interaction identified in (3) with the regional environmental context, and the known distribution of sensitive resources (4).

In practice, the level of detail in available environmental information, and the degree to which project activities could be accurately defined, varied to some extent among alternatives. While an attempt was made to apply an equal level of effort in evaluating each alternative, those that were obviously not viable in terms of producing significant amounts of new, firm water were examined somewhat less closely. On the other hand, some alternatives had relatively recent studies available that provided significantly more detailed information about the site, and the consequences of project implementation, than was available for the majority of other alternatives. However, in this analysis, the major environmental characteristics, potential impacts, and probable mitigation liabilities of each alternative are presented in an objective framework, so that they can be ranked in terms of



Map Source: After W. Frank Blair, 1950.

200 MILES
300 KILOMETERS
N

Figure 3.0-3

Biotic Provinces of Texas
West Central Study Area-Trans Texas
Phase I Report

Paul Price Associates, Inc.

ECOLOGY, WATER QUALITY, CULTURAL RESOURCES, PLANNING

The porous to cavernous formations making up the Edwards and associated limestones constitute the Edwards Aquifer, the ground water source that presently supplies the City of San Antonio, and numerous other users, and which is critical to maintenance of spring habitats containing several endemic, endangered species (Appendix B, Table 50). The aquifer has three parts: the drainage, or catchment area, the recharge zone, and the reservoir zone. Input to the aquifer comes from rainfall and streamflow occuring on the porous limestones and thin, rocky soils capping the Edwards Plateau catchment area. Percolation through the Edwards limestone is stopped by relatively impermeable layers in the older Glen Rose formation. Where rivers flowing across the plateau have carved deep canyons and exposed the base of the Edwards Limestone, spring fed streams arise and flow south and eastward over the impermeable older formations to the recharge zone.

The Edwards recharge zone has a surface area of about 1,500 square miles, with about a third of that in Uvalde County, and the remainder in Kinney, Medina, Bexar, Hays, and Comal counties. Significant recharge occurs along the Balcones fault zone through porous and faulted limestone in stream beds, sinkholes, and fractures.[7] A significant portion of the recharge volume enters the aquifer in stream channels[8].

The aquifer is confined below by relatively impermeable zones in the Glen Rose Formation, and at the upper boundary, in the reservoir zone (also called the artesian area), by a confining layer of impermeable Del Rio Clay. The recharge and reservoir zones of the main portion of the Edwards Aquifer together form a crescent-shaped area extending from Brackettville in Kinney County in the west, to the eastern tip near Kyle in Hays County. To the north, the Edwards Aquifer consists of hydrologically isolated units, like the one that supplies water to Barton Springs in Austin. The width varies from about five to about 30 miles. Water in the reservoir zone exhibits progressively increasing levels of dissolved minerals and lower dissolved oxygen concentrations toward the south and east as the aquifer plunges deeper into the earth and circulation slows. This indistinct boundary is termed the "bad water" line.

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[7]Caran, S. Christopher. 1982. Lineament analysis and inference of geologic structure.

[8]United States Geological Survey. 1989. Compilation of Hydrologic Data for the Edwards Aquifer, San Antonio Area, Texas, 1988. With 1934-1988 Summary, Bulletin 48, November 1989.

The Edwards Aquifer transfers significant quantities of water between river basins, specifically from the Nueces River basin in the west to the Guadalupe-San Antonio basin in the east (Figure 3.0-1). Surface water captured in the western catchment area contributes to flows in the Guadalupe River and its tributaries through spring flows. About 64 percent of the Edwards Aquifer recharge is estimated to occur in the river basins west of San Antonio. Most of the spring flow from the Edwards Aquifer emerges in the Guadalupe River basin, much of it being discharged from the Comal and San Marcos Springs[9]. Historically, the San Marcos Springs have been crucial to Guadalupe River flows because, unlike Comal Springs which are located at a higher aquifer elevation, the San Marcos Springs have historically never ceased flowing. The San Marcos springs have the greatest flow dependability and environmental stability of any spring system in the southwestern United States. Constancy of its spring flow is apparently key to the unique ecosystem found in the uppermost San Marcos River[10].

The subterranean aquatic habitats associated with the Edwards Aquifer support a diverse ecosystem. Vertebrates and macroinvertebrates have been found at depths ranging from 190 to 2,000 ft in the artesian parts of the aquifer. The Edwards Aquifer is the only underground aquatic habitat in Texas in which vertebrate species live[11]. Several Edwards springs support populations of *Eurycea neotenes,* the Texas Salamander, a rare species that is restricted to, and dependent on, spring habitats. This type of adaptation is not uncommon in constant temperature spring habitats, and may go even farther, to endemism, wherein a species may be entirely restricted to a particular spring (Appendix B, Table 50).

The Edwards Plateau vegetational area (Figure 3.0-2) comprises approximately 24 million acres, and is somewhat more extensive, particularly to the west, than Omernik's Central Texas Plateau Ecoregion (Figure 3.0-1). The most important floristic element on

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[9]Harden, R. W. 1988. The Edwards Connection, pp 13-32: in Guadalupe-Blanco River Authority. 1988. The Edwards Aquifer, Underground River of Texas. Guadalupe-Blanco River Authority, Seguin, Texas.

[10]United States Fish & Wildlife Service. 1984. San Marcos Recovery Plan for San Marcos River Endangered and Threatened Species.

[11]Edwards, Robert J., Glen Longley, Randy Moss, John Ward, Ray Mathews, and Bruce Stewart. 1989. A classification of Texas aquatic communities with special consideration toward the conservation of endangered and threatened taxa. Vol. 41, No. 3. The Texas Journal of Science, University of Texas at Austin, Austin, Texas.

the Edwards Plateau is the Grassland Province[12]. The Eastern Deciduous Forest, Cordilleran Forest, and Sonoran Provinces also supply a small number of taxa to the flora of the area. Approximately 775 genera, in 133 plant families comprising 2,544 taxa, occur in the Edwards Plateau Vegetational Area[13]. Of these, 77 species are endemic to this area.

Edwards Plateau vegetation consists of a tall or mid-grass understory and a brushy overstory complex of live oak (*Quercus virginiana*) and other oaks (*Q. fusiformis, Q. buckleyi, Q sinuata* var. *breviloba*), ashe junipers (*Juniperus ashei*), cedar elm (*Ulmus crassifolia*), mesquite (*Prosopis glandulosa*), various species of acacia (*Acacia* sp.), and sumacs, including the prairie flame-leaf (*Rhus copallina* var. *lanceolata*). Other common small trees and bushes are the Carolina buckthorn (*Rhamnus caroliniana*), Mexican buckeye (*Ungnadia speciosa*), agarita (*Mahonia trifoliolata*), Texas persimmon (*Diospyros texana*) , bluewood condalia (*Condalia hookeri*), and Texas buckeye (*Aesculus arguta*). The most important climax grasses include switchgrass (*Panicum virgatum*), several species of bluestem (*Schizachyrium* and *Andropogon* spp.), gramas (*Bouteloua* spp.), Indian grass (*Sorghastrum nutans*), Candian wild rye (*Elymus canadensis*), buffalo grass (*Buchloe dactyloides*) and curly mesquite (*Hilaria belangeri*)[14].

Juniper and mesquite brush are generally considered invaders into a presumed climax of largely grassland or savannah, except on the steeper slopes which have continually supported a dense cedar - oak thicket. Bald cypress (*Taxodium distichum)* occurs along perennial streams and rivers, while pecan (*Carya illinoiensis*), Arizona and little walnut (*Juglans major, J. microcarpa*), sugar hackberry (*Celtis laevigata*), black and sandbar willow (*Salix nigra, S. interior*), and eastern cottonwood (*Populus deltoides*) are more widely distributed in riparian areas of both perennial and intermittent streams.

The corresponding Balconian Biotic Province has a vertebrate fauna consisting of a mixture of species from the Austroriparian, Tamaulipan, Chihuahuan, and Kansan

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[12]Gleason, Henry A. and Arthur Crouquist. 1964.

[13]Stanford, 1976

[14]Correll, D. S., and M. C. Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

Table 3.0-1

	3.8 Type 1 Natural Recharge - Montel (L17)	3.8 Type 1 Natural Recharge - Upper Dry Frio (L17)	3.8 Type 1 Natural Recharge - Concan (L17)	3.8 Type 1 Natural Recharge - Upper Sabinal (L17)	3.8 Type 1 Natural Recharge - Upper Hondo (L17)	3.8 Type 1 Natural Recharge - Upper Verde (L17)	3.8 Type 1 Natural Recharge - Cloptin Crossing (L17)
Yield (acft/yr)	[4]	[4]	[4]	[4]	[4]	[4]	[4]
Conservation Pool (ac)[5]	6,190	1,800	3,840	3,110	2,000	880	6,007
100-year Flood Pool (ac)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Habitat Impacted (ac)							
Developed	235	0	0	0	0	0	228
Grasslands	310	1,086	1,200	871	400	132	301
Crops	0	264	336	1,306	0	0	0
Shrublands	0	0	0	0	0	0	0
Brushlands	1,238	0	1,536	0	0	0	1,201
Park	4,333	0	0	0	0	0	4,205
Woodlands	0	450	699	100	1,332	748	0
Wetlands	74	112	69	833	268	?	72
Riverine Habitat	0	0	0	0	0	0	0
Total Area Affected (ac)	6,190	1,800	3,840	3,110	2,000	880	6,007
Pipeline Right-of-Way	0	0	0	0	0	0	0
Lotic to Lentic Habitat	74	112	69	833	268	?	72
Inundated Area[4]	6,190	1,800	3,840	3,110	2,000	880	6,007
Longterm Impacts	6,190	1,800	3,840	3,110	2,000	880	6,007
Protected Species[2]	no	no	no	no	no	no	yes
Protected Species Habitat[2]	yes	yes	yes	yes	yes	yes	yes
Cultural Resources[2]	no	no	no	no	no	no	yes
Special Resources[2]	yes	yes	yes	no	no	no	yes

[1]Refer to Table 3.0-2 for pipeline ROW impacts for treated water delivery alternatives.
[2]A more detailed explanation appears in the report section text.
[4]Yield (recharge) varies among alternative water sources; combined recharge: (a) maximum size is 71,000 acft/yr ; (b) optimum size is 35,600 acft/yr
[5]A recharge reservoir has a recharge pool, rather than a conservation pool which generally implies a relatively consistent water surface elevation

Table 3.0-1

	3.9 Type 2 Natural Recharge - Indian Creek (L-18)	3.9 Type 2 Natural Recharge - Lower Dry Frio (L-18)	3.9 Type 2 Natural Recharge - Lower Sabinal (L-18)	3.9 Type 2 Natural Recharge - Lower Hondo (L-18)	3.9 Type 2 Natural Recharge - Lower Verde (L-18)	3.9 Type 2 Natural Recharge - San Geranimo (L-18)	3.9 Type 2 Natural Recharge - Cibolo Dam[1] (L-18)
Yield (acft/yr)	[4]	[4]	[4]	[4]	[4]	[4]	[4]
Conservation Pool (ac)[5]	7,650	1,190	1,430	1,260	1,014	330	500
100-year Flood Pool (ac)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Habitat Impacted (ac)							
Developed	0	0	0	0	0	0	0
Grasslands	1,530	519	508	1,085	30	0	50
Crops	0	0	0	0	0	0	0
Shrublands	0	0	0	0	0	0	0
Brushlands	5,355	1,454	1,173	0	53	149	0
Park	0	0	0	4,206	874	0	0
Woodlands	0	0	18	330	26	132	200
Wetlands	765	104	35	81	31	17	250
Riverine Habitat	0	0	0	0	0	0	0
Total Area Affected (ac)	7,650	1,190	1,430	1,260	1,014	330	500
Pipeline Right-of-Way	0	0	0	0	0	0	0
Lotic to Lentic Habitat	0	0	0	0	0	0	0
Inundated Area	7,650	1,190	1,430	1,260	1,730	330	500
Longterm Impacts	7,650	1,190	1,430	1,260	1,730	330	500
Protected Species [2]	no	no	no	no	no	no	no
Protected Species Habitat[2]	yes	yes	yes	yes	yes	yes	yes
Cultural Resources[2]	no	no	no	no	no	no	no
Special Resources[2]	yes	yes	yes	yes	yes	yes	yes

[1]See Appendix B, important species tables and environmental issues discussion in the text.
[2]A more detailed explanation appears in the text.
[4]Yield (recharge) varies among alternative water sources; combined recharge 52,000 acft/yr for optimum size for capture of existing streamflows
[5]A recharge reservoir has a recharge pool, rather than a conservation pool which generally implies a relatively consistent water surface elevation

Table 3.0-1

	3.9 Type 2 Natural Recharge - Dry Comal (L18)	3.9 Type 2 Natural Recharge - Lower Blanco (L18)	3.9 Type 2 Natural Recharge - Leon, Helotes, Government (L18)	3.9 Type 2 Natural Recharge - Salado Creek FRS (L18)	3.9 Type 2 Natural Recharge - Dry Comal (L18)	3.9 Type 2 Natural Recharge - San Marcos FRS (L18)	3.13 Existing Medina Lake (S-13A,B)[2,3]	3.13 Existing Medina Lake (S-13C,D)[2,3]
Yield (acft/yr)	[4]	[4]	[4]	[4]	[4]	[4]	26700/267000	8,800
Conservation Pool (ac)[5]	1,000	1,052	1,380	1,000	265	500	5,575	5,575
100-year Flood Pool (ac)	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Existing	Existing
Habitat Impacted (ac)								
Developed	12	18	0	12	0	0	20	56
Grasslands	0	0	0	0	0	0	0	
Crops	0	0	0	0	0	0	91	78
Shrublands	441	620	0	441	0	0	52	136
Brushlands	332	169	0	332	263	487	6	4
Park	118	228	304	118	0	0	1	28
Woodlands	82	10	1,076	82	0	9	0	0
Wetlands	15	7	5	15	2	4	1	1
Riverine Habitat	0	0	0	0	0	0	1	3
Total Area Affected (ac)	1,000	1,052	1,380	1,000	0	0	172	298
Pipeline Right-of-Way	0	0	0	0	0	0	172	298
Lotic to Lentic Habitat	0	0	0	0	0	0	0	0
Inundated Area	1,000	1,052	1,380	1,000	265	500	0	0
Longterm Impacts	1,000	1,052	1,380	1,000	265	500	172	298
Protected Species[2]	no	no	yes	no	no	no	no	no
Protected Species Habitat[2]	yes	yes	yes	yes	yes	yes	no	no
Cultural Resources[2]	no	no	yes	yes	no	no	no	no
Special Resources[2]	yes	yes	yes	yes	yes	yes	no	no

[1]See Appendix B, important species tables and environmental issues discussion in the text.
[2]A more detailed explanation appears in the text.
[3]See Sections 3.8, 3.9 for recharge zone impacts
[4]Yield based on combination of Type 2 Projects: optimum size is 52,000 acft/yr
[5]A recharge reservoir has a recharge pool, rather than a conservation pool which generally implies a relatively consistent water surface elevation

Table 3.0-1

	3.14 Applewhite Reservoir (S-14)[1]	3.15 Cibolo Reservoir (S-15)[1]	3.16 Goliad Reservoir (S-16)[1]	3.18 San Marcos River to Injection Well Field (G-13A)	3.18 San Marcos River to Recharge Zone (G-13B)	3.19 Lake Dunlap Injection Well Field (G-14A)	3.19 Lake Dunlap Pipeline to Recharge Zone[3] (G-14B)
Yield (acft/yr)	22500/22500/7700	32,300	115,500	6,600	6,600	3,500	3,500
Conservation Pool (ac)	2,500	16,700	28,147	1,203	1,203	1,203	1,203
100-year Flood Pool (ac)	2,500	16,700	28,147	1,203	1,203	1,203	1,203
Habitat Impacted (ac)							
Developed	6	100	0	151	201	54	151
Grasslands	102	2,900	7,760	22	30	62	22
Crops	612	6,850	15,756	1,374	1,427	570	160
Shrublands	0	0	0	14	19	198	14
Brushlands	940	2,510	850	12	16	3	12
Park	0	555	0	4	5	2	4
Woodlands	1,057	3,715	3,028	4	6	2	4
Wetlands	0	0	556	6	7	6	5
Riverine Habitat	1,057	70	416	3	2	2	2
Total Area Affected (ac)	2,717	16,700	28,147	1,589	1,712	2,102	1,577
Pipeline Right-of-Way	0	0	0	376	499	131	148
Lotic to Lentic Habitat	1,057	1,645	416	0	0	0	0
Inundated Area	2,717	16,700	28,147	1,203	1,203	1,203	1,203
Longterm Impacts	2,717	16,700	28,147	1,579	1,702	2,102	1,351
Protected Species[2]	no	yes	no	yes	yes	no	no
Protected Species Habitat[2]	yes	yes	yes	yes	yes	yes	yes
Cultural Resources[2]	yes	yes	no	yes	yes	no	no
Special Resources[2]	yes	yes	no	no	no	no	no

[1] Refer to Table 3.0-2 for pipeline ROW impacts for treated water delivery alternatives.
[2] A more detailed explanation appears in the report section text.
[3] See Sections 3.8, 3.9 for recharge zone impacts

Table 3.0-1									
	3.20 Canyon Lake to Lake Dunlap[3] (G-15)	3.20 Canyon Lake to Lake Dunlap (G-15)	3.21 Cuero Reservoir (G-16)[1]	3.22 Lindenau Reservoir (G-17)[1]	3.23 McFaddin Reservoir (G-18)[1]	3.24 Guadalupe River Dam 7 (G-19)	3.25 Gonzales Reservoir (G-20)	3.26 Lockhart Reservoir (G-21)	3.27 Dilworth Reservoir (G-22)
Yield (acft/yr)	10000/15000	10000/15000	168,000	45,800	37,000	33,300	52,470	7,960	27,000
Conservation Pool (ac)	1,203	1,203	41,500	26,875	1,264	12,830	21,370	2,910	15,400
100-year Flood Pool (ac)	1,203	1,203	67,000	30,906	Not Applicable	14,755	24,980	5,700	20,700
Habitat Impacted (ac)									
Developed	54	151	260	0	0	0	150	0	100
Grasslands	62	22	0	0	0	873	11,560	727	5,967
Crops	570	160	21,028	11,455	730	624	0	873	0
Shrublands	198	14	0	0	0	1,745	0	728	0
Brushlands	3	12	7,184	9,346	133	3,741	7,077	378	5,049
Park	2	4	0		50	0	0	0	0
Woodlands	2	4	11,984	5,641	23	5,236	2,029	116	2,754
Wetlands	6	5	0	0	0	112	188	51	1,462
Riverine Habitat	2	2	1,044	433	340	499	366	37	68
Total Area Affected (ac)	2,102	1,577	41,500	26,875	1,264	12,830	21,370	2,910	15,400
Pipeline Right-of-Way	131	148	0	0	0	0	0	0	0
Lotic to Lentic Habitat	0	0	1,044	433	340	499	366	0	68
Inundated Area	1,203	1,203	41,500	26,875	1,264	12,830	21,370	2,910	15,400
Longterm Impacts	1,334	1,351	41,500	26,875	1,264	12,830	21,370	2,910	15,400
Protected Species[1]	no	no	yes	yes	no	yes	yes	no	no
Protected Species Habitat[2]	yes	yes	yes	yes	yes	yes	yes	yes	yes
Cultural Resources[2]	no	no	yes	yes	no	yes	yes	yes	yes
Special Resources[2]	no	no	yes	yes	no	yes	yes	no	yes

[1]Refer to Table 3.0-2 for pipeline ROW impacts for treated water delivery alternatives.
[2]A more detailed explanation appears in the report section text.
[3]See Sections 3.8, 3.9 for recharge zone impacts

Table 3.0-1

Report Section Alternative	3.28 Colorado River at Lake Austin to recharge (C-13)[3]	3.28 Colorado River at Lake Austin to Medina (C-13)	3.29 Colorado River at Columbus (C-17)	3.30 Shaws Bend Reservoir (C-18)	3.30 Shaws Bend Reservoir pipeline (C-18)[1,3]	3.31 Allens Creek Reservoir (B-10)[1,3,6]
Yield (acft/yr)	68000/50000	68000/50000	125000/50000	100,000		57,000
Conservation Pool (ac)	0	0	0	13,398		8,250
100-year Flood Pool (ac)	0	0	0	23,400		16,000
Habitat Impacted (ac)						
Developed	211	41	241	0	241	78
Grasslands	30	50	123	3,646	123	40
Crops	494	595	464	287	464	4,151
Shrublands	37	82	112	0	112	36
Brushlands	21	94	73	18	73	24
Park	8	40	64	1,655	64	20
Woodlands	8	41	247	3,092	247	3,080
Wetlands	7	6	6	4,700	6	252
Riverine Habitat	10	13	10	1,016	10	1,003
Total Area Affected (acres)	826	963	1,340	13,398	1,340	434
Pipeline Right-of-Way	249	290	403	0	403	131
Lotic to Lentic Habitat	0	0	0	1,016	0	1,255
Inundated Area	0	0	0	13,400	0	8,250
Longterm Impacts	249	290	403	1,3400	403	8,381
Protected Species[1]	yes	no	yes	no	no	no
Protected Species Habitat[2]	yes	yes	yes	yes	yes	yes
Cultural Resources[2]	yes	yes	yes	yes	no	no
Special Resources[2]	yes	yes	yes	yes	yes	yes

[1]Refer to Table 3.0-2 for pipeline ROW impacts for treated water delivery alternatives.
[2]A more detailed explanation appears in the report section text.
[3]See Sections 3.8, 3.9 for recharge zone impacts
[6]See pipeline ROW Section 3.29 from Columbus to San Antonio.

Table 3.0-1 (Concluded)

Report Section Alternative	3.32 Toledo Bend to San Antonio, Pipeline (SB-10A,B,C,)[1,3,6]	3.32 Toledo Bend to San Antonio, Pipeline (SB-10D)[1,6]	3.33 Toledo Bend to Allens Creek Reservoir (SBB-10)[1,6]	3.35 Carrizo Aquifer CZ-10 (A)	3.35 Carrizo Aquifer CZ-10 (B)[3]	3.35 Carrizo Aquifer CZ-10 (C)	3.35 Carrizo Aquifer CZ-10 (D)
Yield (acft/yr)	300,000	600,000	357,800	90,000	90,000	90,000	220,000
Conservation Pool (ac)	0	0	8,250	0	0	0	0
100-year Flood Pool (ac)	0	0	0	0	0	0	0
Habitat Impacted (ac)							
Developed	78	78	78	20	143	20	37
Grasslands	40	40	40	0	0	0	0
Crops	151	151	4,151	1,641	1,054	968	1,147
Shrublands	36	36	36	497	278	40	271
Brushlands	24	0	24	112	112	112	139
Park	20	0	20	306	341	268	1,636
Woodlands	80	0	3,080	16	16	321	527
Wetlands	2	2	252	36	32	32	37
Riverine Habitat	3	3	1,003	8	11	11	16
Total Area Affected (ac)	434	434	8,684	2,636	1,812	1,761	3,762
Pipeline Right-of-Way	131	131	131	1,886	1,427	1,376	3,417
Lotic to Lentic Habitat	0	0	1,255	0	0	0	0
Inundated Area	0	0	8,250	0	0	0	0
Longterm Impacts	131	131	8,381	2,636	1,976	1,466	3,075
Protected Species[2]	no	no	no	yes	yes	yes	yes
Protected Species Habitat[2]	yes	yes	yes	yes	yes	yes	yes
Cultural Resources[2]	no	no	no	yes	yes	yes	yes
Special Resources[2]	yes	yes	yes	yes	yes	yes	yes

[1]Refer to Table 3.0-2 for pipeline ROW impacts for treated water delivery alternatives.
[2]A more detailed explanation appears in the report section text.
[3]See Sections 3.8, 3.9 for recharge zone impacts
[6]See pipeline ROW Section 3.29 from Columbus to San Antonio.

Table 3.0-2
Impacts of Water Treatment Alternative Pipeline Rights-of-Way to The Injection Well Field and the Recharge Reservoir Zone

Treated Water Delivery Alternative	North Water Treatment Plant ROW to Injection Zone	North Water Treatment Plant ROW to Recharge Zone[3]	South Water Treatment Plant ROW Injection Zone	South Water Treatment Plant ROW to Recharge Zone[3]
Yield (acft/yr)	[1]	[1]	[1]	[1]
Conservation Pool (ac)	0	0	0	0
100-year Flood Pool (ac)	0	0	0	0
Habitat Impacted (ac)				
Developed	13	11	84	185
Grasslands	36	9	0	0
Crops	121	29	286	115
Shrublands	45	11	173	225
Brushlands	64	15	14	6
Park	26	6	4	56
Woodlands	26	6	0	0
Wetlands	1	1	3	4
Riverine Habitat	2	1	7	10
Total Area Affected (ac)	335	268	570	602
Pipeline Right-of-Way	101	81	172	181
Lotic to Lentic Habitat	0	0	0	0
Inundated Area	0	0	0	0
Longterm Impacts	101	81	172	181
Protected Species	no[2]	no[3]	no[2]	no[3]
Protected Species Habitat	yes[2]	yes[3]	yes[2]	yes[3]
Cultural Resources	no[2]	no[3]	no[2]	no[3]
Special Resources	no[2]	no[3]	no[2]	no[3]

[1]Refer to specific water development alternative sections for yields
[2]Refer to Section 3.2.3 for injection well field discussion and important resources
[3]Refer to Sections 3.8.3 and 3.9.3 for discussion of recharge reservoirs and important resources

stand-alone alternatives, but are components common to many of the non-local alternatives.

The water supply alternatives evaluated in this report for the West Central Study Area can all be considered to consist of a combination of the following four categories of activity:

1) Water budget alterations - Demand reduction, recycling/reuse, water purchase or barter;

2) Reservoir construction and operation - Conventional main stem and off-channel storage, Types 1 & 2 recharge impoundments;

3) Edwards Aquifer recharge; and

4) Pipeline construction and operation.

Water Budget Alterations - Demand reduction alternatives (L-10) would result in reduced discharge (or reduction in the rate of increase) of treated wastewater to the San Antonio River. However, it could also result in an increase in compensating springflows if the water savings are not captured by other users. Other water budget alternatives involve recycling or reuse of treated wastewater for municipal consumption (L-13), for Edwards Aquifer recharge (L-13), to exchange for Edwards Irrigation water (L-11), to irrigate crops in exchange for Medina Lake water (L-12), in exchange for water lost to the Nueces Basin through enhanced Edwards Aquifer recharge (L-14), and purchase of Edwards irrigation water for municipal use (L-15, S-13, S-14). All have the potential to alter flows in the San Antonio River as wastewater flows are transferred to other locations for reuse rather than being released, or as surface water flows are rerouted. The alternatives that involve recharge enhancement would not result in increased springflows from the San Antonio, Comal or San Marcos springs if the volumes recharged are intercepted and withdrawn for municipal use.

Similar alternatives include purchase and diversion of presently permitted, but unused, reservoir yields (G-15, Canyon Lake), and existing water rights or unappropriated streamflows (G-13, San Marcos River; G-14 and G-17, Guadalupe River; G-18, McFaddin; C-10 through C-17, Colorado River; B-10, Brazos River) in areas outside of Bexar County that would not directly affect the Edwards Aquifer. Water diverted from the Colorado and

Brazos rivers would affect downstream flows and be lost as inflow to their respective estuaries, but would increase flows in the San Antonio River and the Guadalupe Estuary. The other diversions would also affect streamflows at the source and reappear as wastewater discharges and enhanced flows in the San Antonio River. These transfers would have the net result of decreasing estuary inflows by an amount proportional to losses in the system.

The hydrologic analyses reported in Sections 3.12, 3.17, 3.28, and 3.29 show that unless substantial off-channel water storage capacity is constructed, and a high maximum diversion rate is used, diversion projects do not have significant firm yields, nor do they provide much water during extended periods of relatively low rainfall. The Trans-Texas criteria for run-of-the-river diversion projects do not have any provision for drought operation; withdrawals are simply prohibited when ambient streamflows fall below the values outlined in Appendix C. This can result in long periods during which no diversions can be made, affecting not only firm yield, but also yields during non-drought years of lower than average rainfall.

Alternatives L-16, demineralization of Edwards bad water, and L-19, springflow augmentation, are attempts to maintain springflows at Comal and San Marcos springs without curtailing current and future levels of aquifer withdrawal. The former alternative would have the same effects on springflows as do present withdrawals. The latter would likely require extensive study and planning efforts to convince the regulatory agencies with the responsibility of assuring the survival of protected species dependent on the springs that any specific augmentation project will actually maintain the habitat qualities critical to those species.

Reservoir construction and operation - New reservoir construction is being studied for sites in each of the river basins of the West Central Study Area. Conventional storage reservoirs are proposed as parts of Alternatives S-14 (Applewhite), S-15 (Cibolo), S-16 (Goliad), G-16 (Cuero), G-19 (Guadalupe Dam 7), G-20 (Gonzales), G-21 (Lockhart), G-22 (Dilworth), and C-18 (Shaws Bend). Off-channel reservoirs are impoundments that are primarily intended for storage of water delivered from sources other than its own tributary basin, although some of these reservoirs would have substantial natural inflows. Alternatives G-17 (Lindenau), G-18 (McFaddin), and B-10 (Allens Creek) are large reservoirs designed provinces, and supports no endemic species of mammals or reptiles[15]. However, five species of urodele fauna are endemic, neotenic forms that have developed in subterranean drainages and springs of the Edwards Plateau[16]. The golden-cheeked warbler (*Dendroica chrysoparia*) nests only on the Edwards Plateau, primarily in the canyonlands on its eastern and southern margins. The wooded and brushland areas provide food and cover for a variety of birds and mammals, including white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), ringtails (*Bassariscus astutus*), several species of skunks, gray foxes (*Urocyon cinereoargenteus*), coyotes (*Canis latrans*), beaver (*Castor canadensis*), and bobcats (*Felis rufus*). Wintering songbirds such as robins and cedar waxwings feed on the juniper mast. Native wild turkeys feed on the juniper berries. White-tailed deer are abundant and important in this area. On the Edwards plateau, their abundance is strongly associated with the progress of juniper from the hillsides to the level savannahs where deer now have both cover and forage[17,18]. Cultivated fields generally occur in the relatively broad, level stream valleys where deeper soils have accumulated[19]. Upland agriculture consists primarily of livestock grazing and harvest of cedar and oak for fence posts and firewood, respectively.

The Texan biotic province, east of the Edwards Plateau, is characterized by the interdigitation of forest and grassland associations; it encompasses both the Post Oak Savannah and Blackland Prairie, and much of the Gulf Prairies and Marshes vegetational area[20] (Figures 3.0-1 through 3.0-3). Reflecting its ecotonal character, the Texan biotic province does not support any endemic species of vertebrate. Forty-one of the 49 mammals

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[15]Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science, 2(1): pp.93-117.

[16]Ibid.

[17]Bryant, F. C. 1991. Managed Habitats for Deer in Juniper Woodlands of West Texas: in J. E. Rodiek and E. G. Bolen. 1991. *Wildlife and Habitat in Managed Landscapes*. Island Press, Wahington, D.C.

[18]Rodiek, J. E. and E. G. Bolen. 1991. *Wildlife and Habitats in Managed Landscapes*. Island Press, Washington, D. C.

[19]Correll, D. S., and M. C. Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

[20]Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science, 2(1): pp.93-117.

found in the Texan biotic province are also found in the Austroriparian province[21]. These mammals tend to be restricted to the oak-hickory forests, floodplain forests, and peat bogs and marshes. Thirty-nine snake species, five urodele species, and 18 anuran species are found in the Texan province. Most of these are also found in the Austroriparian province[22].

The Post Oak Savannah vegetational area, which covers approximately 8.5 million acres (ac), consists of gently rolling or hilly country, with elevations ranging from 300 to 800 feet (ft) above mean sea level (MSL). Upland soils of the region are light-colored, acid sandy loams or sands. Bottomland soils are light brown to dark gray and acid, with textures ranging from sandy loams to clays. This area is characterized by pastureland, with frequent stands of woodland and occasional cropland. The dominant species of the Post Oak Savannah is post oak (*Quercus stellata*), which occurs in open stands with a ground cover of grasses[23]. Other associated species include blackjack oak (*Quercus marilandica*), black hickory (*Carya texana*), cedar elm (*Ulmus crassifolia*), and eastern redcedar (*Juniperus virginiana*). Important understory shrubs include American beautyberry (*Callicarpa americana*) and farkleberry (*Vaccinium arboreum*). This vegetation type is either considered to be a part of the Eastern Deciduous Forest association or as part of the Prairie association.[24,25,26,27,28,29] The latter view is based upon the occurrence of a climax tall

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[21]Ibid.

[22]Ibid.

[23]Correll, D. S., and M. C. Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

[24]Tharp, B.C. 1939. The vegetation of Texas. Texas Acad. Sci., Anson Jones Press, Houston.

[25]Braun, E.L., 1950. Deciduous forests of eastern North America. Hafner Publ. Co., Inc., New York.

[26]Kuchler, A.W. 1964. Potential natural vegetation of the contermious United States. Amer. Geog. Soc. Sp. Publ. No. 36.

[27]Mahler, W.F. 1980. The mosses of Texas. Southern Methodist University Herbarium, Dallas, Texas.

[28]Weaver, J.E. and F.E. Clements. 1938. Plant Ecology. 2nd Ed. McGraw-Hill Book Co., New York.

grass understory composed of the prairie dominants, little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and big bluestem (*Andropogon gerardi*).

During the last few decades, open savannah has been converted into dense woodland stands of post oak and winged elm (*Ulmus alata*). This has occurred as a result of overgrazing, abandonment from cultivation, and removal of fire. Grazing is the major land use of both upland and bottomland sites within the vegetation type. Large acreages of both upland and bottomland forests have been cleared for grazing and most of this is now in tame pasture.

The Blackland Prairies vegetational area consists of about 11.5 million acres (Figure 3.0-1). This gently rolling to nearly level, well-dissected area has rapid surface drainage. Elevations for the region as a whole are 300 to 800 ft above sea level. Uniform, dark-colored calcareous clays, which are interspersed with gray acid sandy loams, constitute the fertile Blackland soils. According to Thomas, most of the region is under cultivation, although there are some excellent native hay meadows and a few ranches remaining[30].

Floristically, the Blackland Prairies has been classified as a true prairie because of its native vegetation. Little bluestem is considered the climax dominant of the region. Big bluestem, Indiangrass, switchgrass (*Panicum virgatum*), sideoats grama (*Bouteloua curtipendula*), hairy grama (*Bouteloua hirsuta*), tall dropseed (*Sporobolus asper*), silver bluestem (*Bothriochloa saccharoides*), and Texas wintergrass (*Stipa leucotricha*) are other important grasses in the region[31]. If heavy grazing is allowed, Texas wintergrass, buffalo grass (*Buchloe dactyloides*), Texas grama (*Bouteloua rigidiseta*), smutgrass (*Sporobolus indicus*) and many annuals may increase or invade the prairies, causing deterioration of the native community[32]. Other invasive species are mesquite (*Prosopis* sp.) in the southern

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[29]Daubenmire, Rexford. 1978. Plant geography with special reference to North America. Academic Press, New York.

[30]Thomas, G. W. 1975. Texas plants - an ecological summary. In: F. W. Gould. 1975. Texas Plants - a checklist and ecological summary. Texas Agricultural Experiment Station, MP-585/Rev., College Station, Texas.

[31]Correll, D. S., and M. C. Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

[32]Ibid.

portion of the Blackland Prairies, and post oak and blackjack oak in areas of medium- to light-textured soils. Grasses which have been used to seed improved pastures within the Blackland Prairies are dallisgrass (*Paspalum dilatatum*), common and coastal bermudagrass (*Cynodon dactylon*), and some native species.

The South Texas Plains vegetational area (corresponding to the Southern Texas Plains ecoregion[33] and the Tamaulipan Biotic province[34]) is approximately 20 million acres in area. The topography in this region is level to rolling, with elevations ranging from sea level to nearly 1,000 ft. Soil types cover a wide range, from clays to sandy loams, creating variations in soil drainage and moisture-holding capacities. Though there are large areas of cultivated land, most of the area is still range land.

The South Texas Plains region originally supported a grassland or savannah climax vegetation[35]. A long period of grazing and the reduction of fire have affected the plant communities and have led to an increase of brush.[36,37,38] Species which have increased in the area include honey mesquite (*Prosopis glandulosa*), post oak, live oak (*Quercus virginiana*), several acacias (*Acacia* spp.) and members of the cactus family (Cactaceae). Distinct differences in climax plant communities and successional patterns occur on the many range sites that are found in the region.

The dominant species of the South Texas Plains is honey mesquite, which occurs in open to closed stands with a ground cover of herbs and grasses. Other important shrub species include guajillo (*Acacia berlandieri*), blackbrush acacia (*Acacia rigidula*), and

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[33]Omernik, James M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1) pp. 118-125.

[34]Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science, 2(1): pp.93-117.

[35]Thomas, G. W. 1975. Texas plants - an ecological summary. In: F. W. Gould. 1975. Texas Plants - a checklist and ecological summary. Texas Agricultural Experiment Station, MP-585/Rev., College Station, Texas.

[36]Box, T.W., J. Powell, and D.L. Draw. 1967. Influence of fire on south Texas chaparral communities. Ecology 48:955-961.

[37]Bogusch, E.R. 1952. Brush invasion in the Rio Grande Plain of Texas. Texas Journal of Science 1:85-91.

[38]Johnston, M.C. 1963. Past and present grasslands of southern Texas and northeastern Mexico. Ecology 44:456-466.

guayacan (*Porlieria augustifolia*). Important grasses include various species of threeawns (*Aristida* spp.) and bristlegrasses (*Setaria* spp.), Arizona cottontop (*Trichachne californica*), pink pappusgrass (*Pappophorum bicolor*), and common curlymesquite (*Hilaria belangeri*)[39].

The vertebrate fauna of the Tamaulipan biotic province include Neotropical species, grassland species, and some species common to the Austroriparian and the Chihuahuan provinces. Sixty-one species of mammals occur, or have occurred in this region, along with 36 species of snakes, 19 lizards, 2 land turtles, 3 urodeles, and 19 anurans[40].

The Gulf Prairies and Marshes vegetational region of Texas consists of about 9,500,000 acres. This nearly level, slowly drained plain is less than 150 feet in elevation and is cut by sluggish rivers, creeks, bayous and sloughs. Habitats include coastal salt marshes, dunes, priaries, riverbottoms, and fresh water ponds. Soils are acid sands, sandy loams and clays. The upland prairie soils tend to be heavier textured acid clays or clay loams. Much of the region is fertile farmland or pastureland. The climax vegetation of the region is mostly tall grass prairie or post oak savannah[41]. Prinicpal grasses are big bluestem (*Andropogon gerardi*), little bluestem (*Schizachyrium scoparium*), seacoast bluestem (*S. scoparium* var. *litoralis*), indiangrass (*Sorghastrum nutans*), eastern gamma grass (*Tripsacum dactyloides*), Texas wintergrass (*Stipa leucotricha*) and switchgrass (*Panicum virgatum*) and gulf cordgrass (*Spartina* spp.). Seashore saltgrass (*Distichlis spicata*) occurs on moist saline sites. Since the region is heavily used for ranching and agriculture, extensive disturbance has allowed invader species, such as mesquite (*Prosopis glandulosa*), huisache (*Acacia smallii*), prickly pear (*Opuntia* spp.), acacia (*Acacia* spp.), ragweed (*Ambrosia psilostachya*), broomweed (*Xanthocephalum* spp.) and others to become well established.[42,43,44,45]

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[39]Correll, D. S., and M. C. Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

[40]Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science, 2(1): pp.93-117.

[41]Correll, D.S. and M.C. Johnston. 1979. Manual of the vascular plants of Texas. Texas Research Foundation, Renner, Texas. Second printing.

[42]Daubenmire, Rexford. 1978. Plantgeography with special reference to North America. Academic Press, New York.

Heavy grazing and/or abandoned farmland has changed the predominant grasses to species such as broomsedge (*Andropogon virginicus*), smutgrass (*Sporobolus indicus*), threeawns (*Aristida* spp.) and introduced bermudagrass (*Cynodon dactylon*), fesque (*Vulpia* spp.) and dallisgrass (*Paspalum dilatatum*).

Large acreages of both upland and bottomland forests have been cleared for grazing and most of this is in tame pasture. Major creek and river floodplains may retain more or less well developed hardwood forests, but upland areas are generally cleared for cultivation or pasturage. However, uplands support scattered, dense, shrubby thickets of oak, huisache and mesquite, and occasional freshwater marshes in relict drainages. Principal tree and shrub species observed in uplands include live oak (*Quercus virginiana*), post oak (*Q. stellata*), cedar elm (*Ulmus crassifolia*), hackberry (*Celtis laevigata*), honey mesquite, huisache, and yaupon (*Ilex vomitoria*)[46,47,48,49]

San Antonio, in Bexar County, will be the focus of much of the proposed activity assessed in this report. The city lies at the confluence of three Ecoregions, vegetational areas and Biotic Provinces (Figure 3.0-1 through 3.0-3). The Balcones escarpment, marking the southern edge of the Edwards Plateau, divides Bexar County into a northern third of canyons, steep slopes and rocky soils, and a southern two thirds consisting of a nearly level plain sloping from the southeast to the northwest, rising from about 500 feet to 1,000 feet MSL. Southern Bexar County is a transitional zone between the plains and the Central

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[43]Johnston, M.C. 1988. The Vascular Plants of Texas, A List Updating the Manual of the Vascular Plants of Texas. Austin, Texas.

[44]Thomas, G. W. 1975. Texas plants-an ecological summary in: F.W. Gould, Texas Plants - a checklist and ecological summary. Texas Agricultural Experimental Station, MP-585/Rev., College Station, Texas.

[45]Weaver, J.E. and F.E. Clements. 1938. Plant Ecology. 2nd Ed. McGraw-Hill Book Co., New York.

[46]Bureau of Reclamation. 1974. Palmetto Bend Project - Texas Final Environmental Impact Statement. Bureau of Reclamation, U.S. Department of the Interior.

[47]SCS. 1978. Soil survey of Calhoun County, Texas. Soil Conservation Service, Temple, Texas.

[48]SCS. 1981. Soil survey of Brazoria County, Texas. Soil Conservation Service, Temple, Texas.

[49]TDWR. 1977. Land use/land cover maps of Texas. Austin, Texas. LP-62, Reprinted 1978.

Texas Plateau Ecoregion (Edwards Plateau). Prior to development, the area consisted of grasslands and savannahs. Since the inception of development and cattle ranching activities, however, mesquite brushland has invaded the southern portions of the Blackland Prairie, creating brushlands that are similar to those of the South Texas Plains, especially over droughty areas with flatter, deeper sandy loam soils.

In Bexar County alone there are 21 species of amphibians, 72 species of reptiles, 328 species of birds and 55 species of mammals[50]. Amphibians commonly occurring include the Gulf coast toad, Blanchard's cricket frog, and Rio Grande leopard frog. The Red-eared turtle, Guadalupe spiny softshell turtle, diamondback water snake, and western cottonmouth are common reptiles. Sixty-seven of the 328 birds reported are permanent residents, 101 have breeding records, and 199 winter in Bexar County[51]. Game birds include ducks, geese, dove, turkey, and bobwhite. Mammals common to the area include coyote (*Canis latrans*), raccoon (*Procyon lotor*), ringtail (*Bassariscus astutus*), opossum (*Didelphis virginiana*), nutria (*Myocastor coypus*), voles, western and spotted skunks (*Spilogale gracilis* and *S. putorius*), Striped skunks (*Mephitis mephitis*), fox squirrel, eastern cotton tail, and white-tail deer.

3.0.1.4 Environmental Issues

Federal and state endangered and threatened species, species that are candidates for listing as endangered and threatened, and other resources of concern are listed by county in Appendix B, for the entire West Central Study Area. Potential impacts to these protected resources are addressed in the environmental issues subsections of each of the alternative discussions.

Additional water yielded by each alternative, together with the types and areas of probable environmental disturbance are summarized for all alternatives in Tables 3.0-1 and 3.0-2. The four pipeline corridors that might be used to take treated water from a north or a south water treatment plant location to either a well field in Medina County, or to recharge impoundments in northern Bexar County, are shown in Table 3.0-2. These are not

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[50]Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science, 2(1): pp.93-117.

[51]United States Army Corps of Engineers. 1987. Applewhite Reservoir; Draft Environmental Impact Statement. United States Army Corps of Engineers, Fort Worth District, Fort Worth, Texas.

Table 3.0-1
Environmental Issues Summary

Section Number Alternative	3.2 Irrigation Water (L-11)	3.3 Medina Lake Water (L-12a)	3.3 Medina Lake Water (L-12b)	3.4 SAWS for Edwards (L-13B)	3.5 SAR to Choke Canyon (L-14a)	3.7 Demineralization of Edwards "Bad Water" (L-16)[1]
Yield (acft/yr)	38,000	31,000	66,000	92,000	23,400	0
Conservation Pool (ac)	0	0	2,000	0	0	0
100-year Flood Pool (ac)	0	0	0	0	0	0
Habitat Impacted (ac)						0
Developed	36	96	165	96	20	0
Grasslands	0	9	91	12	0	0
Crops	139	257	257	350	0	0
Shrublands	221	224	2,024	377	0	0
Brushlands	20	22	199	31	368	0
Park	0	6	6	7	0	0
Woodlands	0	0	0	0	167	0
Wetlands	8	4	7	3	2	0
Riverine Habitat	5	5	12	5	2	0
Total Area Affected (ac)	424	618	2,761	877	559	0
Pipeline Right-of-Way	127	186	190	240	167	[1] 0
Lotic to Lentic Habitat	0	0	5	0	0	0
Inundated Area	0	0	2,000	0	0	0
Longterm Impacts	127	186	2,761	240	167	[1] 0
Protected Species[2]	no	no	no	no	no	yes
Protected Species Habitat[2]	yes	yes	yes	yes	yes	yes
Cultural Resources[2]	no	no	no	no	no	no
Special Resources[2]	no	no	no	no	no	yes

[1]Refer to Table 3.0-2 for pipeline ROW impacts for treated water delivery alternatives.
[2]A more detailed explanation appears in the report section text.
[3]See Sections 3.8, 3.9 for recharge zone impacts

to provide firm-yield storage for water diverted from the Guadalupe and Brazos Rivers, respectively. Alternatives L-11 and L-13 (Wastewater exchange and reuse), G-13, G-14 and G15 (San Marcos and Guadalupe River diversions), and C-10 through C-17 (Colorado River diversions) all feature small impoundments designed to provide temporary storage so that facilities like pipelines, water treatment plants and injection wells can be operated at near constant rates in spite of variable water availability at the source.

Reservoir construction results in disturbance to vegetation and soils at the dam site, borrow areas, along haul roads, and in other areas used during construction. This may amount to several hundred acres for a large reservoir. Some additional soil erosion and downstream transport of sediments may occur during construction, but appropriate engineering and construction techniques, followed by prompt revegetation of exposed soil surfaces can minimize this source of disturbance.

Reservoir operation results in the more or less permanent inundation of an area upstream of the dam (the conservation, or recharge, pool), and often an additional area (the flood pool) that is intermittently inundated. Where the conservation pool elevation represents the maximum extent of the effects from permanent inundation, the elevation of the 100-year flood pool can be used to define the maximum possible extent of effects resulting from periodic inundation (Table 3.0-1).

The recharge impoundments discussed in Sections 3.8 and 3.9 are located in the Nueces River Basin headwaters along the southern edge of the Edwards Plateau in Medina and Uvalde Counties, in the San Antonio River basin in northern Bexar County, and on the Blanco River in western Hays County. Two reservoir types are examined in this report: Type 1 and Type 2. The Type 1 design (L-17, Section 3.8) is a conventional storage reservoir which would be located upstream of the Edwards Aquifer recharge zone. It is intended to capture and store water for future release downstream to enhance recharge when natural flows are not present, or to be withdrawn directly for local use.

Type 2 reservoirs are designed to impound streamflow directly over the recharge zone to increase recharge to the underlying Edwards Aquifer through the bottom of the impoundment. These reservoirs would be constructed within the recharge zone.

The two recharge reservoir types differ somewhat from conventional storage reservoirs, and from each other, in their environmental consequences. Like conventional storage reservoirs, Type 1 recharge impoundments will eliminate terrestrial habitat through dam construction and permanent inundation to the extent of their conservation pools, while the terrestrial habitat impacts of the Type 2 reservoirs will depend on the amount of clearing desired and the rapidity of pool drainage following capture of runoff. Because the Type 1 sites are located in perennial, typically spring-fed, reaches, they will also tend to affect more significant aquatic habitats and communities, endangered species or resources, and have more downstream impact than the Type 2 reservoirs. Recharge impoundments located in the Nueces River basin are discussed in detail in the Nueces Basin Water Supply Planning Study Phase III report .

In general, potential impacts to terrestrial habitats and populations (particularly higher value areas like riparian woodlands and wetlands), lotic habitats, protected species, and significant cultural resources are directly related to reservoir size. While it is recognized that all the sites are not equivalent, ranking the various reservoir alternatives by their conservation pool areas allows an approximate comparison of the potential impacts to terrestrial systems (Table 3.0-3). In most cases, areas with substantial woody vegetation provide most of the wildlife habitat value, primarily because these habitats have decreased over time as a result of continued disturbance and fragmentation by agricultural activities and other types of development. Remnant prairie habitat is, however, an important exception in the vicinity of Allens Creek Reservoir and its associated pipelines. Inundation of a stream channel results in the conversion of its lotic habitats into lake (lentic) habitat.

Although it is recognized that reservoir construction and operation will affect the aquatic community of the impounded stream reach, there is currently no practical way of mitigating the consequences of converting flowing stream habitat into a lentic environment or of giving mitigation credit where the diversity and abundance of aquatic species has been enhanced as a result of reservoir construction. The rankings in Table 3.0-3 are accompanied by columns listing the approximate acreages of woodland and brushland, and of riverine habitat that would be covered by the conservation pool.

The Type 2 reservoirs (L-18) are somewhat inappropriately ranked with the other reservoir alternatives, since their impacts are generally less extensive than is indicated by

Table 3.0-3
Proposed New Reservoir Construction Alternatives Ranked by Inundated Area

Alternative	Inundated Area (acres)	Wood/Brushland (acres)	Riverine Habitat (acres)
G-16 Cuero	41,500	19,168	?
S-16 Goliad	28,147	3,878	416
G-17 Lindenau	26,875	14,987	?
G-20 Gonzales	21,370	9,106	366
S-15 Cibolo	16,700	6,780	70
G-22 Dilworth	15,400	7,803	68
C-18 Shaws Bend	13,398	4,765	1,016
G-19 Guadalupe Dam 7	12,830	10,722	499
L-18 Indian Ck	7,650	5,355	765
L-17 Montell	6,190	5,571	74
L-17 Concan	3,840	2,235	69
L-17 U Sabinal	3,110	100	833
G-21 Lockhart	2,910	1,222	37
S-14 Applewhite	2,500	1,997	?
L-12b Medina Balancing Reservoir	2,000	1,778	0
L-17 U Hondo	2,000	1,332	268
L-17 UD Frio	1,800	450	112
L-18 L Verde	1,730	953	31
L-18 L Sabinal	1,430	1,191	35
L-18 Leon/Helotes/Government Creeks	1,380	?	?
G-18 McFaddin	1,264	206	?
L-18 L Hondo	1,260	?	81
L-18 LD Frio	1,190	1,454	104
L-18 L Blanco	1,052	?	?
L-18 Dry Comal	1,000	?	?
L-18 Salado	1,000	?	?
L-17 U Verde	880	748	50
L-18 Cibolo 1	500	200	250
G-13 San Marcos Diversion	500	?	?
B-10 Allens Creek	434	124	3
L-18 San Geronimo	330	281	17
L-17 Cloptins Crossing	?	?	?

the size of the conservation pool, and the stream channels inundated tend to be intermittent to the extent that they do not contain substantial areas of lotic habitat. However, some of the alternatives considered (SB-10, SBB-10) supply so much water that to achieve sufficient recharge the Type 2 impoundments would have to be operated in a continuous mode, and would therefore have the same inundation impacts as a conventional reservoir.

All of the new reservoir alternatives have been designed to comply with the Trans Texas criteria for new reservoirs, and presently built or authorized reservoirs were assumed to operate in compliance with their existing permits. Under the Trans-Texas criteria for new reservoirs, bay and estuary inflow requirements are assumed to be met if the instream flow requirements are met.

Edwards Aquifer recharge - Two methods of Edwards Aquifer recharge are considered in this report: a) recharge directly into the confined zone using injection wells, and 2) enhancement of natural recharge in stream channels crossing the outcrop zone by extending the time (and depth) water is held in those reaches. Only a single injection well field has been proposed. This field is located in the area south of Medina and Diversion lakes. The recharge impoundments proposed for development in the Nueces River basin, on the Guadalupe River and on Cibolo Creek (Table 3.0-1, Sections 3.8 and 3.9) would be used only to enhance recharge from naturally occurring streamflows. Additional recharge impoundment sites, located on San Geronimo, Leon, Helotes, and Government creeks in northwestern Bexar County would, along with the injection well field, be used to recharge the aquifer using water from a variety of the sources considered.

Some of the alternatives envision injection or forced recharge of volumes of water (S-16, G-16, C-13, C-17, SB-10) that are large compared to natural recharge taking place at the proposed sites. Aside from questions about water quality, the effects of substantial local increases in the volume and duration of recharge events on Edwards Aquifer fauna is unknown. On the other hand, there is no *a priori* reason to think that such increases would be harmful if water quality is suitable. The characteristically constant temperature, chemical composition and clarity of the water in the reservoir portion of the aquifer, which supplies the springs, is a function of storage in the cavernous limestones of the aquifer, and not of constant quality water entering the recharge zone. Although base flows in the stream reaches above the recharge zone tend to be dominated by springflows from the catchment zone of the Edwards, higher flow regimes are dominated by storm water runoff, and are quite variable in physical and chemical quality. Animals inhabiting the "upstream" parts of the reservoir zone (within the recharge zone) are presently exposed to those variations in the amount and quality of water entering the aquifer.

While the use of water from sources which presently contribute recharge to the aquifer does not appear to carry much risk of adversely affecting the aquifer biota, this may not be the case with other water sources, at least in terms of perception. Substantial effects on the subterranean fauna of the Edwards Aquifer reservoir zone as a result of recharge with treated wastewater (L-13), culturally enriched local reservoir water (S-16, G-16, C-13), or water from a remote source (C-17, C-18, B-10, SB-10, SBB-10) might arise as the result of dissolved oxygen depletion, food web disruption because of changes in the rate and frequency of dissolved and particulate organic matter delivery, some other water quality incompatibility (e.g., pH or hardness levels outside tolerance ranges), or by the introduction of pathogenic organisms (Sections 3.4, 3.8, and 3.9). These potential effects will need to be evaluated in detail in future phases of the Trans Texas Program, although it will be exeedingly difficult to obtain definitive risk assessments in the cryptic aquifer environment.

Pipeline Construction and Operation - Pipelines, a major construction and operational activity associated with most of the alternatives addressed here, affect linear areas of terrestrial habitat as a result of soil disturbance during construction, and through permanent maintenance of a right-of-way (ROW) free of woody vegetation. Because of the relative flexibility of pipeline locations, disturbance of sensitive resources can often be avoided entirely, or substantially minimized.

There is concern that as water from sources that have historically been isolated from each other are mixed in large volumes, organisms from the source waters may become established in the San Antonio-Guadalupe drainage, or in an intervening stream. Numerous recent publications have related instances where non-native species have had unforseen, and sometimes substantial, adverse effects in environments where they had been introduced, intentionally or not. Federal regulation of non-native species introduction is being considered.[52,53,54,55,56]

Dispersal mechanisms are a part of the life histories of all species, and invasion and colonization of new environments is one of the natural processes that play a role in shaping biological community structure. Human activities, however, have greatly increased the rate at which organisms are moved around, either intentionally or inadvertently, and introduced into novel locations. In addition to well-publicized problems like the zebra mussel, many other introductions have been considered beneficial, but the vast majority of successful invasions have passed relatively unnoticed, even when substantial alterations in community composition have resulted.[57,58] For example, the asiatic clam (*Corbicula fluviatilis*) has successfully invaded and colonized North America in the last 50 or so years, probably arriving first at a northwest Pacific port in ballast water. Much was written at one time about this clam that is being repeated today in stories on the zebra mussel (*Dreissena polymorpha*). Although almost completely unnoticed today, there is a huge biomass of asiatic clams in streams and lakes throughout North America, where they clog power plant intakes, and doubtless exert adverse affects upon native species.

Whether perceived as harmful or beneficial, or whether or not there is an observer at all, successful invasions or introductions generally result in some change in the relative abundances of resident native species and their trophic relationships, and increase the rate at which species are replaced. The net result of this process over time appears to lead to an increase in extinction rates and a reduction in global species diversity as formerly isolated

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[52]Hedgpeth, J.W. 1993. Foreign invaders. Science 261:34-34

[53]Carlton, J.T. and J.B. Geller. 1993. Ecological Roulette: The global transport of nonindigenous marine organisms. Science 261:78-82

[54]Travis, J. 1993. Invader threatens Black, Azov seas. Science 262:1366-1367

[55]Lassuy, D.R. 1994. Aquatic nuisance organisms: Aquatic nuisance report overview. Fisheries 19(4):14-17

[56]Horak, D. 1994. Aquatic nuisance organisms: Report has serious flaws. Fisheries 19(4):18-21

[57]Hedgpeth, J.W. 1993. Foreign invaders. Science 261:34-34

[58]EH&A 1975 Investigation of flow requirements from Comal and San Marcos springs to maintain associated aquatic ecosystems, Guadalupe River basin. Espey, Huston & Associates, Inc., Austin, Texas.

assemblages become more homogenous.[59,60]

The areas at risk for non-native species introductions would include the lower Brazos River if Allens Creek is used as a transfer reservoir for Sabine-Neches River water (SBB-10), and the San Antonio River drainage if the northern Bexar County recharge impoundments are used without prior treatment of the water. The exclusive use of pipelines for long range water transportation (from the Colorado, Brazos, and more eastern streams) will tend to minimize, but not eliminate, the inadvertant transport of large animals like fish. Algae, bacteria, protozoa, and the micrometazoans, together with anything else that has a migratory larva, or a dormant or resting life-cycle phase, are expected to be able to survive pipeline transport without great difficulty. Application of biocidal treatment or treatment to drinking water standards, would virtually eliminate the risk of organism transfer.

3.0.1.5 Mitigation Liability

Compensation for unavoidable impacts to wetland and terrestrial wildlife habitats may be requested during permit application processes by any party to the process, but the recommendations of the U.S. Fish and Wildlife Service or Texas Parks and Wildlife Department, depending on the permit involved, generally carry the greatest weight. Likewise, the Texas Historical Commission will recommend appropriate mitigation for potential impacts to cultural resources. In this case, all areas to be disturbed will have to be surveyed and the significance of any site located determined prior to any mitigation recommendation. However, decisions on the actual extent of required mitigation are made by the respective lead permitting agencies, the TNRCC in the case of a water rights permit, and the U.S. Army Corps of Engineers for a permit under Section 404 of the Clean Water Act, or Section 10 of the Rivers and Harbors Act.

Compensation is generally accomplished by acquisition of an appropriate tract(s) of land, together with development, funding, and implementation of a vegetation/wildlife management plan that will generate enough new habitat value over the life of the project

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[59]Hedgpeth, J.W. 1993. Foreign invaders. Science 261:34-34

[60]Carlton, J.T. and J.B. Geller. 1993. Ecological Roulette: The global transport of nonindigenous marine organisms. Science 261:78-82

to compensate for that lost as a result of project construction and operation. Acreage requirements are generally based on replacement of habitat value lost during the life of the project (50-100 years), and may be determined by one of several formal evaluation procedures (e.g., the U.S. Fish and Wildlife Service Habitat Evaluation Procedure), or by more informal agreements among the parties.

Mitigation costs will vary depending on the price and availability of land together with the acreage required to generate the necessary habitat value. Mitigation area management costs can be expected to average $5-10 per acre per year over the life of the project for a moderate level of management. Ownership and management responsibility for the mitigation site may be retained by the owner of the project or transferred (with management funding) to a resource agency (typically Texas Parks and Wildlife Department) agreeable to the parties involved.

Mitigation costs for cultural resource sites that cannot be avoided can be very high, particularly when several occur within a large project.

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3.0.2 Cost Estimating Procedures

Introduction

This study includes preparation of construction cost estimates, total project cost estimates, and estimates of operation and maintenance costs for a variety of project elements. Major structural and non-structural cost elements included in the estimates are listed below:

Structural Costs

1. Water Treatment Plants
2. Dams and Reservoirs Including Recharge Structures
3. Pump Stations
4. Pipelines
5. Relocations
6. Recovery Wells
7. Injection Wells
8. Distribution System Improvements

Non-Structural Costs

1. Engineering - Design, Bidding and Construction Phase Services, Geotechnical, and Surveying
2. Legal Services and Financing
3. Contingencies
4. Permits
5. Environmental - Studies & Mitigation
6. Archeology - Studies & Mitigation
7. Interest During Construction
8. Operations and Maintenance (Annual O&M)
9. Land and Rights-of-Way

The methods used in estimating costs for each of these elements are presented in the following sections.

Structural Costs

1. Water Treatment Plants. Because of the comprehensive range of project alternatives and the anticipated wide variation in the quality of water sources, water treatment costs (including both construction and annual operation and maintenance costs) have been prepared for four treatment processes for appropriate ranges of flows. Processes range from simple disinfection with taste and odor control treatment to facilities capable of purifying reclaimed water. O&M costs are discussed further in Non-Structural Costs, Section 6. It is not the intent of the cost estimating methodology to establish an exact treatment process but rather to estimate the cost of a general treatment process appropriate for bringing the source water quality to the required standard of the receiving system; i.e., potable water distribution system, a stream in the aquifer recharge zone, or an aquifer injection well. The treatment concepts used and a description of the classification of water to be treated for each concept are contained in Table 3.0-4.

Table 3.0-4 Level of Water Treatment for Each Source and Delivery Location				
Water Source	**Delivery Location**			
	Potable Distribution System	**Aquifer Injection**	**Recharge Zone**	**Farm Irrigation**
Edwards Plateau Surface Water	Level 3	Level 2	No Treatment	Not Incl. in Study
Other Surface Water	Level 3[1]	Level 2	No Treatment or Level 2	Not Incl. in Study
Carrizo Aquifer	Level 1	Level 1	No Treatment or Level 1	Not Incl. in Study
Reclaimed Waters	Level 4	Level 4	Not Incl. in Study	No Additional Treatment[2]

(1)This level will be modified to include granular activated carbon (GAC) and pre-ozone treatment where source water contains high proportion of reclaimed water.

(2)Reclaimed water for farm irrigation requires no additional treatment above current secondary treatment standards. Its use is therefore limited to crops not directly consumed.
Description of Treatment Processes:

Level 1: Carrizo Water Treatment - This treatment process would be used for the Carrizo-Wilcox groundwater to lower the iron and manganese content and to disinfect. The process includes application of chlorine dioxide for taste and odor control and addition of phosphate to sequester iron and manganese. Disinfection by chlorine is applied as the final treatment. With this treatment, the Carrizo water is suitable for public water system distribution, aquifer injection, or delivery to the recharge zone.

Level 2: Direct Filtration Treatment - This process would be used for treating waters from sources with anticipated low turbidity and low color where turbidity and taste and odor levels are low. In the direct filtration process, low doses of alum and polymer are used and settling basins are not required as all suspended solids are removed by filters. The process includes alum and polymer addition, rapid mix, flocculation, gravity filtration, and disinfection. Water treated with this process would be suitable for aquifer injection or for delivery to the recharge zone.

Level 3: Conventional Treatment - This process would be used for treating all surface water sources to be delivered to a potable water distribution system. The process includes alum and polymer addition, rapid mix, flocculation, settling, filtration, and disinfection with chlorine. In options where the source contains a large proportion of reclaimed water, this level will be modified to include GAC and pre-ozone treatment. This treatment produces water that is suitable for public water system distribution.

Level 4: Reclaimed Water Treatment - This process would be used for treatment where wastewater effluent is to be reclaimed and delivered to a supply system or injected to the aquifer. The concept includes renovation of wastewater plant effluent by phosphorous removal, storage in a reservoir, blending with surface runoff from the reservoir catchment, followed by conventional water treatment. Phosphorous would be removed from the effluent by lime softening including lime feed, rapid mix, flocculation, settling, recarbonation, and gravity filtration. The final conventional treatment will include ozonation, activated carbon, addition of alum and polymer, rapid mix, flocculation, sedimentation, second application of ozone, filtration, and disinfection with chlorine. This treatment results in water that can be delivered to a public water system for distribution or injected to the aquifer.

2. Water Treatment Costs. Construction and annual operations and maintenance cost are included in Tables 3.0-5 and 3.0-6, respectively. Costs are presented for a range of treatment capacities and for O&M corresponding to an average treatment flow of 95 percent of plant capacity. O&M costs for other than 95 percent of plant capacity are estimated by selecting the appropriate flow and cost from the range shown. Construction costs shown include the costs for all processes required, site work, buildings, storage tanks, sludge handling and disposal, clearwell, pumps and equipment. Plant and O&M cost estimates for levels 2, 3, and 4 include raw water pumping for a total pumping head of 100 feet, and finished water pumping for a total pumping head of 300 feet. Plant and O&M costs for Level 1 include finished water pumping only; raw water pumping for Level 1 is included in the O&M cost of the recovery wells. Additional pump stations and energy costs for raw water pumping are included in Level 4 treatment for the lime softening process.

   All cost estimates are for mid-1994 prices, and based on a projected *Engineering News Record* (ENR) Construction Cost Index (CCI) of 5469. Estimates obtained from references were updated to 1994 level by utilization of the ENR CCI for the appropriate year. A 15 percent allowance for miscellaneous cost items is included in the curves.

3. Dams, Reservoirs, and Appurtenances. The construction costs for these projects were handled individually. Since each reservoir site is unique, costs were based on the specific requirements of the project for the site. Items included in the estimate consisted of the construction cost and the non-structural costs listed above. Most reservoirs in the Trans-Texas program have been studied in the past and previous costs estimated were updated to mid-1994 prices, using either the U.S. BuRec CCI or the ENR CCI.

4. Pump Stations. Pump stations vary in cost according to the discharge and pumping head requirements and structure requirements for housing the equipment and providing proper flow conditions to the pump suction intake. The costs of pumps, housing, motors, and electrical controls were estimated using generalized cost data related to station horsepower derived from actual construction costs of equipment previously installed, escalated to mid-1994 prices. The costs of pump stations in treatment plants were estimated using the references cited and these costs are included in the cost tables for the treatment plants.

5. Pipeline. Pipeline construction costs are influenced by pipe materials, bedding requirements, geologic conditions, urbanization, terrain, and special crossings. The cost estimates include installed cost of pipeline and appurtenances, such as markers, valves, thrust restraint system, corrosion monitoring and control equipment, air and vacuum control valves, blow-off valves, erosion control, revegetation of rights-of-way, fencing, and gates. Costs of special crossings such as railroads, highways, and rivers were estimated on an individual basis.

Table 3.0-5
Water Treatment Plant Costs (Mid-1994 Prices)

Capacity (mgd) [acft/yr]	Level 1	Level 2	Level 3	Level 4
1 [1,120]	$ 505,000	$ 1,700,000	$ 2,400,000	$ 5,400,000
10 [11,200]	$ 2,100,000	$5,500,000	$ 6,800,000	$ 21,000,000
50 [56,000]	$ 6,100,000	$16,000,000	$23,000,000	$ 65,000,000
75 [84,000]	$ 8,800,000	$21,000,000	$33,000,000	$ 90,000,000
100 [112,000]	$10,782,000	$25,200,000	$40,000,000	$120,000,000
150 [168,000]	$16,500,000	$33,000,000	$60,000,000	$180,000,000
200 [224,000]	$19,000,000	$37,000,000	$74,000,000	$240,000,000

Note: Refer to Table 3.0-4 for description of treatment process levels.
Source: Adapted from "Handbook of Public Water Systems," 1986, by Culp/Wesner/Culp.

Table 3.0-6
Water Treatment Annual O&M Costs (Mid-1994 Prices)

Capacity (mgd) [acft/yr]	Level 1	Level 2	Level 3	Level 4
1 [1,120]	$ 100,000	$ 180,000	$ 225,000	$ 350,000
10 [11,200]	$ 560,000	$ 750,000	$ 880,000	$ 2,600,000
50 [56,000]	$ 2,100,000	$ 3,200,000	$ 3,600,000	$ 11,500,000
75 [84,000]	$ 3,200,000	$ 4,800,000	$ 5,600,000	$ 18,000,000
100 [112,000]	$ 3,950,000	$ 6,100,000	$ 7,000,000	$ 24,000,000
150 [168,000]	$ 6,400,000	$ 9,000,000	$10,000,000	$ 36,000,000
200 [224,000]	$ 7,500,000	$12,000,000	$13,000,000	$ 48,000,000

Note: Refer to Table 3.0-4 for description of treatment process levels.
Source: Adapted from "Handbook of Public Water Systems," 1986, by Culp/Wesner/Culp.

Table 3.0-7 includes estimated base pipeline costs per foot for pipeline sizes ranging from 18-inch to 120-inch diameter. The table includes costs based on soil construction (without rock) and rural environment. The costs shown represent the minimum cost range for pipelines.

Costs for specific applications are estimated by adding the increased cost of installation to the cost per foot shown in the table to compensate for geologic conditions such as rock and urbanization. Both of these items will also increase the time for construction.

6. Recovery Wells. The cost of recovery wells in the Carrizo-Wilcox aquifer were obtained from the report "Phase I Evaluation, Carrizo-Wilcox Aquifer, West Central Study Area, Trans-Texas Water Program," LBG-Guyton Associates, December, 1993. The cost is based on these conditions: (a) a standard 16x10-inch underreamed, 30-inch gravel-wall well; (b) well depth is approximately 1,200 feet with 400 feet of stainless steel screen; (c) the pump is a 250-horsepower electric turbine pump; (d) pumping levels would be approximately 400 feet below land surface at the end of 50 years of operation; and (e) well capacity is 1,000 to 1,500 gallons per minute (1,600 to 2,400 acft/yr). The estimated mid-1994 construction cost for the well, pump, motor, site improvements, and one mile of access road is about $570,000 per well.

7. Injection Wells. The cost of Edwards Aquifer recharge wells located in Medina County has been estimated based on a hypothetical average well design and discussion with drillers experienced in drilling Edwards wells of this size. This cost estimate is a reconnaissance level revision of similar cost estimates made by William F. Guyton Associates, Inc. in 1989 in conjunction with the W. E. Simpson Company, Inc., and presented in volume three of the report, "Medina Lake Study for the Edwards Underground Water District."

   For the purpose of estimating the cost of an Edwards Aquifer recharge well, it is assumed that injection could be accomplished with gravity head without plugging and without the need to pressurize the system above ground level. Other necessary facilities which are costed separately include storage and treatment facilities, transfer pipes, a transfer pump, and controls. The expected capacity of each injection well is 4,000 gallons per minute (6,500 acft/yr).

   The cost of a 1,300-foot pilot hole with a 8-3/4-inch minimum diameter and a 1,300-foot recharge well with a 22-inch minimum diameter is estimated to be about $430,000 at mid-1994. The estimate includes complete logging, 850 feet of pressure cemented casing, acid treatment, television survey, development pumping and testing appropriate for both the pilot hole and the recharge well. Site improvements and access roads are estimated to be $60,000 per well. The resulting total construction cost estimate per injection well is $490,000.

Table 3.0-7
Pipeline Costs

Size (inches)	Base Pipeline Cost[1], including Appurtenances ($/LF)
18	33
24	40
30	51
36	68
42	82
48	96
54	111
60	127
66	158
72	188
78	206
84	221
90	233
96	275
102	316
108	357
120	450

[1]Base pipeline cost is for low pressure pipe installed in a soil trench, rural environment. For other conditions (i.e., rock trench, medium or high pressure pipe class, and urban environment), costs were determined for the increased material and installation components, resulting in a cost factor multiplier to be applied to the base pipeline cost. Cost factors ranged from 1.0 to 2.25. Base pipeline costs obtained from Trans-Texas Corpus Christi Service Area Phase 1 Report, inflated to mid-1994.

8. Distribution System Improvements. The introduction of treated water supplies will require improvements to the distribution system of the City of San Antonio and/or other entities. A 1991 report to the City Water Board by Black and Veatch entitled, "Report on Master Plan for Water Works Improvements", included estimated costs for improvements to San Antonio's distribution system to convey treated water from the proposed Applewhite project. This report was used as a basis for estimating the cost of distribution system improvements to deliver treated surface water to the City's system. Using the Applewhite Phase 1 capacity of 50 mgd and water distribution cost of $51,750,000 (1991 cost) results in a mid-1994 cost of $0.31/1,000 gallons or $101 per acft for the first 50 mgd increment.

   For alternatives producing up to 50 mgd, the distribution costs are estimated at $0.31/1000 gallons. Above 50 mgd capacity, the unit cost is lower and specific costs have been determined from information provided in the 1991 report, for similar capacity delivery requirements.

Non-Structural Costs

The costs for engineering, administration, legal, environmental, land, O&M and interest during construction must be added to the construction costs to obtain the project capital cost. The following guides were used for estimating the costs of non-structural items and are common to all alternatives:

1. Engineering, contingencies, financial, and legal services were lumped together and estimated at 30 percent of total construction costs for pipelines and 35 percent for all other facilities. Construction costs include only the cost of building the project facilities and any relocations requiring construction contracts including plant, labor, and materials. Costs for land and rights-of-way, permits, environmental and archeological studies, and mitigation were estimated separately.

2. Land costs vary significantly with location and economic factors. Land costs for reservoirs were estimated by using appropriate costs per acre as obtained from local appraisal districts and include costs for legal services, sales commissions, and surveys in the cost per acre used.

3. Land costs for pipelines include a permanent easement plus a temporary construction easement plus rights to enter the easement for maintenance and repairs. For estimating pipeline rights-of-way cost, the cost was the full land value per acre based on purchase of the land as determined from discussions with the local appraisal districts plus legal, sales, and surveying costs. This full value was applied to a 40-foot permanent easement width for the length of the pipeline. This cost should be adequate to cover the cost of the permanent and temporary construction easements.

4. Permits, environmental studies, and environmental mitigation costs were estimated on an individual project basis utilizing information available and judgment of qualified professionals. In the case of reservoir options, the mitigation costs are based on acreage of each project times the cost per acre to purchase an equal land area.

5. Debt service for all projects was calculated assuming an annual interest rate of 8 percent and a repayment period of 25 years (i.e., debt service factor of 0.0937) applied to total estimated project costs including interest during construction. Interest during construction was calculated assuming the total estimated project cost (excluding interest during construction) will be drawn down at a constant rate per month during the construction period. Interest during construction is the total of interest accrued at the end of the construction period using an 8 percent annual interest rate less 4 percent for investment of available funds; i.e., interest during construction is the average annual project cost for the construction period times the net annual interest rate of 4 percent times the number of years required to construct the facilities.

6. Operation and maintenance costs (O&M)

   a. *Dams, Pump Stations, and Pipelines* - (not including power costs for pumping). Annual O&M costs were calculated at 1.0 percent of the total estimated construction cost for pipelines, 2.5 percent of total estimated construction costs for pump stations, and 1.5 percent of total estimated construction costs for dams. These costs include labor and materials required to maintain the project and regular replacement of equipment. In addition to these costs, power costs were calculated on an annual basis using the appropriate calculated power load and a power rate of $0.06 per kilowatt-hour. Table 3.0-8 lists the elevations of each potential water source and the four primary delivery locations.

   b. *Water Treatment Plants* - Table 3.0-6 contains annual O&M costs which include labor, materials, replacement of equipment, process energy, building energy, chemicals and pumping energy.

7. Presentation of Estimates. Each individual alternative discussion includes cost estimates showing annual total cost and cost per acft of water supplied for each alternative.

Table 3.0-8 Summary of Source and Delivery Elevations	
Potential Water Sources	
Alternative	**Elevation (feet)**
L-11 Exchange Reclaimed Water for Edwards Irrigation Water	410
L-12 Exchange Reclaimed Water for BMA Medina Lake Water	410
L-13 Reclaimed Water Reuse	410
L-14 Transfer of Reclaimed Water to Corpus Christi-Diversion from San Antonio River to Choke Canyon	325
S-13 Medina Lake	900
S-14 Applewhite Reservoir	536
S-15 Cibolo Reservoir	416
S-16 Goliad Reservoir	200
G-13 San Marcos River	520
G-14 Guadalupe River at Lake Dunlap	575
G-15 Canyon Lake (Released to Lake Dunlap)	575
G-16 Cuero Reservoir	242
G-17 Lindenau Reservoir	244
G-18 McFaddin Reservoir	52
C-13 Lake Travis (Delivered to Lake Austin)	492
C-17 Colorado River Delivery at Columbus	180
C-18 Shaws Bend Reservoir	180
B-10 Brazos River- Allens Creek Reservoir	75
SB-10 Sabine River- Toledo Bend Reservoir	175
SBB-10 Sabine and Brazos Rivers	75 and 175
CZ-10 Carrizo Aquifer	Pump lift from 400 feet below ground surface. Ground surface ranges from 375 to 570 ft-msl.
Potential Delivery Locations	
Location	**Elevation**
Injection Well Field	830-900
Recharge Structures	1050-1100
South Water Treatment Plant	540
North Water Treatment Plant	1000

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3.1 Demand Reduction (L-10)

A major public policy objective is to increase water conservation and reduce freshwater use within an area without adversely affecting the area's population and economic growth potentials. The general methods to accomplish this objective are to: (1) reduce per capita water use in the municipal water use category; (2) recycle and reuse, industrial water and substitute treated municipal and industrial wastewater for use in some industries, steam-electric power generation, and irrigation applications; and (3) reduce the quantity of water use in agriculture per acre irrigated. Specific methods of water conservation for municipal and agricultural water use categories will be described below. In addition, estimates will be made of the water conservation potentials and associated costs of each municipal and agricultural water conservation method. The descriptions and analyses are based upon surveys and studies that have been sponsored by the Texas Water Development Board (TWDB), and by other organizations, some of which are in other states having similar conditions and problems. Recycling and reuse of reclaimed water is being evaluated in Sections 3.2, 3.3, and 3.4 of this report.

3.1.1 Municipal Water Conservation

Municipal water, as described in Section 2.2, is freshwater that has been treated to drinking water standards by both public and private water utilities and is supplied to private individuals for direct use by people in and around their homes, and to businesses, commercial establishments and public entities for direct and indirect use by people within commercial and business establishments such as restaurants, offices, laundries, car washes, schools, churches, theaters, hospitals, hotels, motels, and other places of business, and for use by government agencies for fire protection, public place sanitation and recreation, including public swimming pools and irrigation of parks and public areas. The quantity of water used within a typical city or water supply service area for the purposes listed above is expressed in terms of number of gallons per person per day (per capita water use). The objective of municipal water conservation programs is to reduce the per capita water use parameter without adversely affecting the quality of life of the people involved. This can be done by use of plumbing fixtures such as toilets, shower heads, and faucets which are designed for low quantities of flow per unit of use, by the selection and use of more efficient water using appliances such as clothes washers and dishwashers, by modifying lawn and landscaping systems to use grass and plants which require less water, by repair of plumbing and water using appliances to reduce leaks, and by modification of personal behavior which controls the use of plumbing fixtures, appliances, and lawn watering methods.

With respect to plumbing fixtures, in 1991 the Texas Legislature enacted legislation (Senate Bill 587) which established minimum standards for plumbing fixtures sold within Texas[61]. The bill became effective on January 1, 1992 and allowed until January 1, 1993 for wholesalers and retailers to clear existing inventories of pre-standards plumbing fixtures. The standards for new plumbing fixtures, as specified by Senate Bill 587, are as follows:

Fixture	Standard
Wall Mounted Flushometer Toilets	2.00 gallons per flush
All Other Toilets	1.60 gallons per flush
Shower Heads	2.75 gallons per minute at 80 psi
Urinals	1.00 gallons per flush
Faucet Aerators	2.20 gallons per minute at 80 psi
Drinking Water Fountains	Shall be self-closing

The Texas Natural Resource Conservation Commission (TNRCC) has promulgated rules requiring the labeling of both plumbing fixtures and water using appliances sold in Texas. The labels must specify the rates of flow for plumbing fixtures and lawn sprinklers, and the amounts of water used per cycle for clothes washers and dishwashers[62].

The TWDB has estimated that the effect of the new plumbing fixtures in dwellings, offices, and public places will be a reduction in per capita water use of 18 gallons per person

[61]Senate Bill 587, Texas Legislature, Regular Session, 1991, Austin, Texas.

[62]Chapter 290. 30 TAC Sections 290.251, 290,253 - 290.256, 290.260, 290.265, 290.266. Water Hygiene. Texas Register. December 24, 1993. Page 9935.

per day in comparison to what would have occurred with the previous generations of plumbing fixtures[63]. The estimated water conservation effect of 18 gallons per person per day was obtained as follows:

Plumbing Fixture	Water Savings (gallons per person per day)
Toilets -- 1.6 gal/flush	11.5 gallons
Shower Heads -- 2.75 gal/minute	4.0 gallons
Faucet Aerators -- 2.2 gal/minute	2.0 gallons
Urinals -- 1.0 gal/minute	0.3 gallons
Drinking Fountains (self-closing)	0.1 gallons
Total	17.9 (18 GPCD)

The TWDB estimates that the use of the new plumbing fixtures in new construction and in normal replacement of fixtures in existing structures will phase in this conservation effect within Texas by the year 2020. The per capita conservation effects in new construction and normal replacements, when averaged over the entire population, would result in one-third of the savings being realized by year 2000, two-thirds being realized by year 2010, and the final one-third being realized by 2020. These rates were factored into the municipal water demand projections presented in Section 2.0. For example, without the new plumbing fixtures, as required by Senate Bill 587, the municipal water demand projections of Section 2.2.1 would have been six gallons per person per day higher in year 2000, 12 gallons per person per day higher in 2010, and 18 gallons per person per day higher in 2020, 2030, 2040, and 2050. It is further assumed that efficient water using appliances will be used in new construction and in replacement of existing appliances. In addition to the conservative effects of plumbing fixtures, the effects of efficient water using appliances and local water conservation programs were used by the TWDB to make further reductions in projections of municipal water demands of Section 2.2.1.

Given that the water conservation effects of new, low flow plumbing fixtures and more efficient water using appliances will be phased in over the next 25 to 27 years through

[63] "Water Conservation Impacts on Per Capita Water Use," Unpublished Water Planning Information, Texas Water Development Board, Austin, Texas 1992.

the installation of these fixtures and appliances in new construction and replacement of existing fixtures and appliances, it is the purpose of the analyses in this section to identify and evaluate water conservation potentials and estimate costs of specific efforts and programs to gain additional municipal sector water conservation to that which is expected to be phased in, as described above. The following water conservation methods were evaluated (1) public information and education; (2) incentive programs; (3) conservation pricing; (4) leak detection; (5) conservation landscaping; (6) retrofit plumbing fixtures; and (7) gray water use for watering lawns and landscaping.

(1) Public Information and Education

An important and key element to accomplishing water conservation is to inform water users about ways to save water both inside homes and other structures, in landscaping and lawn watering, and in recreation uses. Among the methods for communication of water conservation information are television, radio, and newspaper announcements and advertisements, public displays, bill inserts, brochures, pamphlets, and public and private school curricula to teach conservation to each generation of students.

Public information and education can work in two ways to accomplish water conservation. One way is to inform water users of ways to manage and operate existing and new fixtures and appliances so that less water is used. This includes ideas and practices such as washing full loads of clothes and dishes, using a pail of water instead of a flowing hose to wash automobiles, turning the water off while brushing one's teeth, washing one's hands, or shaving, and watering lawns, gardens, and shrubs during evening as opposed to daytime hours.

A second way public information and education can work to conserve water is to inform and convince water users to obtain and use water efficient plumbing fixtures and appliances, to adopt low water use landscaping plans and plants, to find and repair plumbing leaks, to use gray water for permissible uses such as lawn and shrubbery watering where regulations allow it, and to take advantage of water conservation incentives where available.

It is estimated that, water conservation information programs which communicate to the public through news media and "advertising efforts" and through the schools, has the potential to reduce water use by 1.5 gallons per person per day[64]. The costs of such programs usually run about $0.50 per person per year.

(2) Conservation Incentives

Conservation incentives include factors such as conservation pricing, rebates to water customers to replace existing plumbing fixtures with low flow fixtures, and to replace present landscapes and lawn grasses with xeriscapes and low water using plants and turf grasses. The potential water savings and costs of these conservation measures are incorporated into the retrofit and conservation landscaping measures described below.

(3) Conservation Pricing

The consumer demand for water for municipal purposes is influenced by a number of factors including the price of water and the income levels of the consumers. Over certain ranges of water use, as price increases, the quantity of water used is expected to decline, for a given level of income, when other things such as plumbing fixtures and landscaping arrangements remain unchanged. In a 1991 TWDB study, price and income elasticities of water demand were estimated for each of the 28 Metropolitan Statistical Areas (MSA's) of Texas.[65] For the San Antonio MSA, price elasticity of demand for municipal water use was estimated at -0.22, which means that a 10 percent increase in the price of water would cause a 2.2 percent reduction in use of water, and a 5 percent increase would cause a 1.1 percent reduction, other things such as income held equal. Income elasticity of demand for municipal water in the San Antonio MSA was estimated at 0.94, which means that for a 10 percent increase in income, municipal water use would increase 9.4 percent. Holloway estimated per capita income growth for the San Antonio MSA at 1.2 percent per year during the 1980's. Thus, the positive income effect (income elasticity and per capita income growth) is offsetting one-half of the potential negative price effect of a given municipal

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[64] "Hays County Water and Wastewater Study," Hays County Water Development Board, San Marcos, Texas, May, 1989.

[65] "Understanding Trends in Texas Per Capita Water Consumption," Holloway, M.L., and Bob S. Ball, Southwest Econometrics, Austin, Texas, 1991.

water price increase. For example, so long as per capita income continues to increase at 1.2 percent per year, a 10 percent municipal water price increase would cause only a 1.1 percent reduction in per capita municipal water demand (0.94 x 1.2 = 1.1 percent increase in demand due to income increase of 1.2 percent). If water price is increased by 10 percent, water demand would decline by 2.2 percent. The sum of the income affect and the price effect is (1.1 - 2.2 = - 1.1 percent). Another way of looking at this is that, assuming per capita income continues to increase at 1.2 percent per year, about a 5 percent increase in water rates is required each year to offset the effects of rising income on per capita water use.

(4) Leak Detection and Repair

Where dripping faucets, and leaking showers are found, replacement of valve seats and washers or, if necessary, replacement of leaking parts will reduce per capita water use. Where toilets are flowing because flapper valves are worn or fail to seat properly, replacement of the faulty parts will also save water. The savings from repairing leaks are estimated at 2.2 gallons per person per day.[66]

(5) Conservation Landscaping

Replacement of existing lawns and landscaping with more drought tolerant species, i.e., replacing St. Augustine grass with Buffalo Grass (609 Buffalo Grass or Prairie Buffalo Grass) will reduce per capita water use. The xeriscape technique is estimated to reduce lawn water use by 30 percent.[67] Rebates to homeowners of $0.05 per square foot for replacing St. Augustine with Buffalo grass, with a per dwelling unit limit of $500 is estimated to result in water savings of 10 gallons per person per day[68].

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[66] "City of Austin Report for Water Conservation Plan", Montgomery Watson, Austin, Texas, March, 1993.

[67] "City of Austin Report for Water Conservation Plan," Montgomery Watson, Austin, Texas, March, 1993.

[68] "City of Austin Report for Water Conservation Plan," Montgomery Watson, March, 1993.

(6) Retrofit Plumbing Fixtures

The principal elements of retrofitting plumbing fixtures are the addition of faucet aerators, replacement of shower heads with low flow fixtures, replacement of existing toilets with 1.6 gallon per flush units, and replacement of urinals in public buildings with 1.0 gallons per flush units. The combined savings of retrofitting these fixtures are a reduction in per capita water use of 17.8 gallons at a per person cost of $150.

(7) Gray Water Use for Watering Lawns and Landscaping

This measure requires separate plumbing systems for use of gray water for subsurface irrigation. The technique is being used successfully in unincorporated areas, but is not approved by regulatory agencies for use in cities. Due to the lack of data, it is not possible to estimate the water conservation potentials of this conservation measure, however, the use of reclaimed water for industrial and agricultural purposes is considered in Sections 3.2, 3.3, and 3.4.

(8) Estimated Water Conservation Potentials and Costs

A water conservation program which includes: (1) public information and education; (2) incentives and rebates; (3) conservation pricing; (4) leak detection and repair; (5) landscaping retrofit; and (6) plumbing fixtures retrofit is estimated to reduce municipal water use in the study area by 28 gallons per person per day (Table 3.1-1). This rate would apply to the dwellings of the area in 1993 at the time the plumbing fixtures act became effective. The estimated 33-county study area population in 1993 was 2,869,164 (Table 2-1, based on interpolation between 1990 and 2000). Thus, the potential municipal water conservation from the water conservation program listed above would be about 90,000 acft/yr when fully implemented. Of this total, about 50.5 percent or 45,450 acft would be in the Edwards Aquifer area, since 50.5 percent of the study area population resides in the aquifer area.

It is estimated that the cost of landscaping changes and retrofitting plumbing fixtures to achieve this 28 gallons in per capita reduction in municipal water use would be a per capita outlay in rebates of $11.47 per person per year for a period of eight years, resulting

Table 3.1-1
Potential Additional Water Conservation and Costs[*]
Edwards Aquifer Area
West Central Area -- Trans-Texas Water Program

Conservation Measure	Water Savings: Stand Alone[a] (gpcd)	Water Savings: Combined Measures[b] (gpcd)	Annual Cost Per Person[f] ($)
(1) Public Information and Education	2.0	---	0.174
(2) Conservation Incentives[c]	---	---	---
(3) Conservation Pricing[d]	2.0	---	---
(4) Water Audits Leak Detection and Repair[e]	2.2	---	0.827
(5) Conservation Landscaping	10.0	10.0	0.825
(6) Retrofit Plumbing Fixtures	17.8	17.8	9.642
TOTAL	34.0[*]	27.8	$11.468

[*]In addition to conservation effects already included in water demand projections in Section 2.0.
[a]It is the only conservation measure being used; not additive.
[b]When included as part of conservation program of six conservation measures.
[c]Needed for adoption of other conservation measures.
[d]Assuming a 10 percent price increase with price elasticity of demand at -0.2; income elasticity of demand of 0.94; and income increase of 1.2 percent per year.
[e]Residential, commercial, and manufacturing establishments.
[f]Expressed on a per person basis from computations of water conservation costs of "City of Austin Water Conservation Plan," March 1993, and "San Antonio Water Resources Plan," July 1988.

in a 1994 cost per acre foot of water saved of $272 ($11.47 per person per year for eight years with an interest rate during implementation of four percent, and a capital recovery analysis which assumes an eight percent rate of return on invested capital for a period of 25 years)[69] (Tables 3.1-1 and 3.1-2). (Note: Estimates are thought to have a margin of error of plus or minus 20 percent.)

The costs of water saved through the use of "Best Management Practices" (education, water audits, and retrofit of plumbing and landscaping) in Southern California was estimated at $202 per acre foot[70].

3.1.2 Irrigation Water Conservation

Irrigation water, as described in Section 2.2, is freshwater that is pumped from aquifers and/or diverted from streams and lakes of the study area and applied directly to produce crops, orchards, and hay and pasture in the study area. In the case of groundwater, the irrigation wells are usually located within the fields to be irrigated such that the irrigation water is taken directly from the wells and applied to the land by: (1) flowing water down the furrows, and by (2) sprinklers. In the case of surface water from study area streams and lakes, water is diverted from the source and conveyed by canals and pipelines to the fields where it is then applied by: (1) flowing water down the furrows, and (2) sprinklers. In both the use of groundwater and surface water, the conservation objective is to reduce the quantity of water that is lost to deep percolation, evaporation and evapotranspiration between the originating points (wells in the case of groundwater and 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 between the originating points of the water and the destination locations within the irrigated fields. The principal methods of irrigation water conservation

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[69]"City of Austin Report for Water Conservation Plan," Montgomery Watson, March 1993, with retrofit cost adjustments using cost information, as appropriate, from "San Antonio Water Resources Plan," San Antonio, Texas, July, 1988.

[70]"Assessment of Water Savings from Best Management Practices," Metropolitan Water District of Southern California, Brown and Caldwell Consultants, February, 1991.

Table 3.1-2
Estimated Costs to Retrofit Plumbing Fixtures of a Typical Residence
West Central Trans-Texas Study Area

Items	Number	Costs	
		Unit[a]	Total[a]
Showers and Lavatories			
Low Flow Showerheads	2	$8.91[b]	$17.82
Faucet Aerators	3	1.40[c]	4.20
Adm./Labor/Info.	1	8.50[d]	8.50
Subtotal			$30.52
Toilet Replacements			
Commodes	2	104.76[e]	$209.52
Promotion/Info.	1	10.00[d]	10.00
Disposal	2	10.00[d]	20.00
Adm./Labor/Info.	1	90.00[c]	90.00
Subtotal			$329.52
TOTAL			$360.04
Number of Persons per unit is 2.4			

[a]Includes sales tax at eight percent.
[b]Retail prices range from $2.72 to $13.87 per unit. The price chosen is for a chrome fixture judged to be suitable for most settings.
[c]Retail prices range from $1.19 to $1.60 per unit. The mid-priced fixture was chosen.
[d]"Assessment of Water Savings from Best Management Practices", Metropolitan Water District of Southern California, Brown and Caldwell, February 1991 (San Jose, California experience).
[e]Retail prices range from $77.00 to $288.00 per unit without the seat. It is assumed that seats from existing units can be transferred to new units.

are: (1) low pressure sprinklers; (2) low energy precision application systems (LEPA); (3) surge irrigation; (4) furrow diking; and (5) land leveling and irrigation scheduling. In comparison to the irrigation method (furrow irrigation) of releasing the water into the furrows at the ends of the rows and allowing it to flow across the fields until each furrow has been saturated throughout its entire length, the use of sprinklers, LEPA, surge valves, furrow diking, land leveling, and irrigation scheduling improves application efficiency within the irrigated fields and thereby reduces the total quantity of water needed to produce an irrigated crop.

Given that the TWDB irrigation water demand projections for the West Central Study Area (Edwards Aquifer, Winter Garden, and Gulf Coast areas) have already incorporated significant decreases in irrigation usage through conservation, the potentials for additional conservation may be quite limited. For example, the TWDB irrigation demand projections for the Edwards Aquifer area are 27 percent less in 2020 than in 1990; projections for the Winter Garden counties are 28 percent less by 2020; and projections for the Gulf Coast counties of the Colorado and Guadalupe Basins are 32 percent less in 2020 than was used in 1990. Given that the technological limits of irrigation conservation potential are in the range of reducing water use per acre by 20 to 40 percent, the objectives of increased water conservation above that which is included in the TWDB projections would be to achieve the results at an earlier date, i.e., by 2005 instead of 2020. For the Edwards Aquifer area, the estimated additional water savings above the TWDB projections are 11,240 acft at the year 2005. For the Winter Garden area, the estimated potential additional conservation savings at year 2005 are 20,240 acft/yr. No estimates are given for the Gulf Coast areas since the technology available to that area may not permit achievement of the goals of additional conservation beyond that of TWDB projections for that area. Water conservation methods are described below.

Low pressure sprinklers spray water into the atmosphere above the crops as the sprinkler systems are moved across the fields. 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, which hold both precipitation and sprinkler applied water behind small mounds of earth within the furrows, LEPA and other sprinkler systems can accomplish the irrigation objective with less water than is required for the furrow irrigation method. (Note: Furrow dikes are constructed by towing the furrow diking implement behind planters or cultivators when these operations are performed. The furrow dikes hold water in place within the furrows, allowing it to infiltrate the soil profile as opposed to allowing the water to flow down the furrows and exiting the fields. Furrow dikes have been demonstrated to be useful management tools on both irrigated and non-irrigated cropland.)

Surge irrigation is an alternative method of irrigation, in which water is released from pipes by surge valves located at the head of the furrows as in furrow irrigation methods. The difference between furrow irrigation and surge irrigation is that surge valves allow the flow into the furrows for a period of time (usually 30 minutes to an hour) and then switch the water stream into the adjoining furrow for a period of time. This allows the water to soak into the furrow length which has just been wetted while the neighboring furrow is being watered. On the next cycle, the water stream is switched back to the original furrow where it is discharged into the previously wetted furrow section. On the second, third, and subsequent cycles, the water stream flows over the previously wetted sections much faster and with less deep percolation than if the stream of water had been continuously discharged into the furrow until the entire length had been wetted. In short, the alternation between rows reduces intake rates and increases advance rate which can be managed to reduce deep percolation. Although surge valves and furrow dikes cannot be used within the same row or furrow, furrow dikes and surge valves are sometimes used in alternate furrows.

Low pressure sprinklers and surge valves improve irrigation application efficiency in comparison to furrow irrigation by reducing water requirements per acre in the 10 to 15 percent range, while LEPA combined with furrow diking can reduce water requirements per acre by 30 to 40 percent. In the Edwards Aquifer area, conversion from furrow irrigation to LEPA systems with furrow diking would save about 0.8 acft per acre converted[71]. Use of LEPA and furrow dikes would allow irrigation farmers to produce equivalent yields per acre at lower energy and labor costs of irrigation; i.e., it has been demonstrated that LEPA

[71] "Irrigation Water Use Conservation Potential and the Economic Implications of Adopting More Efficient Irrigation Technology, the Case in Uvalde County," Water for South Texas, Pena, Jose G., and Robert Jenson, Texas Agricultural Experiment Station, Texas A & M University, College Station, Texas, CPR - 5043-5046, October, 1992.

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 in the Edwards Aquifer from the investment would be available to the irrigation farmer who incurred the costs. However, under the Edwards Aquifer Authority's regulatory powers, the water conservation investor could be assured ownership of the conservation savings.

Costs of capital equipment for surge irrigation (valves, piping, and controls) range from $12.50 to $18.75 per acre.[72] The conservation potentials of surge irrigation are to reduce irrigation water use per acre by 10 percent to 20 percent, depending upon soil type, when compared to furrow irrigation. Since the 1984/1989 average irrigation rate per acre was estimated at 2.53 acft (Section 3.6) the water conservation potential of surge irrigation is estimated to range between 0.25 acft and 0.50 acft/acre, which would not be adequate to accomplish the water conservation goals, as projected. Thus, surge irrigation was not given further consideration.

To accomplish the goals of achieving the irrigation conservation potential within the Edwards Aquifer area by year 2005 instead of the TWDB projected year 2020, it would be necessary to install LEPA systems with furrow dikes, or an equivalent conservation method, by year 2005 to an additional 14,050 acres of the area's 120,000 irrigated acres. It is estimated that LEPA systems with furrow dikes could accomplish this level of additional conservation. The capital cost per acre to install LEPA irrigation systems and furrow diking is approximately $325, for a total investment of $4.75 million to equip 14,050 acres. Such an investment is expected to have a life expectancy of 25 years and would save 11,240 acft of water per year at a cost of $38 per acft saved, (for bond financing at eight percent for 25 years). The water saved could represent either a reduction in withdrawals from the Edwards Aquifer or be sold to other entities for their use.

For the Winter Garden area, the potential additional conservation to that projected by the TWDB is 20,040 acft, which would require that an additional 25,050 acres be equipped with LEPA or equivalent conservation systems by 2005. At a cost of $325 per acre

[72]Estimates of costs of irrigation conservation equipment, High Plains Underground Water Conservation District, No. 1, Lubbock, Texas, February, 1994.

for LEPA systems, a water savings of 0.8 acft per acre, eight percent interest and a 25-year recovery of the investment, the cost of water saved would also be $38 per acft. The water saved would contribute to reducing the rate of decline of the Carrizo aquifer from which the Winter Garden area obtains its water supply, since the water would be left in the aquifer for withdrawal at a later date. Although transmissivity of the Carrizo aquifer is much less than that of the Edwards, there is concern that water saved and left in the aquifer via irrigation conservation investments could be lost to neighboring areas.

3.1.3 Water Demand Reduction Summary

The TWDB's high case population and water demand projections, with conservation, for the West Central Study Area are shown in Section 2.0. Potential quantities and associated costs of municipal and agricultural water conservation programs that might be used to reduce the projected water demand of the area are summarized below.

Municipal Demand Reduction

In the case of municipal water demand projections, the TWDB has taken into account the water conservation potentials of the Texas "Plumbing Fixtures Standards Act" of 1991, which establishes maximum flow rates for plumbing fixtures sold in Texas after January 1, 1993. TWDB has estimated that the installation of the low flow plumbing fixtures in new homes, businesses, and public buildings and when replacing fixtures in existing buildings beginning in 1993 will result in a reduction of per capita water use of six gallons per person per day by year 2000, 12 gallons per person per day by 2010, and 18 gallons per person per day by 2020. These water conservation rates were used by TWDB in making the municipal water demand projections shown in Section 2.0; i.e., the municipal water conservation effects of the 1991 Texas Plumbing Fixtures Standards Act have been phased into the municipal water demand projections. The analyses of Section 3.0 pertain to the potentials for further reductions in per capita municipal water use through an organized and funded water conservation program which includes: (1) public information and education; (2) conservation incentives; (3) conservation pricing; (4) leak detection and repair; (5) conservation landscaping; and (6) retrofit of plumbing fixtures of dwellings in existence in 1993, i.e., the population growth after 1993 would be living in dwellings in which the new plumbing fixtures will have been installed. It is estimated that a municipal water conservation program that includes the six water conservation measures listed above could reduce municipal water demand in the study area by 28 gallons per person per day, in addition to the 18 gallons per person per day that is now included in the TWDB municipal water demand projections. This rate, of course, only applies to the 1993 population, which is estimated at 2.87 million. In terms of overall effect within the study area, such a program is estimated to have the potential to reduce municipal water demand (high case, with conservation) by 90,000 acft per year when fully implemented. It is estimated that cost per person per year for the municipal water conservation program outlined above would be $11.47 for a period of eight years, resulting in a cost per acft of water saved of $272 (1994 prices at eight percent on invested capital for 25 years).

Irrigation Demand Reduction

In the case of irrigation water demand, the TWDB projections for the Edwards Aquifer and Winter Garden areas are about 27 percent less in 2020 than was reported to have been used in 1990, and for the Gulf Coast area are 32 percent less. Given that the technological potentials for irrigation conservation per acre are in the 20 to 40 percent range, and the TWDB projections include much of this potential, the objectives of increased agricultural irrigation water conservation above that included in the TWDB projections would be to achieve the results at an earlier date, say by 2005 instead of 2020.

In the Edwards Aquifer area, LEPA systems, combined with furrow diking, is estimated to save 0.8 acft per acre irrigated in comparison to water required for furrow irrigation. Thus, to accomplish the goals of achieving the irrigation conservation potential within the Edwards Aquifer area by year 2005, it would be necessary to install LEPA systems with furrow dikes, or an equivalent conservation method by year 2005, to an additional 14,050 acres of the area's 120,000 irrigated acres. The estimated water savings per year, in addition to that already projected by TWDB for 2005, would be 11,240 at a cost of $38 per acft saved. For the Edwards Aquifer area, the water saved could, if the regulatory powers of SB1477 are applied, represent either a reduction in withdrawals from the Edwards Aquifer or be sold to another entity.

For the Winter Garden area, the potential additional conservation above that projected by TWDB is 20,040 acft, which would require that an additional 25,050 acres be equipped with LEPA or equivalent conservation systems by 2005. The cost of water saved would also be $38 per acft. The water saved could contribute to reducing the rate of decline of the Carrizo aquifer from which the Winter Garden area obtains its water supply, since the water would be left in the aquifer for withdrawal at a later date. Although transmissivity of the Carrizo aquifer is much less than that of the Edwards, there is concern that water saved and left in the aquifer via irrigation conservation investments could be lost to neighboring areas.

3.1.6 Implementation

Success of demand reduction policies will depend on the degree of acceptance by water users, especially with respect to conservation pricing, retrofit of plumbing fixtures, and conservation landscaping. Uncertainty about the effect of demand reduction is present due to the unknown rate at which these policies can be implemented and accepted, and the magnitude of the resulting water savings.

The implementation of demand reduction will reduce the volume of return flows, and uncertainty will be present in the planning of reclaimed water treatment facilities, as well as on the future availability of return flows for river base flow.

Acceptance by water users, especially with respect to conservation pricing is a crucial issue to the implementation of demand reduction policies.

3.2 Exchange Reclaimed Water for Edwards Irrigation Water (L-11)

3.2.1 Description of Alternative

Edwards Aquifer water usage could be reduced by replacing water pumped for irrigation with reclaimed water obtained from municipal wastewater treatment plants. In Bexar and Medina counties, approximately 45,000 acres are irrigated with groundwater, of which approximately 39,000 acres is supplied by the Edwards Aquifer. Reclaimed water, with no additional treatment, is suitable for irrigation of livestock feed, fiber, and forage crops, including cotton, hay, pasture, corn, and pecans. Without some additional treatment, the application of reclaimed water is unsuitable for use on vegetables and fruits for human consumption. Of the total acreage irrigated with Edwards water, approximately 80 percent is planted in crops suitable for reclaimed water irrigation, or 31,000 acres. Using an average annual irrigation application rate of 2 acft/ac, the total irrigation demand on the aquifer in these two counties is 78,000 acft/yr, of which 62,000 acft/yr is for crops suitable for irrigation with reclaimed water.

The availability of reclaimed water to be transferred to irrigated farms and displace aquifer pumpage has been studied for reclaimed water sources exceeding 5,000 acft/yr. Three sources of reclaimed water in Bexar and Medina counties have been identified that produce more than 5,000 acft/yr: Dos Rios Wastewater Treatment Plant (WWTP), Salado Creek WWTP, and Leon Creek WWTP. Plant capacities and 1988 total discharge is listed in Table 3.2-1. Other sources of reclaimed water in the study area are estimated to exceed 5,000 acft/yr by the year 2050, but currently produce less and those sources were not considered in detail in this Phase I study. Those sources are: Saltrillo, Martinez 1, and Martinez 2 owned by the San Antonio River Authority; Medio WWTP owned by the City of San Antonio; and, Cibolo Creek Municipal Authority (Schertz). Table 3.2-2 contains the 1988 return flows for selected small treatment plants in the San Antonio area.

To implement this alternative, reclaimed water would be diverted from inside the Dos Rios WWTP to a pump station and pipeline which would convey the water to Braunig and Calaveras lakes. A pump station would supply a distribution system to the agricultural areas using irrigation in southern and western Bexar County and eastern Medina County. Because of the required pumping head, an intermediate pump station and storage facility

Table 3.2-1
Reclaimed Water Flows

Plant Name (capacity, acft/yr)	1988 Flows (acft)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Dos Rios WWTP (93,000)	6,752	6,357	6,757	6,419	6,472	6,383	6,433	6,719	6,392	6,652	6,915	6,912	79,163
Salado Creek WWTP (40,000)	1,953	2,048	2,598	2,487	2,579	2,855	3,055	2,941	2,689	2,703	2,579	2,662	31,149
Leon Creek WWTP (39,000)	2,279	2,101	2,265	2,192	2,063	2,183	2,332	1,761	1,818	2,280	2,271	2,230	25,775
Total (172,000)	10,984	10,506	11,620	11,098	11,114	11,421	11,820	11,421	10,899	11,635	11,765	11,804	136,087
	Future Water Flows (acft)[1]												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Combined Plant Flows[2]	13,700	13,100	14,500	13,900	13,900	14,200	14,800	14,300	13,600	14,500	14,700	14,800	170,000

[1] Source: Alamo Water Conservation and Reuse District; "Master Plan - 1991"; May 15, 1991.
[2] For study purposes, the increase in future reclaimed water flow from the basins served by Dos Rios, Leon Creek, and Salado Creek plants is assumed be available for reuse at the Dos Rios plant.

Table 3.2-2
1988 Return Flows for Small Treatment Plants -
San Antonio Metro Area

Plant Name (Owner)	1988 Total Return Flow (acft)
Medio Creek (SAWS)	2,550
Martinez I (SARA)	1,690
Martinez II (SARA)	140
Saltrillo (SARA)	3,010
Cibolo Creek Municipal Authority	2,690
Bexar County WCID 16	490
Kelly AFB Plant 1	1,370
Kelly AFB Plant 2	10
Kelly AFB Plant 3	10
Kelly AFB Plant 4	10
Lackland AFB	210
TOTAL	12,180

is needed in the vicinity of Castroville. At the end of the transmission line, a standpipe would be constructed to provide a small amount of elevated storage and reliable pump control and operation. The location of the facilities are shown on Figure 3.2-1.

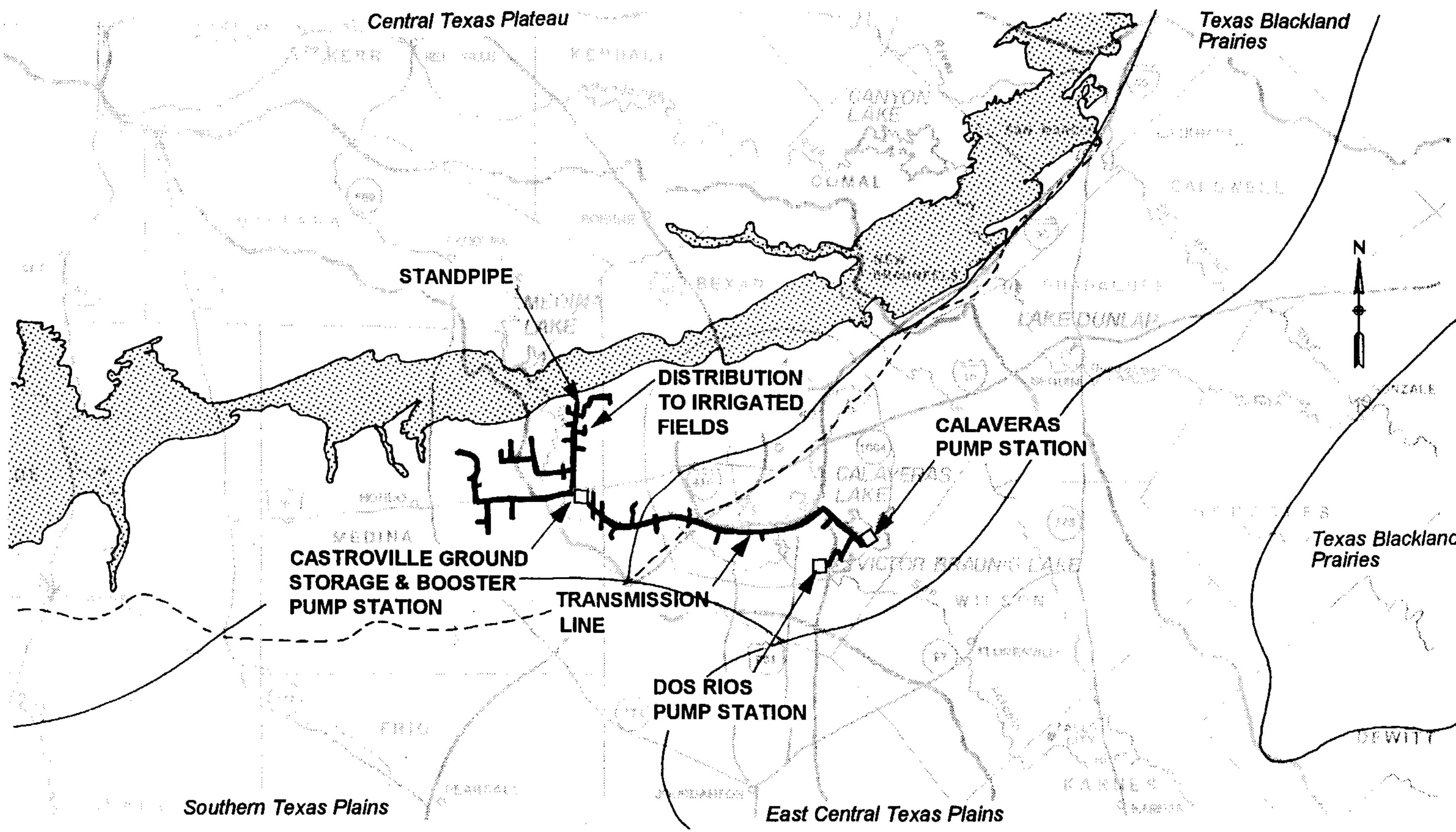
3.2.2 Available Yield

The 1988 and estimated future reclaimed water flow discharged from the three major San Antonio WWTPs is listed in Table 3.2-1. Currently, the only use of reclaimed effluent from the City of San Antonio treatment plants is to supply cooling water to the steam-electric plants at Braunig and Calaveras lakes. However, the Central East Infrastructure Project (i.e., "Tunnel Project") is under construction and, for purposes of analysis for this alternative, is considered an existing demand for reclaimed water.

The availability of reclaimed water for diversion at the treatment plant can be determined by subtracting the requirements of the current uses and instream flow requirements from the available supply. However, for the following reasons, a direct annual average availability calculation cannot be made: the Braunig/Calaveras demand is partially satisfied by surface water runoff from the drainage area contributing to the cooling lakes; the Braunig project has surface water rights that are not tied to reclaimed water return flow; the Calaveras project river diversion rights are tied totally to return flows; and, Braunig and Calaveras each have usable storage that must be modeled for natural and forced evaporation. Therefore, the Guadalupe-San Antonio Basin Model (GSA Model)[73], in conjunction with postprocessing spreadsheet analysis, was used to determine reclaimed water availability. The GSA Model and spreadsheets were used to determine what amount of reclaimed water was necessary to meet Braunig and Calaveras cooling water needs and to satisfy current instream flow requirements. Current instream flow requirements were determined from the TNRCC Braunig Lake diversion permit[74], the CPS Streamflow

[73]HDR Engineering, Inc., "Guadalupe-San Antonio River Basin Recharge Enhancement Study," Edwards Underground Water District, September, 1993.

[74]TNRCC Permit No. 1990 and Diversion No. D-0250.



Legend
- Basin Divide
- Edwards Aquifer Recharge Zone
- "Bad Water" Line
- Ecoregion
- Pipeline Route

0 10 20 Miles
Scale

HDR

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

EXCHANGE RECLAIMED WATER FOR EDWARDS IRRIGATION WATER ALTERNATIVE L-11

FIGURE 3.2-1

Withdrawal Management Plan[75], and a draft of the 1988 Water Resources Plan[76]. The Braunig Lake permit requires a minimum instantaneous flow of 10 cfs at the Elmendorf gage at all times of the year. The CPS Streamflow Withdrawal Management Plan requires a 50 cfs minimum flow from June through September, calculated on a monthly basis. The 1988 Water Resources Plan contains a minimum desirable target flow of 55,000 acft/yr at the Falls City gage and the resulting total annual flow at the Falls City gage was compared to this target.

Net availability was determined by subtracting the various needs from the supply. From these results, the 56-year average, 10-year drought average, and minimum year water availabilities were determined. The modeling parameters used to determine water availability are contained in Table 3.2-4.

Water potentially available on an annual basis at various diversion rates for current return flows and for future estimated return flows are presented in Figure 3.2-2. Table 3.2-3 indicates monthly availability of reclaimed water for a maximum diversion rate of 12,000

Table 3.2-3
Reclaimed Water Availability - Current Return Flows[1]

	Estimated Reclaimed Water Availability (acft)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average for Period of Record	8,859	8,505	7,051	6,861	7,349	5,345	3,087	3,232	5,242	6,807	7,550	7,394	77,282
Drought Average, 1947-56	8,082	7,933	6,290	5,939	6,287	2,858	1,722	1,913	3,833	5,519	6,442	6,852	63,670
Minimum Year, 1956	7,069	8,766	4,898	3,231	5,587	50	0	0	87	3,394	5,234	5,522	43,838

[1] Using 136,000 acft/yr, return flows; year 1988; diversion rate of 12,000 acft/month.

[75]"Streamflow Withdrawal Management Plan"; CPS; no date.

[76]Joint Committee on Water Resources; "San Antonio Regional Water Resources Plan"; July, 1988.

Table 3.2-4
Guadalupe - San Antonio Basin Modeling Parameters - Alternative L-11

Analysis Point:	**San Antonio River @ Elmendorf, USGS Gage 1818**			
Minimum Flow Requirements: Month	Instream Flow Requirement at Analysis Point		Bay & Estuary Inflow Requirement at Salt Water Barrier	
	(acft/mo)	(cfs)	(acft/mo)	(cfs)
Jan	615	10	N/A	N/A
Feb	555	10	N/A	N/A
Mar	615	10	N/A	N/A
Apr	595	10	N/A	N/A
May	615	10	N/A	N/A
Jun	2,975	50	N/A	N/A
Jul	3,075	50	N/A	N/A
Aug	3,075	50	N/A	N/A
Sep	2,975	50	N/A	N/A
Oct	615	10	N/A	N/A
Nov	595	10	N/A	N/A
Dec	615	10	N/A	N/A
Flow Requirements Based On:	Oct-May: TNRCC Permit Restriction; Jun-Sept: CPS Streamflow Withdrawal Management Plan; Annual comparison to 1988 Regional Water Resources Plan			
Edwards Aquifer Pumpage:	400,000 acft/yr			
Return Flows:				
Surface Water Sources:	1988 Actual			
Groundwater Sources:	For Run #1 1988 Actual and for Run #2 Estimated Future			
Tunnel Reuse Project:	Included			
Water Rights:				
Canyon Lake:	50,000 acft/yr			
Hydro Requirement at Lake Dunlap:	600 cfs			
Applewhite Reservoir:	Excluded			
Other Rights:	Full Authorized Amounts			
Steam-electric Diversions:				
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)			
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)			
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)			
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)			
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)			
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)			

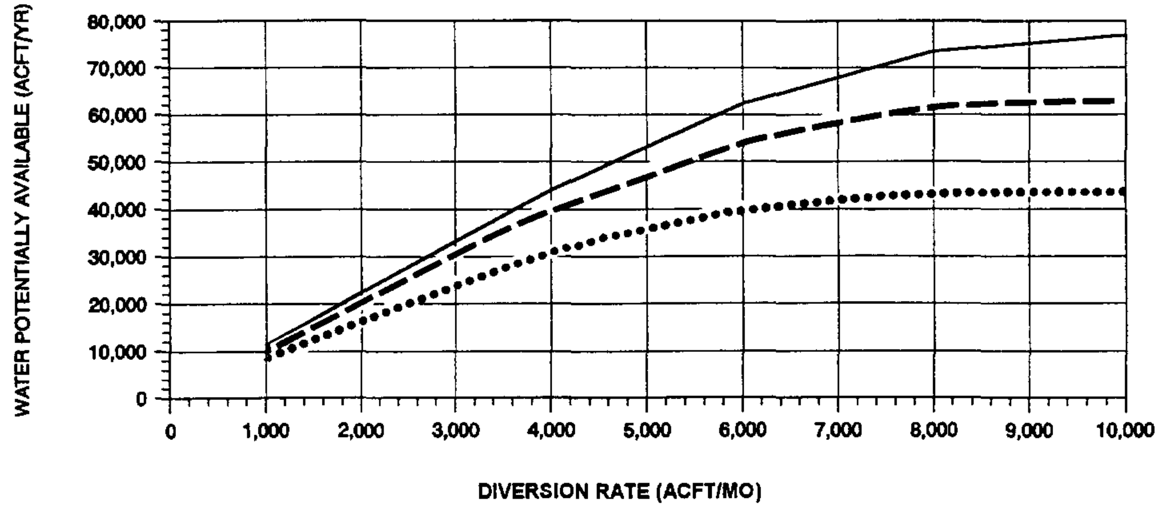
Water Availability for 1988 Return Flows for Run #1 — Annual Water Availability

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	11,000	10,000	8,000
3,000	33,000	31,000	24,000
5,000	53,000	47,000	35,000
7,000	68,000	59,000	42,000
10,000	77,000	63,670	43,838
12,000	77,282	63,670	43,838

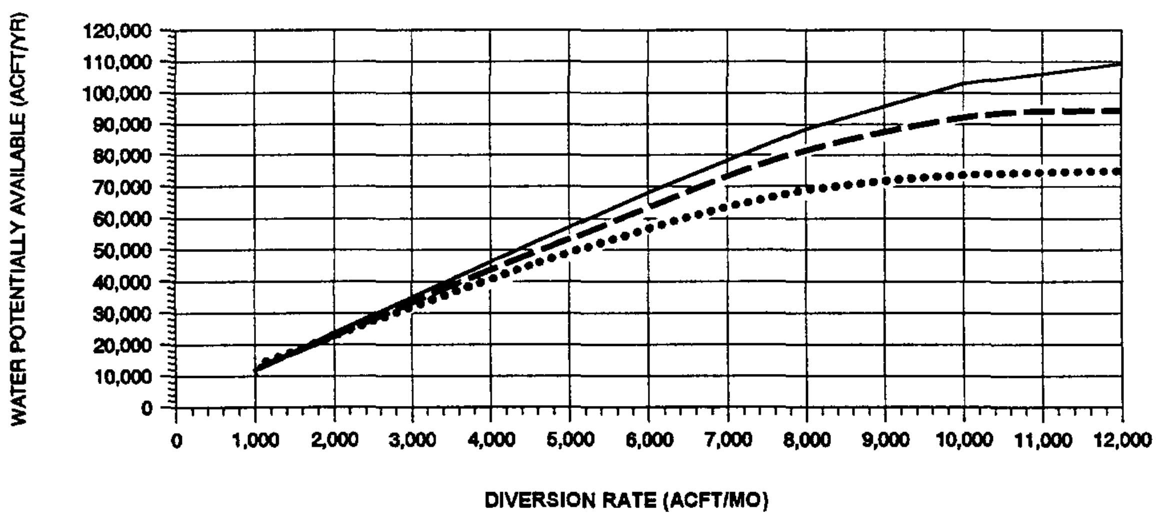
Water Availability for Future Return Flows for Run #2

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	12,000	12,000	12,000
3,000	35,000	34,000	33,000
5,000	57,000	54,000	49,000
7,000	78,000	73,000	63,000
10,000	103,000	92,000	73,000
12,000	109,000	95,000	74,000
14,800	110,266	95,478	74,371

TOTAL RETURN FLOW = 136,087 ACFT/YR



TOTAL RETURN FLOW = 170,000 ACFT/YR



LEGEND

AVERAGE CONDITIONS, 1934-89

DROUGHT AVERAGE, 1947-56

MINIMUM YEAR

TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

HDR Engineering, Inc.

RECLAIMED WATER POTENTIALLY AVAILABLE FOR REUSE ALTERNATIVES L-11, L-12, L-13

FIGURE 3.2-2

acft/month at current return flows. Table 3.2-5 contains the monthly availability values for future estimated return flows at a maximum diversion rate of 14,800 acft/month.

Table 3.2-5
Reclaimed Water Availability - Future Estimated Return Flows[1]

	Estimated Reclaimed Water Availability (acft)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average for Period of Record	11,684	11,331	9,877	9,688	10,175	8,128	5,427	5,701	8,025	9,633	10,377	10,220	110,266
Drought Average, 1947-56	10,908	10,759	9,116	8,765	9,113	5,532	3,622	3,784	6,588	8,345	9,268	9,678	95,478
Minimum Year, 1956	11,099	9,157	7,436	7,852	9,033	2,707	992	877	2,109	7,114	8,327	7,668	74,371

[1] Using 170,000 acft/yr, future estimated annual return flows; 14,800 acft/month diversion rate

For conceptual design and costing, an irrigation system was developed utilizing future estimated return flows for the minimum year, which is consistent with the firm yield methodology used for analysis of other alternatives.

3.2.3 Environmental Issues

Alternative L-11, Exchanging Reclaimed Water for Edwards Aquifer Irrigation Water (Figure 3.2-1), described in the preceding sections, includes a 35-mile water transmission line to irrigated cropland in Medina County. The land use and habitats in the project area reflect its location at the confluence of the Blackland Prairie, Southern Texas Plains, and the East Central Plains Ecoregions. The pipeline traverses the Southern Texas Plains ecoregion and Blairs Tamaulipan Biotic Province (Figures 3.0-1, 3.0-2, 3.0-3)[77,78,79]. The proposed irrigation area is cropland[80], south of Medina Lake, where the Edward's Plateau Ecoregion (or the corresponding Balconian Biotic Province) meets the northern portion of the Southern Texas Plains (Figures 3.0-1 and 3.0-3).

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[77]Omernik, James M. 1987. "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1) pp. 118-125.

[78]Gould, F. W. 1975. The Grasses of Texas, Texas A & M University Press, College Station, Texas.

[79]Blair, W. F. 1950. "The biotic provinces of Texas," Texas Journal of Science 2(1): pp.93-117.

[80]USGS. 1990. NAPP black and white aerial photography. EROS Data Center, Sioux Falls, SD.

The soils of this area range from clay to sandy loams, with pH ranges from basic to slightly acidic. Beginning in the eastern portion, there are deep loamy sands, sandy clay, and deep calcareous clayey soils. Characteristic grasses of sandy loam soils are seacoast bluestem, tanglehead, longspike silver bluestem, big sandbur, and species of bristlegrass, paspalum, chloris, and bunch grasses. Towards the western portion of the transmission line the soil types change from moderately deep and very shallow clayey soils over chalk and marl to shallow and very shallow soils over limestone[81]. The main vegetation types in this area consist of agricultural crops and uncultivated shrubland.

Because Lakes Calaveras and Braunig, with normal storage capacities of 63,200 and 26,500 acre feet, respectively, receive drainage only from the adjacent small agricultural drainages, substantial amounts of water must be diverted from the San Antonio River below its confluence with the Medina River to fill the lakes and compensate for forced evaporation[82,83]. The San Antonio River is heavily influenced by treated wastewater discharges and urban run-off.

Because both lakes currently experience high levels of nutrient loading and exhibit corresponding high levels of primary and secondary production[84]; the additional nutrient loading that would result from increased wastewater inputs is not expected to alter lacustrine aquatic communities. Phytoplankton standing crops have been observed to be extremely high throughout the annual cycle in both lakes, while nitrogen and phosphorus concentrations also remained high; indicating that further stimulation of primary production by increasing nutrient levels is not likely[11]. Episodes of prolonged stratification, localized algal blooms, and dissolved oxygen depletion appear to be suppressed by the continuous mixing driven by cooling flows in each lake. The high ambient concentrations of oxygen demanding materials in the two lakes indicates that input of treated wastewater exhibiting

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[81]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1991. Soil Survey of Bexar County, Texas. USDA.

[82]Gonzales, M. April 1994. Personal Communication. San Antonio River Authority, San Antonio, Texas.

[83]Paul Price. 1989. Seasonal Study of Lake Calaveras and Braunig Lake Phytoplankton Assemblages; Technical report to City Public Services, San Antonio, Texas. Paul Price Assoc. Inc. Austin, Texas.

[84]Ibid.

a BOD_5 on the order of 5 mg/l is also unlikely to result in substantial additional problems with dissolved oxygen.

Because the volumes of water proposed for storage and transfer through these two lakes is large compared to their volumes (38,000 acre feet/year, about 42 percent of combined capacity), the resulting change in residence time may have some effect on nutrient utilization and plankton dynamics that could have wider consequences. Lakes Calaveras and Braunig are culturally enriched and intensively managed artificial systems that presently support a popular and productive sport fishery that includes largemouth and hybrid striped bass, channel and flathead catfish, and numerous other, peripheral species. Assessments of impacts in future phases of the Trans Texas Water Program should include consideration of the potential effects on sportfish production.

The vertebrate fauna present within the proposed area potentially includes neotropical and grassland species, and some species typical of the Chihuahuan Biotic Province. Sixty-one species of mammals occur, or have occurred in this region, along with 36 species of snakes, 19 lizards, 2 land turtles, 3 urodeles, and 19 anurans[85]. However, the historic overgrazing and extensive cultivation has left little habitat for species other than those tolerant of development. The longterm effects of landuse and agricultural practices on wildlife within this general vicinity has been addressed somewhat in the environmental studies prepared for the Applewhite Reservoir and discussed in Section 3.14.3 of this report.

The 35-mile water transmission line from Calaveras and Braunig Lakes to the northern portion of Medina County will result in the disturbance of about 861 acres (Table 3.0-1) during construction. Of this area, about half of the land is cropland and an estimated 30 percent is shrubland. The extent of impacts to wildlife habitats and regional populations will depend largely on the amount of upland shrub and riparian vegetation disturbed by construction and transmission line corridor maintenance activities; but, destruction of wildlife habitat can be avoided in most areas by appropriate siting of the pipeline ROW. Maintenance of a pipeline ROW requires periodic clearing and removal of woody vegetation. Although a pipeline corridor traversing woodland or shrub habitat can provide edge habitat beneficial to some wildlife, where these areas are small and fragmented, additional disturbance should be avoided where practical.

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

Although the Natural Heritage Program does not report any endangered or threatened species directly along the proposed pipeline corridor, some have been reported in the vicinity (Appendix B, Tables 6, 37 and 50). Many of these, such as the Texas tortoise, the reticulate collared lizard, the Texas horned lizard, and the indigo snake, appear to be dependent on shrubland or riparian habitat. The Texas garter snake may be present in wetland habitats (see Table 3.2-6). Surveys for protected species or other biological resources of restricted distribution, or other importance, would be conducted within the proposed construction corridor where potential habitat is present.

The irrigation area in Medina County is not within or upstream of the Edwards Aquifer Recharge Zone (Figure 3.2-1), so irrigating this area with treated effluent is unlikely to affect Edwards Aquifer subterranean species (Table 3.2-6; Appendix B, Table 50). The troglobitic Toothless Blindcat and the Widemouth Blindcat were collected from deep artesian wells in Bexar County located east of the irrigation area and north of the "bad water" line (Fig. 3.2-1)[86,87].

The proposed pipeline corridor and irrigation areas are in the vicinity of significant prehistoric Indian sites and historical sites that are meaningful to the history of Spanish Colonial Texas, the Texas Republic, and early statehood. In Castroville, near the Medina County irrigation area, the Landmark Inn State Historical Park and Castroville Historic District are listed on the National Register of Historic Sites (Table 3.0-1). Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL 96-515), and the Archaeological and Historic Preservation Act (PL 93-291). All areas to be disturbed during construction will be surveyed by qualified professionals for the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

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[86]Longley, G. The biota of the Edwards Aquifer and the implications for Paleozoogeography *in* : Abbott, P.L. and C.M. Woodruff, Jr., editors, 1986. The Balcones Escarpment, Central Texas. Geological Society of America. pp 51-54.

[87]TPWD. 1993. Unpublished data files, Natural Heritage Program, Texas Parks and Wildlife Department, Austin, Texas.

Table 3.2-6
Important Species With Habitats in the Project Vicinity (L-11)

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Texas Tortoise[1]	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T
Reticulate Collared Lizard[1]	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush[1]	NL	T
Texas Horned Lizard[1]	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T
Indigo Snake[1]	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Texas Garter Snake[1]	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL
Blind Texas Salamander	*Typhlomolge rathbuni*	Edwards Aquifer springs and caves, thermally stable; troglobitic	E	E
Toothless Blindcat	*Trogloglanis pattersoni*	Edwards Aquifer; subterranean; from artesian wells in Bexar Co., TX; troglobitic[2]	C2	T
Widemouth Blindcat	*Satan eurystomus*	Edwards Aquifer; subterranean; from artesian wells in Bexar Co., TX; troglobitic[2,3]	C2	T
Texas Cave Diving Beetle	*Haideoporus texanus*	Edwards Aquifer subterranean caverns[4,5,6,7]	C2	NL
Balcones Cave Amphipod	*Stigobromus balconis*	Limestone caves[7]	C2	NL
Bifurcated Cave Amphipod	*Stigobromus bifurcatus*	Spring openings[7] ; Edwards Aquifer subterranean	C2	NL
Texas Cave Shrimp	*Palaemonetes antrorum*	Ezell's Cave and Edwards Aquifer subterranean caverns[5,7]	C2	NL
Mimic Cave Snail	*Phreatodrobia imitata*	Edwards Aquifer subterranean caverns; from artesian wells in Bexar Co., TX; troglobitic[8]	C2	NL

Source: TPWD. Unpublished Texas Natural Heritage Program. Texas Parks and Wildlife, Austin, Texas.
[1]Dixon, J.R. 1987. Amphibians and Reptiles of Texas. Texas A&M Press, College Station, Texas.
[2]Longley, G. and H. Karnei, Jr. 1979a. Status of Satan eurystomus Hubbs and Bailey, the widemouth blindcat. U.S. Fish and Wildlife Services, Endangered species Report 5.
[3]Longley, G. and H. Karnei, Jr. 1979b. Status of Trogloglanis pattersoni Eigenmann, the toothless blindcat. U.S. Fish and Wildlife Service, Endangered species Report 5.
[4]Elliot, W.R. (Bill) Ph.D., personal communication, 1993. Research Associate, Texas Memorial Museum, The University of Texas at Austin. Austin, Texas.
[5]Sissom, S.L.& J.C. Davis. 1979. A monographic study of Ezell's Cave, Hays County, Texas. U.S. Department of the Interior and Nature Conservancy. Contract # 14-16-0002-090. 141pp.
[6]Longley, G. and F.N. Young. 1976. A new subterranean aquatic beetle from Texas (Coleoptera: Dytiscidae-Hydropoorinae). Annals of the Entomological Society of American 69(5):787-792.
[7]Reddell, James, personal communication, 1993. Research Associate (Curator of Arthropods), Texas Memorial Museum, The University of Texas at Austin.
[8]Hershler R. and G. Longley, 1986. Malacologia. 27:127-172.

Implementation of this alternative is expected to require field surveys for vegetation, habitats, and cultural resources during ROW and reservoir site selection to avoid or minimize impacts. When potential protected species habitat, or significant resources cannot be avoided, additional studies would have to be conducted to evaluate habitat use, or eligibility for inclusion in the National Register for Historic Places, respectively. Wetland impacts, primarily pipeline stream crossings, would have to be minimized by ROW selection, appropriate construction methods, including erosion controls and revegetation procedures. Unavoidable impacts involving net losses of wetlands would have to be compensated.

3.2.4 Water Quality and Treatment

[To be completed in future phases of the study.]

3.2.5 Engineering and Costing

A monthly irrigation demand distribution was determined from BMA canal diversion records and applied to an initial trial irrigation demand of 40,000 acft/yr as shown in Table 3.2-7. Table 3.2-7 provides a comparison of monthly water availability (determined from the GSA Model) to the irrigation demand and shows that a net deficit of water exists from June through September of 14,435 acft. Therefore, to create a project with a firm yield of 40,000 acft, storage of at least 14,435 acft must be provided to deliver water from months with excess to the deficit months. In 1990, the City Water Board commissioned a study[88] of reuse options at Dos Rios WWTP and part of the resulting plan included the possible use of limited storage in Braunig and Calaveras Lakes. The potential storage considered in Braunig and Calaveras Lakes is limited to the top three feet of the reservoirs, which is the operational range of the cooling water pumps in the power plants at each lake. The storage capacity in this portion of Braunig is 3,700 acft, and in Calaveras is 9,656 acft, for a total of 13,365 acft. Because the use of this existing storage is much more economical than the construction of a new reservoir, it was decided to analyze the yield of the system using potentially available Braunig and Calaveras storage. Table 3.2-8 is a computation of the firm yield of this alternative using the 13,365 acft of storage in the two lakes. It compares

[88]Black & Veatch Engineers; "Water Management Plan Using Braunig and Calaveras Lake"; 1990.

Table 3.2-7 Monthly Irrigation Demand and Availability				
Month	Monthly Demand Distribution[1] (percent)	Monthly Demand of All Non-Food Acreage[2] (acft/month)	Minimum Year Reclaimed Water Availability[3] (acft/month)	Reclaimed Water Surplus [Deficit] (acft)
January	3.0	1,200	4,000	2,800
February	3.5	1,400	4,000	2,600
March	7.1	2,840	4,000	1,160
April	8.6	3,440	4,000	560
May	9.9	3,960	4,000	40
June	13.9	5,560	2,707	[2,853]
July	15.4	6,160	992	[5,168]
August	14.7	5,880	877	[5,003]
September	8.8	3,520	2,109	[1,411]
October	6.8	2,720	4,000	1,280
November	4.4	1,760	4,000	2,240
December	3.9	1,560	4,000	2,440
Total	100.0	40,000	38,685	[1,315]

[1]Average monthly distribution determined from measured BMA canal diversions, 1956-89.
[2]Calculated monthly demand = Monthly Demand Percentage x 40,000 acft/yr.
[3]Using future estimated return flows; diversion rate = 4,000 acft/month (43 mgd).

Table 3.2-8 Reclaimed Water Firm Yield													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Reclaimed Water Availability[1] (acft)	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	2,707	992	877	2,109	38,685
Monthly Irrigation Demand (acft)	2,584	1,672	1,482	1,140	1,330	2,698	3,268	3,762	5,282	5,852	5,586	3,344	38,000
Monthly Surplus [Deficit] (acft)	1,416	2,328	2,518	2,860	2,670	1,302	732	238	(2,575)	(4,860)	(4,709)	(1,235)	
Accumulated Surplus [Deficit][2] (acft)	1,416	3,744	6,262	9,122	11,792	13,094	13,365	13,365	10,790	5,930	1,221	(14)	

[1]Using future estimated return flows of 170,000 acft/yr; Minimum Year condition; diversion rate of 4,000 acft/month (43 mgd)
[2]Accumulated surplus is limited by storage capacity of Braunig and Calaveras Lakes (13,365 acft).

monthly reclaimed water availability to irrigation demand and shows the monthly surplus or deficit as well as an accumulated surplus/deficit. The table shows that beginning in October, a monthly surplus of water occurs and, that by about April or May, storage reaches its maximum until it is totally depleted by September. This analysis shows that the resulting firm yield of this system, using the limited storage space potentially available in Braunig and Calaveras lakes, is about 38,000 acft/yr.

The target instream flow requirement established in the draft 1988 Regional Water Resources Plan is 55,000 acft per year at the Falls City gage. For 1988 return flows and a reuse diversion rate at the plant of 4,000 acft/month, the instream flow target is met every year with the exception of 1954, when the annual flow passing the Falls City gage would have been 44,000 acft under this alternative. Annual flows would have totaled about 73,000 acft in 1954 without the additional reuse diversion. It is important to note, however, that no reuse diversions would have occurred in any case during the peak summer months of June through September in 1954, because all return flows were needed to meet demands for in-stream flow and cooling. For future return flows and a diversion rate of 4,000 acft/month, the minimum year annual flow is 68,700 acft at Falls City. Consideration of this alternative in later phases will require more detailed hydrologic study to address the required monthly distribution of annual instream flows and possible additional storage requirements to meet summer reuse demands.

The cost to implement this alternative includes the capital cost of the Dos Rios pump station, Calaveras Lake high service pump station, transmission line, Castroville storage and booster pump station, standpipe, lateral distribution lines, and right-of-way for the transmission and distribution lines. Operating costs include the electricity consumed by the pump station, and O&M costs of each of the components.

The Dos Rios diversion pump station cost was determined for a firm pumping capacity of 4,000 acft/month (43 mgd) and the operating cost is dictated by the pumping head created by pipe friction in a 54-inch diameter pipe and the static head of 140 feet. The Calaveras high service pump station cost was determined for a firm pumping capacity of 5,900 acft/month (63 mgd) and the operating cost is dictated by the pumping head created by pipe friction in a 66-inch diameter pipe and the static head of 300 feet, discharging into a storage tank at the Castroville booster pump station. The storage tank capacity is 2 million gallons which is 5 percent of the daily pumping capacity of the Castroville station. The Castroville booster pump station cost was determined for a firm pumping capacity of 3,600 acft/month (39 mgd) and the operating cost is dictated by the pumping head created by pipe friction in a 48-inch diameter pipe and the static head of 200 feet. The standpipe is sized for 15-minutes of storage above a static pressure head of 20-psi at ground elevation at the end of the transmission line.

This alternative project displaces groundwater usage that is widely distributed on farms that currently obtain irrigation water from wells serving individual farms and fields. For analysis, the typical Edwards farm irrigation well is assumed to supply water at a typical irrigation application rate of 10 gpm/acre. To displace existing groundwater usage, reclaimed water must be distributed to each individual irrigation unit (i.e., farm field) at an equivalent rate. Therefore, the distribution system will be an extensive system of pipelines, the smallest of which will be about 12 inches in diameter, discharging at a central point in the field. The transmission lines and pump stations for this alternative, however, are sized for delivery of the peak month demand, resulting in a net capability of only about 2.3 gpm/acre if applied over the entire acreage. Therefore, to meet irrigation flow requirements of 10 gpm/acre, a rotation schedule will have to be implemented whereby each field could receive up to one water application every five days during the highest use month. The capital and O&M cost estimate for this alternative are contained in Table 3.2-9 and show that the unit cost of water for this alternative is about $469 per acft assuming there is no cost involved in obtaining the wastewater flows from SAWS.

3.2.6 Implementation Issues

The degree of success of the Demand Reduction effort (see Alt. L-10) will affect the quantity of reclaimed water available for reuse options; i.e., a successful demand reduction effort will reduce the quantity of reclaimed water available for on-farm use. The implementation of this alternative will be influenced by the degree of acceptance of irrigators, considering that the new irrigation supply is constrained in delivery capability and will require a coordination of an application schedule, all of which is contrasted to the current supply which is under the control of the farmer.

Table 3.2-9 Cost Estimate Summary for Exchange Reclaimed Water for Edwards Irrigation Water (L-11) (Mid - 1994 Prices)	
Item	**Estimated Cost**
Capital Costs	
Transmission Line	$47,390,000
Distribution Line	28,490,000
Dos Rios Pump Station	2,890,000
Calaveras Lake Pump Station	6,510,000
Castroville Pump Station, including Ground Storage	5,060,000
Total Capital Cost	$90,340,000
Engineering, Contingencies and Legal Costs	27,760,000
Land Acquisition	440,000
Environmental Studies and Mitigation	540,000
Interest During Construction	8,730,000
Total Project Cost	$127,810,000
Annual Costs	
Annual Debt Service	$11,980,000
Annual Operation and Maintenance	1,670,000
Annual Power Cost	4,180,000
Total Annual Cost	$17,830,000
Available Project Yield (acft/yr)	38,000
Annual Cost of Water	$469/acft

Other items:

1. Use of reclaimed water restricts farmers to planting non-food crops, possibly resulting in potential lost revenue from lower value crops;
2. Edwards supply has higher on-demand capacity and is more readily available, but requires cash outlays to purchase electricity and maintain pumps and wells.
3. Reuse of reclaimed water reduces return flows to the San Antonio River, consequently reducing base flows.
4. Increased monitoring of water quality above current discharge permit requirements may be required for crop application reuse.
5. Until a regional authority exists to regulate aquifer pumpage, the exchange of reclaimed water for irrigation water or the purchase of irrigation rights will not necessarily reduce demand on the aquifer.
6. Studies Needed:

Monthly Demand Distribution;
Acceptable Irrigation Rotation Schedules;
Vegetation, Habitat, and Cultural Resource Surveys; and
Impact on Sportfish Production in Braunig and Calaveras.

7. Required Permits:
   a. Amendment of current direct discharge permit to a Chapter 310 Use of Reclaimed Water permit; and
   b. Texas Historical Commission permit.

If the Policy Management Committee decides to move forward with further consideration of this water supply alternative, the necessary Phase II studies will require more detailed hydrologic study to address the required monthly demand distribution as well as requirements for monthly and annual instream flows and possible additional storage requirements to meet summer reuse demands.

3.3 Exchange Reclaimed Water for BMA Medina Lake Water (L-12)

3.3.1 Description of Alternative

Medina Lake, located to the west of San Antonio in Medina County, is owned and operated by the Bexar-Medina-Atascosa Counties Water Control and Improvement District (BMA). Privately financed and constructed in the early 1900's, Medina Lake supplies irrigation water to portions of Bexar, Medina, and Atascosa counties. BMA holds a permit to divert up to 66,000 acft/yr into a canal system which supplies local irrigators, however, the current annual irrigation demand supplied by BMA is approximately 35,000 acft/yr[89] (see Section 3.13 for information about Medina Lake water supply). If this irrigation demand were met from other potential water sources, Medina Lake water could be used in other alternatives as a potential supply. The potential uses of Medina Lake water are described in Section 3.13.

Reclaimed water is suitable for irrigation of livestock feed, fiber, and forage crops, including cotton, hay, pasture, corn, and pecans. Unsuitable crops for application of reclaimed water are vegetables and fruits for human consumption. Recent surveys[90] indicate that 18,090 acres are irrigated with BMA water, and it is assumed approximately 80 percent, or 14,500 acres are planted in crops suitable for reclaimed water irrigation. Using an average annual irrigation application rate of 2 acft/ac, the total irrigation demand for BMA water is 36,000 acft/yr, of which 29,000 acft/yr is for crops suitable for irrigation with reclaimed water.

As described in Section 3.2.1 (Alternative L-11), reclaimed water availability has been determined for the three largest City of San Antonio treatment plants (i.e., Dos Rios Wastewater Treatment Plant (WWTP), Salado Creek WWTP, and Leon Creek WWTP). To implement this alternative, reclaimed water would be diverted inside the Dos Rios WWTP with a new pump station discharging to Braunig and Calaveras lakes or to a new storage reservoir. From the storage reservoir, a pump station would supply water through

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[89] Sullivan, Michael P.; "Conditional Probability Methods Used to Determine Regional Water Supply Options for South Bexar County and the Medina Valley"; December 1993.

[90] TWDB Irrigated Acreage Maps in association with Texas State Soil and Water Conservation Board and SCS County Work Units.

a transmission line that discharges into the BMA canal at the Highway 471 crossing, four miles southwest of LaCoste. The location of the proposed facilities are shown on Figure 3.3-1 and 3.3-2.

3.3.2 Available Yield

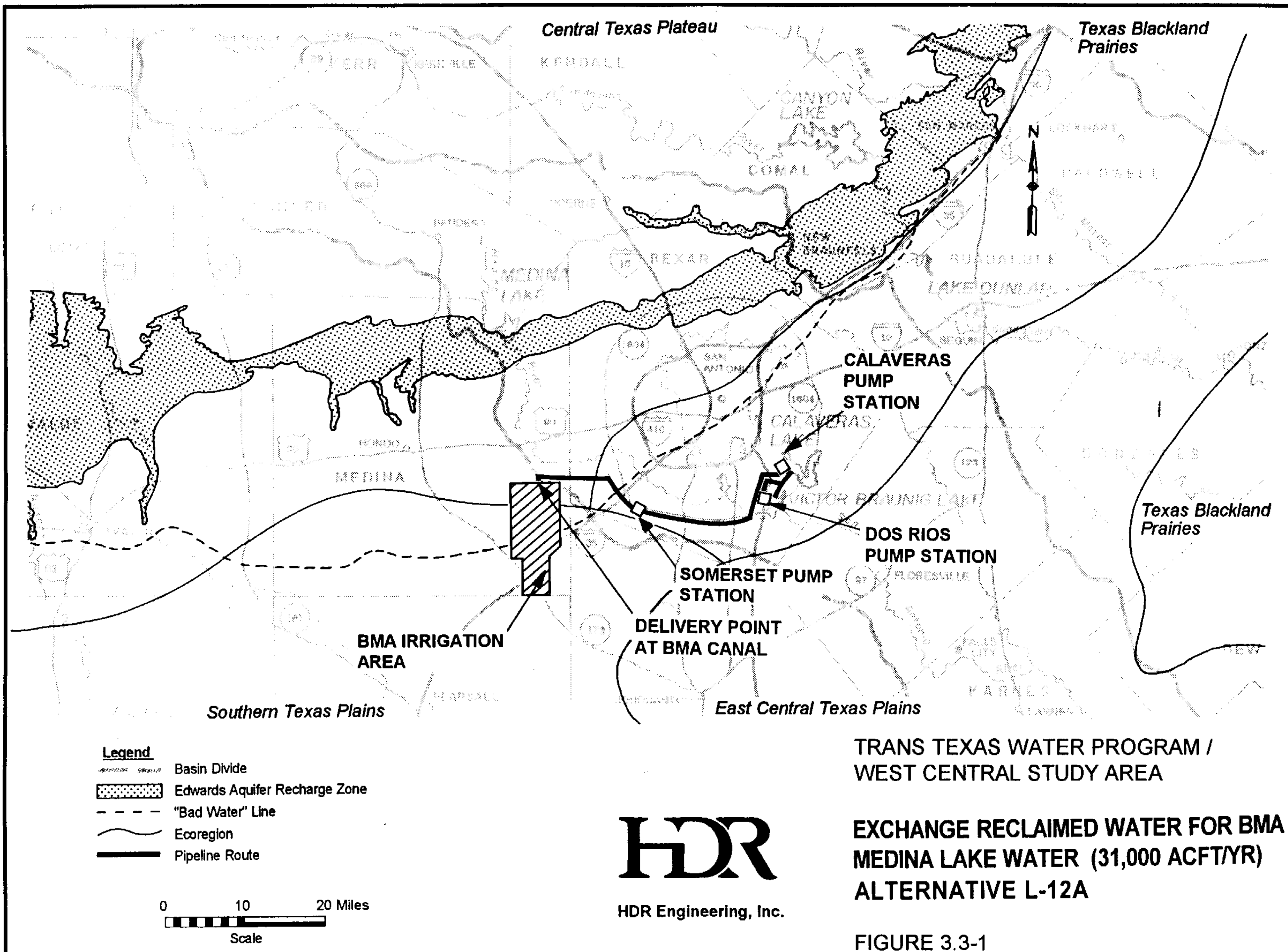
The quantity of reclaimed water available for reuse is the same for this alternative as for Alternative L-11 (Exchange of Reclaimed Water with Edwards Irrigation Water) and is described in Section 3.2.1. Figure 3.2-1 provides an estimate of reclaimed water potentially available on an annual basis at various diversion rates for current and future estimated return flows. For conceptual design and costing, two alternative plans for yield and required storage have been developed:

Plan A — Firm Yield to Supply Current Irrigation. Using future return flows, and potential usable storage in Braunig and Calaveras lakes, provide 29,000 acft/yr of firm supply to the non-food crop irrigation area. This meets the full irrigation requirement, on a firm basis, of the non-food crops in the BMA service area (see Figure 3.3-1).

Plan B — Firm Yield to Supply Full Diversion Rights. Using future return flows, adequate storage would be provided in a new off-channel reservoir to provide a firm yield of 66,000 acft/yr. This quantity is equal to the full BMA water right (see Figure 3.3-2).

