TRANS-TEXAS WATER PROGRAM

North Central
Study Area
Phase II Report

Volume 2

Population, Water Demand Projections, and Water Supply Alternatives

Brazos River Authority

City of Austin

City of Cedar Park

City of Georgetown

City of Hutto

City of Leander

City of Pflugerville

City of Round Rock

Jonah Special Utility District

Manville Water Supply Corporation

Brushy Creek Municipal Utility District

Williamson County

Lower Colorado River Authority

Texas Water Development Board

Texas Natural Resource Conservation Commission

Texas Parks and Wildlife Department

February 1998

HDR

HDR Engineering, Inc.

in association with
Paul Price Associates, Inc.

TRANS-TEXAS WATER PROGRAM
NORTH CENTRAL STUDY AREA
PHASE II REPORT

VOLUME 2

POPULATION, WATER DEMAND PROJECTIONS, AND WATER SUPPLY ALTERNATIVES

Prepared for

City of Austin
City of Cedar Park
City of Georgetown
City of Hutto
City of Leander
City of Pflugerville
City of Round Rock
Jonah Special Utility District
Manville Water Supply Corporation
Brushy Creek Municipal Utility District
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Brazos River Authority

By

HDR Engineering Inc.
in association with
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TRANS-TEXAS WATER PROGRAM
NORTH CENTRAL STUDY AREA
PHASE II REPORT

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TRANS-TEXAS WATER PROGRAM
NORTH CENTRAL STUDY AREA
PHASE II STUDY

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NORTH CENTRAL STUDY AREA
PHASE II REPORT

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TRANS-TEXAS WATER PROGRAM
NORTH CENTRAL STUDY AREA
PHASE II STUDY

1.0 INTRODUCTION

The Trans-Texas Water Program is a comprehensive water resources planning program that includes a full range of water management strategies and water supply options for four major water short areas of Texas, as follows and as shown in Figure 1.0-1:

- North Central (Travis and Williamson Counties),
- West Central (San Antonio/Edwards Aquifer Area),
- South Central (Corpus Christi Area), and
- Southeastern (Houston Metropolitan Area).

The Trans-Texas Water Program was initiated by the Texas Water Development Board (TWDB) in 1992 in an effort to address the water supply needs of these areas in a coordinated, logical, and environmentally responsible manner.[1] The planning studies and implementation actions are being managed, directed, and partially funded by local sponsors of each respective area, and are being conducted in multiple phases. In Phase I, water demands were identified for the period 1990 through 2050, and available options to meet projected demands were identified and evaluated in terms of costs, and environmental advantages and disadvantages. From the results of the Phase I studies, options were selected for more detailed evaluations in Phase II. The results of the Phase II studies will include integrated regional plans to meet the water supply needs of each respective area.

This document is the Phase II Study Report for the North Central Trans-Texas study area. The North Central study began in March of 1994, with the preparation of a Phase I Interim Report for the City of Austin, and was expanded in 1995 to include parts of neighboring Hays and Williamson Counties. This Phase II study effort was directed by the Brazos River Authority for the following local area participants:

- City of Austin,
- City of Cedar Park,
- City of Georgetown,

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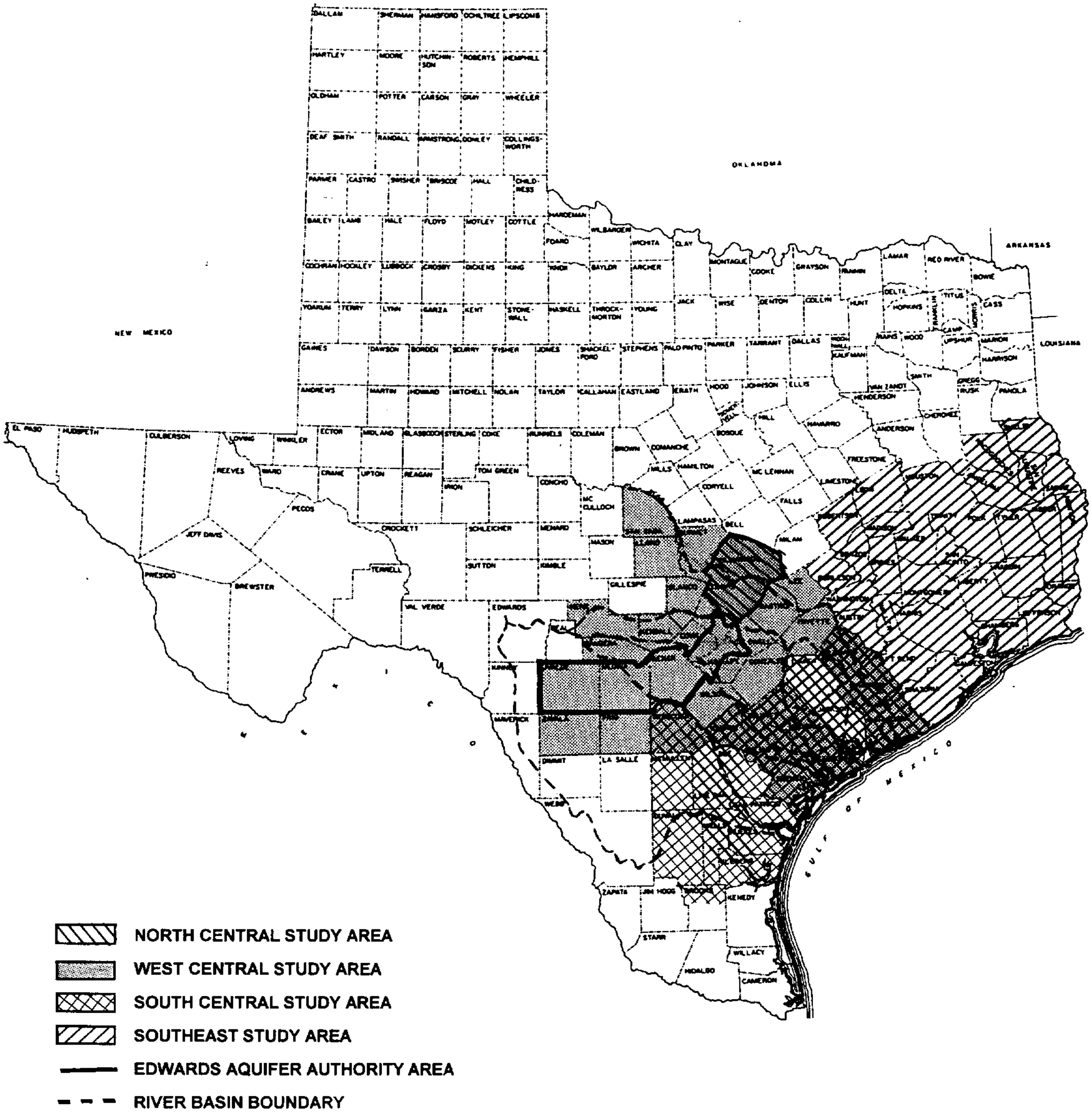
[1] The Texas Water Development Board (TWDB) is the state agency responsible for the preparation and maintenance of a comprehensive state water plan to be used as a flexible guide for the orderly development and management of the state's water resources in order that sufficient water will be available at a reasonable cost to further the economic development of the entire state (Texas Water Code; Sections 16.051 and 16.055).



TRANS TEXAS WATER PROGRAM / NORTH CENTRAL STUDY AREA

STUDY AREA

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FIGURE 1.0-1

- City of Hutto,
- City of Leander,
- City of Pflugerville,
- City of Round Rock,
- Jonah Special Utility District,
- Manville Water Supply Corporation,
- Brushy Creek Municipal Utility District,
- Williamson County, and
- Lower Colorado River Authority.

The Texas Water Development Board, the Texas Natural Resource Conservation Commission, and the Texas Parks and Wildlife Department were also participants in the study effort and served on the Policy Management and Technical Advisory Committees.[2]

1.1 The Study Area

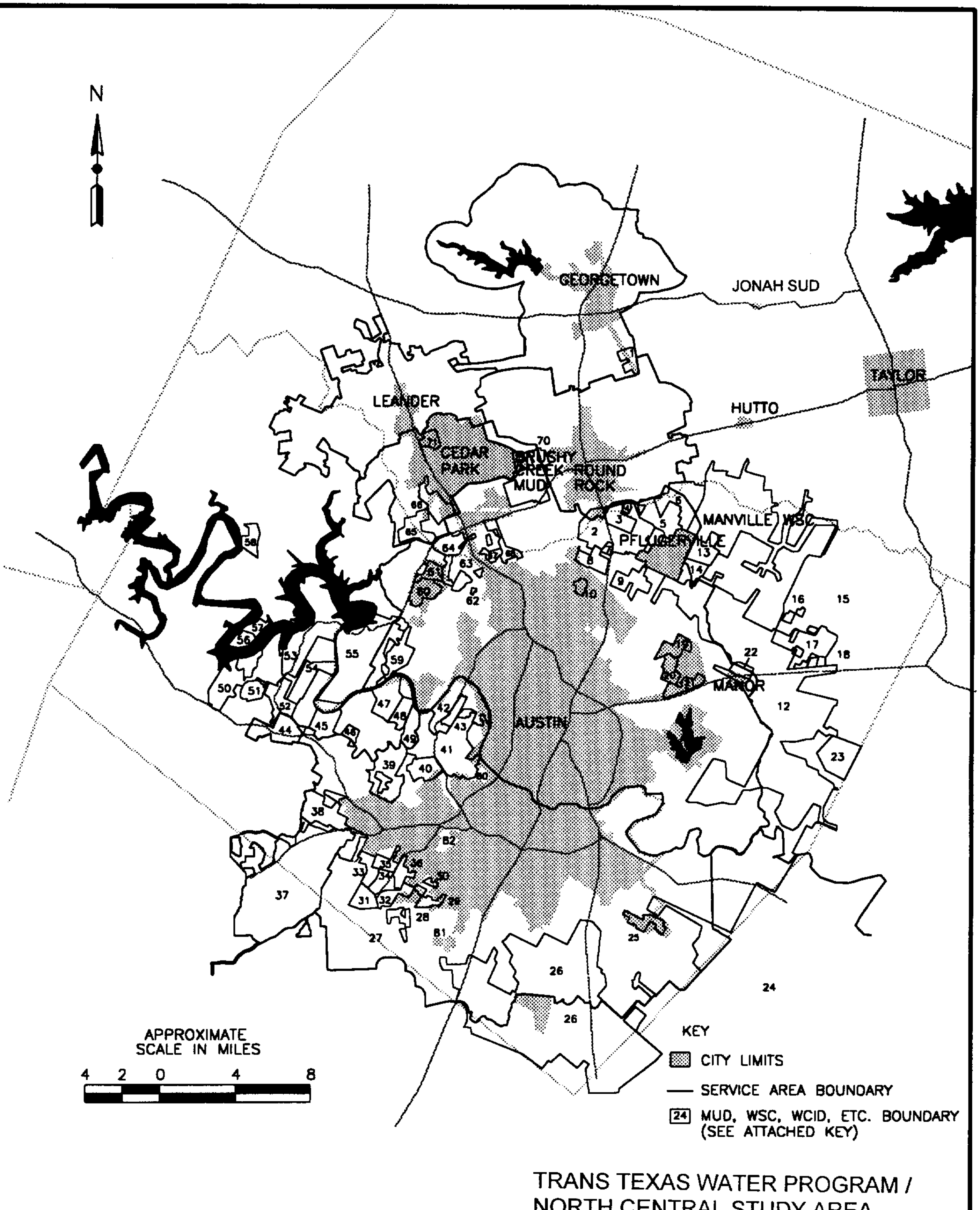
The North Central Trans-Texas study area includes Travis, Williamson, and a small portion of northeastern Hays Counties (Figure 1.1-1) with specific attention to projected population, water demands, water supplies, and water needs of study participants' individual service areas such as:

- City of Austin,
- City of Cedar Park,
- City of Georgetown,
- City of Hutto,
- City of Leander,
- City of Pflugerville,
- City of Round Rock,
- Jonah Special Utility District,
- Manville Water Supply Corporation,
- Brushy Creek Municipal Utility District,
- Areas of Williamson County east of Interstate 35, and
- Areas of Williamson County west of Interstate 35.

Although dryland crop and livestock production are important economic activities in eastern Travis and Williamson Counties, the economy of the study area is predominantly urban, with a

---

[2] The Policy Management Committee (PMC) was chaired by the Brazos River Authority and membership included representatives from each local and state agency participant. The PMC made all policy decisions and directed the work of the consultant (HDR Engineering, Inc.). The Technical Advisory Committee (TAC) was also chaired by the Brazos River Authority and included in its membership representatives of the public, organizations, and the sponsoring water utilities and state agencies. The functions of the TAC included review and comment on study drafts and public input to the PMC.



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

WATER UTILITY
SERVICE AREAS

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FIGURE 1.1-1

Table 1.1-1
Water Utility Service Area Key

1. Meadows Chandler Creek MUD
2. Windermere Utility Co.
3. TP Invest (formerly Orion WSC)
4. Williamson/Travis County MUD2
5. North Travis Co. MUD5
6. North Travis Co. MUD - Future
7. Marsha WSC
8. Wells Branch NAGC MUD 1
9. Northtown MUD
10. Hill Country Utility
11. Not used
12. Manville Water Supply Corp.
13. Northeast Growth Corridor
14. NEGC WSI&DD 2
15. Aqua WSC
16. Cottonwood WCID 3
17. Cottonwood WCID 4
18. Cottonwood WCID 5
19. Austin MUD 3 (North Travis County MUD 3 (Harris Branch))
20. Austin MUD 2 (North Travis County MUD 3)
21. Austin MUD 1 (North Travis County MUD 3)
22. Travis County MUD 2
23. Aqua WSC
24. Aqua WSC
25. Moore's Crossing MUD
26. Creedmoor-Maha WSC
27. Southland Oaks MUD
28. SWTC MUD 1 (Shady Hollow)
29. SAGC MUD 1 (Tanglewood Forest)
30. Southland Oaks MUD
31. Circle "C" MUD 4
32. Circle "C" MUD 1
33. Circle "C" MUD 3
34. Circle "C" MUD 2
35. Village Western Oaks MUD
36. Maple Run MUD
37. Hill Country WSC
38. Travis County WCID 14
39. Travis County WCID 19
40. Lost Creek MUD
41. Travis County WCID 10
42. Lake Austin / 360 Lop Peninsula
43. Davenport Ranch MUD
44. Travis County WCID 14
45. West Travis County MUD 3,4,5 (Bohl's Ranch)
46. Senna Hills MUD
47. Travis County WCID 18
48. Travis County WCID 21
49. Travis County WCID 20
50. Lakeway MUD 1
51. Hurst Creek MUD
52. Travis County WCID 17
53. West Travis County MUD 2
54. West Travis County MUD 1
55. Travis County WCID 17
56. Point Venture WCID
57. Point Venture MUD 2
58. Travis County WCID 15
59. River Place MUD
60. NW Austin MUD 2
61. NW Austin MUD 1
62. NW Travis County MUD 1
63. NW Travis County MUD 2
64. Anderson Mill (WC MUD)
65. Williamson/Travis County MUD 1
68. North Austin MUD 1
69. WC MUD 2 (Brushy Creek)
70. Fern Bluff MUD
71. Block House Creek MUD

72-79. Not used

80. Rollingwood
81. San Leanna
82. Sunset Valley

population of nearly 900,000 in 1996. Water use within the study area is primarily for municipal and domestic, commercial, and light industrial purposes. Total water use in 1995 in the study area was 184,000 acre-feet (one acre-foot is 325,851 gallons) of which 80 percent was for municipal and commercial purposes; 8 percent was for industrial purposes; and 12 percent was for electric power generation, mining, livestock watering, and other purposes. The study area's population growth rate during the 1990 to 1996 period has been approximately 3.5 percent per year, and is projected to be between 2.5 percent and 3.0 percent per year for the next 20 years. Many of the study participants are presently using most of the water supplies available to them, thus it is imperative that additional supplies be obtained in order to meet the needs of the additional population that is locating within their respective service areas.

1.2 Objectives

The objectives of the North Central Trans-Texas study are to:

1. Present projections of population and water demands, and present water supplies for individual study area participants' service areas, and for each of Travis, Williamson, and northeastern Hays Counties.
2. Identify and describe potential water supply options to meet the needs of the study participants.
3. Provide an assessment of the water supply potentials, costs, and environmental advantages and disadvantages of each option.
4. Provide integrated water supply plans for the study area based upon information from objectives 1, 2, and 3 above.

In the study, water supply options focus upon local area water conservation potentials, water reuse, and potential surface and groundwater sources of the Colorado and Brazos River Basins within and near the Travis and Williamson Counties study area.

Travis County
Projections

2.0 POPULATION, WATER DEMAND, AND WATER SUPPLY PROJECTIONS

The Texas Water Development Board's (TWDB) Consensus Population and Water Demand Projections[1] have been used for Travis, Williamson, and Hays Counties, as follows:

- Travis County and each city and unincorporated areas of the county;
- Williamson County and each city and unincorporated areas of the county; and
- Hays County, Barton Springs/Edwards Aquifer Conservation District of Hays County, and Colorado and Guadalupe River Basin Areas of Hays County.

The population and water demand projections are shown for each municipal and water supply participant's service area for each year from 1995 through 2005, by 5-year increments from 2005 through 2020, and by decade from 2020 to 2050, based upon the following TWDB projection cases:

- Most likely population for each city;
- Most likely municipal water demand for below normal precipitation and average conservation for each city;
- Industrial water demand with conservation and base oil prices ($17.00 to $23.00 per bbl for West Texas Crude Oil) for each city;
- Steam-electric power generation water demand—high series for each county;
- Irrigation water demand for aggressive adoption of irrigation technology, and a reduction in Federal Farm Programs by one-half for each county; and
- Livestock water demand—TWDB only series for each county.

For purposes of this study, individual city service area projections such as City of Austin, City of Cedar Park, City of Round Rock, City of Georgetown, City of Leander, and City of Pflugerville were obtained by adding to the respective individual city projections made by TWDB, projections for areas outside the city limits that are also being served by the city. For example, in the case of Austin, the service area population and water demand projections include the TWDB projections for the City of Austin plus projections for those parts of Travis and Williamson Counties that are not within the City, but that are now being served (wholesale and retail) from the Austin water supply system, plus projections for new customers that are expected to be served (wholesale and retail) from the Austin water supply system. Since TWDB does not make projections for those parts of the service areas located outside individual cities, it was necessary to make such projections as a part of this study. The methods used for the Austin service area were to identify individual utility districts (MUDs and WSCs) that have been established to serve

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[1] "Consensus Texas Water Plan Projections of Population and Water Use," Texas Water Development Board, Austin, Texas, February, 1995.

specific housing subdivisions located within the Austin service area, and estimate build-out rates and number of persons per acre developed, as is explained later.

For other cities of the study, where individual utility supplied subdivisions within the respective cities' service areas have not been established, the respective City's water utility connection data were used as the basis for projections. However, it is emphasized that TWDB projections for individual cities were used as the core projections for the respective service areas, with additions made for areas served outside the city.

Historical water use is shown for years 1984 through 1994 (Appendix A: Table 1), and in addition to the population and water demand projections mentioned above, water supplies and water needs of each area are shown.

2.1 Travis County

2.1.1 Population Projections

According to the U.S. Census, the population of Travis County in 1990 was 576,407 and in 1995 was 664,802 (Table 2.1-1). The population of Travis County is projected to increase to 807,027 in year 2000, to 1,246,003 in year 2020, and to 1,718,518 in 2050 (Table 2.1-1 and Figure 2.1-1). (See Appendix A: Table 2 for annual projections through 2005.)

It was estimated that in 1990, the City of Austin, through its retail distribution system located within the City Limits, its wholesale customers located within the City's Extraterritorial Jurisdiction (ETJ), and neighboring communities, including Rollingwood and West Lake Hills, supplied water to approximately 520,589 people (Table 2.1-1). The population of the area (present City Limits plus ETJ) that is expected to be served water by the City of Austin is projected at 729,692 in year 2000, 1,105,543 in 2020, and 1,533,934 in 2050 (Table 2.1-1).

The City of Austin's 1990 population was distributed among the City's eight water service pressure zones in the same proportion as water sales among pressure zones (year closest to 1990 for which such data are available). The TWDB population projections for the City of Austin for years 2000, 2010, 2020, 2030, 2040, and 2050 were allocated among the eight pressure zones based upon City of Austin Water and Wastewater Utility Staff estimates of trends

Table 2.1-1
Population Projections
Travis County Areas
Trans-Texas Water Program

Area	1990	Population Projections								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Austin Service Area										
Northwest A Pressure Zone	85,483	99,331	113,685	136,363	159,040	183,317	207,593	241,561	272,795	307,555
North Pressure Zone	92,636	107,643	135,028	141,539	148,049	165,054	182,059	214,315	224,256	233,477
Central Pressure Zone	168,041	188,545	263,924	275,617	287,311	311,152	334,994	374,030	398,988	412,230
South Pressure Zone	61,522	71,489	74,555	89,601	104,646	116,839	129,032	162,846	190,769	209,570
Far South Pressure Zone	9,171	10,657	11,976	16,961	21,945	24,355	26,765	31,398	34,826	51,378
Southwest A Pressure Zone	47,510	55,207	60,476	69,371	78,267	92,457	106,647	117,872	126,806	149,209
Southwest B Pressure Zone	7,038	8,178	14,817	16,355	17,893	19,919	21,945	36,614	40,369	31,333
Northwest B Pressure Zone	49,188	56,438	55,232	66,394	78,753	85,825	96,509	108,792	117,634	139,182
Subtotal *	520,589	597,487	729,692	812,199	895,904	998,918	1,105,543	1,287,428	1,406,443	1,533,934
Manor[1] *	1,041	1,201	1,424	1,643	1,862	2,035	2,208	2,523	2,728	2,950
Pflugerville Service Area[2] *	4,444	8,888	17,776	31,108	46,662	58,327	69,992	80,471	88,540	92,967
Manville WSC[3]										
Travis County (70.38%/1995) *	6,416	7,400	8,212	9,112	10,012	10,960	11,908	13,819	15,647	17,284
Williamson Co (23.04%/1995)	2,108	2,431	2,698	2,994	3,289	3,601	3,913	4,541	5,141	5,679
Bastrop Co (5.95%/1995)	550	634	704	781	858	940	1,021	1,185	1,341	1,482
Lee County (0.63%/1995)	91	105	118	131	143	156	169	197	224	247
Subtotal	9,165	10,571	11,732	13,017	14,302	15,657	17,011	19,742	22,353	24,692
Remainder/Travis County *	43,917	49,826	49,923	51,008	53,660	55,006	56,352	59,127	64,998	71,383
Travis County Total *	576,407	664,802	807,027	905,070	1,008,100	1,125,246	1,246,003	1,443,368	1,578,356	1,718,518

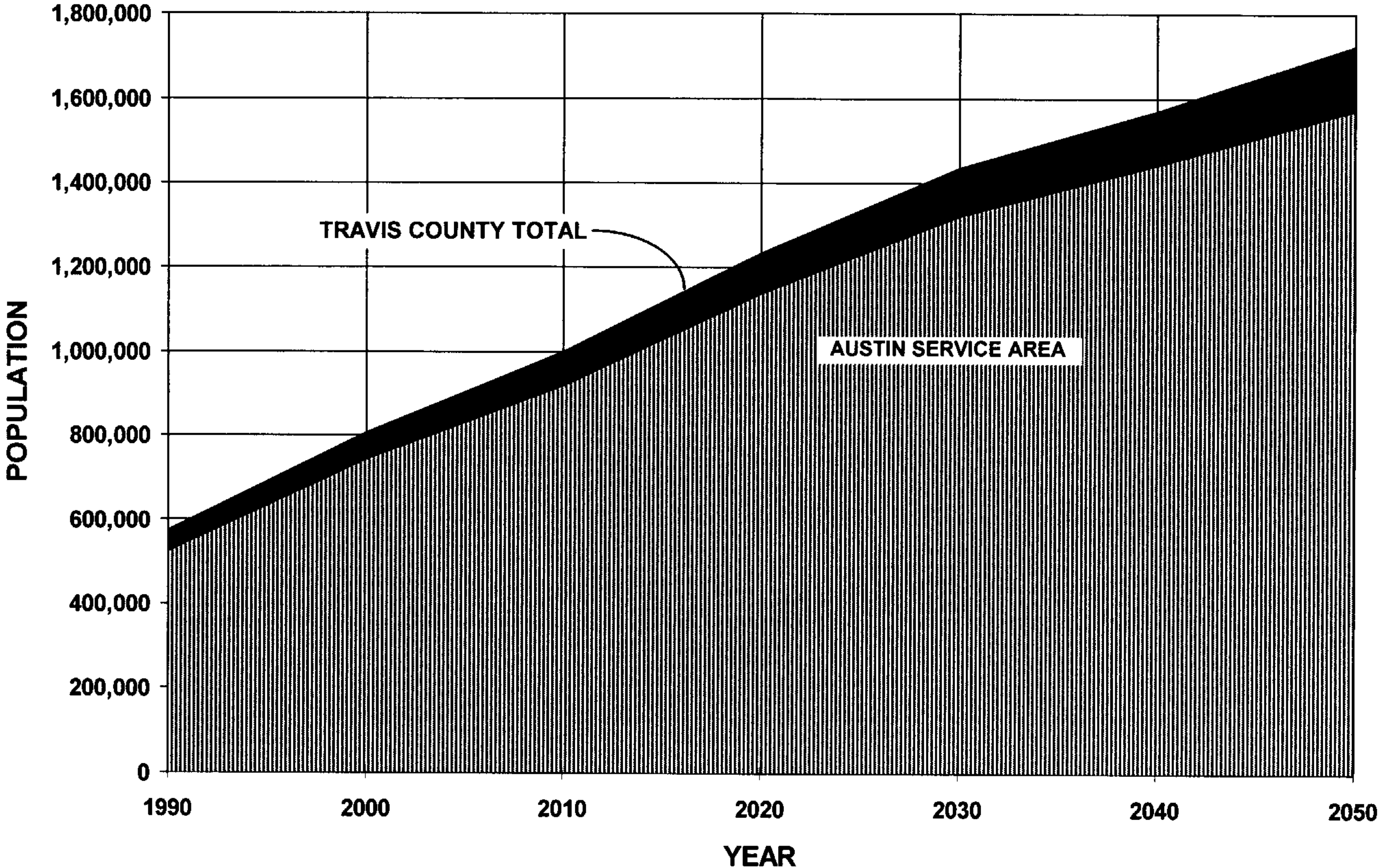
Source: Texas Water Development Board, 1996 Consensus Water Plan Projections, Most Likely Case; as modified.

[1] May be served from COA's Central Pressure Zone.

[2] May be served from COA's Northwest A Pressure Zone.

[3] May be served from COA's North Pressure Zone.

*Areas within Travis County, and included in Travis County totals.



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

POPULATION PROJECTIONS
TRAVIS COUNTY

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FIGURE 2.1-1

in water deliveries to pressure zones.[2] Projected total population (inside the City Limits plus ETJ) to be served via each pressure zone was obtained by adding to the TWDB projections for the City, as allocated among pressure zones, projections of the populations of residential subdivisions that are supplied by Municipal Utility Districts (MUDs) and Water Supply Corporations (WSCs) located within the respective pressure zones within the City's ETJ that presently purchase water wholesale from the City. The population of the developing residential subdivisions located in the City's ETJ was projected based upon the build-out estimates and assumptions stated below.

Factors	Numeric Value
• Area of Subdivision in Acres	Number
• People per Acre	
– North, Northwest, Central, and South Zones	6.50
– Southwest Zones	5.33
• People per Connection (County Average)	2.40

Pressure Zone	Buildout Degrees in Percent of Maximum						
	1990	2000	2010	2020	2030	2040	2050
Northwest A	20	45	66	85	95	97	98
North	NA	NA	NA	NA	NA	NA	NA
Central	10	15	25	33	40	45	50
South	65	70	75	80	85	90	95
Far South	NA	NA	NA	NA	NA	NA	NA
Southwest A	26	45	60	75	80	85	90
Southwest B	21	45	60	75	80	85	90
Northwest B	34	50	70	85	90	95	98

NA = Not applicable since areas do not have MUDs nor WSCs.

The population of Manor was 1,041 in 1990 and is projected at 2,208 in 2020 and 2,950 in 2050 (Table 2.1-1). Pflugerville had a population of 4,444 in 1990 and is projected to grow to 17,776 in year 2000, to 46,662 in 2010, to 69,992 in 2020, and to 92,967 in 2050 (Table 2.1-1).

The population served by Manville Water Supply Corporation was estimated at 9,165 in 1990 and is projected to increase to 17,011 in 2020, and to 24,692 in 2050 (Table 2.1-1). The areas of Travis County not included in the City of Austin, Manor, Pflugerville, and Manville Water Supply Corporation Service Areas of Travis County had a population of 43,917 in 1990, and are projected to have population of 56,352 in 2020, and 71,383 in 2050 (Table 2.1-1).

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[2] "Water Distribution System Long-Range Planning Guide," Water and Wastewater Utility, City of Austin 1994. The staff estimates are for years 2000, 2010, 2017, and 2037, thus it was necessary to interpolate to 2020, 2030, 2040, and 2050.

Although projections are shown for these areas, some of them, including Manor, Pflugerville, Manville WSC, and other water purveyors and subdivisions may consider obtaining water from the City of Austin. The projected quantities of water needed for the individual service areas of Travis County are shown in Section 2.1.2.

2.1.2 Water Demand Projections

Water demand projections for municipal, industrial, steam-electric power, irrigation, mining, and livestock uses are presented below. As defined by the TWDB,

> "...for planning purposes, municipal water use includes both residential and commercial water uses. Commercial water use includes business establishments, public offices, and institutions but does not include industrial water use. Residential and commercial uses are categorized together because they are similar types of uses (i.e., they both use water primarily for drinking, cleaning, sanitation, air conditioning, and landscape watering)."

Industrial water use is that quantity of water used in the manufacturing of products and includes water used for product washing, production process cooling, or for mixing and incorporating into finished goods. Steam-electric power water demand is the quantity of water used in boilers for powering electricity generating machinery and for cooling the electric power production processes. Water for mining purposes is the quantity used to wash and process building materials such as sand and gravel, rock quarrying, and petroleum extraction. Livestock water demand is mainly drinking and sanitation water for cattle, poultry, horses, swine, sheep, and goats.

"Per Capita Water Use:[3] The quantity of water used for municipal purposes is reported to the Texas Water Development Board on an annual basis by cities and other water suppliers such as rural water supply corporations, municipal utility districts, fresh water supply districts, and other types of water suppliers. The types of information reported include groundwater and/or surface water use, source of the water (aquifer, river, reservoir, or stream), water sales and water purchases to other municipalities and end-users, number of service connections, and estimated population served. This information provides for the identification of the water use and water supply network for each geographical area of Texas.

"In calculating the per capita water use for a specific entity, all water sales to other municipalities, industries, or other utilities are removed from the reported total water produced (pumpage or diversions) in order to arrive at the quantity of water used for municipal purposes

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[3] Unpublished Texas Water Development Board Planning Procedures, Austin, Texas, 1996.

by that specific entity. Annual per capita water use, typically stated in gallons per capita daily (gpcd), is then calculated by dividing the adjusted reported annual water use for a specific entity by its estimated annual population. Annual population estimates developed by the State Data Census Population Estimation Program are used for calculating city per capita water use.

"The diversity of the state with respect to climatic conditions, population density, and the availability of water is indicative of the wide-range of per capita water use estimates by geographical area across the state, as well as the varying quantities of water used on an annual basis. From a climatological perspective, rainfall conditions play a major role in the quantity of water used for municipal purposes, particularly for outdoor purposes. During below-normal rainfall conditions, people tend to use more water than during normal or average weather conditions. To portray this weather-related phenomenon, two types of per capita water use estimates were calculated for use in the consensus water planning efforts. One estimate assumes below-normal rainfall conditions; the other assumes normal weather conditions. These two estimates were incorporated into two separate scenarios of municipal water use forecasts.