3.3.3 Environmental Issues

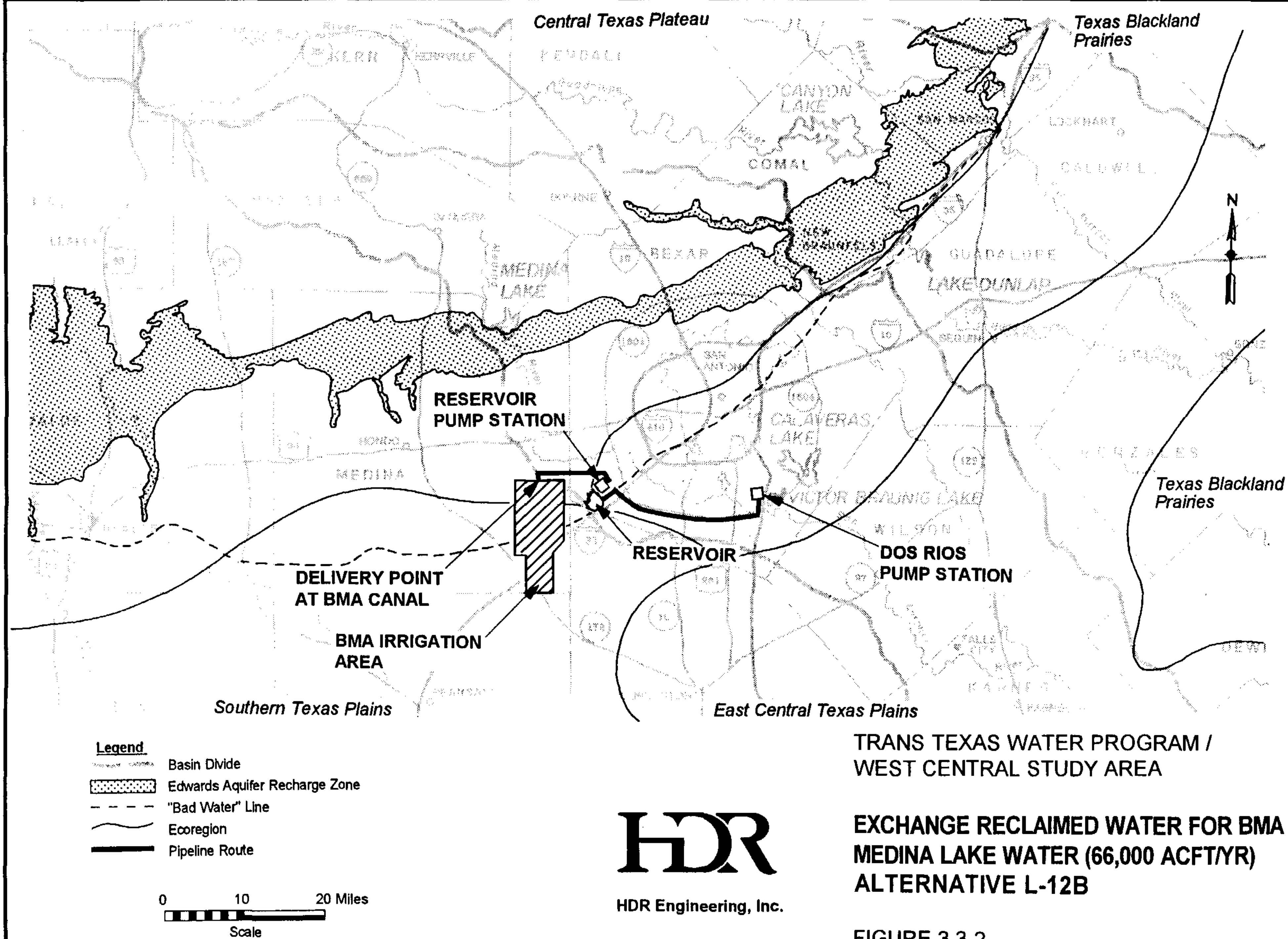
Alternative L-12A, Exchanging Reclaimed Water for BMA Medina Lake Water (Figure 3.3-1 and 3.3-2), involves the storage of treated wastewater in Lakes Calaveras and Braunig, as in Alternative L-11, or construction of a larger storage reservoir for pipeline transport to irrigated areas in Medina County during periods when it can be used. The irrigated area is an existing use and would not be altered by construction activities. Alternative L-12B involves the use of a new off-channel reservoir as shown on Figure 3.2-1.



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

EXCHANGE RECLAIMED WATER FOR BMA MEDINA LAKE WATER (31,000 ACFT/YR) ALTERNATIVE L-12A

FIGURE 3.3-1



HDR

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

EXCHANGE RECLAIMED WATER FOR BMA MEDINA LAKE WATER (66,000 ACFT/YR) ALTERNATIVE L-12B

FIGURE 3.3-2

The land use and habitats in the project area reflect its location at the confluence of the Blackland Prairie, Southern Texas Plains, and the East Central Plains Ecoregions (Figures 3.0-1, 3.0-2, 3.0-3)[91,92,93]. Calaveras Lake and Braunig Lake are steam electric cooling water reservoirs surrounded by cropland, pasture and shrubland[94]. This alternative (L-12) is in the same general vicinity as the alternative described in Section 3.2 (L-11). Therefore, the soils, biotic communities and protected species described in Section 3.2.3 apply to this proposed alternative. Similarly, the descriptions of and potential impacts to Calaveras and Braunig Lakes in Section 3.2.3 are applicable to this alternative.

The proposed pipeline corridor (748 acres)[95] is located primarily in cropland, with South Texas Plains shrubland comprising about 36 percent (Table 3.0-1). The proposed irrigation area is cropland, south of Medina Lake, where the Edward's Plateau Ecoregion and the Balconian Biotic Province meets (Figure 3.0-3)[96] the northern portion of the Southern Texas Plains (Figures 3.0-1)[97]. The proposed off-channel storage reservoir (Figure 3.2-2) is located in approximately 2,000 acres of shrubland on the edge of suburban development[98]. Lakes Calaveras and Braunig are culturally enriched and intensively managed artificial systems that presently support a popular and productive sport fishery that includes largemouth and hybrid striped bass, channel and flathead catfish, and numerous other, peripheral species. Assessments of impacts in future phases of the Trans-Texas Water Program should include consideration of the potential effects on sportfish production. The volume of water proposed for storage and transfer through Lake Calaveras and Braunig

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[91]Omernik, James M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1) pp. 118-125.

[92]Gould, F. W. 1975. The Grasses of Texas. Texas A & M University Press, College Station, Texas.

[93]Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science 2(1): pp.93-117.

[94]USGS. 1990. NAPP black and white aerial photography. EROS Data Center, Sioux Falls, SD

[95]Ibid.

[96]Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science 2(1): pp.93-117.

[97]Omernik, James M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1) pp. 118-125.

[98]USGS. 1990. NAPP black and white aerial photography. EROS Data Center, Sioux Falls, SD

Lake is about 30,000 acft/yr, about 35 percent of their combined capacity, and the resulting change in residence time may have some effect on nutrient utilization and plankton dynamics that could have wider consequences.

Although the Natural Heritage Program does not report any endangered or threatened species directly along the proposed pipeline corridor, some have been reported in the vicinity (Appendix B, Tables 6 and 37). Many of these, such as the Texas tortoise, the reticulate collared lizard, the Texas horned lizard, and the indigo snake appear to be dependent on shrubland (Table 3.2-1). Destruction of potential habitat can be avoided in most areas by appropriate siting of the pipeline ROW. Surveys for protected species or other biological resources of restricted distribution, or other importance, would be conducted within the proposed construction corridor where habitat is present.

The irrigation area in Medina County is not within or upstream of the Edwards Aquifer recharge zone (Figure 3.3-1), so irrigating this area with treated effluent is unlikely to affect Edwards Aquifer subterranean species (Table 3.2-1). The troglobitic Toothless Blindcat and the Widemouth Blindcat were collected from artesian wells in Bexar County[99,100] located east of the irrigation area and north of the "bad water" line (Fig. 3.3-1).

Because this alternative involves the use of water that would otherwise have been released for irrigation, Edwards Aquifer recharge from Medina and Diversion lakes would not be significantly affected, and implementation of this alternative would reduce the City of San Antonio's demand on the Edwards Aquifer. However, only approximately half of the Medina Lake water made available will appear as treated wastewater flow, so the other half needed for irrigation will have to come from existing wastewater flows that are in excess of flows needed to meet any required instream flow criteria.

In Castroville, near the Medina County irrigation area, the Landmark Inn State Historical Park and Castroville Historic District are listed on the National Register of

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[99]Longley, G. and H. Karnei, Jr. 1979a. Status of *Satan eurystomus Hubbs* and Bailey, the widemouth blindcat. U.S. Fish and Wildlife Services, Endangered species Report 5.

[100]Longley, G. and H. Karnei, Jr. 1979b. Status of *Trogloglanis pattersoni* Eigenmann, the toothless blindcat. U.S. Fish and Wildlife Service, Endangered species Report 5.

Historic Sites (Table 3.0-1). Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL 96-515), and the Archaeological and Historic Preservation Act (PL 93-291). All areas to be disturbed during construction will be first surveyed by qualified professionals for the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

Implementation of this alternative is expected to require field surveys for vegetation, habitats, and cultural resources during ROW and reservoir site selection to avoid or minimize impacts. When potential protected species habitat, or significant resources cannot be avoided, additional studies would have to be conducted to evaluate habitat use, or eligibility for inclusion in the National Register for Historic Places, respectively. Wetland impacts, primarily pipeline stream crossings, would have to be minimized by ROW selection, appropriate construction methods, including erosion controls and revegetation procedures. Unavoidable impacts involving net losses of wetlands would have to be compensated.

3.3.4 Water Quality and Treatment

[To be considered in subsequent phases of this study.]

3.3.5 Engineering and Costing

Plan A - Yield to Supply Current Irrigation

Monthly irrigation demands were determined from BMA canal diversion records and applied to the total annual irrigation demand of 29,000 acft (non-food crop irrigated acreage using Edwards water) as shown in Table 3.3-1.

Table 3.3-1 also provides a comparison of monthly available future return flows with the irrigation demand. This table shows that, with a maximum monthly diversion rate of 3,000 acft, a net deficit of water exists from June through September of 8,627 acft. Therefore, to create a project with firm yield capacity, storage must be provided. As discussed in Section 3.2.5, there is limited storage volume (about 13,300 acft) in Braunig and

Table 3.3-1 Monthly Irrigation Demand and Availability				
Month	Monthly Demand Distribution[1] (percent)	Monthly Demand of All Non-Food Acreage[2] (acft/month)	Minimum Year Reclaimed Water Availability[3] (acft/month)	Reclaimed Water Surplus [Deficit] (acft)
January	3.0	870	3,000	2,130
February	3.5	1,015	3,000	1,985
March	7.1	2,059	3,000	941
April	8.6	2,494	3,000	506
May	9.9	2,871	3,000	129
June	13.9	4,031	2,707	(1,324)
July	15.4	4,466	992	(3,474)
August	14.7	4,263	877	(3,386)
September	8.8	2,552	2,109	(443)
October	6.8	1,972	3,000	1,028
November	4.4	1,276	3,000	1,724
December	3.9	1,131	3,000	1,869
Total	100.0	29,000	30,685	

[1]Average monthly distribution determined from measured BMA canal diversions, 1956-89.
[2]Calculated monthly demand = Monthly Demand Percentage x 29,000 acft/yr.
[3]Using future estimated return flows; diversion rate = 3,000 acft/month (32 mgd).

Table 3.3-2 Reclaimed Water Firm Yield - Plan A													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Reclaimed Water Availability[1] (acft)	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	2,707	992	877	2,109	30,685
Monthly Irrigation Demand (acft)	2,088	1,351	1,197	921	1,075	2,180	2,640	3,039	4,267	4,728	4,513	2,702	30,700
Monthly Surplus [Deficit] (acft)	912	1,649	1,803	2,079	1,926	820	360	(39)	(1,560)	(3,736)	(3,636)	(593)	
Accumulated Surplus [Deficit][2] (acft)	912	2,562	4,364	6,443	8,369	9,189	9,549	9,510	7,949	4,214	578	(15)	

[1]Using future estimated return flows of 170,000 acft/yr return flows; year 1988; Minimum Year condition; diversion rate of 3,000 acft/month (32 mgd).
[2]Accumulated surplus is limited by storage capacity of Braunig and Calaveras Lakes (13,365 acft).

Calaveras lakes that would potentially be used to firm up the delivery of reclaimed water. Table 3.3-2 compares monthly water availability to demand and shows the monthly surplus or deficit as well as an accumulated surplus/deficit. The table shows that beginning in October, a monthly surplus of water exists and the surplus must be stored until during the following summer months from June through September. This table shows that with a maximum diversion rate of 3,000 acft/month and a storage volume of 9,459 acft (72 percent of that potentially available in Braunig and Calaveras), the resulting firm yield of the system is about 31,000 acft/yr.

The major cost elements of the reclaimed water system include the Dos Rios pump station, Calaveras Lake high service pump station, Somerset booster station, transmission line to the BMA canal, and right-of-way for the transmission line. The cost elements of the Medina Lake supply system are described in Section 3.13.5. Operating costs include the electricity consumed by the pump stations and treatment plant, and O&M costs of each of the components.

The Dos Rios diversion pump station cost was determined for a firm pumping capacity of 3,000 acft/month (32 mgd) and the operating cost is dictated by the pumping head created by pipe friction in a 48-inch diameter pipe and the static head of 140 feet. The Calaveras high service pump station cost was determined for a firm pumping capacity of 4,800 acft/month (51 mgd) and the operating cost is dictated by the pumping head created by pipe friction in a 54-inch diameter pipe and the static head of 165 feet discharging into the BMA canal. The capital and O&M cost estimate for this alternative is contained in Table 3.3-3. Because this project must be combined with the Medina Lake water trade (Alt. S-13) to obtain a net increased water supply to the area, the unit cost calculation is contained in the Medina Lake cost table, Table 3.13-3.

Plan B - Firm Yield to Supply Full Diversion Right

A monthly irrigation demand distribution was determined from BMA canal diversion records and applied to a potential total annual irrigation demand of 66,000 acft as shown in Table 3.3-4, and compared to the monthly availability of reclaimed water using future return flows and a diversion rate of 10,000 acft/month.

Table 3.3-3
Cost Estimate Summaries for Exchange of Reclaimed Water for BMA Medina Lake Water (L-12)
(Mid - 1994 Prices)

Item	Alt. L-12A 31,000 acft/yr	Alt. L-12B 66,000 acft/yr
Capital Costs		
Pipeline	$38,030,000	$60,670,000
Dos Rios Pump Station	2,080,000	5,730,000
Calaveras Pump Station	4,900,000	5,900,000
Somerset Pump Station	3,460,000	27,010,000
Total Capital Cost	$48,470,000	$99,310,000
Engineering, Contingencies, and Legal Costs	15,040,000	31,700,000
Land Acquisition	200,000	10,710,000
Environmental Studies and Mitigation	200,000	8,070,000
Interest During Construction	1,730,000	6,140,000
Total Project Cost	$65,640,000	$155,930,000
Annual Costs		
Annual Debt Service	$6,150,000	$14,610,000
Annual Operation and Maintenance	730,000	1,430,000
Annual Power Cost	2,690,000	4,260,000
Total Annual Cost	$9,570,000	$20,300,000
Available Project Yield (acft/yr) (Reclaimed Water for Irrigation)	31,000	66,000
Annual Cost of Water*	N/A	N/A

*This project must be combined with the Medina Lake water purchase (Alt. No. S-13) to obtain a net increased water supply to the area. Refer to Table 3.13-3 for net unit cost calculation.

Table 3.3-4 Monthly Irrigation Demand and Availability				
Month	**Monthly Demand Distribution[1] (percent)**	**Monthly Irrigation Demand[2] (acft/month)**	**Minimum Year Reclaimed Water Availability[3] (acft/month)**	**Reclaimed Water Surplus [Deficit] (acft)**
January	3.0	1,980	9895	7,915
February	3.5	2,310	10000	7,690
March	7.1	4,686	7724	3,038
April	8.6	5,676	6057	381
May	9.9	6,534	8413	1,879
June	13.9	9,174	2876	[6,298]
July	15.4	10,164	855	[9,309]
August	14.7	9,702	1955	[7,747]
September	8.8	5,808	2913	[2,895]
October	6.8	4,488	6220	1,732
November	4.4	2,904	8061	5,157
December	3.9	2,574	8348	5,774
Total	100.0	66,000	73,317	

[1]Average monthly distribution determined from measured BMA canal diversions, 1956-89.
[2]Calculated monthly demand = Monthly Demand Percentage x 66,000 acft/yr.
[3]Using future estimated return flows; diversion rate = 10,000 acft/month (107 mgd).

Table 3.3-4 also provides a comparison of monthly availability of future return flows (determined from the GSA Model) to the demand and shows that a net deficit of water exists from June through September of 26,249 acft or almost twice the storage volume potentially available in Braunig and Calaveras lakes.

Using future return flows, a study was made to determine the amount of storage required to create a firm yield of 66,000 acft/yr, which is the full permitted diversion right of BMA. A possible storage reservoir location was chosen from which to develop reservoir and dam geometry and an elevation-area-capacity curve typical of the area. For a diversion rate at the treatment plant of 10,000 acft/month, the storage required to provide 66,000 acft/yr of firm supply is 32,000 acft. A potential reservoir site which could produce this amount of storage was investigated. A site was found in the vicinity of FM 1604 and IH-35 in southwestern Bexar County as shown on Figure 3.3-2. This site would have a conservation pool capacity of 32,000 acft, surface area of 2,000 acres, and a drainage area of 15 square miles.

The major cost elements of the Plan B system include the Dos Rios diversion pump station, transmission line to the new reservoir, storage reservoir, reservoir intake and pump station, transmission line to the BMA canal, and right-of-way for the transmission line. Operating costs include the electricity consumed by the pump stations and O&M costs of each of the components.

The Dos Rios diversion pump station cost was determined for a firm pumping capacity of 10,000 acft/month (107 mgd) and the operating cost is dictated by the pumping head created by pipe friction in a 78-inch diameter pipe and the static head of 230 feet. The reservoir pump station cost was determined for a firm pumping capacity of 11,000 acft/month (118 mgd) and the operating cost is dictated by the pumping head created by pipe friction in a 84-inch diameter pipe and the static head of 160 feet, discharging into the BMA canal. The capital and O&M cost estimate for this alternative is contained in Table 3.3-3. Because this project must be combined with the Medina Lake water trade (Alt. S-13) to obtain a net increased water supply to the area, the unit cost calculation is contained in the Medina Lake cost table, Table 3.13-3.

3.3.6 Implementation Items

The degree of success of the Demand Reduction effort (see Alt. L-10) will affect the quantity of reclaimed water available for reuse options; i.e., a successful demand reduction effort could reduce the quantity of reclaimed water available for delivery to the BMA canal. However, this alternative could provide a much more reliable supply to the BMA canal than currently exists, thereby creating a net benefit to irrigators of the alternative.

Other items:

1. Use of reclaimed water restricts farmers to planting non-food crops, possibly resulting in:
    a. potential lost revenue from lower value crops;
    b. for supply to the BMA canal, all farms obtaining irrigation water from the canal must convert to non-food crops, requiring possible compensation to farmers to make the change.
2. Reuse of reclaimed water reduces return flows to the San Antonio River, consequently reducing base flows.

3. Increased monitoring of water quality above current discharge permit requirements may be required for crop application reuse.
4. TNRCC approval of the purchase of the BMA water rights for conversion to municipal use.
5. Necessary Permits:
    a. TNRCC amendment of current direct discharge permit to a Chapter 310 Use of Reclaimed Water permit; and
    b. Texas Historical Commission permit.

If the Policy Management Committee decides to move forward with further consideration of this water supply alternative, the necessary Phase II studies will require more detailed hydrologic and water quality studies.

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3.4 Reclaimed Water Reuse (L-13)

Recycling / Reuse Plans by SAWS (L-13A)

The recent conservation and reuse report by SAWS[101], states:

> "reuse of treated effluent is an essential element of the SAWS water resources and conservation planning. The general policy for reuse is that the City of San Antonio should develop a program to reuse wastewater as a substitute for other supplies".

The goals contained in the current SAWS reuse plan are to have 30,000 to 50,000 acft/yr of reuse in place by the year 2008. Planned projects include providing water to the Mission del Lago Golf Course; providing water to the central and eastern portion of the City by way of the San Antonio River Tunnel; and, providing water to the west and northwest area from the Medio Creek and Leon Creek watersheds.

The Central-East Infrastructure Project (i.e., "Tunnel Project") is currently under construction and will consume approximately 11,000 acft/yr of reclaimed water. Reclaimed water is supplied from the Leon Creek WWTP to Mitchell Lake from which water is supplied to Mission del Lago golf course and also to the San Antonio River Flood Tunnel outlet during normal flow periods. The reclaimed water flows through the tunnel and is pumped from the inlet end, providing a beneficial movement of water through the tunnel during low flow periods. From the inlet end, reclaimed water is distributed to the Brackenridge Park/Olmos Park areas, and is released into the San Antonio River and Salado Creek. The reuse of water by this project is displacing the current use of Edwards Aquifer water for irrigation at Trinity University, Olmos Creek golf course, Sunken Gardens, Botanical Gardens, Ft. Sam Houston, and other locations.

The Westside Infrastructure Project consists of two parallel pipelines to divert up to 10,000 acft/yr of treated reclaimed water to customers in the west and northwest areas of San Antonio. Untreated wastewater will be diverted from the Leon Creek Sewer Outfall at its intersection with West Loop 410 and be piped to the Medio Creek WWTP. After

[101]San Antonio Water System, "Water Conservation and Reuse Plan", November 1993.

treatment, the reclaimed water will be pumped back to the same area of Leon Creek and Loop 410 at which point some of the water would be conveyed to the north for customers in the IH 10 Corridor, some would be pumped to the northwest area near Loop 1604, and a portion would be released to Leon Creek for irrigation use. The implementation schedule for this project is not known.

SAWS staff has stated that the estimated cost of the Westside project is $33 million and O&M cost is estimated to be $660,000/yr. The total annual cost per acft of water would be $375.

Reclaimed Water to the Edwards Aquifer (L-13B)

3.4.1 Description of Alternative

On an annual basis, a substantial amount of reclaimed water is available from the San Antonio Water System treatment plants for reuse. The results of a study to determine water availability were reported in Section 3.2 and summarized in Tables 3.2-4 and 3.2-5. The monthly distribution of availability is uneven, with the majority of reclaimed water available in the winter (i.e., non-irrigation months). Tables 3.4-1 and 3.4-2 present the monthly distribution of water available during drought conditions for current and one future date return flows; Table 3.4-2 shows that only 20 percent of the water is available for the peak usage months June through September.

Table 3.4-1
Reclaimed Water Availability - Current Return Flows[1]

	Estimated Reclaimed Water Availability (acft)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Drought Average, 1947-56	8,082	7,933	6,290	5,939	6,287	2,858	1,722	1,913	3,833	5,519	6,442	6,852	63,670
Percent of Total	12.7	12.5	9.9	9.3	9.9	4.5	2.7	3.0	6.0	8.7	10.1	10.8	100.0

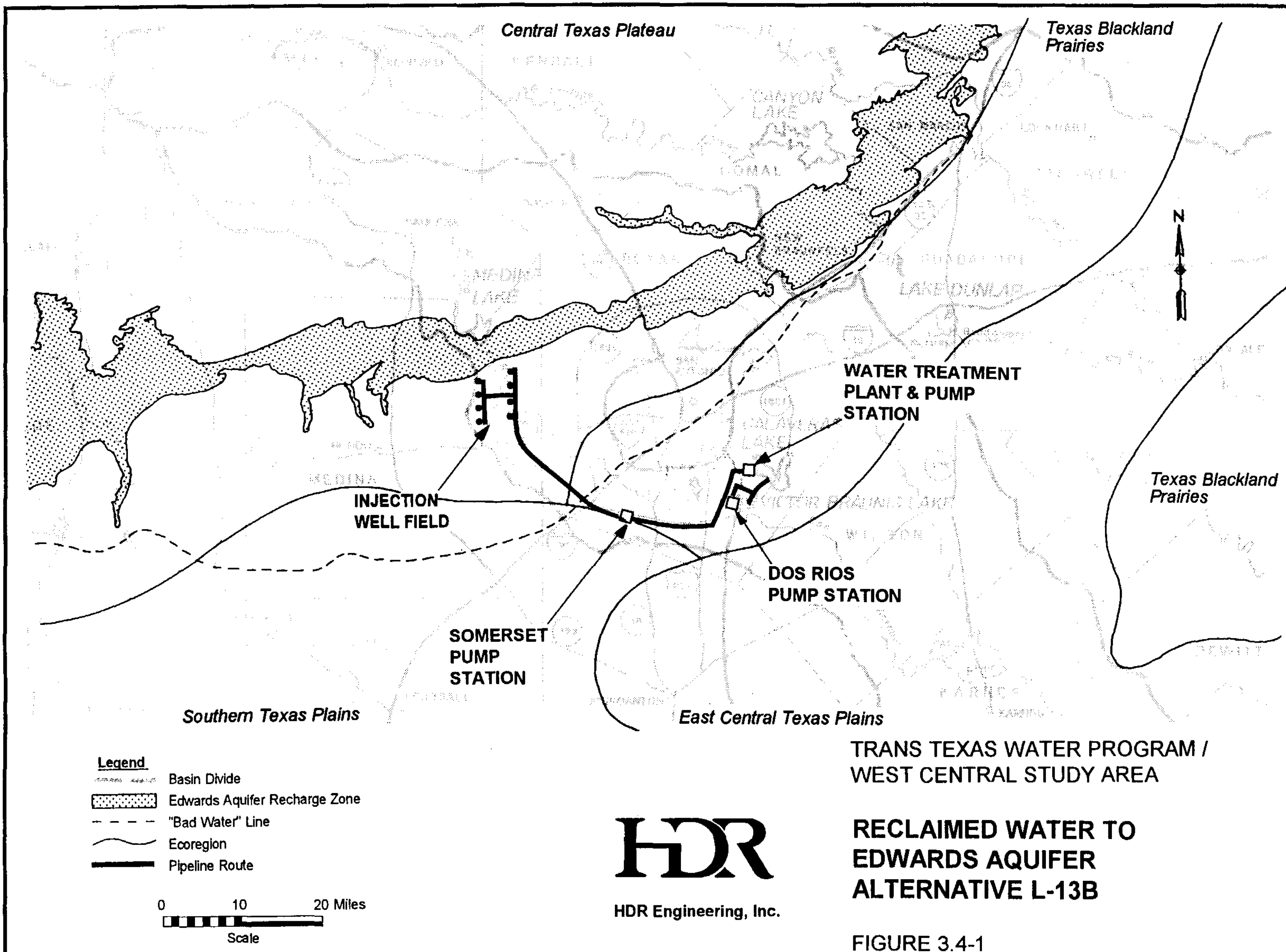
[1] Using 136,000 acft/yr, return flows; year 1988; with 12,000 acft/month diversion rate.

Table 3.4-2 Reclaimed Water Availability - Future Estimated Return Flows[1]													
	Estimated Reclaimed Water Availability (acft)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Drought Average, 1947-56	10,908	10,759	9,116	8,765	9,113	5,532	3,622	3,784	6,588	8,345	9,268	9,678	95,478
Percent of Total	11.4	11.3	9.5	9.2	9.5	5.8	3.8	4.0	6.9	8.7	9.7	10.1	100.0
[1] Using 170,000 acft/yr, future estimated annual return flows; with 14,800 acft/month diversion rate.													

A possible way to use of this water, which would not require the construction of a new reservoir for storage, would be to purify the water with a high level of treatment and augment the Edwards Aquifer supply by injecting the water into the aquifer through a recharge well. The aquifer would serve as a storage facility and hold the water until needed. With this plan, little water is lost to evaporation and the efficiency of the system could be much greater than using an open storage reservoir (some water could be discharged as springflows from the aquifer). The Edwards Underground Water District has studied[102] the recharge potential of an area south of Diversion Lake on the east side of the BMA Canal and found conditions favorable for installation of injection wells to supply water into the aquifer. The layout of this alternative is shown in Figure 3.4-1.

The major elements required to implement this alternative include a diversion and pump station at the Dos Rios WWTP, use of Calaveras Lake for storage and blending, a reclaimed water treatment facility (which includes short term storage and blending), a pump station and transmission line to the injection wells, a booster pump station, and an injection well field. At the well field, ground storage and a re-pressurization pump station would be required.

[102] W.E. Simpson Company, Inc., "Medina Lake Study, Volume Three, Recharge Evaluation", no date.



HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

RECLAIMED WATER TO EDWARDS AQUIFER ALTERNATIVE L-13B

FIGURE 3.4-1

3.4.2 Available Yield

For future return flows and a diversion rate of 10,000 acft/month, the long term average annual availability of reclaimed water is 103,000 acft/yr. During the 10-year drought, 92,000 acft/yr would be available on the average and, during the minimum year, 73,000 acft would be available. Water recharged to the aquifer is stored in the aquifer for later discharge to springs or wells. Because of the aquifer storage and delayed delivery, the firm yield of this alternative would be higher than the minimum year reclaimed water availability with the 10-year drought average, or about 92,000 acft/yr, being more representative of the quantity of water available.

3.4.3 Environmental Issues

Recycling and reuse plans by the San Antonio Water System (L-13A) and reclaimed water recharged to the Edward's aquifer (L-13B) are presented in Figure 3.4-1. The areas affected by these options are generally described and potential impacts discussed in Section 3.2.3. The mix of habitats in the pipeline corridor depicted for L13-B are listed in Table 3.0-1. About a third of the corridor is shrubland, almost half is cropland, and the remainder is primarily rural and suburban developed land. Implementation of the "Tunnel Project," and the Westside Infrastructure project described earlier, (Alternative L13-A) will require construction of a 35 mile reclaimed water delivery pipeline that would disturb about 417 acres.

Alternative L-13B would divert available water from the San Antonio Water System and, after appropriate treatment, inject it into the Edward's aquifer through a field of injection wells. Storing water within the aquifer would avoid the potential environmental effects and socioeconomic costs of reservoir construction, and would conserve water by eliminating the evaporative losses associated with surface storage. The environmental issues pertaining to the major elements required to implement this alternative (diversion and pump station at the Dos Rios Waste Water Treatment Plant, the reclaimed water treatment facility (which includes short term storage and blending), pump station and transmission line to the injection wells, and the injection well field) are presented below.

The proposed site for the injection well field is an area south of Diversion Lake on the east side of the BMA Canal (Figure 3.4-1). The injection well field would affect an estimated 768 acres within a primarily cropland area containing about 24 percent of uncultivated shrubland[103].

The pipeline corridor would begin at Calaveras Lake and run along the southern margin of San Antonio to the injection well field site to the west of the city. The majority of the vegetation in the western portion of this corridor has been converted to cropland, while land use in the eastern portion has become increasingly suburban or rural-residential[104]. The pipeline construction ROW would disturb about 535 acres. About 161 acres would be maintained free of woody vegetation as a permanent ROW (Table 3.0-1).

Protected species potentially inhabiting undeveloped and brushy successional areas in the vicinity of this alternative are listed in Table 3.2-6. Selection of a pipeline ROW that minimizes disturbance to woodland, dense brush, and riparian habitats is recommended. Because approximately 72 percent of the proposed corridor consists of cropland, wildlife habitats tend to be small and fragmented, and consequently, these areas may be disproportionately valuable to regional populations. Where disturbance to these habitats cannot be avoided, field surveys for protected species and other resources should be conducted.

Calaveras Lake, the site for short term storage and blending, is currently used for steam electric plant cooling and industrial water supply. Water levels in the reservoir are maintained by runoff from the surrounding agricultural land and water diverted from the San Antonio River[105,106]. Nutrient loading is already substantial in this impoundment, which exhibits correspondingly high levels of primary and secondary production[107]. The

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[103]USGS, 1990, NAPP Black and White Aerial Photography, EROS Data Center, Sioux Falls, South Dakota.

[104]Ibid.

[105]Gonzales, M., April 1994, Personal Communication, San Antonio River Authority, San Antonio, Texas.

[106]Paul Price. 1989. Seasonal Study of Lake Calaveras and Braunig Lake Phyto Plankton Assemblages; Technical Report to City Public Service, San Antonio, Texas. Paul Price Associates, Inc., Austin, Texas.

[107]Ibid.

additional nutrients in the wastewater stream from the Dos Rios Waste Water Treatment Plant (Table 3.2-5 in 3.2.2), are unlikely to have any discernible effects on Calaveras Lake. However, the introduction of either treated wastewater or Calaveras Lake water to the Edwards Aquifer has potential to adversely affect subterranean populations. Although nutrient enrichment is unlikely to have any effect on light limited primary producers, increasing concentrations of oxygen-demanding materials will tend to reduce dissolved oxygen levels, and enhance production by the decomposers (bacteria and fungi) that constitute the base of the food web in the Edwards Aquifer community[108]. Potential water quality problems will need to be addressed in a later phase of this study, along with potential impacts to subterranean species.

Transfer of the proposed water quantities for recharge to the Edwards Aquifer would reduce flow in the San Antonio River, although controls on future withdrawals from the Edwards Aquifer are expected to mostly increase springflow into the Guadalupe River. The hydrologic consequences to the San Antonio River of this and other reuse and recycle alternatives will be examined in more detail in later phases of the Trans Texas Program.

Cultural resources are likely to be present in the area. Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL 93-291). Surveys by qualified professionals would be conducted on all areas designated for construction in order to determine the presence of significant cultural resources, and the need to avoid or to mitigate disturbance to those sites.

Implementing this alternative is expected to require field surveys for vegetation, habitats, and cultural resources during selecting a ROW alignment that avoids or minimizes impacts. When potential protected species habitat, or significant cultural resources, cannot be avoided, additional studies would have to be conducted to evaluate habitat use, or eligibility for inclusion in the National Register of Historic Places, respectively. Wetland impacts, primarily pipeline stream crossings would have to be minimized by ROW selection,

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[108]Sharp, J.M. and D.C. McKinney, 1994, "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas; Phase I - Feasibility Study (DRAFT) CRWR 247," Center for Research in Water Resources, University of Texas at Austin.

appropriate construction methods, including erosion controls and revegetation procedures. Unavoidable impacts, involving net losses of wetlands would have to be compensated.

3.4.4 Water Quality and Treatment

Reclaimed water must be highly purified to potable quality before placement into the aquifer. Black & Veatch[109] studied the use of reclaimed water for potable use and proposed using Braunig and Calaveras Lakes for blending reclaimed water with surface water or supplemental groundwater. The lakes would provide some degree of polishing treatment from residence in the open reservoir. Treatment Level 4, described in Section 3.0, is essentially the same treatment process proposed by Black & Veatch, and includes the use of Calaveras Lake for polishing and blending. Although a new storage facility could be constructed at the wastewater treatment plant site, the preferred method would be to utilize Calaveras Lake. After secondary treatment at the Dos Rios WWTP, the reclaimed water diverted for reuse would be treated for nutrient removal (phosphorus removal) and then pumped to Calaveras Lake. Reclaimed water discharged to the river from the Dos Rios plant and other wastewater plants would not be treated for nutrient removal. Cooling water make-up diverted from the San Antonio River under the existing Braunig Lake permit might be co-mingled with Calaveras and the need for nutrient removal treatment of this water will require further study. From Calaveras, the water would be pumped to the Level 4 treatment plant (Table 3.0-4) and then a high service pump station would convey the water to a booster pump station at Somerset that supplies the injection well field.

3.4.5 Engineering and Costing

The diversion and pump station at Dos Rios WWTP is sized to deliver 10,000 acft/month (107 mgd) to the reuse system. The Simpson report estimates the injection well capacity to be 4,000 gpm per well, which would require an injection well field size of 19 wells for this alternative. The project facilities are shown on Figure 3.4-1.

The major cost elements of the reclaimed water system include the Dos Rios diversion pump station, Calaveras pump station, Level 4 treatment plant (Table 3.0-4) and

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[109]Black & Veatch Engineers-Architects, "Water Management Plan Using Braunig & Calaveras Lakes", 1990.

high service pump station, transmission line to the injection well field, injection well field, and right-of-way for the transmission line. Operating costs include the electricity consumed by the pump stations and treatment plant, O&M costs of each of the components, and debt service.

The Dos Rios diversion pump station cost was determined for a firm pumping capacity of 10,000 acft/month (107 mgd). The Calaveras pump station, Level 4 treatment plant, and high service pump station are also sized for 10,000 acft/month (107 mgd). The operating cost is dictated by the pumping head created by pipe friction in a 78-in. diameter pipe and the static head of 140 feet.

The capital and O&M cost estimates for this alternative are contained in Table 3.4-3. The unit cost of this alternative is $761 per acft.

3.4.6 Implementation Issues

The degree of success of the Demand Reduction effort (see Alt. L-10) will affect the quantity of reclaimed water available for reuse options; i.e., a successful demand reduction effort will reduce the quantity of reclaimed water available.

1. Reuse of reclaimed water reduces return flows to the San Antonio River, consequently reducing base flows.
2. Detailed feasibility studies are needed to determine adequate water quality protection measures for the aquifer.
3. If deemed to be feasible, then a public education program to obtain public acceptance will likely be required.

<u>Requirements Specific to Pipelines</u>

1. Necessary permits:
    a. TNRCC Interbasin Transfer permit.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    c. GLO Sand and Gravel Removal permits.
    d. Coastal Coordinating Council review.
    e. TPWD 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

Table 3.4-3 Cost Estimate Summary for Reclaimed Water to the Edwards Aquifer (L-13B) (Mid - 1994 Prices)	
Item	**Estimated Cost**
Capital Costs	
Transmission Pipeline	$83,900,000
Dos Rios Pump Station	4,550,000
Calaveras Pump Station	5,650,000
Somerset Pump Station	5,390,000
Injection Field Pump Station	3,700,000
Ground Storage - Injection Field	2,000,000
Injection Wells	12,250,000
Level 4 Treatment Plant	128,400,000
Total Capital Cost	$245,840,000
Engineering, Contingencies, and Legal Costs	81,480,000
Land Acquisition	310,000
Environmental Studies and Mitigation	5,230,000
Interest During Construction	22,800,000
Total Project Cost	$355,660,000
Annual Costs	
Annual Debt Service	$33,330,000
Annual Operation and Maintenance	27,520,000
Annual Power Cost	9,190,000
Total Annual Cost	$70,040,000
Available Project Yield (acft/yr)	92,000
Annual Cost of Water	$761/acft

Terminal Delivery Alternatives

Requirements Specific to Injection Wells

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests.
   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.

d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
e. Source water quality testing for Safe Drinking Water Act regulated constituents.

2. Necessary permits:
   a. TNRCC Injection Well permit
   b. Texas Historical Commission permit
   c. Texas Parks and Wildlife sand, gravel, and marl permit.
3. Right-of-way and easement acquisition.

If the Policy Management Committee decides to move forward with further consideration of this water supply alternative, the necessary Phase II studies will require more extensive feasibility studies, including detailed hydrologic and biologic studies.

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3.5 Transfer of Reclaimed Water to Corpus Christi Through Choke Canyon Reservoir (L-14)

3.5.1 Description of Alternative

The Edwards Underground Water District has been studying several types of recharge enhancement structures to be constructed in the Nueces River Basin either upstream or within the Edwards recharge zone to enhance the yield of the aquifer. Because a part of this program includes projects which would divert surface water from the Nueces Basin, these projects would have the effect of reducing the firm yield of the Choke Canyon Reservoir/Lake Corpus Christi (CC/LCC) System. Table 3.5-1 lists the three potential recharge programs under consideration, the additional drought recharge made available to the aquifer in the Nueces River Basin, and the reduction in the yield of the CC/LCC System for each program.

Table 3.5-1
Recharge Enhancement and Yield Reduction of Various Recharge Programs in the Nueces Basin Located Upstream of the CC/LCC System

Type of Program	Drought Recharge Enhancement (1947-56) In Nueces River Basin (acft/yr)	Estimated Yield Reduction of CC/LCC System (acft/yr)
Type 2-Program	27,850	5,900
Type 1-Maximum Program	30,280	7,700(E)
Type 1-Optimum Program	26,870	4,900(E)

Source: HDR, Inc., "Regional Water Supply Planning Study, Phase III, Recharge Enhancement, Nueces River Basin," Nueces River Authority, November 1991.

(E) - Estimated

To mitigate for the reduced CC/LCC System yield, this alternative considers diverting a portion of the San Antonio Water System reclaimed water from the San Antonio River near Falls City and transferring it to Choke Canyon Reservoir to replace the lost yield. Since the most likely program to be constructed is the Type 2-Program, which reduces CC/LCC yield by about 5,900 acft/yr, this is the program selected for analysis in this section.

The major facilities needed for this alternative include a diversion structure in the San Antonio River, surface water intake and pump station, transmission line to Choke Canyon Reservoir, and discharge structure in Choke Canyon Reservoir.

3.5.2 Available Yield

The impact to the firm yield of the CC/LCC system Type 2 Program is 5,900 acft/yr as measured at the Calallen Diversion Dam downstream of Lake Corpus Christi. However, channel and evaporation losses in the CC/LCC System average about 30 percent, therefore, these losses would require a diversion from the San Antonio River of about 8,400 acft/yr. Because of the higher availability of reclaimed water in non-summer months in the San Antonio River and the available storage in the CC/LCC system, the intake and pump station on the San Antonio River are sized to capture the annual volume in an 8.4 month period. This requires a diversion rate of 1,000 acft/month (10.8 mgd).

The GSA Model was applied assuming in a worst case scenario that the full Trans-Texas Environmental Criteria would apply to this alternative. Water availability at the Falls City diversion point was obtained using the model parameters contained in Table 3.5-2. This table indicates that no water is available in the minimum year (1956). For the CC/LCC System, the drought of record occurred from 1961 to 1964, during which time no water would have been available for transfer from the San Antonio River for the 36-month period from 1962 to 1964. Because of the severe lack of water available to transfer to Choke Canyon, with the Trans-Texas Environmental Criteria in place, this alternative was analyzed assuming the transfer would occur under existing water rights held by the City of San Antonio within the San Antonio River Basin.

3.5.3 Environmental Issues

Alternative L-14 diverts San Antonio River flow at Falls City via a transmission line southwest through Campbellton and then south to Choke Canyon Reservoir. Proposed facilities include a diversion structure in the San Antonio River near Falls City and an

Table 3.5-2
Guadalupe - San Antonio Basin Modeling Parameters - Alternative L-14

Analysis Point: **San Antonio River @ Falls City**

Minimum Flow Requirements:

Month	Instream Flow Requirement at Analysis Point (acft/mo)	Instream Flow Requirement at Analysis Point (cfs)	Bay & Estuary Inflow Requirement at Salt Water Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Salt Water Barrier (cfs)
Jan	6,730	112	119,235	1,977
Feb	6,042	100	111,426	1,848
Mar	9,591	159	118,399	1,964
Apr	10,646	177	108,476	1,799
May	13,663	227	260,311	4,317
Jun	13,133	218	252,135	4,182
Jul	7,721	128	86,267	1,431
Aug	6,509	108	71,697	1,189
Sep	8,327	138	177,444	2,943
Oct	6,392	106	172,249	2,857
Nov	5,687	94	92,774	1,539
Dec	5,848	97	103,130	1,710

Flow Requirements:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Tunnel Reuse Project:	Excluded
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Excluded
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Availability — Annual Water Availability

Maximum Diversion Rate (acft/month)	1934-89 Average Conditions (acft/yr)	1947-56 Drought Conditions (acft/yr)	Minimum Year (acft/yr)
500	1,906	450	0
1,000	3,797	900	0
2,000	7,516	1,770	0
3,000	11,147	2,485	0
4,000	14,690	3,185	0

estimated 46-mile transmission line to Choke Canyon Reservoir. This alternative is entirely within the South Texas Plains Ecoregion (Figure 3.0-1) and the corresponding South Texas Plain vegetational area (Figure 3.0-2).[110,111]

The South Texas Plains is dissected by streams flowing into the Rio Grande River and the Gulf of Mexico. Soils in this area range from clays to sandy loams, and vary in reaction from very basic to slightly acid. This wide range of soil types is responsible for great differences in soil drainage and moisture holding capacities within this region[112,113]. Wetlands in the project area consist of riverine habitats of the Atascosa and the San Antonio Rivers, their tributaries, and associated palustrine habitats, typically wetlands along the riverbasins[114].

The transmission line corridor is within a wide band of mesquite - blackbrush brushlands and mesquite - granjeno woods surrounded by cropland. Construction would impact an estimated 5,576 acres of ROW and maintenance activities would permanently affect about 1,673 acres. Mesquite - blackbrush brushlands are the main vegetational community (70%) in the proposed project corridor. The brushlands are dominated by honey mesquite, blackbrush and other thornbrush species, including lotebush, ceniza, whitebrush, agarito, granjeno, yucca, Texas pricklypear, bluewood, and desert yaupon. The herbaceous layer is a mixture of purple three-awn, pink pappusgrass, hairy tridens, hairy grama, coldenia, and dogweed[115]. The mesquite - granjeno woods occupy a central band between the brushland corridor which is more typical of the South Texas Plains of Kleberg and Jim Wells Counties. This dense woods is characterized by honey mesquite, granjeno, retama,

[110]Omernik, James M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1) pp. 118-125.

[111]Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press, College Station, Texas.

[112]Ibid.

[113]McMahan, C.A., R.G. Frye, K.L. Brown. 1984. The Vegetation Types of Texas. Texas Parks and Wildlife Department. Austin, Texas.

[114]Ibid.

[115]McMahan, C.A., R.G. Frye, K.L. Brown. 1984. The Vegetation Types of Texas. Texas Parks and Wildlife Department. Austin, Texas.

bluewood, woollybucket bumelia, catclaw, tasajillo, lotebush, whitebush, and desert yaupon. The woods are about 30 percent of the total area within the corridor. The brushland and the relatively dense woods provide the best wildlife habitat for endemic species such as the regionally important and protected jaguarundi, ocelot and Texas tortoise. An estimated 240 vertebrate species utilize this habitat type, including 5 amphibians, 45 reptiles, 150 birds, and 41 mammals[116].

Depending on the transmission line alignment, construction impact may be minimized or avoided by locating in less sensitive cropland and cattle-grazed upland brushland whenever possible. Construction impacts across rivers and streams should be minimized. Although water quality and biota of the Nueces and San Antonio Rivers are similar, an analysis of potential effects arising from water quality differences or from the introduction of organisms not native to the Nueces Basin should be conducted.

Although the Natural Heritage Program does not report any endangered or threatened species directly along the proposed pipeline corridor, some have been reported in the vicinity (Appendix B, Tables 6, 37 and 50). Many of these appear to be dependent on thorn bush and woods habitat, such as the jaguarundi, ocelot, Texas tortoise, indigo snake, reticulated collared lizard, Texas scarlet snake, and Texas horned lizard. The Texas garter snake, black-spotted newt, sheep frog, and lesser Rio Grande siren may be present in wetland habitats (see Table 3.5-3). Surveys for protected species or other biological resources of restricted distribution, or other importance, would be conducted within the proposed construction corridor where potential habitat is present.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL 96-515), and the Archaeological and Historic Preservation Act (PL 93-291). All areas to be disturbed during construction would be surveyed by qualified professionals for the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

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[116]Blair, W. Frank. 1950. "The Biotic Provinces of Texas," Texas Journal of Science, Vol. 2, No. 1: pp. 93-112.

Table 3.5-3
Important Species With Habitat Within the Proposed Project Area

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Endemic grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL
Texas Scarlet Snake	*Cemophora coccinea lineri*	mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	C2	T
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture to remain	C2	E
Parks' Jointweed	*Polygonella parksii*	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer	3C	NL
Silvery Wild Mercury	*Argythamnia argyraea*	South Texas Plains, perennial herb, also in Kinney, LaSalle and Maverick Counties	3C	NL

Table 3.5-4 Cost Estimate for Transfer of Reclaimed Water to Corpus Christi Through Choke Canyon Reservoir (L-14) (Mid - 1994 Prices)	
Item	**Estimated Cost**
Capital Cost	
Pipeline and Pump Station	$17,890,000
Channel Dam on San Antonio River	1,750,000
Total Capital Costs	19,640,000
Engineering, Contingencies, and Legal	6,070,000
Environmental Studies and Mitigation	210,000
Land Acquisition	210,000
Interest During Construction	1,010,000
Total Project Cost	**$27,140,000**
Annual Cost	
Annual Debt Service	2,538,000
Annual Operation and Maintenance Cost	270,000
Annual Power Cost	410,000
Total Annual Cost	**$3,218,000**

Requirements Specific to Pipelines

1. Necessary permits:
   a. TNRCC Interbasin Transfer permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   c. GLO Sand and Gravel Removal permits.
   d. Coastal Coordinating Council review.
   e. TPWD 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

If the Policy Management Committee decides to move forward with further consideration of this water supply alternative, Phase II studies will need to include hydrologic analysis of loss rates and make-up water needed for full CC/LCC yield restoration and water quality compatibility studies of the co-mingled water in Choke Canyon Reservoir.

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3.6 Purchase (or Lease) of Edwards Irrigation Water for Municipal and Industrial Use (L-15)

The purposes of this section are to: (1) estimate probable ranges of quantities of Edwards irrigation water that might be available for transfer to municipal and industrial use by purchase or lease, and (2) estimate impacts of such transfers upon the local economies of Uvalde, Medina, and Bexar counties. The analyses performed were based upon the provisions of Senate Bill 1477 (SB 1477), 1993 Regular Session, Texas Legislature, using data from the Texas Water Development Board and studies by the Texas Agricultural Experiment Station, Texas Agricultural Extension Service, and others, as referenced. The provisions of SB 1477 that apply to purchase or lease of Edwards irrigation water are presented below. (Note: SB 1477 has not been implemented due to a challenge of the method of selecting members of the Edwards Aquifer Authority Board of Directors).

3.6.1 Provisions for Purchase (or Lease) of Edwards Irrigation Water

SB 1477, Section 1.14, limits the quantity of water that can be withdrawn from the Edwards Aquifer in each calendar year for the period ending December 31, 2007 to no more than 450,000 acft, and for the period beginning January 1, 2008 to no more than 400,000 acft. Section 1.14, Subsection h, prescribes that the Edwards Aquifer Authority shall implement and enforce water management practices, procedures, and methods to ensure that not later than December 31, 2012, the continuous minimum spring flows of the Comal Springs and the San Marcos Springs are maintained to protect endangered and threatened species to the extent required by federal law. The annual quantity associated with this latter requirement is not specified in the Act. Estimates of springflow augmentation necessary to meet current U.S. Fish and Wildlife specified springflows are presented in Section 3.10 of this report.

Section 1.15 of SB 1477 provides that the Edwards Aquifer Authority (Authority) shall manage withdrawals and points of withdrawal from the aquifer by granting permits. Section 1.16 specifies the method for issuing permits:

> "An existing user may apply for an initial regular permit by filing a declaration of historical use of underground water withdrawn from the aquifer during the historical period from June 1, 1972, through May 31, 1993."

The deadline for declaration of historical use was March 1, 1994. The Act further provides (Section 1.16, Subsection e) that

> "To the extent water is available for permitting, the board shall issue the existing user a permit for withdrawal of an amount of water equal to the user's maximum beneficial use of water without waste during any one calendar year of the historical period. If a water user does not have historical use for a full year, then the authority shall issue a permit for withdrawal based on an amount of water that would normally be beneficially used without waste for the intended purpose for a calendar year. If the total amount of water determined to have been beneficially used without waste under this subsection exceeds the amount of water available for permitting, the authority shall adjust the amount of water for withdrawal under the permits proportionately to meet the amount available for permitting. An existing irrigation user shall receive a permit for not less than two acft a year for each acre of land the user actually irrigated in any one calendar year during the historical period. An existing user who has operated a well for three or more years during the historical period shall receive a permit for at least the average amount of water withdrawn annually during the historical period."

The manner in which water rights may be transferred is specified in Section 1.34:

> "(a) Water withdrawn from the aquifer must be used within the boundaries of the authority. (b) The authority by rule may establish a procedure by which a person who installs water conservation equipment may sell the water conserved. (c) A permit holder may lease permitted water rights, but a holder of a permit for irrigation use may not lease more than 50 percent of the irrigation water rights initially permitted. The user's remaining irrigation water rights must be used in accordance with the original permit and must pass with transfer of the irrigated land."

3.6.2 Irrigation Water Use Information -- Edwards Aquifer Area

In the Edwards Aquifer area, irrigation with water from the aquifer and from Medina Lake supplements annual precipitation, which averages 24 inches in the west and 30 inches in the east. The quantity of irrigation water applied per acre can vary from a few inches when precipitation is above average to as much as 42 inches on some high water demand crops during drought years. At the time of this report, permits for Edwards water under SB 1477 have not yet been issued, thus the principal information available for an estimate of future supplies of water potentially available for purchase or lease is the history of irrigation water use in Uvalde, Medina, and Bexar counties.(Tables 3-6.1, 2, 3, and 4)[118]. While irrigated acreage in Bexar County has declined from its peak of 29,900 acres in 1964 to 17,300 acres in 1989 (Table 3.6-3) largely because of a shift in land use, irrigated acreage in each of Uvalde and Medina counties has increased from approximately 13,000 acres in 1954 to approximately 50,000 acres in 1989, the most recent year for which information is available (Tables 3.6-1 and 2). The decline in irrigation in Bexar County is largely due to a shift in land use from agricultural production into urban uses such as subdivisions for homes and into business and industrial uses. The steady increase in irrigated acreages in Uvalde and Medina Counties during the last 30 years has been in response to economic opportunities in those counties, i.e., the production of food and fiber crops to meet commercial demands.

Source and Use of Irrigation Water

In Uvalde County from 1958 through 1989, more than 94 percent of irrigation water was obtained from the Edwards Aquifer (Table 3.6-1). In fact, the Edwards Aquifer has been the only significant source of water available within Uvalde County, where irrigation water use has increased from 18,000 acft annually in 1958 to more than 150,000 acft annually in 1989.

In Medina and Bexar counties, surface water from Medina Lake and Edwards Aquifer water has been used for irrigation (Tables 3.6-2 and 3). Although surface water supplies from Medina Lake have fluctuated widely between droughts and periods of high rainfall, this source supplied between 45 percent and 55 percent of irrigation water used in Medina and Bexar counties between 1958 and 1979. During this period, annual surface water use for irrigation in Uvalde, Medina, and Bexar counties ranged form a low of 31,000 acft in 1958 to a high of 70,600 acft in 1989, with annual surface water use largely in the 50,000 to 60,000 acft range (Table 3.6-4).

[118]"Surveys of Irrigation in Texas -- 1958, 1964, 1974, 1979, 1984, and 1989", Report 329, Texas Water Development Board, Austin, Texas, 1991.

Table 3.6-1
Estimates of Irrigated Acreages and Irrigation Water Use in Uvalde County -- Edwards Aquifer Area[1]
West Central Area -- Trans-Texas Water Program

	Acres Irrigated			Water Use in Acre-Feet[1]		
Year	Ground Water	Surface Water	Total Acres	Ground Water[2]	Surface Water	Total Water
1958	12,733	1,212	13,945	17,119	1,071	18,190
1964	20,314	1,065	21,379	33,361	679	34,040
1969	34,496	1,100	39,596	48,523	1,034	49,557
1974	39,022	1,390	40,412	68,542	2,082	70,624
1979	37,932	1,680	39,612	75,915	2,576	78,491
1984	49,500	1,870	51,370	149,447	2,736	152,183
1989	48,782	250	49,032	151,378	588	151,966
84/89 Average	49,141	1,060	50,201	150,412	1,662	152,074

Source: "Surveys of Irrigation in Texas -- 1958, 1964, 1969, 1974, 1979, 1984, and 1989", Report 329, Texas Water Development Board, Austin, Texas 1991
[1] Estimated quantities at the well-head in the case of ground water, and at the source (storage reservoir or stream diversion point) in the case of surface water. In the case of surface water irrigation systems, the estimate of conveyance losses is 15 percent between the diversion point and the irrigated fields.
[2] Groundwater is obtained primarily from the Edwards Aquifer.

Table 3.6-2
Estimates of Irrigated Acreages and Irrigation Water Use in Medina County -- Edwards Aquifer Area[1]
West Central Area -- Trans-Texas Water Program

	Acres Irrigated			Water Use in Acre-Feet[1]		
Year	Ground Water	Surface Water	Total Acres	Ground Water[2]	Surface Water[3]	Total Water
1958	8,000	5,400	13,400	11,232	12,542	24,632
1964	9,064	10,500	19,564	14,461	27,891	42,352
1969	13,110	13,100	26,210	32,668	35,255	67,932
1974	21,200	13,250	34,450	41,033	33,687	74,720
1979	24,800	13,250	38,050	43,637	25,568	69,205
1984	31,916	14,952	46,868	84,911	48,568	133,479
1989	34,623	19,202	53,825	113,089	55,705	168,794
84/89 Average	33,269	17,077	50,346	99,000	52,136	151,136

Source: "Surveys of Irrigation in Texas -- 1958, 1964, 1969, 1974, 1979, 1984, and 1989", Report 329, Texas Water Development Board, Austin Texas 1991
[1] Estimated quantities at the well-head in the case of ground water, and at the source (storage reservoir or stream diversion point) in the case of surface water. In the case of surface water irrigation systems, the estimate of conveyance losses is 15 percent between the diversion point and the irrigated fields.
[2] Groundwater is obtained primarily from the Edwards Aquifer.
[3] The principal source of surface water is Medina Lake.

Table 3.6-3 Estimates of Irrigated Acreages and Irrigation Water Use in Bexar County -- Edwards Aquifer Area[1] West Central Area -- Trans-Texas Water Program						
	Acres Irrigated			Water Use in Acre-Feet[1]		
Year	Ground Water	Surface Water	Total Acres	Ground Water[2]	Surface Water[3]	Total Water
1958	16,600	10,500	27,100	24,350	17,464	41,814
1964	15,261	14,700	29,961	32,400	34,554	66,954
1969	15,694	13,535	29,229	19,583	17,589	37,172
1974	12,244	14,218	26,462	13,699	16,415	30,114
1979	10,530	13,521	24,051	15,832	22,844	38,676
1984	10,515	9,589	20,104	23,489	18,030	41,519
1989	10,862	6,483	17,345	23,851	14,338	38,189
84/89 Average	10,688	8,036	18,724	23,670	16,184	39,854

Source: "Surveys of Irrigation in Texas -- 1958, 1964, 1969, 1974, 1979, 1984, and 1989", Report 329, Texas Water Development Board, Austin Texas 1991

[1] Estimated quantities at the well-head in the case of ground water, and at the source (storage reservoir or stream diversion point) in the case of surface water. In the case of surface water irrigation systems, the estimate of conveyance losses is 15 percent between the diversion point and the irrigated fields.

[2] Groundwater is obtained primarily from the Edwards Aquifer.

[3] The principal source of surface water is Medina Lake.

Table 3.6-4 Estimates of Irrigated Acreages and Irrigation Water Use Totals of Uvalde, Medina, and Bexar Counties -- Edwards Aquifer Area[1] West Central Area -- Trans-Texas Water Program						
	Acres Irrigated			Water Use in Acre-Feet[1]		
Year	Ground Water	Surface Water	Total Acres	Ground Water[2]	Surface Water[3]	Total Water
1958	37,333	17,112	54,445	52,701	31,077	83,778
1964	44,639	26,265	70,904	80,222	63,124	143,346
1969	63,300	27,735	91,035	100,774	53,878	154,652
1974	72,466	28,858	101,324	123,274	52,184	175,458
1979	73,262	28,451	101,713	135,384	50,988	186,372
1984	91,931	26,411	118,342	257,847	69,334	327,181
1989	94,267	25,935	120,202	288,318	70,631	358,949
84/89 Average	93,099	26,173	119,272	273,082	69,983	343,065

Source: "Surveys of Irrigation in Texas -- 1958, 1964, 1969, 1974, 1979, 1984, and 1989", Report 329, Texas Water Development Board, Austin Texas 1991

[1] Estimated quantities at the well-head in the case of ground water, and at the source (storage reservoir or stream diversion point) in the case of surface water. In the case of surface water irrigation systems, the estimate of conveyance losses is 15 percent between the diversion point and the irrigated fields.

[2] Groundwater is obtained primarily from the Edwards Aquifer.

[3] The principal source of surface water is Medina Lake.

In Medina County, groundwater use from the Edwards Aquifer for irrigation has increased from 11,000 acft in 1958 to approximately 42,000 acft annually during the 1970's, and to 113,000 acft in 1989 (Table 3.6-2). Edwards Aquifer water use for irrigation in Bexar County has shown a different trend, declining from an estimated 32,000 acft in 1964 to 13,000 acft in 1974, after which it increased to 23,000 acft annually during the 1980's, which is a return to near the 1958 level (Table 3.6-3).

For the three county (Uvalde, Medina, and Bexar) area, total water use for irrigation has increased from 83,700 acft in 1958 to 358,700 acft in 1989 (Table 3.6-4). Of these totals, Edwards Aquifer water use was 52,700 acft (62.7 percent of the total) in 1958 and had increased to 288,300 acft (80 percent of the total) in 1989 (Table 3.6-4).

3.6.3 Crops Irrigated -- Acreage and Water Use -- Edwards Aquifer Area

Irrigation surveys by the Texas Water Development Board show 17 crops being irrigated in the Edwards Aquifer area, with corn, cotton, forage, hay, and vegetables having the largest acreages (Table 3.6-5). An average of the acreages reported in the 1984 and 1989 surveys gives a total of 137,957 acres of crops irrigated annually on 119,272 acres of land (Tables 3.6-4 and 3.6-5)[119]. (Note: 18,685 acres are double cropped, thus the difference in irrigated acreage and acres of crops irrigated).

For average weather conditions, estimated irrigation water requirements for 137,957 acres of irrigated crops are 203,300 acft annually, and in dry conditions, 357,000 acft annually (Table 3.6-5)[120]. (Note: these estimates are the totals of surface water and groundwater from Medina Lake and the Edwards Aquifer, and the latter estimate (357,000 acft) compares closely with the irrigation survey estimates for which the 1984/1989 average was 343,065 acft (Table 3.6-4).)

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[119]Data for 1984 and 1989 were averaged in order to reduce some of the variations in acreages planted annually, and in year-to-year variations in water use that results from variations in annual rainfall.

[120]Computations are based upon irrigation rates from "Texas Crop Enterprise Budgets, Southwest Texas District", B-1241 (C13), Texas Agricultural Extension Service, The Texas A&M University System, College Stations, Texas, 1993.

Table 3.6-5
Crops Irrigated with Acreages and Estimated Water Use for each Crop -- Edwards Aquifer Area West Central Area -- Trans Texas Water Program

Crops Irrigated (1984/1989 Average[2])	County			Edwards Aquifer Area Acres[2]	Water Use[1]			
					Per Acre		Total	
	Uvalde Acres[2]	Medina Acres[2]	Bexar Acres[2]		Average Weather (in)	Dry Weather (in)	Average Weather acre-feet (1,000)	Dry Weather acre-feet (1,000)
Cotton	17,494	2,876	40	20,410	18	30	30.6	51.0
Grain Sorghum	2,364	5,888	273	8,525	14	24	9.9	17.0
Corn	22,327	20,110	7,021	49,458	20	32	82.4	131.8
Wheat	6,256	1,399	0	7,655	12	24	7.6	15.2
Other Grains	3,891	557	430	4,878	12	24	4.9	9.8
Forage Crops	3,150	7,000	1,013	11,163	20	40	18.6	37.2
Peanuts	0	1,592	677	2,269	21	42	4.0	8.0
Soybeans	192	1,900	10	2,102	12	24	2.1	4.2
Other Oil Crops	92	0	0	92	13	26	0.1	0.2
Pecans (Mature)	915	2,050	0	2,965	16	32	4.0	8.0
Vineyard	100	1	0	101	16	32	0.1	0.2
Other Orchard	10	6	0	16	10	20	0.1	0.2
Alfalfa	100	135	0	235	18	36	0.3	0.6
Hay-Pasture	1,605	7,247	7,183	16,035	16	32	21.4	42.8
Vegetables (shallow)	7,000	500	703	8,203	18	32	12.3	21.8
Vegetables (deep)	1,000	600	1,126	2,726	16	28	3.6	6.4
Other (Est.)	312	230	582	1,124	14	28	1.3	2.6
TOTAL[2]	66,808	52,091	19,058	137,957	--	--	203.3	357.0

Source: "Surveys of Irrigation in Texas -- 1958, 1964, 1969, 1974, 1979, 1984, and 1989", Report 329, Texas Water Development Board, Austin, Texas 1991.

[1] Estimated from "Texas Crop Enterprise Budgets, Southwest Texas District", B-1241 (C13), Texas Agricultural Extension Service, The Texas A&M University System, College Station, Texas, 1993. Data by Jose G. Pena.

[2] Crop acres is the average of the acreages of the 1984 and 1989 surveys, and includes double cropping on 18,685 acres.

The average weather and dry weather irrigation requirements (Table 3.6-5) indicate the variation in total water use in the Edwards Aquifer area that might be attributed to weather conditions, holding constant other things such as crops and acreages irrigated. These quantities assume existing irrigation methods without additional water conservation. For example, the dry weather water requirement is 153,000 acft/yr greater than the average weather requirement for the Edwards Aquifer area (Table 3.6-5). However, only the water freed up by timely rains during the irrigation season can be saved for later use or made available for other purposes such as sale or lease for municipal and industrial use. As will be discussed below, irrigation water conservation programs could assist in making a part of the 153,000 acft available for sale or lease.

The 1984/1989 estimated average acreage being irrigated with water from the Edwards Aquifer was 93,099 acres (Table 3.6-6). The estimated average annual quantity of Edwards Aquifer water applied to the 93,099 acres was 273,082 acft in the late 1980's (Table 3.6-6). This is 78 percent of total acreage (1984/1989 average) irrigated and 79 percent of total water used for irrigation (1984/1989) within the Edwards Aquifer area.

3.6.4 Estimates of Edwards Irrigation Water Potentially Available for Purchase (or Lease)

To transfer Edwards Aquifer irrigation water for municipal or industrial uses, farmers might sell or lease a part or all of their supply. If an irrigator were to sell or lease only a part, a decision about how to use the remainder would be necessary. In addition, the decision to sell or lease Edwards irrigation water requires consideration of conservation potentials, with a view to selling or leasing water saved, as provided in SB 1477 for Edwards irrigation permits[121]. The decision with respect to water conservation is further complicated by consideration of alternative irrigation strategies and land use changes, including: (1) selling or leasing the part of the irrigation supply that is saved through conservation and continuing to irrigate all of the previously irrigated acres with the remaining quantity; (2) selling or leasing a part of the irrigation supply (a part in addition

[121]It should be noted that without permits or some other way to manage withdrawals from the aquifer, the title to purchased or leased water would be less secure than in the case with permits. Thus, under today's conditions, potential purchasers or lessors may not be interested in considering purchase or lease of Edwards irrigation water as discussed herein.

Table 3.6-6
Estimates of Acreages Irrigated Using Edwards Aquifer Water
Edwards Aquifer Area
West Central Area -- Trans Texas Water Program

Year	Uvalde County		Medina County		Bexar County		Edwards Aquifer Area	
	Acres	Edwards Water Use	Acres	Edwards Water Use	Acres	Edwards Water Use	Acres	Edwards Water Use
1958	12,733	17,119	8,000	11,232	16,600	24,350	37,333	52,701
1964	20,314	33,361	9,064	14,461	15,261	32,400	44,639	80,222
1969	34,496	48,523	13,110	32,668	15,694	19,583	63,300	100,774
1974	39,022	68,542	21,200	41,033	12,244	13,699	72,466	123,274
1979	37,932	75,915	24,800	43,637	10,530	15,832	73,262	135,834
1984	49,500	149,447	31,916	84,911	10,515	23,489	91,931	257,847
1989	48,782	151,378	34,623	113,089	10,862	23,851	94,267	288,318
84/89 Average Land Acres	49,141	150,412	33,269	99,000	10,688	23,670	93,099	273,082
Crop Acres	56,839	---	38,482	---	12,362	---	107,683*	---

Source: "Surveys of Irrigation in Texas -- 1958, 1964, 1969, 1974, 1979, 1984, and 1989", Report 329, Texas Water Development Board, Austin, Texas 1991. Note: This is a summary of Table 3.6-1, Table 3.6-2, and Table 3.6-3).

*The estimated number of acres of crops irrigated on the 93,099 land acres irrigated with Edwards water; i.e., proration of the 18,685 acres that are double cropped within the area gives 14,584 acres that are double cropped and irrigated with Edwards Aquifer water.

to that which can be saved by conservation) with a reduction in irrigated acreage, but with remaining acreage continuing to be operated with either a full or a partial application; and (3) selling or leasing all of the irrigation water supply, with conversion of irrigated acreages to dryland (unirrigated) crops.

The choices outlined above affect the quantities of Edwards irrigation water that are potentially available for purchase or lease. Estimates are made below for the following potential choices available to irrigation farmers: (1) hold irrigated acreages constant, implement irrigation water conservation, and sell/lease the water saved (irrigated acreage constant/irrigation water conservation); (2) hold irrigated acreages constant at present levels and change irrigation strategy from full irrigation during dry periods (no irrigation conservation) to average irrigation (with conservation), and sell/lease of the reduction in irrigation use (irrigated acreage constant/average weather irrigation strategy); (3) hold irrigated acreages constant at present levels with a plan for full irrigation during dry periods (no irrigation conservation) and sell/lease surplus irrigation supply in average years when rains occur (irrigated acreage constant/dry weather irrigation strategy); and (4) convert irrigated acreages to dryland production, selling or leasing the full irrigation supply (irrigated acreage converted to dry land).

(1) Irrigated Acreage Constant/Irrigation Water Conservation: Estimates of irrigation water requirements, without water conservation, range from 1.47 acft per acre for average weather conditions to 2.59 acft/acre for dry weather conditions (computed from totals of Table 3.6-5). In Section 3.1.2, Irrigation Water Conservation, it was estimated that in the Edwards Aquifer area, conversion from furrow irrigation to Low Energy Precision Application systems (LEPA) combined with furrow diking could save 0.8 acft/acre converted. This level of water saving would apply only to the dry weather, without conservation case, as shown in Table 3.6-6. Although some savings would be expected for the average weather, without conservation case, data applicable to such conditions are not available. Thus, estimates are provided only for the dry weather, without conservation case, as follows:

Estimated Edwards Aquifer water use, per crop acre irrigated using the 1984/1989 average of 107,683 acres (dry weather, without conservation), was 2.53 acft (Table 3.6-6). If it is assumed that the LEPA/furrow diking irrigation method is applied to 80 percent of the 107,683 acres for the dry weather, without water conservation case, the estimated water savings would be about 68,900 acft/yr (107,683 x 0.8 x 0.8 = 68,917). Such a water conservation program, if as successful as expected, could allow continued irrigation of the 107,683 acres of crops now supplied with water from the Edwards Aquifer, but instead of 2.53 acft/acre, the rate with LEPA/furrow diking is assumed to be 1.79 acft on 86,146 acres and 2.53 acft on the remaining 21,536 acres. Under provisions of SB 1477, the 68,900 acft of water saved could be sold or leased, provided irrigation farmers were awarded permits for the estimated quantity of Edwards water used (273,082 acft) in the 1984/1989 period (Table 3.6-6). (Note: The quantity of Edwards irrigation water to be permitted is not known, thus a better estimate of irrigation water made available through water conservation cannot be made at this time.) However, since the 273,082 acft represents a likely maximum quantity which could be awarded, the potential 68,900 acft/yr likewise represents a likely maximum.

(2) **Irrigated Acreage Constant/Average Weather Irrigation Strategy**: If irrigation farmers who use Edwards Aquifer water were offered compensation for adopting an irrigation strategy for average weather conditions whereby in dry years they would still only use quantities equivalent to average year conditions, the estimate of the potential quantity of water that might be available for sale or lease could be about 69,824 acft per year. The estimated savings during dry years is 1.05 feet (calculated as: 2.54' - 1.49' = 1.05). Rounding this figure to 1.00 and applying this reduction in water use over 69,824 acres results in a potential annual reduction of about 69,800 acft[122].

The estimate presented above is based upon a sale or lease of 12 acre-inches (one acft) per acre, or 39 percent of a total estimated use of 30.43 acre-inches (2.54 acft) in dry

[122]Based on an estimate that 75 percent of acreage receiving irrigation water from the Edwards Aquifer in 1984/1989 would receive an irrigation permit for two acft/acre under terms of SB 1477.

weather conditions[123]. Of course permits or other conditions would have to be in place to assure purchasers or lessors that such arrangements would be secure. These estimates are based on the assumption that the purchase or lease terms are sufficient to allow the irrigating farmers to plan and operate their irrigation enterprises as if every year were an average rainfall year; i.e., a maximum of 18 inches of irrigation would be needed and the 12 additional inches that had historically been used during dry years would be sold or leased for municipal and industrial uses. During average weather years, crop yields would develop as expected, other things such as insects, diseases, and frost-free dates being equal, and the expected farm income and expenses would materialize. However, during dry years, crop yields would be lower than for average weather conditions, and in some cases might be zero. For the dry year case, irrigation farm income would suffer without some form of compensation. The price for water sold or leased would need to be set to compensate irrigation farmers in order for them to be willing to consider sale or lease of water. In addition, the economy would suffer due to a reduction in the quantity of farm produce to be marketed.

(3) **Irrigated Acreage Constant/Dry Weather Irrigation Strategy**: In the case described above, the sale or lease of Edwards irrigation water would be done as a result of a change in irrigation strategy to one suited to average weather conditions. If, however, a different approach were taken in which the farmers were to plan irrigation on the basis of a dry weather strategy, with conservation, and plan to sell or lease that part of the irrigation supply that was not needed during years when average or wet weather occurred, then during average and wet years, some quantity of Edwards irrigation water might be available for sale or lease. However, data with which to make estimates are not available and this option was not given further consideration.

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[123]In a 1993 study entitled "Economic and Hydrologic Implications of Proposed Edwards Aquifer Management Plans," McCarl, Bruce, et.al.) estimated that 87,000 acft of Edwards aquifer irrigation would be transferred to municipal and industrial uses by year 2000 if total Edwards Water use is limited to 400,000 acft when Edwards water levels at index well J-17 is above 666 feet and 350,000 acft when the level at J-17 drops below 625 acft. The study was based upon the assumption that water would be allocated among uses through a market mechanism in which total community welfare is maximized.

(4) **Irrigated Acreage Converted to Dryland**: The possibility exists under SB 1477 to sell or lease irrigation water supplies and convert up to one-half of the farmer's irrigated land to dryland production. The quantity of water potentially available would depend upon the price offered, and under the provisions of SB 1477 the maximum quantity available for purchase would be one-half of the volume of irrigation water permitted, which of course, is not known at this time. For perspective, the estimated acreage receiving Edwards water for irrigation in the late 1980's was 93,099 acres (Table 3.6-6). If, as provided under SB 1477, the irrigators are awarded permits for two acft/acre on 75 percent of acreage receiving irrigation water from the Edwards Aquifer in 1984/1989, then the quantity potentially available for sale or lease would be 69,800 acft (figured as 50 percent x 2 acft/acre x 93,099 x 75 percent). The relationship between the estimated quantity of Edwards water used in 1990 (519,796 acft) to the 400,000 acft/yr of water that SB 1477 allows to be withdrawn from the Edwards Aquifer beginning in 2008 is the basis for the estimate that 75 percent of the 1984/1989 average acreage receiving Edwards irrigation water would receive an irrigation permit of 2 acft per acre.

3.6.5 Regional Economic Effects of Edwards Irrigation Water Transfer

The purposes of this section are: (1) present estimates of the economic value of crops produced in Uvalde, Medina, and Bexar counties using Edwards Aquifer water; and (2) present estimates of the economic impacts of transferring various quantities of Edwards irrigation water to municipal and industrial uses.

The estimated gross value of irrigated crops produced in the Edwards Aquifer area in 1993 was $85.01 million (Table 3.6-7). Costs of carrying out irrigated production are estimated at $75.78 million leaving $9.23 million to pay returns to land, irrigation water, and farm management (Table 3.6-7). Approximately 13.8 percent ($11.7 million) is produced in Bexar County, 37.7 percent ($32.0 million) in Medina County and 48.5 percent ($41.3 million) in Uvalde County.

The annual value of crops produced (irrigated plus dry land) in the Edwards Aquifer irrigation area (Uvalde, Medina, and Bexar counties) is approximately $103.89 millon (Table

Table 3.6-7
Estimated Value and Costs of Irrigated Production
Edwards Aquifer Area
Trans-Texas Water Program

Crop	Acres Irrigated	Value of Production[1]		Production Costs[2]		Returns to Land, Water and Management ($ millions)[3]
		Per Acre (dollars)	Total ($ millions)	Per Acre ($ millions)	Total ($ millions)	
Cotton	20,410	$764	$15.59	$610	$12.45	$3.14
Grain Sorghum	8,525	226	1.93	284	2.42	-0.49
Corn	49,458	381	18.84	362	17.90	0.94
Wheat	7,655	168	1.29	216	1.65	-0.36
Other Grain	4,878	140	0.68	165	0.80	-0.12
Forage	11,163	650	7.25	606	6.76	0.49
Peanuts	2,269	1460	3.31	706	1.60	1.71
Soybeans	2,102	231	0.48	293	0.61	-0.13
Other Oil	92	296	0.03	282	0.02	0.01
Pecans	2,965	1500	4.44	1219	3.61	0.83
Vineyard	101	4914	0.49	4130	0.42	0.07
Other Orchard	16	750	0.01	645	0.01	0.00
Alfalfa	235	650	0.15	506	0.12	0.03
Pasture	16,035	350	5.61	384	6.16	-0.55
Veg. (Shallow)	8,203	2458	20.16	2065	16.94	3.22
Veg. (Deep)	2,726	1331	3.63	1209	3.30	0.33
Other	1,124	1000	1.12	902	1.01	0.11
TOTAL[4]	137,957	----	$85.01	----	$75.78	$9.23

[1] Calculated at 1993 prices for farm products; "Texas Crop Enterprise Budgets, Southwest District," B-1241 (C13), Texas Agricultural Extension Service, The Texas A & M University System, College Station, Texas 1993.
[2] Ibid. All expenses of irrigated production except payment to land, water and management.
[3] Total value of production minus production costs.
[4] Includes 18,685 acres that are double cropped.

3.6-7)[124]. The multiplier for agricultural production for the Edwards Aquifer area is estimated at 2.11, which means that for each dollar of agricultural crop value at the farm, the total business effect within the area is $2.11[125]. Thus, the gross business in the local economy that results from the $103.89 million of crop production is estimated at $217.46 million, of which $179.37 million (82.5 percent) is from irrigated production and $38.08 million (17.5 percent) is from dryland crops.

Farm value of production per acre irrigated with Edwards water is estimated at $616 and farm value of production per acft of Edwards water used for irrigation is $210 ($57.36 million divided by 273,082 acft from Table 3.6-8). When the multiplier is applied, the gross economic benefit of an acre of irrigated production is approximately $1,300. When expressed in terms of economic impact per acft of Edwards water used for irrigation, the gross economy-wide benefit is $443 ($210 x 2.11 = $443). Thus, for each acft of Edwards water transferred from irrigation to other uses, resulting in loss of irrigation production, the local area economy could expect to be reduced by approximately $443 dollars per year, in 1993 prices, provided the irrigation land was not converted to dryland farming. Such losses would not occur in cases where the water transferred is Edwards water saved through irrigation conservation programs in which irrigated production is not reduced. However, in these cases, it would be necessary to make investments in irrigation water conservation equipment, such as LEPA and furrow diking implements. Such investments are estimated at $325 per acre (Section 3.1.2).

If irrigated land is converted to dryland production, the dryland production would offset $249 of the negative effect from the loss of an acre of land irrigated from the Edwards Aquifer ($118 value of dryland production per acre x $2.11 = $249), leaving a net negative impact upon the local economy of $1,051 (per acre irrigated) ($1,300 per acre irrigated minus $249 per acre farmed dryland). The net economic loss per acre-foot of Edwards irrigation water that might be transferred to municipal and industrial uses is estimated at

[124]Estimated using date from "Texas Crop Enterprise Budgets, Southwest Texas District," B-1241 (C13), Texas Agricultural Extension Service, The Texas A & M University System, College Station, Texas, 1993. The average value of dryland crops was computed at $118 per acre.

[125]Unpublished Output Multipliers; Lonnie L. Jones, PhD, Department of Agricultural Economics, Texas A & M University, College Station, Texas, April 1994.

Table 3.6-8 Estimated Annual Value of Irrigated and Dryland Crop Production Edwards Aquifer Area Trans-Texas Water Program	
Type of Production	**Annual Value (million dollars)**
Irrigated Crops (137,957 acres)[1]	
Edwards Aquifer (273,082 acft) (107,683 acres)	57.36
Surface Water (69,983 acft) (30,274 acres)	27.65
Total Value of Irrigated Crops (Table 3.6-7)	85.01
Dryland Crops (153,000 acres)[2]	18.05
Total Value of All Crops	$103.06

[1]1993 prices and 1984/1989 average acreages as computed in Table 3.6-5.
[2] Estimated from "Texas Field Crops Statistics", U.S. Department of Agriculture and Texas Department of Agriculture Cooperating, Austin Texas 1985, 1990, and 1992.

	Crop Acreages		
County	Dryland	Irrigated	Total
Uvalde	18,000	67,000	84,000
Medina	60,000	52,000	112,000
Bexar	75,000	19,000	94,000
Total*	153,000	138,000	290,000

*Note: Rounded to nearest 1,000

$415 per acft ($1,051/2.53 acft/acre; Table 3.6-6) if the land is converted into dryland production.

As estimated by McCarl, et.al., if 87,000 acft of Edwards Aquifer water is transferred to municipal and industrial uses, effect on the local economy would be a net loss of farm production of $17.12 million (34,387 acres at 2.53 acft/acre) resulting in an economic loss of $36.12 million, assuming the 34,387 acres were converted to dryland production[126]. The study by McCarl et.al., concluded that agricultural income of the area could be reduced by as much as 55 percent by year 2000, if this level of irrigation transfer were made. Total

[126]"Economic and Hydrologic Implications of Proposed Edwards aquifer Management Plans," McCarl, B.A., Wayne Jordan, R. Lynn Williams, Lonnie Jones, and Carl R. Dillon, Texas A & M University, College Station, Texas, March, 1993.

income from agriculture was estimated at $76.73 million per year, thus the losses would be estimated at $42.84 million, or $492 per acft of water, which is 18.5 percent higher than the $415 per acft estimate presented above.

3.6.6 Summary

Irrigation in the Edwards Aquifer irrigation area of Uvalde, Medina, and Bexar counties has been applied to 119,272 acres of land of which 18,685 acres are double cropped, giving total crop acres irrigated of 137,957 (1984/1989 average). Estimated average annual water use for the 1984/1989 dates was 343,065 acft, of which 273,082 acft, or 79.6 percent was from the Edwards Aquifer. Acreage irrigated using Edwards water is estimated at 93,099.

The quantity of Edwards Aquifer irrigation water that could be made available for purchase or lease through irrigation water conservation on existing acres irrigated with Edwards water is estimated at about 68,900 acft/yr. However, it should be noted that until permits are established that determine the quantities available for irrigation, it cannot be concluded that water conservation programs would result in the quantities mentioned above.

If irrigation farmers were to adopt an average weather irrigation strategy with conservation, it is estimated that perhaps 69,824 acft of Edwards irrigation water could be available for purchase or lease. However, a system of permits or other means of limiting withdrawal from the aquifer would need to be in place in order to establish quantities and to interest potential purchasers or lessors in buying or leasing Edwards water.

If irrigation farmers were to decide to convert irrigated acreages to dryland production and sell or lease the associated Edwards irrigation water, the maximum quantity available under terms of SB 1477 would be one-half the permitted irrigation quantities. Since permits have not been issued, this quantity cannot be firmly quantified, except to say that the quantity would probably be about 69,800 acft, since SB 1477 provides that a permit can be issued for two acft per acre of irrigated land that qualifies for such permits. Under this option, under provisions of SB 1477, the 50 percent of permitted water remaining with the land would either continue to be used for irrigation, or perhaps by agreement, could be left in the aquifer in order to contribute toward keeping the aquifer at a higher level.

The estimated value of agricultural production in the Edwards Aquifer area, in 1993 prices, was $103.89 million, of which $85.01 million (82 percent) was from irrigated crops. Of the $85.01 million in value of irrigated production, $57.36 million or 67 percent was estimated to originate from acreages irrigated with Edwards water.

The multiplier for agricultural production for the Edwards Aquifer area is estimated at 2.11, as discussed above (Section 3.6.5). Thus, the economic effect of irrigation using Edwards irrigation water is estimated at $121.02 ($57.36 million x 2.11) million annually.

Farm value of production per acre irrigated with Edwards water is estimated at $616, and farm value per acft of production of Edwards water used estimated at $210. When the multiplier is applied, the gross economic effect per acft of Edwards water is $443. Thus, for each acft of Edwards water transferred from irrigation that results in loss of irrigation production, the area economy could expect to be reduced by approximately $443 dollars per year, in 1993 prices, provided the irrigation land is not converted to dryland farming. If irrigated land were converted to dryland production, the dryland production would offset a part of the loss from reduced irrigation. On an acft-of-irrigation-water basis, the recovery from dryland is estimated at $28.00, leaving a net loss to the overall economy of $415 per acft. Such losses would not occur, however, if the water transferred were obtained through irrigation water conservation programs that do not reduce overall irrigation production.

A study by McCarl, et.al., of Texas A & M University concluded that agriculturally produced income of the area could be reduced by as much as 55 percent by year 2000, if 87,000 acft of irrigation water were transferred to municipal and industrial uses[127]. Total agricultural income was estimated at $76.73 million per year, thus the loss would be estimated at $42.84 million, or $492 per acft of water, which is 18.5 percent higher than the $415 per acft estimate presented above.

3.6.7 Implementation Issues

Until a regional authority exists to regulate aquifer pumpage, the purchase of irrigation rights will not necessarily reduce demand on the aquifer. The value of the

[127] In the San Antonio Water System, "Recommended Water Resource Plan," presented to the Mayor's 2050 Water Resources Committee, an irrigation water lease option of 50,000 acft/yr average and 30,000 acft/yr firm, was included at a cost of $150 per acft, San Antonio, Texas, April 27, 1994.

Edwards irrigation water use permits provided for by SB 1477, when these are awarded, will need to be studied in order to estimate the cost of purchasing or leasing Edwards irrigation water for municipal/industrial uses.

An evaluation should be made of the effect on the aquifer of changing monthly demand distribution patterns which could result if this alternative were implemented.

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3.7 Demineralization of Edwards "Bad Water" (L-16)

3.7.1 Description of Alternative

Demineralization is the process by which dissolved mineral and saline constituents such as calcium, magnesium, sulfate, dolomite, and gypsum compounds are removed from water. Demineralization processes (also called desalting processes) can be used to purify sea water, brackish groundwater, and effluent from wastewater treatment plants to produce water for municipal and industrial needs. Due to the comparatively high costs of these processes, demineralization is used mainly in arid regions where the importation of freshwater is very costly. Various demineralization processes are operated in the United States, primarily in Florida, California, Texas, and the U.S. Virgin Islands. According to the TWDB[128], there are approximately 89 desalting plants in Texas located throughout the State producing water for municipal, industrial, and power generation supplies.

Beginning at the downdip limit of fresh water in the Edwards Aquifer, the aquifer contains water that is classified as slightly saline to brine. For reference, saline water is classified by the categories in Table 3.7-1. Locally, the down dip fresh water limit is referred to as the "bad-water line" which occurs where the total dissolved solids reach 1000 mg/l.

Table 3.7-1
Classification of Saline Water

Classification	Dissolved-solids concentration (milligrams per liter)
Fresh	<1,000
Slightly saline	1,000 - 3,000
Moderately saline	3,000 - 10,000
Very saline	10,000 - 35,000
Brine	>35,000

Source: Winslow, A.G., and Kister, L.P., "Saline Water Resources of Texas," U.S.G.S. Water Supply Paper 1365, 1956.

[128]Texas Water Development Board, "Desalting in Texas, A Status Report", May 1992.

Currently a number of irrigation wells tap slightly saline water to the south of the Edwards "bad-water line" to irrigate crops that are tolerant of the saline water. The potential water resource alternative considered here is to pump saline water from south of the Edwards "bad-water line" and to demineralize it to drinking water standards.

3.7.2 Available Yield

The following discussion was developed from information submitted by LBG/Guyton Associates to HDR Engineering for the Trans-Texas Water Program Analysis.

Three sets of monitor wells have been constructed that transect the "bad-water line", one set in Bexar County, one set in Comal County, and one set in Hays County. The bad water line transect in Bexar County was completed in 1986 with a total of seven wells at three sites. The Bexar County transect is in close proximity to a major well field known as Artesia Station used to supply freshwater to the City of San Antonio. Long-term observations of water level changes with time and shorter term pumping tests indicate that not only is there hydraulic communication vertically within the wells but hydraulic communication exists across the "bad-water line" because changes in water levels are seen in all the wells both fresh and saline[129]. The same general observations have been made for the transect wells in Comal and Hays counties. This indicates that both fresh and saline zones of the Edwards Aquifer are in the same artesian system.

Additionally, flow is thought to go from the freshwater zone to the saline zone mostly in the western part of the aquifer[130]. Increased pumping in the saline zone may increase that flow pattern and directly remove more water from the freshwater zone. Therefore, if substantial amounts of water are withdrawn from the Edwards Aquifer saline zone, a comparative decrease of the artesian pressure and available water in the freshwater zone would occur, which would result in decreased springflow at Comal and San Marcos springs. <u>Pumping water from the saline zone would almost be the same as pumping from the freshwater zone.</u>

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[129]Guyton Associates, 1986.

[130]Maclay and Land, L.F. "Simulation of Flow in the Edwards Aquifer, San Antonio Region, Texas and Refinement of Storage and Flow Concepts", U.S.G.S. Open-File Report 86-532, 1987.

Demineralization processes are very sensitive to changes in water quality, and the cost of treating brackish groundwater could rise dramatically if the feedstock water quality degrades significantly and more energy is required by the process. Therefore, development of a brackish groundwater source must be carefully planned, and a pumping rate yield which will maintain water quality and minimize salt water intrusion must be determined. Particular attention must be given to well locations, spacings, and pumping arrangements to minimize the long term impact on feed water salinity.

No firm data exists on which to determine a long-term "yield" of saline water from the Edwards. Duffin[131] estimates that over 2 million acft of saline water could be in storage in the Edwards Aquifer in the San Antonio region. Using Duffin's estimate, a possible supply amount during the 50-year planning period would be 40,000 acft/yr. For costing purposes, a 36 mgd facility (i.e., 40,000 acft/yr) is conceptualized that will produce water for 50 years from the 2 million acft of saline water estimated by Duffin. Using a brine production rate of 10 percent of total pumpage, the aquifer withdrawal rate would actually be 40 mgd (i.e. 44,800 acft/yr). However, the firm yield of this alternative is effectively 0 acft/yr if pumping water from the saline zone effectively is the same as pumping water from the fresh water zone.

3.7.3. Environmental Issues

Extraction and demineralization of water from the deeper (down-dip) portions of the Edwards Aquifer that exhibit high dissolved solids levels, low dissolved oxygen concentrations, and other water quality problems has been proposed as a possible water supply source. It is not certain how these withdrawals might affect springflows or the resident troglobitic fauna that is confined to the upper, oxygenated zone. However, withdrawals from the bad water zones will likely draw down the aquifer as much as equivalent withdrawals in the upper zone, equally affecting springflow and the volume of aerobic habitat in the aquifer. Upper zone water drawn down into the bad water portion

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[131]Duffin, G.C., "Subsurface Saline Water Resources in the San Antonio Area, Texas," TWDB Open-File Report, 1974.

of the aquifer will subject the fresh water to the same conditions that result in low dissolved oxygen and high dissolved solids or "bad water". This may be considered a fatal flaw.

The environmental consequences of producing potable water by demineralization are primarily determined by: 1) the nature of the source water, 2) the characteristics of the location used to receive the brine discharge, and 3) the energy-intensive nature of the various processes.

Due to the small areas involved, direct disturbance of plant and animal communities by facility and pipeline construction is generally not substantial, and not different from conventional water treatment and distribution systems. Where the source water body is very large compared to the amounts withdrawn for treatment, direct operational effects of these facilities generally result from the need to dispose of the suspended and dissolved solids removed from the source water.

Disposal of materials removed from raw water is generally accomplished by discharging a concentrate consisting of a fraction (about 10 percent in this case) of raw water volumetric input, and containing almost all of the dissolved materials in the original raw water volume. For a source having a TDS of about 10,000 mg/l (moderately saline), the discharge would be a brine with a TDS in the range of about 100,000 mg/l. Obviously, there are no freshwater bodies into which such effluents could or would be discharged. The other disposal options are injection to a deep formation or evaporation ponds. Production of large quantities of fresh water by any of the methods discussed in the preceding sections requires substantial energy use. Environmental impacts resulting from construction and operation of additional electric generating capacity required as a result of implementing a desalination alterative could be regarded as an impact of that facility.

3.7.4 Water Quality and Treatment

[To be completed in subsequent phases of the study.]

3.7.5 Engineering and Costing

Demineralization processes are divided into three primary classifications: Distillation, Electrodialysis/Electrodialysis Reversal (ED/EDR), and Reverse Osmosis (RO).

3.5.4 Water Quality and Treatment

[To be considered in subsequent phases of this study.]

3.5.5 Engineering and Costing

The major cost elements for this alternative would include the San Antonio River diversion structure, water intake, and pump station, transmission line to Choke Canyon Reservoir, and the discharge structure into the reservoir. The San Antonio River intake and pump station are sized to deliver 1,000 acft/month (10.8 mgd) through a 30-inch diameter transmission line. The operating cost was determined for a total pumping head of 535 feet and an annual water delivery of 8,400 acft/yr. Capital and O&M costs for this alternative are contained in Table 3.5-4.

The cost of this alternative could be included as a part of Alternative L-18, Type 2 Natural Recharge Enhancement Projects to mitigate the yield impacts associated with development of the recharge program.

The total annual cost of this alternative is $3,218,000 as shown in Table 3.5-4. This is $818,400 per annum more or 34 percent higher than the annual costs included for water rights mitigation costs in Alternative L-18 in a previous study.[117] The costs estimated in the previous study were estimated based on replacement water cost for the South-Central Study Area. One possible way to further reduce the cost of this alternative would be to combine it with Alternative L-3 (i.e., use of groundwater from Campbellton Wells) as identified in the Trans-Texas South-Central Phase I-Interim Report. This combined alternative is included as part of the Phase II study for the South-Central area.

3.5.6 Implementation Issues

Because of the lack of water potentially available to transfer to Choke Canyon Reservoir under the Trans-Texas Environmental Criteria, this alternative water supply may not be viable unless the transfer were to occur under existing water rights. Additionally, a bed-and-banks permit from the TNRCC may be required to transfer the water from the wastewater plants to the point of diversion.

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[117]HDR Engineering, Inc., 1994, Edwards Aquifer Recharge Enhancement Project, Phase IVA, Edwards Underground Water District, San Antonio, Texas.

Distillation processes produce purified water by vaporizing a portion of the saline feedstock to form steam. Since the salts dissolved in the feedstock are nonvolatile, they remain unvaporized and the steam formed is captured as a pure condensate. Distillation processes are normally very energy-intensive, quite expensive, and are generally used for large-scale desalination of sea water. Heat is usually supplied by steam produced by boilers or from a turbine power cycle used for electric power generation. Distillation plants are commonly dual facilities which produce purified water and electricity.

The remaining two desalination methods, ED/EDR and RO, are membrane processes which are commonly used for the demineralization of saline sources. These processes utilize semipermeable membranes which allow selected ions to pass through while other ions are blocked. These membranes are used in the processes to isolate and remove the dissolved salt ions from the feedstock. The dissolved salt ions are removed from the feedstock by attracting the ions to electrical charges or by driving the ions out of solution with high pressure. As a result, both ED/EDR and RO are also very energy-intensive.

The most recent technological advancements in demineralization processes have occurred in membrane technology. These advances have lowered the operating pressures of the membrane processes and have developed methods to accomplish more than TDS removal. Membranes can now also be used for water softening and for the removal of organic constituents.

Desalination of slightly to moderately saline water is performed by a number of communities across the United States that have no other economical choice for a potable water supply. With recent improvements of demineralization technologies, desalination of slightly saline to very saline water is technically feasible. However, desalination of "oilfield type" heavy brines found in the Edwards much further to the south of the "bad-water line", which can have dissolved solids greater than 100,000 mg/l, is probably not economically feasible. This does not take into consideration the problem of removing the hydrocarbons and hydrogen sulfide that will be dissolved in this water. As a result, the only Edwards Aquifer saline water that should be considered for desalination is relatively close to the interface between the freshwater and saline-water zones.

Since demineralization processes use enormous amounts of energy, the cost of the process is controlled mainly by the amount of energy required to purify the water and is directly related to the TDS concentration of the feedstock. Therefore, desalination of sea water would be much more expensive than demineralization of brackish groundwater since the TDS of the feedstock differs by about a factor of 10.

Degradation of the raw water supply is possible over time as brine may migrate toward the supply wells. Therefore, before any desalination process is considered feasible, a comprehensive evaluation of the quality of the groundwater available and the long-term dependability of the water quality should be completed.

The Brazos River Authority's Lake Granbury Surface Water Treatment System (SWATS), which was designed by HDR Engineering, is a demineralization plant typical of those in Texas which supply water for municipal use. The operation and maintenance cost to treat the 2,500 mg/l TDS feedstock to potable conditions is typically around $295 per acft. Coupled with the annual capital cost for the facility, the cost to produce water is approximately $650 per acft.

An additional issue which may influence the cost of constructing a demineralization facility in the San Antonio area is the presence of an adequate and dependable power supply. All of the processes discussed above are energy-intensive and could require construction or expansion of the local power generation facilities.

For Phase I comparison purposes, a 36 mgd facility has been conceptualized and a cost estimate developed. This conceptual plan would be located south of the "bad water line," but a specific site was not chosen. For costing purposes, the supply wells are expected to produce 1,300 gpm each and the brine waste would be discharged to injection wells placed into the Buda, Navarro, or Austin formations at 70 gpm per well. The capital and O&M cost estimate is contained in Table 3.7-2.

Table 3.7-2 Cost Estimate Summary for Demineralization of Edwards "Bad Water" (L-16) (Mid - 1994 Prices)	
Item	**Estimated Cost**
Capital Costs	
Supply Wells	$12,100,000
Injection Wells	18,420,000
Treatment Plant	58,000,000
Supply Pipelines	12,440,000
Injection Pipelines	8,290,000
Delivery System	34,780,000
Total Capital Cost	$144,030,000
Engineering, Contingencies, and Legal Costs	49,370,000
Land Acquisition	330,000
Environmental Studies and Mitigation	5,000,000
Interest During Construction	13,910,000
Total Project Cost	$212,640,000
Annual Costs	
Annual Debt Service	$19,920,000
Annual Operation and Maintenance	11,940,000
Annual Power Cost	1,920,000
Total Annual Cost	$33,780,000
Available Project Yield (acft/yr)	No increased net yield.
Annual Cost of Water	N/A

3.7.6 Implementation Issues

The main implementation issues to be addressed in the development of a demineralization facility are the expected feedstock water quality and the location and environmental impacts of brine disposal. In order to give this alternative further consideration, a thorough groundwater study would be needed, including the study of aquifer yields and TDS levels. The environmental concerns which must be addressed will require several permits. Permitting for some desalting facilities constructed in Florida and California has taken several years to complete. The cost of performing an environmental study of the impacts of the facility and its brine discharge coupled with the costs of obtaining permits would be high. Due to the high costs of demineralization, the difficulty of brine disposal, and the likely possibility of no net effective increase in water supply, it is recommended that this alternative not be considered for further study at this time.

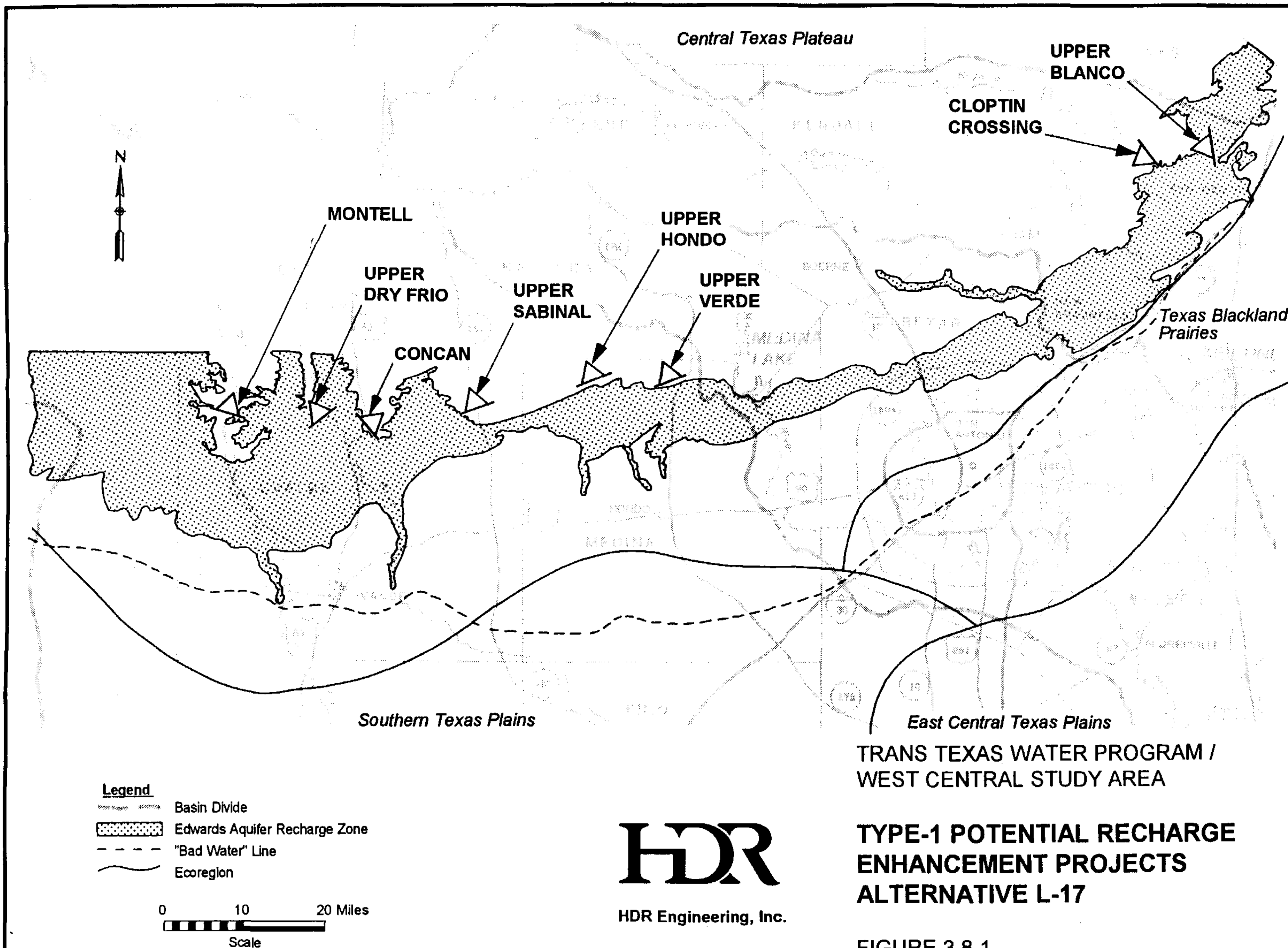
3.8 Natural Recharge - Type 1 Projects (L-17)

3.8.1 Description of Alternatives

Two types of recharge enhancement reservoirs have been analyzed in a series of studies sponsored by the Edwards Underground Water District beginning in 1990. Type 1 reservoirs are catch-and-release structures located upstream of the Edwards recharge zone, and Type 2 Reservoirs are immediate recharge structures located within the recharge zone. This alternative deals with the potential construction of Type 1 projects. Type 1 structures are generally operated to release water at the maximum recharge rate of the downstream channel. These structures release water as quickly as possible to the aquifer, thereby minimizing evaporation losses and maximizing long-term average recharge. Under this type of operation, reservoir levels will fluctuate more than might normally be expected due to the large release rates.

The location of each of the eight Type 1 recharge projects considered herein is shown in Figure 3.8-1. Six of the projects are located in the Nueces River Basin and affect inflows to the Choke Canyon/Lake Corpus Christi Reservoir System (CC/LCC System) and the Nueces Estuary. These six projects include Montell, Upper Dry Frio, Concan, Upper Sabinal, Upper Hondo, and Upper Verde. One previously identified site in the Nueces Basin (i.e., Upper Seco) was not included in this study because the quantity of enhanced recharge during the drought was extremely small (i.e., 290 acft/yr) and the associated unit costs were extremely high. On the Blanco River, the Cloptin Crossing and Upper Blanco sites are included in this study. Cloptin Crossing Reservoir was identified and studied by the Corps of Engineers in the 1960's[132]. It is the largest of all eight sites with a 283,400 acft conservation pool. The Upper Blanco Reservoir would likely be much smaller with a 24,290 acft conservation pool.

[132]U.S. Army Corps of Engineers (USCE), "Survey Report on the Edwards Aquifer Underground Reservoir Guadalupe, San Antonio, and Nueces River Tributaries, Texas," Edwards Underground Water District, December, 1964.



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TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

TYPE-1 POTENTIAL RECHARGE ENHANCEMENT PROJECTS ALTERNATIVE L-17

FIGURE 3.8-1

Type 1 recharge projects considered in previous studies[133,134,135] have been grouped into two programs for consideration in this study. The first program is the "Maximum Conservation Capacity Program" and includes all six projects in the Nueces Basin constructed to their largest potential size as well as the Cloptin Crossing project on the Blanco River. These seven projects could impound a maximum of 908,000 acft in their combined conservation storage pools and periodically inundate a total of 23,880 acres. The second program is the "Optimum Conservation Capacity Program" and includes all the same projects as in the Maximum Program except that the Cloptin Crossing project is replaced with the Upper Blanco project. In the Optimum Program, the recharge projects have been downsized from the Maximum Program to a size that generally results in the lowest annual cost per unit of recharge enhancement at each location. For all projects except the Upper Verde project, this optimum size was about 10 percent of the maximum size. For the Upper Verde project, the optimum size was about 25 percent of the maximum size. The seven sites in the Optimum Program impound a maximum of 90,200 acft in their combined conservation pools which is only about 10 percent of the Maximum Program and periodically inundate a total of 4,660 acres or about 20 percent of that for the Maximum Program.

3.8.2 Available Yield

Available yield or recharge enhancement volumes were calculated using the Nueces River Basin Model[136] subject to average and drought conditions. <u>Average conditions</u> represent the average annual recharge rate for the entire 56-year period (1934-1989) analyzed. <u>Drought conditions</u> represent the average annual recharge rate for the 10-year period from 1947 through 1956, which is when the most severe drought of record occurred.

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[133]HDR Engineering, Inc., "Nueces River Basin Regional Water Supply Planning Study, Phase I," Nueces River Authority, May, 1991.

[134]HDR Engineering, Inc., "Guadalupe-San Antonio River Basin Recharge Enhancement Study," Vols. I, II, and III, Edwards Underground Water District, September, 1993.

[135]HDR Engineering, Inc., "Nueces River Basin Regional Water Supply Planning Study, Phase III - Recharge Enhancement," Nueces River Authority, November 1991.

[136]HDR Engineering, Inc., "Nueces River Basin Regional Water Supply Planning Study, Phase I," Nueces River Authority, May, 1991.

Analyses of recharge enhancement projects presented in this study were performed honoring all existing water rights to the maximum extent possible, with one exception. This exception involved the water rights of the CC/LCC System in which case impacts would not be mitigated by releases, but instead were assumed to be purchased. Other alternatives may be available to mitigate the impact of the recharge projects on the CC/LCC System such as Alternative L-14 which considers the transfer of San Antonio River water into Choke Canyon Reservoir.

For the Maximum Conservation Capacity Program, recharge could be enhanced by 146,985 acft/yr for average conditions and 70,970 acft/yr for drought conditions as shown in Table 3.8-1. For the Optimum Program, recharge could be enhanced by 75,900 acft/yr for average conditions and 35,620 acft/yr for drought conditions; both amounts being equal to about 50 percent of the Maximum Program. The impacts on the yield of the CC/LCC System are shown in Table 3.8-1 and total about 7,700 acft/yr for the Maximum Program and about 4,900 acft/yr for the Optimum Program.

Application of the Trans-Texas environmental criteria for reservoir pass-throughs for instream flows and estuarine flows was not included in the Phase 1 study scope of work for the Type 1 recharge projects. Strict application of these criteria would likely reduce the quantities of water available for the Cloptin Crossing and Upper Blanco sites. However, it is unlikely that these criteria will significantly affect the recharge enhancement potential of the other six sites as all of these sites are located on streams that normally do not contribute flows to streams downstream of the recharge zone. Calculated and estimated reductions in average estuarine inflows are shown on Table 3.8-1. The impact on the average inflow to the Nueces Estuary due to all six Nueces Basin sites being constructed at this optimum size amounts to a reduction of about 8,900 acft/yr or about three percent. The impact of the Cloptin Crossing Reservoir on the average inflow to the Guadalupe Estuary (measured at the Saltwater Barrier) would be a reduction of 16,000 acft/yr or about one percent. The average impact of the Upper Blanco Reservoir would be about 11,400 acft/yr or less than one percent of the average annual flow passing the Saltwater Barrier in the Guadalupe-San Antonio River Basin. Additional analysis of the projects in the Nueces

Table 3.8-1
Summary of Recharge Enhancement Potential for Type 1 Reservoir Programs

Type 1 Project	Percent Capacity	Capacity (acft)	Surface Area (ac)	Recharge Enhancement (acft/yr) 1934-1989 Average Conditions	Recharge Enhancement (acft/yr) 1947-1956 Drought Conditions	Reduction in Average Estuarine Inflow (acft/yr)	Reduction in CC/LCC System Yield (acft/yr)
Maximum Conservation Capacity Program							
Montell	100	252,300	6,190	39,220	17,850	5,510(E)	3,700(E)
Upper Dry Frio	100	60,000	1,800	9,540	2,900	1,400(E)	600(E)
Concan	100	149,000	3,840	15,950	3,890	2,400(E)	1,100(E)
Upper Sabinal	100	93,300	3,110	19,000	2,590	2,800(E)	1,500(E)
Upper Hondo	100	47,000	2,000	9,420	1,140	1,400(E)	600(E)
Upper Verde	100	23,000	880	5,580	1,910	800(E)	200(E)
Cloptin Crossing	100	283,400	6,060	48,275	40,690	16,000(E)	0
TOTAL		908,000	23,880	146,985	70,970		7,700(E)
Optimum Conservation Capacity Program							
Montell	10	25,230	1,460	32,090	14,750	3,700(E)	3,200(E)
Upper Dry Frio	10	6,000	440	5,840	2,630	800(E)	200(E)
Concan	10	14,900	710	8,740	3,850	1,300(E)	500(E)
Upper Sabinal	10	9,330	550	11,240	2,590	1,700(E)	700(E)
Upper Hondo	10	4,700	350	4,700	1,140	700(E)	200(E)
Upper Verde	25	5,750	350	4,540	1,910	700(E)	100(E)
Upper Blanco	N/A	24,290	800	8,750(E)	8,750	11,400(E)	0
TOTAL		90,200	4,660	75,900	35,620		4,900(E)

[E] - Estimated on the basis of comparisons with recent work performed on the Type-2 recharge structures.

River Basin shows that natural recharge of the Carrizo-Wilcox aquifer would be reduced by less than 1 percent. Frequency of overbank inundation in the braided reach of the Nueces River would be reduced by less than 1 percent while the frequency of zero flows (which presently occur about 40 percent of the time) would be essentially unaffected.

3.8.3 Environmental Issues

Type 1 Reservoirs are catch and release structures that would be located upstream of the Edwards Aquifer recharge zone. They would be operated to store water during periods of surplus, while releases would be maintained at the maximum recharge rate possible in the downstream channel during periods when flow over the recharge zone would have been less under historical conditions. These structures would be located within the stream channel and may maintain storage contents for months or even years.

Suitable sites for the Type 1 Reservoirs are located in the area encompassing the headwaters of the Nueces River Basin along the southern margin of the Edwards Plateau in Medina and Uvalde Counties, and the Blanco River along the southeastern margin of the Edwards Plateau in Hays County. There are four Type 1 reservoir sites in Uvalde County (Montell, Upper Dry Frio, Concan, Upper Sabinal), two Type 1 reservoir sites in Medina County (Upper Hondo, Upper Verde), and two Type 1 reservoir sites in Hays County (Cloptin Crossing, Upper Blanco) (Fig. 3.8-1).

These proposed reservoirs are located in the southern and southeastern portion of Omernik's Central Texas Plateau which is bordered by the Texas Blackland Prairies to the east and the Southern Texas Plains to the south (Fig 3.8-1)[137]. Omernik describes the area as tablelands with moderate relief, plains with high hills, and open high hills dominated by juniper-mesquite-oak savannahs and bluestem grasses with dry mollisols. Correll and Johnston describe the vegetation of the Central Texas Plateau as dense stands of ashe juniper, various scrub oaks and mesquite[138]. The dominant climax grasses of the ecoregion include switchgrass, several species of bluestem and grama, Indian grass, Canada wild-rye, curly mesquite and buffalo grass. The rocky limestone outcrops typically support a tall or mid-grass understory and a brush overstory complex of live oak, Texas oak, shinnery oak, junipers and mesquite. Juniper and mesquite brush are generally thought of as invaders into

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[137] Omernik, James M., 1987, "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1) pp. 118-125.

[138] Correll, D.S., and M.C. Johnston, 1979, Manual of the Vascular Plants of Texas, Texas Research Foundation, Renner, Texas.

a presumed climax of largely grassland or savannah, except on the steeper slopes which have continually supported dense cedar and oak thickets.

Blair considered this area to be in the Balconian Biotic Province and characterized it as an intermixture of faunal elements of other major provinces[139]. The vertebrate fauna of the Balconian Province contains species from the Austroriparian, Tamaulipan, Chihuahuan and Kansan Biotic Provinces. Blair's description of the vegetation of the area generally agrees with Omernik, Correll and Johnston, and Gould's descriptions. The flood plains of the streams consist of mesic forests of live oak, elm, hackberry and pecan, with cypress lining some streams[140]. Gould described the climax grasses of the Edwards Plateau as a tall or mid-grass understory composed of switchgrasses and bluestems[141].

Soils of Medina County are light colored, brownish to reddish and well drained with areas of dark loamy surfaces over clayey subsoils[142]. In the southeast portion of the county the soils are deep with light colored loam over mottled, clayey subsoils. The soils of northern Uvalde County are light to dark, well drained, loamy soils with accumulations of lime[143]. The southern part of the county has soils which are light colored, well drained, gray to black cracking clayey soils with high shrink- swell potential. The soils of Hays County are slightly acidic with loamy surfaces over cracking, clayey subsoils and acidic cracking, clayey soils that have a high shrink-swell potential[144].

Within the Nueces River Basin, the primary land use is agricultural. About 84 percent of the area of Medina and Uvalde Counties was estimated to be rangeland, 6 percent

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

[140]Ibid.

[141]Gould, F.W., 1975. The Grasses of Texas, Texas A&M University Press, College Station, Texas.

[142]Clements, John, 1988, Texas Facts: A Comprehensive Look at Texas Today County by County, Clements Research II, Inc., Dallas, Texas.

[143]Ibid.

[144]Ibid.

pasture, and 10 percent cropland[145]. Primary land use of Hays County is agricultural with 75 percent of the land in farms and ranches, 8 percent of this is in harvested cropland and less than 1 percent irrigated[146].

The conventional Type 1 Reservoirs will eliminate terrestrial habitat through dam construction and permanent inundation to the extent of their recharge pools. Because the Type 1 sites are located in perennial, typically spring-fed, reaches, aquatic habitat quality tends to be high and of particular importance in arid areas with a scarcity of permanent surface water. The regional gradients in precipitation and evaporation are such that aridity increases from east to west. Species diversity and productivity are both nearly always greater in perennially flowing streams and springs than in intermittent systems, even when permanent pools persist in the latter. Because perennial flow often occurs in isolated situations in the western half of Texas, unique (endemic) species may be present. For those reasons, and because perennial flow appears to be a diminishing resource there, the sensitivity of lotic habitats, including springs, may be considered high. Recharge pool levels and major types of habitat that would be inundated as a result of operation of these Type 1 reservoirs are listed below in Table 3.8-2.

Operation of the Type 1 structures will affect streamflows below each reservoir, resulting in reduced flood peaks entering the recharge zone, and increased frequency and duration of low flows covering the recharge zone. Application of the Trans-Texas Criteria for new reservoirs does not appear to be appropriate for these sites. Minimum flows based on hydrology at the dam sites will not be reflective either of aquatic habitat conditions over the recharge zones, or of contributions to streamflows below the recharge zones. All the streams considered in the Nueces basin are intermittent over the recharge zone, and aquatic communities there would benefit by increasing the periods during which lotic conditions are present.

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[145]HDR Engineering, Inc., 1991, "Regional Water Supply Planning Study Phase III Recharge Enhancement, Nueces River Basin."

[146]Clements, John, 1988, Texas Facts: A Comprehensive look at Texas Today County by County, Clements Research II, Inc., Dallas, Texas.

Table 3.8-2 Habitats Affected by Operation of Type 1 Recharge Reservoirs					
Reservoir	**Conservation Pool (acres)**	**Grasslands (%)**	**Brushlands (%)**	**Woodlands (%)**	**Wetlands (acres)**
Montell	6,190	5%	20%	75%	1.2
Upper Dry Frio	1,800	75%	0%	25%	6.2
Concan	3,840	40%	40%	20%	1.8
Upper Verde	880	15%	0%	85%	14
Upper Sabinal	3,110	70%	0%	30%	26.8
Upper Hondo	2,000	20%	0%	80%	13.4
Cloptin Crossing	No information available				
Upper Blanco	No information available				

Conversely, the Blanco River, although also intermittent over the recharge zone, is less so and retains very large perennial pool habitats which support productive and diverse communities comparable to perennial streams in the region. Blanco River recharge is believed to contribute to local springflows, which do rejoin surface flow at the San Marcos Blanco River confluence.

Effects to the Nueces Estuary inflows, and on the yield of the Choke Canyon (CC) - Lake Corpus Christi (LCC) system, are presented in Section 3.8.2 and Table 3.8-1. CC/LCC system yields would be reduced slightly (4,900 acft/yr under the optimum capacity scenario) and fully compensated for by users of the enhanced Edwards recharge. Projected reductions in Nueces Bay inflows would be similarly small (8,900 acft/yr under the optimum capacity scenario) and at least partially offset by water imported to the system to replace the reduced yield.

While the absolute value of reductions in Guadalupe River flows at the Saltwater Barrier (11,400 acft/yr for the Upper Blanco site, optimum capacity scenario) is larger than that of the Nueces River, it is only about 1% of average annual gaged inflow to San Antonio Bay.

Other potentially affected downstream areas include the so called "braided reach" of the Nueces River between Cotulla and Simmons. Operation of the Montell site would decrease median inflow to this reach from 350 to 250 acft/month but the frequency of overbank inundation would be reduced by less than 1 percent, while the frequency and duration of zero flow episodes would be unchanged (Unpub. hydrologic analysis, HDR Engineering, Inc.).

Substantial effects on the subterranean fauna of the Edwards Aquifer reservoir zone as a result of recharge projects appears unlikely so long as water quality of the recharge reservoir can be maintained. The characteristically constant temperature, chemical composition and clarity of the water in the reservoir portion of the aquifer which supplies the springs, is largely a function of storage in the cavernous limestones of the aquifer, and not of constant quality water entering the recharge zone.

The potentially long periods of impoundment in Type 1 reservoirs may alter water quality as suspended materials that would have been transported downstream settle out, and as a result of thermal stratification and subsequent dissolved oxygen (D.O.) depletion in isolated bottom waters. Since discharge of D.O. depleted waters would be adverse to both downstream aquatic communities and to the aquifer fauna (if reaeration is not accomplished before recharge), the outlet works of the Type 1 structures would need to allow for discharge of water from various depths in the reservoirs.

Because of the many canyons, rugged terrain, past geologic history and biogeographical location of the south and southeastern portions of the Edwards Plateau, many rare and endemic species of plants exist. These rare and endemic species are represented by lipferns (*Cheilanthes* spp.), cloakferns (*Notholaena* spp.), *Anemia mexicana*, halberd fern (*Tectaria heracleifolia*), hairy maidenhair fern (*Adiantum tricholepis*), cliff brakes (*Pellaea*), columbine (*Aquilegia canadensis*), *Anemone edwardsensis*, wand butterfly-bush (*Buddleja racemosa*), mock orange (*Philadelphus* spp.), american smoke-tree (*Cotinus americana*), spicebush (*Benzoin aestivale*), siverbells, (*Styrax platanifolia* and *S. texana*), netleaf forestiera (*Forestiera reticulata*), plateau milkvine (*Matelea edwardsensis*), basin bellflower (*Campanula reverchonii*), Lindheimer crownbeard (*Verbesina lindheimeri*), *Lythrum ovalifolium*, *Tridens buckleyanus*, twisted leaf yucca (*Yucca rupicola*), sotol (*Dasylirion heteracanthium*), bracted twist-flower (*Streptanthus bracteatus*), and cliff bedstraw (*Galium correllii*)[147].

[147]Correll, D.S., and M.C. Johnston, 1979, Manual of the Vascular Plants of Texas, Texas Research Foundation, Renner, Texas.

In addition to the rare and/or endemic species listed above there are numerous protected and candidate species in the study areas as well as in the Edwards Aquifer and in springs fed by the aquifer (Table 3.8-3; Appendix B Table 50). None of these species have been reported to occur within the proposed dam and impoundment locations, but some have been observed in the vicinity of several sites and suitable habitat for one or more protected species appears to be present at some of the sites. Both the biogeographical setting and present knowledge indicates that field surveys should be conducted at appropriate seasons to determine the presence or absence of protected species habitat and assess the probability of use of each site by protected species.

Table 3.8-3
Important Species with Habitat in the Project Vicinity (L-17)
Edwards Plateau and Edwards Aquifer

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T
Blind Texas Salamander	*Typhlomolge rathbuni*	Edwards Aquifer springs and caves, thermally stable; troglobitic [1,5]	E	E
Blind Blanco Salamander	*Typhlomolge robusta*	Blanco River; subterranean; gravel bed of Dry Blanco only occurrence; troglobitic [1,5]	C2	E
Comal Blind Salamander	*Eurycea tridentifera*	Honey Creek and limestone caves [1]	C2	T
Cascade Caverns Salamander	*Eurycea latitanus*	Cascade Caverns [5,7]	C2	T
San Marcos Salamander	*Eurycea nana*	San Marcos River & springs; under rocks & matted stream vegetation [1,5]	T	E
Texas Salamander	*Eurycea neotenes*	Edwards Aquifer creeks gravel bottom, emergent vegetation; underground & rocks, ledges [1,5]	C2	T

Table 3.8-3
Important Species with Habitat in the Project Vicinity (L-17)
Edwards Plateau and Edwards Aquifer

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Widemouth Blindcat	*Satan eurystomus*	Edwards Aquifer; subterranean; from artesian wells in Bexar Co., TX; troglobitic	C2	T
Toothless Blindcat	*Trogloglanis pattersoni*	Edwards Aquifer; subterranean; from artesian wells in Bexar Co., TX; troglobitic [1, 3]	C2	T
Texas Cave Shrimp	*Palaemonetes antrorum*	Ezell's Cave and Edwards Aquifer subterranean caverns [5, 8]	C2	NL
Mimic Cave Snail	*Phreatodrobia imitata*	Edwards Aquifer subterranean caverns; from artesian wells in Bexar Co., TX; troglobitic [5,7]	C2	NL
Balcones Cave Amphipod	*Stigobromus balconis*	Limestone caves [7]	C2	NL
Bifurcated Cave Amphipod	*Stigobromus bifurcatus*	Spring openings [7]	C2	NL
Comal Springs Water Beetle	*Heterelmis comalensis*	Comal Springs [4]	C2	NL
Comal Springs Dryopid Beetle	*Stigoparnus comalinses*	Comal Springs [9]	NL [9]	NL
Ezell's Cave Amphipod	*Stigobromus flagellatus*	Ezell's Cave; Edwards Aquifer subterranean caverns [7,8]	C2	NL
Flint's Net-spinning Caddisfly	*Cheumatopsyche flinti*	Honey Creek [1]	C2	NL
Peck's Cave Amphipod	*Stygobromus pecki*	Comal Springs	C2	
San Marcos Saddle-case Caddisfly	*Protoptila arca*	San Marcos River [1]	C2	NL
Texas Cave Diving Beetle	*Haideoporus texanus*	Edwards Aquifer subterranean caverns[1,7,8]	C2	NL

[1]Longley, G. 1975. Environmental assessment, upper San Marcos River watershed. Soil Conservation Service. Contract AG-48-SCS 02156. 367 pp.
[2]Longley, G. and H. Karnei, Jr. 1979a. Status of *Satan eurystomus* Hubbs and Bailey, the widemouth blindcat. U.S. Fish and Wildlife Services, Endangered species Report 5.
[3]Longley, G. and H. Karnei, Jr. 1979b. Status of *Trogloglanis pattersoni* Eigenmann, the toothless blindcat. U.S. Fish and Wildlife Service, Endangered species Report 5.
[4]Longley, G. & FN Young. 1976. A new subterranean aquatic beetle from Texas (Coleoptera: *Dytiscidae-Hydropoorinae*). Annals of the Entomological Society of American 69(5):787-792.
[5]Elliot, W.R. (Bill) Ph.D., personal communication, 1993. Research Associate, Texas Memorial Museum, The University of Texas at Austin. Austin, Texas.
[6]Edwards, Robert J., Glen Longley, Randy Moss, John Ward, Ray Mathews, and Bruce Stewart. 1989. A Classification of Texas Aquatic Communities with Special Consideration Toward the Conservation of Endangered and Threatened Taxa. Vol. 41, No. 3. The Texas Journal of Science, University of Texas at Austin, Austin, Texas.
[7]Reddell, James, personal communication, 1993. Research Associate (Curator of Arthropods), Texas Memorial Museum, The University of Texas at Austin. Austin, Texas.
[8]Sissom, S.L.& J.C. Davis. 1979. A monographic study of Ezell's Cave, Hays County, Texas. U.S. Department of the Interior and Nature Conservancy. Contract # 14-16-0002-090. 141pp.
[9]Alisa Shull. 1993. Personal Communication, USFWS, Austin, Texas.
Source: Texas Natural Heritage Program. 1993 Unpublished. Data Base Program Files. Resource Protection Division, TPWD. Austin, Texas.

While each of these reservoir sites has some potential to affect private interests and recreation, the Concan site is the only location that would impact a popular recreational reach (on the Frio River) that has experienced substantial riparian resort and residential development. The two Blanco River sites may also have some impact on recreation and on riparian residential property.

Texas Archeological Research Laboratory files were examined and data on 231 archaeological sites determined to occur in the upper Nueces River Basin were compiled[148]. Known historic sites in the study area were compiled from the National Register of Historic Places. All site locations were plotted on 7.5 minute quadrangle maps and assessed for the probability that they would be affected by construction of one of the proposed recharge reservoirs. However, these statistics reflect strong sample bias and an absolute lack of information from some areas. This information has not been compiled for the Upper Blanco and Cloptin Crossing sites as its predictive utility is small. Burned rock middens are the most common archeaological site (130, 56 percent) in the Upper Nueces Basin, with rock quarries (9), rock shelters (5), and caves (3) comprising the other 44 percent of the sites. Nine historic sites are recorded in the study area, and at 22 sites (9.5 percent), no information beyond the location is available[149].

Because none of these recharge reservoirs have been adequately surveyed, all areas to be disturbed during construction would have to be surveyed by qualified professionals for the presence of significant cultural resources. Measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

3.8.4 Water Quality and Treatability

[To be completed in a later phase.]

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[148]HDR Engineering, Inc., 1991, "Regional Water Supply Planning Study Phase III Recharge Enhancement, Nueces River Basin."

[149]Ibid.

3.8.5 Engineering and Costing

Preliminary cost estimates for all Type 1 recharge enhancement projects located in the Nueces River Basin were prepared in 1991 by HDR[150]. For the current study, previous estimates of Total Project Cost and Total Annual Cost were increased by 12 percent, based upon changes in the Construction Cost Index (CCI). The updated cost estimates are presented in Table 3.8-4. A cost estimate for the Cloptin Crossing site was prepared by updating the 1986 cost estimate prepared by Espey, Huston & Associates by the appropriate CCI's. The revised cost estimate for the Cloptin Crossing site is shown in Table 3.8-4. A preliminary cost estimate for the Upper Blanco site was prepared for this study and is also shown in Table 3.8-4.

As seen on the top portion of Table 3.8-4, the Maximum Conservation Capacity Program has a total cost of $462,845,000 and a total annual cost of $45,592,000. Under this Program, drought recharge is enhanced by about 70,970 acft/yr, which results in a unit cost of water of $642 per acft/yr. The Optimum Program is summarized in the bottom half of Table 3.8-4. It has a total cost of $155,969,000 and a total annual cost of $16,384,000. Under this program, drought recharge is enhanced by about 35,620 acft/yr which results in a unit cost of water of $460 per acft/yr.

3.8.6 Implementation Issues

In order to fully evaluate the potential benefits from development of the Type 1 recharge program to the Edwards Aquifer, including springflows, additional modeling work is required. One potential benefit of the Type 1 projects which has not been investigated is the possibility of holding water in storage until aquifer levels reach selected critical levels at which time the gates on selected Type 1 structures could be opened to recharge the aquifer. Although the effects of evaporation (while the water is being held in storage)

[150]HDR Engineering, Inc., "Nueces River Basin Regional Water Supply Planning Study, Phase III, Recharge Enhancement," Nueces River Authority, November, 1991.

Table 3.8-4 Summary of Costs for Recharge Enhancement Programs - Type 1 Reservoirs (L-17)				
Type 1 Project	**Total Project Costs[1]**	**Total Annual Costs[1,3]**	**Drought Conditions Recharge Enhancement[1] (acft/yr)**	**Annual Water Cost for Drought Conditions ($/acft/yr)**
Maximum Conservation Capacity Program				
Montell	$141,893,000	$15,106,000	17,850	$846
Upper Dry Frio	37,633,000	3,481,000	2,900	1,200
Concan	71,534,000	6,662,000	3,890	1,713
Upper Sabinal	62,969,000	5,880,000	2,590	2,270
Upper Hondo	36,556,000	3,383,000	1,140	2,968
Upper Verde	18,300,000	1,748,000	1,910	915
Cloptin Crossing[2]	93,960,000	9,332,000	40,690	229
TOTAL	$462,845,000	$45,592,000	70,970	—
WEIGHTED AVERAGE	—	—	—	$642
Optimum Conservation Capacity Program				
Montell	$61,507,000	$7,441,000	14,750	$504
Upper Dry Frio	15,654,000	1,447,000	2,630	550
Concan	21,312,000	1,999,000	3,850	519
Upper Sabinal	19,512,000	1,839,000	2,590	710
Upper Hondo	14,144,000	1,307,000	1,140	1,146
Upper Verde	9,582,000	941,000	1,910	493
Upper Blanco	14,258,000	1,410,000	8,750	161
TOTAL	$155,969,000	$16,384,000	35,620	—
WEIGHTED AVERAGE	—	—	—	$460

[1]Total project costs, annual costs, and recharge enhancement quantities for all projects (except Cloptin Crossing and Upper Blanco) were taken from November 1991 report entitled "Regional Water Supply Planning Study Phase III Recharge Enhancement" prepared by HDR Engineering, Inc. All cost figures were increased by a CCI of 12 percent to obtain 1994 estimated costs.
[2]Total project costs and annual costs for the Cloptin Crossing site were obtained from 1986 Espey, Huston & Associates' report entitled "Water Availability Study for the Guadalupe and San Antonio River Basins", and updated to 1994 cost based on CCI with addition of Capitalized Interest. Recharge enhancement quantities for the Cloptin Crossing site were obtained from a September 1993 Report entitled "Recharge Enhancement Study, Guadalupe-San Antonio River Basin" prepared by HDR Engineering, Inc.
[3]Total annual cost includes cost to purchase water rights in San Antonio Basin to offset effects of yield impacts on Choke Canyon/Lake Corpus Christi Reservoir system.

would reduce water availability, it could make some water available at critical times. Additionally, if the Type 1 projects move forward, it may be appropriate to apply the Trans-Texas environmental criteria to determine if project yields are significantly affected.

1. Necessary permits could include:
   a. TNRCC Water Right and Storage permits.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   c. GLO Sand and Gravel Removal permits.
   d. GLO Easement for use of state-owned land.
   e. TPWD Sand, Gravel, and Marl permit

2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.

3. Right-of-way must be acquired.

4. Relocations and crossings:
   a. Highways and railroads
   b. Other utilities

3.9 Natural Recharge - Type 2 Projects (L-18)

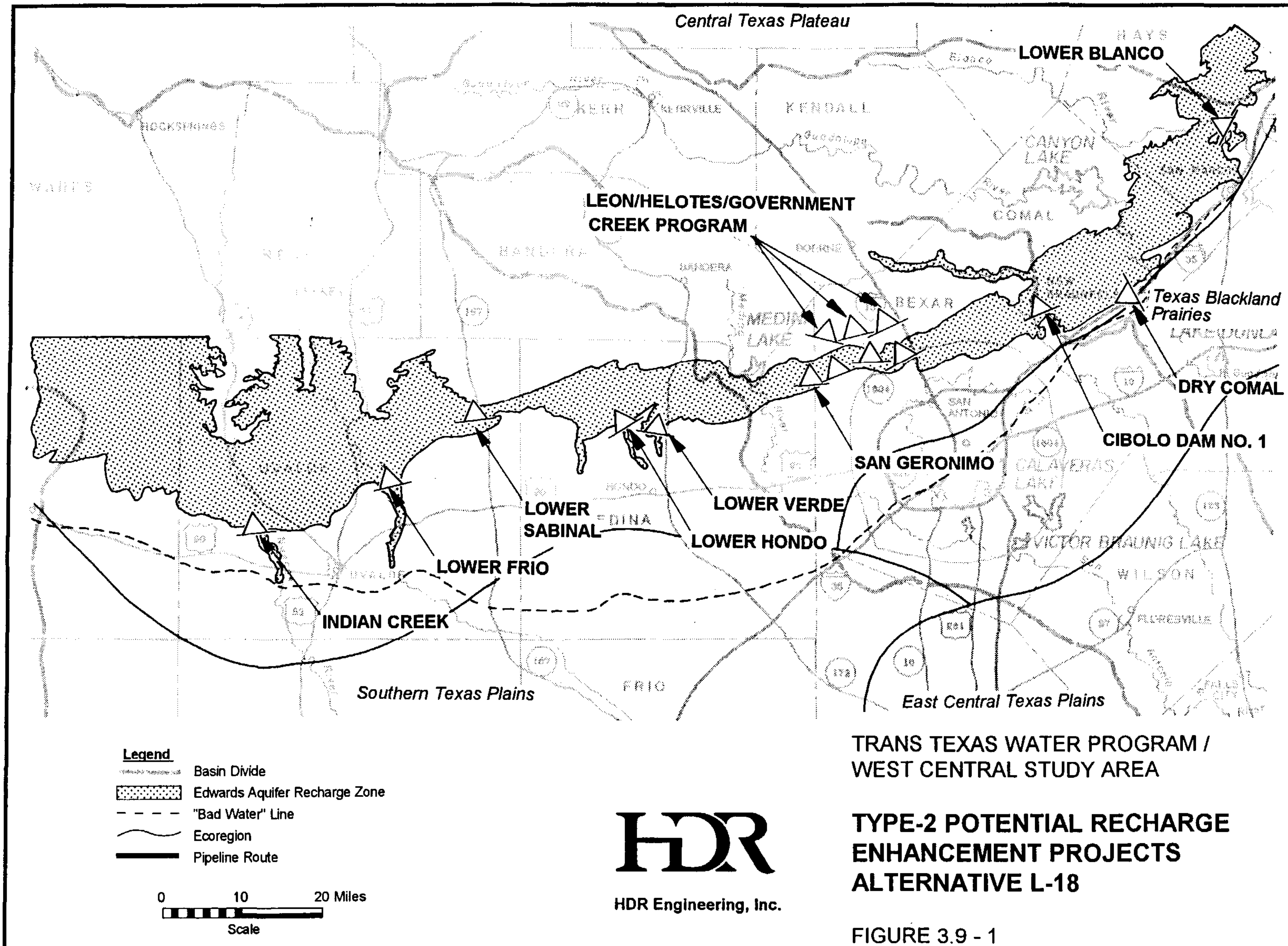
3.9.1 Description of Alternatives

As explained in Section 3.8, two types of recharge enhancement reservoirs have been analyzed in a series of studies sponsored by the Edwards Underground Water District beginning in 1990. Type 1 reservoirs were described and analyzed in Section 3.8. This alternative deals with the potential construction of Type 2 projects, which are immediate recharge structures located within the recharge zone. Type 2 structures are, generally speaking, normally dry and impound water only for a few days or weeks following storm events. These structures recharge water very quickly to the aquifer, typically draining at a rate of two to three feet per day. This large recharge rate minimizes evaporation losses and maximizes recharge.

The location of each of the Type 2 recharge projects most favorable for development are shown in Figure 3.9-1. Five of the projects are located in the Nueces River Basin and affect inflows to the Choke Canyon/Lake Corpus Christi Reservoir System (CC/LCC System) and the Nueces Estuary. These five projects include Indian Creek, Lower Frio, Lower Sabinal, Lower Hondo, and Lower Verde. Other previously identified Type 2 sites in the Nueces Basin were not included in this study because the quantity of enhanced recharge during the drought was extremely small and the associated unit costs were extremely high.

In the San Antonio and Guadalupe River Basins, up to ten new recharge projects are being considered. These include San Geronimo, Cibolo Dam No. 1, Dry Comal, Lower Blanco, and potentially up to six small Soil Conservation Service (SCS) type reservoirs in the Leon/Helotes/Government Creek watersheds. Other previously identified recharge enhancement projects in the San Antonio and Guadalupe River basins considered in this study include projects to modify the outlets on existing SCS Floodwater Retarding Structures (SCS-FRS) on the Salado, Dry Comal, and San Marcos River watersheds. These modifications would either eliminate or reduce the outlet sizes on existing SCS-FRS dams resulting in additional recharge.

The Type 2 projects in the Nueces River Basin have undergone considerably more study than the Type 2 projects in the Guadalupe-San Antonio River Basin. Cost estimates



TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

TYPE-2 POTENTIAL RECHARGE ENHANCEMENT PROJECTS ALTERNATIVE L-18

FIGURE 3.9 - 1

for projects in the Nueces River Basin have previously been prepared while no significant costing efforts have yet been undertaken on the San Antonio and Guadalupe River Basin projects. For the Nueces River Basin projects, an optimum size has previously been determined for each project and is used in this study. However, in the San Antonio and Guadalupe River Basins, costs have not yet been determined for these projects and an optimum size has not been determined. Therefore, the storage capacity of each Type 2 project presented in this report for the San Antonio and Guadalupe River Basins generally represents the upper limit of the reasonable storage potential at each site. A Type 2 program consisting of fifteen potential new storage projects is presented in this study as shown in Figure 3.9-1. These projects would impound a total of 170,405 acft in their combined recharge storage pools and periodically inundate about 9,303 acres as indicated on Table 3.9-1.

3.9.2 Available Yield

Available yield or recharge enhancement volumes were calculated for the Type 2 structures using the Nueces River Basin Model and the Guadalupe-San Antonio River Basin Model, subject to average and drought conditions. Average conditions represent the average annual recharge rate for the entire 56-year period (1934-1989) analyzed. Drought conditions represent the average annual recharge rate for the 10-year period from 1947 through 1956, which is when the most severe drought of record occurred as in the case of Type 1 projects (Section 3.8). Analyses of recharge enhancement projects presented in this study were performed honoring all existing water rights to the maximum extent possible, with one exception. This exception involved the water rights of the CC/LCC System, in which case impacts were not mitigated by releases, but were assumed to be purchased. Other alternatives may be available to mitigate the impact of the recharge projects on the CC/LCC System such as Alternative L-14 which considers the transfer of San Antonio River water into Choke Canyon Reservoir.

For the Type 2 Recharge Program, recharge could be enhanced by 125,327 acft/yr for average conditions and 51,986 acft/yr for drought conditions as shown in Table 3.9-1.

Table 3.9-1
Summary of Recharge Enhancement Potential for Type 2 Reservoir Program (L-18)

Type 2 Project	Capacity (acft)	Surface Area (ac)	Recharge Enhancement (acft/yr)		Reduction in Average Estuarine Inflow[1,2] (acft/yr)	Reduction in CC/LCC System Yield[1] (acft/yr)
			1934-1989 Average Conditions[1,2]	1947-1956 Drought Conditions[1,2]		
Nueces River Basin Type-2 Program						
Indian Creek	61,750	3,657	29,307	18,596	2,998	2,953
Lower Frio	17,500	1,099	17,064	3,980	2,594	1,152
Lower Sabinal	8,750	454	16,442	2,358	2,566	1,229
Lower Hondo	2,800	232	6,779	1,193	1,134	403
Lower Verde	3,600	334	4,850	1,719	728	170
Subtotal - Nueces Basin	94,400	5,776	74,442	27,846	10,020	5,907
San Antonio-Guadalupe Basin Type-2 Program - New Structures						
San Geronimo	3,500	330[(E)]	1,715	560	—	N/A
Cibolo Dam No. 1	10,000	500[(E)]	8,485	1,265	—	N/A
Dry Comal	2,075	265	1,335	520	—	N/A
Lower Blanco	35,230	1,052	31,495	19,465	—	N/A
Leon/Helotes/Gov.	25,200	1,380[(E)]	5,205	1,815	—	N/A
San Antonio-Guadalupe Basin Type-2 Program - Outlet Modifications						
Salado Creek FRS	—	—	485	0	—	N/A
Dry Comal FRS	—	—	1,145	390	—	N/A
San Marcos FRS	—	—	1,020	125	—	N/A
Subtotal GSA Basins	76,005	3,527[(E)]	50,885	24,140	32,700[(E)]	N/A
TOTAL ALL BASINS	170,405	9,303[(E)]	125,327	51,986	42,720[(E)]	5,907

[E] - Estimated.
[1]Recharge enhancement, estuarine inflow reduction and CC/LCC system yield reduction quantities for all Nueces River Basin projects were taken from April 19, 1994 Progress Meeting No. 3 Report for "Nueces River Basin Edwards Aquifer Recharge Enhancement Study - Phase IVA," prepared by HDR Engineering, Inc.
[2]Recharge enhancement quantities and estimates of Estuarine Inflow Reductions for all San Antonio and Guadalupe River Basin projects were taken from September 1993 report entitled "Guadalupe-San Antonio River Basin Recharge Enhancement Study," prepared by HDR Engineering, Inc.

The impact on the CC/LCC System totals 5,907 acft/yr for the Type 2 Program, which is about 3 percent of the system yield.

Application of the Trans-Texas environmental criteria for reservoir pass-throughs for instream flows and estuarine flows was not included in the Phase 1 study scope of work for the Type 2 recharge projects. Strict application of these criteria would likely reduce the quantities of water available for the Indian Creek and Lower Blanco sites. However, it is unlikely that these criteria will significantly affect the recharge enhancement potential of the other sites, as most of these sites are located on streams that, under normal weather conditions, do not contribute flows downstream of the recharge zone. The impact on the average inflow to the Nueces Estuary due to the five Nueces Basin sites is a reduction of about 10,020 acft/yr or about four percent. The impact of the remaining sites on the average inflow to the Guadalupe Estuary (as measured at the Saltwater Barrier) would be a reduction of about 32,700 acft/yr or about two percent (Table 3.9-1). Additional analysis of the projects in the Nueces River Basin shows that natural recharge of the Carrizo-Wilcox aquifer would be reduced by less than 1 percent. Frequency of overbank inundation in the braided reach of the Nueces River would be reduced by less than 1 percent while the frequency of zero flows (which presently occur about 40 percent of the time) would be essentially unaffected.

3.9.3 Environmental Issues

As explained in Section 3.9-1, Type 2 Reservoirs are immediate recharge (direct percolation) structures that drain from the bottom of the reservoir into the recharge zone until the entire volume is exhausted, usually within a period of less than one month. Type 2 reservoirs are intended to impound flows that would have otherwise crossed and exited the recharge zone.

Suitable sites for the Type 2 Reservoirs are located in the area encompassing the headwaters of the Nueces River Basin along the Southern margin of the Edwards Plateau in Medina and Uvalde Counties, and the headwaters of the San Antonio and Guadalupe rivers along the Southeastern margin of the Edwards Plateau in Bexar and Comal Counties, respectively (Figure 3.9-1). There are three Type 2 reservoir sites in Uvalde County (Indian

Creek, Lower Frio and Lower Sabinal), three Type 2 reservoir sites in Medina County (Lower Hondo, Lower Verde and San Geronimo), seven Type 2 reservoir sites in Bexar County (Leon, Helotes, Government Creek and Cibolo Dam #1), one Type 2 reservoir site in Comal County (Dry Comal), and one Type 2 reservoir site in Hays County (Lower Blanco).

As in the case for Type 1 projects, all of the Type 2 Recharge project sites are located in Omernik's Central Texas Plateau Ecoregion and the corresponding ecotones of Gould, Blair and Correll and Johnston[151,152,153,154] (see Section 3.8.3 Alt. L-17).

The soils in the area of Cibolo Creek, on the edge of Bexar and Comal Counties are composed of Tarrant, rolling (TaC) and Tarrant, hilly (TaD) associations[155,156]. The Tarrant associations are very dark grayish-brown calcareous clay loam with an underlying layer of fractured limestone. Tarrant soils have rapid surface drainage, low water retention capabilities and water erosion is a hazard. Soils in the area of Dry Comal Creek, Comal County, are primarily of the Rumple-Comfort (RUD), Eckrant-Rock outcrop and Comfort-Rock outcrop associations[157]. The RUD association consists of shallow and moderately deep soils made up of approximately 60 percent Rumple soils, 20 percent Comfort soils and 20 percent other soils. Rumple soil is dark reddish brown very cherty clay loam about 10 inches thick with the subsoils being dark reddish brown very cherty clay and dark reddish brown extremely stony clay that is about 75 percent limestone fragments with an underlying

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[151] Omernik, James M., 1987, "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1) pp. 118-125.

[152] Correll, D.S., and M.C. Johnston, 1979, Manual of the Vascular Plants of Texas, Texas Research Foundation, Renner, Texas.

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

[154] Gould, F.W., 1975, The Grasses of Texas, Texas A&M University Press, College Station, Texas.

[155] United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station, 1984, Soil Survey of Comal and Hays Counties, Texas, USDA

[156] United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station, 1984, Soil Survey of Bexar County, Texas, USDA

[157] United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station, 1984, Soil Survey of Comal and Hays Counties, Texas. USDA.

layer of indurated fractured limestone. The RUD association is noncalcareous, permeability is moderately slow to slow, available water capacity is very low and water erosion is a moderate hazard. The Eckrant-Rock outcrop consists of barren exposures of indurated limestone with dark gray extremely stony clay and an underlying layer of indurated fractured limestone. ErG associations are moderately alkaline and noncalcareous, permeability is moderately slow, available water holding capacity is very low and water erosion is a severe hazard. The Comfort-Rock outcrop consists of dark brown extremely stony clay with an underlying layer of indurated fractured limestone. CrD associations are mildly alkaline and noncalcareous, permeability is slow, available water capacity is very low and water erosion is a slight hazard. Soils of Medina and Uvalde Counties were discussed in section 3.8.3 of Alt. L-17.

The terrestrial habitat impacts of the Type 2 reservoirs will depend on the amount of clearing done, frequency of inundation, and the rapidity of pool drainage following capture of run-off. Operation of a Type 2 recharge structure on Parker's Creek in Medina County for 20 years has resulted in little or no impact to terrestrial vegetation beyond an approximately 20 acre cleared area immediately upstream of the dam. Conservation (Recharge) pool levels and major types of habitat that would be inundated as a result of operation of the Type 2 reservoirs being studied here are listed in Table 3.9-2.

The types of dissolved and suspended materials entering the recharge zone is not expected to be altered by the Type 2 reservoirs. As only brief impoundment and immediate recharge will take place there will be no opportunity for thermal stratification to set up or for oxidation of entrained organic material to deplete dissolved oxygen levels (see Water Quality, Section 3.8 Alt. L-17). The presence of the dams will increase sediment deposition in the upstream channel, and extend the duration of recharge events.

Because Type 2 Reservoirs are immediate recharge (direct percolation) structures that drain directly into karst features (fractures, holes, and/or caves) present below the stream channel, disturbance of the local karst system and its fauna is a possibility. The fauna inhabiting these caves are usually small in both species diversity and population size, and are adapted to relatively stable physical habitats, which presumably makes them particularly sensitive to disturbances outside of the natural regime. The results of the investigation of

Table 3.9-2
Habitats Affected by Operation of Type 2 Recharge Reservoirs (L-18)

Reservoir	Recharge* Pool (acres)	Grassland (%)	Brush (%)	Developed (%)	Crops (%)	Woodlands (%)	Wetland (acres)
Indian Creek	3,657	20%	80%				10.4
Lower Frio	1,099	20%	80%				7.4
Lower Sabinal	454						
Lower Hondo	232	70%				30%	5.5
Lower Verde	334	3%				97%	8.2
San Geronimo Creek	330^E		45%			40%	5
Leon/Helotes /Govern-ment Creek	1380^E	No information available					
Cibolo Dam #1	500^E	10%				40%	50
Dry Comal Creek	265^E	5%	10%	5%	50%	20%	10

E = estimated * corresponds to conservation pool of a conventional reservoir

the karst fauna in northern Bexar County, however, seem to indicate that caves with biological communities have not been encountered in streambeds there[158]. Streambed openings in the recharge zone are subject to sedimentation during flow events. Openings in the streambed itself would tend to fill most rapidly since they are exposed to bed load movements. Openings in the stream bank would be exposed to successively smaller sediment loads and particle size at successively higher elevations. The interiors of all such openings however, would be exposed to the erosive force of flowing water, lessening the likelihood that an organized "terrestrial" community would be able to develop and persist in such a location.

[158]Elliot, William R., 1993, "Cave Fauna Conservation in Texas", Proceedings of the 1991 National Cave Management Symposium, Bowling Green Kentucky, American Cave Conservation Association, Horse Cave Kentucky.

Karst openings in the vicinity of the recharge structures that presently experience periodic flooding may be inundated for longer periods, or experience an increase in the maximum elevation to which the water rises following a runoff event, causing flow across the recharge zone. Both terrestrial and aquatic communities are extensive in the karst openings associated with the Edwards limestone, and significant threats to these habitats presently exist as a result of human activities in many areas, including northern Bexar County[159,160]. The extent of intermittently flooded karst zones that would be affected hydrologically by the proposed Type 2 structures is unknown, as is the extent to which these zones are inhabited, and how hydrologic changes might affect resident communities.

Two caves in the vicinity of the proposed Type 2 Recharge sites in northern Bexar County, Government Creek Bat Cave and Surprise Cave have been explored and the faunas have been inventoried[161]. (Table 3.9-3). There are also caves in the vicinity of San Geronimo Creek, but none have been explored. In the vicinity of Culebra Creek, lack of access to the property has prevented a search for caves. No caves have been identified in the vicinity of Deep or Limekiln Creeks.

A petition to the United States Fish and Wildlife Service to list as endangered or threatened nine new species of invertebrates with limited distributions in caves of northern Bexar County has been filed (Table 3.9-3). The petition identifies specific inhabited caves, and a study is underway to identify additional habitat areas. The USFWS has recently performed a study having to do with the petition, but it has not yet been released. All of the Type 2 recharge sites are in areas that have potential for caves containing endangered species[162].

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[159]Elliot, William R. 1993, "Cave Fauna Conservation in Texas," Proceedings of the 1991 National Cave Management Symposium, Bowling Green Kentucky, American Cave Conservation Association, Horse Cave Kentucky.

[160]Longley, G., 1981, "The Edwards Aquifer: Earth's Most Diverse Ground Water Ecosystem?" Internatl. J. Speleol. 11:123-128.

[161]Veni, George, Personal Communication, April 22, 1994.

[162]Ibid.

Table 3.9-3 Species listed for Protection on Petition to USFWS		
Species	**Cave Name**	**County**
Cicurina (new species 1) (Troglobitic spider)	Madla's Cave	Bexar
Cicurina (new species 2) (Troglobitic spider)	Braken Bat Cave	Bexar
Cicurina (new species 3) (Troglobitic spider)	Government Canyon Bat Cave	Bexar
Cicurina (new species 4) (Troglobitic spider)	Robber Baron Cave	Bexar
Neoleptoneta microps	Government Canyon Bat Cave	Bexar
Texella (new species)	Robber Baron Cave	Bexar
Rhadine exilis	John Wagner Ranch Cave No. 3 (Marnock Cave)	Bexar
Rhadine infernalis	Government Canyon Bat Cave, Cave of the Woods, Genesis Cave, Helotes Blowhole, Isopit, Kamikaze Cricket Cave, Poison Ivy Pit, and Wurzbach Bat Cave	Bexar
Batrisodes (Excayodes) (new species)	Helotes Hilltop Cave	Bexar

Government Creek Bat Cave (Table 3.9-3) is located in the immediate vicinity of the potential recharge site on that stream. Although the known opening of this cave is located well above the impoundment elevation, the depth to which *Cicurina* n.s. 3, habitat extends is not known, and additional site surveys would be required to determine whether it might be affected by an increase in the duration of inundation events, or by an increase in the maximum inundation elevation within the cave. On-site surveys of the reservoir and surrounding areas and mitigation or relocation of the project may be required if caves with protected species are found and will be affected by project development. Government Canyon, including the Government Canyon Bat Cave site, is the location of a new state park. The Government Canyon State Park plan includes environmental resource preservation, a preserve for nesting Golden-Cheeked Warblers and Black-Capped Vireos, and some recreational facilities. Natural recharge in the canyon may not conflict with preserving the area's environmental resources and the park development plan, although extensive dam construction may conflict.

Protected and candidate species known or thought to occur in the study areas of Uvalde and Medina counties are listed in Section 3.8.3 (Table 3.8-3). Species known or thought to occur in Bexar and Comal Counties are listed in Table 3.9-4.

Table 3.9-4 Protected Species with Habitat in the Project Vicinity				
			Listing Agency	
Common Name	**Scientific Name**	**Habitat Preference**	**USFWS**	**TPWD**
Black-capped vireo	*Vireo atricapillus*	Semi-open Broad-leaved shrublands	E	E
Golden-cheeked Warbler	*Dendroica chrsoparia*	Woodlands with oaks and old juniper	E	E
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL
Whistling - duck, Fulvous	*Dendrocygna bicolor*	Ponds and freshwater marshes	C2	NL
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T
Texas Mock-Orange	*Philadelphus texensis*	On limestone bluffs and among boulders on the Edwards Plateau	C2	NL

The Government Creek area is known to contain numerous prehistoric sites and a 17th century Spanish colonial trail. Other recharge sites may contain similar cultural resources. Cultural resources protection on public lands in Texas, or lands affected by projects regulated under Department of the Army permits, is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National

Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction will be first surveyed by qualified professionals for the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

3.9.4 Water Quality and Treatability

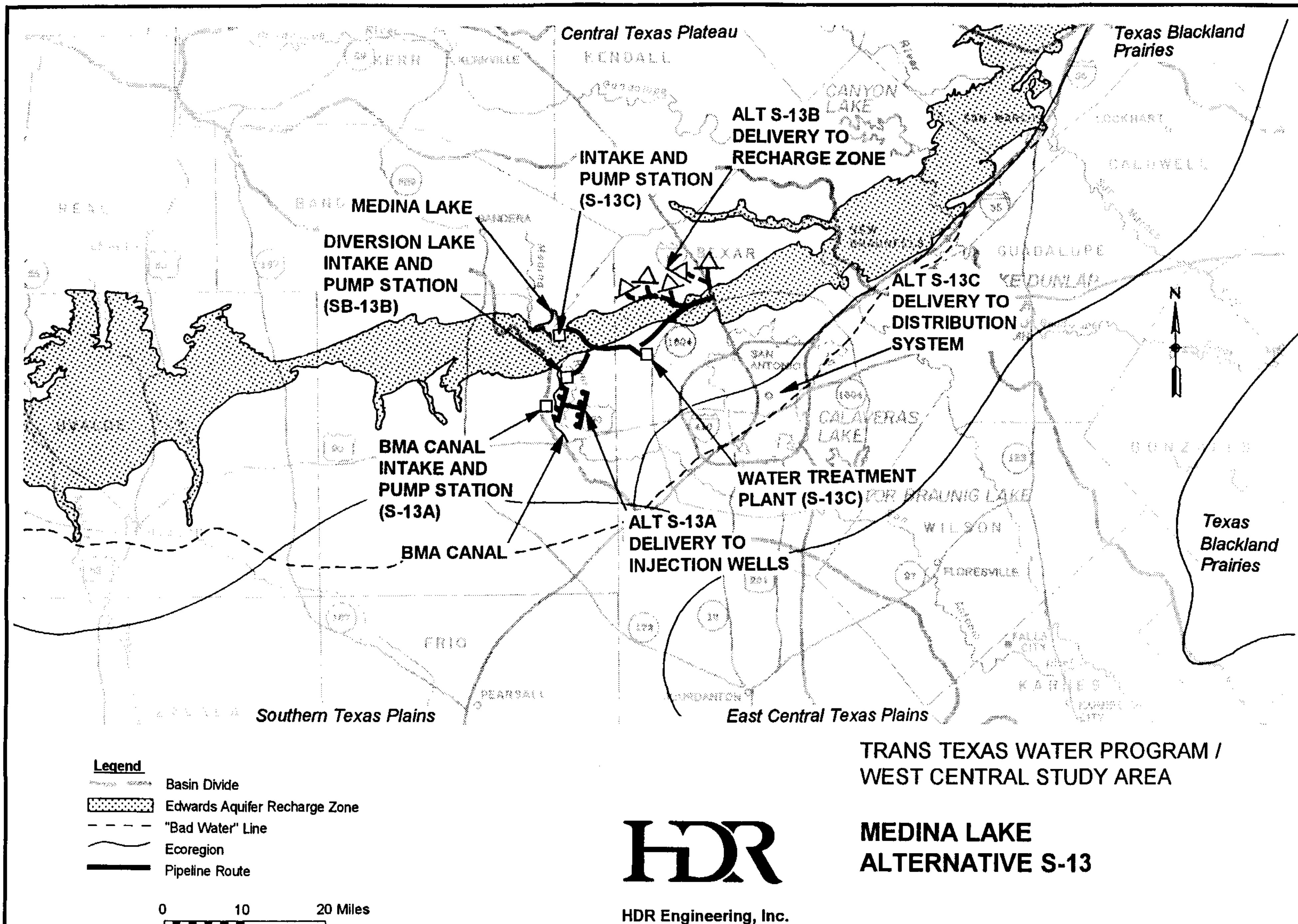
[To be completed in a later phase.]

3.9.5 Engineering and Costing

Preliminary cost estimates for all Type 2 recharge enhancement projects located in the Nueces River Basin were prepared in 1994 by HDR[163]. A composite cost estimate was prepared for this study by utilizing the average unit cost of storage for projects in the Nueces River Basin and applying this cost to the total storage volume of projects in the Guadalupe-San Antonio River Basin. The Nueces River Basin average unit cost was adjusted upward by a factor of 5 percent to account for any differences in land prices and potential cost for work associated with the modification of the outlet structures for the existing SCS/FRS structures in the Guadalupe-San Antonio River Basin. These costs estimates are presented in Table 3.9-5.

As seen in Table 3.9-5, the Type 2 Recharge Program has a total cost of $248,903,000 and a total annual cost of $26,254,000. Under this Program, drought recharge is enhanced by about 52,000 acft/yr, which results in an estimated unit cost of water of $505 per acft/yr.

[163]HDR Engineering, Inc., "Nueces River Basin Edwards Aquifer Recharge Study, Phase IVA," Edwards Underground Water District, May, 1994.



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MEDINA LAKE
ALTERNATIVE S-13

FIGURE 3.13-1

Table 3.9-5 Summary of Costs for Recharge Enhancement Programs - Type 2 Reservoirs (L-18)				
Type 2 Recharge Program	**Total Program Costs[1,2]**	**Total Annual Costs[1,2]**	**Drought Conditions Recharge Enhancement[1] (acft/yr)**	**Annual Water Cost for Drought Conditions ($/acft/yr)**
Nueces River Program	$143,256,000	$16,446,000	27,846	$591
San Antonio and Guadalupe River Programs	105,647,000	9,808,000	24,140	406
TOTAL	$248,903,000	$26,254,000	51,986	$505

[1]Total program costs, annual costs, and recharge enhancement quantities for the Nueces River Program were taken from April 19, 1994 Progress Meeting No. 3 Report for "Nueces River Basin Edwards Aquifer Recharge Enhancement Study - Phase VIA" prepared by HDR Engineering, Inc.
[2]Total program costs and annual costs for the San Antonio and Guadalupe River Programs were estimated based on the unit costs of storage for the composite Nueces River Program (i.e., without the Indian Creek pipeline) inflated by 5 percent to account for potential land price differences and the potential cost of the SCS outlet modification program.

3.9.6 Implementation Issues

In order to fully evaluate the potential benefits to well yields and springflows from development of the Type 2 recharge program, additional modeling work is required. Additionally, the projects in the San Antonio and Guadalupe River Basins need to have site specific cost estimates prepared so the optimum size project at each site can be determined.

The Trans-Texas environmental criteria may need to be applied (if determined to be appropriate) to the recharge projects in subsequent study phases.

1. Necessary permits could include:
   a. TNRCC Water Right and Storage permits;
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines;
   c. GLO Sand and Gravel Removal permits; and
   d. GLO Easement for use of state-owned land.

2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact;
   b. Habitat mitigation plan;
   c. Environmental studies; and
   d. Cultural resource studies.

3. Right-of-way must be acquired.

4. Relocations and crossings:
   a. Highways and railroad; and
   b. Other utilities.

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3.10 Springflow Augmentation (L-19)

This section addresses the status of two separate studies undertaken during the past several years which would augment or add to springflows occurring from the Edwards Aquifer. The first study is entitled "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase I - Feasibility Study." This study is being undertaken by the Center for Research in Water Resources at the University of Texas at Austin, and a draft report has been prepared. The study deals with the two major spring systems in the San Antonio portion of the Edwards Aquifer. The second study is entitled "Engineering Assessment and Environmental Inventory and Issues Report - Artificial Recharge Enhancement - Onion Creek, Hays County, Texas." This study was prepared by Donald G. Rauschuber & Associates, Inc. (and others) and completed in April, 1992. This second study deals with the potential to enhance recharge to the Barton Springs segment of the Edwards Aquifer, thereby potentially increasing the flow of Barton Springs which flow into the Colorado River at Austin, Texas.

Part A of this alternative contains excerpts from this first study dealing with the Comal and San Marcos Spring systems and Part B contains excerpts from the second study dealing with enhanced recharge to that portion of aquifer which contributes to the flow of Barton Springs.

3.10.1A Description of Springflow Augmentation Study of Comal and San Marcos Springs

> "Comal and San Marcos springs, two of the largest natural discharge points for the Edwards Aquifer, create the Comal and San Marcos Rivers. The springs provide important economic and recreational resources to the communities of New Braunfels and San Marcos, and create habitats for several endangered species. Potential augmentation to the springs to maintain the habitat for the endangered species is the impetus for this aspect of this study."
>
> "Possible augmentation methods include, but are not limited to, supplemental surface discharges into each spring lake at the head waters; indirect methods such as local recharge through recharge structures, injection into the geological formation near the springhead, other techniques."

"Augmenting the flow of Comal and San Marcos Springs in the Edwards Aquifer is feasible from geological, biological, and hydrological perspectives under certain conditions. On the one hand, springflow augmentation water could be introduced into the aquifer through injection, infiltration, locally enhanced recharge, or regionally enhanced recharge. The major pathways of groundwater flow leading to Comal and San Marcos Springs are reasonably well identified, and the mechanics of introducing additional water into these groundwater corridors are relatively simple. On the other hand, augmentation water could be delivered directly to the spring lakes at Comal and San Marcos Springs. These augmentation methods and the appropriate augmentation sites are discussed below."

Comal Springs

"In the case of Comal Springs where the major pathways to the spring are laterally extensive, hydraulic gradients may be adversely affected (less inclined toward the spring) by heavy pumping to the west such as in the San Antonio area. Once the stage or altitude of the pressure head in the aquifer falls below the altitude of the outlets at Comal Springs (623 ft) the springs will stop flowing and the groundwater in the aquifer will bypass the springs as underflow. At these times of low stage, augmentation water introduced into the aquifer may not cause enough of a rise in the altitude of the stage at New Braunfels to initiate flow at Comal Springs. In addition, water introduced into the aquifer adjacent to Comal Springs, or even into the spring pool itself, may not remain at the surface but may move vertically downward through the spring orifices and become incorporated with the underflow.

It is generally accepted that Comal springs receives very little recharge locally [Ogden, et al, 1986; Pearson, et al, 1975; Thompson and Hayes, 1979]. Five groundwater traces performed by Pearson and Wyerman [1975] at Comal failed to show in any of the spring orifices. Also, dye injected into a well in Panther Canyon by Rettman did not show up at the nearest spring orifice. The only traces of it were in the spring discharge point furthest to the west from the injection point. In addition to these tracer tests, chemical parameters (such as magnesium hardness, calcium hardness, specific conductance, pH, and temperature) measured periodically and plotted versus time and precipitation seem to also indicate that the springs receive very little local recharge [Ogden, et al, 1986]. If this is the case, then any attempt at locally enhancing surface recharge (e.g., a dam on Bleiders Creek) will not contribute significantly to spring flow."

San Marcos Springs

"Augmentation of flow for San Marcos Springs is less problematical than for Comal Springs. This is due to the fact that San Marcos Springs has a lower altitude than Comal Springs and is closer to the eastern extremity of the aquifer at the groundwater divide near the Town of Kyle. One advantage of this lower-level outlet is that some of the water bypassing Comal Springs, even at times of low aquifer levels when Comal Springs could cease to flow, may reach San Marcos Springs. This implies that there is a linkup of groundwater flow corridors from the Comal Springs Fault to the San Marcos Springs (Hueco Springs) Fault. Thus, augmentation attempts designed to benefit Comal Springs also may ultimately augment San Marcos Springs.

Because sources of recharge for San Marcos Springs are less regional and relatively local, augmentation attempts here may be less likely to fail in times of low stages in the Edwards Aquifer. Hydraulic gradients in the aquifer's pathways leading to San Marcos Springs may be more inclined toward the springs because of shorter distance from the recharge areas of relatively high altitude in Comal and Hays Counties to the lower altitudes at San Marcos Springs. Heavy pumping in the San Antonio area also may not impact the local flow regime associated with the San Marcos Springs Fault. Therefore, increments of water introduced into the flow corridors even during low aquifer stages should ultimately reach San Marcos Springs.

The 'plumbing' at San Marcos Springs, while not quite as complex as that at Comal, is similarly fractured and karstified. Like Comal, the area around the springs contains several major normal faults and smaller cross faults that create flow barriers and permeable zones. However, San Marcos Springs receive a considerable amount of local recharge through the bed of the blanco River, in addition to flow from the direction of the City of San Antonio [Ogden, et al., 1986]. Ogden et al. [1986] suggest that a recharge dam placed on the Blanco River could provide "... up to 80,000 acre-feet/year of enhanced recharge...". They suggest drilling in the bed of the river and diverting water into bedrock sinkholes along the banks of the river as two ways of enhancing recharge to the springs."

U.S. Fish and Wildlife Criteria

"In June, 1993, the U.S. Fish and Wildlife Service established criteria for streamflow believed necessary to protect listed species and critical habitat in the San Marcos and Comal Springs and the Edwards Aquifer under the Endangered Species Act [S.D. Hamilton, U.S. Fish and Wildlife Service, written commun., June 25, 1993]. These criteria identify the flows at which "take" of endangered, threatened, or protected species are believed to occur. "Take" is the killing, harassment, or any other action that harms a listed species. As take applies only to anima species, flows are set to maintain the "likelihood of survival and recovery" to protect Texas wild rice. Table 3.10-1 summarizes the minimum springflows believed necessary to prevent reduction in survival and reproduction of threatened or endangered species in the spring systems.

The minimum instantaneous springflow for San Marcos Springs is effectively 100 cfs to protect all threatened and endangered species, but the 2 salamander species would be protected as low as 60 cfs. Flows less than 100 cfs are believed to be necessary to provide suitable habitat for the fountain darter and Texas wild rice and prevent increases in downstream water temperatures to protect the San Marcos gambusia.

The minimum instantaneous springflow for Comal Springs is 200 cfs to protect the fountain darter but could drop to 150 cfs if the rams horn snail were controlled. The rams horn snail is tropical and requires warm water. The lower limit for growth and reproduction is about the temperature of flows from Comal Springs (22-23°C). At flows lower than about 200 cfs, water temperatures would warm sufficiently in Landa Lake to permit an expansion of the snail population. In addition, the lower current velocities present at low flows would allow the snails to feed on plants previously not available to them due to high velocities [Dr. T. Arsuffi, University of Southwest Texas, oral commun., December, 1993]. Severe loss of habitat for fountain darters is believed to occur at flows less than 150 cfs."

Table 3.10-1
Preferred Habitat, Designated Critical Habitat, and Minimum Springflows for the Conservation of Threatened or Endangered Species in the San Marcos or Comal Springs Ecosystems

Threatened or Endangered Species	Preferred Habitat	Designated Critical Habitat	Minimum Springflow (cfs)	Comments
		San Marcos Ecosystem		
Fountain darter *(Etheostoma fonticola)*	Thermally constant water; vegetated stream bottom, specifically, mats of filamentous green algae *(Rhizoclonium* sp.), but also Florida elodea and water primrose. Young fish prefer pools where flow is minimal, while adults occur throughout areas with suitable vegetation, including riffles.	Spring Lake and its outflow; San Marcos River, downstream about 0.8 km below Interstate 35 bridge.	100	
San Marcos gambusia *(Gambusia georgei)*	Thermally constant, quiet water adjacent to sections of moving water; muddy substrates with minimal silt; shade.	San Marcos River, downstream from Hopkins Street (Highway 12) bridge to about 0.8 km downstream of Interstate 35 bridge.	100	Search efforts for this species have been unsuccessful since 1983; species may be extinct.
San Marcos salamander *(Eurycea nana)*	Water temperatures <30°C, with lower oxygen consumption at 25°C; flowing water with protection from floods; shallow spring areas with limestone shelf and boulders covered with a lush moss *(Leptoictyium riparium)*; sand and gravel substrate covered with thick mats of a coarse filamentous bluegreen algae *(Lyngbya* sp.); and variety of rooted macrophytes at edges of habitat.	Spring Lake, principally areas around spring openings; San Marcos River, downstream about 50 m from Spring Lake Dam, principally rocky areas.	60	
Texas wild rice *(Zizania texana)*	Thermally constant, flowing water with protection from floods; unimpeded light. Plants often grow in the swiftest currents of the shallowest areas near the middle of the river in clones that are firmly rooted in gravel substrate.	Spring Lake and outflow, downstream to confluence with the Blanco River.	ND	

Source: "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase I - Feasibility Study," March 1, 1994, (Draft Report), Center for Research in Water Resources, University of Texas at Austin.

Table 3.10-1 (continued)
Preferred Habitat, Designated Critical Habitat, and Minimum Springflows for the Conservation of Threatened or Endangered Species in the San Marcos or Comal Springs Ecosystems

Threatened or Endangered Species	Preferred Habitat	Designated Critical Habitat	Minimum Springflow (cfs)	Comments
Comal Ecosystem				
Fountain darter *(Etheostoma fonticola)*	Thermally constant water; vegetated stream floors, specifically, mats of filamentous green algae *(Rhizoclonium* sp.), but also Florida elodea and water primrose. Young fish prefer pools where flow is minimal, while adults occur throughout areas with suitable vegetation, including riffles.	ND - Found throughout Comal River up-stream of the San Antonio Street bridge; historically, downstream to below confluence with Blanco River.	200	Species was extirpated during the 1950's due to reduced springflows, but was reintroduced.
			150	If ramshorn snail is controlled.

Source: "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase I - Feasibility Study," March 1, 1994, (Draft Report), Center for Research in Water at Austin.

3.10.2A Estimated Quantities of Augmentation Water Needed for Comal and San Marcos Springs

> "Estimates were made of the quantity and duration of augmentation water needed to maintain flow in the Comal or San Marcos Springs systems at specified threshold flow rates, e.g., take levels, under representative future aquifer pumping rates. These quantities and durations were derived from estimated deficits of spring flow from threshold levels computed using the Texas Water Development Board Edwards Aquifer simulation model GWSIM4 [TWDB, 1992] and USGS recharge estimates for 1934 - 1990. The purpose of these computations is to show, under possible future pumping and historic recharge conditions, how much augmentation water would need to be added to the spring systems if spring flow is to be maintained at a specific threshold flow level. The monthly springflow results from the simulation model were used to compute deficits." "The spatial distribution of pumping used in the simulations was estimated by the TWDB for the year 1989 [Oral communication, David Thorkildson and Paul McElhaney, Texas Water Development Board, 1993].

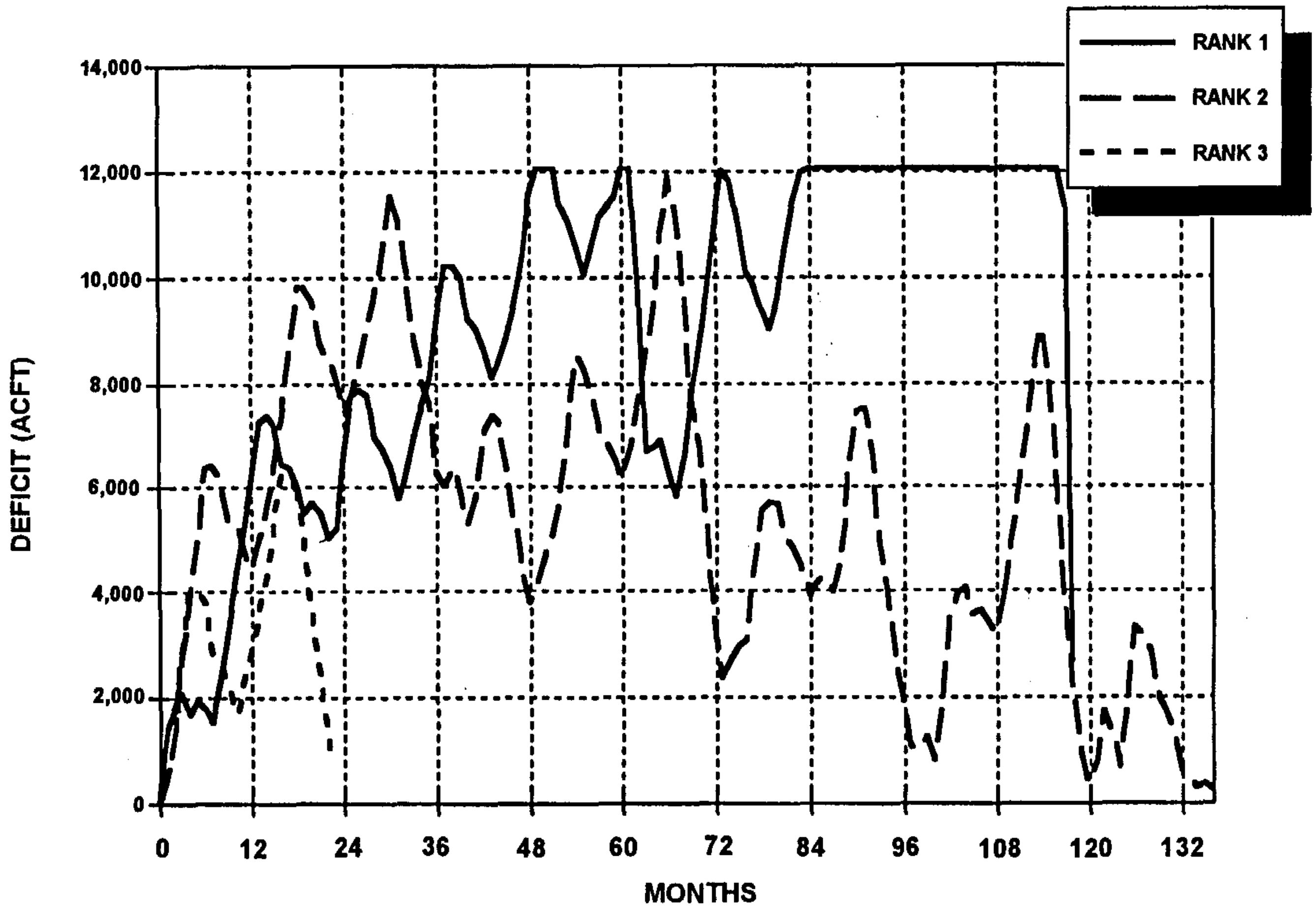
The results of these computations show that if a threshold flow level at Comal Springs of 200 cfs is to be maintained through the drought of record, a maximum deficit of 1,069,436 AF would occur over a 118 month period if the total pumpage from the aquifer is 400,000 AF/yr and the historic recharge record is repeated. If this water is to be delivered directly to Landa Lake at Comal Springs, this deficit volume represents the total amount of augmentation water needed under these conditions. For these conditions, the average and maximum monthly deficits over the duration of the deficit are 9063 AF/mo (108,756 AF/yr) and 12,038 AF/mo (144,456 AF/yr), respectively. This water would need to be supplied according to the distribution shown in Figure 3.10-1 which is derived from the computed springflow values.

Similarly, the simulation results show that if a threshold flow level at San Marcos Springs of 100 cfs is to be maintained through the drought of record, a maximum deficit of 251,812 AF would occur over a 93 month period if the total pumpage from the aquifer is 400,000 AF/yr and the historic recharge is repeated. If this water is to be delivered directly to Spring Lake at San Marcos Springs, this deficit volume represents the total amount of augmentation water needed under these conditions. For these conditions, the average and maximum monthly deficits over the duration of the deficit are 2,708 AF/mo (32,496 AF/yr) and 4,017 AF/mo (48,204 AF/yr), respectively. This water would need to be supplied according to the distribution shown in Figure 3.10-2 which is derived from the computed springflow values.

Since, to the best of our knowledge, no currently listed endangered species are dependent on the flow in the spring orifices at Comal or San Marcos Springs, augmentation water could be delivered directly to Landa and Spring Lakes."

3.10.3A Potential Springflow Augmentation Sources and Estimated Costs

"Various alternative water sources have been suggested for use as sources of augmentation water for Comal and San Marcos Springs. Some of these are unavailable due to economic, political or legal reasons; others appear feasible but have not been fully investigated. These feasible alternatives could have a beneficial impact on existing water supplies and spring flows, but they are not without drawbacks, commonly environmental."



NOTE:

Duration of rank 1, 2 and 3 deficits of Comal Springs flow from 200 cfs threshold flow rate with annual pumpage of 400,000 acft/yr.

Source: "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase 1 Feasibility Study", March 1, 1994, (Draft Report), Center for Research in Water Resources, University of Texas at Austin.

HDR

HDR Engineering, Inc.

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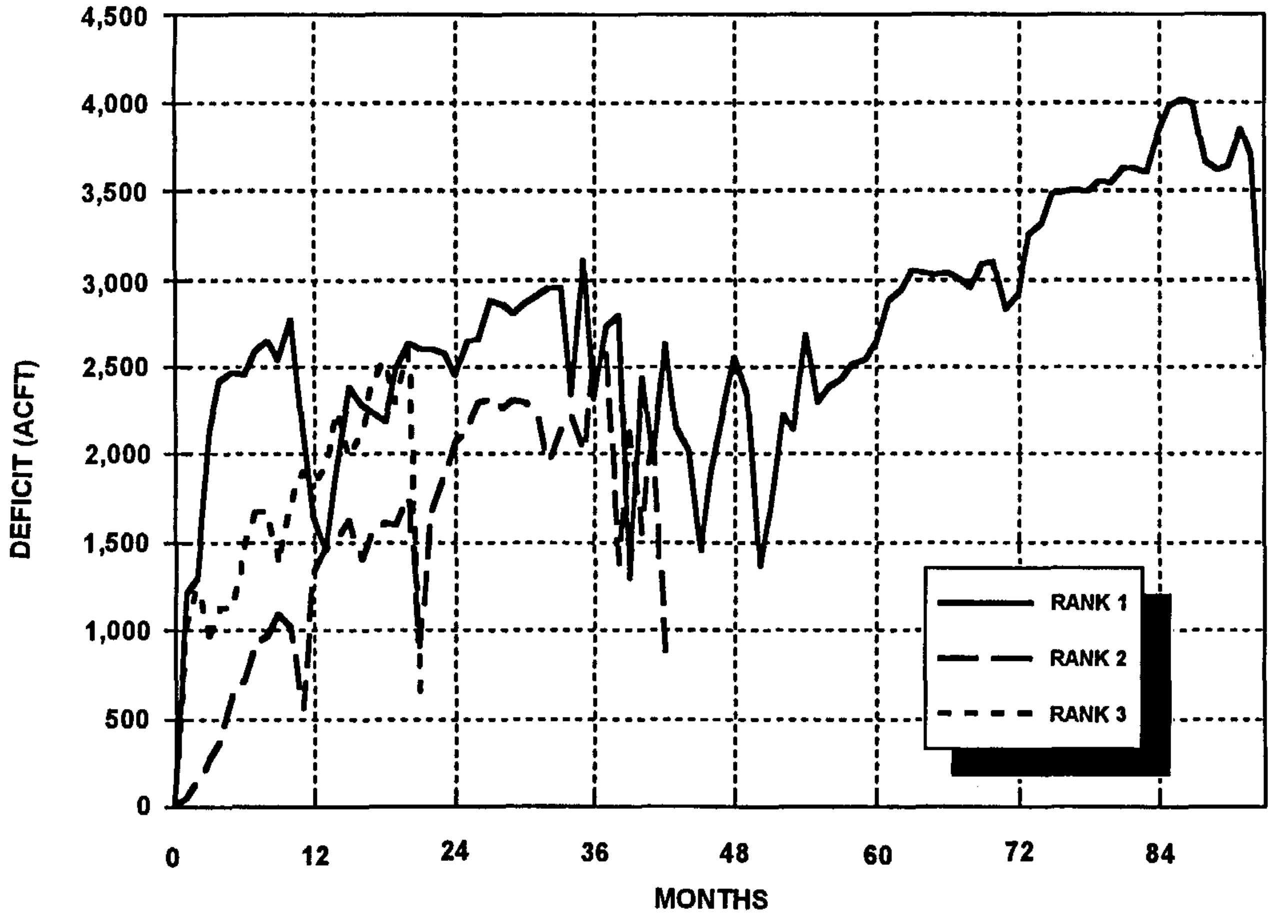
DURATION OF DEFICITS COMAL SPRINGS FLOW

FIGURE 3.10 - 1



NOTE:

Duration of rank 1, 2 and 3 deficits of San Marcos Springs flow from 100 cfs threshold flow rate with annual pumpage of 400,000 acft/yr.

Source: "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase 1 Feasibility Study", March 1, 1994, (Draft Report), Center for Research in Water Resources, University of Texas at Austin.

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DURATION OF DEFICITS SAN MARCOS SPRINGS FLOW

FIGURE 3.10 - 2

> "In searching for sources of springflow augmentation, it is assumed that any water used for augmentation must have roughly the same quality (i.e., chemical properties) as the water currently in the Edwards Aquifer or the spring systems. This assumption is based on the objective of preserving the environmental conditions that currently maintain the endangered species that rely on the springflow of the Edwards Aquifer."

A listing of the most likely springflow augmentation alternative presented in the study is included on Table 3.10-2. This table summarizes the results of the augmentation study to date and does not contain complete costing information since the costing portion of the report is still being developed.

As shown in this table, estimated capital costs range from a low of $44,733,015 to a high of $691,95,881. These costs do not include the cost of any raw water purchase nor do they include estimates of operation and maintenance costs as the report states that these costs are still being developed.

Table 3.10-2
Summary of Possible Water Sources, Delivery Methods, and Preliminary Costs for Springflow Augmentation Alternatives[5]

Description of Alternative[1]	Water Source	Delivery Method	Estimated Capital Costs[2,3]
Injection (Alt. 1)	Edwards Aquifer at location 10 miles SE of Comal Springs	Injection Wells	$69,082,200
Injection (Alt. 2)	LCRA water for San Marcos Springs; Edwards-Trinity aquifer in Crockett and Val Verde counties for Comal Springs	Injection Wells	$526,299,882
Injection (Alt. 3)	Edwards-Trinity aquifer in Crockett, Terrell, and Val Verde counties	Injection Wells	$691,945,881
Injection (Alt. 2) (w/ Max. Size Recharge Dams)	All Type 1 recharge dams at max. size; LCRA water for San Marcos Springs; Edwards-Trinity aquifer in Crockett and Val Verde Counties for Comal Springs	Injection Wells	N/A
Artificial Subsurface Flow Barriers[4]	Recirculation of San Marcos River water for San Marcos Springs recirculation of Comal River water for Comal Springs	Injection Wells	$44,733,015

[1]Maximum delivery rates for all alternatives are 100 cfs to San Marcos Springs and 200 cfs to Comal Springs.
[2]Operation and maintenance costs are unavailable at this time.
[3]If water for these alternatives could be discharged directly to spring lakes at San Marcos and Comal Springs through a manifold system, the cost for each of the above alternatives could be reduced by $2,577,200.
[4]This alternative is not suggested for implementation except as a measure of last resort and should only be attempted as the last phase of a carefully planned and executed solution.
[5]Source "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase 1 - Feasibility Study "March 1, 1994 (Draft Report) Center for Research in Water Resources, University of Texas at Austin.

3.10.4A Environmental Issues Associated with Springflow Augmentation of San Marcos and Comal Springs

The minimum springflows prescribed by the U.S. Fish and Wildlife Service to prevent the "take" of individuals from federally listed endangered or threatened species populations dependent on the Comal and San Marcos springs appears to be sufficient to maintain the (lotic) habitat conditions typical of the two spring lakes and the upper portions of the two rivers originating there, as long as minimum flows do not become constant flows[1,2,3]. Although maintaining minimum areas of lotic habitat in these reaches is critical, it is probably just as important that water temperature, pH, alkalinity and hardness, and transparency (and possibly other parameters) continue to exhibit average values, and restricted ranges of variation, similar to those now characterizing the spring dependent environments in San Marcos and New Braunfels. Except for injection points near the springs, or recharge rates that are large relative to existing ones, recharged augmentation water would be conditioned by mixing and detention within the aquifer. Scenarios calling for augmentation directly into Landa or Spring Lakes should include provisions for assuring that appropriate water quality characteristics are achieved and maintained in the influent. Endangered and threatened (and candidate) species believed to be present in the Comal and San Marcos Springs environments are listed in Appendix B, Tables 13, 23, and 50.

The effects of construction and operation of recharge impoundments on the Blanco River are addressed in Section 3.8.

<u>San Marcos Springs</u>

> "In the San Marcos system, the Texas Wild Rice is of great importance, and it grows in a very different habitat. Habitats

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[1]Espy, Huston & Associates, Inc., 1975, "Investigation of Flow Requirements from Comal and San Marcos Springs to Maintain Associated Aquatic Ecosystems," Document #7503. Submitted to Texas Water Development Board, Austin, Texas.

[2]U. S. Fish and Wildlife Service, 1984, San Marcos River Recovery Plan, U. S. Fish and Wildlife Service, Albuquerque, New Mexico. pp. v + 109.

[3]Sharp, J.M. and D. C. McKinney, 1994, "Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase I - Feasibility Study (DRAFT) CRWR 247," Center for Research in Water Resources, University of Texas at Austin.

with a rather high flow and a gravely substrate are best for the wild rice." "A good example of wild rice habitat is the area of the park on the campus of Southwest Texas University. These habitats are generally about four to six feet deep, and the Wild Rice grows up to the water surface. The plant grows well wherever similar conditions ar found in other areas of the river. Where it grows under different habitat characteristics, it does not appear to proliferate as much. Because the fountain darter has a preference for certain vegetation, flow velocity, and substrate combinations, their existing habitats would be devastated by a shift in flow velocity. The San Marcos Salamander would also be hurt by a change in the flow velocity from the springs. If the flow became too great, the salamander would be swept downstream to less suitable environmental. Yet the salamander requires flowing water for its habitat, indicating that too low a flow velocity be as great a problem. A low flow would increase deposition of silt in salamander habitats, rendering them unsuitable. Under a large enough flow alteration, the species may not be able to adjust, and they would die out. San Marcos River is unique because of its combination of habitats, which is due in part to the flow velocities in the river.

The San Marcos springs have never gone dry in historical times, so that is not the greatest danger to the river. A much more serious threat is a drop in the amount of flow and therefore the flow rate in the channel. This could occur through drought conditions or over-pumping of the Edwards Aquifer. A drop in flow rate would change the substrate in the channel to one of predominantly more small gravels and fines, including mud. If the substrate the Texas Wild Rice grows in is altered, the plant would likely die. There is tolerance for some drop in flow rate, but only to the point of accumulation of fines. Current U.S. Fish and Wildlife estimates of the flow necessary for the Wild Rice is 100 cfs or 2.8 m^3/sec yearly in order to maintain the species. Augmentation of the flow would best be done through either Spring Lake or local recharge. Increased local recharge is one of the most natural ways to augment the flow in the San Marcos River, because the flow already has a significant local component. Spring Lake is the head of the channel and its flow supplies the channel. By putting more water into Spring Lake in times of low flow, the system would maintain higher flows."

Comal Springs

"In the Comal system, foundation darters are shown to be most abundant where flow velocities are low. Most of the system contains important darter habitat however, because where flow velocities are high, darters live either in the boundary layer or in the shelter provided by large substrate material. Where this is combined with a structure provided by vegetation, optimum fountain darter habitat is found; habitats of low flow velocity and either riccia or filamentous algae. Bleiders Creek, parts of Landa Lake, the middle portion of the old channel, and some of the edge habitat in the new channel provide these optimum habitats. In the interest of maintaining the existence of the species dependent on the flow of the Comal River system, these are the habitat areas that should be augmented. Generally, the substrate in these areas is muddy. Because the habitats are dependent on their flow velocities for maintenance of the substrate, vegetation, and soil input, any alteration to the flow rate would effect all of the components of the habitats. The plants each appear to prefer different substrates for growth. If the substrates change, the distribution of vegetation will change accordingly. Because the Fountain Darter and Riffle Beetle each have a preference for certain vegetation, flow velocity, and substrate conditions, their existing habitats would be devastated by a shift in flow velocity. Under a great enough flow alteration, the species may not be able to adjust, and they would die out.

A drop in the depth of the flow in these areas due to drought or over-pumping of the Edwards Aquifer, would result in serious habitat loss if the vegetation emerged and died. A drop in depth would also change the flow, and most likely the substrate found in these areas. A loss of flow in Comal may also cause the Rams Horn Snail to proliferate, which would then destroy most of the vegetation. The snail feeds on the vegetation in the lake and river, it is capable of clearing an entire area of plants. A proliferation of the rams horn snail would therefore have a devastating effect on fountain darter habitats. There is tolerance for some drop in depth, but not too much. A current U.S. Fish and Wildlife estimate of the flow necessary for the survival of the species is 200 cfs or 5.7 m^3/sec yearly, or 4.2 m^3/sec yearly if the rams horn snail can be controlled. Augmentation of the flow would best be done through Landa Lake. Bleiders Creek can be supplied by backwater from the lake, and the old channel flows from the lake. By putting more water into Landa Lake in times of low flow, the majority of the system would be preserved."

3.10.5A Implementation Issues for Springflow Augmentation of San Marcos and Comal Springs

[To be completed in later study phases if this concept continues to be carried forward by PMC]

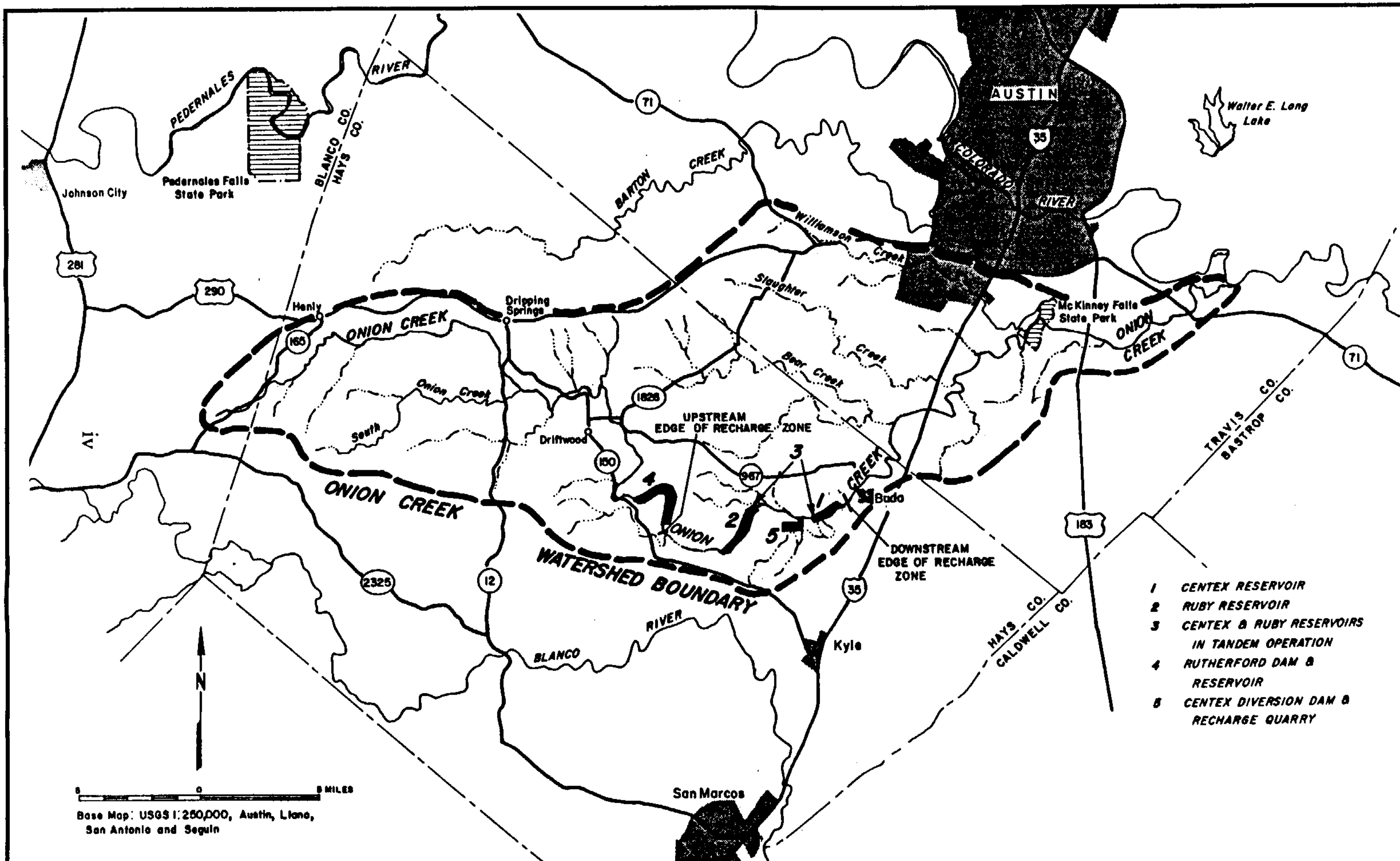
3.10.1B Description of Artificial Recharge Enhancement Study for Barton Springs Segment of Edwards Aquifer

"The purpose of this investigation was to perform an engineering and environmental assessment of five artificial recharge enhancement projects on Onion Creek in Hays County, Texas. This investigation, sponsored by the Barton Springs/Edwards Aquifer Conservation District (District), involved detailed field investigations, engineering, geological, and environmental assessments, and a review of institutional requirements related to the implementation of one or more of the following project alternatives" (Figure 3.10-3).

1. Alternative No. 1 - CenTex Reservoir (271 acft);
2. Alternative No. 2 - Ruby Reservoir (435 acft);
3. Alternative No. 3 - CenTex Reservoir and Ruby Reservoir Tandem Operation;
4. Alternative No. 4 - Rutherford Dam and Reservoir (3,670 acft); and
5. Alternative No. 5 - CenTex Diversion Dam and Recharge Quarry (1,000 acft).

"The CenTex Reservoir (Alternative No. 1) and Ruby Reservoir (Alternative No. 2) involves the construction and operation of "on-channel" reservoirs situated directly on the Recharge Zone within Onion Creek. These alternatives would temporarily impound water over known moderate and high recharge zones of Onion Creek. The CenTex Reservoir (Alternative No. 1) and Ruby Reservoir (Alternative No. 2) were evaluated as individual-stand along projects and as tandem reservoirs (Alternative No. 3), assuming both reservoirs were constructed.

The fourth alternative (No. 4), Rutherford Dam and Reservoir involves the construction of a dam and reservoir located immediately above the Recharge Zone on Onion Creek. This



SOURCE:

"Engineering Assessment and Environmental Inventory and Issues Report Artificial Recharge Enhancement Onion Creek, Hays County, Texas"

Prepared by Donald G. Rauschuber and Associates, Inc. and Others, April, 1992.

HDR

HDR Engineering, Inc.

LOCATIONS OF THE PROPOSED PROJECT ALTERNATIVES WITHIN THE ONION CREEK WATERSHED

FIGURE 3.10 - 3

impoundment would store water during flood events. Water would be subsequently released after a flood subsides at a rate that is less than the maximum recharge rate (approximate 160 cfs) of Onion Creek.

"A fifth alternative (No. 5), CenTex Diversion Dam and Recharge Quarry, involves the construction of a diversion dam on Onion Creek above Barber Falls. Flood water would be diverted through a diversion channel to an existing CenTex Materials, Inc., quarry (pit). Water stored in the quarry would be recharged to the Edwards Aquifer via a series of recharge wells.

In 1970, an estimated 70 million gallons (215 acft) of groundwater was withdrawn from the Barton Springs segment of the Edwards Aquifer. Dependency on groundwater has increased to over 1.1 billion gallons (3,376 acft) in 1990. Over the last two decades, major groundwater pumping centers have been developed in the Buda-San Leanna area. These centers provide water to over an estimated 30,000 people, and to numerous industrial, commercial and agricultural entities.

Historically, during hot, dry summer months and extended periods of low rainfall, water levels in the Barton Springs segment of the Edwards Aquifer have significantly declined as discharge exceeds natural recharge to the groundwater system. Likewise, springflows from Barton Springs and other associated springs have been considerably reduced to critical levels.

Although conservation plans implemented by the District will "slow down" the increase in dependency on groundwater resources, artificial recharge enhancement projects must be constructed to increase the quantity of water being recharged during storm events. Maintenance of historical groundwater supplies and discharges through Barton Springs can be achieved through implementation of water conservation programs with artificial recharge enhancement projects."

"Water consumed from the aquifer is withdrawn by wells, however, natural spring discharge, through Barton Springs and other associated springs, provides a high quality recreational and environmental resource for the City of Austin. In addition, natural spring discharge from the aquifer serves as a portion of the municipal water supply for the City of Austin and other communities located downstream of Austin, and serves to maintain base flow in the Colorado River."

The aquifer is recharged principally by vertical migration of water leakage from streams flowing across its Recharge Zone. Much of the recharge is derived from direct runoff associated with specific rainfall events on and upstream of the recharge area. Onion, Bear, Little Bear, Slaughter, Williamson, and Barton Creeks provide most of the recharge to the aquifer. It is estimated that 34 percent of the 37,400 acre-feet (af) of annual average recharge (1941 - 1988 period) the aquifer receives from these creeks originates from the Onion Creek watershed located on and above the Recharge Zone."

3.10.2B Estimated Quantities of Artificial Recharge

Baseline Recharge (Without the Projects)

"Daily stream flow estimates for Onion Creek above the downstream end of the Recharge Zone was developed for the period January 1, 1941 through June 30, 1979. This was performed to facilitate mathematical modeling analyses of the recharge enhancement project alternatives. Based on these analyses, it is estimated that the total average annual flow available for recharge during the 1941 through 1988 period was about 43,100 acft. This ranged from a minimum annual flow of 406 acft in 1956 to a maximum available flow of 122,259 acft in 1973."

"Not all stream flow that enters the Recharge Zone from the Onion Creek watershed is available for recharge. Onion Creek, like other creeks providing recharge to the Barton Springs segment of the Edwards Aquifer, has a maximum infiltration rate that can transmit water from the creek bed to the water table. Field and analytical investigations performed, as part of this study, indicate that the maximum recharge rate of Onion Creek is about 160 cfs. These investigations show that about 135 cfs is lost to recharge in the 7.6 creek mi reach above Barber Falls and 25 cfs is lost in the 2.0 creek mi reach below Barber Falls to the downstream end of the Recharge Zone."

"Using a maximum recharge rate of 160 cfs, daily estimates of recharge were made. For this analysis, daily estimated stream flow rates of less than or equal to 160 cfs entering an occurring over the Recharge Zone were "recharged". Likewise, only 160 cfs was recharged when available estimated stream flow was greater than 160 cfs. Using this methodology, it was estimated that 43,100 acft of available average annual inflow approximately 28,700 acft is recharged. This results in an average annual stream flow at Buda (downstream of the Recharge Zone) of about 14,400 af for the 1941 through 1988 period."

Enhanced Recharge (With the Projects)

"Hydrological analyses of the various project alternatives and "without" conditions were performed using the daily computer simulation model SIMYLD. Onion Creek and tributary inflows for each alternative were estimated by applying appropriate unit runoff ratios to the calculated or measured daily stream flows for Onion Creek near Driftwood. Daily net evaporation data for quadrangles segmented along one degree parallels of latitude and medians of longitude were obtained from the Texas Water Development Board (TWDB). Daily net reservoir evaporation for the study area was computed by applying a weighted average to the appropriate quadrangles evaporation rates reported by the TWDB. Baseline recharge rates were assigned to each creek reach based on actual flow-loss studies performed by the USGS and on investigations performed in this study. The maximum recharge rate of 160 cfs was distributed over the Recharge Zone of Onion Creek. Reservoir area-elevation-capacity relationships for each alternative were developed from field survey information and USGS 7.5 minute topographic quadrangles."

"The results from the SIMYLD simulations are summarized in Table 3.10-3. Values of total and incremental increase in the recharge and resulting outflow below the Recharge Zone (at Buda) for each project alternative are also presented in this table."

3.10.3B Environmental Issues Associated with Artificial Recharge Enhancement for Barton Springs Segment of Edwards Aquifer

Rauschuber et al[4] evaluated five scenarios for recharging the Barton Springs Edwards Aquifer through recharge impoundments on Onion Creek and found no major

[4]Rauschuber & Associates, Inc., 1992, Onion Creek Recharge Project: Engineering Assessment and Environmental Inventory Issues Report of Artificial Recharge Enhancement. Austin, Texas.

Table 3.10-3 Summary of Total and Incremental Increase in Recharge and Resulting Flows at Buda for Each Project Alternative				
Alternative	**Average Annual Inflow (AF)**	**Average Annual Recharge (AF)**	**Average Annual Recharge Increase (AF)**	**Average Annual Outflow (AF)**
Historical Base Condition	43,116	28,686	----	14,430
1. Centex Reservoir	43,116	29,447	762	13,674
2. Ruby Reservoir	43,121	29,829	1,143	13,298
3. Centex Reservoir and Ruby Reservoir Tandem Operation	43,116	30,261	1,576	12,851
4. Rutherford Dam and Reservoir	43,116	32,201	3,515	10,810
5. Centex Diversion Dam and Recharge Quarry	43,139	34,404	5,718	8,736

Source: "Engineering Assessment and Environmental Inventory and Issues Report, Artificial Recharge Enhancement, Onion Creek, Hays County, Texas," Prepared by Donald R. Rauschuber & Associates, Inc. and Others, April, 1992.

environmental impacts or problems associated with any of the alternatives. The largest proposed impoundment (Rutherford Dam and Impoundment) would be a Type 1 structure located upstream of the recharge zone. It would have a permanent pool covering about 35 acres, and a maximum recharge pool that would inundate 252 acres of stream channel and upland savannah for about 6% of the time (22 days/year). The remaining alternatives consist of two small Type 2 structures (Ruby and CenTex reservoirs) located within the recharge zone, a system operation scenario using the two Type 2 impoundments, and a scenario that envisions a diversion dam that would direct flood flows into an existing quarry, which would be modified to enhance recharge rates.

The two Type 2 structures would together cause periodic inundation (about 7% of the time, 26 days/year) of about 78 acres of existing stream channel and riparian vegetation. The diversion and quarry alternative would impact only about one acre of natural habitat, and periodically inundate existing quarry floors.

Operation of any of these alternatives would reduce streamflows entering the reach of Onion Creek between the recharge zone and its mouth on the Colorado River. Hydrologic analysis included a provision for maintaining downstream flows only in the case of the Type 1 structure. Rutherford Dam would be designed to release stored water at rates which would maximize recharge[5]. During low flow periods, inflows would be passed downstream as uncontrolled spills when the 35 acre permanent pool was full. The Type 2 structures and the Diversion Dam-Quarry alternative would have only an uncontrolled spillway for releases, and all inflows would be stored and recharged unless the impoundment is full.

The Type 2 alternatives would reduce monthly average flows in the lowest reach by 10-15% except during August, when average streamflow would decline to 40 to 60% of baseline flows[6]. Operation of the Type 1 impoundment, or of the Diversion Dam-Quarry alternative would result in larger decreases in monthly average flows in the lowest reach, on the order of 25-65%. The Diversion Dam-Quarry alternative would have the largest effect, and the most pronounced summer flow reductions.

The "streamflow reductions" resulting from impoundment operations were represented statistically as monthly average flows, but actual flow reductions below these structures would vary considerably depending on climatic conditions. When flood flows are refilling an empty impoundment, no water is passed downstream. When the impoundments are full and spilling, reductions of flow downstream will equal the difference between baseline recharge and the impoundment enhanced recharge rate. During low flow periods, when streamflows enter impoundments at rates less than the rate of recharge (net evaporation is probably insignificant in these small impoundments), reservoir levels will decline, and no downstream flows will occur. These effects will not be evenly distributed in time, but will be pronounced during dry years and largely unnoticeable in normal to wet years.

Lower (below Buda) Onion Creek presently receives flow from the recharge zone only intermittently. It has other, large tributaries that would be unaffected, and the Colorado River serves as both a refuge and a reservoir of potential colonists for the lowermost reach of Onion Creek. These facts suggest that impacts to the biological communities of lower Onion Creek would be difficult to detect during most years, that

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[5]Ibid.

[6]Ibid.

during drought conditions additional stress from lack of inflows may result in the reach immediately below the recharge zone, and that these projects would not preclude rapid recovery of the stream community following exceptionally dry periods.

No archaeological or historical sites that would be affected by construction or operation of any of these recharge sites were found during the cultural resources survey[7].

3.10.4B Engineering and Costing

> "The projected capital, operation and maintenance (O&M), and gallonage (per 1,000 gallons and per acre-foot recharged) costs for each project alternative is presented in Table 3.10-4. The capital cost for each alternative range from $2.9 million for Rutherford Dam and Reservoir to $0.60 million for the CenTexReservoir. At an anticipated annual interest rate of 8 percent for 25 years, annual debt service costs range from about $268,000 for Rutherford Dam and Reservoir to approximately $56,000 for CenTex Reservoir. Estimated annual operation and maintenance costs for the alternatives evaluated range from $60,000 for the CenTex Diversion Dam and Recharge Quarry to $15,000 for Ruby Reservoir alternative. The CenTex Dam and Recharge Quarry alternative would provide for the lowest unit cost of water recharged at $0.10 per 1,000 gallons ($33.00 per acft). However, this alternative will require many years to implement and fully develop, due to current mining activities of CenTex Materials, Inc. CenTex Reservoir, Ruby Reservoir and Rutherford Dam and Reservoir provide comparable costs of about $0.28 to $0.29 per 1,000 gallons ($91.00 to $94.00 per acft) of water recharged. The CenTex Reservoir and Ruby Reservoir Tandem Operation is the most expensive alternative at a projected cost of $0.34 per 1,000 gallons ($111.00 per acft)."

3.10.5B Implementation Issues

[To be completed in later study phases if this concept continues to be carried forward by PMC]

[7] Ibid.

Table 3.10-4
Preliminary Projected Costs

Alternative	1992 Capital Costs	Annual Debt Service[1]	Estimated Annual O & M Cost	Estimated Total Annual Costs	Estimated Annual Recharge Potential (AF)	Projected Cost Per 1000 Gal[2]	Projected Cost Per Acre Foot[2]
1. Centex Reservoir	$601,670	$56,360	$15,000	$71,360	768	$0.29	$94.00
2. Ruby Reservoir	952,080	89,190	15,000	104,190	1,152	0.28	91.00
3. Centex Reservoir and Ruby Reservoir Tandem Operation	1,553,750	14,550	30,000	175,550	1,576	0.34	111.00
4. Rutherford Dam and Reservoir	2,856,150	267,560	50,000	337,560	3,515	0.28	91.00
5. Centex Quarry	1,317,890	123,460	60,000	183,460	5,718	0.10	33.00

Source: "Engineering Assessment and Environmental Inventory and Issues Report, Artificial Recharge Enhancement, Onion Creek, Hays County, Texas," Prepared by Donald R. Rauschuber & Associates, Inc. and Others, April, 1992.

[1]8% for 25 years.

[2](Annual debt service + annual O & M) ÷ (Estimated Annual Recharge Potential)

3.11 Existing Water Rights in Nueces River Basin (N-10)

The Texas Natural Resource Conservation Commission (TNRCC) maintains a master listing of all water rights and applications for water rights within the state. A listing of all water rights in the Nueces River Basin was extracted and tabulated. The annual diversion rights in the Nueces Basin total 530,046 acft. Water rights in terms of authorized diversions for the entire basin are summarized by type of use in Table 3.11-1. Municipal and industrial water rights are the dominant types of use in the basin, totaling over 85 percent of all authorized diversion rights (Table 3.11-1). Authorized municipal and industrial diversion rights of the City of Corpus Christi (et al.) comprise almost 84 percent of total basin diversion rights. The Edwards Underground Water District owns all authorized diversion rights for recharge, which comprise less than 1 percent of total basin diversion rights.

Table 3.11-1
Summary of Water Rights by Type of Use

Type of Use	Authorized Diversion (acft/yr)	Percent of Total Authorized Diversion
Municipal		
A. City of Corpus Christi (et al.)	215,142	
B. Others	6,933	
Subtotal - Municipal	222,075	41.9
Industrial		
A. City of Corpus Christi (et al.)	228,530	
B. Other	368	
Subtotal - Industrial	228,898	43.2
Irrigation		
A. Zavala-Dimmit Co. WID #1	27,996	
B. Others	48,761	
Subtotal - Irrigation	76,757	14.5
Mining	16	0.0
Recharge	2,290	0.4
Other	10	0.0
TOTALS	530,046	100%

Reference: HDR Engineering, Inc., "Nueces River Basin Regional Water Supply Planning Study-Phase I," Nueces River Authority, May, 1991.

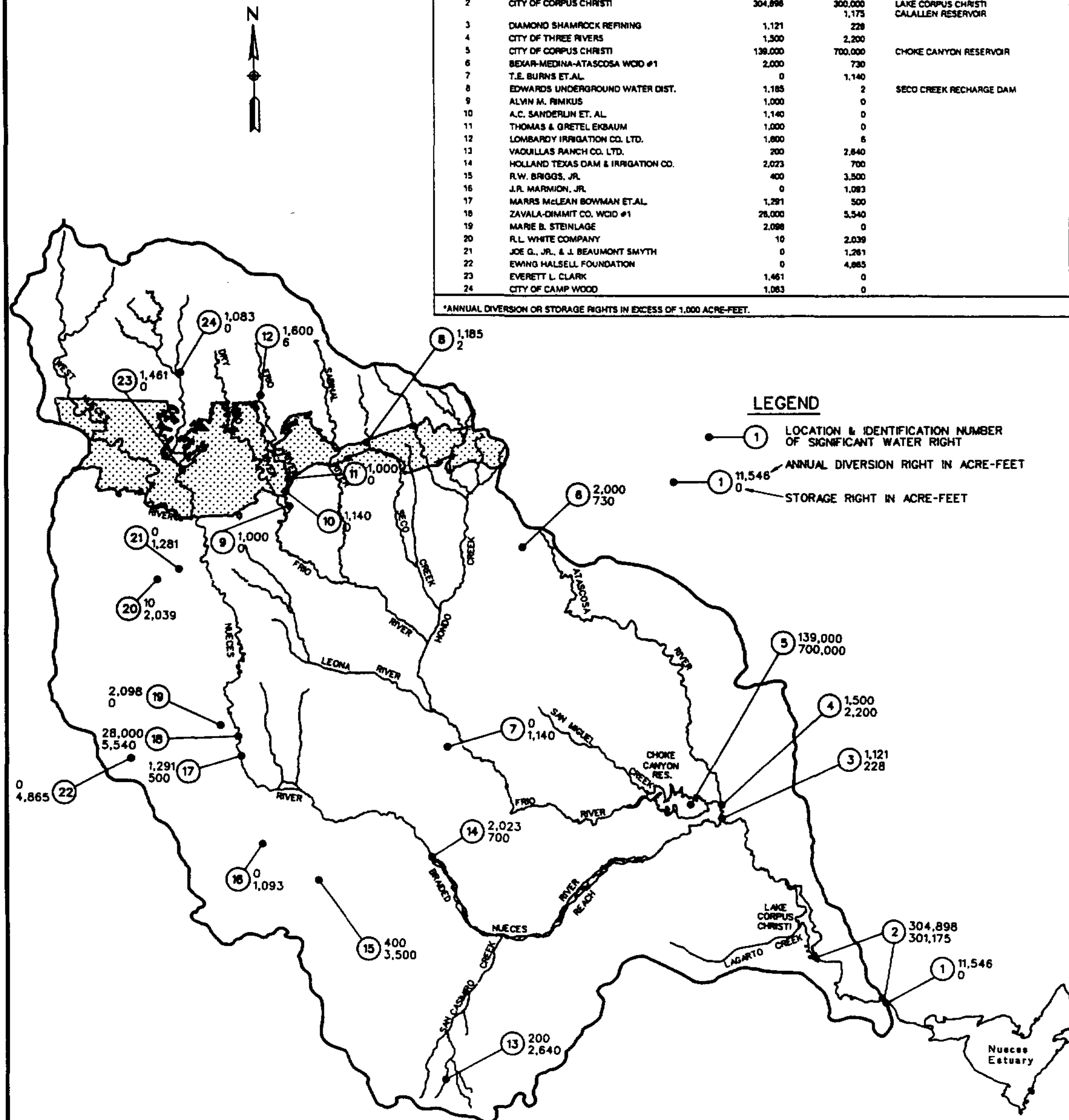
There are a total of 24 owners of storage or annual diversion rights in excess of 1,000 acft in the Nueces River Basin. The geographic location of each of these significant water rights is shown in Figure 3.11-1 along with a listing of the associated diversion and storage rights. The sum of these 24 diversion rights represents almost 95 percent of total diversion rights in the Nueces River Basin.

A review of water rights in the Nueces River Basin was made to determine if there were any unutilized or underutilized water rights. A review of Figure 3.11-1 shows that there are only two significant water rights permits other than those held by the City of Corpus Christi. One of these permits is held by the Nueces County Water Control and Improvement District No. 3 (District No.3) located in Robstown, Texas. The District has the right to divert 11,545 acft/yr of water from the Calallen Reservoir pool located downstream of Lake Corpus Christi. For the seven year period from 1983 through 1989, the most water utilized under this permit was 5,737 acft. This represents about 50 percent of their total authorized use. Assuming District No. 3 would consider selling a portion of this right, the transfer of this amount of water would not be an economically attractive source for the West Central Study Area to use directly because of the remote location of this right. However, it could be a potential mitigation source to offset the impacts of the recharge structures discussed in Sections 3.8 and 3.9. A water rights purchase and exchange may be possible whereby the West Central Study participants would purchase a portion of the rights held by District No. 3 and then allow the South Central Study entities use of those rights as compensation for impacts of the recharge projects proposed in the Nueces River Basin. The potential purchase of this water right is one of the alternatives (i.e., N-4) being considered in the South-Central study area to supply the needs of the Corpus Christi service area.

The only other significant water rights in the Nueces River Basin are those rights held by the Zavala-Dimmit County Water Control and Improvement District Number 1 (District No. 1). Water rights held by District No. 1 include the right to divert up to 28,000 acft per year from the Upper Nueces Reservoir (located on the main stream of the Nueces River) for the irrigation of up to 14,000 acres. District No. 1 has the right to impound 5,540

IDENT. NO.	OWNER	DIVERSION RIGHTS (AC-FT/YR)	STORAGE RIGHTS (AC-FT)	NOTES
1	NUECES COUNTY WCID #3	11,546	0	
2	CITY OF CORPUS CHRISTI	304,898	300,000 1,175	LAKE CORPUS CHRISTI CALALLEN RESERVOIR
3	DIAMOND SHAMROCK REFINING	1,121	228	
4	CITY OF THREE RIVERS	1,500	2,200	
5	CITY OF CORPUS CHRISTI	139,000	700,000	CHOKE CANYON RESERVOIR
6	BEXAR-MEDINA-ATASCOSA WCID #1	2,000	730	
7	T.E. BURNS ET.AL.	0	1,140	
8	EDWARDS UNDERGROUND WATER DIST.	1,185	2	SECO CREEK RECHARGE DAM
9	ALVIN M. RIMKUS	1,000	0	
10	A.C. SANDERLIN ET. AL.	1,140	0	
11	THOMAS & GRETEL EKBAUM	1,000	0	
12	LOMBARDY IRRIGATION CO. LTD.	1,600	6	
13	VAQUILLAS RANCH CO. LTD.	200	2,640	
14	HOLLAND TEXAS DAM & IRRIGATION CO.	2,023	700	
15	R.W. BRIGGS, JR.	400	3,500	
16	J.R. MARMION, JR.	0	1,093	
17	MARRS McLEAN BOWMAN ET.AL.	1,291	500	
18	ZAVALA-DIMMIT CO. WCID #1	28,000	5,540	
19	MARIE B. STEINLAGE	2,098	0	
20	R.L. WHITE COMPANY	10	2,039	
21	JOE G., JR., & J. BEAUMONT SMYTH	0	1,281	
22	EWING HALSELL FOUNDATION	0	4,865	
23	EVERETT L. CLARK	1,461	0	
24	CITY OF CAMP WOOD	1,083	0	

*ANNUAL DIVERSION OR STORAGE RIGHTS IN EXCESS OF 1,000 ACRE-FEET.



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

HDR

SIGNIFICANT WATER RIGHTS IN NUECES RIVER BASIN

HDR Engineering, Inc.

FIGURE 3.11-1

acft under various permits which range in priority dates from 1913 to 1947. A review of water use records obtained from the TNRCC shows that during the seven year period from 1983 to 1989, District No. 1 has fully utilized their rights for at least three of those years. Hence, it appears that there would be no significant water available to the West Central Study Area from this source. Mitigation of potential impacts to District No. 1 would, however, be a component of the development of an Edwards Aquifer recharge enhancement project on the Nueces River.

3.12 San Antonio River Unappropriated Streamflow (S-10, -11, -12)

The Guadalupe - San Antonio River Basin Model[8] was used to estimate monthly quantities of unappropriated streamflow potentially available at the following locations (See Figure 3.12-1) in the San Antonio River Basin:

- San Antonio River at Elmendorf (S-10);
- San Antonio River at Falls City (S-11); and
- San Antonio River at Goliad (S-12).

Calculations were performed for four scenarios selected to present a reasonable range of unappropriated streamflow potentially available during average (1934-89), drought (1947-56), and minimum year conditions. All scenarios included Trans-Texas Environmental Criteria (See Appendix C), full utilization of existing water rights, and spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures. Existing rights included hydropower water rights on the Guadalupe River of 600 cfs at Lake Dunlap and a Canyon Lake firm yield of 50,000 acft/yr. The four scenarios analyzed are further described as follows:

Scenario A1: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir included.

Scenario A2: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir excluded.

Scenario B1: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir included.

Scenario B2: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir excluded.

Unappropriated streamflow potentially available under each scenario at all three locations was computed subject to maximum diversion rates ranging from 500 acft/month (8 cfs) to 60,000 acft/month (995 cfs). Detailed tables summarizing unappropriated

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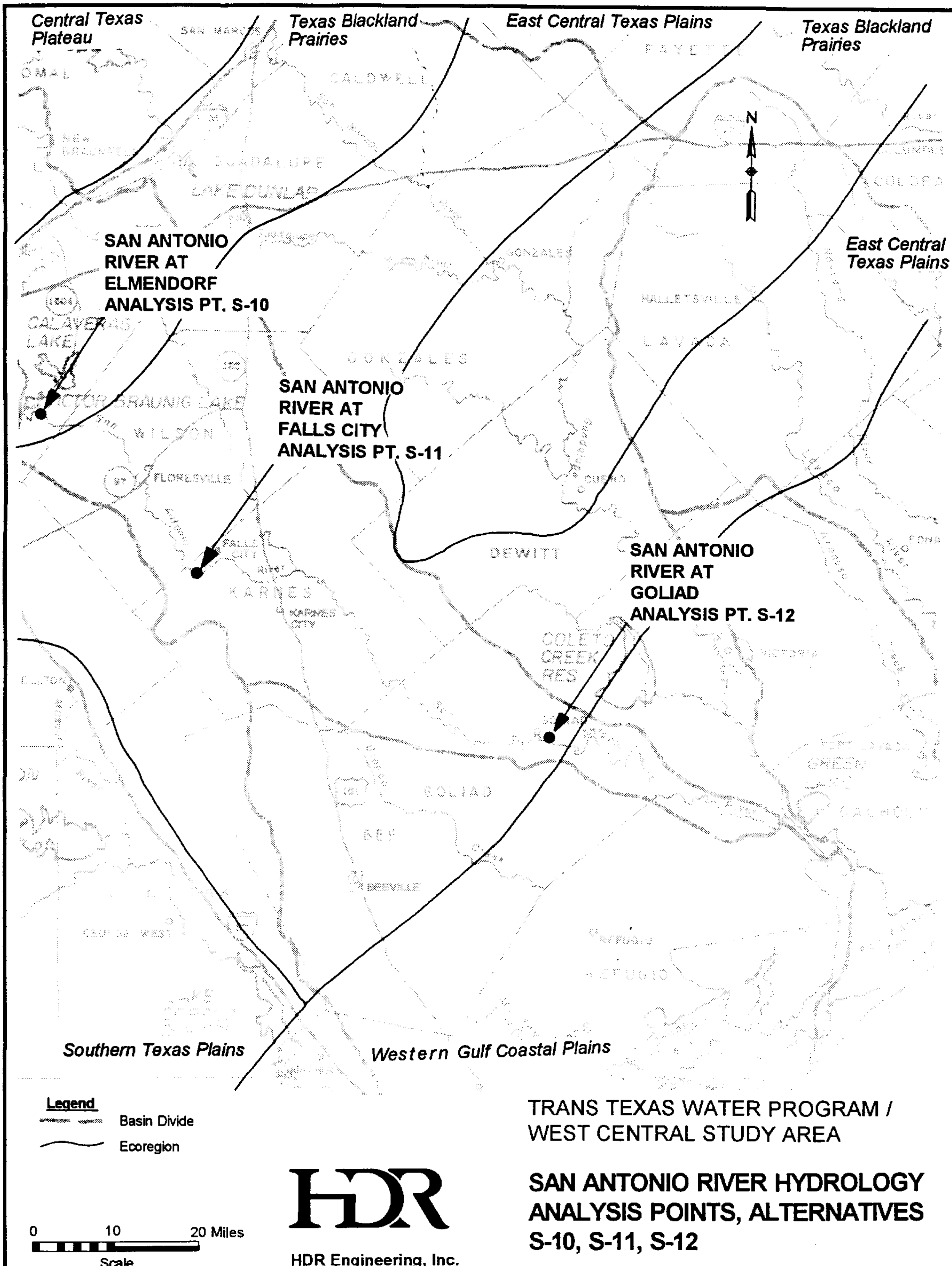
[8]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.



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WEST CENTRAL STUDY AREA

SAN ANTONIO RIVER HYDROLOGY ANALYSIS POINTS, ALTERNATIVES S-10, S-11, S-12

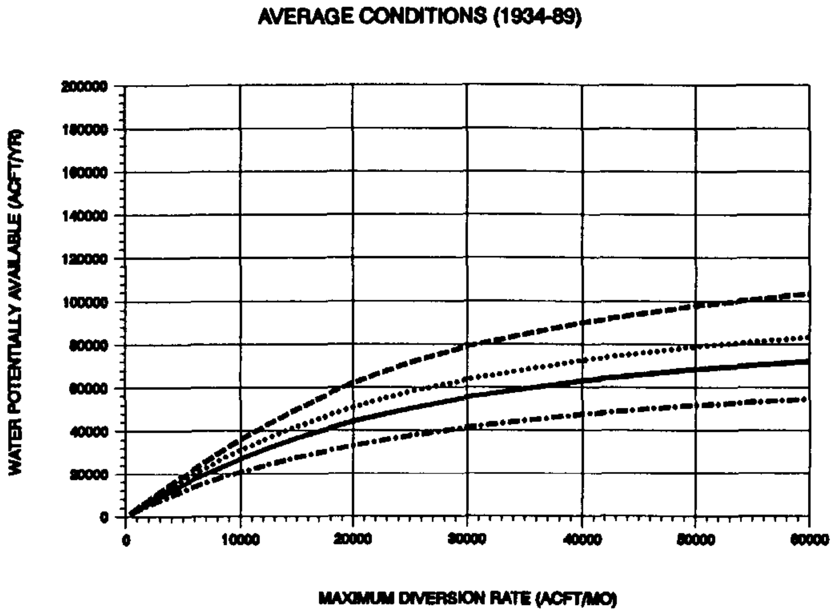
FIGURE 3.12-1

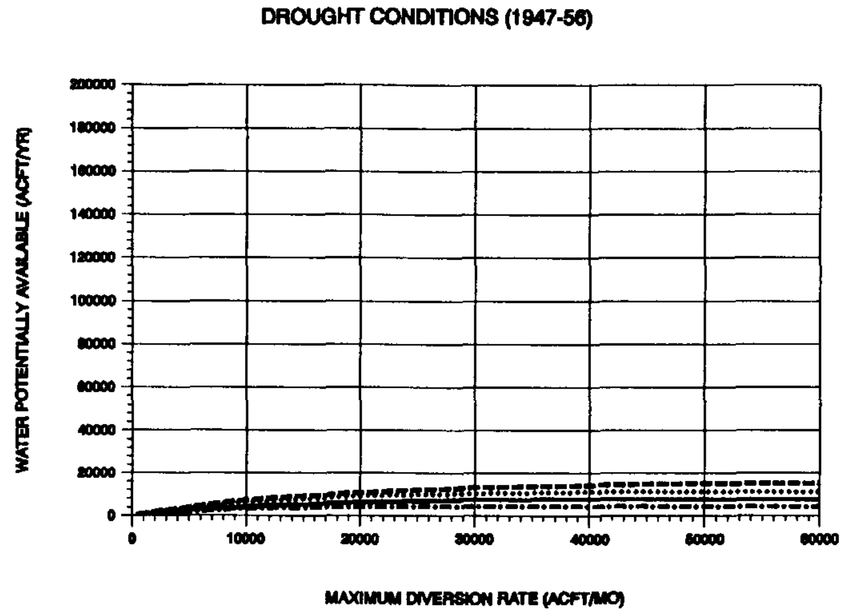
streamflow at each location under each scenario along with pertinent assumptions are included in Appendix D.

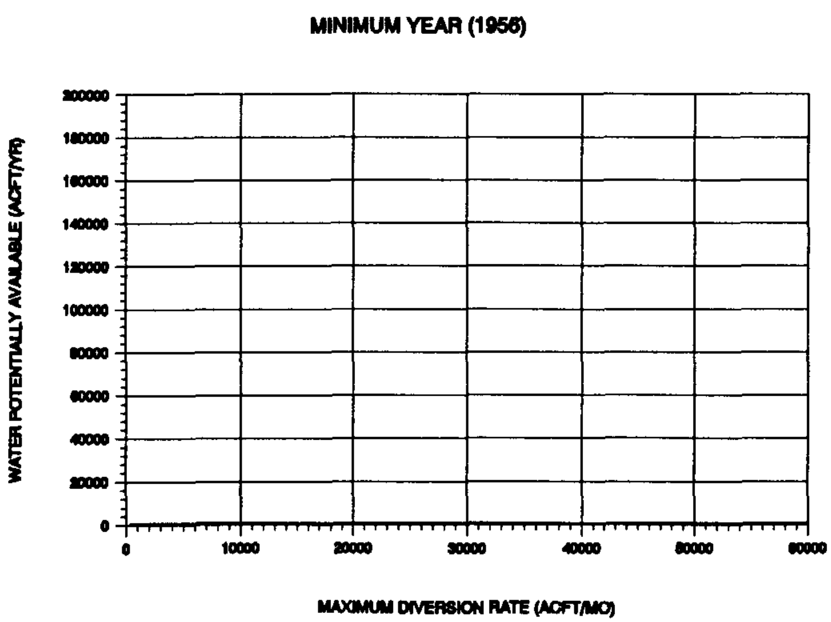
San Antonio River at Elmendorf (S-10)

Estimates of unappropriated streamflow potentially available from the San Antonio River at Elmendorf were calculated for average, drought, and minimum year conditions (Figure 3.12-2 with a graph for each condition). Scenario A2 (Return Flows set to 1988 levels, Applewhite Reservoir excluded) yielded the greatest quantity of unappropriated streamflow, while Scenario B1 (No Return Flows, Applewhite Reservoir included) produced the least quantity. For the maximum diversion rate of 60,000 acft/month, the quantity of unappropriated streamflow potentially available under Scenario A2 would be 103,500 acft/yr for average conditions, 15,100 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956) (Figure 3.12-2). For the same maximum diversion rate, the quantity of unappropriated streamflow potentially available under Scenario B1 would be 54,600 acft/yr for average conditions, 4,300 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956). Modeling results indicate that freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier, would be reduced by 73,000 acft/yr (4 percent) under Scenario A2 and 38,400 acft/yr (3 percent) under Scenario B1, for average conditions with a maximum diversion rate of 60,000 acft/month.

As indicated in Figure 3.12-2, unappropriated streamflow estimates for the San Antonio River at Elmendorf are more significantly affected by return flows than by water rights associated with Applewhite Reservoir. When return flows are decreased from the basin-wide 1988 level of 177,600 acft/yr to 0 acft/yr, unappropriated streamflow decreased by about 32 percent for average conditions and 55 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month. When Applewhite Reservoir was included, however, unappropriated streamflow decreased by about 22 percent for average conditions and 36 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month.







LEGEND

SYMBOL	SCENARIO	RETURN FLOWS	APPLEWHITE RESERVOIR
• • • • •	A1	1988	INCLUDED
- - - -	A2	1988	EXCLUDED
—- · —	B1	NONE	INCLUDED
——	B2	NONE	EXCLUDED

ASSUMPTIONS: EDWARDS AQUIFER PUMPAGE = 400,000 ACFT/YR
HYDROPOWER = 600 CFS
CANYON YIELD = 50,000 ACFT/YR

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TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

UNAPPROPRIATED STREAMFLOW SAN ANTONIO RIVER AT ELMENDORF ALTERNATIVE S-10

FIGURE 3.12-2

San Antonio River at Falls City (S-11)

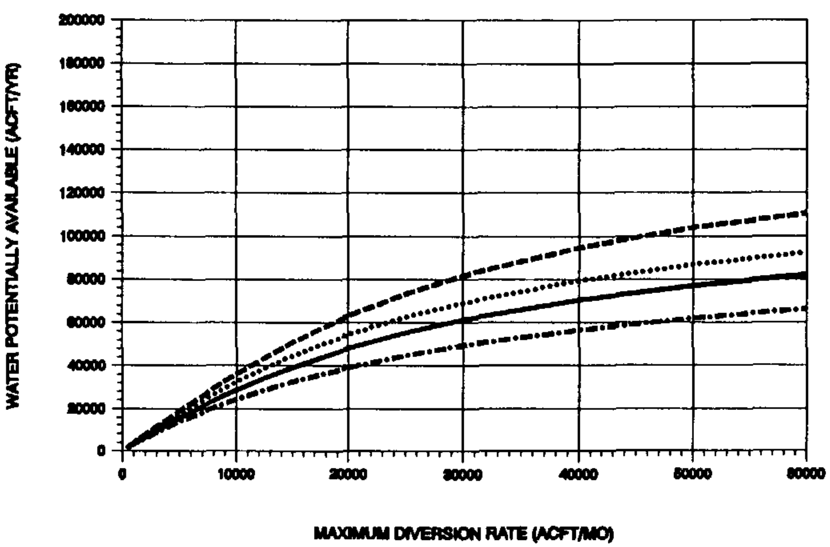
Estimates of unappropriated streamflow potentially available from the San Antonio River at Falls City were calculated for average, drought, and minimum year conditions (Figure 3.12-3, with a graph for each condition). Scenario A2 (Return Flows set to 1988 levels, Applewhite Reservoir excluded) yielded the greatest quantity of unappropriated streamflow, while Scenario B1 (No Return Flows, Applewhite Reservoir included) produced the least quantity. For the maximum diversion rate of 60,000 acft/month, the quantity of unappropriated streamflow potentially available under Scenario A2 would be 110,400 acft/yr for average conditions, 15,100 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956) (Figure 3.12-3). For the same maximum diversion rate, the quantity of unappropriated streamflow potentially available under Scenario B1 would be 66,300 acft/yr for average conditions, 5,100 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956). Modeling results indicate that freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier, would be reduced by 84,400 acft/yr (5 percent) under Scenario A2 and 50,500 acft/yr (3 percent) under Scenario B1, for average conditions with a maximum diversion rate of 60,000 acft/month.

As indicated in Figure 3.12-3, unappropriated streamflow estimates for the San Antonio River at Falls City are more significantly affected by return flows than by water rights associated with Applewhite Reservoir. When return flows were decreased from the basin-wide 1988 level of 177,600 acft/yr to 0 acft/yr, unappropriated streamflow decreased by about 33 percent for average conditions and 55 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month. When Applewhite Reservoir was included, however, unappropriated streamflow decreased by about 18 percent for average conditions and 31 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month.

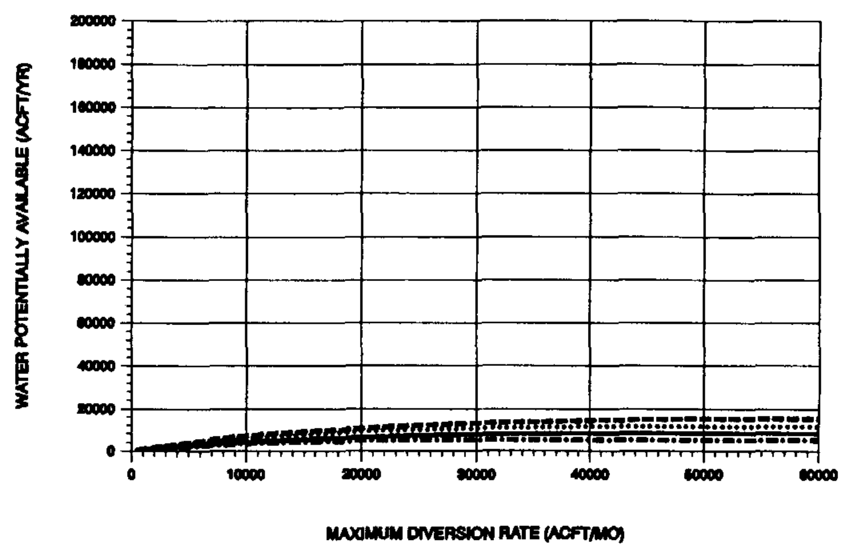
San Antonio River at Goliad (S-12)

Figure 3.12-4 presents estimates of unappropriated streamflow potentially available from the San Antonio River at Goliad for average, drought, and minimum year conditions, with a graph for each condition. Again, Scenario A2 (Return Flows set to 1988 levels,

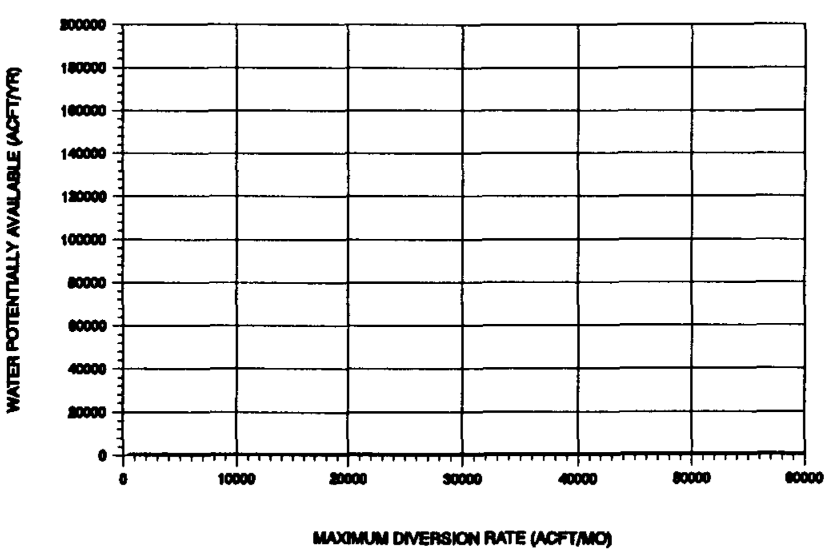
AVERAGE CONDITIONS (1934-89)



DROUGHT CONDITIONS (1947-56)



MINIMUM YEAR (1956)



LEGEND

SYMBOL	SCENARIO	RETURN FLOWS	APPLEWHITE RESERVOIR
•••••	A1	1988	INCLUDED
- - - -	A2	1988	EXCLUDED
—-—	B1	NONE	INCLUDED
——	B2	NONE	EXCLUDED

ASSUMPTIONS: EDWARDS AQUIFER PUMPAGE = 400,000 ACFT/YR
HYDROPOWER = 600 CFS
CANYON YIELD = 50,000 ACFT/YR

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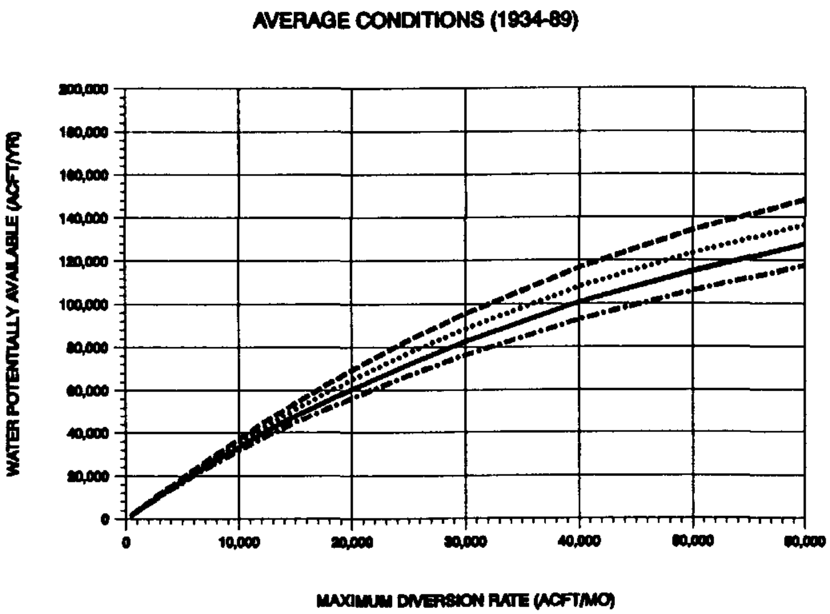
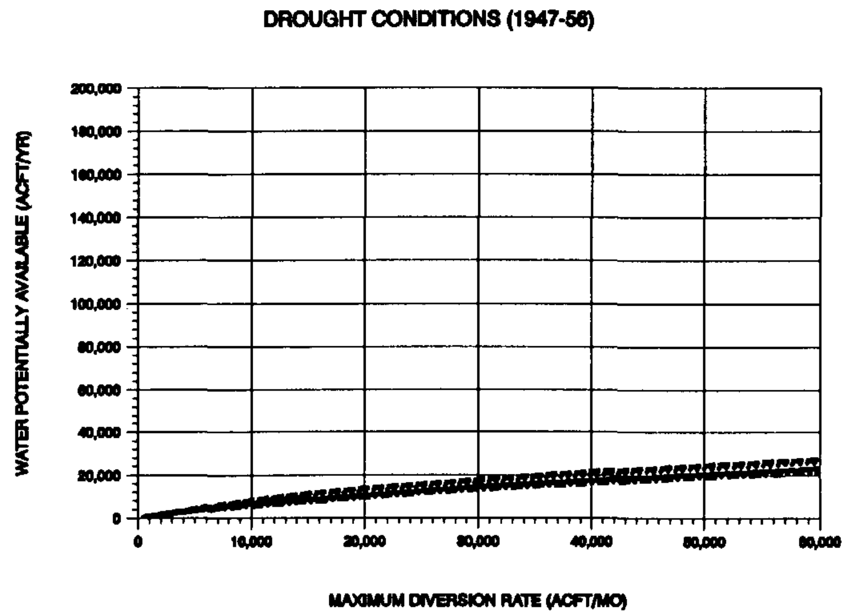
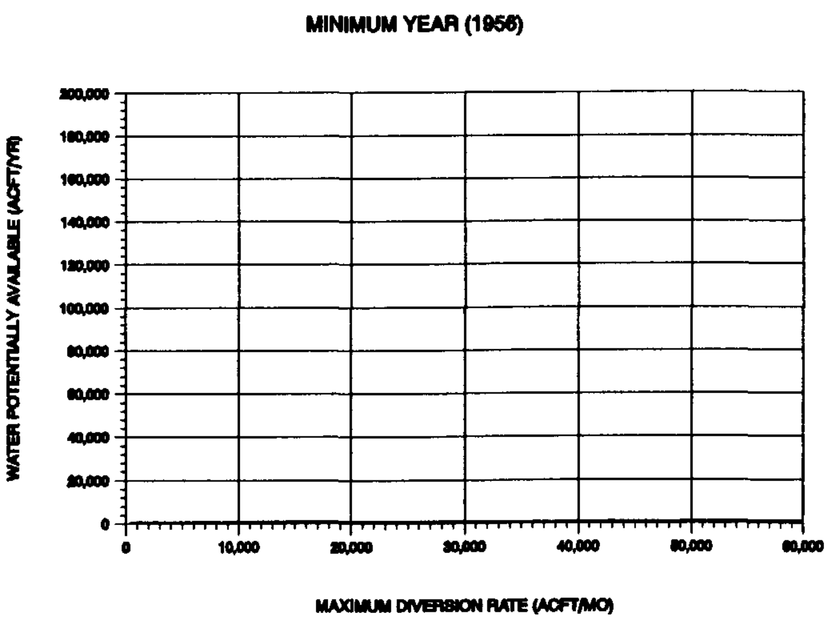
WEST CENTRAL STUDY AREA

UNAPPROPRIATED STREAMFLOW
SAN ANTONIO RIVER AT FALLS CITY
ALTERNATIVE S-11

FIGURE 3.12-3







LEGEND

SYMBOL	SCENARIO	RETURN FLOWS	APPLEWHITE RESERVOIR
•••••	A1	1988	INCLUDED
- - - -	A2	1988	EXCLUDED
—-—	B1	NONE	INCLUDED
——	B2	NONE	EXCLUDED

ASSUMPTIONS: EDWARDS AQUIFER PUMPAGE = 400,000 ACFT/YR
HYDROPOWER = 600 CFS
CANYON YIELD = 50,000 ACFT/YR

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UNAPPROPRIATED STREAMFLOW SAN ANTONIO RIVER AT GOLIAD ALTERNATIVE S-12

FIGURE 3.12-4

Applewhite Reservoir excluded) yielded the greatest quantity of unappropriated streamflow, while Scenario B1 (No Return Flows, Applewhite Reservoir included) produced the least quantity (Figure 3.12-4). For the maximum diversion rate of 60,000 acft/month, the quantity of unappropriated streamflow potentially available under Scenario A2 would be 148,100 acft/yr for average conditions, 27,600 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956). For the same maximum diversion rate, the quantity of unappropriated streamflow potentially available under Scenario B1 would be 117,600 acft/yr for average conditions, 21,200 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956). Modeling results indicate that freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier, would be reduced by 125,300 acft/yr (8 percent) under Scenario A2 and 79,800 acft/yr (5 percent) under Scenario B1, for average conditions with a maximum diversion rate of 60,000 acft/month.

As indicated in Figure 3.12-4, unappropriated streamflow estimates for the San Antonio River at Goliad are more significantly affected by return flows than by water rights associated with Applewhite Reservoir. When return flows were decreased from the basin-wide 1988 level of 177,600 acft/yr to 0 acft/yr, unappropriated streamflow decreased by about 14 percent for average conditions and 17 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month. When Applewhite Reservoir was included, however, unappropriated streamflow decreased by about 8 percent for average conditions and 7 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month.

3.13 Medina Lake (S-13)

3.13.1 Description of Alternative

Medina Lake is located on the Medina River in Medina and Bandera Counties about 25 miles northwest of San Antonio. The project was constructed between 1911 and 1913 and is presently owned and operated by the Bexar-Medina-Atascosa Counties Water Control and Improvement District Number 1 (BMA). Project components also include Diversion Lake and an extensive system of distribution canals and laterals constructed primarily for the delivery of water for irrigation purposes. Medina Lake has a conservation storage capacity of approximately 254,000 acft; controls 634 square miles of the Medina River watershed; and inundates approximately 5,575 acres at conservation pool level.

BMA water rights associated with Medina Lake would be obtained for potable use by outright purchase or by replacement with reclaimed water from SAWS to meet irrigation demands as described in Alt. L-12 (Section 3.3). Four alternative uses of water from Medina Lake have been studied: (1) diversion of water from the canal system (when available), with delivery to injection wells to recharge the Edwards Aquifer (Alt G-13A); (2) diversion of water from Diversion Lake (when available), with delivery to recharge structures in the Edwards Aquifer recharge zone (Alt G-13B); (3) diversion of the firm yield from Medina Lake, delivery to a water treatment plant, and distribution in the San Antonio municipal water system (Alt G-13C); and (4) diversion of the firm yield of Medina Lake and Applewhite Reservoir operated as a system from Applewhite Reservoir, delivery to a water treatment plant, and distribution in the San Antonio municipal water system (Alt G-13D). The fourth alternative use of water from Medina Lake is presented in Section 3.14 of this report, which addresses alternative uses of water from Applewhite Reservoir. The locations of Medina Lake and the alternative conveyance systems are shown in Figure 3.13-1.

3.13.2 Available Supply and Yield

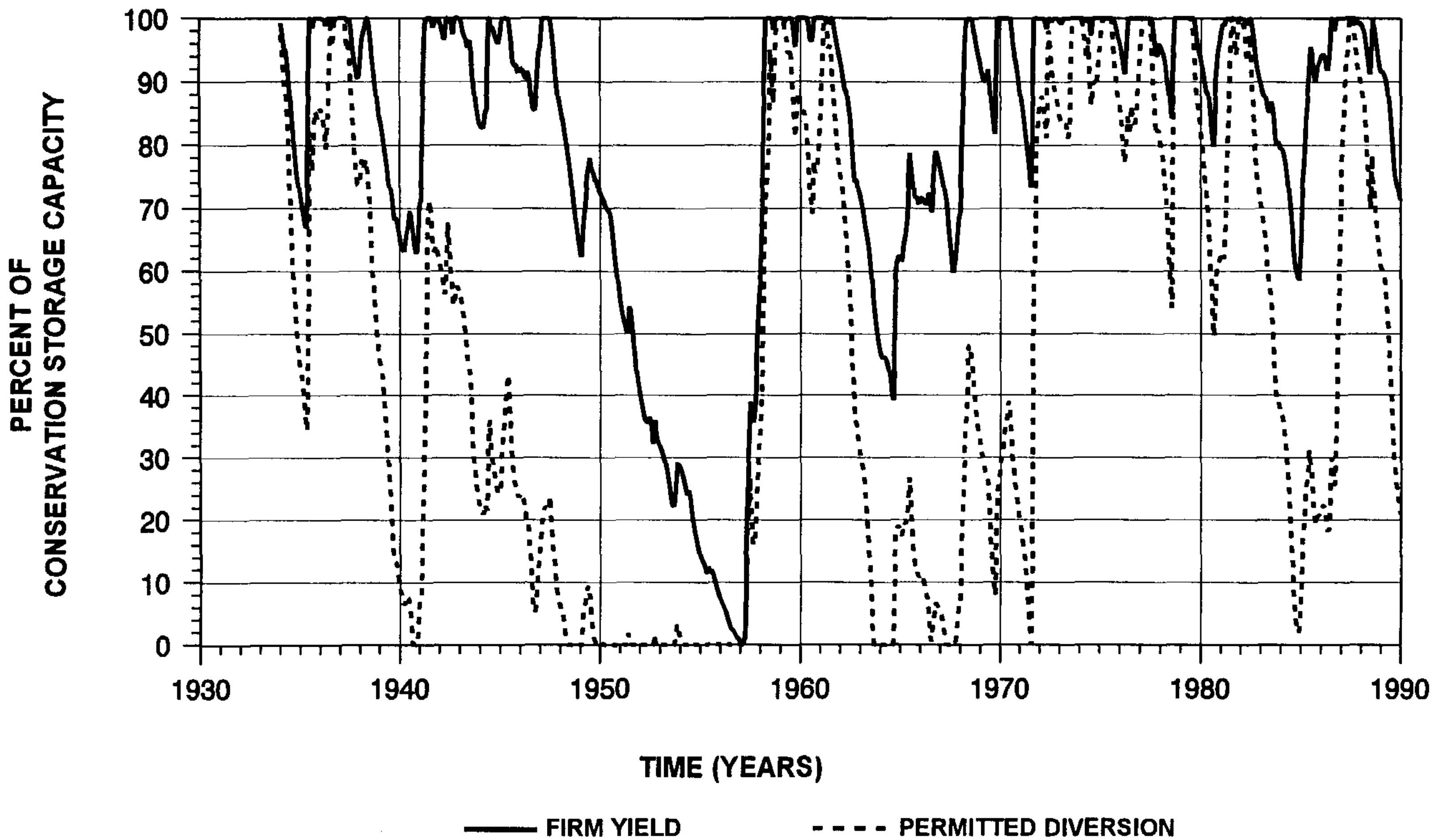
The available supply of water from Medina and Diversion Lakes, under existing BMA operation policy and water rights totalling 66,750 acft/yr, was estimated in the performance of this study. The Guadalupe - San Antonio River Basin Model[9] (GSA Model) was applied to simulate releases from Medina Lake for the monthly diversion of water from Diversion Lake up to a maximum of 66,750 acft/yr in accordance with the typical monthly pattern for irrigation and to the extent that such water would have been available during the 1934-89 period. All upstream water rights junior to BMA were excluded from this analysis and consideration of downstream water rights was unnecessary as the BMA rights are senior to all mainstem rights between Medina Lake and the Gulf of Mexico. As both Medina and Diversion Lakes are located over the Edwards Aquifer recharge zone and both Medina and Diversion Dams experience leakage, the GSA Model includes relationships developed by Espey, Huston & Associates, Inc.[10] for estimating monthly recharge and leakage based on reservoir stage. Available supplies under the permitted diversion rights of 66,750 acft/yr and for the typical annual irrigation diversion pattern were estimated to be 57,970 acft/yr for average conditions, 26,750 acft/yr for drought conditions, and 500 acft in the minimum year (1956).

The firm yield or dependable annual supply of surface water which could be obtained from Medina Lake without shortage through the drought of record is significantly less than the total of the BMA permitted diversion rights. In order to obtain the greatest reasonable estimate of firm water yield for municipal use, simulated diversions were made from Medina Lake at a uniform monthly rate rather than from Diversion Lake under the monthly pattern for irrigation use. The firm yield of Medina Lake subject to these assumptions is about 8,770 acft/yr as determined by successive approximation using the GSA Model.

Figure 3.13-2 illustrates simulated Medina Lake storage fluctuations for the 1934-89 historical period, if operated for maximum firm yield (solid line), and if operated for maximum available supply under existing BMA water rights (dotted line). As is apparent in Figure 3.13-2, Medina Lake contents would typically be significantly greater if operated for maximum firm yield. This would result in enhancement of Edwards Aquifer recharge

[9] HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

[10] Espey, Huston & Associates, Inc., "Medina Lake Hydrology Study," Edwards Underground Water District, March, 1989.



NOTES

FIRM YIELD: 8,770 ACFT/YR
PERMITTED DIVERSION: 66,750 ACFT/YR
CONSERVATION STORAGE CAPACITY: 254,000 ACFT
SCENARIO:

- EDWARDS AQUIFER DEMAND OF 400,000 ACFT/YR
- RETURN FLOWS SET AT 1988 LEVELS
- HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
- APPLEWHITE RESERVOIR INCLUDED

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STORAGE TRACES
MEDINA LAKE
ALTERNATIVE S-13

FIGURE 3.13-2

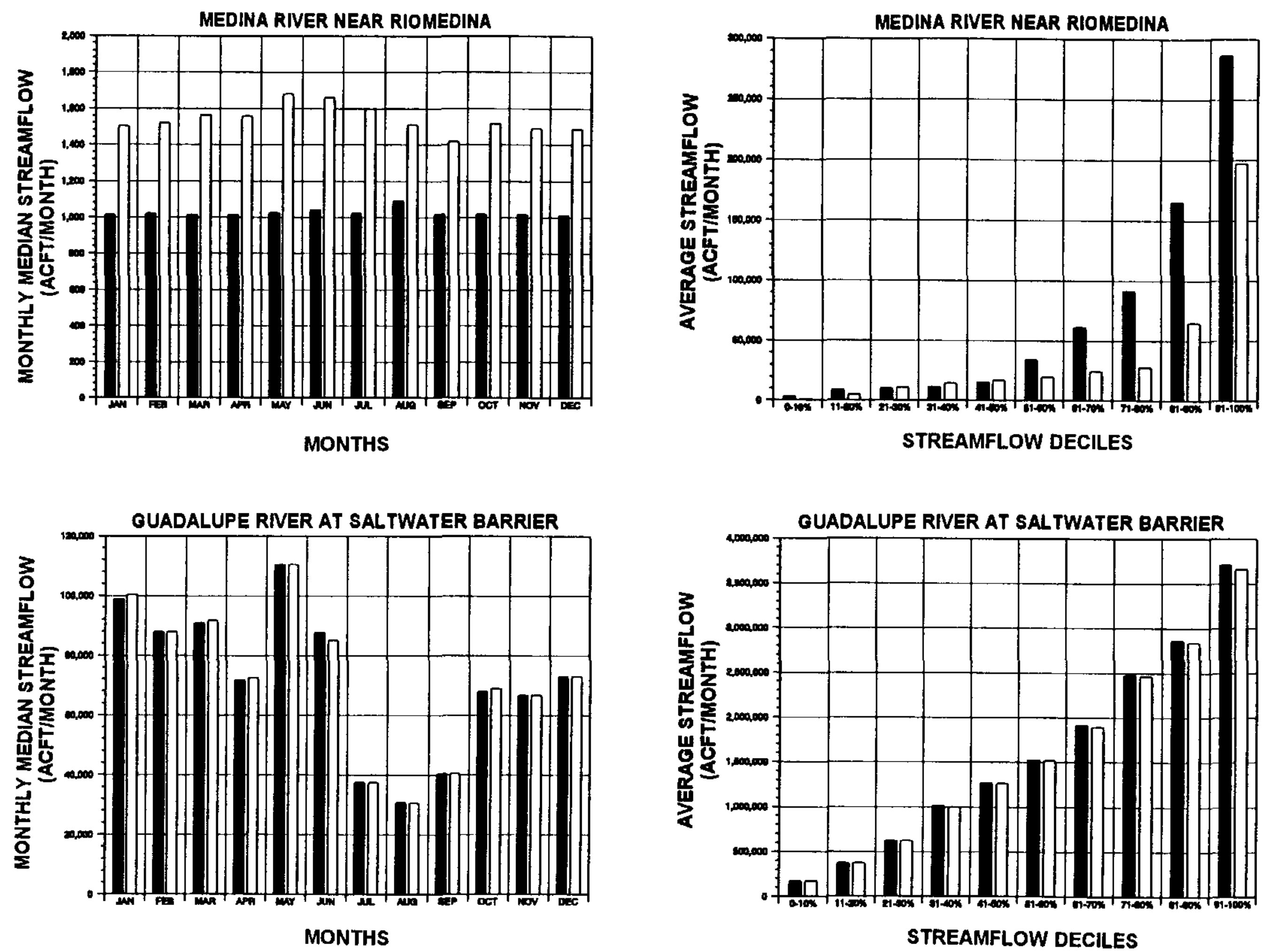
relative to that which would occur if operated for maximum available supply under existing BMA water rights. Recharge enhancement above current recharge from Medina and Diversion lakes associated with the operation of Medina Lake for maximum firm yield was estimated to be 9,670 acft/yr for average conditions, 20,250 acft/yr for drought conditions, and 4,750 acft/yr in the minimum year (1956).

Monthly median streamflows and annual streamflows averaged by decile, under firm yield and permitted (maximum available supply) operations, are presented in Figure 3.13-3 for both the Medina River near Riomedina (ID# 1805) and the Saltwater Barrier near Tivoli (ID# 1888). Median monthly streamflows in the Medina River would be reduced somewhat under firm yield operations due to reduced leakage from Diversion Lake, while average annual flows in the Medina River would be increased due to the increased frequency of spills from Medina Lake. Monthly median and annual decile average streamflows at the Saltwater Barrier would be essentially unaffected by a change from permitted to firm yield operations. Freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier would be increased by an average of 14,310 acft/yr or about 1 percent under firm yield operations at Medina Lake.

3.13.3 Environmental Issues

The environmental issues of using reclaimed San Antonio water for irrigation are identified and discussed in Section 3.3.5. The environmental issues associated with the transfer and use of Medina Lake water are identified and discussed below.

The ROW needed to construct the pipeline to the injection well field (Alt. S-13A) would result in the disturbance of less than 150 acres, while the construction ROW to the recharge structures north of San Antonio (Alt. S-13B) would disturb approximately 330 acres. A pipeline ROW to a south side water treatment plant (Alt. 13D) would disturb about 475 acres. Vegetation and land use characteristics in the areas traversed by those ROWs would be the same as those discussed in Sections 3.4.3, 3.9.3, and discussed in the Environmental Overview, Section 3.0.2. It is assumed that adverse impacts would be avoided and minimized to the extent practical by careful ROW selection in subsequent phases, using the vegetation, land use, and protected species information compiled during



LEGEND

■ WITH PROJECT

□ WITHOUT PROJECT

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TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

CHANGES IN STREAMFLOW MEDINA LAKE ALTERNATIVE S-13

FIGURE 3.13-3

Phase 1. Use of the Medina County injection well field and the impoundment structures in the Edwards recharge zone are discussed in the report sections mentioned above.

Medina Lake is located within the Central Texas Plateau Ecoregion[11] (see Figure 3.0-1), on the southern edge of the Edwards Plateau vegetational area[12] (see Figure 3.0-2), and in the Balconia Biotic Province[13] (see Figure 3.0-3). Top of the conservation pool is at 1,064 feet MSL with a surface area of 5,575 acres. Edwards Aquifer recharge in the Medina River basin occurs primarily from Medina Lake and the smaller Diversion Lake, which is located immediately downstream and is the diversion point for irrigation water. During the period 1934-1989, this recharge has averaged 41,830 acft/yr, and ranged from 10,250 acft in 1951 to 53,270 acft in 1936[14].

Soil types in the vicinity of Medina Lake are characterized by the undulating Brackett association and undulating Tarrant Rock outcrop association on uplands with slopes from 1 to 8 percent. The steep Tarrant-Brackett association is found on uplands with steep slopes between 20 and 45 percent. These areas are low in available water capacity, and are used for range and wildlife habitat[15].

Vegetation surrounding Medina Lake includes Live Oak-Mesquite-Ashe Juniper Parks and Woods. Existing wetland habitats within the lake boundaries are classified as lacustrine and consist of deep and shallow open-water habitats where wetland vegetation is not a dominant feature. In upstream and downstream reaches of the Medina River, the Medina Irrigation Canal, Diversion Lake, and tributary streams, riverine and palustrine wetlands occur. These areas are generally small in size and are typically associated with a drainage feature or water body. In addition to open-water and streambed wetland areas,

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[11]Omernik, James M. 1986. "Ecoregions of the conterminous United States." Annals of the Association of American Geographers, 77(1). pp. 118-125.

[12]Gould, Frank W., 1975, The Grasses of Texas, Texas A & M University, College Station, Texas.

[13]Blair, W.F. 1950. "The biotic provinces of Texas". Tex. J. Sci. 2:93-117.

[14]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

[15]U.S. Department of Agriculture, Soil Conservation Service (SCS). 1977. Soil Survey of Bandera County, Texas. In cooperation with Texas Agricultural Experiment Station, Texas A & M University, College Station.

small areas of forested wetlands dominated by either broad-leaved deciduous or needle-leaved deciduous species occur downstream of the Medina Lake dam.

Because Medina Lake is an existing reservoir, selection of these alternative uses (S-13A-D) would not have direct impacts on existing land uses within the reservoir boundaries. The primary environmental concerns associated with the S-13 alternatives include the potential for impact to the Edwards Aquifer recharge quantity and quality, and the potential for impacts to downstream flows and bay and estuary inflows.

For alternatives S-13A and S-13B, approximately the same amount of water that is currently taken from Medina Lake and used for crop irrigation would be diverted as natural recharge to the Edwards Aquifer. Thus, the quantity of recharge to the Edwards would increase under these scenarios. Under these alternatives, the diversion from Medina Lake would also take place at approximately the same time of year as the current irrigation withdrawals. Alternative S-13A, which involves injection to the aquifer, may include treatment to ensure acceptable water quality. Streamflow in the Medina River below Diversion Lake would be essentially unchanged under these alternatives.

Under Alternative S-13C, firm yield water diverted from Medina Lake would be delivered directly to water treatment facilities in San Antonio, rather than being routed through the Edwards Aquifer. Water presently being released from the Medina-Diversion Lake system for irrigation would be purchased for municipal use. Recharge to the Edwards Aquifer from Medina and Diversion Lakes would increase 24 percent over the present condition (by an estimated 9,670 acft/yr) based on longterm average. During critical drought years (i.e., 1956) additional recharge is estimated to be about 4,750 acft/yr, while the largest recharge increases (on the order of 20,250 acft/yr) would occur during dry, but non-critical periods. Under current operation, Medina Lake would have been drafted to very low levels during those conditions, leaving little water for recharge. Retaining water in Medina Lake also means that spills will occur more frequently, increasing average annual flows in the Medina River below Diversion Lake.

Figure 3.13-3 shows both reductions of 30 to 40 percent in monthly median flows at Riomedina with Alternative S-13C in place and increases in all annual flow deciles, but particularly in the 60 to 90 percent range. These seemingly inconsistent results reflect the elimination of zero flow episodes that have been the result of irrigation withdrawals, and maintenance of a higher average water surface elevations of Medina Lake, resulting in an increase in the frequency and magnitude of uncontrolled spills. Figure 3.13-3, Guadalupe River at Salt Water Barrier, shows negligible effects on inflows to the Guadalupe Estuary from operation of this alternative, although annual average inflows would increase by about 14,000 acft/yr.

Alternative S-13D involves operating Medina Lake as a system with Applewhite Reservoir, so that releases from Medina Lake would occur only when needed to meet the firm yield of the Applewhite-Medina system. This alternative will result in increased recharge through Medina Lake and enhanced flows downstream of Diversion Lake relative to the current conditions. Water would be diverted from Applewhite Reservoir to water treatment facilities in San Antonio (See Alternative S-14, Section 3.14).

Under Alternatives S-13A and S-13B, water surface elevations in Medina Lake would continue to fluctuate as they do at present. Alternatives S-13C and S-13D would result in more stable lake levels, and Medina Lake would, on average, contain more water than is now the case.

One Category 2 federal candidate species, bracted twistflower (*Strepthanthus bracteatus*), has been recorded near the reservoir (Appendix B, Tables 3, 6, and 37). Category 2 indicates that the species is under review for possible listing as endangered or threatened, but more information is needed by USFWS before a listing decision can be made. Because no inundation will occur outside the existing reservoir, this species will be unaffected by this alternative. The widemouth blindcat (*Satan eurystomus*) and the toothless blindcat (*Trogloglanis pattersoni*), both candidates for federal listing and listed as threatened by the Texas Parks and Wildlife Department, are troglobitic species known only from deep wells in the Edwards Aquifer beneath the City of San Antonio. Because the S-13 alternatives are expected to increase recharge and not affect recharge water quality, adverse impacts on these species are not anticipated.

No impacts to cultural resources are anticipated as a result of modified Medina Reservoir operations. Cultural resources surveys will be required in areas to be disturbed by construction of facilities (pipeline, well houses, etc.) associated with the S-13 alternatives.

Because Medina Lake is an existing reservoir, no mitigation requirements are anticipated for the reservoir itself. Mitigation may be required for impacts associated with the intake structures, pump stations, injection wells, recharge structures, water treatment plant, and delivery systems identified for the S-13 alternatives if sensitive ecological or cultural resources are identified in a future phase of this study.

3.13.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.13.5 Engineering and Costing

Alternative S-13A: Delivery to Aquifer Injection Wells

For this alternative, water would be diverted from the BMA Canal and pumped a short distance to the injection well field in eastern Medina County. Implementation of this alternative would require the purchase of BMA water rights or would exchange the delivery of Medina Lake water to irrigators in southern Medina County for reclaimed water from San Antonio; i.e., reclaimed water from San Antonio would substitute for the current supply.

The diversion rate from the canal, as well as the delivery to the wells, would vary monthly according to the historic annual distribution pattern of water delivered to the canal system. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Section 3.0.2). The major facilities required to implement this alternative are:

Canal Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Water Treatment Plant (Level 2)
Finished Water Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The reservoir intake and pump station would be sized to deliver 10,300 acft/month (110 mgd) through an 84-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 11 feet and an annual water delivery of 57,970 acft/yr.

Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $6,230,000 (Table 3.13-1). Operation and maintenance costs, including power, total $7,790,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $14,020,000 (Table 3.13-1).

Alternative L-12, "Exchange Reclaimed Water for BMA Medina Lake Water" describes the availability, necessary facilities, and estimated cost to implement a delivery system for reclaimed water. The combined cost of the complete system to obtain Medina Lake water for new uses coupled with the reclaimed water delivery system will be the sum of the annual unit costs of the two systems. The estimated annual cost for the reclaimed water system is $9,570,000 (delivery capacity of 31,000 acft/yr, Section 3.3.5) and for the Medina Lake supply, the estimated annual cost is $14,020,000, for a total estimated annual system cost of $23,590,000 (Table 3.13-1). The drought conditions supply of 26,700 acft/yr from Medina Lake was used to calculate the water supply volume used to estimate annual unit cost for the complete system of $884/acft. If current unit prices for the sale of water from Medina Lake were applied (thereby eliminating the reclaimed water delivery system), the unit cost of this alternative would decrease.

Alternative S-13B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the project yield would be diverted through an intake and pumped in a transmission line to small recharge structures in northwestern Bexar County located over the recharge zone. BMA water rights would be purchased or San Antonio reclaimed water would be diverted to the irrigators to replace the Medina Lake irrigation supply.

The diversion rate from the reservoir, as well as the delivery to the recharge zone, would vary monthly according to the historic annual distribution pattern of water delivered to the canal system. The benefit from this project would be the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Concerns that the imported water is of different quality than the existing recharge water and

Table 3.13-1
Cost Estimate Summaries for Purchase of BMA Medina Lake Water (S-13)
(Mid- 1994 Prices)

Item	Alt. S-13A Divert and Inject to Aquifer	Alt. S-13B Divert to Recharge Zone	Alt. S-13C Divert to WTP and Municipal Supply
Capital Costs			
Transmission and Pumping	$3,400,000	$19,950,000	$7,000,000
Treatment Plant	26,760,000		5,820,000
Delivery System	13,530,000	10,460,000	6,960,000
Total Capital Cost	$43,690,000	$30,410,000	$19,780,000
Engineering, Contingencies, and Legal Costs	14,990,000	9,340,000	5,930,000
Land Acquisition	220,000	480,000	270,000
Environmental Studies and Mitigation	4,050,000	1,870,000	300,000
Interest During Construction	3,550,000	2,310,000	1,050,000
Total Project Cost	$66,500,000	$44,410,000	$27,330,000
Annual Costs			
Annual Debt Service	$6,230,000	$4,160,000	$2,560,000
Annual Operation and Maintenance	7,070,000	620,000	830,000
Annual Power Cost	720,000	1,840,000	230,000
Subtotal	$14,020,000	$6,620,000	$3,620,000
Irrigation Supply from Reclaimed Water[(1)]	9,570,000	9,570,000	9,570,000
Total Annual Cost	$23,590,000	$16,190,000	$13,190,000
Available Project Yield (acft/yr)	26,700[(2)]	26,700[(2)]	8,800[(3)]
Annual Cost of Water	$884/acft	$606/acft	$1,499/acft 29,000[(4)] $455/acft

(1)Annual cost from Alt L-12A (Section 3.3) to supply 31,000 acft/yr to BMA Irrigators.
(2)Drought average supply (1947-1956).
(3)Firm yield supply delivered to WTP.
(4)Alt. S-13C enhances recharge 20,200 acft/yr above current amount, for total project yield of 29,000 acft/yr.

the need for treatment of the imported water will require follow-on study. The major facilities required to implement this alternative are:

Intake and Pump Station
Raw Water Pipeline to Recharge Zone
Recharge Structures

The reservoir intake and pump station is sized to deliver 10,300 acft/month (110 mgd) through an 84-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 240 feet and an annual water delivery of 57,970 acft/yr. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $4,160,000. Operation and maintenance costs, including power, total $2,460,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $6,620,000 (Table 3.13-1). The estimated annual cost for the reclaimed water system is $9,570,000 (delivery capacity of 31,000 acft/yr, Section 3.3.5) for a total estimated annual system cost of $16,190,000. The drought conditions supply of 26,700 acft/yr from Medina Lake was used to calculate the estimated annual unit cost for the complete system of $606/acft (Table 3-13.1). If current unit prices for the sale of water from Medina Lake were applied (thereby eliminating the reclaimed water delivery system), the unit cost of this alternative would decrease.

Alternative S-13C: Delivery to the Municipal Distribution System

For this alternative, the firm yield of Medina Lake would be diverted through an intake and pumped in a transmission line to a water treatment plant proposed in the northwest quadrant of the City near FM 1604. BMA water rights would be purchased or replaced with reclaimed San Antonio water. The diversion rate from the reservoir would vary monthly according to the historic annual distribution pattern of water delivered to the canal system. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Water Treatment Plant (Level 3, see Table 3.0-4)

Finished Water Pump Station
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 750 acft/month (8 mgd) through a 24-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 130 feet and an annual water delivery of 8,800 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $2,560,000 (Table 3.13-1). Operation and maintenance costs, including power, total $1,060,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $3,620,000 (Table 3.13-1). The estimated annual cost for the reclaimed water system is $9,570,000 (delivery capacity of 31,000 acft/yr, Section 3.3.5) for a total estimated annual system cost of $13,190,000. The firm yield supply of 8,800 acft/yr from Medina Lake was used to calculate the combined estimated annual unit cost for the complete system of $1,499/acft (Table 3.13-1). If drought recharge enhancement associated with this option is added to the firm yield, the estimated annual unit cost is reduced to about $455/acft. If current unit prices for the sale of water from Medina Lake were applied (thereby eliminating the reclaimed water delivery system), the unit cost of this alternative would decrease.

Alternative S-13D: Systems Operations with Applewhite Reservoir

The engineering and costing for the system operation of Medina and Applewhite reservoirs is discussed in Section S-14D.

3.13.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

TNRCC approval must be obtained to change the use and points of diversion of the BMA water rights.

Requirements Specific to Pipelines (S-13, All)

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (S-13A)

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer.
   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.
   d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
   e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
   a. TNRCC Injection Well permit.
   b. Texas Historical Commission permit.
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (S-13B)

1. Detailed field investigations of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
   a. TNRCC Water Rights and Storage permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
   c. GLO Sand and Gravel Removal permit.
   d. TPWD Sand, Gravel, and Marl permit.

4. Permitting, at a minimum, will require these studies:
   a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
   b. Study of impact on karst geology organisms from a sustained recharge program.
   c. Other environmental studies.
   d. Cultural resource studies.

Requirements Specific to Treatment and Distribution

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

3.14 Applewhite Reservoir (S-14)

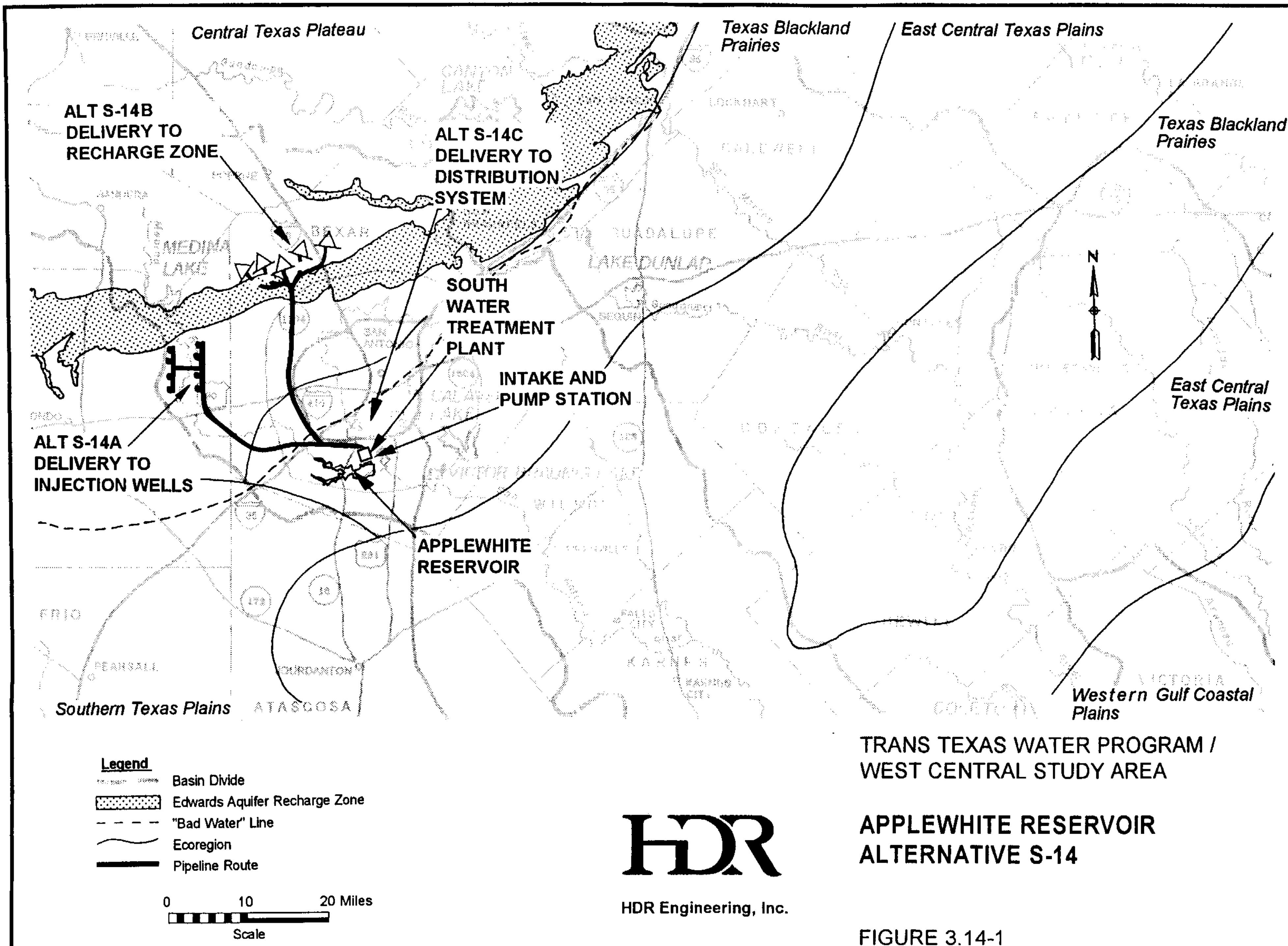
3.14.1 Description of Alternative

Applewhite Reservoir is a partially completed municipal water supply project sponsored by the City of San Antonio and located on the Medina River in southern Bexar County. Construction of the reservoir project was initiated in 1990 and suspended by referendum in 1991. Applewhite Reservoir would have a conservation storage capacity of approximately 45,250 acft; would control 1,070 square miles of the Medina River watershed; and would inundate approximately 2,500 acres at conservation pool level.

Four alternative uses of water from Applewhite Reservoir are considered in this study: (1) diversion of full permitted rights from the reservoir (when available) with delivery to injection wells to recharge the Edwards Aquifer (Alt G-14A); (2) diversion of full permitted rights from the reservoir (when available) with delivery to recharge structures in the Edwards Aquifer recharge zone (Alt G-14B); (3) diversion of the firm yield from the reservoir, delivery to a water treatment plant, and distribution in the San Antonio municipal water system (Alt G-14C); and (4) diversion of the firm yield of Medina Lake and Applewhite Reservoir operated as a system from Applewhite Reservoir, delivery to a water treatment plant, and distribution in the San Antonio municipal water system (Alt G-14D). The locations of Applewhite Reservoir and the alternative conveyance systems are shown in Figure 3.14-1.

3.14.2 Available Supply and Yield

The available supply and firm yield from a completed Applewhite Reservoir under existing water rights totalling 57,700 acft/yr, were estimated both with return flows to the San Antonio River set to 1988 levels and without return flows (Note: The return flows as discussed here do not enter Applewhite, but instead, are continued to be discharged at existing locations downstream of the dam). All simulations include the spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures, hydropower water rights subordinated to 600 cfs at Lake Dunlap, and a Canyon



HDR

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TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

APPLEWHITE RESERVOIR ALTERNATIVE S-14

FIGURE 3.14-1

Lake firm yield equal to the existing permitted diversion of 50,000 acft/yr[16]. All upstream and downstream water rights junior to Applewhite Reservoir, including those rights associated with the proposed Leon Creek Diversion (12,300 acft/yr), were excluded from this analysis. In accordance with the permit, in this analysis inflows up to 4 cfs were passed through Applewhite Reservoir into the Medina River. Appendix D contains detailed tabular summaries of assumptions applied and results obtained in the analysis of Applewhite Reservoir.

The Guadalupe - San Antonio River Basin Model[17] (GSA Model) was used to estimate monthly quantities of total streamflow and streamflow not committed to downstream water rights at the reservoir site which, in turn, were used to compute available supply and firm yield. For modelling purposes, streamflows for the Medina River near Somerset (ID# 1808) were assumed representative of inflows to Applewhite Reservoir. Available supply and firm yield were computed using an original model (RESSIM) specifically written to simulate reservoir operations subject to inflow passage criteria, using water availability estimates from the GSA Model.

The RESSIM model was applied to simulate diversions from Applewhite Reservoir up to a maximum of 57,700 acft/yr at a uniform monthly rate to the extent that such water would have been available during the 1934-89 period. Available supply under the permitted diversion rights of 57,700 acft/yr with return flows set to 1988 levels was estimated to be 47,060 acft/yr for average conditions, 22,460 acft/yr for drought conditions, and 2020 acft in the minimum year (1956). Available supply under the permitted diversion rights of 57,700 acft/yr, with all return flows set to zero, was estimated to be 45,160 acft/yr for average conditions, 20,440 acft/yr for drought conditions, and 450 acft in the minimum year (1954). These estimates of available supply show increased sensitivity to return flow exclusion during drought periods.

The firm yield or dependable annual supply of surface water which could be obtained

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[16] Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[17] HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

from Applewhite Reservoir, without shortage, through the drought of record is significantly less than the total of the permitted diversion rights. The firm yield of Applewhite Reservoir as computed using the RESSIM model is about 7,700 acft/yr with return flow set to 1988 levels and 6,240 acft/yr with all return flows set to zero. As is apparent in these results, the firm yield of Applewhite Reservoir is sensitive to the exclusion of return flows.

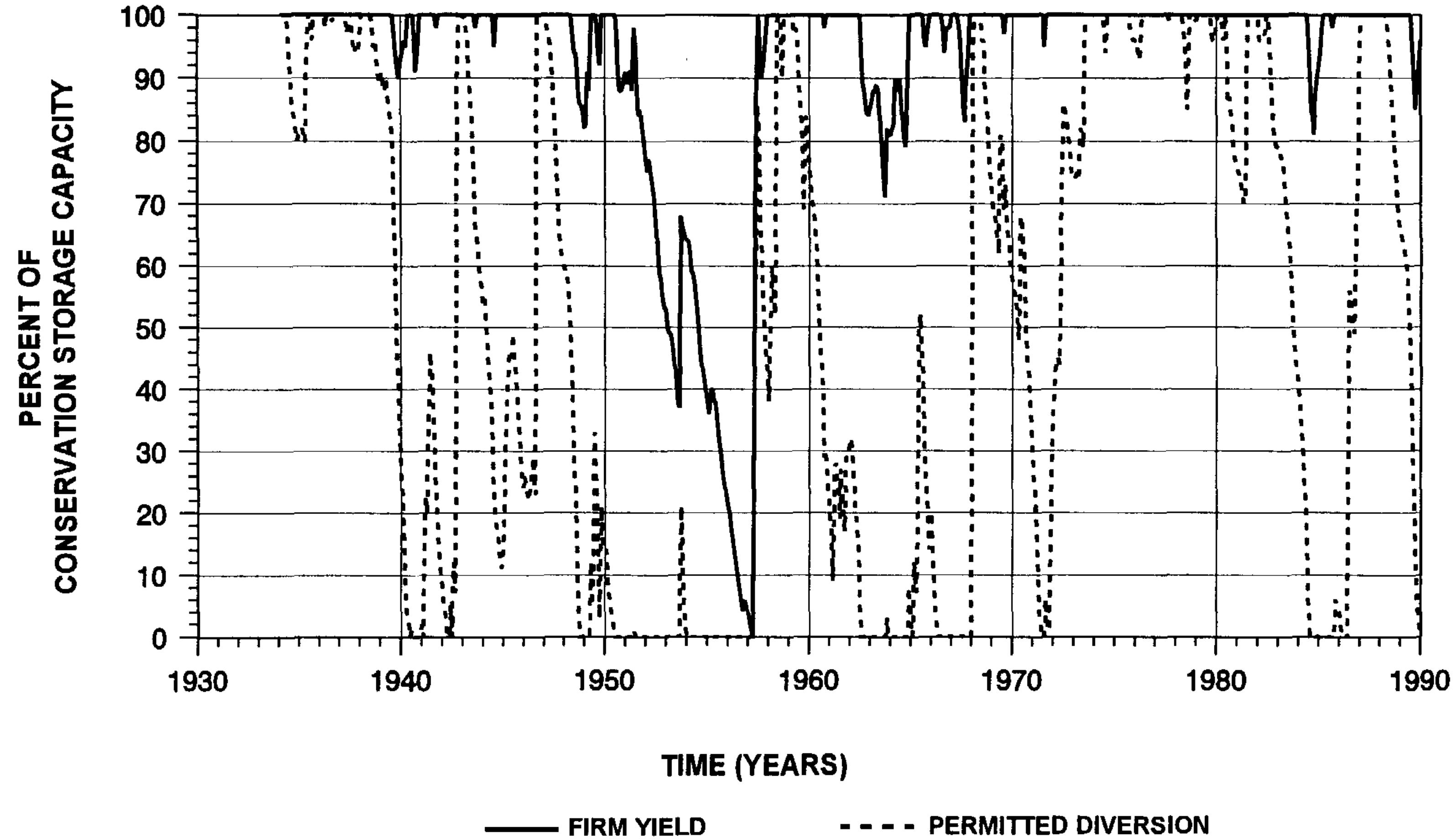
Figure 3.14-2 illustrates simulated Applewhite Reservoir storage fluctuations for the 1934-89 historical period if operated for maximum firm yield (solid line) and if operated for maximum available supply under permitted diversion rights (dotted line). As is apparent in Figure 3.14-2, reservoir contents would typically be significantly greater if operated for firm yield. Simulations indicate that Applewhite Reservoir would be essentially full 74 percent of the time if operated for firm yield.

The firm yield of Applewhite Reservoir and Medina Lake operated as a system was evaluated in this study assuming the purchase of water rights at Medina and Diversion Lakes totalling 66,750 acft/yr presently held by the Bexar-Medina-Atascosa Counties Water Control and Improvement District Number 1 (BMA). Subject to the general assumptions summarized in the first paragraph of this Section 3.14.2, all diversions from Medina and Diversion Lakes were eliminated, return flows were included at 1988 levels, and system firm yield would be diverted from Applewhite Reservoir at a uniform monthly rate. The GSA Model was modified to simulate system operations under the following simple policy:

1) When Applewhite Reservoir storage at the end of the previous month is greater than 20 percent of capacity, all available inflows are stored in Medina Lake; and
2) When Applewhite Reservoir storage at the end of the previous month is less than 20 percent of capacity, 25,000 acft is released from Medina Lake.

All water rights junior to BMA and located upstream of Diversion Lake were excluded from this analysis, while only those rights junior to Applewhite Reservoir were excluded throughout the remainder of the Guadalupe - San Antonio River Basin.

The firm yield of the Medina / Applewhite system subject to these assumptions is about 14,900 acft/yr, as determined by successive approximation, using the GSA Model. Medina Lake contents would typically be significantly greater under the system operation policy, resulting in enhancement of Edwards Aquifer recharge relative to that which would occur if operated for maximum available supply under existing BMA water rights. Recharge



NOTES

FIRM YIELD: 7,700 ACFT/YR
PERMITTED DIVERSION: 57,700 ACFT
CONSERVATION STORAGE CAPACITY: 45,250 ACFT
SCENARIO:

- EDWARDS AQUIFER DEMAND OF 400,000 ACFT/YR
- RETURN FLOWS SET AT 1988 LEVELS
- HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
- LEON CREEK DIVERSION EXCLUDED

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WEST CENTRAL STUDY AREA

STORAGE TRACES
APPLEWHITE RESERVOIR
ALTERNATIVE S-14

FIGURE 3.14-2

enhancement associated with the system operation of Medina Lake and Applewhite Reservoir was estimated to be 10,560 acft/yr for average conditions, 22,570 acft/yr for drought conditions, and 4,250 acft/yr in the minimum year (1956).

3.14.3 Environmental Issues

The physical features of the proposed Applewhite Reservoir, its proposed location and associated structures have been described by the U. S. Army Corps of Engineers, Fort Worth District, in Draft and Final Environmental Impact Statements[18,19]. Applewhite Reservoir would be located on the Medina River in Bexar County where it would inundate about 2,500 acres at a conservation pool elevation of 536 feet-MSL (Table 3.0-1). Because Applewhite Reservoir was designed to pass the 100-year flood at conservation elevation 536 feet-MSL Table 3.0-1 shows the conservation pool and 100-year flood pool to have the same area. Unlike the project described by the USCE, Alternative S-14 does not divert flood flows from Leon Creek to Applewhite Reservoir. The proposed water treatment plant would be connected by a 5,400-ft-long raw water pipeline to the reservoir (Figure 3.14-1).

The three Applewhite Reservoir water use alternatives are shown in Figure 3.14-1. Treated water from Applewhite would be injected in the Edwards at the Medina County well field, Alternative S-14A, or would be used to recharge the Edwards at the type 2 recharge impoundments described in Section 3.9 (Alternative S-14B). Alternative S-14C contemplates direct municipal water use in the SAWS utility distribution system. From the water treatment plant the proposed pipeline corridors and the two recharge alternatives would be the same as those assessed in Sections 3.4.3, 3.9.3, and discussed in the Environmental Overview, Section 3.0.1. In this study, it has been assumed that adverse impacts would be avoided and minimized to the extent practical by careful corridor selection in subsequent phases using the vegetation, land use, and protected species information compiled during Phase 1, and that residual impacts for all alternatives would be similar.

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[18]U.S. Army Corps of Engineers, 1987, Applewhite Reservoir, Draft Environmental Impact Statement, Ft. Worth District, Ft. Worth, Texas;

[19]U.S. Army Corps of Engineers, 1989, Applewhite Reservoir, Final Environmental Statement, Ft. Worth, Texas.

The proposed reservoir lies at the intersection of the Blackland Prairie Ecoregion, the Southern Texas Plains, and the East Central Plains Ecoregion[20], while both the Medina River and Leon Creek originate within the Central Texas Plateau Ecoregion (Figure 3.0-1). The proposed reservoir is within the South Texas Plains vegetational area that encompasses the southern third of Bexar County (Figure 3.0-2). This area is also called the Rio Grande Plains[21] and corresponds roughly to Blair's[22] Tamaulipan Biotic Province (Figure 3.0-3).

Soil associations in southern Bexar County are a mosaic of clays and sandy loams[23]. Calcareous clays of the Lewisville - Houston terrace soil associations underlie southern urban San Antonio. Clay loams and sandy loams in the San Antonio - Crockett and the Hockley - Webb - Crockett associations cover the eastern and southern uplands. These soil associations are generally in irrigated cultivation, vacant mesquite - thornbrush range, and suburban development. Soil associations of the San Antonio River, Medina River and Leon Creek waterways are the Venus - Frio - Trinity soils. These are deep calcareous clay loams and clays found in bottomlands and stream terraces. Where the latter soils association is not in cultivation, riparian forest, mesquite brush, and recreational uses are prevalent[24].

The riparian forests along the Medina River, Leon Creek and minor tributaries within the proposed project area consists of a bald cypress, sycamore, eastern cottonwood, black willow, hackberry, elm, boxelder, and pecan overstory. The understory is sparse and limited by occasional flooding and grazing pressure. Managed pecan groves within the riparian corridor are used as pasture and have a grass cover. The riparian woodlands provide important habitat and migration corridors for wildlife. Wetlands in southern Bexar County occur in narrow bands within the stream channels and impoundments. Vegetation

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[20]Omernik, James M., 1986, "Ecoregions of the conterminous United States," EPA/600/D - 86,USEPA, Corvallis, Oregon.

[21]Gould, Frank W., 1975, <u>The Grasses of Texas</u>, Texas A & M University, College Station, Texas.

[22]Blair, W. Frank, 1950, The biotic provinces of Texas, The Texas Journal of Science, Vol 2, No. 1:93-117.

[23]Soil Conservation Service, 1991, Soil Survey Bexar County, Texas, Series 1962, No. 12. Reissued June 1991. U.S. Department of Agriculture.

[24]Ibid.

abruptly changes to mesquite brushland at the stream valley walls. Environmental studies estimate that 250 vertebrate species including 11 amphibians, 36 reptiles, 170 birds and 36 mammals live in and use the riparian forests[25].

The brushlands are dominated by honey mesquite and other species, including whitebrush, agarito, huisache, yucca, Texas persimmon, and bluewood condalia. The herbaceous layer is a mixture of silver bluestem, plains lovegrass, buffalo grass, curly mesquite, purple three-awn, and hooded windmill grass. Brushlands dominate in the south and western portions of the proposed project area. An estimated 240 vertebrate species utilize this habitat type, including 5 amphibians, 45 reptiles, 150 birds, and 41 mammals[26].

In 1984, a Habitat Evaluation Procedure (HEP) was performed to determine probable impacts on terrestrial wildlife and initiate mitigation planning for potential loss of habitat and associated wildlife populations. The vegetational and land use baseline for mitigation planning is presented in Table 3.14.-1. This HEP study included a buffer area around the proposed reservoir that may experience indirect effects from secondary facilities and development.

Table 3.14-1
Applewhite Dam and Reservoir Land Use Baseline

	Riparian Acres	Brushland Acres	Rangeland Acres	Cropland Acres	Urban Acres	Total Acres
Conservation Pool 536 feet-MSL	908	940	62	584	6	2500
Total Study Acreage	1,395	4,014	1,563	12,969	1,266	21,207

Source: U.S. Army Corps of Engineers, "Applewhite Reservoir, Draft Environmental Impact Statement," Ft. Worth District, Ft. Worth, Texas, 1987.

The dominant land use within the project area is presently farming and ranching. Because most rangeland and pasture lands in this area are heavily grazed, the HEP concluded that grazing was probably the single most important limiting factor to wildlife

[25]U.S. Army Corps of Engineers, 1987, Applewhite Reservoir, Draft Environmental Impact Statement, Ft Worth District, Ft. Worth, Texas.

[26]Ibid.

species in the project area. They concluded that when rangeland is in good condition, it can support approximately 155 vertebrate species. Small rural developments noted in the assessments as ranchettes do provide some habitat to urban compatible wildlife species[27].

Aquatic habitats in the Medina River consist of riffles, pools, runs, and sand and gravel bars. Sampling was conducted in the mid-1980's to inventory habitats and biological communities of the reservoir site. Above Leon Creek, which enters the Medina River just below the proposed dam, invertebrate populations in the Medina River were diverse, indicating dissolved oxygen levels were adequate to maintain healthy aquatic communities. Below the confluence with Leon Creek, invertebrate assemblages showed decreased diversity and an increase in the number of organisms more typical of enriched conditions or low dissolved oxygen levels[28].

Of a total of 68 fish species potentially occurring within this section of the San Antonio River basin, the assessment studies collected 13 species of fish from the Medina River between Diversion Dam and the San Antonio River. Mosquitofish, red shiner and bullhead minnows were the most abundant species below Leon Creek, while speckled chub, blacktail shiner, and mimic shiner were the most abundant upstream. Bluegill and largemouth bass juveniles were abundant in littoral areas and pools throughout the creek[29].

When water levels in the proposed Applewhite Reservoir reach the conservation pool level (536 feet MSL), approximately 18 miles of riverine habitat will be inundated. However, Alternative S14 does not include Leon Creek diversion dam reservoir, so inundation would affect a lesser amount of riverine habitat, all of it along the Medina River, Elm Creek, Indian Creek and Medio Creek. Riverine habitat inundated by Alternative S-14 at the conservation pool level is an estimated 15 acres.

Depending on the operating scenario, the reservoir may experience significant fluctuations in pool elevations during normal to dry years. Figure 3.14-2 shows the variation in reservoir capacity modeled over the period of record using the presently

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[27]Ibid.

[28]Ibid.

[29]Ibid.

permitted Applewhite reservoir operation, compared with the capacity using the S-14C (firm yield) scenario. Compared to the permitted operation, S-14C would have water in the reservoir most of the time. S-14D, the reservoir systems operation scenario, would experience fluctuations in water surface elevations similar to those of S-14C. Alternatives S-14A and S-14B reservoir operations would be similar to those described in the environmental impact statements, and would experience similar fluctuations in water surface elevation. All Alternative S-14 operations would meet the existing permit requirement of a continuous release of 4.0 cfs through Applewhite Dam, plus releases as necessary to maintain a 10 cfs flow at the USGS gage on the Medina River at U.S. Highway 281.

Return flows from the proposed Applewhite Reservoir water used by municipal and industrial customers would be returned to the Medina River just above its confluence with the San Antonio River through the Dos Rios Wastewater Treatment Plant. No significant downstream effects were predicted by the environmental studies and assessment reports, and the Texas Water Commission estimated that Applewhite Reservoir operation would reduce inflow to San Antonio Bay by 1.8 percent, an amount having a minimal effect on the bay. Later studies by Freese and Nichols, Inc., using basic calculations developed in the Texas Department of Water Resources Guadalupe River Estuary Study, estimated that projected total average bay inflow with Applewhite Reservoir in operation would be in excess of 2.6 million acft/year. This average exceeds the long-term minimum inflow requirements for subsistence (1.6 million acft/year) and shrimp harvest enhancement (2.26 million acft/year) developed by the Texas Water Resources Guadalupe River Estuary Study[30].

The pipeline corridor for Alternative S-14A to the Medina County injection well field (Figure 3.14-1) is primarily through an area of about 50 percent cropland, 30 percent shrubland, and 20 percent developed areas (Table 3.0-1). The only major stream crossing is Leon Creek. The pipeline corridor to the Type 2 recharge impoundments in northern Bexar County crosses through shrub and cropland into developed suburban land. The developed area was estimated at 31 percent, shrubland at about 37 percent, and cropland at 20 percent of the route (Table 3.0-1). The recharge reservoir sites are described in Section 3.9. Potential impacts to Edwards Aquifer and spring-flow dependent species are

[30] Ibid.

also discussed in Sections 3.0.1 and 3.9.

No adverse impacts to protected species (Appendix B, Table 6 and Table 37) that migrate through the proposed project area were identified. The Applewhite environmental assessment predicted no adverse effects for protected species dependent on the Edwards Aquifer, Comal Springs and San Marcos Spring flows (Appendix B Table 50). Important species with habitat in the project vicinity are listed below in Table 3.14-2.

Table 3.14-2
Important Species With Habitats in the Project Vicinity (S-14)

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions of underground burrows, under objects;	NL	T
Reticulate Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, hides under rocks when inactive[2].	C2	T
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods[1]	NL	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain[2]	NL	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures[2]	C2	NL

[1]TPWD. 1988 Unpublished. Endangered/Threatened Species Data File.
[2]Dixon, James R. 1987. Amphibians and Reptiles of Texas. Texas A&M Press, College Station, Texas
Source: TPWD. Unpublished Texas Natural Heritage Program. Texas Parks and Wildlife, Austin, Texas.

The Texas horned lizard is found in open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees over soils that may vary in texture from sandy to rocky. The Texas tortoise would be expected within the arid thornbrush section of the project area, although its population may have been affected by overgrazing. Overgrazing may have affected the indigo snake populations similarly. Most of the riverine forest in the proposed project area is heavily impacted by grazing and may provide only limited habitat for the Texas garter snake and the state protected timber rattlesnake. Mitigation plans that restrict or prohibit grazing in bottomland hardwoods may increase habitat for the timber rattlesnake.

A wildlife mitigation plan was developed by an interagency team from U.S. Fish and Wildlife Service, Texas Parks and Wildlife Department and U.S. Army Corps of Engineers. This potential plan currently has no sponsor or manager. The mitigation program would improve wildlife habitat by eliminating grazing on lands at the perimeter of the reservoir and in a preserved corridor of the Medina River between Castroville and the upper boundary of the Applewhite Reservoir.

Cultural resource surveys have identified and recorded 87 prehistoric and historic sites within the flood pool and associated construction area. Of these sites, 43 are at or below the conservation pool elevation. The most significant impacts of the proposed reservoir would be to historic sites that directly relate to the evolution from Spanish colonization through statehood. Prehistoric sites range from lithic scatters to temporary settlements by hunters and gatherers. Fifteen historic sites and three prehistoric sites may be eligible for the National Register. Most of the remaining sites will require further work to determine eligibility. Sites labeled as eligible in the assessment reports appear to meet National Register of Historic Places eligibility requirements as listed in 36 CFR 60. However, the final testing and mitigation program agreement has not been settled. A Programmatic Memorandum of Agreement between the Corps of Engineers, the Texas Historical Commission, the Advisory Council on Historic Preservation and the City of San Antonio would define the testing and mitigation procedures necessary to comply with Federal and state antiquities regulations. In March 1994, portions of the Rancho de Perez within the proposed reservoir were nominated for state archeological landmark status by the

Antiquities Committee of the State of Texas. Any activity affecting a designated landmark would require coordination with the Antiquities Committee.

3.14.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.14.5 Engineering and Costing

Alternative S-14A: Delivery to Aquifer Injection Wells

For this alternative, the Applewhite yield would be diverted through an intake and pumped in a transmission line to the injection well field in eastern Medina County. The diversion rate from the reservoir, as well as the delivery to the wells would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Section 3.0.2). The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Water Treatment Plant (Level 2)
Finished Water Pump Station
Finished Water Booster Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The cost estimate for the dam and reservoir is an update of a previous cost estimate performed by Freese & Nichols which was updated by multiplying the individual cost components by the ratio (mid 1994/1991) of the relevant Bureau of Reclamation Construction Cost Indexes. The reservoir intake and pump station is sized to deliver 4,850 acft/month (52 mgd) through a 54-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 329 feet and an average annual water delivery of 57,700 acft/year. Operating cost of the finished water pumping system was determined for the total static lift of 310 feet. Financing the project over 25 years at an 8.0

percent annual interest rate results in an annual expense of $16,700,000 (Table 3.14-3). Operation and maintenance costs, including power, total $9,590,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $26,290,000. For a drought average annual yield of 22,500 acft, the resulting annual cost of water is $1,168 per acft.

Alternative S-14B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the Applewhite yield would be diverted through an intake and pumped in a transmission line to small recharge structures in northwestern Bexar County located over the recharge zone. The diversion rate from the reservoir, as well as the delivery to the recharge zone would be uniform throughout the year. The benefit from this project would be the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Concerns that the imported water is of different quality than the existing recharge water and the need for treatment of the imported water will require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of imported water. To determine the cost to treat the imported water, a typical direct filtration process, treatment level 2, Table 3.0-4 was assumed. The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Recharge Zone
Raw Waterline Booster Pump Stations
Recharge Structures

The reservoir intake and pump station is sized to deliver 4,850 acft/month (52 mgd) through a 54-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 767 feet and an average annual water delivery of 57,700 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $15,040,000 without a treatment plant, and $17,250,000 with treatment plant (Table 3.14-3). Operation and maintenance costs, including power, total $8,390,000

Table 3.14-3
Cost Estimate Summaries for Applewhite Reservoir (S-14)
(Mid- 1994 Prices)

Item	Alt. S-14A Divert and Inject to Aquifer	Alt. S-14B Divert to Recharge Zone	Alt S-14C Divert to WTP and Municipal System	Alt. S14-D Divert to WTP and Municipal System
Capital Costs				
Dam and Reservoir	$43,500,000	$43,500,000	$43,500,000	$43,500,000
Transmission and Pumping	37,280,000	39,830,000	1,370,000	1,770,000
Treatment Plant	16,400,000	16,400,000	5,330,000	8,420,000
Delivery System	7,980,000	8,100,000	6,090,000	12,170,000
Total Capital Cost	$105,160,000	$107,830,000[1] $91,430,000[2]	$56,290,000	$65,860,000
Engineering, Contingencies, and Legal Costs	35,550,000	36,280,000[1] 30,510,000[2]	19,320,000	22,060,000
Land Acquisition	600,000	850,000[1] 800,000[2]	80,000	80,000
Environmental Studies and Mitigation	26,466,000	26,070,000	24,030,000	24,030,000
Interest During Construction	10,480,000	13,030,000[1] 11,700,000[2]	7,270,000	7,980,000
Total Project Cost	$178,250,000	$184,040,000[1] $160,510,000[2]	$106,990,000	$120,010,000
Annual Costs				
Annual Debt Service	$16,700,000	$17,250,000[1] $15,040,000[2]	$10,030,000	$11,250,000
Annual Operation and Maintenance	4,850,000	5,050,000[1] 1,720,000[2]	1,430,000	1,930,000
Annual Power Cost	4,740,000	6,670,000	80,000	150,000
Irrigation Supply from Reclaimed Water	N/A	N/A	N/A	9,570,000
Total Annual Cost	$26,290,000	$28,970,000[1] $23,430,000[2]	$11,540,000	$22,900,000
Available Project Yield (acft/yr)	22,500[3]	22,500[3]	7,700[4]	14,900[5]
Annual Cost of Water	$1,168/acft	$1,288/acft[1] $1,041/acft[2]	$1,498/acft	$1,537/acft 37,500[6] $611/acft

[1]Cost with treatment prior to surface recharge.
[2]Cost without treatment prior to surface recharge.
[3]Drought average yield.
[4]Firm yield supply of Applewhite Reservoir delivered to WTP.
[5]Combined firm yield supply of Medina Lake and Applewhite Reservoir delivered to WTP.
[6]Alt. S-14D enhances recharge 22,600 acft/yr above current amount, for total project yield of 37,500 acft/yr.

without a treatment plant, and $11,720,000 with a treatment plant. The annual costs, including debt repayment, interest, and operation and maintenance, total $23,430,000 without a treatment plant, and $28,970,000 with a treatment plant. For a drought annual average yield of 22,500 acft, the resulting annual cost of water is $1,041 per acft without a treatment plant, and $1,288 acft with a treatment plant (Table 3.14-3).

Alternative S-14C: Delivery to the Municipal Distribution System

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the South Water Treatment Plant. The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Water Treatment Plant (Level 3, see Table 3.0-4)
Finished Water Pump Station
Transmission Line to Distribution System
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 642 acft/month (7 mgd) through a 24-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 24 feet and an annual water delivery of 7,700 acft/year. Operating cost of the finished water pumping system was determined for a total static lift of 300 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $10,030,000 (Table 3.14-3). Operation and maintenance costs, including power, total $1,510,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $11,540,000. For an annual firm yield of 7,700 acft, the resulting annual cost of water is $1,498 per acft (Table 3.14-3).

Alternative S-14D: Combined Operation of Medina Lake and Applewhite Reservoir - Delivery to the Municipal Distribution System

For this alternative, the combined yield of the Medina Lake and Applewhite Reservoir would be diverted through an intake at Applewhite and pumped in a transmission line to the South Water Treatment Plant. The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and the resulting reduction in demand on the aquifer. The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Water Treatment Plant (Level 3, Table 3.0-4)
Finished Water Pump Station
Transmission Line to Distribution System
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 1,240 acft/month (13 mgd) through a 30-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 24 feet and an annual water delivery of 14,900 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $11,250,000 (Table 3.14-3). Operation and maintenance costs, including power, total $2,080,000. The cost of the reclaimed water system to supply irrigation water to the BMA District as a replacement for Medina Lake water is estimated to be $9,570,000 per year (delivery capacity of 31,000 acft/yr, see Section 3.3.5). The annual costs, including debt repayment, interest, replacement water, and operation and maintenance, total $22,900,000. For an annual firm yield of 7,700 acft, the resulting annual cost of water is $1,537 per acft (Table 3.14-3). If recharge enhancement associated with this alternative is added to the firm yield, the estimated annual cost is reduced to about $611/acft.

3.14.6 Implementation Issues

The Corps of Engineers Section 404 permit issued for this project is due to expire at the end of 1994. Unless the permit can be renewed or extended, then significant additional permitting efforts, including environmental and hydrologic studies would be required.

Reservoir Alternatives (S-14, All)

An institutional arrangement is needed to implement projects including financing on a regional basis.