"To better represent current-day water use as affected by existing plumbing, appliances, and conservation technology, the assumed normal weather per capita water use is based on the average per capita water use over the last 5 years of record (1987-1991) for each entity. The assumed below-normal rainfall condition per capita water use is based on the highest per capita water use recorded by an entity over the last 10 years of record (1982-1991). For planning purposes, the assumed below-normal rainfall per capita water use variable is constrained to an upper limit of 25 percent above the calculated (5-year average) normal condition per capita water use variable. This constraint was used as an adjustment for water conservation practices put in place after 1985."

"Municipal Water Conservation:[4] Municipal water conservation is increasingly recognized by water utilities as a very cost-effective approach for extending water supplies. In addition, many conservation strategies are simply good management alternatives. Staffs of the three agencies have estimated a likely range of water conservation savings that could be attained over the 1990-2050 planning period. These are included in alternative municipal water use forecast scenarios. These potential savings are based on assumptions regarding the rate of implementation of indoor plumbing conservation measures as well as the rates of implementation of conservation measures in seasonal, dry-year irrigation, and other municipal water uses. These four municipal use sub-categories and associated potential savings assumptions are presented below:

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[4] Ibid.

Components of Municipal Water Conservation Savings

Areas of Potential Municipal Water Use Savings	**Expected Conservation Savings**	**Advanced Conservation Savings**
Indoor Plumbing Savings	20.5 gallons per capita daily	21.7 gallons per capita daily
Seasonal Water Savings	7.0% of total seasonal use	20% of total seasonal use
Dry-Year Irrigation Savings	10.5% of dry-year seasonal use	20% of dry-year seasonal use
Other Municipal Savings	5% of total average yearly use	7.5% of total average year use

"A primary assumption associated with the definition of the "expected" municipal water conservation case is that these levels of savings are likely to occur from both market forces and regulatory requirements. The typical plumbing fixtures and appliances available for purchase are noticeably more water-efficient than those sold in earlier decades. The availability of water-efficient landscaping in the marketplace and improved landscaping practices are changing outdoor water uses. Better public education on efficient indoor and outdoor water uses and pricing "signals" from the marketplace are also changing consumer behavior.

"In addition to the market-type forces, a driving force underlying the expected municipal water conservation savings is the likely effect produced by the State Water-Efficient Plumbing Act passed in 1991. Not only are these potential water savings from the implementation of the Act substantial, but they are also economically sound from a cost-saving perspective, do not require day-to-day behavior changes by the consumer, affect the larger year-round base water use, and will occur with a relatively high degree of predictability.

"The primary difference between the expected and advanced conservation savings scenarios is one of timing. The majority of the additional savings reflected in the advanced conservation case arises from accelerating the effect of the plumbing bill with municipal utilities engaging in active water-efficient plumbing retro-fit programs. Some additional savings are from slightly more aggressive assumptions on seasonal, dry-year urban irrigation, and other municipal uses. The advanced conservation scenario represents the maximum technical potential for water conservation savings. The expected scenario represents feasible strategies for water conservation savings that are economically sound.

"Unique projected water conservation savings patterns were projected for each individual municipality and rural area considered in the forecasts, as well as for the state as a whole. These projected savings estimated by the consensus planning staff are provided as guidelines for regional and local water planners and managers. Although staffs of the three agencies feel the identified array of conservation measures embodied in the projections are reasonable and feasible, the particular selection of specific water conservation goals and implementation of strategies to achieve those goals are primary responsibilities of the utility manager and local government.

"Each entity's projected municipal water conservation savings (measured in gallons) are subtracted from the appropriate estimated value of the two per capita water use scenarios, the assumed below-normal rainfall conditions, and the assumed normal weather conditions. In most instances, this calculation results in declining per capita water use for each city and community. An example of how the expected and advanced conservation cases affect the two per capita water use scenarios is presented below.

Impact of Municipal Water Conservation Savings on State Average Per Capita Water Use

Below-Normal Rainfall Conditions*

	2000	2010	2020	2030	2040	2050
Planning Per Capita Use	189	189	189	189	189	189
Expected Case Conservation	181	172	164	160	157	156
Advanced Case Conservation	175	161	151	149	147	146
Plumbing Code Only	185	179	175	171	168	167

Normal Weather Conditions

	2000	2010	2020	2030	2040	2050
Planning Per Capita Use	165	165	165	165	165	165
Expected Case Conservation	157	149	141	137	134	133
Advanced Case Conservation	152	140	130	128	126	125
Plumbing Code Only	160	155	150	146	143	142

* Highest annual per capita water use over the last 10 years, constrained to an upper limit of 25 percent above the normal conditions per capita water use."

The projections for each water service area are presented below for the TWDB most likely population and water demand case for below normal precipitation and average water conservation conditions, as outlined above.

Municipal water demand projections were made by multiplying projected per capita municipal water use, in gallons per person per day, for each water supplier (Table 2.1-2) by the projected population of each supplier's service area, as shown in Table 2.1-1 of Section 2.1-1. The resulting computations were then expressed in acre-feet per year. The computation is as follows: $\frac{(Population) \times (gpcd) \times (365)}{325{,}851} = \text{Acre-Feet / Year.}$

Table 2.1-2
Per Capita Water Demand Projections
Travis County Areas
Trans-Texas Water Program

			Projected					
Supplier	**1990 gpcd***	**1995 gpcd**	**2000 gpcd**	**2010 gpcd**	**2020 gpcd**	**2030 gpcd**	**2040 gpcd**	**2050 gpcd**
Austin Service Area	170	154	204	195	188	185	184	182
Manor	154	150	146	136	128	126	124	123
Pflugerville Service Area	156	180	170	158	156	156	156	156
Manville WSC	107	156	146	131	131	131	131	131
Remainder Travis Co.	163	163	213	201	198	185	182	180

From TWDB Water Demand Projections; gpcd means gallons per person per day.
*gpcd means gallons per person per day. The gpcd rates shown here are from TWDB reported water use for 1990 and 1995 (actual water use), and for 2000 through 2030 are for below normal precipitation, with average water conservation.

In 1990, total municipal water use in Travis County was 108,872 acre-feet (acft) of which 99,129 acft was used in Austin's service area, 180 acft was used in Manor, 777 acft was used in Pflugerville, 769 acft was used by Manville WSC's Travis County customers, and 8,018 acft was used in the remainder of Travis County (Table 2.1-3). (See Appendix A: Table 1 for a list of Travis County water suppliers and reported water use for each supplier for the period 1984 through 1994 and Appendix A: Table 3 for annual projections for the period 1995 through 2005.) Total water use in the county in 1990 was 136,544 acft, when industrial use of 14,003 acft, steam-electric power generation use of 9,369 acft, irrigation use of 800 acft, mining use of 2,288 acft, and livestock use of 942 acft are included (Table 2.1-3 and Figure 2.1-2).

Table 2.1-3
Water Demand Projections
Travis County Areas
Trans-Texas Water Program

Area	Use in 1990	Projections (acft/yr)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Municipal										
Austin Service Area										
Northwest A Pressure Zone	16,277	17,134	25,977	30,548	34,738	39,219	43,715	50,056	56,223	62,698
North Pressure Zone	17,639	18,568	30,854	31,707	32,337	35,312	38,338	44,410	46,219	47,596
Central Pressure Zone	31,998	32,523	60,307	61,744	62,754	66,568	70,543	77,506	82,231	84,036
South Pressure Zone	11,715	12,331	17,036	20,072	22,857	24,996	27,171	33,745	39,317	42,723
Far South Pressure Zone	1,746	1,838	2,737	3,799	4,793	5,210	5,636	6,506	7,178	10,474
Southwest A Pressure Zone	9,047	9,523	13,819	15,541	17,095	19,780	22,458	24,425	26,135	30,417
Southwest B Pressure Zone	1,340	1,411	3,386	3,664	3,908	4,261	4,621	7,587	8,320	6,387
Northwest B Pressure Zone	9,366	9,735	12,620	14,874	17,201	18,361	20,323	22,544	24,244	28,373
Subtotal *	99,129	103,064	166,735	181,949	195,683	213,708	232,804	266,779	289,866	312,705
Manor Service Area[1] *	180	202	233	259	284	301	317	356	379	406
Pflugerville Service Area[2] *	777	1,792	3,385	5,714	8,258	10,257	12,230	14,061	15,471	16,245
Manville WSC Service Area[3]										
Travis County (70.38%/1995) *	769	1,293	1,343	1,408	1,469	1,608	1,747	2,028	2,296	2,536
Williamson Co (23.04%/1995)	253	425	441	463	483	528	574	666	754	833
Bastrop Co (5.95%/1995)	66	111	115	121	126	138	150	174	197	217
Lee County (0.63%/1995)	11	18	19	20	21	23	25	29	33	36
Subtotal	1,098	1,847	1,919	2,012	2,099	2,297	2,496	2,897	3,280	3,623
Remainder/Travis County *	8,018	9,097	11,911	11,827	12,081	12,322	12,498	12,252	13,250	14,392
Municipal Total *	108,872	115,448	183,606	201,158	217,775	238,196	259,596	295,476	321,262	346,284

Table 2.1-3 continued

Area		Use in 1990	Projections (acft/yr)								
			1995	2000	2005	2010	2015	2020	2030	2040	2050
Industrial[4]	*	14,003	14,152	25,832	26,283	26,730	27,050	27,369	27,875	29,011	30,226
Steam-Electric[5]	*	9,639	12,698	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500
Irrigation	*	800	765	731	699	667	638	609	557	508	464
Mining	*	2,288	3,584	4,880	4,813	4,746	4,996	5,246	5,791	6,407	7,116
Livestock	*	942	906	906	906	906	906	906	906	906	906
Travis County Total*		136,544	147,553	229,455	247,359	264,324	285,286	307,226	344,105	371,594	398,496

Source: Texas Water Development Board, 1996 Consensus Water Plan Projections, Most Likely Case: Dry Weather/Average Water Conservation.
Estimates by pressure zone in Austin Service Area prepared by HDR Engineering, Inc.

[1] May be served from COA's Central Pressure Zone.

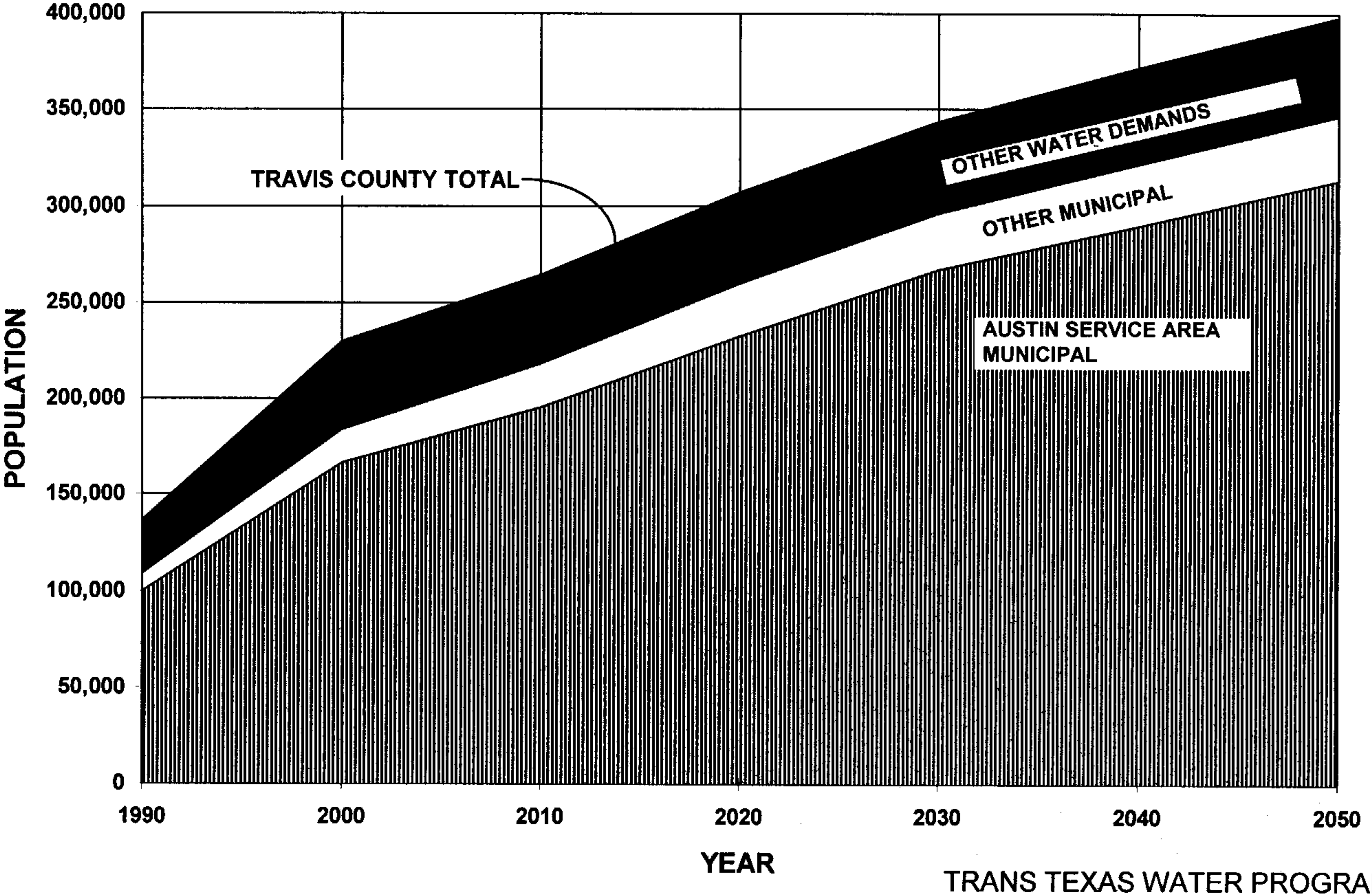
[2] May be served from COA's Northwest A Pressure Zone.

[3] May be served from COA's North Pressure Zone.

[4] TWDB projection was adjusted upward to include a new industry that was announced in early 1996.

[5] Includes 6,500 acft/yr of make-up water for natural evaporation at Lake Long.

*Areas within Travis County, and included in Travis County totals.



OTHER WATER DEMANDS

- INDUSTRIAL
- STEAM-ELECTRIC
- IRRIGATION
- MINING
- LIVESTOCK

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

WATER DEMAND PROJECTIONS
TRAVIS COUNTY

FIGURE 2.1-2

Projected municipal water use for dry weather and average water conservation conditions for the City of Austin service area customers is 166,735 acft/yr in year 2000, 232,804 acft/yr in 2020, and 312,705 acft/yr in 2050 (Table 2.1-3). For Manor, municipal water use is projected to increase from 180 acft/yr in 1990 to 406 acft/yr in 2050 (Table 2.1-3).

For Pflugerville, municipal water use is projected to increase from 777 acft/yr in 1990 to 3,385 acft/yr in 2000, and 16,245 acft/yr in 2050 (Table 2.1-3). For the Manville WSC service area, municipal water use is projected to increase from 1,098 acft/yr in 1990 to 3,623 acft/yr in 2050, of which 70.4 percent is estimated to be located in Travis County (Table 2.1-3). For the remainder of the County not served by Austin, Manor, Pflugerville, and the Manville WSC, municipal water demand is projected to increase from 8,018 acft/yr in 1990 to 12,498 acft/yr in 2020, and 14,392 acft/yr in 2050 (Table 2.1-3).

Industrial water use projections are based upon projected growth of industry in Travis County. Industrial water use is projected to increase from 14,003 acft/yr in 1990 to 27,369 acft/yr in 2000, and to 30,226 acft in 2050 (Table 2.1-3).

Steam-electric power use in 1990 was 9,639 acft/yr and is currently projected to remain constant at 13,500 acft/yr from 2000 to 2050 (Table 2.1-3). Irrigation water use was 800 acft/yr in Travis County in 1990 and is projected to decline to 464 acft/yr in 2050 (Table 2.1-3). Mining water use for the production of sand and gravel was 2,288 acft/yr in 1990 and is projected to increase to 7,116 acft/yr in 2050 as the area grows, whereas livestock water use is projected to remain constant at about 900 acft/yr throughout the 50-year projection period (Table 2.1-3).

Total water demand for Travis County is projected to increase from 136,544 acft/yr in 1990 to 229,455 acft/yr in 2020, and to 398,496 acft/yr in 2050 (Table 2.1-3). In 1990, 83.7 percent of water use in Travis County was for municipal purposes. By 2020, municipal demand is projected to be 84.5 percent of the total, and by 2050 municipal demand is projected to be 86.9 percent of total water demand in Travis County.

2.1.3 Current Water Supplies

In previous sections, population and water demand projections have been presented for Travis County and for individual water service areas of the county for the period 1995 through 2050. In this section, water supplies that are presently available to meet the projected future needs of each service area of the county will be presented. In Section 2.1.4, water supplies will be compared to the projected demands in order to show the future points in time at which additional water supplies may be needed, and the quantity needed, on an annual basis through the year 2050. In later sections of the report, water supply alternatives to meet the projected needs will be identified, described, and evaluated as to quantity and cost of additional supply that can be provided by each alternative. Water supply and demand comparisons are presented for each of the following water supply service areas: (1) City of Austin, (2) Manor, (3) Pflugerville, (4) Manville Water Supply Corporation, and (5) the remainder of Travis County.

2.1.3.1 City of Austin

The City of Austin holds run-of-river water rights under Certificates of Adjudication 14-5471A and 14-5489, and has entered into a "Settlement Agreement" with the Lower Colorado River Authority (LCRA) which specifies the quantities available from the City's run-of-river rights, and that the City's water rights are backed by storage in LCRA's reservoirs when run-of-river flows are not available, as is depicted in subsequent paragraphs and in Table 2.1-4. The diversion points are located along Lake Austin and Town Lake with no limitation on the points of diversion (Figure 2.1-3).

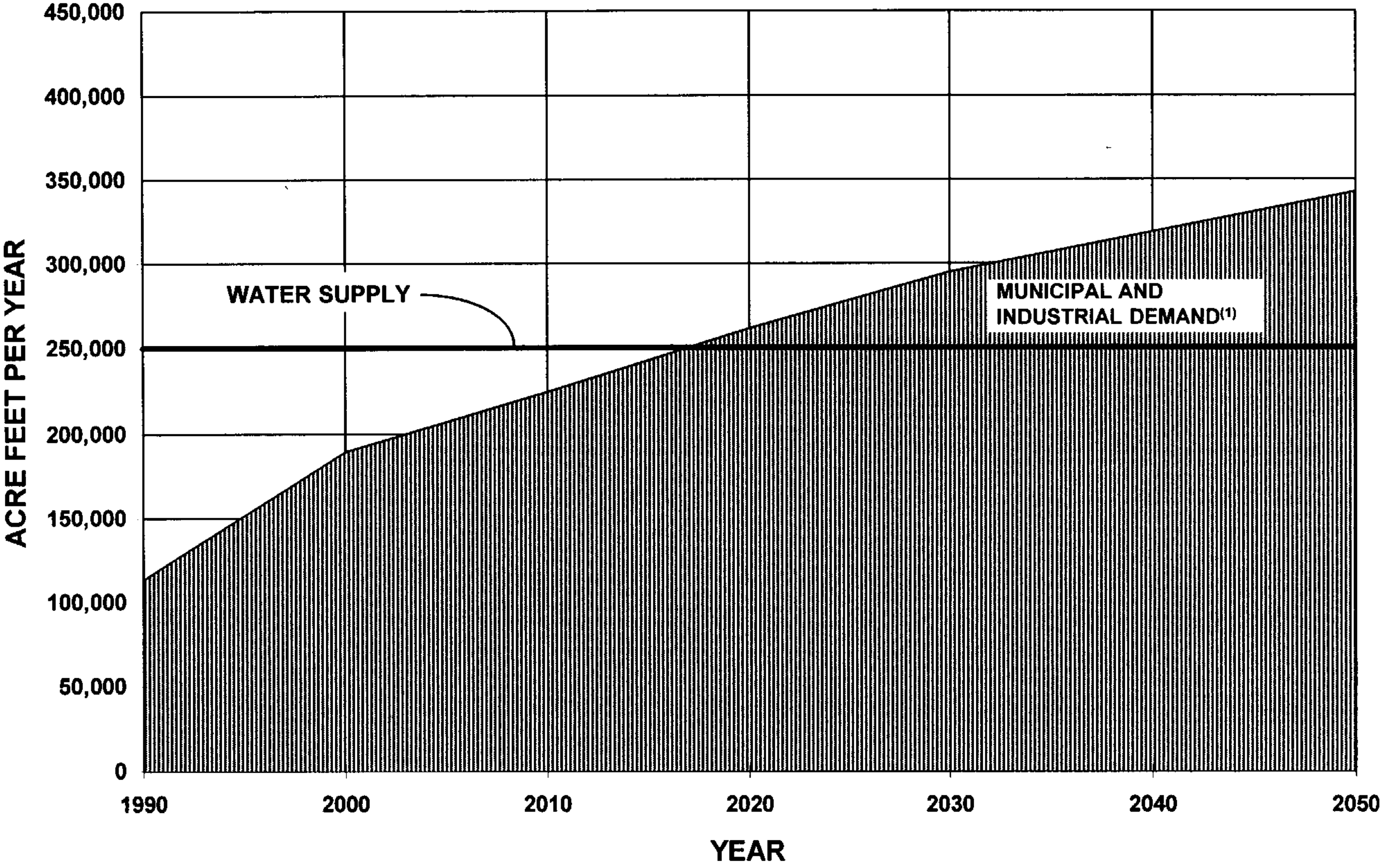
Table 2.1-4
City of Austin Existing Water Rights

Permitted Use	Certificate of Adjudication	Priority Date	Quantity (acft/yr)
Municipal	14-5471	June 30, 1913	250,000[1]
	14-5471	June 27, 1914	22,403
	14-5489	August 20, 1945	<u>20,300</u>
Total			292,703
Steam Electric	14-5471	June 30, 1913	24,000
	14-5489	February 23, 1965	<u>16,156</u>
Total			40,156[2]
Irrigation	14-5471	June 30, 1913	150
	14-5471	June 30, 1913	<u>1,000</u>[3]
Total			1,150

[1] Includes the 1,000 acft/yr of water currently being used for irrigation.

[2] Permit limits consumptive use to quantity shown. There is no limit on diversion rate of pass-through diversions.

[3] This 1,000 acft/yr right is a temporary change of municipal use which expires after December 31, 2011.



(1) INCLUDES PROJECTED 5,600 ACFT/YR WATER SALE TO CITY OF PFLUGERVILLE.

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

WATER DEMAND AND SUPPLY COMPARISON - AUSTIN SERVICE AREA

FIGURE 2.1-4

Table 2.1-5 continued

Area	Use in 1990	Projections (acft/yr) 1995	2000	2005	2010	2015	2020	2030	2040	2050
City of Austin - Steam Electric										
Steam-Electric Demand										
Forced Evaporation	3,139	6,198	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Natural Evap (Lake Long only	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500	6,500
Total Demand	9,639	12,698	13,500	13,500	13,500	13,500	13,500	13,500	13,500	13,500
Steam-Electric Supply (Surface)	40,156	40,156	40,156	40,156	40,156	40,156	40,156	40,156	40,156	40,156
Supply minus Demand[4]	30,517	27,458	26,656	26,656	26,656	26,656	26,656	26,656	26,656	26,656

* Demand projections are fron Table 2.1-2. Water supply information is from records of The Texas Natural Resource Conservation Commission and The Texas Water Development Board. Austin Industrial Demand includes requirements for a new industry announced in early 1996.

[1] Contract through year 2000.

[2] Total contract amount of 10 mgd peak day delivery with estimated annual use of 5,600 acft/yr.

[3] Firm yield of Austin's permits, as backed up with storage in the Lower Colorado River Authority's lakes.

[4] Positive values mean projected surpluses, while ( ) values mean projected shortages.

[5] Run-of-River rights to Colorado River flows, therefore, entire quantity may not be available every year.

[6] Estimated quantities of contracts with Lower Colorado River Authority for water from Lake Travis.

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Table 2.1-5 continued

Area	Use in 1990	Projections (acft/yr)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Manville WSC Service Area										
Municipal Demand										
Travis County (70.38%/1995	769	1,293	1,343	1,408	1,469	1,608	1,747	2,028	2,296	2,536
Williamson Co (23.04%/1995)	253	425	441	463	483	528	574	666	754	833
Bastrop Co (5.95%/1995)	66	111	115	121	126	138	150	174	197	217
Lee County (0.63%/1995)	11	18	19	20	21	23	25	29	33	36
Subtotal	1,098	1,847	1,919	2,012	2,099	2,297	2,496	2,897	3,280	3,623
Water Supply(Ground)	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
Supply minus Demand[4]	702	(47)	(119)	(212)	(299)	(497)	(696)	(1,097)	(1,480)	(1,823)
Remainder of Travis County										
Municipal Demand	8,018	9,097	11,911	11,827	12,081	12,322	12,498	12,252	13,250	14,392
Industrial Demand	187	229	3,601	3,829	4,052	4,212	4,371	4,624	5,192	5,800
Irrigation Demand	800	765	731	699	667	638	609	557	508	464
Mining Demand	2,288	3,584	4,880	4,813	4,746	4,996	5,246	5,791	6,407	7,116
Livestock Demand	942	906	906	906	906	906	906	906	906	906
Total Demand	12,235	14,581	22,029	22,074	22,452	23,074	23,630	24,130	26,263	28,678
Water Supply										
Surface[5]	5,576	5,576	5,576	5,576	5,576	5,576	5,576	5,576	5,576	5,576
Surface Contracts/Lake Travis[6]	6,300	41,286	41,286	41,286	41,286	41,286	41,286	41,286	41,286	41,286
Ground(Edwards and Trinity)	8,855	8,855	8,855	8,855	8,855	8,855	8,855	8,855	8,855	8,855
Total Supply	20,731	55,717	55,717	55,717	55,717	55,717	55,717	55,717	55,717	55,717
Supply minus Demand[4]	8,496	41,136	33,688	33,643	33,265	32,643	32,087	31,587	29,454	27,039
Travis County Summary										
Total M&I Demand	122,876	129,600	209,438	227,440	244,505	265,246	286,965	323,351	350,273	376,510
Total M&I Supply	277,131	312,117	312,117	312,117	312,117	312,117	312,117	312,117	312,117	312,117
Supply minus Demand	154,255	182,517	102,679	84,677	67,612	46,871	25,152	(11,234)	(38,156)	(64,393)

Table 2.1-5
Water Demand and Supply Projections and Comparisons
Travis County Areas
Trans-Texas Water Program

Area	Use in 1990	Projections (acft/yr)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
City of Austin										
Municipal Demand (M)	99,129	103,064	166,735	181,949	195,683	213,708	232,804	266,779	289,866	312,705
Industrial Demand (I)	13,816	13,923	22,231	22,454	22,678	22,838	22,998	23,251	23,819	24,426
Total M&I Demand	112,945	116,987	188,966	204,403	218,361	236,546	255,802	290,030	313,685	337,131
Round Rock Contract[1]	0	5,376	5,376	0	0	0	0	0	0	0
Pflugerville Contract[2]	0	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600
Total Demand	112,945	127,963	199,942	210,003	223,961	242,146	261,402	295,630	319,285	342,731
Water Supply (Surface)[3]	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000	250,000
Supply minus Demand[4]	137,055	122,037	50,058	39,997	26,039	7,854	(11,402)	(45,630)	(69,285)	(92,731)
Manor Service Area										
Municipal Demand	180	202	233	259	284	301	317	356	379	406
Water Supply (Ground)	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900
Supply minus Demand[4]	2,720	2,698	2,667	2,642	2,616	2,600	2,583	2,544	2,521	2,494
Pflugerville Service Area										
Municipal Demand	777	1,792	3,385	5,714	8,258	10,257	12,230	14,061	15,471	16,245
Water Supply										
Austin Contract[5]	0	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600	5,600
Ground	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1,700
Total Supply	1,700	7,300	7,300	7,300	7,300	7,300	7,300	7,300	7,300	7,300
Supply minus Demand[4]	923	5,508	3,915	1,586	(958)	(2,957)	(4,930)	(6,761)	(8,171)	(8,945)

Municipal Water Rights: The City of Austin currently holds run-of-river rights to 292,703 acft/yr of municipal water from the Colorado River (Table 2.1-4).[5] However, availability of water from the Colorado River under these rights would be substantially less than 292,703 acft/yr during drought conditions, and Austin and the LCRA have an agreement in which the City's water rights (up to 250,000 acft/yr) are backed up by storage in LCRA's reservoirs. Consequently, Austin's firm water supply for municipal and industrial use is 250,000 acft/yr.

Steam-Electric Water Rights: The City currently has 40,156 acft/yr of water rights for consumptive use associated with steam electric power generation. Under the steam-electric rights, the City may divert any quantity available as pass-through cooling without limit. The first 24,000 acft/yr of the City's rights is the most senior portion with a priority date of June 30, 1913. This water may be diverted anywhere along the perimeter of Lake Austin or Town Lake and is utilized for the Holly Street Power Plant.

The second right is for 16,156 acft/yr and has a priority date of February 23, 1965. The diversion point for this right is downstream of Longhorn Dam and downstream of both the Walnut Creek and the Govalle Wastewater Treatment Plant discharge points. This right is used to maintain the lake level of Walter E. Long Lake, which is the source of cooling water at the City's Decker Power Plant.

2.1.3.2 Manor

The City of Manor, though a joint effort with Travis County Municipal Utility District No. 2, obtains its water supply from a well field located in the Colorado River Alluvium Aquifer approximately 4 miles south of the city. It is estimated that the aquifer has a long-term yield of approximately 2.6 mgd or 2,900 acft/yr.[6] This is the quantity of supply that is used in the water demand and supply comparisons of this study.

2.1.3.3 Pflugerville

The City of Pflugerville has wells in the Edwards Aquifer north of the Colorado River which have a yield at the present time of approximately 1,700 acft/yr. Since this section of the Edwards Aquifer appears to be at or near full development,[7] Pflugerville has a contract with the

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[5] Austin Study Area: Phase I Interim Trans-Texas Study Report, City of Austin and Texas Water Development Board, Austin, Texas, August, 1994.

[6] Availability of Groundwater Supplies for the Wilbarger Creek Basin, R.W. Harden and Associates, Inc., Austin, Texas, September, 1988.

[7] Ibid.

City of Austin to provide a peak day supply of 10 mgd, with an estimated annual supply of 5 mgd or 5,600 acft. These quantities are used in the supply and demand comparisons of this study.

2.1.3.4 Manville Water Supply Corporation

The Manville Water Supply Corporation (WSC) obtains its water from wells in the Carrizo-Wilcox, Edwards, and Colorado River alluvium aquifers. Present capacity of the Manville WSC wells is approximately 1,800 acft/yr. This is the quantity of supply used in this study for the Manville WSC water demand and supply comparisons.

2.1.3.5 Remainder of Travis County

Areas in southern Travis County are supplied from the underlying Barton Springs Edwards Aquifer, and areas in western Travis County are supplied from the underlying Trinity Group of Aquifer Units and Lake Travis through contracts with LCRA. The estimated total dependable supply from the aquifers is approximately 8,855 acft/yr.,[8] with surface water contracts of approximately 41,286 acft/yr. In addition, individual industries, and farmers and ranchers hold permits to use 5,576 acft/yr of surface water from streams of Travis County including the Colorado River. These are the quantities used in this study in the comparisons of water supply and demands for these remaining areas of Travis County.

2.1.4 Water Demand and Supply Comparisons

2.1.4.1 City of Austin

A comparison of projected water demands for municipal and industrial purposes for the City of Austin service area shows that the City's presently available supply of 250,000 acft/yr of surface water can meet projected demands through the year 2017 (Table 2.1-5 and Figure 2.1-4). By 2020, demands exceed supplies by 11,402 acft/yr; in 2050, demands exceed supplies by 92,731 acft/yr (Table 2.1-5 and Figure 2.1-4).