1. Most, if not all of these permits have already been obtained for construction of the project. Some of the permits may expire before the project is restarted and permit renewals may be necessary:
    a. TNRCC Water Right and Storage permits.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
    c. GLO Sand and Gravel Removal permits.
    d. GLO Easement for use of state-owned land.
    e. Coastal Coordinating Council review.
    f. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, would require these studies:
    a. Bay and estuary inflow impact.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.
3. Relocations:
    a. Highways and railroads
    b. Other utilities

Requirements Specific to Pipelines (S-14, All)

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    b. GLO Sand and Gravel Removal permits.
    c. Coastal Coordinating Council review.
    d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (S-14A)

1. Required testing programs:
    a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer.
    b. Test drilling and pilot recharge program is required.
    c. Large scale recharge test program.
    d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
    e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
    a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (S-14B)

1. Detailed field investigations of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits:
    a. TNRCC Water Rights and Storage permit.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
    c. GLO Sand and Gravel Removal permit.
    d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
    a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
    b. Study of impact on karst geology organisms from a sustained recharge program.
    c. Other environmental studies.
    d. Cultural resource studies.

Requirements Specific to Treatment and Distribution (S-14)

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

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3.15 Cibolo Reservoir (S-15)

3.15.1 Description of Alternative

Cibolo Reservoir is a proposed impoundment on Cibolo Creek in Wilson County located about 8 miles east of Floresville. The project has been studied several times[31], most recently by Espey, Huston & Associates, Inc. which in 1986 studied two sites located on Cibolo Creek[32]. The lower of the two sites is used for this analysis and is shown on Figure 3.15-1.

The proposed dam would be an earthfill embankment with a gate-controlled concrete spillway to control the 748 square-mile watershed. The dam embankment would extend about 4 miles across the Cibolo Creek valley and provide a conservation storage capacity of 409,700 acft at elevation 416 feet MSL; at conservation pool the surface area would be 16,700 acres; the probable maximum flood elevation would be 426 feet; and approximately 18 miles of stream channel would be inundated by the reservoir.

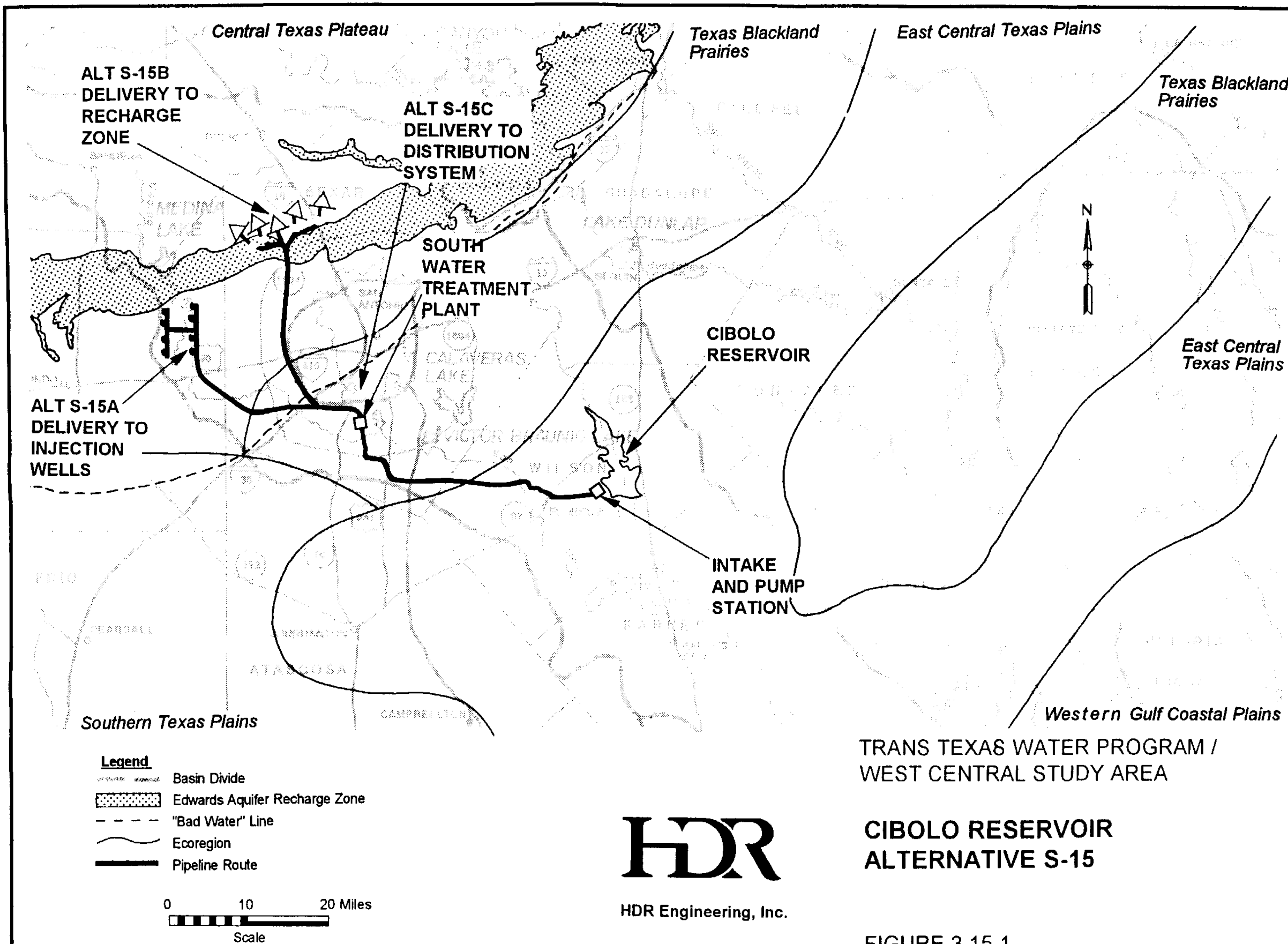
Three alternative uses of water from this reservoir have been studied and are shwon on Figure 3.15-1. These include: (1) delivery to injection wells to recharge the Edwards Aquifer (Alt S-15A); (2) delivery to recharge structures in the Edwards Aquifer recharge zone (Alt S-15B); and (3) delivery to a water treatment plant and with distribution in the San Antonio municipal water system (Alt S-15C).

3.15.2 Available Yield

The firm yield of the proposed Cibolo Reservoir was computed subject to four scenarios chosen to represent a reasonable range of hydrologic assumptions. Under each of these scenarios, firm yield was computed subject to three capacity thresholds which limit passage of reservoir inflows as specified in the Trans-Texas Environmental Criteria (see Appendix C) during times of drought. All scenarios include the spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures,

[31]USBR, "Feasibility Report, Cibolo Project, Texas," February, 1971. USBR, "Texas Basins Project," February, 1965.

[32]Espey, Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," February, 1986.



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

CIBOLO RESERVOIR ALTERNATIVE S-15

FIGURE 3.15-1

full utilization of existing water rights, and hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr[33]. The four scenarios analyzed are further described as follows:

Scenario 1: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir excluded.

Scenario 2: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir included.

Scenario 3: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir included.

Scenario 4: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir excluded.

The Guadalupe - San Antonio River Basin Model[34] (GSA Model) was used to estimate monthly quantities of total streamflow and unappropriated streamflow potentially available at the reservoir site which, in turn, were used to compute the firm yield of Cibolo Reservoir. For modelling purposes, streamflows for Cibolo Creek near Falls City (ID #1850) were assumed to be representative of inflows to Cibolo Reservoir. The firm yield of Cibolo Reservoir was computed using an original model (RESSIM) specifically written to simulate reservoir operations subject to the Trans-Texas Environmental Criteria for new reservoirs, using water availability estimates from the GSA Model. A summary of the firm yield estimates for each scenario and capacity threshold analyzed is provided in Table 3.15-1. As is apparent in this table, estimated firm yield of Cibolo Reservoir is sensitive to capacity threshold and return flows in the Guadalupe - San Antonio River Basin, but is much less sensitive to the exclusion of Applewhite Reservoir. Inclusion of return flows increases the firm yield by about 16 percent, while exclusion of Applewhite Reservoir increases the firm yield by about 3 percent. Appendix D contains a detailed summary of the inflow passage

[33]Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[34]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

Table 3.15-1
Summary of Cibolo Reservoir Firm Yield Estimates

Scenario[1]	Estimate of Firm Yield (acft/yr) — Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]: 40%	60%	80%
1	30,600	33,000	37,500
2	25,400	28,100	31,200
3	29,700	32,300	36,600
4	26,200	28,600	32,700

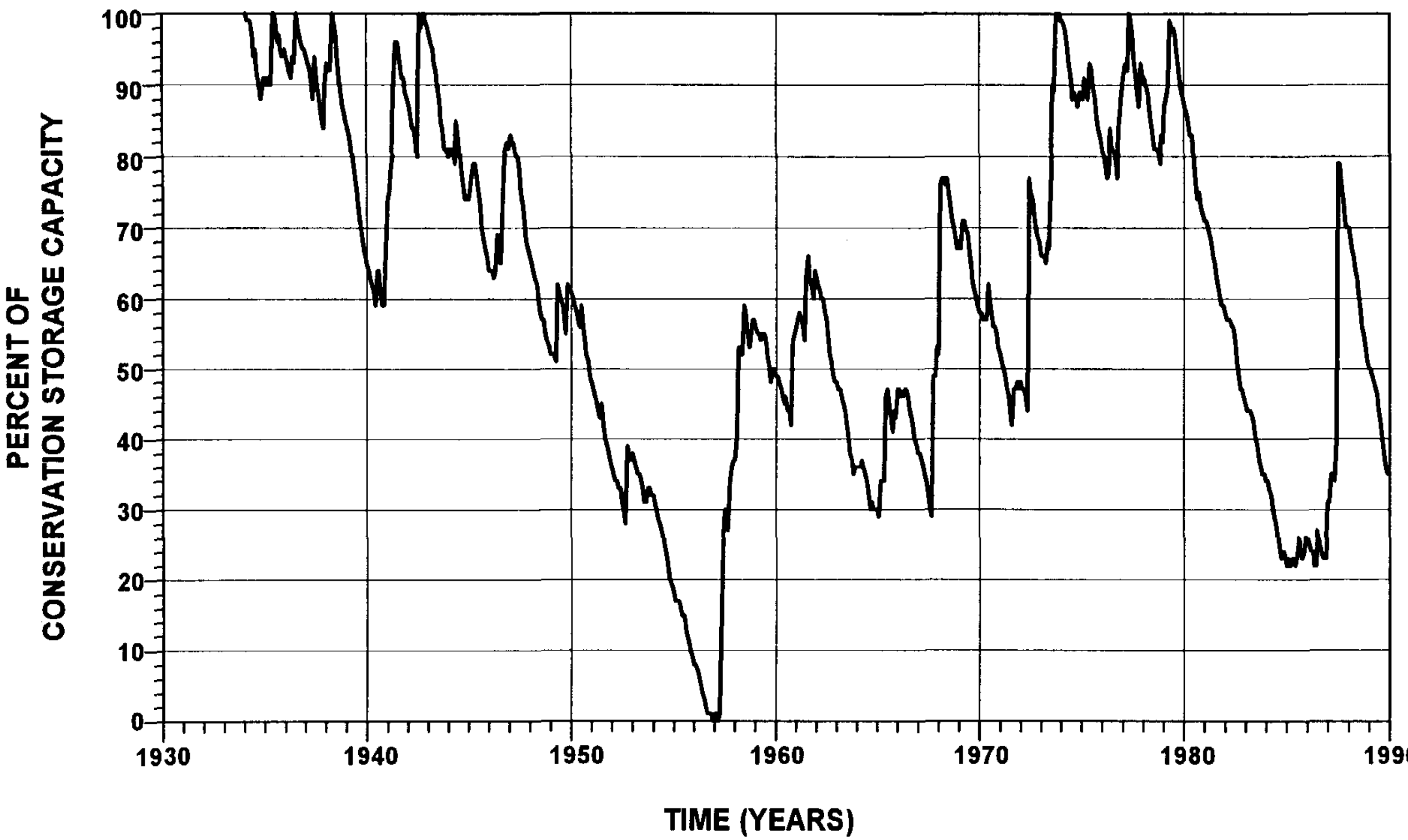
Notes:

1) All scenarios include the springflows from a fixed Edwards Aquifer pumpage of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights, and hydropower water rights subordinated to 600 cfs resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr.
   - Scenario 1: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir excluded.
   - Scenario 2: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir included.
   - Scenario 3: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir included.
   - Scenario 4: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir excluded.

2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.

requirements applied for Cibolo Reservoir.

Scenario 3, with a 60 percent capacity threshold, was selected for consideration of cost and analysis of potential environmental impacts because it is the most representative of existing return flows and includes the currently permitted Applewhite Reservoir. Figure 3.15-2 illustrates the simulated Cibolo Reservoir storage fluctuations for the 1934-89 historical period if operated under the Trans-Texas Environmental Criteria subject to diversion of the firm yield of 32,300 acft/yr. Simulated reservoir storage fell below the 60 percent capacity threshold about 50 percent of the time resulting in the frequent passage of inflows only up to the drought median natural streamflow. As a result, median monthly streamflows at the site were significantly reduced. Corresponding reductions in flow at the Saltwater Barrier, however, were less noticeable due to the large intervening volume of flow between the two locations. Monthly median streamflows and annual streamflows averaged



NOTES

FIRM YIELD: 32,300 ACFT/YR
CONSERVATION STORAGE CAPACITY: 409,700 ACFT
60% CAPACITY THRESHOLD
SCENARIO 3:

- EDWARDS AQUIFER DEMAND OF 400,000 ACFT/YR
- RETURN FLOWS SET AT 1988 LEVELS
- HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
- APPLEWHITE RESERVOIR INCLUDED

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

STORAGE TRACE
CIBOLO RESERVOIR
ALTERNATIVE S-15

FIGURE 3.15-2

by decile, with and without the project, are presented in Figure 3.15-3 for the reservoir site and for the Saltwater Barrier. Under Scenario 3 with a 60 percent capacity threshold, freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier, would be reduced by an average of 59,000 acft/yr or about 4 percent.

3.15.3 Environmental Issues

A specific construction corridor for the pipeline segment between the proposed reservoir and the south side water treatment facility has not been selected and assessed for this phase of the Trans Texas Water Program. From the southside water treatment facility the proposed pipeline corridors and the two recharge alternatives would be the same as those assessed in Sections 3.4.3, 3.9.3, and discussed in the Environmental Overview, Section 3.0.1. It is assumed that adverse impacts would be avoided and minimized to the extent practical by careful corridor selection, using vegetation, land use, and protected species information, and that residual impacts for all alternatives would be similar.

The proposed Cibolo Reservoir is in the East Central Texas Plains Ecoregion and the South Texas Plains vegetation region (Figures 3.0-1 and 3.0-2)[35,36]. Omernik describes the ecoregion as irregular plains with oak and hickory woodlands, with some cropland and pasture on dry alfisols soils[37]. Correl and Johnston describe the South Texas Plains ecotone as being characterized by open prairies and a growth of mesquite, granjeno, cacti, clepe, coyotillo, guayacan, white brush, brasil, bisbirinda, cenizo, huisache, catclaw, black brush, guajillo and other small trees and shrubs[38]. There are distinct differences in climax plant communities and successional patterns depending upon local soils, topography, and position on the regional moisture gradient.

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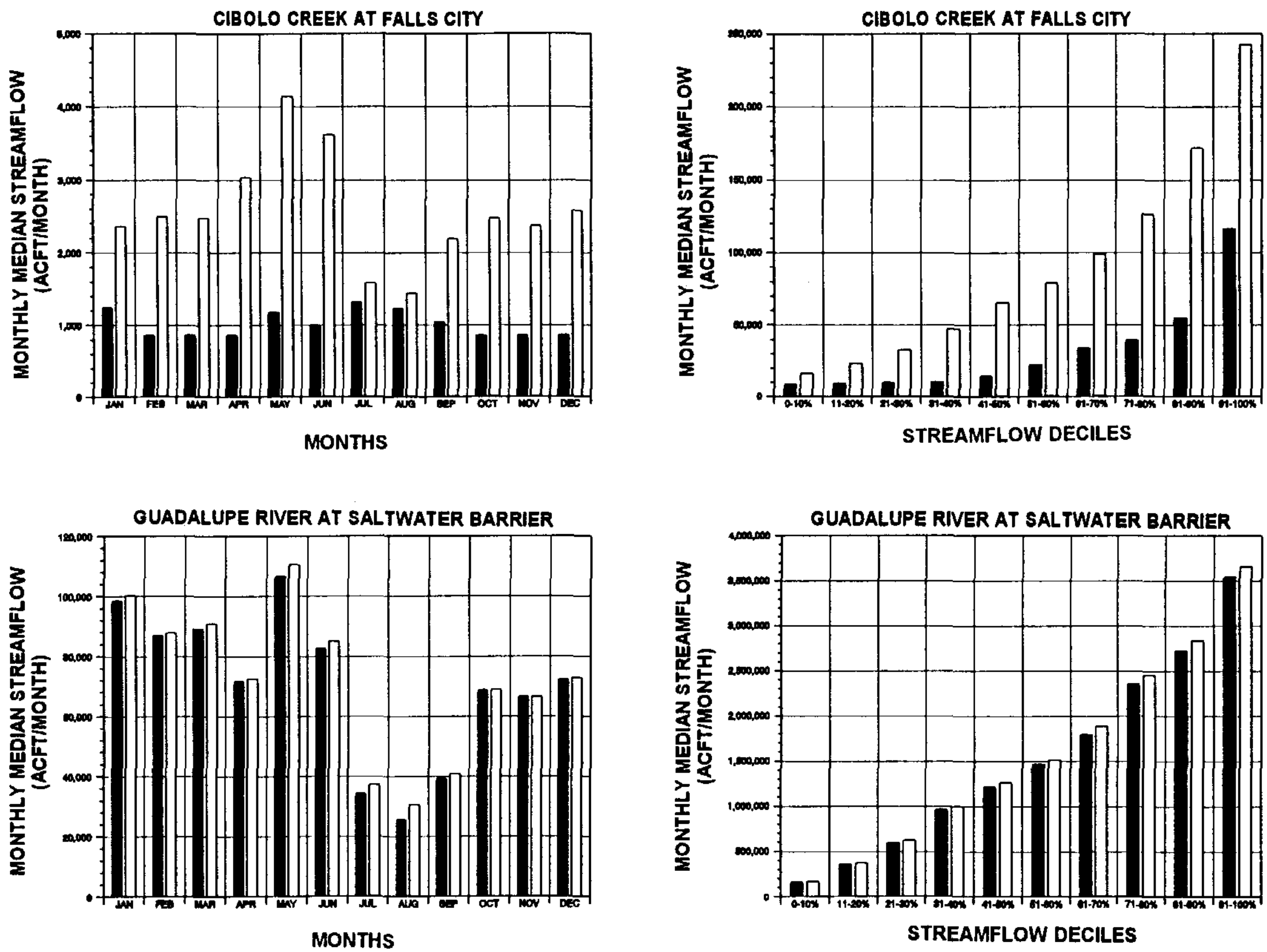
[35]Omernik, James M., 1987, "Ecoregions of the Conterminous United States," EPA/600/D-86, U.S. EPA, Corvallis, Oregon.

[36]Gould, Frank W., 1975, The Grasses of Texas, Texas A & M University, College Station, Texas.

[37]Omernik, James M., 1987, "Ecoregions of the Conterminous United States," EPA/600/D-86, U.S. EPA, Corvallis, Oregon.

[38]Correll, D.S., and M.C. Johnston. 1979, Manual of the Vascular Plants of Texas, Texas Research Foundation, Renner, Texas.



LEGEND

■ WITH PROJECT
□ WITHOUT PROJECT

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

CHANGES IN STREAMFLOW CIBOLO RESERVOIR ALTERNATIVES-15

FIGURE 3.15-3

Soil types in the area of the proposed reservoir are of the Wilco-Floresville-Miguel (WFM), Elmendorf-Luling-Denhawken (ELD), and Tabor-Crockett (TC) associations[39]. The WFM association exhibits deep, nearly level to sloping, well drained, slowly permeable, and very slowly permeable sandy and loamy soils that have clayey lower layers. The ELD association consists of deep, nearly level to gently sloping, well drained, very slowly permeable, loamy and clayey soils that have clayey lower layers. The TC association has deep, nearly level to gently sloping, moderately well drained, very slowly permeable sandy and loamy soils that have clayey lower layers[40].

Characteristic grasses of the sandy loam soils are seacoast bluestem, species of *Setaria*, *Paspalum*, *Chloris* and *Trichloris*, silver bluestem and coast sandbur. The characteristic grasses on the clay and clay loams are silver bluestem, Arizona cottontop, buffalo grass, curly mesquite, and species of *Setaria*, *Pappophorum* and *Bouteloua*. Grasses of the oak savannahs are mainly seacoast bluestem, Indian grass, switch grass, crinkle-awn and species of *Paspalum*. The brush and shrub communities often occur as scattered, overgrown pastures or abandoned cultivated fields surrounded by cultivated land.

Blair considers this area to be in the Tamaulipan Biotic Province which he characterizes as being dominated by thorny brush, including mesquite, various species of *Acacia* and *Mimosa*, granjeno, lignum vitae, cenizo, white brush, prickly pear, tasajillo, *Condalia*, and *Castel*[41].

Although recent improvements in wastewater treatment facilities have greatly improved the quality of surface water in the upper reaches of Cibolo Creek, water quality remains poor in its middle reaches due to multiple municipal point source discharges[42]. Specific water quality assessments should be completed in later phases of the Trans-Texas study, if the proposed Cibolo Reservoir should continue to be considered as an alternative water

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[39]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station, 1975, Soil Survey of Goliad County, Texas, USDA.

[40]Ibid.

[41]Blair, W. Frank, 1950, The Biotic Provinces of Texas, Texas Journal of Science, Vol 2, No. 1: pp. 93-117.

[42]Texas Water Development Board, December 1990, "Water for Texas; Today and Tomorrow," Texas Water Development Board, Austin, Texas.

supply.

The reservoir would inundate approximately 16,700 acres of land and approximately 18 miles of stream channel (about 1,645 acres of lotic habitat) would be converted to lentic (lake) habitat[43]. Direct impacts resulting from inundation would include converting grasslands (2,900 acres), croplands (6,850 acres), brushlands (2,510 acres), parklands (555 acres), woodlands (3,715 acres), and wetlands (70 acres) into lentic aquatic habitat (Table 3.0-1). Of particular significance is the loss of bottomland hardwood and riparian communities, and hydric soils along the creek and in the floodplain, which represent important wildlife habitat. Bottomland hardwood and riparian forest habitat types are not extensive in this region. Substantial areas of these woodlands have been cleared in order to convert the land to agricultural uses. As the extent of these habitat types is reduced, the value of the remaining areas increases. An indication of the ecological value of these habitats is the inclusion and preliminary listing in The Natural Areas of Texas of a zone averaging 0.5 mile wide on Cibolo Creek as it flows through Wilson County[44].

The vertebrate community within the area of the proposed reservoir includes species from both the Tamaulipan and Texan Biotic Provinces[45]. The vertebrate community of the Texan province consists of approximately 49 species of mammals, 16 species of lizards, 2 species of Terrapene, at least 39 species of snakes, 5 species of urodeles, 18 species of anurans and an undetermined number of bird species. In addition, some of the vertebrate community of the Tamaulipan Biotic Province may be found in the area. Vertebrates of this biotic province may include neotropical, grassland, Austroriparian and some Chihuahuan province species. At least 61 species of mammals, 36 species of snakes, 19 species of lizards, 2 species of Terrapene, 3 urodeles and 19 anurans occur in the Tamaulipan province. Six of the 19 species of lizards of this province occur in the state only in this province. One species of land turtle, *Gopherus berlandieri*, is restricted to the Tamaulipan. Six of the 36 species of snakes known from the Tamaulipan are unknown from other provinces in the

[43]Espey, Huston & Associates, Inc., 1986, "Water Availability Study for the Guadalupe and San Antonio River Basins".

[44]Ibid.

[45]Blair, W. Frank, 1950, The Biotic Provinces of Texas, Texas Journal of Science, Vol 2, No. 1:93-117.

state, however only two of them range as far north as the proposed reservoir. One species of urodel and five of the 19 species of anurans are restricted to this province but probably do not range as far north as the study area.

Several important aquatic species that warrant attention are the river darter *(Percina shumardi)*, the freshwater prawn *(Macrobrachium carcinus)*, and the American eel *(Anguilla rostrata)*[46]. The river darter, an unprotected non-game fish, occurs in Cibolo Creek. The American eel and the freshwater prawn, although not recently collected, are known to have occurred historically in the Guadalupe River basin. Reservoir development would alter the fishery from that of a stream (lotic) habitat to a reservoir (lentic) habitat. Species dependent upon a lotic type habitat for their life cycle would be eliminated within the lentic habitat.

Compensation will likely be required where unavoidable losses of ecologically important habitats occurs. Texas Parks and Wildlife Department has estimated that full compensation of terrestrial habitat losses for the project outlined by Espey, Huston & Associates, Inc., would require 28,958 acres of land under a minimum management scenario[47].

While none have been reported from the reservoir site, several protected and candidate species listed by the Natural Heritage Program for Wilson County (Appendix B, Table 48) may have habitat in the vicinity of the proposed reservoir (Table 3.15-2). Many of these species appear to be dependent on upland habitats, including the reticulate collared lizard, Texas horned lizard, the Indigo snake, and Texas tortoise. Neither the warbler nor the vireo is likely to be present near the reservoir site, but the bald eagle, zone-tailed hawk, Texas garter snake and big red sage could occur within the reservoir site. Implementation of this alternative will require surveys for protected species or other biological resources of restricted distribution within the proposed reservoir area.

Firm yield, when operation of this alternative is modeled to meet the Trans Texas criteria for new reservoirs, is 32,300 acft/yr and could be diverted to any of the three possible use scenarios annually.

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[46] Ibid.

[47] Espey, Huston & Associates, Inc., 1986, "Water Availability Study, for the Guadalupe - San Antonio River Basins."

Table 3.15-2
Protected Species with Habitat in the Project Vicinity (S-15)

Common Name	Scientific Name	Habitat Preference	Listing Agency USFWS	Listing Agency TPWD
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E
Black-capped vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands	E	E
Golden-cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oaks and old juniper	E	E
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions, hides under objects;	NL	T
Reticulate Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush[1]	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks[1]	C2	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures[1]	C2	NL
Big Red Sage	*Salvia penstemonoides*	Moist creek and stream bed edges historic; in native plant nursery trade[2]	C2	NL

Source: TPWD, Unpublished 1994. Texas Natural Heritage Program, Texas Parks and Wildlife, Austin, Texas.
[1]Dixon, J.R., 1987, Amphibians and Reptiles of Texas, Texas A & M Press, College Station, Texas.
[2]TPWD, Texas Natural Heritage Program, Special Plant List, last observed or collected prior to 1930.

An archaeological investigation in 1967 (41WN1-41WN28, 41WN31-41WN56) recorded 54 sites in the proposed Cibolo Reservoir dating from the Archaic, Neo-American, and Historic periods. Of 21 sites recommended for investigation 7 were recommended for excavation[48]. The area covered for this survey was confined to the immediate first terrace and did not constitute a comprehensive survey of the entire reservoir site[49]. In addition, site 41WN72 was recorded by Texas A&M University in 1979 on the western edge of the proposed reservoir.

Cultural resources protection on public lands in Texas, or lands affected by projects regulated under Department of the Army permits, is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resources Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction will be first surveyed by qualified professionals for the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

3.15.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.15.5 Engineering and Costing

The cost estimate for the dam and reservoir is an update of a previous cost estimate performed by EHA[50]. That cost estimate was updated by multiplying the individual cost components by the ratio (mid 1994/1991) of the relevant Bureau of Reclamation Construction Cost Indexes.

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[48]Ibid.

[49]Ibid.

[50]Ibid.

Alternative S-15A: Delivery to Aquifer Injection Wells

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission pipeline to the injection well field in eastern Medina County. The diversion rate from the reservoir, as well as the delivery to the wells would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2). The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Station
Water Treatment Plant (Level 2)
Finished Water Pump Station
Finished Water Booster Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The reservoir intake and pump station is sized to deliver 2,700 acft/month (45 cfs) through a 42-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 130 feet and an annual water delivery of 32,300 acft/yr. Operating cost of the finished water pumping system was determined for the total static lift of 310 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $30,890,000 (Table 3.15-3). Operation and maintenance costs, including power, total $8,750,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $39,640,000. For an annual firm yield of 32,300 acft, the resulting annual cost of water is $1,227 per acft.

Alternative S-15B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to small recharge structures in northwestern Bexar County located over the recharge zone. The diversion rate from the

Table 3.15-3
Cost Estimate Summaries for Cibolo Reservoir and Pipeline (S-15)
(Mid- 1994 Prices)

Item	Alt. S-15A Divert and Inject to Aquifer	Alt. S-15B Divert to Recharge Zone	Alt. S-15C Divert to WTP and Municipal Systems
Capital Costs			
Dam and Reservoir	\$114,430,000	\$114,430,000	\$114,430,000
Transmission and Pumping	51,560,000	53,420,000	26,890,000
Treatment Plant	10,450,000	10,450,000	14,430,000
Delivery System	5,220,000	2,880,000	25,220,000
Total Capital Cost	\$181,660,000	\$181,180,000(1) \$170,730,000(2)	\$180,970,000
Engineering, Contingencies, and Legal Costs	61,450,000	61,370,000(1) 57,710,000(2)	59,750,000
Land Acquisition	34,640,000	34,720,000(1) 34,670,000(2)	34,150,000
Environmental Studies and Mitigation	30,970,000	30,340,000	29,030,000
Interest During Construction	20,970,000	22,680,000(1) 21,830,000(20	19,954,000
Total Project Cost	\$329,690,000	\$330,290,000(1) \$315,280,000(2)	\$323,860,000
Annual Costs			
Annual Debt Service	\$30,890,000	\$30,950,000(1) \$29,540,000(2)	\$30,350,000
Annual Operation and Maintenance	2,700,000	4,490,000(1) 2,590,000(2)	4,020,000
Annual Power Cost	6,050,000	5,380,000	2,040,000
Total Annual Cost	\$39,640,000	\$40,820,000(1) \$37,510,000(2)	\$36,410,000
Available Project Yield (acft/yr)	32,300	32,300	32,300
Annual Cost of Water	\$1,227/acft	\$1,264/acft(1) \$1,161/acft(2)	\$1,127/acft

(1)Cost with treatment prior to surface recharge.
(2)Cost without treatment prior to surface recharge.

reservoir, as well as the delivery to the recharge structures would be uniform throughout the year. The benefit from this project would be the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Concerns that the imported water is of different quality than the existing recharge water and the need for treatment of the imported water will require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of the imported water. To determine the cost to treat the imported water, a typical direct filtration process (Treatment Level 2, see Table 3.0-4) was assumed.

The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Recharge Zone or Treatment Plant
Raw Waterline Booster Pump Station
Recharge Structures
Treatment Plant Items (if determined to be needed):
- Water Treatment Plant (Level 2)
- Finished Water Pump Station
- Finished Water Booster Pump Stations, 2 required
- Transmission Line to Recharge Zone

The reservoir intake and pump station is sized to deliver 2,700 acft/month (45 cfs) through a 42-inch diameter pipeline. The operating cost was determined for the total raw water static lift to the treatment plant of 130 feet and an annual water delivery of 32,300 acft/yr. If no treatment plant is required, then the operating cost is determined for the total raw water static lift to the recharge structures of 890 feet. For a treatment plant, the operating cost of the finished water pumping system was determined for the total static lift of 760 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $30,950,000 with a treatment plant and $29,540,000 with no treatment plant (Table 3.15-3). Operation and maintenance costs, including power, total $9,870,000, including the treatment plant and are $7,970,000 without a treatment plant. The annual costs, including debt repayment, interest, and operation and maintenance, total $40,820,000, including the treatment plant and are $37,510,000 without a treatment plant. For an annual firm yield of 32,300 acft, the resulting annual cost of water, including a treatment plant, is $1,264 per acft, and is $1,161 per acft without a treatment plant (Table 3.15-3).

Alternative S-15C: Delivery to the Municipal Distribution System

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the South Water Treatment Plant. The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations
Water Treatment Plant (Level 3, see Table 3.0-4)
Finished Water Pump Station
Transmission Line to Distribution System
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 2,700 acft/month (45 cfs) through a 42-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 130 feet and an annual water delivery of 32,300 acft/yr. Operating cost of the finished water pumping system was determined for a total static lift of 300 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $30,350,000 (Table 3.15-3). Operation and maintenance costs, including power, total $6,060,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $36,410,000. For an annual firm yield of 32,300 acft, the resulting annual cost of water is $1,127 per acft (Table 3.15-3).

3.15.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Reservoir Alternatives (S15, A11)

1. It will be necessary to obtain these permits:
    a. TNRCC Water Right and Storage permits.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
    c. GLO Sand and Gravel Removal permits.
    d. GLO Easement for use of state-owned land.
    e. Coastal Coordinating Council review.
    f. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
    a. Bay and estuary inflow impact.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.
3. Land will need to be acquired through either negotiations or condemnation.
4. Relocations for the reservoir include:
    a. Highways and railroads
    b. Other utilities

Requirements Specific to Pipelines (S15, A11)

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    b. GLO Sand and Gravel Removal permits.
    c. Coastal Coordinating Council review.
    d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (S-15A)

1. Required testing programs:
    a. Detailed field investigation of existing supply wells, including performance tests.
    b. Test drilling and pilot recharge program is required.
    c. Large scale recharge test program.
    d. Water compatibility testing and assessment of treatment needs (if any),

3.16 Goliad Reservoir (S-16)

3.16.1 Description of Alternative

The proposed Goliad Reservoir site is located on the San Antonio River upstream of Goliad, Texas, and was first proposed in 1965 by the USBR[51] as a water supply option for the City of Corpus Christi. Since the original proposal, the project was studied again by the USBR in 1983, and in 1986, Espey, Huston & Associates[52] (EHA) studied a slightly smaller reservoir about 4 miles from the USBR site. The site studied by EHA is used for this analysis and is shown on Figure 3.16-1.

The Goliad site proposed by EHA is approximately eight miles west of the City of Goliad. The dam would be an earthfill embankment with a gate-controlled, concrete spillway to control the 3,892 square mile watershed. The dam embankment would extend about 2.5 miles across the San Antonio River valley and provide a conservation storage capacity of 707,500 acft at elevation 200.0 feet-msl; at conservation pool the surface area would be 27,810 acres; the probable maximum flood elevation would be 210 feet; and, approximately 43 miles of stream channel would be inundated by the reservoir.

Three alternative uses of water from this reservoir have been studied: (1) delivery to injection wells to recharge the Edwards Aquifer (Alt S-16A); (2) delivery to recharge structures in the Edwards Aquifer recharge zone (Alt S-16B); and (3) delivery to a water treatment plant, with distribution in the San Antonio municipal water system (Alt S-16C).

3.16.2 Available Yield

The firm yield of the proposed Goliad Reservoir was computed subject to four scenarios chosen to represent a reasonable range of hydrologic assumptions. Under each of these scenarios, firm yield was computed subject to three capacity thresholds which limit passage of reservoir inflows as specified in the Trans-Texas Environmental Criteria (See Appendix C) during times of drought. All scenarios include the spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures,

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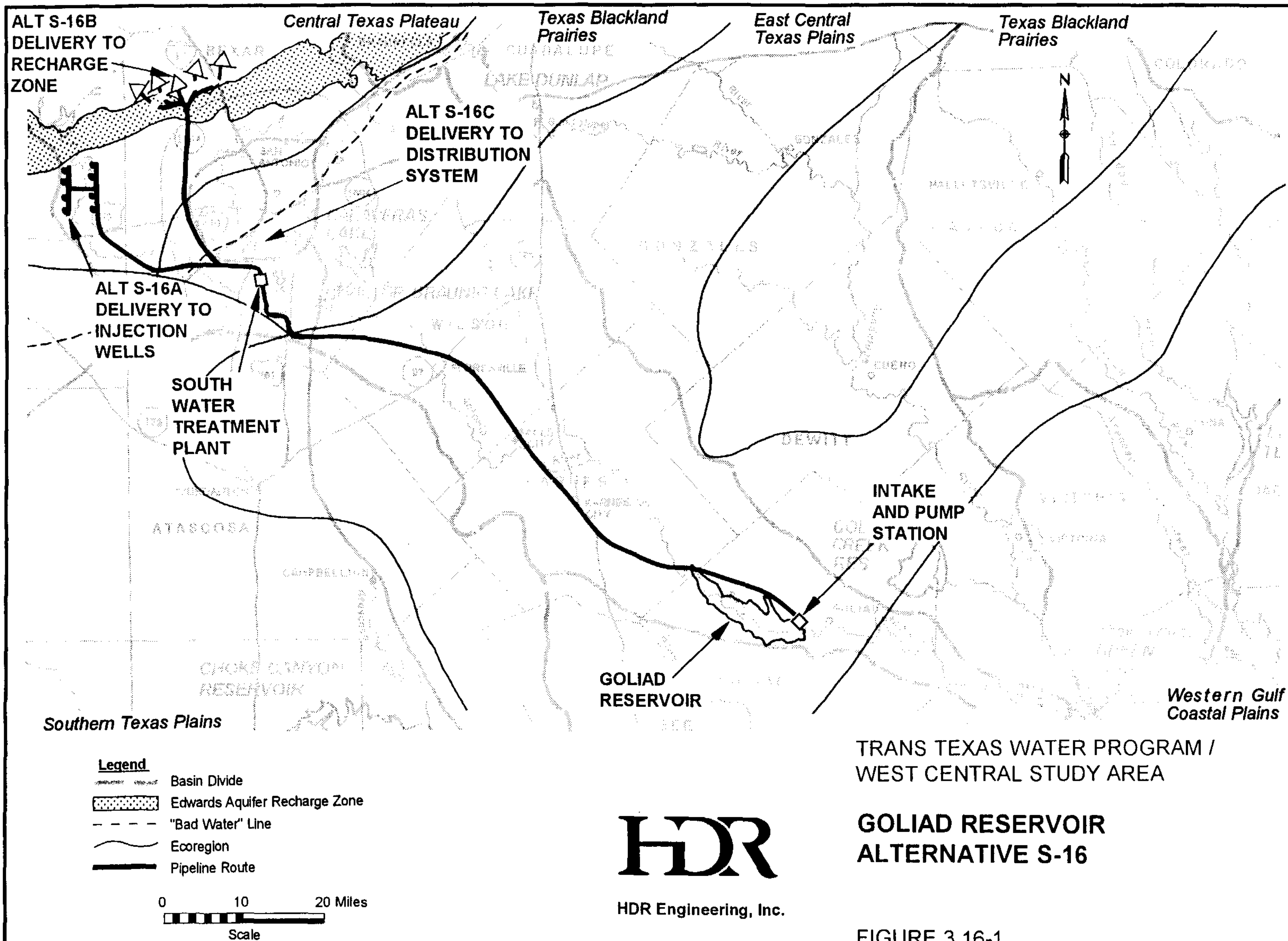
[51] USBR, "Texas Basins Project," February 1965.

[52] Espey Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," February, 1986.



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GOLIAD RESERVOIR ALTERNATIVE S-16

FIGURE 3.16-1

full utilization of existing water rights, and hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr[53]. The four scenarios analyzed are further described as follows:

Scenario 1: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir excluded.

Scenario 2: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir included.

Scenario 3: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir included.

Scenario 4: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir excluded.

The Guadalupe - San Antonio River Basin Model[54] (GSA Model) was used to estimate monthly quantities of total streamflow and unappropriated streamflow potentially available at the reservoir site which, in turn, were used to compute the firm yield of Goliad Reservoir. For modelling purposes, streamflows for the San Antonio River at Goliad (ID #1885) were assumed to be representative of inflows to Goliad Reservoir. The firm yield of Goliad Reservoir was computed using an original model (RESSIM) specifically written to simulate reservoir operations subject to the Trans-Texas Environmental Criteria for new reservoirs, using water availability estimates from the GSA Model. A summary of the firm yield estimates for each scenario and capacity threshold analyzed is provided in Table 3.16-1.

[53]Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[54]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

Table 3.16-1 Summary of Goliad Reservoir Firm Yield Estimates			
	Estimate of Firm Yield (acft/yr)		
	Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]		
Scenario[1]	40%	60%	80%
1	95,100	124,200	141,600
2	59,200	82,300	92,700
3	81,400	115,500	130,600
4	67,700	85,400	97,200

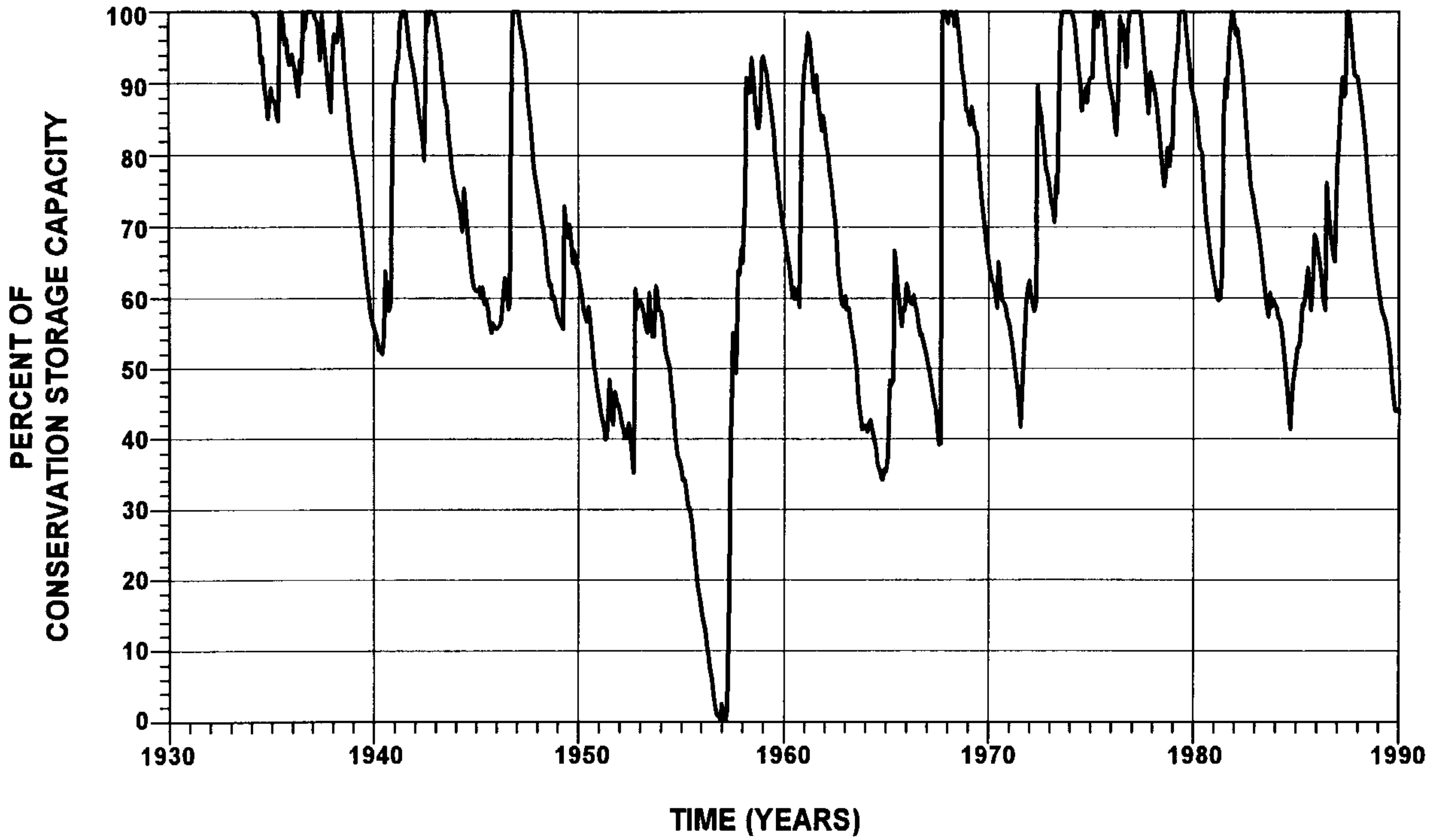
Notes:
[1]All scenarios include the springflows from a fixed Edwards Aquifer pumpage of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights, and hydropower water rights subordinated to 600 cfs resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr.

- Scenario 1: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir excluded.
- Scenario 2: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir included.
- Scenario 3: Return flows in the Guadalupe - San Antonio River Basin set to 1988 levels. Proposed Applewhite Reservoir included.
- Scenario 4: No return flows in the Guadalupe - San Antonio River Basin. Proposed Applewhite Reservoir excluded.

[2]The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.

Estimated firm yield of Goliad Reservoir is quite sensitive to capacity threshold and return flows in the Guadalupe - San Antonio River Basin, but is somewhat less sensitive to the exclusion of Applewhite Reservoir (Table 3.16-1). Inclusion of return flows increases the firm yield by about 40 percent, while exclusion of Applewhite Reservoir increases the firm yield by only about 4 percent to 8 percent. Appendix D contains a detailed summary of the inflow passage requirements applied for Goliad Reservoir.

Scenario 3, with a 60 percent capacity threshold, was selected for consideration of cost and analysis of potential environmental impacts because it is the most representative of existing return flows and includes the currently permitted Applewhite Reservoir. Figure 3.16-2 illustrates the simulated Goliad Reservoir storage fluctuations for the 1934-89 historical period if operated under the Trans-Texas Environmental Criteria subject to



NOTES

FIRM YIELD: 115,500 ACFT/YR
CONSERVATION STORAGE CAPACITY: 707,500 ACFT
60% CAPACITY THRESHOLD
SCENARIO 3:

- EDWARDS AQUIFER DEMAND OF 400,000 ACFT/YR
- RETURN FLOWS SET AT 1988 LEVELS
- HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
- APPLEWHITE RESERVOIR INCLUDED

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STORAGE TRACE
GOLIAD RESERVOIR
ALTERNATIVE S-16

FIGURE 3.16-2

diversion of the firm yield of 115,500 acft/yr. Simulated reservoir storage fell below the 60 percent capacity threshold about 40 percent of the time resulting in the frequent passage of inflows only up to the drought median natural streamflow. As a result, median monthly streamflows at the site were noticeably reduced. Corresponding reductions at the Saltwater Barrier, however, were less noticeable due to the larger volume of flow at this location. Monthly median streamflows and annual streamflows averaged by decile, with and without the project, are presented in Figure 3.16-3 for the site and the Saltwater Barrier. Under Scenario 3 with a 60 percent capacity threshold, freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier would be reduced by an average of 167,000 acft/yr or about 10 percent.

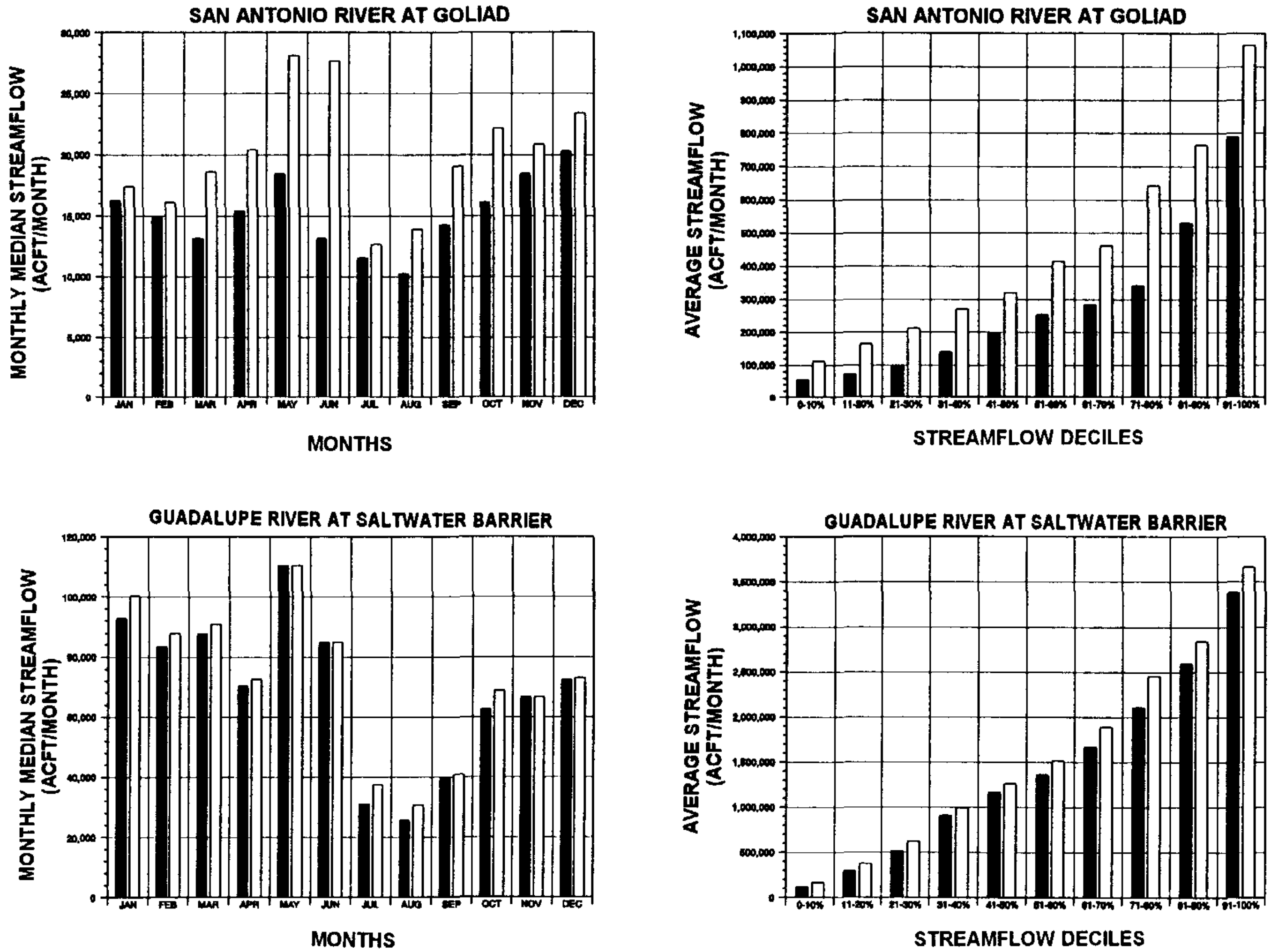
3.16.3 Environmental Issues

In addition to the reservoir described in Section 3.16.1, this alternative would include a pipeline approximately 80 miles long to deliver Goliad water to the South Water Treatment Plant (Figure 3.16-1) for either delivery to the injection well site (Alt S-16A) or delivery to the recharge zone (Alt S-16B). The proposed reservoir is within the East Central Texas Plains Ecoregion (Figure 3.16-1). Omernik describes the ecoregion as irregular plains of oak and hickory woodlands with some cropland and pasture on dry alfisols soils[55]. Regional descriptions of the vegetation and wildlife are found in the Environmental Overview Section 3.0.1.

Soil types in the area of the proposed reservoir are Leming-Papalote (LP) association, Runge-Sarnosa (RS) association, and Aransas-Sinton (AS) association[56]. The LP association is described as being nearly level to gently sloping, deep, slightly acid or neutral, sandy and loamy soils of the uplands; the RS association is gently sloping to sloping, deep, neutral to moderately alkaline, loamy soils of the uplands; the AS association is nearly level, deep, moderately alkaline, clayey and loamy soils of the bottomlands. The RS and AS

[55]Omernik, James M., 1987, Ecoregions of the Conterminous United States, Annals of the Association of American Geographers, 77(1), pp. 118-125.

[56]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station, 1975, Soil Survey of Goliad County, Texas, USDA.



<u>LEGEND</u>

■ WITH PROJECT
□ WITHOUT PROJECT

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CHANGES IN STREAMFLOW
GOLIAD RESERVOIR
ALTERNATIVE S-16

FIGURE 3.16-3

soil associations are well drained and moderately permeable and have low shrink-swell potential. The LP soil association is moderately well drained and has a slowly permeable subsoil that has moderate shrink-swell potential.

The pipeline route to the South Water Treatment Plant has not been selected, however, the general corridor is presented on Figure 3.16-1. This route follows the San Antonio River basin to San Antonio through cropland and post oak grassland park typical of the East Central Texas Plains Ecoregion described in Section 3.0.1. The total acreage affected by construction is estimated at 8,862 acres of which 2,658 acres would be within the maintained ROW (Table 3.0-1).

Application of the Trans Texas instream flow criteria to the Goliad Reservoir alternative results in a firm annual yield of 115,000 acft, assuming drought operation commences when reservoir content falls below 60 percent capacity. Historical median discharges at Goliad, by month, together with median flows modeled for the same period of record with the project in place are shown in Figure 3.16-3. Changes in monthly median flows reflect reductions in average discharge over the entire range of river flows. Figure 3.16-3 shows reductions in average river flow below Goliad Reservoir amounting to about 50 percent at the lower range of annual flows (driest 30 percent of years), declining to approximately 25 percent reductions in the top half of annual flows.

With respect to potential effects on the Guadalupe Estuary, Figure 3.16-3 shows only small changes from historical monthly median and annual average discharge statistics at the salt water barrier at Tivoli. The most pronounced reductions, those in the July and August medians, appear to reflect the effects of drought operation on summer low flows during extended dry periods. Annual median and average Guadalupe River flows would decline by about 8 and 10 percent, respectively.

Because of the relatively large wastewater component in the San Antonio River, Goliad Reservoir may experience elevated nutrient loading rates. If it is assumed that ambient phosphorus levels at Goliad would be similar to those typical in the lower Guadalupe River (0.3 mg/l) if the City of San Antonio's wastewater were not present, annual total phosphorus (TP) loading to Goliad Reservoir would be about 172,000 kg per year. An ultimate wastewater flow of 66,000 acre feet per year of treated wastewater with an average TP of 1 mg/l would add about 80,000 kg of phosphorus to the upper river each year.

Indirect impacts of reservoir construction and operation would include land use changes in the areas surrounding the reservoir, and mitigation would likely be required to compensate for losses of terrestrial habitat. The impacted area would include approximately 556 acres of wetlands, primarily the San Antonio River Channel (45 river miles), Cabezo, Charo, and Hord Creeks, portions of Escondido, Ecleto, Hondo, and Cottonwood Creeks, and vegetated wetlands on the floodplain. Inundated uplands would consist of 3,100 acres of woods, brush and shrublands, 24,807 acres of grass and cropland and 192 acres of developed areas[57]. Indirect impacts of reservoir construction and operation would include land use changes in the areas surrounding the reservoir, and mitigation will likely be required to compensate for losses of terrestrial habitat. Impacts to the reservoir area would include replacing terrestrial habitat and lotic aquatic habitat with lentic aquatic habitat. Of particular significance is the loss of bottomland hardwood and riparian communities, and hydric soils along the creek and in the floodplain, which represents important wildlife habitat. Wetland mapping has not been completed for this area, so a detailed inventory of wetland types is not available for this assessment.

The vertebrate community within the area of the proposed reservoir is made up primarily of those found in the Tamaulipan Biotic Province[58]. Vertebrates of this biotic province may include neotropical, grassland, Austroriparian and some Chihuahuan province species. At least 61 species[59] of mammals, 36 species of snakes, 19 species of lizards, 2 species of Terrapene, 3 urodeles and 19 anurans occur in the Tamaulipan province. Six of the 19 species of lizards of this province occur in the state only in this province. One species of land turtle, Texas tortoise (Table 3.16-2) is restricted to the Tamaulipan. Six of the 36 species of snakes known from the Tamaulipan province are unknown from other provinces in the state, however only two of them range as far north as the proposed

[57]USGS, 1990. EROS Center, Color aerial photos.

[58]Espey Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," February, 1986.

[59]Ibid.

Table 3.16-2
Important Species with Habitat in the Project Vicinity (S-16)

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition; not seen since 1989	E	E
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and old juniper	E	T
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions, underground burrows[1]	NL	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of Coastal Plain	NL	T
Reticulated Collared Lizard	*Crotaphytus reticulatus*	South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils;	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks[1]	C2	T
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas, arroyos, canals, ditches and depressions; requires moisture	C2	E
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	NL	T

Source: Texas Parks and Wildlife Department, 1994, Texas Natural Heritage Program Files, March, 1994.
[1]Dixon, J.R., 1987, Amphibians and Reptiles of Texas, Texas A&M Press, College Station, Texas.

reservoir. One species of urodel and 5 of the 19 species of anurans are restricted to this province but probably do not range as far north as the study area[60].

Important species are listed in Appendix B, Tables 5, 20, 26, and 40, respectively, for Bee, Goliad, Karnes, and San Patricio Counties. Species with habitat in the project vicinity are listed in Table 3.16-2. Although no protected species occurrences have been reported in the Goliad reservoir site, several of those listed for Goliad and Karnes Counties have habitat requirements or preferences that indicate that they could be present within the area. Several marine endangered species that may utilize San Antonio Bay should be considered in evaluating the potential effects of the modified inflow regime resulting from this alternative.

With regard to cultural resources, there is some information that numerous cultural resource sites are located within the proposed reservoir[61]. A systematic pedestrian survey of the entire reservoir site will be required to search for surface indications of cultural deposits, while a geomorphologic study to evaluate the potential for buried deposits is also a likely requirement. Sites that may be located within the project area will have to be tested for cultural and historical significance, and for eligibility for listing on the National Register.

The potential environmental effects resulting from the construction and operation of water transport pipelines depends to a large extent on the exact placement of the construction corridor. In general, sensitive habitats, or habitats critical to the survival or protected species are rare or of restricted distribution so that adverse impacts can often be avoided or minimized. More generally distributed habitats, although perhaps important to regional wildlife populations in some areas, may not be so easy to avoid, but because of the limited area affected by these corridors are unlikely to result in significant impacts. Specific construction corridors for these alternatives have not been selected and assessed for this phase of the Trans-Texas Water Program. Instead it has been assumed that adverse impacts would be avoided and minimized to the extent practical by careful corridor selection in subsequent phases using vegetation, land use, and protected species information.

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[60]Ibid.

[61]Texas Historical Commission, Unpublished, September 1993, Letter to Ms. Patsy Light, Friends for Conservation of the San Antonio River Basin.

Environmental effects potentially resulting from using the proposed Medina County injection well field and the Bexar County recharge dams located on the Edwards outcrop are addressed in the Environmental Overview, Section 3.0.1.

3.16.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.16.5 Engineering and Costing

The cost estimate for the dam and reservoir is an update of a previous cost estimate performed by EHA[62]. That cost estimate was updated by multiplying the individual cost components by the ratio (mid 1994/1991) of the relevant Bureau of Reclamation Construction Cost Indexes.

Alternative S-16A: Delivery to Aquifer Injection Wells

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the injection well field in eastern Medina County. The diversion rate from the reservoir, as well as the delivery to the wells would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, 3 required
Water Treatment Plant (Level 2, Table 3.0-4)
Finished Water Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

[62]Espey Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," February, 1986. Austin, Texas.

The reservoir intake and pump station is sized to deliver 9,600 acft/month (103 mgd) through a 78-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 450 feet and an annual water delivery of 115,500 acft/yr. Operating cost of the finished water pumping system was determined for the total pumping head of 310 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $52,160,000 (Table 3.16-3). Operation and maintenance costs, including power, total $28,650,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $80,810,000. For an annual firm yield of 115,500 acft, the resulting annual cost of water is $700 per acft (Table 3.16-3).

Alternative S-16B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to small recharge structures in northwestern Bexar County located over the recharge zone. The diversion rate from the reservoir, as well as the delivery to the recharge structures would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Concerns that the imported water is of different quality than the existing runoff and the need for treatment of the Goliad water will require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of the imported water. To determine the cost to treat the imported water, a typical direct filtration process (Treatment Level 2, see Table 3.0-4) was assumed.

The major facilities required to implement this alternative are:

- Dam and Reservoir
- Reservoir Intake and Pump Station
- Raw Water Pipeline to Recharge Zone or Treatment Plant
- Raw Waterline Booster Pump Stations, 3 required
- Recharge Structures
- Treatment Plant Items (if determined to be needed):
  - Water Treatment Plant (Level 2)
  - Finished Water Pump Station
  - Finished Water Booster Pump Stations, 1 required
  - Transmission Line to Recharge Zone

Table 3.16-3
Cost Estimate Summaries for Goliad Reservoir and Pipeline (S-16)
(Mid- 1994 Prices)

Item	Alt. S-16A Divert and Inject to Aquifer	Alt. S-16B Divert to Recharge Zone	Alt. S-16C Divert to WTP and Municipal System
Capital Costs			
Dam and Reservoir	$102,610,000	$102,610,000	$102,610,000
Transmission and Pumping	175,960,000	177,620,000	124,670,000
Treatment Plant	25,250,000	25,250,000	41,250,000
Delivery System	17,180,000	15,540,000	72,440,000
Total Capital Cost	$321,000,000	$321,020,000[1] $295,770,000[2]	$340,970,000
Engineering, Contingencies, and Legal Costs	104,300,000	104,440,000[1] 95,600,000[2]	106,680,000
Land Acquisition	56,700,000	57,180,000[1] 57,130,000[2]	56,120,000
Environmental Studies and Mitigation	37,740,000	37,510,000	33,810,000
Interest During Construction	36,930,000	38,320,000[1] 35,590,000[2]	36,090,000
Total Project Cost	$556,670,000	$558,470,000[1] $521,600,000[2]	$573,670,000
Annual Costs			
Annual Debt Service	$52,160,000	$52,330,000[1] $48,870,000[2]	$53,750,000
Annual Operation and Maintenance	10,030,000	13,160,000[1] 6,880,000[2]	14,060,000
Annual Power Cost	18,620,000	19,740,000	7,570,000
Total Annual Cost	$80,810,000	$85,230,000[1] $75,490,000[2]	$75,380,000
Available Project Yield (acft/yr)	115,500	115,500	115,500
Annual Cost of Water	$700/acft	$738/acft[1] $654/acft[2]	$653/acft

[1]Cost with treatment prior to surface recharge.
[2]Cost without treatment prior to surface recharge.

The reservoir intake and pump station is sized to deliver 9,600 acft/month (103 mgd) through a 78-inch diameter pipeline. The operating cost was determined for the total raw water pumping head to the treatment plant of 350 feet and an annual water delivery of 115,500 acft/yr. If no treatment plant is required, then the operating cost is determined for the total raw water pumping head to the recharge structures of 1,100 feet. For a treatment plant, the operating cost of the finished water pumping system was determined for a pumping head of 760 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $52,330,000 with a treatment plant and $48,870,000 with no treatment plant (Table 3.16-3). Operation and maintenance costs, including power, total $32,900,000, including the treatment plant and are $26,620,000 without a treatment plant. The annual costs, including debt repayment, interest, and operation and maintenance, total $85,230,000 including the treatment plant and are $75,490,000 without a treatment plant. For an annual firm yield of 115,500 acft, the resulting annual cost of water, including a treatment plant, is $738 per acft, and is $654 per acft without a treatment plant (Table 3.16-3).

Alternative S-16C: Delivery to the Municipal Distribution System

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the South Water Treatment Plant. The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, 3 required
Water Treatment Plant (Level 3, see Table 3.0-4)
Finished Water Pump Station
Transmission Line to Distribution System
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 9,600 acft/month (103 mgd) through a 78-inch diameter pipeline. The operating cost was determined for the total raw water pumping head of 350 feet and an annual water delivery of 115,500 acft/yr. Operating cost of the finished water pumping system was determined for the total pumping head of 300 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $53,750,000 (Table 3.16-3). Operation and maintenance costs, including power, total $21,630,00. The annual costs, including debt repayment, interest, and operation and maintenance, total $75,380,000. For an annual firm yield of 115,500 acft, the resulting annual cost of water is $653 per acft (Table 3.16-3).

3.16.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Reservoir Alternatives (S-16, All)

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   c. GLO Sand and Gravel Removal permits.
   d. GLO Easement for use of state-owned land.
   e. Coastal Coordinating Council review.
   f. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.
3. Land will need to be acquired through either negotiations or condemnation.
4. Relocations for the reservoir include:
   a. Highways and railroads
   b. Other utilities

Requirements Specific to Pipelines (S-16, All)

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.

   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (S-16A)

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer for this large a quantity.
   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.
   d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
   e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
   a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (S-16B)

1. Detailed field investigation of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
   a. TNRCC Water Rights and Storage permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
   c. GLO Sand and Gravel Removal permit.
   d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
   a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
   b. Study of impact on karst geology organisms from a sustained recharge program.
   c. Other environmental studies.

d. Cultural resource studies.

Requirements Specific to Treatment and Distribution (S-16C)

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

3.17 Guadalupe River Unappropriated Streamflow (G-10, -11, -12, -13, -14)

The Guadalupe - San Antonio River Basin Model[63] was used to estimate monthly quantities of unappropriated streamflow potentially available at the following locations (See Figure 3.17-1) in the Guadalupe River Basin:

- Guadalupe River near Gonzales (G-10);
- Guadalupe River near Cuero (G-11);
- Guadalupe River at the Saltwater Barrier (G-12);
- San Marcos River below the Blanco River Confluence (G-13); and
- Guadalupe River at Lake Dunlap (G-14).

Calculations were performed for four scenarios selected to present a reasonable range of unappropriated streamflow potentially available during average (1934-89), drought (1947-56), and minimum year conditions. All scenarios included Trans-Texas Environmental Criteria (see Appendix C), full utilization of existing water rights (including those associated with Applewhite Reservoir), and return flows set to 1988 levels. The four scenarios analyzed are further described as follows:

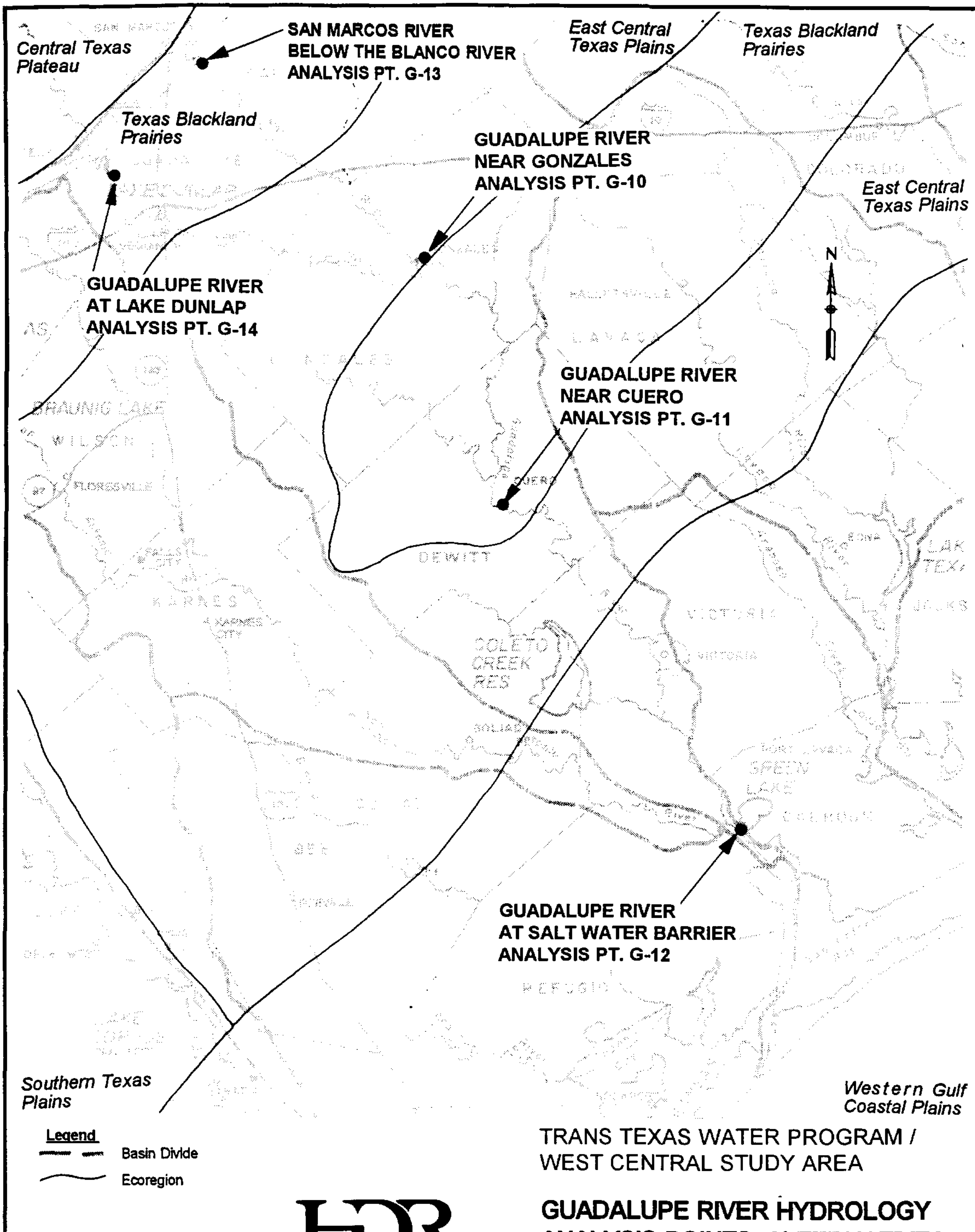
Scenario A: Spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures. Hydropower water rights are subordinated to 365 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 52,600 acft/yr[64].

Scenario B: Spring flows resulting from a fixed Edwards Aquifer pumpage rate of 200,000 acft/yr with existing recharge structures. Hydropower water rights are subordinated to 365 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 66,000 acft/yr[65]. Canyon Lake firm yield is greater than that in Scenario A because inflow passage at Canyon Lake to sustain senior downstream water and hydropower rights is reduced by increased discharge from Comal Springs.

[63]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

[64]Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[65]Ibid.



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GUADALUPE RIVER HYDROLOGY ANALYSIS POINTS, ALTERNATIVES G-10, G-11, G-12, G-13, G-14

FIGURE 3.17-1

Scenario C: Spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures. Hydropower water rights are subordinated to 0 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 74,100 acft/yr[66]. Canyon Lake firm yield is greater than that in Scenario A because inflow passage at Canyon Lake to sustain hydropower water rights is not required.

Scenario D: Spring flows resulting from a fixed Edwards Aquifer pumpage rate of 200,000 acft/yr with existing recharge structures. Hydropower water rights are subordinated to 0 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 86,000 acft/yr[67]. Canyon Lake firm yield is greater than that in Scenario A because inflow passage at Canyon Lake to sustain hydropower water rights is not required and inflow passage at Canyon Lake for senior downstream water rights is reduced by increased discharge from Comal Springs.

Unappropriated streamflow potentially available under each scenario at the five locations was computed subject to maximum diversion rates ranging from 500 acft/month (8 cfs) to 60,000 acft/month (995 cfs). Detailed tables summarizing unappropriated streamflow at each location under each scenario along with pertinent assumptions are included in Appendix D.

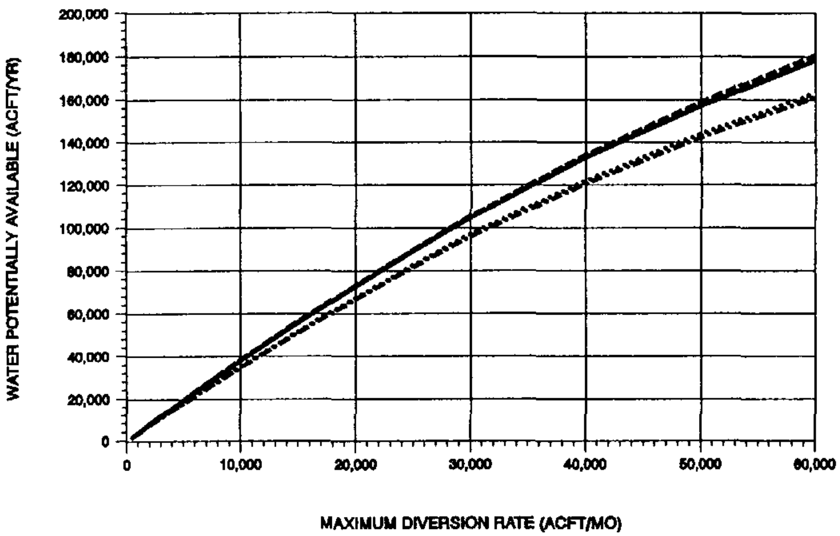
Guadalupe River near Gonzales (G-10)

Figure 3.17-2 presents estimates of unappropriated streamflow potentially available from the Guadalupe river near Gonzales under average, drought, and minimum year conditions. Scenario B (Aquifer Pumpage = 200,000 acft/yr, Hydropower = 365 cfs) yielded the greatest quantity of unappropriated streamflow, while Scenario C (Aquifer Pumpage = 400,000 acft/yr, Hydropower = 0 cfs) produced the least. For the maximum diversion rate considered (60,000 acft/month), the quantity of unappropriated streamflow potentially available under Scenario B would be 180,500 acft/yr for average conditions, 38,300 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956) (Figure

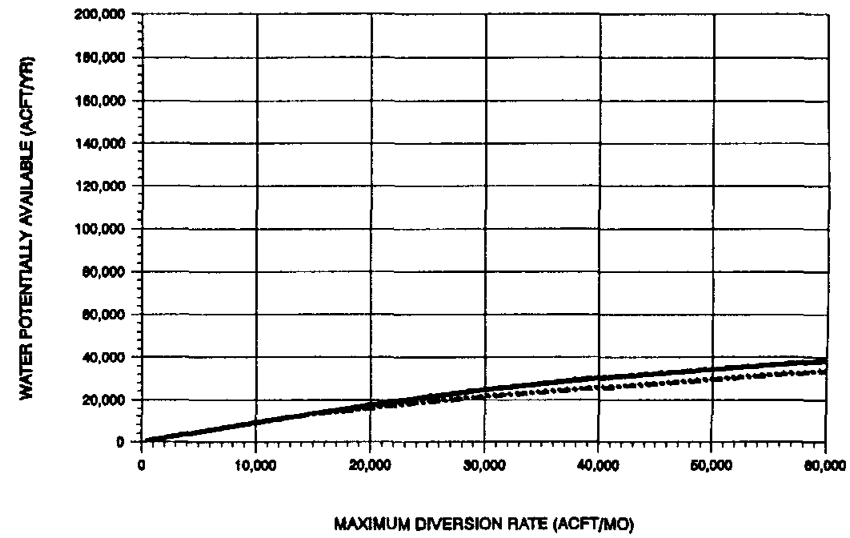
[66]Ibid.

[67]Ibid.

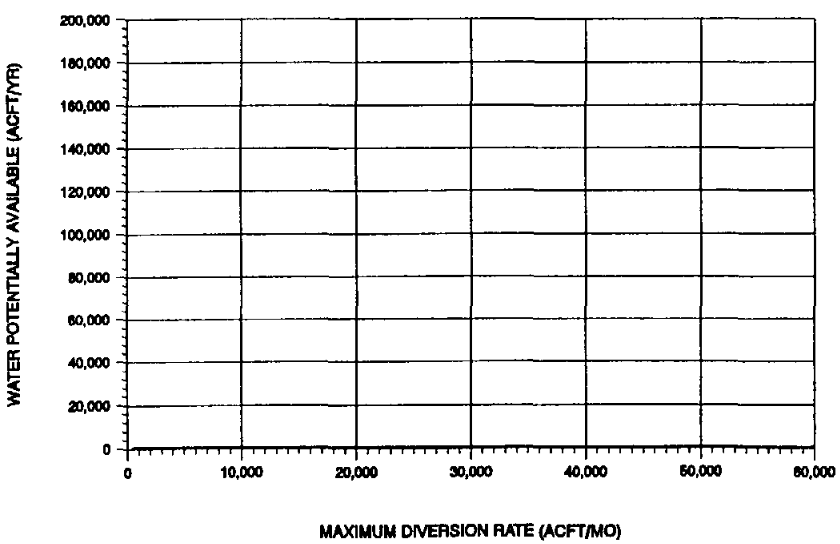
AVERAGE CONDITIONS (1934-89)



DROUGHT CONDITIONS (1947-56)



MINIMUM YEAR (1956)



LEGEND

SYMBOL	SCENARIO	AQUIFER PUMPAGE (ACFT/YR)	HYDRO POWER (CFS)	CANYON YIELD (ACFT/YR)
●●●●●	A	400,000	365	52,600
- - - -	B	200,000	365	66,000
—·—	C	400,000	0	74,100
——	D	200,000	0	86,000

ASSUMPTIONS: 1988 RETURN FLOWS AND APPLEWHITE RESERVOIR INCLUDED.

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UNAPPROPRIATED STREAMFLOW GUADALUPE RIVER NEAR GONZALES ALTERNATIVE G-10

FIGURE 3.17-2

3.17-2). For the same maximum diversion rate, the quantity of unappropriated streamflow potentially available under Scenario C would be 159,600 acft/yr for average conditions, 33,200 acft/yr for drought conditions, and 0 acft/yr for minimum year (1956).

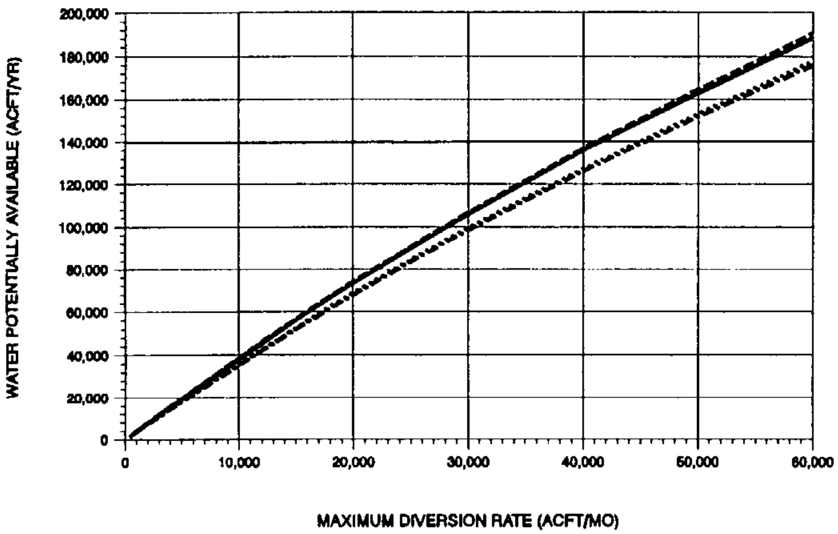
Freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier, would be reduced by 146,800 acft/yr (9 percent) for Scenario B and 129,400 acft/yr (8 percent) for Scenario C, for average conditions with a maximum diversion rate of 60,000 acft/month. As indicated in Figure 3.17-2, unappropriated streamflow estimates near Gonzales are more significantly affected by the Edwards Aquifer pumpage rate than by hydropower water rights. When the Edwards Aquifer pumpage rate was decreased from 400,000 acft/yr to 200,000 acft/yr, unappropriated streamflow increased by about 11 percent for average conditions and 12 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month. When the hydropower water rights were subordinated from 365 cfs to 0 cfs, however, unappropriated streamflow decreased by 1 percent for average conditions and 1 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month.

Guadalupe River near Cuero (G-11)

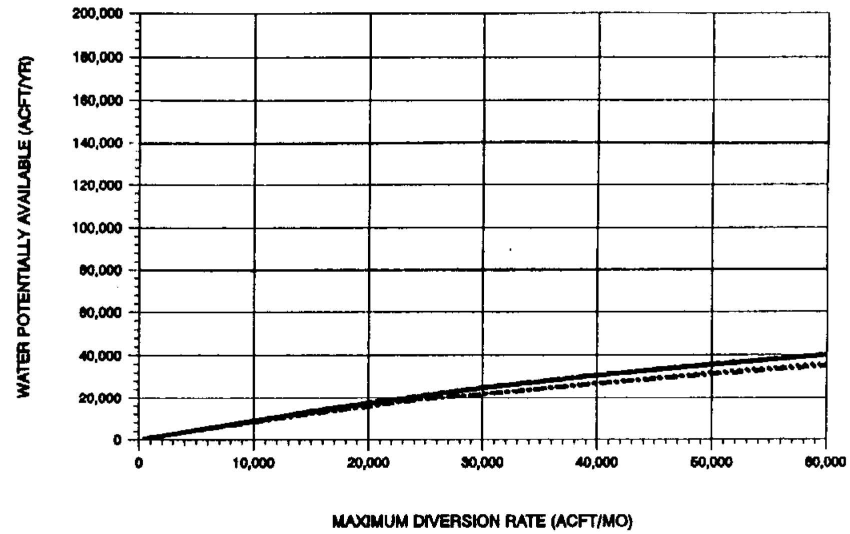
Figure 3.17-3 presents estimates of unappropriated streamflow potentially available from the Guadalupe River near Cuero under average, drought, and minimum year conditions. Scenario B (Aquifer Pumpage = 200,000 acft/yr, Hydropower = 365 cfs) yielded the greatest quantity of unappropriated streamflow, while Scenario C (Aquifer Pumpage = 400,000 acft/yr, Hydropower = 0 cfs) produced the least. For the maximum diversion rate considered (60,000 acft/month), the quantity of unappropriated streamflow potentially available under Scenario B would be 190,400 acft/yr for average conditions, 40,000 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956). For the same maximum diversion rate, the quantity of unappropriated streamflow potentially available under Scenario C would be 175,000 acft/yr for average conditions, 34,900 acft/yr for drought conditions, and 0 acft/yr for minimum year (1956) (Figure 3-17-3).

Freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier, would be reduced by 168,500 acft/yr (10 percent) for Scenario B and 154,600 acft/yr (10 percent for Scenario C, for average conditions with a maximum diversion rate of 60,000

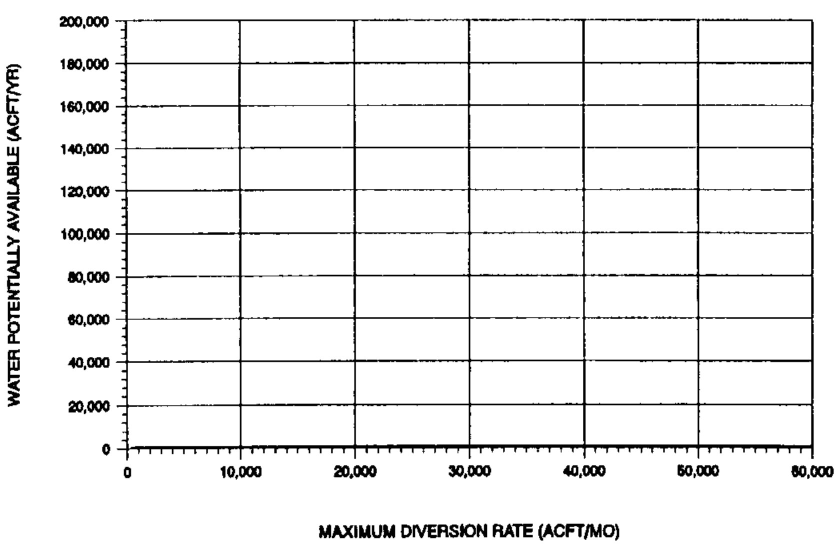
AVERAGE CONDITIONS (1934-89)



DROUGHT CONDITIONS (1947-56)



MINIMUM YEAR (1956)



LEGEND

SYMBOL	SCENARIO	AQUIFER PUMPAGE (ACFT/YR)	HYDRO POWER (CFS)	CANYON YIELD (ACFT/YR)
● ● ● ● ●	A	400,000	365	52,600
- - - -	B	200,000	365	66,000
—·—	C	400,000	0	74,100
——	D	200,000	0	86,000

ASSUMPTIONS: 1988 RETURN FLOWS AND APPLEWHITE RESERVOIR INCLUDED.

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UNAPPROPRIATED STREAMFLOW GUADALUPE RIVER NEAR CUERO ALTERNATIVE G-11

FIGURE 3.17-3

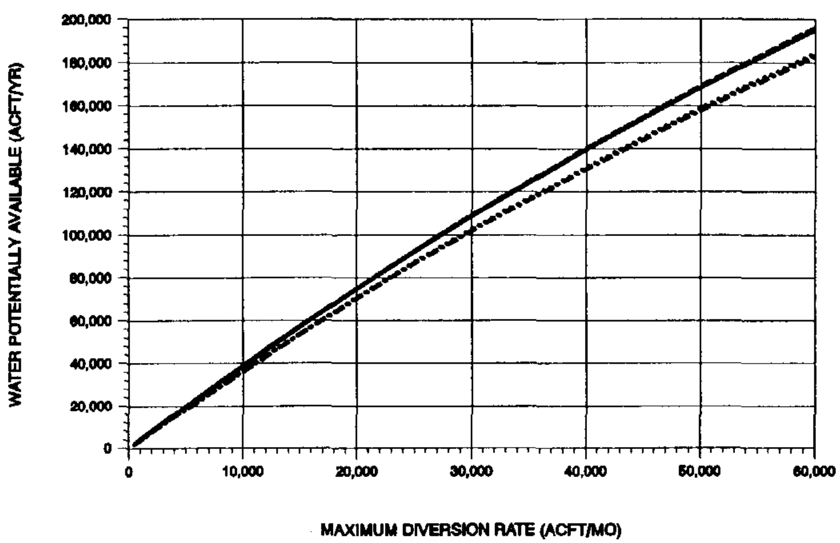
acft/month. As indicated in Figure 3.17-3, unappropriated streamflow estimates near Cuero are more significantly affected by the Edwards Aquifer pumpage rate than by hydropower water rights. When the Edwards Aquifer pumpage rate was decreased from 400,000 acft/yr to 200,000 acft/yr, unappropriated streamflow increased by about 7 percent for average conditions and 13 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month. When the hydropower water rights were subordinated from 365 cfs to 0 cfs, however, unappropriated streamflow decreased by 1 percent for average conditions and 2 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month.

Guadalupe River at the Saltwater Barrier (G-12)

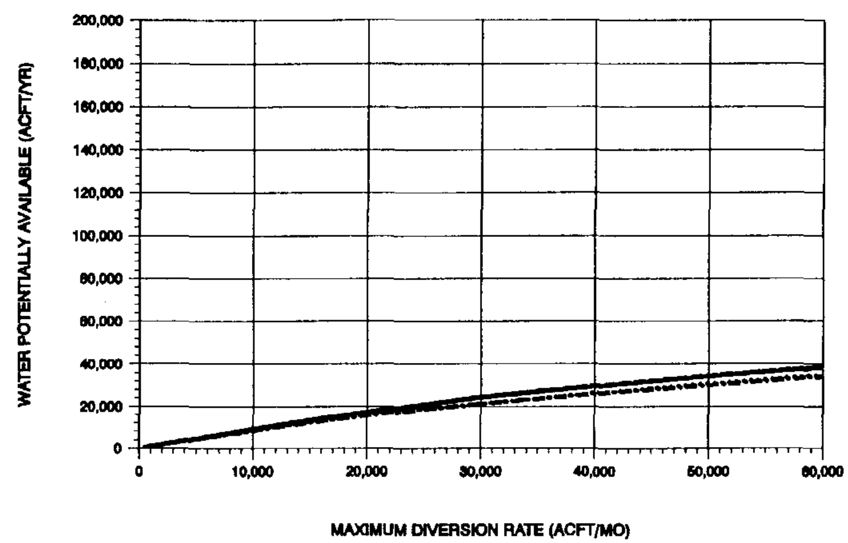
Figure 3.17-4 presents estimates of unappropriated streamflow potentially available from the Guadalupe River at the Saltwater Barrier under average, drought, and minimum year conditions. Again, Scenario B (Aquifer Pumpage = 200,000 acft/yr, Hydropower = 365 cfs) yielded the greatest quantity of unappropriated streamflow, while Scenario C (Aquifer Pumpage = 400,000 acft/yr, Hydropower = 0 cfs) produced the least. For the maximum diversion rate of 60,000 acft/month, the quantity of unappropriated streamflow potentially available under Scenario B would be 196,000 acft/yr for average conditions, 38,300 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956). For the same maximum diversion rate, the quantity of unappropriated streamflow potentially available under Scenario C would be 182,200 acft/yr for average conditions, 33,800 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956).

Freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier, would be reduced by 196,000 acft/yr (12 percent) for Scenario B and 182,200 acft/yr (11 percent) for Scenario C, for average conditions with a maximum diversion rate of 60,000 acft/month. As indicated in Figure 3.17-4, unappropriated streamflow estimates at the Saltwater Barrier are more significantly affected by the Edwards Aquifer pumpage rate than by hydropower water rights. When the Edwards Aquifer pumpage rate was decreased from 400,000 acft/yr to 200,000 acft/yr, unappropriated streamflow increased by about 6 percent for average conditions and 12 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month. When the hydropower water rights were subordinated

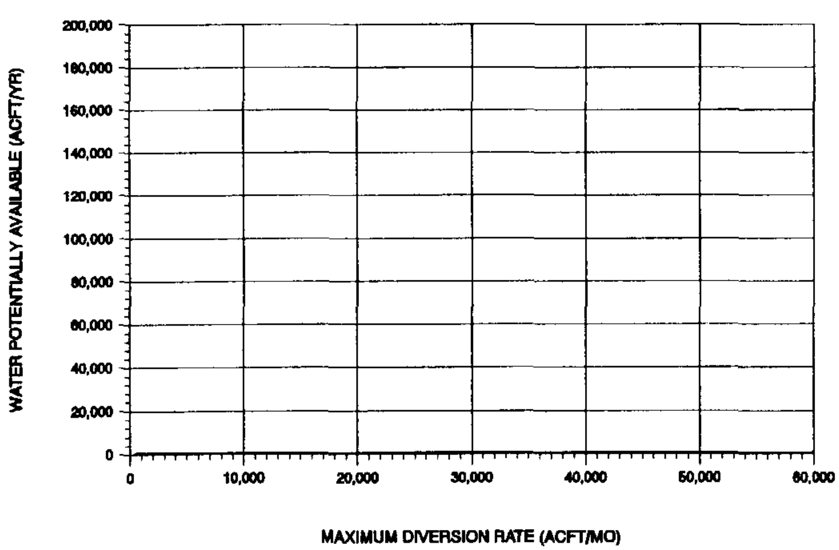
AVERAGE CONDITIONS (1934-89)



DROUGHT CONDITIONS (1947-56)



MINIMUM YEAR (1956)



LEGEND

SYMBOL	SCENARIO	AQUIFER PUMPAGE (ACFT/YR)	HYDRO POWER (CFS)	CANYON YIELD (ACFT/YR)
• • • • •	A	400,000	365	52,600
- - - -	B	200,000	365	66,000
—·—	C	400,000	0	74,100
——	D	200,000	0	86,000

ASSUMPTIONS: 1988 RETURN FLOWS AND APPLEWHITE RESERVOIR INCLUDED.

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UNAPPROPRIATED STREAMFLOW GUADALUPE RIVER AT SALT WATER BARRIER, ALTERNATIVE G-12

FIGURE 3.17-4

from 365 cfs to 0 cfs, however, unappropriated streamflow decreased by less than 1 percent for average conditions and 2 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month.

San Marcos River Below the Blanco River Confluence (G-13)

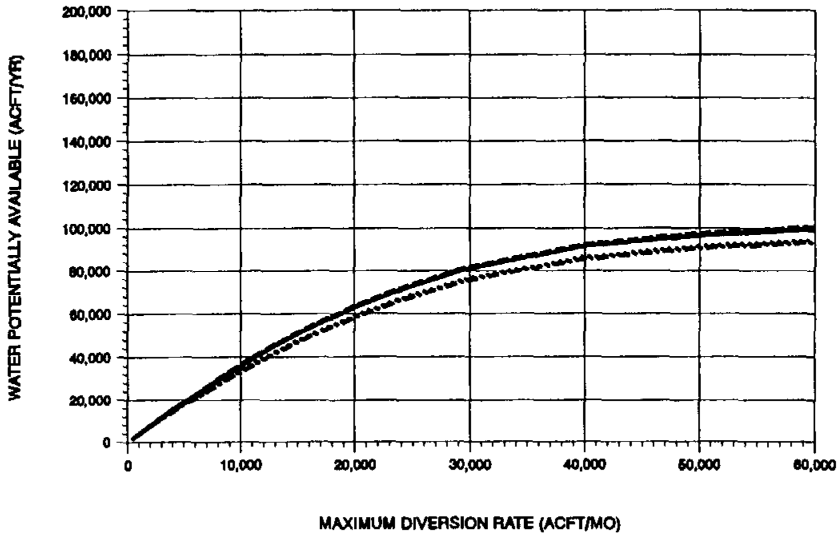
Figure 3.17-5 presents estimates of unappropriated streamflow potentially available from the San Marcos River below the Blanco River confluence under average , drought, and minimum year conditions. Once again, Scenario B (Aquifer Pumpage = 200,000 acft/yr, Hydropower = 365 cfs) yielded the greatest quantity of unappropriated streamflow, while Scenario C (Aquifer Pumpage = 400,000 acft/yr, Hydropower = 0 cfs) produced the least. For the maximum diversion rate of 60,000 acft/month, the quantity of unappropriated streamflow potentially available under Scenario B would be 100,500 acft/yr for average conditions, 21,300 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956). For the same maximum diversion rate, the quantity of unappropriated streamflow potentially available under Scenario C would be 93,300 acft/yr for average conditions, 20,200 acft/yr for drought conditions, and 0 acft/yr for minimum year (1956).

Freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier would be reduced by 66,800 acft/yr (4 percent) for Scenario B and 62,000 acft/yr (4 percent) for Scenario C, for average conditions with a maximum diversion rate of 60,000 acft/month. As indicated in Figure 3.17-5, unappropriated streamflow estimates for the San Marcos River below the Blanco River confluence are more significantly affected by the Edwards Aquifer pumpage rate than by hydropower water rights. When the Edwards Aquifer pumpage rate was decreased from 400,000 acft/yr to 200,000 acft/yr, unappropriated streamflow increased by about 7 percent for average conditions and 5 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month. When the hydropower water rights were subordinated from 365 cfs to 0 cfs, however, unappropriated streamflow decreased by 1 percent for average conditions and 1 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month.

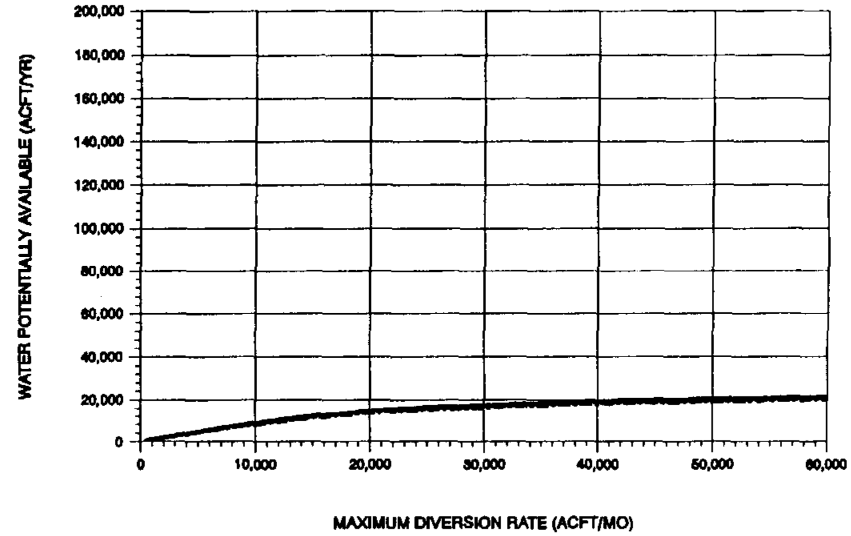
Guadalupe River at Lake Dunlap (G-14)

Figure 3.17-6 presents estimates of unappropriated streamflow potentially available from the Guadalupe River at Lake Dunlap under average, drought, and minimum year

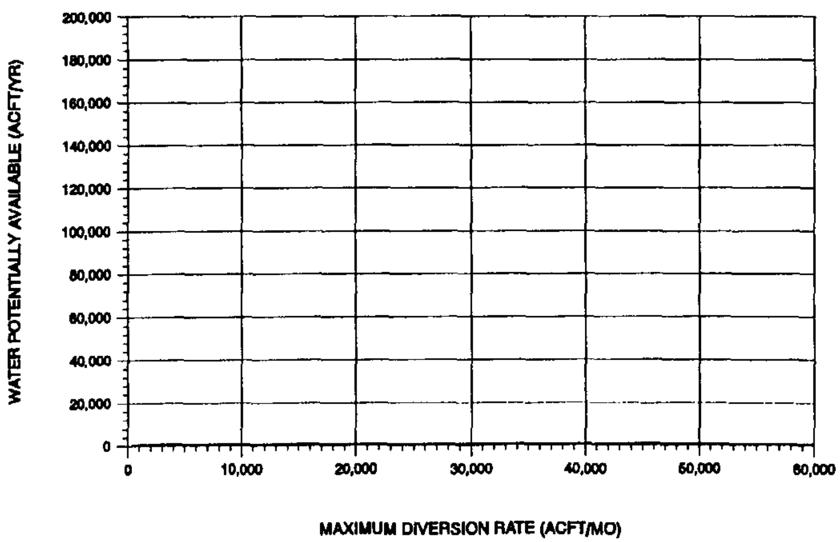
AVERAGE CONDITIONS (1934-89)



DROUGHT CONDITIONS (1947-56)



MINIMUM YEAR (1956)



LEGEND

SYMBOL	SCENARIO	AQUIFER PUMPAGE (ACFT/YR)	HYDRO POWER (CFS)	CANYON YIELD (ACFT/YR)
•••••	A	400,000	365	52,600
- - - -	B	200,000	365	66,000
—-—	C	400,000	0	74,100
——	D	200,000	0	86,000

ASSUMPTIONS: 1988 RETURN FLOWS AND APPLEWHITE RESERVOIR INCLUDED.

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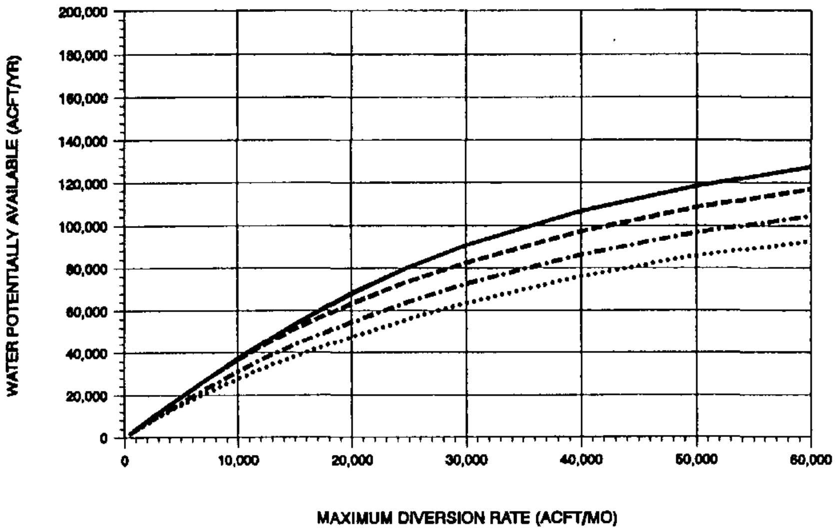
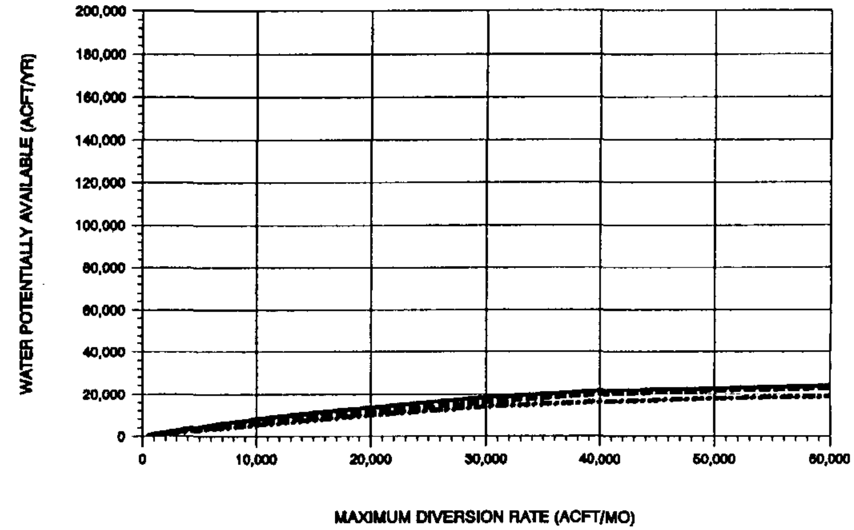
UNAPPROPRIATED STREAMFLOW SAN MARCOS RIVER BELOW BLANCO RIVER CONFLUENCE, ALTERNATIVE G-13

FIGURE 3.17-5

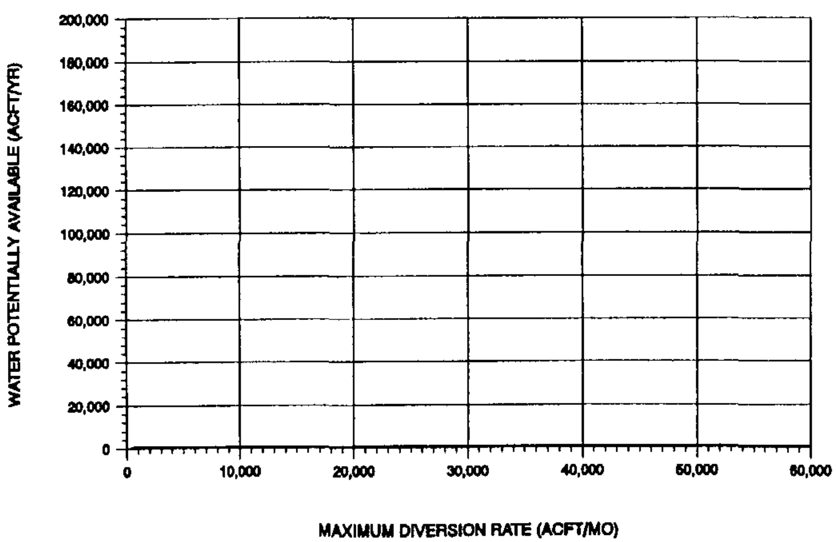
AVERAGE CONDITIONS (1934-89)



DROUGHT CONDITIONS (1947-56)



MINIMUM YEAR (1956)



LEGEND

SYMBOL	SCENARIO	AQUIFER PUMPAGE (ACFT/YR)	HYDRO POWER (CFS)	CANYON YIELD (ACFT/YR)
• • • • •	A	400,000	365	52,600
- - - -	B	200,000	365	66,000
— - —	C	400,000	0	74,100
———	D	200,000	0	86,000

ASSUMPTIONS: 1988 RETURN FLOWS AND APPLEWHITE RESERVOIR INCLUDED.

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UNAPPROPRIATED STREAMFLOW GUADALUPE RIVER AT LAKE DUNLAP ALTERNATIVE G-14

FIGURE 3.17-6

conditions. Unlike the other four diversion locations analyzed in the basin, Scenario D (Aquifer Pumpage = 200,000 acft/yr, Hydropower = 0 cfs) yielded the greatest quantity of unappropriated streamflow, while Scenario A (Aquifer Pumpage = 400,000 acft/yr, Hydropower = 365 cfs) produced the least. For the maximum diversion rate of 60,000 acft/month, the quantity of unappropriated streamflow potentially available under Scenario D would be 127,500 acft/yr for average conditions, 23,700 acft/yr for drought conditions, and 0 acft/yr for the minimum year (1956). For the same maximum diversion rate, the quantity of unappropriated streamflow potentially available under Scenario A would be 92,400 acft/yr for average conditions, 18,400 acft/yr for drought conditions, and 0 acft/yr for minimum year (1956). Scenario D yielded the greatest quantity of unappropriated streamflow at Lake Dunlap, rather than Scenario B (Aquifer Pumpage 200,000 acft/yr, Hydropower = 365 cfs), due to the location of Lake Dunlap upstream, rather than downstream, of the hydropower water rights. On the other hand, Scenario A (Aquifer Pumpage = 400,000 acft/yr, Hydropower = 365 cfs) produced the least quantity of unappropriated streamflow potentially available at Lake Dunlap due to the lesser springflows and greater downstream hydropower water rights (365 cfs).

Freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier, would be reduced by 64,700 acft/yr (4 percent) under Scenario A and 88,000 acft/yr (5 percent) under Scenario D, for average conditions with a maximum diversion rate of 60,000 acft/month. Although the hydropower water rights had a more significant impact on unappropriated streamflow at this location than any of the other Guadalupe River Basin locations considered (i.e., G-10, -11, -12, -13), the assumed Edwards Aquifer pumpage rate still produced the greater change in unappropriated streamflow potentially available at Lake Dunlap (See Figure 3.17-6). When the Edwards Aquifer pumpage rate was decreased from 400,000 acft/yr to 200,000 acft/yr, unappropriated streamflow increased by about 24 percent for average conditions and 24 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month. When the hydropower water rights were subordinated from 365 cfs to 0 cfs, however, unappropriated streamflow increased by 11 percent for average conditions and 3 percent for drought conditions, assuming a maximum diversion rate of 60,000 acft/month.

3.18 Diversion of San Marcos River Unappropriated Streamflow (G-13)

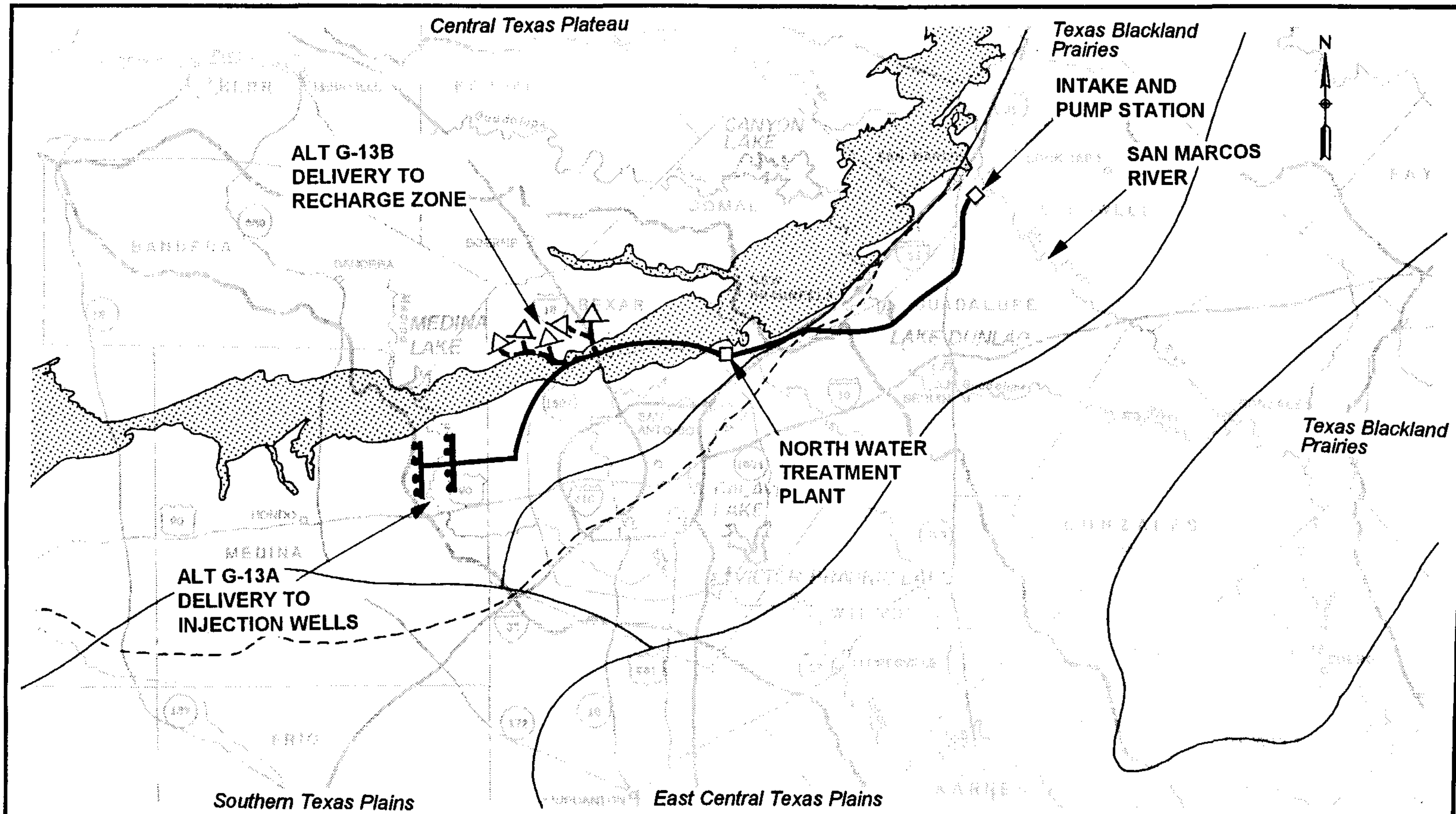
3.18.1 Description of Alternative

This alternative includes the diversion of potentially available unappropriated streamflow from the San Marcos River below the Blanco River confluence and delivery to the West Central Study Area. Section 3.17 describes the availability of water for four hydrologic scenarios at various points in the Guadalupe River basin and from that analysis a single scenario was chosen for sizing and costing this alternative. The hydrologic analysis found that no firm yield exists for this alternative. For treatment and distribution to a municipal system, a firm yield is essential to assure a dependable water supply during drought conditions to justify the investment of funds. Consequently, as no firm yield is available, the treatment and distribution option for this water supply was not considered. For the recharge options, either by well injection or recharge structures, the aquifer provides significant storage that provides a yield for the recharge alternatives. Aquifer recharge options have been studied based on average drought flows for the 10-year period from 1947-1956. For development of unit costs, the yield for these options was estimated using the average availability during the historic drought flow sequence from 1947 to 1956.

For the recharge options, a river intake and pump station would be constructed just downstream of the San Marcos and Blanco River confluence. The non-uniform pattern of availability requires sizing the pump station and pipeline for a much larger capacity than the average annual yield of the project. Consequently, to reduce the cost of the conveyance facilities, a small off-channel balancing reservoir near the river intake is proposed to allow pumping at a more uniform rate and thereby decrease the size of the facilities. For study purposes, the site chosen for off-channel storage is immediately south of the diversion on a small unnamed tributary of the river. The diversion location and delivery facilities are shown on Figure 3.18-1.

3.18.2 Available Yield

The yield of the proposed project was determined in terms of average recharge (1934-89) and drought average recharge (1947-56). The scenario chosen to analyze the project included the following hydrologic assumptions:



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SAN MARCOS RIVER ALTERNATIVE G-13

FIGURE 3.18-1

- Spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures;
- Full utilization of existing water rights (including those associated with Applewhite Reservoir);
- Return flows set at 1988 levels; and
- Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr[68].

The Guadalupe - San Antonio River Basin Model[69] (GSA Model) was used to estimate monthly quantities of unappropriated streamflow potentially available at the diversion location subject to the Trans-Texas Environmental Criteria which, in turn, were used to compute the yield of the project. An off-channel reservoir site was identified near the diversion location with a conservation capacity of 5,900 acft. Streamflow at the river diversion location would be diverted into the off-channel reservoir as available at a non-uniform rate. The off-channel reservoir would serve as a balancing reservoir, allowing for water to be delivered at a constant uniform pumping rate thereby decreasing the size and cost of the pumping and pipeline facilities. An optimization of the cost of the project in terms of the maximum diversion rate from the river and the uniform diversion rate from the off-channel reservoir was performed. The optimization found that the lowest unit cost of water was with the combination of a maximum diversion rate from the river of 10,000 acft per month and a uniform diversion rate from the off-channel reservoir of 4,800 acft per month. The average recharge that could be obtained for the 1934-89 period was computed to be 23,500 acft/yr. The drought average recharge for the 1947-56 period was computed to be 6,600 acft/yr. The analysis showed that streamflow could be diverted from the San Marcos River about 31 percent of the time on average (1934-89) and 8 percent of the time during the drought period (1947-56). Monthly median streamflows, both at the river diversion location and at the Salt Water Barrier, were essentially unaffected. Monthly median streamflows and annual streamflows averaged by decile, with and without the

[68]Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[69]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study." Volumes I, II, and III, Edwards Underground Water District, September, 1993.

project, are presented in Figure 3.18-2 both at the site and at the Saltwater Barrier. Freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier would be reduced by an average of 23,500 acft/yr or about 2 percent.

3.18.3 Environmental Issues

In Alternative G-13, water would be diverted from the San Marcos River below the Blanco River confluence to a proposed off-channel reservoir (Figure 3.18-1) that would be located immediately south of the San Marcos River and east of IH35. The dam and impoundment together with the water treatment plant and appurtenances would cover 1,213 acres. Water from the reservoir would be treated and piped to San Antonio for recharge of the Edwards Aquifer. This would be accomplished through distribution of water to an injection well field in Medina County (G-13A), or the impoundment structures in the Edwards recharge zone north of San Antonio (G-13B). This alternative employs the same pipeline routes as the Guadalupe and Colorado River diversion alternatives (G-14, G-15, and C-10 through C-13, respectively) discussed in Sections 3.19, 3.20, and 3.28. Use of the Medina County injection well field and the Edwards Aquifer recharge zone are addressed in Sections 3.4, 3.9 and 3.0.2, Environmental Overview.

The land use and habitat types in the project area reflect its location at the confluence of the Blackland Prairies and Post Oak Savannah vegetational regions (Figure 3.18-1)[70,71]. The soils of the proposed off-channel reservoir and pipeline corridors include a range from light-colored, acid sandy loams (upland), and dark-gray acid sandy loams and clays (bottomland) to fairly uniform dark-colored calcareous clays. Climax grasses of the Post Oak Savannah are little bluestem, Indian grass, switch grass, purpletop, silver bluestem and Texas wintergrass. The overstory is primarily post oak and blackjack oak. The Blackland Prairies are also characterized by these grasses, as well as sideoats grama, hairy

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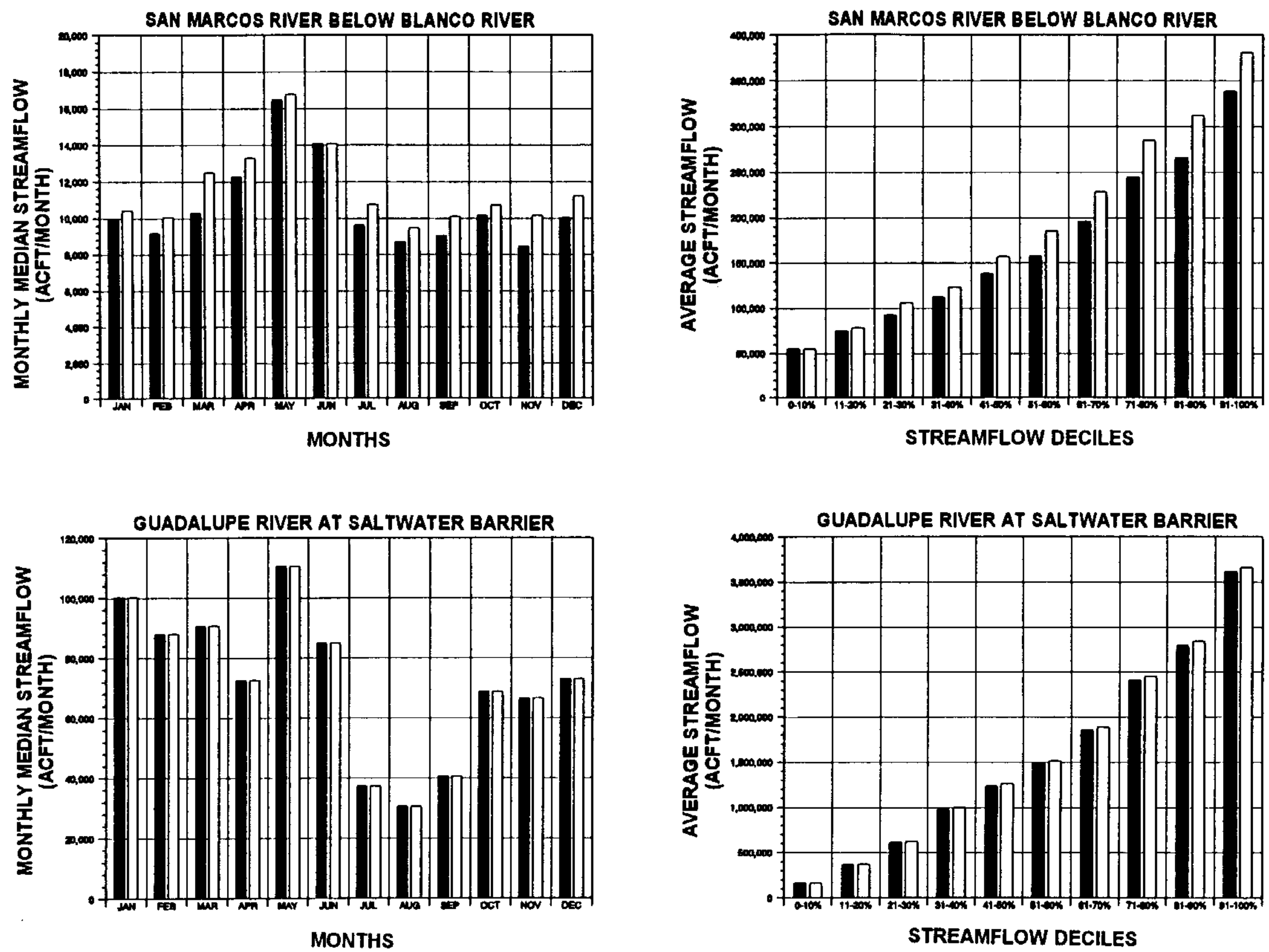
[70]Gould, F.W., 1975, "The Grasses of Texas", Texas A&M University Press, College Station, Texas.

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



LEGEND

■ WITH PROJECT
□ WITHOUT PROJECT

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CHANGES IN STREAMFLOW SAN MARCOS RIVER DIVERSION ALTERNATIVE G-13

FIGURE 3.18 - 2

grama and tall dropseed. Post oak and blackjack oak are also present as overstory, although only small remnants of this upland woodland are generally present in this ecoregion[72].

The proposed site for the off-channel reservoir and the northeastern half of the proposed pipelines are primarily cropland (80 percent)[73,74]. The injection well field and the southwestern half of the pipelines cross a region that is about 50 percent developed, 20 percent cropland and the remainder a mix of brush, shrub and grassland[75]. With the majority of the project area located in either cropland or urbanized areas, terrestrial impacts can generally be avoided or minimized by careful selection of the pipeline ROW. To achieve this, the pipeline ROW alignment should avoid the small areas of wildlife habitat in the live oak-mesquite-ashe juniper parks and live oak-ashe juniper woods north of San Antonio, as well as the mesquite-live oak-bluewood parks found in eastern Medina County.[76].

The pipeline construction ROWs would result in disturbance to about 970 acres for the Medina well field alternative (G-13A), or about 727 acres for the recharge zone alternative (G-13B). Permanently maintained ROW will amount to 292 acres, or 218 acres, for the two alternatives, respectively. The San Marcos River intake structure would be located downstream of the critical habitat reach. Its construction would impact less than 0.25 acre of riparian woodland. Since the San Marcos River is a popular recreational waterway, the river intake structure should be compatible with the surrounding uses.

The Texas Natural Heritage Program does not report any endangered or threatened species directly along the proposed pipeline corridor through the primarily cropland plain from San Marcos to San Antonio. However, some species have been reported in the vicinity of San Antonio (Appendix B, Tables 6 and 37). Impacts and affected environments in the recharge zone and injection field are addressed more specifically in Sections 3.2, 3.8, 3.9,

[72]Correl, D.S. and M.C. Johnston, 1979, "Manual of the Vascular Plants of Texas", Texas Research Foundation, Renner, Texas.

[73]TPWD, 1984, "The Vegetation Types of Texas," Austin, Texas.

[74]USGS, 1990, NAPP Black and White Aerial Photography, EROS Data Center, Sioux Falls, South Dakota.

[75]TPWD, 1984, "The Vegetation Types of Texas," Austin, Texas.

[76]Ibid.

and 3.10. Along the pipeline corridor the urban fringe areas of woodland, brushland, shrubland, and grassland in northern Bexar and eastern Medina Counties may provide habitat for several endangered or threatened species, such as the Texas tortoise, reticulate collared Lizard, black-capped vireo, golden-cheeked warbler and indigo snake. Surveys for protected species or other biological resources of restricted distribution would be conducted within the proposed construction corridor where described habitat is present.

The upper San Marcos River is spring-fed from the Edwards Aquifer and Sink Creek. During times of flood flows, additional water comes from runoff and normally dry creeks. The upper San Marcos River has a relatively constant temperature regime and stable water quality until it reaches the existing San Marcos wastewater treatment plant, about 0.5 mile above the confluence with the Blanco River. Minimum springflow since 1956 has been 46 cfs and the maximum 427 cfs with the average being 165 cfs[77]. The San Marcos River is a major tributary to the Guadalupe River and has provided most of the Guadalupe River flow discharge during drought periods. Endangered or threatened species critical habitat in the San Marcos River is primarily within the reach that runs from the headwaters (Spring Lake) to just above the Blanco River confluence (see Section 3.10).

Although lacking a firm yield, the proposed project would have an average drought period yield of 6600 acft/yr and a period of record average yield of 23,500 acft/yr while complying with the Trans-Texas criteria for new diversion projects. Implementation of alternative G-13 would reduce monthly median flows below the diversion point by 5 to 10 percent during most months. Maximum reductions on the order of 1600-2000 acft/mo (about 20 percent) would occur in March and November (Figure 3.18-2). Although reductions in average flows would occur in all but the lowest streamflow deciles, the largest changes would reduce the upper stream flow deciles by 15 to 20 percent or 40-50,000 acft/yr (Figure 3.18-2). Changes in monthly median steamflows in the Guadalupe at the saltwater barrier (i.e. gaged inflows to San Antonio Bay) are not perceptible at the scale used for Figure 3.18-2, although slight reductions in average streamflow can be seen in all but the lowest three flow deciles (Figure 3.18-2). Annual average flows at the salt water barrier

[77]Longley, Glenn, 1975, "Environmental Assessment Upper San Marcos River Watershed," Environmental Sciences of San Marcos, San Marcos, Texas.

would be reduced by 23,613 acre feet.

The potential environmental effects resulting from the construction and operation of water transport pipelines depends to a large extent on the exact placement of the construction corridor. In general, sensitive habitats, or habitats critical to the survival or protected species are rare or of restricted distribution so that adverse impacts can often be avoided or minimized. More generally distributed habitats, although perhaps important to regional wildlife populations in some areas, may not be so easy to avoid, but because of the limited area affected by these corridors, they are unlikely to result in significant impacts. A specific construction corridor for the segment between the proposed reservoir and the south side water treatment facility has not been selected and assessed for this phase of the Trans-Texas Water Program. From that point to the two recharge alternatives, the proposed pipeline corridors would be the same as those assessed in Section 3.4.3, and discussed in the Environmental Overview, Section 3.0.1. Instead, it has been assumed that adverse impacts would be avoided or minimized to the extent practical by careful corridor selection in subsequent phases using the vegetation, land use, and protected species information compiled during Phase 1, and that residual impacts for all alternatives would be similar.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources.

3.18.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.18.5 Engineering and Costing

Alternative G-13A: Delivery to Aquifer Injection Wells

For this alternative, the potentially available run-of-river water would be pumped from the San Marcos River at a diversion downstream of the Blanco River confluence. The run-of-river water would be pumped to a balancing off-channel reservoir at a non-uniform rate. From the off-channel reservoir, water would be pumped, also at a non-uniform annual rate, to the injection well field in eastern Medina County. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to municipal and irrigation wells and possibly to springflow. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

River Intake and Pump Station
Raw Water Pipeline to Off-Channel Reservoir
Off-channel Reservoir and Dam
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Water Pipeline Booster Pump Station
Water Treatment Plant (Level 2, see Table 3.0-4)
Finished Water Pump Stations
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The river intake and pump station is sized to deliver 10,000 acft/month (166 cfs) through a 78-inch diameter pipeline. The operating cost was determined for the river pump station static lift of 80 feet and a long-term average annual water delivery of 23,500 acft/year. The off-channel reservoir usable storage volume is 5,900 acft. The reservoir intake and pump station is sized to deliver 4,800 acft/month (80 cfs) through a 54-inch diameter pipeline. The operating cost for conveyance of the water to the treatment plant is for a static lift of 400 feet and an annual water delivery of 23,500 acft/year. Operating cost of the finished water pumping system was determined for the static lift of 50 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $16,190,000 (Table 3.18-1). Operation and maintenance costs, including power, total $7,830,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $24,020,000. For a drought average availability of 6,600 acft, the resulting annual cost of water is $3,640 per acft (Table 3.18-1).

Table 3.18-1
Cost Estimate Summaries for San Marcos River Diversion (G-13)
(Mid- 1994 Prices)

Item	Alt. G-13A Divert to Injection Wells	Alt. G-13B Divert to Recharge Structures
Capital Costs		
River Diversion, Transmission and Pumping	$90,240,000	75,540,000
Off-Channel Reservoir	3,860,000	3,860,000
Treatment Plant	16,400,000	N/A
Delivery System	7,670,000	5,470,000
Total Capital Cost	$118,170,000	$84,870,000
Engineering, Contingencies, and Legal Costs	37,490,000	26,530,000
Land Acquisition	2,790,000	2,580,000
Environmental Studies and Mitigation	4,610,000	3,050,000
Interest During Construction	9,730,000	5,790,000
Total Project Cost	$172,790,000	$122,820,000
Annual Costs		
Annual Debt Service	$16,190,000	$11,510,000
Annual Operation and Maintenance	4,670,000	1,340,000
Annual Power Cost	3,160,000	3,110,000
Total Annual Cost	$24,020,000	$15,960,000
Available Project Yield (acft/yr)	6,600	6,600
Annual Cost of Water	$3,640/acft	$2,420/acft

Alternative G-13B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the potentially available run-of-river water would be pumped from the San Marcos River at a diversion downstream of the Blanco River confluence. The run-of-river water would be pumped to a balancing off-channel reservoir at a non-uniform rate. From the off-channel reservoir, water would be pumped, also at a non-uniform annual rate, to small recharge structures in northwestern Bexar County located over the recharge zone. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly to springflows.

The major facilities required to implement this alternative are:

River Intake and Pump Station
Raw Water Pipeline to Off-Channel Reservoir
Off-channel Reservoir and Dam
Reservoir Intake and Pump Station
Recharge Structures
Transmission Line to Recharge Zone

The reservoir intake and pump station is sized to deliver 10,000 acft/month (166 cfs) through a 78-inch diameter pipeline. The operating cost was determined for the off-channel reservoir pump station lift to the recharge structures of 450 feet and an annual water delivery of 23,500 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $11,510,000 (Table 3.18-1). Operation and maintenance costs, including power, total $4,450,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $15,960,000. For a drought average availability of 6,600 acft/yr, the resulting annual cost of water is $2,420 per acft (Table 3.18-1).

3.18.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Reservoir Alternatives (G-13, All)

1. It will be necessary to obtain these permits for the San Marcos River diversion and the off-channel storage reservoir:
    a. TNRCC Water Right and Storage permits.
    b. TNRCC Interbasin Transfer Approval.

   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal permits.
   e. GLO Easement for use of state-owned land.
   f. Coastal Coordinating Council review.
   g. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.
3. Land will need to be acquired either through negotiations or condemnation.
4. Relocations for the reservoir include:
   a. Highways
   c. Other utilities

<u>Requirements Specific to Pipelines (G-13, All)</u>

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

<u>Terminal Delivery Alternatives</u>

<u>Requirements Specific to Injection Wells (G-13A)</u>

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests.
   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.
   d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
   e. Source water quality testing for Safe Drinking Water Act regulated constituents.

2. Necessary permits:
    a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (G-14B)

1. Detailed field investigation of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
    a. TNRCC Water Rights and Storage permit.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
    c. GLO Sand and Gravel Removal permit.
    d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
    a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
    b. Study of impact on karst geology organisms from a sustained recharge program.
    c. Other environmental studies.
    d. Cultural resource studies.

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3.19 Diversion of Guadalupe River at Lake Dunlap Unappropriated Streamflow (G-14)

3.19.1 Description of Alternative

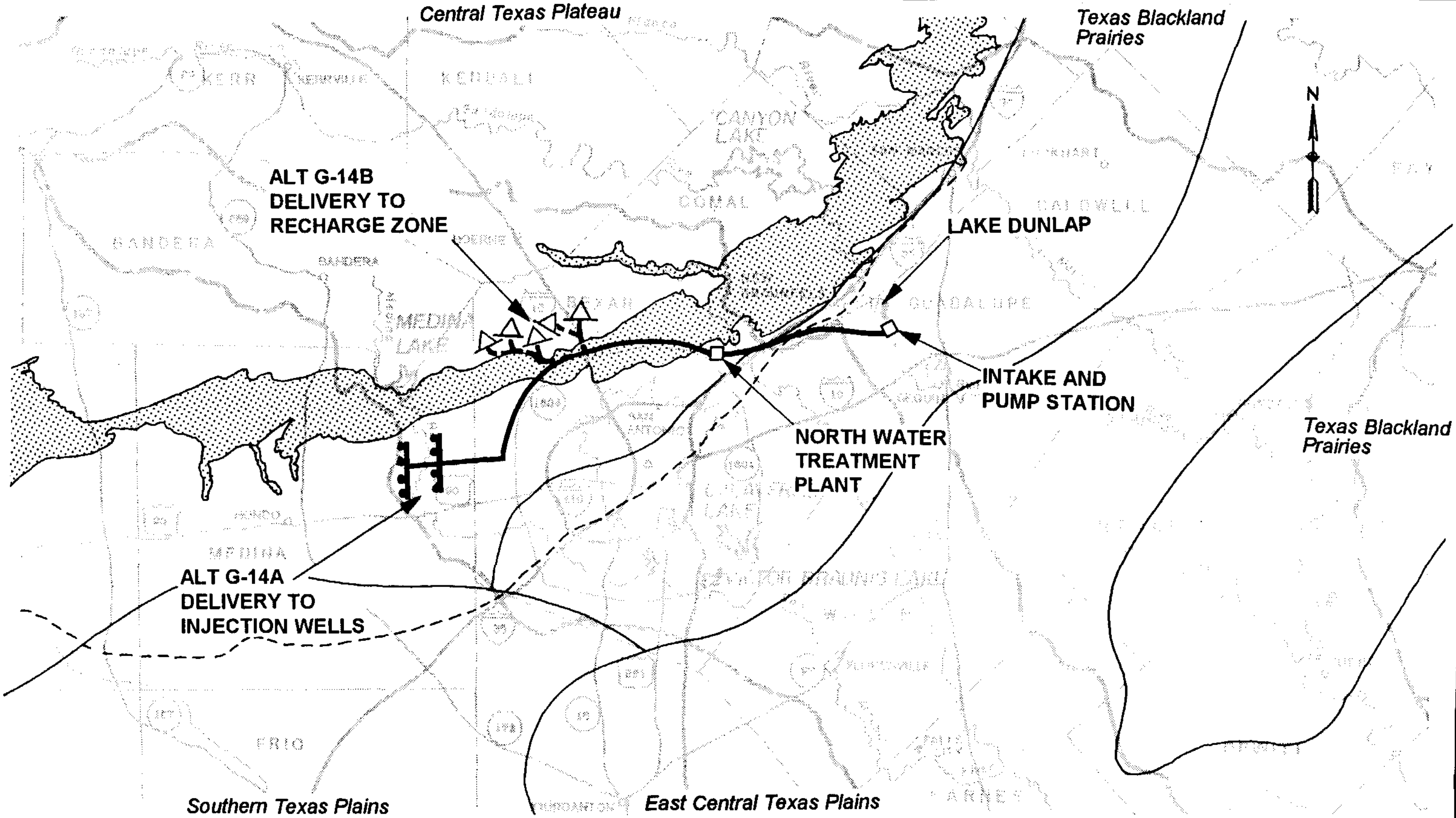
This alternative includes the diversion of potentially available unappropriated streamflow from the Guadalupe River at Lake Dunlap, with delivery to the West Central Study Area. Section 3.17 describes the availability of water for four hydrologic scenarios at various points in the Guadalupe River basin and from that analysis a single scenario was chosen for conceptualizing and cost estimating this diversion project. The hydrologic analysis found that no firm yield exists for this alternative, very similar to the situation found for Alt. G-13 in Section 3.18.1 (San Marcos River Diversion). For development of unit costs, the yield chosen for analysis was the average annual availability using the historic drought flow sequence from 1947 to 1956.

A river intake and pump station would be constructed at Lake Dunlap with the diversion location and delivery facilities as shown on Figure 3.19-1. The non-uniform pattern of availability requires a large capacity pump station and pipeline. Consequently, to reduce the cost of the conveyance facilities, a small off-channel balancing reservoir near the river intake is included to allow pumping at a more uniform rate and allowing for down-sizing of the transmission facilities. For study purposes, the site chosen for off-channel storage is on Santa Clara Creek, west of Lake Dunlap. With the addition of the off-channel reservoir, the alternative has a small firm yield of 500 acft/yr.

3.19.2 Available Yield

Water availability for the proposed project was determined in terms of average recharge (1934-89) and drought average recharge (1947-56). The scenario chosen to analyze the project included the following hydrologic assumptions:

- Spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures;
- Full utilization of existing water rights (including those associated with Appewhite Reservoir);
- Return flows set at 1988 levels; and



Legend

- Basin Divide
- Edwards Aquifer Recharge Zone
- "Bad Water" Line
- Ecoregion
- Pipeline Route

0 10 20 Miles

Scale

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GUADALUPE RIVER AT LAKE DUNLAP
ALTERNATIVE G-14

FIGURE 3.19-1

- Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr[78].

The Guadalupe - San Antonio River Basin Model[79] (GSA Model) was used to estimate monthly quantities of unappropriated streamflow potentially available at the diversion location subject to the Trans-Texas Environmental Criteria. A potential off-channel reservoir with a conservation capacity of 5,900 acft, was located near the diversion location. Streamflow at the river diversion location would be diverted into the off-channel reservoir, when available, at a non-uniform rate. The off-channel reservoir would serve as a balancing reservoir, allowing for water to be delivered at a constant pumping rate thereby decreasing the size and cost of the transmission facilities. An optimization of the cost of the project in terms of the maximum diversion rate from the river and the uniform withdrawal rate from the off-channel reservoir was performed. The optimization found that the lowest unit cost of water was with the combination of a maximum diversion rate from the river of 10,000 acft per month and a uniform withdrawal rate from the off-channel reservoir of 4,800 acft per month. The average recharge that could be obtained for the 1934-89 period was computed to be 12,300 acft/yr. The drought average recharge for the 1947-56 period was computed to be 3,500 acft/yr. The analysis showed that unappropriated streamflow could be diverted from Lake Dunlap about 17 percent of the time on average (1934-89) and 4 percent of the time during the drought period (1947-56). As a result, monthly median streamflows at the river diversion location were slightly affected and were essentially unaffected at the Saltwater Barrier. Monthly median streamflows and annual streamflows averaged by decile, with and without the project, are presented in Figure 3.19-2 for both at the site and at the Saltwater Barrier. Freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier would be reduced by less than 12,300 acft/yr on the average, or less than 1 percent.

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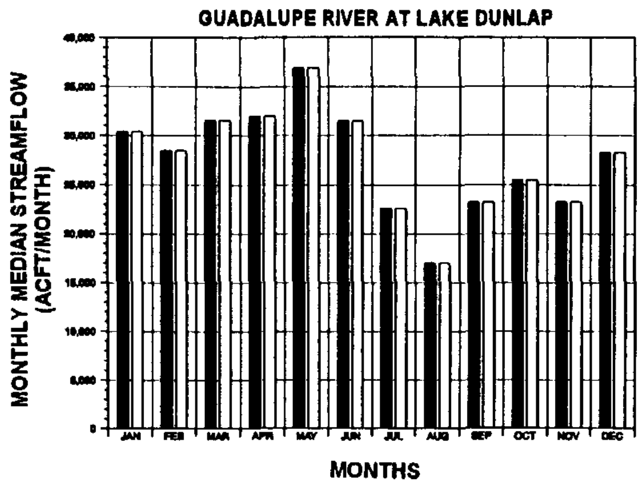
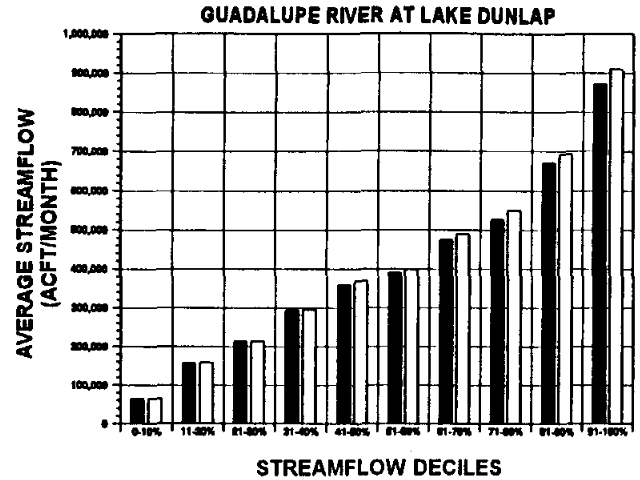
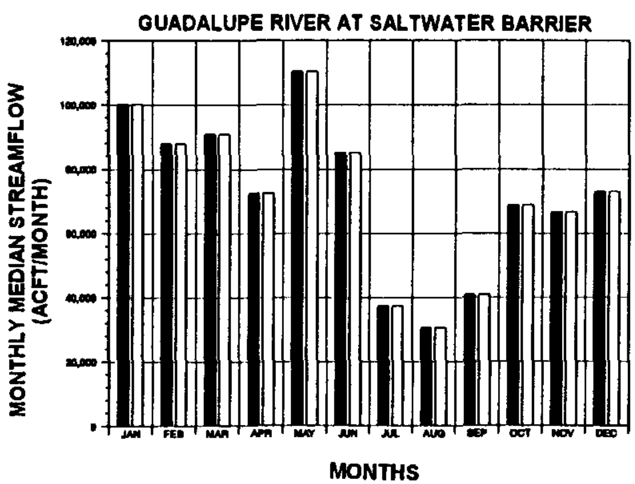
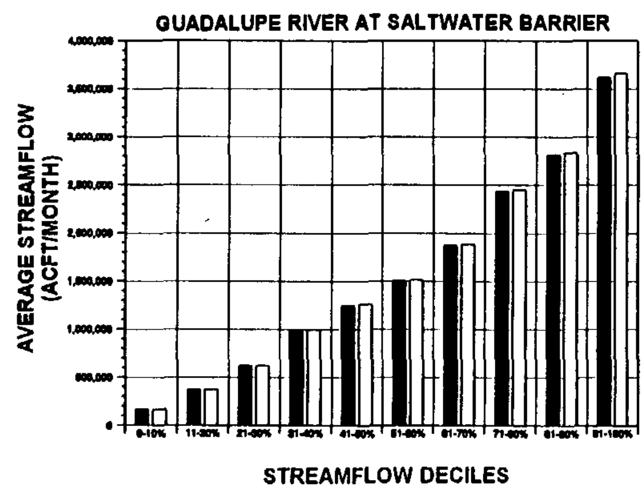
[78]Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[79]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study." Volumes I, II, and III, Edwards Underground Water District, September, 1993.









LEGEND

■ WITH PROJECT
□ WITHOUT PROJECT

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CHANGES IN STREAMFLOW LAKE DUNLAP DIVERSION ALTERNATIVE G-14

FIGURE 3.19 - 2

3.19.3 Environmental Issues

Lake Dunlap is a small hydroelectric reservoir located on the Guadalupe River below New Braunfels (Figure 3.19-1). Water released from Canyon Lake and springflow from Comal Springs are its major sources of water. Lake Dunlap is a long, moderately deep lake filling the Guadalupe River channel. Its water exhibits alkaline to near neutral pH and high alkalinity[80].

In alternative G-14, water would be diverted from the Guadalupe River at Lake Dunlap to a proposed off-channel reservoir on Santa Clara Creek (Figure 3.19-1). The dam and impoundment together with the water treatment plant and appurtenances would cover an estimated 1,213 acres. The water from the reservoir would be treated and piped to San Antonio for recharge of the Edwards Aquifer. This would be accomplished either through distribution of the water to an injection well field in Medina County (G-14A), or to the Edwards Aquifer recharge zone north of San Antonio (G-14B). This alternative employs the same pipeline corridor as the Guadalupe River diversion alternative (G-15) discussed in Section 3.20. Use of the injection field and the Edwards Aquifer recharge zone are addressed in the Environmental Overview Section 3.0.2, and Sections 3.2, 3.8, 3.9 and 3.10.

The land use and habitat types in the project area reflect its location at the confluence of the Blackland Prairies and Post Oak Savannah vegetational regions (Figure 3.19-1)[81,82]. The soils of the proposed off-channel reservoir and pipeline corridors range from light-colored, acid sandy loams (upland), dark-gray acid sandy loams and clays (bottomland) to fairly uniform dark-colored calcareous clays. Climax grasses of the Post Oak Savannah are little bluestem, Indian grass, switch grass, purpletop, silver bluestem and Texas wintergrass. The overstory is primarily post oak and blackjack oak. The Blackland Prairies are also characterized by these grasses, as well as sideoats grama, hairy grama and tall dropseed. Post oak and blackjack oak are typically present as overstory, although only

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[80]Lockett, C.L., 1976, "Classification of Seventeen Central Texas Reservoirs," Master's Thesis, Southwest Texas State University.

[81]Gould, F.W., 1975, The Grasses of Texas, Texas A&M University Press, College Station, Texas.

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

small remnants of this upland woodland are generally present in this ecoregion[83].

The proposed site for the off-channel reservoir and the northeastern third of the proposed pipeline corridor are primarily cropland (50 percent) and brush (36 percent) with the remaining area a mixture of park, woods and wetlands (Table 3.0-1). The pipeline corridor to the injection well field (G-14A) crosses into the northern City of San Antonio urban area. The corridor is an estimated 50 percent developed, 35 percent cropland, while the remainder is a mixture of brush, shrub, grass, woods and wetland[84]. With the majority of the project area located in either cropland or urbanized areas, terrestrial impacts can generally be avoided or minimized by careful selection of the pipeline ROW. To accomplish this, the pipeline alignment should avoid the fragmented wildlife habitat along the corridor through urban fringe live oak-mesquite-ashe juniper parks and live oak-ashe juniper woods north of San Antonio and the mesquite-live oak-bluewood parks in eastern Medina County when pipeline ROW alignment is selected[85].

The pipeline construction ROWs would result in disturbance of about 403 acres for the injection well field alternative (G-14A), or about 540 acres for the recharge zone alternative (G-14B). Permanently maintained ROW will amount to 163 acres, or 121 acres, for the two alternatives, respectively. Less than 0.25 acre of riparian woods bordering the lake shore would be within the construction site at the intake at Lake Dunlap. Because Lake Dunlap is both a recreational lake used for boating, fishing and camping and a hydroelectric power source, the intake structure should be planned for compatibility with both uses. Alternative G-14 is projected to have only a slight effect on streamflow, either at the diversion point, or in the Guadalupe River at the saltwater barrier (Figure 3.19-2). However, this alternative also has very little firm yield, and has an average drought yield of only 3,500 acft/yr.

The Texas Natural Heritage Program does not report any endangered or threatened species within the proposed pipeline corridor (Appendix B, Tables 6 and 37). The corridor

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[83]Correl, D.S., and M.C. Johnston, 1979, Manual of the Vascular Plants of Texas, Texas Research Foundation, Renner, Texas.

[84]USGS, 1990, NAPP black and white aerial photography. EROS Data Center, Sioux Falls, South Dakota.

[85]TPWD, 1984, The Vegetation Types of Texas. Austin, Texas.

south of New Braunfels at Lake Dunlap to urban San Antonio is in primarily cropland plains. Important species with habitats in the project vicinity and along the pipeline corridor in Guadalupe County are listed in Table 3.19-1.

Table 3.19-1
Important Species With Habitat Within the Project Vicinity, Guadalupe County (G-14)

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands	C2	T
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	3C	NL
Texas Garter Snake	*Thamnophis sirtalis annectans*	Varied, especially moist habitats	C2	NL
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T
Blue Sucker	*Cycleptus elongatus*	Large rivers crossing eastern Edwards Plateau to Gulf Coast	C2	T
Guadalupe Bass	*Micropterus terculi*	Streams of eastern Edwards Plateau	C2	NL

Source: Texas Natural Heritage Program Files, December 1993

The blue sucker, a candidate for federal protection, has occurred in the Guadalupe River, although the presence of several dams in this reach of the Guadalupe suggests that it may no longer be present[86].

The black-capped vireo and golden-cheeked warbler are protected species with habitats near the pipeline corridor at San Antonio. However, only a minor amount of this habitat is near the corridor (Table 3.0-1), and the pipeline ROW alignment selection could avoid those areas. Other important species with habitats along the pipeline corridor in Bexar County are listed in Table 3.19-2.

[86]Espey, Huston & Associates, Inc., 1986, Water Availability Study for the Guadalupe and San Antonio River Basins.

Table 3.19-2 Important Species With Habitat Within The Project Vicinity, Bexar County (G-14)				
Common Name	**Scientific Name**	**Habitat Preference**	**Listing Agency**	
			USFWS	**TPWD**
Black-capped vireo	*Vireo atricapillus*	Semi-open Broad-leaved shrublands	E	E
Golden-cheeked Warbler	*Dendroica chrsoparia*	Woodlands with oaks and old juniper	E	E
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions	NL	T
Reticulate Collared Lizard	*Crotaphytus reticulatus*	South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, hides under rocks	C2	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL
Source: Texas Natural Heritage Program Files, December 1993				

Impacts and affected environment in the Edward aquifer recharge zone and the injection well field are addressed in more detail in Sections 3.0.1, 3.8, 3.9 and 3.10. Surveys for the presence of protected species within the pipeline corridor, off-channel reservoir, and treatment plant would be conducted within the proposed construction corridor where disturbance of wildlife habitat cannot be avoided.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources.

3.19.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.19.5 Engineering and Costing

Alternative G-14A: Delivery to Aquifer Injection Wells

For this alternative, the potentially available run-of-river water would be pumped from the Guadalupe River at a diversion located in the pool formed by the existing Lake Dunlap channel dam. The run-of-river water would be pumped to a balancing off-channel reservoir at a non-uniform rate. From the off-channel reservoir, water would be pumped, also at a non-uniform rate, to the injection well field in eastern Medina County. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly to springflow. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

River Intake and Pump Station
Raw Water Pipeline to Off-Channel Reservoir
Off-Channel Reservoir and Dam
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Water Treatment Plant (Level 2, see Table 3.0-4)
Finished Water Pump Stations
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The river intake and pump station is sized to deliver 10,000 acft/month (166 cfs) through a 78-inch diameter pipeline. The operating cost was determined for the river pump station static lift of 175 feet and a long-term average annual water delivery of 12,300 acft/yr. The off-channel reservoir usable storage volume is 5,900 acft. The reservoir intake and pump station is sized to deliver 4,800 acft/month (80 cfs) through a 54-inch diameter pipeline. The operating cost for conveyance of the water to the treatment plant is for a static lift of 250 feet and an annual water delivery of 12,300 acft/yr. Operating cost of the finished water pumping system was determined for the static lift of 50. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $14,310,000 (Table 3.19-3). Operation and maintenance costs, including power, total

$5,970,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $20,280,000. For a drought average availability of 3,500 acft, the resulting annual cost of water is $5,793 per acft (Table 3.19-3).

Table 3.19-3
Cost Estimate Summaries for Guadalupe River at Lake Dunlap Diversion (G-14)
(Mid- 1994 Prices)

Item	Alt. G-19A Divert to Injection Wells	Alt. G-19B Divert to Recharge Structures
Capital Costs		
River Diversion, Transmission and Pumping	$77,000,000	$62,290,000
Off-Channel Reservoir	3,860,000	3,860,000
Treatment Plant	16,400,000	N/A
Delivery System	7,660,000	4,610,000
Total Capital Cost	$104,920,000	$70,760,000
Engineering, Contingencies, and Legal Costs	33,390,000	22,130,000
Land Acquisition	2,710,000	2,450,000
Environmental Studies and Mitigation	4,230,000	2,340,000
Interest During Construction	7,470,000	4,730,000
Total Project Cost	$152,720,000	$102,410,000
Annual Costs		
Annual Debt Service	$14,310,000	$9,600,000
Annual Operation and Maintenance	4,670,000	1,070,000
Annual Power Cost	1,300,000	1,360,000
Total Annual Cost	$20,280,000	$12,030,000
Available Project Yield (acft/yr)	3,500	3,500
Annual Cost of Water	$5,793	$3,437

Alternative G-14B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the potentially available run-of-river water would be pumped from the Guadalupe River at a diversion located in the pool formed by the existing Dunlap channel dam. The run-of-river water would be pumped to a balancing off-channel reservoir at a non-uniform rate. From the off-channel reservoir, water would be pumped, also at a non-uniform rate, to small recharge structures in northwestern Bexar County located over the recharge zone. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly to springflow.

The major facilities required to implement this alternative are:

River Intake and Pump Station
Raw Water Pipeline to Off-Channel Reservoir
Off-channel Reservoir and Dam
Reservoir Intake and Pump Station
Recharge Structures
Transmission Line to Recharge Zone

The reservoir intake and pump station is sized to deliver 10,000 acft/month (166 cfs) through a 78-inch diameter pipeline. The operating cost was determined for the off-channel reservoir pump station lift to the recharge structures of 250 feet and an annual water delivery of 12,300 acft/yr. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $9,600,000 (Table 3.19-3). Operation and maintenance costs, including power, total $2,430,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $12,030,000. For a drought average availability of 7,500 acft/yr, the resulting annual cost of water is $3,437 per acft (Table 3.19-3).

3.19.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Reservoir Alternatives (G-14, All)

1. It will be necessary to obtain these permits for the off-channel storage reservoir:
   a. TNRCC Water Right and Storage permits.
   b. TNRCC Interbasin Transfer Approval.
   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal permits.
   e. GLO Easement for use of state-owned land.
   f. Coastal Coordinating Council review.
   g. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.
3. Land will need to be acquired either through negotiations or condemnation.
4. Relocations for the reservoir include:
   a. Highways and railroads
   b. Other utilities

Requirements Specific to Pipelines (G-14, All)

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (G-14A)

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer.
   b. Test drilling and pilot recharge program is required.

    c. Large scale recharge test program.
    d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
    e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
    a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

<u>Requirements Specific to Surface Recharge Structures (G-14B)</u>

1. Detailed field investigations of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
    a. TNRCC Water Rights and Storage permit.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
    c. GLO Sand and Gravel Removal permit.
    d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
    a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
    b. Study of impact on karst geology organisms from a sustained recharge program.
    c. Other environmental studies.
    d. Cultural resources studies.

<u>Requirements Specific to Treatment and Distribution</u>

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

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3.20 Canyon Lake (Released to Lake Dunlap) (G-15)

3.20.1 Description of Alternative

This alternative considers the purchase of uncommitted stored water in Canyon Lake for delivery to various points in the West Central Study Area. Two annual purchase volumes supplying water to three delivery points have been studied and Table 3.20-1 keys the project numbering system to the alternatives. Canyon Lake and the conveyance system to San Antonio are shown on Figure 3.20-1.

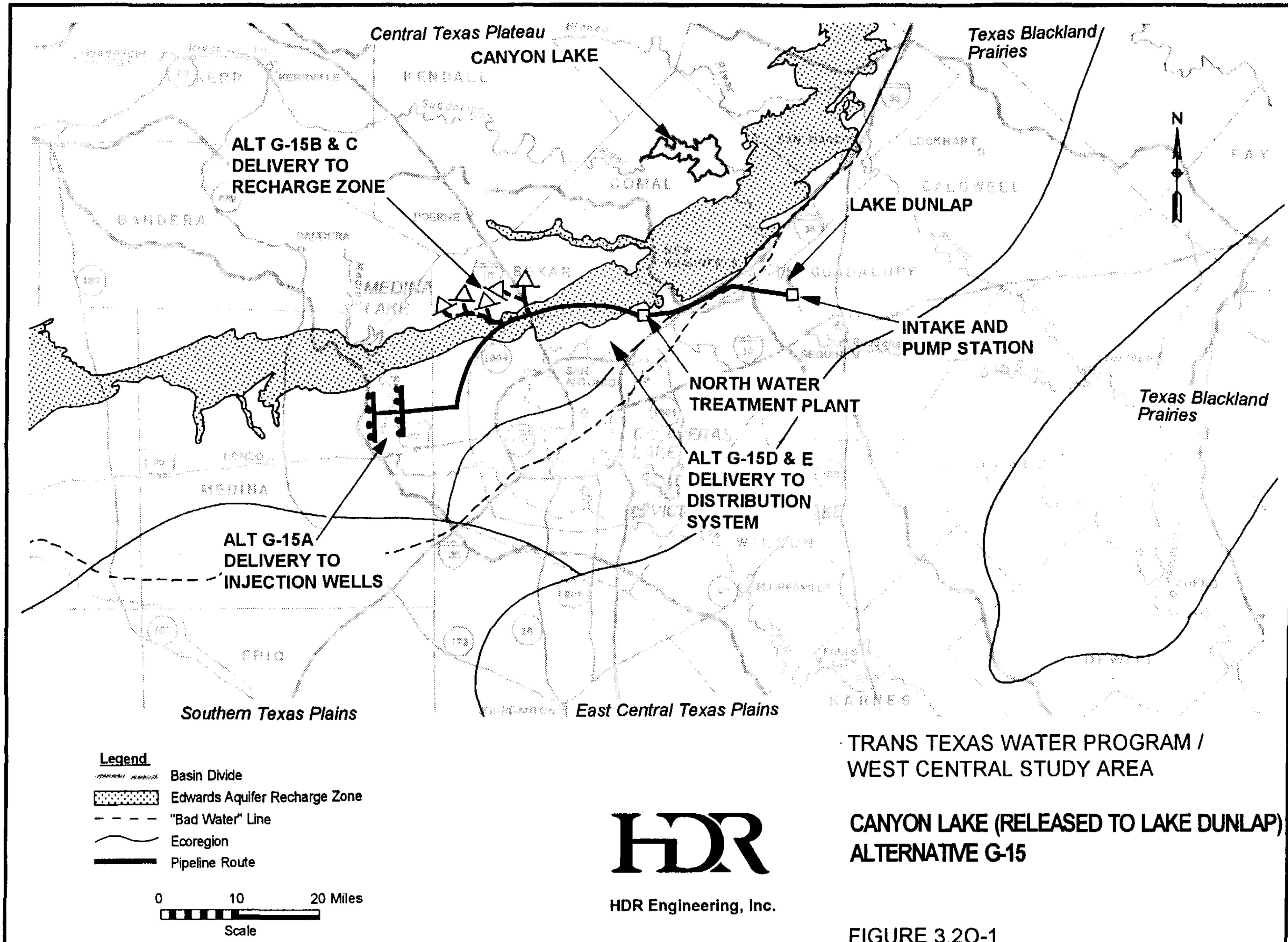
Table 3.20-1
Definition of Alternatives for Canyon Lake Water (Released to Lake Dunlap) Project (Alternative G-15)

Alternative	Project Yield (acft/yr)	Delivery Location
G-15A	10,000	Injection Wells to Aquifer
G-15B	10,000	Recharge Zone
G-15C	15,000	Recharge Zone
G-15D	10,000	North Water Treatment Plant
G-15E	15,000	North Water Treatment Plant

Canyon Lake is located on the Guadalupe River in Comal County and is about 14 miles west of San Marcos and 12 miles northwest of New Braunfels. The project was built by the Corps of Engineers beginning in 1958, with impoundment beginning in 1964. The reservoir contains 366,400 acft of conservation storage; controls 1,425 square miles of drainage area; and inundates 12,890 acres at normal lake level.

3.20.2 Available Yield

The permitted yield of Canyon Lake is 50,000 acft/yr and is based on honoring a 600 cfs GBRA hydroelectric right. Approximately 32,000 acft/yr of the Canyon Lake yield is presently committed, and approximately 10,000 acft/yr is available for diversion out of



TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

CANYON LAKE (RELEASED TO LAKE DUNLAP)
ALTERNATIVE G-15

FIGURE 3.2O-1

basin[87], provided that new water sources are developed for future in basin use.

The firm yield of Canyon Lake could possibly be increased to approximately 66,000 acft/yr by GBRA further subordinating its downstream hydroelectric rights to 365 cfs. This would require a permit amendment. In this case, the total out-of-basin diversion could be approximately 15,000 acft/yr. Table 3.20-1 defines the alternative delivery points studied for each availability of water.

3.20.3 Environmental Issues

Alternative G-15 involves diverting existing permitted water that is currently unused in Canyon Lake. This alternative would increase flows in the Guadalupe River between Canyon Dam and Lake Dunlap. Below the proposed diversion, Guadalupe River flows would remain about the same, relative to the existing condition, and part of the diverted water would return to the system as treated wastewater flows in the San Antonio River. Water surface elevations in Canyon Lake would fluctuate somewhat more than at present with this alternative in place. However, this change would occur whenever this water is sold and diverted, regardless of the identity of the end user.

3.20.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.20.5 Engineering and Costing

Alternative G-15A: Delivery to Aquifer Injection Wells at 10,000 acft/yr Rate

For this alternative, the project yield would be diverted through an intake and pumped in a transmission line to the injection well field in eastern Medina County. The diversion rate from the reservoir, as well as the delivery to the wells would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant

[87]Memorandum from GBRA to HDR Engineering, April 18, 1994.

(Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Station
Water Treatment Plant (Level 2, Table 3.0-4)
Finished Water Pump Station
Finished Water Booster Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The reservoir intake and pump station is sized to deliver 830 acft/month (9 mgd) through a 24-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 425 feet and an annual water delivery of 10,000 acft/year. Operating cost of the finished water pumping system was determined for the total static lift of 50 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $4,590,000 (Table 3.20-2a). The annual cost of water purchased from GBRA is $53/acft, for a total payment of $530,000 per year. Operation and maintenance costs, including power and purchase of stored water, total $3,060,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $7,650,000. For an annual yield of 10,000 acft, the resulting annual cost of water is $765 per acft (Table 3.20-2a) (Prices are with treatment).

Alternative G-15B: Delivery to Recharge Structures in the Recharge Zone at 10,000 acft/yr Rate

For this alternative, the project yield would be diverted through an intake and pumped in a transmission line to small recharge structures in northwestern Bexar County located over the recharge zone. The diversion rate from the reservoir, as well as the delivery to the recharge zone would be uniform throughout the year. The benefit from this

Table 3.20-2a
Cost Estimate Summaries for Purchase of Canyon Lake Water (G-15)
(Released to Lake Dunlap)
(Mid- 1994 Prices)

Item	Alt. G-15A Divert and Inject to Aquifer	Alt. G-15B Divert to Recharge Zone	Alt. G-15C Divert to Recharge Zone
Capital Costs			
Transmission and Pumping	$26,770,000	$20,830,000	$26,380,000
Treatment Plant	5,080,000		
Delivery System	1,630,000	1,850,000	2,290,000
Total Capital Cost	$33,480,000[(1)] $28,400,000[(2)]	$22,680,000	$28,670,000
Engineering, Contingencies, and Legal Costs	10,570,000[(1)] 8,790,000[(2)]	6,570,000	8,880,000
Land Acquisition	970,000[(1)] 920,000[(2)]	740,000	770,000
Environmental Studies and Mitigation	1,640,000	920,000	1,060,000
Interest During Construction	2,300,000[(1)] 2,030,000[(2)]	1,240,000	1,580,000
Total Project Cost	$48,960,000[(1)] $41,780,000[(2)]	$32,150,000	$40,960,000
Annual Costs			
Annual Debt Service	$4,590,000[(1)] $3,920,000[(2)]	$3,010,000	$3,840,000
Annual Operation and Maintenance	1,110,000[(1)] 420,000[(2)]	340,000	430,000
Purchase of Stored Water	530,000	530,000	795,000
Annual Power Cost	1,420,000	1,480,000	1,930,000
Total Annual Cost	$7,650,000[(1)] $6,290,000[(2)]	$5,360,000	$6,995,000
Available Project Yield (acft/yr)	10,000	10,000	15,000
Annual Cost of Water	$765/acft[(1)] $629/acft[(2)]	$536/acft	$467/acft

[(1)]Cost with treatment prior to surface recharge.
[(2)]Cost without treatment prior to surface recharge.

project would be the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. The major facilities required to implement this alternative are:

Raw Water Pipeline to Recharge Zone
Raw Waterline Booster Pump Stations
Recharge Structures

The reservoir intake and pump station is sized to deliver 830 acft/month (9 mgd) through a 24-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 656 feet and an annual water delivery of 10,000 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $3,010,000 (Table 3.20-2a). The annual cost of water purchased from GBRA is $53/acft, for a total payment of $530,000 per year. Operation and maintenance costs, including power and purchase of stored water, total $2,350,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $5,360,000. For an annual yield of 10,000 acft, the resulting annual cost of water is $536 per acft (Table 3.20-2a).

Alternative G-15C: Delivery to Recharge Structures in the Recharge Zone at 15,000 acft/yr Rate

For this alternative, the project yield would be diverted through an intake and pumped in a transmission line to recharge structures in northwestern Bexar County. The diversion rate from the reservoir, as well as the delivery to the recharge zone would be uniform throughout the year. The benefit from this project would be the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. The major facilities required to implement this alternative are:

Raw Water Pipeline to Recharge Zone
Raw Waterline Booster Pump Stations
Recharge Structures

The reservoir intake and pump station is sized to deliver 1,250 acft/month (13 mgd) through a 30-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 656 feet and an annual water delivery of 15,000 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $3,840,000 (Table 3.20-2a). The annual cost of water purchased from GBRA is $53/acft, for a total payment of $795,000 per year. Operation and maintenance costs, including power and purchase of stored water, total $3,155,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $6,995,000. For an annual yield of 15,000 acft, the resulting annual cost of water is $467 per acft (Table 3.20-2a).

Alternative S-15D: Delivery to the Municipal Distribution System at 10,000 acft/yr Rate

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the North Water Treatment Plant. The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Station
Water Treatment Plant (Level 3, see Table 3.0-4)
Finished Water Pump Station
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 830 acft/month (9 mgd) through a 24-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 425 feet and an annual water delivery of 10,000 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $3,080,000 (Table 3.20-2b). The annual cost of water purchased from GBRA is $53 acft, for a total payment of $530,000 per year. Operation and maintenance costs, including power and purchase of stored water, total $2,250,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $5,330,000. For an annual firm yield of 10,000 acft, the resulting annual cost of water is $533 per acft (Table 3.20-2b).

Table 3.20-2b
Cost Estimate Summaries for Purchase of Canyon Lake Water(G-15)
(Released to Lake Dunlap)
(Mid- 1994 Prices)

Item	Alt. G-15D Divert to WTP and Municipal System	Alt. G-15E Divert to WTP and Municipal System
Capital Costs		
Transmission and Pumping	$8,850,000	$11,210,000
Treatment Plant	6,310,000	8,420,000
Delivery System	8,700,000	13,530,000
Total Capital Cost	$23,860,000	$33,160,000
Engineering, Contingencies, and Legal Costs	7,160,000	9,840,000
Land Acquisition	310,000	310,000
Environmental Studies and Mitigation	260,000	260,000
Interest During Construction	1,260,000	1,970,000
Total Project Cost	$32,850,000	$45,540,000
Annual Costs		
Annual Debt Service	$3,080,000	$4,270,000
Annual Operation and Maintenance	950,000	1,330,000
Purchase of Stored Water	530,000	795,000
Annual Power Cost	770,000	1,050,000
Total Annual Cost	$5,330,000	$7,445,000
Available Project Yield (acft/yr)	10,000	15,000
Annual Cost of Water	$533/acft	$497/acft

(1) Cost with treatment prior to surface recharge.
(2) Cost without treatment prior to surface recharge.

Alternative S-15E: Delivery to the Municipal Distribution System at 15,000 acft/yr Rate

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the North Water Treatment Plant. The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Station
Water Treatment Plant (Level 3, see Table 3.0-4)
Finished Water Pump Station
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 1,250 acft/month (13 mgd) through a 30-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 425 feet and an annual water delivery of 15,000 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $4,270,000 (Table 3.20-2b). The annual cost of water purchased from GBRA is $53/acft, for a total payment of $795,000 per year. Operation and maintenance costs, including power and purchase of stored water, total $3,175,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $7,445,000. For an annual firm yield of 15,000 acft, the resulting annual cost of water is $497 per acft (Table 3.20-2b).

3.20.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Requirements Specific to Pipelines (G15, All)

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (G-15A)

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer.
   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.
   d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
   e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
   a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (G-15B, C)

1. Detailed field investigation of each potential recharge site to determine natural and expected recharge rate.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
   a. TNRCC Water Rights and Storage permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
   c. GLO Sand and Gravel Removal permit.
   d. TPWD Sand, Gravel, and Marl permit.

4. Permitting, at a minimum, will require these studies:
   a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
   b. Study of impact on karst geology organisms from a sustained recharge program.
   c. Other environmental studies.
   d. Cultural resource studies.

Requirements Specific to Treatment and Distribution (G-15D, E)

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into SAWS water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

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3.21 Cuero Reservoir (G-16)

3.21.1 Description of Alternative

Cuero Reservoir is a proposed major impoundment on the Guadalupe River in Dewitt and Gonzales counties and would be located about 4 miles north of the town of Cuero. Several studies of the reservoir have been performed[88,89], the latest of which is by Espey, Huston & Associates[90] in 1986, which provided the siting and basic data for this study. The location of the project is shown on Figure 3.21-1.

The dam would be an earthfill embankment with a gate-controlled concrete spillway to control the 4,166 square-mile watershed. The dam embankment would extend about 4.7 miles across the Guadalupe River valley and provide a conservation storage capacity of 1,167,000 acft at elevation 242 feet MSL; at conservation pool the surface area would be 41,500 acres; the probable maximum flood elevation would be 252 feet; and, approximately 50 miles of the Guadalupe River channel would be inundated by the reservoir.

Three alternative uses of water from this reservoir have been studied: (1) delivery to injection wells to recharge the Edwards Aquifer (Alt G-16A); (2) delivery to recharge structures in the Edwards Aquifer recharge zone (Alt G-16B); and (3) delivery to a water treatment plant and distribution in the SAWS municipal water system (Alt G-16C). All of these alternatives are shown on Figure 3.21-1.

3.21.2 Available Yield

The firm yield of the proposed Cuero Reservoir was computed for this Phase I study utilizing the Trans-Texas Environmental Criteria (see Appendix C) subject to three scenarios chosen to present a reasonable range of hydrologic assumptions. Under each of these scenarios, firm yield was computed subject to three capacity thresholds which limit passage of reservoir inflows during times of drought as specified in the Trans-Texas Environmental

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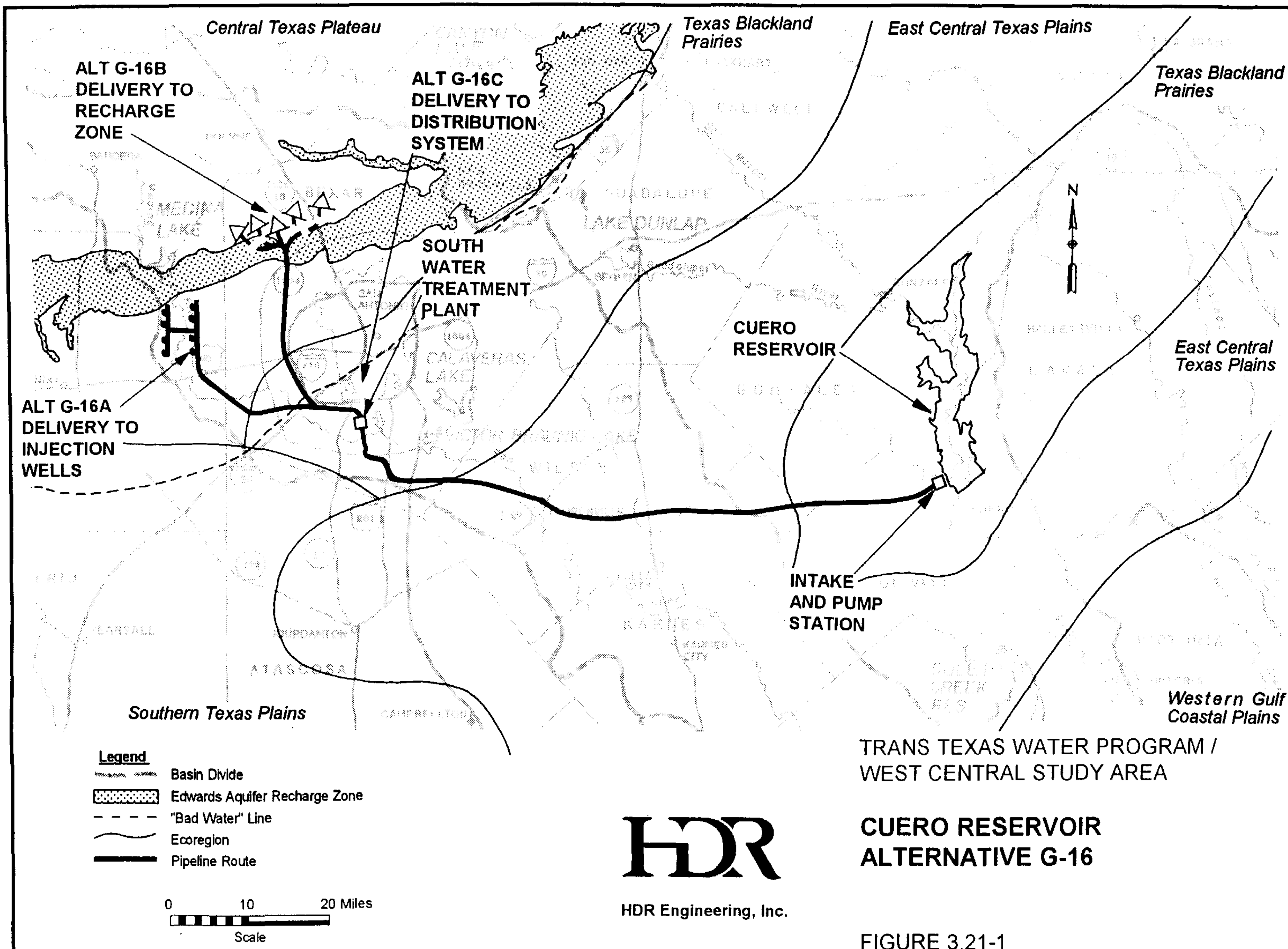
[88]Texas Water Development Board, "A Summary of the Preliminary Plan for Proposed Water Resources Development in the Guadalupe River Basin," July, 1966.

[89]U.S. Bureau of Reclamation, "Summary of Special Report San Antonio - Guadalupe River Basins Study, Texas Basin Project," November, 1978.

[90]Espey, Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," Guadalupe-Blanco River Authority, February, 1986.



CUERO RESERVOIR
ALTERNATIVE G-16

FIGURE 3.21-1

Criteria. All scenarios include the spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights (including those associated with Applewhite Reservoir), and return flows set to 1988 levels. The three scenarios analyzed are further described as follows:

Scenario 1: Hydropower water rights subordinated to 0 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 74,100 acft/yr[91].

Scenario 2: Hydropower water rights subordinated to 365 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 52,600 acft/yr[92].

Scenario 3: Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr[93].

The Guadalupe - San Antonio River Basin Model[94] (GSA Model) was used to estimate monthly quantities of total streamflow and unappropriated streamflow potentially available at the reservoir site which, in turn, were used to compute the firm yield of Cuero Reservoir. For modelling purposes, streamflows for the Guadalupe River at Cuero (ID# 1758) less those for Sandies Creek near Westhoff (ID# 1750) were assumed to be representative of inflows to Cuero Reservoir. The firm yield of Cuero Reservoir was computed using an original model (RESSIM) specifically written to simulate reservoir operations subject to the Trans-Texas Environmental Criteria for new reservoirs, using water availability estimates from the GSA Model. A summary of the firm yield estimates for each scenario and capacity threshold analyzed is provided in Table 3.21-1.

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[91]Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[92]Ibid

[93]Ibid

[94]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

Table 3.21-1 Summary of Cuero Reservoir Firm Yield Estimates			
	Estimate of Firm Yield (acft/yr)		
	Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]		
Scenario[1]	40%	60%	80%
1	117,000	163,000	187,000
2	118,000	168,000	193,000
3	118,000	168,000	193,000

Notes:
[1]All scenarios include the springflows from a fixed Edwards Aquifer pumpage of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights (including Applewhite Reservoir), and return flows set to 1988 levels.

Scenario 1: Hydropower water rights subordinated to 0 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 74,100 acft/yr.

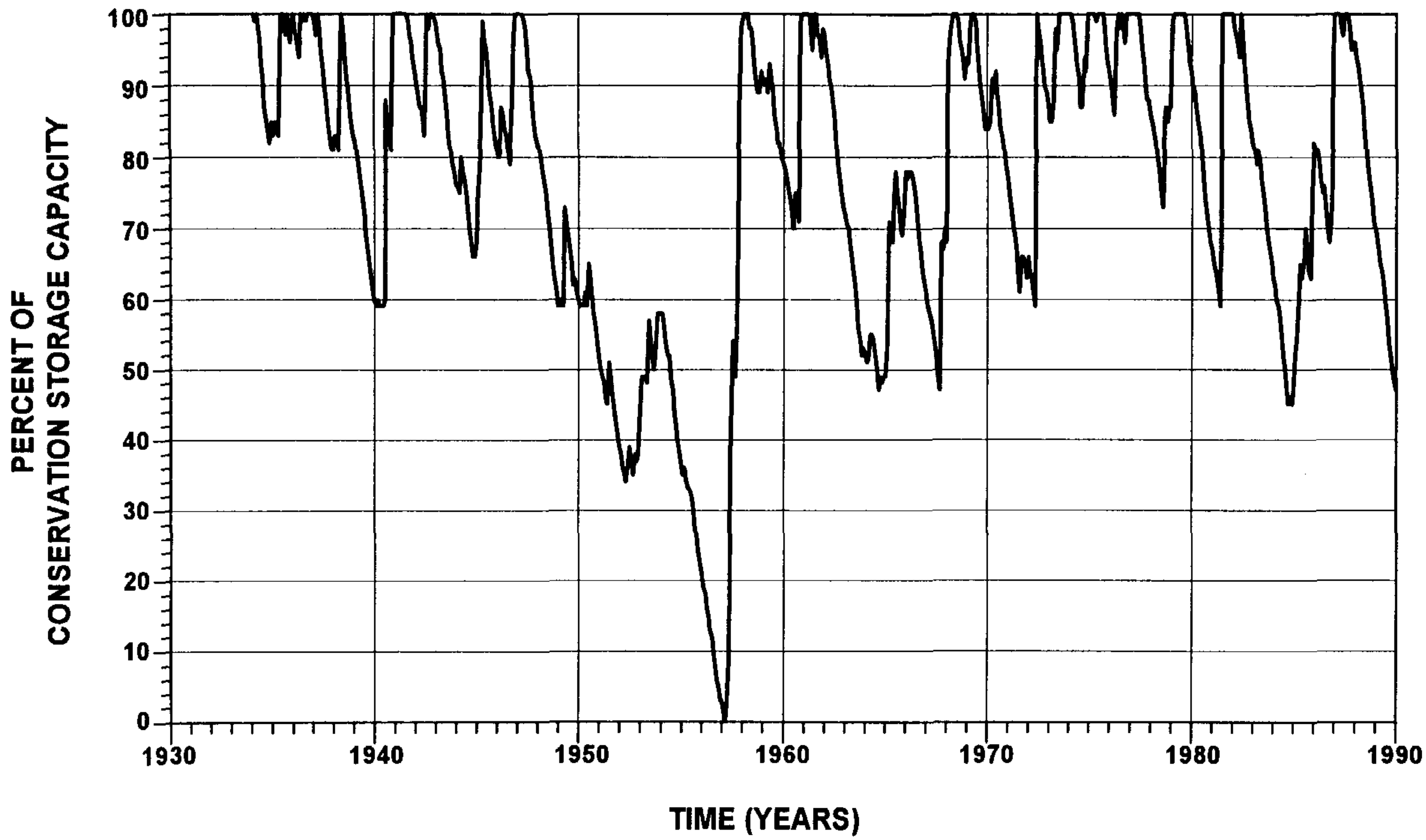
Scenario 2: Hydropower water rights subordinated to 365 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 52,600 acft/yr.

Scenario 3: Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr.

[2]The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.

As is apparent in this table, estimated firm yield for Cuero Reservoir is not particularly sensitive to hydropower subordination since the firm yield of Canyon Lake was modified concurrently. However, the firm yield is quite sensitive to capacity threshold for drought contingency operations. Appendix D contains detailed summaries of the inflow passage requirements applied at Cuero Reservoir.

Scenario 3, with a 60 percent capacity threshold, was selected for consideration of cost and analysis of potential environmental impacts because it is representative of current hydropower subordination and diversion rights associated with Canyon Lake. Figure 3.21-2 illustrates simulated Cuero Reservoir storage fluctuations for the 1934-89 historical period if operated under the Trans-Texas Environmental Criteria subject to diversion of the firm yield of 168,000 acft/yr. Simulated reservoir storage remained above the 60 percent capacity threshold about 79 percent of the time resulting in the frequent passage of inflows up to the monthly mean or median natural streamflow. As a result, monthly median streamflows at the site and at the Saltwater Barrier are essentially unaffected by the reservoir. Monthly



NOTES

FIRM YIELD: 168,000 ACFT/YR
CONSERVATION STORAGE CAPACITY: 1,167,000 ACFT
60% CAPACITY THRESHOLD
SCENARIO 3:

- EDWARDS AQUIFER DEMAND OF 400,000 ACFT/YR
- RETURN FLOWS SET AT 1988 LEVELS
- HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
- APPLEWHITE RESERVOIR INCLUDED

HDR

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

FIRM YIELD STORAGE TRACE
CUERO RESERVOIR
ALTERNATIVE G-16

FIGURE 3.21-2

median streamflows and annual streamflows averaged by decile, both at the site and at the Saltwater Barrier, are presented in Figure 3.21-3 for conditions both with and without the project. Under Scenario 3 with a 60 percent capacity threshold, freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier would be reduced by an average of 249,500 acft/yr or about 16 percent.

3.21.3 Environmental Issues

This alternative involves dam construction and inundation of approximately 41,500 acres along a 50-mile reach of the Guadalupe River (see Figure 3.21-1). Alternative G-16 consists of three alternative uses of water resources obtained through the construction and operation of the proposed Cuero Reservoir. Under Alternative G-16A, the yield of Cuero Reservoir would be diverted to pumping facilities for delivery to injection wells placed into the Edwards Aquifer. This alternative, which involves imported recharge, involves treatment to ensure acceptable water quality. Alternative G-16B also involves imported recharge, potentially with treatment to ensure acceptable water quality. Under this alternative, water from Cuero Reservoir would be diverted to a pump station and delivered to the recharge zone on the Edwards formation outcrop. The treatment and distribution alternative, G-16C, involves use of an intake and pump station on Cuero Reservoir, with delivery of the water directly to a water treatment plant. Specific pipeline routes required to transport the surface water supplies to delivery locations will be addressed in a future phase of this project and only general pipeline corridors are considered here.

The proposed Cuero Reservoir spans portions of Gonzales and DeWitt counties. It is located in the Texas Blackland Prairies ecoregion[95] (see Figure 3.0-1), in the ecotonal region between the Post Oak Savannah and Blackland Prairie vegetational regions[96] (see Figure 3.0-2), and within the Texan biotic province as described by Blair[97] (see Figure 3.0-3).

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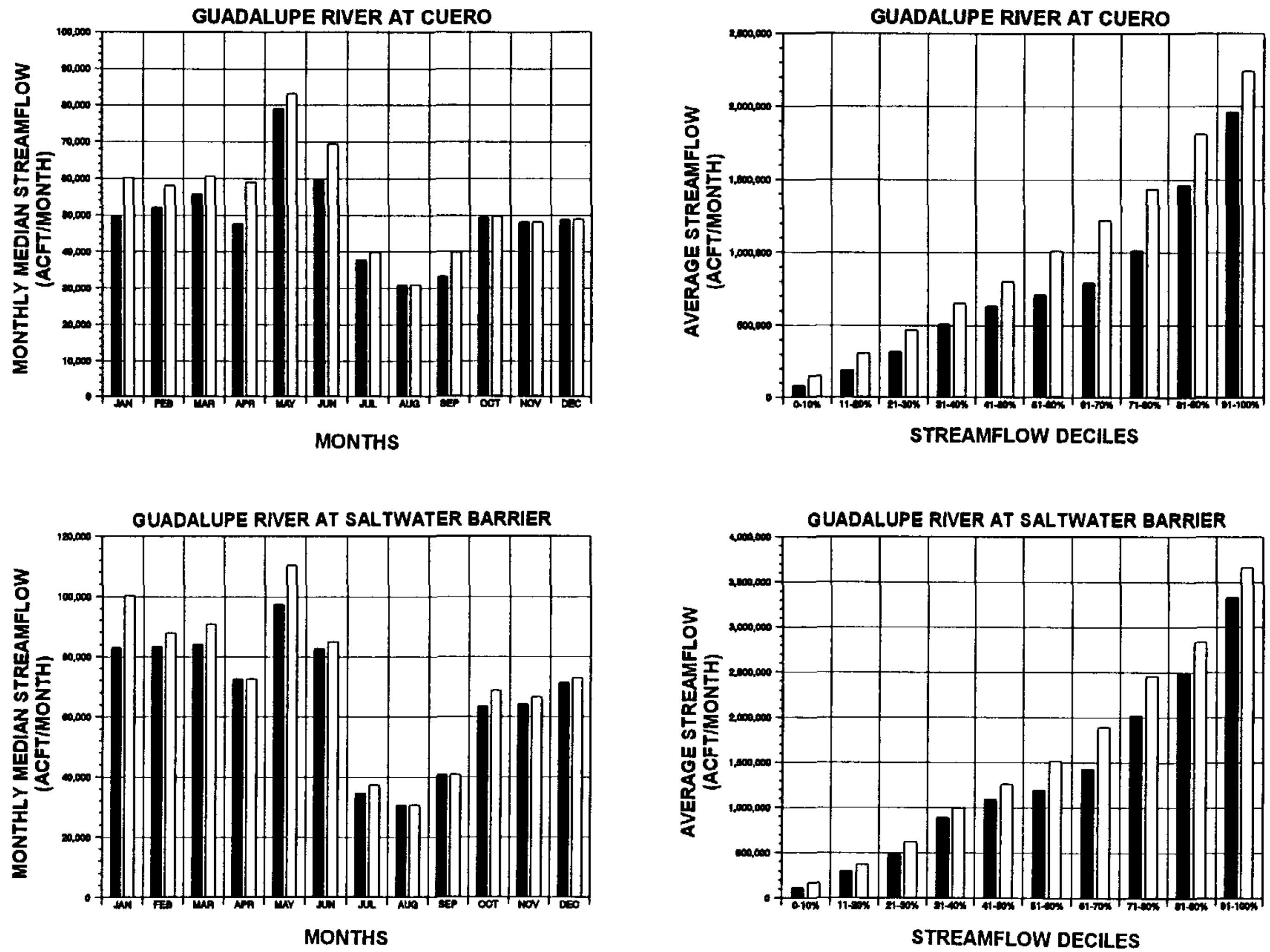
[95]Omernik, James M., 1986, "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1). pp. 118-125.

[96]Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press, Texas Agricultural Experiment Station, College Station, Texas.

[97]Blair, W.F. 1950. The biotic provinces of Texas. Tex. J. Sci. 2:93-117.



LEGEND

■ WITH PROJECT
□ WITHOUT PROJECT

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

CHANGES IN STREAMFLOW
CUERO RESERVOIR
ALTERNATIVE G-16

FIGURE 3.21-3

Within the floodplains, soils of the Meguin-Trinity association are found. These soils are somewhat poorly drained, calcareous loamy and clayey soils. They are well suited to range, improved pasture and crops. The Sarnosa-Shiner association is found on uplands. These are nearly level, well-drained, moderately permeable, calcareous loamy soils used for range and wildlife, but also suited to pasture[98].

The upland forest community type is fairly limited in extent, comprising only about 5 percent of the woodland acreage within the boundaries of the reservoir site (see Table 3.0-1). Dominant overstory species within this community type include post oak, cedar elm, honey mesquite, and live oak. In the understory and shrub layers, honey mesquite, acacias, cedar elm, and prickly pear (*Opuntia* spp.) occur. Grasses and forb species comprise the herbaceous stratum in this community type[99].

Bottomland and riparian forests comprise approximately 95 percent (about 10,792 acres) of the wooded acreage in the proposed reservoir site (see Table 3.0-1). A variety of reptiles, amphibians, mammals, and bird species rely on these habitats for food and cover. These forest types are similar in terms of species composition and in terms of certain edaphic and hydrologic factors, but differ in extent due to differences in floodplain characteristics. Bottomland forest stands, which occur along the Guadalupe River, and where floodplains are wide along major streams, are characterized by a dense overstory canopy and a well-developed understory and shrub layer. Riparian forest stands generally occur in narrow floodplains of minor streams, and are thereby limited to narrow bands of woody vegetation immediately adjacent to the streams.

Brushland, which occupies approximately 6,991 acres (see Table 3.0-1), is the dominant community type in the wooded upland portions of the proposed reservoir site, and is also present in some lowland areas. This community type occurs primarily as a result of overgrazing and fire suppression, which have allowed woody species to increase in areas that were formerly covered by grasslands or savannah community types. The thick nature of the

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[98]U.S. Department of Agriculture, Soil Conservation Service (SCS). 1978a. Soil Survey of DeWitt County, Texas. In cooperation with the Texas Agricultural Experiment Station, Texas A&M University, College Station.

[99]Espey, Huston & Associates, Inc. (EH&A). 1986. Water Availability Study for the Guadalupe and San Antonio River Basins. Prepared for San Antonio River Authority, Guadalupe-Blanco River Authority, and City of San Antonio. Volumes I and II. EH&A Document No. 85580. February.

heavy pumpage and water-level declines with regard to the Gulf Coast aquifer in the Houston area, does not appear to be a problem in Atascosa County.

Hydraulic Characteristics

An aquifer's hydraulic characteristics are generally described in terms of its coefficients of transmissivity and storage. These were determined generally for the Carrizo-Wilcox aquifer by conducting pumping tests in selected wells and from well performance tests conducted by water well drilling and servicing companies (Klemt and others, 1976, and Thorkildsen and others, 1989) and are a measure of an aquifer's ability to transmit and store water. Transmissivity and storage can also be used to determine proper well spacing, interference between pumping wells and to predict water-level drawdowns around pumping wells.

The following transmissivities for the Carrizo Sand in the study area are, in general, representative of the aquifer where it is under confined conditions 5 to 10 miles downdip from the outcrop: (a) Atascosa County, 200,000 gallons per day per foot (gpd/ft); (b) Wilson County, 150,000 gpd/ft; Gonzales County, 75,000 gpd/ft; (c) Caldwell County, 50,000 gpd/ft; (d) Bastrop County, 50,000 gpd/ft. The transmissivity of the Simsboro water-bearing sands north of the San Marcos Arch in Bastrop County is probably on the order of 30,000 gpd/ft. The transmissivities given are consistent with those reported by: Klemt and others (1976), Shafer (1965) and Follett (1966 and 1970). In the outcrop, the transmissivities of these units are, in general, about half of the above.

Coefficients of storage for the Carrizo and Simsboro sands in the study area probably range from 0.0001 to 0.001 and from 0.05 to 0.30 in the artesian and water-table portions of the study area, respectively (Thorkildsen and others, 1989). Duffin and Elder (1979), based on seismic refraction studies on the Carrizo outcrop, estimated the storage coefficient (specific yield) of the aquifer under water-table conditions in Atascosa, Bexar, Wilson and Guadalupe Counties to be on the order of 0.30.

Vertical leakage to and from the more important Carrizo and Simsboro sands of the Carrizo-Wilcox aquifer is through confining beds (aquitards). In order to estimate the leakage rate, the vertical hydraulic conductivity of the confining bed and the difference in head between the aquifer and the confining bed must be approximated. For the purposes of estimating leakance, a vertical hydraulic conductivity of 0.002 gallons per day per square foot for the confining interval was used (Morris and Johnson, 1966).

Chemical Quality

The Carrizo-Wilcox aquifer yields fresh to slightly saline water which is acceptable for most irrigation, public supply and industrial purposes in Texas (Muller and Price, 1979). In the outcrop, the aquifer contains hard (high calcium and magnesium) water that is usually low in dissolved solids content. Downdip, the water becomes softer due to calcium loss through clay cation exchange for sodium, has a higher temperature (generally ranging from 80° to 90° F), and contains more dissolved solids.

In general, water quality of the Carrizo-Wilcox aquifer in the study area is good and meets the National Primary Drinking Water Regulations standards required for public health. However, secondary standards for pH and iron may not be met. Water exceeding secondary standards poses an aesthetic problem, not a health risk. Additionally, hydrogen sulfide and methane gas may be found locally within the aquifer.

The following paragraph taken from Thorkildsen and others (1989) may appropriately describe the iron content problem with respect to the Carrizo-Wilcox aquifer in the study area, the only possible exception being Wilson County (parenthetical statements added by LBG-Guyton Associates):

> "The only significant water quality problem in the study area is the erratic occurrence of sands containing water with high concentrations of iron. While there are a few isolated areas where almost all wells produce high iron water, in most cases it is difficult, if not impossible, to predict the iron concentration until the well is completed

and samples collected and analyzed. This is further complicated by the fact that iron concentration varies not only from area to area, but vertically within the same well from sand bed to sand bed within the aquifer. Since it is difficult and expensive to collect samples for chemical analysis from every sand interval encountered when drilling a test hole or well, the quality of the water finally produced (with respect to iron) often depends on chance in properly selecting the intervals to be screened. Fortunately, high iron concentrations in water can be reduced by several relatively inexpensive methods, including aeration, addition of chemicals, et cetera, and the iron removed by settling, or filtration."

A reconnaissance-level study of water quality was made using data supplied by the Texas Water Development Board for wells completed in the Carrizo-Wilcox aquifer within the study area. Two methods were used to initially evaluate the available water-quality data. Both methods used the following data selection criteria: (a) only water analyses performed from 1965 to present were utilized and (b) only water samples from wells completed in either the Carrizo or Simsboro water-bearing sands of the aquifer were used.

While many hundreds of additional analyses were available from the Board for wells which reportedly screened the Carrizo-Wilcox aquifer, many of these have large uncertainties associated with the completion data available and, thus, were not used. By carefully selecting analyses on the basis of well completion, the water-quality data should more accurately represent the better designed and constructed wells in the area and the true water-quality potential of the aquifer. It should be noted, however, that on the reconnaissance level many uncertainties regarding sampling, analytical techniques and well completions with regard to the available data remain.

The first method was to use all of the available analyses, including multiple analyses for individual wells. All of the data available from the Board within the study area and meeting the aforementioned criteria was included except for three values out of the total 715 analyses which were impossibly high or low probably as a result of data entry errors. These three erroneous values were deleted. The average concentrations of chloride, iron and sulfate ions were determined as well as the average pH and total dissolved solids concentration. The results of this work indicated the average of the above chemical constituents and parameters met National Primary and Secondary Drinking Water Regulations standards.

The second method was to use only the single most recent analysis for each well which met the selection criteria. The resulting data set was more carefully edited to eliminate erroneously high and low values resulting from entry errors in the Board's database or because of poor analyses. From 2 to 10 percent of the values for each constituent or property were deleted for this reconnaissance investigation. Using this method, average values for chloride, sulfate, iron, TDS and pH were determined, as well as the number of analyses, maximum values and minimum values. The results are presented in the following table. Constituent values are given in milligrams per liter except for pH.

Constituent	Number of Wells	Range	Average	Drinking Water Standards for Texas
Chloride	319	15-206	47	300
Sulfate	316	7-293	45	300
Iron	132	0.0-1.9	0.22	0.3
TDS	304	69-557	269	1,000
pH	322	6-8	6.8	≥7.0

As shown in the above tables, water quality of the Carrizo-Wilcox aquifer in the study area, including iron concentration, is quite favorable. However, the character of the water appears to be locally variable. Some of the local variability seen in the results of the analyses is probably dependent on the selection, testing, sampling, analytical and well completion techniques used.

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However, it may be possible to predict the iron concentrations generally within the study area using geochemical methods. Broom (1966) found that shallow Carrizo-Wilcox ground waters in East Texas, in recharge areas, were found to be relatively free of iron, probably due to prior removal of available iron by oxidizing waters. Deep reduced ground waters were also relatively free of iron, probably due to removal of free iron by precipitation of pyrite. Within the transition zone between oxidizing and reducing conditions, iron dissolved in the ground water was stable. Therefore, within the study area, wells which are proposed to be drilled within the above transition zone may produce high iron-bearing waters and wells which are located outside of this zone may be relatively free of iron.

Careful study of the distribution of wells which produce water containing objectionable concentrations of iron may reveal areas to be favored for development or avoided. An attempt was made on a preliminary basis to test this hypothesis by repeating the two investigation methods described above for individual counties within the study area. However, due to the many uncertainties in the available data and the small number of analyses meeting the selection criteria in some counties, the results were inconclusive. The collection of additional water-quality data with better control, the use of statistical methods to manipulate the data in future studies, and research of the geochemical controls of iron in ground water are recommended.

Well Construction and Costs

Public water supply wells which are completed in the Carrizo-Wilcox aquifer should utilize well screens. These wells should be underreamed, gravel-packed and cemented from ground surface down to screened intervals. Twelve- to 16-inch surface casing is usually cemented in place some distance below the water level and 8- to 12-inch hole casing extended to total depth. Electric logs are commonly used to locate the water-bearing zones (screen intervals) in the wells.

For the purpose of estimating the capital cost of a public water supply well which would be capable of pumping 1,000 to 1,500 gallons per minute, the following assumptions were used: (a) the well is a standard 16 x 10-inch underreamed, 30-inch, gravel-wall well; (b) well depth is approximately 1,200 feet with 400 feet of stainless steel screen; (c) the pump is a 250-horsepower electric turbine pump; and (d) pumping levels would be approximately 400 feet below land surface at the end of 50 years of operation. Each well is estimated to cost $450,000 including the pump and motor.

The above costs do not cover service/access roads, treatment facilities, engineering, easements, contingencies, transfer piping and pipelines.

GROUND-WATER AVAILABILITY

The amount of ground water that can be developed by wells from the Carrizo-Wilcox aquifer in the study area on a long-term basis (50 years or more) is directly related to the ability of the aquifer to transmit water from the outcrop to points of discharge (lateral transmission capacity) and the amount of interformational leakage which may occur as a result of pumping from the aquifer. Available ground water, for the purpose of this study, includes lateral transmission capacity from outcrop areas and interformational leakage to the Carrizo (and Simsboro in Bastrop County) from the hydraulically connected Wilcox sands and clays less the present day ground-water pumpage. The amount of water available from storage, for the purpose of this investigation, was not considered as a source of available water.

Available Ground Water for Future Development

The principal ground-water development scenario proposed in this report involves a possible line of relatively widely spaced wells extending from about the western part of Atascosa County to the Bastrop-Lee County line and parallel to the Carrizo-Wilcox outcrop located approximately 7 miles downdip from the edge of the Carrizo-Wilcox outcrop. This scenario would spread the pumpage over a large area and take advantage of the transmission capacity of the aquifer, interformational leakage and recharge effects from the outcrop in order to minimize water-level declines.

The proposed development scenario is based on the following assumptions: (a) the effect of pumping is such that static water levels are drawn down to a depth along the line of discharge so that the hydraulic gradient from the outcrop ranges from 20 feet per mile in Atascosa County to 25 feet per mile in Bastrop County; (b) the line of discharge would consist of about 140 wells spaced approximately 1 mile apart and located as described above; (c) lowering of water levels in the outcrop is assumed to be minor with no resulting change in transmissivity and storage; and (d) leakage into the Carrizo and Simsboro sands is assumed to occur from the hydraulically connected sands and clays of the Wilcox only. Figure 4 illustrates the above assumptions.

The lateral transmission capacity of the Carrizo-Wilcox aquifer can be approximated for the proposed development scenario by using the formula

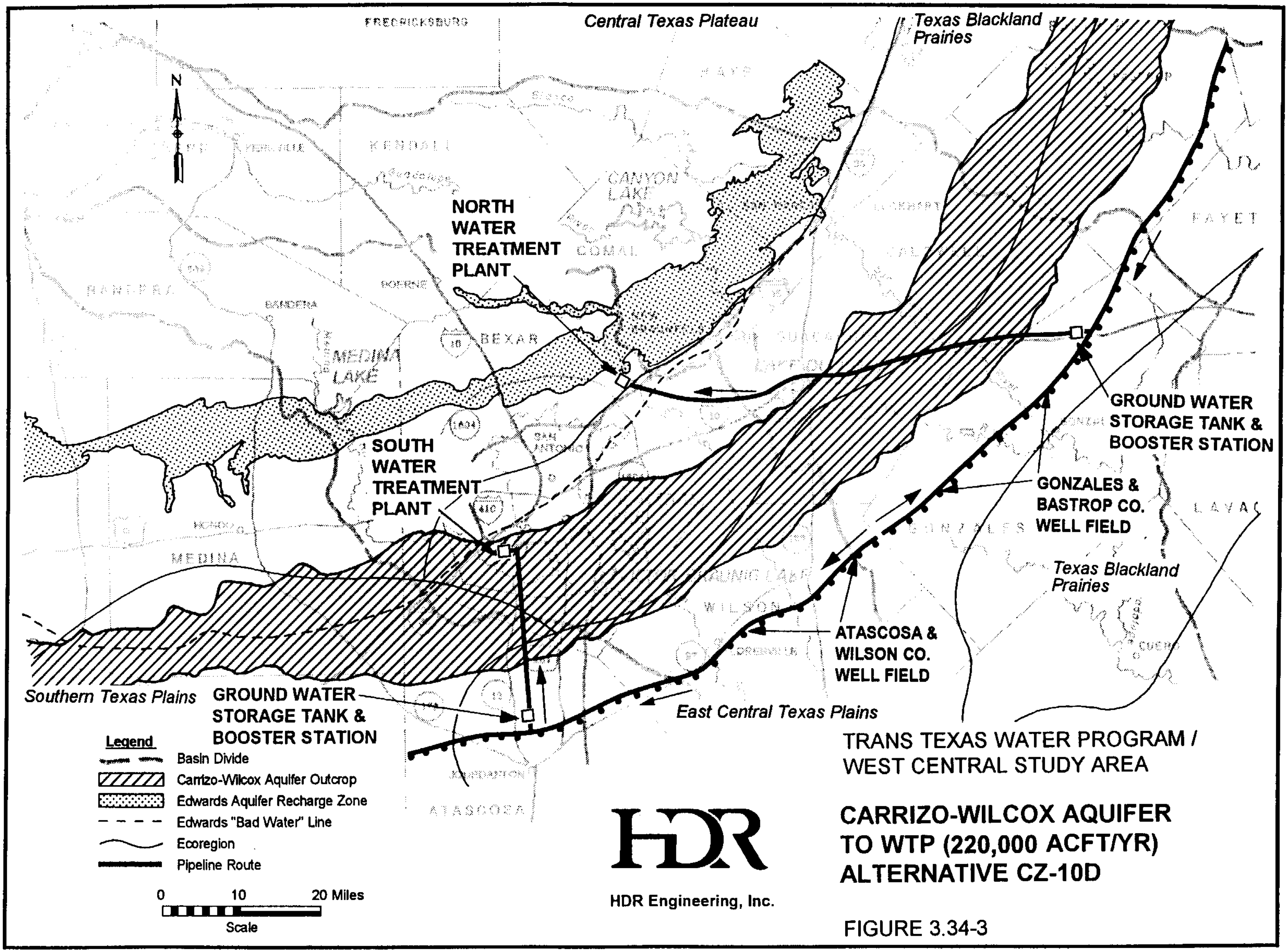
$$Q_{LT} = TWI$$

where

Q_{LT}	=	the average quantity of water in gallons per day moving through the aquifer;
T	=	the average coefficient of transmissivity in gallons per day per foot of aquifer;
W	=	the width of the aquifer in miles parallel to the strike of the formation; and
I	=	the average hydraulic gradient in feet per mile.

Interformational leakage exists in the Carrizo-Wilcox aquifer where pumping has lowered the head in the Carrizo (and Simsboro in Bastrop County) downdip from the outcrop and leakage into these water-bearing sands occurs from hydraulically connected Wilcox sands and clays. The following assumptions apply: (a) leakage is vertical and proportional to the difference in head; (b) hydraulic head in the Wilcox source sands and clays remains constant; and (c) storage in the confining bed may be neglected. Figure 4 illustrates the above assumptions.

The amount of leakage for the Carrizo-Wilcox aquifer may be approximated by the formula



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

CARRIZO-WILCOX AQUIFER TO WTP (220,000 ACFT/YR) ALTERNATIVE CZ-10D

FIGURE 3.34-3

San Antonio (Alt. CZ-10B); and, (3) a treatment plant with subsequent delivery to the San Antonio water distribution system (Alt CZ-10C and CZ-10D). Figures 3.34-1, 3.34-2, and 3.34-3 indicate the well field locations, the transmission corridors, and delivery locations.

Guyton states that the possibilities are good for artificially recharging the Carrizo-Wilcox outcrop and increasing the water availability of the aquifer. Artificial storage and recovery (ASR) is a technique of treating water to drinking water standards, injecting the water into an aquifer formation using dual-purpose wells, storing the water in the formation, and then recovering the water by pumping when needed. The ASR technology has the added benefit of increasing water availability in the downdip areas of the aquifer. As an example, the City of San Antonio could install ASR wells to the Carrizo in southern Bexar County and store water imported from another basin. The imported water recharged to the Carrizo would be available for later use by San Antonio or other aquifer users.

3.34.2 Available Yield

LBG-Guyton has performed a preliminary estimate of potential groundwater availability based on the following assumptions:

(1) the long term water balance requires that effective recharge (as a percentage of total rainfall) on the Carrizo-Wilcox outcrop increase in all four counties with increases ranging from 5 percent to 15.6 percent in Atascosa County and from 3 percent to 6.9 percent in Bastrop County.

(2) development of the aquifer results in a drawdown of static water levels at the line of discharge so that the hydraulic gradient from the outcrop increases to 20 feet per mile in Atascosa County and to 25 feet per mile in Bastrop County;

(3) lowering of water levels in the outcrop does not significantly change the formation transmissivity or storage; and,

(4) leakage into the formation occurs from the hydraulically connected sands and clays of the Wilcox group.

Table 3.34-1 contains a summary of the results provided by LBG-Guyton for potential water availability from new well field development.

Table 3.34-1
Carrizo-Wilcox Ground Water Availability

County[1]	Transmission from Outcrop[1] (acft/yr)	Inter-formational Leakage[2] (acft/yr)	1990 Pumpage[3] (acft/yr)	Estimated Ground Water Available for Additional Development (acft/yr)
Atascosa	67,200	18,400	59,100	26,500
Wilson	54,000	26,200	15,800	64,400
Gonzales	47,800	42,600	9,300	81,100
Bastrop	34,400	25,600	8,100	51,900
TOTALS	203,400	112,800	92,300	223,900

[1] The estimated quantity of water the Carrizo (and Simsboro in Bastrop County only) will transmit under an assumed hydraulic gradient established between the recharge area and points of discharge located downdip from the outcrop.
[2] The estimated interformational leakage into the Carrizo (and Simsboro in Bastrop County only) in response to the additional development of these water-bearing sands.
[3] The 1990 Carrizo-Wilcox ground water withdrawals estimated by county include pumpage from upgradient areas within adjacent counties, with the exception of Lee County.

Source: Adapted from "Phase I Evaluation, Carrizo-Wilcox Aquifer, West-Central Study Area, Trans-Texas Water Program", LBG-Guyton Associates, January, 1994.

The potential well field yield and delivery points for each alternative are:

Alternative	Description and Figure No.	Potential Yield (acft)	Delivery Location
CZ-10A	Carrizo Aquifer Development in Atascosa & Wilson Counties (Figure 3.34-1)	90,000	Injection Wells Near BMA Canal
CZ-10B	Carrizo Aquifer Development in Atascosa & Wilson Counties (Figure 3.34-1)	90,000	Recharge Zone
CZ-10C	Carrizo Aquifer Development in Atascosa & Wilson Counties (Figure 3.34-2)	90,000	Surface WTP and Distribution
CZ-10D	Carrizo Aquifer Development in Atascosa, Wilson, Gonzales, and Bastrop Counties (Figure 3.34-3)	220,000	Surface WTP and Distribution

3.34.3 Environmental Issues

The Carrizo-Wilcox aquifer encompasses several formations of hydrologically connected cross-bedded sands interspersed with clay, sandstone, silt, and lignites (Wilcox Group) and overlying massive sands of the Carrizo formation. These formations outcrop in a southwest-northeast trending crescent near the inland margin of the Gulf Coastal Plain (Figure 3.34-1), and dip downward toward the coast. Aquifer recharge occurs over the general surface of the outcrop area[76]. The thickness of the Carrizo in the downdip artesian areas at the study site ranges from about 400 feet in Gonzales and Caldwell Counties to more than 1000 feet in Atascosa County. The maximum thickness of the Carrizo aquifer in this area is about 2,500 feet.

The project area extends from Atascosa county northeast to Bastrop county. It consists of all or parts of Atascosa, Wilson, Bexar, Guadalupe, Gonzales, Caldwell, Bastrop,

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[76]LBG-Guyton Associates, 1994, "Phase I Evaluation Carrizo-Wilcox Aquifer West-Central Study Area Trans-Texas Water Program," Prepared for HDR Engineering, Inc., Austin, Texas (Also Appendix to this report).

Fayette and Lee Counties. The larger municipalities of the study area are: Pleasanton, Floresville, Seguin, Gonzales, Luling, Lockhart, Smithville and Bastrop. The project area includes land primarily in the Post Oak Savannah vegetational area in the northeast, and the Blackland Prairies vegetational area in the south. Only a portion of the study area (Atascosa County) lies within the South Texas Plains vegetational area (Figure 3.34.1)[77]. The Blackland Prairies soils are fairly uniform, dark-colored calcareous clays interspersed with some gray acid sandy loams. Most of this fertile area has been cultivated, although a few native hay meadows and ranches remain. Little bluestem is the dominant grass of the native assemblage with other important grasses present including big bluestem, Indian grass, switchgrass, tall dropseed, silver bluestem and Texas wintergrass. Under heavy grazing, buffalo grass, Texas grama, smutgrass and many annuals increase or invade native pastures. Mesquite, post oak and blackjack oak also invade or increase under these conditions.

The Post Oak Savannah upland soils are light-colored, acid sandy loams or sands. Bottomland soils are light-brown to dark-gray and acid, ranging in texture from sandy loams to clays. Most of the Post Oak Savannah is still in native or improved pastures although small farms are common.

The South Texas Plains is dissected by streams flowing into the Rio Grande and the Gulf of Mexico. Soils in this area range from clays to sandy loams, and vary in reaction from very basic to slightly acid. This wide range of soil types is responsible for great differences in soil drainage and moisture holding capacities within this region[78,79]. Wetlands in the project area consist of riverine habitats of Cibolo Creek, the San Antonio, Guadalupe and Colorado Rivers and their tributaries, as well as associated palustrine habitats which are generally composed of narrow bands of wetlands along these watercourses.

Vertebrate fauna typifying these regions include the opossum, raccoon, weasel, skunk, white-tailed deer, and bobcat. The coyote and javelina are found mainly in brush/shrub

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[77]Gould, F.W., 1975, "The Grasses of Texas," Texas A&M University Press, College Station, Texas.

[78]Ibid.

[79]McMahan, C.A., R.G. Frye, K.L. Brown, 1984, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Austin, Texas.

areas and the red and gray fox in woodlands[80]. A wide variety of species of amphibians, reptiles and birds are also found throughout the region[81,82].

The 70 mile well field/pipeline, and the 25 mile transfer pipeline and water treatment plant in alternatives CZ-10A, B, and C (Figures 3.34-1, 3.34-2) would be constructed within the South Texas Plains and Blackland Prairie vegetational areas[83,84]. The northern San Antonio portions of the delivery pipelines of alternatives CZ-10 A and B cross into the Edwards Plateau Ecoregion. Alternative CZ-10D extends the well field into the Post Oak Savannah vegetation region[85,86].

The estimated areas required for construction of the four scenarios encompassed by this alternative are: CZ-10A, 2,628 acres; CZ-10B, 1,975 acres; CZ-10C, 1,762 acres and CZ-10D, 5,376 acres. Cropland, together with shrub and brushland dominate the landscapes in which alternatives CZ-10A through CZ-10C would lie. Alternative CZ-10D extends into the Post Oak Savannah and would be in an area less impacted by ongoing agricultural activity (Table 3.0-1).

The potential environmental effects resulting from the construction and operation of well pads and water transport pipelines depend to a large extent on the exact placement of the construction corridor. In general, habitats critical to the survival of important and protected species are locally restricted so that adverse impacts can often be avoided or

[80]Jones, K.J., et al., May 1988, "Annotated Checklist of Recent Land Mammals of Texas," Occasional Papers, The Museum, Texas Tech University No. 119.

[81]McMahan, C.A., R.G. Frye, K.L. Brown, 1984, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Austin, Texas.

[82]Jones, K.J., et al, May 1988, "Annotated Checklist of Recent Land Mammals of Texas," Occasional Papers, The Museum, Texas Tech. Univ. No. 119.

[83]Gould, F.W., 1975, "The Grasses of Texas," Texas A&M University Press, College Station, Texas.

[84]McMahan, C.A., R.G. Frye, K.L. Brown, 1984, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Austin, Texas.

[85]McMahan, C.A., R.G. Frye, K.L. Brown, 1984, "The Vegetation Types of Texas," Texas Parks and Wildlife Department, Austin, Texas.

[86]Jones, K.J., et al, May 1988, "Annotated Checklist of Recent Land Mammals of Texas," Occasional Papers, The Museum. Texas Tech. Univ. No. 119.

minimized by site and alignment selection. More generally distributed habitats, although perhaps important to regional wildlife populations in some areas, may not be so easy to avoid, but the limited area affected by these corridors allows for insignificant impacts.

Plant and animal species listed by the USFWS and TPWD as endangered or threatened in the project area, and those with candidate status for listing are presented in Table 3.34-2. Because this alternative would extend through three ecoregions in nine counties, all the species listed in Table 3.34-2 have habitat requirements or preferences that suggest they could be present within the project area. Surveys for protected species or other biological resources of restricted distribution, or other importance, would be conducted within the proposed construction corridors where preliminary studies have indicated that habitat may be present.

The primary impacts that would result from construction and operation of alternative CZ-10 include temporary disturbance to soils and habitat during construction of wells, pipelines and other facilities; permanent conversion of existing habitats or land uses to maintained pipeline ROW; disturbance of minor acreages for construction of water treatment plants, storage stations and well injection fields; and mixing of treated aquifer water with waters of the Edwards Aquifer. Water quality impacts on the Edward aquifer from treated Carrizo-Wilcox Aquifer water should be studied in a later phase of Trans-Texas. Indirect effects of construction may include mitigation areas converted to alternate uses to compensate for losses of terrestrial habitat.

Because there are no known metazoan inhabitants present, withdrawing water from the Carrizo aquifer would not impact an endemic fauna. These withdrawals may, however, lower the water table to some extent in the outcrop area, potentially affecting the water budgets of streams and ponds in the area. Northeast of Atascosa County, the Carrizo aquifer appears to be full and is discharging water to streams and rivers that cross the outcrop (Figure 3.34-1)[87]. It is intended that the proposed well field would lower water levels in outcrop areas so that additional storage space would be created in the aquifer,

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[87]LBG-Guyton Associates, 1994, "Phase 1 Evaluation Carrizo-Wilcox Aquifer West-Central Study Area Trans-Texas Water Program," Prepared for HDR Engineering, Inc., Austin, Texas (Also Appendix A to this report).

Table 3.34-2
Important Species with Habitat in the Project Vicinity (CZ-10)

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin[1]	C1	NL
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov.	NL	T
Houston Toad	*Bufo Houstonensis*	Loamy, friable soils, temporary rain pools, flooded field, ponds surrounded by forest or grass; reintroduced to Colorado Co.	E	E
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive[1]	C2	T
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporarily wet areas, arroyos, canals, ditches and shallow depressions; requires moisture to remain	C2	E
	Streptanthus bracteatus	In shallow, well drainage gravely clays and clay loams over limestone in oak-juniper woods, wooded slopes, canyon bottoms and sandy river margins	C2	NL

Source: Texas Natural Heritage Program, 1993, Unpublished, Data base files, Natural Resource Protection Division, Texas Parks and Wildlife Department.
[1]Dixon, James R., 1987, Amphibians and Reptiles of Texas, Texas A & M University Press, College Station, Texas.

increasing infiltration of surface-water runoff[88]. As a result, it is possible that the base flows of streams crossing the recharge zone would be reduced, and that channel losses could increase on the outcrop. The rates of water loss from permanent ephemeral ponds could also increase. Because of limited groundwater storage capacity, the potential for significant losses of stream baseflow is probably not a major concern. Enhancement of seepage losses, however, may prove to be of more concern.

[88]Ibid.

Detailed hydrologic information regarding watertable drawdown is not available at present, but lowering the Carrizo aquifer water table in Fayette and Bastrop Counties could possibly impact Houston toad habitat (Table 3.34-1). The Houston toad uses the vernal pools (temporary ponds that typically contain water during the spring and dry completely during the summer) provided by the saturated sands of the Carrizo aquifer as their breeding habitat[89]. The Texas garter snake, lesser siren and bracted twistflower populations could also be impacted as they inhabit wet areas in the project area (Table 3.34-1).

Construction in brush/shrub habitat and maintenance activities would potentially impact populations of the Texas tortoise and Texas horned lizard. Since over half of the proposed well field corridor in alternatives CZ-10A, B and C consists of cropland (Table 3.2-1), wildlife habitats tend to be small and fragmented, and may be disproportionately valuable to regional wildlife populations. Construction impact can generally be minimized or avoided, however, by locating project features in less sensitive cropland, pasture or upland woodland whenever possible. Construction across rivers and streams should be minimized, as riparian zones support wetlands and are valuable to wildlife. Mitigation may be required for impacts associated with the pump stations, injection wells, recharge structures, water treatment plants, and pipelines identified for the CZ-10 alternatives if sensitive ecological or cultural resources are identified in a future phase of this study.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL 96-515), and the Archaeological and Historic Preservation Act (PL 93-291). All areas to be disturbed during construction would be surveyed by qualified professionals for the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

[89]Andrew H. Price, 1994, Personal Communication, Resource Protection Division, Texas Parks and Wildlife Department, Austin, Texas.

3.34.4 Water Quality and Treatment

In the study area, the Carrizo-Wilcox aquifer yields water that meets the National Primary Drinking Water Regulations standards required for public health. However, secondary standards for iron may be exceeded in certain areas and hydrogen sulfide or methane gas may be found in localized areas. Treatment Level 1 (Table 3.0-4) will produce Carrizo-Wilcox water that meets primary and secondary standards for public water supply or to inject to the Edwards Aquifer. For injection to the Edwards, compatibility tests must be performed to determine the potential for precipitates forming upon mixing of the two sources that could clog the injection wells.

3.34.5 Engineering and Costing

Well fields, transmission pipelines, and delivery systems have been sized and costed for two annual delivery volumes: the lower amount is for development of a well field in Atascosa and Wilson counties only (Figures 3.34-1 and 3.34-2), resulting in an estimated yield of 90,000 acft/yr; the larger amount is for development of a well field in Atascosa, Wilson, Gonzales, and Bastrop counties (Figure 3.34-3), for an estimated 220,000 acft/yield.

<u>Alternative CZ-10A: Delivery to Aquifer Injection Wells</u>

For this alternative, a well field would be developed in Wilson and Atascosa counties with an estimated yield of 90,000 acft/yr. The yield would be pumped in a transmission line to the injection well field in eastern Medina County. The delivery to the injection wells would be uniform throughout the year. The benefit from this project includes the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and springs. Prior to injection to the aquifer, the water would be treated (Treatment Level 1, Table 3.0-4). The major facilities required to implement this alternative are:

Well Field and Collection Lines
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Station
Water Treatment Plant (Level 1, Table 3.0-4)
Finished Water Pump Station
Finished Water Booster Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The well field is sized to deliver 7,500 acft/month (80 mgd) through a collection and transmission pipeline sized from 18 to 72-inches in diameter. The operating cost was determined for the total raw water pumping head of 650 feet and an annual water delivery of 90,000 acft/year. Operating cost of the finished water pumping system was determined for a static lift of 310 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $26,860,000 (Table 3.34-3). Operation and maintenance costs total $6,460,000 and power costs are estimated to be $15,070,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $48,390,000. For an annual firm yield of 90,000 acft, the resulting annual cost of water is $538 per acft (Table 3.34-3).

Alternative CZ-10B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, a well field would be developed in Wilson and Atascosa counties with an estimated yield of 90,000 acft/yr. The yield would be pumped in a transmission line to recharge structures in northwestern Bexar County. The delivery to the recharge structures would be uniform throughout the year. The benefit from this project includes the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and springs. The yield from this alternative will be placed in open impoundments and mixed with surface runoff present in the local watershed. There is no known water quality condition that requires the imported water to be treated prior to placement in a natural stream or surface impoundment. However, there may be concerns that the imported water is of different quality than the existing runoff and the need for treatment of the imported water may require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of the imported water. The major facilities required to implement this alternative are:

- Well Field and Collection Lines
- Raw Water Pipeline to Treatment Plant
- Raw Waterline Booster Pump Station
- Transmission Line to Recharge Structures
- Recharge Structures
- Treatment Plant Items (if determined to be needed):
    - Water Treatment Plant (Level 1, Table 3.0-4)
    - Finished Water Pump Station

Table 3.34-3
Cost Estimate Summaries for Carrizo-Wilcox Aquifer Development Alternative (CZ-10)
(Mid- 1994 Prices)

Item	Alt. CZ-10A Inject to Aquifer	Alt. CZ-10B Deliver to Recharge Zone	Alt. CZ-10C Deliver to WTP and Municipal System	Alt. CZ-10D Deliver to WTP and Municipal System
Capital Costs				
Well Field	$40,920,000	$40,920,000	$40,920,000	$79,630,000
Transmission Lines/Pump Stations/ Ground Storage	125,920,000	139,560,000	82,310,000	260,320,000
Treatment Plant	9,310,000	9,310,000[1]	9,310,000	22,240,000
Delivery System	15,680,000	6,500,000	76,520,000	176,950,000
Total Capital Cost	$191,830,000	$196,290,000[1] $186,980,000[2]	$209,060,000	$539,140,000
Engineering, Contingencies, and Legal Costs	61,200,000	62,750,000[1] 59,490,000[2]	42,620,000	114,790,000
Land Acquisition	2,450,000	3,340,000	1,860,000	4,770,000
Environmental Studies & Mitigation	7,260,000	6,060,000	3,310,000	7,360,000
Interest During Construction	23,880,000	24,340,000[1] 23,590,000[2]	17,290,000	44,780,000
Total Project Cost	$286,620,000	$292,780,000[1] $279,460,000[2]	$274,140,000	$710,840,000
Annual Costs				
Annual Debt Service	$26,860,000	27,430,000[1] 26,190,000[2]	$25,690,000	$66,610,000
Annual Operation & Maintenance	6,460,000	6,800,000[1] 2,960,000[2]	5,540,000	13,820,000
Annual Power Cost	15,070,000	7,180,000	5,900,000	23,740,000
Total Annual Cost	$48,390,000	$41,410,000[1] $36,330,000[2]	$37,130,000	$104,170,000
Available Project Yield (acft/yr)	90,000	90,000	90,000	220,000
Annual Cost of Water	$538/acft	$460/acft[1] $404/acft[2]	$413/acft	$474/acft

[1] Cost with treatment prior to surface recharge.
[2] Cost without treatment prior to surface recharge.

Finished Water Booster Pump Stations
Transmission Line to Recharge Zone

The well field is sized to deliver 7,500 acft/month (80 mgd) through a collection and transmission pipeline 18 to 72-inches in diameter. The operating cost was determined for the total raw water pumping head to the treatment plant of 650 feet and an annual water delivery of 90,000 acft/year. If no treatment plant is required, then the operating cost is determined for a static lift to the recharge structures of 1,340 feet. For a treatment plant, the operating cost of the finished water pumping system was determined for a static lift of 690 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $27,430,000 with a treatment plant and $26,190,000 with no treatment plant (Table 3.34-3). Operation and maintenance costs total $6,800,000, including the treatment plant and are $2,960,000 without a treatment plant. Power costs are estimated to be $7,180,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $41,410,000 including the treatment plant and are $36,330,000 without a treatment plant. For an annual firm yield of 90,000 acft, the resulting annual cost of water, including a treatment plant, is $460 per acft, and is $404 per acft without a treatment plant (Table 3.34-3).

Alternative CZ-10C: Delivery to the Municipal Distribution System - 90,000 acft Yield

For this alternative, a well field would be developed in Wilson and Atascosa counties with an estimated yield of 90,000 acft/yr and pumped in a transmission line to the South Water Treatment Plant. The delivery rate to the treatment plant would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and the resulting reduction in demand on the aquifer. The major facilities required to implement this alternative are:

Well Field and Collection Lines
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Station
Water Treatment Plant (Level 1, see Table 3.0-4)
Finished Water Pump Station
Transmission Line to Distribution System
Distribution System Improvements

The well field is sized to deliver 7,500 acft/month (80 mgd) through a collection and transmission pipeline sized from 18 to 72-inches in diameter. The operating cost was determined for the total raw water pumping head of 650 feet and an annual water delivery of 90,000 acft/year. Operating cost of the finished water pumping system was determined for the total pumping head of 300 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $25,690,000 (Table 3.34-3). Operation and maintenance costs total $5,540,000, and power costs are estimated to be $5,900,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $37,130,000. For an annual firm yield of 90,000 acft, the resulting annual cost of water is $413 per acft (Table 3.34-3).

Alternative CZ-10D: Delivery to the Municipal Distribution System - 220,000 acft Yield

For this alternative, a well field would be developed in Wilson, Atascosa, Gonzales, and Bastrop counties with an estimated yield of 220,000 acft/yr and pumped in transmission lines to two water treatment plants. The delivery rate to the treatment plants would be uniform throughout the year. The benefit from this project includes the addition of a new potable water supply to the San Antonio distribution system and the resulting reduction in demand on the aquifer. The major facilities required to implement this alternative are:

Well Fields and Collection Lines
Raw Water Pipelines to Treatment Plants
Raw Waterline Booster Pump Stations, 2 required
Ground Storage Tanks
North Water Treatment Plant (Level 1, Table 3.0-4)
South Water Treatment Plant (Level 1, Table 3.0-4)
Finished Water Pump Stations
Finished Water Booster Pump Stations, 2 required
Transmission Lines to Distribution System
Distribution System Improvements

The Wilson/Atascosa well field is sized to deliver 7,500 acft/month (80 mgd) through collection and transmission pipelines sized from 18 to 72-inches diameter. The operating cost was determined for the total raw water pumping head from the aquifer to the treatment plant of 650 feet and an annual water delivery of 90,000 acft/year. The Gonzales/Bastrop well field is sized to deliver 10,800 acft/month (116 mgd) through 18 to 84-inch diameter pipelines. The operating cost was determined for the total raw water pumping head of 1,400 feet and an annual water delivery of 130,000 acft/yr. Operating costs of the finished water pumping systems from the water treatment plants was determined for a total pumping head of 300 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $66,610,000 (Table 3.34-3). Operation and maintenance costs are $13,820,000 and power costs are estimated to be $23,740,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $104,170,000. For an annual firm yield of 220,000 acft, the resulting annual cost of water is $474 per acft (Table 3.34-3).

3.34.6 Implementation Issues

The amount of ground water that can be developed by wells from the Carrizo-Wilcox aquifer in the study area on a long-term basis is directly related to the ability of the aquifer to transmit additional water from the outcrop to points of discharge and the amount of interformational leakage which may occur as a result of pumping from the aquifer. Both of these requirements must be verified by a technical ground water investigation, including hydrogeologic mapping, updated inventory of existing wells, test drilling, test pumping, computer modeling, and chemical analysis. This investigation program would be used to determine the most efficient well completion, optimum pumping rate, pump setting, well spacing, water treatment requirements, water-level drawdown impacts in the outcrop and within the area favorable for development.

If such a well field is developed, possibilities are good for artificially recharging the Carrizo-Wilcox outcrop and increasing the water-producing potential of the aquifer. Previous studies have identified Atascosa, Wilson, and southern Bexar Counties as being favorable for artificial recharge projects.

Permitting requirements must be addressed before proceeding with the development of the well field and artificial recharge projects. These include, for the most part, permits from the TNRCC and Evergreen Underground Water District. The District's permitting responsibilities include new well construction, changes to existing wells, construction and operation of recharge facilities and transportation of water from the District.

Requirements Specific to Pipelines (CZ-10, All)

An institutional arrangement is needed to implement projects including financing on a regional basis.

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    b. GLO Sand and Gravel Removal permits.
    c. Coastal Coordinating Council review.
    d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (CZ-10A)

1. Required testing programs:
    a. Detailed field investigation of existing supply wells, including performance tests.
    b. Test drilling and pilot recharge program is required.
    c. Large scale recharge test program.
    d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
    e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
    a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (CZ-10B)

1. Detailed field investigations of each potential site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
    a. TNRCC Water Rights and Storage permit.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
    c. GLO Sand and Gravel Removal permit.
    d. TPWD Sand, Gravel, and Marl permit.

4. Permitting, at a minimum, will require these studies:
    a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
    b. Study of impact on karst geology organisms from a sustained recharge program.
    c. Other environmental studies.
    d. Cultural resource studies.

<u>Requirements Specific to Treatment and Distribution (CZ-10C,D)</u>

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

APPENDIX A

REPORT ON CARRIZO AQUIFER

PHASE I EVALUATION
CARRIZO-WILCOX AQUIFER
WEST-CENTRAL STUDY AREA
TRANS-TEXAS WATER PROGRAM

Prepared for

HDR Engineering, Inc.
Austin, Texas

January 1994

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brushland vegetation makes this an excellent nesting habitat for a variety of bird species. It also provides ample food and cover for a number of rodents and other mammalian species, including the white-tailed deer and collared peccary. The protected Texas tortoise utilizes brush habitats for cover, and for food in the form of cacti and herbaceous undergrowth.[100]

The grassland community types represent approximately 13,796 acres within the proposed reservoir site (see Table 3.0-1), and include managed pastures, oldfields, and ROW. The majority of the grassland within the reservoir site is used as grazing land for livestock.

Substantial areas of cropland (approximately 6,691 acres) occur within the proposed reservoir site (see Table 3.0-1), primarily within the Guadalupe River floodplain. Principal crops grown in the region include grain sorghum, corn, cotton, wheat, and peanuts[101].

Wetlands, which occupy approximately 2,402 acres within the proposed Cuero Reservoir site (see Table 3.0-1), include riverine habitats; palustrine forested, scrub/shrub, emergent, and open-water wetlands; and limited areas of lacustrine open-water habitat. Forested wetlands (i.e., swamps) are limited to areas within the Guadalupe River floodplain and occur primarily in association with oxbow lakes and sloughs. Scrub/shrub and emergent wetlands (i.e., marshes) occur in wet depressions and around the edges of aquatic habitats within the proposed reservoir site.

The aquatic habitats of the Guadalupe River in the Cuero Reservoir are dominated by the mainstream river and several major permanent creeks such as Peach, Denton McCoy, and Cuero. Both the mainstem river and permanent creeks are relatively low gradient streams with meandering channels. Numerous oxbows have been formed in the mainstem of the Guadalupe River. The banks of all permanent water bodies are generally relatively steep and comprised primarily of clay. However, some areas of Peach Creek and Denton Creek have sandy banks and sandy substrate. Generally, the bottom is clay in permanent

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[100]Ibid.

[101]Ibid.

water areas[102].

The primary impacts that would result from construction and operation of the Cuero Reservoir include conversion of existing habitats and land uses within the conservation pool to open water, and potential downstream effects due to modification of the existing flow regime. The Cuero Reservoir site would be permanently inundated to 242 feet MSL with a surface area of 41,500 acres. The 100-year flood elevation would be 257 feet MSL, with a resulting surface area of 57,500 acres. Approximately 13,796 acres of grassland, 6691 acres of cropland, 11,360 acres of woodlands, 6,991 acres of shrubland, 1,464 acres of wetlands, 938 acres of riverine habitat, and 260 acres of developed land would be converted to open water upon dam construction (see Table 3.0-1). In addition to long-term impacts within the conservation pool, minor changes to existing resources situated between the conservation pool elevation and flood pool elevation could be anticipated due to occasional temporary inundation during flood events.

Potential downstream impacts would include modification of the streamflow regime below the dam, and reduced inflows to San Antonio Bay. It is assumed that as a new reservoir without a current operating permit, the Cuero Reservoir would be required to meet the Trans-Texas Water Program "New Reservoir" criteria for instream flows and freshwater inflows to bays and estuaries. Hydrologic modeling was conducted to determine the firm yield of Cuero Reservoir and to evaluate the potential impacts of reservoir operation on instream flows and freshwater inflows to bays and estuaries. The baseline flows used in the following comparisons were developed using the assumption that all existing water rights are fully utilized, so the analysis would consider cumulative hydrologic impacts.

A yield of 168,000 acft/year was projected with the Trans-Texas criteria in place, using a 60 percent reservoir capacity trigger. Modeling results indicate that, under this scenario, the monthly median streamflow on the Guadalupe River at Cuero is reduced fairly uniformly throughout the year relative to without-project conditions, with the greatest reductions (approximately 10,000 to 12,000 acft/month) occurring in January, May, and June. The greatest decreases in average streamflow on the Guadalupe River at Cuero (37

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[102]Ibid.

to 44 percent) occur in the lowest range of streamflow deciles (i.e., less than 20 percent).

The criteria for freshwater inflow to bays and estuaries are assumed to be met if the reservoir criteria are met. Modeling of the monthly median streamflow at the saltwater barrier indicates flow reductions of about 17 percent in January, but ranges from zero to about 10 percent of all the other monthly medians. Decreases in average streamflow at the saltwater barrier range from about 10 to 25 percent in all streamflow deciles except the lowest, where average flow declines by almost one third. Annual average flows at the salt water barrier are projected to decline from 1,609,270 to 1,359,770 acft/yr under Alternative G-16. According to relationships established in Texas Department of Water Resources studies, this would be more than sufficient inflow to maintain the salinity structure of the Guadalupe Estuary (Alternative I, Sustenance), but not enough to meet the requirements of Alternative II (Maintenance of historical fisheries harvest)[103].

Plant and animal species listed by the USFWS and TPWD as endangered or threatened, and those with candidate status for listing in DeWitt and Gonzales counties are presented in Tables 14 and 21 of Appendix B. Those species with potential habitat in the vicinity of the proposed reservoir are listed in Table 3.21-2. The Texas Natural Heritage Program records include reported occurrences of the Texas meadow-rue (*Thalictrum texanum*), a USFWS candidate species for protection, in Gonzales County along the Guadalupe River just upstream of the town of Gonzales[104], which is located near the Cuero Reservoir site.

Of the species listed in Table 3.21-2, two are river dependent, Cagle's map turtle and the blue sucker. The Cagle's map turtle has been observed within the proposed reservoir area[105]. The blue sucker has not been recently reported in the lower Guadalupe

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[103]Texas Department of Water Resources, 1980, "Guadalupe Estuary: A study of the Influence of Freshwater Inflows," LP-107, Austin, Texas.

[104]Texas Natural Heritage Program (TNHP). 1985 and 1994. Unpublished data from element records. Austin, Texas.

[105]Killebrew, F.C., 1991, "Habitat Characteristics and Feeding Ecology of Cagle's Map Turtle (*Graptemys caglei*) Within the Proposed Cuero and Lindenau Reservoir Sites," Prepared for Texas Parks and Wildlife Department under interagency contract with the Texas Water Development Board, 15 pp.

Table 3.21-2
Important Species With Habitat Within the Project Vicinity (G-16)

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, or uses underground burrows; active March-November	NL	T
Reticulate Collared Lizard	*Crotaphytus reticulatus*	South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks[1]	C2	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL
Blue Sucker	*Cycleptus elongatus*	Large rivers throughout Mississippi River Basin south and west in major freshwater streams of Texas to Rio Grande River	C2	T
Big Red Sage	*Salvia penstemonoides*	Moist creek and stream bed edges; historic; introduced in native plant nursery trade	C2	NL
Texas Meadow-rue	*Thalictrum texanum*	Coastal plains and savannah of south east Texas; known in Brazos and Waller Cos.; historic in Harris Co.	C2	NL
Mulenbrock's Umbrella Sedge	*Cyperus grayioides*	Prairie grasslands, moist meadows in Texas, Louisiana, Illinois	C2	NL
Prairie Dawn (also called Texas Bitterweed)	*Hymenoxys texana*	Gulf prairie and marshes in poorly drained depressions or at the base of mima mounds in open grasslands in almost barren areas; known in Ft. Bend and Harris Cos.; historic collection from LaSalle Co.	E	E

Source: TPWD, Unpublished files, Texas Natural Heritage Program, Texas Parks and Wildlife, Austin, Texas.
[1]Dixon, J.R. 1987. Amphibians and Reptiles of Texas. Texas A&M Press, College Station, Texas.

River[106]. If the species is present, this reach would likely be rendered unsuitable for construction of a main-stem impoundment. A survey of the reservoir site will be required to determine whether populations of or potential habitat for species of concern occur.

Several important aquatic species that warrant attention are the river darter (*Percina shumardi*), the freshwater prawn (*Macrobrachium carcinus*), and the American eel (*Anguilla rostrata*). The river darter, an unprotected non-game fish, has been reported on the Guadalupe River in the Cuero project area[107]. The American eel and the freshwater prawn, although not recently collected, are known to have occurred historically in the Guadalupe River basin. Reservoir development would alter the fishery from that of a stream (lotic) habitat to a reservoir (lentic) habitat. Species dependent on a lotic habitat for their life cycle would be eliminated within the lentic habitat.

The proposed Cuero Reservoir has been subjected to an intensive cultural resources investigation. A total of 357 archaeological sites were recorded at or below the 270-ft MSL contour elevation, including five previously recorded sites that were revisited in a survey conducted by the Texas Historical Commission (THC) and the Texas Water Development Board[108].

Sites containing prehistoric components accounted for 293 of the 357 sites recorded, and ranged from Paleo-Indian to Historic occupations. Archaeological testing and surface collection for 133 sites, additional survey of about 3,300 acres of land not accessible at the time of initial survey, extensive historical records research, and controlled excavations of 14 sites within and on the margin of the area to be flooded were recommended by Fox

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[106]Academy of Natural Sciences (ANS). 1991. A review of chemical and biological studies on the Guadalupe River, Texas, 1949-1989. Report No. 91-9. Acad. Nat. Sci. Phil. Philadelphia, PA.

[107]Espey, Huston & Associates, Inc., (EH&A), 1986, "Water Availability Study for the Guadalupe and San Antonio River Basin," Prepared for San Antonio River Authority, Guadalupe-Blanco River Authority and City of San Antonio, Volumes I and II, EH&A Document No. 85580, February.

[108]Fox, D.E., R.J. Mallouf, Nancy O'Malley and W.M. Sorrow, 1974, "Archaeological Resources of the Proposed Cuero I Reservoir, DeWitt and Gonzales Counties, Texas," *Archaeological Survey Report* No. 12, Texas Historical Commission and Texas Water Development Board, Austin.

et al.[109] prior to project inundation. Areas not subjected to survey were not identified.

Nominated to the National Register of Historic Places (NRHP) in June 1974 by the THC, virtually the entire proposed Cuero Reservoir was accepted by Federal review agencies as the Cuero I Archaeological District in October 1974. The Cuero I Archeological District, located in DeWitt and Gonzales counties, extends over a 45-mile long area of the lower Guadalupe River Basin between Cuero and Gonzales. This area is larger than the area covered by the proposed Cuero Reservoir.

Outside the 242 ft MSL flood pool, at about the 245 ft MSL contour, is the Braches Home, located about 12 miles southeast of Gonzales. The house is listed on the NRHP. One historical marker commemorating Dr. W. W. White is located within the Cuero Reservoir area. Four other markers commemorating the Cuero I Archaeological District, the Braches Home, the Sam Houston Oak, and the town of Concrete, are located between the 242 and 265 ft MSL contours. The State Historic Building Inventory lists one structure within the proposed reservoir, the Miles Squire Bennett House. This house is located in DeWitt County approximately two miles north of the dam site. Only the foundation, chimney and cistern remain. The frame house has been disassembled.

No previously recorded Historic Architectural Buildings Survey (HABS) structures, Registered Log Cabins or Natural Landmarks are located within the proposed reservoir area.

Within the 242 ft MSL reservoir elevation, an EH&A reconnaissance survey[110] identified 82 possibly significant historic resources, including seven cemeteries. Excluding the cemeteries, the potential resources are farmsteads, houses, and other buildings that may have been associated with the early communities of the area. At least twenty other possible historic structures and 18 cemeteries are located between the 242 and 300 ft MSL contours. Down river from the dam, four structures and three cemeteries were also recorded. These cultural resources are noted due to their proximity to the proposed dam.

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[109] Ibid.

[110] Espey, Huston & Associates, Inc., (EH&A), 1986, "Water Availability Study for the Guadalupe and San Antonio River Basin," Prepared for San Antonio River Authority, Guadalupe-Blanco River Authority and City of San Antonio, Volumes I and II, EH&A Document No. 85580, February.

Laws have been implemented by the Federal and Texas State governments to protect cemeteries. These resources should either be avoided or dealt with appropriately. Special procedures for handling cemeteries, as outlined in Vernon's Annotated Revised Civil Statues of the State of Texas (Title 26, Article 912a-10 and 912a-11), will have to be followed for the Cuero Reservoir site.

Because the proposed Cuero I Reservoir has been intensively surveyed and consequently placed on the NRHP as the Cuero I Archaeological District, resurvey most likely will not be called for in the permitting process. The 3,300 acres not surveyed by Fox et al.[111] will most likely require survey.

3.21.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.21.5 Engineering and Costing

The cost estimate for the dam and reservoir is an update of a previous cost estimate performed by EHA[112]. That cost estimate was updated by multiplying the individual cost components by the ratio (mid 1994/1991) of the relevant Bureau of Reclamation Construction Cost Indexes.

<u>Alternative G-16A: Delivery to Aquifer Injection Wells</u>

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission pipeline to the injection well field in eastern Medina County. The diversion rate from the reservoir, as well as the delivery to the wells would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and possibly springs. Prior to injection to the aquifer, the water would be

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[111]Fox, D.E., R.J. Mallouf, Nancy O'Malley and W.M. Sorrow, 1974, "Archaeological Resources of the Proposed Cuero I Reservoir, DeWitt and Gonzales Counties, Texas," *Archaeological Survey Report* No. 12, Texas Historical Commission and Texas Water Development Board, Austin.

[112]Espey, Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," Guadalupe-Blanco River Authority, February, 1986.

treated in a direct filtration plant (Treatment Level 2, see Table 3.0-4). The major facilities required to implement this alternative include:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Water Booster Pump Stations, (3 required)
Water Treatment Plant (Level 2)
Finished Water Pump Station
Finished Water Booster Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The reservoir intake and pump station is sized to deliver 14,000 acft/month (244 cfs) through a 96-inch diameter pipeline. The operating cost was determined for a static lift of 300 feet and an annual water delivery of 168,000 acft/yr. Operating cost of the finished water pumping system was determined for the total static lift of 310 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual cost of $76,010,000 (Table 3.21-2). Operation and maintenance costs, including power, total $39,560,000. Total annual costs, including debt repayment, interest, and operation and maintenance, total $115,570,000. For an annual firm yield of 168,000 acft, the resulting annual cost of water is $688 per acft (Table 3.21-2).

Alternative G-16B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission pipeline to small recharge structures in northwestern Bexar County located over the recharge zone. The diversion rate from the reservoir, as well as the delivery to the recharge structures would be uniform throughout the year. The benefit from this project would be the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and possibly springs. Concerns that the imported water is of different quality than the existing recharge water and the possible need for treatment of the Cuero water will require follow-on study. However, for comparison and information purposes, project cost estimates have been prepared with and

Table 3.21-2
Cost Estimate Summaries for Cuero Reservoir (G-16)
(Mid- 1994 Prices)

Item	Alt. G-16A Divert and Inject to Aquifer	Alt. G-16B Divert to Recharge Zone	Alt. G-16C Divert to WTP and Municipal Systems
Capital Costs			
Dam and Reservoir	$160,860,000	$160,860,000	$160,860,000
Transmission and Pumping	229,720,000	231,060,000	162,740,000
Treatment Plant	33,570,000	33,570,000	62,000,000
Delivery System	24,130,000	23,660,000	100,030,000
Total Capital Cost	$448,280,000	$449,150,000[1] 415,580,000[2]	$485,640,000
Engineering, Contingencies, and Legal Costs	146,110,000	146,650,000[1] 134,900,000[2]	152,720,000
Land Acquisition	83,850,000	84,560,000[1] 84,510,000[2]	83,210,000
Environmental Studies and Mitigation	74,330,000	75,340,000	69,900,000
Interest During Construction	58,580,000	59,550,000[1] 56,820,000[2]	58,310,000
Total Project Cost	$811,150,000	$815,250,000[1] $767,150,000[2]	$849,780,000
Annual Costs			
Annual Debt Service	$76,010,000	$76,390,000[1] 71,880,000[2]	$79,620,000
Annual Operation and Maintenance	15,050,000	15,640,000[1] 6,200,000[2]	14,660,000
Annual Power Cost	24,510,000	30,650,000	14,580,000
Total Annual Cost	$115,570,000	122,680,000[1] 108,740,000[2]	$108,860,000
Available Project Yield (acft/yr)	168,000	168,000	168,000
Annual Cost of Water	$688/acft	$730/acft[1] $647/acft[2]	$648/acft

[1]Cost with treatment prior to surface recharge.
[2]Cost without treatment prior to surface recharge.

without treatment of the imported water. To determine the cost to treat the imported water, a typical direct filtration process (Treatment Level 2, see Table 3.0-4) was assumed.

The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Recharge Zone or Treatment Plant
Raw Waterline Booster Pump Station
Recharge Structures
Treatment Plant Items (if determined to be needed):
- Water Treatment Plant (Level 2)
- Finished Water Pump Station
- Finished Water Booster Pump Stations, 2 required
- Transmission Line to Recharge Zone

The reservoir intake and pump station is sized to deliver 14,000 acft/month (244 cfs) through a 96-inch diameter pipeline. The operating cost was determined for the raw water static lift to the treatment plant of 300 feet and an annual water delivery of 168,000 acft/yr. If no treatment plant is required, then the operating cost is determined for the total raw water static lift to the recharge structures of 1060 feet. For a treatment plant, the operating cost of the finished water pumping system was determined for a static lift of 760 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual cost of $76,390,000 with a treatment plant and $71,880,000 with no treatment plant (Table 3.21-2). Operation and maintenance costs, including power, total $46,290,000, with the treatment plant and are $36,860,000 without a treatment plant. The annual costs, including debt repayment, interest, and operation and maintenance, total $122,680,000 with the treatment plant and are $108,740,000 without a treatment plant. For an annual firm yield of 168,000 acft, the resulting annual cost of water, with a treatment plant, is $730 per acft, and is $647 per acft without a treatment plant (Table 3.21-2).

Alternative G-16C: Delivery to the Municipal Distribution System

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the South Water Treatment Plant. The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the SAWS distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, 3 required
Water Treatment Plant (Level 3, see Table 3.0-4)
Finished Water Pump Station
Transmission Line to Distribution System
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 14,000 acft/month (244 cfs) through a 96-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 300 feet and an annual water delivery of 168,000 acft/yr. Operating cost of the finished water pumping system was determined for the total static lift of 300 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $79,620,000. Operation and maintenance costs, including power, total $29,240,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $108,860,000. For an annual firm yield of 168,000 acft, the resulting annual cost of water is $648 per acft (Table 3.21-2).

3.21.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Reservoir Alternatives (G-16, All)

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits.
   b. TNRCC Interbasin Transfer Approval.
   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal permits.
   e. GLO Easement for use of state-owned land.
   f. Coastal Coordinating Council review.
   g. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.

b. Habitat mitigation plan.
c. Environmental studies.
d. Cultural resources studies.

3. Land will need to be acquired through either negotiations or condemnation.
4. Relocations for the reservoir include:
    a. Highways and railroads
    b. Other utilities

Requirements Specific to Pipelines (G-16, A11)

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    b. GLO Sand and Gravel Removal permits.
    c. Coastal Coordinating Council review.
    d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (G-16A)

1. Required testing programs:
    a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer for this large a quantity.
    b. Test drilling and pilot recharge program is required.
    c. Large scale recharge test program.
    d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
    e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
    a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (G-16B)

1. Detailed field investigation of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
    a. TNRCC Water Rights and Storage permit.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
    c. GLO Sand and Gravel Removal permit.
    d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
    a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
    b. Study of impact on karst geology organisms from a sustained recharge program.
    c. Other environmental studies.
    d. Cultural resources studies.

Requirements Specific to Treatment and Distribution (G-16C)

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

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3.22 Lindenau Reservoir (G-17)

3.22.1 Description of Alternative

Lindenau Reservoir is a proposed reservoir located on Sandies Creek, a tributary of the Guadalupe River in Dewitt and Gonzales counties. The project would impound water available from the Sandies Creek watershed as well as water diverted from the Guadalupe River during periods of flow in excess of downstream needs. This reservoir was proposed as a water supply for in-basin needs as part of the Texas Basins Project[113] in the mid-1960's. Since then, several studies of the reservoir have been performed[114,115], the latest of which is by Espey, Huston & Associates, Inc.,[116] in 1986, which provided the siting and basic data for this study. The location of the dam is shown on Figure 3.22-1.

The dam would be an earthfill embankment with an uncontrolled roller-compacted-concrete spillway to control the 678 square-mile watershed. The dam embankment would extend about 2 miles across the Sandies Creek valley and provide a conservation storage capacity of 606,280 acft at elevation 232 feet-msl; at conservation pool the surface area would be 26,875 acres; the probable maximum flood elevation would be 244 feet; and, approximately 30 miles of Sandies Creek channel would be inundated by the reservoir.

Three alternative uses of water from this reservoir have been studied and are shown on Figure 3.22-1. These include: (1) delivery to injection wells to recharge the Edwards Aquifer (Alt G-17A); (2) delivery to recharge structures in the Edwards Aquifer recharge zone (Alt G-17B); and (3) delivery to a water treatment plant and distribution in the San Antonio municipal water system (Alt G-17C).

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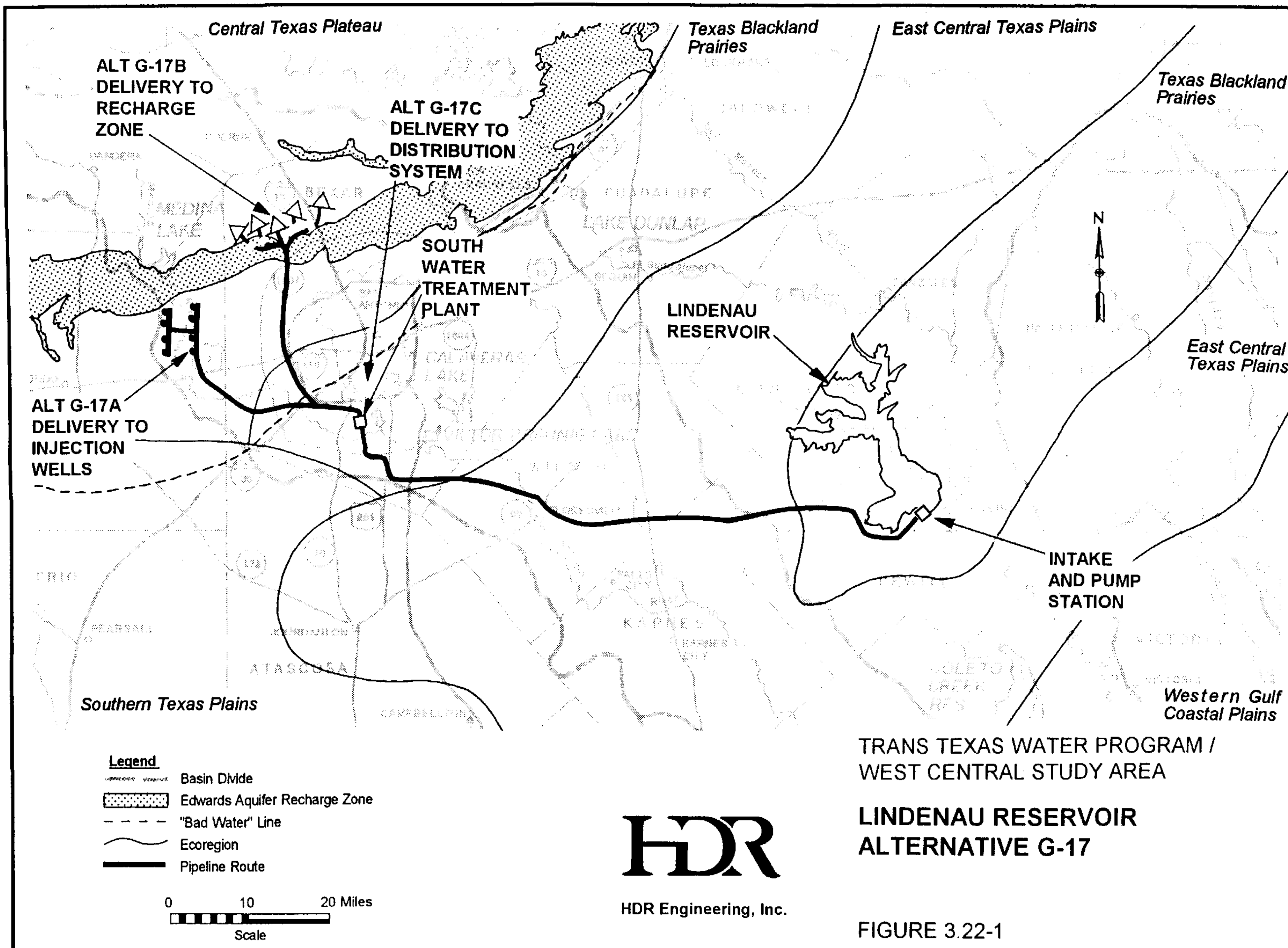
[113]United States Bureau of Reclamation, "Texas Basins Project," February, 1965.

[114]Texas Water Development Board, "A Summary of the Preliminary Plan for Proposed Water Resources Development in the Guadalupe River Basin," July, 1966.

[115]U.S. Bureau of Reclamation, "Summary of Special Report San Antonio - Guadalupe River Basins Study, Texas Basin Project," November, 1978.

[116]Espey, Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins," Guadalupe-Blanco River Authority, February, 1986.



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

LINDENAU RESERVOIR ALTERNATIVE G-17

FIGURE 3.22-1

3.22.2 Available Yield

The firm yield of the proposed Lindenau Reservoir was computed subject to three scenarios chosen to present a reasonable range of hydrologic assumptions. Under each of these scenarios, firm yield was computed subject to three capacity thresholds which limit passage of reservoir inflows as specified in the Trans-Texas Environmental Criteria (see Appendix C) during times of drought. All scenarios include the spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights (including those associated with Applewhite Reservoir), and return flows set to 1988 levels. The three scenarios analyzed are further described as follows:

Scenario 1: Hydropower water rights subordinated to 0 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 74,100 acft/yr[117].

Scenario 2: Hydropower water rights subordinated to 365 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 52,600 acft/yr[118].

Scenario 3: Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr[119].

The Guadalupe - San Antonio River Basin Model[120] (GSA Model) was used to estimate monthly quantities of total streamflow and unappropriated streamflow potentially available at the reservoir site which, in turn, were used to compute the firm yield of Lindenau Reservoir. For modelling purposes, streamflows for Sandies Creek near Westhoff (ID# 1750) were assumed to be representative of inflows to Lindenau Reservoir. Monthly

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[117]Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[118]Ibid

[119]Ibid

[120]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

estimates of unappropriated streamflow potentially available for diversion from the Guadalupe River at Cuero (ID# 1758) were determined applying the Trans-Texas Environmental Criteria and assuming full control of the Sandies Creek watershed above the proposed reservoir.

Diversions from the Guadalupe River to supplement natural inflows were included to increase the yield of the reservoir. Daily gaged flows for the Guadalupe River at Cuero (ID #1758) for the 1964-89 period were analyzed in order to determine a typical percentage of water available on a monthly basis which could be diverted on a daily basis subject to dowstream water rights, selected diversion rates, and daily streamflow variations. This analysis indicated that, on average, about 80 percent of the monthly volume of unappropriated streamflow (with the Trans-Texas Environmental Criteria applied) could be diverted to Lindenau Reservoir from the Guadalupe River when the daily distribution of flows was considered. Maximum monthly diversions to Lindenau Reservoir were, therefore, limited to 80 percent of the estimated water available in the Guadalupe River.

The firm yield of Lindenau Reservoir was computed using an original model (RESSIM) specifically written to simulate reservoir operations subject to the Trans-Texas Environmental Criteria for new reservoirs, using water availability estimates from the GSA Model. A sensitivity analysis was performed to assess the effect of the monthly diversion rate from the Guadalupe River on the firm yield of Lindenau Reservoir. Based on this analysis, a maximum monthly Guadalupe River diversion rate of 40,000 acft was selected for use in computing the firm yield. A summary of the firm yield estimates for each scenario and capacity threshold analyzed is provided in Table 3.22-1.

As is apparent in this table, estimated firm yield for Lindenau Reservoir is not particularly sensitive to hydropower subordination and is only slightly more sensitive to the capacity threshold for drought contingency operations. Appendix D contains a summary of the inflow passage requirements applied for Lindenau Reservoir.

The firm yield of Lindenau reservoir considering only inflows from the Sandies Creek watershed and operated with a 60 percent capacity threshold was computed to be approximately 32,400 acft/yr. Incorporating a maximum diversion rate of 40,000 acft per

Table 3.22-1 Summary of Lindenau Reservoir Firm Yield Estimates			
	Estimate of Firm Yield (acft/yr)[1]		
	Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[3]		
Scenario[2]	40%	60%	80%
1	43,800	45,200	48,700
2	44,400	45,800	49,200
3	44,400	45,800	49,200

Notes:
[1]Firm yield based on diversion of unappropriated streamflow potentially available at the Guadalupe River at Cuero (ID #1758) subject to a maximum diversion rate of 40,000 acft per month.
[2]All scenarios include the springflows from a fixed Edwards Aquifer pumpage of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights (including Applewhite Reservoir), and return flows set to 1988 levels.

Scenario 1: Hydropower water rights subordinated to 0 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 74,100 acft/yr.

Scenario 2: Hydropower water rights subordinated to 365 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 52,600 acft/yr.

Scenario 3: Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr.

[3]The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.

month from the Guadalupe River resulted in a firm yield of 45,800 acft/yr which represents a 41 percent increase. Variation of the maximum monthly diversion rate from 20,000 acft per month to 60,000 acft per month resulted in firm yield estimates ranging from 41,800 acft/yr to 47,000 acft/yr, respectively.

All of the firm yield estimates for Lindenau Reservoir presented in Table 3.22-1 are substantially less than those estimated in past studies. For example, Espey, Huston & Associates reported the firm yield of Lindenau Reservoir to be about 107,000 acft/yr[121]. The primary reason for the difference in yield estimates is the limitation on the volume of water that can be pumped into the reservoir from the Guadalupe River imposed by the

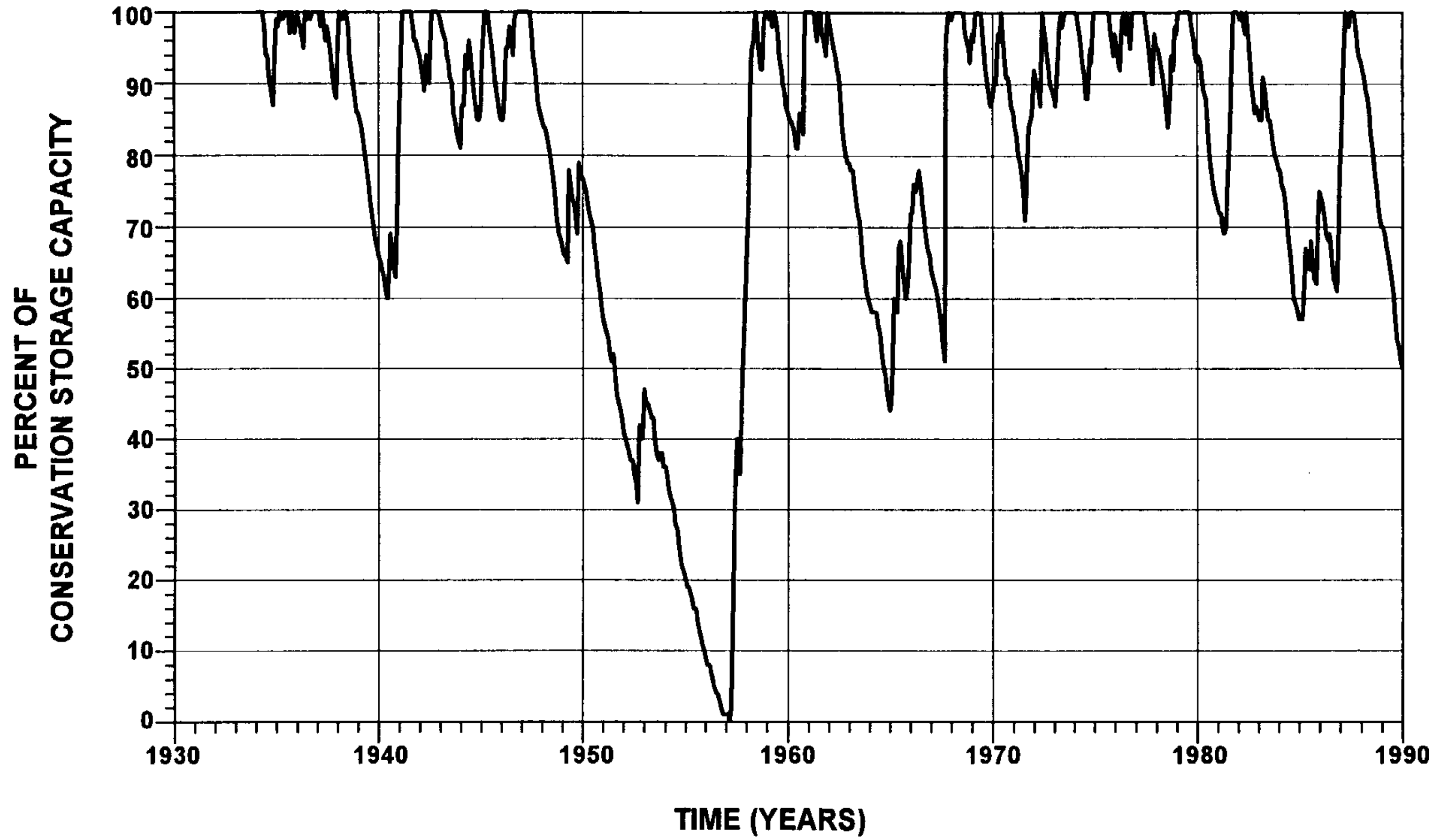
[121] Espey, Huston & Associates, "Water Availability for the Guadalupe and San Antonio River Basins," Guadalupe-Blanco River Authority, February, 1986.

Trans-Texas Environmental Criteria governing freshwater inflows to bays and estuaries. During the critical period (June, 1947 to February, 1957), the Trans-Texas Environmental Criteria allows for diversions to occur from the Guadalupe River in only 5 out of 117 months, or about 4 percent of the time. For the overall period analyzed, 1934 to 1989, diversions from the Guadalupe River could have occurred about 24 percent of the time. If diversions from the Guadalupe River were limited only by the passage of flows to honor downstream water rights, the firm yield of Lindenau Reservoir would be approximately 117,000 acft/yr.

Scenario 3, with a 60 percent capacity threshold, was selected for consideration of cost and analysis of potential environmental impacts because it is representative of current hydropower subordination and diversion rights associated with Canyon Lake. Figure 3.22-2 illustrates simulated Lindenau Reservoir storage fluctuations for the 1934-89 historical period if operated under the Trans-Texas Environmental Criteria subject to diversion of the firm yield of 45,800 acft/yr. Simulated reservoir storage remained above the 60 percent capacity threshold about 82 percent of the time resulting in the frequent passage of inflows from the Sandies Creek watershed up to the monthly mean or median natural streamflow. As a result, monthly median streamflows at the site were only slightly affected by the reservoir, while monthly median streamflows at the Saltwater Barrier were essentially unaffected. Monthly median streamflows and annual streamflows averaged by decile, with and without the project, are presented in Figure 3.22-3 for the Guadalupe River, and in Figure 3.22-4 for Sandies Creek, for conditions both at the site and at the Saltwater Barrier. Under Scenario 3 with a 60 percent capacity threshold, freshwater inflows to the Guadalupe Estuary, as measured at the Saltwater Barrier, would be reduced by an average of 96,800 acft/yr or about 6 percent.

3.22.3 Environmental Issues

This alternative involves dam construction and inundation of approximately 26,875 acres along a 30-mile reach of Sandies Creek, a tributary of the Guadalupe River (see Figure 3.22-1). The Lindenau Reservoir would be operated in conjunction with a diversion from the Guadalupe River. Alternative G-17 consists of three alternative uses of water



NOTES

FIRM YIELD: 45,800 ACFT/YR
CONSERVATION STORAGE CAPACITY: 606,000 ACFT
60% CAPACITY THRESHOLD
SCENARIO 3:

- EDWARDS AQUIFER DEMAND OF 400,000 ACFT/YR
- RETURN FLOWS SET AT 1988 LEVELS
- HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
- APPLEWHITE RESERVOIR INCLUDED

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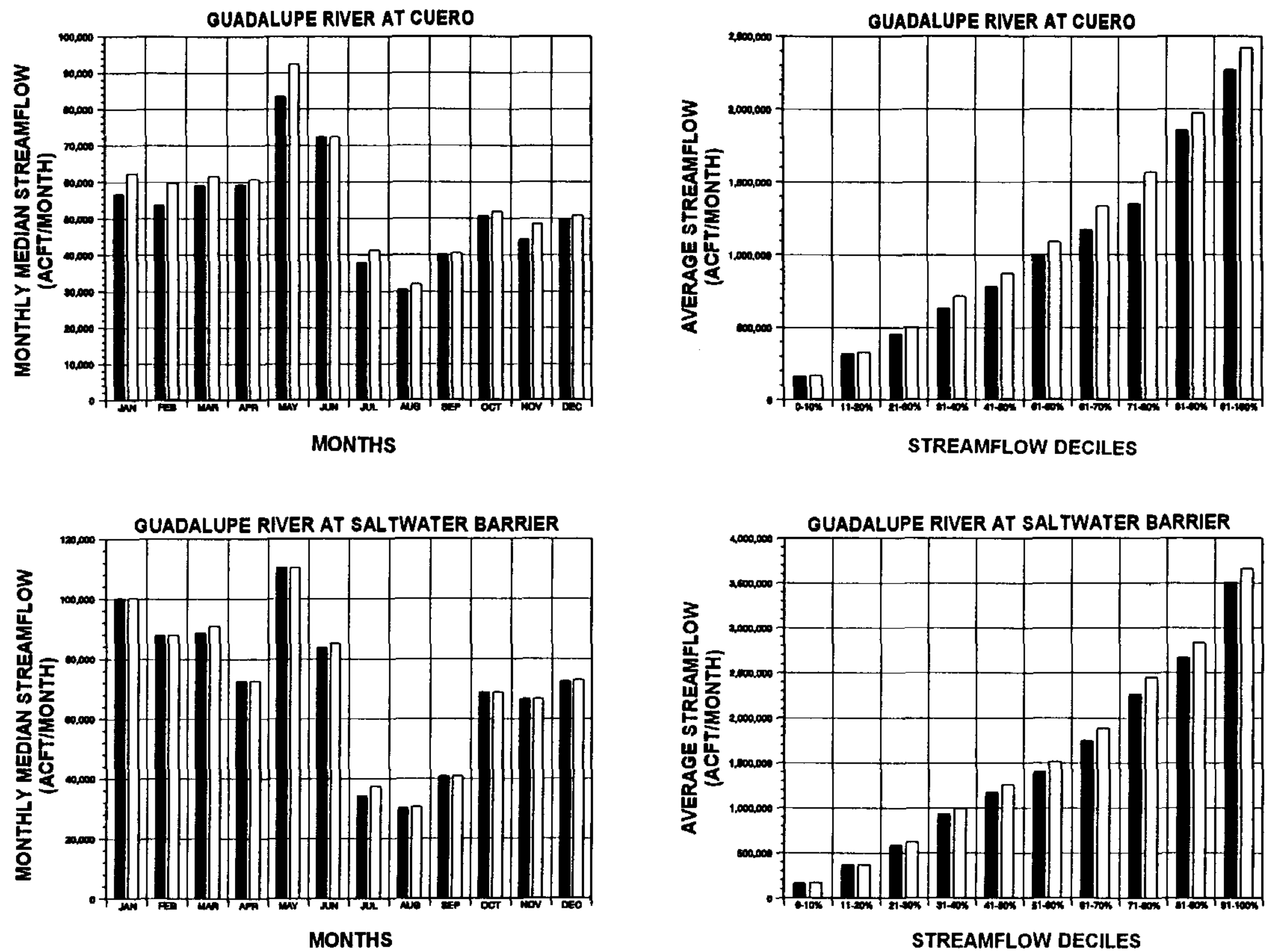
STORAGE TRACE
LINDENAU RESERVOIR
ALTERNATIVE G-17

FIGURE 3.22-2



LEGEND

■ WITH PROJECT
□ WITHOUT PROJECT

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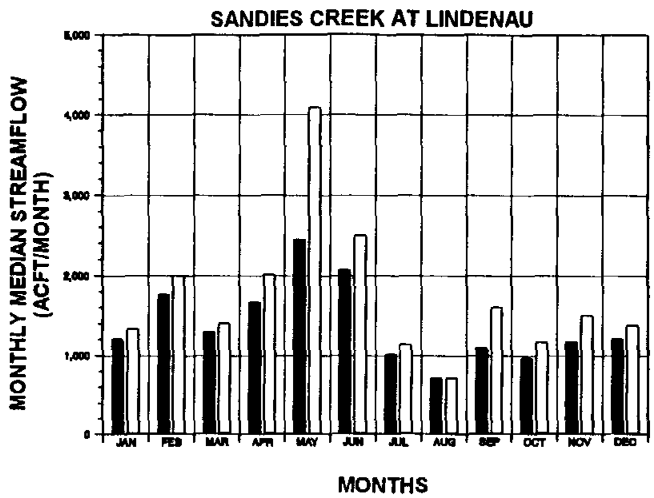
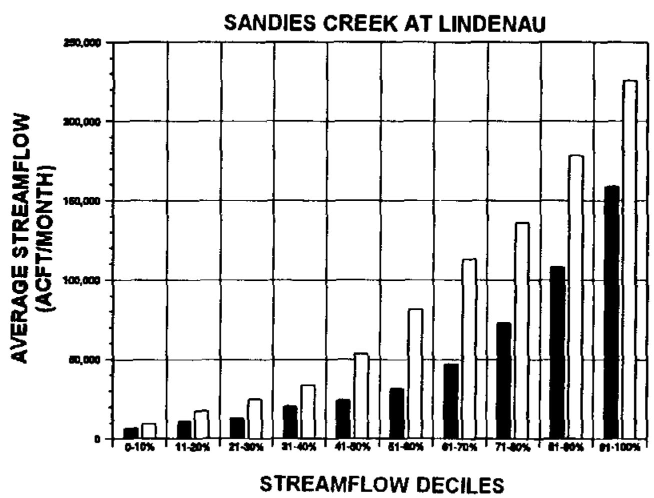
CHANGES IN STREAMFLOW - GUADALUPE RIVER WITH LINDENAU RESERVOIR - ALTERNATIVE G-17

FIGURE 3.22-3





LEGEND

■ WITH PROJECT
□ WITHOUT PROJECT

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CHANGES IN STREAMFLOW -
SANDIES CREEK AT LINDENAU
RESERVOIR - ALTERNATIVE G-17

FIGURE 3.22 - 4

resources obtained through the construction and operation of the proposed Lindenau Reservoir, with a diversion from the Guadalupe River. Under Alternative G-17A, the yield of Lindenau Reservoir is diverted to pumping facilities for delivery to injection wells placed into the Edwards Aquifer. This alternative, which involves imported recharge, provides for treatment to ensure acceptable water quality. Alternative G-17B also involves imported recharge, potentially with treatment to ensure acceptable water quality. Under this alternative, water from Lindenau Reservoir is diverted to a pump station and delivered to the recharge zone on the Edwards formation outcrop. The treatment and distribution alternative, G-17C, involves use of an intake and pump station on Lindenau Reservoir and delivery of the water directly to a water treatment plant.

The proposed Lindenau Reservoir spans portions of Gonzales and DeWitt counties. It is located in the Texas Blackland Prairies ecoregion[122] (see Figure 3.0-1), in the ecotonal region between the Post Oak Savannah and Blackland Prairie vegetational regions[123] (see Figure 3.0-2), and within the Texan biotic province[124] (see Figure 3.0-3).

Soils of the Meguin-Trinity association are found within the floodplains. These soils are somewhat poorly drained, calcareous loamy and clayey soils. They are well suited to range, improved pasture and crops. The Sarnosa-Shiner association is found on uplands. These are nearly level, well-drained, moderately permeable, calcareous loamy soils used for range and wildlife, but also suited to pasture[125].

The upland forest community type comprises approximately 20 percent of the total woodland acreage within the reservoir boundaries (see Table 3.0-1). Dominant overstory species within the upland forest community type include post oak, cedar elm, honey mesquite, and live oak. In the understory and shrub layers, honey mesquite, acacias, cedar

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[122]Omernik, James M., 1986, "Ecoregions of the Conterminous United States", Annals of the Association of American Geographers, 77(1). pp. 118-125.

[123]Gould, F.W., 1975, The Grasses of Texas, Texas A&M University Press, Texas Agricultural Experiment Station, College Station, Texas.

[124]Blair, W.F., 1950, "The Biotic Provinces of Texas," Tex. J. Sci. 2:93-117.

[125]U.S. Department of Agriculture, Soil Conservation Service (SCS). 1978a. Soil Survey of DeWitt County, Texas. In cooperation with the Texas Agricultural Experiment Station, Texas A&M University, College Station.

elm, and prickly pear (*Opuntia* spp.) occur. Grasses and forb species comprise the herbaceous stratum in this community type[126].

Bottomland and riparian forests comprise approximately 80 percent (about 4,306 acres) of the wooded acreage within the proposed reservoir boundaries (see Table 3.0-1). A variety of reptiles, amphibians, mammals, and bird species rely on the bottomland/riparian forests for food and cover[127].

Brushland, which occupies approximately 8,409 acres (see Table 3.0-1), is the dominant community type in the wooded upland portions of the proposed reservoir site, and is also present in some lowland areas. This community type occurs primarily as a result of overgrazing and fire suppression, which have allowed woody species to increase in areas that were formerly covered by grasslands or savannah community types. Brushlands are dominated by low trees and shrubs, with a ground cover of forbs and grasses[128]. The thick nature of the brushland vegetation makes this an excellent nesting habitat for a variety of bird species.

The grassland community types represent approximately 9,390 acres within the reservoir site (see Table 3.0-1), and include managed pastures, oldfields, and pipeline, utilities, and transportation rights-of-way. The majority of the grassland within the reservoir site is used as grazing land for livestock[129]. Woody species in the grassland habitats are either sparse or absent. Ground cover is occasionally thick, thus providing good cover for a variety of rodent species which in turn provide food for carnivores, such as the coyote, northern harrier, and common barn-owl. A variety of reptiles, mammals, and birds also use

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[126]Espey, Huston & Associates, Inc. (EH&A), 1986, Water Availability Study for the Guadalupe and San Antonio River Basins. Prepared for San Antonio River Authority, Guadalupe-Blanco River Authority, and City of San Antonio. Volumes I and II. EH&A Document No. 85580. February.

[127]Ibid.

[128]Ibid.

[129]U.S. Department of Agriculture, Soil Conservation Service (SCS), 1977, Soil Survey of Bandera County, Texas. In cooperation with Texas Agricultural Experiment Station, Texas A&M University, College Station. April.

grassland habitats for food and cover[130].

Cropland is limited within the proposed reservoir site, occupying approximately 904 acres (see Table 3.0-1) and occurring primarily within major floodplains. Principal crops grown in the region include grain sorghum, corn, cotton, wheat, and peanuts[131].

Wetlands, which occupy approximately 2,789 acres (including 193 acres of riverine habitat) within the Lindenau Reservoir site (see Table 3.0-1), include riverine habitats; palustrine forested, scrub/shrub, emergent, and open-water wetlands; and limited areas of lacustrine open-water habitat. Forested wetlands (i.e., swamps) are limited to areas within major floodplains[132].

The Lindenau project area has a much more dendritic creek system than does the Cuero project area. Sandies Creek is the major aquatic habitat in the project area and is smaller than the Guadalupe River. Generally, the channel area is no more than 20 to 25 ft wide. Bank slope is more gentle than the Guadalupe River. Vegetation generally reaches to the water's edge, even under low-flow conditions. The channel is more of a shallow V-shape than U-shape. Therefore, as flow increases, the creeks quickly widen out. Several of the tributaries of Sandies Creek are perennial, and have marshy areas associated with them. Gravel bars occur in the channels of several tributaries[133].

Salt flats occur within the Lindenau Reservoir site in poorly drained areas with loamy, highly saline sediments. The climax plant community in these areas is an open grassland composed of salt-tolerant herbaceous species. Dominant species include Gulf cordgrass (*Spartina spartinae*), switchgrass (*Panicum virgatum*), seashore saltgrass (*Distichlis spicata*), alkali sacaton (*Sporobolus airoides*), bushy sea-oxeye (*Borrichia frutescens*), devilweed aster (*Aster spinosus*), and wild buckwheat (*Eriogonum* sp.). Gulf cordgrass and switchgrass decrease as a result of heavy grazing by livestock and continuous burning,

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[130]Espey, Huston & Associates, Inc. (EH&A), 1986, Water Availability Study for the Guadalupe and San Antonio River Basins. Prepared for San Antonio River Authority, Guadalupe-Blanco River Authority, and City of San Antonio. Volumes I and II. EH&A Document No. 85580. February.

[131]Ibid.

[132]Ibid.

[133]Ibid.

leaving bushy sea-oxeye and devilweed aster as the dominant components of the habitat[134,135]. Portions of the salt flats, which retain water for long periods of time due to low permeability and poor drainage, may be considered wetlands by some definitions.

The primary impacts that would result from construction and operation of the Lindenau Reservoir include conversion of existing habitats and land uses within the conservation pool to open water, and potential downstream effects due to modification of the existing flow regime. The Lindenau Reservoir would be permanently inundated to 232 feet MSL with a surface area of 26,875 acres. Approximately 9,390 acres of grassland, 8,409 acres of brushland, 5,383 acres of woodland, 904 acres of cropland, 2,596 acres of wetlands, and 193 acres of riverine habitat would be converted to open water (see Table 3.0-1).

Indirect effects of reservoir construction may include land use changes in the area surrounding the reservoir and in mitigation areas that may be converted to alternate uses to compensate for losses of terrestrial habitat.

Potential downstream impacts would include modification of the streamflow regime below the dam, and reduced inflows to San Antonio Bay. It is assumed that as a new reservoir without a current operating permit, the Lindenau Reservoir would be required to meet the Trans-Texas Water Program "New Reservoir" criteria for instream flows and freshwater inflows to bays and estuaries. Operation of the reservoir and Guadalupe River pump station to meet these criteria has a significant effect on (i.e., reduction of) the firm yield of the reservoir.

Hydrologic modeling was conducted to determine the annual yield of Lindenau Reservoir and to evaluate the potential impacts of reservoir operation on instream flows and freshwater inflows to bays and estuaries. A yield of 45,800 acft/year can be obtained with the Trans-Texas criteria in place, using a 60 percent reservoir capacity trigger. Modeling results indicate that, under this scenario, the monthly median streamflow on Sandies Creek at Lindenau is reduced fairly uniformly throughout the year relative to without-project

[134]U.S. Department of Agriculture, Soil Conservation Service (SCS), 1978a, Soil Survey of DeWitt County, Texas. In cooperation with the Texas Agricultural Experiment Station, Texas A&M University, College Station.

[135]Thomas, G.W., 1975, "Texas Plants - An Ecological Summary. *In:* F.W. Gould Texas Plants - A Checklist and Ecological Summary," Texas Agricultural Experiment Station, MP-585/Rev., College Station, Texas.

conditions. The greatest reduction (approximately 14,000 acft/month) occurs in May, the peak streamflow month. Reductions of the monthly median streamflow on the Guadalupe River at Cuero due to the proposed diversion associated with the Lindenau Reservoir alternatives are relatively minor, with the greatest reduction (approximately 8,000 acft/month) occurring during the peak streamflow month of May. The greatest decreases in average streamflow on Sandies Creek at Lindenau occur in the upper range of streamflow deciles (i.e., 51 to 60 percent and greater). Average streamflows on the Guadalupe River at Cuero are reduced only slightly as a result of the proposed Lindenau diversion.

The criteria for freshwater inflow to bays and estuaries are assumed to be met if the reservoir criteria are met. Modeling of the monthly median streamflow and average streamflow at the saltwater barrier indicate flow reductions that are minor or negligible throughout the year and throughout the range of streamflow deciles.

Plant and animal species listed by the USFWS and TPWD as endangered or threatened, and those with candidate status for listing in DeWitt and Gonzales counties are presented in Tables 14 and 21 of Appendix B. The Texas Natural Heritage Program records include reported occurrences of Texas meadow-rue (*Thalictrum texanum*), a USFWS candidate species for protection, in Gonzales County along the Guadalupe River just upstream of the town of Gonzales[136], which is located near the Lindenau reservoir site.

Those species with potential habitat in the vicinity of the proposed reservoir are listed in Table 3.22-2. Of the species listed this table, three are river dependent: Cagle's map turtle, blue sucker and the Guadalupe bass. The Cagle's map turtle has been observed within the proposed reservoir area[137]. The blue sucker has not been recently reported in the lower Guadalupe River[138]. If the species is present, it would render this reach unsuitable for the construction of an impoundment. A survey of the reservoir site may be

[136]Texas Natural Heritage Program (TNHP), 1985 and 1994, Unpublished data from element records, Austin, Texas.

[137]Killebrew, F.C., 1991.,"Habitat Characteristics and Feeding Ecology of Cagle's Map Turtle (*Graptemys caglei*) Within the Proposed Cuero and Lindenau Reservoir Sites," Prepared for Texas Parks and Wildlife Department under interagency contract with the Texas Water Development Board. 15 pp.

[138]Academy of Natural Sciences (ANS), 1991, "A Review of Chemical and Biological Studies on the Guadalupe River, Texas," 1949-1989. Report No. 91-9. Acad. Nat. Sci. Phil. Philadelphia, PA.

Table 3.22-2
Important Species With Habitat Within the Project Vicinity (G-17)

Common Name	Scientific Name	Habitat Preference	Listing Agency USFWS	Listing Agency TPWD
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition	E	E
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with nearby resting sites; nests in forested river bottoms	E	E
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin[2]	C1	NL
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky; burrows in soil, or uses rodent burrows, or hides under rocks when inactive.	C2	T
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus or uses underground burrows; active March-Nov.	NL	T
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands[2]	NL	T
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporarily wet areas such as arroyos, canals, ditches and shallow depressions; aestivates underground during dry periods[1]	C2	E
Blue Sucker	*Cycleptus elongatus*	Large rivers through the Mississippi Basin; In Texas, major streams southward to the Rio Grande[1]	C2	T
Guadalupe Bass	*Micropterus treculi*	Rivers of the Edwards Plateau including portions of the Brazos, Colorado, Guadalupe, and San Antonio River Basins; also the lower Colorado River and introduced in the Nueces River system[1]	C2	NL
Texas Meadow-rue	*Thalictrum texanum*	Coastal plains and savannah of south east Texas; known in Brazos and Waller Co.s; historic in Harris Co.	C2	NL
Mulenbrock's Umbrella Sedge	*Cyperus grayioides*	Prairie grasslands, moist meadows in Texas, Louisiana, Illinois	C2	NL

[1]Source: TPWD. 1988 Unpublished list. Resource Protection Division. Texas Parks and Wildlife Department. Austin, Texas.
[2]Dixon, J.R. 1987. Amphibians and Reptiles of Texas. Texas A&M Press, College Station, Texas.
Source for all other habitat preference information: Texas Natural Heritage Program, December 1993, unpublished files.

required prior to dam construction to determine whether populations of or potential habitat for species of concern occur in the area to be impacted.

Although no cultural resource investigations have been conducted in the proposed Lindenau Reservoir, eleven sites were recorded adjacent to the upper reaches of Rocky Creek in Gonzales County. Located as a part of the University of Texas San Antonio Conquista Project[139], all sites were reported as lithic scatter sites. One site revealed two *Angostura* fragments, suggesting a Paleo-Indian occupation. No other diagnostics were recorded.

One hundred eighty-five recorded cultural resources sites within Gonzales County have been listed by the Texas Archeological Research Laboratory. In addition, 258 sites are recorded in DeWitt County. Within the 26,875-acre study area encompassed by the 232-ft elevation of the proposed reservoir, no cultural resources sites have been recorded. The study area has not been subjected to a systematic cultural resources survey. It is probable that, if the area is surveyed, cultural resources sites will be located, some of which may exhibit the criteria necessary for nomination to the NRHP. A significant portion of the Lindenau site is also within the Cuero I Archaeological District, whose boundaries were identified by latitude and longitude coordinates.

The National Register of Historic Places (NRHP) lists six sites in Gonzales County and four sites in DeWitt County. There are no NRHP sites within the proposed reservoir area. The Guide to Official Texas Historical Markers lists 79 markers within Gonzales County and 64 markers within DeWitt County. One marker (Salt Flats) is located within the Lindenau reservoir area. A second marker, located at 250 ft MSL in elevation, commemorates the town of Westhoff. A single State Historic Inventory Site, the Sandies Creek Bridge, is located within the Lindenau study area. In the town of Westhoff, another Historic Inventory site, the First Baptist Church, is located at the 250 ft MSL contour. No previously recorded Historic Architectural Buildings Survey (HABS) structures, State Archeological Landmarks, Registered Log Cabins or Natural Landmarks are located within the proposed reservoir area. At least three cemeteries are located within the study site.

[139]McGraw, A. Joachim, 1979, A Preliminary Archaeological Survey for the Conquista Project in Gonzales, Atascosa and Live Oak counties, Texas. Center for Archaeological Research, the University of Texas at San Antonio, Survey Report 76.

Laws have been implemented by the Federal and Texas State governments to protect cemeteries. These resources should either be avoided or dealt with appropriately. Special procedures for handling cemeteries, as outlined in Vernon's Annotated Revised Civil Statutes of the State of Texas (Title 26, Article 912a-10 and 912a-11), will have to be followed for the Lindenau Reservoir site.

3.22.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.22.5 Engineering and Costing

The cost estimate for the dam and reservoir is an update of a previous cost estimate performed by EHA[140]. That cost estimate was updated by multiplying the individual cost components by the ratio (mid 1994/1991) of the relevant ENR and Bureau of Reclamation Construction Cost Indexes.

<u>Alternative G-17A: Delivery to Aquifer Injection Wells</u>

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the injection well field in eastern Medina County. The diversion rate from the reservoir, as well as the delivery to the wells would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2) (Table 3.0-4). The major facilities required to implement this alternative are:

Guadalupe River Diversion, Pump Station, and Pipeline
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, two required

[140]Espey, Huston & Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins, "Guadalupe-Blanco River Authority, February, 1986.

Water Treatment Plant (Level 2, Table 3.0-4)
Finished Water Pump Station
Finished Water Booster Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The Guadalupe River intake and pump station are sized to deliver 40,000 acft/month through a 108-inch diameter pipeline. The reservoir intake and pump station are sized to deliver 3,820 acft/month (41 mgd) through a 48-inch diameter pipeline. The operating cost was determined for a raw water static lift of 300 feet and an annual water delivery of 45,800 acft/yr. Operating cost of the finished water pumping system was determined for a total static lift of 310 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $40,300,000 (Table 3.22-3). Operation and maintenance costs, including power, total $15,170,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $55,470,000. For an annual firm yield of 45,800 acft, the resulting annual cost of water is $1,211 per acft (Table 3.22-3).

Alternative G-17B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to small recharge structures in northwestern Bexar County located over the recharge zone. The diversion rate from the reservoir, as well as the delivery to the recharge structures would be uniform throughout the year. The benefit from this project includes the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Concerns that the imported water is of different quality than the existing recharge water and the need for treatment of the imported water will require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of the imported water. To determine the cost to treat the imported water, a typical direct filtration process (Treatment Level 2, see Table 3.0-4) was assumed.

The major facilities required to implement this alternative are:

Guadalupe River Diversion, Pump Station and Pipeline
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Recharge Zone or Treatment Plant

Table 3.22-3
Cost Estimate Summaries for Lindenau Reservoir (G-17)
(Mid- 1994 Prices)

Item	Alt. G-17A Divert and Inject to Aquifer	Alt. G-17B Divert to Recharge Zone	Alt. G-17C Divert to WTP and Municipal Supply
Capital Costs			
Dam and Reservoir	$84,890,000	$84,890,000	$84,880,000
Transmission and Pumping	106,600,000	108,930,000	77,210,000
Treatment Plant	13,640,000	13,640,000	19,360,000
Delivery System	7,100,000	5,730,000	35,660,000
Total Capital Cost	$212,230,000	$213,190,000[(1)] $199,550,000[(2)]	$217,110,000
Engineering, Contingencies, and Legal Costs	70,190,000	70,190,000[(1)] 65,410,000[(2)]	69,580,000
Land Acquisition	62,680,000	62,830,000[(1)] 62,780,000[(2)]	62,150,000
Environmental Studies and Mitigation	56,300,000	55,560,000	53,870,000
Interest During Construction	28,720,000	29,660,000[(1)] 28,550,000[(2)]	28,670,000
Total Project Cost	$430,120,000	$431,430,000[(1)] $411,850,000[(2)]	$431,390,000
Annual Costs			
Annual Debt Service	$40,300,000	$40,420,000[(1)] 38,590,000[(2)]	$40,420,000
Annual Operation and Maintenance	5,420,000	5,530,000[(1)] 2,890,000[(2)]	5,140,000
Annual Power Cost	9,750,000	11,250,000	6,260,000
Total Annual Cost	$55,470,000	$57,200,000[(1)] $52,730,000[(2)]	$51,820,000
Available Project Yield (acft/yr)	45,800	45,800	45,800
Annual Cost of Water	$1,211/acft	$1,249/acft[(1)] $1,151/acft[(2)]	$1,132/acft

[(1)]Cost with treatment prior to surface recharge.
[(2)]Cost without treatment prior to surface recharge.

Raw Waterline Booster Pump Station, two required
Recharge Structures, five required
Treatment Plant Items (if needed):
    Water Treatment Plant (Level 2)
    Finished Water Pump Station
    Finished Water Booster Pump Stations, two required
    Transmission Line to Recharge Zone

The Guadalupe River intake and pump station are sized to deliver 40,000 acft/month through a 108-inch pipeline. The reservoir intake and pump station is sized to deliver 3,820 acft/month (41 mgd) through a 48-inch diameter pipeline. The operating cost was determined for a total raw water static lift to the treatment plant of 300 feet and an annual water delivery of 45,800 acft/year. If no treatment plant is required, then the operating cost is determined for the total raw water pumping head to the recharge structures of 1290 feet. For a treatment plant, the operating cost of the finished water pumping system was determined for a total static lift of 990 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $40,420,000 with a treatment plant and $38,590,000 with no treatment plant (Table 3.22-3). Operation and maintenance costs total $16,780,000, with the treatment plant and are $14,140,000 without a treatment plant. The annual costs, including debt repayment, interest, and operation and maintenance, total $57,200,000 with the treatment plant and are $52,730,000 without a treatment plant. For an annual firm yield of 45,800 acft, the resulting annual cost of water, including a treatment plant, is $1,249 per acft, and is $1,151 per acft without a treatment plant (Table 3.22-3).

<u>Alternative G-17C: Delivery to the Municipal Distribution</u>

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the South Water Treatment Plant (Figure 3.22-1). The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project includes the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Guadalupe River Diversion, Pump Station, and Pipeline
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations
Water Treatment Plant (Level 3, see Table 3.0-4)
Distribution System Improvements

The river intake and pump station are sized to delivery 40,000 acft/month through a 108-inch diameter pipeline. The reservoir intake and pump station is sized to deliver 3,820 acft/month (41 mgd) through a 48-inch diameter pipeline. The operating cost was determined for a total raw water static lift of 300 feet and an annual water delivery of 45,800 acft/year. Operating cost of the finished water pumping system was determined for the total static lift of 300 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $40,420,000 (Table 3.22-3). Operation and maintenance costs, including power, total $11,400,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $51,820,000. For an annual firm yield of 45,800 acft, the resulting annual cost of water is $1,132 per acft (Table 3.22-3).

3.22.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Reservoir Alternatives (G-17, All)

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits.
   b. TNRCC Interbasin Transfer Approval.
   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal permits.
   e. GLO Easement for use of state-owned land.
   f. Coastal Coordinating Council review.
   g. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.

    d. Cultural resource studies.
3. Land will need to be acquired by negotiation or condemnation.
4. Relocations for the reservoir include:
    a. Highways and railroads
    b. Other utilities

Requirements Specific to Pipelines (G-17, All)

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    b. GLO Sand and Gravel Removal permits.
    c. Coastal Coordinating Council review.
    d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (G-17A)

1. Required testing programs:
    a. Detailed field investigation of existing supply wells, including performance tests.
    b. Test drilling and pilot recharge program is required.
    c. Large scale recharge test program.
    d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
    e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
    a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (G-17B)

1. Detailed field investigations of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
   a. TNRCC Water Rights and Storage permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
   c. GLO Sand and Gravel Removal permit.
   d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
   a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
   b. Study of impact on karst geology organisms from a sustained recharge program.
   c. Other environmental studies.
   d. Cultural resource studies.

Requirements Specific to Treatment and Distribution

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

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3.23 McFaddin Reservoir (G-18)

3.23.1 Description of Alternative

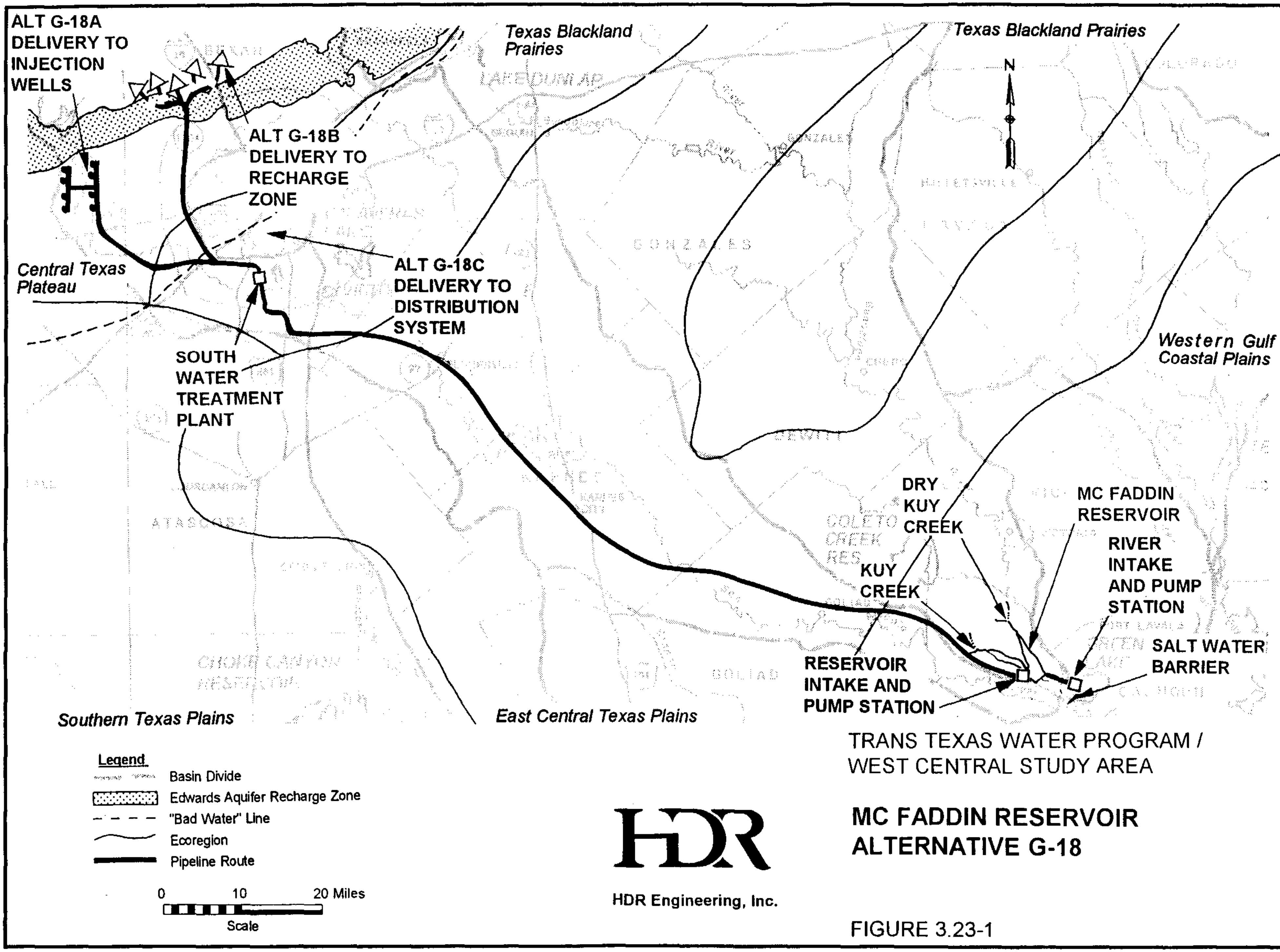
McFaddin Reservoir is a proposed off-channel reservoir located on Kuy and Dry Kuy Creeks, both of which are small tributaries to the San Antonio River located immediately upstream of the San Antonio and Guadalupe River confluence. The project would impound water available from the Kuy and Dry Kuy creek watersheds as well as water diverted from the small reservoir pool located at the Saltwater Barrier under rights held by the Guadalupe-Blanco River Authority (GBRA). The site is about 3.5 miles west of McFaddin, Texas and is shown on Figure 3.23-1. The proposed site was selected due to the favorable topographic relief at the confluence of the two creeks. The natural watershed draining to the site encompasses 52.5 square miles.

The dam would be a 3,000 foot earthfill embankment with a gate-controlled, concrete ogee spillway to control the 52.5 square mile watershed. The top of the embankment would be at elevation 51.5 feet msl; the conservation storage capacity is 9,200 acft at elevation 45 feet-msl; the surface area at conservation pool is 660 acres; and, approximately 6 miles of Kuy Creek stream channel would be inundated. Diversion facilities would be located near the Guadalupe and San Antonio River confluence at the Saltwater Barrier and would include a gated intake channel, pump station, and pipeline to the reservoir.

Three alternative uses of water from this reservoir have been studied and are shown on Figure 3.23-1. These include: (1) delivery to injection wells to recharge the Edwards Aquifer (Alt G-18A); (2) delivery to recharge structures in the Edwards Aquifer recharge zone (Alt G-18B); and (3) delivery to a water treatment plant and distribution in the San Antonio municipal water system (Alt G-18C).

3.23.2 Available Yield

The firm yield of the proposed McFaddin Reservoir was computed subject to three scenarios chosen to present a reasonable range of hydrologic assumptions. Under each of these scenarios, firm yield was computed subject to three capacity thresholds which limit passage of reservoir inflows as specified in the Trans-Texas Environmental Criteria (see Appendix C) during times of drought. All scenarios include the spring flows resulting from



MC FADDIN RESERVOIR ALTERNATIVE G-18

FIGURE 3.23-1

a fixed Edwards Aquifer pumpage rate of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights (including those associated with Applewhite Reservoir), and return flows set to 1988 levels. The three scenarios analyzed are further described as follows:

Scenario 1: Hydropower water rights subordinated to 0 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 74,100 acft/yr[141].

Scenario 2: Hydropower water rights subordinated to 365 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 52,600 acft/yr[142].

Scenario 3: Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr[143].

For the period of 1934-89, monthly flow estimates for the ungaged watershed of Kuy Creek were developed by prorating gaged flow measurements for the nearby Coleto Creek watershed based on drainage area. The Guadalupe - San Antonio River Basin Model[144] (GSA Model) was used to estimate monthly quantities of available streamflow that could be diverted at the Saltwater Barrier under the existing GBRA Calhoun Canal Division water rights. A group of water rights (senior to Canyon Lake) exist at this location with an authorized diversion volume totalling 172,500 acft/yr, of which 40,000 acft/yr has been identified as potentially available for purchase[145]. The GSA Model was utilized to determine the percentage of the monthly allocation for these senior water rights that would be met for each month of the 1934-89 period. As a group, the senior water rights were found to be fully satisfied about 97 percent of the time, however, during the worst year

[141]Espey, Huston & Associates, Inc., "Engineering Analyses and Hydrologic Modeling to Determine the Effects of Subordination of Hydropower Water Rights," Guadalupe-Blanco River Authority, March, 1993.

[142]Ibid

[143]Ibid

[144]HDR Engineering, Inc., "Guadalupe - San Antonio River Basin Recharge Enhancement Study," Volumes I, II, and III, Edwards Underground Water District, September, 1993.

[145]Guadalupe-Blanco River Authority, Memorandum to HDR, April 18, 1994.

(1956) a four month period (June through September) existed during which the water rights were not fully satisfied that would have resulted in an annual diversion of only 83 percent of the total allocated. To determine the monthly quantity of water that could be diverted to McFaddin Reservoir from the Saltwater Barrier during the 1934-89 period monthly percentages of water available under the grouped senior rights were applied to the 40,000 acft/yr that is potentially available for purchase. These monthly quantities, along with the estimated inflows from the 52.5 sq.mi. watershed, were used to compute the firm yield of McFaddin Reservoir.

The firm yield of McFaddin Reservoir was computed using an original model (RESSIM) specifically written to simulate reservoir operations subject to Trans-Texas Environmental Criteria for new reservoirs, using water availability estimates from the GSA Model. A sensitivity analysis of reservoir firm yield to conservation storage capacity was performed. Based on this analysis, the optimum conservation storage capacity was found to be about 9,200 acft and this volume was selected for use in computing the firm yield of the project. A summary of the firm yield estimates for each scenario and capacity threshold analyzed is provided in Table 3.23-1. As is apparent in this table, estimated firm yield for McFaddin Reservoir is not particularly sensitive to hydropower subordination and is only slightly more sensitive to the capacity threshold for drought contingency operations. The firm yield of the reservoir, without the diversion of 40,000 acft/yr water rights at the Saltwater Barrier, is approximately 1,750 acft/yr for a reservoir capacity threshold of 60 percent, hence, the diversion of water rights provide about 95 percent of the total firm yield of the reservoir, depending on the combination of scenario and capacity threshold.

Scenario 3, with a 60 percent capacity threshold, was selected for consideration of cost and analysis of potential environmental impacts because it is representative of current hydropower subordination and diversion rights associated with Canyon Lake. Figure 3.23-2 illustrates simulated McFaddin Reservoir storage fluctuations for the 1934-89 historical period, if operated under the Trans-Texas Environmental Criteria and subject to diversion of the firm yield of 37,200 acft/yr. Simulated reservoir storage remained above the 60 percent capacity threshold about 97 percent of the time and remained above 90 percent full for 93 percent of time resulting in the frequent passage of inflows from the Kuy Creek

Table 3.23-1 Summary of McFaddin Reservoir Firm Yield Estimates			
	Estimate of Firm Yield (acft/yr)[1]		
	Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[3]		
Scenario[2]	40%	60%	80%
1	37,000	37,000	37,400
2	37,100	37,200	37,500
3	37,100	37,200	37,500

Notes:

1) Firm yield based on diversion of available water from the purchase of 40,000 acft/yr of water rights (senior to Canyon Lake) from the GBRA Calhoun Canal Division.

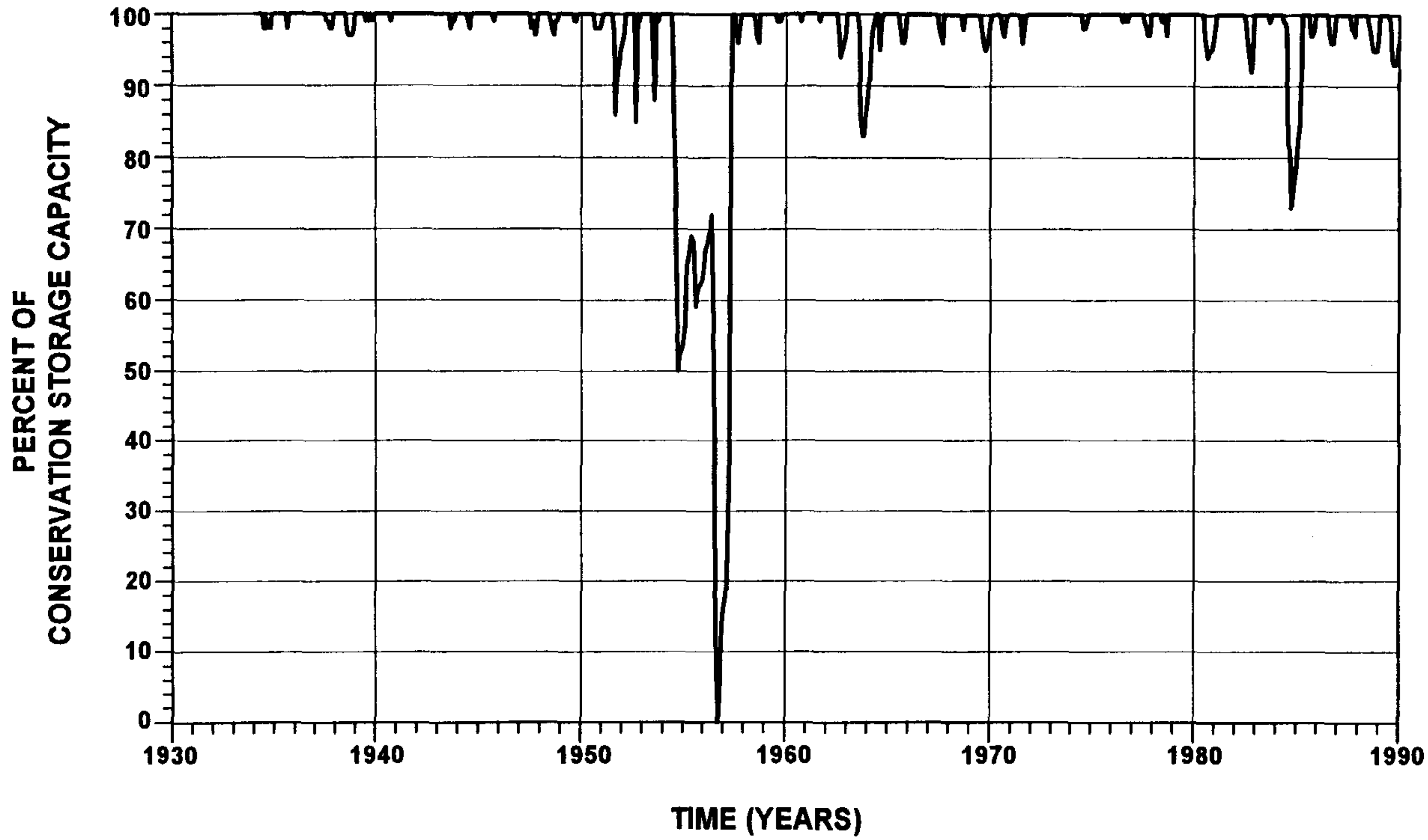
2) All scenarios include the springflows from a fixed Edwards Aquifer pumpage of 400,000 acft/yr with existing recharge structures, full utilization of existing water rights (including Applewhite Reservoir), and return flows set to 1988 levels.
   - Scenario 1: Hydropower water rights subordinated to 0 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 74,100 acft/yr.
   - Scenario 2: Hydropower water rights subordinated to 365 cfs at Lake Dunlap resulting in a Canyon Lake firm yield of approximately 52,600 acft/yr.
   - Scenario 3: Hydropower water rights subordinated to 600 cfs at Lake Dunlap resulting in a Canyon Lake firm yield equal to the existing permit of 50,000 acft/yr.

3) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows, up to the median monthly natural flow during the January, 1954 through December, 1956 historical period.

watershed up to the monthly mean or median natural streamflow. As a result, monthly median streamflows were essentially unaffected by the reservoir at the site and at the Saltwater Barrier. Monthly median streamflows and annual streamflows averaged by decile, with and without the project, are presented in Figure 3.23-3 for conditions both at the site and at the Saltwater Barrier. Under Scenario 3 with a 60 percent capacity threshold, freshwater inflows to the Guadalupe Estuary as measured at the Saltwater Barrier would be reduced by an average of 3,800 acft/yr considering flows originating from the Kuy Creek watershed or less than 1 percent.

3.23.3 Environmental Issues

The primary purpose of McFaddin Reservoir would be to store unappropriated water diverted from the Salt Water Barrier Reservoir. The stored water would be transferred by



NOTES

FIRM YIELD: 37,200 ACFT/YR
CONSERVATION STORAGE CAPACITY: 9,200 ACFT
60% CAPACITY THRESHOLD
SCENARIO 3:

- EDWARDS AQUIFER DEMAND OF 400,000 ACFT/YR
- RETURN FLOWS SET AT 1988 LEVELS
- HYDROPOWER RIGHTS SUBORDINATED TO 600 CFS AT LAKE DUNLAP
- APPLEWHITE RESERVOIR INCLUDED

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

FIRM YIELD STORAGE TRACE MC FADDIN RESERVOIR ALTERNATIVE G-18

FIGURE 3.23-2

pipeline from McFaddin Reservoir to the south side water treatment facility (Figure 3.23-1). After treatment, the water may be directly injected in the Edwards Aquifer or transferred to the recharge zone. From the treatment plant, the proposed pipeline corridors would be the same as those assessed in Section 3.4.3 and discussed in the Environmental overview, Section 3.0.2.

The reservoir lies entirely within the Western Gulf Coastal Plain Ecoregion[146] (Figure 3.2-1). This Ecoregion is distinguished by its mosaic of native bluestem and sacahuista grasses, croplands and improved grazing lands. Soils are primarily vertisols. Blair's regional classification places the reservoir site close to the boundaries of the Texan and Tamaulipan Biotic Provinces[147]. Blair describes the Texan Biotic Province as a broad ecotone between western grasslands and eastern forests, while the Tamaulipan Biotic Province is dominated by thorny subtropical brush with pedocal soils. Blair's biogeographical listing of wildlife fauna for these two provinces is a mix of western grassland-associated and eastern forest associated species (Texan), and a mixture of Neotropical, grassland, some Austroriparian and some Chihuahuan species (Tamaulipan).

The reservoir is within Gould's Gulf Prairies and Marshes vegetation region, which is characterized as the coastal plain inland to elevations near 150 feet[148]. It is primarily prairie, often poorly drained in its eastern reaches, dissected by streams flowing into the Gulf, and with narrow belts of low wet marsh and oak woodlands immediately adjacent to the coast. Correll and Johnston described the climax vegetation of the region as being tall grass prairie and post oak savannah[149]. However, the climax vegetation has generally been reduced to small areas and replaced with crops or pastures, and then often invaded by mesquite, oak, prickly pear, and several acacias.

USDA and the Texas Agricultural Experiment Station describe the soils of Victoria

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[146] Omernik, James M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1) pp. 118-125.

[147] Blair, W. F. 1950. The biotic provinces of Texas. Texas Journal of Science 2(1): pp 93-117

[148] Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press, College Station, Texas.

[149] Correll, D.S., and M.C. Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

County, McFaddin Reservoir site as being Lake Charles clay on both the nearly level uplands (LaA), and on slopes adjacent to drainages (LaD)[150]. This soil is poorly drained, permeability is slow and available water capacity is high.

The proposed reservoir site's vegetation is influenced primarily by ongoing agricultural disturbance and its location at the confluence of Dry Kuy and Kuy Creek[151]. The proposed reservoir will inundate approximately 1,235 acres at elevation 55 ft MSL, including wetlands (340 acres), crop and grass lands (730 acres), and riparian brush and woodlands (165 acres).

The water quality of natural runoff into the proposed McFaddin Reservoir should be relatively good. Water quality of diversions from the Guadalupe River to McFaddin Reservoir are expected to be good, as reflected by water quality data collected by TNRCC on the Guadalupe River at SMN Station 1803.01 located at SH175 approximately 2 miles south of Victoria[152]. Water quality data include dissolved oxygen, nutrient, and inorganic loads.

A specific pipeline construction corridor for this alternative has not been selected and assessed for this phase of the Trans-Texas Water Program. The potential environmental effects resulting from the construction and operation of water transport pipelines depends to a large extent on the exact placement of the construction corridor. It has been assumed that adverse impacts would be avoided and minimized to the extent practical by careful pipeline ROW selection in subsequent phases, using vegetation, land use, and protected species information. In general, sensitive habitats, or habitats critical to the survival of protected species are rare or of restricted distribution so that adverse impacts can often be avoided or minimized. More generally distributed habitats, although perhaps important to regional wildlife populations in some areas, may not be so easy to avoid, but because of the limited area affected by these corridors, they are unlikely to result in significant impacts.

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[150]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1982. Soil Survey of Victoria County, Texas. USDA

[151]Ibid.

[152]TNRCC. 1993. Unpublished Guadalupe annual balance summary. Texas Natural Resources Conservation Commission, Austin, Texas.

Environmental effects potentially resulting from using the proposed Medina County injection well field and the Bexar County recharge dams located on the Edwards outcrop are addressed in the Environmental Overview, Section 3.0.1, and the recharge Sections 3.8.3 and 3.9.3.

Although no federal or state protected species have been reported to occur in the reservoir site (see Appendix B, Table 44), several listed species, including nesting bald eagles and Attwater's Prairie Chicken are known to inhabit nearby areas, and habitat for some of them may be present in the project area (see Table 3.23-2). An on-site investigation will be necessary to further evaluate wetland impacts and the potential for effects on state and federally listed endangered and threatened species. Reservoir development would likely require compensation for the loss of about 505 acres of wetland and woody riparian vegetation.

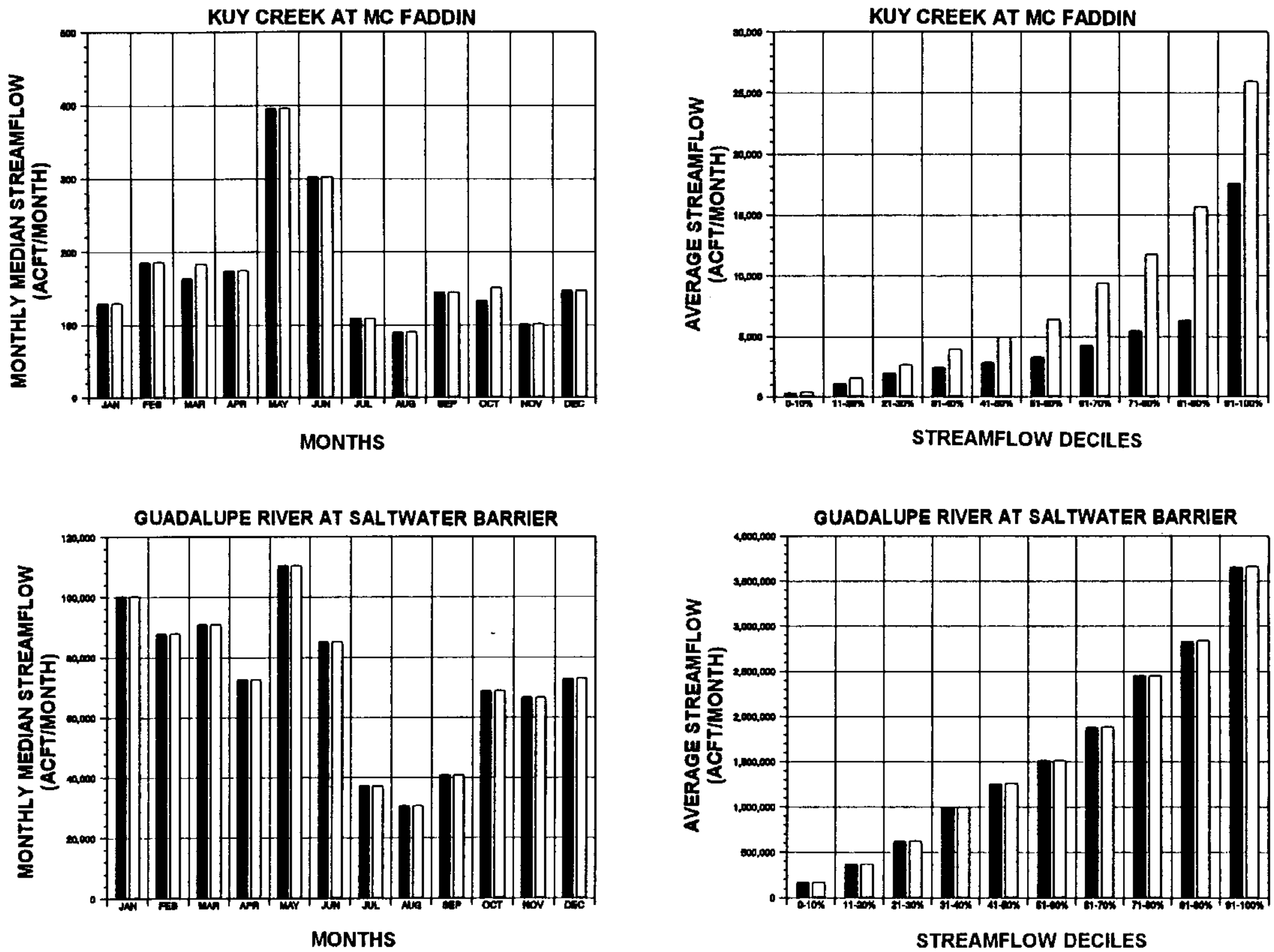
The proposed McFaddin Reservoir (G-17), as Figure 3.23-3 shows, would be operated to maintain monthly median flows in Kuy Creek downstream to its confluence with the Guadalupe River, but large proportions of the higher flow deciles would be substantially reduced. No substantial effects on the Guadalupe River at the salt water barrier are shown in Figure 3.23-3, since the total annual discharge changes by an average of only 3,783 acft. Because the baseline flows were modeled with all existing water rights fully exercised (cumulative impacts), and Guadalupe River diversions would be made under an existing, purchased right, only the water captured from Kuy and Dry Kuy Creeks appears to have effect on river flow.

In addition to habitat mitigation, a reservoir management plan may be needed. The lands adjacent to the reservoir could be monitored to control the growth of woody vegetation and encourage the development of desirable bottomland species, providing suitable shoreline habitat for wildlife. This could possibly be accomplished through seasonal inundation and dewatering.

Table 3.23-2
Important Species With Habitat in the Vicinity of the Proposed Project (G-18)

Common Name	Scientific Name	Habitat Preference	Listing Agency USFWS	Listing Agency TPWD
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; aestivates underground during dry periods	C2	E
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporarily wet areas, arroyos, canals, ditches and shallow depressions; requires moisture	C2	E
Indigo Snake	*Drymarchon coralis*	Grassland Prairie to coastal sand hills; prefers woodland and mesquite savannah of Coastal Plain	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks	C2	T
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions	NL	T
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T
Welder Machaeranthera	*Machaeranthera heterocarpa*	Shrubland-invaded grasslands, rights-of-way, and open mesquite - huisache woodlands on mostly grey colored clayey to silty soils over Beaumont and Lissie formations on the coastal prairie	C2	NL

Sources: Texas Parks and Wildlife Department. Unpublished data, December 1993. Texas Natural Heritage Program Files; TPWD, Endangered Resources Annual Status Report (E.R.A.S.R.) Appendix G Special Plant List; and TPWD, Unpublished May 1988 species data list by county.



LEGEND

■ WITH PROJECT
□ WITHOUT PROJECT

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WEST CENTRAL STUDY AREA

CHANGES IN STREAMFLOW
MC FADDIN RESERVOIR
ALTERNATIVE G-18

FIGURE 3.23-3

Cultural resources protection on public lands in Texas, or lands affected by projects regulated under Department of the Army permits, is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

3.23.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.23.5 Engineering and Costing

Alternative G-18A: Delivery to Aquifer Injection Wells

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the injection well field in eastern Medina County. The diversion rate from the reservoir, as well as the delivery to the wells would be uniform throughout the year. The benefit from this project would be the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

Guadalupe River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, 3 required
Water Treatment Plant (Level 2)
Finished Water Pump Station
Finished Water Booster Pump Stations, 2 required
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The reservoir intake and pump station is sized to deliver 3,080 acft/month (33 mgd) through a 48-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 495 feet and an annual water delivery of 37,000 acft/year. Operating cost of the finished water pumping system was determined for the total static lift of 310 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $20,000,000 (Table 3.23-3). Purchase of water is estimated to cost $53/acft/yr for firm water, for a total annual cost of $1,960,000. Operation and maintenance costs, including power, total $12,080,000. The annual costs, including debt repayment, interest, purchase of water, and operation and maintenance, total $34,040,000. For an annual firm yield of 37,000 acft, the resulting annual cost of water is $920 per acft (Table 3.23-3).

Alternative G-18B: Delivery to Recharge Structures in the Recharge Zone

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to recharge structures in northwestern Bexar County. The diversion rate from the reservoir, as well as the delivery to the recharge structures would be uniform throughout the year. The benefit from this project would be the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and springs. The yield from this alternative will be placed in an open impoundment and mixed with surface runoff present in the local watershed. There is no known water quality condition that requires the imported water to be treated prior to placement in a natural stream or surface impoundment. However, there may be concerns that the imported water is of different quality than the existing runoff and the need for treatment of the McFaddin water may require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of the imported water. To determine the cost to treat the imported water, a typical direct filtration process (Treatment Level 2, Table 3.0-4) was assumed.

The major facilities required to implement this alternative are:

Guadalupe River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Dam and Reservoir

Table 3.23-3
Cost Estimate Summaries for McFaddin Reservoir and Pipeline (G-18)
(Mid- 1994 Prices)

Item	Alt. G-18A Divert and Inject to Aquifer	Alt. G-18B Divert to Recharge Zone	Alt. G-18C Divert to WTP and Municipal System
Capital Costs			
Dam and Reservoir	$11,500,000	$11,500,000	$11,500,000
Transmission and Pumping	119,200,000	121,180,000	91,720,000
Treatment Plant	11,540,000	11,540,000	16,110,000
Delivery System	5,400,000	3,090,000	28,700,000
Total Capital Cost	$147,640,000	$147,310,000[1] $135,770,000[2]	$148,030,000
Engineering, Contingencies, and Legal Costs	46,490,000	46,470,000[1] 42,430,000[2]	44,980,000
Land Acquisition	2,500,000	2,600,000[1] 2,550,000[2]	2,010,000
Environmental Studies and Mitigation	3,880,000	3,390,000	1,940,000
Interest During Construction	12,980,000	14,530,000[1] 13,590,000[2]	13,400,000
Total Project Cost	$213,490,000	$214,300,000[1] $197,730,000[2]	$210,360,000
Annual Costs			
Annual Debt Service	$20,000,000	$20,080,000[1] $18,530,000[2]	$19,710,000
Purchase of Water	1,960,000	1,960,000	1,960,000
Annual Operation and Maintenance	4,130,000	4,190,000[1] 2,030,000[2]	3,890,000
Annual Power Cost	7,950,000	9,230,000	5,480,000
Total Annual Cost	$34,040,000	$35,460,000[1] $31,750,000[2]	$31,040,000
Available Project Yield (acft/yr)	37,000	37,000	37,000
Annual Cost of Water	$920/acft	$958/acft[1] $858/acft[2]	$839/acft

[1] Cost with treatment prior to surface recharge.
[2] Cost without treatment prior to surface recharge.

Reservoir Intake and Pump Station
Raw Water Pipeline to Recharge Zone or Treatment Plant
Raw Waterline Booster Pump Stations
Recharge Structures, 3 required
Treatment Plant Items (if determined to be needed):
- Water Treatment Plant (Level 2)
- Finished Water Pump Station
- Finished Water Booster Pump Stations, 3 required
- Transmission Line to Recharge Zone

The reservoir intake and pump station is sized to deliver 3,080 acft/month (33 mgd) through a 48-inch diameter pipeline. The operating cost was determined for a total raw water static lift to the treatment plant of 495 feet and an annual water delivery of 37,000 acft/year. If no treatment plant is required, then the operating cost is determined for the total raw water static lift to the recharge structures of 1,185 feet. For a treatment plant, the operating cost of the finished water pumping system was determined for a total static lift of 690 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $20,080,000 with a treatment plant and $18,530,000 with no treatment plant (Table 3.23-3). Purchase of water is estimated to cost $53/acft/yr for firm water, for a total annual cost of $1,960,000. Operation and maintenance costs total $13,420,000 , including the treatment plant and are $11,260,000 without a treatment plant. The annual costs, including debt repayment, interest, purchase of water, and operation and maintenance, total $35,460,000 including the treatment plant and are $31,750,000 without a treatment plant. For an annual firm yield of 37,000 acft, the resulting annual cost of water, including a treatment plant, is $958 per acft, and is $858 per acft without a treatment plant.

Alternative G-18C: Delivery to the Municipal Distribution System

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the South Water Treatment Plant. The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other entities and the resulting reduction in demand on the aquifer. The major facilities required to implement this alternative are:

Guadalupe River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, 3 required
Water Treatment Plant (Level 3, see Table 3.0-4)
Finished Water Pump Station
Finished Water Booster Pump Stations, 1 required
Distribution System Improvements

The reservoir intake and pump station is sized to deliver 3,080 acft/month (33 mgd) through an 48-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 495 feet and an annual water delivery of 37,000 acft/year. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $19,710,000 (Table 3.23-3). Purchase of water is estimated to cost $53/acft/year for firm water, for a total annual cost of $1,960,000. Operation and maintenance costs, including power, total $9,370,000. The annual costs, including debt repayment, interest, purchase of water, and operation and maintenance, total $31,040,000. For an annual firm yield of 37,000 acft, the resulting annual cost of water is $839 per acft (Table 3.23-3).

3.23.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Reservoir Alternatives (G-18, All)

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits.
   b. TNRCC Interbasin Transfer Approval may be required.
   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal permits.
   e. GLO Easement for use of state-owned land.
   f. Coastal Coordinating Council review.
   g. TPWD Sand, Gravel, and Marl permit

2. Permitting, at a minimum, will require these studies:
    a. Bay and estuary inflow impact.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.
3. Land will need to be acquired by negotiation or condemnation.
4. Relocations for the reservoir include:
    a. Highways and railroads
    b. Other utilities

Requirements Specific to Pipelines (G-18A)

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    b. GLO Sand and Gravel Removal permits.
    c. Coastal Coordinating Council review.
    d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (G-18A)

1. Required testing programs:
    a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer.
    b. Test drilling and pilot recharge program is required.
    c. Large scale recharge test program.
    d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
    e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits could include:
    a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures

1. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
2. Necessary permits:
   a. TNRCC Water Rights and Storage permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
   c. GLO Sand and Gravel Removal permit.
   d. TPWD Sand, Gravel, and Marl permit.
3. Permitting, at a minimum, will require these studies:
   a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
   b. Study of impact on karst geology organisms from a sustained recharge program.
   c. Other environmental studies.
   d. Cultural resource studies.

Requirements Specific to Treatment and Distribution

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

3.24 Guadalupe River Dam No. 7 (G-19)

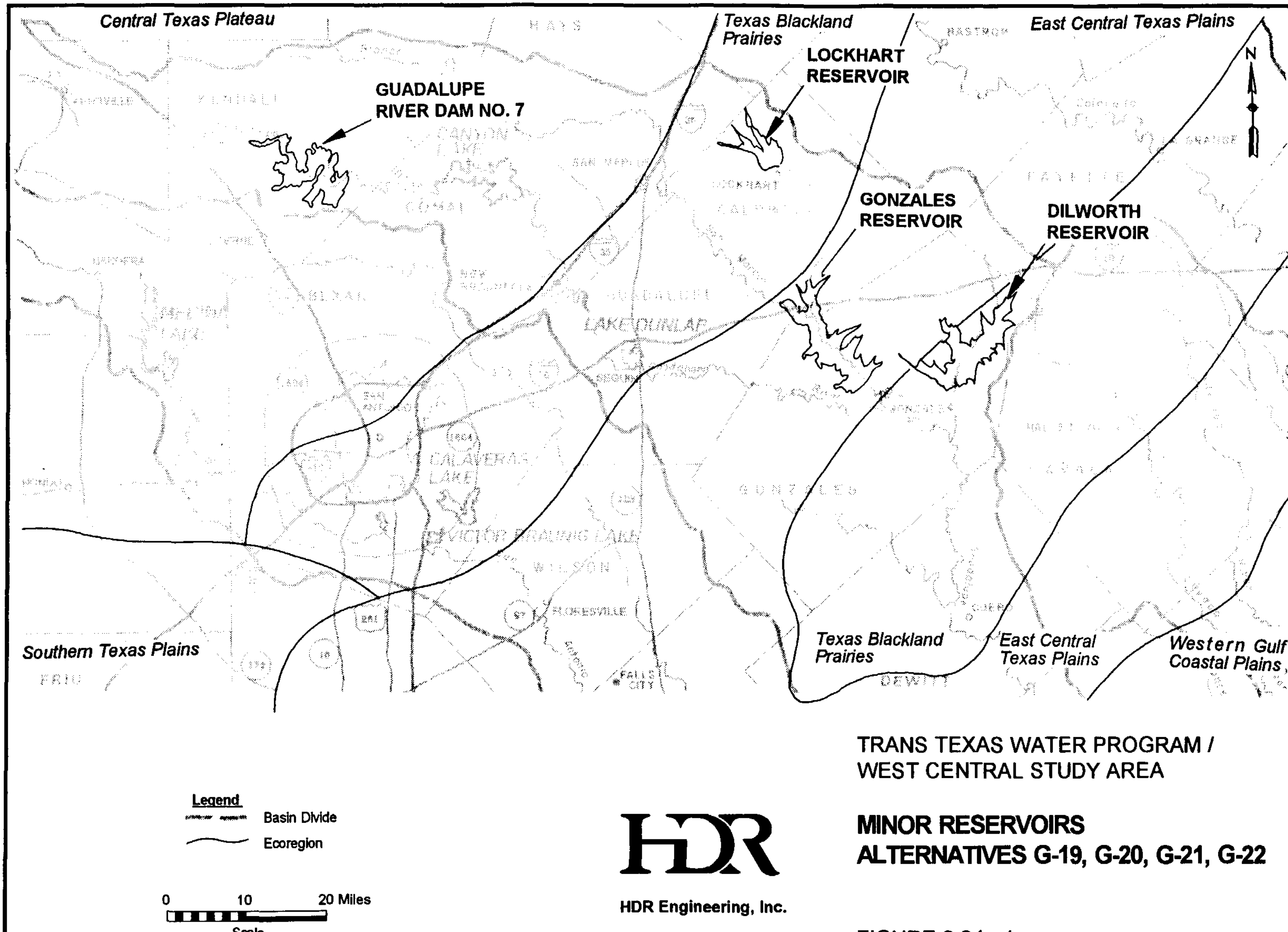
3.24.1 Description of Alternative

The Guadalupe River Dam No. 7 site was originally proposed in 1953 in the "Initial Plan" of the Guadalupe-Blanco River Authority (GBRA) and was proposed to be located on the Guadalupe River at a location 30 miles west of New Braunfels, as shown in Figure 3.24-1. In a report entitled "Preliminary Report on the Proposed Guadalupe River Dam No. 7 and No. 8," the project's original purpose was primarily for power development. In 1959, Forrest and Cotton, Inc. studied Dam No. 7 as a water conservation project, located at a site seven river miles upstream from the original study location (drainage area at the upstream location is 1,124 square miles, which is 78 percent of the drainage area of Canyon Lake). The most recent published study of the Guadalupe Dam No. 7 project was performed in October 1981 by Espey, Huston and Associates, Inc. (EHA) in their report entitled "Upper Guadalupe River Dam No. 7," in which the site was again studied with respect to water conservation potential.

The Dam No. 7 embankment, as described by EHA, is a typical rock-filled section with an earthen core and random fill outer shells. The dam crest is set at a maximum elevation of 1,263 ft-MSL and the spillway consists of a 4,000 to 4,500-foot long section cut into a nearby hill. The conservation storage available in the reservoir at elevation 1,242 ft-msl is 600,000 acft.

3.24.2 Available Yield

Yield estimates for Guadalupe Dam No. 7 were determined in the 1981 EHA report honoring numerous different combinations of water rights. The final yield estimate for the study was based on honoring all downstream water rights except the full GBRA hydropower rights below the Comal River, which were only partly satisfied. EHA estimated the combined yield of Dam No. 7 and Canyon Lake to be 87,100 acft/yr with the increment of yield attributable to Dam No. 7 being approximately 33,300 acft/yr or about 38 percent of the combined yield. The yields presented here have not been adjusted to reflect Trans-Texas criteria for pass-through, instream needs and bay and estuary needs. It is very likely that the yields from previous studies will be significantly reduced when the Trans-Texas environmental criteria for reservoirs are applied.



HDR

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

MINOR RESERVOIRS ALTERNATIVES G-19, G-20, G-21, G-22

FIGURE 3.24 - 1

3.24.3 Environmental Issues

Alternative (G-19) involves dam construction and inundation of approximately 12,830 acres along a 31-mile reach of the Guadalupe River. Associated pipelines for transporting the surface water to a water treatment plant may be addressed in a future phase of this project if this alternative is considered in the future.

The proposed Guadalupe Dam No. 7 is located in the eastern portion of Kendall County within the Central Texas Plateau ecoregion[153] (see Figure 3.0-1), on the southern edge of the Edwards Plateau vegetational area of Texas[154] (see Figure 3.0-2), and within the Balconian biotic province[155] (Figure 3.0-3).

The project area is heavily wooded (41 percent of total land area), with large expanses of brush and scrublands (43%) and small quantities of grassland, cropland, and wetland (see Table 3.0-1). The wooded upland areas typically support open to closed stands of plateau oak, Texas oak, shinnery oaks, Ashe juniper, cedar elm, and honey mesquite, with a tall or mid-grass understory. The most important grasses in these upland areas are little bluestem, gramas, curly mesquite, and buffalo grass. The wooded upland areas are primarily undeveloped, with open areas generally used for rangeland.[156]

The stream-side vegetation present along the Dam No. 7 site is typical for streams of this size on the Edwards Plateau. These bottomland areas support a gallery forest of baldcypress, pecan, elms, ashes, sycamore, Texas sugarberry, and burr oak. The most important grasses in the bottomland areas are switchgrass and Canada wild-rye. The wooded bottomland areas are typically undeveloped, while open bottomland areas with deep soils are generally used for rangeland and crops[157].

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[153]Omernik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1). pp. 118-125.

[154]Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press, Texas Agricultural Experiment Station, College Station, Texas.

[155]Blair, W.F. 1950. The biotic provinces of Texas. Tex. J. Sci. 2:93-117.

[156]Espey, Huston & Associates, Inc. (EH&A). 1981. Upper Guadalupe River Basin Water Supply Project, Final Report. Prepared for Upper Guadalupe River Authority and Guadalupe-Blanco River Authority. EH&A Document No. 81137-R1. October.

[157]Ibid.

Soils in the Dam No. 7 reservoir site consist of the well-drained Boerne fine sandy loam in the floodplains, and the gently undulating Eckrant-Comfort and steep Eckrant-Rock outcrop associations on uplands and hills. These associations are composed of shallow, cobbly, stony and mildly alkaline soils. The upland soils are poorly suited to cropland, improved pasturelands, urban uses and recreation due to a stony clay surface layer, large stones, rock outcrops, shallow rooting depth, steep slopes, and very low available water capacity. Thus, rangeland is the most common usage[158].

Areas which can be classified as wetlands by the U.S. Army Corps of Engineers and/or the U.S. Fish and Wildlife Service occur at the site. Wetlands in the project region consist of the riverine habitats of the Guadalupe River and its tributaries, and associated palustrine habitats generally consisting of fairly narrow bands of wetlands along the watercourses. The majority of the riverine and palustrine wetlands are in the unconsolidated shore or unconsolidated bottom class, although forested wetlands also occur within both the riverine and palustrine classes.

The assemblage of eastern, western, and endemic species and aquatic habitats closely associated with somewhat rugged terrestrial habitats makes the project site both biologically and aesthetically important[159]. Woodland-inhabiting fauna expected to typify the wildlife of the project area include the white-tailed deer, Virginia opossum, eastern cottontail, raccoon, ladder-backed woodpecker, blue jay, cañon wren, cardinal, Texas spiny lizard, and western diamondback rattlesnake, among others[160].

The Guadalupe River and its tributary streams are typically deeply incised channels with narrow floodplains, leading to high rates of runoff and flash flood conditions during major storm events. At other times these streams tend to flow relatively shallowly over rock or gravel beds, with high water clarity. The narrow channels are frequently shaded by

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[158]U.S. Department of Agriculture, Soil Conservation Service (SCS). 1981. Soil Survey of Kendall County, Texas. In cooperation with Texas Agricultural Experiment Station, Texas A&M University, College Station. March.

[159]Espey, Huston & Associates, Inc. (EH&A). 1981. Upper Guadalupe River Basin Water Supply Project, Final Report. Prepared for Upper Guadalupe River Authority and Guadalupe-Blanco River Authority. EH&A Document No. 81137-R1. October.

[160]Ibid.

streamside woodlands. Aquatic vegetation is limited by the scouring of stormwater flows and shading, as well as the low frequency of suitable substrate (muck or mud)[161]. The Upper Guadalupe River (Segment 1806) from the upper end of Canyon Lake to the headwaters is designated for contact recreation and considered to have exceptional quality aquatic habitat[162]. Springs and shallow headwaters are numerous in the reservoir site. In addition, the major streams provide series of riffle and pool habitat. Common game fish of importance, when mature, are restricted primarily to the deeper pool areas. Spring and minor headwater habitats may serve as refugia from predators and competition for some aquatic species, including some small fish. Characteristic aquatic-associated species that may occur at the Dam No. 7 site include nutria, water snakes and several species of anurans and waterfowl. The Dam No. 7 site, because of its location on the Guadalupe River, probably receives significant utilization by migratory waterfowl and fish-eating birds[163].

The primary impacts that would result from construction and operation of the Dam No. 7 Reservoir include conversion of existing habitats and land uses within the conservation pool to open water (see Table 3.0-1), and potential downstream effects due to modification of the existing flow regime. The Dam No. 7 reservoir site would be permanently inundated to 1,242 feet MSL with a surface area of 12,830 acres. The probable maximum flood (PMF) would inundate an area of approximately 15,500 acres. The area of permanent inundation represents the project area. Approximately 499 acres of riverine habitat would be converted to lacustrine habitat. Other resources of potential concern within the reservoir site include a cemetery, Century Caverns, and Camp Alfazar. Golden Fawn Ranch is located on the proposed reservoir boundary and could be impacted. Indirect effects of reservoir construction may include land use changes in the area surrounding the reservoir and in mitigation areas that may be converted to alternate uses to compensate for losses of terrestrial habitat.

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[161] Ibid.

[162] Texas Water Commission (TWC). 1991. Texas Surface Water Quality Standards. Texas Administrative Code, Section 307.

[163] Espey, Huston & Associates, Inc. (EH&A). 1981. Upper Guadalupe River Basin Water Supply Project, Final Report. Prepared for Upper Guadalupe River Authority and Guadalupe-Blanco River Authority. EH&A Document No. 81137-R1. October.

Potential downstream impacts would include modification of the streamflow regime below the dam, and reduced inflows to San Antonio Bay. Detailed hydrologic information regarding these system modifications is not available for this reservoir alternative. However, it is assumed that as a new reservoir without a current operating permit, the Dam No. 7 would be required to meet the Trans-Texas Water Program criteria for instream flows and freshwater inflows to bays and estuaries. Operation of the reservoir to meet these criteria would likely have a significant effect on (i.e., reduction of) the firm yield of the reservoir.

Plant and animal species listed by the USFWS and TPWD as endangered or threatened in Kendall County, and those with candidate status for listing are presented in Table 27 of Appendix B. The Texas Natural Heritage Program records include reported occurrences of the Texas salamander (*Eurycea neotenes*) and the Guadalupe bass (*Micropterus treculi*), both Category 2 candidate species, in the Dam No. 7 reservoir area. In addition, a number of the species listed for Kendall County have habitat requirements or preferences that indicate that they could be present within the reservoir site. A survey of the reservoir site may be required prior to dam construction to determine whether populations of or potential habitat for species of concern occur in the area to be impacted.

The Guadalupe River may be considered a unique and ecologically sensitive area. The Texas Natural Area Survey[164] identified the Guadalupe River from its west boundary to its east boundary in Kendall County as a natural area. The Guadalupe River from Canyon Lake to its headwaters near Kerrville is on the preliminary inventory list of the Heritage Conservation and Recreation Service (HCRS) for possible inclusion in the National Wild and Scenic Rivers Program[165]. The HCRS is within the U.S. Department of the Interior. Although the river is not officially protected by occurring on the inventory list, the HCRS will require interagency consultation for projects which may adversely affect the river.

Habitat types of importance to aquatic organisms of limited range or occurrence

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[164]Texas Natural Area Survey. 1973. The natural areas of Texas (preliminary listing). Student Council on Pollution and Environment.

[165]Espey, Huston & Associates, Inc. (EH&A). 1981. Upper Guadalupe River Basin Water Supply Project, Final Report. Prepared for Upper Guadalupe River Authority and Guadalupe-Blanco River Authority. EH&A Document No. 81137-R1. October.

within the proposed Dam No. 7 site include springs and shallow headwaters, as well as the riffle/pool habitat of the Guadalupe River proper. The springs and headwater areas are often important to aquatic species which cannot persist under the competition/predation regime of larger water bodies, or are unable to survive the greater environmental fluctuation there. The Guadalupe bass, a federal Category 2 candidate species, is restricted to the clear, relatively fast-flowing streams of the eastern Edwards Plateau.

The Upper Guadalupe River watershed, situated within the Central Texas cultural area, has rich potential for yielding both historic and prehistoric sites. No complete survey of Dam No. 7 reservoir site has been conducted. Based on the results of previous research performed in the Upper Guadalupe watershed[166,167,168], and on the known history and prehistory of the area, sites reflecting thousands of years of local habitation can be expected to be encountered. The Texas Archeological Research Laboratory lists a total of 78 recorded sites within the 1,274 square mile area that comprises Kendall County, Texas. Six prehistoric sites from the Archaic and Neo-American period, five habitation sites and one pictograph have been located within the designated study area[169].

That portion of the Guadalupe River which is under consideration for designation as a National Wild and Scenic River has been ranked as outstandingly remarkable in scenic, recreation, and geologic values. The river segment has been recommended for inclusion in the proposed Texas Natural Rivers System. According to the Texas Parks and Wildlife Department, the river is rated as the No. 1 recreation river and the No. 2 scenic river in the state. Portions of the river have also been noted in the Texas Natural Areas Survey. The Survey notes the existence of rare vegetation, two major waterfalls, numerous rapids, and

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[166]Briggs, A.K. 1970. Preliminary Archaeological Survey of Study Area on the Guadalupe River. *Office of the State Archaeologist, Special Reports* 13.

[167]Bass, F. A., and T. R. Hester. 1975. An Archaeological Survey of the Upper Cibolo Creek Watershed, Central Texas: Center for Archaeological Research, *Archaeological Survey Report* No. 8.

[168]Kelly, T.C. and T.R. Hester. 1976. Archaeological Investigations at Sites in the Upper Cibolo Creek Watershed, Central Texas. Center for Archaeological Research, Archaeological Survey Report No. 17.

[169]Espey, Huston & Associates, Inc. (EH&A). 1981. Upper Guadalupe River Basin Water Supply Project, Final Report. Prepared for Upper Guadalupe River Authority and Guadalupe-Blanco River Authority. EH&A Document No. 81137-R1. October.

limestone bluffs. Interagency consultation would be required for a project (such as the proposed Dam No. 7) which may adversely affect the river.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources.

Implementation of this reservoir alternative is expected to require field surveys to document vegetation/habitat types and cultural resources that may be impacted by the proposed reservoir. Where impacts to potential protected species habitat or significant cultural resources cannot be avoided, additional studies may be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. Compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

3.24.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.24.5 Engineering and Costing

For this report, the cost estimate for Guadalupe River Dam No. 7 is an update of the cost estimate prepared by EHA in October, 1981. EHA estimated the total project costs for Guadalupe River Dam No. 7 to be $147,194,000 in 1981 dollars. The 1981 cost estimate was updated by multiplying estimated construction material quantities and land requirements by current 1994 unit prices. Where construction quantities were not available, costs were calculated by multiplying the individual cost components contained in the previous estimate by a Construction Cost Index (CCI) ratio or Bureau of Reclamation (BUREC) Construction index ratio. It is interesting to note that land prices in Texas, according to the BUREC, have declined nine percent since 1981. The mid-1994 estimated total project cost estimate for Guadalupe Dam No. 7 is $129,731,000 as summarized in Table 3.24-1. The annual cost

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of the project, including operation and maintenance would be $13,382,000 (Table 3.24-1). The cost of pumping, delivery, and treatment system have not been included in this alternative. If this alternative is pursued, significant additional work is required to update relocation costs, mineral rights costs, mitigation costs, environmental and archaeological studies costs, and other significant cost items which may have substantially changed since the project was last studied.

Table 3.24-1
Cost Estimate for Guadalupe River Dam No. 7 and Reservoir (G-19)
(Mid - 1994 Prices)

Item	Estimated Cost
Capital Cost	
Relocations	$14,835,000
Diversion and Care of Water	1,500,000
Reservoir Clearing	9,048,000
Embankment	27,909,000
Slopes	420,000
Spillway	14,083,000
Grout Curtain	3,275,000
Total Capital Cost	71,070,000
Engineering, Legal, and Contingencies	24,875,000
Environmental Studies and Mitigation	11,856,000
Land Acquisition	12,320,000
Interest During Construction	9,610,000
Total Project Cost	**$129,731,000**
Annual Cost	
Annual Debt Service	12,156,000
Annual Operation and Maintenance	1,226,000
Total Annual Cost	**$13,382,000**
Annual Project Yield	33,300 acft

Note: Annual cost of raw water at reservoir with no conveyance or treatment is $402/acft.

3.25 Gonzales Reservoir (G-20)

3.25.1 Description of Alternative

The Gonzales Reservoir site was originally proposed by the United States Army Corps of Engineers (COE) in 1950. In the COE's original study entitled "Report on Survey of Guadalupe and San Antonio Rivers and Tributaries, Texas for Flood Control and Allied Purposes", the Gonzales Reservoir site was to provide flood control, water conservation, and development of hydroelectric power. The site is located on the San Marcos River about five river miles upstream of its confluence with the Guadalupe River (refer to Figure 3.24-1 in previous section). At this location, the drainage area is 1,344 square miles.

The Gonzales Reservoir would consist of a 15,700-foot long earthen embankment with a top-of-dam elevation of 354 ft-MSL and a maximum dam height of 104 feet. The spillway system would consist of a 480-foot long concrete section equipped with 12 tainter gates with a crest elevation of 309 ft-MSL. The reservoir conservation pool would contain 560,000 acft at a water surface elevation of 344 ft-MSL. At this elevation, the reservoir's surface area would be 21,370 acres.

3.25.2 Available Yield

Yield estimates for Gonzales Reservoir were determined from a 1959 report entitled "Report on Supplement to the Initial Plan of Development of the Guadalupe-Blanco River Authority" by Forrest and Cotton, Inc. (FC). The critical period for the reservoir is the 1947-1957 drought and the yield at the Gonzales site, ignoring any other potential reservoir projects on the San Marcos River, was estimated at 87,690 acft/yr based on historical springflows. However, FC estimated that the firm yield would be reduced if the flow of San Marcos Springs decreased due to increased pumping of the Edwards Aquifer. It was estimated that if San Marcos springflow decreased to 57,400 acft/yr, the firm yield of Gonzales Reservoir would decrease to 52,470 acft/yr. The yields presented here have not been adjusted to reflect Trans-Texas criteria for pass-through, instream needs, and bay and estuary needs. It is very likely that the yields from these previous studies will be significantly reduced when the Trans-Texas environmental criteria is applied.

3.25.3 Environmental Issues

This alternative (G-20) involves dam construction and inundation of approximately 21,370 acres along a 31-mile reach of the San Marcos River (see Figure 3.24-1). Associated pipelines for transporting the surface water to a water treatment plant will be addressed in a future phase of this project and are not considered here.

The proposed Gonzales Reservoir is located in north-central Gonzales County on the boundary between the Texas Blackland Prairie and the East Central Texas Plains ecoregion[170] (Figure 3.0-1), in the Post Oak Savannah vegetational area of Texas[171] (Figure 3.0-2), and the Texas biotic province[172] (Figure 3.0-3).

Vegetation types within the proposed Gonzales Reservoir project area on the San Marcos River include grassland and cropland (54 percent), brushland (33 percent), upland and bottomland woodlands (9 percent), wetlands (3 percent), and developed areas (1 percent) (see Table 3.0-1). Common grassland species include little bluestem, silver bluestem, sand lovegrass, beaked panicum, threeawn, sprangle-grass, tickclover, and various introduced grasses used in pastures and rangeland. Brushlands are typically dominated by honey mesquite, huisache, prickly pear, other small trees and shrubs, and a variety of grasses, including threeawns, lovegrasses, gramas, and bluestems. In the upland woodlands, post oak, blackjack oak, honey mesquite, live oak, and cedar elm are common overstory species. Typical overstory species in the bottomland woodlands include American elm, cedar elm, pecan, green ash, Eastern cottonwood, sycamore, black willow, and Texas sugarberry[173]. Wetlands within the conservation pool consist primarily of riverine perennial habitat, with small quantities of palustrine emergent, forested and scrub/shrub wetlands, and stockponds.

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[170]Omernik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1). pp. 118-125.

[171]Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press, Texas Agricultural Experiment Station, College Station, Texas.

[172]Blair, W.F. 1950. The biotic provinces of Texas. Tex. J. Sci. 2:93-117.

[173]McMahan, C.A., R.G. Frye, K.L. Brown. 1984. The Vegetation Types of Texas, Including Cropland. Texas Parks and Wildlife Department, Austin, Texas.

Within the floodplains, soils are a calcareous black clay of Tinn clay and Bosque clay loam. These soils have the highest fertility in the county, thus making excellent cropland. Gholson and Sunev soils are a fine loamy sand found in uplands with slopes of 1-5 percent and 3-8 percent, respectively[174].

The primary impacts that would result from construction and operation of the Gonzales Reservoir include conversion of existing habitats and land uses within the conservation pool to open water, and potential downstream effects due to modification of the existing flow regime. Permanent inundation of the Gonzales Reservoir would yield a conservation pool with a surface area of 21,370 acres. The 100-year flood pool (maximum water surface elevation) would be 349 feet MSL, with a surface area of 24,980 acres. Approximately 11,560 acres of grassland and cropland, 7,077 acres of brushland, 2,029 acres of woodland, 188 acres of wetlands (including 366 acres of riverine habitat), and 150 acres of developed land would be converted to open water (see Table 3.0-1). Indirect effects of reservoir construction may include land use changes in the area surrounding the reservoir and in mitigation areas that may be converted to alternate uses to compensate for losses of terrestrial habitat.

Potential downstream impacts would include modification of the streamflow regime below the dam, and reduced inflows to San Antonio Bay. Detailed hydrologic information regarding these system modifications is not available for this reservoir alternative. However, it is assumed that as a new reservoir without a current operating permit, the Gonzales Reservoir would be required to meet the Trans-Texas Water Program criteria for instream flows and freshwater inflows to bays and estuaries. Operation of the reservoir to meet these criteria would likely have a significant effect on (i.e., reduction of) the firm yield of the reservoir.

The San Marcos River within the project area is classified by the Texas Parks and Wildlife Department as having potential for scenic river designation. Reservoir construction would also inundate the 179-acre Palmetto State Scenic Park, which contains a unique area

[174]U.S. Department of Agriculture, Soil Conservation Service (SCS). 1994. Personal communication with Gonzales County Soil Survey Staff. March.

of subtropical vegetation[175].

Plant and animal species listed by the USFWS and TPWD as endangered or threatened, and those with candidate status for listing in Gonzales County are presented in Table 21 of Appendix B. The Texas Natural Heritage Program records include reported occurrences within the proposed reservoir of the Cagle's map turtle, a C1 USFWS candidate species and the Guadalupe bass, a C2 candidate for Federal protection. The proposed reservoir site may contain potential habitat for other threatened, endangered and candidate species that have been recorded in the county. A survey of the reservoir site may be required prior to dam construction to determine whether populations of or potential habitat for species of concern occur in the area to be impacted.

Several community facilities and towns within the reservoir site would be affected by the Gonzales Reservoir. The cities of Slayden and Ottine would be fully or partially inundated. Little Hill Church and the Gonzales Warm Springs Rehabilitation Foundation are located within the reservoir boundaries and would be inundated. In addition, the Texas State Elks Association Crippled Children's Hospital is located adjacent to the conservation pool and may be impacted.

Cultural resources known to occur within the Gonzales Reservoir site include the McKeller and Princeville cemeteries. Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction could first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources.

Implementation of this reservoir alternative is expected to require field surveys to document vegetation/habitat types and cultural resources that may be impacted by the proposed reservoir. Where impacts to potential protected species habitat or significant cultural resources cannot be avoided, additional studies may be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places,

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[175]U.S. Bureau of Reclamation. 1978. Special Report on the San Antonio-Guadalupe River Basins Study. November, 1978.

respectively. Compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

3.25.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.25.5 Engineering and Costing

The preliminary cost estimate for Gonzales Reservoir is an update of a previous cost estimate performed by the United States Study Commission in 1960. The Study Commission estimated the total project costs for Gonzales Reservoir to be $24,374,000 in 1960 dollars. The 1960 cost estimate was updated by multiplying estimated construction quantities by current 1994 unit prices. Where construction quantities were not available, costs were calculated by multiplying the individual cost components of the previous estimate by a CCI or BUREC index ratio.

The mid-1994 total project cost estimate for Gonzales Reservoir is $131,388,000 as summarized in Table 3.25-1, and the annualized project cost, including operation and maintenance is $13,430,000. The cost of a pumping, delivery, and treatment system was not estimated for this alternative. If this alternative is pursued, significant additional work is required to update relocation costs, mineral rights, mitigation costs, environmental and archaeological studies costs, and other significant cost items which may have changed since this project was last studied. It should be noted that the 1960 cost estimate and 1994 cost update for Dilworth Reservoir does not include the relocation of Interstate 10.

Table 3.25-1 Cost Estimate for Gonzales Dam and Reservoir (G-20) (Mid - 1994 Prices)	
Item	**Estimated Cost**
Capital Costs	
Embankment	$13,813,000
Diversion and Care of Water	332,000
Reservoir Clearing	10,803,000
Spillway	21,169,000
General Items	893,000
Relocations	17,846,000
Total Capital Cost	64,856,000
Engineering, Legal, and Contingencies	22,700,000
Environmental Studies and Mitigation	16,600,000
Land Acquisition	17,500,000
Interest During Construction	9,732,000
Total Project Cost	**$131,388,000**
Annual Costs	
Annual Debt Service	12,311,000
Annual Operation and Maintenance	1,119,000
Total Annual Cost	**$13,430,000**
Annual Project Yield	**52,740 acft/yr**
Note: Annual cost of raw water at the reservoir with no conveyance or treatment is $256/acft.	

3.26 Lockhart Reservoir (G-21)

3.26.1 Description of Alternative

The Lockhart dam and reservoir project was first proposed in 1959 by Forrest and Cotton, Inc. (FC) in their report "Report on Supplement to the Initial Plan of Development of the Guadalupe-Blanco River Authority". The City of Lockhart's primary source of municipal water supply is groundwater, and the Lockhart project was proposed to provide additional municipal and industrial water to the local area. The site is located at river mile 30.5 on Plum Creek (drainage area of 118 square miles), a tributary of the San Marcos River, just north of Lockhart (see Figure 3.24-1).

Forrest and Cotton developed a preliminary design for the Lockhart project based on a field inspection, as adequate topographic information was not available. The embankment, as proposed, would be approximately 5,900 feet long with a maximum crest height of 73 feet above the streambed (elevation 508 ft-MSL). The spillway system would consist of a 250-foot uncontrolled broad-crested weir with a crest at elevation 482 ft-MSL. The conservation pool capacity, as proposed, would be at elevation 482 ft-MSL and would contain 50,000 acft. At this elevation, the reservoir's surface area would be 2,910 acres.

3.26.2 Available Yield

Yield estimates for Lockhart Reservoir were determined in the 1959 FC report. The critical period for the site is the 1947-1957 drought, and the firm yield of the Lockhart project is estimated at 7,960 acft/yr. The yield presented here has not been adjusted to reflect Trans-Texas criteria for pass-through, instream needs and bay and estuary needs. It is very likely that the yields from previous studies will be significantly reduced when the Trans-Texas environmental criteria for reservoirs are applied.

3.26.3 Environmental Issues

Alternative G-21 encompasses dam construction and inundation of approximately 2,910 acres along a 5-mile reach of Plum Creek, a tributary of the San Marcos River (see Figure 3.24-1). Associated pipelines for transporting the surface water to a water treatment plant may be addressed in a future phase of this project if Alternative G-21 is considered.

The proposed Lockhart Reservoir site is located in north Caldwell County within the Texas Blackland Prairies ecoregion[1] (see Figure 3.0-1), in the Blackland Prairie vegetational area of Texas[2] (see Figure 3.0-2), and in the Texan biotic province[3] (see Figure 3.0-3). Vegetation types within the Lockhart Reservoir project area include crops (30 percent), native and introduced grasses (25 percent), brushland and shrubland (38 percent), small quantities of woodlands (4 percent), and intermittent river and palustrine scrub/shrub and forested wetlands (3 percent) (see Table 3.0-1).

Within the proposed Lockhart Reservoir site, Heiden clays, which are frequently eroded, are found on uplands with slopes ranging from 3 to 8 percent. They are well-drained and frequently used for crops or pasture. Houston black clays are found on smooth uplands. They are moderately well-drained and are used for crops. Trinity clays have formed in calcareous, clayey, alluvial sediments on floodplains along streams where slopes are less than 1 percent. These areas are used predominantly for crops and improved pasture. Frequently flooded Trinity soils are on nearly level floodplains. These soils are flooded several times a year and are used mostly for pasture[4].

The primary impacts that would result from construction and operation of the Lockhart Reservoir include conversion of existing habitats and land uses within the conservation pool to open water, and potential downstream effects due to modification of the existing flow regime. The Lockhart Reservoir would be permanently inundated to 482 feet MSL with a surface area of 2,910 acres. The 100-year flood dam elevation would be 508 feet MSL with a surface area of 5,700 acres. Approximately 1,600 acres of grassland and cropland, 1,106 acres of brushland and shrubland, 116 acres of woodland, and 88 acres of wetlands (including 37 acres of riverine habitat) would be converted to open water upon

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[1]Omernik, James M., 1986, "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1). pp. 118-125.

[2]Gould, F.W., 1975, The Grasses of Texas, Texas A&M University Press, Texas Agricultural Experiment Station, College Station, Texas.

[3]Blair, W.F., 1950, "The Biotic Provinces of Texas," Tex. J. Sci. 2:93-117.

[4]U.S. Department of Agriculture, Soil Conservation Service (SCS). 1978b. Soil Survey of Caldwell County, Texas. In cooperation with Texas Agricultural Experiment Station, Texas A&M University, College Station. July.

dam construction (see Table 3.0-1). Based on available information, no communities or other special resources are located within the reservoir area. Indirect effects of reservoir construction may include land use changes in the area surrounding the reservoir and in mitigation areas that may be converted to alternate uses to compensate for losses of terrestrial habitat.

Potential downstream impacts would include modification of the streamflow regime below the dam, and reduced inflows to San Antonio Bay. Reduced inflows would equate to the quantity of water diverted from the reservoir for use as water supply and not returned to San Antonio Bay, plus the amount of water lost to evaporation from the reservoir. Detailed hydrologic information regarding these system modifications is not available for this reservoir alternative. However, it is assumed that as a new reservoir without a current permit, the Lockhart Reservoir would be required to meet the Trans-Texas Water Program "New Reservoir" criteria for instream flows and freshwater inflows to bays and estuaries. Operation of the reservoir to meet these criteria would likely have a significant effect on (i.e., reduction of) the firm yield of the reservoir.

In addition to long-term impacts within the conservation pool, minor changes to existing resources situated between the conservation pool elevation and flood pool elevation could be anticipated due to occasional temporary inundation during flood events.

No protected species have been recorded in the study area, although the area may provide potential habitat to the nine endangered, threatened or candidate species found in Caldwell County (Appendix B, Table 10). Other protected species may use habitats in the area during migration.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). Implementation of this reservoir alternative is expected to require field surveys by qualified professionals to document vegetation/habitat types and cultural resources that may be impacted by the proposed reservoir. Where impacts to potential protected species habitat or significant cultural resources could not be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National

Register of Historic Places, respectively. Compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

3.26.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.26.5 Engineering and Costing

The preliminary cost estimate for Lockhart Reservoir is an update of a previous cost estimate performed by the United States Study Commission in 1960. The Study Commission estimated the total project costs for Lockhart Reservoir to be \$4,535,000 in 1960 dollars. The 1960 cost estimate was updated by multiplying estimated construction quantities by current 1994 unit prices. Where construction quantities were not available, costs were calculated by multiplying the individual cost components of the previous estimate by a CCI or BUREC index ratio.

The mid-1994 estimated total project cost estimate for Lockhart Reservoir is \$33,303,000 as summarized in Table 3.26-1. The annualized project cost, including operation and maintenance, is \$3,391,000. The costs of pumping, delivery, and treatment system were not estimated for this alternative. If this alternative is pursued, significant additional work would be required to update relocation costs, mineral rights costs, mitigation costs, and other significant cost items which may have changed since this project was last studied.

Table 3.26-1 Cost Estimate for Lockhart Dam and Reservoir (G-21) (Mid - 1994 Prices)	
Item	**Estimated Cost**
Capital Costs	
Embankment	$8,082,000
Diversion	166,000
Reservoir Clearing	443,000
Spillway	3,812,000
Relocations and Alterations	332,000
Outlet Works	2,870,000
Total Capital Costs	15,705,000
Engineering, Legal, and Contingencies	5,497,000
Environmental Studies and Mitigation	4,504,000
Land Acquisition	5,130,000
Interest During Construction	2,467,000
Total Project Cost	**$33,303,000**
Annual Cost	
Annual Debt Service	$3,120,000
Annual Operation and Maintenance	271,000
Total Annual Cost	**$3,391,000**
Annual Project Yield	7,960 acft/yr
Note: Annual cost of raw water at the reservoir with no conveyance or treatment is $426/acft.	

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The updated construction cost estimate for Dilworth Reservoir is $76,538,000, as summarized in Table 3.27-1, resulting in an annualized project cost, including operation and maintenance of $7,724,000. The costs for pumping, delivery, and treatment system have not been included in this alternative. If this alternative is pursued, significant additional work will be required to update relocation costs, mineral rights costs, mitigation costs, environmental and archaeological studies costs, and other significant cost items which may have substantially changed since this alternative was last studied.

Table 3.27-1
Cost Estimate for Dilworth Dam and Reservoir (G-22)
(Mid - 1994 Prices)

Item	Estimated Cost
Capital Costs	
Relocations	$186,000
Diversion	166,000
Reservoir Clearing	3,823,000
Embankment	11,665,000
Spillway	14,684,000
Outlet Works	1,466,000
Total Capital Cost	$31,990,000
Engineering, Legal, and Contingencies	11,197,000
Environmental Studies and Mitigation	13,192,000
Land Acquisition	14,490,000
Interest During Construction	5,669,000
Total Project Cost	**$76,538,000**
Annual Cost	
Annual Debt Service	7,172,000
Annual Operation and Maintenance	552,000
Total Annual Cost	**$7,724,000**
Annual Project Yield (Estimated)	27,000 acft/yr
Note: Annual cost of raw water at the reservoir with no conveyance or treatment is $286/acft.	

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3.28 Colorado River at Lake Austin (C-10, -11, -12, -13)

3.28.1 Description of Alternative

This alternative evaluates potential diversion of water from the Colorado River at Lake Austin and pumping the water to the West-Central study area for use. This diversion location is shown on Figure 3.28-1. Water could potentially be obtained by either purchase of stored water from LCRA, or by purchase of existing run-of-river water rights, or both. Purchase of stored water has been studied before by the TWDB[12] and the GSAMA Advisory Technical Water Committee[13]; however, no prior investigation of purchasing existing water rights could be found.

Four significant water rights in the Lower Colorado River Basin are held by downstream irrigators: Lakeside Irrigation Division of LCRA, Garwood Irrigation Company, Pierce Ranch, and Gulf Coast Irrigation Division of LCRA. Additionally, there are two significant upstream diverters: the City of Austin and the LCRA. Other major water diversions from the Colorado include the South Texas Nuclear Project and two power plants (Sim Gideon and Fayette) which are owned and operated by LCRA and supplied from stored water. The location of all major diverters is shown on Figure 3.28-1.

Upstream rights held by the LCRA to impound river water in the Highland Lakes are junior to several major downstream rights as shown in Table 3.28-1. Inflows to the Highland Lakes must, therefore, be passed through the lakes when necessary to satisfy senior downstream water rights. In a recent settlement between the City of Austin and LCRA, rights owned by LCRA have been subordinated to the City of Austin, but some portions of these rights have retained seniority relative to other rights.

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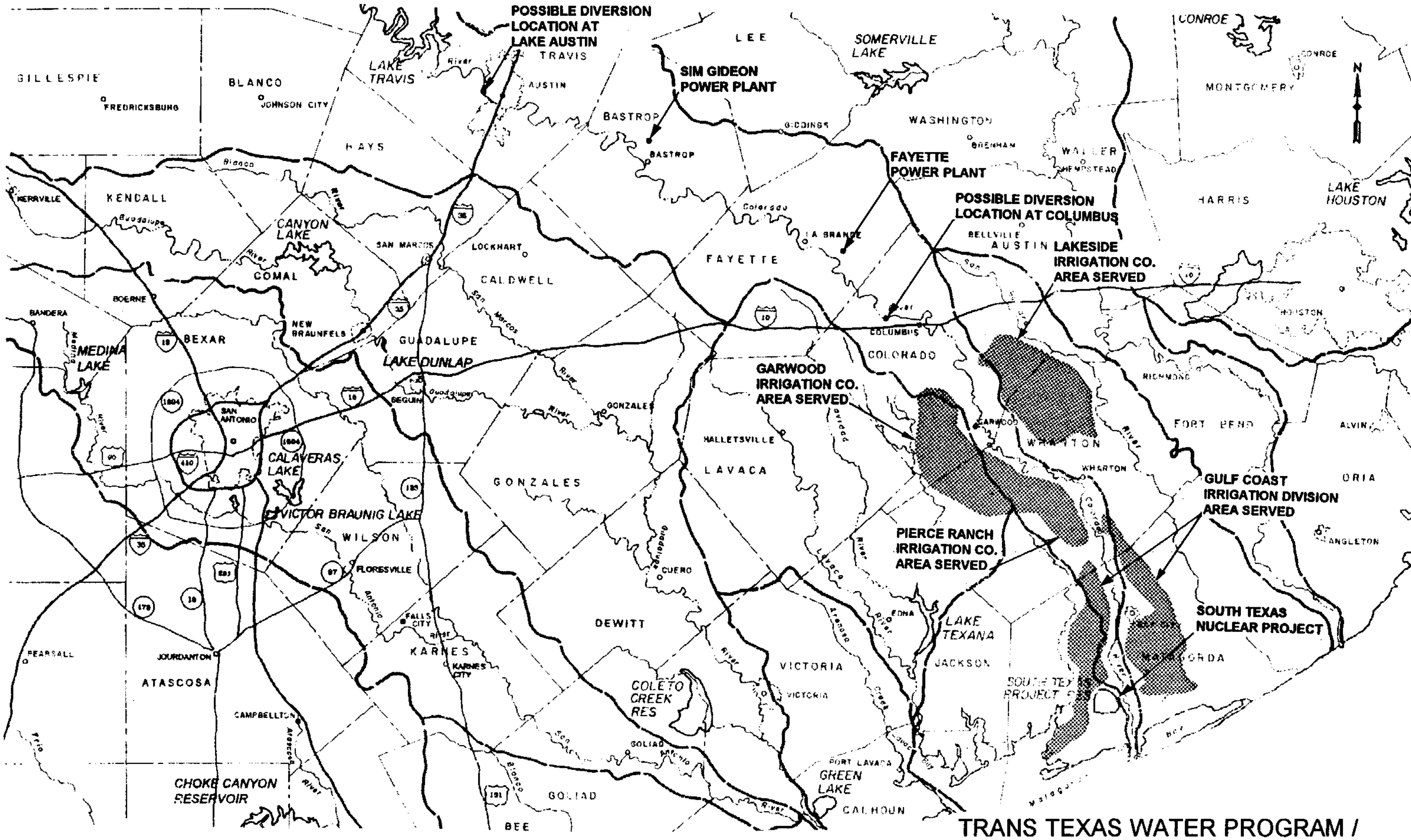
[12]Texas Water Development Board, "Unit Cost Comparisons for Alternative Water Supplies for Bexar County," May 1990.

[13]Project Control, Consultants to Greater San Antonio Metropolitan Area Advisory Technical Water Committee, "Bexar County Water Supply Projects," August 1990.



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

Legend

Basin Divide

0 10 20 Miles
Scale

HDR

HDR Engineering, Inc.

COLORADO RIVER HYDROLOGY ANALYSIS POINTS, ALTERNATIVES C-10, C-11, C-12, C-14, C-15, C-16

FIGURE 3.28-1

Table 3.28-1 Major Water Rights in the Lower Colorado Basin	
Water Right Holder	**Seniority of Right**
Garwood Irrigation Co.	November 1900
Gulf Coast Irr. Div. - LCRA	December 1900 & November 1987
Lakeside Irr. Div. - LCRA	January 1901 & November 1987
Pierce Ranch	September 1907
City of Austin	June 1913
Highland Lakes - LCRA	March 1938

3.28.2 Colorado River Water Potentially Available at Lake Austin (C-10, C-11, C-12)

A. LCRA Stored Water Purchase

Based on findings presented to the Texas Water Commission, it appears that approximately 50,000 acft/yr of uncommitted firm water is potentially available at Lake Travis[14]. For purposes of this study, it was assumed that this uncommitted water could be made available for purchase. If not used in conjunction with a purchase of existing water rights, the full 50,000 acft/yr could be obtained at a uniform rate throughout each year, since uniform operation results in the most cost effective transmission facilities. This is a similar scenario to previous investigations of transporting water from the Colorado River Basin to the Bexar County area. On the other hand, if purchased in conjunction with existing run-of-river water rights, the contract water could be obtained in a non-uniform manner in order to balance seasonal run-of-river water availability so that the two combined produce a relatively uniform diversion.

B. Run-of-River Water Right Purchase(s)

If a new water right were obtained on the Colorado River today, it would only have access to flows originating downstream of or spilling from the Highland Lakes that were in

[14] Texas Water Commission, "Order Approving LCRA's Water Management Plan and Amending Certificates of Adjudication Nos. 14-5478 and 14-5482," September 7, 1989.

excess of downstream water rights and in excess of instream and estuarine inflow requirements. Water availability under these conditions in the vicinity of Austin is not a frequent occurrence and would not provide a reliable supply. Therefore, opportunities to buy portions of senior downstream run-of-river rights were investigated under two purchase scenarios. The first scenario includes the purchase of portions of the four major downstream irrigation rights that have historically (i.e., within the past 10 years) remained unutilized and have not been committed to other users. The second scenario involved the acquisition of both the unutilized water rights as well as the purchase of water historically used to grow a second rice crop, within the year. This purchase could necessitate payment for the lost opportunity to grow and sell a second crop.

The first purchase scenario investigated involved the acquisition of unutilized and otherwise uncommitted water rights from the four major downstream diverters. Water use over the past ten years by each of diverters was reviewed and compared to their diversion rights. It was found that Lakeside utilized all of its right, Garwood used all but about 35,000 acft/yr of its right, Pierce Ranch used half of its right, or 55,000 acft/yr, and Gulf Coast utilized all but about 20,000 acft/yr of its right. The unutilized water at Garwood, however, is presently reserved by Corpus Christi and was not considered available in this analysis. The aggregate unutilized rights, therefore, represent potential water availability of about 75,000 acft/yr as indicated in Table 3.28-2. Unutilized rights at Pierce Ranch have recently been purchased by the LCRA and converted to municipal use, but have not yet been committed. For purposes of this study it has been assumed that this right would retain its original seniority date if purchased.

The second purchase scenario investigated included the acquisition of both unutilized water rights and water historically used for growing a second rice crop. Water use over the past ten years by each of the diverters was analyzed and showed that the second crop requirement averaged about 38 percent of historical use. As shown in Table 3.28-3, 213,550 acft of water per year was used for second crop production. Combined unutilized rights and second crop rights account for a total potential water supply of 288,550 acft/yr.

Table 3.28-2 Unutilized Water Purchase					
Diverter	**Priority Date**	**Use**	**Utilized Water Right (acft)**	**Unutilized Water Right (acft)**	**Total Water Right (acft)**
Lakeside - LCRA					
subordinated	11/1987	irrigation	78,750	0	78,750
unsubordinated	1/1901*	irrigation	52,500	0	52,500
Total			131,250	0	131,250
Garwood					
A - Garwood	11/1900	irrigation	133,000	0	133,000
B - Corpus Christi	11/1900	municipal	35,000	0	35,000
Total			168,000	0	168,000
Pierce Ranch					
A - Pierce Estate	9/1907	irrigation	55,000	0	55,000
B - LCRA	9/1907	municipal	0	55,000	55,000
Total			55,000	55,000	110,000
Gulf Coast -LCRA					
subordinated	11/1987	irrigation	13,930	20,000	33,930
unsubordinated	12/1900*	irrigation	228,570	0	228,570
Total			242,500	20,000	262,500
Totals			596,750	75,000	671,750

*This portion of the water right has been subordinated to the City of Austin, but not to other more junior rights.

Table 3.28-3 Unutilized & Second Crop Water Purchase						
Diversion	**Priority Date**	**Use**	**Utilized Water Right (acft)**	**Unutilized Water Right (acft)**	**Second Crop Water Use (acft)**	**Total Water Right (acft)**
Lakeside - LCRA						
subordinated	11/1987	irrigation	28,750	0	50,000	78,750
unsubordinated	1/1901*	irrigation	52,500	0	0	52,500
Total			81,250	0	50,000	131,250
Garwood						
A - Garwood	11/1900	irrigation	82,500	0	50,500	133,000
B - Corpus Christi	11/1900	municipal	35,000	0	0	35,000
Total			117,500	0	50,500	168,000
Pierce Ranch						
A - Pierce Estate	9/1907	irrigation	34,100	0	20,900	55,000
B - LCRA	9/1907	municipal	0	55,000	0	55,000
Total			34,100	55,000	20,900	110,000
Gulf Coast - LCRA						
subordinated	11/1987	irrigation	0	20,000	13,930	33,930
unsubordinated	12/1900*	irrigation	150,350	0	78,220	228,570
Total			150,350	20,000	92,150	262,500
Totals			383,200	75,000	213,550	671,750

*This portion of water right has been subordinated to the City of Austin but not to other more junior rights.

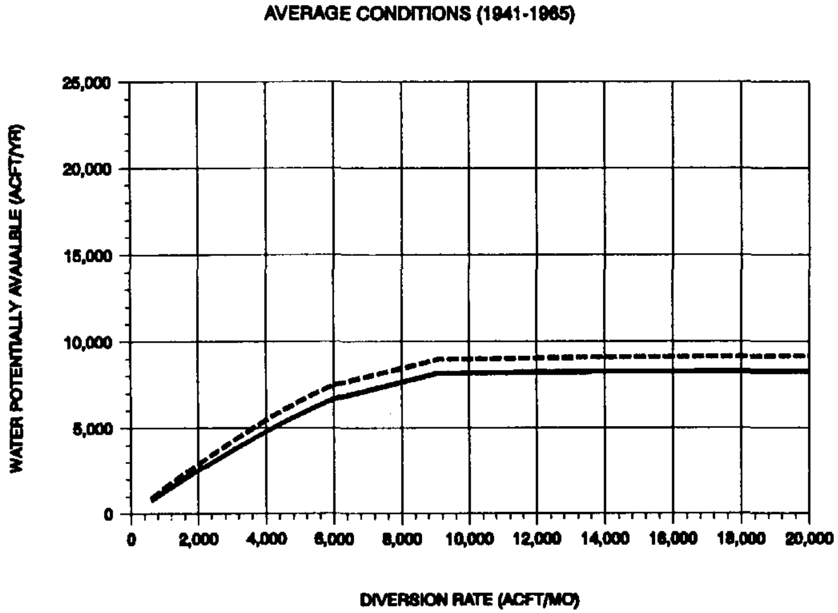
Because these water right purchases would be for of run-of-river rights and not stored water, they are not necessarily available in each and every year. Furthermore, run-of-river rights which are purchased from downstream diverters are not completely transferable to diversion locations upstream since the opportunity to capture a portion of the intervening run-of-river flows is lost, hence, availability decreases as rights are transferred further upstream. Water availability under these rights at specific diversion locations was determined using the Colorado River Daily Allocation Program (DAP). This computer model was developed by LCRA and used in this study by the LCRA staff to determine water availability. The model simulates the flows in the Colorado River and allocates these flows to diverters, based on seniority of water rights. The model is currently the best available tool for evaluating run-of-river availability in the Lower Colorado River; however, as with all models, it has some limitations. Run-of-river water rights are issued for specified maximum annual and instantaneous diversion rates. In the senior water rights on the Lower Colorado River, there are no restrictions as to when water may be diverted or how much of it may be used consumptively. This situation is very flexible which makes it difficult to model. In the LCRA model this situation is simplified by assigning each right a fixed diversion amount for each day of the year. The total of the daily diversion amounts exactly equals the total annual right. If any portion of a daily diversion amount cannot be met from run-of-river flows, the model does not allow for that deficit to be recovered on a later date. In actual practice, however, a diverter could make up for the lack of availability at some later time if water became available. Therefore, the assumptions inherent in the modeling procedure may result in a conservative estimate of water availability (i.e., underestimation of water potentially available) from purchase of water rights.

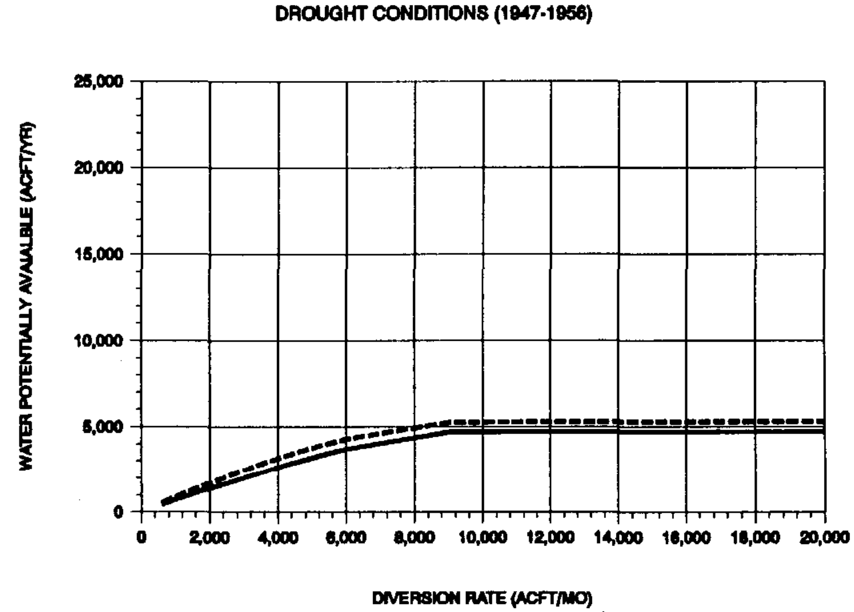
In order to obtain estimates of water availability, the daily allocation program was used to determine water availability in the Colorado River. In this Phase I analysis, water rights being considered for purchase were subordinated to the City of Austin, while all other water rights were fully honored. The model was used to determine water availability at a new diversion location with existing rights reduced by the amount to be purchased. An estimate of water made available at Lake Austin by the purchase could then be determined by examining the increase in availability on a daily basis. Additional analyses of results obtained from the LCRA model were performed to obtain estimates of water availability for a range of maximum monthly diversion rates. This procedure was repeated for simulations with and without return flows from the City of Austin.

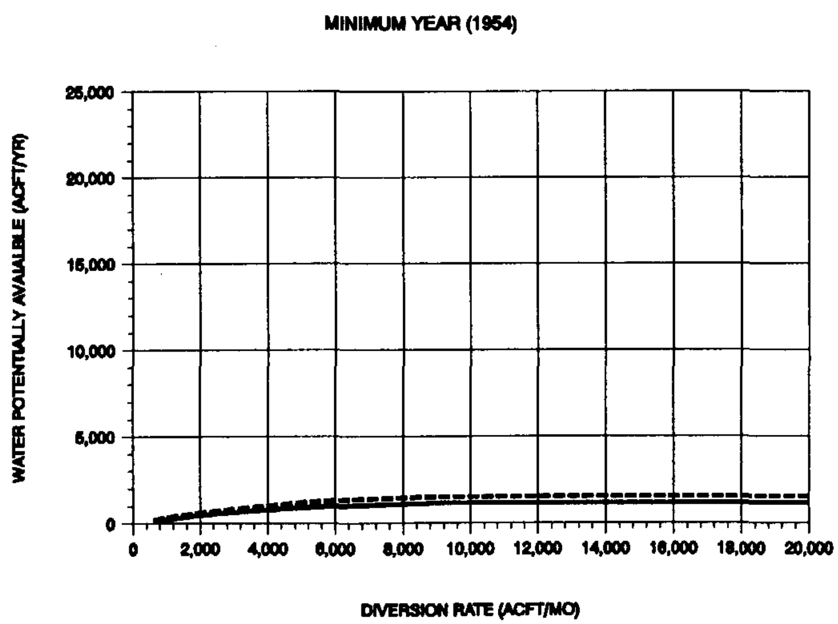
Daily diversions were simulated and summarized for average conditions (1940-65 period) and drought conditions (1947-56 period) as well as the minimum year diversion. Figure 3.28-2 shows that water available from a purchase of 75,000 acft of unutilized rights yields only 9,000 acft/yr during average conditions and 5,000 acft/yr during the 10-year drought period. Similarly, Figure 3.28-3 shows that water available from the combined purchase of 288,550 acft of unutilized rights and second crop use is less than 20,000 acft/yr under average conditions even at large diversion rates, and less than 12,000 acft/yr under drought conditions. In either case, the effect of City of Austin return flow on water availability is small at this diversion point, since it is upstream of the effluent discharge locations. It is apparent that the loss of intervening run-of-river flows due to locating the diversion point at Lake Austin would greatly reduce the availability of water purchased from water rights owners located some 230 river miles downstream. Therefore, water availability at Lake Austin is dramatically less than the quantity being considered for purchase.

C. Colorado River Water Alternatives from Lake Austin

In order to bracket the many water supply alternatives possible from Lake Austin, two water purchase arrangements, delivering to three alternative delivery points in the West-Central study area, were studied. First, the purchase of 50,000 acft/yr of stored water from LCRA was investigated. Secondly, the purchase of 50,000 acft/yr of stored water from LCRA combined with the purchase of both the 75,000 acft/yr of unutilized water rights and 213,500 acft/yr of second crop water rights was studied. (Refer to Table 3.28-3 for proposed source of purchased water rights.) For each of the two purchase options, three delivery alternatives were investigated. They included delivery to injection wells in the Edwards Aquifer, delivery to recharge structures, and delivery to a treatment and distribution system at San Antonio. The two purchase scenarios and three delivery options resulted in six alternatives being investigated as shown in Table 3.28-4 and Figure 3.28-4.







LEGEND

WITH AUSTIN RETURN FLOWS

WITHOUT AUSTIN RETURN FLOWS

ASSUMPTIONS:

1. PURCHASE OF 75,000 ACFT/YR OF RUN-OF-RIVER RIGHTS
2. DIVERSIONS SUBORDINATED TO THE CITY OF AUSTIN
3. AVAILABILITY REPRESENTS A CONSERVATIVE (I.E., LOW) ESTIMATE

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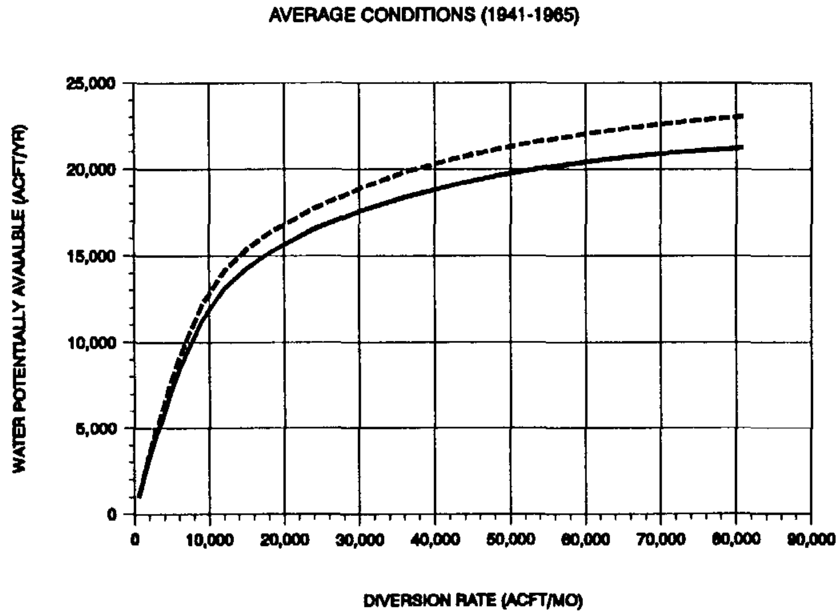
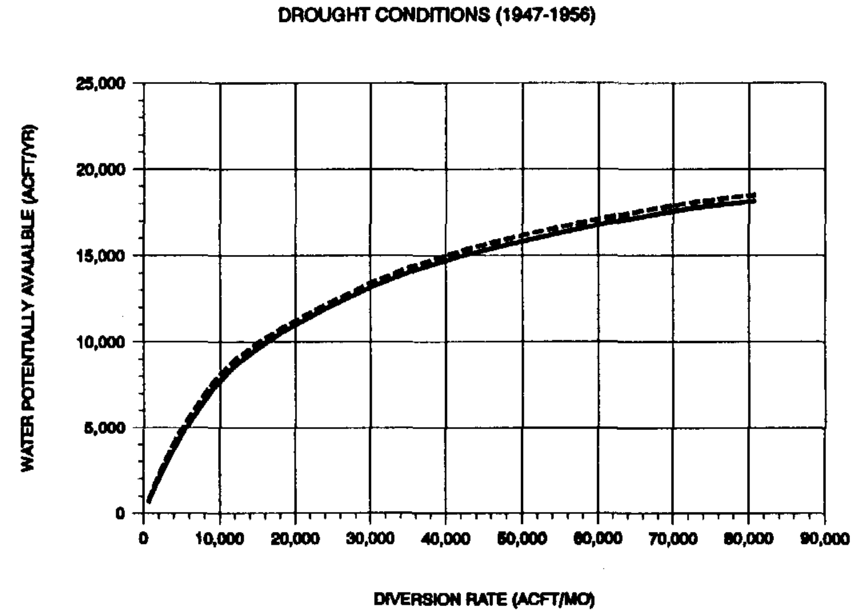
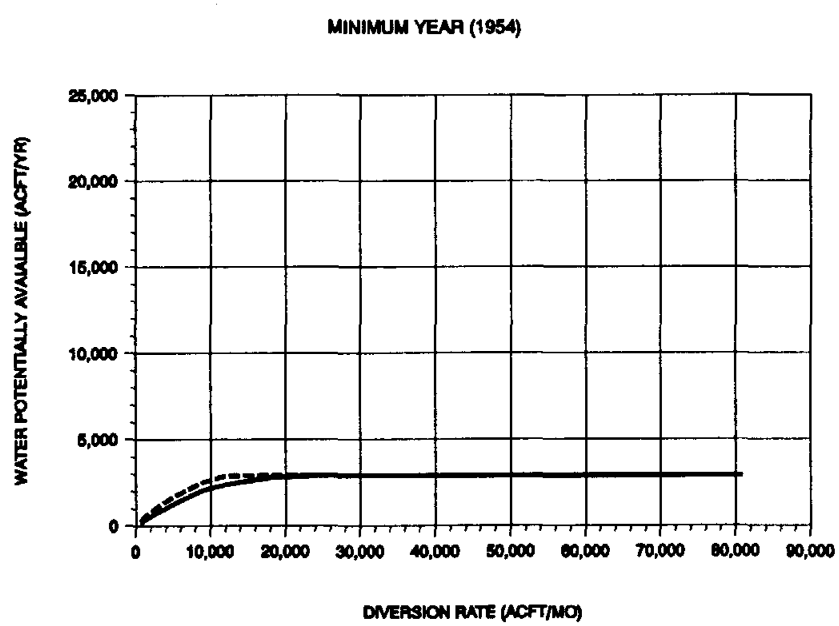
WEST CENTRAL STUDY AREA

DIVERSION OF UNUTILIZED MAJOR RIGHTS AT LAKE AUSTIN ALTERNATIVE C-11

FIGURE 3.28-2







LEGEND

WITH AUSTIN RETURN FLOWS

WITHOUT AUSTIN RETURN FLOWS

ASSUMPTIONS:

1. PURCHASE OF 288,550 ACFT/YR OF RUN-OF-RIVER RIGHTS
2. DIVERSIONS SUBORDINATED TO THE CITY OF AUSTIN
3. AVAILABILITY REPRESENTS A CONSERVATIVE (I.E., LOW) ESTIMATE

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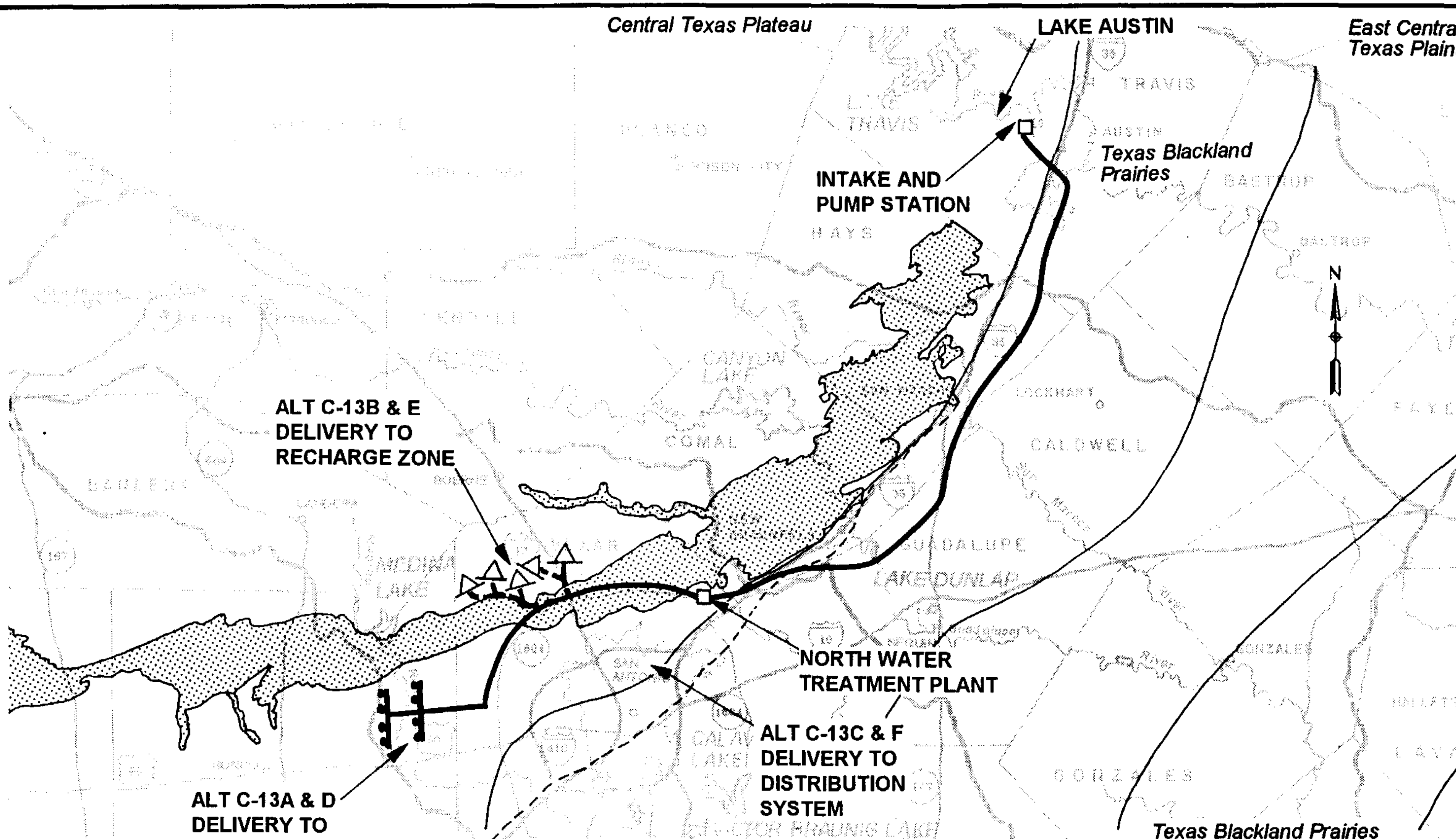
TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

DIVERSION OF UNUTILIZED MAJOR RIGHTS AND SECOND CROP IRRIGATION AT LAKE AUSTIN, ALTERNATIVE C-12

FIGURE 3.28-3



Legend

- Basin Divide
- Edwards Aquifer Recharge Zone
- "Bad Water" Line
- Ecoregion
- Pipeline Route

0 10 20 Miles
Scale

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

HDR

HDR Engineering, Inc.

COLORADO RIVER AT LAKE AUSTIN ALTERNATIVE C-13

FIGURE 3.28-4

Table 3.28-4 Definition of Alternatives for Colorado River at Lake Austin (Alternative C-13)		
Delivery Location	**Purchase of Stored Water (50,000 acft/yr)**	**Purchase of Stored Water and Run-of-River Rights (68,000 acft/yr)**
Injection Wells to Aquifer	C-13D	C-13A
Recharge Zone	C-13E	C-13B
North Water Treatment Plant	C-13F	C-13C

For purposes of this Phase I analysis, it was assumed that the 50,000 acft/yr of stored water would be available at Lake Austin. The stored water was also assumed to be available on demand as needed so it could be diverted either uniformly or non-uniformly, depending on the availability of other purchased water rights.

For the second group of alternatives, the run-of-river water would be diverted at Lake Austin and pumped in combination with the stored water. The average 10-year drought yield of the run-of-river purchases, which totals approximately 18,000 acft/yr at the purchased diversion rate, could be made available at a uniform rate throughout the year by utilizing storage in Lake Travis. Preliminary inquires to the LCRA indicate that storage could potentially be made available in Lake Travis which would significantly minimize the size of pumping and transmission facilities required.

3.28.3 Environmental Issues

Diversion of water from the Colorado River at Lake Austin (Alternatives C-10, -11, -12, -13) includes two water purchase arrangements, a diversion from Lake Austin, and three alternative delivery points: a water treatment facility for direct use or injection of the water, and the two Edwards Aquifer recharge facilities in northern Bexar County and eastern Medina County (Figure 3.28-1 and Table 3.28-4). Included in this alternative is an 83- to 123-mile transmission pipeline (depending upon delivery point). This transmission pipeline begins on the eastern margin of the Central Texas Plateau ecoregion, and traverses the Texas Blackland Prairies and Southern Texas Plains ecoregions to the south (see Figure 3.0-

1)[15]. This area runs along the confluence of Blair's Balconian, Texan, and Tamaulipan biotic provinces (see Figure 3.0-3)[16].

The corridor in which the proposed pipeline ROW would be placed traverses a wide variety of different soil types. In the northern portion of the corridor the soils are shallow, gravelly, calcareous, loamy soils overlying interbedded limestone and marl[17]. The typical vegetation of this type of soil consists of mid and tall grasses, an overstory of brush and a few trees, the majority of which has been brought under cultivation. Significant grasses on this soil type include little and big bluestem, indiangrass, switchgrass, sideoats grama, hairy grama, dropseed, longspike silver bluestem, and wintergrass[18]. As the corridor travels through Hays and Guadalupe counties, the soils are clay type soils over shale or stream terraces[19,20]. Towards the end of the transmission line in Bexar County the soils change from shallow to moderately deep stony soils over limestone[21]. Dominant grasses of the Southern Texas Plains region include longspike silver bluestem, California cottontop, buffalograss, curlymesquite, and a variety of species of bristlegrass, pappusgrass, and grama[22]. Agriculture is the predominant land use in this portion of the project area.

Water quality and water treatability will be specifically addressed in a later phase of this study. The effects of pumping the additional water into the recharge zone and injection wells is discussed in detail in Sections 3.0.1, 3.8, 3.9, 3.10, and 3.32.

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[15]Omernik, James M., 1987, "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1) pp. 118-125.

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

[17]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1974. Soil Survey of Travis County, Texas, USDA.

[18]Gould, F. W., 1975, The Grasses of Texas, Texas A & M University Press, College Station, Texas.

[19]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1984. Soil Survey of Hays and Comal Counties, Texas. USDA.

[20]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1977. Soil Survey of Guadalupe County, Texas. USDA.

[21]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1991. Soil Survey of Bexar County, Texas USDA.

[22]Gould, F. W., 1975, The Grasses of Texas, Texas A & M University Press, College Station, Texas.

The fauna present in areas where suitable habitat remains will be typically neotropical and grassland species[23]. In most of the Blackland Prairie, historic overgrazing and intensive agricultural land use has left little habitat for species other than those tolerant of development. Suburban, rural-residential, and urban land uses have affected wildlife habitats and populations in the vicinity of San Antonio and Austin.

The 83-mile transmission pipeline would affect a total area of 826 acres from Lake Austin to the Edward's aquifer recharge zone in northern Bexar County. The 123-mile pipeline ROW would expose a total of 936 acres from Lake Austin to the injection wells in Medina County to construction disturbance. Within the City of Austin, the line from the Lake Austin intake to Montopolis Drive would be laid in a deep tunnel through the Austin chalk, minimizing surface impact to a largely urban recreational and riparian environment. The remainder of the ROW construction would be similar to that assessed elsewhere in this report. Of the remaining portion of the corridor, approximately 60 percent has been converted to cropland, with only a little over 10 percent remaining as uncultivated shrubland (see Table 3.0-1). An approximately 30-foot wide corridor free of woody vegetation would be maintained for the life of the project. Impacts on wildlife habitats can generally be avoided by locating the pipeline ROW in previously disturbed areas, such as crop and pasture lands. A cleared pipeline ROW through a woodland or brushy habitat could be beneficial to some wildlife by providing edge habitat, except that the majority of these areas are small, fragmented remnants, and do not suffer a shortage of edges.

Although the Texas Natural Heritage Program does not report any observation of endangered or threatened species within the proposed pipeline corridor, some have been reported in the vicinity (see Table 3.28-5). Many of these appear to be dependent on shrubland or riparian habitat, such as the Texas tortoise, the reticulate collared lizard, the Texas horned lizard, and the Indigo snake. The Texas garter snake may be present in wetland habitats. Implementation of this alternative is expected to require field surveys for protected species, vegetation, habitats, and cultural resources during ROW selection to avoid or minimize impacts.

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

Table 3.28-5 Important Species With Habitats in the Project Vicinity (C-13)				
Common Name	**Scientific Name**	**Habitat Preference**	**Listing Agency**	
			USFWS	**TPWD**
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies depressions under objects	NL	T
Reticulate Collared Lizard	*Crotaphytus reticulatus*	South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Texas Horned Lizard	Phrynosoma cornutum	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks	C2	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures[1]	C2	NL
Hill Country Wild-Mercury	*Argythamnia aphoroides*	Shallow to moderately deep clays and clay loams over limestone in grasslands associated with plateau live oak, on rolling uplands	C2	NL
Blue Sucker	*Cycleptus elongatus*	Rivers crossing eastern Edwards Plateau to coast	C2	T
Guadalupe Bass	*Micropterus terculi*	Streams of eastern Edwards Plateau	C2	NL

Source: TPWD. Unpublished Texas National Heritage Program. Texas Parks and Wildlife , Austin, Texas.
[1]Dixon, J. R. 1987. Amphibians and Reptiles of Texas. Texas A & M Press, College Station, Texas.

When potential protected species habitat, or other significant resources cannot be avoided, additional studies would have to be conducted to evaluate habitat use, or eligibility for inclusion in the National Register for Historic Places, respectively. Wetland impacts, primarily pipeline stream crossings, can be minimized by ROW selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

All areas to be disturbed during construction first will be surveyed by qualified professionals for the presence of significant cultural resources. Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL 96-515), and the Archaeological and Historical Preservation Act (PL 93-291).

3.28.4 Water Quality and Treatment

[To be provided in subsequent phases of this study.]

3.28.5 Engineering and Costing

Pump station and transmission pipelines have been sized and costed for two annual delivery volumes. The first amount is for the purchase of 50,000 acft/yr stored water in Lake Travis. The second volume includes the purchase of 288,500 acft/yr run-of-river rights in addition to the purchase of the stored water. Six alternative project configurations for yield and delivery points have been studied as defined in Table 3.28-4. The location of the transmission pipeline, booster pump stations, and delivery points are shown on Figure 3.28-4.

Alternative C-13A: LCRA Stored Water and Purchase of Run-of-River Water Rights Delivered to Aquifer Injection Wells

For this alternative, 50,000 acft/yr of firm water would be purchased from LCRA from Lake Travis and 288,500 acft/yr of run-of-river rights would be purchased from senior right holders. The stored water and the run-of-river water available under drought conditions would be diverted from Lake Austin and pumped at a generally uniform rate to the injection well field as shown in Figure 3.28-4 The benefit from this alternative would include the enhanced recharge of the aquifer and the increased availability of water to supply wells and possibly springs. Prior to injection to the aquifer the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, three required
Water Treatment Plant (Level 2, Table 3.0-4)
Finished Water Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The intake and pump station would be sized to pump 5,670 acft/month (61 mgd) through a 60-inch diameter pipeline. The operating cost was determined for a raw water static lift of 570 feet and an average annual water delivery under drought conditions of 68,000 acft/year. The current cost of purchasing firm water from LCRA is $105 per acft/yr. The cost of the run-of-river water rights were estimated to cost $64 per acft under a one time payment agreement based on Garwood run-of-river right (marketed at $400/acft) and pro-rated for the estimated firm yield delivery at the point of transfer. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $26,940,000 (Table 3.28-5a). Operation and maintenance costs total $15,510,000. The annual costs, including debt repayment, interest, and operation and maintenance, and raw water purchases total $47,700,000. For an annual firm yield of 68,000 acft/yr, the resulting annual cost of water is $701 per acft (Table 3.82-5a).

Alternative C-13B: LCRA Stored Water and Purchase of Run-of-River Water Rights Delivered to Recharge Structures

For this alternative, stored water and purchased run-of-river water would be diverted at an intake on Lake Austin and pumped in a transmission line to small recharge structures in northwestern Bexar County, located over the recharge zone, as shown in Figure 3.28-4. The diversion rate from Lake Austin, as well as the delivery to the recharge structures, would be generally uniform throughout the year at the same rates as Alternative C-13A above. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and possibly springs. Concerns that the imported water is of different quality than the existing recharge water and the need for treatment of the Colorado water will require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of the imported water. To determine the cost to treat the imported water, a typical direct filtration process (Treatment Level 2, see Table 3.0-4) was assumed. The major facilities required to implement this alternative include:

Intake and Pump Station
Raw Water Pipeline to Recharge Zone or Treatment Plant
Raw Waterline Booster Pump Stations, three required

Recharge Structures, four required
Treatment Plant Items (if needed):
  Water Treatment Plant (Level 2)
  Finished Water Pump Station
  Transmission Line to Recharge Zone

The intake and pump station would be sized to deliver 5,670 acft/month (61 mgd) through a 60-inch diameter pipeline. The operating cost was determined for the total raw water static lift to the treatment plant of 570 feet and an annual water delivery of 68,000 acft. The cost of purchasing raw water from LCRA and the irrigation companies is the same as Alternative C-13A above. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $24,630,000 with a treatment plant and $22,150,000 with no treatment plant (Table 3.28-5a). Operation and maintenance costs total $16,410,000, including the treatment plant and are $12,540,000 without a treatment plant. The annual costs, including debt repayment, interest, operation and maintenance, and raw water purchases total $46,280,000 including the treatment plant and total $39,930,000 without a treatment plant. For an annual firm yield of 68,000 acft/yr, the resulting annual cost of water, with a treatment plant, is $681 per acft, and is $587 per acft without a treatment plant (Table 3.28-5a).

Alternative C-13C: LCRA Stored Water and Purchase of Run-of-River Water Rights Delivered to Municipal Distribution System

For this alternative, the stored and purchased run-of-river water would be diverted through an intake and pumped in a transmission line to the North Water Treatment Plant as shown in Figure 3.28-4. The diversion rate would be generally uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio water distribution system and possibly other municipal systems in the surrounding areas. The major facilities required to implement this alternative are:

Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, three required
Water Treatment Plant (Level 3, see Table 3.0-4)
Distribution System Improvements

Table 3.28-5a
Cost Estimate Summaries for Colorado River at Lake Austin (C-13A,B,C)
(Mid- 1994 Prices)

Item	Alt. C-13A Divert and Inject to Aquifer	Alt. C-13B Divert to Recharge Zone	Alt. C-13C Divert to WTP and Municipal Systems
Capital Costs			
Transmission and Pumping	$157,740,000	$141,620,000	$106,820,000
Treatment Plant	18,140,000	18,140,000	27,290,000
Delivery System	10,080,000	9,540,000	51,120,000
Total Capital Cost	$185,960,000	$169,300,000[1] $151,160,000[2]	$185,230,000
Engineering, Contingencies, and Legal Costs	57,820,000	52,770,000[1] 46,420,000[2]	55,050,000
Land Acquisition	1,420,000	1,500,000[1] 1,440,000[2]	700,000
Purchase of Water Rights	18,460,000	18,460,000	18,460,000
Environmental Studies and Mitigation	5,760,000	4,980,000	2,650,000
Interest During Construction	18,090,000	15,840,000[1] 13,880,000[2]	16,940,000
Total Project Cost	$287,510,000	$262,850,000[1] 236,340,000[2]	$279,030,000
Annual Costs			
Annual Debt Service	$26,940,000	$24,630,000[1] $22,150,000[2]	$26,150,000
Purchase of Stored Water	5,250,000	5,250,000	5,250,000
Annual Operation and Maintenance	6,180,000	6,080,000[1] 2,210,000[2]	5,910,000
Annual Power Cost	9,330,000	10,320,000	7,440,000
Total Annual Cost	$47,700,000	$46,280,000[1] 39,930,000[2]	$44,750,000
Available Project Yield (acft/yr)	68,000	68,000	68,000
Annual Cost of Water	$701/acft	$681/acft[1] $587/acft[2]	$658/acft

[1]Cost with treatment prior to surface recharge.
[2]Cost without treatment prior to surface recharge.

The reservoir intake and pump station would be sized to deliver 5,670 acft/month (61 mgd) through a 60-inch diameter pipeline. The operating costs were determined for a total raw water pumping head of 570 feet and an annual water delivery of 68,000 acft/year. The cost of purchasing raw water from LCRA and the irrigation companies is the same as Alternative C-13A above. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $26,150,000 (Table 3.28-5a). Operation and maintenance costs total $13,360,000. The annual costs, including debt repayment, interest, operation and maintenance, and raw water purchases total $44,750,000. For an annual firm yield of 68,000 acft/yr, the resulting annual cost of water is $658 per acft (Table 3.28-5a).

Alternative C-13D: LCRA Stored Water Delivered to Aquifer Injection Wells

For this alternative, 50,000 acft/yr of water would be purchased from LCRA from the firm yield of Lake Travis. The purchased water would be diverted from Lake Austin and pumped at a uniform rate to the injection well field as shown in Figure 3.28-4 The benefits from this alternative would include the enhanced recharge of the aquifer and the increased availability of water to municipal supply wells and possibly springs. Prior to injection to the aquifer the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, three required
Water Treatment Plant (Level 2)
Finished Water Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The reservoir intake and pump station would be sized to deliver 4,170 acft/month (45 mgd) through a 54-inch diameter pipeline. The operating cost was determined for the total raw water pumping head of 570 feet and an annual water delivery of 50,000 acft/year. The cost of purchasing raw water from LCRA is based on a cost of $105 per acft/yr. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $21,980,000 (Table 3.28-5b). Operation and maintenance costs total $11,550,000. Annual costs, including debt repayment, interest, raw water costs, and operation and

Table 3.28-5b
Cost Estimate Summaries for Colorado River at Lake Austin (C-13D,E,F)
(Mid- 1994 Prices)

Item	Alt. C-13D Divert and Inject to Aquifer	Alt. C-13E Divert to Recharge Zone	Alt. C-13F Divert to WTP and Municipal Systems
Capital Costs			
Transmission and Pumping	$139,830,000	$126,110,000	$95,820,000
Treatment Plant	14,600,000	14,600,000	20,830,000
Delivery System	7,440,000	6,040,000	39,130,000
Total Capital Cost	$161,870,000	$146,750,000[1] $132,150,000[2]	$155,780,000
Engineering, Contingencies, and Legal Costs	50,200,000	45,630,000[1] 40,530,000[2]	46,390,000
Land Acquisition	1,390,000	1,390,000[1] 1,340,000[2]	700,000
Environmental Studies and Mitigation	5,260,000	4,460,000	2,650,000
Interest During Construction	15,850,000	14,680,000[1] 13,890,000[2]	14,490,000
Total Project Cost	$234,570,000	$212,910,000[1] 192,370,000[2]	$220,010,000
Annual Costs			
Annual Debt Service	$21,980,000	$19,950,000[1] $18,020,000[2]	$20,620,000
Purchase of Stored Water	5,250,000	5,250,000	5,250,000
Annual Operation and Maintenance	4,870,000	4,770,000[1] 1,900,000[2]	4,520,000
Annual Power Cost	6,670,000	7,440,000	5,370,000
Total Annual Cost	$38,770,000	$37,410,000[1] $32,610,000[2]	$35,760,000
Available Project Yield (acft/yr)	50,000	50,000	50,000
Annual Cost of Water	$775/acft	$749/acft[1] $653/acft[2]	$715/acft

[1]Cost with treatment prior to surface recharge.
[2]Cost without treatment prior to surface recharge.

maintenance, total $38,770,000. For an annual firm yield of 50,000 acft/yr, the resulting annual cost of water is $775 per acft (Table 3.28-5b).

Alternative C-13E: LCRA Stored Water Delivered to Recharge Structures

For this alternative, the purchased water would be diverted at an intake at Lake Austin and pumped in a transmission line to small recharge structures in northwestern Bexar County, located over the recharge zone, as shown in Figure 3.28-4. The diversion rate from the reservoir, as well as the delivery to the recharge structures, would be uniform throughout the year at the same rate as alternative C-13 D above. The benefits from this project would include the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and possibly springs. Concerns that the imported water is of different quality than the existing recharge water and the need for treatment of the Colorado water will require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of the imported water. To determine the cost to treat the imported water, a typical direct filtration process (Treatment Level 2, see Table 3.0-4) was assumed. The major facilities required to implement this alternative are:

- Intake and Pump Station
- Raw Water Pipeline to Recharge Zone or Treatment Plant
- Raw Waterline Booster Pump Stations, three required
- Recharge Structures, three required
- Treatment Plant Items (if determined to be needed):
  - Water Treatment Plant (Level 2)
  - Finished Water Pump Station
  - Transmission Line to Recharge Zone

The reservoir intake and pump station would be sized to deliver 4,170 acft/month (45 mgd) through a 54-inch diameter pipeline. The operating cost was determined for the raw water static lift to the treatment plant of 572 feet and an annual water delivery of 50,000 acft/year. The cost of purchasing raw water from LCRA is based on a cost of $105 per acft/yr. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $19,950,000 with a treatment plant and $18,020,000 with no treatment plant (Table 3.28-5b). Operation and maintenance costs total $12,210,000, including the treatment plant and are $9,338,000 without a treatment plant. The annual costs, including debt repayment, interest, raw water purchases, and operation and maintenance, total $37,410,000 with the treatment plant and are $32,610,000 without a treatment plant. For an annual firm yield of 50,000 acft/yr, the resulting annual cost of water, with a treatment plant, is $749 per acft, and is $653 per acft without a treatment plant (Table 3.28-5b).

Alternative C-13F: LCRA Stored Water Delivered to Municipal Distribution System

For this alternative, the purchased water would be diverted and pumped in a transmission line to the North Water Treatment Plant as shown in Figure 3.28-4. The diversion rate from Lake Austin would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding areas. The major facilities required to implement this alternative include:

Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, three required
Water Treatment Plant (Level 3, see Table 3.0-4)
Distribution System Improvements

The intake and pump station is sized to deliver 4,170 acft/month (45 mgd) through a 54-inch diameter pipeline. The operating cost was determined for the total raw water static lift of 570 feet and an annual water delivery of 50,000 acft/year. Raw water cost from LCRA is based on a cost of $105 per acft/yr. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $20,620,000 (Table 3.28-5b). Operation and maintenance costs total $9,890,000. The annual costs, including debt repayment, interest, raw water costs, and operation and maintenance, total $35,760,000. For an annual firm yield of 50,000 acft/yr, the resulting annual cost of water is $715 per acft (Table 3.28-5b).

3.28.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Requirements Specific to Transfer of Existing Water Rights (C-13, All)

1. Obtain TNRCC approval for amendments to the existing water right to reflect
   a. The new water use,
   b. The new diversion point, and
   c. Interbasin transfer.

2. Water rights sales and contracts must be approved by the TNRCC.

Requirements Specific to Pipelines (C-13, All)

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (C-13A & D)

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests.
   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.
   d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
   e. Source water quality testing for Safe Drinking Water Act regulated constituents.

2. Necessary permits:
    a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (C-13B, E)

1. Detailed field investigation of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
    a. TNRCC Water Rights and Storage permit.
    b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
    c. GLO Sand and Gravel Removal permit.
    d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
    a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
    b. Study of impact on karst geology organisms from a sustained recharge program.
    c. Other environmental studies.
    d. Cultural resource studies.

Requirements Specific to Treatment and Distribution

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

3.29 Colorado River at Columbus (C-14, -15, -16, -17)

3.29.1 Description of Alternative

This alternative involves the potential diversion of water from the Colorado River near Columbus, Texas and pumping of this water to the West-Central study area for use. The diversion location is shown in Figure 3.29-1. As described in Section 3.28.1, water could potentially be obtained by the purchase of stored water from LCRA, or by purchase of existing run-of-river water rights, or both. The location of the diversion point relative to the existing water rights in the lower portion of the basin makes it a more beneficial location for purchase of water rights from downstream rights holders in terms of increased water availability than the Lake Austin location.

3.29.2 Water Potentially Available at Columbus

The methodologies and assumptions in determining water availability at the Columbus diversion location are substantially the same as those presented in Section 3.28.2 for the Lake Austin alternatives. Therefore, the following paragraphs regarding purchase of a water contract or run-of-river rights present only additional pertinent assumptions and results.

A. LCRA Stored Water Purchase

As described in Section 3.28.2, 50,000 acft/yr of firm water is potentially available for purchase from Lake Travis. If purchased, the water would be released from Lake Travis and allowed to flow down the Colorado River to the Columbus diversion location. For purposes of this analysis, it is assumed that the purchased water would be available in its entirety with the LCRA providing for any transmission losses which may occur between Lake Travis and the downstream diversion point. Stored water could be diverted independently or in conjunction with purchased run-of-river rights.

B. Run-of-River Water Right Purchase(s)

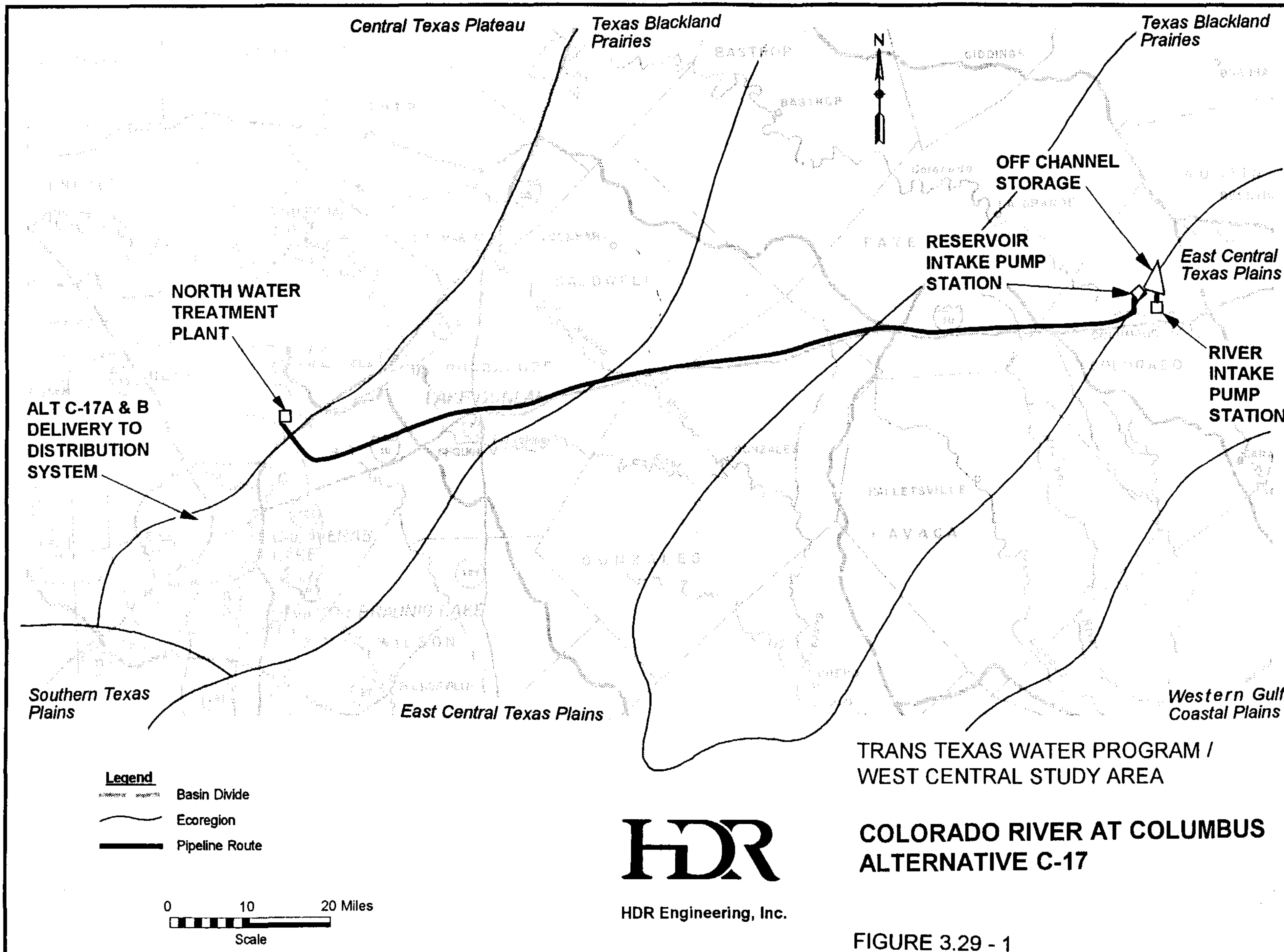
As described in Section 3.28.2, conservative (i.e., low) estimates of water availability were calculated and summarized for average and drought conditions as well as the minimum year diversion. Figure 3.29-2 shows that water available from a purchase of 75,000 acft of unutilized rights with City of Austin return flows will provide about 35,000 acft/yr under average conditions and 17,000 acft/yr during drought conditions at large diversion rates. These estimates decrease by about 6,000 acft/yr if City of Austin return flows are not included in the model. Similarly, Figure 3.29-3 shows that water available from the combined purchase of 288,550 acft of unutilized rights and second crop use is in excess of 80,000 acft/yr under average conditions and 48,000 acft/yr during drought conditions at large diversion rates. These estimates decrease by about 16,000 acft/yr under average conditions if City of Austin return flows are not included in the model. These estimates of water availability are substantially higher than the Lake Austin alternatives due both to the interception of more intervening run-of-river flows as well as better utilization of City of Austin return flows (when included).

C. Colorado River Water Alternatives from Columbus

Two water supply alternatives from Columbus have been studied. The first is simply a purchase of 50,000 acft/yr of stored water from LCRA. The second is to purchase 50,000 acft/yr of stored water combined with 75,000 acft/yr of unutilized run-of-river water rights and 213,500 acft/yr of second crop run-of-river water rights. (Refer to Table 3.28-3 for proposed source of purchased rights.) In each case the water is delivered to the West Central Study Area for treatment and distribution.

It is assumed for this Phase I Study that the 50,000 acft per year of stored water would be available in full at the point of diversion regardless of diversion location. The stored water is also available on demand so it could be diverted uniformly or non-uniformly depending on the need.

The run-of-river water would be diverted at Columbus at a 1,340 cfs capacity pump station. This diversion capacity is equal to the proportion of the permitted rate being



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

HDR

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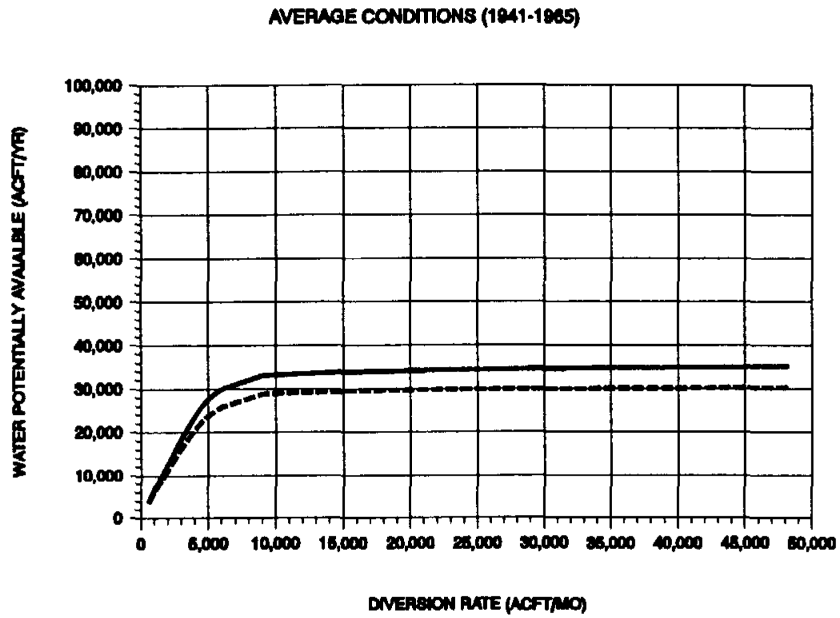
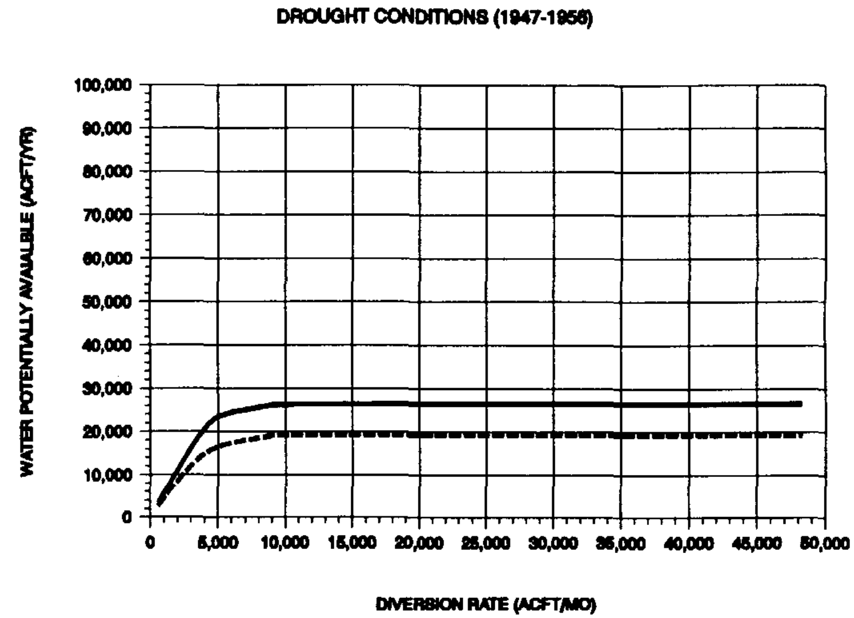
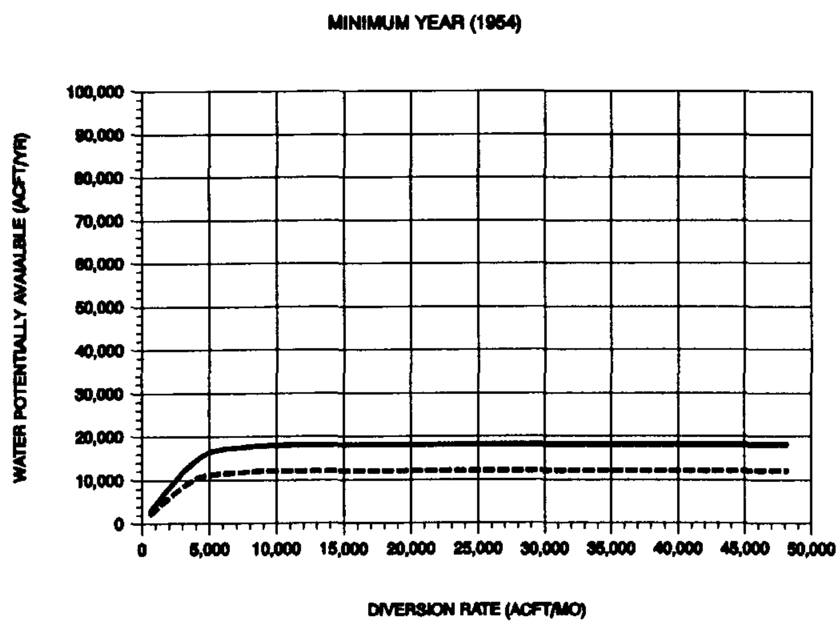
COLORADO RIVER AT COLUMBUS ALTERNATIVE C-17

FIGURE 3.29 - 1







LEGEND

WITH AUSTIN RETURN FLOWS

WITHOUT AUSTIN RETURN FLOWS

ASSUMPTIONS:

1. PURCHASE OF 75,000 ACFT/YR OF RUN-OF-RIVER RIGHTS
2. DIVERSIONS SUBORDINATED TO THE CITY OF AUSTIN
3. AVAILABILITY REPRESENTS A CONSERVATIVE (I.E., LOW) ESTIMATE

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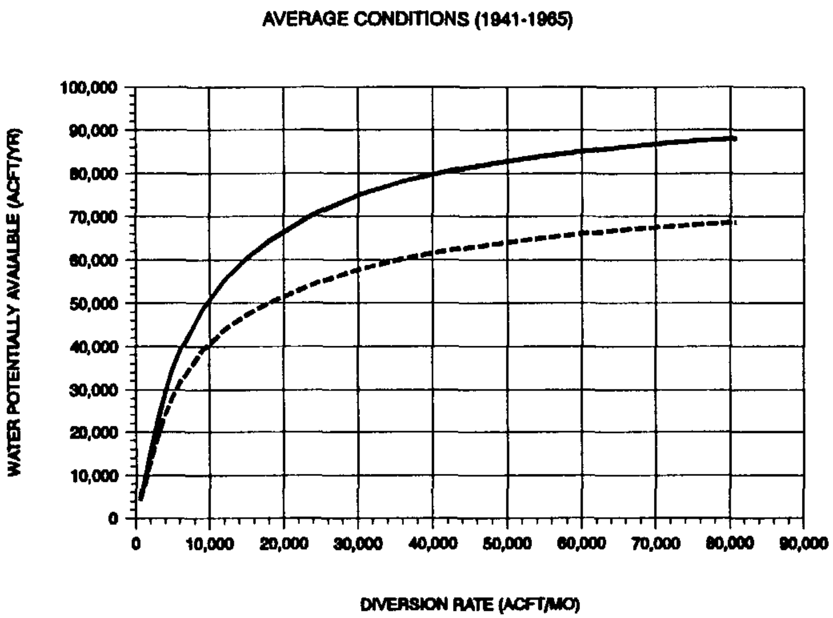
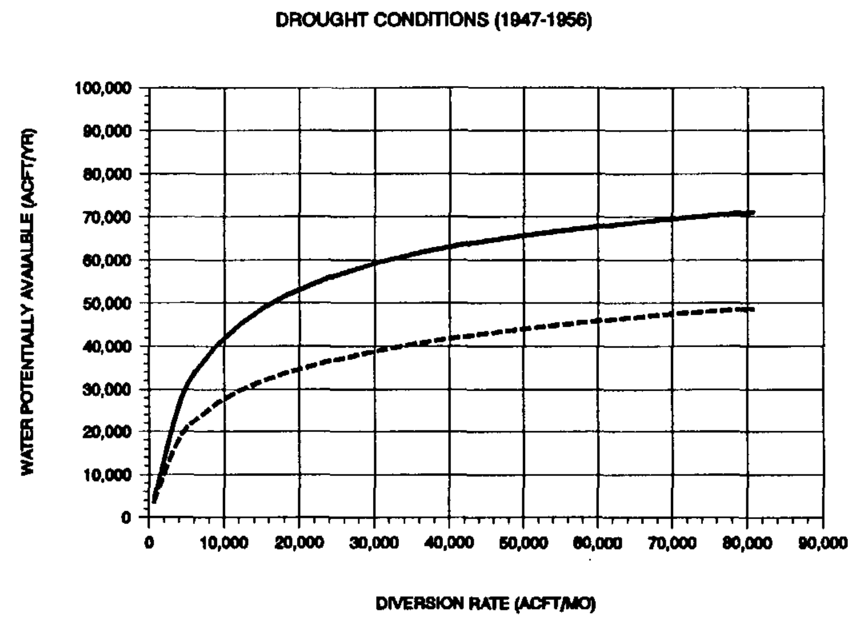
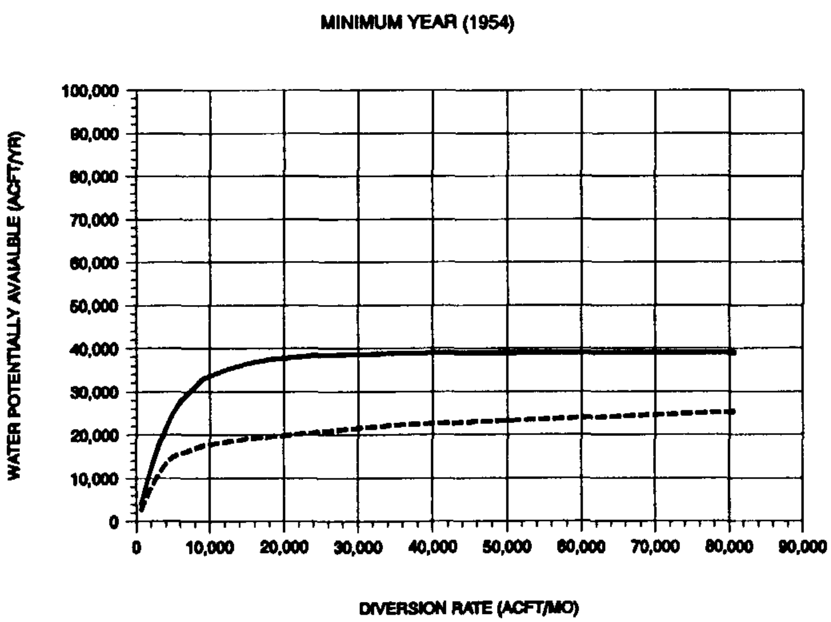
DIVERSION OF UNUTILIZED MAJOR RIGHTS AT COLUMBUS ALTERNATIVE C-15

FIGURE 3.29-2







LEGEND

WITH AUSTIN RETURN FLOWS

WITHOUT AUSTIN RETURN FLOWS

ASSUMPTIONS:

1. PURCHASE OF 288,550 ACFT/YR OF RUN-OF-RIVER RIGHTS
2. DIVERSIONS SUBORDINATED TO THE CITY OF AUSTIN
3. AVAILABILITY REPRESENTS A CONSERVATIVE (I.E., LOW) ESTIMATE

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TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

DIVERSION OF UNUTILIZED MAJOR RIGHTS AND SECOND CROP IRRIGATION AT COLUMBUS, ALTERNATIVE C-16

FIGURE 3.29-3

purchased with the water right. Availability, however, would vary widely from year to year. Therefore, only that portion which could be made available on a firm yield basis is considered to be available to the West Central Study Area. The maximum capture in the worst year of record using the maximum pumping capacity of 1,340 cfs is 39,000 acft. This amount could be obtained every year but would require approximately 17,000 acft of storage during the drought to enable uniform delivery throughout the year and provide for an economical transmission pipeline. The firm yield could be increased to 75,000 acft/yr by using 112,000 acft of storage capacity. The maximum yield that could be obtained would be about 85,000 acft/yr and would require 400,000 acft of storage.

Based on the hypothetical off-channel reservoir sizes considered, the 112,000 acft capacity is the most effective reservoir size. Any additionally capacity provides a substantially smaller increase in firm yield. A brief study was made to determine possible off-channel storage sites, and the Cummins Creek[24] site was chosen for analysis purposes. This site is located on Cummins Creek in Colorado County, just north of Columbus as shown in Figure 3.29-1.

3.29.3 Environmental Issues.

The alternative to divert water from the Colorado River near Columbus includes the two water purchase arrangements discussed in Section 3.28, i.e., purchasing stored water, purchasing existing run-of-river rights, or both. By diverting the water further down the Colorado River so that it is in closer proximity to the existing water rights, this alternative would increase water availability in comparison to diversion at Lake Austin (Section 3.28). Included in this alternative is a 115-mile transmission pipeline traversing the Texas Blackland Prairies and East Central Texas Plains Ecoregions[25].

A wide variety of soil types are present along this pipeline corridor. Beginning in Fayette County at Columbus and continuing through Gonzales County, the soils are alkaline

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[24]USBR Letter to Texas Department of Water Resources, September 15, 1977, describing the Hydrology Investigation for the Colorado Coastal Plain Project.

[25]Omernik, James M., 1987, "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1) pp. 118-125.

loamy to clayey soils[26]. The vegetation of these counties alternates between Post Oak Savannah species, mainly tall grasses, mesquite trees, oaks, and elms, and Blackland Prairie flora, typically grassland species[27]. As the transmission line continues through Guadalupe and Bexar counties the vegetation becomes more dominantly Blackland Prairie vegetation, including little bluestem, feathery bluestem, sideoats grama, plains lovegrass, indiangrass, hairy dropseed, buffalograss, Texas wintergrass, live oak, shin oak, and Ashe juniper[28]. The soil types which support the vegetation types in this region include moderately well drained sandy to clayey soils over stream terraces or limestone[29,30].

Water quality and water treatability will be specifically addressed in a later phase of this study. The effects of pumping the additional water into the recharge zone and injection wells is discussed in detail in Sections 3.0.1, 3.8, 3.9, 3.10.

The fauna present in areas where suitable habitat remains will be typically neotropical and grassland species[31]. On-site surveys will be necessary to determine the specific fauna of the corridor since the pipeline corridor is a mosaic of the Post Oak Savannah and the Blackland Prairie ecoregions and could potentially include a wide variety of species.

The 115-mile transmission pipeline will affect a total area of 1,340 acres. Cultivation accounts for approximately 34 percent of this area (see Table 3.0-1). Woodlands, brushlands, and shrublands comprise roughly 31 percent, grasslands an additional nine percent, and the remaining area is largely developed (e.g. roadways). The construction of the pipeline and injection well sites would include the clearing and removal of woody vegetation. An approximately 30-foot wide corridor free of woody vegetation would be

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[26]Clements, J., 1988, Texas Facts, Clements Research II, Inc. Dallas, Texas.

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

[28]Gould, F. W., 1975, The Grasses of Texas, Texas A & M University Press, College Station, Texas.

[29]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1977. Soil Survey of Guadalupe County, Texas. USDA.

[30]United States Department of Agriculture, Soil Conservation Service and Texas Agricultural Experiment Station. 1991. Soil Survey of Bexar County, Texas USDA.

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

maintained for the life of the project. Destruction of potential habitat can be avoided by diverting the corridor through previously disturbed areas, such as croplands. Selection of a pipeline ROW alongside the existing habitat could also be beneficial to some wildlife by providing edge habitat; however, the majority of these areas are small and fragmented, so care should be taken to ensure minimum impact.

Although the Natural Heritage Program does not report any endangered or threatened species directly along the proposed pipeline corridor, some have been reported in the vicinity (see Table 3.29-1). Many of these appear to be dependent on shrubland or riparian habitat, such as the Texas tortoise, the reticulate collared lizard, the Texas horned lizard, and the Indigo snake. The Texas garter snake may be present in wetland habitats and the timber rattlesnake may be found in riparian woody vegetation. For approximately two miles at the beginning of the pipeline corridor, construction would encroach on the northern portion of what is considered to be essential habitat for the Attwater's Prairie Chicken[32]; however, no Attwater's Prairie Chicken currently occupy the area, and effects of the construction on this habitat should be minimal. Implementation of this alternative is expected to require field surveys for protected species, vegetation, habitats, and cultural resources during ROW selection to avoid or minimize impacts.

When potential protected species habitat or significant resources cannot be avoided, additional studies would have to be conducted to evaluate habitat use, or eligibility for inclusion in the National Register for Historic Places, respectively. Wetland impacts, primarily pipeline stream crossings, could be minimized by ROW selection and appropriate construction methods, including erosion controls and revegetation procedures. Compensation for net losses of wetlands would be required where impacts are unavoidable.

All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources. Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL 96-515), and the Archaeological and Historical Preservation Act (PL 93-291).

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[32]Attwater's Prairie Chicken Recovery Team, 1983, Attwater's Prairie Chicken Recovery Plan. U. S. Fish and Wildlife Service.

Table 3.29-1 Important Species With Habitats in the Project Vicinity (C-17)				
Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions under objects; active March-November	NL	T
Reticulate Collared Lizard	*Crotaphytus reticulatus*	South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Texas Horned Lizard	*Phrynosoma comutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks	C2	T
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL
Timber Rattlesnake	*Crotalus horridus*	Riparian woods, in dense vegetation	NL	T
Source: TPWD. Unpublished, 1994, Texas National Heritage Program. Texas Parks and Wildlife , Austin, Texas.				

3.29.4 Water Quality and Treatment

[To be provided in subsequent phases of this study.]

3.29.5 Engineering and Costing

Alternative C-17A: LCRA Stored Water and Purchase of Run-of-River Water Rights Delivered to Municipal Distribution System - 125,000 acft/yr Rate

For this alternative, the run-of-river and stored water would be pumped from the Colorado River at a diversion facility near Columbus, Texas. The diversion facility would require a low head channel dam to supply a large pumping station. The run-of-river water would be pumped to an off-channel reservoir at a non-uniform rate. LCRA stored water from Lake Travis would be used to supplement run-of-river water during periods of minimal availability. An off-channel reservoir would be needed to deliver the run-of-river water at a more uniform rate, and hence less expensively, to the West Central Study Area. Additionally, off-channel storage provides a greater firm capacity than a diversion without storage. From the off-channel reservoir, water would be pumped at a uniform rate to the North Water Treatment Plant as shown in Figure 3.29-1. The benefit from this project would include addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding areas. The major facilities required to implement this alternative are:

River Intake, Pump Station, and Small Channel Dam
Raw Water Pipeline to Off-Channel Reservoir
Off-channel Reservoir and Dam
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Water Pipeline Booster Pump Stations, three required
Water Treatment Plant (Level 3, see Table 3.0-4)
Distribution System Improvements

The Colorado River intake and pump station for this alternative is sized to deliver 81,000 acft/month (866 mgd) through three 120-inch diameter pipes to the off-channel reservoir. It was assumed that LCRA stored water could be pumped during periods of low run-of-river availability to minimize pumping capacity and storage requirements. Operating cost were calculated based on transmitting water from the Colorado River to the balancing reservoir with a raw water static lift of 78 feet and an annual water delivery of 125,000 acft/year. The reservoir intake and pump station is sized to deliver 10,400 acft/month (112 mgd) to the municipal water treatment plant. Operating costs were determined to transmit water from the reservoir to the treatment plant with a raw water static lift of 747 feet and an annual water delivery of 125,000 acft/year. Operating cost of the finished water pumping system was determined for the total pumping head of 300 feet. Raw water costs for the purchase of stored water from LCRA were estimated at $105 per acft/yr. The cost of the water run-of-river rights were estimated to cost $64 per acft under a one-time payment agreement based on the Garwood run-of-river right (marketed at $400/acft) and pro-rated for the estimated firm yield delivery at the point of delivery. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual cost of $55,560,000 (Table 3.29-2). Operation and maintenance costs total $29,940,000. The annual costs, including debt repayment, interest, raw water purchases, and operation and maintenance, total $90,750,000. For an annual firm yield of 125,000 acft, the resulting annual cost of water is $726 per acft/yr (Table 3.29-2).

Table 3.29-2
Cost Estimate Summaries for Colorado River at Columbus (C-17)
(Mid- 1994 Prices)

Item	Alt. C-17A Divert to WTP and Municipal Systems	Alt. C-17B Divert to WTP and Municipal Systems
Capital Costs		
Dam and Reservoir	$45,900,000	$0
Transmission and Pumping	227,790,000	101,530,000
Treatment Plant	44,640,000	20,980,000
Delivery System	76,810,000	39,130,000
Total Capital Cost	$395,140,000	$161,640,000
Engineering, Contingencies, and Legal Costs	120,850,000	48,470,000
Land Acquisition	11,220,000	1,210,000
Purchase of Water Rights	18,400,000	N/A
Environmental Studies and Mitigation	10,190,000	2,160,000
Interest During Construction	37,180,000	14,560,000
Total Project Cost	$592,980,000	$228,040,000
Annual Costs		
Annual Debt Service	$55,560,000	$21,370,000
Purchase of Stored Water	5,250,000	5,250,000
Annual Operation and Maintenance	11,650,000	4,710,000
Annual Power Cost	18,290,000	7,840,000
Total Annual Cost	$90,750,000	$39,170,000
Available Project Yield (acft/yr)	125,000	50,000
Annual Cost of Water	$726/acft	$783/acft

Alternative C-17B: LCRA Stored Water Delivered to Municipal Distribution System

For this alternative, the stored water from Lake Travis would be diverted from a river intake and pumped in a transmission line to the North Water Treatment Plant as shown in Figure 3.29-1. The release rate from Lake Travis as well as the diversion rate from the river would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

River Intake, Pump Station, and Small Channel Dam
Raw Water Pipeline to Treatment Plant
Raw Water Pipeline Booster Pump Stations
Water Treatment Plant (Level 3, see Table 3.0-4)
Distribution System Improvements

The intake and pump station is sized to deliver 4,170 acft/month (45 mgd) through a 54-inch diameter pipeline. The operating cost was determined for a raw water static lift of 820 feet and an annual water delivery of 50,000 acft/year. Operating cost of the finished water pumping system was determined for a total pumping head of 300 feet. The cost of purchasing raw water from LCRA is based on a cost of $105 per acft/yr. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $21,370,000 (Table 3.29-2). Operation and maintenance costs total $12,550,000. The annual costs, including debt repayment, interest, raw water purchases, and operation and maintenance, total $39,170,000. For an annual firm yield of 50,000 acft/yr, the resulting annual cost of water is $783 per acft (Table 3.29-2).

3.29.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Requirements Specific to Transfer of Existing Water Rights (C-17, All)

1. Obtain TNRCC approval for amendments to the existing water right to reflect
   a. The new water use,
   b. The new diversion point, and

   c. Interbasin transfer.
2. Water rights sales and contracts must be approved by the TNRCC.

Reservoir Alternatives (C-17A)

1. Necessary permits for the off-channel storage reservoir could include:
   a. TNRCC Water Right and Storage permits.
   b. TNRCC Interbasin Transfer Approval.
   c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
   d. GLO Sand and Gravel Removal review.
   e. GLO Easement for use of state-owned land.
   f. Coastal Coordinating Council review.
   g. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.
3. Land must be acquired through either negotiations or condemnation.
4. Relocations for the reservoir include:
   a. Highways and railroads
   b. Other utilities

Requirements Specific to Pipelines (C-17, All)

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Treatment and Distribution

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

3.30 Shaws Bend Reservoir (C-18)

3.30.1 Description of Alternative

Shaws Bend Reservoir was proposed and studied by the U.S. Bureau of Reclamation (USBR) in 1986[33] and all of the information for this alternative was obtained from that study. The objective of the 1986 study was to determine the potential to increase the yield of the lower Colorado River to meet future water demands. The 1986 study showed that Shaws Bend Reservoir was the preferred plan to accomplish this objective. However, after the 1986 study was completed, no further study of the reservoir was made. The project was also considered by the GSAMA Advisory Technical Water Committee[34], after being suggested by the TWDB[35], but was subsequently rejected.

The site for the Shaws Bend reservoir is shown on Figure 3.30-1. As originally proposed by the USBR, it would be located approximately 4 miles southeast of the City of La Grange, Texas. The reservoir would be formed by an earthfill embankment and releases would be controlled through a gated spillway. The dam embankment would extend approximately 5,600 feet across the Colorado River valley with a crest elevation of 241 ft-msl. The reservoir would provide an initial conservation storage of 132,220 acft at elevation 220 ft-MSL and inundate 12,400 acres at this elevation. The reservoir would extend about 34.5 river-miles upstream.

3.30.2 Available Yield

The USBR estimated the potential increase in system yield that would result from construction of Shaws Bend reservoir for two scenarios. The first scenario included no stored sediment (or initial reservoir conditions) and the second included 50 years of stored sediment. In both scenarios, the analyses assumed that O.H. Ivie (Stacy) Reservoir would be in place although, at that time, it had not been constructed. The hydrology for the

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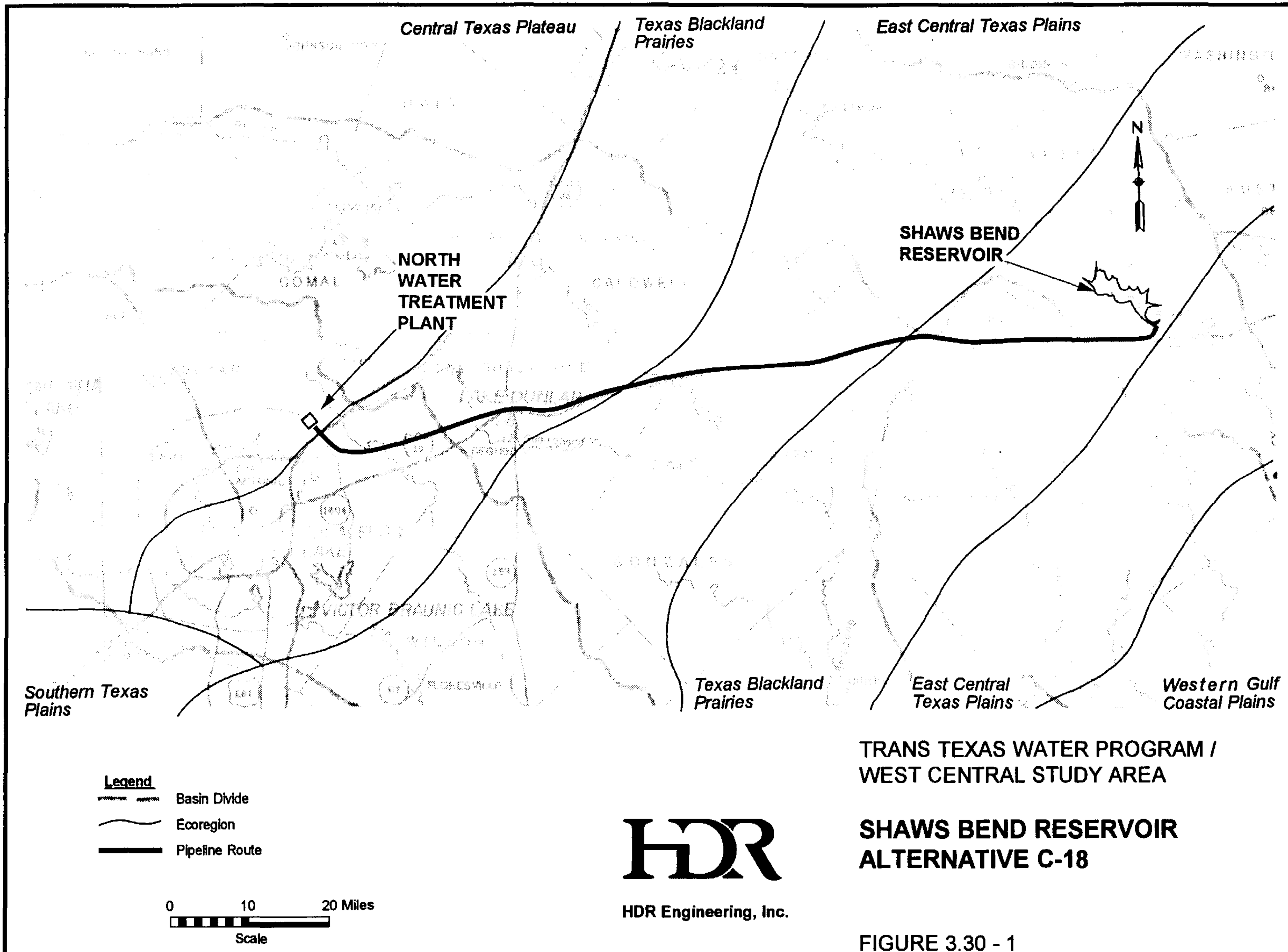
[33]U.S. Bureau of Reclamation, "Colorado Coastal Plains Project," July 1986, revised August 1986.

[34]Project Control, Consultants to Greater San Antonio Metropolitan Area Advisory Technical Water Committee, "Bexar County Water Supply Projects," August 1990.

[35]Texas Water Development Board, "Unit Cost Comparisons for Alternative Water Supplies for Bexar County," May 1990.



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

SHAWS BEND RESERVOIR ALTERNATIVE C-18

FIGURE 3.30 - 1

analyses was based on flow sets produced by the Texas Department of Water Resources[36]. The yields associated with these two scenarios were estimated as 140,000 acft and 128,000 acft, respectively, and did not consider requirements for in-stream flows or fresh water flows for the downstream estuary.

For purposes of this Phase I study, it was estimated that the Trans-Texas environmental criteria would reduce the 50-year firm yield of the Shaws Bend Reservoir from 128,000 acft/yr to 100,000 acft/yr or about 22 percent. A more precise estimate of the firm yield of the reservoir will need to be made using reservoir operation studies in subsequent Trans-Texas studies if this alternative is given further consideration. The estimated firm yield of 100,000 acft/yr was utilized in determining the unit cost of water for the Shaws Bend Reservoir alternative. For purposes of sizing and costing the required pipeline from Shaws Bend Reservoir, it was assumed that the full yield of the project would be delivered to the North Surface Water Treatment plant site as shown in Figure 3.30-1.

3.30.3 Environmental Issues

The Shaws Bend Reservoir would impound the Lower Colorado River in Colorado and Fayette counties. The proposed dam site is located approximately 4.1 river miles above the U.S. Highway 71 bridge crossing in Columbus, Colorado County, Texas (Figure 3.30-1). The reservoir project description (Table 3.30-1) and much of the environmental characterization, is taken from two reports: the ECS Technical Services[37] April 1985 report to the Bureau of Reclamation and the Bureau of Reclamation[38] "Report Concluding the Colorado Coastal Plains Project". The ECS report was an environmental inventory and impacts assessment that compared Shaws Bend Reservoir with a series of small reservoirs. The 1986 Bureau of Reclamation report selected Shaws Bend as the preferred alternative for the Colorado Coastal Plains Project.

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[36]Texas Department of Water Resources, "Present and Future Surface-Water Availability in the Colorado River Basin, Texas," LP-60, June 1978.

[37]ECS, 1985, Environmental Resources Assessment, Colorado Coastal Plains Project, Texas. ECS Technical Services.

[38]Bureau of Reclamation, 1986, Report Concluding the Study on Colorado Coastal Plains Project, Texas. Southwest Region, Amarillo, Texas.

The reservoir lies entirely within the East Central Texas Plains Ecoregion[39], (Figure 3.0-1). Sandwiched between two prairies, the Texas Blackland Prairie and the Western Gulf Coastal Plain, this ecoregion is distinguished by its mosaic of woodlands and croplands. Blair's[40] regional classification places the reservoir in the Texan Biotic Province (Figure 3.0-3), a "broad ecotone" between western grasslands and eastern forests. Blair's biogeographical listing of wildlife fauna of this region, like the vegetation, is a mix of western grassland-associated and eastern forest-associated organisms. The reservoir is within the Post Oak Savannah[41] vegetational area of Texas (Figure 3.0-2). Immediately north of the upper reservoir boundary is the Blackland Prairie vegetational area.

The Post Oak Savannah is characterized by gently rolling to hilly terrain with an understory that is typically tall grass and an overstory that is primarily post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*)[42]. Most of the Post Oak Savannah is composed of improved pastures and small farms. The Blackland Prairie's gently rolling to nearly level plain is largely under cultivation with a few areas in native hay meadows and ranches[43]. The soils of the East Central Texas Plains are characteristically dry alfisols[44]. Within the reservoir are clayey and loamy Brazoria - Norwood soils, typical of floodplains and river terraces[45]. Brazoria soils are poorly drained hydric soils[46] that support hydrophytic vegetation.

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[39]Omernik, James M., 1987, "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1) pp. 118-125.

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

[41]Gould, F. W., 1975, The Grasses of Texas, Texas A & M University Press, College Station, Texas.

[42]Correll, D.S., and M.C. Johnston, 1979, Manual of the Vascular Plants of Texas, Texas Research Foundation, Renner, Texas.

[43]Ibid.

[44]Omernik, James M., 1987, "Ecoregions of the Conterminous United States," Annals of the Association of American Geographers, 77(1) pp. 118-125.

[45]SCS, 1978, General Soils Map, Colorado County, Texas, Sheet 4R36426.

[46]SCS, 1991, "Hydric Soils of the United States," Miscellaneous Publication No. 1491, U.S. Department of the Agriculture.

The vegetation of the reservoir site is primarily influenced by its location in the Colorado River floodplain, which accounts for about a third of the habitat within the reservoir's 23,400-acre flood easement and about 60 percent of an approximately 13,398-acre conservation pool and construction area (Table 3.30-1). The wetlands and river terrace are primarily forested with pecans, cottonwoods, sycamores, and willows. Live oak, post oak and water oak cover the upper river terraces and upland areas. Savannah, mesquite - huisache brushland, grassland, improved pasture, and crops comprise about half of the reservoir area.

Table 3.30-1
Shaws Bend Reservoir
Habitats Within Proposed Reservoir Construction Area and Conservation Pool [1]

Summary of Land Use	Acres	Land Use Within Conservation Pool	Acres
Crop	287	Crop	0
Upland Woodland	3,092	Upland Woodland	0
Park	1,655	Savannah	1,170
Brushland	18	Brushland	0
Grassland and Pasture	6,012	Grassland and Pasture	3,591
Riverine (R2) Wetland	1,016	Riverine (R2) Wetland	1,016
Forested Wetland	1,318	Forested Wetland	4,700
Total Acres	13,398	Total Acres	10,477

[1]Bureau of Reclamation 1986 Report concluding the study on Colorado Coastal Plans Project, Texas. Southwest Region, Amarillo, Texas.

The Bureau of Reclamation study applied U.S. Fish and Wildlife Services Habitat Evaluation Procedure cover type categories to evaluate the vegetation communities to be affected by the proposed reservoir[47]. These vegetation cover types have been grouped

[47]Bureau of Reclamation, 1986, Report Concluding the Study on Colorado Coastal Plains Project, Texas. Southwest Region, Amarillo, Texas.

(Table 3.30-1) into categories corresponding to those used throughout this report[48] for comparison with other projects in Table 3.0-1.

The Texas Water Development Board's River Basin Simulation Program estimated that the reservoir would yield 140,000 acft/yr initially and after 50 years would yield 128,000 acft/yr. The Bureau of Reclamation estimated that annual inflow to Matagorda Bay would be reduced by 2 percent and that reservoir operation would reduce the Colorado River sediment load to Matagorda Bay by 57 percent.

The Shaws Bend Reservoir pipeline to San Antonio would follow the IH-10 corridor. This estimated 83-mile pipeline corridor is discussed in section 3.28.3 and presented in Table 3.0-1.

The Bureau of Reclamation[49] concluded that the continued existence of protected species or candidates for protection would not be affected by the project. Surveys for five protected or rare plant species failed to locate Texas meadow-rue, Navasota ladies'-tresses, blue-star, spikerush, or prairie dawn within the project area. Additional field studies revealed that the project area soils are unsuitable for populations of the endangered Navasota ladies'-tresses. However, the study recommended that the proposed dam site, adjacent uplands, and lands within the conservation pool should be thoroughly surveyed again for Texas meadow-rue prior to construction, since this plant adapts to prairie and oak forest with a shrub - grass understory. The Bureau of Reclamation agreed to survey the reservoir for evidence of nesting American bald eagles prior to project construction. Important species proposed or listed for protection that may be present in the project vicinity are listed in Table 3.30-2. The Texas garter snake may be present in wetland habitats and grasslands. The Timber rattlesnake is associated with dense bottomland woods. The Texas horned lizard and the western smooth green snake may be present in grassland areas. Two fish, the blue sucker and the Guadalupe bass are known to inhabit this portion of the Colorado River. The implementation of the Shaws Bend Alternative C-18 would require field surveys for protected species, vegetation and habitats.

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[48]McMahan, C.A., R.G. Frye, K.L. Brown, 1984, The Vegetation Types of Texas, Including Cropland. Texas Parks and Wildlife Department, Austin, Texas.

[49]SCS, 1991, "Hydric Soils of the United States," Miscellaneous Publication No. 1491, U.S. Department of the Agriculture.

3.27 Dilworth Reservoir (G-22)

3.27.1 Description of Alternative

The Dilworth dam and reservoir project was first proposed by the United States Army Corps of Engineers (COE) in 1950. The COE report "Report on Survey of Guadalupe and San Antonio Rivers and Tributaries, Texas for Flood Control and Allied Purposes" presented the Dilworth site as a flood control project. The site was not deemed very effective in a flood control role, however, and the dam and reservoir were not recommended for construction. The Dilworth site has not been formally studied for its water conservation potential.

The Dilworth site is located at river mile 13.1 on Peach Creek (drainage area of 438 square miles), a tributary of the San Marcos River, approximately six miles east of the City of Gonzales (see Figure 3.24-1). The dam design consists of a 15,700-foot earthen embankment with a top-of-dam crest elevation of 307 ft-MSL (maximum dam height of 67 feet). The spillway system would consist of a 700-foot controlled concrete weir section with radial gates at a crest elevation of 280 ft-MSL. Operating under this proposed embankment and spillway configuration, the reservoir would have a conservation pool capacity of 275,000 acft at a water surface elevation of 293 ft-MSL. At this elevation, the reservoir's surface area would be 15,400 acres.

3.27.2 Available Yield

Yield estimates for Dilworth Reservoir proposed as a water conservation project could not be located, but were estimated for purposes of this study from data presented by EHA[5] for Cloptin's Crossing Reservoir. The EHA yield estimate of 35,000 acft/yr was adjusted for drainage area, storage, depth of runoff, and evaporation, resulting in an estimated yield for Dilworth Reservoir of 27,000 acft/yr. The yield presented here does not reflect Trans-Texas criteria for pass-through, instream needs and bay and estuary needs. It is very likely that the yield will be significantly reduced when the Trans-Texas criteria for reservoirs are applied.

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[5]Espey, Huston and Associates, Inc., "Water Availability Study for the Guadalupe and San Antonio River Basins, Volume I," February, 1986.

3.27.3 Environmental Issues

Alternative G-22 includes dam construction and inundation of approximately 15,400 acres along a 13-mile reach of Peach Creek, a tributary of the San Marcos River. Associated pipelines for transporting the surface water to a water treatment plant are not considered here. If this alternative is considered in a later phase, the pipeline corridors will be included. This site should not be constructed in conjunction with the Cuero Reservoir, since Cuero's backwater would affect the tailwater of Dilworth.