In the case of City of Austin steam-electric power generation water demands, the future demands for the time period from 2000 through 2050 are still undecided because the City is still

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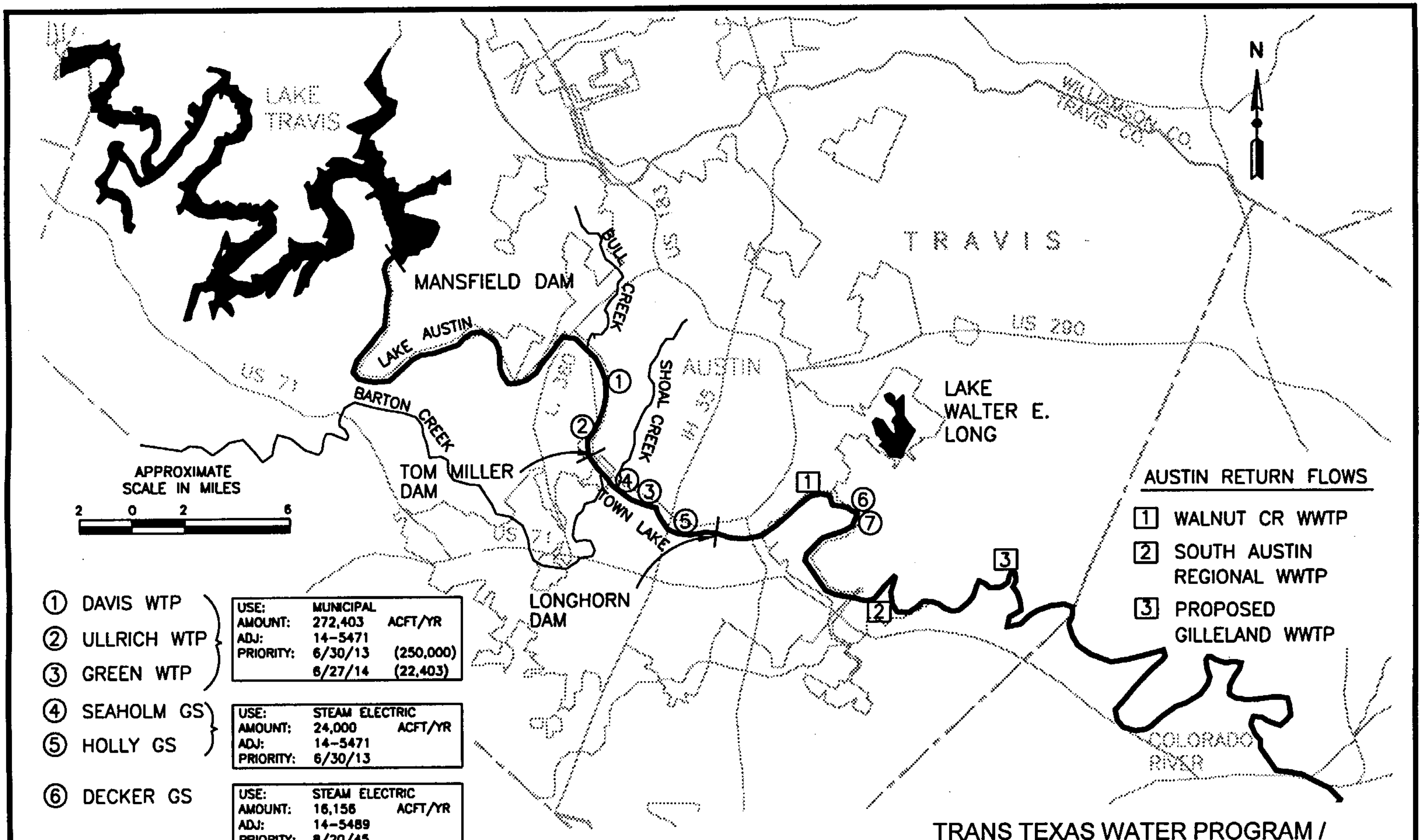
[8] Texas Water Development Board Groundwater Supply Information, Austin, Texas, 1992.



	USE:	AMOUNT:	ADJ:	PRIORITY:
① DAVIS WTP ② ULLRICH WTP ③ GREEN WTP	MUNICIPAL	272,403 ACFT/YR	14-5471	6/30/13 (250,000) 6/27/14 (22,403)
④ SEAHOLM GS ⑤ HOLLY GS	STEAM ELECTRIC	24,000 ACFT/YR	14-5471	6/30/13
⑥ DECKER GS	STEAM ELECTRIC	16,156 ACFT/YR	14-5489	8/20/45
⑦ DECKER MUNI	MUNICIPAL	20,300 ACFT/YR	14-5489	8/20/45

WWTP: WASTEWATER TREATMENT PLANT
WTP: WATER TREATMENT PLANT
GS: GENERATING STATION

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

EXISTING WATER RIGHTS WITH CURRENT DIVERSION LOCATIONS

HDR

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FIGURE 2.1-3

in the process of making generation planning decisions for that time period. Current estimated demands are not projected to increase above 13,500 acft/yr. The City's supply available for these purposes is 40,156 acft/yr which suggests, under current projections, a surplus supply of steam-electric power generation water of 26,656 acft/yr (Table 2.1-5).

2.1.4.2 Manor

A comparison of projected water demands for Manor with Manor's supply of approximately 2,900 acft/yr shows a surplus of 2,667 acft/yr in 2000, 2,583 acft/yr in 2020, and 2,494 acft/yr in 2050 (Table 2.1-5).

2.1.4.3 Pflugerville

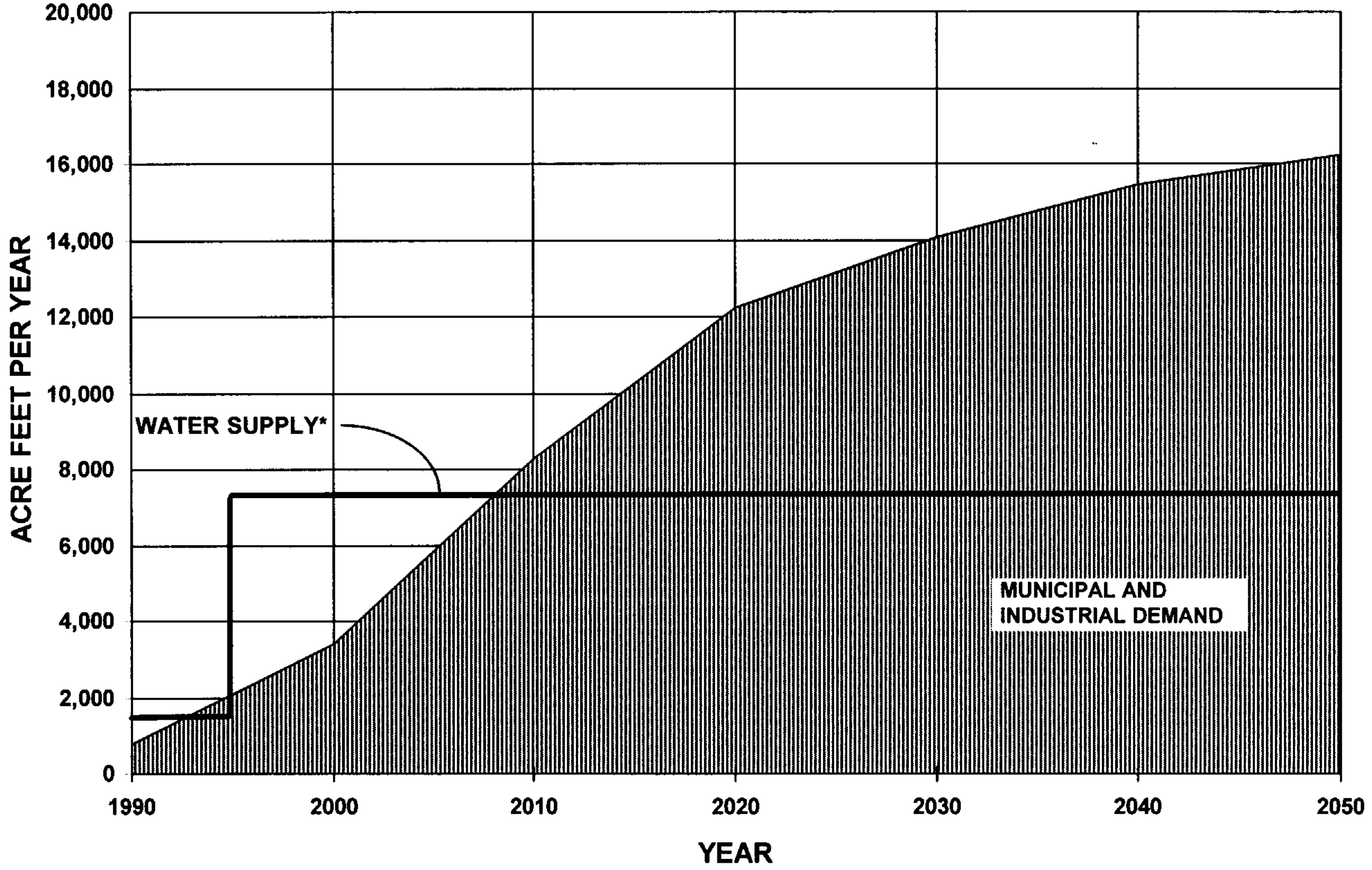
Pflugerville's projected municipal water supplies of 1,700 acft/yr of groundwater and contract with City of Austin for 5,600 acft/yr of surface water appear to be adequate to meet projected demands to approximately year 2008 (Table 2.1-5 and Figure 2.1-5). In year 2010, Pflugerville's projected shortage is 958 acft/yr, and in 2050 is 8,945 acft/yr with a 2050 demand of 16,245 acft/yr (Table 2.1-5).

2.1.4.4 Manville Water Supply Corporation

Manville Water Supply Corporation's (Manville WSC) present supply of approximately 1,800 acft/yr is barely adequate to meet present demands. Projected demands show that Manville WSC needs an additional supply of 119 acft/yr in 2000, 212 acft/yr in 2005, 696 acft/yr in 2020, and 1,823 acft/yr in 2050 (Table 2.1-5 and Figure 2.1-6).

2.1.4.5 Remainder of Travis County

Projected municipal water demands in housing subdivisions and for individual dwellings of unincorporated areas of Travis County increase from 8,018 acft/yr in 1990 to 11,911 acft/yr in 2000 and to 14,392 acft/yr in 2050 (Table 2.1-5). At the present time, these needs are met from the Trinity and Barton Springs Edwards aquifers, which have an estimated yield of approximately 8,855 acft/yr and contracts with LCRA for 41,286 acft/yr of water from the Highland Lakes (Table 2.1-5).



* INCLUDES PROJECTED 5,600 ACFT/YR WATER PURCHASE FROM CITY OF AUSTIN

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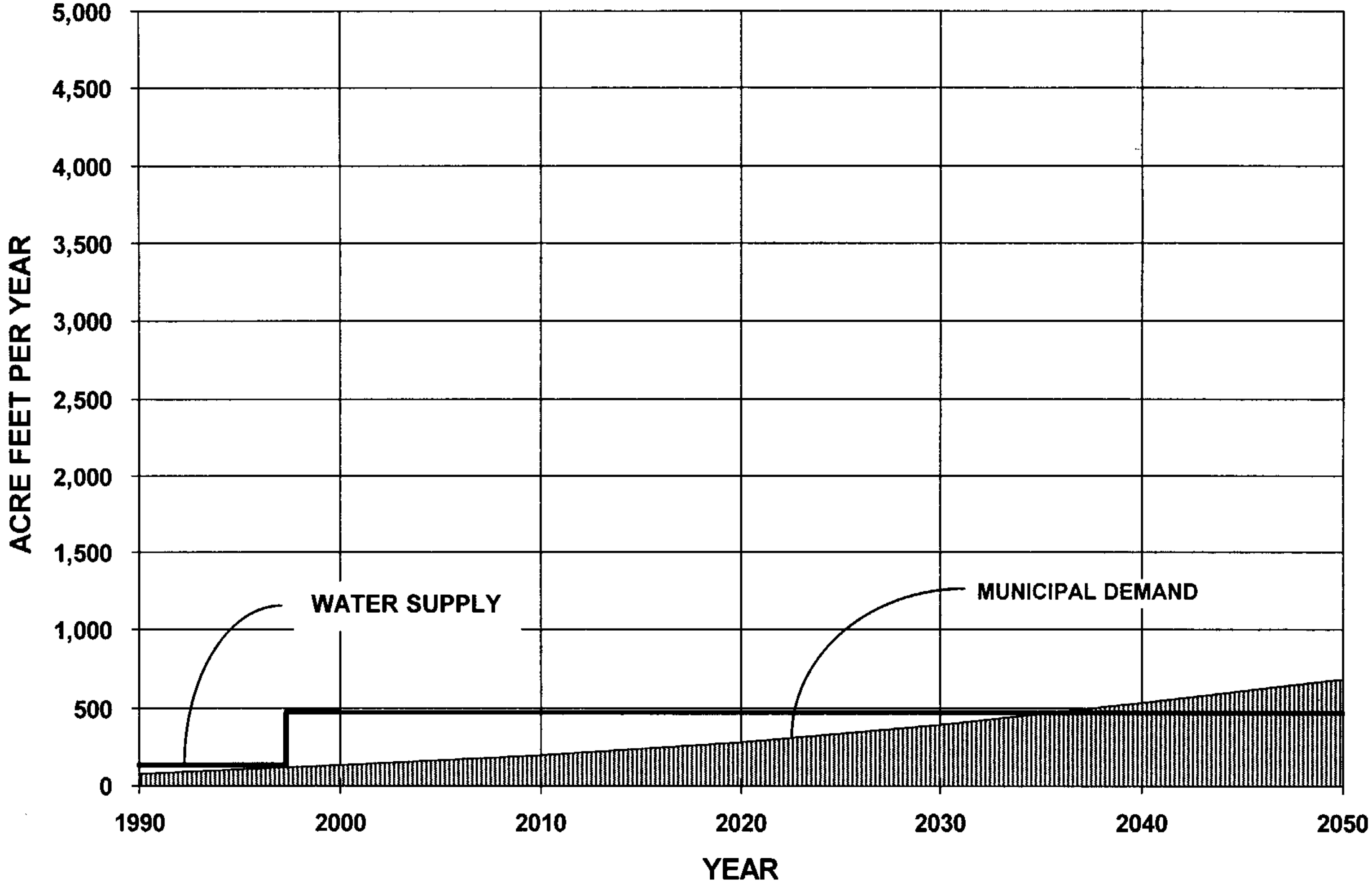
TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

WATER DEMAND AND SUPPLY COMPARISON - CITY OF PFLUGERVILLE

FIGURE 2.1-5



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NORTH CENTRAL STUDY AREA

HDR Engineering, Inc.

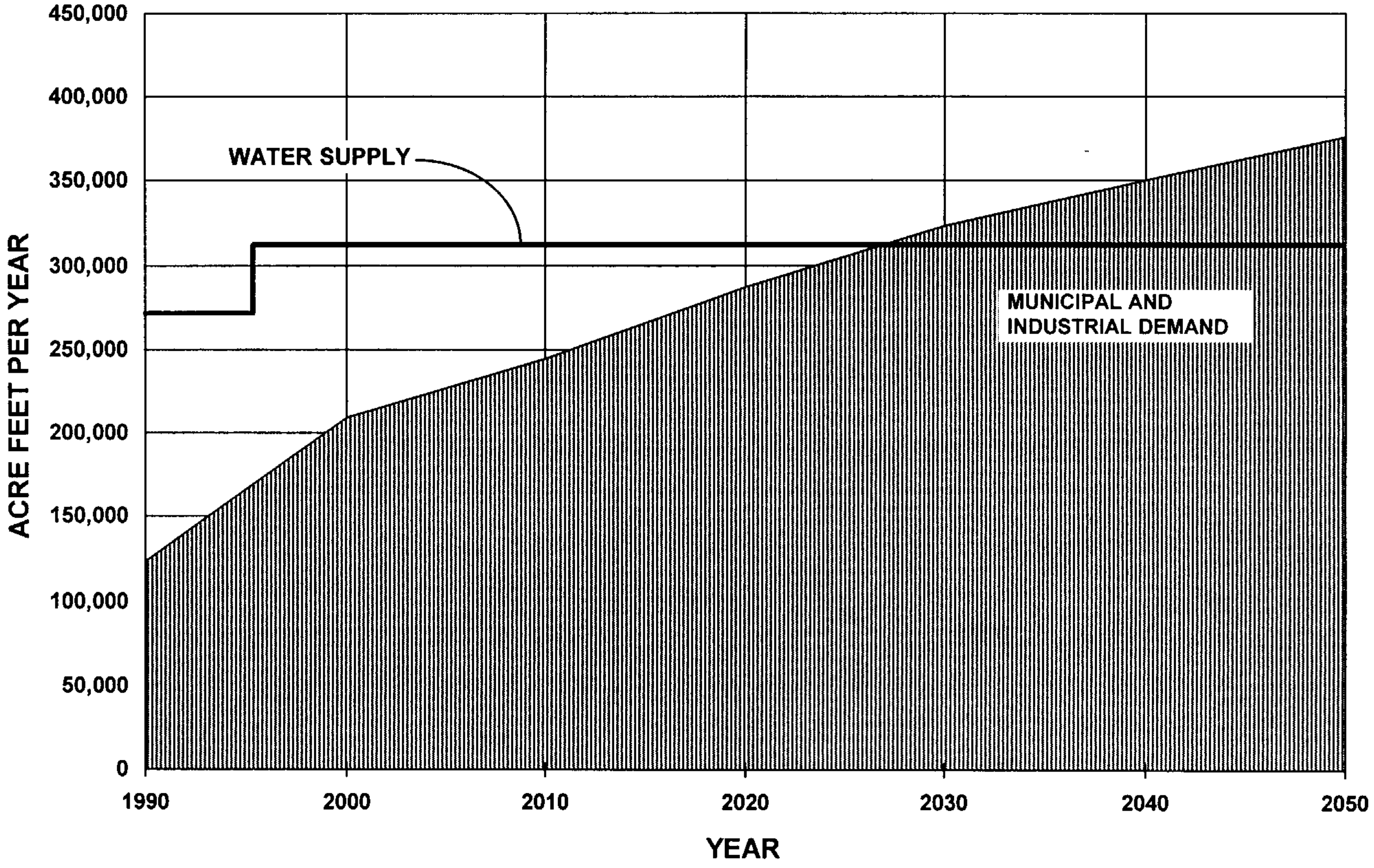
WATER DEMAND AND SUPPLY COMPARISON - MANVILLE WSC

FIGURE 2.1-6

In addition to municipal demands within Travis County that are not served by Austin, Manor, Pflugerville, or the Manville WSC there are industrial, irrigation, mining, and livestock demands (Table 2.1-5). The industrial water demands not included in one of the systems listed above are projected to increase from 187 acft/yr in 1990 to 3,601 acft/yr in 2000, to 4,371 acft/yr in 2020, and to 5,800 acft/yr in 2050. Mining demands (which are primarily for building materials production, such as sand and gravel) are projected to increase from 2,288 acft/yr in 1990 to 4,880 acft/yr in 2000, and to 7,116 acft/yr in 2050 (Table 2.1-5). The total projected demands for municipal, industrial, irrigation, mining, and livestock that are not included in the service area demands of Austin, Manor, Pflugerville, and the Manville WSC increase from 12,235 acft/yr in 1990 to 22,029 acft/yr in 2000, and to 28,678 acft/yr in 2050 (Table 2.1-5). Surface water use permits presently held by individual mining, and industrial establishments and irrigators of Travis County are 5,576 acft/yr, which together with the 8,855 acft/yr of groundwater mentioned above, and the 41,286 acft/yr contracts with LCRA for Highland Lakes water brings the potential supply available to meet the water needs of the remainder of Travis County to approximately 55,717 acft/yr (Table 2.1-5). However, since the supply is not available throughout the county, there is an immediate shortage in some areas of the county. For example, present needs are being met in some areas by overdrafting the Trinity and Barton Springs Edwards Aquifers. The projected shortage in year 2030 is 11,234 acft/yr and in 2050 is 64,393 acft/yr (Table 2.1-5).

2.1.4.6 Travis County Municipal and Industrial Water Demand and Supply Summary

In 1990, municipal and industrial water use was 122,876 acft/yr, and under dry weather conditions with conservation is projected to increase to 209,438 acft/yr in 2000 and to 376,510 acft/yr in 2050 (Table 2.1-5). Supply available within Travis County from existing sources for municipal and industrial use is approximately 312,117 acft/yr (Table 2.1-5 and Figure 2.1-7). In about the year 2026, demand is projected to equal the available supply, resulting in projected shortages in following years. In 2030, projected shortages in the County are 11,234 acft/yr, and in 2050 projected shortages are 64,393 acft/yr (Table 2.1-5 and Figure 2.1-7).



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

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WATER DEMAND AND SUPPLY COMPARISON - TRAVIS COUNTY

FIGURE 2.1-7

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Williamson County
Projections

2.2 Williamson County

2.2.1 Population Projections

The population of Williamson County was 139,551 in 1990 (U.S. Census Report) and was estimated by the Bureau of Census to be 184,234 in 1995. The TWDB Williamson County population projections for the year 2000 are 226,848, for 2020 are 520,307, and for 2050 are 805,868 (Table 2.2-1 and Figure 2.2-1) (see Appendix A, Table 6 for annual projections for 1995 through 2005). The 1990 population of the Round Rock Service Area was estimated at 33,971, and is projected to increase to 58,742 in year 2000, to 140,605 in year 2020, and to 197,313 in 2050 (Table 2.2-1 and Figure 2.2-1). The population of the Georgetown Service Area in 1990 was estimated at 18,690, and is projected to increase to 33,357 in 2000, to 77,409 in 2020, and to 163,777 in 2050 (Table 2.2-1 and Figure 2.2-1). The Georgetown Sun City residential development is within the City of Georgetown and is projected to be 70 percent developed by 2010 and fully developed with a population of 17,384 by 2020. The Sun City population is included in the Georgetown population projections. The population of Cedar Park and its service area in 1990 was 11,534 and is projected at 27,249 in 2000, 61,941 in 2020, and 87,542 in 2050 (Table 2.2-1). The population of Leander was 5,617 in 1990, and the population of the Leander Service Area is projected at 9,381 in 2000, 20,214 in 2020, and 39,195 in 2050 (Table 2.2-1). Projections for other entities and areas of Williamson County are also shown in Table 2.2-1.

2.2.2 Water Demand Projections

Per capita municipal water use in Williamson County was approximately 157 gallons per day in 1990, and for dry weather conditions with average rates of water conservation, including the effects of the 1991 plumbing fixtures act is projected to be 172 gallons per day in the year 2000, and 148 gallons per day in 2050 (Table 2.2-2). In 1990, per capita water use varied among water suppliers of the county from a low of 84 gallons per day in the unincorporated areas to 175 – 203 gallons per day for the city service areas. See Table 2.2-2 for per capita water use projections for each water service area for which population projections are shown in Table 2.1-1.

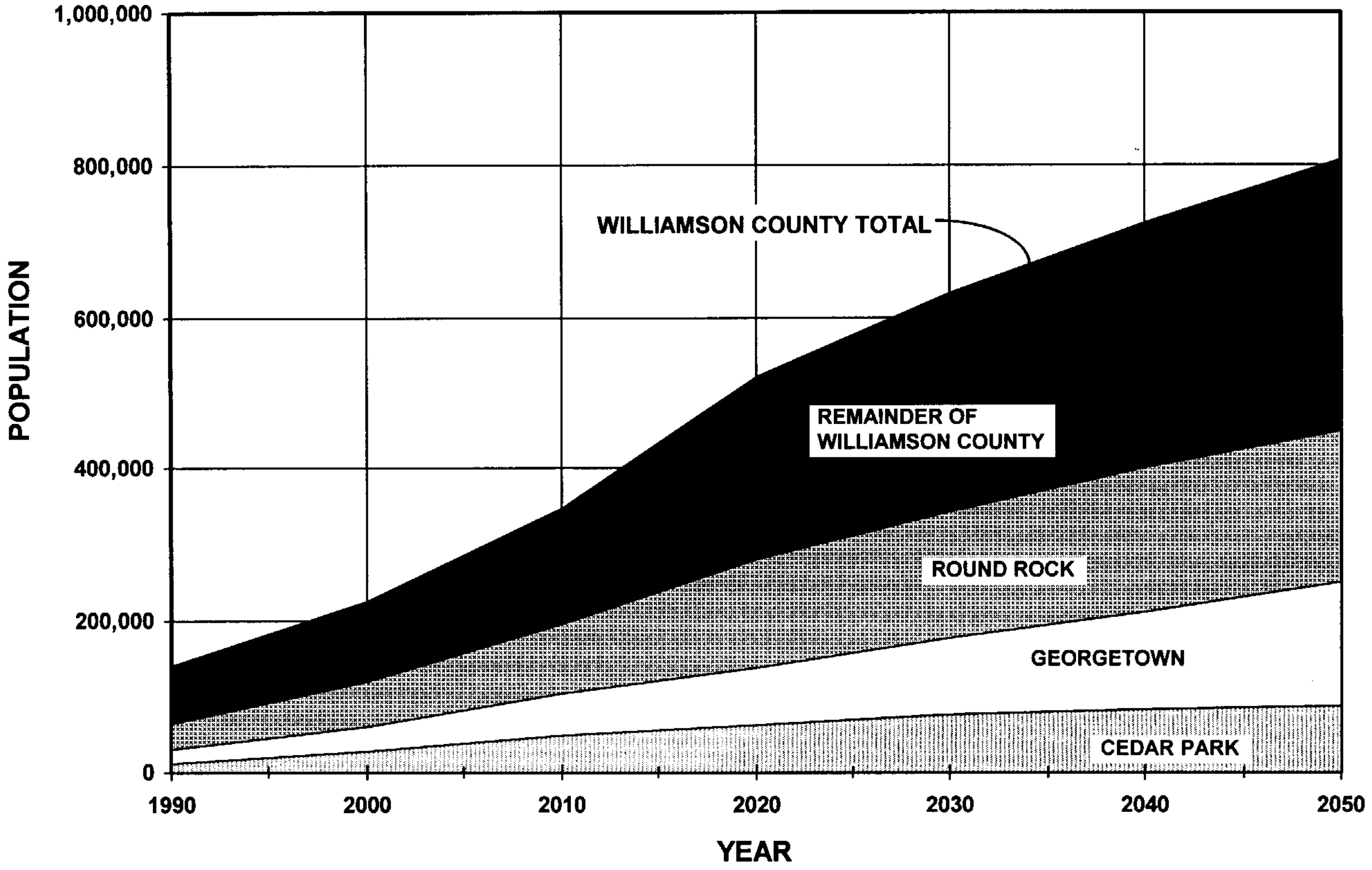
Table 2.2-1
Population Projections
Williamson County Areas
Trans-Texas Water Program

Area	1990	Population Projections								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Round Rock Service Area	33,971	44,848	58,742	74,353	92,430	115,430	140,605	165,487	189,521	197,313
Austin Service Area	2,444	3,227	7,458	9,440	13,292	16,600	21,555	28,036	32,106	36,767
Cedar Park Service Area	11,534	20,547	27,249	36,556	48,404	55,173	61,941	76,306	83,458	87,542
Leander Service Area	5,617	7,802	9,381	12,787	15,557	18,928	20,214	26,478	32,333	39,195
Brushy Creek	5,630	8,538	12,589	18,498	20,648	21,723	22,798	23,800	23,800	23,800
Liberty Hill	970	1,281	1,435	1,816	2,125	2,654	3,145	4,436	5,962	7,632
Georgetown Service Area	18,690	24,674	33,357	42,222	54,419	67,960	77,409	100,432	128,994	163,777
Taylor	11,472	15,145	16,025	20,284	22,028	27,509	30,886	35,597	41,021	48,996
Jonah SUD	5,113	6,750	7,212	9,129	9,931	12,402	13,346	17,505	22,408	27,992
Hutto	703	928	1,065	1,348	1,578	1,971	2,280	3,216	4,322	5,532
Other Water Utilities/East/I-35[1]	6,517	7,631	7,941	9,321	10,361	14,384	19,191	22,755	24,625	25,910
Other Water Utilities/West/I-35[2]	16,806	19,680	20,480	24,039	26,722	37,097	49,493	57,890	59,805	63,220
Remainder of County/East/I-35	12,050	14,111	14,685	17,236	19,161	26,599	35,487	42,258	44,934	47,211
Remainder of County/West/I-35	8,033	9,073	9,223	10,096	10,754	14,928	21,957	26,872	29,430	30,982
Williamson County Total	139,551	184,234	226,842	287,126	347,410	433,358	520,307	631,068	722,719	805,868

Source: Texas Water Development Board, 1996 Consensus Water Plan Projections, Most Likely Case.

[1] Bartlett, Granger, Jarrell/Schwertner, Noack, Thrall, Walburg WSC, and Weir.

[2] Andice, Blockhouse MUD, Chisholm Trail WSC, Durham Park, Fern Bluff, Florence, South San Gabriel River Ranches, Berry Creek,and Tal/Tex.



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

POPULATION PROJECTIONS
WILLIAMSON COUNTY

HDR Engineering, Inc.

FIGURE 2.2-1

Table 2.2-2
Per Capita Water Demand Projections*
Williamson County Areas
Trans-Texas Water Program

Area	Use in 1990	Per Capita Water Demand Projections (gpcd)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Round Rock Service Area	175	175	199	199	175	175	163	155	155	158
Austin Service Area	170	154	165	165	158	158	157	156	150	147
Cedar Park Service Area	157	156	180	175	171	168	165	163	159	158
Leander Service Area	138	158	180	175	171	169	165	163	159	158
Brushy Creek	156	156	180	175	171	169	165	163	159	158
Liberty Hill	125	125	125	125	125	125	125	125	125	125
Georgetown Service Area	203	203	189	180	171	165	159	155	152	151
Taylor	159	159	168	162	157	153	149	147	145	145
Jonah SUD	115	115	115	115	115	115	115	115	115	115
Hutto	91	91	110	110	110	110	110	110	110	110
Other Water Utilities/East/I-35[2]	159	145	138	132	132	132	132	132	132	132
Other Water Utilities/West/I-35[3]	164	148	138	132	132	132	132	132	132	132
Remainder of County/East/I-35	84	84	132	132	132	132	132	132	132	132
Remainder of County/West/I-35	84	87	140	150	157	157	142	141	136	136
Williamson County Total	157	163	172	173	162	161	153	149	147	148

*Gallons per person per day (gpcd). The gpcd rates shown are from TWDB reported water use for 1990 and 1995 (actual water use) for 2000 through 2030 are for below normal precipitation, with average water conservation.

[1] See Section 2.1.2 for TWDB's explanation of how per capita water demands are calculated.

[2] Bartlett, Granger, Jarrell/Schwertner, Noack, Thrall, Walburg WSC, and Weir.

[3] Andice, Blockhouse MUD, Chisolm Trail WSC, Durham Park, Fern Bluff, Florence, South San Gabriel River Ranches, Berry Creek,and Tal/Tex.

In 1990, total water use in Williamson County was 28,189 acft of which 24,482 acft or 86.6 percent was for municipal purposes (Table 2.2-3).[9] (See Appendix A: Table 5 for a list of Williamson County water suppliers and reported water use of each supplier's service area for the period 1984 through 1994, and Appendix A: Table 7 for annual water demand projections for the period 1995 through 2005.) Projected water demand for the county in year 2000 is 50,304 acft/yr and in 2050 is 162,005 acft/yr (Table 2.2-3 and Figure 2.2-2). During the period 1990 to 2050, municipal water demand in Williamson County is projected to increase from 24,482 acft/yr to 133,526 acft/yr (Table 2.2-3). Water use in 1990, together with projections for each water supply service area, are shown in Table 2.2-3. For example, water use in the Round Rock area in 1990 was reported at 6,652 acft/yr. The projected demand for the Round Rock area in year 2000 is 13,087 acft/yr, in 2020 is 25,636 acft/yr, and in 2050 is 34,987 acft/yr. For Georgetown, projected water use increases from 4,250 acft/yr in 1990 to 27,800 acft/yr in 2050, and for Cedar Park, projected demand increases from 2,024 acft/yr in 1990 to 15,493 acft/yr in 2050 (Table 2.2-3). The projections for the other service areas can be seen in Table 2.2-3.