The proposed Dilworth Reservoir is located in northeastern Gonzales County on the boundary between the Texas Blackland Prairies and the East Central Texas Plains ecoregions[6] (see Figure 3.0-1), in the Post Oak Savannah region of Texas[7] (see Figure 3.0-2), and in the Texan biotic province[8] (see Figure 3.0-3).

Vegetation types within the proposed Dilworth Reservoir project area include bottomland and upland woodlands, shrubland, grassland, cropland, and wetlands. Stream-side vegetation within the proposed reservoir is typical of pecan-elm forests. These forests are found in bottomlands along the Brazos, Colorado, Guadalupe, San Antonio and Frio rivers. They contain, among other species, American elm, cedar elm, cottonwood, sycamore, black willow, yaupon, greenbriar, Johnsongrass, frostweed and western ragweed[9].

Upland areas are dominated by post oak woods, forest and grassland mosaics. These areas are typically found on sandy soils. Common species include blackjack oak, eastern redcedar, mesquite, black hickory, live oak, hackberry, yaupon, American beautyberry, hawthorn, little bluestem, beaked panicum, three-awn and tickclover[10].

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[6]Omernik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1). pp. 118-125.

[7]Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press, Texas Agricultural Experiment Station, College Station, Texas.

[8]Blair, W.F. 1950. The biotic provinces of Texas. Tex. J. Sci. 2:93-117.

[9]McMahan, C.A., R.G. Frye, K.L. Brown. 1984. The Vegetation Types of Texas, Including Cropland. Texas Parks and Wildlife Department, Austin, Texas.

[10]Ibid.

Within the floodplains, soils are a calcareous black clay classified as Tinn clay and Bosque clay loam. These soils have the highest fertility in the county, thus making excellent cropland. Gholson and Sunev soils are a fine loamy sand found in uplands with slopes of 1 to 5 percent and 3 to 8 percent, respectively[11].

Wetlands within the reservoir site include approximately 1,530 acres of palustrine forested, scrub/shrub, emergent and intermittent riverine wetlands.

The primary impacts that would result from construction and operation of the Dilworth Reservoir include conversion of existing habitats and land uses within the conservation pool to open water, and potential downstream effects due to modification of the existing flow regime. The Dilworth Reservoir site would be permanently inundated to 293 feet MSL with a surface area of 15,400 acres. The 100-year flood dam elevation would be 300 feet MSL with a surface area of 20,700 acres. Approximately 5,049 acres of brushlands, 5,967 acres of grasslands and cropland, 2,754 acres of woodlands, 1,530 acres of wetlands (including 68 acres of riverine habitat), and 100 acres of developed land would be converted to open water upon inundation (see Table 3.0-1). Several lakes would be inundated by the reservoir, including Post Oak, Laws, Jones, Wood, Mooney, Pogue, Bailey, Lee, Rinehart, and Long. The town of Little New York and St. James Cemetery would also be inundated by the proposed reservoir. Indirect effects of reservoir construction may include land use changes in the area surrounding the reservoir and in mitigation areas that may be converted to alternate uses to compensate for losses of terrestrial habitat.

Potential downstream impacts would include modification of the streamflow regime below the dam, and reduced inflows to San Antonio Bay. Reduced inflows would equate to the quantity of water diverted from the reservoir for use as water supply and not returned to San Antonio Bay, plus the amount of water lost to evaporation from the reservoir. Detailed hydrologic information regarding these system modifications is not available for this reservoir alternative. However, it is assumed that as a new reservoir without a current operating permit, the Dilworth Reservoir would be required to meet the Trans-Texas Water Program "New Reservoir" criteria for instream flows and freshwater inflows to bays and

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[11]U.S. Department of Agriculture, Soil Conservation Service (SCS). 1994. Personal communication with Gonzales County Soil Survey Staff. March.

estuaries. Operation of the reservoir to meet these criteria would likely have a significant effect on (i.e., reduction of) the firm yield of the reservoir.

No protected species have been recorded on the site, but the area may provide potential habitat for ten threatened, endangered or candidate species that occur in Gonzales County (see Table 21, Appendix B). Other protected species may use habitats in the area during migration. A survey of the reservoir site may be required prior to dam construction to determine whether populations of or potential habitat for species of concern occur in the area to be impacted.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). Implementation of this reservoir alternative is expected to require field surveys by qualified professionals to document vegetation/habitat types and cultural resources that may be impacted by the proposed reservoir. Where impacts to potential protected species habitat or significant cultural resources could not be avoided, additional studies would be necessary to evaluate habitat use and/or value, or eligibility for inclusion in the National Register of Historic Places, respectively. Compensation would be required for unavoidable adverse impacts involving net losses of wetlands.

3.27.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.27.5 Engineering and Costing

The cost estimate for Dilworth Reservoir is an update of a previous cost estimate performed by the United States Study Commission in 1960. The Study Commission estimated the total project costs for Dilworth Reservoir to be $9,249,000 in 1960 dollars. The 1960 cost estimate was updated by multiplying estimated construction quantities by current 1994 unit prices. Where construction quantities were not available, costs were calculated by multiplying the individual cost components of the previous estimate by the CCI or BUREC ratio.

Tables 3.30-2
Important Species With Habitat in the Shaws Bend Project Vicinity (C-18)

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
American Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native coastal prairie grassland with diverse habitat of short-, mid-, and tallgrass; 50 percent climax	E	E
Houston Toad	*Bufo Houstonensis*	Loamy, friable soils, temporary rain pools, flooded fields, ponds surrounded by forest or grass; reintroduced to Colorado Co.	E	E
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil or hides under rocks when inactive	C2	T
Timber Rattlesnake	*Crotalus horridus*	Riparian woods, in dense vegetation	NL	T
Western Smooth Green Snake	*Opeodrys vernalis blanchardi*	Coastal grasslands	NL	E
Blue Sucker	*Cycleptus elongatus*	Large rivers throughout Mississippi River Basin south and west in major freshwater streams of Texas to Rio Grande	C2	T
Guadalupe Bass	*Micropterus treculi*	Rivers of the Edwards Plateau including portions of the Brazos, Colorado, Guadalupe, and San Antonio River Basins; also the lower Colorado River and introduced in the Nueces River system	C2	NL
Texas Meadow-rue	*Thalictrum texanum*	Coastal plains and savannah of south east Texas; known in Brazos and Waller Cos; historic in Harris Co.[1]	C2	NL
Mulenbrock's Umbrella Sedge	*Cyperus grayioides*	Prairie grasslands, moist meadows in Texas, Louisiana, Illinois	C2	NL

Tables 3.30-2 Continued Important Species With Habitat in the Shaws Bend Project Vicinity (C-18)				
Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Navasota Ladies-tresses	*Spiranthes parksii*	Open wooded margins of minor tributaries in Post Oak woodlands of the Post Oak Savannah; known in Brazos, Burleson, Grimes, Jasper, Lee, Leon, Madison, Robertson, and Washington Cos.	E	E
Prairie Dawn (also called Texas Bitterweed)	*Hymenoxys texana*	Gulf prairie and marshes in poorly drained depressions or at the base of mima mounds in open grasslands in almost barren areas; known in Ft. Bend and Harris Cos.; historic collection from LaSalle Co.[2]	E	E

[1]Texas Parks and WilDlife, 05/09/88 ; occurrence based on historic range
[2]ECS Technical Services. 1985.Report to the Bureau of Reclamation, Colorado Coastal Plains Project
Source for all other occurrence in county: Texas Natural Heritage Program, December 1993, unpublished files, Texas Parks and Wildlife Department, Austin, Texas

Two environmentally unique areas, Harvey Creek Woodlands and Horseshoe Bend Woodlands, would be affected by the proposed reservoir. Harvey Creek is about 30 acres of relatively undisturbed mature oaks, elms, and hackberry trees. The creek provides a continuous water supply to the numerous pools and riffles along the reach above the confluence with the Colorado River. This pristine bottomland with pools and riffles would be totally inundated by the conservation pool. Horseshoe Bend Woodlands, relatively undisturbed for more than 30 years, is approximately 100 acres dominated by an elm-ash-hackberry community with relatively homogeneous stands of cottonwood, hackberry and other bottomland trees. The central portion of this woodland has a remnant oxbow lake that was cut off from the Colorado River during the 1940's. Other area oxbow lakes have generally been cleared for agricultural purposes. The Horseshoe Bend Woodlands would be 70 percent inundated by the conservation pool.

The Bureau of Reclamation agreed to a mitigation plan with U.S. Fish and Wildlife Services for the habitat inundated. Mitigation included planting 4,000 acres of bottomland with native hardwoods to create a forested wetland within a 6,000-acre wildlife management area. Mitigation plans included the areas directly affected by the reservoir inundation, areas disturbed by construction, and an estimated 2,180 acres of pecan orchard adjoining the reservoir site that may be killed by the raised groundwater table. Results of a Habitat Evaluation Procedure conducted by the USFWS indicated that about 46,000 acres managed to encourage woodland development would be needed to compensate for terrestrial habitat losses.

With regard to cultural resources, about 200 - 250 prehistoric and historic sites were identified in the project area. Some sites would be destroyed by project construction and others would be less vulnerable to destruction as a result of inundation[50]. Burnham's Crossing, a historic ferry crossing and trade center, would be inundated regardless of conservation pool level since most of the site lies below the 200-foot contour. A site mitigation plan will be required to avoid loss of historically significant resources[51]. A systematic survey of the entire reservoir site would be required to search for surface indications of cultural deposits, while a geomorphic study to evaluate the potential for buried deposits is also a likely requirement. Sites located would have to be tested for archaeological or historic significance and for eligibility for listing on the National Register, and the need for additional study, salvage, or other mitigation determined prior to construction.

3.30.4 Water Quality and Treatment

[To be completed in future phases of the study.]

3.30.5 Engineering and Costing

For this report, the cost estimate for Shaws Bend dam and reservoir is an update of the cost estimate prepared by the USBR in their 1986 report. The USBR estimated total project costs for the Shaws Bend dam and reservoir to be $234,083,000 in 1985 dollars. The USBR reservoir project included recreational and wildlife development costs which were not

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[50]SCS, 1991, "Hydric Soils of the United States," Miscellaneous Publication No. 1491, U.S. Department of the Agriculture.

[51]Ibid.

included in this 1994 cost update. The estimated cost for constructing and operating the pipeline from Shaws Bend Reservoir to the North Water Treatment Plant site was calculated using current unit costs and estimated quantities for materials, labor, and easements. The 72-inch pipeline size was determined based on a flow rate of 100,000 acft/yr (179 cfs) and the pumping head dictated by pipe friction and the ground profile along the proposed route.

The estimated total project cost estimate for Shaws Bend dam, reservoir, pipeline, and treatment plant is $604,460,000 as summarized in Table 3.30-3. The annual cost of the project, including operation and maintenance is $81,560,000. This results in a unit cost of treated water of $816 per acft delivered (Table 3.30-3).

Table 3.30-3
Cost Estimate Summary for Shaws Bend Reservoir (C-18)
(Mid- 1994 Prices)

Item	**Alt. C-18 Divert to WTP and Municipal System**
Capital Costs	
Dam and Reservoir	73,260,000
Transmission and Pumping	162,000,000
Treatment Plant	37,000,000
Delivery System	65,670,000
Total Capital Cost	$337,930,000
Engineering, Contingencies, and Legal Costs	104,720,000
Land Acquisition	58,860,000
Environmental Studies and Mitigation	62,140,000
Interest During Construction	40,810,000
Total Project Cost	$604,460,000
Annual Costs	
Annual Debt Service	$56,640,000
Annual Operation and Maintenance	9,900,000
Annual Power Cost	15,020,000
Total Annual Cost	$81,560,000
Available Project Yield (acft/yr)	100,000
Annual Cost of Water	$816/acft

(1) Cost with treatment prior to surface recharge.
(2) Cost without treatment prior to surface recharge.

3.30.6 Implementation Issues

Reservoir Alternatives (C-18)

1. It will be necessary to obtain these permits for the off channel storage reservoir:
    a. TNRCC Water Right and Storage permits.
    b. TNRCC Interbasin Transfer Approval.
    c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
    d. GLO Sand and Gravel Removal permits.
    e. GLO Easement for use of state-owned land.
    f. Coastal Coordinating Council review.
    g. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
    a. Bay and estuary inflow impact.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.
3. Land will need to be acquired either through negotiations or condemnation.
4. Relocations for the reservoir include:
    a. Highways and railroads
    b. Other utilities

Requirements Specific to Pipelines (C-18)

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
    b. GLO Sand and Gravel Removal permits.
    c. Coastal Coordinating Council review.
    d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Treatment and Distribution (C-18)

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

3.31 Allens Creek Reservoir (B-10)

3.31.1 Description of Alternative

Allens Creek Reservoir is a proposed off-channel reservoir located on Allens Creek, a small tributary of the Brazos River in Austin County. The reservoir site is located two miles north of the town of Wallis, Texas. The location of the reservoir is shown on Figure 3.31-1. The project would impound water available from the Allens Creek watershed as well as water diverted and pumped from the Brazos River during periods of flow in excess of downstream needs.

The Allens Creek Reservoir project was originally proposed by Houston Lighting and Power Co. (HL&P) as a cooling lake for a nuclear power plant and the site was studied in 1974 by URS/Forrest and Cotton[52]. URS made a second study in 1977 with a different dam alignment and smaller reservoir[53]. HL&P eventually abandoned plans for a power plant at the Allens Creek site and subsequently the Brazos River Authority (BRA) obtained an option to purchase the reservoir site from HL&P. In 1988, BRA retained Freese & Nichols to study the yield and cost of the proposed reservoir[54]. As part of the Trans-Texas Water Program, Freese & Nichols and Brown & Root re-evaluated the yield of the reservoir with the application of the Trans-Texas Environmental Criteria.[55]

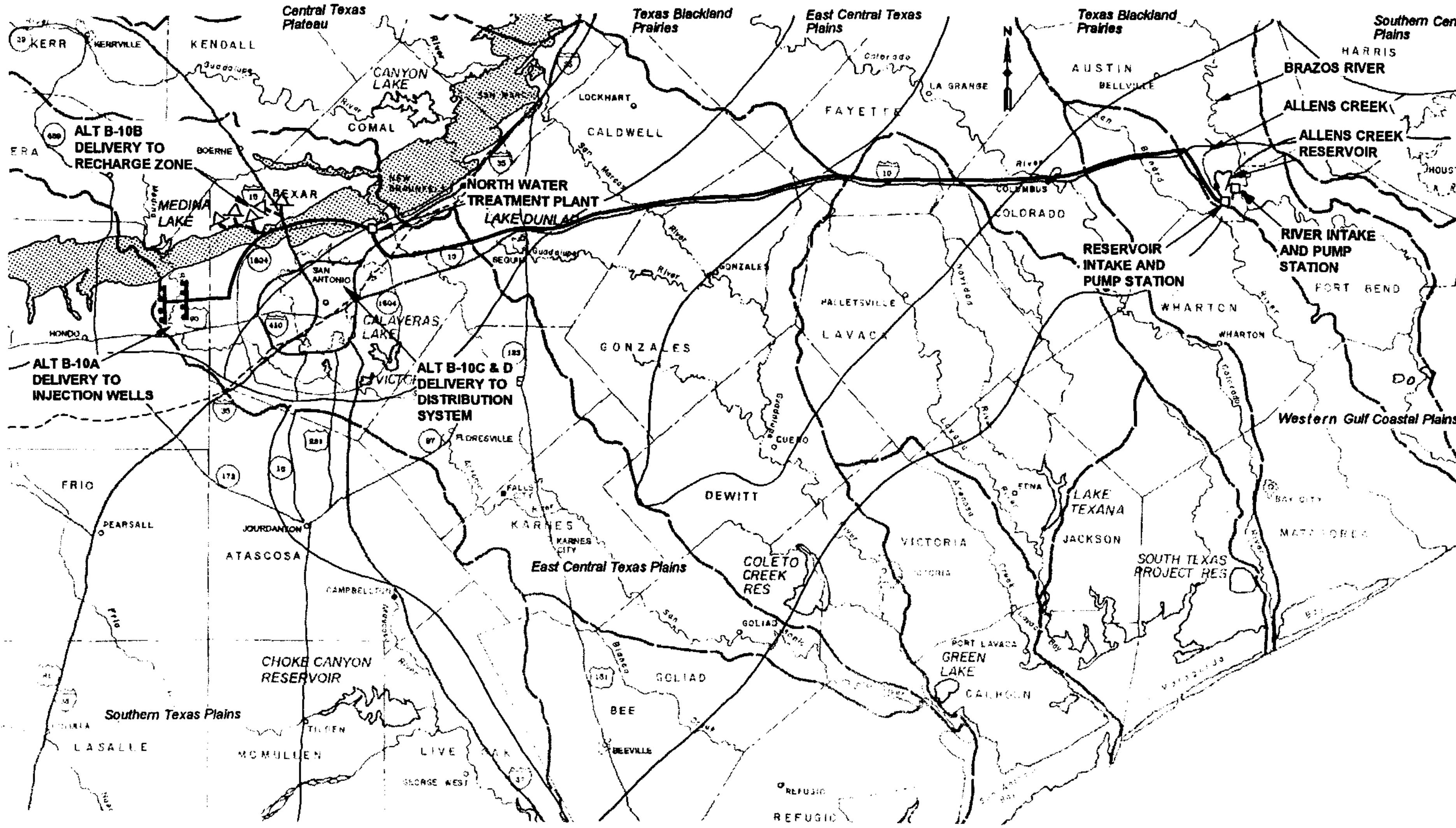
The dam configuration studied by Freese & Nichols is the layout from the 1974 URS report, with minor changes. The dam would be a 26,200-foot earthfill embankment with a top width of 20 feet and 3-to-1 side slopes on both the upstream and downstream sides. The top of the embankment would be at elevation 136.5 feet; the probable maximum flood elevation in the reservoir would be 129.2 feet; and the top of the conservation pool would

[52]URS/Forrest and Cotton, "Allens Creek Dam and Reservoir on Allens Creek, Brazos River Basin, Austin County, Texas" (prepared for Houston Lighting and Power Company), January 1974.

[53]URS/Forrest and Cotton, "Allens Creek Dam and Reservoir on Allens Creek, Brazos River Basin, Austin County, Texas" (prepared for Houston Lighting and Power Company), July 1977.

[54]Freese & Nichols, Inc., "Brazos River Authority, Yield Analysis and Cost Estimate for Allens Creek Reservoir", February 1989.

[55]Brown & Root, Inc. and Freese & Nichols, Inc., "Trans-Texas Water Program, Southeast Area Phase I Report", March 1994.



Legend

- Basin Divide
- Edwards Aquifer Recharge Zone
- "Bad Water" Line
- Ecoregion
- Pipeline Route

0 10 20 Miles
Scale

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

ALLENS CREEK RESERVOIR ALTERNATIVE B-10

FIGURE 3.31-1

be elevation 118.0 feet with a surface area of 8,250 acres. Approximately six miles of stream channel along Allen's Creek would be inundated by the reservoir.

The outlet works consist of a 60-inch diameter pipe in the spillway, and a 500-foot uncontrolled concrete ogee spillway with a crest elevation of 118.0 feet. Because the Brazos River would reach the embankment under high flow conditions, slope protection would be needed to protect the downstream face of the dam below elevation 120.0 feet as well as the entire upstream face. The design flood on the Brazos River exceeds the spillway elevation and the spillway would be designed to accommodate flow from the river into the reservoir. Two small dikes of compacted earthfill on the southern shore of the reservoir would be needed to raise the shoreline above the elevation of the Allens Creek probable maximum flood.

Diversion facilities on the Brazos River would include a gated intake channel, pump station, two parallel pipelines to the reservoir, and a discharge structure in the reservoir.

3.31.2 Available Yield

The Allens Creek drainage area controlled by the reservoir would be 58.3 square miles and water available for storage from the watershed during the critical dry period was estimated to be 3,407 acft/yr. To create a more significant project yield, water must be pumped into the reservoir from the Brazos River during times when flow in the river is sufficient to satisfy senior downstream water rights. Freese & Nichols[56] reports that the Texas Water Commission estimated the volume of unappropriated water in the Brazos at the proposed diversion to be an average of 3,137,000 acft/yr, with a minimum annual volume of 40,800 acft (1956), and a maximum annual volume of 8,854,000 acft (1957). During the critical dry period from March, 1954 through February 1957, an average of 174,756 acft/yr would be available. These estimates were computed on a monthly basis, using historical flows between 1947 and 1976 adjusted to reflect watershed conditions and existing water rights as of June 30, 1986; no instream or bay and estuary inflow requirements were applied.

[56]Freese & Nichols, Inc., "Brazos River Authority, Yield Analysis and Cost Estimate for Allens Creek Reservoir", February 1989.

The volume of Brazos River water that can be diverted and stored is limited by the capacity of the diversion pumps and by the daily flow distribution in the Brazos River, as well as by the reservoir storage volume. In 1994, Freese & Nichols/Brown & Root[57] updated previous yield studies of Allens Creek Reservoir for application of the Trans-Texas Environmental Criteria and recent water rights granted. They estimated that for a diversion rate of 820 cfs, the project firm yield would be 57,800 acft/yr and for a diversion rate of 1,900 cfs, the firm yield would increase to 85,000 acft/yr. For purposes of this study, the river diversion rate was set at 820 cfs for a firm yield of 57,800 acft/yr.

An alternative scenario was evaluated which includes not only unappropriated streamflow but also the purchase of stored water from BRA's existing reservoirs for diversion into the Allens Creek site. For purposes of this analysis it is assumed that the stored water would be delivered during periods of time when the unappropriated water is not being pumped and would not require an increase in the pumping capacity of the river intake. BRA has indicated that currently, up to 95,000 acft/yr is available for purchase from storage. This volume of water combined with the unappropriated water would create a combined project yield of 152,800 acft/yr (57,800 acft/yr unappropriated water plus 95,000 acft/yr purchased water). Should this project continue past Phase I as an alternative water supply for the West Central Area, a reservoir operations study, including the delivery of stored water, would probably indicate that the combined firm yield is in excess of 152,800 acft/yr.

3.31.3 Environmental Issues

The proposed Allens Creek Reservoir will provide two benefits: a uniform delivery rate regardless of Brazos River flows, allowing the transmission pipeline to be fully utilized year round, and sedimentation of suspended material during storage, prior to placement in the cross country transmission pipeline. This alternative includes a transmission pipeline from Allens Creek Reservoir to the crossing of IH-10 and the Colorado River, and would use the same transmission pipeline corridor from the IH-10 and Colorado River crossing to

[57]Brown & Root, Inc. and Freese & Nichols, Inc., "Trans-Texas Water Program, Southeast Area Phase I Report", March, 1994.

San Antonio as discussed in Section 3.29.3. The transmission pipeline from the proposed Allens Creek Reservoir begins in Omernik's Western Gulf Coastal Plains Ecoregion[58] (southern Austin County). It then extends across the East Central Texas Plains (northern Austin County and eastern Colorado County) and Texas Blackland Prairies Ecoregions (western Colorado County) before reaching the IH-10 and Colorado River crossing. Water from Allens Creek would be used for i) delivery to Edward's Aquifer injection wells (see Section 3.4), ii) delivery to recharge structures in the recharge zone (see Section 3.8 and 3.9), and iii) delivery to the San Antonio municipal distribution system.

The proposed Allens Creek reservoir is located in the Western Gulf Coastal Plain as described by Omernik[59]. This ecoregion is distinguished by its mosaic of bluestem and sacahuista grasses, croplands and grazing lands. Soils are primarily vertisols. Gould categorizes this area as being in the Gulf Prairies and Marshes vegetational region of Texas[60] which is a prairie region extending inland from the Gulf of Mexico to elevations near 150 feet. It is a mosaic of grasslands and savannahs dissected by streams flowing into the Gulf. Live oak woodlands and narrow belts of low wet marsh occur immediately adjacent to the coast. Correll and Johnston described the climax vegetation as being tall grass prairie and post oak savannah, such as big bluestem, seacoast bluestem, Indian grass, eastern gama grass, gulf muhly, species of *Panicum* and others[61]. However the climax vegetation has generally been reduced to small areas and replaced with mesquite, oak, prickly pear, and several *acacias*.

Blair categorizes this area as being in the Texan Biotic Province[62]. The Texan Biotic Province as described by Blair is a broad ecotone between western grasslands and eastern

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[58]Ibid.

[59]Omernik, James M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1) pp. 118-125.

[60]Gould, F.W., 1975, The Grasses of Texas, Texas A & M University Press, College Station, Texas.

[61]Correll, D.S., and M.C. Johnston. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

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

forests. Blair's biogeographical listing of wildlife fauna for this province is a mix of western grassland-associated and eastern forest associated species.

The two dominant soil types found in the area to be inundated by the proposed reservoir consist mainly of Brazoria Clays. Brazoria Clay (BrA), 0 to 1 percent slopes, and the Brazoria Clay (Bs), depressional, are both deep level soils on flood plains adjacent to the Brazos River. Brazoria clays are moderately alkaline, calcareous, and poorly drained. Surface runoff and permeability are slow, the available water capacity is high and erosion hazard is slight. The BRA soil (0 to 1 percent slopes) is used mainly for pasture and crops, is well suited to corn, soybeans, and forage sorghums, and is poorly suited to urban uses. Brazoria depressional soil is slightly lower than surrounding soils and is subject to flooding for short periods. It is used mainly for pasture and range, with some areas in cropland. This soil is poorly suited to urban use because of the hazard of flooding.

The Allens Creek Reservoir site is presently used primarily for farm land and pasture, but it still supports large stands of trees and associated vegetation[63]. The riparian vegetation consists of cedar, elm, black willow, hackberry, soapberry, pecan, ash, and poison oak. The area that would be inundated by the proposed reservoir is a complex mosaic of woodlands, grasslands and croplands which have a steady water supply and together provide a high quality habitat for a wide variety of species[64].

Direct impacts of the proposed reservoir would include construction of the dam, inundation of 8,250 acres of primarily bottomland hardwoods and croplands, the withdrawal of water from the Brazos River, and the construction of a pipeline and ROW maintenance from Allens Creek to a connecting pipeline in the vicinity of the crossing of IH-10 and the Colorado River. Construction of the 36 mile transmission line will affect a total area of 435 acres (see Table 3.0-1). The largest habitat types that will be impacted by construction are croplands (151 acres), woodlands (80 acres), and developed areas (78 acres). The construction of the pipeline would include the clearing and removal of woody vegetation. In addition, the pipeline ROW (131 acres) would be maintained for the life of the project.

[63]Freese and Nichols, Inc.; Brazos River Authority, Yield Analysis and Cost Estimate for Allens Creek Reservoir; February, 1989.

[64]Ibid.

Impacts on wildlife habitats can be minimized by locating the pipeline ROW in previously disturbed areas, such as crop and pasture lands. A cleared pipeline ROW through a woodland or brushy habitat could be beneficial to some wildlife by providing edge habitat, except where fragmented habitat remnants do not suffer a shortage of edges.

Although the Texas Natural Heritage Program does not report any endangered or threatened species within the pipeline corridor, several rare prairie remnant communities have been confirmed and located within the proposed one-mile wide corridor (see Table 3.31-1). Several protected species occurrences have been confirmed in the vicinity, such as the Texas tortoise, the reticulate collared lizard, the Texas horned lizard, the Indigo snake, and the Texas garter snake. These remnant communities and the habitat of these protected species should be avoided where practical.

The pipeline corridor will be traversing what is considered to be essential habitat for the Attwater's Prairie Chicken (APC)[65]. The transmission line at Allens Creek Reservoir is approximately 2 miles east of the closest confirmed observation of APC, and is within 5 miles of 12 confirmed occurrences[66]. The APC is dependent on areas that are composed of more than 50 percent tall grass prairie climax species, such as big and little bluestem, Indiangrass and brownseed paspalum. The effects of construction on this habitat would be minimal if a proper corridor is chosen. If appropriate revegetation and management procedures are employed within the transmission line ROW, the habitat could be managed for the benefit of the APC. Implementation of this alternative is expected to require field surveys for protected species, vegetation, habitats, and cultural resources during ROW selection to avoid or minimize adverse impacts.

A 650-acre area of bottomland hardwood surrounding a pond, Alligator Hole, is located within the proposed conservation pool[67]. This bottomland hardwood community appears to be frequently inundated by flood flows and is considered to be wetland habitat

[65]United States Fish and Wildlife Service. 1992. Attwater's Prairie Chicken Recovery Plan. Albuquerque, NM. vii + 48 pp.

[66]Texas Parks and Wildlife Department, Resource Protection Division,Natural Heritage Program. 1994

[67]Freese and Nichols, Inc.; Brazos River Authority, Yield Analysis and Cost Estimate for Allens Creek Reservoir; February, 1989.

Table 3.31-1
Protected Species with Habitat in the Project Vicinity (B-10)

Common Name	Scientific Name	Habitat Preference	Listing Agency	
			USFWS	TPWD
Attwater's Prairie-Chicken	*Typanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition; Austin and Colorado Counties	E	E
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with nearby resting sites, nesting in forested river bottoms in coastal Texas	E	E
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E
Houston Toad	*Bufo Houstonensis*	Loamy soils temporary rain pools, flooded field, ponds surrounded by forest or grass; reintroduced in Colorado Co., Texas	E	E
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL
Western Smooth Green Snake	*Opeodrys vernalis blanchardi*	Coastal grasslands	NL	E
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T
Reticulated Collared Lizard	*Crotaphytus reticulatus*	South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	NL	T
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or hides under rocks		
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas arroyos, canals, ditches and depressions; requires moisture	C2	E

Table 3.31-1 Continued Protected Species with Habitat in the Project Vicinity (B-10)				
Common Name	**Scientific Name**	**Habitat**	**Listing Agency**	
			USFWS	**TPWD**
Texas Meadow-rue	*Thalictrum texanum*	Coastal plains and savannah of south east Texas; known in Brazos and Waller Cos.; historic in Harris Co.	C2	NL
Mulenbrock's Umbrella Sedge	*Cyperus grayioides*	Prairie grasslands, moist meadows in Texas, Louisiana, Illinois	C2	NL
Sandhill Four-O'Clock	*Mirabilis collina*	Sandy thickets and on hillsides	NL	C2
Navasota Ladies-tresses	*Spiranthes parksii*	Open wooded margins of minor tributaries in post oak woodlands of the post oak Savannah; know in Brazos, Burleson, Grimes, Jasper, Lee, Leon, Madison, Robertson, and Washington Cos.	E	E
Prairie Dawn, also called Texas Bitterweed	*Hymenoxys texana*	Gulf prairie and marshes in poorly drained depressions or at the base of mima mounds in open grasslands in almost barren areas; known in Ft. Bend and Harris Cos.; historic collection from LaSalle Co.	E	E
Source: Texas Natural Heritage Program; Unpublished 1994. Texas Parks and Wildlife.				

(USGS, Wallis Quad) which would probably require mitigation. Wetland mapping has not been completed for this area, so a detailed inventory of wetland types is not available for this assessment. An on-site survey to delineate wetlands would be required in future phases of the Trans-Texas Water Program.

There are several protected and candidate species listed for Austin and some of the surrounding counties that may have habitat in the vicinity of the proposed reservoir. Species of particular concern are the Attwater's Prairie Chicken, which prefer native prairie remnants, the timber rattlesnake, black-spotted newt, white-faced ibis, Rio Grande lesser siren, sheep frog and Texas meadow-rue, which prefer bottomland hardwoods, marshes and other wetland areas. The species in Table 3.31-1 would require an on-site survey and possibly require mitigation if impacted by the proposed reservoir.

The water quality of natural runoff into the proposed Allens Creek Reservoir is not known. The Brazos River Basin's overall surface water quality is relatively good, with only localized areas of concern, such as natural and man-made salt pollution, and localized problems of low dissolved oxygen and elevated fecal coliform levels[68]. Specific water quality assessments will be completed in later phases of the Trans-Texas study, if diversions from the Brazos River to the proposed Allens Creek Reservoir should continue to be considered as an alternative water supply.

A more precise estimate of the firm yield of the project will need to be made using reservoir operation studies in subsequent Trans-Texas studies if this alternative is given further consideration. The Brazos River has already filled its Pleistocene river valley with sediments, so that its estuary consists only of the lower few miles of channel before it discharges into the Gulf of Mexico.

Cultural resources protection on public lands in Texas, or lands affected by projects regulated under Department of the Army permits, is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National Historic Preservation Act (PL96-515), and the Archaeological and Historic Preservation Act (PL93-291). All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided. Previous investigations have revealed large numbers of archaeological sites around the perimeter of the proposed reservoir[69]. It is probable that some further testing and mitigation in the reservoir pool would be needed.

3.31.4 Water Quality and Treatment

[To be provided in subsequent phases of this study.]

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[68]Texas Water Development Board. December 1990. Water for Texas; Today and Tomorrow. Texas Water Development Board, Austin, Texas.

[69]Freese and Nichols, Inc.; Brazos River Authority, Yield Analysis and Cost Estimate for Allens Creek Reservoir; February, 1989.

3.31.5 Engineering and Costing

Pump station and transmission pipelines have been sized and costed for two annual delivery volumes: the lower amount includes only unappropriated water rights. This scenario produces a firm yield of 57,800 acft/yr. The second scenario or delivery option also includes the purchase of stored water from the Brazos River Authority (BRA) and is added to the unappropriated rights. For this analysis, 95,000 acft/yr of stored water is assumed to be purchased from BRA, resulting in a total annual firm yield of 152,800 acft for the second scenario.

Four alternative project configurations including three delivery points have been studied as defined in Table 3.31-2. The location of the transmission pipeline and delivery points are shown on Figure 3.31-1.

Table 3.31-2
Definition of Alternatives for Allens Creek Reservoir Project
(Alternative B-10)

Alternative	Project Yield (acft/yr)	Delivery Location
B-10A	57,800	Injection Wells to Aquifer
B-10B	57,800	Recharge Zone
B-10C	57,800	North Water Treatment Plant
B-10D	152,800	North Water Treatment Plant

Alternative B-10A: Delivery to Aquifer Injection Wells at Rate of 57,800 acft/yr

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the injection well field in eastern Medina County. The diversion rate from the reservoir, as well as the delivery to the wells would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, four required
Water Treatment Plant (Level 2)
Finished Water Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

Cost estimate summaries for the Allens Creek project and each alternative delivery, are provided in Table 3.31-2. The cost estimate for the reservoir and dam is an update of the estimate prepared by Freese & Nichols, in which they estimated the reservoir and dam to cost $57 million in 1988 dollars, including permitting and environmental mitigation; the cost estimate for the river diversion, pump station, and pipeline is $15.9 million for 480 cfs capacity and $24.9 million for 770 cfs capacity. The 1988 cost estimate for each of the project components was updated by multiplying the individual cost components of the estimate by the relevant ENR CCI or USBR construction cost index ratios (1994/1988). The mid-1994 estimated total project cost for the dam and reservoir totals $121,490,000.

River intake and pump station are sized to deliver 50,000 acft/month into Allens Creek Reservoir through two 120-inch diameter pipes. The reservoir intake and pump station is sized to deliver 4,900 acft/month (52 mgd) to the West Central Study Area through a 54-inch diameter pipeline. The operating cost was determined for the raw water static head of 880 feet and an annual water delivery of 57,800 acft/year. Operating cost of the finished water pumping system was determined for the total static head of 50 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $40,360,000 (Table 3.31-3). Operation and maintenance costs total $21,970,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $62,330,000. For an annual firm yield of 57,800 acft, the resulting annual cost of water is $1,079 per acft (Table 3.31-3).

Table 3.31-3 Cost Estimate Summaries for Allens Creek Reservoir (B-10) Mid- 1994 Prices)				
Item	Alt. B-10A Divert and Inject to Aquifer	Alt. B-10B Divert to Recharge Zone	Alt. B-10C Divert to WTP and Municipal System	Alt. B-10D Divert to WTP and Municipal System
Capital Costs				
Dam and Reservoir	$48,710,000	$48,710,000	$48,710,000	$48,710,000
Transmission and Pumping	189,310,000	174,600,000	143,700,000	265,720,000
Treatment Plant	16,320,000	16,320,000	23,640,000	54,570,000
Delivery System	8,520,000	8,760,000	45,420,000	88,920,000
Total Capital Cost	$262,860,000	$248,390,000[(1)] 232,070,000[(2)]	$261,470,000	$457,920,000
Engineering, Contingencies, and Legal Costs	84,080,000	79,430,000[(1)] 73,720,000[(2)]	81,310,000	139,970,000
Land Acquisition	29,010,000	29,060,000[(1)] 29,010,000[(2)]	28,300,000	28,300,000
Environmental Studies and Mitigation	25,610,000	24,530,000	22,500,000	22,500,000
Interest During Construction	29,180,000	27,700,000[(1)] 26,370,000[(2)]	26,710,000	51,910,000
Total Project Cost	$430,740,000	$409,110,000[(1)] $385,700,000[(2)]	$420,290,000	$700,600,000
Annual Costs				
Annual Debt Service	$40,360,000	$38,330,000[(1)] $36,140,000[(2)]	$39,380,000	$65,650,000
Purchase of Stored Water	N/A	N/A	N/A	1,820,000
Annual Operation and Maintenance	6,920,000	6,850,000[(1)] 3,550,000[(2)]	6,570,000	13,550,000
Annual Power Cost	15,050,000	15,360,000	12,720,000	25,890,000
Total Annual Cost	$62,330,000	$60,540,000[(1)] $55,050,000[(2)]	$58,670,000	$106,910,000
Available Project Yield (acft/yr)	57,800	57,800	57,800	152,800
Annual Cost of Water	$1,079/acft	$1,047/acft[(1)] $952/acft[(2)]	$1,015/acft	$700/acft

[(1)]Cost with treatment prior to surface recharge.
[(2)]Cost without treatment prior to surface recharge.

Alternative B-10B: Delivery to Recharge Structures in the Recharge Zone at a Rate of 57,800 acft/yr

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to small recharge structures in northwestern Bexar County located on the recharge zone. The diversion rate from Allens Creek Reservoir, as well as the delivery to the recharge structures would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and possibly springs. Concerns that the imported water is of different quality than the existing recharge water and the need for treatment of the imported water will require follow-on study. For comparison and information purposes, project cost estimates have been prepared with and without treatment of the imported water. To determine the cost to treat the imported water, a typical direct filtration process (Treatment Level 2, Table 3.0-4) was assumed.

The major facilities required to implement this alternative are:

River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Recharge Zone or Treatment Plant
Raw Waterline Booster Pump Stations, four required
Recharge Structures, four required
Treatment Plant Items (if needed):
- Water Treatment Plant (Level 2, Table 3.0-4)
- Finished Water Pump Station
- Transmission Line to Recharge Zone

The river intake and pump stations are sized to delivery 50,000 acft/month through two 120-inch diameter pipes. The reservoir intake and pump station is sized to deliver 4,900 acft/month (52 mgd) through a 54-inch diameter pipeline. The operating cost was determined for the raw water static lift to the treatment plant of 880 feet and an annual water delivery of 57,800 acft/year. If no treatment plant is required, then the operating cost is determined for the total raw water static lift to the recharge structures of 230 feet. For a treatment plant, the operating cost of the finished water pumping system was determined for the total pumping head of 300 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $38,330,000 with a treatment plant and

$36,140,000 with no treatment plant (Table 3.31-3). Operation and maintenance costs total $22,210,000 including the treatment plant and are $18,910,000 without a treatment plant. The annual costs, including debt repayment, interest, and operation and maintenance, total $60,540,000 including the treatment plant and are $55,050,000 without a treatment plant. For an annual firm yield of 57,800 acft, the resulting annual cost of water, including a treatment plant, is $1,048 per acft, and is $953 per acft without a treatment plant (Table 3.31-3).

Alternative B-10C: Delivery to the Municipal Distribution System at a Rate of 57,800 acft/yr

For this alternative, the firm yield of the proposed reservoir would be diverted through an intake and pumped in a transmission line to the North Water Treatment Plant (Figure 3.31-1). The diversion rate from the reservoir would be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, four required
Water Treatment Plant (Level 3, see Table 3.0-4)
Distribution System Improvements

The river intake and pump station are sized to deliver 50,000 acft/month through two 120-inch diameter pipes. The reservoir intake and pump station is sized to deliver 4,900 acft/month (52 mgd) through a 54-inch diameter pipeline. The operating cost was determined for the raw water static lift of 880 feet and an annual water delivery of 57,800 acft/year. Operating cost of the finished water pumping system was determined for the static lift of 300 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $39,380,000 (Table 3.31-3). Operation and maintenance costs total $19,290,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $58,670,000. For an annual firm yield of 57,800 acft, the resulting annual cost of water is $1,015 per acft (Table 3.31-3).

Alternative B-10D: Delivery to the Municipal Distribution System - at a Rate of 152,800 acft/yr Firm Yield

The facilities necessary for this alternative are identical to Alternative B-10C, with the only difference being the size of certain futures to handle the larger annual yield of this project. The major facilities required to implement this alternative are:

River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, four required
Water Treatment Plant (Level 3, see Table 3.0-4)
Distribution System Improvements

The river intake and pump station are sized to deliver 50,000 acft/month through two 120-inch diameter pipes. The reservoir intake and pump station is sized to deliver 12,750 acft/month (137 mgd) through a 90-inch diameter pipeline. The operating cost was determined for the total raw water pumping head of 880 feet and an annual water delivery of 152,000 acft/year. The estimated purchase price of stored water from BRA is $19.15/acft per year. Operating cost of the finished water pumping system was determined for the total pumping head of 300 feet. Financing the project over 25 years at an 8 percent annual interest rate results in an annual expense of $65,650,000 (Table 3.31-3). Operation and maintenance costs total $39,440,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $106,910,000. For an annual firm yield of 152,800 acft, the resulting annual cost of water is $700 per acft (Table 3.31-3).

3.31.6 Implementation Issues (B-10, All)

An institutional arrangement is needed to implement projects including financing on a regional basis.

1. It will be necessary to obtain these permits:
   a. TNRCC Water Right and Storage permits.

b. TNRCC Interbasin Transfer Approval.
c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
d. GLO Sand and Gravel Removal permits.
e. GLO Easement for use of state-owned land.
f. Coastal Coordinating Council review.
g. TPWD Sand, Gravel, and Marl permit

2. Permitting, at a minimum, will require these studies:
   a. Bay and estuary inflow impact.
   b. Habitat mitigation plan.
   c. Environmental studies.
   d. Cultural resource studies.
3. Land will need to be acquired by negotiations or condemnation.
4. Relocations for the reservoir include:
   a. Highways and railroads
   b. Other utilities

Requirements Specific to Pipelines (B-10, All)

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (B-10A)

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer.
   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.
   d. Eater compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.

   e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
   a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (B-10B)

1. Detailed field investigations of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
   a. TNRCC Water Rights and Storage permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
   c. GLO Sand and Gravel Removal permit.
   d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
   a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
   b. Study of impact on karst geology organisms from a sustained recharge program.
   c. Other environmental studies.
   d. Cultural resource studies.

Requirements Specific to Treatment and Distribution (B-10C, D)

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

3.32 Toledo Bend Reservoir (SB-10)

3.32.1 Description of Alternative

Toledo Bend Reservoir on the Sabine River is jointly owned and operated by the Sabine River Authority of Texas (SRA) and the Sabine River Authority of Louisiana. By agreement between Texas and Louisiana, each state shares equally in the yield of the reservoir, which has a total annual firm yield of 2,086,600 acft[70]. The Texas portion of the yield is 50 percent or 1,043,300 acft/yr. However, the SRA holds permits from the TNRCC to divert only 750,000 acft/yr or 72 percent of the yield. The remaining portion of the yield (i.e. 293,300) is currently unpermitted.

In the Southeast Study Area Report of the Trans-Texas Water Program[71], Brown & Root has studied various delivery routes to transport water from the reservoir to meet water demands at several locations in the Southeast Area. Additionally, the study included an analysis of possible routes to transfer water from the Southeast Area to the South Central and West Central Study Areas, and two potential points of transfer in the Brazos basin were identified. One is at Lake Somerville, an existing BRA reservoir in Burleson and Washington counties, and the other is at BRA's proposed Allens Creek Reservoir to be located in Austin County. The Southeast Study Area report did not include an estimate of the cost to deliver Toledo Bend water to either of these locations.

In order to determine a cost of water for this alternative, a cost analysis was performed to determine the cost to construct a water delivery system to the West Central Study Area from Toledo Bend Reservoir. Water from Toledo Bend would be transferred by pipeline through the Southeast Area by one of the alternative conveyance routes identified by Brown & Root to a connecting pipeline in the general vicinity of the proposed Allens Creek Reservoir along the IH-10 corridor in Austin County. For this alternative, the water would not be blended with any other supplies but would remain in the transmission pipe, without any intermediate impoundment, for terminal delivery to the West Central Study Area. Two delivery rates have been studied and three points of delivery are

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[70]Brown & Root, Inc. and Freese & Nichols, Inc.; "Trans-Texas Water Program, Southeast Area, Phase I Report," March 1994.

[71]Ibid.

considered: (1) to the aquifer via injection wells (Alt SB-10A); (2) to the aquifer via recharge structures (Alt SB-10B); and, (3) to the municipal distribution system (Alt SB-10B and SB-10C). The location of the delivery facilities is shown on Figure 3.32-1.

3.32.2 Available Yield

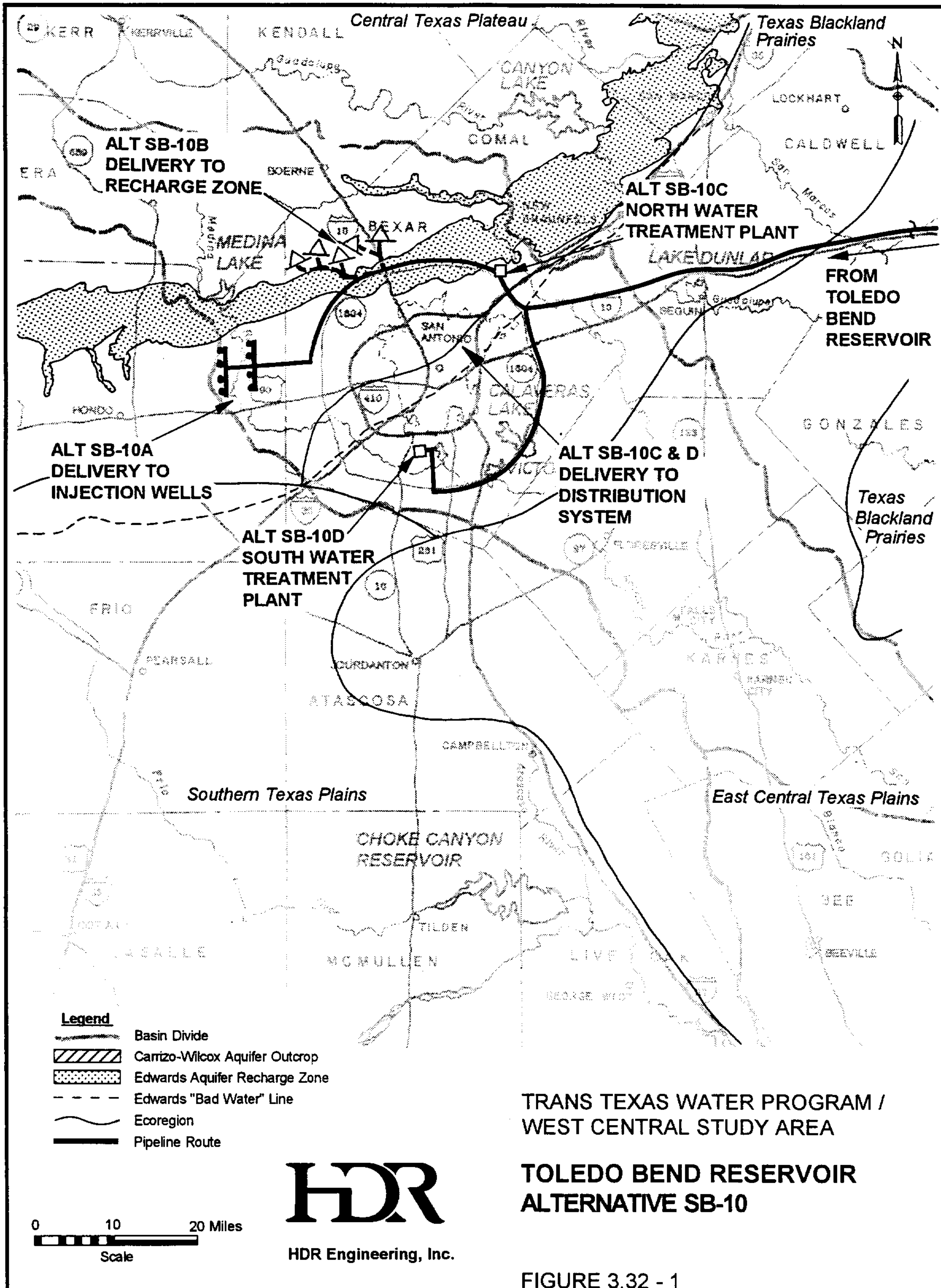
Brown & Root reports a projected water surplus in the Southeast Area of 1,618,000 acft/yr in year 2000, but by the year 2050 the projected demand exceeds currently available supplies. Although no water is projected to be available for interbasin transfer at the end of the planning horizon, there presently is excess availability, creating at least a temporary water supply to be considered for interbasin transfer. For Phase I analysis purposes, TWDB, in consultation with study participants and consultants, has defined three alternative demand scenarios for interbasin transfer of water from the area. The first scenario includes no needs being met by area water and no water transfer; scenario two provides for transfer of 600,000 acft/yr from the area; and scenario three provides for a transfer of 300,000 acft/yr. According to the water demand projections contained in the Southeast Study, 600,000 acft/yr of surplus could be available until the year 2025, and 300,000 acft/yr could be available until the year 2035.

3.32.3 Environmental Issues

Environmental setting, water quality and the potential effects of several water transport routes from Toledo Bend Reservoir to locations on the Brazos River are addressed in the Draft Phase I Report for the Southeast Study Area of the Trans-Texas Water Program.

Water from Toledo Bend would be transferred through the southeast area by one of the alternative transmission routes evaluated by Brown & Root to a connecting pipeline in the general area of the IH-10 corridor in southern Austin County, near the proposed Allens Creek Reservoir[72]. For a detailed description of the pipeline corridor along IH-10 from the

[72]Brown & Root, Inc. and Freese & Nichols, Inc., March 1994, Trans-Texas Water Program, Southeast Area, Phase I Report.



TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

TOLEDO BEND RESERVOIR ALTERNATIVE SB-10

FIGURE 3.32 - 1

vicinity of Allen's Creek Reservoir to San Antonio's North Treatment Plant refer to Section 3.31 (Alt. B-10).

Because each of the proposed delivery rates from the Southeast Area exceeds the capacity of any single terminal delivery point a combination of alternative scenarios will have to be used. An additional water treatment facility will have to be built to handle the supply.

Use of the injection well field is discussed in Sections 3.0.1 and 3.4.3, while the use of Type 2 recharge reservoirs is addressed in Section 3.9.3. However, this alternative envisions the injection or percolation recharge of far greater quantities of water than any of the other alternatives, and consequently involves some differences in proposed operation. For example, standing water would have to be maintained constantly in the five Type 2 recharge impoundments located in northern Bexar County to achieve a recharge rate of 200,000 acft/yr. Likewise, the injection well field would require either additional wells, or higher capacity wells to achieve higher recharge rates.

Water chemistry transformations resulting from thermal stratification, a potential concern in large Type 1 impoundments, would be avoided in continuously recharging Type 2 impoundments by maintaining appropriately brief residence times. Water delivered to these sites (or the injection well field) by pipeline, particularly if it has been treated, would not contain significant suspended material, and could be depleted in both oxygen and oxidizable organic matter as a consequence of its residence in the pipeline.

Continuous recharge to the Edwards Aquifer is now taking place in both natural (Guadalupe River, Blanco River) and man-made situations (Medina-Diversion Lakes), but there is no knowledge of how (or if) the aquifer fauna exposed to that water differs from assemblages in areas receiving intermittent recharge water. It is assumed that subterranean communities experiencing carbon and energy input as pulses of organic matter carried by periodic recharge events would respond in some way when input becomes a continuous flow with a relatively low content of particulate organic matter. However, only a few generalizations are available to evaluate the potential effects of this alternative, particularly when the proposed recharge water differs in origin and quality from that typical of streams originating on the Edwards Plateau.

- Recharge rates of 200-400,000 acft/yr are substantial compared to existing, normal levels of recharge, and coupled with increased rates of withdrawal would reduce detention time and tend to increase mixing in the aquifer.

- Since significant reaeration is unlikely within the aquifer, recharge water must contain sufficient oxygen to maintain present conditions, while excessive concentrations of oxygen-demanding materials could also adversely affect oxygen levels within the aquifer. On the other hand, the carrying capacity of the aquifer environment might be enhanced by modest additions to its carbon and energy budget.

- Since primary production within the aquifer is light-limited, variations in nutrient concentrations are unlikely to have any important effects, except in special circumstances. For example, ammonia exerts an immediate oxygen demand, and high concentrations (>1 mg/l) could impact dissolved oxygen levels within local areas of the aquifer. Nitrate (NO^{3}-) can function as the final electron acceptor in the metabolism of certain chemoautotrophic microbial species that are likely to be present at the margin of the anoxic zone. It seems unlikely, however, that mixing rates would be sufficient to bring enough recharged nitrate into contact with the bad water line to have any effect on resident chemoautotrophic populations, particularly since the anoxic (bad water) zone appears to be the result of insufficient circulation.

- Many aquatic organisms are sensitive to pH levels. While Toledo Bend water tends to exhibit a more acid pH than Edwards Plateau water, it also tends to be poorly buffered, suggesting that any adverse conditions may be localized.

- Toledo Bend water tends to contain lower concentrations of dissolved solids, particularly with respect to alkalinity and hardness, than does Edwards Plateau water. While aquatic organisms typical of harder and more alkaline waters are often (but not in all cases) tolerant of "soft" water, the converse is not generally true.

The primary impacts that would result from construction and operation include temporary disturbance to soils and habitat during construction of wells, pipelines and other facilities, as well as permanent conversion of existing habitats or land uses to maintained pipeline ROW; disturbance of minor acreages for construction of water treatment plants, storage stations and well injection fields; and mixing of treated Toledo Bend water with waters of the Edwards Aquifer. Water quality impacts on the Edwards Aquifer from treated Toledo Bend water will be studied in a later phase of Tran-Texas, if this alternative is selected for further consideration.

Cultural resources protection on public lands in Texas is afforded by the Antiquities Code of Texas (Title 9, Chapter 191, Texas Natural Resource Code of 1977), the National

Historic Preservation Act (PL 96-515), and the Archaeological and Historic Preservation Act (PL 93-291). All areas to be disturbed during construction would first be surveyed by qualified professionals to determine the presence or absence of significant cultural resources. Additional measures to mitigate impacts may be required by the presence of significant cultural deposits that cannot be avoided.

3.32.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.32.5 Engineering and Costing

Pump station and transmission pipelines have been sized and costed for two annual delivery volumes: 600,000 acft/yr and 300,000 acft/yr. However, because of the magnitude of these delivery volumes, the sizing of the terminal delivery points was revised. For the injection well delivery option, Guyton[73] estimates that an injection well field south of Diversion Lake with 11 injection wells will have a capacity of 73,000 acft/yr. Assuming that usage of a much larger injection well area would allow a proportional increase in the number of wells and the recharge capacity, then approximately 45 wells would be needed to deliver 300,000 acft/yr to the aquifer and 90 wells would be needed to deliver 600,000 acft/yr.

For the recharge dam delivery option, the five recharge structures considered were upsized to each deliver 60,000 acft/yr for the 300,000 acft/yr option and 120,000 acft/yr for the 600,000 acft/yr option. Each of the these structures would be sized with a recharge pool of about 115 acres for the 300,000 acft/yr option and 230 acres for the larger delivery rate.

For the municipal system delivery option, delivery would be split to both the North and South proposed surface water treatment plants in order to distribute the treated water more uniformly to the various pressure zones within the City's distribution system. For this delivery option, the capacity of each water treatment plant would be 134 mgd (300,000 acft/yr total), or 268 mgd (600,000 acft/yr total).

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[73]W.E. Simpson Co, Bryant-McClelland Consultants, and W.F. Guyton Assoc; "Medina Lake Study, Volume Three: Recharge Evaluation"; no date.

To implement this alternative, water would be diverted at Toledo Bend Reservoir and pumped in a large diameter transmission pipeline (or two pipelines for the larger diversion rate) through the Southeast Study Area and then along the IH-10 corridor to the Southeast Area. For purposes of the Phase 1 costing analysis the delivery rate was assumed to be uniform throughout the year to each delivery location.

Table 3.32-1 defines the alternative delivery points studied for each flow rate.

Table 3.32-1
Definition of Alternatives for Toledo Bend Reservoir
(Alternative SB-10)

Alternative	Project Yield (acft/yr)	Delivery Location
SB-10A	300,000	Injection Wells to Aquifer
SB-10B	300,000	Recharge Zone
SB-10C	300,000	Water Treatment Plants (50% to North WTP; 50% to South WTP)
SB-10D	600,000	Water Treatment Plants (50% to North WTP; 50% to South WTP)

Alternative SB-10A: Delivery to Aquifer Injection Wells - 300,000 Acft/Yr Rate

For this alternative, the project yield would be delivered to the injection well field in eastern Medina County. The diversion rate from the Toledo Bend reservoir, as well as the delivery to the wells was assumed to be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, five required
Water Treatment Plant (Level 2, Table 3.0-4)
Finished Water Pump Station

Finished Water Booster Pump Stations, one required
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The Toledo Bend intake and pump station is sized to deliver 25,000 acft/month through an 120-inch diameter pipeline. The operating cost was determined for the static lift of 882 feet and an annual water delivery of 300,000 acft/yr. Operating cost of the finished water pumping system was determined for the total static lift of 50 feet. The cost of purchasing water from the Sabine River Authority was estimated to be $25 per acft/yr. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $180,290,000 (Table 3.32-2). Operation and maintenance costs, including power, total $105,230,000. The annual costs, including debt repayment, interest, water purchase, and operation and maintenance, total $293,020,000. For an annual firm yield of 300,000 acft, the resulting annual cost of water is $977 per acft (Table 3.32-2).

<u>Alternative SB-10B: Delivery to Recharge Structures in the Recharge Zone - 300,000 acft/yr Rate</u>

For this alternative, the project yield would be diverted through an intake and pumped in a transmission line to recharge structures in northwestern Bexar County located over the recharge zone. The diversion rate from the reservoir, as well as the delivery to the recharge structures would be uniform throughout the year. The benefit from this project would include the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Concerns that the imported water is of different water than the existing recharge water and the need for treatment of the imported water will require follow up study. For comparison and information purposes, project cost estimates have been prepared both with and without treatment of the imported water. The cost to treat the imported water prior to surface recharge was determined based on the cost of a typical direct filtration process (Treatment Level 2, Table 3.0-4).

The major facilities required to implement this alternative are:

Table 3.32-2
Cost Estimate Summaries for Toledo Bend Water Supply (Alt. SB-10)
(Mid- 1994 Prices)

Item	Alt. SB-10A Divert and Inject to Aquifer	Alt. SB-10B Divert to Recharge Zone	Alt. SB-10C Divert to WTP and Municipal Systems	Alt. SB-10D Divert to WTP and Municipal Systems
Capital Costs				
Transmission and Pumping	$1,245,340,000	$1,253,280,000	$1,109,000,000	$1,949,500,000
Treatment Plant	43,800,000	49,200,000	107,200,000	186,080,000
Delivery System	49,210,000	42,570,000	156,010,000	291,200,000
Total Capital Cost	$1,338,350,000	$1,345,050,000[1] $1,295,850,000[2]	$1,372,210,000	$2,426,780,000
Engineering, Contingencies, and Legal Costs	412,960,000	415,500,000[1] 398,280,000[2]	417,490,000	733,950,000
Land Acquisition	3,930,000	6,010,000[1] 5,960,000[2]	3,790,000	5,180,000
Environmental Studies and Mitigation	10,610,000	16,620,000	7,290,000	10,160,000
Interest During Construction	158,260,000	157,430,000[1] 153,450,000[2]	147,930,000	273,960,000
Total Project Cost	$1,924,110,000	$1,940,610,000[1] $1,870,160,000[2]	$1,948,710,000	$3,452,030,000
Annual Costs				
Annual Debt Service	$180,290,000	$181,830,000[1] $175,230,000[2]	$182,590,000	$323,450,000
Annual Operation and Maintenance	32,180,000	35,850,000[1] 17,750,000[2]	32,390,000	57,790,000
Purchase of Stored Water	7,500,000	7,500,000	7,500,000	15,000,000
Annual Power Cost	73,050,000	86,040,000	60,700,000	120,530,000
Total Annual Cost	$293,020,000	$311,220,000[1] $286,520,000[2]	$283,180,000	$516,770,000
Available Project Yield (acft/yr)	300,000	300,000	300,000	600,000
Annual Cost of Water	$977/acft	$1,037/acft[1] $955/acft[2]	$944/acft	$861/acft

[1]Cost with treatment prior to surface recharge.
[2]Cost without treatment prior to surface recharge.

Reservoir Intake and Pump Station
Raw Water Pipeline to Recharge Zone or Treatment Plant
Raw Waterline Booster Pump Stations, five required
Recharge Structures, five required
Treatment Plant Items (if determined to be needed):
- Water Treatment Plant (Level 2)
- Finished Water Pump Station
- Finished Water Booster Pump Stations, one required
- Transmission Line to Recharge Zone

The Toledo Bend intake and pump station is sized to deliver 25,000 acft/month through an 120-inch diameter pipeline. The operating cost was determined for the static lift of 880 feet and an annual water delivery of 300,000 acft/yr. If no treatment plant is required, then the operating cost is determined for the total raw water static lift to the recharge structures of 1,112 feet. The cost of purchasing water from the Sabine River Authority was estimated to be $25 per acft/yr. For a treatment plant, the operating cost of the finished water pumping system was determined for the total static lift of 230 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $181,830,000 with a treatment plant and $175,230,000 with no treatment plant (Table 3.32-2). Operation and maintenance costs, including power, total $121,890,000, including the treatment plant and are $103,790,000 without a treatment plant. The annual costs, including debt repayment, interest, water purchase, and operation and maintenance, total $311,220,000, including the treatment plant and are $286,520,000 without a treatment plant. For an annual firm yield of 300,000 acft, the resulting annual cost of water, including a treatment plant, is $1,037 per acft, and is $955 per acft without a treatment plant (Table 3.32-2).

Alternative SB-10C: Delivery to the Municipal Distribution System - 300,000 acft/yr Rate

For this alternative, the project yield would be diverted through an intake and pumped in a transmission line to the North and South Water Treatment Plants. The diversion rate from the reservoir was assumed to be uniform throughout the year. The benefit from this project would be the addition of a new potable water supply to the San

Antonio distribution system and possibly other municipal systems in the surrounding area. The major facilities required to implement this alternative are:

Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, seven required
North Water Treatment Plant (Level 3, see Table 3.0-4)
South Water Treatment Plant
Finished Water Pump Stations
Pipelines to Distribution System
Distribution System Improvements

The Toledo Bend intake and pump station is sized to deliver 25,000 acft/month through an 120-inch diameter pipeline. The operating cost was determined for the static lift of 880 feet and an annual water delivery of 300,000 acft/yr. The project yield was assumed to be split equally for delivery to the North and South water treatment plants. The cost of purchasing water from Sabine River Authority was estimated to be $25 per acft/yr. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $182,590,000 (Table 3.32-2). Operation and maintenance costs, including power, total $93,090,000. The annual costs, including debt repayment, interest, water purchase, and operation and maintenance, total $283,180,000. For an annual firm yield of 300,000 acft, the resulting annual cost of water is $944 per acft (Table 3.32-2).

<u>Alternative SB-10D: Delivery to the Municipal Distribution System - 600,000 acft/yr Rate</u>

The facilities necessary for this alternative are similar to Alternative SB-10C, with the only difference being the larger annual yield of this project. The major facilities required to implement this alternative are:

Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, seven required
North Water Treatment Plant (Level 3, see Table 3.0-4)
South Water Treatment Plant
Finished Water Pump Stations
Pipelines to Distribution System
Distribution System Improvements

The Toledo Bend intake and pump station is sized to deliver 50,000 acft/month through an 120-inch diameter pipeline. The operating cost was determined for the static lift of 880 feet and an annual water delivery of 600,000 acft/yr. Operating cost of the finished water pumping system was determined for the total pumping head of 300 feet. The project yield was assumed to be delivered split equally for delivery to the North and South water treatment plants. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $323,450,000 (Table 3.32-2). Operation and maintenance costs, including power, total $178,320,000. The annual costs, including debt repayment, interest, water purchase, and operation and maintenance, total $516,770,000. For an annual firm yield of 600,000 acft, the resulting annual cost of water is $861 per acft (Table 3.32-2).

3.11.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Requirements Specific to Pipelines (SB-10, All)

1. Necessary permits:
   a. TNRCC Interbasin Transfer permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   c. GLO Sand and Gravel Removal permits.
   d. Coastal Coordinating Council review.
   e. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (SB-10A)

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer.

   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.
   d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
   e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
   a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

<u>Requirements Specific to Surface Recharge Structures (SB-10B)</u>

1. Detailed field investigations of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
   a. TNRCC Water Rights and Storage permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
   c. GLO Sand and Gravel Removal permit.
   d. TPWD Sand, Gravel, and Marl permit.
4. Permitting, at a minimum, will require these studies:
   a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
   b. Study of impact on karst geology organisms from a sustained recharge program.
   c. Other environmental studies.
   d. Cultural resource studies.

<u>Requirements Specific to Treatment and Distribution (SB-10D)</u>

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

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3.33 Allens Creek Reservoir and Toledo Bend Reservoir (SBB-10)

3.33.1 Description of Alternative

This alternative considers the combined transfer of water from the Sabine and Brazos basins to the West Central Area in a common pipeline installed from Allens Creek Reservoir along the IH-10 corridor. The proposed transmission pipeline route for interbasin transfer of water from the Southeast Area is along the IH-10 corridor and passes near the location of the proposed Allens Creek reservoir in Austin County. The proximity of the Allens Creek Reservoir to the transmission pipeline route would create a possible economic conjunctive use of transmission and pumping facilities with a combined yield from Allens Creek and Toledo Bend reservoirs. Allens Creek Reservoir and Toledo Bend Reservoir are more fully described in Section 3.31 and 3.32, respectively.

For this alternative, the Toledo Bend transmission pipeline would discharge into Allens Creek reservoir, thereby providing balancing storage for uniform operation of the intake and pump station conveying the combined yield to the West Central Area.

The project formulation for study purposes includes two alternative delivery rates (described below), and three points of delivery in the West Central Area: (1) to the aquifer by injection wells (Alt SBB-10A); (2) to the aquifer by surface recharge structures (Alt SBB-10B); and, to the San Antonio municipal distribution system (Alt SBB-10C and SBB-10D).

3.33.2 Available Yield

The quantity from Toledo Bend Reservoir to be used for study purposes is 300,000 acft/yr (see Section 3.32.2). Two quantities from Allens Creek Reservoir are also studied: the firm yield, which is based on pumping unappropriated flows into the project is estimated to be 57,800 acft/yr; and, a larger diversion of 152,800 acft/yr, assuming the purchase of 95,000 acft/yr of stored water from the Brazos River Authority. Thus, the combined annual quantities studied were 357,800 acft/yr and 452,800 acft/yr (300,000 acft/yr from Toledo Bend plus the combined Allens Creek firm yield and purchased water from BRA).

3.33.3 Environmental Issues

Alternative SBB-10 considers the use of Allens Creek Reservoir to receive water transferred from the Sabine River Basin for transport to the West Central Area through the pipelines described in Sections 3.31 and 3.29. This alternative differs from the Allens Creek alternative discussed in Section 3.31 only in that Allens Creek reservoir would serve as the receiving point for water coming from the Trans-Texas Water Program Southeast study area. Potential environmental effects would be the same as those outlined in Section 3.31, with the addition of possible problems from water quality incompatibilities and transferring live organisms from other river basins. Transfer of 300,000 acft/yr of water from Toledo Bend Reservoir, or other eastern sources through the Allens Creek Reservoir would result in this reservoir's water quality becoming very similar to that of the eastern source. In addition, East Texas water could spill into the Brazos River during operation of this alternative.

At this time, literature review relating to both water quality and interbasin organism transfer has not revealed any specific risk factors. Generally, aquatic organisms from harder water with higher total dissolved solids are often tolerant of soft waters with low dissolved solids concentrations, while soft water biota are less likely to be able to successfully adapt to the reverse conditions. On the whole, however, the aquatic biota of the western Austroriparian Biotic Province is very similar to that of the Texan Biotic Province. All of the western Gulf drainages are part of the large ecotone between eastern and western biotas[74], but the Brazos River provides a particularly instructive example within this context. While the Brazos main stem has a fish fauna with strong western affinities, the Navasota River, a major tributary of the Brazos, exhibits a fish assemblage much more typical of the eastern woodlands[75]. The point being that for the fish, at least, distributions are not defined by stream divides, but by the same complex of habitat factors that seem to shape terrestrial population distributions (Section 3.0.1). Additional study of these questions should be conducted during future study phases of the Trans-Texas Water Program.

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[74]Conner, J.V. and R.D. Suttkus, 1986, "Zoogeography of Freshwater Fishes of the Western Gulf Slope of North America," *in:* Hocutt, C.H. and E.O. Wiley, 1986, "The Zoogeography of North American Freshwater Fishes," John Wiley and Sons, New York.

[75]Hubbs, 1957, Distributional Patterns of Texas Fresh-Water Fishes. Southwest. Nat. 2: 89-104.

3.33.4 Water Quality and Treatability

[To be completed in subsequent phases of the study.]

3.33.5 Engineering and Costing

Pump stations and transmission pipelines have been sized and costed for annual delivery volumes of 357,800 acft/yr and 452,800 acft/yr being conveyed to three delivery points. Table 3.33-1 defines the alternative delivery points studied for each quantity of water.

Table 3.33-1
Definition of Alternatives for Combined Allens Creek and Toledo Bend Project (Alternative SBB-10)

Alternative	Project Yield (acft/yr)	Delivery Location
SBB-10A	357,800	Injection Wells to Aquifer
SBB-10B	357,800	Recharge Zone
SBB-10C	357,800	Water Treatment Plants (50% to North WTP; 50% to South WTP)
SBB-10D	452,800	Water Treatment Plants (50% to North WTP; 50% to South WTP)

<u>Alternative SBB-10A: Delivery to Aquifer Injection Wells - 357,800 Firm Yield</u>

For this alternative, the project yield would be delivered to the injection well field in eastern Medina County. The diversion rate from Allens Creek reservoir, with water from Toledo Bend being brought into Allens Creek, as well as the delivery to the wells was assumed to be uniform throughout the year. The benefit from this project includes the enhanced recharge to the aquifer and the increased availability of water to supply wells and possibly springs. Prior to injection to the aquifer, the water would be treated in a direct filtration plant (Treatment Level 2, Table 3.0-4). The major facilities required to implement this alternative are:

Toledo Bend Intake and Pump Station
Pipeline from Toledo Bend to Allens Creek
Brazos River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Allens Creek Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, four required
Water Treatment Plant (Level 2, Table 3.0-4)
Finished Water Pump Station
Transmission Line to Injection Well Field
Aquifer Injection Well Field

The Toledo Bend intake and pump station is sized to deliver 25,000 acft/month to Allens Creek Reservoir through a 120-inch diameter pipeline. The Brazos River intake and pump station is sized to deliver 50,000 acft/month into Allens Creek Reservoir through two 120-inch diameter pipes. The Allens Creek Reservoir intake and pump station is sized to deliver 30,000 acft/month to the West Central Area through two 96-inch diameter pipes. The estimated cost of stored water from Toledo Bend Reservoir is $25 per acft/yr. The operating cost was determined for the static lift of 62 feet at the Brazos intake and 880 feet at the Allens Creek pump station. The annual water delivery would be 300,000 acft/year from Toledo Bend and 357,800 acft/yr through the Allens Creek pump station. Operating cost of the finished water pumping system was determined for a total static lift of 300 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual cost of $208,820,000 (Table 3.33-2). Operation and maintenance costs total $124,490,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $340,800,000. For an annual firm yield of 357,000 acft, the resulting annual cost of water is $952 per acft (Table 3.33-2).

Alternative SBB-10B: Delivery to Recharge Structures in the Recharge Zone - 357,800 acft/yr Firm Yield

For this alternative, the project yield would be diverted through an intake and pumped in a transmission line to small recharge structures in northwestern Bexar County located over the recharge zone. The diversion rate from Toledo Bend and Allens Creek reservoirs, as well as the delivery to the recharge structures would be uniform throughout

Table 3.33-2
Cost Estimate Summaries for Allens Creek And Toledo Bend Reservoir (SBB-10)
(Mid- 1994 Prices)

Item	Alt. SBB-10A Divert and Inject to Aquifer	Alt. SBB-10B Divert to Recharge Zone	Alt. SBB-10C Divert to WTP and Municipal System	Alt. SBB-10D Divert to WTP and Municipal System
Capital Costs				
Dam and Reservoir	$48,710,000	$48,710,000	$48,710,000	$48,710,000
Transmission and Pumping	1,354,280,000	1,282,280,000	1,199,520,000	$1,357,530,000
Treatment Plant	49,200,000	49,200,000	126,160,000	149,960,000
Delivery System	60,780,000	50,080,000	182,930,000	226,130,000
Total Capital Cost	$1,512,970,000	$1,430,270,000(1) $1,381,070,000(2)	$1,557,320,000	$1,782,330,000
Engineering, Contingencies, and Legal Costs	468,830,000	444,110,000(1) 426,890,000(2)	475,660,000	542,350,000
Land Acquisition	32,290,000	33,310,000(1) 33,260,000(2)	31,400,000	31,400,000
Environmental Studies and Mitigation	33,170,000	39,550,000	29,140,000	29,140,000
Interest During Construction	181,190,000	169,830,000(1) 165,840,000(2)	173,100,000	194,270,000
Total Project Cost	$2,228,450,000	$2,117,070,000(1) $2,046,610,000(2)	$2,266,620,000	$2,579,490,000
Annual Costs				
Annual Debt Service	$208,810,000	$198,370,000(1) $191,770,000(2)	$212,380,000	$241,700,000
Purchase of Stored Water	7,500,000	7,500,000	7,500,000	9,320,000
Annual Operation and Maintenance	37,200,000	37,280,000(1) 19,180,000(2)	37,540,000	44,490,000
Annual Power Cost	87,290,000	89,120,000	72,750,000	83,440,000
Total Annual Cost	$340,800,000	$332,270,000(1) $307,570,000(2)	$330,170,000	$378,950,000
Available Project Yield (acft/yr)	357,800	357,800	357,800	452,800
Annual Cost of Water	$952/acft	$929/acft(1) $860/acft(2)	$923/acft	$837/acft

(1)Cost with treatment prior to surface recharge.
(2)Cost without treatment prior to surface recharge.

the year. The benefit from this project would include enhanced recharge to the aquifer and the increased availability of water to municipal supply wells and possibly springs. Concerns that the imported water would need to be treated prior to recharge will require follow-on study. Because of these concerns and for comparative purposes, project cost estimates have been prepared both with and without treatment of the imported water. The cost to treat the imported water prior to surface recharge was determined based on the cost of a typical direct filtration process (Treatment Level 2, Table 3.0-4).

The major facilities required to implement this alternative are:

Toledo Bend Intake and Pump Station
Pipeline from Toledo Bend to Allens Creek
Brazos River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Allens Creek Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Recharge Zone or Treatment Plant
Raw Waterline Booster Pump Stations, four required
Recharge Structures, five required
Treatment Plant Items (if determined to be needed):
- Water Treatment Plant (Level 2, Table 3.0-4)
- Finished Water Pump Station
- Transmission Line to Recharge Zone

The Toledo Bend intake and pump station is sized to deliver 25,000 acft/month to Allens Creek Reservoir through a 120-inch diameter pipeline. The Brazos River intake and pump station is sized to deliver 50,000 acft/month to Allens Creek Reservoir through two 120-inch diameter pipes. The Allens Creek Reservoir intake and pump station is sized to deliver 30,000 acft/month to the West Centra Area through a 96-inch diameter pipeline. The estimated purchase price of stored water from Toledo Bend Reservoir is $25 per acft/yr. The operating cost was determined for the static lift of 62 feet at the Brazos intake and 880 feet at the Allens Creek pump station. The annual water delivery would be 300,000 acft/year from Toledo Bend and 357,800 acft/yr through the Allens Creek pump station. If no treatment plant is required, then the operating cost is determined for a total static lift to the recharge structures of 1,112 feet. For a treatment plant, the operating cost of the finished water pumping system was determined for a total static lift of 230 feet. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual cost of $198,370,000 with a treatment plant and $191,770,000 with no treatment plant (Table 3.33-2). Operation and maintenance costs total $126,400,000, including the treatment plant and are $108,300,000 without a treatment plant. The annual costs, including debt repayment, interest, and operation and maintenance, total $332,270,000 including the treatment plant and are $307,570,000 without a treatment plant. For an annual firm yield of 357,000 acft, the resulting annual cost of water, including a treatment plant, is $929 per acft, and is $860 per acft without a treatment plant (Table 3.33-2).

Alternative SBB-10C: Delivery to the Municipal Distribution System - 357,800 acft Firm Yield

For this alternative, the project yield would be diverted through an intake and pumped in a transmission line to the North and South Water Treatment Plants. The diversion rate from Toledo Bend and Allens Creek reservoirs was assumed to be uniform throughout the year. The benefit from this project includes the addition of a new potable water supply to the San Antonio distribution system and the resulting reduction in demand on the aquifer. The major facilities required to implement this alternative are:

Toledo Bend Intake and Pump Station
Pipeline from Toledo Bend to Allens Creek
Brazos River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Allens Creek Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, four required
North Water Treatment Plant (Level 3, see Table 3.0-4)
South Water Treatment Plant
Distribution System Improvements

The Toledo Bend intake and pump station is sized to deliver 25,000 acft/month to Allens Creek Reservoir through a 120-inch diameter pipeline. The Brazos River intake and pump station is sized to deliver 50,000 acft/month to Allens Creek Reservoir through two 120-inch diameter pipes. The Allens Creek Reservoir intake and pump station is sized to deliver 30,000 acft/month to the West Central Area through a 96-inch diameter pipeline.

The estimated purchase price of stored water from Toledo Bend Reservoir is $25 per acft/yr. The operating cost was determined for the static lift of 62 feet at the Brazos intake and 880 feet at the Allens Creek pump station. The annual water delivery would be 300,000 acft/year from Toledo Bend and 357,800 acft/yr through the Allens Creek pump station. The project yield was assumed to be divided equally for delivery to the North and South water treatment plants. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual expense of $212,380,000 (Table 3.33-2). Operation and maintenance costs total $110,290,000. The annual costs, including debt repayment, interest, and operation and maintenance, total $330,170,000. For an annual firm yield of 357,800 acft, the resulting annual cost of water is $923 per acft (Table 3.33-2).

<u>Alternative SBB-10D: Delivery to the Municipal Distribution System - 452,800 acft Firm Yield</u>

The facilities necessary for this alternative are identical to Alternative SBB-10C, with the only difference being the larger annual yield of this project. The major facilities required to implement this alternative are:

Toledo Bend Intake and Pump Station
Pipeline from Toledo Bend to Allens Creek
Brazos River Diversion, Intake, and Pump Station
Pipeline from River Pump Station to Reservoir
Allens Creek Dam and Reservoir
Reservoir Intake and Pump Station
Raw Water Pipeline to Treatment Plant
Raw Waterline Booster Pump Stations, four required
North Water Treatment Plant (Level 3, see Table 3.0-4)
South Water Treatment Plant
Distribution System Improvements

The Toledo Bend intake and pump station is sized to deliver 25,000 acft/month to Allens Creek Reservoir through a 120-inch diameter pipeline. The Brazos River intake and pump station is sized to deliver 50,000 acft/month to Allens Creek Reservoir through two 120-inch diameter pipes. The Allens Creek Reservoir intake and pump station is sized to deliver 38,000 acft/month to the West Central Area through a 108-inch diameter pipeline. The estimated purchase price of stored water is $25 per acft/yr from Toledo Bend Reservoir and \$19.15 per acft/yr from BRA. The operating cost was determined for the static lift of 62 feet at the Brazos intake and 880 feet at the Allens Creek pump station. The annual water delivery would be 300,000 acft/year from Toledo Bend and 357,800 acft/yr through the Allens Creek pump station. The project yield was assumed to be split equally for delivery to the North and South water treatment plants. Financing the project over 25 years at an 8.0 percent annual interest rate results in an annual cost of \$241,700,000 (Table 3.33-2). Operation and maintenance costs total \$127,930,000. The annual costs, including debt repayment, interest, and operation and maintenance, total \$378,950,000. For an annual firm yield of 452,800 acft, the resulting annual cost of water is \$837 per acft (Table 3.33-2).

3.33.6 Implementation Issues

An institutional arrangement is needed to implement projects including financing on a regional basis.

Reservoir Alternatives (SBB-10, All)

1. It will be necessary to obtain these permits for the off-channel storage reservoir:
    a. TNRCC Water Right and Storage permits.
    b. TNRCC Interbasin Transfer Approval.
    c. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir and pipelines.
    d. GLO Sand and Gravel Removal permits.
    e. GLO Easement for use of state-owned land.
    f. Coastal Coordinating Council review.
    g. TPWD Sand, Gravel, and Marl permit
2. Permitting, at a minimum, will require these studies:
    a. Bay and estuary inflow impact.
    b. Habitat mitigation plan.
    c. Environmental studies.
    d. Cultural resource studies.
3. Land will need to be acquired either through negotiations or condemnation.
4. Relocations for the reservoir include:
    a. Highways and railroads
    b. Other utilities

Requirements Specific to Pipelines (SBB-10, All)

1. Necessary permits:
   a. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. Coastal Coordinating Council review.
   d. TPWD 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

Terminal Delivery Alternatives

Requirements Specific to Injection Wells (SBB-10A)

1. Required testing programs:
   a. Detailed field investigation of existing supply wells, including performance tests and possible modeling of the aquifer.
   b. Test drilling and pilot recharge program is required.
   c. Large scale recharge test program.
   d. Water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
   e. Source water quality testing for Safe Drinking Water Act regulated constituents.
2. Necessary permits:
   a. TNRCC Injection Well permit
3. Right-of-way and easement acquisition.

Requirements Specific to Surface Recharge Structures (SBB-10B)

1. Detailed field investigations of each potential recharge site to determine natural and expected recharge rates.
2. For water imported to the recharge zone: water compatibility testing and assessment of treatment needs (if any), including biological and chemical characteristics.
3. Necessary permits could include:
   a. TNRCC Water Rights and Storage permit.
   b. U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits.
   c. GLO Sand and Gravel Removal permit.
   d. TPWD Sand, Gravel, and Marl permit.

4. Permitting, at a minimum, will require these studies:
    a. Determination of impact on plans for parkland, wildlife preserves, and other conservation programs.
    b. Study of impact on karst geology organisms from a sustained recharge program.
    c. Other environmental studies.
    d. Cultural resources studies.

<u>Requirements Specific to Treatment and Distribution (SBB-10C,D)</u>

1. Detailed study needed of the cost of pumping and transmission pipeline improvements necessary to effectively integrate the new supply into the City's water supply system.
2. Study needed of cost to convey and distribute water to other area water utilities.

3.34 Carrizo-Wilcox Aquifer (CZ-10)

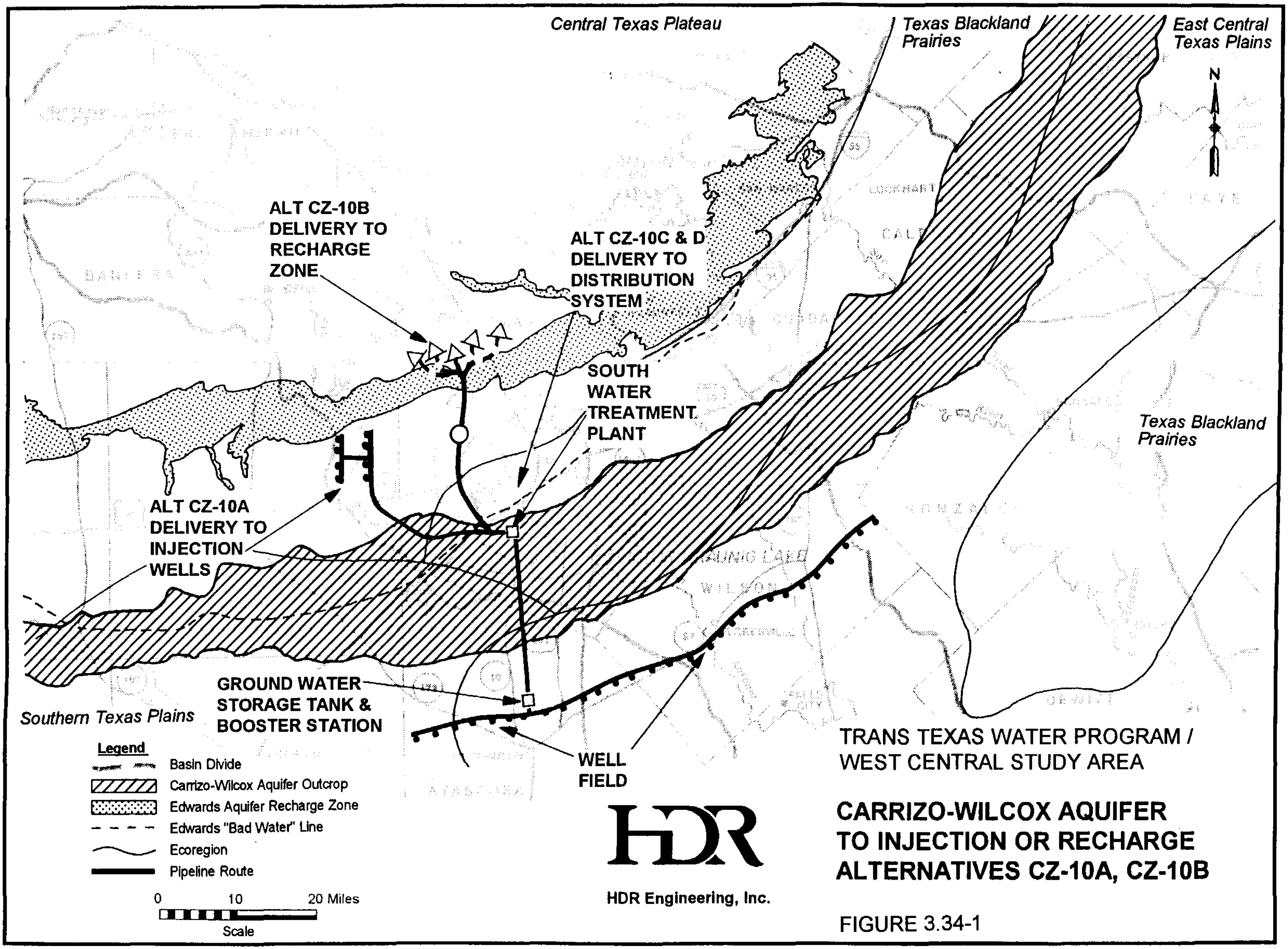
3.34.1 Description of Alternative

The Carrizo-Wilcox aquifer is one of the most extensive aquifers in Texas, furnishing water to an area from the Rio Grande to the northeast corner of the state. The aquifer provides large quantities of ground water to counties in the study area, including Zavala, Frio, Atascosa, Wilson, Gonzales, Bastrop, and others. The Evergreen Underground Water Conservation District of Atascosa, Wilson, and Frio Counties, which is a special legislative district, has jurisdiction to regulate new wells, well spacing, and transfer of Carrizo water out of the District.

For this study, a regional reconnaissance-level evaluation of the water supply potential of the Carrizo-Wilcox aquifer has been performed by LBG-Guyton Associates. Their report is included in Appendix A. In Wilson, Gonzales, and Bastrop counties, the aquifer is nearly full, and there are indications that it discharges water to overlying formations and to rivers crossing the recharge zone, as well as rejecting some recharge available to the aquifer. On a preliminary basis, the report concludes that more than 200,000 acft/yr of ground water can be developed by wells in Bastrop, Gonzales, Wilson, and Atascosa Counties. The analysis indicates that development of the aquifer will enhance recharge by increasing the hydraulic gradient in the formation and transmitting additional recharge from the outcrop that is currently rejected to surface streams.

Two alternative well field development scenarios have been studied. The smaller development would consist of approximately 70 wells spaced one mile apart and drilled along a line extending from western Atascosa County to the Wilson-Gonzales county line and parallel to the Carrizo-Wilcox outcrop about seven miles downdip (southeast) from the outcrop edge. The second scenario consists of 140 wells spaced one mile apart and drilled along a line extending from western Atascosa County to the Bastrop-Lee County line. The two proposed well field developments and aquifer outcrop are shown on Figures 3.34-1, 3.34-2, and 3.34-3.

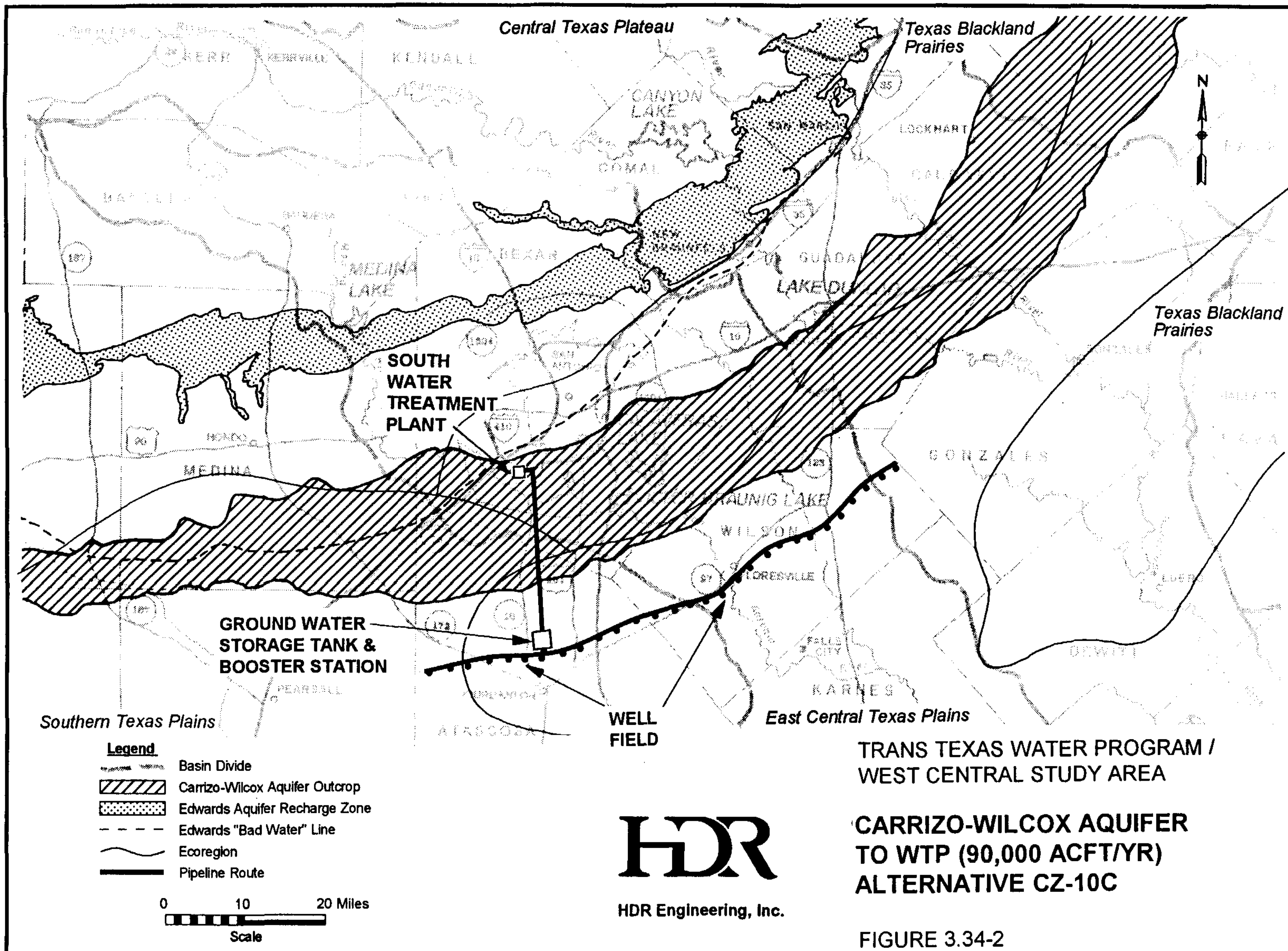
Three alternative delivery locations for the water supply have been studied: (1) an injection well field near the BMA Canal (Alt. CZ-10A); (2) the recharge zone northwest of



TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA

CARRIZO-WILCOX AQUIFER TO INJECTION OR RECHARGE ALTERNATIVES CZ-10A, CZ-10B

FIGURE 3.34-1


Central Texas Plateau
Texas Blackland Prairies
Texas Blackland Prairies
KERR
KENDALL
CANYON LAKE
COMAL
LOCKHART
BEXAR
MEDINA LAKE
LAKE DUNLAP
GUADALUPE
SOUTH WATER TREATMENT PLANT
MEDINA
HONDO
GONZALES
BRAUNIG LAKE
WILSON
FLORESVILLE
GROUND WATER STORAGE TANK & BOOSTER STATION
WELL FIELD
PEARSALL
ATASCOSA
FALLS CITY
KARNES
DEWITT
Southern Texas Plains
East Central Texas Plains
N
Legend
Basin Divide
Carrizo-Wilcox Aquifer Outcrop
Edwards Aquifer Recharge Zone
Edwards "Bad Water" Line
Ecoregion
Pipeline Route
0
10
20 Miles
Scale
HDR
HDR Engineering, Inc.
TRANS TEXAS WATER PROGRAM / WEST CENTRAL STUDY AREA
CARRIZO-WILCOX AQUIFER TO WTP (90,000 ACFT/YR) ALTERNATIVE CZ-10C
FIGURE 3.34-2

PHASE I EVALUATION
CARRIZO-WILCOX AQUIFER
WEST-CENTRAL STUDY AREA
TRANS-TEXAS WATER PROGRAM

INTRODUCTION

The anticipated future water demands of entities located in the West-Central Study Area may have to be met with additional sources other than those presently relied upon. One possible alternative is the development of a large well field which would draw water from the Carrizo-Wilcox aquifer. Previous studies by the Texas Water Development Board and others have shown that significant quantities of water (greater than 100,000 acre-feet per year) may be capable of being developed from the aquifer for municipal supplies.

Location and Extent of the Study Area

The study area is shown on Figure 1 and extends from Atascosa County, south of San Antonio, Texas, northeast to Bastrop County which is southeast of Austin, Texas. It consists of all or parts of Atascosa, Wilson, Bexar, Guadalupe, Wilson, Gonzales, Caldwell, Bastrop, Fayette and Lee Counties for the most part. The larger towns of the study area are: Pleasanton, Floresville, Seguin, Gonzales, Luling, Lockhart, Smithville and Bastrop.

Purpose and Scope

The primary objective of this study is to conduct a regional reconnaissance-level evaluation of the Carrizo-Wilcox aquifer with emphasis on the Carrizo and Simsboro Sands in the study area. The scope of this work includes the following: (a) collection and review of readily available basic data; (b) review of selected reports; (c) development of a reconnaissance-level water budget for an assumed large withdrawal in Atascosa, Wilson, Gonzales and Bastrop Counties; (d) development of reconnaissance-level well and well field costs; (e) evaluation of the potential feasibility of artificial recharge projects; and (f) a report with tabulations and illustrations.

Acknowledgements

We wish to express our grateful acknowledgement to all individuals and organizations who participated in this study. The cooperation of federal and state agencies, especially the Texas Water Development Board, is also gratefully acknowledged.

Special acknowledgement is extended to Mr. Norman Alford, Mr. David Thorkildsen and Mr. Steve Densmore of the Texas Water Development Board. These men generously provided basic data, technical information and advice which contributed toward the successful completion of this study.

Finally, appreciation is expressed to Mr. Rudy Hagen of Alsay Incorporated, Mr. Carl Crowell of Crowell Drilling Company, and Mr. James Zimmermann of Peerless Equipment Company. Their helpful cooperation and interest contributed toward the successful completion of this investigation and a better understanding of Carrizo-Wilcox water wells and drilling costs.

Metric Conversions

Multiply inch-pound unit	By	To obtain metric units
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallon (gal)	3.785	liter (l)
acre-foot (ac-ft)	1,233	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallons per minute (gpm)	0.06308	liters per second (l/s)
gallons per minute per foot (gpm/ft)	0.2070	liters per second per meter (l/s/m)
degree Fahrenheit (°F)	5/9 x (°F - 32)	degree Celsius (°C)

CARRIZO-WILCOX AQUIFER

The name "Carrizo" was first applied to the thick, massive sand beds that overlie the sands, silts and clays of the Wilcox Group in the vicinity of Carrizo Springs, Texas around the turn of the century. Because the sands of the Wilcox Group are hydraulically connected with the Carrizo Sand, the term "Carrizo-Wilcox aquifer" is often used.

Water-Bearing Strata

The Carrizo-Wilcox aquifer of Eocene (early Tertiary) age is one of the most extensive aquifers in Texas, furnishing water to wells in a wide belt extending from the Rio Grande to the Arkansas and Louisiana border. The aquifer provides large quantities of ground water to wells throughout the study area (Figure 1). The aquifer consists of hydrologically connected interbedded sands, clays, silts and discontinuous lignite beds of the Wilcox Group and overlying massive sands of the Carrizo (Table 1). These sediments were deposited by large, fluvial-deltaic river systems which were sourced in the Rocky Mountains and Ouachita-Arbuckle Mountains (Ayers and Lewis, 1985). Above the Carrizo Sand are the clays and interbedded fine sands of the Reklaw Formation.

The San Marcos Arch, which generally trends northwest-southeast parallel to the Guadalupe and Caldwell County line, is a structural high which affected the deposition of the Carrizo-Wilcox. The aquifer thins over the arch and thickens to the north and south.

In the portion of the study area located south of the arch, the Carrizo Sand is the preferred source of ground water with only minor amounts of water being withdrawn from the sand and clays of the underlying Wilcox Group. The thickness of the Carrizo in the downdip artesian areas ranges upward from 400 feet in Gonzales and Caldwell Counties to more than 1,000 feet in Atascosa County. The maximum thickness of the Carrizo-Wilcox aquifer in this area is on the order of 2,500 feet.

North of the arch, sediments of both the Wilcox Group and Carrizo Sand provide significant water for various purposes. The three formations of the Wilcox Group which underlie the Carrizo are: the Calvert Bluff, Simsboro and Hooper Formations. Together, these units make up the Carrizo-Wilcox aquifer which on the average is about 1,500 feet thick. In this portion of the study area, the Carrizo and Simsboro Sands are the more important water-bearing units of the aquifer and collectively are about 700 feet thick.

Recharge, Discharge and Movement

The Carrizo-Wilcox aquifer is recharged by precipitation in the outcrop area and in certain situations by seepage from lakes, streams and rivers crossing the outcrop area. The average annual precipitation rates given by city and county below are the latest 30-year normal period compilation, as of January 1, 1989 (The Dallas Morning News, 1991, from State Climatologist of Texas, College Station).

City	County	Average (inches)
Poteet	Atascosa	27.8
Floresville	Wilson	29.4
Seguin	Guadalupe	31.4
Luling	Caldwell	34.7
Smithville	Bastrop	36.5

Significant factors which control the amount of water recharged include: topography of the land surface, amount and kind of vegetative cover, soil characteristics and hydraulic conductivity of the rocks and soils exposed in the outcrop. Surface topography exerts a strong control on ground-water movement within the aquifer, with recharge occurring in the outcrop and moving downgradient into the aquifer and/or discharging to topographic lows along river basins.

The percentage of the average annual precipitation falling on the outcrop that enters the Carrizo-Wilcox aquifer and is transmitted downdip is often referred to as effective recharge. Computer simulations (Thorkildsen and others, 1989) indicate, at the present time, the effective recharge to the Carrizo-Wilcox aquifer in Bastrop County is on the order of an inch per year or approximately three percent of the average annual precipitation rate. Additional studies by LBG-Guyton Associates indicate that effective recharge ranges from about five percent in Atascosa County decreasing northward to approximately three percent in Bastrop County.

Ground water in the Carrizo-Wilcox aquifer moves downward from the recharge zone (outcrop) to the zone of saturation and then generally in the direction of the potentiometric gradient to points of discharge such as wells. The potentiometric surface is an imaginary surface that everywhere coincides with the static water pressure in the aquifer. The estimated amount of ground water discharged by wells (pumpage) from the Carrizo-Wilcox aquifer for each of the counties in the study area for the period 1960-1990 is provided in Table 2. Figure 2 illustrates the discharge by wells from the Carrizo-Wilcox for Atascosa, Wilson, Gonzales and Bastrop Counties for the above period. The winter 1992-93 potentiometric surface of the Carrizo-Wilcox aquifer is illustrated on Figure 3. The locations of large-capacity wells (public water supply, industrial and irrigation) from the Texas Water Development Board data base are illustrated on Figure 5.

During the period 1900-1930, large-scale irrigation development of the Carrizo Sand took place in the Winter Garden District of South Texas (primarily Dimmit and Zavala Counties) due to the introduction of the efficient deep-well pump. Later irrigation development spread northeast to Frio and Atascosa Counties during the 1950's. The Winter Garden District, Frio and Atascosa Counties have provided on the order of 200,000 to 300,000 acre-feet per year of ground water to wells since the 1960's.

The other counties (Wilson, Gonzales, etc.) northeast of Atascosa County are not as well developed as the Winter Garden District, and Frio and Atascosa Counties. This suggests that Wilson, Gonzales and Bastrop Counties are favorable for the development of additional ground water. In fact, the results of many ground-water studies (Klemt and others, 1976, and Thorkildsen and others, 1989, etc.) indicate the Carrizo-Wilcox aquifer is essentially full in the study area northeast of Atascosa County and is currently discharging water to the streams and rivers where it crosses the outcrop. Also, there is a component of vertical upward leakage (interformational flow) from the Carrizo-Wilcox into younger water-bearing rocks, especially in the far downdip parts of the aquifer; because, as the transmissivity of the aquifer decreases in the downdip direction, interformational flow must also occur into overlying formations.

The effects of developing the Carrizo Sand have caused water levels in Atascosa County to decline over the years. Payne (1991) reports the only county in the study area that has had significant water-level declines from 1980 to 1990 was Atascosa County, with up to 40 feet occurring in the water-table portion of the aquifer (northeastern part of the county) and up to 100 feet occurring in the artesian portion of the aquifer (southwestern part of the county). However, prior to 1980, water-level declines in the outcrop were on the order of 1 to 2 feet per year, and in the artesian areas, generally less than 5 feet per year. Subsidence, which has been associated with

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Table

1 Water-Bearing Characteristics of the Carrizo-Wilcox Aquifer

2 Pumpage from the Carrizo-Wilcox Aquifer

3 Carrizo-Wilcox Ground-Water Availability

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(at end of report)

Figure

1 Location and Extent of the Study Area

2 Approximate Total Pumpage from the Carrizo-Wilcox Aquifer for Those Counties Where Additional Ground Water May Be Developed by Wells

3 Altitude of Water Levels in the Carrizo-Wilcox Aquifer, Spring 1993

4 Diagrammatic Cross-Section through the Carrizo-Wilcox Aquifer Illustrating the Lowering of Water Levels in the Carrizo and Simsboro Sands in Response to an Approximate Line of Discharge Located about 7 Miles Downdip and Parallel to the Outcrop, Bastrop County

5 Location of Public Water Supply, Industrial, and Irrigation Wells and Areas Favorable for Artificial Recharge and the Development of Additional Ground Water from the Carrizo-Wilcox Aquifer

$$Q_{VL} = (P/M)HA$$

where

Q_{VL}	=	leakage rate in gallons per day from Wilcox source sands and clays through confining beds into the Carrizo and/or Simsboro sands;
P	=	vertical hydraulic conductivity of Wilcox confining beds (0.002 gallons per day per square foot);
M	=	thickness of Wilcox confining beds (50 feet);
H	=	difference between the head in the aquifer and in the source beds, in feet; and
A	=	area of confining bed through which leakage takes place, in square feet.

The following table summarizes the values used to estimate the lateral transmission capacity (Q_{LT}) and interformational leakage (Q_{VL}) to the Carrizo (and Simsboro in Bastrop County only) based on the proposed development scenario.

	Atascosa	Wilson	Gonzales	Bastrop
Transmissivity (T) (gpd/ft)	100,000	75,000	37,500	40,000
Aquifer Width (W) (miles)	30	32.1	45.5	30.75
Hydraulic Gradient (I) (ft/mi)	20	20	25	25
Leakage Area (A) (ft^2)	5.85×10^9	6.26×10^9	8.88×10^9	6.00×10^9
Drawdown (H) (ft)	70	93.3	107.1	95.2

The total available ground water (Q) in the study area may be estimated by the formula

$$Q = Q_{LT} + Q_{VL} - \text{Pumpage (1990)}$$

Based on the above hydraulic gradients, leakance factors, aquifer coefficients and pumpage (Table 2), the ground water available from the Carrizo-Wilcox aquifer for development by wells in the study area is upwards of 200,000 acre-feet per year in excess of current ground-water pumpage (Table 3). This estimate is based on limited data and needs much further refinement. The effective recharge as a percentage of average annual rainfall required to sustain the above estimate ranges from 15.6 percent in Atascosa County to 6.9 percent in Bastrop County. Figure 5 illustrates the location of the proposed line of pumpage.

Implementation Issues

To fully determine and understand the effects of developing and utilizing ground water from such a well field requires computer modeling and major planning. A technical ground-water investigation should be the first step in the planning process. This investigation should include detailed hydrogeologic mapping, an inventory of existing wells, test drilling, test pumping and chemical analysis of water from the producing aquifer. Such preliminary data can be used to determine the most efficient well completion, optimum pumping rate, efficient pump setting and optimum well spacing, water treatment requirements if the water is high in iron, water-level drawdown impacts in the outcrop and within the area favorable for development, optimum alignment of the supply pipeline, and alignment of interior pipelines.

If water levels are lowered in the Carrizo-Wilcox outcrop areas by the proposed well field, then some of the base-flow discharge from the aquifer will be salvaged, additional storage space would be created in the aquifer, and, as a result, increased quantities of surface-water runoff would infiltrate into the additional space in the aquifer. Thus, base and flood flows for the San Antonio River, Cibolo Creek, Guadalupe River, Colorado River, etc. would be impacted to some degree and would need to be more fully analyzed to be accurately quantified. This water also supports fauna and flora in the above creeks and rivers and outcrop areas. The expectation that there will be drawdown in the outcrop raises the issue as to what the magnitude of the hydrologic and environmental impact will be.

The results of the water-availability analysis indicate that significant quantities of water could enter the Carrizo (and Simsboro in Bastrop County only) as leakage from the hydraulically connected sands and clays of the Wilcox because of the pumpage-imposed vertical hydraulic gradients. At first, the interformational leakage estimate shown on Table 3 may seem high. However, if the total area affected is considered, only about an inch of water per year is needed to produce the above estimate.

Because of the presence of relatively poor quality water in at least some portions of the Wilcox, this interformational leakage may not have a desirable effect on the Carrizo and Simsboro Sands. There is also the possibility interformational leakage may occur from water-bearing strata which overlie the Carrizo (Thorkildsen and others, 1989). Without additional data and geochemical studies, it is almost impossible to predict the water-quality effects due to leakance.

One of the alternatives for the West-Central Trans-Texas Study Area utilizes injection wells to recharge the Edwards aquifer with water developed from the Carrizo-Wilcox aquifer. An investigation by W. E. Simpson, Bryant-McClelland Consultants and William F. Guyton Associates (1989) indicates conditions are favorable for recharging the Edwards aquifer with wells in an area which is roughly midway between the City of Castroville and Medina Lake (Figure 5). The plan called for a series of gravity-fed recharge wells that would be capable of injecting 100 cubic feet per second (45,000 gallons per minute) of water from Medina Lake into the Edwards aquifer. This plan could be modified to use water developed from the Carrizo-Wilcox aquifer.

It appears that water from the Carrizo-Wilcox aquifer can be safely injected into the Edwards aquifer as the water quality of both aquifers is excellent. For injection purposes, laboratory tests with Edwards cores and water from the two aquifers can be run to determine if any incompatibilities may exist between the two water chemistries. Incompatibility may result in precipitation that could cause clogging in the well or aquifer. Chemical incompatibilities may be resolved by treating the water from the Carrizo-Wilcox aquifer before injecting into the Edwards aquifer. Empirical testing and geochemical modeling should be performed before injection so that the effects of injecting Carrizo-Wilcox water into the Edwards aquifer can be assessed. Further study of this issue needs to be conducted in a later phase.

State and local permitting requirements must also be addressed before the proposed well field can be constructed and operated. The agencies involved may include the following: (a) Texas Natural Resource Conservation Commission if downstream users are determined to be impacted due to reduced flood and base inflows to the above rivers; (b) Texas Department of Transportation if construction of the well field and/or pipelines are proposed within highway right-of-ways; (c) Evergreen Underground Water District if wells are drilled and completed which produce more than 25,000 gallons per day, and transportation of the water out of the District is proposed. The District's boundaries include all the territory contained within Atascosa, Frio, and Wilson Counties. Additional details with regard to the District will be provided in the "Hydrogeologic and Other Uncertainties" subsection of the following "Artificial Recharge" section of the report.

ARTIFICIAL RECHARGE

Possibilities are good for artificially recharging the Carrizo-Wilcox outcrop and increasing the water-producing potential of the aquifer further. Previous studies have identified Atascosa, Wilson and southern Bexar Counties as being favorable for artificial recharge projects.

There are two broad types of recharge projects: aquifer storage and recovery (ASR) and conventional recharge projects. In general, ASR projects treat water to drinking water standards, inject the water using dual-purpose wells and store it underground locally for later use. Conventional recharge projects utilize a variety of techniques (basins, trenches, etc.), usually over a wide area, to increase the amount of water entering an aquifer's recharge zone.

Basic Concept

The following paragraph taken from Barnes (1956) indicates the potential of the Carrizo-Wilcox aquifer to supply over 100,000 acre-feet per year in Atascosa, Bexar and Wilson Counties.

"It is believed possible to develop from 50 to 75 million gallons of water per day from wells located in and immediately downdip from the Carrizo outcrop in the Wilson County area. For a long-term supply, approximately 50 percent of this amount would have to be supplied from artificial recharge by spreading water over the Carrizo outcrop. It is noted that a large area of Carrizo outcrop also is available for increased use in adjacent Atascosa and Bexar Counties, provided recharge is increased by water spreading. By proper development and recharge of the large permeable Carrizo outcrop, extending about 55 miles from northern Wilson County to western Atascosa County, it is believed feasible to develop a permanent water supply of about 100 million gallons a day, or about 2 million gallons a day for each mile of outcrop."

There are a number of rivers which flow through the study area and over the outcrop of the Carrizo-Wilcox which might provide water for ASR and/or artificial recharge projects. The Atascosa River, San Antonio River, Cibolo Creek, Guadalupe River, San Marcos River and Colorado River may be viable sources of supply for future consideration.

Evaluation of Proposed Recharge Sites

The possibility of increasing recharge by lowering water levels and spreading water over the outcrop in the study area appears to be excellent, the more favorable areas being in Atascosa, Bexar and Wilson Counties. Also, ASR projects in these counties seem feasible where more effective use of water treatment plant and/or transmission pipeline capacity can be obtained. ASR projects using dual-purpose wells reduce the need for expensive and environmentally sensitive above-ground storage facilities which tend to reduce water availability due to evaporation.

The historical water-level declines in the Carrizo outcrop areas of the above counties are small. CH2M Hill and Lee Wilson & Associates (1991), using a limited amount of Texas Water Development Board monitoring well data, report average annual declines in the Carrizo water-table areas ranging from 1.6 feet in northwestern Atascosa County to 0.3 foot in northern Wilson County since 1980. In general, Payne (1991) is in agreement with the above investigators; however, she does report water-table declines of 20-40 feet in northeastern Atascosa County for the period 1980-1990.

CH2M Hill and Lee Wilson & Associates identified the following four general areas as candidates for recharge sites on the outcrop of the Carrizo: (a) northwestern Atascosa County along the Atascosa River (also known as the Rossville site); (b) north-central Atascosa County, located on the Bexar-Atascosa County line; (c) southern Bexar County, located a short distance east of the Bexar-Atascosa County line; and (d) northern Wilson County, located between the San Antonio River and Cibolo Creek. The locations of the above areas are illustrated on Figure 5.

CH2M Hill and Lee Wilson & Associates (1991) used a number of factors, in addition to water levels, in selecting the northwestern Atascosa County area for a proposed recharge demonstration project. In general, the above areas were evaluated with respect to the following: (a) amounts of continuous clay layers above the water table; (b) hydraulic conductivity and thickness of the saturated interval; (c) water quality; (d) land availability, access, costs, zoning and environmental issues; and (e) location of the area relative to sources of water and users. For purposes of screening the above sites, the Bexar-Medina-Atascosa (BMA) Irrigation District's canal system was selected as the water source. It should also be noted, all of the candidate recharge areas may have a problem with high iron content water.

The southern Bexar County and northern Wilson County areas, from a hydrogeologic perspective, appear favorable for ASR and/or artificial recharge projects. However, these areas were not selected for further investigation because of problems related to being linked to BMA's canal system and, to some degree, difficulties obtaining suitable sites. The north-central Atascosa County area does not seem favorable because of marginal permeabilities, a thin saturated interval in addition to many of the problems described above.

<u>Northwestern Atascosa County</u>

The northwest Atascosa County recharge site is located about 20 miles southwest of San Antonio and covers about 36 square miles of the Carrizo outcrop (Figure 5). The town of Rossville is located very close to the southern edge of the area; therefore, the recharge site is commonly referred to as the "Rossville site."

The Rossville site was selected by CH2M Hill and Lee Wilson & Associates for a proposed recharge demonstration project because reconnaissance-level studies, under an assumed set of conditions, indicated the area was favorable for both spreading basins and recharge injection wells. The northern portion of the area would be favorable for wells. For spreading basins, the southern areas are more favorable.

The investigators determined the following based on the above studies:

(1) The soils covering the general area of the site are very permeable. Also, the Carrizo water-bearing sands in the subsurface are transmissive and porous. These conditions would facilitate the rapid recharge of water either through the use of spreading basins or recharge injection wells. Studies indicated that approximately 432,000 acre-feet of water over a 15-year recharge cycle (2,400 acre-feet per month) could be recharged at the site.

(2) During the recharge cycle, relatively small amounts of recharged water would be lost to the Atascosa River. About 52,000 acre-feet of water would be lost downstream through the river from the Carrizo outcrop over the 15 years if spreading basins were used. If recharge injection wells were used, about 43,000 acre-feet would be lost downstream through the river from the Carrizo outcrop over the 15 years. Losses to other water-bearing sands should be relatively small, about 2 percent of the recharged water.

(3) During the 10-year production cycle, studies indicated that about 3,600 acre-feet per month (432,000 acre-feet of water) could be withdrawn from the site. Because of the above described losses to the ground-water system, the produced water would come from both recharged waters and storage.

From a hydrogeological point of view, the site appears favorable for the proposed ASR project. However, water levels need to be lowered in the vicinity of the site in the initial phases of such a project. This is because water is lost to the Atascosa River when water levels are above the riverbed due to the percolation from spreading basins or injection of recharge water.

Hydrogeologic and Other Uncertainties

The CH2M Hill and Lee Wilson & Associates reconnaissance-level studies of the Rossville site pointed out a number of uncertainties with regard to Carrizo-Wilcox artificial recharge projects in the San Antonio region. These uncertainties are hydrogeological, environmental and institutional in nature.

At this time, sources of good quality recharge water have not been identified which will economically and reliably meet the demand requirements of a recharge site and/or sites. It must be demonstrated that the water is of a compatible chemical character and low turbidity if ASR wells are to be used. This will require site-specific knowledge of the Carrizo-Wilcox water chemistry as well as source water chemistry.

The stratigraphic distribution of interbedded clays and lignites in the Carrizo-Wilcox can be quite variable in the outcrop. More site-specific hydrologic information must be gathered to be certain that, if spreading basins are used, shallow clay-free sites are found because of potential losses through perched springs or seeps. With regard to wells, transmissivity, storage coefficient, saturated thickness, etc. must be known in order that the recharge and/or production well field can be designed and recharge and/or withdrawal rates estimated.

The lowering of Carrizo-Wilcox water levels in the outcrop will create favorable conditions for artificial recharge projects and reduce base flows from the aquifer to many of the rivers and creeks which cross the outcrop. Presently, the San Antonio River, Cibolo Creek, Guadalupe River and Colorado River are, for the most part, receiving base inflows from the Carrizo-Wilcox aquifer. Therefore, before proceeding with any general lowering of water levels in the outcrop, both the regulatory aspects of the water rights and environmental issues need to be worked out in advance with the Texas Natural Resource Conservation Commission (TNRCC).

The potential recharge sites which have been studied so far are located in Atascosa, Bexar and Wilson Counties. Atascosa and Wilson Counties are within the boundaries of the Evergreen Underground Water Conservation District (EUWCD). The EUWCD was created by House Bill 116, which was passed by the Texas Legislature in 1965 pursuant to Article XVI, Section 59, of the Texas Constitution. This enabling legislation established a Board of Directors, setting forth the Board's powers and duties, and providing administrative procedures to be followed in the performance of those powers and duties. Generally, the Board may adopt rules for the purpose of conserving, preserving, protecting and recharging the underground water in the District. In particular, the Board has the authority to issue permits for recharge and recovery wells, operation of recharge facilities, and to deny transportation of water outside of its boundaries. Based on the above discussion, it does appear the EUWCD has the authority to encourage or block any proposed artificial recharge project within their district.

While the TNRCC does have some general supervisory powers with regard to underground water conservation districts, it does not have the jurisdiction to determine the validity of a district's rules. The power to review the validity of a district's rules lies with the district court. Therefore, the resolution of untested regulatory and jurisdictional issues comprises the greatest area of uncertainty concerning the future of ASR and/or artificial recharge projects in the San Antonio region.

SUMMARY

In Atascosa, Wilson, Gonzales, Bastrop and adjacent counties the Carrizo-Wilcox aquifer consists of hydrologically connected interbedded sands, clays, silts and discontinuous lignite beds of the Wilcox Group and overlying massive sands of the Carrizo. In the outcrop, the aquifer is under water-table conditions. For the most part, the aquifer is under confined conditions downdip from the outcrop. The Carrizo Sand is the most continuous and permeable water-bearing unit of the aquifer and in the downdip areas ranges upward from 400 feet to more than 1,000 feet in thickness. Except for Atascosa County, the aquifer is nearly full, ground-water withdrawals from the aquifer are small, the aquifer currently takes in only a limited amount of available recharge in the outcrop, and it presently provides base flow to many of the rivers which cross the outcrop.

Throughout the study area, the Carrizo-Wilcox aquifer yields ground water of a chemical quality which meets the National Primary Drinking Water Regulations standards required for public health. However, secondary standards for iron may be exceeded in certain areas. Additionally, hydrogen sulfide and methane gas may be found locally within the aquifer.

Preliminary estimates indicate that upwards of 200,000 acre-feet of ground water can be developed by wells in the study area. The wells should be widely spaced and drilled along a line extending from about the western part of Atascosa County to the Bastrop-Lee County line and parallel to the Carrizo-Wilcox outcrop about 7 miles downdip from the outcrop edge. At these locations, the aquifer is under confined conditions. The well field would consist of approximately 140 wells with the construction cost of each estimated at $450,000, which includes the pump and motor. The above cost is exclusive of engineering, site work, treatment, conveyance easements and contingencies. Water to supply these wells would come from existing available recharge, interformational leakage and some storage in the aquifer. This water could be used either directly for public water supply needs or be used to artificially recharge the Edwards aquifer west of San Antonio.

If such a well field were constructed, pumpage sufficiently increased, and water levels moderately lowered, possibilities are good for artificially recharging the Carrizo-Wilcox outcrop and increasing the water-producing potential of the aquifer. Previous studies have identified Atascosa, Wilson and southern Bexar Counties as being favorable for artificial recharge projects.

Permitting requirements must be addressed before proceeding with the construction of the above described well field and artificial recharge projects. These include, for the most part, permits from the TNRCC and Evergreen Underground Water District. The District's current permitting responsibilities have been interpreted to include: new well construction, changes to existing wells, construction and operation of recharge facilities and transportation of water from the District.

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TABLE 1. WATER-BEARING CHARACTERISTICS OF THE CARRIZO-WILCOX AQUIFER

System	Series	Group	South of the Colorado River	North of the Colorado River	Character of Rocks	Water-Bearing Properties	
Tertiary	Eocene	Claiborne	Reklaw Formation	Reklaw Formation	Clay with interbedded fine sand	Aquitard	Yields small quantities of slightly to moderately saline water
			Carrizo Sand	Carrizo Sand	Massive cross-bedded coarse to fine sand	Carrizo-Wilcox Aquifer	Principal aquifer yields moderate to large quantities of fresh to slightly saline water
		Wilcox		Calvert Bluff Formation Simsboro Sand Hooper Formation	Interbedded sand, clay and silt with discontinuous beds of lignite		
		Midway			Shales and clays with minor amounts of interbedded fine sand	Aquitard	Not known to yield water to wells

Yield, in gallons per minute: Small - less than 50
Moderate - 50 to 1,000
Large - over 1,000

Salinity (total dissolved solids), in milligrams per liter: Fresh - less than 1,000
Slightly saline - 1,000 to 3,000
Moderately saline - 3,000 to 10,000

TABLE 2. PUMPAGE FROM THE CARRIZO-WILCOX AQUIFER
(Pumpage expressed in acre-feet)

County	Use	1960	1970	1980	1990
Atascosa	Domestic	1,010	830	1,040	1,220
	Public Supply	1,930	2,010	2,810	4,370
	Industrial	220	840	1,170	670
	Irrigation	30,920	51,980	55,670	50,910
	Livestock	140	140	140	130
	Total	34,220	55,800	60,830	57,300
Bastrop	Domestic	270	280	710	960
	Public Supply	830	1,600	3,770	6,390
	Industrial	20	150	80	30
	Irrigation	50	420	0	10
	Livestock	390	390	400	370
	Total	1,560	2,840	4,960	7,760
Bexar	Domestic	340	340	340	340
	Public Supply	20	190	490	600
	Industrial	50	80	50	150
	Irrigation	3,380	3,380	3,390	1,640
	Livestock	30	30	30	40
	Total	3,820	4,020	4,300	2,770
Caldwell	Domestic	390	370	480	530
	Public Supply	1,270	1,840	1,730	2,270
	Industrial	0	0	0	20
	Irrigation	210	150	50	110
	Livestock	120	120	130	10
	Total	1,990	2,480	2,390	2,940
Fayette	Domestic	200	200	220	240
	Public Supply	0	0	0	0
	Industrial	0	0	0	0
	Irrigation	100	100	230	140
	Livestock	0	0	0	0
	Total	300	300	450	380

Table 2. Estimated Pumpage from the Carrizo-Wilcox Aquifer (Continued)

County	Use	1960	1970	1980	1990
Gonzales	Domestic	650	520	570	590
	Public Supply	380	1,100	1,150	1,670
	Industrial	0	0	0	10
	Irrigation	280	1,640	440	1,300
	Livestock	790	790	790	160
	Total	2,100	4,050	2,950	3,730
Guadalupe	Domestic	590	550	840	1,170
	Public Supply	0	0	0	10
	Industrial	0	40	30	10
	Irrigation	1,390	970	1,330	1,360
	Livestock	120	120	120	80
	Total	2,100	1,680	2,320	2,630
Lee	Domestic	250	200	280	330
	Public Supply	320	870	1,090	1,680
	Industrial	0	0	0	0
	Irrigation	0	190	70	120
	Livestock	240	240	240	210
	Total	810	1,500	1,680	2,340
Wilson	Domestic	1,430	1,000	1,330	1,790
	Public Supply	8,400	1,180	1,960	3,510
	Industrial	40	60	400	330
	Irrigation	11,820	10,820	6,310	9,070
	Livestock	250	250	260	180
	Total	21,940	13,310	10,260	14,880
TOTAL PUMPAGE		**68,840**	**85,980**	**90,140**	**94,730**

Data from Texas Water Development Board, 1993.

APPENDIX B

PROTECTED ENDANGERED AND THREATENED SPECIES

APPENDIX B

Protected Endangered and Threatened Species Within the Study Area and Downstream

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	Guide to Symbols and Distribution Sources

TABLE 1- ARANSAS COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Aplomado Falcon	*Falco femoralis*	Grasslands, coastal prairies; open terrain - scattered trees; nests in yuccas and mesquite	E	E	[1] Possible; transient/ historic
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition; Aransas NWR	E	E	endemic; Aransas NWR recovery plan
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	wintering / transient
Becard, Rose-throated	*Pachyramphus aglaiae*	Wooded canyons, forests, riversides, large trees; nests in Rio Grande Valley south of Falcon Dam	NL	T	wintering / transient possible endemic
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast waters and bays	E	E	endemic
Eskimo Curlew	*Numenius borealis*	Coastal plains	E	E	[1] Possible; at periphery
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Piping Plover	*Charadrius melodus*	Beaches and Mudflats	E	E	wintering / transient
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Sooty Tern	*Sterna fuscata*	Coastal wetland islands during breeding season; offshore and Gulf of Mexico	NL	T	wintering / transient
Swallow-Tailed Kite	*Elanoides forficatus*	Open forested areas	C3	T	[1]confirmed / transient
Tyrannulet, Beardless -, Northern	*Camptostoma imberbe*	Extreme Southern Rio Grande Valley	NL	T	rare
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Desert grasslands, prairie brushlands	NL	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migratory
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] confirmed
Zoned-tailed Hawk	*Buteo albonotatus*	Desert Mountains and western rivers	NL	T	[1]possible / migratory
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains	NL	E	[1]possible endemic
Gulf Coast hog-nosed skunk	*Conepatus leuconotus texensis*	Gulf Coast, Aransas Co. to Cameron; brushlands; usually nocturnal, secretive	C1	NL	potential
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	[1] probable
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; extreme So. TX	E	E	[1] Probable
Dolphin, Rough-Toothed	*Steno bredanensis*	Offshore waters; usually off edge of continental shelf	NL	T	[1] Possible; at periphery
Dolphin, Spotted, Atlantic	*Stenella plagiodon*	Offshore waters 5mi ; seasonally may approach shore	NL	T	[1] Possible; at periphery
Whale, Black Right	*Balaena glacialis*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Blue	*Balaenoptera musculus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Dwarf Sperm	*Kogia simus*	Gulf of Mexico and coastal bays	NL	T	[1] Possible; at periphery
Whale, False Killer	*Pseudorca crassidens*	Gulf of Mexico and coastal bays	NL	T	[1] Possible; at periphery
Whale, Fin	*Balaenoptera physalus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Gervais' Beaked	*Mesoplodon europaeus*	Probably warm temperate offshore waters	NL	T	[1] Possible; at periphery
Whale, Goose-Beaked	*Ziphius cavirostris*	Gulf of Mexico	NL	T	[1] Possible; at periphery
Whale, Killer	*Orcinus orca*	Gulf of Mexico and occasionally large rivers	NL	T	[1] Possible; at periphery
Whale, Pygmy Killer	*Feresa attenuata*	Gulf of Mexico	NL	T	[1] Possible; at periphery
Whale, Pygmy Sperm	*Kogia breviceps*	Deep Gulf waters; close to shore during calving season	NL	T	[1] Possible; at periphery
Whale, Short-Finned	*Globicephala macrorhynchus*	Deep offshore waters; sometimes close to shore	NL	T	[1] Possible; at periphery
Whale, Sperm	*Physeter macrocephalus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Green Turtle, Atlantic	*Chelonia mydas mydas*	Gulf coast and bay waters and beaches	T	T	endemic
Hawksbill Sea Turtle	*Eretmochelys imbricata imbricata*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1]confirmed occurrence
Leatherback Sea Turtle	*Dermochelys coriacea*	Gulf coast, bay waters and beaches; scattered beach nesting	E	E	[1] confirmed occurence
Loggerhead Sea Turtle	*Caretta caretta*	Gulf coast, bay waters and beaches; scattered beach nesting	T	E	[1] confirmed occurence
Ridley, Kemp's, Sea Turtle	*Lepidochelys kempi*	Gulf coast, bay waters and beaches; scattered beach nesting	E	E	[1] confirmed occurence

TABLE 1- ARANSAS COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Cat-eyed Snake, Northern	*Leptodeira s. septentrionalis*	Coastal thorn thicket; principal microhabitat is dense vegetation bordering ponds and watercourses	NL	E	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Racer, Specked	*Drymobius margaritiferus*	Dense thickets heavily littered with plant debris; generally near water	NL	E	possible
Texas Scarlet Snake	*Cemophora coccinea lineri*	Sand floored thicket immediately adjacent to the Gulf	NL	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	endemic
Opposum Pipefish	*Microphis brachyurus*	Gulf of Mexico south coastal bays in various habitats, *Spartina* marshes or *Sargassum*	NL	T	confirmed
Black Lace Cactus	*Echinocereus reichenbachii albertii*	Grows in extremely heavy brush and very localized	E	E	possible
Lila de los Llanos-Chandlers Crag Lily	*Anthericum chandleri*	Lower Rio Grande Valley; South Coastal Texas	C2	NL	endemic
Roughseed Sea-purslane	*Sesuvium trianthemoides*	Dunes of coastal South Texas	C2	NL	possibly extinct
Slender Rush-pea	*Hoffmannseggia tenella*	Gulf Coast prairies and marshes; clayey soils near creeks with buffalo grass, spear grass, mesquite and prickly pear	E	E	endemic
South Texas Ragweed	*Ambrosia cheiranthiflora*	Open prairie, various shrublands on deep clay soils	C1	NL	endemic
Texas Windmill Grass	*Chloris texensis*	Sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants; also roadsides and with coastal prairie edemics in slightly saline soils in bare areas around pimple mounds	C2	NL	endemic

TABLE 2- ATASCOSA COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Black-capped Vireo	*Vireo atricapillus*	Semi-open Broad-leaved shrublands	E	E	nesting/migratory
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast waters and bays	E	E	transient
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and old juniper	E	T	nesting
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open wooded and forested areas; southern U.S. coastal plains	NL	T	transient
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E[1]	T	migratory
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas Islands	E	E	migratory[1]
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	probable[1]
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic

Reticulate Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	endemic[3]
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky; burrows in soil, enters rodent burrow, or hides under rocks	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	C2	T	probable [1]
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture to remain	C2	E	probable[1]
Parks' Jointweed	*Polygonella parksii*	South Texas Plains; subherbaceous annual in deep loose sands	3C	NL	endemic
Silvery Wild Mercury	*Argythamnia argyraea*	South Texas Plains, perennial herb, also in Kinney, LaSalle, Maverick Co.	3C	NL	endemic

TABLE 3 - BANDERA COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	migrating
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E	nesting
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central TX; ashe juniper-oak woodlands - Edward's Plateau; areas with similar geology; Brazos & Colorado Rivers	E	T	nesting
Gray Hawk	*Buteo nitidus maximus*	Cotton-willow woodlands of Rio Grande, mature woodlands of river valleys, and associated semi-arid mesquite and scrubland	C2	T	[1]possible
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	[1]probable
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Open forested areas	3C	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	[1]probable
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways	E[2]	T	dispersal
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	[1]probable
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushland and forests	T	E	historic endemic
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	[1]possible
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects	NL	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Salamander	*Eurycea neotenes*	Springs of the Edwards and Balcones escarpment	C2	NL	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches, depressions; requires moisture	C2	E	[1]possible
Big Red Sage	*Salvia penstemonoides*	In seepage on limestone ledges, banks of streams, seasonally wet clay or silt soils in creekbeds; available in the native plant nursery trade	C2	NL	endemic
Glass Mountains Coral-root	*Hexalectris nitida*	Saprophytic; Among rocks in shade canyons of Trans Peco; also oak-juniper woods at lower elevations in its Eastern range; oak humus maybe a common factor	C2	NL	endemic
Tobusch fishhook cactus	*Ancistrocactus tobuschii*	In juniper-oak association; limestone soils at about 488 meters elevation	E	E	endemic

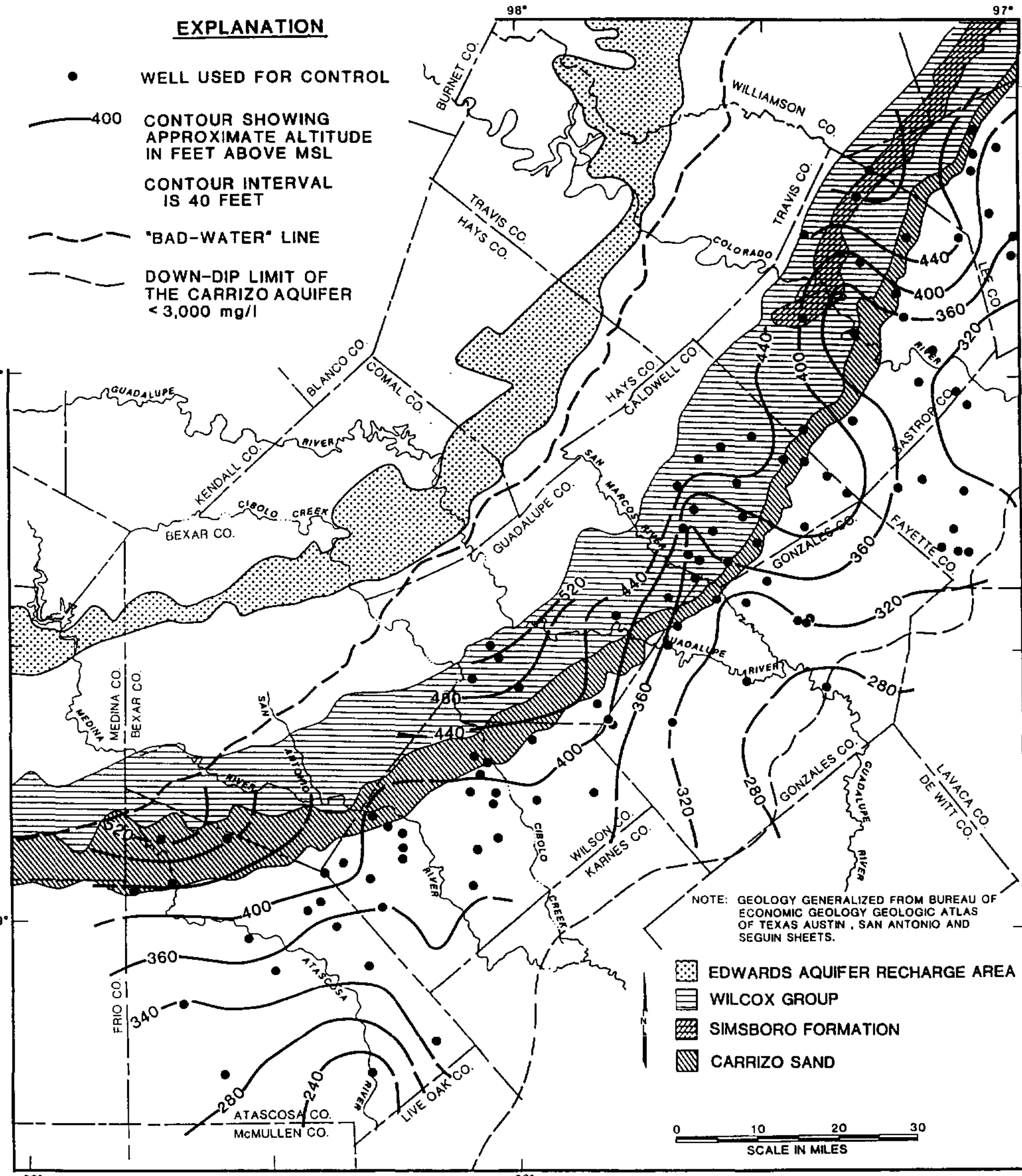

FIGURE 3

ALTITUDE OF WATER LEVELS IN THE CARRIZO-WILCOX AQUIFER, SPRING 1993

TABLE 4 - BASTROP COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E	migratory
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E	nesting
Golden-cheeked Warbler	*Dendroica chrsoparia*	Woodlands with oaks and mature juniper	E	E	nesting
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on sandbars of large rivers, dispersal	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied, moist open land with tall trees for nesting	T	T	endemic
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E[3]	T	transient
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	transient
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migratory
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	endemic
Houston Toad	*Bufo Houstonensis*	Loamy, friable soils, temporarily rain pools, flooded fields, ponds surrounded by forest or grass;	E	E	endemic
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporally wet areas, arroyos,canals,ditches and shallow depressions; requires moisture	C2	E	[1] possible
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation; grass, cactus, scattered brush; soil may vary from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks	C2	T	endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands, reclusive in dense thickets	NL	T	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throught the Mississippi Basin; In Texas, major streams southward to the Rio Grande	C2	T	endemic

TABLE 5 - BEE

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	nesting; wintering
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	endemic
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] migratory
Red Wolf	*Canis rufus*	Southern riparian and pine forests; may only remain in Liberty Chambers and Jefferson Co.s [2]	E	E	historic range
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	[2]probable
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation ;grass, cactus, scattered brush; soil may vary from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks			[1]probable endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies, sand hills; thorn brush woodland and mesquite savannah coastal plain	NL	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of Rio Grande Valley, lower South Texas Plains, South Coastal Prairie and marshes	NL	T	endemic

TABLE 6 - BEXAR COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Black-capped vireo	*Vireo atricapillus*	Semi-open Broad-leaved shrublands	E	E	nesting/migratory
Golden-cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oaks and old juniper	E	E	nesting/migrant
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open wooded and forested areas; southern U.S. coastal plains	NL	T	transient
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E[2]	T	dispersal
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas Islands	E	E	migratory
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	endemic
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL	[3]endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic
Reticulate Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	[1]probable
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL	[3]endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T	[1]possible
Blind Texas Salamander	*Typhlomolge rathbuni*	Edwards Aquifer springs and caves, thermally stable; troglobitic	E	E	[3]endemic
Toothless Blindcat	*Trogloglanis pattersoni*	Edwards Aquifer; subterranean; from artesian wells in Bexar Co., TX; troglobitic [4;6]	C2	T	endemic
Widemouth Blindcat	*Satan eurystomus*	Edwards Aquifer; subterranean; from artesian wells in Bexar Co., TX; troglobitic [4;5]	C2	T	endemic
Texas Cave Diving Beetle	*Haideoporus texanus*	Edwards Aquifer subterranean caverns[7;8;9;10]	C2	NL	endemic
Balcones Cave Amphipod	*Stygobromus balconius*	Limestone caves [10]	C2	NL	endemic
Bifurcated Cave Amphipod	*Stygobromus bifurcatus*	Spring openings [10]	C2	NL	endemic
Texas Cave Shrimp	*Palaemonetes antrorum*	Ezell's Cave and Edwards Aquifer subterranean caverns [7;8]	C2	NL	endemic
Mimic Cave Snail	*Phreatodrobia imitata*	Edwards Aquifer subterranean caverns; from artesian wells in Bexar Co., TX; troglobitic [11]	C2	NL	endemic
Broadpod Rushpea	Caesalpinia brachycarpa	Edwards Plateau, gravely and rocky limestone soils	C2	NL	endemic
Parks' Jointweed	*Polygonella parksii*	South Texas Plains; subherbaceous annual in deep loose sands, spring-summer	3C	NL	endemic
Silvery Wild Mercury	*Argythamnia argyraea*	South Texas Plains, perennial herb, also in Kinney, LaSalle and Maverick Counties	3C	NL	endemic

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[2] Longley, G. and H. Karnei, Jr. 1979a. Status of *Satan eurystomus Hubbs* and Bailey, the widemouth blindcat. U.S. Fish and Wildlife Services, Endangered species Report 5.
[3] Longley, G. and H. Karnei, Jr. 1979b. Status of *Trogloglanis pattersoni* Eigenmann, the toothless blindcat. U.S. Fish and Wildlife Service, Endangered species Report 5.
[4] Longley, G. & FN Young. 1976. A new subterranean aquatic beetle from Texas (Coleoptera: *Dytiscidae-Hydropoorinae*). Annals of the Entomological Society of American 69(5):787-792.
[5] Elliot, W.R. (Bill) Ph.D., personal communication, 1993. Research Associate, Texas Memorial Museum, The University of Texas at Austin. Austin, Texas.
[6] Edwards, Robert J., Glen Longley, Randy Moss, John Ward, Ray Mathews, and Bruce Stewart. 1989. A Classification of Texas Aquatic Communities with Special Consideration Toward the Conservation of Endangered and Threatened Taxa. Vol. 41, No. 3. The Texas Journal of Science, University of Texas at Austin, Austin, Texas.
[7] Reddell, James, personal communication, 1993. Research Associate (Curator of Arthropods), Texas Memorial Museum, The University of Texas at Austin. Austin, Texas.
[8] Sissom, S.L.& J.C. Davis. 1979. A monographic study of Ezell's Cave, Hays County, Texas. U.S. Department of the Interior and Nature Conservancy. Contract # 14-16-0002-090. 141pp.
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Source: Texas Natural Heritage Program. 1993 Unpublished. Data Base Program Files. Resource Protection Division, TPWD. Austin, Texas.