2.2.3 Current Water Supplies

In this section, the water supplies that are presently available to each of the 10 study participants and the remainder of Williamson County are presented. The quantities are tabulated in Section 2.2.4 along with each participant's projected demands.

2.2.3.1 Round Rock

Round Rock has an estimated groundwater supply from its Williamson County Edwards Aquifer wells of 5,040 acft/yr, a contract with the Brazos River Authority for 6,720 acft/yr of water from Lake Georgetown, a contract with the Brazos River Authority for 18,134 acft/yr of Stillhouse Hollow Lake water, and a contract with the City of Austin for 5,376 acft/yr through the year 2000. Total supplies available to Round Rock from ground and surface sources is estimated at 25,270 acft/yr in 2000, and 29,894 acft/yr for the period 2010 through 2050 (Table 2.2-4).

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[9] Municipal water demand projections were made by multiplying projected per capita water use, in gallons per person per day for each water supplier (Table 2.2-2) by the projected population of each supplier's service area (Table 2.2-1) and expressing the result in acre-feet per year (see Section 2.1.2).

Table 2.2-3
Water Demand Projections
Williamson County Areas
Trans-Texas Water Program

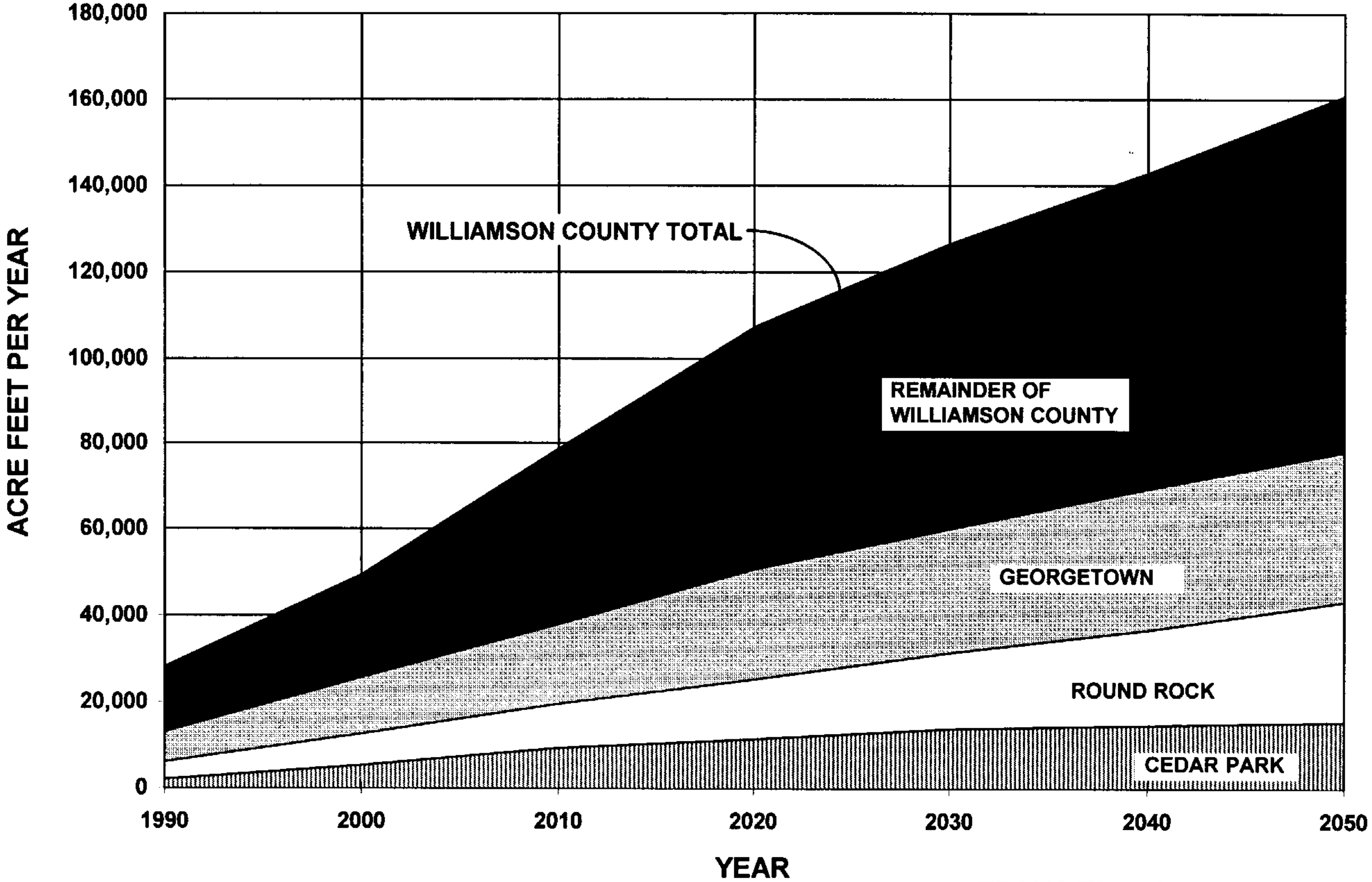
Area	Use in 1990	Projections (acft/yr) 1995	2000	2005	2010	2015	2020	2030	2040	2050
Municipal										
Round Rock Service Area	6,652	8,782	13,087	16,565	18,165	22,685	25,636	28,727	32,881	34,987
Austin Service Area	494	652	1,378	1,745	2,352	2,938	3,791	4,899	5,394	6,054
Cedar Park Service Area	2,024	3,590	5,494	7,166	9,271	10,382	11,448	13,932	14,864	15,493
Leander Service Area	871	1,380	1,891	2,506	2,979	3,625	3,736	4,832	5,759	6,934
Brushy Creek	984	1,500	2,538	3,626	3,955	4,112	4,214	4,345	4,239	4,212
Liberty Hill	136	180	201	254	298	372	440	621	834	1,068
Georgetown Service Area	4,250	5,611	7,052	8,513	10,444	12,560	13,826	17,416	21,962	27,800
Taylor	2,038	2,691	3,016	3,818	3,874	4,838	5,155	5,861	6,663	7,958
Jonah SUD	660	871	930	1,177	1,281	1,600	1,722	2,258	2,891	3,611
Hutto	72	95	131	166	194	242	281	396	532	681
Other Water Utilities/East/I-35[1]	1,191	1,239	1,228	1,379	1,533	2,128	2,839	3,367	3,643	3,834
Other Water Utilities/West/I-35[2]	3,165	3,262	3,166	3,557	3,625	5,305	7,167	8,264	8,749	9,254
Remainder of County/East/I-35	1,167	1,541	1,961	2,352	2,835	3,936	5,251	6,252	6,648	6,985
Remainder of County/West/I-35	778	1,027	1,448	1,700	1,890	2,440	3,343	4,239	4,394	4,655
Total Municipal	24,482	32,420	43,521	54,523	62,696	77,163	88,848	105,409	119,453	133,526
Industrial[3]	326	519	3,424	8,547	14,146	15,052	16,296	18,739	21,598	24,937
Steam-Electric	0	0	0	0	0	0	0	0	0	0
Irrigation	160	160	160	160	160	160	160	160	160	160
Mining	1,713	1,799	1,885	1,865	1,845	1,870	1,896	1,949	2,007	2,068
Livestock	1,508	1,314	1,314	1,314	1,314	1,314	1,314	1,314	1,314	1,314
Williamson County Total	28,189	36,212	50,304	66,409	80,161	95,559	108,514	127,571	144,532	162,005

Source: Texas Water Development Board, 1996 Consensus Water Plan Projections, Most Likely Case: Dry Weather/Average Water Conservation.

[1] Bartlett, Granger, Jarrell/Schwertner, Noack, Thrall, Walburg WSC, and Weir.

[2] Andice, Blockhouse MUD, Chisolm Trail WSC, Durham Park, Fern Bluff, Florence, South San Gabriel River Ranches, Berry Creek,and Tal/Tex.

[3] TWDB projections adjusted to include requirements for new industry announced in early 1996.



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

WATER DEMAND PROJECTIONS
WILLIAMSON COUNTY

HDR Engineering, Inc.

FIGURE 2.2-2

Table 2.2-4
Water Demand and Supply Projections and Comparisons
Williamson County Areas
Trans-Texas Water Program

Area	Use in 1990	Projections (acft/yr)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Round Rock Service Area										
Municipal Demand (M)	6,652	8,782	13,087	16,565	18,165	22,685	25,636	28,727	32,881	34,987
Industrial Demand (I)	163	174	2,608	7,103	11,598	11,603	12,009	12,625	13,643	14,681
Brushy Creek MUD Contract[1]		3,360	3,360	3,360						
Total M&I Demand	6,815	12,316	19,055	27,028	29,763	34,288	37,645	41,352	46,524	49,668
Water Supply										
Surface/Lake Georgetown	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720
Surface/Stillhouse HollowLake		8,134	18,134	18,134	18,134	18,134	18,134	18,134	18,134	18,134
Surface/Contract with Austin[2]		5,376								
Surface/Total	6,720	20,230	24,854	24,854	24,854	24,854	24,854	24,854	24,854	24,854
Ground(Edwards Aquifer)	5,040	5,040	5,040	5,040	5,040	5,040	5,040	5,040	5,040	5,040
Total Supply	11,760	25,270	29,894	29,894	29,894	29,894	29,894	29,894	29,894	29,894
Supply minus Demand[3]	4,945	12,954	10,839	2,866	131	(4,394)	(7,751)	(11,458)	(16,630)	(19,774)
Austin Service Area										
Municipal Demand (M)[4]	494	652	1,378	1,745	2,352	2,938	3,791	4,899	5,394	6,054
Water Supply (Surface)[5]	494	652	1,378	1,745	2,352	2,938	3,000	3,000	3,000	3,000
Supply minus Demand[3]	0	0	0	0	0	0	(791)	(1,899)	(2,394)	(3,054)

Table 2.2-4 continued

Area	Use in 1990	Projections (acft/yr)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Cedar Park Service Area										
Municipal Demand (M)	2,024	3,590	5,494	7,166	9,271	10,382	11,448	13,932	14,864	15,493
Industrial Demand (I)	0	180	288	405	798	1,069	1,294	1,883	2,355	2,856
Contract with Leander[6]			2,400							
Total M&I Demand	2,024	3,770	5,782	7,571	10,069	11,451	12,742	15,815	17,219	18,349
Water Supply (Surface)[7]	7,000	7,000	9,400	7,000	7,000	7,000	7,000	7,000	7,000	7,000
Supply minus Demand[3]	4,976	3,230	3,618	(571)	(3,069)	(4,451)	(5,742)	(8,815)	(10,219)	(11,349)
Leander Service Area										
Municipal Demand (M)	871	1,380	1,891	2,506	2,979	3,625	3,736	4,832	5,759	6,934
Industrial Demand (I)	0	0	40	80	125	180	250	350	500	1,000
Total M&I Demand	871	1,380	1,931	2,586	3,104	3,805	3,986	5,182	6,259	7,934
Water Supply										
Contract with Cedar Park/LCRA[6]			2,400							
Contract/Stillhouse Hollow Lake			2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700
Contract/Chisolm Trail SUD[8]		784	403	313	224	112				
Ground(Trinity Aquifer)	871	596	392	0	0	0	0	0	0	0
Total Supply	871	1,380	5,895	3,013	2,924	2,812	2,700	2,700	2,700	2,700
Supply minus Demand[3]	0	0	3,964	427	(180)	(993)	(1,286)	(2,482)	(3,559)	(5,234)
Brushy Creek Municipal Water District										
Municipal Demand (M)	984	1,500	2,538	3,626	3,955	4,112	4,214	4,345	4,239	4,212
Water Supply										
Contract with Round Rock[9]	3,360	3,360	3,360	3,360						
Contract/Stillhouse Hollow Lake			4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Ground (Edwards Aquifer)	112	112	1,792	1,792	1,792	1,792	1,792	1,792	1,792	1,792
Total Supply	3,472	3,472	9,152	9,152	5,792	5,792	5,792	5,792	5,792	5,792
Supply minus Demand[3]	2,488	1,972	6,614	5,526	1,837	1,680	1,578	1,447	1,553	1,580

Table 2.2-4 continued

Area	Use in 1990	Projections (acft/yr)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Liberty Hill										
Municipal Demand (M)	136	180	201	254	298	372	440	621	834	1,068
Water Supply (Ground) [10]	200	200	200	200	200	200	200	200	200	200
Supply minus Demand[3]	64	20	(1)	(54)	(98)	(172)	(240)	(421)	(634)	(868)
Georgetown Service Area										
Municipal Demand (M)	4,250	5,611	7,052	8,513	10,444	12,560	13,826	17,416	21,962	27,800
Industrial Demand (I)	130	130	398	809	1,425	1,950	2,443	3,481	4,600	5,800
Total M&I Demand	4,380	5,741	7,450	9,322	11,869	14,510	16,269	20,897	26,562	33,600
Water Supply										
Contract/Lake Georgetown	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720	6,720
Contract/Stillhouse Hollow Lake		5,448	15,448	15,448	15,448	15,448	15,448	15,448	15,448	15,448
Ground (Edwards Aquifer)	3,360	3,360	3,360	3,360	3,360	3,360	3,360	3,360	3,360	3,360
Total Supply	10,080	15,528	25,528	25,528	25,528	25,528	25,528	25,528	25,528	25,528
Supply minus Demand[3]	5,700	9,787	18,078	16,206	13,659	11,018	9,259	4,631	(1,034)	(8,072)
Taylor										
Municipal Demand (M)	2,038	2,691	3,016	3,818	3,874	4,838	5,155	5,861	6,663	7,958
Industrial Demand (I)	33	35	90	150	200	250	300	400	500	600
Total M&I Demand	2,071	2,726	3,106	3,968	4,074	5,088	5,455	6,261	7,163	8,558
Water Supply										
Contract/Granger Lake	6,721	6,721	6,721	6,721	6,721	6,721	6,721	6,721	6,721	6,721
Ground	0	0	0	0	0	0	0	0	0	0
Total Supply	6,721	6,721	6,721	6,721	6,721	6,721	6,721	6,721	6,721	6,721
Supply minus Demand[3]	4,650	3,995	3,615	2,753	2,647	1,633	1,266	460	(442)	(1,837)

Table 2.2-4 continued

Area	Use in 1990	Projections (acft/yr)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Jonah SUD										
Municipal Demand (M)	660	871	930	1,177	1,281	1,600	1,722	2,258	2,891	3,611
Water Supply										
Contract/Stillhouse Hollow Lake	2,439	2,439	2,439	2,439	2,439	2,439	2,439	2,439	2,439	2,439
Ground (Edwards Aquifer)	2,688	2,688	2,688	2,688	2,688	2,688	2,688	2,688	2,688	2,688
Total Supply	5,127	5,127	5,127	5,127	5,127	5,127	5,127	5,127	5,127	5,127
Supply minus Demand[3]	4,467	4,256	4,197	3,950	3,846	3,527	3,405	2,869	2,236	1,516
Hutto										
Municipal Demand (M)	72	95	131	166	194	242	281	396	532	681
Water Supply										
Contract with Manville WSC	336	336	336	336	336	336	336	336	336	336
Ground (Edwards Aquifer)	131	131	131	131	131	131	131	131	131	131
Total Supply	467	467	467	467	467	467	467	467	467	467
Supply minus Demand[3]	395	372	336	301	273	225	186	71	(65)	(214)
Other Water Utilities/East of I35										
Municipal Demand (M)	1,191	1,239	1,228	1,379	1,533	2,128	2,839	3,367	3,643	3,834
Water Supply (Ground)	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,300
Supply minus Demand[3]	109	61	72	(79)	(233)	(828)	(1,539)	(2,067)	(2,343)	(2,534)
Other Water Utilities/West of I35										
Municipal Demand (M)	3,165	3,262	3,166	3,557	3,625	5,305	7,167	8,264	8,749	9,254
Water Supply										
Contract/Stillhouse Hollow Lake	1,110	1,110	1,110	1,110	1,110	1,110	1,110	1,110	1,110	1,110
Ground	3,342	3,342	3,342	3,342	3,342	3,342	3,342	3,342	3,342	3,342
Total Supply	4,452	4,452	4,452	4,452	4,452	4,452	4,452	4,452	4,452	4,452
Supply minus Demand[3]	1,287	1,190	1,286	895	827	(853)	(2,715)	(3,812)	(4,297)	(4,802)

Table 2.2-4 continued

Area	Use in 1990	Projections (acft/yr)								
		1995	2000	2005	2010	2015	2020	2030	2040	2050
Remainder of County/East of I35										
Municipal Demand (M)	1,167	1,541	1,961	2,352	2,835	3,936	5,251	6,252	6,648	6,985
Water Supply (Ground)	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541	1,541
Supply minus Demand[3]	374	0	(420)	(811)	(1,294)	(2,395)	(3,710)	(4,711)	(5,107)	(5,444)
Remainder of County/West of I35										
Municipal Demand (M)	778	1,027	1,448	1,700	1,890	2,440	3,343	4,239	4,394	4,655
Water Supply (Ground)	1,027	1,027	1,027	1,027	1,027	1,027	1,027	1,027	1,027	1,027
Supply minus Demand[3]	249	0	(421)	(673)	(863)	(1,413)	(2,316)	(3,212)	(3,367)	(3,628)
Total Municipal Demand	24,482	32,420	43,521	54,523	62,696	77,163	88,849	105,409	119,453	133,526
Other Water Demands										
Industrial	326	347	2,653	8,435	13,057	14,596	15,154	17,579	19,919	23,688
Steam-Electric	0	0	0	0	0	0	0	0	0	0
Irrigation	160	160	160	160	160	160	160	160	160	160
Mining	1,713	1,799	1,885	1,865	1,845	1,870	1,896	1,949	2,007	2,068
Livestock	1,508	1,314	1,314	1,314	1,314	1,314	1,314	1,314	1,314	1,314
Total Other Demands	3,707	3,620	6,012	11,774	16,376	17,940	18,524	21,002	23,400	27,230
Other Water Supply										
Ground	3,620	3,620	3,620	3,620	3,620	3,620	3,620	3,620	3,620	3,620
Williamson County Summary										
Total M&I Demand	24,808	32,767	46,174	62,958	75,753	91,759	104,003	122,988	139,372	157,214
Total M&I Supply[6]	58,132	77,757	105,702	100,787	97,945	98,419	98,369	98,369	98,369	98,369
Supply minus Demand[3]	33,324	44,990	59,528	37,829	22,192	6,660	(5,634)	(24,619)	(41,003)	(58,845)

Footnotes are continued on next page.

Table 2.2-4 continued

Source: Water Demand Projections are from Texas Water Development Board, 1996 Concensus Water Plan Projections, Most Likely Case: Dry Weather/Average Water Conservation. Water Supply information is from TWDB ground and surface water studies, individual Water Suppliers', information, and HDR computations for this study.

[1] Contract terminates in year 2006.

[2] Contract terminates in year 2000.

[2] Contract terminates in year 2000.

[3] Positive values mean projected surpluses, while ( ) values mean projected shortages.

[4] Included in City of Austin Northwest A pressure Zone demands listed in Table S-4.

[5] Included in City of Austin supplies listed in Table S-4.

[6] Contract with Cedar Park and the Lower Colorado River Authority, which terminates in year 2000.

[7] Assuming that contracts with the Lower Colorado River Authority are renewed to continue beyond present 2014 expiration date.

[8] Present contract is projected to decline from 784 acft/yr in 1995 to 112 acft/yr in 2015 , and to zero thereafter.

[9] Contract with Round Rock, which expires in 2006.

[10] Liberty Hill is supplied by Chisolm Trail WSC.

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2.2.3.2 Austin in Williamson County

The City of Austin serves a small area of south central Williamson County. Austin's water supplies are described in Section 2.1.3.1, which will not be repeated here. It is anticipated that supplies available to Austin will be used to meet the projected needs of the City of Austin Service Area, including those parts located in Williamson County. Given that the demand/supply comparison for the Austin service area shows shortages beginning in about 2016 (Section 2.1.4.1), it is estimated that the supply available to the Austin service area of Williamson County from present Austin supplies would be adequate through about 2016 and that the supply for this area from Austin's present supplies would be 3,000 acft/yr from 2014 through 2050 (Table 2.2-4).

2.2.3.3 Cedar Park

The City of Cedar Park water supply is obtained from Lake Travis through two contracts with the Lower Colorado River Authority (LCRA). The first contract, which terminates on June 1, 2014, but is renewable on an annual basis if both parties agree to a renewal, provides for a maximum diversion of 7,000 acft/yr. A second contract for 2,400 acft/yr was obtained in 1996 and provides this water to Cedar Park, which in turn provides 2,400 acft/yr of water to neighboring Leander through year 2000, at which time the 2,400 acft/yr reverts to LCRA. Thus, it is assumed that if these contracts are renewed upon expiration, Cedar Park's water supply is 7,000 acft/yr for the period 2000 through 2050 (Table 2.2-4).

2.2.3.4 Leander

Leander obtains its water through a wholesale services contract with Chisholm Trail Special Utility District from wells and through a contract with Cedar Park. The Trinity Group Aquifer in which Leander's wells are completed is inadequate to continue to meet the City's needs (i.e., well yields are predicted to decline from the 871 acft supplied in 1990 to 392 acft/yr in 2000 and to zero in 2005). Chisholm Trail Special Utility District (SUD) provides a supply of water which is projected to decline from 0.7 mgd (784 acft/yr) in 1995, to 0.36 mgd (403 acft/yr) in 2000, to 0.28 mgd (313 acft/yr) in 2005, to 0.2 mgd (224 acft/yr) in 2010, to 0.1 mgd (112 acft/yr) in 2015.

The contract between Leander and Cedar Park provides Leander with up to 2,400 acft/yr of treated water through the year 2000 (Section 2.2.3.3). The Cedar Park/Leander agreement is based upon the condition that LCRA agrees to provide Cedar Park an additional 2,400 acft/yr of water to meet part of Leander's water needs.[10] In 1996, Leander arranged to contract with the Brazos River Authority (BRA) to obtain 2,700 acft/yr of water from Stillhouse Hollow Lake. Thus, until the year 2001, Leander has a supply of 5,895 acft/yr and thereafter has 2,700 acft/yr of supply from Stillhouse Hollow Lake, plus small quantities from Chisholm Trail SUD (Table 2.2-4).

2.2.3.5 Brushy Creek Municipal Utility District

Brushy Creek Municipal Utility District's (MUD) Edwards Aquifer wells yield 1,792 acft/yr. The District has a contract with Round Rock, which expires in 2006, for 3,360 acft/yr of surface water and has obtained 4,000 acft/yr of Stillhouse Hollow Lake water from BRA. Thus, the Brushy Creek MUD water supply is 9,152 acft/yr through 2006, and 5,792 acft/yr thereafter (Table 2.2-4).

2.2.3.6 Liberty Hill

Liberty Hill has a water supply contract with Chisholm Trail Water Supply Corporation (WSC) for 200 acft/yr (Table 2.2-4).

2.2.3.7 Georgetown

Through contracts with the Brazos River Authority, Georgetown has 6,720 acft/yr of water from Lake Georgetown, and 15,448 acft/yr of water from Stillhouse Hollow Lake. In addition, Georgetown's Edwards Aquifer wells have an estimated dependable yield of 3,360 acft/yr, bringing Georgetown's water supply to a total of 25,528 acft/yr (Table 2.2-4).

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[10] The Cedar Park/Leander contract includes a formula for calculating modifications to the term of the contract for different quantities of additional water obtained by each entity, and other special conditions.

2.2.3.8 Taylor

Taylor has a water supply contract with the Brazos River Authority for 6,721 acft/yr of water from Granger Lake (Table 2.2-4).

2.2.3.9 Jonah Specialty Utility District

Through a contract with the Brazos River Authority, the Jonah Specialty Utility District (SUD) has a water supply of 2,439 acft/yr from Stillhouse Hollow Lake. In addition, Jonah SUD has an estimated groundwater supply of 2,688 acft/yr from the Edward Aquifer, bringing its total supply to 5,127 acft/yr (Table 2.2-4).

2.2.3.10 Hutto

Hutto has an estimated groundwater supply of 131 acft/yr from the Edwards Aquifer and a contract for 336 acft/yr from Manville WSC (Table 2.2-4).

2.2.3.11 Other Water Utilities/East of IH-35

In the Williamson County areas east of IH-35, there are seven water utilities (Bartlett, Granger, Jarrell/Schwertner, Noack WSC, Thrall, Walburg WSC, and Weir) in addition to the participants of this study. These utilities presently depend upon groundwater obtained from the Edwards and Trinity Aquifers. The estimated supply available to these seven utilities is approximately 1,300 acft/yr (Table 2.2-4).

2.2.3.12 Other Water Utilities/West of IH-35

In the Williamson County areas west of IH-35, there are 11 water utilities (Andice, Blockhouse MUD, Chisholm Trail SUD, Durham Park, Fern Bluff, Florence, High Gabriel WSC, South San Gabriel River Ranches, San Gabriel River Ranches, Berry Creek, and Tal/Tex) in addition to the participants of this study. These utilities depend upon groundwater from the Edwards and Trinity Aquifers with one entity obtaining surface water through a contract with the Brazos River Authority for 1,610 acft/yr water from Stillhouse Hollow Lake. The estimated total supply available to the 11 utilities is 4,952 acft/yr of which 1,610 acft/yr is surface water and 3,342 acft/yr is groundwater (Table 2.2-4).

2.2.3.13 Remainder of County/East of IH-35

Approximately 14,111 people lived in Williamson County areas east of IH-35 in 1995 that did not have water service from public water utilities. The population of these areas is projected to increase to 19,161 in 2010, and to 47,211 in 2050.[11] At the present time, water is obtained for individual homes and businesses from wells developed in local aquifers. The quantity available is estimated at about 1,541 acft/yr (Table 2.2-4).

2.2.3.14 Remainder of County/West of IH-35

The population of those areas of Williamson County west of IH-35 that do not have water service from public water utilities is estimated at 9,073 in 1995, and is projected to grow to about 30,982 in 2050.[12] Water supplies are obtained through wells completed in local aquifers and are estimated at about 1,027 acft/yr (Table 2.2-4).

2.2.3.15 Williamson County Water Supply Summary

Estimated total water supply from all sources—local groundwater, existing reservoirs and contracts with LCRA and BRA for water from Lake Travis and Stillhouse Hollow Lake located outside the County—was approximately 70,900 acft/yr in 1990 and is projected to be 116,570 acft/yr in 2000, and 109,441 acft/yr in 2050 (Table 2.2-4). The reasons for the projected decline in quantity available between the years 2000 and 2050 is a projected decline in groundwater supplies and the expiration of short-term contracts between Leander and LCRA for water from Lake Travis of the Colorado River Basin.

2.2.4 Water Demand and Supply Comparisons

The projected water demands of Section 2.2.2 and the projected water supplies of Section 2.2.3 are brought together in this section, in order to compare water supplies available to each study participant with projected water demands, in order to estimate the time at which additional supplies will be needed, and the quantity that will be needed for future dates through the year 2050. A comparison is presented for each study participant (Table 2.2-4).

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[11] As growth occurs in these presently unserved areas, water supply utilities can be expected to be organized to serve the area, or existing utilities will extend service to parts or all of the area.

[12] Ibid.

2.2.4.1 Round Rock

For the Round Rock service area, projected water demands are estimated to exceed projected water supplies in about 2010 (Table 2.2.4 and Figure 2.2-3). Projected shortages in 2010 are 131 acft/yr, in 2015 are 4,394 acft/yr, in 2020 are 7,751 acft/yr, and in 2050 are 19,774 acft/yr (Table 2.2-4 and Figure 2.2-3).

2.2.4.2 Austin

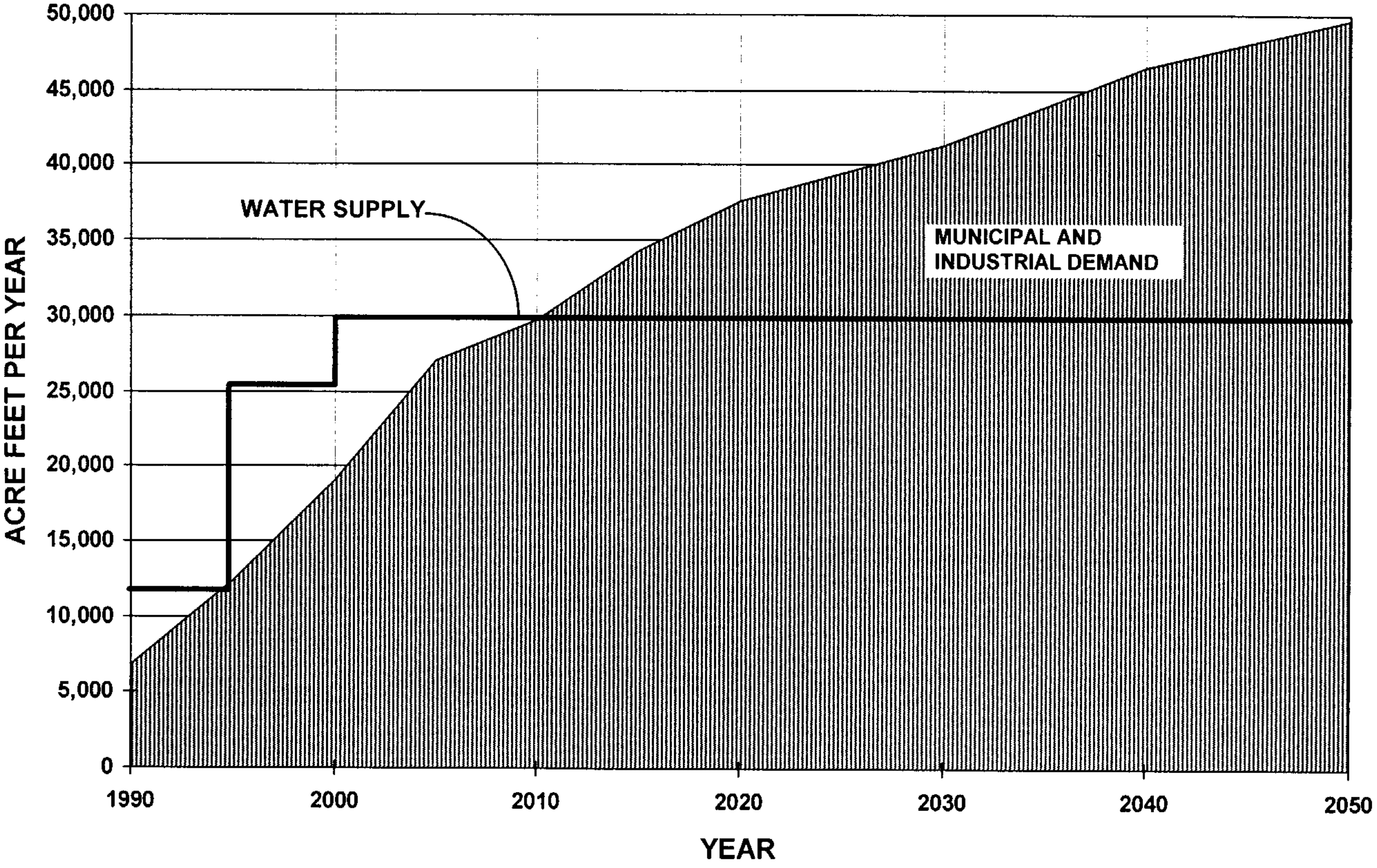
Water demands in the Austin service area located within Williamson County are projected to increase from 652 acft/yr in 1995 to 2,352 acft/yr in 2010, and to 6,054 acft/yr in 2050. Projected demands upon the City of Austin service area increase to equal presently available supplies in about the year 2016, which when applied uniformly to the service area, customers show a shortage for this part of the system of 791 acft/yr in 2020, 1,899 acft/yr in 2030, and 3,054 acft/yr in 2050 (Table 2.2-4).

2.2.4.3 Cedar Park

Cedar Park's surface water supplies of 7,000 acft/yr from Lake Travis via contracts with LCRA, assuming present contracts are renewed on or before expiration, are projected to meet projected demands of the Cedar Park service area until about 2003. Projected shortages in 2010 are 3,069 acft/yr, and by 2050 are 11,349 acft/yr (Table 2.2-4 and Figure 2.2-4).

2.2.4.4 Leander

Leander's present groundwater supplies are temporary in nature (i.e., well yields and water quality are declining such that no usable groundwater supply is expected to be available after the year 2004). Surface water supplies of 2,803 acft/yr are through short-term contracts with neighboring Cedar Park and the Chisholm Trail WSC with 2,700 acft/yr through long-term contracts with BRA. Thus, Leander has projected supplies adequate to meet projected demands through about 2005. Projected shortages occur after 2005, and are 180 acft/yr in 2010, 1,286 acft/yr in 2020, and 5,234 acft/yr in 2050 (Table 2.2-4 and Figure 2.2-5).



(1) Includes 5,376 acft/yr contract from City of Austin, 1996 to 2000.

(2) Contract to Brushy Creek MUD for 3,360 acft expires in 2006.

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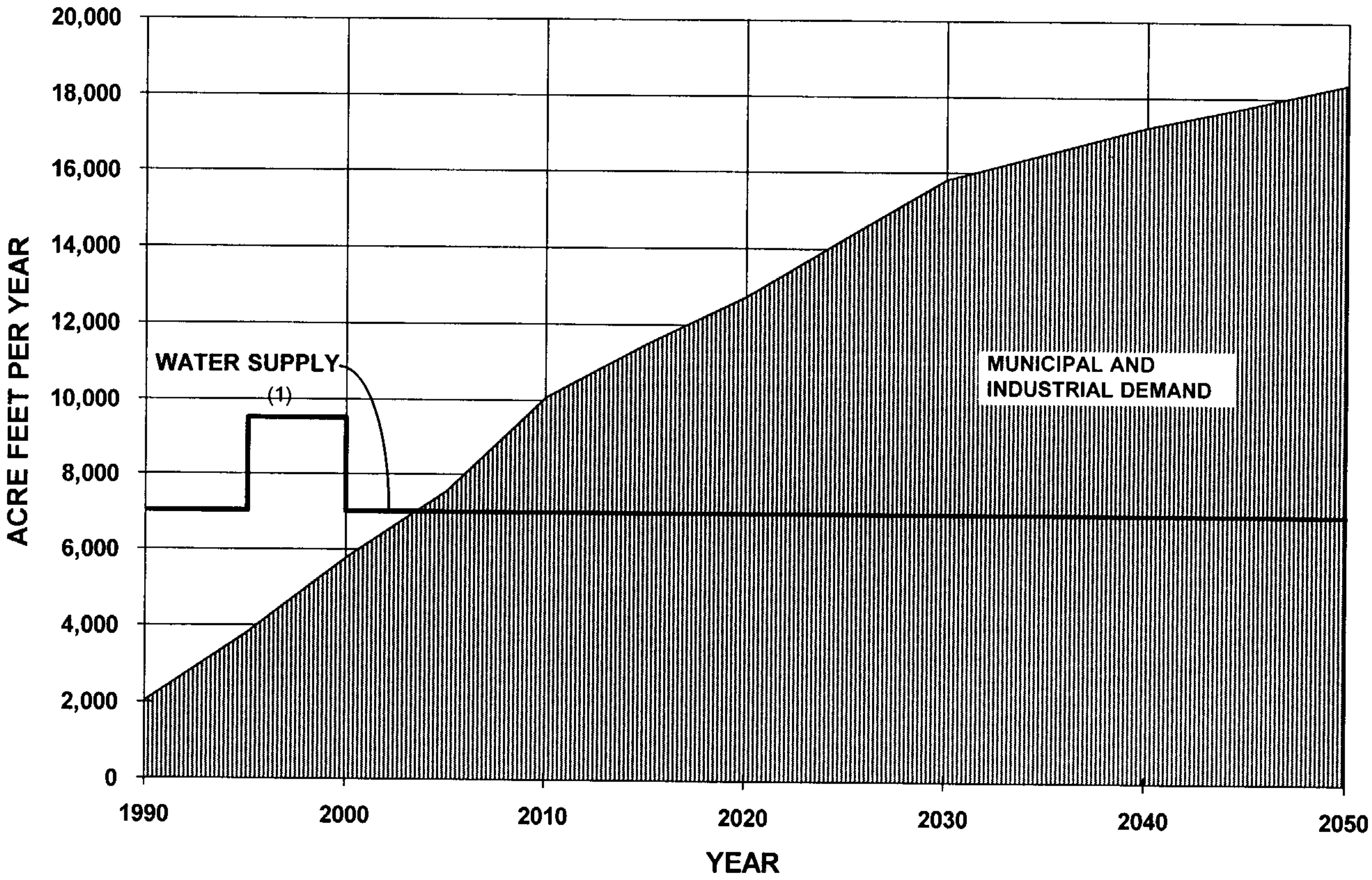
WATER DEMAND AND SUPPLY COMPARISON - ROUND ROCK

FIGURE 2.2-3



(1) Contract with LCRA
To Provide 2,400 acft to
Neighboring Leander

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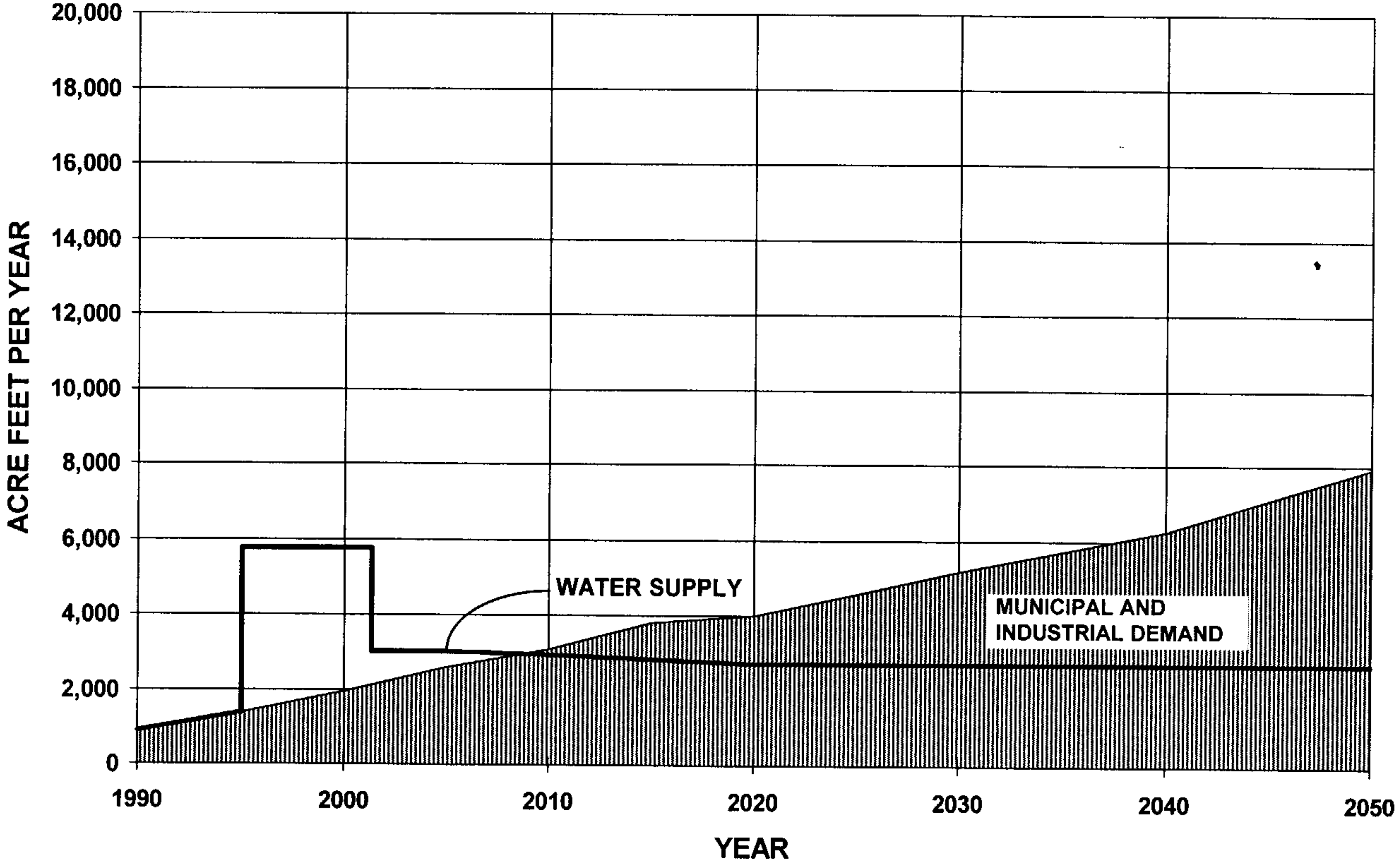
**WATER DEMAND AND
SUPPLY COMPARISON -
CEDAR PARK**

FIGURE 2.2-4



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WATER DEMAND AND SUPPLY COMPARISON - CITY OF LEANDER

FIGURE 2.2-5

2.2.4.5 Brushy Creek MUD

The Brushy Creek MUD's Edwards Aquifer wells yield 1,792 acft/yr. The District's water supply contract with Round Rock for 3,360 acft/yr expires in 2006. In 1996, Brushy Creek MUD arranged to obtain 4,000 acft/yr of Stillhouse Hollow Lake water from BRA. Thus, with the Stillhouse Hollow Lake water, the Brushy Creek MUD projected demands can be met through the projection period if the Edwards Aquifer Wells can continue to supply 1,792 acft/yr (Table 2.2-4 and Figure 2.2-6).

2.2.4.6 Liberty Hill

Liberty Hill's projected water demands increase to 201 acft/yr in 2000, which almost exactly equals the present 200 acft/yr of supply available via contract with the Chisolm Trail WSC. Assuming the present contract is continued, Liberty Hill would have a shortage of 54 acft/yr in 2005, 98 acft/yr in 2010, 240 acft/yr in 2020, and 868 acft/yr in 2050 (Table 2.2-4).

2.2.4.7 Georgetown

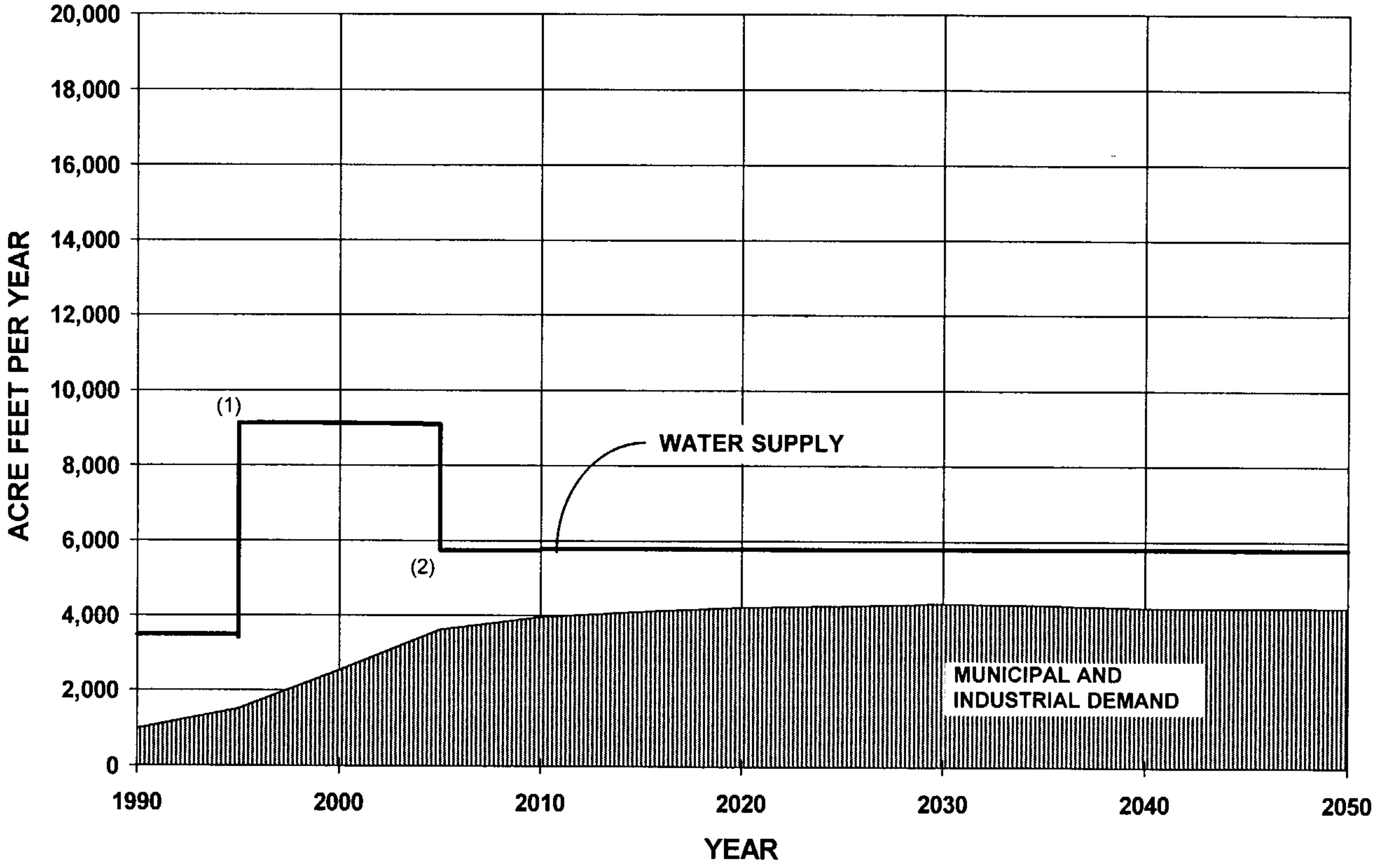
Georgetown's projected water supplies of 25,528 acft/yr (22,168 acft/yr of surface water and 3,360 acft/yr of groundwater) are adequate to meet projected demands to about the year 2038. Projected shortages in 2040 are 1,034 acft/yr, and in 2050 are 8,072 acft/yr (Table 2.2-4 and Figure 2.2-7).

2.2.4.8 Taylor

Taylor's water supply of 6,721 acft/yr from Granger Lake is projected to be adequate to meet projected demands to approximately 2035. In 2040, projected shortages are 442 acft/yr and in 2050 are 1,837 acft/yr (Table 2.2-4).

2.2.4.9 Jonah Special Utility District

Jonah SUD's surface water supply of 2,439 acft/yr and groundwater supply of 2,688 acft/yr (total of 5,127 acft/yr) is greater than projected demands through 2050 (Table 2.2-4 and Figure 2.2-8). Based on these projections, Jonah SUD has a surplus of 4,197 acft/yr in 2000, 3,405 acft/yr in 2020, and 1,516 acft/yr in 2050 (Table 2.2-4 and Figure 2.2-8).



(1) Contract with BRA to purchase 4,000 acft/yr from Lake Stillhouse Hollow.

(2) Contract for 3,360 acft/yr from Round Rock expires in 2006.

HDR

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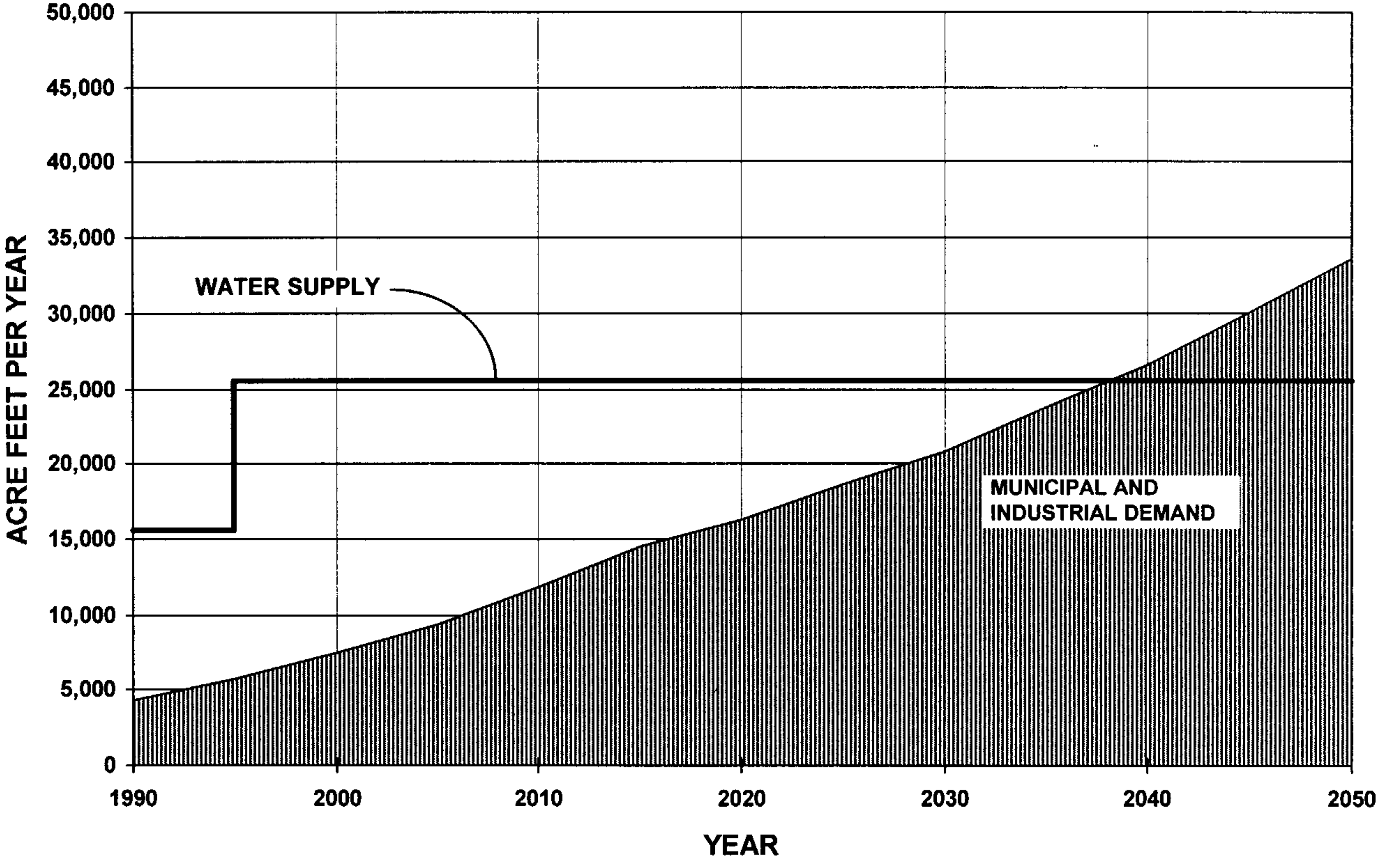
TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

**WATER DEMAND AND
SUPPLY COMPARISON -
BRUSHY CREEK MUD**

FIGURE 2.2-6



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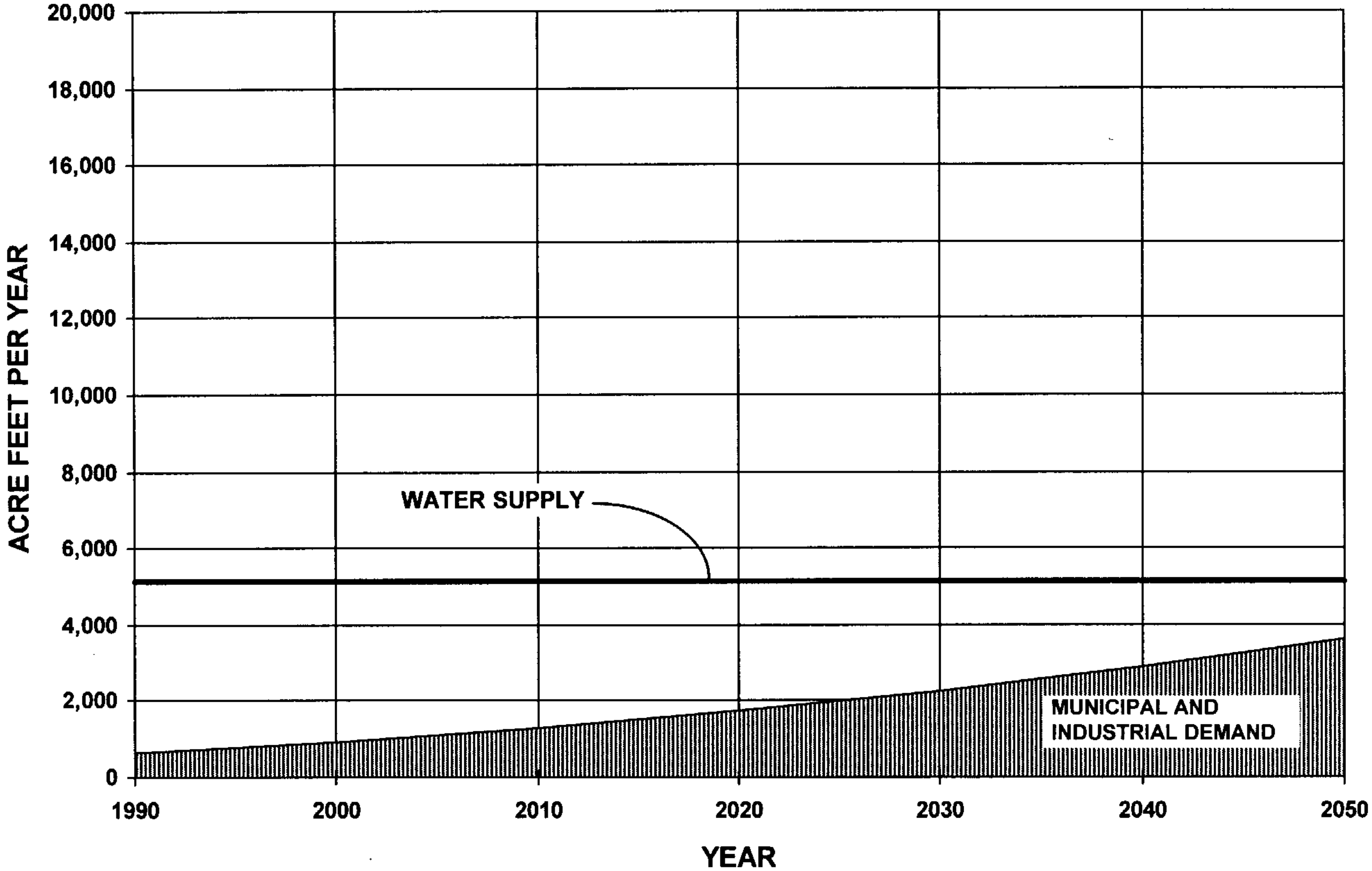
WATER DEMAND AND SUPPLY COMPARISON - GEORGETOWN

HDR Engineering, Inc.

FIGURE 2.2-7



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NORTH CENTRAL STUDY AREA

WATER DEMAND AND SUPPLY COMPARISON - JONAH SUD

FIGURE 2.2-8

2.2.4.10 Hutto

Hutto's present supply of 467 acft/yr from local groundwater sources and Manville WSC is projected to meet demands through year 2000. A recently concluded contract to purchase 336 acft/yr from Manville WSC will support demands until about 2040 (Table 2.2-4 and Figure 2.2-9).

2.2.4.11 Other Water Utilities/East of IH-35

Estimated water supplies of the seven water utilities east of IH-35, that are not study participants, of 1,300 acft/yr are projected to meet demands to about 2003 (see Section 2.2.3.11). Projected shortages in year 2005 are 79 acft/yr, in 2020 are 1,539 acft/yr, and in 2050 are 2,534 acft/yr (Table 2.2-4).

2.2.4.12 Other Water Utilities/West of IH-35

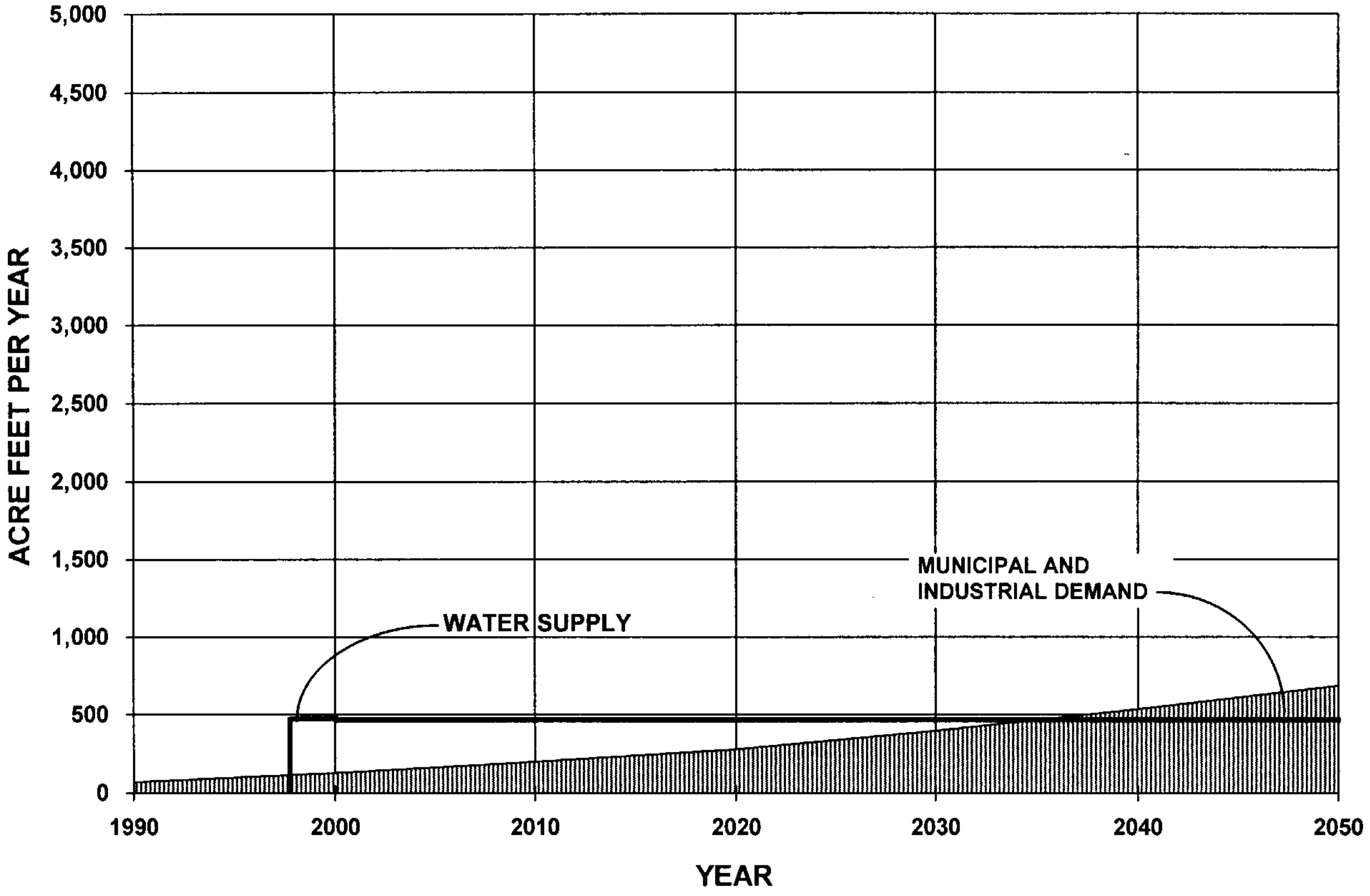
Estimated water supplies of the 11 water utilities west of IH-35, that are not study participants, of 4,952 acft/yr are projected to meet demands to about the year 2014 (see Section 2.2.3.11). Projected shortages in these areas in 2015 are 353 acft/yr, in 2020 are 2,215 acft/yr, and in 2050 are 4,302 acft/yr (Table 2.2-4).

2.2.4.13 Remainder of Williamson County/East of IH-35

For that part of Williamson County east of IH-35 that depends upon individual household and business wells completed in local aquifers, the estimated present supplies of 1,541 acft/yr are about equal to present demands. Projected shortages in 2000 are 420 acft/yr, in 2020 are 3,710 acft/yr, and in 2050 are 5,444 acft/yr (Table 2.2-4).

2.2.4.14 Remainder of Williamson County/West of IH-35

For that part of Williamson County west of IH-35 that depends upon individual household and business wells completed in local aquifers, the estimated present supplies of 1,027 acft/yr are about equal to present demands. However, unless these supplies can be increased,



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

WATER DEMAND AND SUPPLY COMPARISON - CITY OF HUTTO

HDR Engineering, Inc.

FIGURE 2.2-9

projected shortages of 421 acft/yr occur in year 2000, and increase to 2,316 acft/yr in 2020, and to 3,628 acft/yr in 2050 (Table 2.2-4).

2.2.4.15 Williamson County Summary of Municipal and Industrial Water Demands

In 1990, total municipal and industrial (M&I) water use was 24,808 acft/yr. Projected M&I water demand in year 2000 is 46,174 acft/yr, in 2020 is 104,003 acft/yr and in 2050 is 157,214 acft/yr. Supplies available within the county from local groundwater, existing surface water reservoirs (Georgetown and Granger), and through contracts with LCRA and BRA for water from Lakes Travis and Stillhouse Hollow, respectively, are large enough to meet projected total M&I demands within the county through about the year 2018 (Table 2.2-4 and Figure 2.2-10).[13] Williamson County M&I water shortages in 2030 are projected at 24,619 acft/yr, and in 2050 are 58,845 acft/yr (Table 2.2-4).