TABLE 7 - BLANCO COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Black-capped vireo	*Vireo atricapillus*	Semi-open Broad-leaved shrublands	E	E	nesting/migratory
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast waters and bays	E	E	transient
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and old juniper	E	T	nesting
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open wooded and forested areas; southern U.S. coastal plains	NL	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	NL	T	migratory
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas Islands	E	E	migratory
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.	NL	T	probable
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, or under rocks	C2	T	endemic
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL	endemic
Guadalupe Bass	*Micropterus treculi*	Rivers of the Edwards Plateau; includes portions of Brazos, Colorado, Guadalupe, San Antonio River basins; also lower Colorado and introduced in Nueces River system	C2	NL	endemic
Blue Sucker	*Cycleptus elongatus*	Rivers crossing eastern Edwards Plateau to coast	C2	T	[2]possible
Texas Salamander	*Eurycea neotenes*	Springs of the Edwards Plateau	C2	NL	endemic
Canyon Mock-Orange	*Philadelphus ernestii*	Edwards Plateau	C2	NL	endemic
Silvery Wild Mercury	*Argythamnia argyraea*	South Texas Plains, perennial herb, also in Kinney, LaSalle and Maverick Counties	3C	NL	endemic
Hill Country Wild Mercury	*Argythamnia aphoroides*	Edwards Plateau, perennial herb	C2	NL	endemic

TABLE 8 - BROOKS COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	wintering transient
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	endemic
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic/ nesting
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] migratory
Gulf Coast hog-nosed Skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	potential
Red Wolf	*Canis rufus*	Oak-hickory -pine forest, riparian forest; possible Liberty, Chambers, Jefferson Counties,TX	E	E	historic
Texas Tortoise	*Gopherus berlandieri*	Open brush - grass understory; open grass and bare ground are avoided; in shallow depression	NL	T	[1]possible endemic
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic

TABLE 9 - BURNET COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Black-capped vireo	*Vireo atricapillus*	Semi-open Broad-leaved shrublands	E	E	nesting/migratory
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast waters and bays	E	E	transient
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and old juniper	E	T	nesting
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Zone-tailed Hawk	*Buteo albonotatus*	Semi-aird canyon edges of Southwest U.S.	NL	T	[2]possible
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throughout Mississippi River Basin south and west in major freshwater streams of Texas to Rio Grande River	C2	T	[2]possible
Basin Bellflower	*Campanula reverchonii*	On granite rocks and soils in the Llano region of the Edwards Plateau	3C	NL	endemic
Edwards Plateau Cornsalad	*Valerianella texana*	Seasonally moist, shallow gravelly soils, downslope margin of rock outcrops in oak-juniper woodland	C2	NL	endemic
Rock quillwort	*Isoetes lithophila*	Very shallow, seasonally wet sand or gravel in vernal pools on granite or gneiss outcrops	C2	NL	endemic

TABLE 10 - CALDWELL COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water; nests in riparian areas of the Coastal Plains	E	E	migratory/ nesting
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E	migratory
Golden-cheeked Warbler	*Dendroica chrsoparia*	Woodlands with oaks and mature juniper	E	E	[1] possible
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on sandbars of large rivers, dispersal	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied, moist open land with tall trees for nesting	T	T	endemic
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E[3]	T	dispersal
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	migrating
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	migrating
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporally wet areas, arroyos,canals,ditches and shallow depressions; requires moisture to remain	C2	E	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation; grass, cactus, scattered brush; soil may vary from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks	C2	T	endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands, reclusive in dense thickets	NL	T	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throught the Mississippi Basin; In Texas, major streams southward to the Rio Grande	C2	T	[1] possible
Bracted Twistflower	*Streptanthus bracteatus*	In shallow, well drained gravely clays and clay loams over limestone in oak-juniper woods, wooded slopes, canyon bottoms and sandy river margins	C2	NL	endemic

TABLE 11- CALHOUND COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition; not seen since 1967 in Calhound County	E	E	endemic; historic
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E	wintering / nesting
Becard, Rose-throated	*Pachyramphus aglaiae*	Wooded canyons, forests, riversides, large trees	NL	T	endemic
Brown Pelican	*Pelecanus occidentalis*	Gulf, salt bays and coastal areas	E	E	endemic
Eskimo Curlew	*Numenius borealis*	Coastal fields	E	E	migratory
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Piping Plover	*Charadrius melodus*	Beaches and Mudflats	T	E	wintering / transient
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Sooty Tern	*Sterna fuscata*	Coastal wetland islands	NL	T	[1] wintering/ transient
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open wooded areas	C3	T	endemic
Western Snowy Plover	*Charadrius alexandrinus nivosus*	Gulf Coastal beaches in Texas, avoids thick vegetation and narrow beaches; found worldwide	C2	NL	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	migrating
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E	T	[1] probable
Dolphin, Rough-Toothed	*Steno bredanensis*	Offshore waters, usually off edge of continental shelf	NL	T	[1] possible; at periphery
Dolphin, Spotted, Atlantic	*Stenella plagiodon*	Generally offshore 5 mi. or 100 fathoms deep; seasonally may approach very close to shore	NL	T	[1] possible; at periphery
Whale, Black Right	*Balaena glacialis*	Gulf of Mexico and coastal bays	E	E	[1] possible; at periphery
Whale, Blue	*Balaenoptera musculus*	Gulf of Mexico and coastal bays	E	E	[1] possible; at periphery
Whale, Finback	*Balaenoptera physalus*	Gulf of Mexico and coastal bays	E	E	[1] possible; at periphery
Whale, Sperm	*Physeter macrocephalus*	Gulf of Mexico and coastal bays	E	E	[1] possible; at periphery
Whale, Dwarf Sperm	*Kogia simus*	Gulf of Mexico and coastal bays	NL	T	[1] possible; at periphery
Whale, Pygmy Sperm	*Kogia breviceps*	Deep offshore waters; close to shore when calving	NL	T	[1] possible; at periphery
Whale, False Killer	*Pseudorca crassidens*	Tropical and temperate seas; Gulf of Mexico; occasionally stranded in bays or estuaries	NL	T	[1] possible; at periphery
Whale, Killer	*Orcinus orca*	Gulf of Mexico; occasionally large rivers	NL	T	[1] possible; at periphery
Whale, Pygmy Killer	*Feresa attenuata*	Warm offshore waters	NL	T	[1] possible; at periphery
Whale, Gervais' Beaked	*Mesoplodon europaeus*	Warm temperate offshore waters	NL	T	[1] possible; at periphery
Whale, Goose-Beaked	*Ziphius cavirostris*	Gulf of Mexico	NL	T	[1] possible; at periphery
Whale, Short-Finned	*Globicephala macrorhynchus*	Deep offshore waters; sometimes close to shore	NL	T	[1] possible; at periphery
Green Sea Turtle	*Chelonia mydas*	Gulf coast, bay waters and beaches	T	T	endemic
Hawksbill Sea Turtle	*Eretmochelys imbricata imbricata*	Gulf coast and bay waters and beaches	E	E	[1]probable
Leatherback Sea Turtle	*Dermochelys coriacea*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1] robable
Loggerhead Sea Turtle	*Caretta caretta*	Gulf coast and bay waters and beaches; scattered beach nesting	T	E	endemic

TABLE 11- CALHOUND COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Ridley, Kemp's, Sea Turtle	*Lepidochelys kempi*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	endemic
Texas Diamondback Terrapin	*Malaclemys terrapin*	Gulf coast shoreline	C2	NL	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov.	NL	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks when inactive	C2	T	endemic
Gulf Saltmarsh Snake	*Nerodia clarkii*	Estuaries, beaches, crayfish and fiddler crab burrows	C2	NL	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grassy prairies to sand hills; thorn brush woodland and mesquite savannah of coastal prairies	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; aestivates underground during dry periods	C2	E	[1] possible;
Sheep Frog	*Hypopachus variolosus*	Marshes of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	C2	T	endemic
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporally wet areas, arroyos, canals, ditches, depressions; requires moisture to remain	C2	E	endemic

TABLE 12 - COLORADO COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native coastal prairie grassland with diverse habitat of short-, mid-, and tallgrass; 50% climax	E	E	endemic
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	wintering, nesting
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	endemic
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Swallow-tailed Kite, American	*Elanoides forficatus*	Forests in water, Southern US coastal plains	C3	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E [2]	T	migratory
Red Wolf	*Canis rufus*	Southern riparian and pine forest; may exist in Liberty, Chambers, Jefferson Counties,TX [3]	E	E	historic
Houston Toad	*Bufo Houstonensis*	Loamy, friable soils, temporary rain pools, flooded field, ponds surrounded by forest or grass; reintroduced to Colorado Co.	E	E	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil,hides under rocks	C2	T	endemic
Timber Rattlesnake	*Crotalus horridus*	Riparian woods, in dense vegetation	NL	T	endemic
Western Smooth Green Snake	*Opeodrys vernalis blanchardi*	Coastal grasslands	NL	E	endemic

TABLE 13 - COMAL COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting/resting sites	E	E	wintering / transient
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied, open land with tall trees for nesting	3C	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
Zone-tailed Hawk	*Buteo albonotatus*	Semi-aird canyon edges of Southwest U.S.	NL	T	historic nesting
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands	E	E	nesting/migrant
Golden-cheeked Warbler	*Dendroica chrsoparia*	Woodlands with oaks and old juniper	E	E	nesting/migrant
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Whistling - duck, Fulvous	*Dendrocygna bicolor*	Ponds and freshwater marshes	C2	NL	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E	T	dispersal
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	3C	NL	resident
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation; grass, cactus, scattered brush; soil may vary from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks	C2	T	endemic
Texas Garter Snake	*Thamnophis sirtalis annectans*	Varied, especially moist habitats	C2	NL	endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T	[1] possible
Texas Mock-Orange	*Philadelphus texensis*	On limestone bluffs and among boulders on the Edwards Plateau	C2	NL	endemic

TABLE 14 - DEWITT COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition	E	E	endemic
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	wintering\ transient
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	endemic
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Swallow-Tailed Kite, American	*Elanoides forficatus*	Varied; open land, nesting in forested river bottoms	3C	T	migratory
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	migrating
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E[2]	T	[1] dispersal
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL	[3] endemic

TABLE 14 - DEWITT COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil or hides under rocks	C2	T	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov.	NL	T	[1] probable
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T	[3] endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporarily wet areas; arroyos, canals, ditches; aestivates underground during dry periods	C2	E	[1] probable

TABLE 15 - DIMMIT COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	transient
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	endemic
Black Bear	Ursus americanus	Mountains, broken country, woods, brushland and forests	T	E	endemic
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	[1]possible
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; primarily extreme south TX	E	E	[1]probable
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects	NL	T	endemic
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	C2	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil or hides under rocks	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; thorn brush woodland and mesquite savannah of coastal plain	NL	T	[3] endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial	NL	T	[1]possible
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas, arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	[3] endemic
Dimmit Sunflower	*Helianthess praecox spp. hirtus*	Known only to sands in Dimmit County, Rio Grande Plains	C2	NL	endemic

TABLE 16 - DUVAL COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	wintering
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	endemic
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	[1] possible,wintering
Gray Hawk	*Buteo nitidus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	C2	T	[1] possible,wintering

TABLE 16 - DUVAL COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	migratory
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Swallow-tailed Kite, American	*Elanoides forficatus*	Open wooded and forested areas near water; tall trees for nesting; southern U.S. coastal plains	NL	T	transient
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic / nesting
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E	T	migratory
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	[1] probable
Gulf Coast hog-nosed skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	[1] potential
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E	endemic
Red Wolf	*Canis rufus*	Southern riparian and pine forest; may exist in Liberty, Chambers, Jefferson Counties,TX [2]	E	E	[1]historic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	[2]probable
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	[1]probable
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	Sand floored thicket immediately adjacent to the Gulf	NL	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	endemic
Black Lace Cactus	*Echinocereus reichenbachii* var. *albertii*	Openings in dense brush on sandy soils on South Texas Plains	E	E	endemic

TABLE 17 - EDWARDS COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting/resting sites	E	E	wintering / transient
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon,-Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied, open land with tall trees for nesting	3C	T	endemic
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	transient
Zone-tailed Hawk	*Buteo albonotatus*	Semi-aird canyon edges of Southwest U.S.	NL	T	historic nesting
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands	E	E	nesting/migrant
Golden-cheeked Warbler	*Dendroica chrsoparia*	Woodlands with oaks and old juniper	E	E	nesting/migrant
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	resident
Wood Stork	*Mycteria americana*	Coastal wetlands	E	T	dispersal
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushland and forests	T	E	endemic
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains	NL	E	[1]potential
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	[3]endemic
Broadpod Rushpea	*Caesalpinia brachycarpa*	In gravelly or rocky limestone soils of the Edwards Plateau; small groups in widely scattered populations	C2	NL	endemic
Edwards Plateau Capul Negro (Edwards Plateau Brasil)	*Condalia hookeri var edwadsiana*	Known from a single thicket in shallow clay soil ona dry rocky limestone slope in a pasture with live oak and common Edwards Plateau shrubs	C2	NL	endemic; may be extinct
Sonora Fleabane	*Erigeron mimegletes*	Western part of Edwards Plateau	C2	NL	endemic
Texas Snowbells	*Styrax texana*	In limestone crevices of cliffs along streams; Edwards Plateau	E	E	endemic
Tobusch fishhook cactus	*Ancistrocactus tobuschii*	In juniper-oak association; limestone soils at about 488 meters elevation	E	E	endemic

TABLE 18 - FAYETTE

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	transient/nesting
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	forests in water, Southern US coastal plains	C3	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	migratory
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E	T	transient

TABLE 18 - FAYETTE (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Timber Rattlesnake	*Crotalus horridus*	Riparian woods, in dense vegetation	NL	T	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throughout Mississippi River Basin south and west in major freshwater streams of Texas to Rio Grande River	C2	T	endemic

TABLE 19 - FRIO COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	[1]possible
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	[1]possible
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	nesting
Gray Hawk	*Buteo mitidus maximus*	Cotton-willow woodlands of Rio Grande, mature woodlands of river valleys, and associated semi-arid mesquite and scrubland	C2	T	[1]possible
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	transient
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	[1]possible
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	transient
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	endemic
Black Bear	Ursus americanus	Mountains, broken country, woods, brushland and forests	E	E	[1]possible
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	[1]possible
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	[1]possible
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; primarily extreme south TX	E	E	[1]possible
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects	NL	T	[1]possible
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	C2	T	[1]possible
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, hides under rocks	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Salamander	Eurycea neotenes	Springs of the Edwards and Balcones escarpment	C2	NL	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throught the Mississippi Basin; In Texas, major streams southward to the Rio Grande	C2	T	endemic
Guadalupe Bass	*Micropterus treculi*	Large rivers crossing the Edwards Plateau to the coast; Nueces River in Zavala County	C2	NL	endemic

TABLE 20 - GOLIAD COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition	E	E	endemic; not seen since 1989
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	wintering / nesting
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and old juniper	E	T	[1] possible; periphery
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E	T	migratory
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	endemic
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active	NL	T	[2]endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Endemic grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas, arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	NL	T	endemic

TABLE 21 - GONZALES COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E	migratory
Golden-cheeked Warbler	*Dendroica chrsoparia*	Woodlands with oaks and old juniper	E	E	[1] possible
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open forested areas	3C	T	migratory
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic

TABLE 21 - GONZALES COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E[2]	T	dispersal
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL	[3] endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov.	NL	T	probable
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporally wet areas, arroyos,canals,ditches and shallow depressions; requires moisture to remain	C2	E	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks when inactive	C2	T	endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands, dense thickets	NL	T	[3] endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throught the Mississippi Basin; In Texas, major streams southward to the Rio Grande	C2	T	[1] possible
Guadalupe Bass	*Micropterus treculi*	Rivers of the Edwards Plateau including portions of the Brazos, Colorado, Guadalupe, and San Antonio River Basins; also the lower Colorado River and introduced in the Nueces River system	C2	NL	[1] possible

TABLE 22 GAUDALUPE COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting/resting sites	E	E	wintering / transient
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied, open land with tall trees for nesting	3C	T	resident
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands	E	E	nesting/migrant [1]
Golden-cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oaks and old juniper	E	E	nesting/migrant
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	resident
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating transient
Wood Stork	*Mycteria americana*	Coastal wetlands	E**	T	dispersal
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands	C2	T	resident
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	3C	NL	resident
Texas Garter Snake	*Thamnophis sirtalis annectans*	Varied, especially moist habitats	C2	NL	resident
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T	potential
Blue Sucker	*Cycleptus elongatus*	Rivers crossing eastern Edwards Plateau to coast	C2	T	resident
Guadalupe Bass	*Micropterus terculi*	Streams of eastern Edwards Plateau	C2	NL	resident

TABLE 22 GAUDALUPE COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Fountain Darter	*Etheostoma fonticola*	San Marcos River to confluence with Blanco River; associated with San Marcos Salamander in quite, clear water	E	E	resident
San Marcos Gambusia	*Gambusia georgei*	San Marcos River to confluence with Blanco River, large clear spring-fed river	E	E	resident, possibly extinct
Big Red Sage	*Salvia penstemonoides*	Moist rich ledges, rocky level creek floodplain; reintroduced through native plant nursey trade	C2	NL	historic endemic

TABLE 23 HAYS COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting/resting sites	E	E	wintering / transient
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied, open land with tall trees for nesting	3C	T	resident
Zone-tailed Hawk	*Buteo albonotatus*	semi-aird canyon edges of Southwest U.S.	NL	T	historic nesting [1]
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands	E	E	nesting/migrant
Golden-cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oaks and old juniper	E	E	nesting/migrant
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	resident
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating transient
Wood Stork	*Mycteria americana*	Coastal wetlands	E**	T	dispersal
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands	C2	T	resident
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	3C	NL	resident
Texas Garter Snake	*Thamnophis sirtalis annectans*	Varied, especially moist habitats	C2	NL	resident
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T	not confirmed **
Blue Sucker	*Cycleptus elongatus*	Rivers crossing eastern Edwards Plateau to coast	C2	T	resident
Guadalupe Bass	*Micropterus terculi*	Streams of eastern Edwards Plateau	C2	NL	resident
Fountain Darter	*Etheostoma fonticola*	San Marcos River to confluence with Blanco River; associated with San Marcos Salamander in quite, clear water	E	E	resident
San Marcos Gambusia	*Gambusia georgei*	San Marcos River to confluence with Blanco River, large clear spring-fed river	E	E	resident, possibly extinct
Canyon Mock - Orange	*Philadelphus ernestii*	Edwards Plateau	C2	NL	resident
Hill Country Wild-Mercury	*Argythamnia aphoroides*	Shallow to moderately deep clays and clay loams over limestone in grasslands associated with plateau live oak, on rolling uplands	C2	NL	resident [1]

TABLE 24 - JACKSON

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E	wintering / nesting
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	resident
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	resident
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	resident
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	resident
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] migratory
Texas Diamondback Terrapin	*Malaclemys terrapin*	Littoral zone and coastal waters of Gulf of Mexico	C2	NL	
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation (grass, cactus, scattered brush , scrubby trees);when inactive burrows in soil (various rocky to sandy), hides under rocks	C2	T	resident
Marshelder Dodder	*Cuscuta attenuata*	Parasitic; only collected on Marsh-Elder *Iva annua* in Texas	C2	NL	[2]endemic

TABLE 25 JIM WELLS COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	transient/winter
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory
White-tailed Hawk	*Buteo albicaudatus*	Desert grasslands, prairie brushlands	NL	T	migratory
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migratory
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E	T	[1] possible
Zoned-tailed Hawk	*Buteo albonotatus*	Desert Mountains and western rivers	NL	T	[1]possible / migratory
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains	NL	E	[1]possible
Gulf Coast hog-nosed skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	potential
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	[1] probable
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; primarily extreme south Texas	E	E	[1] probable
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas, arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	NL	T	endemic
Black Lace Cactus	*Echinocereus reichenbachii albertii*	Grows in extremely heavy brush and very localized	E	E	endemic
South Texas Ragweed	*Ambrosia cheiranthiflora*	Open prairie, various shrublands on deep clay soils	C1	NL	endemic
Lila de los Llanos / Chandlers Crag Lily	*Anthericum chandleri*	Lower Rio Grande Valley; South Coastal Texas	C2	NL	endemic

TABLE 24 - JACKSON

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E	wintering / nesting
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	resident
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	resident
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	resident
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	resident
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] migratory
Texas Diamondback Terrapin	*Malaclemys terrapin*	Littoral zone and coastal waters of Gulf of Mexico	C2	NL	
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation (grass, cactus, scattered brush , scrubby trees);when inactive burrows in soil (various rocky to sandy), hides under rocks	C2	T	resident
Marshelder Dodder	*Cuscuta attenuata*	Parasitic; only collected on Marsh-Elder *Iva annua* in Texas	C2	NL	[2]endemic

TABLE 25 JIM WELLS COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	transient/winter
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory
White-tailed Hawk	*Buteo albicaudatus*	Desert grasslands, prairie brushlands	NL	T	migratory
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migratory
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E	T	[1] possible
Zoned-tailed Hawk	*Buteo albonotatus*	Desert Mountains and western rivers	NL	T	[1]possible / migratory
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains	NL	E	[1]possible
Gulf Coast hog-nosed skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	potential
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	[1] probable
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; primarily extreme south Texas	E	E	[1] probable
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas, arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	NL	T	endemic
Black Lace Cactus	*Echinocereus reichenbachii albertii*	Grows in extremely heavy brush and very localized	E	E	endemic
South Texas Ragweed	*Ambrosia cheiranthiflora*	Open prairie, various shrublands on deep clay soils	C1	NL	endemic
Lila de los Llanos / Chandlers Crag Lily	*Anthericum chandleri*	Lower Rio Grande Valley; South Coastal Texas	C2	NL	endemic

TABLE 26 - KARNES

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	wintering / nesting
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and old juniper	E	T	[1] possible; periphery
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	migratory
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	[1] potential
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	dispersal
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	migrating
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	NL	T	migratory
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	[1] potential; at periphery of range
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Endemic grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	[1] potential; at periphery of range
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	[1] potential; at periphery of range
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	[1] potential; at periphery of range

TABLE 27 - KENDALL COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting/resting sites	E	E	wintering / transient
Golden Eagle	*Aquila chrysaetos*	wild expanses of open country, whether of mountains, plains or canyons	NL	T	potential
Fulvous Whistling Duck	*Dendrocygna bicolor*	grassy freshwater marshes and ponds	NL	T	migrant
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied, open land with tall trees for nesting	3C	T	potential

TABLE 27 - KENDALL COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Zone-tailed Hawk	*Buteo albonotatus*	semi-aird canyon edges of Southwest U.S.	NL	T	[1]potential
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands	E	E	nesting/migrant
Golden-cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oaks and old juniper	E	E	nesting/migrant
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	resident
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	migrating transient
Wood Stork	*Mycteria americana*	Coastal wetlands	E**	T	dispersal
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands	C2	T	resident
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	3C	NL	resident
Baird's Rat Snake	*Elaphe bairdii*	rocky, wooded canyons and forested uplands	NL	T	endemic
Mexican Milk snake	*Lampropeltis triangulum annulata*	variety, from sand dunes to cultivated fields	NL	T	endemic
Texas Garter Snake	*Thamnophis sirtalis annectans*	Varied, especially moist habitats	C2	NL	resident
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T	[1] periphery of range
Blue Sucker	*Cycleptus elongatus*	Rivers crossing eastern Edwards Plateau to coast	C2	T	resident
Guadalupe Bass	*Micropterus terculi*	Streams of eastern Edwards Plateau	C2	NL	resident
Big Red Sage	*Salvia penstemonoides*	Moist rich ledges, rocky level creek floodplain	C2	S1S2	endemic
Canyon Mock - Orange	*Philadelphus ernestii*	Edwards Plateau	C2	NL	endemic
Edge Falls Anemone	*Anemone edwardsiana var. petraea*	Shallow to moderately deep clays and clay loams over limestone in grasslands associated with plateau live oak, on rolling uplands	C2	S1	endemic
Glass Mountains Coral-root	*Hexalectris nitida*	Along rocks in shaded canyons	C2	S2	endemic
Hill Country Wild Mercury	*Argythamnia aphoroides*	Edwards Plateau	C2	NL	historic

TABLE 28 - KERR

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	migrating
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E	nesting
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	nesting
Gray Hawk	*Buteo mitidus maximus*	Cotton-willow woodlands of Rio Grande, mature woodlands of river valleys, and associated semi-arid mesquite and scrubland	C2	T	[1]possible
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	[1]probable
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory

TABLE 28 KERR COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Swallow-tailed Kite, American	*Elanoides forficatus*	Open forested areas	3C	T	migratory
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	[1]probable
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E	T	dispersal
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	[1]probable
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushland and forests	T	E	historic endemic
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	[1]possible
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C1	NL	[3] endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Salamander	*Eurycea neotenes*	Springs of the Edwards and Balcones escarpment	C2	NL	endemic
Comal Blind Salamander	*Eurycea tridentifera*	Cave and skinholes with considerable water and without fish	C2	T	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	[1]possible
Hill Country Wild-Mercury	*Argythamnia aphoroides*	Shallow to moderately deep clays and clay loams over limestone in grasslands associated with plateau live oak, on rolling uplands	C2	NL	endemic
Big Red Sage	*Salvia penstemonoides*	In seepage on limestone ledges, banks of streams, seasonally wet clay or silt soils in creekbeds; available in the native plant nursery trade	C2	NL	historic endemic

TABLE 29 - KINNEY COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting/resting sites	E	E	wintering / transient
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied, open land with tall trees for nesting	3C	T	endemic
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E	nesting
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	transient
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	potential

TABLE 29 - KINNEY COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Gray Hawk	*Buteo mitidus maximus*	Cotton-willow woodlands of Rio Grande, mature woodlands of river valleys, and associated semi-arid mesquite and scrubland	C2	T	[1]possible
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	resident
Wood Stork	*Mycteria americana*	Coastal wetlands	E	T	dispersal
Zone-tailed Hawk	*Buteo albonotatus*	Semi-aird canyon edges of Southwest U.S.	NL	T	historic nesting
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushland and forests	T	E	endemic
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains	NL	E	[1]potential
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	[3]endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throughout Mississippi River Basin south and west in major freshwater streams of Texas to Rio Grande River	C2	T	[1] potential
Mexican Stoneroller	*Campostoma ornatum*	Headwater streams along the crest of the Sierra Madre Occidential; records from Kinney Val Verde	C2	T	
Broadpod Rushpea	*Caesalpinia brachycarpa*	In gravelly or rocky limestone soils of the Edwards Plateau; small groups in widely scattered populations	C2	NL	endemic
Texas Trumpets	*Acleisanthes crassifloria*	Edwards Plateau restricted; in well drained, calcareous gravelly loams over caliche, along nad near the Rio Grande River on gentle to moderate slopes often sparsely vegetated openings in cenizo; on Austin chalk or Uvalde gravel	C2	NL	endemic
Tobusch fishhook cactus	*Ancistrocactus tobuschii*	In juniper-oak association; limestone soils at about 488 meters elevation	E	E	endemic

TABLE 30 - KLEBERG COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Gulf Coast hog-nosed skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	potential
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	possible; habitat buffer zone
Ocelot	*Felis pardalis*	dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E	area is habitat buffer zone; possible endemic
Audubon's Oriole	*Icterus graduacauda audubonii*	South Texas dense woods, midlevel in trees foraging in pairs	C2	NL	potential
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting/resting sites	E	E	wintering / transient
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast and salt bays	E	E	[1]possible endemic
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Loggerhead Shrike	*Lanius ludovicianus*	South Texas	C2	NL	potential

TABLE 30 - KLEBERG COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Mountain Plover	*Charadrius montanus*	arid plains, short grass prairies and arid plains	C2	NL	potential
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Piping Plover	*Charadrius melodus*	Beaches and Mudflats	E	E	wintering / transient
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Sennett's Hooded Oriole	*Icterus cucullatus sennetti*	South Texas; dense palm frons, cotton woods and willows in riparian areas	C2	NL	potential
Sooty Tern	*Sterna fuscata*	Pantropical, nesting on offshore islands Florida, historically bred on Louisiana and Texas shore	NL	T	transient/ nesting
Texas Botteri's Sparrow	*Aimophila botterii texana*	South Texas in dense tall grass; very secretive	C2	T	potential
Texas Olive Sparrow	*Arremonops rufivirgatus rufivirgatus*	South Texas in brushy thickets; secretive	C2	NL	potential

TABLE 31 - LA SALLE COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
American Swallow-tailed Kite	*Elanoides forficatus*	Varied, moist open land with tall trees for nesting	T	T	potential
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	winter migrant
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	transient
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	potential
Gray Hawk	*Buteo mitidus maximus*	Cotton-willow woodlands of Rio Grande, mature woodlands of river valleys, and associated semi-arid mesquite and scrubland	C2	T	[1]possible
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	transient
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migrant
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migrant
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	potetial
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	possible migratory
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	
Black Bear	Ursus americanus	Mountains, broken country, woods, brushland and forests			
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; primarily extreme south Texas	E	E	
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	C2	T	endemic

TABLE 31 - LA SALLE COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	potential
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throught the Mississippi Basin; In Texas, major streams southward to the Rio Grande	C2	T	potential
Silvery Wild Mercury	*Argythamnia argyraea*	South Texas Plains, perennial herb, also in Atascosa, Kinney, and Maverick Counties	3C	NL	endemic
Texas Bitterweed (Texas Prairie Dawn)	Hymenoxys texana	Gulf Prairies and marshes, Ft. Bend and Harris Co. poorly drained depressions or at the base of amima mounds in almost barren areas of open grasslands with peppergrass, *Limnosciadium pumilum*, little barley, and *Nostoc*	E	E	endemic

TABLE 32 - LEE COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
American Swallow-tailed Kite	*Elanoides forficatus*	Varied, moist open land with tall trees for nesting	T	T	potential
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	migratory
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	migratory
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E	T	dispersal
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation, grass, cactus, scattered brush or scrubby trees; soils vary sandy to rocky; burrows, enters rodent burrow, or hides under rocks	C2	T	endemic

TABLE 33 - LIVE OAK COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	wintering/transient
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	endemic
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic

TABLE 33 - LIVE OAK COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] migratory
Gulf Coast hog-nosed Skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	potential
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	possible;
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	[2]probable
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides when inactive	C2	T	[2]probable
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; thorn brush woodland, mesquite savannah of coastal plain	NL	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground in dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions;	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	NL	T	endemic

TABLE 34 - LLANO COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Black-capped vireo	*Vireo atricapillus*	Semi-open Broad-leaved shrublands	E	E	nesting/migratory
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast waters and bays	E	E	transient
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and old juniper	E	T	nesting
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Zone-tailed Hawk	*Buteo albonotatus*	Semi-aird canyon edges of Southwest U.S.	NL	T	[2]possible
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil or hides under rocks	C2	T	endemic
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throughout Mississippi River Basin south and west in major freshwater streams of Texas to Rio Grande River	C2	T	[2]possible
Basin Bellflower	*Campanula reverchonii*	On granite rocks and soils in the Llano region of the Edwards Plateau	3C	NL	endemic
Edwards Plateau cornsalad	*Valerianella texana*	Seasonally moist, shallow gravelly soils, downslope of rock outcrops in oak-juniper woodland	C2	NL	endemic
Rock quillwort	*Isoetes lithophila*	Very shallow, seasonally wet sand or gravel in vernal pools on granite or gneiss outcrops	C2	NL	endemic

TABLE 35 - MATAGORDA COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Prairie-Chicken	*Typanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition	E	E	
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E	wintering / nesting
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast and salt bays	E	E	endemic
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Piping Plover	*Charadrius melodus*	Beaches and Mudflats	E	E	nesting
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open wooded and forested areas	NL	T	transient
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E	T	transient
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	potential
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E	potential
Red Wolf	*Canis rufus*	Oak-hickory -pine forest, southern riparian forest	E	E	historic range
Whale, Black Right	*Balaena glacialis*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Blue	*Balaenoptera musculus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Fin	*Balaenoptera physalus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Sperm	*Physeter macrocephalus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Green Turtle, Atlantic	*Chelonia mydas mydas*	Gulf coast and bay waters and beaches; scattered beach nesting	T	T	[1]probable
Hawksbill Sea Turtle	*Eretmochelys imbricata imbricata*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1]probable
Leatherback Sea Turtle	*Dermochelys coriacea*	Gulf coast, bay waters and beaches; scattered beach nesting	E	E	[1]probable
Loggerhead Sea Turtle	*Caretta caretta*	Gulf coast and bay waters and beaches; scattered beach nesting	T	E	[1]probable
Ridley, Kemp's, Sea Turtle	*Lepidochelys kempi*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1]probable
Texas Diamondback Terrapin	*Malaclemys terrapin littoralis*	Gulf coast shoreline	C2	NL	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov.	NL	T	[1]probable
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	C2	T	[1]probable
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation (grass, cactus, scattered brush, scrubby trees); when inactive burrows in soil (various texture, sandy to rocky), or hides under rocks	C2	T	endemic

TABLE 35 - MATAGORDA COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Gulf Saltmarsh Snake	*Nerodia clarkii*	Estuaries and beaches; crayfish and fiddler crab burrows	C2	NL	endemic
Western Smooth Green Snake	Opheodrys vernalis	Coastal grasslands, short grass	NL	E	endemic
Texas Garter Snake	Thamnophis sirtalis annectens	Moist pastures and moist vacant fields, grasslands	C2	NL	endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T	[1] endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T	probable
Indigo Snake	*Drymarchon corais erebennus*	Grassland Prairie to sand hills; usually thorn brush woodland and mesquite savannah of coastal plains	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T	endemic
Timber rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T	[1]confirmed endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; aestivates underground during dry periods	C2	E	[1]probable
Mexican Treefrog	*Smilisca baudinii*	Rio Grande Valley, vegetation in wet areas	NL	T	[2]confirmed
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture to remain	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	[1]probable
Black Lace Cactus	*Echinocerus reichenbachii var. albertii*	Brushy, grassy areas with huisache, mesquite, blackbrush, retama, shrubs; South Texas Plains	E	E	[3]endemic
Plains Gumweed	*Grindelia oolepis*	Tight black clay-gumbo soils in coastal part of Rio Grande Plains	3C	NL	endemic
Texas Windmill Grass	*Chloris texensis*	Sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants; also roadsides and with coastal prairie edemics in slightly saline soils in bare areas around pimple mounds	C2	NL	endemic
Welder Machaeranthera	*Machaeranthera heterocarpa*	Shrub invaded grasslands and rights-of-way on mostly gray colored clayey to silty soils over Beaumont and Lissie Formations	C2	NL	endemic

TABLE 36 MCMULLEN COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	wintering\ transient
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	endemic
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] migratory

TABLE 36 MCMULLEN COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Red Wolf	*Canis rufus*	Oak-hickory -pine forest, southern riparian forest; may still exist in Liberty, Chambers, Jefferson Counties,TX [2]	E	E	[1] historic
Reticulate Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	[2] probable
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation, grass, cactus, scattered brush or scrubby trees; soils vary sandy to rocky; burrows, enters rodent burrow, or hides under rocks	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	C2	T	[1] probable
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	[1] probable

TABLE 37 - MEDINA COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	migrating
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E	nesting
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	nesting
Gray Hawk	*Buteo mitidus maximus*	Cotton-willow woodlands of Rio Grande, mature woodlands of river valleys, and associated semi-arid mesquite and scrubland	C2	T	[1] possible
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	[1] probable
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Open forested areas	3C	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	[1] probable
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E [2]	T	dispersal
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	[1] probable
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushland and forests	T	E	historic endemic
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	[1] possible
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic

TABLE 37 - MEDINA COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Salamander	*Eurycea neotenes*	Springs of the Edwards and Balcones escarpment	C2	NL	endemic
Comal Blind Salamander	*Eurycea tridentifera*	Cave and skinholes with considerable water and without fish	C2	T	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	[1]possible
Bracted Twistflower	*Streptanthus bracteatus*	Edwards Platuea, wooded slopes and sandy river edges; April - May	C2	NL	endemic
Texas Mock Orange	*Philadelphus texensis*	On limestone bluffs and among boulders on the Edwards Plateau	3C	NL	endemic

TABLE 38 - NUECES COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Aplomado Falcon	*Falco femoralis*	Grasslands Prairies	E	E	[1] Possible; at periphery/migratory
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	wintering / transient
Becard, Rose-throated	*Pachyramphus aglaiae*	Wooded canyons, forests, riversides, large trees; nests in Rio Grande Valley south of Falcon Dam	NL	T	wintering / transient possible endemic
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast waters and bays	E	E	endemic
Eskimo Curlew	*Numenius borealis*	Coastal plains	E	E	[1] potential, migratory
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Piping Plover	*Charadrius melodus*	Beaches and Mudflats	E	E	wintering / transient
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Sooty Tern	*Sterna fuscata*	Coastal wetland islands during breeding season; offshore and gulf at other times	NL	T	wintering / transient
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open forested areas	C3	T	[1]confirmed / transient
Tyrannulet, Breadless -, Norther	*Camptostoma imberbe*	Extreme Southern Rio Grande Valley	NL	T	rare
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Desert grasslands, prairie brushlands	NL	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migratory
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] confirmed
Zoned-tailed Hawk	*Buteo albonotatus*	Desert Mountains and western rivers	NL	T	[1]possible / migratory

TABLE 38 - NUECES COUNTY (CONTINUED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains	NL	E	[1]possible endemic
Gulf Coast hog-nosed Skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	potential
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	[1]probable
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; primarily extreme south Texas	E	E	[1]Probable
Dolphin, Rough-Toothed	*Steno bredanensis*	Offshore waters; usually off edge of continental shelf	NL	T	[1] Possible; at periphery
Dolphin, Spotted, Atlantic	*Stenella plagiodon*	Offshore waters 5mi. or 100 fathoms; seasonally may approach close to shore	NL	T	[1] Possible; at periphery
Whale, Black Right	*Balaena glacialis*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Blue	*Balaenoptera musculus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Dwarf Sperm	*Kogia simus*	Gulf of Mexico and coastal bays	NL	T	[1] Possible; at periphery
Whale, False Killer	*Pseudorca crassidens*	Gulf of Mexico and coastal bays	NL	T	[1] Possible; at periphery
Whale, Fin	*Balaenoptera physalus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Whale, Gervais' Beaked	*Mesoplodon europaeus*	Probably warm temperate offshore waters	NL	T	[1] Possible; at periphery
Whale, Goose-Beaked	*Ziphius cavirostris*	Gulf of Mexico	NL	T	[1] Possible; at periphery
Whale, Killer	*Orcinus orca*	Gulf of Mexico and occasionally large rivers	NL	T	[1] Possible; at periphery
Whale, Pygmy Killer	*Feresa attenuata*	Gulf of Mexico	NL	T	[1] Possible; at periphery
Whale, Pygmy Sperm	*Kogia breviceps*	Deep Gulf waters; close to shore during calving season	NL	T	[1] Possible; at periphery
Whale, Short-Finned	*Globicephala macrorhynchus*	Deep offshore waters; sometimes close to shore	NL	T	[1] Possible; at periphery
Whale, Sperm	*Physeter macrocephalus*	Gulf of Mexico and coastal bays	E	E	[1] Possible; at periphery
Green Turtle, Atlantic	*Chelonia mydas mydas*	Gulf coast and bay waters and beaches	T	T	endemic
Hawksbill Sea Turtle	*Eretmochelys imbricata imbricata*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1]confirmed occurrence
Leatherback Sea Turtle	*Dermochelys coriacea*	Gulf coast, bay waters and beaches; scattered beach nesting	E	E	[1] confirmed occurence
Loggerhead Sea Turtle	*Caretta caretta*	Gulf coast, bay waters and beaches; scattered beach nesting	T	E	[1] confirmed occurence
Ridley, Kemp's, Sea Turtle	*Lepidochelys kempi*	Gulf coast, bay waters and beaches; scattered beach nesting	E	E	[1] confirmed occurence
Cat-eyed Snake, Northern	*Leptodeira s. septentrionalis*	Coastal thorn thicket; principal microhabitat is dense vegetation bordering ponds and watercourses	NL	E	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Racer, Specked	*Drymobius margaritiferus*	Dense thickets heavily littered with plant debris; generally near water	NL	E	possible
Texas Scarlet Snake	*Cemophora coccinea lineri*	Sand floored thicket immediately adjacent to the Gulf	NL	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	endemic
Opposum Pipefish	*Microphis brachyurus*	Gulf of Mexico south coastal bays in various habitats, *Spartina* marshes or *Sargassum*	NL	T	confirmed

TABLE 38 - NUECES COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Black Lace Cactus	*Echinocereus reichenbachii albertii*	Grows in extremely heavy brush and very localized	E	E	possible
Chandlers Crag Lily	*Anthericum chandleri*	Lower Rio Grande Valley; South Coastal Texas	C2	NL	endemic
Roughseed Sea-purslane	*Sesuvium trianthemoides*	Dunes of coastal South Texas	C2	NL	possibly extinct
Slender Rush-pea	*Hoffmannseggia tenella*	Gulf Coast prairies and marshes; clayey soils near creeks with buffalo grass, spear grass, mesquite and prickly pear cactus	E	E	endemic
South Texas Ragweed	*Ambrosia cheiranthiflora*	Open prairie, various shrublands on deep clay soils	C1	NL	endemic
Texas Windmill Grass	*Chloris texensis*	Sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants; also roadsides, with coastal prairie edemics in slightly saline soils in bare areas around pimple mounds	C2	NL	endemic

TABLE 39 - REFUGIO COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Prairie-Chicken	*Typanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition	E	E	endemic
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E	wintering / nesting
Brown Pelican	*Pelecanus occidentalis*	Gulf Coast and salt bays	E	E	[1]possible endemic
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and old juniper	E	T	[1] possible; periphery
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Piping Plover	*Charadrius melodus*	Beaches and Mudflats	E	E	wintering / transient
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open wooded and forested areas	NL	T	transient
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda and Aransas Islands	E	E	migrating
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E	T	dispersal
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	[1]confirmed occurrence
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland and live oak mottes; avoids open areas; primarily extreme south Texas	E	E	[1] confirmed occurrence
Red Wolf	*Canis rufus*	Oak-hickory -pine forest, southern riparian forest; may still exist in Liberty, Chambers, Jefferson Counties,TX [2]	E	E	historic range
Green Turtle, Atlantic	*Chelonia mydas mydas*	Gulf coast and bay waters and beaches; scattered beach nesting	T	T	[1]probable
Hawksbill Sea Turtle	*Eretmochelys imbricata imbricata*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1]probable
Loggerhead Sea Turtle	*Caretta caretta*	Gulf coast and bay waters and beaches; scattered beach nesting	T	E	[1]probable

TABLE 39 REFUGIO COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Ridley, Kemp's, Sea Turtle	*Lepidochelys kempi*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1] probable
Texas Diamondback Terrapin	*Malaclemys terrapin littoralis*	Gulf coast shoreline	C2	NL	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov.	NL	T	confirmed endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation (grass, cactus, scattered brush, scrubby trees); when inactive burrows in soil (various texture, sandy to rocky) or hides under rocks	C2	T	confirmed endemic
Gulf Saltmarsh Snake	*Nerodia clarkii*	Estuaries and beaches; crayfish and fiddler crab burrows	C2	NL	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grassland Prairie to sand hills; thorn brush woodland and mesquite savannah of coastal plains	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T	endemic
Timber rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T	[1]confirmed endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; aestivates underground during dry periods	C2	E	[1]probable
Mexican Treefrog	*Smilisca baudinii*	Rio Grande Valley, vegetation in wet areas	NL	T	[2]confirmed
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas; arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	NL	T	[1]probable
Black Lace Cactus	*Echinocerus reichenbachii var. albertii*	Brushy, grassy areas with huisache, mesquite, blackbrush, retama, shrubs; South Texas Plains	E	E	[3]endemic
Plains Gumweed	*Grindelia oolepis*	Tight black clay-gumbo soils in coastal part of Rio Grande Plains	3C	NL	endemic
Texas Windmill Grass	*Chloris texensis*	Sandy to sandy loam soils in relatively bare areas in coastal prairie grassland remnants; also roadsides, with coastal prairie edemics in slightly saline soils in bare areas around pimple mounds	C2	NL	endemic
Welder Machaeranthera	*Machaeranthera heterocarpa*	Shrub invaded grasslands; ROWs on mostly clayey to silty soils over Beaumont - Lissie Formations	C2	NL	endemic

TABLE 40 - SAN PATRICIO COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Brown Pelican	*Pelecanus occidentalis*	Ocean, bays and coastal	E	E	endemic
Interior Least Tern	*Sterna antillarum athalassos*	Large river sand bars	E	E	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Piping Plover	*Charadrius melodus*	Coastal beaches and mudflats	T	T	wintering / transient
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
White-Faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
White-Tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic

TABLE 40 - SAN PATRICIO COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	migratory
Gulf Coast hog-nosed Skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	potential
Black -Spotted Newt	*Notophthalmus meridionalis*	Wet or temporarily wet areas such as arroyos, canal, ditches and shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporarily wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture to remain	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	[1]possible
Texas Diamondback Terrapin	*Malaclemys terrapin*	Littoral zone and coastal waters of Gulf of Mexico	C2	NL	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush - grass understory; open grass and bare ground are avoided; occupies shallow depression at base of bush/cacti; active Mar.-Nov.	NL	T	[1]possible endemic
Timber Rattlesnake	*Crotalus horridus*	Prefers dense extensive forest; also open upland pine and deciduous woods and second growth pasture of unused farmland; bootomland woodlands	NL	T	[1]possible endemic
Indigo Snake	*Drymarchon corais erebennus*	Grassland prairies to coastal sandhills; prefers woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks when inactive	C2	T	endemic
Mathis Spiderling	*Boerhavia mathisiana*	Open thorn shrublands in shallow sandy to gravely soils over limestone or on bare limestone or caliche outcrops; vicinity of Lake Corpus Christi	C2	NL	endemic

TABLE 41 - SAN SABA COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Black-capped Vireo	*Vireo atricapillus*	Semi-open Broad-leaved Shrublands	E	E	nesting
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with Oak and Old Juniper	E	T	nesting
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	potential
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E	T	dispersal
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas Islands	E	E	[1]migratory
Concho River Snake	*Nerodia harteri paucimaculata*	Middle Colorado River drainage; flowing water, rapids and rocky river banks	T	E	endemic
Texas Garter Snake	*Thamnophis sirtalis annectans*	Varied; especially moist habitats	C2	NL	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic

TABLE 42 - TRAVIS COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	potential wintering
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E	nesting
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	nesting
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	transient
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	transient
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied; open land, nesting in forested river bottoms	T	T	[1]nesting/migratory
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E[2]	T	[1]dispersal
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	transient
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	potential, at periphery
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	[1]endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	potential, at periphery
Texas Garter Snake	*Thamnophis sirtalis annectens*	Moist pastures and vacant fields, varied habitats	C2	NL	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-September	NL	T	potential
Barton Springs Salamander	*Eurycea sosorum*	Barton Springs of the Edwards Aquifer; Balcones Escarpment	C2	NL	endemic
Jolleyville Plateau Salamander	*Eurycea sp. 1*	Springs below the Jollyville Plateau; Balcones Escarpment	C2	NL	endemic
Texas Salamander	*Eurycea neotenes*	Springs of the Edwards Plateau	C2	NL	endemic
Guadalupe Bass	*Micropterus treculi*	Streams and reservoirs of Eastern Edwards Plateau	C2	NL	endemic
Smalleye Shiner	*Notropis buccula*	Large rivers and streams	C2	NL	endemic
Bee Creek Cave Harvestman	*Texella reddelli*	Six caves in karst formations Balcones Escarpment	E	NL	endemic
Kretschmarr Cave Mold Beetle	*Texamaurops reddelli*	Sinkhole cave, karst formation Balcones Escarpment	E	NL	endemic
Tooth Cave Ground Beetle	*Rhadine persephone*	Sinkhole cave, karst formation Balcones Escarpment	E	NL	endemic
Tooth Cave Spider	*Neoleptoneta myopica*	Sinkhole cave, karst formation Balcones Escarpment	E	NL	endemic
Basin Bellflower	*Campanula reverchonii*	Edwards Plateau, granite rocky soils and thin limestone soils	C3	NL	endemic
Bracted Twistflower	*Streptanthus bracteatus*	Gravely clays, clay loams over limestone; oak-juniper woods, canyon bottoms, sandy river margins	C2	NL	endemic
Canyon Mock-orange	*Philadelphus ernestii*	On limestone bluffs of canyon lands in Edwards Plateau	C2	NL	endemic
Correll's False Dragon-head	*Physostegia correllii*	In wet silty clay loams along streams, irrigation channels, and roadside drainage ditches	C2	NL	endemic
Texana Croton	*Croton Alabamensis var texensis*	Loamy clay soils on rocky slopes in mesic limestone ravines; locally abundant on deeper soils	C2	NL	endemic

TABLE 43 - UVALDE COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	migrating
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	[1]possible
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	nesting
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	migrating
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migrating
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migrating
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	[1] probable
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E[2]	T	dispersal
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	[1] probable
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushland and forests	T	E	historic endemic
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	C2	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-September	NL	T	endemic
Texas Salamander	*Eurycea neotenes*	Springs of the Edwards and Balcones escarpment	C2	NL	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throught the Mississippi Basin; In Texas, major streams southward to the Rio Grande	C2	NL	possible
Guadalupe Bass	*Micropterus treculi*	Large rivers crossing the Edwards Plateau to the coast	C2	NL	endemic
Headwater Catfish	*Ictalurus lupus*	Edwards Plateau, isolated in clear flowing streams	3C	NL	endemic
Bracted Twistflower	*Streptanthus bracteatus*	Edwards Plateau, wooded slopes and sandy river edges; April - May	C2	NL	endemic
Hill Country Wild-Mercury	*Argythamnia aphoroides*	Shallow to moderately deep clays and clay loams over limestone in grasslands associated with plateau live oak, on rolling uplands	C2	NL	endemic
Sabinal Prairie Clover	*Dalea sabinalis*	Edwards Plateau, isolated local	C2	NL	endemic
Sonora Fleabane	*Erigeron mimegletes*	Grasslands in shallow clay soils over limestone, possibly more frequent in areas poorly drained during spring	C2	NL	endemic
Texas Grease Bush	*Forsellesia texensis*	Dry limestone ledges and chalk bluffs above Nueces River; isolated	C2	NL	endemic
Texas Mock Orange	*Philadelphus texensis*	On limestone bluffs and among boulders on the Edwards Plateau	3C	NL	endemic
Tobusch Fishhook Cactus	*Ancistrocactus tobuschii*	Gravel terraces along drainages, limestone ledges, ridges, and rocky hills in opening of live oak - juniper woodland	E	E	endemic

TABLE 44 - VICTORIA COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Prairie-Chicken	*Typanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition	E	E	endemic
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites; nesting in riparian forests near water	E	E	wintering / nesting
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays and coastal areas	E	E	possible
Eskimo Curlew	*Numenius borealis*	Coastal Prairie	E	E	[1] possible; at periphery
Ferruginous hawk	*Buteo regalis*		C2		
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open forested areas	3C	T	migratory
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] probable
Red Wolf	*Canis rufus*	Varied, Coastal Prairie and sandhills	E	E	historic range
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; aestivates underground during dry periods	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	[1]probable
Siren, Lesser, Rio Grande	*Siren intermedia texana*	Wet or temporally wet areas, arroyos,canals,ditches and shallow depressions; requires moisture to remain	C2	E	endemic
Cagles Map Turtle	Graptemys caglei	Waters of the Guadalupe River in pools and on banks and logs;Dewitt and Lavaca Co.s and north	C1	NL	potential, at periphery
Green Sea Turtle	*Chelonia mydas*	Gulf coast and bay waters and beaches; scattered beach nesting	T	T	probable
Hawksbill Sea Turtle	*Eretmochelys imbricata imbricata*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1]possible
Indigo Snake	*Drymarchon coralis*	Grassland Prairie to coastal sand hills; preferswoodland and mesquite savannah of Coastal Plain	NL	T	endemic
Loggerhead Sea Turtle	*Caretta caretta*	Gulf coast and bay waters and beaches; scattered beach nesting	E / T[3]	E	possible
Ridley, Kemp's, Sea Turtle	*Lepidochelys kempi*	Gulf coast and bay waters and beaches; scattered beach nesting	E	E	[1] possible
Texas Diamondback Terrapin	*Malaclemys terrapin littoralis*	Gulf coast bays and beaches; littoral zones	C2	NL	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, rodent burrow, or hides under rocks when inactive	C2	T	endemic
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-Nov.	NL	T	endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T	[1] endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-Sept.	NL	T	probable

TABLE 44 - VICTORIA COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Guadalupe Bass	*Micropterus treculi*	Rivers of the Edwards Plateau including portions of the Brazos, Colorado, Guadalupe, and San Antonio River Basins; also the lower Colorado River and introduced in the Nueces River system	C2	NL	[1]possible
Welder Machaeranthera	*Machaeranthera heterocarpa*	shrubland invaded grasslands, rights-of-way, and open mesquite - huisache woodlands on mostly grey colored clayey to slity soils over Beaumont and Lissie formations on the coastal prairie	C2	NL	endemic

TABLE 45 - WEBB COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Aplomado Falcon	*Falco femoralis*	Grasslands and coastal prairies; open terrain with scattered trees; nests in yuccas and mesquite	E	E	transient
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	endemic
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	migratory
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	migratory
Loggerhead Shrike	*Lanius ludovicianus*	South Texas	C2	NL	endemic
Mountain Plover	*Charadrius montanus*	Arid plains, short grass prairies and arid plains	C2	NL	endemic
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	transient
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	dispersal
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	potential
Black Bear	*Ursus americanus*	Mountains, broken country, woods, brushland and forests	E	E	potential
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	[1]possible
Gulf Coast hog-nosed Skunk	*Conepatus leuconotus texensis*	Gulf Coast from Aransas Co. to Cameron; brushlands; usually nocturnal and secretive	C1	NL	potential
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	[1]probable
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; primarily extreme south Texas	E	E	[1]probable
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	C2	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-September	NL	T	potential

TABLE 45 - WEBB COUNTY (CONCLUDED)

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throught the Mississippi Basin; In Texas, major streams southward to the Rio Grande	C2	T	endemic
Concho Pupfish	*Cyprinodon eximius*	Clear flowing waters; From Conchos River, Chihuahua, Mexico to Devils River, Texas; found in Alamito, Dolan, & Terlingua Creeks & Devils River; Devils River population distinct from Alamito and Conchos populations	C2	T	endemic
Phanton Shiner	*Notropis orca*	Lower Rio Grande, Mexico, New Mexico, Texas; former USFWScandidate delisted because thought to be extinct	NL	E	may be extinct
Rio Grande Shiner	*Notropis jemezanus*	Original range was Rio Grande Basin including the Pecos, Conchos, San Juan, and Salado drainages, now in decline and spottily distributed.	C2	NL	endemic
Ashy Dogweed	*Thymophylla (Dyssodia) tephroleuca*	Grassland-brush terrain of the Rio Grande Plains	E	E	endemic
Kleberg Saltbush	*Atriplex Klebergorum*	Silty or clayey soils of the south Texas coast	3C	NL	endemic
McCart's Whitlow-wort	*Paronychia maccartii*	Hard packed brick-red sands of Webb Co. in the Rio Grande Plains; March and April;	C2	NL	endemic

TABLE 46 - WHARTON COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Prairie-Chicken	*Tympanuchus cupido attwateri*	Native gulf coastal prairies of the coastal plain; 50% climax grass species composition	E	E	historic
Bald Eagle	*Haliaeetus leucocephalus*	Near large water bodies with near by resting sites, nesting in forested river bottoms	E	E	nesting/ wintering
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E	E	endemic
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	C2	T	endemic
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL	T	endemic
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	endemic
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas islands	E	E	migrating
Wood Stork *	*Mycteria americana*	Coastal wetlands, dispersal	E *	T	[1] migratory
Red Wolf	*Canis rufus*	Southern riparian and pine forest; may exist in Liberty, Chambers, Jefferson Counties,TX [2]	E	E	historic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic

TABLE 46 - WHARTON COUNTY (CONCLUDED0

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL	T	possible [1]
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie and marshes	NL	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	[1]probable endemic

TABLE 47 - WILLIAMSON COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Arctic Peregrine Falcon	*Falco peregrinus tundrius*	Open coastal plains	E	T	[1] migratory
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting and resting sites	E	E	[1] wintering
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-juniper woodlands with distinctive patchy, two-layered shrub - tree aspect	E	E	nesting/migratory
Golden-Cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and mature juniper	E	T	nesting/migratory
Interior Least Tern	*Sterna antillarum athalassas*	Nesting on large river sandbars	E	E	[1] migratory
Swallow-tailed Kite, American	*Elanoides forficatus*	Varied; open land, nesting in forested river bottoms	T	T	[1]nesting/migratory
Wood Stork	*Mycteria americana*	Post-breeding; in wetlands of the coastal plain, major waterways, and lower Mississippi valley	E [2]	T	[1] dispersal
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	[1] endemic
Texas Garter Snake	*Thamnophis sirtalis annectans*	Varied; but especially moist habitats	C2	NL	[1] endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland woodlands	NL	T	[1] endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Georgetown Salamander	*Eurycea sp. 5*	Georgetown vicinity springs of the Balcones Escarpment	C2	NL	endemic
Jollyville Plateau Salamander	*Eurycea sp. 1*	Springs below the Jollyville Plateau; Balcones Escarpment	C2	NL	endemic
Guadalupe Bass	*Micropterus treculi*	Streams of Eastern Edwards Plateau	C2	NL	endemic
Bee Creek Cave Harvestman	*Texella reddelli*	Six caves in karst formations Balcones Escarpment	E	NL	endemic
Kretschmarr Cave Mold Beetle	*Texamaurops reddelli*	Sinkhole cave, karst formation Balcones Escarpment	E	NL	endemic
Tooth Cave Ground Beetle	*Rhadine persephone*	Sinkhole cave, karst formation Balcones Escarpment	E	NL	endemic

TABLE 3. CARRIZO-WILCOX GROUND-WATER AVAILABILITY

County [1]	Hydraulic Gradient [2] (feet/mile)	Transmission from Outcrop [2] (ac-ft/yr)	Inter-formational Leakage [3] (ac-ft/yr)	Transmission and Interformational Leakage as a Percentage of Average Annual Rainfall Applied to the Outcrop	1990 Pumpage [4] (ac-ft/yr)	Estimated Ground Water Available for Additional Development (ac-ft/yr)
Atascosa	20	67,200	18,400	15.6	59,100	26,500
Wilson	20	54,000	26,200	12.9	15,800	64,400
Gonzales	25	47,800	42,600	8.7	9,300	81,100
Bastrop	25	34,400	25,600	6.9	8,100	51,900
TOTALS		203,400	112,800		92,300	223,900

[1] Counties where ground-water withdrawals are proposed in order to develop the assumed hydraulic gradients shown in column 2.

[2] The estimated quantity of water the Carrizo (and Simsboro in Bastrop County only) will transmit under an assumed hydraulic gradient (column 2) established between the recharge area and points of discharge located downdip from the outcrop.

[3] The estimated interformational leakage into the Carrizo (and Simsboro in Bastrop County only) in response to the additional development of these water-bearing sands.

[4] The 1990 Carrizo-Wilcox ground-water withdrawals estimated by county include pumpage from upgradient areas within adjacent counties, with the exception of Lee County.

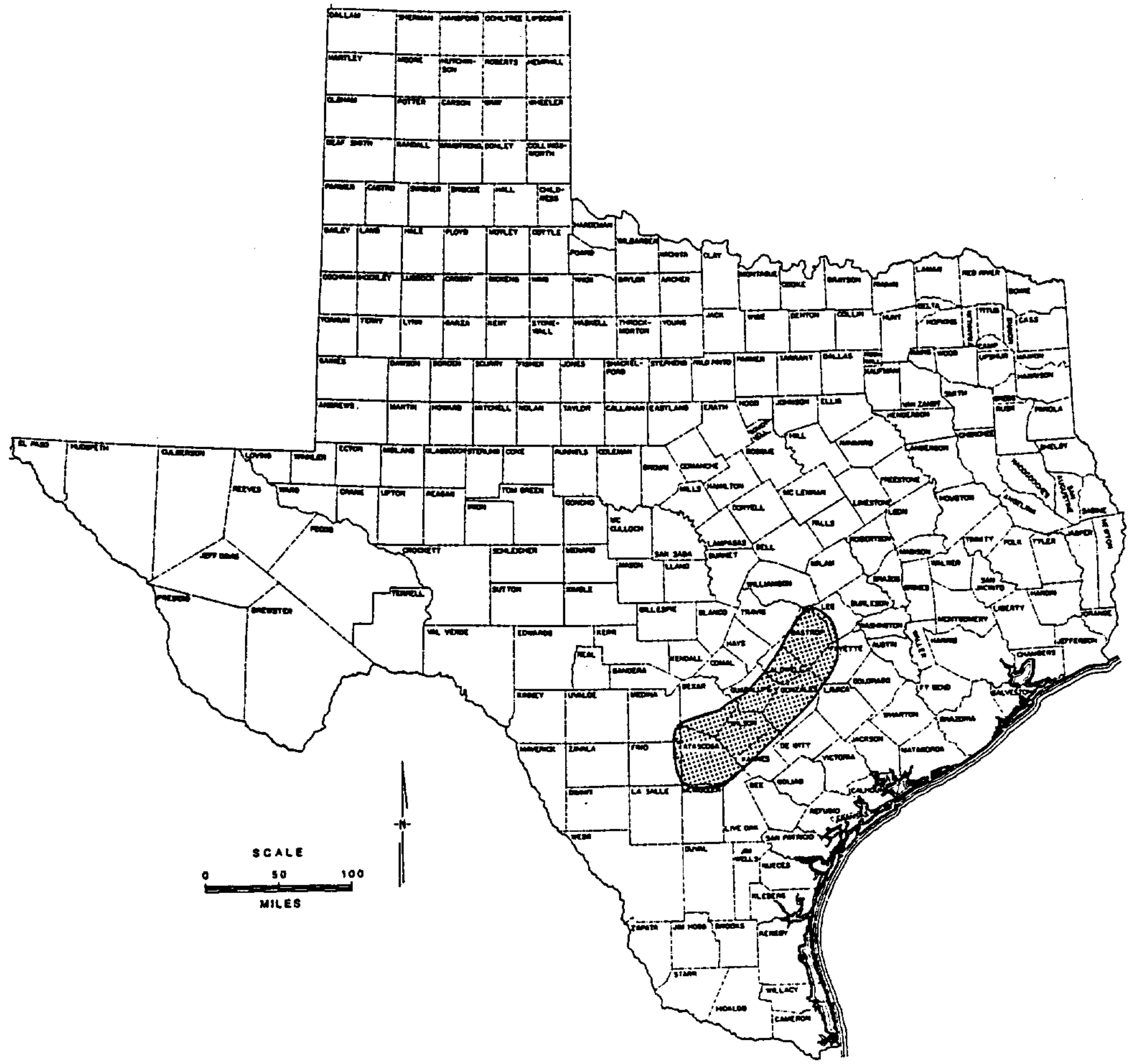

FIGURE 1
LOCATION AND EXTENT OF THE STUDY AREA

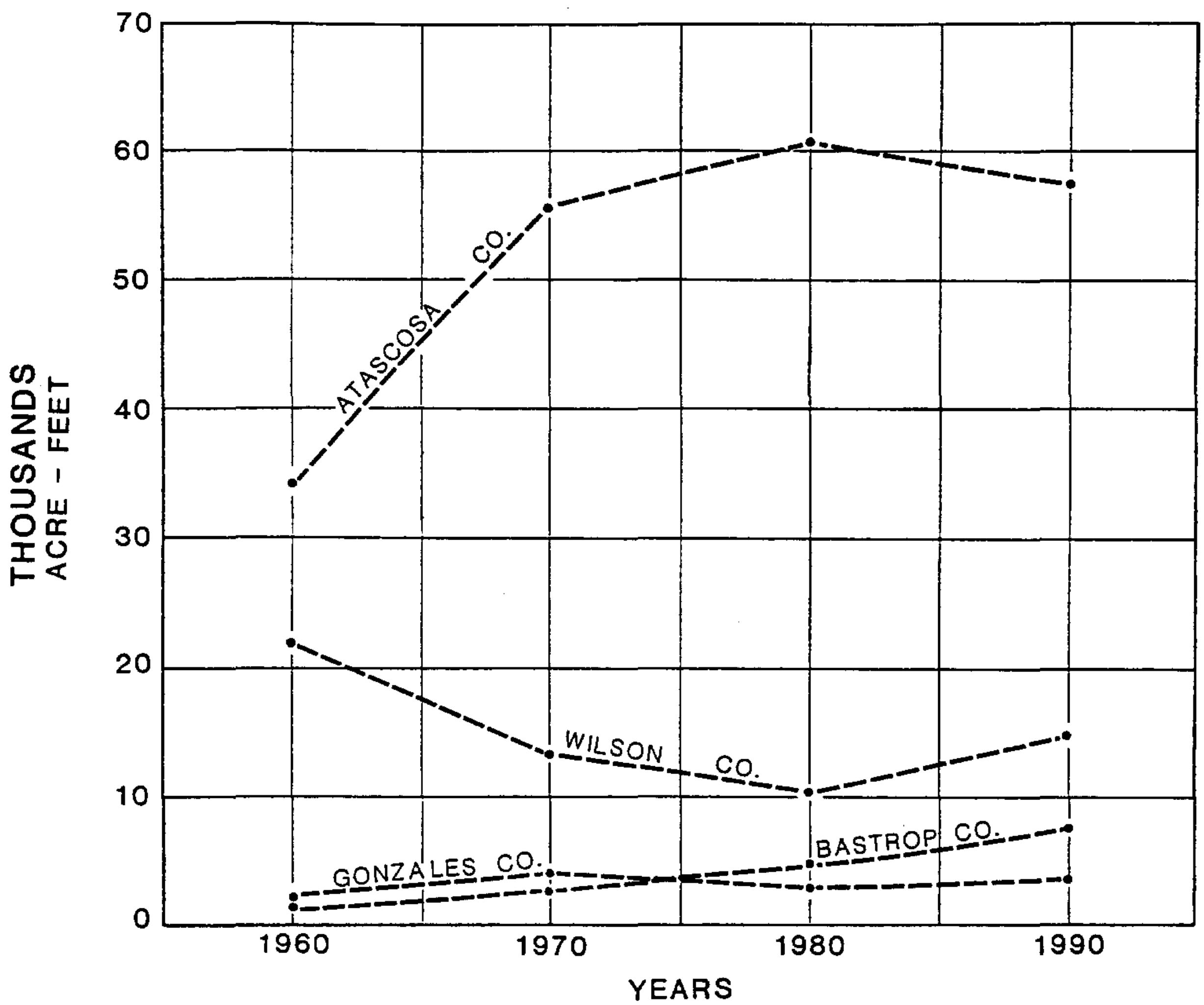

FIGURE 2

APPROXIMATE TOTAL PUMPAGE FROM THE CARRIZO-WILCOX AQUIFER FOR THOSE COUNTIES WHERE ADDITIONAL GROUND WATER MAY BE DEVELOPED BY WELLS

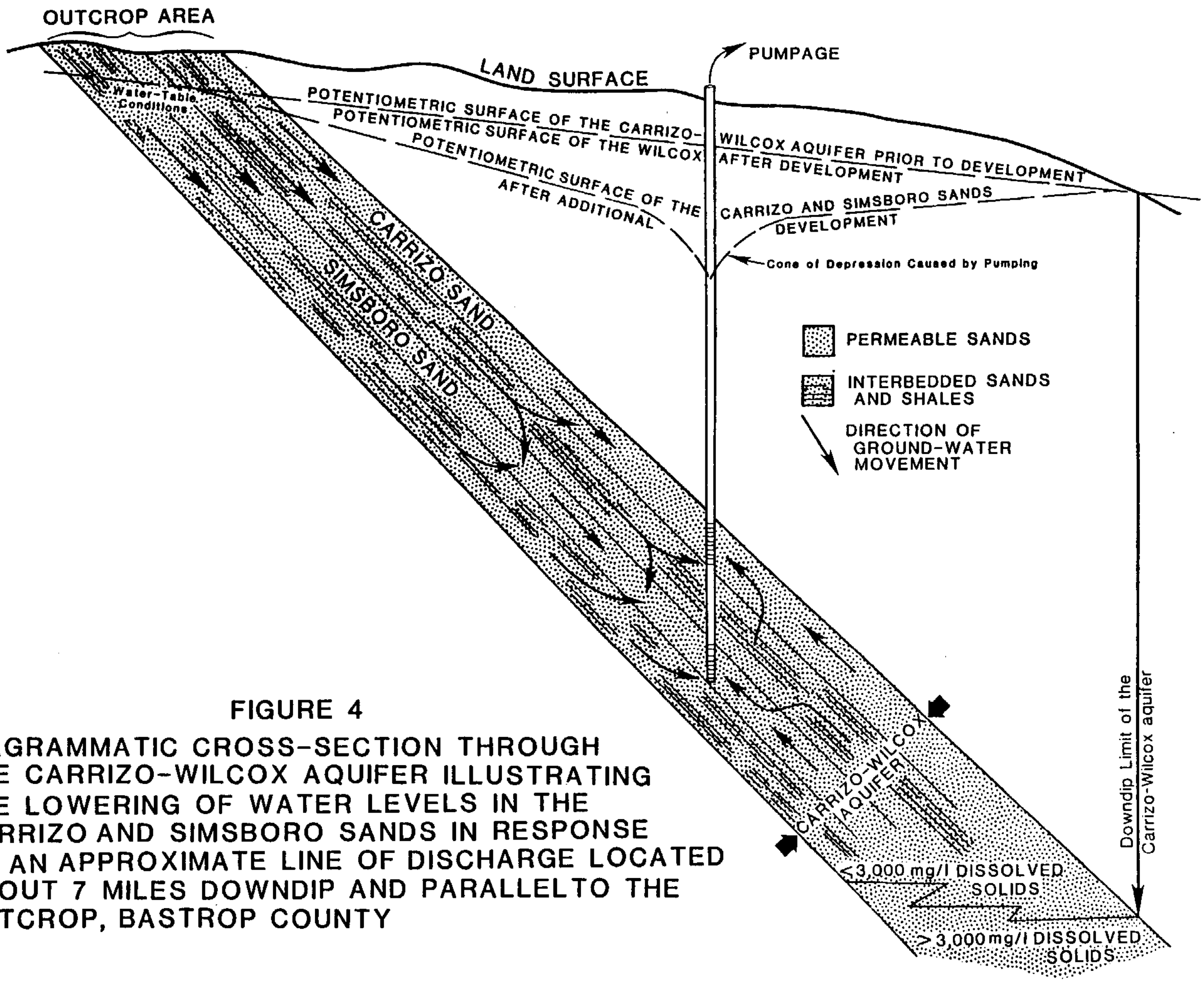

FIGURE 4

DIAGRAMMATIC CROSS-SECTION THROUGH THE CARRIZO-WILCOX AQUIFER ILLUSTRATING THE LOWERING OF WATER LEVELS IN THE CARRIZO AND SIMSBORO SANDS IN RESPONSE TO AN APPROXIMATE LINE OF DISCHARGE LOCATED ABOUT 7 MILES DOWNDIP AND PARALLELTO THE OUTCROP, BASTROP COUNTY

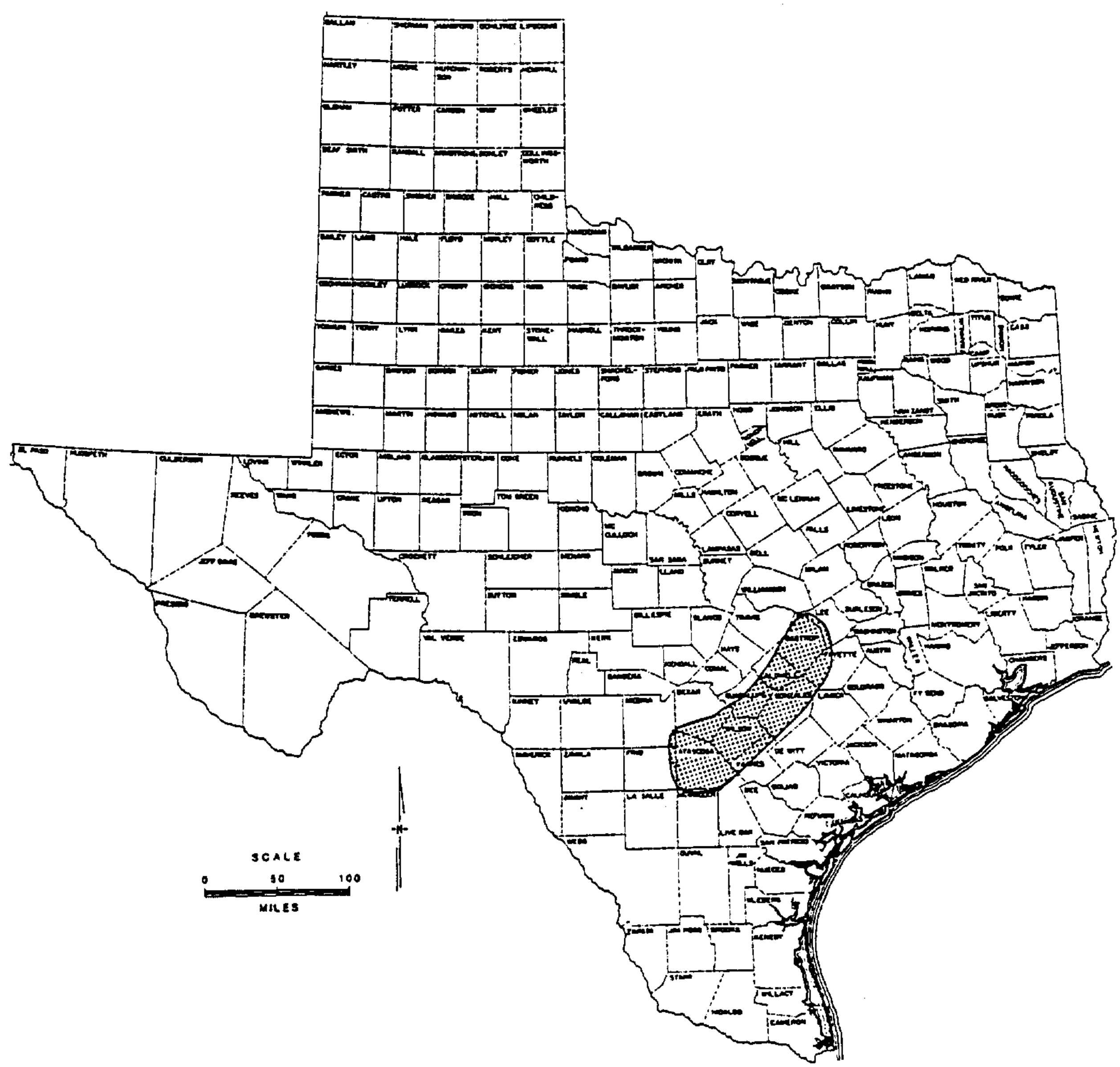

FIGURE 1
LOCATION AND EXTENT OF THE STUDY AREA

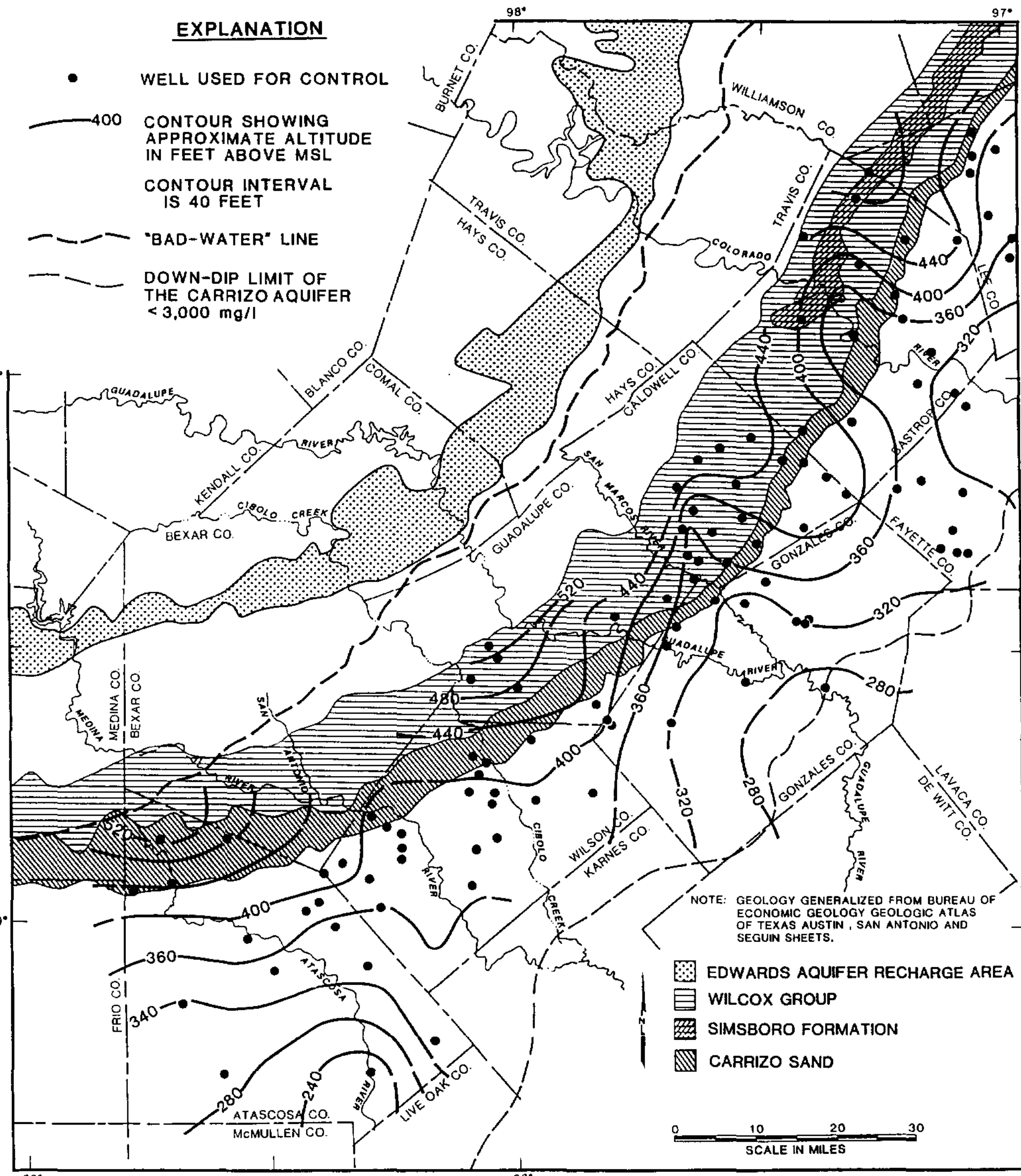

FIGURE 3

ALTITUDE OF WATER LEVELS IN THE CARRIZO-WILCOX AQUIFER, SPRING 1993

TABLE 48 - WILSON COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient [1]
Black-capped Vireo	*Vireo atricapillus*	Semi-open Broad-leaved shrublands	E	E	nesting/ migratory [1]
Golden-cheeked Warbler	*Dendroica chrsoparia*	Woodlands with oaks and old juniper	E	E	nesting/migrant
Interior Least Tern	*Sterna antillarum athalassos*	Large river sandbars	E	E	migratory [1]
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory [1]
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory [1]
Swallow-Tailed Kite, American	*Elanoides forficatus*	Open wooded and forested areas; southern U.S. coastal plains	NL	T	transient [1]
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	migratory [1]
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E [2]	T	migratory [1]
Whooping Crane	*Grus americana*	Coastal wetlands; Matagorda & Aransas Islands	E	E	migratory [1]
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	endemic [1]
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic [1]
Reticulate Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	NL	T	probable [1]
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides or under rocks when inactive.	C2	T	endemic [4]
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic [1]
Texas Garter Snake	*Thamnophis sirtalis annectens*	Varied, especially wet areas; bottomlands and pastures	C2	NL	endemic [3]
Big Red Sage	*Salvia penstemonoides*	In seepage on limestone ledges, banks of streams, seasonally wet clay or silt soils in creekbeds; available in native plant nursery trade	C2	NL	endemic, historical [4]
Parks' Jointweed	*Polygonella parksii*	South Texas Plains; subherbaceous annual in deep loose sands,	3C	NL	endemic

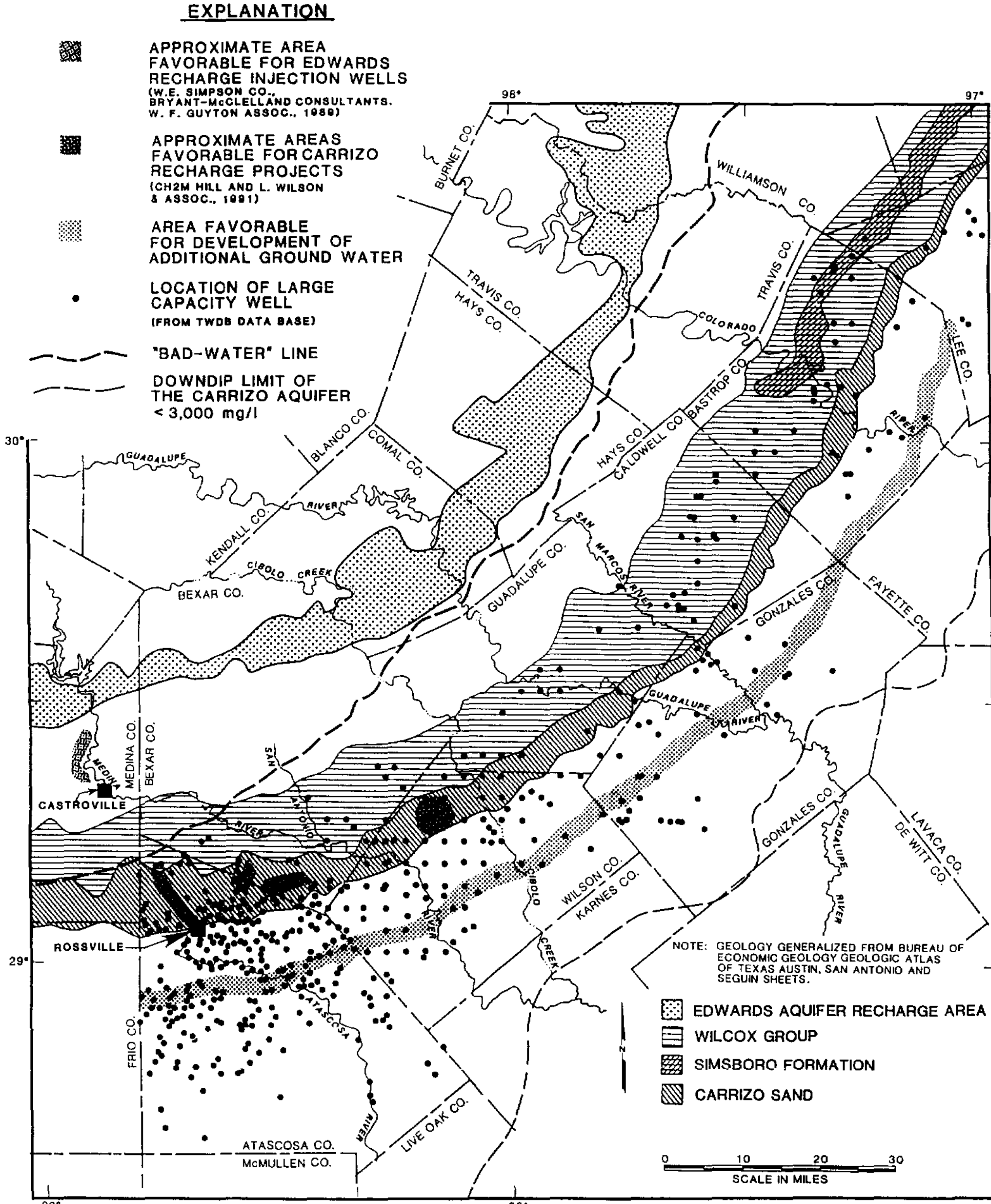

FIGURE 5

LOCATION OF PUBLIC WATER SUPPLY, INDUSTRIAL, AND IRRIGATION WELLS AND AREAS FAVORABLE FOR ARTIFICIAL RECHARGE AND DEVELOPMENT OF ADDITIONAL GROUND WATER FROM THE CARRIZO-WILCOX AQUIFER

TABLE 49 - ZAVALA COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
Common Black Hawk	*Buteogallus anthracinus*	Nesting in trees on floodplains of the Lower Rio Grande; wintering in Mexico and south Texas	NL	T	endemic
Golden-checked Warbler	*Dendroica chrysoparia*	Nesting in about 31 counties in central Texas; ashe juniper-oak woodlands of the Edward's Plateau ; adjacent areas with similar geology; Brazos and Colorado River basins	E	T	migratory
Gray Hawk	*Buteo mitidus maximus*	Cotton-willow woodlands of Rio Grande, mature woodlands of river valleys, and associated semi-arid mesquite and scrubland	C2	T	[1]possible
Interior Least Tern	*Sterna antillarum athalassos*	Nesting on large river sandbars	E	E	migratory
Loggerhead Shrike	*Lanius ludovicianus*	South Texas	C2	NL	endemic
Mountain Plover	*Charadrius montanus*	Arid plains, short grass prairies and arid plains	C2	NL	endemic
Peregrine Falcon, American	*Falco peregrinus anatum*	Open coastal areas	E	E	migratory
Peregrine Falcon, Arctic	*Falco peregrinus tundrius*	Open coastal areas	T	T	migratory
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	transient
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E [2]	T	migratory
Zone-tailed Hawk	*Buteo albonotatus*	Canyons and wooded river bottoms in Southwest U.S.A.	NL	T	transient
Black Bear	Ursus americanus	Mountains, broken country, woods, brushland and forests	T	E	[1]potential
Coati	*Nasua nasua*	Arid open plains, Rio Grande plains in woodlands,	NL	E	[1]possible
Jaguarundi	*Felis yagouaroundi*	South Texas thick brushlands, favors areas near water	E	E	[1]probable
Ocelot	*Felis pardalis*	Dense chaparral thickets; mesquite-thorn scubland, live oak mottes; primarily extreme south Texas	E	E	[1]probable
Texas Tortoise	*Gopherus berlandieri*	Open brush with grass understory; open grass and bare ground are avoided; occupies shallow depressions at base of bush or cactus, underground burrows, under objects; active March-November	NL	T	endemic
Reticulated Collared Lizard	*Crotaphytus reticulatus*	Native grass prairies of South Texas Plains; usually thorn brush, mesquite-blackbrush	C2	T	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil, enters rodent burrow, or hides under rocks when inactive	C2	T	endemic
Indigo Snake	*Drymarchon corais erebennus*	Grass prairies and sand hills; usually thorn brush woodland and mesquite savannah of coastal plain	NL	T	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April-September	NL	T	endemic
Black-spotted Newt	*Notophthalmus meridionalis*	Wet or temporally wet arroyos, canals, ditches, shallow depressions; aestivates underground during dry periods	C2	E	endemic
Rio Grande Lesser Siren	*Siren intermedia texana*	Wet or temporally wet areas such as arroyos, canals, ditches and shallow depressions; requires moisture	C2	E	endemic
Sheep Frog	*Hypopachus variolosus*	Wet areas of the Rio Grande Valley, lower South Texas Plains, Southern Coastal Prairie	NL	T	endemic
Blue Sucker	*Cycleptus elongatus*	Large rivers throught the Mississippi Basin; In Texas, major streams southward to the Rio Grande	C2	T	possible
Guadalupe Bass	*Micropterus treculi*	Large rivers crossing the Edwards Plateau to the coast; Nueces River in Zavala County	C2	NL	endemic
Tobusch Fishhook Cactus	*Ancistrocactus tobuschii*	Gravel terraces along drainages, limestone ledges, ridges, and rocky hills in opening of live oak - juniper woodland	E	E	possible

TABLE 50 - EDWARDS AQUIFER DEPENDENT SPECIES AND KARST GEOLOGY ASSOCIATED SPECIES

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD
Blind Texas Salamander	*Typhlomolge rathbuni*	Edwards Aquifer springs and caves, thermally stable; troglobitic [1,5]	E	E
Blind Blanco Salamander	*Typhlomolge robusta*	Blanco River; subterranean; gravel bed of Dry Blanco only occurrence; troglobitic [1,5]	C2	E
Comal Blind Salamander	*Eurycea tridentifera*	Honey Creek and limestone caves [1]	C2	T
Cascade Caverns Salamander	*Eurycea latitanus*	Cascade Caverns [5,7]	C2	T
Georgetown Salamander	*Eurycea sp. 5*	Georgetown vicinity springs of the Balcones Escarpment	C2	NL
Jollyville Plateau Salamander	*Eurycea sp. 1*	Springs below the Jollyville Plateau; Balcones Escarpment	C2	NL
San Marcos Salamander	*Eurycea nana*	San Marcos River & springs; under rocks & matted stream vegetation [1,5]	T	E
Texas Salamander	*Eurycea neotenes*	Edwards Aquifer creeks gravel bottom, emergent vegetation; underground & rocks, ledges [1,5]	C2	T
Fountain Darter	*Etheostoma fonticola*	San Marcos River to confluence with Blanco River; associated with San Marcos Salamander and San Marcos Gambusia [C]	E	E
San Marcos Gambusia	*Gambusia georgei*	San Marcos River to confluence with Blanco River, large clear spring-fed river [C]	E	E
Widemouth Blindcat	*Satan eurystomus*	Edwards Aquifer; from artesian wells in Bexar Co.; troglobitic [1,2]	C2	T
Toothless Blindcat	*Trogloglanis pattersoni*	Edwards Aquifer; from artesian wells in Bexar Co.; troglobitic [1,3]	C2	T
Texas Cave Shrimp	*Palaemonetes antrorum*	Ezell's Cave and Edwards Aquifer subterranean caverns [5,8]	C2	NL
Mimic Cave Snail	*Phreatodrobia imitata*	Edwards Aquifer; from artesian wells in Bexar Co.; troglobitic [5,7]	C2	NL
Balcones Cave Amphipod	*Stigobromus balconis*	Limestone caves [7]	C2	NL
Bee Creek Cave Harvestman	*Texella reddelli*	Six caves in karst formations Balcones Escarpment	E	NL
Kretschmarr Cave Mold Beetle	*Texamaurops reddelli*	Sinkhole cave, karst formation Balcones Escarpment	E	NL
Tooth Cave Ground Beetle	*Rhadine persephone*	Sinkhole cave, karst formation Balcones Escarpment	E	NL
Bifurcated Cave Amphipod	*Stigobromus bifurcatus*	Spring openings [7]	C2	NL
Comal Springs Water Beetle	*Heterelmis comalensis*	Comal Springs [4]	C2	NL
Comal Springs Dryopid Beetle	*Stigoparnus comalinses*	Comal Springs [9]	NL [9]	NL
Ezell's Cave Amphipod	*Stigobromus flagellatus*	Ezell's Cave; Edwards Aquifer subterranean caverns [7,8]	C2	NL
Flint's Net-spinning Caddisfly	*Cheumatopsyche flinti*	Honey Creek [1]	C2	NL
Peck's Cave Amphipod	*Stygobromus pecki*	Comal Springs	C2	
San Marcos Saddle-case Caddisfly	*Protoptila arca*	San Marcos River [1]	C2	NL
Texas Cave Diving Beetle	*Haideoporus texanus*	Edwards Aquifer subterranean caverns [1,7,8]	C2	NL
Texas Wildrice	*Zizania texana*	San Marcos River to confluence with Blanco River [C]	E	E

These footnotes apply to this table:

[C] Critical Habitat : 50 CFR 17.95 (e); from spring to confluence of San Marcos with Blanco River.

[1] Longley, G. 1975. Environmental assessment. upper San Marcos River watershed. Soil Conservation Service. Contract AG-48-SCS 02156. 367 pp.

[2] Longley, G. and H. Karnei, Jr. 1979a. Status of *Satan eurystomus Hubbs* and Bailey, the widemouth blindcat. U.S. Fish and Wildlife Services, Endangered species Report 5.

[3] Longley, G. and H. Karnei, Jr. 1979b. Status of *Trogloglanis pattersoni* Eigenmann, the toothless blindcat. U.S. Fish and Wildlife Service, Endangered species Report 5.

[4] Longley, G. & FN Young. 1976. A new subterranean aquatic beetle from Texas (Coleoptera: *Dytiscidae-Hydropoorinae*). Annals of the Entomological Society of American 69(5):787-792.
[5] Elliot, W.R. (Bill) Ph.D., personal communication, 1993. Research Associate, Texas Memorial Museum, The University of Texas at Austin. Austin, Texas.
[6] Edwards, Robert J., Glen Longley, Randy Moss, John Ward, Ray Mathews, and Bruce Stewart. 1989. A Classification of Texas Aquatic Communities with Special Consideration Toward the Conservation of Endangered and Threatened Taxa. Vol. 41, No. 3. The Texas Journal of Science, University of Texas at Austin, Austin, Texas.
[7] Reddell, James, personal communication, 1993. Research Associate (Curator of Arthropods), Texas Memorial Museum, The University of Texas at Austin. Austin, Texas.
[8] Sissom, S.L.& J.C. Davis. 1979. A monographic study of Ezell's Cave, Hays County, Texas. U.S. Department of the Interior and Nature Conservancy. Contract # 14-16-0002-090. 141pp.
[9] Alisa Shull. 1993. Personal Communication, USFWS,Austin, Texas.

TABLE 51 -CAVE DWELLING SPECIES FROM NORTH AND NORTHWESTERN BEXAR COUNTY - LISTED IN PENDING PETITION

Species	Cave
Cicurina (new species 1) (Troglobitic spider)	Madla's Cave
Cicurina (new species 2) (Troglobitic spider)	Braken Bat Cave
Cicurina (new species 3) (Troglobitic spider)	Government Canyon Bat Cave
Cicurina (new species 4) (Troglobitic spider)	Robber Baron Cave
Neoleptoneta microps	Government Canyon Bat Cave
Texella (new species)	Robber Baron Cave
Rhadine exilis	John Wagner Ranch Cave No. 3 (Marnock Cave)
Rhadine infernalis	Government Canyon Bat Cave, Cave of the Woods, Genesis Cave, Helotes Blowhole, Isopit, Kamikaze Cricket Cave, Poison Ivy Pit, and Wurzbach Bat Cave
Batrisodes (Excayodes) (new species)	Helotes Hilltop Cave

TABLE 52 - ALLENS CREEK RESERVOIR ASSOCIATED SPECIES - AUSTIN COUNTY

Common Name	Scientific Name	Habitat Preference	Listing USFWS	Agency TPWD	Potential Occurrence in County
Attwater's Greater Prairie Chicken	*Tympanuchus cupido attwateri*	Native coastal prairie grassland with diverse habitat of short-, mid-, and tallgrass; 50% climax	E	E	endemic
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby resting sites	E	E	winter transient
White-faced Ibis	*Plegadis chihi*	Freshwater marshes	C2	T	transient
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	E [2]	T	dispersal
Houston Toad	*Bufo houstonensis*	Loamy, friable soils, temporary rain pools, flooded field, ponds surrounded by forest or grass	E	E	endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky, burrows in soil or hides under rocks	C2	T	endemic
Western Smooth Green Snake	*Opeodrys vernalis blanchardi*	Coastal grasslands, temporary rain pools in short grass	NL	E	endemic
Texas Garter Snake	*Thamnophis sirtalis annectens*	Moist pastures and vacant fields near water			
Mohlenbrock's Umbrella-sedge	*Cyperus grayiodes*	Prairie grasslands, moist meadows in Texas, Louisiana, Illinois	C2	NL	endemic
Sandhill Four-O'Clock	*Mirabilis collina*	In sandy soils near streams of the coastal plains; this record is in question	C2	NL	potential

For Appendix B:

Symbols Under Listing Agency Are As Follows: C1-USFWS Candidate Category C2-USFWS Candidate Category For Protection; C3-USFWS No Longer A Candidate For Protection; NL- Not Listed For Protection; E-Endangered; T-Threatened.

Protected Endangered And Threatened Species Listed By The U.S. Department Of The Interior (50 Cfr 17.11 & 17.12, 23 August 1993) Candidate Species (50 Cfr 17, 6 January 1989; 21 February 1990; 21 November 1991)

Texas Parks And Wildlife Department (31 T.A.C. Sec. 65.171 - 174 & 65.181 - 184)

Source For Occurrence and Status: Texas Heritage Program Files, Unpublished December 1993. Computer Database Search, Mapped Locations, and Reports. Texas Parks And Wildlife Department. Austin, Texas

[1] Texas Parks And Wildlife, 05/09/88. Potential For Occurrence Based On Historic Range

[*] Note: Wood Stork is Listed Endangered Populations Alabama, Florida, Georgia, North Carolina, South Carolina

[3] Dixson, James R. 1987. Amphibians And Reptiles Of Texas, With Keys, Taxonomic Synopses, Bibliography, And Distribution Maps. Texas A&M University Press, College Station, Texas.

[4] Armstrong, David M., Jerry R. Choate, And J. Knox Jones, Jr. 1986. Distributional Patterns Of Mammals In The Plains States. Occational Papers, The Mueseum, Texas Tech University, No. 105, Texas Tech University Press, Lubbock, Texas

APPENDIX C

TRANS-TEXAS ENVIRONMENTAL CRITERIA

TRANSTEXAS WATER PROGRAM
ENVIRONMENTAL ASSESSMENT

Water Quality

Preliminary water quality impact assessment of affected State waters must include evaluation of water quality standards attainment, chemical and biological compatibility of mixed waters, coastal salt water intrusion, and nutrients for compliance with drinking water standards. The recommended methodology, if any, for each analysis is given as follows:

1. Water Quality Standards Attainment

   A. Chloride, Sulfate, Total Dissolved Solids--Mass balance these constituents under a 7-day, 2-year, low flow (7Q2) condition to insure that the Standards are not violated.

   B. Dissolved Oxygen--If any interbasin transfer scenarios result in a reduction of a river's 7Q2, or if the baseflow is significantly reduced during spring spawning months [defined as the first half of the year when water temperatures are 63°-73°F in TWC Rule 307.7.(b)3. Aquatic Life], then simplified mathematical modeling must be performed to evaluate compliance with the Standard. Basic modeling assumptions are listed below:

   - Summer Analysis
     Headwater--7Q2 flow conditions
     Temperature--average of the three
     hottest months, plus one standard deviation, from the closest USGS station with water temperature data
     Discharges--full permitted effluent
     flow and quality
     BOD--compute BODu = $BOD_{5\ day} \times 2.3$
     K_n--nitrification rate = 0.30/day
     K_d--BOD oxidation rate = 0.10/day
     Reaeration--use Texas equation

   - Spring Spawning Analysis
     Same as above, except
     Headwaters--10th percentile monthly
     low flow conditions
     Temperature--90th percentile monthly
     high temperature conditions

   C. pH--No recommended method.

   D. Temperature--Mass balance temperature to insure compliance with the maximum temperature criteria, as well as the "rise over ambient" Standard.

   E. Fecal Coliform--No recommended method.

2. Chemical and Biological Compatibility of Waters

A. Formation of precipitates, etc.--No recommended method.

B. Introduction of exotic plants and animals--No recommended method.

3. Salt Water Intrusion

A. Migration of coastal salt wedge and effect of intrusion up tidal rivers--No recommended method.

B. Effect on water supply operations--No recommended method.

C. Effect on freshwater marshes/wetlands--No recommended method.

4. Nutrients

A. Potable water limits--Determine compliance with Drinking Water Standards.

B. Potential for nuisance aquatic vegetation--No recommended method.

<u>Instream Flows</u>

A relatively rapid assessment of instream flow needs to maintain downstream fish and wildlife habitats affected by the TransTexas Water Program can be performed by using the TPWD-modified Tennant's Method (Lyons 1979), which is based on a fixed percentage of median (50th percentile) monthly flows. At any point in a river basin intercepted by the TransTexas Water Program, streamflows must be passed downstream in an amount up to 60% of the median monthly flows from March through September, and 40 % of the median monthly flows from October through February. Streamflows above these monthly flow limits are to be considered available for other beneficial uses and interbasin transfer. Water stored in existing reservoirs will not be allocated to instream uses and released downstream to make up for normal flows below the specified limits.

<u>Freshwater Inflows to Bays and Estuaries</u>

For preliminary planning purposes, the freshwater inflow needs of the bays and estuaries can be conservatively estimated as a function of selected central tendency values. The typical bi-modal distribution of monthly rainfall runoff during the historical period is enhanced by requiring the pass through of normal inflows up to the mean (arithmetic average) monthly flow in May-June and September-October, while the minimum maintenance needs are satisfied with inflows up to the median (50th percentile) monthly flow in the remaining months of the year. Water stored in existing reservoirs will not be allocated to bay and estuary uses and released downstream to make up for normal flows below the specified limits.

<u>New Reservoirs</u>

Existing reservoirs that could potentially contribute to the TransTexas Water Program will be evaluated as to the effects on downstream flows and freshwater inflows to bays and estuaries under their existing state and federal permits which authorize their current operations, while any new reservoirs involved in the Program's future water storage and distribution system will be considered to operate such that they pass through impounded

streamflows up to the mean (arithmetic average) monthly flow in April-June and August-October, and median (50th percentile) streamflows in the remaining months of the year, as long as reservoir capacity is above 60%. When reservoir capacity is below 60%, the water management operations will recognize drought contingency by passing through up to the median daily flow of the stream observed during the historical drought of record. The analysis will be repeated at 40% and 80% capacity thresholds to demonstrate a range of feasible solutions for operating any new reservoirs.

APPENDIX D

GSA BASIN MODEL - PARAMETER SUMMARY TABLES

Appendix D

GSA Basin Model - Parameter Summary Tables

The following tables contain listings of parameter values used for application of the Guadalupe-San Antonio Basin Model for various report sections. The tables also contain output of the model for water potentially available at given diversion rates for the modeled parameters.

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River at Elmendorf Unappropriated Streamflow - Alternative S-10
Scenario A1

Analysis Point: San Antonio River near Elmendorf (USGS Gage 1818)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River near Elmendorf (USGS Gage 1818) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	5,556	92	119,235	1,977
Feb	5,269	87	111,426	1,848
Mar	8,582	142	118,399	1,964
Apr	9,817	163	108,476	1,799
May	11,918	198	260,311	4,317
Jun	10,226	170	252,135	4,182
Jul	6,308	105	86,267	1,431
Aug	5,617	93	71,697	1,189
Sep	7,177	119	177,444	2,943
Oct	6,078	101	172,249	2,857
Nov	4,728	78	92,774	1,539
Dec	5,102	85	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:

- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:

- Canyon Lake: 50,000 acft/yr
- Hydro Requirement at Lake Dunlap: 600 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:

- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,641	900	0
5,000	16,952	3,716	0
10,000	31,021	6,154	0
20,000	50,889	9,154	0
40,000	72,548	11,045	0
60,000	83,358	11,045	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River at Elmendorf Unappropriated Streamflow - Alternative S-10
Scenario A2

Analysis Point: San Antonio River near Elmendorf (USGS Gage 1818)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River near Elmendorf (USGS Gage 1818) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	5,556	92	119,235	1,977
Feb	5,269	87	111,426	1,848
Mar	8,582	142	118,399	1,964
Apr	9,817	163	108,476	1,799
May	11,918	198	260,311	4,317
Jun	10,226	170	252,135	4,182
Jul	6,308	105	86,267	1,431
Aug	5,617	93	71,697	1,189
Sep	7,177	119	177,444	2,943
Oct	6,078	101	172,249	2,857
Nov	4,728	78	92,774	1,539
Dec	5,102	85	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:

Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual

Water Rights:

Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Excluded
Other Rights:	Full Authorized Amounts

Steam-electric Diversions:

Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,879	900	0
5,000	18,910	3,922	0
10,000	35,880	7,153	0
20,000	62,058	10,719	0
40,000	90,054	14,204	0
60,000	103,499	15,090	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River at Elmendorf Unappropriated Streamflow - Alternative S-10
Scenario B1

Analysis Point: San Antonio River near Elmendorf (USGS Gage 1818)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River near Elmendorf (USGS Gage 1818) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	5,556	92	119,235	1,977
Feb	5,269	87	111,426	1,848
Mar	8,582	142	118,399	1,964
Apr	9,817	163	108,476	1,799
May	11,918	198	260,311	4,317
Jun	10,226	170	252,135	4,182
Jul	6,308	105	86,267	1,431
Aug	5,617	93	71,697	1,189
Sep	7,177	119	177,444	2,943
Oct	6,078	101	172,249	2,857
Nov	4,728	78	92,774	1,539
Dec	5,102	85	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: None
- Groundwater Sources: None

Water Rights:
- Canyon Lake: 50,000 acft/yr
- Hydro Requirement at Lake Dunlap: 600 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 0 acft/yr
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 0 acft/yr
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	2,534	385	0
5,000	11,690	1,585	0
10,000	20,678	3,013	0
20,000	32,973	4,152	0
40,000	47,620	4,328	0
60,000	54,622	4,328	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River at Elmendorf Unappropriated Streamflow - Alternative S-10
Scenario B2

Analysis Point: San Antonio River near Elmendorf (USGS Gage 1818)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River near Elmendorf (USGS Gage 1818) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	5,556	92	119,235	1,977
Feb	5,269	87	111,426	1,848
Mar	8,582	142	118,399	1,964
Apr	9,817	163	108,476	1,799
May	11,918	198	260,311	4,317
Jun	10,226	170	252,135	4,182
Jul	6,308	105	86,267	1,431
Aug	5,617	93	71,697	1,189
Sep	7,177	119	177,444	2,943
Oct	6,078	101	172,249	2,857
Nov	4,728	78	92,774	1,539
Dec	5,102	85	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	None
Groundwater Sources:	None
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Excluded
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	0 acft/yr
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	0 acft/yr
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,154	600	0
5,000	14,614	2,479	0
10,000	26,954	3,979	0
20,000	44,238	6,231	0
40,000	63,073	7,696	0
60,000	72,163	7,696	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River near Falls City Unappropriated Streamflow - Alternative S-11
Scenario A1

Analysis Point: San Antonio River near Falls City (USGS Gage 1835)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River near Falls City (USGS Gage 1835) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	6,730	112	119,235	1,977
Feb	6,042	100	111,426	1,848
Mar	9,591	159	118,399	1,964
Apr	10,646	177	108,476	1,799
May	13,663	227	260,311	4,317
Jun	13,133	218	252,135	4,182
Jul	7,721	128	86,267	1,431
Aug	6,509	108	71,697	1,189
Sep	8,327	138	177,444	2,943
Oct	6,392	106	172,249	2,857
Nov	5,687	94	92,774	1,539
Dec	5,848	97	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,707	894	0
5,000	17,396	3,663	0
10,000	32,332	6,172	0
20,000	54,443	9,172	0
40,000	79,480	11,358	0
60,000	92,230	11,358	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River near Falls City Unappropriated Streamflow - Alternative S-11
Scenario A2

Analysis Point: San Antonio River near Falls City (USGS Gage 1835)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River near Falls City (USGS Gage 1835) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	6,730	112	119,235	1,977
Feb	6,042	100	111,426	1,848
Mar	9,591	159	118,399	1,964
Apr	10,646	177	108,476	1,799
May	13,663	227	260,311	4,317
Jun	13,133	218	252,135	4,182
Jul	7,721	128	86,267	1,431
Aug	6,509	108	71,697	1,189
Sep	8,327	138	177,444	2,943
Oct	6,392	106	172,249	2,857
Nov	5,687	94	92,774	1,539
Dec	5,848	97	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 50,000 acft/yr
- Hydro Requirement at Lake Dunlap: 600 cfs
- Applewhite Reservoir: Excluded
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,914	900	0
5,000	18,994	3,886	0
10,000	36,093	7,020	0
20,000	63,109	10,612	0
40,000	94,647	14,186	0
60,000	110,372	15,093	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River near Falls City Unappropriated Streamflow - Alternative S-11
Scenario B1

Analysis Point: San Antonio River near Falls City (USGS Gage 1835)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River near Falls City (USGS Gage 1835) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	6,730	112	119,235	1,977
Feb	6,042	100	111,426	1,848
Mar	9,591	159	118,399	1,964
Apr	10,646	177	108,476	1,799
May	13,663	227	260,311	4,317
Jun	13,133	218	252,135	4,182
Jul	7,721	128	86,267	1,431
Aug	6,509	108	71,697	1,189
Sep	8,327	138	177,444	2,943
Oct	6,392	106	172,249	2,857
Nov	5,687	94	92,774	1,539
Dec	5,848	97	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:

Surface Water Sources:	None
Groundwater Sources:	None

Water Rights:

Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts

Steam-electric Diversions:

Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	0 acft/yr
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	0 acft/yr
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,019	484	0
5,000	13,621	1,803	0
10,000	24,217	3,303	0
20,000	39,126	4,713	0
40,000	56,481	5,107	0
60,000	66,270	5,107	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River near Falls City Unappropriated Streamflow - Alternative S-11
Scenario B2

Analysis Point: San Antonio River near Falls City (USGS Gage 1835)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River near Falls City (USGS Gage 1835) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	6,730	112	119,235	1,977
Feb	6,042	100	111,426	1,848
Mar	9,591	159	118,399	1,964
Apr	10,646	177	108,476	1,799
May	13,663	227	260,311	4,317
Jun	13,133	218	252,135	4,182
Jul	7,721	128	86,267	1,431
Aug	6,509	108	71,697	1,189
Sep	8,327	138	177,444	2,943
Oct	6,392	106	172,249	2,857
Nov	5,687	94	92,774	1,539
Dec	5,848	97	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: None
- Groundwater Sources: None

Water Rights:
- Canyon Lake: 50,000 acft/yr
- Hydro Requirement at Lake Dunlap: 600 cfs
- Applewhite Reservoir: Excluded
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 0 acft/yr
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 0 acft/yr
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,327	600	0
5,000	15,449	2,569	0
10,000	28,644	4,124	0
20,000	48,084	6,484	0
40,000	70,504	8,212	0
60,000	81,962	8,212	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River at Goliad Unappropriated Streamflow - Alternative S-12
Scenario A1

Analysis Point: San Antonio River at Goliad (USGS Gage 1885)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River at Goliad (USGS Gage 1885) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	8,427	140	119,235	1,977
Feb	8,396	139	111,426	1,848
Mar	14,265	237	118,399	1,964
Apr	15,490	257	108,476	1,799
May	20,618	342	260,311	4,317
Jun	21,588	358	252,135	4,182
Jul	10,660	177	86,267	1,431
Aug	10,369	172	71,697	1,189
Sep	14,633	243	177,444	2,943
Oct	8,770	145	172,249	2,857
Nov	8,202	136	92,774	1,539
Dec	8,318	138	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,755	900	0
5,000	18,391	4,206	0
10,000	35,474	7,789	0
20,000	65,028	12,516	0
40,000	107,783	20,128	0
60,000	136,474	26,079	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River at Goliad Unappropriated Streamflow - Alternative S-12
Scenario A2

Analysis Point: San Antonio River at Goliad (USGS Gage 1885)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River at Goliad (USGS Gage 1885) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	8,427	140	119,235	1,977
Feb	8,396	139	111,426	1,848
Mar	14,265	237	118,399	1,964
Apr	15,490	257	108,476	1,799
May	20,618	342	260,311	4,317
Jun	21,588	358	252,135	4,182
Jul	10,660	177	86,267	1,431
Aug	10,369	172	71,697	1,189
Sep	14,633	243	177,444	2,943
Oct	8,770	145	172,249	2,857
Nov	8,202	136	92,774	1,539
Dec	8,318	138	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 50,000 acft/yr
- Hydro Requirement at Lake Dunlap: 600 cfs
- Applewhite Reservoir: Excluded
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,909	900	0
5,000	19,127	4,313	0
10,000	37,225	8,313	0
20,000	69,493	13,777	0
40,000	116,659	21,648	0
60,000	148,114	27,648	0

Guadalupe - San Antonio Basin Modeling Parameters
Applewhite Reservoir - Alternative S-14
Firm Yield

Analysis Point: Medina River near Somerset (USGS Gage 1808)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	246	4	N/A	N/A
Feb	222	4	N/A	N/A
Mar	246	4	N/A	N/A
Apr	238	4	N/A	N/A
May	246	4	N/A	N/A
Jun	238	4	N/A	N/A
Jul	246	4	N/A	N/A
Aug	246	4	N/A	N/A
Sep	238	4	N/A	N/A
Oct	246	4	N/A	N/A
Nov	238	4	N/A	N/A
Dec	246	4	N/A	N/A
Drought Median	N/A	N/A	N/A	N/A

Flow Requirements Based On:	Certificate of Adjudication
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Excluded Junior Rights Upstream and Downstream
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)
Reservoir Firm Yield Estimate[1]:	
Firm Yield	7,700 acft/yr

Notes:
1) Firm yield diverted directly from Applewhite Reservoir in accordance with a uniform monthly demand distribution. Leon Creek diversion excluded.

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River at Goliad Unappropriated Streamflow - Alternative S-12
Scenario B1

Analysis Point: San Antonio River at Goliad (USGS Gage 1885)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River at Goliad (USGS Gage 1885) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	8,427	140	119,235	1,977
Feb	8,396	139	111,426	1,848
Mar	14,265	237	118,399	1,964
Apr	15,490	257	108,476	1,799
May	20,618	342	260,311	4,317
Jun	21,588	358	252,135	4,182
Jul	10,660	177	86,267	1,431
Aug	10,369	172	71,697	1,189
Sep	14,633	243	177,444	2,943
Oct	8,770	145	172,249	2,857
Nov	8,202	136	92,774	1,539
Dec	8,318	138	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 50,000 acft/yr
- Hydro Requirement at Lake Dunlap: 600 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 0 acft/yr
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 0 acft/yr
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,467	732	0
5,000	16,764	3,239	0
10,000	31,674	5,479	0
20,000	56,362	9,479	0
40,000	92,653	16,148	0
60,000	117,569	21,237	0

Guadalupe - San Antonio Basin Modeling Parameters
San Antonio River at Goliad Unappropriated Streamflow - Alternative S-12
Scenario B2

Analysis Point: San Antonio River at Goliad (USGS Gage 1885)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Antonio River at Goliad (USGS Gage 1885) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	8,427	140	119,235	1,977
Feb	8,396	139	111,426	1,848
Mar	14,265	237	118,399	1,964
Apr	15,490	257	108,476	1,799
May	20,618	342	260,311	4,317
Jun	21,588	358	252,135	4,182
Jul	10,660	177	86,267	1,431
Aug	10,369	172	71,697	1,189
Sep	14,633	243	177,444	2,943
Oct	8,770	145	172,249	2,857
Nov	8,202	136	92,774	1,539
Dec	8,318	138	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 50,000 acft/yr
- Hydro Requirement at Lake Dunlap: 600 cfs
- Applewhite Reservoir: Excluded
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 0 acft/yr
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 0 acft/yr
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,581	800	0
5,000	17,498	3,630	0
10,000	33,448	6,479	0
20,000	60,586	10,487	0
40,000	100,593	17,414	0
60,000	127,525	23,271	0

Guadalupe - San Antonio Basin Modeling Parameters
Medina Lake - Alternative S-13
Available Supply

Analysis Point: Diversion Lake

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	N/A	N/A	N/A	N/A
Feb	N/A	N/A	N/A	N/A
Mar	N/A	N/A	N/A	N/A
Apr	N/A	N/A	N/A	N/A
May	N/A	N/A	N/A	N/A
Jun	N/A	N/A	N/A	N/A
Jul	N/A	N/A	N/A	N/A
Aug	N/A	N/A	N/A	N/A
Sep	N/A	N/A	N/A	N/A
Oct	N/A	N/A	N/A	N/A
Nov	N/A	N/A	N/A	N/A
Dec	N/A	N/A	N/A	N/A
Drought Median	N/A	N/A	N/A	N/A

Flow Requirements Based On:	Certificate of Adjudication
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Excluded Junior Rights Upstream
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)
Reservoir System Available Supply Estimates[1]:	
1934-89 Average Available Supply	57,970 acft/yr
1947-56 Drought Average Available Supply	26,750 acft/yr
Minimum Year (1956) Available Supply	490 acft/yr

Notes:
1) Available supply computed under existing Bexar-Medina-Atascosa Water Control and Improvement District #1 water rights totalling 66,750 acft/yr with diversions in accordance with typical monthly demand distribution for irrigation.

Guadalupe - San Antonio Basin Modeling Parameters
Medina Lake - Alternative S-13
Firm Yield

Analysis Point: Medina Lake

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	N/A	N/A	N/A	N/A
Feb	N/A	N/A	N/A	N/A
Mar	N/A	N/A	N/A	N/A
Apr	N/A	N/A	N/A	N/A
May	N/A	N/A	N/A	N/A
Jun	N/A	N/A	N/A	N/A
Jul	N/A	N/A	N/A	N/A
Aug	N/A	N/A	N/A	N/A
Sep	N/A	N/A	N/A	N/A
Oct	N/A	N/A	N/A	N/A
Nov	N/A	N/A	N/A	N/A
Dec	N/A	N/A	N/A	N/A
Drought Median	N/A	N/A	N/A	N/A

Flow Requirements Based On: Certificate of Adjudication

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:

Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual

Water Rights:

Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Excluded Junior Rights Upstream

Steam-electric Diversions:

Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield[1] and Recharge Enhancement[2] Estimates:

Firm Yield	8,770 acft/yr
1934-89 Average Recharge Enhancement	9,670 acft/yr
1947-56 Drought Average Recharge Enhancement	20,250 acft/yr
Minimum Year (1956) Recharge Enhancement	4,750 acft/yr

Notes:
1) Firm yield diverted directly from Medina Lake in accordance with a uniform monthly demand distribution.
2) Baseline for recharge enhancement estimation is recharge associated with diversion of available supply under existing Bexar-Medina-Atascosa Water Control and Improvement District #1 water rights totalling 66,750 acft/yr with diversions in accordance with typical monthly demand distribution for irrigation.

Guadalupe - San Antonio Basin Modeling Parameters
Applewhite Reservoir - Alternative S-14
Available Supply

Analysis Point:	Medina River near Somerset (USGS Gage 1808)			
Minimum Flow Requirements:	Inflow Passage Requirement at Reservoir		Bay & Estuary Inflow Requirement at Saltwater Barrier	
Month	(acft/mo)	(cfs)	(acft/mo)	(cfs)
Jan	246	4	N/A	N/A
Feb	222	4	N/A	N/A
Mar	246	4	N/A	N/A
Apr	238	4	N/A	N/A
May	246	4	N/A	N/A
Jun	238	4	N/A	N/A
Jul	246	4	N/A	N/A
Aug	246	4	N/A	N/A
Sep	238	4	N/A	N/A
Oct	246	4	N/A	N/A
Nov	238	4	N/A	N/A
Dec	246	4	N/A	N/A
Drought Median	N/A	N/A	N/A	N/A
Flow Requirements Based On:	Certificate of Adjudication			
Edwards Aquifer Pumpage:	400,000 acft/yr			
Return Flows:				
Surface Water Sources:	1988 Actual			
Groundwater Sources:	1988 Actual			
Water Rights:				
Canyon Lake:	50,000 acft/yr			
Hydro Requirement at Lake Dunlap:	600 cfs			
Applewhite Reservoir:	Included			
Other Rights:	Excluded Junior Rights Upstream and Downstream			
Steam-electric Diversions:				
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)			
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)			
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)			
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)			
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)			
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)			
Reservoir Available Supply Estimates[1]:				
1934-89 Average Available Supply	47,060 acft/yr			
1947-56 Drought Average Available Supply	22,460 acft/yr			
Minimum Year (1956) Available Supply	2,020 acft/yr			

Notes:
1) Available supply computed under existing City of San Antonio water rights totalling 57,700 acft/yr for Applewhite Reservoir excluding the Leon Creek diversion. Available supply diverted from Applewhite Reservoir in accordance with a uniform monthly demand distribution.

Guadalupe - San Antonio Basin Modeling Parameters
Applewhite Reservoir / Medina Lake System - Alternatives S-13 and S-14
Firm Yield

Analysis Point: Medina River near Somerset (USGS Gage 1808)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	246	4	N/A	N/A
Feb	222	4	N/A	N/A
Mar	246	4	N/A	N/A
Apr	238	4	N/A	N/A
May	246	4	N/A	N/A
Jun	238	4	N/A	N/A
Jul	246	4	N/A	N/A
Aug	246	4	N/A	N/A
Sep	238	4	N/A	N/A
Oct	246	4	N/A	N/A
Nov	238	4	N/A	N/A
Dec	246	4	N/A	N/A
Drought Median	N/A	N/A	N/A	N/A

Flow Requirements Based On: Certificate of Adjudication

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:

Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual

Water Rights:

Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Excluded Rights Junior to Medina Lake Upstream of Medina Lake Excluded All Rights Junior to Applewhite Reservoir Excluded Bexar-Medina-Atascosa Water Control and Improvement District #1 Diversions

Steam-electric Diversions:

Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield[1] and Recharge Enhancement[2] Estimates:

Firm Yield	14,900 acft/yr
1934-89 Average Recharge Enhancement	10,560 acft/yr
1947-56 Average Recharge Enhancement	22,570 acft/yr
Minimum Year (1956) Recharge Enhancement	4,250 acft/yr

Notes:
1) Firm yield diverted from Applewhite Reservoir in accordance with a uniform monthly demand distribution. Leon Creek diversion excluded. System operation policy: Release 25,000 acft from Medina Lake when end-of-month storage in Applewhite Reservoir falls below 20 percent of conservation capacity; otherwise, store all Medina Lake inflows.
2) Baseline for recharge enhancement estimation is recharge associated with diversion of available supply under existing Bexar-Medina-Atascosa Water Control and Improvement District #1 water rights totalling 66,750 acft/yr with diversion in accordance with typical monthly demnad distribution for irrigation.

Guadalupe - San Antonio Basin Modeling Parameters
Cibolo Reservoir - Alternative S-15
Scenario 1

Analysis Point: Cibolo Creek near Falls City (USGS Gage 1860)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	1,814	30	N/A	N/A
Feb	2,080	34	N/A	N/A
Mar	2,210	37	N/A	N/A
Apr	9,897	164	N/A	N/A
May	14,430	239	N/A	N/A
Jun	13,128	218	N/A	N/A
Jul	1,460	24	N/A	N/A
Aug	3,526	58	N/A	N/A
Sep	10,592	176	N/A	N/A
Oct	6,928	115	N/A	N/A
Nov	1,884	31	N/A	N/A
Dec	2,040	34	N/A	N/A
Drought Median[1]	872	14	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Excluded
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	30,600
60%	33,000
80%	37,500

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Cibolo Reservoir - Alternative S-15
Scenario 2

Analysis Point: Cibolo Creek near Falls City (USGS Gage 1860)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	1,814	30	N/A	N/A
Feb	2,080	34	N/A	N/A
Mar	2,210	37	N/A	N/A
Apr	9,897	164	N/A	N/A
May	14,430	239	N/A	N/A
Jun	13,128	218	N/A	N/A
Jul	1,460	24	N/A	N/A
Aug	3,526	58	N/A	N/A
Sep	10,592	176	N/A	N/A
Oct	6,928	115	N/A	N/A
Nov	1,884	31	N/A	N/A
Dec	2,040	34	N/A	N/A
Drought Median[1]	872	14	N/A	N/A

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:

Surface Water Sources:	None
Groundwater Sources:	None

Water Rights:

Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts

Steam-electric Diversions:

Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	25,400
60%	28,100
80%	31,200

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Cibolo Reservoir - Alternative S-15
Scenario 3

Analysis Point: Cibolo Creek near Falls City (USGS Gage 1860)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	1,814	30	N/A	N/A
Feb	2,080	34	N/A	N/A
Mar	2,210	37	N/A	N/A
Apr	9,897	164	N/A	N/A
May	14,430	239	N/A	N/A
Jun	13,128	218	N/A	N/A
Jul	1,460	24	N/A	N/A
Aug	3,526	58	N/A	N/A
Sep	10,592	176	N/A	N/A
Oct	6,928	115	N/A	N/A
Nov	1,884	31	N/A	N/A
Dec	2,040	34	N/A	N/A
Drought Median[1]	872	14	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	29,700
60%	32,300
80%	36,600

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Cibolo Reservoir - Alternative S-15
Scenario 4

Analysis Point: Cibolo Creek near Falls City (USGS Gage 1860)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	1,814	30	N/A	N/A
Feb	2,080	34	N/A	N/A
Mar	2,210	37	N/A	N/A
Apr	9,897	164	N/A	N/A
May	14,430	239	N/A	N/A
Jun	13,128	218	N/A	N/A
Jul	1,460	24	N/A	N/A
Aug	3,526	58	N/A	N/A
Sep	10,592	176	N/A	N/A
Oct	6,928	115	N/A	N/A
Nov	1,884	31	N/A	N/A
Dec	2,040	34	N/A	N/A
Drought Median[1]	872	14	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	None
Groundwater Sources:	None
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Excluded
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	26,200
60%	28,600
80%	32,700

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Goliad Reservoir - Alternative S-16
Scenario 1

Analysis Point: San Antonio River at Goliad (USGS Gage 1885)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	21,068	349	N/A	N/A
Feb	20,989	348	N/A	N/A
Mar	23,775	394	N/A	N/A
Apr	40,890	678	N/A	N/A
May	63,752	1,057	N/A	N/A
Jun	71,977	1,194	N/A	N/A
Jul	17,766	295	N/A	N/A
Aug	24,419	405	N/A	N/A
Sep	59,764	991	N/A	N/A
Oct	47,657	790	N/A	N/A
Nov	20,505	340	N/A	N/A
Dec	20,794	345	N/A	N/A
Drought Median[1]	4,476	74	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Excluded
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	95,100
60%	124,200
80%	141,600

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Goliad Reservoir - Alternative S-16
Scenario 2

Analysis Point: San Antonio River at Goliad (USGS Gage 1885)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	21,068	349	N/A	N/A
Feb	20,989	348	N/A	N/A
Mar	23,775	394	N/A	N/A
Apr	40,890	678	N/A	N/A
May	63,752	1,057	N/A	N/A
Jun	71,977	1,194	N/A	N/A
Jul	17,766	295	N/A	N/A
Aug	24,419	405	N/A	N/A
Sep	59,764	991	N/A	N/A
Oct	47,657	790	N/A	N/A
Nov	20,505	340	N/A	N/A
Dec	20,794	345	N/A	N/A
Drought Median[1]	4,476	74	N/A	N/A

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:

- Surface Water Sources: None
- Groundwater Sources: None

Water Rights:

- Canyon Lake: 50,000 acft/yr
- Hydro Requirement at Lake Dunlap: 600 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:

- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	59,200
60%	82,300
80%	92,700

Notes:

1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Goliad Reservoir - Alternative S-16
Scenario 3

Analysis Point:	San Antonio River at Goliad (USGS Gage 1885)			
Minimum Flow Requirements:	Inflow Passage Requirement at Reservoir		Bay & Estuary Inflow Requirement at Saltwater Barrier	
Month	(acft/mo)	(cfs)	(acft/mo)	(cfs)
Jan	21,068	349	N/A	N/A
Feb	20,989	348	N/A	N/A
Mar	23,775	394	N/A	N/A
Apr	40,890	678	N/A	N/A
May	63,752	1,057	N/A	N/A
Jun	71,977	1,194	N/A	N/A
Jul	17,766	295	N/A	N/A
Aug	24,419	405	N/A	N/A
Sep	59,764	991	N/A	N/A
Oct	47,657	790	N/A	N/A
Nov	20,505	340	N/A	N/A
Dec	20,794	345	N/A	N/A
Drought Median[1]	4,476	74	N/A	N/A
Flow Requirements Based On:	Trans-Texas Environmental Criteria			
Edwards Aquifer Pumpage:	400,000 acft/yr			
Return Flows:				
Surface Water Sources:	1988 Actual			
Groundwater Sources:	1988 Actual			
Water Rights:				
Canyon Lake:	50,000 acft/yr			
Hydro Requirement at Lake Dunlap:	600 cfs			
Applewhite Reservoir:	Included			
Other Rights:	Full Authorized Amounts			
Steam-electric Diversions:				
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)			
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)			
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)			
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)			
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)			
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)			

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	81,400
60%	115,500
80%	130,600

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Goliad Reservoir - Alternative S-16
Scenario 4

Analysis Point: San Antonio River at Goliad (USGS Gage 1885)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	21,068	349	N/A	N/A
Feb	20,989	348	N/A	N/A
Mar	23,775	394	N/A	N/A
Apr	40,890	678	N/A	N/A
May	63,752	1,057	N/A	N/A
Jun	71,977	1,194	N/A	N/A
Jul	17,766	295	N/A	N/A
Aug	24,419	405	N/A	N/A
Sep	59,764	991	N/A	N/A
Oct	47,657	790	N/A	N/A
Nov	20,505	340	N/A	N/A
Dec	20,794	345	N/A	N/A
Drought Median[1]	4,476	74	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	None
Groundwater Sources:	None
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Excluded
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	67,700
60%	85,400
80%	97,200

Notes:

1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River near Gonzales Unappropriated Streamflow - Alternative G-10
Scenario A

Analysis Point: Guadalupe River near Gonzales (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement at Guadalupe River at Cuero (Gage 1758) (acft/mo)	Instream Flow Requirement (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement (cfs)
Jan	29,067	482	119,235	1,977
Feb	27,952	464	111,426	1,848
Mar	41,402	687	118,399	1,964
Apr	43,546	722	108,476	1,799
May	61,261	1,016	260,311	4,317
Jun	51,054	847	252,135	4,182
Jul	32,065	532	86,267	1,431
Aug	25,915	430	71,697	1,189
Sep	34,423	571	177,444	2,943
Oct	23,705	393	172,249	2,857
Nov	22,278	369	92,774	1,539
Dec	23,299	386	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	52,600 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,670	900	0
5,000	18,085	4,500	0
10,000	35,415	8,778	0
20,000	67,502	16,405	0
40,000	122,019	25,767	0
60,000	163,045	45,018	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River near Gonzales Unappropriated Streamflow - Alternative G-10
Scenario B

Analysis Point: Guadalupe River near Gonzales (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement at Guadalupe River at Cuero (Gage 1758) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	29,067	482	119,235	1,977
Feb	27,952	464	111,426	1,848
Mar	41,402	687	118,399	1,964
Apr	43,546	722	108,476	1,799
May	61,261	1,016	260,311	4,317
Jun	51,054	847	252,135	4,182
Jul	32,065	532	86,267	1,431
Aug	25,915	430	71,697	1,189
Sep	34,423	571	177,444	2,943
Oct	23,705	393	172,249	2,857
Nov	22,278	369	92,774	1,539
Dec	23,299	386	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 200,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 66,000 acft/yr
- Hydro Requirement at Lake Dunlap: 365 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,972	900	0
5,000	19,630	4,500	0
10,000	38,533	9,000	0
20,000	73,426	17,693	0
40,000	134,148	30,297	0
60,000	180,504	38,297	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River near Gonzales Unappropriated Streamflow - Alternative G-10
Scenario C

Analysis Point: Guadalupe River near Gonzales (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement at Guadalupe River at Cuero (Gage 1758) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	29,067	482	119,235	1,977
Feb	27,952	464	111,426	1,848
Mar	41,402	687	118,399	1,964
Apr	43,546	722	108,476	1,799
May	61,261	1,016	260,311	4,317
Jun	51,054	847	252,135	4,182
Jul	32,065	532	86,267	1,431
Aug	25,915	430	71,697	1,189
Sep	34,423	571	177,444	2,943
Oct	23,705	393	172,249	2,857
Nov	22,278	369	92,774	1,539
Dec	23,299	386	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 74,100 acft/yr
- Hydro Requirement at Lake Dunlap: 0 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,634	900	0
5,000	17,753	4,500	0
10,000	34,820	8,778	0
20,000	66,714	16,101	0
40,000	120,066	25,266	0
60,000	159,638	33,226	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River near Gonzales Unappropriated Streamflow - Alternative G-10
Scenario D

Analysis Point: Guadalupe River near Gonzales (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement at Guadalupe River at Cuero (Gage 1758) (acft/mo)	Instream Flow Requirement (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement (cfs)
Jan	29,067	482	119,235	1,977
Feb	27,952	464	111,426	1,848
Mar	41,402	687	118,399	1,964
Apr	43,546	722	108,476	1,799
May	61,261	1,016	260,311	4,317
Jun	51,054	847	252,135	4,182
Jul	32,065	532	86,267	1,431
Aug	25,915	430	71,697	1,189
Sep	34,423	571	177,444	2,943
Oct	23,705	393	172,249	2,857
Nov	22,278	369	92,774	1,539
Dec	23,299	386	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 200,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 86,000 acft/yr
- Hydro Requirement at Lake Dunlap: 0 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,901	900	0
5,000	19,318	4,500	0
10,000	38,030	9,000	0
20,000	72,769	17,473	0
40,000	132,944	29,945	0
60,000	178,099	37,945	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Cuero Unappropriated Streamflow - Alternative G-11
Scenario A

Analysis Point: Guadalupe River at Cuero (USGS Gage 1758)

Minimum Flow Requirements:

Month	Instream Flow Requirement at Analysis Point (acft/mo)	Instream Flow Requirement at Analysis Point (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	29,067	482	119,235	1,977
Feb	27,952	464	111,426	1,848
Mar	41,402	687	118,399	1,964
Apr	43,546	722	108,476	1,799
May	61,261	1,016	260,311	4,317
Jun	51,054	847	252,135	4,182
Jul	32,065	532	86,267	1,431
Aug	25,915	430	71,697	1,189
Sep	34,423	571	177,444	2,943
Oct	23,705	393	172,249	2,857
Nov	22,278	369	92,774	1,539
Dec	23,299	386	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	52,600 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,696	900	0
5,000	18,295	4,500	0
10,000	35,833	8,551	0
20,000	68,704	16,038	0
40,000	127,299	26,724	0
60,000	177,605	35,707	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Cuero Unappropriated Streamflow - Alternative G-11
Scenario B

Analysis Point: Guadalupe River at Cuero (USGS Gage 1758)

Minimum Flow Requirements:

Month	Instream Flow Requirement at Analysis Point (acft/mo)	Instream Flow Requirement at Analysis Point (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	29,067	482	119,235	1,977
Feb	27,952	464	111,426	1,848
Mar	41,402	687	118,399	1,964
Apr	43,546	722	108,476	1,799
May	61,261	1,016	260,311	4,317
Jun	51,054	847	252,135	4,182
Jul	32,065	532	86,267	1,431
Aug	25,915	430	71,697	1,189
Sep	34,423	571	177,444	2,943
Oct	23,705	393	172,249	2,857
Nov	22,278	369	92,774	1,539
Dec	23,299	386	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	200,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	66,000 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,988	900	0
5,000	19,625	4,500	0
10,000	38,557	9,000	0
20,000	73,945	17,530	0
40,000	136,925	30,640	0
60,000	190,391	40,015	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Cuero Unappropriated Streamflow - Alternative G-11
Scenario C

Analysis Point: Guadalupe River at Cuero (USGS Gage 1758)

Minimum Flow Requirements:

Month	Instream Flow Requirement at Analysis Point (acft/mo)	Instream Flow Requirement at Analysis Point (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	29,067	482	119,235	1,977
Feb	27,952	464	111,426	1,848
Mar	41,402	687	118,399	1,964
Apr	43,546	722	108,476	1,799
May	61,261	1,016	260,311	4,317
Jun	51,054	847	252,135	4,182
Jul	32,065	532	86,267	1,431
Aug	25,915	430	71,697	1,189
Sep	34,423	571	177,444	2,943
Oct	23,705	393	172,249	2,857
Nov	22,278	369	92,774	1,539
Dec	23,299	386	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	74,100 acft/yr
Hydro Requirement at Lake Dunlap:	0 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,661	900	0
5,000	17,950	4,350	0
10,000	35,246	8,350	0
20,000	67,765	15,838	0
40,000	125,593	26,524	0
60,000	174,996	34,939	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Cuero Unappropriated Streamflow - Alternative G-11
Scenario D

Analysis Point: Guadalupe River at Cuero (USGS Gage 1758)

Minimum Flow Requirements:

Month	Instream Flow Requirement at Analysis Point (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	29,067	482	119,235	1,977
Feb	27,952	464	111,426	1,848
Mar	41,402	687	118,399	1,964
Apr	43,546	722	108,476	1,799
May	61,261	1,016	260,311	4,317
Jun	51,054	847	252,135	4,182
Jul	32,065	532	86,267	1,431
Aug	25,915	430	71,697	1,189
Sep	34,423	571	177,444	2,943
Oct	23,705	393	172,249	2,857
Nov	22,278	369	92,774	1,539
Dec	23,299	386	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	200,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	86,000 acft/yr
Hydro Requirement at Lake Dunlap:	0 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,916	900	0
5,000	19,316	4,500	0
10,000	38,079	9,000	0
20,000	73,259	17,331	0
40,000	135,864	30,319	0
60,000	188,364	39,694	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Saltwater Barrier Unappropriated Streamflow - Alternative G-12
Scenario A

Analysis Point: Guadalupe River at the Saltwater Barrier (ungaged)

Minimum Flow Requirements:

Month	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	119,235	1,977
Feb	111,426	1,848
Mar	118,399	1,964
Apr	108,476	1,799
May	260,311	4,317
Jun	252,135	4,182
Jul	86,267	1,431
Aug	71,697	1,189
Sep	177,444	2,943
Oct	172,249	2,857
Nov	92,774	1,539
Dec	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	52,600 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,750	900	0
5,000	18,531	4,482	0
10,000	36,311	8,482	0
20,000	70,760	15,817	0
40,000	131,474	26,016	0
60,000	184,275	34,449	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Saltwater Barrier Unappropriated Streamflow - Alternative G-12
Scenario B

Analysis Point: Guadalupe River at the Saltwater Barrier (ungaged)

Minimum Flow Requirements:

Month	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	119,235	1,977
Feb	111,426	1,848
Mar	118,399	1,964
Apr	108,476	1,799
May	260,311	4,317
Jun	252,135	4,182
Jul	86,267	1,431
Aug	71,697	1,189
Sep	177,444	2,943
Oct	172,249	2,857
Nov	92,774	1,539
Dec	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	200,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	66,000 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	4,054	900	0
5,000	19,935	4,500	0
10,000	38,960	9,000	0
20,000	75,024	17,345	0
40,000	140,298	29,512	0
60,000	195,993	38,297	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Saltwater Barrier Unappropriated Streamflow - Alternative G-12
Scenario C

Analysis Point: Guadalupe River at the Saltwater Barrier (ungaged)

Minimum Flow Requirements:

Month	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	119,235	1,977
Feb	111,426	1,848
Mar	118,399	1,964
Apr	108,476	1,799
May	260,311	4,317
Jun	252,135	4,182
Jul	86,267	1,431
Aug	71,697	1,189
Sep	177,444	2,943
Oct	172,249	2,857
Nov	92,774	1,539
Dec	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 74,100 acft/yr
- Hydro Requirement at Lake Dunlap: 0 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,750	900	0
5,000	18,416	4,307	0
10,000	36,108	8,307	0
20,000	70,190	15,641	0
40,000	130,337	25,765	0
60,000	182,247	33,765	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Saltwater Barrier Unappropriated Streamflow - Alternative G-12
Scenario D

Analysis Point: Guadalupe River at the Saltwater Barrier (ungaged)

Minimum Flow Requirements:

Month	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	119,235	1,977
Feb	111,426	1,848
Mar	118,399	1,964
Apr	108,476	1,799
May	260,311	4,317
Jun	252,135	4,182
Jul	86,267	1,431
Aug	71,697	1,189
Sep	177,444	2,943
Oct	172,249	2,857
Nov	92,774	1,539
Dec	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	200,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	86,000 acft/yr
Hydro Requirement at Lake Dunlap:	0 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,916	900	0
5,000	19,316	4,500	0
10,000	38,079	9,000	0
20,000	73,259	17,331	0
40,000	135,864	30,319	0
60,000	188,364	39,694	0

Guadalupe - San Antonio Basin Modeling Parameters
San Marcos River below the Blanco River Confluence
Unappropriated Streamflow - Alternative G-13
Scenario A

Analysis Point: San Marcos River below the Blanco River Confluence (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Marcos River at Luling (USGS Gage 1720) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	5,440	90	119,235	1,977
Feb	5,619	93	111,426	1,848
Mar	10,537	175	118,399	1,964
Apr	10,512	174	108,476	1,799
May	13,508	224	260,311	4,317
Jun	12,632	209	252,135	4,182
Jul	7,307	121	86,267	1,431
Aug	6,407	106	71,697	1,189
Sep	7,371	122	177,444	2,943
Oct	5,024	83	172,249	2,857
Nov	4,756	79	92,774	1,539
Dec	5,070	84	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	52,600 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,639	900	0
5,000	17,673	4,500	0
10,000	33,913	8,310	0
20,000	59,041	13,944	0
40,000	86,468	18,460	0
60,000	94,294	20,460	0

Guadalupe - San Antonio Basin Modeling Parameters
San Marcos River below the Blanco River Confluence
Unappropriated Streamflow - Alternative G-13
Scenario B

Analysis Point: San Marcos River below the Blanco River Confluence (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Marcos River at Luling (USGS Gage 1720) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	5,440	90	119,235	1,977
Feb	5,619	93	111,426	1,848
Mar	10,537	175	118,399	1,964
Apr	10,512	174	108,476	1,799
May	13,508	224	260,311	4,317
Jun	12,632	209	252,135	4,182
Jul	7,307	121	86,267	1,431
Aug	6,407	106	71,697	1,189
Sep	7,371	122	177,444	2,943
Oct	5,024	83	172,249	2,857
Nov	4,756	79	92,774	1,539
Dec	5,070	84	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 200,000 acft/yr

Return Flows:

- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:

- Canyon Lake: 66,000 acft/yr
- Hydro Requirement at Lake Dunlap: 365 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:

- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,938	900	0
5,000	19,090	4,500	0
10,000	36,688	8,695	0
20,000	63,582	14,570	0
40,000	92,278	19,288	0
60,000	100,504	21,288	0

Guadalupe - San Antonio Basin Modeling Parameters
San Marcos River below the Blanco River Confluence
Unappropriated Streamflow - Alternative G-13
Scenario C

Analysis Point: San Marcos River below the Blanco River Confluence (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Marcos River at Luling (USGS Gage 1720) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	5,440	90	119,235	1,977
Feb	5,619	93	111,426	1,848
Mar	10,537	175	118,399	1,964
Apr	10,512	174	108,476	1,799
May	13,508	224	260,311	4,317
Jun	12,632	209	252,135	4,182
Jul	7,307	121	86,267	1,431
Aug	6,407	106	71,697	1,189
Sep	7,371	122	177,444	2,943
Oct	5,024	83	172,249	2,857
Nov	4,756	79	92,774	1,539
Dec	5,070	84	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:

Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual

Water Rights:

Canyon Lake:	74,100 acft/yr
Hydro Requirement at Lake Dunlap:	0 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts

Steam-electric Diversions:

Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,603	900	0
5,000	17,358	4,444	0
10,000	33,263	8,063	0
20,000	58,234	13,697	0
40,000	85,518	18,213	0
60,000	93,343	20,213	0

Guadalupe - San Antonio Basin Modeling Parameters
San Marcos River below the Blanco River Confluence
Unappropriated Streamflow - Alternative G-13
Scenario D

Analysis Point: San Marcos River below the Blanco River Confluence (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement for San Marcos River at Luling (USGS Gage 1720) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	5,440	90	119,235	1,977
Feb	5,619	93	111,426	1,848
Mar	10,537	175	118,399	1,964
Apr	10,512	174	108,476	1,799
May	13,508	224	260,311	4,317
Jun	12,632	209	252,135	4,182
Jul	7,307	121	86,267	1,431
Aug	6,407	106	71,697	1,189
Sep	7,371	122	177,444	2,943
Oct	5,024	83	172,249	2,857
Nov	4,756	79	92,774	1,539
Dec	5,070	84	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 200,000 acft/yr

Return Flows:

- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:

- Canyon Lake: 86,000 acft/yr
- Hydro Requirement at Lake Dunlap: 0 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:

- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,866	900	0
5,000	18,767	4,500	0
10,000	36,117	8,695	0
20,000	62,873	14,570	0
40,000	91,568	19,288	0
60,000	99,506	21,288	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Lake Dunlap Unappropriated Streamflow - Alternative G-14
Scenario A

Analysis Point: Guadalupe River at Lake Dunlap (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement for Guadalupe River at Lake Wood (ungaged) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	14,237	236	119,235	1,977
Feb	13,866	230	111,426	1,848
Mar	23,510	390	118,399	1,964
Apr	24,285	403	108,476	1,799
May	28,526	473	260,311	4,317
Jun	24,917	413	252,135	4,182
Jul	20,266	336	86,267	1,431
Aug	17,322	287	71,697	1,189
Sep	18,859	313	177,444	2,943
Oct	13,617	226	172,249	2,857
Nov	12,996	216	92,774	1,539
Dec	14,320	237	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 52,600 acft/yr
- Hydro Requirement at Lake Dunlap: 365 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,324	564	0
5,000	15,102	2,564	0
10,000	27,661	5,064	0
20,000	47,669	9,934	0
40,000	76,056	15,834	0
60,000	92,431	18,383	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Lake Dunlap Unappropriated Streamflow - Alternative G-14
Scenario B

Analysis Point: Guadalupe River at Lake Dunlap (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement for Guadalupe River at Lake Wood (ungaged) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	14,237	236	119,235	1,977
Feb	13,866	230	111,426	1,848
Mar	23,510	390	118,399	1,964
Apr	24,285	403	108,476	1,799
May	28,526	473	260,311	4,317
Jun	24,917	413	252,135	4,182
Jul	20,266	336	86,267	1,431
Aug	17,322	287	71,697	1,189
Sep	18,859	313	177,444	2,943
Oct	13,617	226	172,249	2,857
Nov	12,996	216	92,774	1,539
Dec	14,320	237	103,130	1,710

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 200,000 acft/yr

Return Flows:

Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual

Water Rights:

Canyon Lake:	66,000 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts

Steam-electric Diversions:

Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,948	800	0
5,000	19,142	3,580	0
10,000	36,570	6,298	0
20,000	63,447	11,298	0
40,000	97,151	19,852	0
60,000	117,081	22,451	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Lake Dunlap Unappropriated Streamflow - Alternative G-14
Scenario C

Analysis Point: Guadalupe River at Lake Dunlap (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement for Guadalupe River at Lake Wood (ungaged) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	14,237	236	119,235	1,977
Feb	13,866	230	111,426	1,848
Mar	23,510	390	118,399	1,964
Apr	24,285	403	108,476	1,799
May	28,526	473	260,311	4,317
Jun	24,917	413	252,135	4,182
Jul	20,266	336	86,267	1,431
Aug	17,322	287	71,697	1,189
Sep	18,859	313	177,444	2,943
Oct	13,617	226	172,249	2,857
Nov	12,996	216	92,774	1,539
Dec	14,320	237	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	74,100 acft/yr
Hydro Requirement at Lake Dunlap:	0 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,522	731	0
5,000	16,259	2,961	0
10,000	30,878	5,461	0
20,000	53,505	10,331	0
40,000	82,875	15,893	0
60,000	99,949	17,667	0

Guadalupe - San Antonio Basin Modeling Parameters
Guadalupe River at Lake Dunlap Unappropriated Streamflow - Alternative G-14
Scenario D

Analysis Point: Guadalupe River at Lake Dunlap (ungaged)

Minimum Flow Requirements:

Month	Instream Flow Requirement for Guadalupe River at Lake Wood (ungaged) (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	14,237	236	119,235	1,977
Feb	13,866	230	111,426	1,848
Mar	23,510	390	118,399	1,964
Apr	24,285	403	108,476	1,799
May	28,526	473	260,311	4,317
Jun	24,917	413	252,135	4,182
Jul	20,266	336	86,267	1,431
Aug	17,322	287	71,697	1,189
Sep	18,859	313	177,444	2,943
Oct	13,617	226	172,249	2,857
Nov	12,996	216	92,774	1,539
Dec	14,320	237	103,130	1,710

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	200,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	86,000 acft/yr
Hydro Requirement at Lake Dunlap:	0 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Water Potentially Available

Maximum Diversion Rate (acft/month)	1934-89 Average (acft/yr)	1947-56 Drought Average (acft/yr)	Minimum Year (acft/yr)
1,000	3,897	900	0
5,000	19,109	4,334	0
10,000	37,126	8,052	0
20,000	68,198	13,572	0
40,000	106,713	21,560	0
60,000	127,490	23,690	0

Guadalupe - San Antonio Basin Modeling Parameters
Cuero Reservoir - Alternative G-16
Scenario 1

Analysis Point: Guadalupe River at Cuero (USGS Gage 1758)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	67,956	1,127	N/A	N/A
Feb	64,256	1,066	N/A	N/A
Mar	68,534	1,137	N/A	N/A
Apr	103,868	1,723	N/A	N/A
May	157,739	2,616	N/A	N/A
Jun	146,608	2,431	N/A	N/A
Jul	51,371	852	N/A	N/A
Aug	52,110	864	N/A	N/A
Sep	82,987	1,376	N/A	N/A
Oct	91,596	1,519	N/A	N/A
Nov	53,055	880	N/A	N/A
Dec	56,337	934	N/A	N/A
Drought Median[1]	10,461	173	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	74,100 acft/yr
Hydro Requirement at Lake Dunlap:	0 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield (acft/yr)
40%	117,000
60%	163,000
80%	187,000

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Cuero Reservoir - Alternative G-16
Scenario 2

Analysis Point: Guadalupe River at Cuero (USGS Gage 1758)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	67,956	1,127	N/A	N/A
Feb	64,256	1,066	N/A	N/A
Mar	68,534	1,137	N/A	N/A
Apr	103,868	1,723	N/A	N/A
May	157,739	2,616	N/A	N/A
Jun	146,608	2,431	N/A	N/A
Jul	51,371	852	N/A	N/A
Aug	52,110	864	N/A	N/A
Sep	82,987	1,376	N/A	N/A
Oct	91,596	1,519	N/A	N/A
Nov	53,055	880	N/A	N/A
Dec	56,337	934	N/A	N/A
Drought Median[1]	10,461	173	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	52,600 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield (acft/yr)
40%	117,000
60%	163,000
80%	187,000

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Cuero Reservoir - Alternative G-16
Scenario 3

Analysis Point: Guadalupe River at Cuero (USGS Gage 1758)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	67,956	1,127	N/A	N/A
Feb	64,256	1,066	N/A	N/A
Mar	68,534	1,137	N/A	N/A
Apr	103,868	1,723	N/A	N/A
May	157,739	2,616	N/A	N/A
Jun	146,608	2,431	N/A	N/A
Jul	51,371	852	N/A	N/A
Aug	52,110	864	N/A	N/A
Sep	82,987	1,376	N/A	N/A
Oct	91,596	1,519	N/A	N/A
Nov	53,055	880	N/A	N/A
Dec	56,337	934	N/A	N/A
Drought Median[1]	10,461	173	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield (acft/yr)
40%	118,000
60%	168,000
80%	193,000

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Lindenau Reservoir - Alternative G-17
Scenario 1

Analysis Point: Sandies Creek near Westhoff (USGS Gage 1750)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir[1] (Sandies Creek) (acft/mo)	(cfs)	Instream Flow Requirement at Guadalupe River Diversion Location[2] (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier for River Diversion[3] (acft/mo)	(cfs)
Jan	1,391	23	29,067	482	119,235	1,977
Feb	1,996	33	27,952	464	111,426	1,848
Mar	1,372	23	41,402	687	118,399	1,964
Apr	9,946	165	43,546	722	108,476	1,799
May	13,883	230	61,261	1,016	260,311	4,317
Jun	14,245	236	51,054	847	252,135	4,182
Jul	1,138	19	32,065	532	86,267	1,431
Aug	2,288	38	25,915	430	71,697	1,189
Sep	13,840	230	34,423	571	177,444	2,943
Oct	7,281	121	23,705	393	172,249	2,857
Nov	1,518	25	22,278	369	92,774	1,539
Dec	1,372	23	23,299	386	103,130	1,710
Drought Median[4]	837	14	N/A	N/A	N/A	N/A

Flow Requirements Based On: Trans-Texas Environmental Criteria

Edwards Aquifer Pumpage: 400,000 acft/yr

Return Flows:
- Surface Water Sources: 1988 Actual
- Groundwater Sources: 1988 Actual

Water Rights:
- Canyon Lake: 74,100 acft/yr
- Hydro Requirement at Lake Dunlap: 0 cfs
- Applewhite Reservoir: Included
- Other Rights: Full Authorized Amounts

Steam-electric Diversions:
- Braunig Lake (consumptive use): 12,000 acft/yr (full permitted amount)
- Braunig Lake (river diversion): 12,000 acft/yr (full permitted amount as needed)
- Calaveras Lake (consumptive use): 37,000 acft/yr (full permitted amount)
- Calaveras Lake (river diversion): 60,000 acft/yr (full permitted amount as needed)
- Coleto Creek Reservoir (consumptive use): 12,500 acft/yr (full permitted amount)
- Coleto Creek Reservoir (river diversion): 20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates[5]

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[6]	Estimate of Firm Yield (acft/yr)
40%	43,800
60%	45,200
80%	48,700

Notes:
1) Inflow passage requirement at reservoir site on Sandies Creek applied only to inflows from the Sandies Creek watershed.
2) Instream flow requirement for Guadalupe River diversion at Cuero (USGS Gage 1758) only applied to determine water potentially available for diversion into Lindenau Reservoir assuming full control of the Sandies Creek watershed.
3) Bay & Estuary inflow requirement at Saltwater Barrier only applied to determine water potentially available for diversion from the Guadalupe River at Cuero (USGS Gage 1758) into Lindenau Reservoir assuming full control of the Sandies Creek watershed.
4) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
5) Firm yield estimates include inflows from the Sandies Creek watershed and diversion from the Guadalupe River at Cuero (USGS Gage 1758). Water potentially available for diversion from the Guadalupe River at Cuero was limited to 80 percent of the estimated monthly water available to account for daily streamflow variations. Monthly diversions from the Guadalupe River were also subjected to a maximum diversion rate of 40,000 acft per month.
6) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Lindenau Reservoir - Alternative G-17
Scenario 2

Analysis Point: Sandies Creek near Westhoff (USGS Gage 1750)

Minimum Flow Requirements:	Inflow Passage Requirement at Reservoir[1] (Sandies Creek)		Instream Flow Requirement at Guadalupe River Diversion Location[2]		Bay & Estuary Inflow Requirement at Saltwater Barrier for River Diversion[3]	
Month	(acft/mo)	(cfs)	(acft/mo)	(cfs)	(acft/mo)	(cfs)
Jan	1,391	23	29,067	482	119,235	1,977
Feb	1,996	33	27,952	464	111,426	1,848
Mar	1,372	23	41,402	687	118,399	1,964
Apr	9,946	165	43,546	722	108,476	1,799
May	13,883	230	61,261	1,016	260,311	4,317
Jun	14,245	236	51,054	847	252,135	4,182
Jul	1,138	19	32,065	532	86,267	1,431
Aug	2,288	38	25,915	430	71,697	1,189
Sep	13,840	230	34,423	571	177,444	2,943
Oct	7,281	121	23,705	393	172,249	2,857
Nov	1,518	25	22,278	369	92,774	1,539
Dec	1,372	23	23,299	386	103,130	1,710
Drought Median[4]	837	14	N/A	N/A	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	52,600 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates[5]

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[6]	Estimate of Firm Yield (acft/yr)
40%	44,400
60%	45,800
80%	49,200

Notes:
1) Inflow passage requirement at reservoir site on Sandies Creek applied only to inflows from the Sandies Creek watershed.
2) Instream flow requirement for Guadalupe River diversion at Cuero (USGS Gage 1758) only applied to determine water potentially available for diversion into Lindenau Reservoir assuming full control of the Sandies Creek watershed.
3) Bay & Estuary inflow requirement at Saltwater Barrier only applied to determine water potentially available for diversion from the Guadalupe River at Cuero (USGS Gage 1758) into Lindenau Reservoir assuming full control of the Sandies Creek watershed.
4) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
5) Firm yield estimates include inflows from the Sandies Creek watershed and diversion from the Guadalupe River at Cuero (USGS Gage 1758). Water potentially available for diversion from the Guadalupe River at Cuero was limited to 80 percent of the estimated monthly water available to account for daily streamflow variations. Monthly diversions from the Guadalupe River were also subjected to a maximum diversion rate of 40,000 acft per month.
6) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
Lindenau Reservoir - Alternative G-17
Scenario 3

Analysis Point: Sandies Creek near Westhoff (USGS Gage 1750)

Minimum Flow Requirements:	Inflow Passage Requirement at Reservoir[1] (Sandies Creek)		Instream Flow Requirement at Guadalupe River Diversion Location[2]		Bay & Estuary Inflow Requirement at Saltwater Barrier for River Diversion[3]	
Month	(acft/mo)	(cfs)	(acft/mo)	(cfs)	(acft/mo)	(cfs)
Jan	1,391	23	29,067	482	119,235	1,977
Feb	1,996	33	27,952	464	111,426	1,848
Mar	1,372	23	41,402	687	118,399	1,964
Apr	9,946	165	43,546	722	108,476	1,799
May	13,883	230	61,261	1,016	260,311	4,317
Jun	14,245	236	51,054	847	252,135	4,182
Jul	1,138	19	32,065	532	86,267	1,431
Aug	2,288	38	25,915	430	71,697	1,189
Sep	13,840	230	34,423	571	177,444	2,943
Oct	7,281	121	23,705	393	172,249	2,857
Nov	1,518	25	22,278	369	92,774	1,539
Dec	1,372	23	23,299	386	103,130	1,710
Drought Median[4]	837	14	N/A	N/A	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates[5]

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[6]	Estimate of Firm Yield (acft/yr)
40%	44,400
60%	45,800
80%	49,200

Notes:

1) Inflow passage requirement at reservoir site on Sandies Creek applied only to inflows from the Sandies Creek watershed.
2) Instream flow requirement for Guadalupe River diversion at Cuero (USGS Gage 1758) only applied to determine water potentially available for diversion into Lindenau Reservoir assuming full control of the Sandies Creek watershed.
3) Bay & Estuary inflow requirement at Saltwater Barrier only applied to determine water potentially available for diversion from the Guadalupe River at Cuero (USGS Gage 1758) into Lindenau Reservoir assuming full control of the Sandies Creek watershed.
4) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
5) Firm yield estimates include inflows from the Sandies Creek watershed and diversion from the Guadalupe River at Cuero (USGS Gage 1758). Water potentially available for diversion from the Guadalupe River at Cuero was limited to 80 percent of the estimated monthly water available to account for daily streamflow variations. Monthly diversions from the Guadalupe River were also subjected to a maximum diversion rate of 40,000 acft per month.
6) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.

Guadalupe - San Antonio Basin Modeling Parameters
McFaddin Reservoir - Alternative G-18
Scenario 1

Analysis Point: Kuy Creek at McFaddin Reservoir Site (ungaged)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	(cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	(cfs)
Jan	132	2	N/A	N/A
Feb	213	4	N/A	N/A
Mar	195	3	N/A	N/A
Apr	715	12	N/A	N/A
May	1,323	22	N/A	N/A
Jun	1,043	17	N/A	N/A
Jul	117	2	N/A	N/A
Aug	240	4	N/A	N/A
Sep	1,408	23	N/A	N/A
Oct	1,116	19	N/A	N/A
Nov	121	2	N/A	N/A
Dec	150	3	N/A	N/A
Drought Median[1]	9	< 1	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	74,100 acft/yr
Hydro Requirement at Lake Dunlap:	0 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	37,000
60%	37,000
80%	37,400

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.
3) Firm yield based on diversion of available water from the purchase of 40,000 acft/yr of water rights (senior to Canyon Lake) from the GBRA Calhoun Canal Division.

Guadalupe - San Antonio Basin Modeling Parameters
McFaddin Reservoir - Alternative G-18
Scenario 3

Analysis Point: Kuy Creek at McFaddin Reservoir Site (ungaged)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	132	2	N/A	N/A
Feb	213	4	N/A	N/A
Mar	195	3	N/A	N/A
Apr	715	12	N/A	N/A
May	1,323	22	N/A	N/A
Jun	1,043	17	N/A	N/A
Jul	117	2	N/A	N/A
Aug	240	4	N/A	N/A
Sep	1,408	23	N/A	N/A
Oct	1,116	19	N/A	N/A
Nov	121	2	N/A	N/A
Dec	150	3	N/A	N/A
Drought Median[1]	9	< 1	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	50,000 acft/yr
Hydro Requirement at Lake Dunlap:	600 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	37,100
60%	37,200
80%	37,500

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.
3) Firm yield based on diversion of available water from the purchase of 40,000 acft/yr of water rights (senior to Canyon Lake) from the GBRA Calhoun Canal Division.

Guadalupe - San Antonio Basin Modeling Parameters
McFaddin Reservoir - Alternative G-18
Scenario 2

Analysis Point: Kuy Creek at McFaddin Reservoir Site (ungaged)

Minimum Flow Requirements:

Month	Inflow Passage Requirement at Reservoir (acft/mo)	Inflow Passage Requirement at Reservoir (cfs)	Bay & Estuary Inflow Requirement at Saltwater Barrier (acft/mo)	Bay & Estuary Inflow Requirement at Saltwater Barrier (cfs)
Jan	132	2	N/A	N/A
Feb	213	4	N/A	N/A
Mar	195	3	N/A	N/A
Apr	715	12	N/A	N/A
May	1,323	22	N/A	N/A
Jun	1,043	17	N/A	N/A
Jul	117	2	N/A	N/A
Aug	240	4	N/A	N/A
Sep	1,408	23	N/A	N/A
Oct	1,116	19	N/A	N/A
Nov	121	2	N/A	N/A
Dec	150	3	N/A	N/A
Drought Median[1]	9	< 1	N/A	N/A

Flow Requirements Based On:	Trans-Texas Environmental Criteria
Edwards Aquifer Pumpage:	400,000 acft/yr
Return Flows:	
Surface Water Sources:	1988 Actual
Groundwater Sources:	1988 Actual
Water Rights:	
Canyon Lake:	52,600 acft/yr
Hydro Requirement at Lake Dunlap:	365 cfs
Applewhite Reservoir:	Included
Other Rights:	Full Authorized Amounts
Steam-electric Diversions:	
Braunig Lake (consumptive use):	12,000 acft/yr (full permitted amount)
Braunig Lake (river diversion):	12,000 acft/yr (full permitted amount as needed)
Calaveras Lake (consumptive use):	37,000 acft/yr (full permitted amount)
Calaveras Lake (river diversion):	60,000 acft/yr (full permitted amount as needed)
Coleto Creek Reservoir (consumptive use):	12,500 acft/yr (full permitted amount)
Coleto Creek Reservoir (river diversion):	20,000 acft/yr (full permitted amount as needed)

Reservoir Firm Yield Estimates

Reservoir Capacity Threshold for Implementation of Drought Contingency Operations[2]	Estimate of Firm Yield[3] (acft/yr)
40%	37,100
60%	37,200
80%	37,500

Notes:
1) Median monthly natural flow during the January, 1954 to December, 1956 historical period.
2) The capacity threshold is the percentage of reservoir conservation storage that triggers a change from normal to drought contingency operations under the Trans-Texas Environmental Criteria for new reservoirs. Drought contingency operations provide for the release of inflows up to the median monthly natural flow during the January, 1954 to December, 1956 historical period.
3) Firm yield based on diversion of available water from the purchase of 40,000 acft/yr of water rights (senior to Canyon Lake) from the GBRA Calhoun Canal Division.