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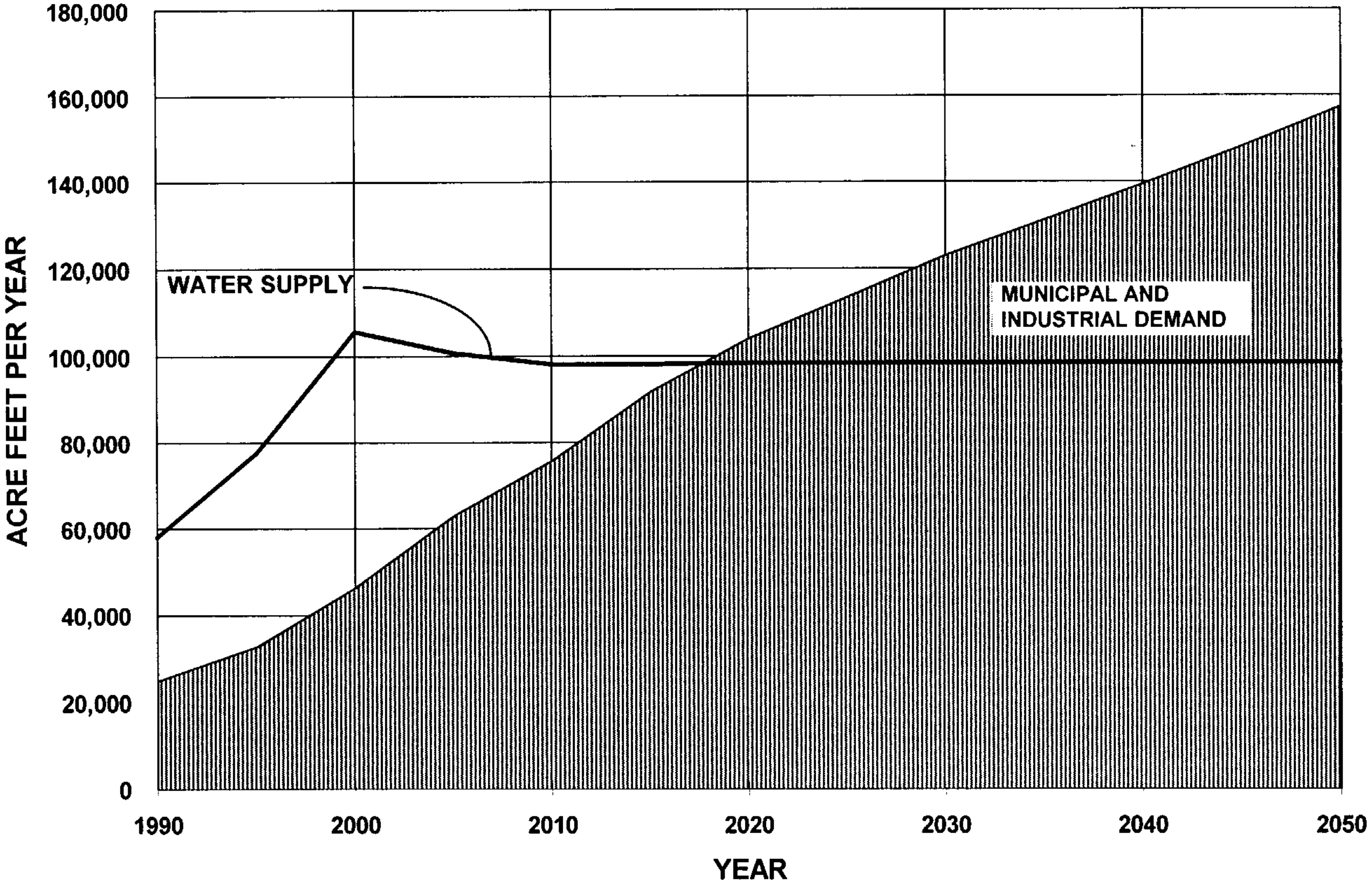
[13] Note: These are comparisons of county totals and do not address the question of being able to deliver available supplies to locations where water is needed. In fact, as the previous discussions show, some entities will have shortages before 2013, while others have supplies that will meet their respective needs beyond that date.



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

HDR
HDR Engineering, Inc.

**WATER DEMAND AND
SUPPLY COMPARISON -
WILLIAMSON COUNTY**

FIGURE 2.2-10

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Water Supply Alternatives

3.0 WATER SUPPLY ALTERNATIVES

Water supply alternatives available to the study area have been determined from several sources, including Phase I studies of the Brazos study area and Austin study area, and input from project sponsors. A total of 18 primary water supply alternatives with 38 sub-alternative configurations have been evaluated in this study. Each of the alternatives and sub-alternatives was evaluated for water supply potential, environmental effects, and cost. Alternatives have been grouped into three general categories as follows:

- **Conservation and Reuse**
- **Brazos River Basin Sources**
- **Colorado River Basin Sources**

The alternatives are listed in Table 3.0-1 and the approximate geographic locations of the alternatives are shown in Figure 3.0-1 in Volume 1, as well as in individual figures within this section of the report.

3.1 Methods and Procedures

The water supply alternatives have been studied on a stand-alone basis and have been evaluated for water supply potential, environmental effects, water quality, cost, and implementation issues. In most cases, the report section for each water supply alternative is divided into six subsections arranged as follows:

Subsection	Contents
1	Description of Alternative
2	Available Supply
3	Environmental Issues
4	Water Quality and Treatability
5	Engineering and Costing
6	Implementation Issues

Table 3.0-1
Water Supply Alternatives — North Central Study Area

Alt No.	Description
Conservation/Local Alternatives	
Alt No.	**Description**
L-9	Accelerated and Additional Municipal Water Conservation for the Austin Service Area
L-21	Accelerated and Additional Municipal Water Conservation for Williamson County Area
L-5	Reclaimed Water Reuse — Areas in the Colorado River Basin
L-8	Reclaimed Water Reuse — Areas in the Brazos River Basin
Brazos River Basin Sources	
Alt No.	**Description**
B-1	Purchase of Water from Brazos River Authority at Lake Stillhouse Hollow Delivered to Lake Georgetown
B-6	Purchase of Water from Brazos River Authority at Lake Granger Delivered to Lake Georgetown
B-8	Water Availability from Little River or Brushy Creek
B-9	South Fork Reservoir
CZ-2	Use of Carrizo-Wilcox Aquifer to Augment Lake Georgetown Yield
Colorado River Basin Sources	
Alt No.	**Description**
C-7	Water Available from Austin's Existing Rights
B-7	Purchase and Transfer of Yield from Lake Somerville in the Brazos River Basin to the Colorado River
C-2	Purchase of Uncommitted Stored Water from LCRA for Diversion at Lake Travis
C-4	Purchase of Water from LCRA Near Lake Buchanan Delivered to Lake Georgetown
C-5	Purchase of Irrigation Rights in the Lower Colorado River Basin with Off-Channel Storage Near Columbus in Exchange for Additional Water from Lake Travis
C-6	Potential Use of Austin Steam-Electric Generation Water Rights for Municipal use
CZ-1	Use of Carrizo-Wilcox Aquifer to Augment Colorado River Flows
BC-1	System Operation of Lake Stillhouse Hollow and Lake Travis
BC-2	Purchase of Uncommitted Water Stored in Lake Travis to Augment Lake Georgetown

3.1.1 Water Delivery Locations

While some supply alternatives could provide increased water supply to the entire study area, other alternatives could realistically only provide service to one or perhaps two entities. New water supplies from each alternative could potentially be delivered to the project participants at any of a variety of locations in which case, each delivery variation would create a different project cost. To allow direct comparison of costs between stand-alone alternatives and to reduce the number of cost combinations and variations, five key locations for delivery of treated water were chosen for development of cost estimates The five delivery locations for treated water used for comparison of alternatives are:

- **City of Austin Service Area**. For water supply alternatives that could be diverted at Lake Travis, costs were estimated for construction of WTP 4 on Lake Travis and necessary distribution facilities to convey new water supplies into Austin's distribution system and to supply wholesale customers on the periphery of the Austin system.
- **Cedar Park WTP**. For supply alternatives that could be diverted at Lake Travis through Cedar Park's facilities, costs were estimated for expansion of the treatment and pumping facilities at the Cedar Park plant. In some cases, costs of treated water conveyance facilities from the Cedar Park plant to other entities were also estimated as part of the stand-alone project analysis.
- **City of Round Rock WTP and City of Georgetown WTP**. Round Rock and Georgetown each own and operate separate intake and treatment facilities at Lake Georgetown and expansion of either of these facilities could benefit others. For alternatives resulting in additional water supply in Lake Georgetown, costs were estimated for expansion of these existing facilities.
- **Williamson County Regional WTP**. This would be a potential new water treatment plant to be located at or near Round Rock's existing water treatment plant and could possibly provide service to one or more of these entities: Georgetown, Round Rock, Cedar Park, Leander, Brushy Creek MUD, Pflugerville, Hutto, and possibly others.

These delivery locations and potential users of the water from these treatment plants are shown in Figure S-17 in Volume 1.

3.1.2 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. Pump Stations
2. Pipelines
3. Water Treatment Plants
4. Water Storage Tanks
5. Off-Channel Reservoirs
6. Well Fields

Non-Structural Costs

1. Engineering - Design, Bidding and Construction Phase Services, Geotechnical, and Surveying
2. Legal Services
3. Contingencies
4. Permits
5. Environmental - Studies & Mitigation
6. Archeology - Studies & Mitigation
7. Land and Rights-of-Way
8. Interest During Construction
9. Financing
10. Operations and Maintenance
11. Electricity
12. Program Costs, such as for conservation programs

The methods used in estimating costs are as follows:

Structural Costs

1. 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, motors, and electrical controls were estimated using a generalized cost data related to station horsepower derived from actual construction costs of equipment previously installed, escalated to first-quarter 1997 prices.

2. Pipeline. Pipeline construction costs are influenced by pipe materials, bedding requirements, geologic conditions, urbanization, terrain, and special crossings. Table 3.1-1 included estimated base pipeline costs per foot for pipeline sizes ranging from 12-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. The cost estimates pertain to 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, revegetation, rights-of-way, fencing, and gates. Costs of special crossings such as railroads, highways, and rivers were estimated on an individual basis.

3. Water Treatment. 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. Conventional treatment process, including alum and polymer addition, rapid mix, flocculation, settling, filtration, and disinfection with chlorine is costed. Treatment plant costs include processes, site work, buildings, storage tanks, sludge handling and disposal, clearwell, pumps, and equipment. Finished water pumping (high service pumping) is also included in the costs. Operation and maintenance costs include labor, materials, replacement of equipment, process energy, building energy, chemicals, and high service pumping energy. Costs for water treatment plants other than the proposed City of Austin WTP 4 were estimated using recent bid prices. Estimated costs for the City of Austin WTP 4 were developed from the Long Range Planning Guide, prepared by the Austin Water Utility and from bid information specific to the WTP 4 project.

Table 3.1-1
Base Pipeline Costs

Sizes (inches)	Base Pipeline Costs[1] including Appurtenances ($/LF)
12	26
18	37
24	44
30	56
36	74
42	91
48	114
54	120
60	139
66	171
72	205
78	224
84	241
90	254
96	298
102	343
108	388
114	435
120	489

[1] Base pipeline cost is for normal operating pressure pipe installed in a soil trench, rural environment. For other conditions (i.e., rock trench, 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. Costs are first-quarter 1997. ENR CCI = 5653.

4. Water Storage Tanks. Costs were estimated for ground storage tanks using welded steel construction. Costs are inclusive of foundations, site work, and limited site piping.

5. Off-Channel Reservoirs. The construction costs for these elements 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.

6. Well Fields. 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, and from recent bid prices. The cost is based on these conditions: (a) a standard 16 x 10-inch undereamed, 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).

Construction Cost Indices

Updates of previous cost estimates to first-quarter 1997 price levels and trending of unit costs were performed using an ENR Construction Cost Index (CCI) of 5653.

Non-Structural Costs

The costs for engineering, administration, legal, environment, 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 as 30% of total construction costs for pipelines and 35% for all other facilities (unless otherwise noted). Construction costs include only the cost of building the project facilities and any relocations requiring construction contracts including 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. Costs include 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 right-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 district 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 covers the cost of the permanent and temporary easement.

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

5. Debt service and interest during construction. Debt service for all projects was calculated assuming an interest rate of 8 percent for 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 9 percent annual interest rate less 4 percent of investment of available funds. Interest during construction was calculated as the average 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. Operations and maintenance costs (O&M) (not including power costs for pumping). Annual O&M costs were calculated as 1.0 percent of the total estimated construction cost for pipelines, as 2.5 percent of total estimated construction costs for pump stations, and as 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 calculated horsepower input and a power purchase cost of $0.06 per kwhr.

7. Presentation of Estimates. Cost estimates were prepared to show total capital costs, total project costs, total annual costs, and the unit cost of the alternative as cost per acre-foot of water delivered.

   It should be noted that the unit cost of the alternative (i.e., $ per acft) is for full utilization of the supply available. For many of the alternatives, the unit cost in early years of a project life when utilization is less than full capacity, will be significantly higher than reported here.

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Environmental Overview

3.1.3 Environmental Overview

INTRODUCTION

Each of the following sections describing an alternative water supply project contains an environmental analysis consisting of a brief description of the environmental setting of the particular project area, and a brief discussion of the probable environmental consequences and mitigation liabilities of that alternative. This section presents the methods used to perform the evaluations, a broad overview of the environmental characteristics and concerns of the 13 county geographical area encompassed by the North Central region of the Trans-Texas Water Program, and a comparative discussion of the potential environmental effects and mitigation needs that would accompany implementation of the various water supply alternatives.

MATERIALS AND METHODS

The environmental analyses reported in this document are not exhaustive, site specific 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 include the Texas Parks and Wildlife Department; Resource Protection Division; Texas Natural Heritage Program (TNHP) data and mapping files for endangered, protected and sensitive resources; Texas Organization for Endangered Species' (TOES) listings of endangered, threatened and rare animals and plants; the U.S. Fish and Wildlife Service National Wetland Inventory (NWI) maps; NHAP aerial photography; Texas Archeological Research Library; and the U. S. Department of Agriculture Soil Conservation County Soil Surveys. Information from these sources, including cultural resources, natural resources, protected species, and potential wetland areas was mapped on 7.5 minute quadrangles maps of the study area maintained at Paul Price Associates, Inc. References to specific data sources are provided in footnotes and text.

Because the need for environmental studies and mitigation activities typically result from the need to obtain state and federal permits, a regulatory review was performed on each alternative to identify potential conflicts with the environmental compliance standards. With respect to most of the alternatives considered here the Clean Water Act (33 USC 1344), the Rivers 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) are usually the controlling regulations. 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.

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 Archeological and Historic Preservation Act (PL93-291).

The Texas Water Development Board has adopted guidelines[1], developed cooperatively with Texas Parks and Wildlife Department, that outline major environmental concerns that must be addressed in evaluating the various water supply alternatives. This outline was not meant to be exhaustive or exclusive, but that the listed concerns were 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 instream flow requirements have not been established for most Texas waters, a uniform set of streamflow criteria has been applied to all new (unpermitted)

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[1] Texas Water Development Board, Texas Parks and Wildlife Department, and Texas Natural Resource Conservation Commission, "Consensus Criteria for Environmental Water Needs"

projects so they can be evaluated on a uniform basis. Alternatives that involve the use of existing, permitted facilities are evaluated under presently prevailing instream flow requirements.

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

1) Each alternative selected for consideration was mapped on 7.5 minute topographic maps,

2) Descriptions of construction methods and operational characteristics of each alternative were obtained from HDR Engineering,

3) The general environmental effects of project components were identified: for example, construction activities that may disturb soils and vegetation, stream crossing methods or other potential wetland disturbances, potential changes in historical streamflows, circulation patterns, or water quality, continuing vegetation management, permanent structures, inundation of lotic, riparian and upland habitats, land use changes, and waste production and discharge.

4) For each alternative and an appropriate buffer zone, available information was compiled and mapped on protected, rare and sensitive species, communities and environmental features, wetlands, public properties, terrestrial vegetation and habitats, Land use, aquatic habitats, pre-existing environmental problems, and regulatory constraints.

5) The final step was to 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) to assess the nature and probable significance of the environmental consequences of implementing a particular alternative.

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 we attempted 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, may have been examined somewhat less closely. On the other hand, some alternatives had relatively recent studies available that provided significantly more detailed information than was available for the majority of other alternatives. We are confident, however, that this report outlines the major environmental characteristics, potential impacts, and probable mitigation liabilities of each alternative in a reasonably objective framework, so that they can be ranked in terms of the nature and levels of environmental impact associated with each of them.

In making these assessments, we assumed that all alternatives involving new construction will require environmental and cultural resources surveys, including endangered species evaluations. We assumed that all significant adverse impacts from any alternative implemented will have to be mitigated by first attempting to avoid the impact, then by minimizing the impact to the extent practicable, and finally by compensating for unavoidable impacts. Based on past experience, we expect that the amount of effort that will have to be invested in environmental studies and interactions with resource agencies, and the likelihood of encountering significant environmental and cultural resources problems, will be proportional to the area to be disturbed, the characteristics and regional distribution of habitats (or cultural sites) to be affected, and to the degree of flexibility in available in siting project facilities and operational activities.

ENVIRONMENTAL SETTING

Climate

The North Central Texas study area is a subtropical zone where the humid gulf plains begin to grade into the more arid southern plains. The study area lies across three climatic divisions, the South Central, North Central and Edwards Plateau Climatic Divisions.[2] Bastrop, Burleson, Colorado, Fayette, Hays, Lee, Travis and Washington counties are in the South Central division; Bell, Milam and Williamson counties are in the southern part of the North Central division; and Burnet and Llano counties are on the eastern boundary of the Edwards Plateau Climatic Division. Across Texas, humidity and precipitation tend to decrease from east to west and average temperature decrease from north to south. Temperature variations are more pronounced in the western North Central Climactic Division due to the controlling influence of arid continental air while temperature ranges in the South Central division are moderated by the

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[2] Natural Fibers Information Center. "The Climates of Texas Counties". Natural Fibers Information Center, The University of Texas, Austin, Texas. 1987

Gulf Coast humid air. The Balcones fault marks the division between coastal plains and more arid upland Edwards Plateau. All three regions are characterized by a precipitaton regime dominated by discrete events, frontal passages, local convective storms and hurricane outliers. A substantial year to year variation in precipitation is also typical of the study area.

Physiography

Ecoregions are areas of land with similar geology, soils, vegetation and climate such that it encourages similar assemblages of animals to inhabitat the land creating a unique environment distinct from other bordering vegetation and organism assemblages. Many individuals and organizations have tried to describe and delineate the ecoregions of the United States.[3,4,5,6,7,8] Of the many different examples of delineations of ecoregions, Omernik's was specifically designed for water quality management and attempted to include aquatic ecosystems as one of the factors defining an ecoregion.[9] The Trans-Texas North Central study region contains several ecoregions. The different ecoregions occur in bands as seen in Figure 3.1-1. Omernik's classification of the ecoregions of the conterminous United States place the study in an area containing the Central Texas Plateau, the Texas Blackland Prairies, the East Central Texas Plains and the Western Gulf Coastal Plain.[10] Omernik delineated ecoregions based on the hypothesis that ecosystems and their components display regional patterns that reflect spatially variable combinations of underlying causal factors such as climate, geology, physiography, soils and vegetation.

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[3] Herbertson, AJ. The Major Natural Regions: An Essay in Systematic Geography. Geographical Journal 25:300-312. 1905.

[4] Austin, ME. Land Resource Regions and Major Land Resources Areas of the United States. Rev. ed. Agricultural Handbook 296. Soil Conservation Service, US Department of Agriculture, Washington, DC. 1972.

[5] Bailey, RG. Ecoregions of the United States. Map (scale 1:7,500,000). Intermountain Region, Forest Service, US Department of Agriculture, Ogden, Utah. 1976.

[6] Kuchler, AW. Potential Natural Vegetation. Map (scale 1:7,500,000). The National Atlas of the Unites States of America, pp. 89-91. US Geological Society, Washington, DC. 1970.

[7] Trewartha, GT. An introduction to weather and climate. 2nd edition. McGraw-Hill, New York. 1943.

[8] Omernik, J.M. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77:118-125. 1987.

[9] Omernik, J.M. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77:118-125. 1987.

[10] Omernik, J.M. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77:118-125. 1987.

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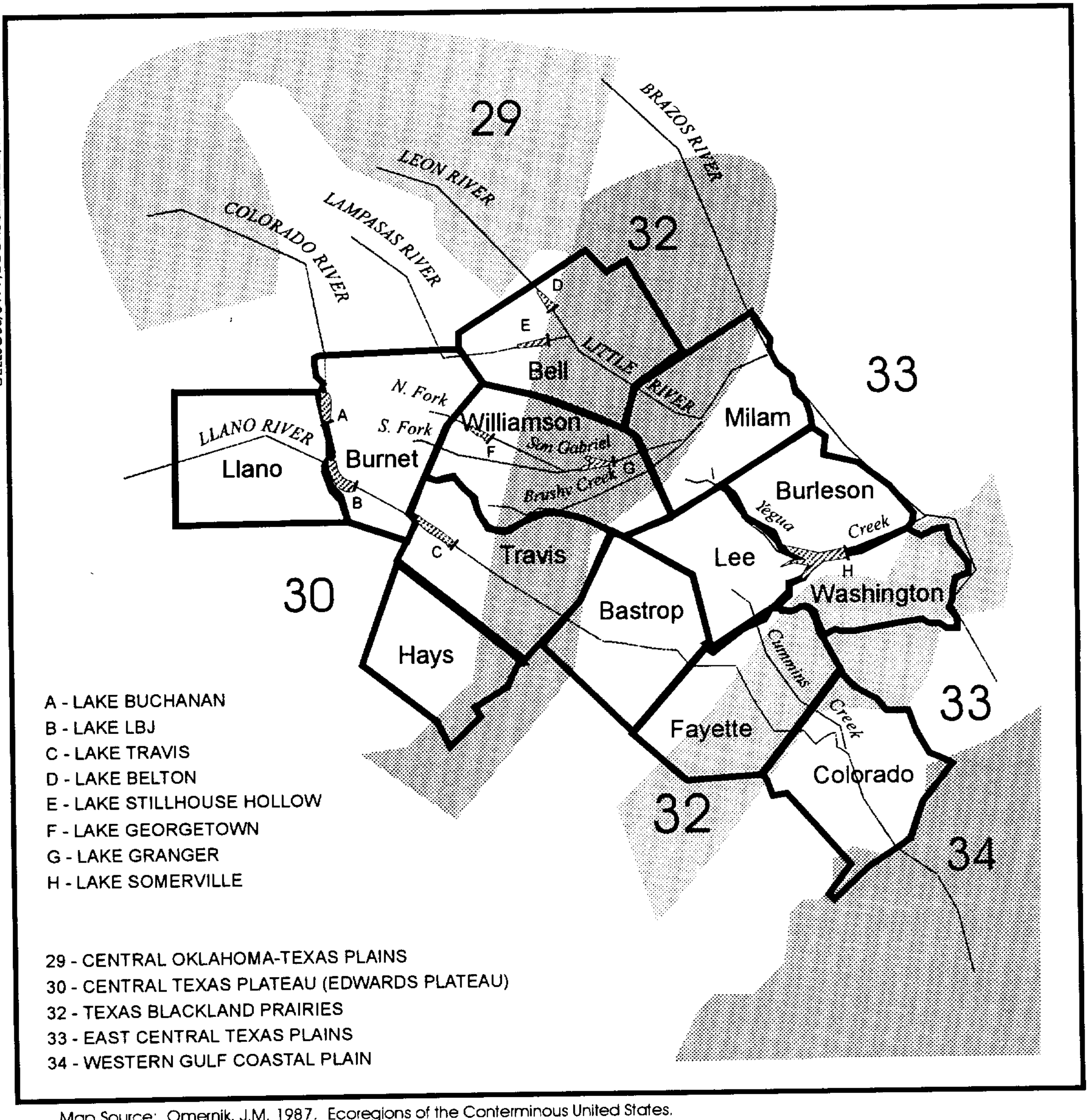

Map Source: Omernik, J.M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77:118-125.

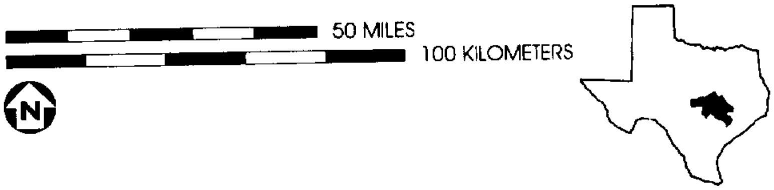

Figure 3.1-1

Ecoregions
Trans Texas Water Program
North Central Study Area

Paul Price Associates, Inc.

ECOLOGY, WATER QUALITY, CULTURAL RESOURCES, PLANNING

The physiographic regions of the study area are defined by the Balcones Fault zone which divides the western plateaus and upland plains of the Edwards Plateau from the rolling to hilly Blackland prairies and eastern forests. His brief discussion of the vegetation describes the Central Texas Plateau, west of the Balcones Escarpment, as tablelands with moderate relief, plains with hills and open high hills covered with a juniper/oak or mesquite/oak savannah. The Texas Blackland prairies east of the Balcones Escarpment are irregular grassland plains or tablelands of juniper/oak savannah and mesquite/oak savannah. In contrast, the East Texas Central Plains, east of and interspersed with the Texas Blackland Prairies are irregular plains of oak and hickory. The Western Gulf Coastal Plains are a flat bluestem/sacahuista prairie. The divisions between and descriptions of these different ecoregions closely resemble the vegetational areas of Texas, described by Gould.[11] Vegetational areas are regions whose dominant plant community and distribution patterns (savannahs, forests, parks, etc.) are distinctly different from other nearby vegetation groups. The Central Texas Plateau ecoregion is comparable to the Edwards Plateau vegetational area, the Texas Blackland Prairies ecoregion is nearly identical to the Blackland Prairies vegetational area, the East Central Texas Prairies ecoregion is equivalent to the Post Oak Savannah vegetational area and the Western Gulf Coastal Plains ecoregion corresponds to the Gulf Prairies and Marshes vegetational area (Figure 3.1-2).

Geology

Geologic units that outcrop within the study area include: 1) the very old (Cambrian and Precambrian), igneous and metamorphic formations of the Llano uplift in the northwest, and 2) the sedimentary sandstones, limestones and unconsolidated sands that outcrop as successfully younger belts as one progresses to the southeast toward the Gulf of Mexico.[12,13,14,15] These

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

[12] University of Texas at Austin, Bureau of Economic Geology. Geologic Atlas of Texas, San Antonio Sheet. Austin, Texas. 1982.

[13] University of Texas at Austin, Bureau of Economic Geology. Geologic Atlas of Texas, Llano Sheet. Austin, Texas. 1981.

[14] University of Texas at Austin, Bureau of Economic Geology. Geologic Atlas of Texas, Seguin Sheet. Austin, Texas. 1974.

[15] University of Texas at Austin, Bureau of Economic Geology. Geologic Atlas of Texas, Austin Sheet. Austin, Texas. 1982.

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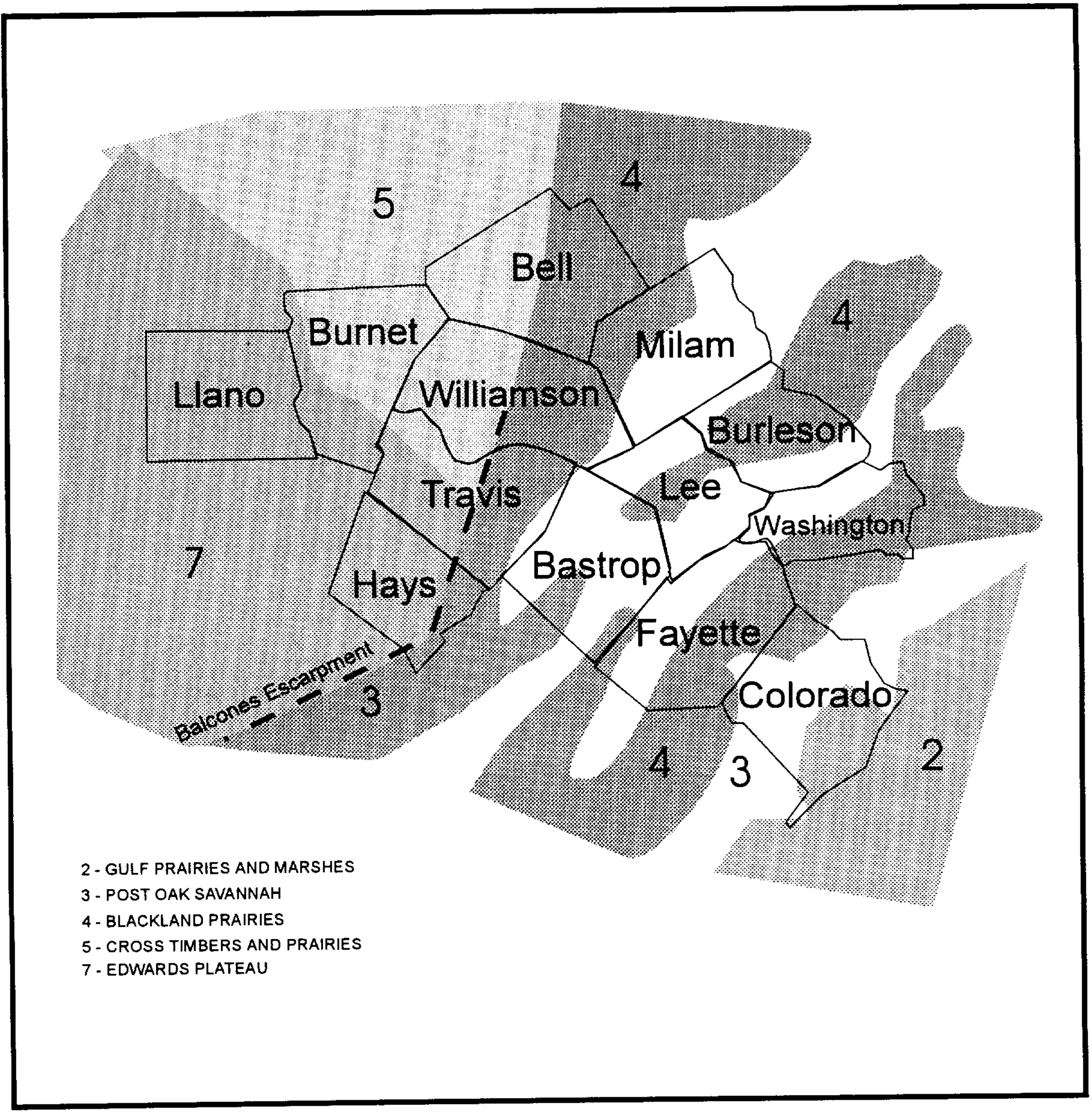

Map Source: Gould, F.W. 1975. The Grasses of Texas. Texas A&M University Press. College Station, Texas.

50 MILES
100 KILOMETERS

N

Figure 3.1-2

Vegetational Areas
Trans Texas Water Program
North Central Study Area

Paul Price Associates, Inc.

ECOLOGY, WATER QUALITY, CULTURAL RESOURCES, PLANNING

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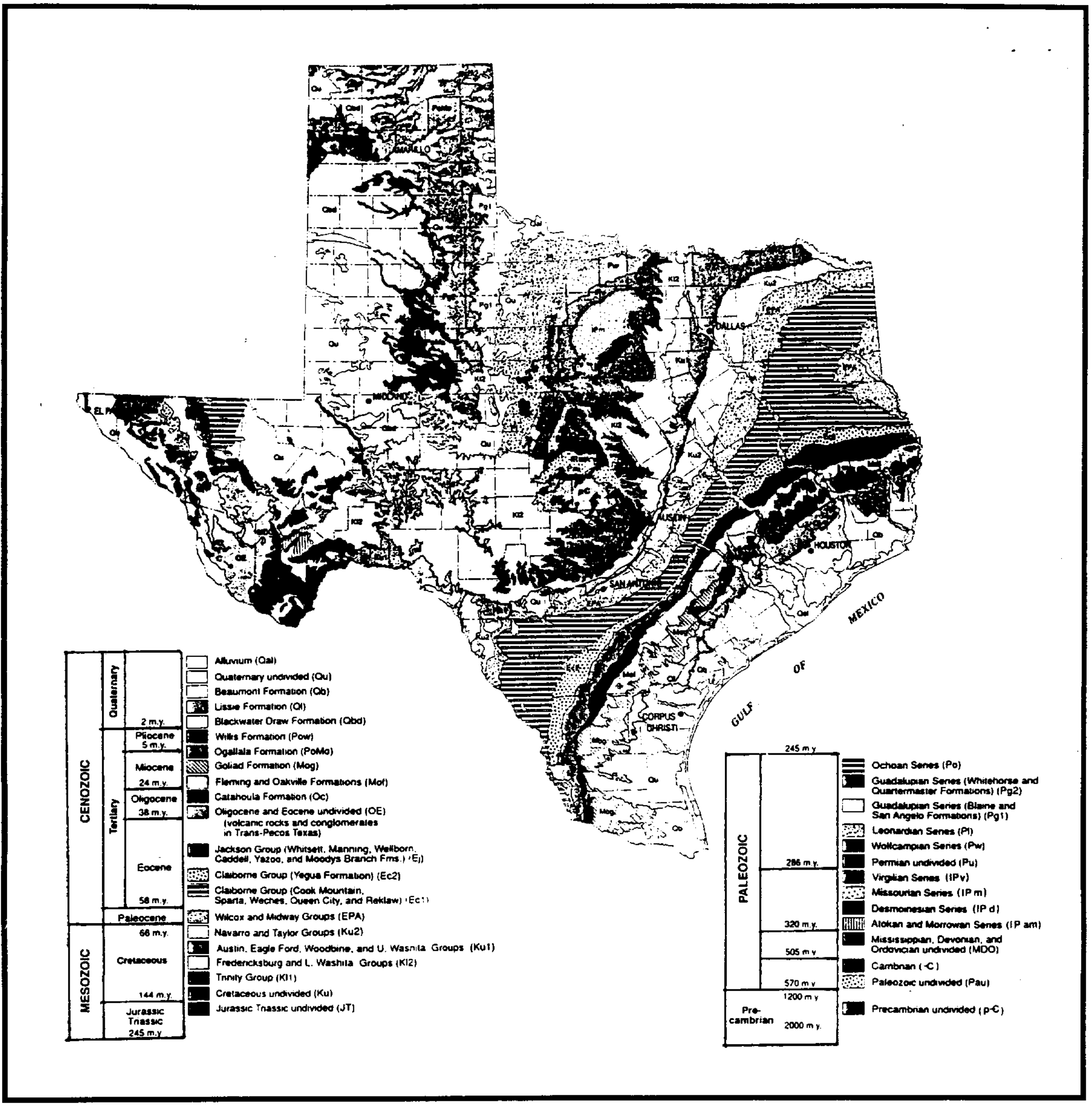

Map Source: Bureau of Economic Geology. 1992. Geology of Texas. Bureau of Economic Geology, University of Texas at Austin, Austin, Texas.

Figure 3.1-3

Geology of Texas
Trans Texas Water Program
North Central Study Area

Paul Price Associates, Inc.

ECOLOGY, WATER QUALITY, CULTURAL RESOURCES, PLANNING outcrops are locally overlain by the youngest formations, Quaternary riverine deposits such as the Leona Formation and fluvial terrace deposits Figure 3.1-3.

The limestone deposits of the Trans-Texas North Central study area deserve special mention due to the impact their uplift and karst features have on the present day central Texas geography and biota. The Edwards limestones were deposited as calcareous marine sediments under a shallow, tropical sea 140 million years ago during the Cretaceous Period.[16] During the Cretaceous, regional uplifting resulted in partial erosion of the upper Edwards sediments and non-deposition of Del Rio Clay in the Geology of Texas Trans Texas Water Program North Central Study Area northern and western portions of modern day Edwards Plateau.[17] The Edwards Formation contributed to the stratigraphic and to the climatic factors that control surface and subsurface water resource development known as the Edwards Aquifer. The aquifer development occurred within rocks of the Edwards Limestone and equivalent limestones. Major recharge occurs in streambed underlain with faulted or cavernous limestone and on low-relief, plateau uplands underlain by karstic limestone.[18]

Some karst features may have formed at this time.[19] More marine calcareous sediments were deposited during the Upper Cretaceous.[20] Regional uplift in the Early Tertiary. The Cretaceous formations were tilted and fractured. Erosion of the Cretaceous limestones included solutional widening of fractures by groundwater. Mountain-building to the west initiated major stream development.[21]

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[16] Elliott, William R. and George Veni, editors. The Caves and Karst of Texas: A Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau. National Speleological Society, Huntsville, Alabama. 1994.

[17] Elliott, William R. and George Veni, editors. The Caves and Karst of Texas: A Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau. National Speleological Society, Huntsville, Alabama. 1994.

[18] Woodruff, C.M., Jr. and P.L. Abbott Drainage-Basin Evolution and Aquifer Development in a Karstic Limestone Terrain, South-Central Texas, USA. Earth Surface Processes, 4(4): pp. 319-334. 1979.

[19] Elliott, William R. and George Veni, editors. The Caves and Karst of Texas: A Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau. National Speleological Society, Huntsville, Alabama. 1994.

[20] Elliott, William R. and George Veni, editors. The Caves and Karst of Texas: A Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau. National Speleological Society, Huntsville, Alabama. 1994.

[21] Elliott, William R. and George Veni, editors. The Caves and Karst of Texas: A Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau. National Speleological Society, Huntsville, Alabama. 1994.

On the surface, the Miocene was a period of uplift and fault activity. The Llano region was uplifted nearly 2,000 feet. Since the uplifting, Cretaceous deposits on the domed uplift have eroded, exposing the earlier igneous and metamorphic rocks beneath the younger deposits. The oldest outcrops of granites, schists and gneisses (e.g., Enchanted Rock) are found in Llano County, the western-most portion of the Trans-Texas North Central study area.

The Miocene was another period of faulting, especially Balcones Faulting. The ancestral Pecos River was probably begining to exise the Edwards carbonates, developing new outlets (springs) for groundwater discharge and enhancing groundwater circulation. These sinks probably did not reach the surface. The modern Edwards aquifer system was largely created by process started by the Balcones faulting system of fractures and faults, many perpendicular to the dip of the Cretaceous strata. Groundwater moved along the open fractures towards discharge points at the bottom of stream valleys at lower elevations. A continuously circulating discharge system developed. Dissolution enlarged the initial flow paths along the faults. The enhanced circulation formed large phreatic conduits. These conduits enlarged and many collapsed creating subsidence sinkholes underground.[22] Because groundwater downdip into the deeper, less permeable sections of the Edward Formation was restricted, it lacks the solution enlargements, recrystalization, and calcitized dolomite characteristic of the equivalent rocks updip. [23] The "bad water" line is a boundary that was not crossed by circulating ground water. Although the interconnections among fresh water, "bad water," and the deep brines is speculative, patterns of groundwater flow can be inferred from the location of recharge, discharge and the distribution of hydraulic head. By the late Miocene or Early Pliocene portions of the limestone were exposed to the surface and extensive karstification began.[24] This period was instrumental in creating many of the caves, springs and surface karst features that characterize the Edwards Plateau today.

The porous, honey-combed formations making up the Edwards and associated limestones constitute the Edwards Aquifer, the ground water source of numerous municipal and other users.

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[22] Elliott, William R. and George Veni, editors. The Caves and Karst of Texas: A Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau. National Speleological Society, Huntsville, Alabama. 1994.

[23] Abbott. 1975.

[24] Elliott, William R. and George Veni, editors. The Caves and Karst of Texas: A guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau. National Speleological Society, Huntsville, Alabama. 1994.

and which is critical to the maintenance of the spring habitats critical to the survival of several endangered species. The aquifer has three parts: 1) the drainage, or catchment area, 2) the recharge zone, and 3) the reservoir zone. Input to the aquifer comes from rainfall 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.

Along the Balcones fault zone recharge occurs through porous and faulted limestone in stream beds, sinkholes, and fractures, rather than over the general land surface.[25] About 75 percent of the recharge volume enters the aquifer in stream channels[4].[26] The aquifer reservoir 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 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. The width varies from about 5 to about 30 miles.[27] 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.

Karst is a term used to describe land formations created when calcium carbonate dissolved from limestone bedrock creates numerous sinkholes and caves. The fractures in the Balcones Fault Zone and caused by processes active on the Edwards Formation. Some karst features act as important recharge features and aquifer features desccribed in the preceeding discussion. Downcutting by water and faulting increased dissection and created karst "islands habitats" that are barriers to distribution of species adapted to cave conditions, troglobites. Troglobites of the Edwards require, little light, high humidities and most require stable

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[25] Caran, S. Christopher. Lineament Analysis and Inference of Geologic Structure. 1982.

[26] 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.

[27] 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.

temperatures, generaly warm and moist conditions. These karst habitats depend on surface plant and animal communities for nutrients and energy in the form of leaf mulch, plant roots, organic debris washing into the feature, and animals and insects which forage on the surface and return underground for rest and shelter.

As the Edwards Uplift eroded in the late Miocene and Early Pliocene,[28] ancient rivers deposited rich soils from the mountains in the coastal zones of the inland sea, which today constitute the Blackland Prairie and Post Oak Savannah. These deposits also formed the Wilcox and Midway Groups and the Carrizo Sands, which are major aquifers supplying groundwater to the region east of the Balcones Escarpment. In the Quaternary, localized deposits of sands and gravels from various sources and ages were deposited in the river systems. Deposited in the Leona Formation or as fluvial terraces, these relatively recent formations outcrop locally along upland divides and usually occur juxtaposed against older geologic deposits parallel to modern river and stream valleys.

Glaciers receded, and sea levels rose during the Early Holocene warming trend. A hotter and dryer climate led to the retreat of conifers and other species. In Central Texas mixed deciduous woods were largely replaced by oak savanna.[29]

BIOGEOGRAPHY

The projects under consideration in the Trans-Texas North Central study area lie within four of the ten vegetational areas of Texas, the Cross Timbers and Prairies, the Edwards Plateau, the Blackland Prairie, and the Post Oak Savannah, as described by Gould in 1975 (Figure 3.1-2).[30] A fifth vegetational area, the Gulf Prairies and Marshes vegetational area, extends into the southeastern third of Colorado County.

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[28] Elliott, William R. and George Veni, editors. The Caves and Karst of Texas: A Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau. National Speleological Society, Huntsville, Alabama. 1994.

[29] Black, S.L. Central Texas Plateau Prairie. From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos Texas. Thomas H. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bemont. Arkansas Archeological Survey Research Series Number 33:17-38. Center for Archaeological Research at the University of Texas at San Antonio, Texas A & M University, and the Arkansas Archeological Survey. 1989.

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

The northwestern part of the project area lies within the Cross Timbers and Prairies vegetational area (the western half of Bell, Williamson and Travis Counties north of the Colorado River). The southwestern part of the project area lies within the Edwards Plateau vegetational area (western Travis County south of the Colorado River, Hays, and Llano Counties). Southeast of the Balcones Escarpment, the project area is characterized by alternating bands of the Post Oak Savannah and Blackland Prairies vegetational areas.

Eastern Bell, Williamson, and Travis Counties, and western Milam County lie primarily within the Blackland Prairies. Bastrop, Lee, and Burleson Counties, and the northwestern halves of Fayette and Washington Counties lie within the Post Oak Savannah. The southeastern halves of Fayette and Washington Counties, and most of Colorado County lie within another band of the Blackland Prairie vegetational area. The Balcones Escarpment divides the Cross Timbers and Prairies and the Edwards Plateau from areas of the Post Oak Savannah and Blackland Prairie.

Cross Timbers and Prairies

The Cross Timbers and Prairies vegetational area comprises a large area of closely associated prairies and woodlands (Figure 3.1-2).[31] In this area, soils vary from slightly acidic sandy or clay loams to dark calcareous clays over limestone. Topography is rolling to hilly and deeply dissected, with rapid surface drainage. Marked variation in vegetative cover is associated with differences in the area's soils and topography.

The predominant grasses of the Cross Timbers and Prairies vegetational area typically include little bluestem (*Schizachyrium scoparium* var. *frequens*), big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*) , switchgrass (*Panicum virgatum*), tall dropseed (*Sporobolus asper),* Canada wild-rye (*Elymus canadensis*), and Texas wintergrass (*Stipa leucotricha*).[32] Common woody vegetation has been traditionally dominated by oaks such as shinnery (*Q. havardii*), blackjack (*Q. marilandica*), post (*Q. stellata*), and live (*Quercus*

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[31] Ibid.

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

virginiana), however, woody brush plants such as mesquite and juniper have invaded this vegetational area.[33]

Edwards Plateau

The Edwards Plateau vegetational area is a deeply dissected, rapidly drained rocky plain with broad, flat or undulating divides (Figure 3.1-2). The Edwards Plateau is underlain by horizontally bedded hard to soft dolomitic limestone and marl from shallow, marine Cretaceous sediments, as described in the geology subsection. The Edwards limestone is a cavernous forming, dolomite- and chert-honeycombed limestone whose karst features are described in greater detail in the geology section. Surfaces are typically a plateau bordered by scarps with subsurface caverns of the upper Edwards Aquifer (refer to the geology section for a more detailed account of the aquifer). The shallow and stony soils are formed in limestone and marl in long ridges. Deeper calcareous, clayey soils are found in stream and creek valleys.[34] Its mostly shallow soils found within the study area are underlain by limestone and caliche. The Plateau's vegetation has historically been grassland or open savannah-type plains with tree or brushy species found along rocky slopes and stream bottoms. Stream bottom habitats were created as rivers, fed by numerous springs, cut canyons through the plateau, especially near its margins, and formed unique niches for a variety of plant species.

Throughout the more savannah-type plains of the Edward's Plateau, brush species are generally considered as "invaders", with the climax stages composed of grassland. Within this area, the steeper canyon slopes have historically supported a dense oak-Ashe juniper thicket. The most important climax grasses of the Plateau include switchgrass, several species of bluestems and gramas, Indian grass, Canada wild-rye (*Elymus canadensis*), curly mesquite (*Hilaria berlangeri*), and buffalograss (*Buchloe dactyloides*). The rough, rocky areas typically support a tall or mid-grass understory and a brush overstory complex consisting primarily of live oak (*Quercus virginiana*), Texas oak (*Q. buckleyi*), shinnery oak (*Q. havardii*), Ashe juniper (*Juniperus ashei*), and mesquite (*Prosopis glandulosa*). The ferns as well as many of the

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[33] Ramos, Mary G. (ed), 1996-1997 Texas Almanac. Dallas Morning News, Inc., Communications Center. Dallas, Texas. 1995.

[34] Soil Conservation Service. Williamson County. U.S. Department of Agriculture.

flowering plants which are common to the area are primarily lithophilous ("rock-loving"), and are represented primarily by various species of lipferns (*Cheilanthes* spp.), cloak-ferns (*Notholaena* spp.), and cliff brakes (*Pellaea* spp.). Columbine (*Aquilegia canadensis*), and endemic species such as anemone *(Anemone edwardsianas)* and wand butterfly-bush (*Buddlega racemosa*) are also present. These plants are sometimes found together with species such as mockorange (*Philadelphus* spp.), American smoke-tree (*Cotinus americana*), spicebush (*Benzoin aestivale*), and the endemic silver bells (*Styrax platanifolia* and *S. texana*) on large boulders and in shaded ravines.

With overgrazing of the Edwards Plateau in the last century, the dominant vegetation has changed from its historical climax community. Overgrazing by cattle creates a disturbed habitat where the invasive brush and junipers can dominate if this condition persists. Dominate native grass would be little bluestem with indiangrass, big bluestem, wildrye, side oats grama, dropseed, and others in this community. Woody plants, about 15 percent of cover, would primarily include post oaks, live oaks, cedar elm, and hackberry. Under heavy grazing pressure, little bluestem, indiangrass and big bluestem are replaced by sideoats grama, Texas wintergrass, buffalo grass and silver bluestem. If pressure continues ashe juniper, agarita, mesquite, pricklypear, annual grasses and forbs dominate.

Balcones Escarpment

Interstate 35 and the Balcones Escarpment marks the southern and eastern boundaries of the Cross Timbers and Prairies, and the Edwards Plateau (Figure 3.1-2 (I-35 not shown)). It is characterized by a complex of porous, faulted limestones, which allow substantial volumes of water to flow into the Edwards Aquifer, particularly in stream beds, sinkholes, and fractures.[35] The Balcones Escarpment has many sinkholes, caves, and solution features with springs frequently flowing where the base of the Edwards limestone formations are exposed to the surface. The ecotone, or ecological transition zone between the Edwards Plateau and the Blackland Prairie forms unique habitats favorable to a number of rare and protected species. The isolated springs and caves which are common along the enscarpment favor

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[35] Caran, C.S. Lineament Analysis and Inference of Geologic Structure. 1982.

endemism in which organisms become narrowly adapted to the local environment. In the most extreme cases an entire species may be limited to a particular spring or cave. In addition to containing many endemic species, the Balcones Enscarpment delineates conspicuous changes in climate, vegetation, and animal life which occur with the transition from the Cross Timbers and Prairies, and the Edwards Plateau to the Blackland Prairies and Post Oak Savannah.

Blackland Prairie

The Blackland Prairie vegetational area (Figure 3.1-2) has experienced extensive agricultural development. Its highly productive and fertile soils are relatively uniform, dark-colored clays interspersed with some gray, acid, sandy, loams.[36] The topography of this area is gently rolling, and marked by numerous hills with rounded slopes. The Blackland Prairie, which is broken by tree-lined tributaries of rivers such as the Brazos and Colorado, is considered a true prairie, marking some of the southern-most reaches of the Great Plains.

As a true prairie, grasses constitute a large portion of the native flora in the Blackland Prairie. Little bluestem (*Schizachyrium scoparium* var. *frequens*) is the climax dominant of this vegetational area. Other important grasses include big bluestem (*Andropogon gerardii*) , Indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), sideoats grama (*Bouteloua curtipendula*), hairy grama, (*Bouteloua hirsuta*), tall dropseed (*Sporoboulus asper*), silver bluestem (*Bothriochloa saccharoides* var. *torreyana*) and Texas wintergrass (*Stipa leucotricha*). Under heavy grazing, Texas wintergrass, buffalograss (*Buchloe dactyloides*), Texas grama (*Bouteloua rigidiseta*), smutgrass (*Sporoboulus indicus*), and many annuals increase within or invade these areas. Mesquite has invaded hardland sites of the southern portion of the Blackland Prairies. Numbers of post oak (*Q. stellata*) and blackjack oak (*Q. marilandica*) increase on the medium-to-light-textured soils. Although classified as a true prairie, the Blackland Prairie has substantial amounts of timber, especially along the streams that traverse it. Common tree species include a variety of oaks, pecan (*Carya illinioensis*), cedar elm (*Ulmus crassifolia*), bois d'arc

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[36] Schmidly, D.J. Texas Mammals East of the Balcones Fault Zone. Texas A&M University Press. College Station, Texas. 1983.

(*Maclura pomifera*), and mesquite. There is evidence that the brush and tree densities in this area have increased dramatically from the virgin condition.[37]

Post Oak Savannah

The Post Oak Savannah vegetational area (Figure 3.1-2) has undergone agricultural development, but livestock grazing tends to be more important than row crop production. The topography of the Post Oak Savannah is gently rolling to hilly, and the entire area slopes gently from the nothwest to the southwest. Soils on the uplands 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. Like all of the other vegetational areas in this region, the Post Oak Savannah contains many small streams, in addition to sections of the Colorado and Brazos Rivers.

Climax grasses on the Post Oak Savannah include little bluestem, Indian grass, switchgrass, purpletop (*Tridens flavus*), silver bluestem (*Bothriochloa saccharoides* var. *torreyanna*), Texas wintergrass, and narrowleaf woodoats (*Chasmanthium sessiliflorum*). Although the overstory is primarily post oak and blackjack oak, many other brush and weedy species are also common within this vegetational area. Some invading plants found in this area are red lovegrass (*Eragrostis oxylepis*), broomsedge (*Andropogon virginicus*), splitbeard bluestem (*Andropogon ternarius*), yankeeweed (*Eupatorium compositifolium*), bullnettle (*Cnidoscolus texanus*), greenbrier (*Smilax* sp.), yaupon (*Ilex vomitoria*), smutgrass (*Sporobolus indicus*), and western ragweed (*Ambrosia trifida*).

ENDANGERED, THREATENED, AND CANDIDATE SPECIES

Table 3.1-2 lists the endangered, threatened, and candidate species found in the Trans-Texas North Central area and their potential occurrence within the project area. Individual species are discussed in their appropriate alternative sections.

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

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Table 3.1-2

Endangered and Threatened Species For Bastrop (BA), Bell (BE), Burleson (BL), Burnet (BN), Colorado (CO), Fayette (FA), Hays (HA), Lee (LE), Llano (Ll), Milam (MI), Travis (TR), Williamson (WI) and Washington (WA) Counties, Texas

Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
Cave Myotis	*Myotis velifer*	Cave-dwelling; may also roost in rock crevices, old-buildings, and bridges	NL[1,5]	NL[6]	NL[8]	BE, BN, HA, LL, TR, WI	endemic
Elliot's short-tail Shrew	*Blarina hylophaga*	Groups of live oak trees on sandy soils, grassy vegetation	NL[1,5]	NL[6]	NL[8]	BA	endemic
Grey Wolf	*Canis Lupus*	Southern riparian and pine forest	E[1]	E[9]	E[8]	LL	historic
Llano Pocket Gopher	*Geomys texensis*	Deep, brown loamy sands or gravely sandy loams	NL[1,5]	NL[6]	NL[8]	LL	endemic
Red Wolf	*Canis rufus*	Southern riparian and pine forest	E[1]	E[9]	E[8]	BN, CO, LL	historic
AVES:							
American Peregrine Falcon	*Falco peregrinus anatum*	Open Coastal areas	E[1]	E[9]	E[8]	BA, BE, BL,BN, CO, FA, HA, LE, MI,TR, WA,WI	migratory
American Swallow-tailed Kite	*Elanoides forficatus*	Varied, moist open land with tall trees for nesting	NL[1,5]	T[9]	T[8]	BA, BE, BL CO, FA, LE, MI, TR, WI	endemic
Arctic Peregrine Falcon	*Falco peregrinus tundris*	Open Coastal Plain	E (S/A)[1]	T[9]	T[8]	BA, BE,BL,BN, CO, FA, HA, LE, LL, MI, TR, WA, WI	migratory
Attwater's Prairie Chicken	*Tympnuchus cupido attwateri*	Native coastal prairie grassland with diverse habitat of short, mid, and tallgrass; 50% climax	E[1]	E[9]	E[8]	CO	endemic
Bachman's Sparrow	*Aimophila aestivalis*	Mature longleaf pine-palmetto savannas, open pine woods, overgrown fields.	NL[1,5]	T[9]	WL[8]	LE	endemic
Bald Eagle	*Haliaeetus leucocephalus*	Large bodies of water with nearby roosting and nesting sites	T[1]	T[9]	E[8]	BA, BE, BL, BN, CO, FA, HA, LE, LL, MI, TR, WA, WI	migratory
Black-capped Vireo	*Vireo atricapillus*	Semi-open broad-leaved shrublands, oak-	E[1]	E[9]	T[8]	BA, BE, BN,FA,	migratory

Table 3.1-2
Endangered and Threatened Species For Bastrop (BA), Bell (BE), Burleson (BL), Burnet (BN), Colorado (CO), Fayette (FA), Hays (HA), Lee (LE), Llano (Ll), Milam (MI), Travis (TR), Williamson (WI) and Washington (WA) Counties, Texas

Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
		juniper woodlands with distinctive patchy, two-layered shrub-tree aspect				HA, LL, MI, TR, WI	
Brown Pelican	*Pelecanus occidentalis*	Ocean, salt bays, and coastal areas	E[1]	E[9]	E[8]	BA, BE,BL,BN, CO, FA, LE, LL, MI, TR, WA, WI	transient
Eskimo Curlew	*Numenius borealis*	Prairies, pastures, plowed fields, estuaries	E[1]	E[9]	E[8]	WA	Possibly extinct
Golden-cheeked Warbler	*Dendroica chrysoparia*	Woodlands with oak and mature juniper	E[1]	E[9]	T[8]	BA, BE, BN, HA, LE, LL, MI, TR, WI	migratory
Henslow's Sparrow	*Ammodramus henslowii*	Tallgrass prairie, wet meadows, sedge marshes, weedy fields.	NL[1,5]	NL[6,9]	NL[8]	BL, CO, FA, LE,MI,WA	Rare winter resident
Interior Least Tern	*Sterna antillarum*	Nesting on large river sandbars	E[1]	E[9]	E[8]	BA, BE, BN, FA,	transient

[1] U.S. Fish and Wildlife Service Division of Endangered Species. U.S. listed vertebrate animal species index by lead region and status as of January 31,1997. U.S. Fish and Wildlife Endangered Species Home Page.

[2] U.S. Fish and Wildlife Service Division of Endangered Species. U.S. listed invertebrate animal species index by lead region and status as of January 31,1997. U.S. Fish and Wildlife Endangered Species Home Page.

[3] U.S. Fish and Wildlife Service Division of Endangered Species. U.S. listed flowering plant species index by lead region and status as of January 31,1997. U.S. Fish and Wildlife Endangered Species Home Page.

[4] U.S. Fish and Wildlife Service Division of Endangered Species. U.S. listed Non-flowering plant species index by lead region and status as of January 31,1997. U.S. Fish and Wildlife Endangered Species Home Page.

[5] Federal Register. September 19, 1997. 50 CFR Part 17. Review of plant and animal taxa that are candidates and proposed for listing as endangered or threatened species. Fish and Wildlife Service Division, U.S. Department of the Interior. Proposed Rule.

[6] Texas Biological and Conservation Data System. Texas Parks and Wildlife Department, Endangered Resources Branch. County lists of Texas' special species. (Bastrop, Bell, Burleson, Burnet, Colorado, Fayette, Hays, Lee, Llano, Milam, Travis, Washington and Williamson Counties revised Jan. 13, 1997)

[7] Texas Organization for Endangered Species. August 1993. Endangered, threatened and watch lists of Texas plants. TOES Publication 9, third revision.

[8] Texas Organization for Endangered Species. January 1988. Endangered, threatened and watch lists of vertebrates of Texas. TOES Publication 6.

[9] Texas Biological and Conservation Data System. Texas Parks and Wildlife Department, Endangered Resources Branch. Species with Federal or Texas State Endangered or Threatened Status. Dec. 1996

[10] Texas Organization for Endangered Species. Sept. 1988. Invertebrates of Special Concern TOES Publication 7.

E - Endangered PE - Proposed endangered S/A - threatened due to similarity of appearance to protected species T - Threatened C - Candidate NL - Not Listed WL - Watch List
V - Category V TOES Plant Watch List

Table 3.1-2

Endangered and Threatened Species For Bastrop (BA), Bell (BE), Burleson (BL), Burnet (BN), Colorado (CO), Fayette (FA), Hays (HA), Lee (LE), Llano (Ll), Milam (MI), Travis (TR), Williamson (WI) and Washington (WA) Counties, Texas

Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
	athalassas					HA, LE, LL, MI, TR, WI	
Mountain Plover	*Charadrius montanus*	Western plains; shortgrass prairies; Western Panhandle and Trans-Pecos	C[1,5]	NL[6,9]	NL[8]	BA, BE, BL, BN, CO, FA, HA, LE, LL, MI, TR, WA, WI	transient
Peregrine Falcon	*Falco Peregrinus*	Open coastal areas	E (S/A)[1]	NL[6,9]	NL[8]	BL, CO, HA, TR, WI	transient
Piping Plover	*Charadrius melodus*	Beaches, coastal flats	T[1]	T[9]	T[8]	BA, BE, BL, CO, FA, LE, MI, TR, WA, WI	transient
Red-cockaded Woodpecker	*Picoides borealis*	Longleaf pine savannahs	E[1]	E[9]	E[8]	WA	endemic
Reddish Egret	*Egretta rufescens*	Coastal wetland islands	NL[1,5]	T[9]	NL[8]	BA, CO	transient
White-faced Ibis	*Plegadis chihi*	Bays, marshes, lakes, ponds; Coastal Plains, inland in eastern Texas	NL[1,5]	T[9]	T[8]	BA, BE, BL, BN, CO, FA, HA, LE, LL, MI, TR, WA, WI	transient
White-tailed Hawk	*Buteo albicaudatus*	Grasslands and coastal prairies	NL[1,5]	T[9]	T[8]	CO, TR	endemic
Whooping Crane	*Grus americana*	Coastal wetlands, Matagorda and Aransas Islands	E[1]	E[9]	E[8]	BA, BE, BL, BN, CO, FA, HA, LE, LL, MI, TR, WA, WI	transient
Wood Stork	*Mycteria americana*	Coastal wetlands, dispersal	NL[1,5]	T[9]	T[8]	BA, BE, BL, BN, CO, FA, HA, LE, LL, MI, TR, WA, WI	endemic

Table 3.1-2
Endangered and Threatened Species For Bastrop (BA), Bell (BE), Burleson (BL), Burnet (BN), Colorado (CO), Fayette (FA), Hays (HA), Lee (LE), Llano (Ll), Milam (MI), Travis (TR), Williamson (WI) and Washington (WA) Counties, Texas

Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
Zone-tailed Hawk	*Buteo albonotatus*	Arid scrub, pine-oak woodland; mountains of Trans-Pecos and western Edwards Plateau	NL[1,5]	T[9]	T[8]	HA, LL, TR, MI	transient
REPTILES:							
Cagle's Map Turtle	*Graptemys caglei*	Waters of the Guadalupe River Basin	C[5]	NL[6,9]	NL[8]	HA	endemic
Concho Water Snake	*Nerodia paucimaculata*	Concho and upper Colorado river courses with mixture of shallow riffles and deeper flowing pools	T[1]	E[9]	E[8]	LL	endemic
Texas Indigo Snake	*Drymarchon corais erebennus*	Open arid and semi-arid regions with sparse vegetation including grass, cactus, scattered	NL[1,5]	T[9]	WL[8]	TR	endemic

[1] U.S. Fish and Wildlife Service Division of Endangered Species. U.S. listed vertebrate animal species index by lead region and status as of January 31,1997. U.S. Fish and Wildlife Endangered Species Home Page.

[2] U.S. Fish and Wildlife Service Division of Endangered Species. U.S. listed invertebrate animal species index by lead region and status as of January 31,1997. U.S. Fish and Wildlife Endangered Species Home Page.

[3] U.S. Fish and Wildlife Service Division of Endangered Species. U.S. listed flowering plant species index by lead region and status as of January 31,1997. U.S. Fish and Wildlife Endangered Species Home Page.

[4] U.S. Fish and Wildlife Service Division of Endangered Species. U.S. listed Non-flowering plant species index by lead region and status as of January 31,1997. U.S. Fish and Wildlife Endangered Species Home Page.

[5] Federal Register. September 19, 1997. 50 CFR Part 17. Review of plant and animal taxa that are candidates and proposed for listing as endangered or threatened species. Fish and Wildlife Service Division, U.S. Department of the Interior. Proposed Rule.

[6] Texas Biological and Conservation Data System. Texas Parks and Wildlife Department, Endangered Resources Branch. County lists of Texas' special species. (Bastrop, Bell, Burleson, Burnet, Colorado, Fayette, Hays, Lee, Llano, Milam, Travis, Washington and Williamson Counties revised Jan. 13, 1997)

[7] Texas Organization for Endangered Species. August 1993. Endangered, threatened and watch lists of Texas plants. TOES Publication 9, third revision.

[8] Texas Organization for Endangered Species. January 1988. Endangered, threatened and watch lists of vertebrates of Texas. TOES Publication 6.

[9] Texas Biological and Conservation Data System. Texas Parks and Wildlife Department, Endangered Resources Branch. Species with Federal or Texas State Endangered or Threatened Status. Dec. 1996

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Endangered and Threatened Species For Bastrop (BA), Bell (BE), Burleson (BL), Burnet (BN), Colorado (CO), Fayette (FA), Hays (HA), Lee (LE), Llano (Ll), Milam (MI), Travis (TR), Williamson (WI) and Washington (WA) Counties, Texas

Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
		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					
Keeled Earless Lizard	*Holbrookia propinqua*	Prefers sandy environments, common on sand dunes and barrier beaches within its range	NL[1,5]	NL[6,9]	NL[8]	HA	endemic
Spot-tailed Earless Lizard	*Holbrookia lacerata*	Rocky desert flats, areas with sparse vegetation or mesquite-prickly pear associations, and the uplands of the Edwards Plateau	NL[1,5]	NL[6,9]	NL[8]	BA, HA, TR	endemic
Texas Garter Snake	*Thamnophis sirtalis annectans*	Varied, especially in moist habitats	NL[1,5]	NL[6,9]	NL[8]		endemic
Texas Horned Lizard	*Phrynosoma cornutum*	Varied, sparsely vegetated uplands, open desert and grasslands	NL[1,5]	T[9]	T[8]	BA, BE, BL,BN, CO, FA, HA, LE, LL, MI, TR, WA, WI	endemic
Texas Scarlet Snake	*Cemophora coccinea lineri*	Mixed hardwood scrub on sandy soils; feeds on reptile eggs; semi-fossorial; active April through September	NL[1,5]	T[9]	WL[8]	TR	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 through November	NL[1,5]	T[9]	T[8]	TR	endemic
Timber Rattlesnake	*Crotalus horridus*	Bottomland hardwoods	NL[1,5]	T[9]	NL[8]	BA, BE, BL, CO,	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
						FA, HA, LE, MI, TR, WI	
Western Smooth Green Snake	*Ohpeodrys vernalis blanchardi* or *Liochlorophis vernalis*	Coastal grasslands	NL[1,5]	E[9]	E[8]	CO, FA	endemic
AMPHIBIANS:							
Barton Springs Salamander	*Eurycea sosorum*	Barton Springs of the Edwards Aquifer; Balcones Escarpment	E[1]	NL[6,9]	NL[8]	TR	endemic
Blanco Blind Salamander	*Eurycea robusta*	Subterranean aquatic karst	NL[1,5]	E[6]	NL[8]	HA	endemic
Blanco River Springs Salamander	*Eurycea pterophila*	Subterranean aquatic karst and springs	NL[1,5]	NL[6,9]	NL[8]	HA, TR	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
Edwards Plateau Spring Salamander	*Eurycea* sp 7	Subterranean aquatic karst and springs	NL[1,5]	NL[6,9]	NL[8]	HA, TR	endemic
Georgetown Salamander	*Eurycea* sp. 5	Georgetown vicinity, springs of the Balcones Escarpment	NL[1,5]	NL[6,9]	NL[8]	WI	endemic
Houston Toad	*Bufo houstonensis*	Loamy, friable soils, temporary rain pools, flooded fields, ponds surrounded by forest or grass	E[1]	E[9]	E[8]	BA, BL, FA, CO, MI	endemic
Jollyville Plateau Salamander	*Eurycea* sp. 1	Springs below the Jollyville Plateau; Balcones Escarpment	NL[1,5]	NL[6,9]	NL[8]	TR, WI	endemic
Lesser Rio Grande Salamander	*Siren intermedia texana*	Wet or temporarily wet areas, arroyos, canals, ditches, and shallow depressions; requires moisture.	NL[1,5]	T[6]	E[8]	BA	endemic
Pedernales River Springs Salamander	*Eurycea* sp 6	Pedernales River Springs, Travis County	NL[1,5]	NL[6,9]	NL[8]	TR	endemic
Salado Springs Salamander	*Eurycea* sp 2	The Salado Springs system along Salado Creek, Bell County	NL[1,5]	NL[6,9]	NL[8]	BE	endemic
San Marcos Salamander	*Eurycea nana*	Spring flows, submerged vegetation	T[1]	T[6]	T[8]	HA	endemic
Texas Blind Salamander	*Typhlomolge rathbuni*	Subterranean streams of the Purgatory Creek system	E[1]	E[6]	T[8]	HA	endemic
Texas Salamander	*Eurycea neotenes*	Springs of the Edwards Aquifer and Balconies Escarpment	NL[1,5]	NL[6,9]	NL[8]	TR, WI	endemic
FISH:							
Blue Sucker	*Cycleptus elongatus*	Larger rivers throughout the Mississippi Basin; In Texas, major streams southward to the Rio Grande	NL[1,5]	T[9]	NL[8]	BA, BL, CO, FA, HA, TR	endemic
Fountain Darter	*Ethestoma fonticola*	San Marcos River to confluence with Blanco River; associated with San Marcos	E[1]	E[9]	E[8]	HA	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
		Salamander in quiet, clear water.					
Guadalupe Bass	*Micropterus treculi*	Clear flowing streams of eastern Edwards Plateau	NL[1,5]	NL[6,9]	WL[8]	BE, BN, CO, HA, LL, MI,TR, WI	endemic
San Marcos Gambusia	*Gambusia georgei*	San Marcos River to confluence with Blanco River, large clear spring-fed river	E[1]	E[9]	E[8]	HA	endemic
Smalleye Shiner	*Notropis buccula*	Medium to large rivers	NL[1,5]	NL[6,9]	WL[8]	BE, BL, TR	endemic
INVERTEBRATES:							
Amphipod	*Stygobromus russelli*	Subterranean waters throughout the Balcones Fault Zone and eastern Edwards Plateau	NL[2,5]	NL[6,9]	SOC[10]	TR	endemic
Bee Creek Cave	*Texella reddelli*	Karst formations of the Balcones	E[2]	NL[6,9]	SOC[10]	TR, WI	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
Harvestman		Escarpment					
Bifurcated Cave Amphipod	*Stygobromus bifurcatus*	Subterranean waters throughout the Balcones Fault Zone and eastern Edwards Plateau	$NL^{2,5}$	$NL^{6,9}$	SOC^{10}	TR	endemic
Bone Cave Harvestman	*Texella reyesi*	Karst formations of the Balcones Escarpment	E^{2}	$NL^{6,9}$	$NL^{6,10}$	TR, WI	endemic
Coffin Cave Mold Beetle	*Batrisodes texanus*	Karst formations of the Balcones Escarpment	E^{2}	$NL^{6,9}$	$NL^{6,10}$	WI	endemic
Comal Springs Riffle Beetle	*Heterelmis comalensis*	Headwater springs to the Comal River	PE^{5}	PE^{6}	$NL^{6,10}$	HA	endemic
Edwards Aquifer Diving Beetle	*Haideoporus texanus*	Springs of the Edwards Aquifer	$NL^{2,5}$	$NL^{6,,9}$	SOC^{10}	HA	endemic
Ezell's Cave Amphipod	*Stygobromus flagellatus*	Ezell's Cave, Hays County	$NL^{2,5}$	$NL^{6,9}$	SOC^{10}	HA	endemic
Flint's Net-Spinning Caddisfly	*Cheumatopsyche flinti*	Honey Creek, Hays County	$NL^{2,5}$	$NL^{6,9}$	SOC^{10}	HA	endemic
Kretschmarr Cave Mold Beetle	*Texamaurops reddelli*	Karst formations of the Balcones Escarpment	E^{2}	$NL^{6,9}$	SOC^{10}	TR, WI	endemic
San Marcos Saddle-Case Caddisfly	*Protoptila arca*	San Marcos River	$NL^{2,5}$	$NL^{6,9}$	SOC^{10}	HA	endemic
Texas Asaphomyian Tabanid Fly	*Asaphomyia texanus*	Larvae burrow in relic sand dunes; adults feed on flowers in meadows around relic sand dunes	$NL^{2,5}$	$NL^{6,9}$	SOC^{10}	CO	endemic
Texas Cave Shrimp	*Palaemonetes antrorum*	Edwards Aquifer and Ezell's Cave, Hays County	$NL^{2,5}$	$NL^{6,9}$	SOC^{10}	HA	endemic
Tooth Cave Blind Rove Beetle	*Cylindropsis* sp. 1	Karst formations of the Balcones Escarpment, Sinkhole Cave	$NL^{2,5}$	$NL^{6,9}$	SOC^{10}	TR	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
Tooth Cave Ground Beetle	*Rhadine persephone*	Karst formations of the Balcones Escarpment	E[2]	NL[6,9]	SOC[10]	TR, WI	endemic
Tooth Cave Pseudoscorpion	*Tartarocreagris texana*	Karst formations of the Balcones Escarpment	E[2]	NL[6,9]	SOC[10]	TR	endemic
Tooth Cave Spider	*Neoleptoneta myopica*	Karst formations of the Balcones Escarpment	E[2]	NL[6,9]	SOC[10]	TR	endemic
MOLLUSKS							
Horseshoe Liptooth	*Polygyra hippocrepis*	Waters of Hays County	NL[2,5]	NL[6,9]	NL[6,10]	HA	endemic
PLANTS:							
Basin Bellflower	*Campanula reverchonii*	Scattered vegetation on dry gravels and very shallow sandy soils derived from	NL[3,5]	NL[6,9]	V[7]	BN, LL, TR	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
		Precambrian igneous and metamorphic rocks, on open slopes and rock outcrops.					
Bracted Twistflower	*Streptanthus bracteatus*	Shallow, well drained gravely clays and clay loams over limestone, in oak-juniper woodlands and associated openings, on steep to moderate slopes and in canyon bottoms of the Edwards Plateau; April through May	NL[3,5]	NL[6,9]	V[7]	TR.	endemic
Branched Gay-feather	*Liatris cymosa*	Somewhat barren grassland openings in post oak woodlands on tight clay, chalky or gravely soils, sometimes over Catahoula Formation.	NL[3,5]	NL[6,9]	V[7]	BL, WA	endemic
Canyon Mock- orange	*Philadelphus ernestii*	Edwards Plateau, solution pitted outcrops of Cretaceous limestone on caprock along mesic canyons, usually in shade of mixed evergreen/deciduous canyon woodland	NL[3,5]	NL[6,9]	V[7]	HA, TR	endemic
Correll's False Dragon-head	*Physotegia correllii*	Wet silty clay loams on streamsides, in creekbeds, irrigation channels, and roadside drainage ditches.	NL[3,5]	NL[6,9]	V[7]	TR	endemic
Edwards Plateau Cornsalad	*Valerianella texana*	Very shallow, well drained but seasonally moist gravely soils derived from igneous or metamorphic rocks, often along the downslope margin of rock outcrops, in full	NL[3,5]	NL[6,9]	V[7]	BN, LL	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
		sun or in partial shade of oak-juniper woodland.					
Elmendorf's Onion	*Allium elmendorfii*	Grassland openings in post oak woodlands on deep well drained sands derived from Queen City and similar Eocene formations; habitat on coastal plain and Llano uplift	NL[3,5]	NL[6,9]	V[7]	LL	endemic
Glass Mountains Coral-root	*Hexalectris nitida*	Beneath oaks or in cedar - oak groves on the Edwards Plateau	NL[3,5]	NL[6,9]	NL[6,7]	BE, HA, TR	endemic
Hill Country Wild-mercury	*Argythamnia aphoroides*	Shallow to moderately deep clays and clay loams over limestone, in grasslands associated with plateau live oak woodlands, mostly on rolling uplands	NL[3,5]	NL[6,9]	V[7]	HA, TR	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
Mulenbrock's Umbrella Sedge	*Cyperus grayioides*	Prairie grasslands, moist meadows	NL[3,5]	NL[6,9]	NL[6,7]	BL, CO	endemic
Navasota Ladies-tresses	*Spiranthes parksii*	Open wooded margins of post oak woodlands in sandy loams along intermittent tributaries of the Brazos and Navasota Rivers, often in areas where edaphic factors (such as high aluminum content of soil) or hydrologic factors (such as a perched water table) limits competing vegetation in herbaceous layer	E[3]	E[9]	E[7]	BL, CO, FA, LE, WA	endemic
Parks' Jointweed	*Polygonella parksii*	Early successful grasslands and openings in post oak woodlands on deep loose whitish sands of Carrizo and other Eocene formations.	NL[3,5]	NL[6,9]	V[7]	BL	endemic
Prairie Dawn or Texas Bitterweed	*Hymenoxys texana*	Gulf prairie and marshes in poorly drained sparsely vegetated areas at the base of mima mounds in open grasslands in almost barren areas on slightly saline soils which are sticky when wet and powdery when dry	E[3]	E[9]	E[9]	CO	endemic
Rock Quillwort	*Isoetes lithophila*	Very shallow seasonally wet sand, gravel and organic matter in vernal pools on granite or gneiss outcrops.	NL[4,5]	NL[6,9]	V[7]	BN, LL	endemic
Texabama Croton	*Croton alabamensis* var *texensis*	Mostly deciduous or evergreen-deciduous woodlands in duff-covered loamy clay soils on rocky slopes in comparatively mesic limestone ravines, often locally abundant on deeper soils on small terraces in canyon bottoms.	NL[3,5]	NL[6,9]	V[7]	TR	endemic

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Common Name	Scientific Name	Habitat Preference	USFWS Listing	TPWD Listing	TOES Listing	Counties of Occurrence	Potential Occurrence
Texas Grease Bush	*Forsellesia texensis*	Dry limestone ledges and chalk bluffs.	NL[3,5]	NL[9]	V[7]	TR	endemic
Texas Meadow-rue	*Thalictrum texanum*	Margins of mesic woodlands or forests on alluvial terraces, rarely in moist ditches on partially shaded roadsides.	NL[3,5]	NL[9]	V[7]	CO	endemic
Texas Wild Rice	*Zizania texana*	Known only from the San Marcos River (Hays County) where it occurs in clear flowing water from springs of constant cool temperature.	E[3]	E[9]	E[7]	HA	endemic
Warnock's Coral-root	*Hexalectris warnockii*	Among rocks in shaded canyons on the Edwards Plateau	NL[3,5]	NL[6,9]	NL[6,7]	HA	endemic

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V - Category V TOES Plant Watch List

REGIONAL WATER RESOURCES

The primary water resources of the study area consist of the Brazos and Colorado River drainages, including the systems of flood control and water supply reservoirs that have been constructed in these basins, and ground waters in portions of the Edwards, Trinity and Carrizo-Wilcox aquifers (Figure 3.1-1).

Brazos River Basin

The Brazos River Basin is bounded on the north by the Red River basin, on the east by the Trinity and San Jacinto River Basins and the San Jacinto-Brazos Coastal Basin, and on the south and west by the Colorado River Basin and the Brazos-Colorado Coastal Basin. Major population centers in the Brazos River Basin include the Cities of Lubbock, Abilene, Waco, Temple-Killeen, Bryan-College Station, Round Rock, Georgetown-Cedar Park-Leander, Sugarland-Richmond-Rosenburg and the Brazosport area. There are 33 major water supply reservoirs within the Brazos River Basin. The counties which contain projects under consideration in the Brazos River Basin include Bell, Burleson, Lee, Milam, Washington, and Williamson. The Brazos River Authority (BRA) owns, operates, or has acquired storage in twelve reservoirs as part of its Basin-wide water system to supply water for in-basin uses, and exports to the Trinity and San Jacinto-Brazos Basins. The alternatives considered in the following sections involve four of these reservoirs: Stillhouse Hollow, Lake Georgetown, Lake Somerville, and Lake Granger.

Stillhouse Hollow

Stillhouse Hollow Reservoir is a 226,063 acft capacity impoundment on the Lampasas River in Bell County, near the cities of Killeen, Belton, and Temple. At 622 ft-msl, the 6,430-acre impoundment was built in 1968 by the U.S. Army Corps of Engineers for the purposes of flood control, municipal water use, and recreation. Recreational facilities operated by the U.S. Army Corps of Engineers provide swimming areas, boat ramps, picnicking, and camp sites for over 2.8 million visitor hours in 1994.[38] The drainage area above Stillhouse Hollow Reservoir is

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[38] Ramos, Mary G. (ed.). 1995. 1996-1997 Texas Almanac. Dallas Morning News, Inc., Communications Center. Dallas, Texas.

1,300 square miles located within the Blackland Prairie, and the Cross Timbers and Prairies vegetational areas.[39]

Texas Parks and Wildlife Department (TPWD) routinely conducts fish sampling studies on Stillhouse Hollow using electrofishing, gill netting, and frame netting.[40] The reservoir is deep and clear with low productivity, although production increases in the upper end of the lake. The reservoir contains good sport fish populations including catfish (channel, blue, flathead), bass (largemouth, white, smallmouth), sunfish (bluegill, etc.), and forage fish (gizzard and threadfin shad). However, fish populations and densities are lower than other lakes in the area due to the rocky substrate and the lack of woody or vegetative cover. TPWD made stocking efforts in 1993 and 1994 to increase densities of smallmouth bass and Florida largemouth bass.[41] In the 1995 survey conducted by TPWD, *Hydrilla* sp. was observed, for the first time in this reservoir, covering 19.7 acres.[42]

Lake Georgetown

Lake Georgetown reservoir is a 37,010 acft capacity impoundment on the North San Gabriel River in Williamson County located west of the City of Georgetown. At 791 ft-msl, the 1,297-acre impoundment was built in 1980 by the U.S. Army Corps of Engineers for the purposes of flood control, municipal water use, and recreation. Recreational facilities operated by the U.S. Army Corps of Engineers provided swimming areas, boat ramps, picnicking, and camp sites for over 4.4 million visitor hours in 1994.[43] The drainage area above Lake Georgetown reservoir is 246 square miles located within the Edwards Plateau vegetational area.[44]

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[39] Mitchell, J.M. Survey Report for Stillhouse Hollow Reservoir, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas. 1996.

[40] Ibid.

[41] Ibid.

[42] Ibid.

[43] Ramos, Mary G. (ed.). 1996-1997 Texas Almanac. Dallas Morning News, Inc., Communications Center. Dallas, Texas. 1995.

[44] Terre, D.R. and S.J. Magnelia. Survey Report for Georgetown Reservoir, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas. 1996.

Fish sampling studies are routinely conducted by TPWD on Lake Georgetown reservoir using electrofishing, gill netting, and frame netting.[45] In addition, a creel survey was conducted by TPWD from March to May 1995 to assess angler use and catch.[46] The reservoir is deep and clear with no aquatic vegetation observed by TPWD in 1995.[47] Rocks and woody debris provide good habitat for white crappie, catfish (blue, channel, flathead), bass (largemouth, white, smallmouth), sunfish (bluegill, etc.), threadfin shad, and some gizzard shad. Stocking attempts have been made by TPWD to increase the densities of sport fish such as channel catfish, hybrid striped bass, smallmouth bass, largemouth bass, and walleye.[48] Results from the creel survey showed that total angling pressure on the reservoir was 12.6 man-hours/acre and that anglers rated their fishing success compared to other places they fish as predominantly average (42%).[49]

Lake Somerville

Lake Somerville reservoir, located south of Somerville, is a 155,062 acft capacity impoundment on Yegua Creek in Burleson, Lee, and Washington Counties. At 238 ft-msl, the 11,456-acre impoundment was built in 1972 by the U.S. Army Corps of Engineers for the purposes of municipal water for the city of Brenham, irrigation, and flood control. Recreational facilities operated by the U.S. Army Corps of Engineers provided swimming areas, boat ramps, picnicking, and camp sites for over 15 million visitor hours in 1994.[50] The drainage area above Lake Somerville reservoir is 1,006 square miles and is located within the Post Oak Savannah vegetational area.[51]

Fish sampling studies are routinely conducted by TPWD on Lake Somerville reservoir using electrofishing, gill netting, and frame netting.[52] The reservoir is fairly clear and shallow, with a mean depth of 11 feet and a maximum depth of 38 feet. In 1994, TPWD observed some

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[45] Ibid.

[46] Ibid.

[47] Ibid.

[48] Ibid.

[49] Ibid.

[50] Ramos, Mary G. (ed.). 1996-1997 Texas Almanac. Dallas Morning News, Inc., Communications Center. Dallas, Texas. 1995.

[51] Webb, M.A and J.C. Henson. Survey Report for Lake Sommerville, 1994. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas. 1995.

[52] Ibid.

floating and emergent aquatic vegetation covering about 85 acres. Fish species such as hybrid striped bass, white bass, white crappie, catfish, gizzard shad, and sunfish are important to the fishery of the reservoir. TPWD has made recent attempts to increase the densities of sport fish such as hybrid striped bass through stocking.[53]

Lake Granger

The Lake Granger reservoir has a capacity of 54,280 acft and is located on the San Gabriel River in Williamson County between the City of Granger and the City of Taylor. The impoundment has a surface area of 4,009 acres and at a conservation pool of 504 ft-msl. Lake Granger is owned and operated by the U.S. Army Corps of Engineers and was built for flood control, water supply, and recreation. Recreational facilities operated by the U.S. Army Corps of Engineers provided swimming areas, boat ramps, picnicing, and camp sites for over 1.5 million visitor hours in 1994.[54] Parks include Friendship Park which is located on the north shore, and Taylor and Wilson H. Fox Parks located on the south shore. The drainage area above Lake Granger is 709 square miles and is located within the Blackland Prairies, and Cross Timbers and Prairies vegetational areas.

Texas Parks and Wildlife Department conducts fish sampling studies on Lake Granger using electrofishing in the fall and gillnetting in the spring. The lake is shallow, turbid, and aquatic vegetation along its margins is sparse. Fisheries biologists representing TPWD estimate that lake levels fluctuate about 3 to 4 feet. Woody cover provides habitat for white crappie, catfish (channel, blue, flathead), largemouth bass, white bass (which are popular with fishermen), sunfish (bluegill and green), gizzard shad, and threadfin shad. Recent stocking of Lake Granger has included channel catfish, striped bass, coppernose bluegill, and Florida largemouth bass.[55]

Granger Wildlife Management Area, which is operated by Texas Parks and Wildlife Department, comprises 11,116 acres of upland grassland with some bottomland hardwoods. Wildlife includes mourning dove, quail, fox squirrel, rabbits, pheasant and migrant waterfowl.

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[53] Ibid.

[54] Ramos, Mary G. (ed.). 1996-1997 Texas Almanac. Dallas Morning News, Inc., Communications Center. Dallas, Texas. 1995.

[55] Terre, D.R. and S.J. Magnelia. Survey Report for Granger Reservoir, 1994. Statewide Freshwater Fisheries Monitoring and Management Program, Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas. 1995.

Nature trails are provided and hunting (shotgun only) is allowed in season, but no additional public recreational facilities are available.

Around Lake Granger, large numbers of double-crested cormorants, American white pelicans, ring-billed gulls, Forster's terns, ospreys and several species of waterfowl are present in the spring and fall when bird-watching is best. [56] Hawks tend to be most common at the Pecan Grove Wildlife Management Area below the dam in winter, where Red-tailed, Ferruginous and rough-legged hawks and northern harrier are often present. The brushy habitats in the Texas Parks and Wildlife management areas provide habitat for sixteen species of wintering sparrows. Nesting birds include wood ducks, eastern screech-owls, and Barn, great horned, and barred owls. Horned lark, mountain plover, chestnut-collared long-spur, McCown's long-spur, and lapland long-spur occasionally winter in fields west of Lake Granger.

Colorado River Basin

The Colorado River Basin is bounded on the north and east by the Brazos River basin, and on the south and west by the Lavaca, Guadalupe, Nueces, and Rio Grand basins. The Colorado River originates in Dawson County, Texas and flows 600 miles to Matagorda Bay on the Gulf of Mexico. The Colorado flows through a rolling, mostly prairie terrain, entering the rugged Hill Country around San Saba, and issuing from the Balcones Escarpment near Austin, in Travis County, where it then flows across the Coastal Plain to the Gulf of Mexico. The Colorado River basin has 26 major water supply reservoirs. Major water diverters in the basin are the Colorado River Municipal Water District, Lower Colorado River Authority (LCRA), and irrigation companies in the lower part of the basin. The LCRA and irrigation companies export water to areas in the Brazos-Colorado, Colorado-Lavaca, and Lavaca basins. The counties which contain projects under consideration in the Colorado River Basin include Bastrop, Burnet, Colorado, Fayette, Hays, Llano, and Travis.

Several alternatives considered in this report concern the Highland Lakes on the Colorado River. The Highland Lakes are reservoirs built between 1935 and 1951 by the LCRA, which was established in 1934. These lakes constitute a valuable resource because they serve as water

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[56] Kutac, E.A. and S. C. Coran. Birds and Other Wildlife of South Central Texas: A Handbook. University of Texas Press. Austin, Texas. 1994.

supplies, provide recreational centers, function as sediment and flood control, and generate hydroelectric power for the region and its metropolitan areas. The Highland Lakes occupy a 150 mile stretch of the Colorado River and in order from north to south, consist of Lake Buchanan, Inks Lake, Lake Lyndon Baines Johnson (LBJ), Lake Marble Falls, Lake Travis, and Lake Austin. There is an electrical generating station at each dam in the Highland Lakes chain. Together these stations provide more than 240 megawatts of capacity to the LCRA electric system. Although hydroelectricity was once a major source of power to the LCRA service area, it now supplies less than seven percent of LCRA needs. In addition to providing electricity, Mansfield dam on Lake Travis has markedly reduced the threat of serious flooding on the lower Colorado River. The Highland Lakes also provide increasingly significant recreational attractions, where numerous parks, commercial enterprises, and private residents are supported by the vacation, camping, hunting, fishing, and boating industries lining the lakes.

Lake Buchanan

Lake Buchanan is the oldest, widest, and northernmost of the Highland Lakes. Buchanan Dam was built primarily to supply hydroelectricity and store water for water supply, and is the largest of the Highland Lakes dams. It is over two miles long, and its three generating units have a capacity of 37,500 kilowatts. Lake Buchanan, located west of Burnet County, is a 918,000 acft capacity impoundment at 1020.35 ft-msl on the Colorado River in Burnet, Llano, and San Saba Counties. The reservoir is about 30 miles long and 5 miles wide at the widest point. This 23,060-acre impoundment was built in 1937 by the Lower Colorado River Authority (LCRA) for the purposes of hydroelectric power, municipal water use, and recreation. Recreational facilities include Colorado Bend State Park and three Burnet County Parks as well as several other privately owned marinas and lodges with both lake and shoreline public access.[57] The drainage area above Lake Buchanan is 31,250 square miles of which 11,900 square miles probably do not contribute water.[58] The reservoir lies within the Edwards Plateau, and the Cross Timbers and Prairies vegetational areas.

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[57] Terre, D.R. and S.J. Magnelia. Survey Report for Buchanan Reservoir, 1993. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas. 1994.

[58] Ibid.

Fish sampling studies are routinely conducted by TPWD on Lake Buchanan reservoir using electrofishing, gill netting, and frame netting. The reservoir is deep and clear with no aquatic vegetation observed by TPWD in 1993. In addition to the lack of vegetative cover, very little habitat is found in the form of woody debris. Broken rock and sandy banks account for 96.5 percent of the shoreline habitat. Striped bass are important to the fishery of the reservoir and have been stocked by TPWD since the late 1970's. Largemouth bass, white bass, sunfish, catfish, and crappie are also important to the sport fishery industry, with gizzard shad and some threadfin shad important forage fish.[59]

Inks Lake

Inks Lake, located west of Burnet County, is a 17,545 acft capacity impoundment on the Colorado River in Burnet and Llano Counties. The 830-acre impoundment was built immediately below Lake Buchanan in 1938 by the Lower Colorado River Authority (LCRA) for the purposes of hydroelectric power, municipal water use, and recreation. Inks Lake is 4.2 miles long and 3,000 feet wide at its maximum width and covers 802 acres at a flood pool of 888 ft-msl. Inks Lake State Park borders the reservoir and provides public access to about 30 percent of the shoreline, while other significant portions have been developed by residential property owners or by the Lower Colorado River Authority.[60] The eastern shore of Inks Lake State Park is the second most popular state park in Texas.[61] The drainage area is similar to that of Lake Buchanan. The drainage size of Inks Lake is approximately 31,250 square miles of which 11,900 do not contribute water. The Inks Lake drainage area lies within the Edwards Plateau, and the Cross Timbers and Prairies vegetational areas.

Fish sampling studies are routinely conducted by TPWD on Inks Lake using electrofishing, gill netting, and frame netting. The reservoir is deep and clear with aquatic vegetation accounting for less than 2 percent of the reservoir's acreage. In addition to the lack of vegetative cover, very little habitat is found in the form of woody debris. Broken rock, sandy

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[59] Ibid.

[60] Terre, D.R. and S.J. Magnelia. Survey Report for Inks Reservoir, 1993. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas. 1994.

[61] Lake Buchanan & Inks Lake. Lake Buchanan/Inks Lake Chamber of Commerce. Buchanan Dam, Texas.

banks, and concrete account for 98.4 percent of the shoreline habitat. Important sport fish include crappie (white and black), bass (largemouth, white, striped and hybrid striped, Guadalupe), catfish (channel, blue, flathead), sunfish (bluegill, etc.), and forage fish (gizzard and threadfin shad). Additional stocking attempts have included Rainbow trout, Coho Salmon, and Northern Pike.[62]

Lake Lyndon B. Johnson

Lake Granite Shoals was renamed for President Lyndon B. Johnson in 1965. It was formed by Alvin Wirtz dam which is 118.3 feet high and 5,491.4 feet long and was constructed in 1950. The lake is located approximately five miles southwest of the city of Marble Falls and was originally constructed to provide hydroelectric power for short periods each day during peak demand. Wirtz Dam has 10 floodgates but no spillway. Lake LBJ provides cooling water for LCRA's Thomas C. Ferguson Power Plant along Horseshoe Bay. At a power pool elevation of 825 ft-msl the reservoir is 21.15 miles long and its maximum length is 10,800 feet wide. The lake covers 6,375 acres and has a capacity of 138,500 acft. Lake LBJ does not have the storage capacity of Lake Buchanan or Lake Travis but it is the third largest of the Highland Lakes. Longhorn Caverns State Park and LRCA Wirtz park, which provide recreational facilities, are located near Lake LBJ.

Lake Marble Falls

Lake Marble Falls is formed behind Max Starke Dam which was constructed from 1949 to 1955 for hydroelectricity. The dam is 98.8 feet high and 859.5 feet long. At a power pool elevation of 738 ft-msl the reservoir is 5.75 miles long and its maximum width is 1,080 feet. The lake covers 780 acres, and has a capacity of 8,760 acft. It is located in Burnet County and runs through the City of Marble Falls. Lake Marble Falls is a comparatively small lake which winds for 6 miles between limestone bluffs. Marble Falls City Park is located on Lake Marble Falls.

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[62] Terre, D.R. and S.J. Magnelia. Survey Report for Inks Reservoir, 1993. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas. 1994.

Lake Travis

Lake Travis is formed behind Mansfield Dam which was constructed from 1937 to 1941 by the LCRA and Bureau of Reclamation. Mansfield Dam has 24 floodgates and serves as the only flood-control structure for the lower river basin. The dam and Lake Travis also provide water storage and hydroelectricity for the LCRA. At the top of the conservation and power pool, Lake Travis is 63.75 miles long and 4.5 miles wide at its widest point. The lake covers 18,929 acres and has a capacity of 1,170,752 acft. When the lake's elevation excedes 681 ft-msl, the LCRA begins floodgate releases under the direction of the U.S. Army Corps of Engineers. The lake was created for use as a water supply, flood control, and for hydroelectric generation. In addition, it now supports a thriving recreational industry. Lake Travis is located in Travis County approximately 13 miles northwest of Austin and lies on the Edwards Plateau. LCRA's Big Sandy Park and Travis County Parks provide recreational facilities near this lake.

Lake Austin

Lake Austin is formed behind Tom Miller Dam which was built in 1938-1940. The dam was built to provide electricity and water supply. It is 100.5 feet high and 1,590 feet long. At the power pool of 492.8 ft-msl the reservoir is 20.5 miles long and has a maximum width of 1,300 feet. The lake covers 1,830 acres and has a capacity of 21,000 acft.

CULTURAL RESOURCES OF CENTRAL TEXAS

Early attempts to synthesize the results of archeological investigations in Native-American sites in Texas were made in the 1930s by Pearce and Sayles.[63,64] In the 1940s Kelley[65] proposed a more comprehensive cultural chronology for the area. In the 1950s, Suhm, Krieger and Jelks[66] produced a cultural synthesis that proposed four broad temporal divisions in the human occupation of the New World. These four stages of human culture became known as the Paleo-Indian, the

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[63] Pearce, J.E. The Present Status of Texas Archeology. Bulletin of the Texas Archelogical Society. Volume 4:44:54. 1932.

[64] Sayles, E. B. An Archeological Survey of Texas. Medallion Papers 17 1935.

[65] Kelley, J.C. The Lehmann Rock Shelter: A Stratified Site of the Toyah, Uvalde, and Round Rock Foci. Bulletin of the Texas Archeological and Paleontological Society. Volume 18:115-128. 1947.

[66] Suhm, D.A., A.D. Krieger and E. B. Jelks. An Introductory Handbook of Texas Archeology. Bulletin of the Texas Archeological Society. Volume 25. 1954.

Archaic, the Prehistoric, and the Historic Periods. In 1960 Suhm expanded on the 1954 work.[67] During the 1960s, refinements on previously constructed models for a Central Texas cultural chronology were proposed by various authors.[68,69,70] These studies were followed by Johnson's important statistical analysis.[71] Johnson's extensive review was grounded more firmly on collected data and relied less on speculation and unproved assumptions than earlier syntheses. A Central Texas chronology was proposed in the 1970s by Weir.[72] Prewitt attempted to refine this interpretation in the 1980s.[73,74]

These studies, while insightful, by necessity used small amounts of data, some of which is scientifically suspect. Many writers have expressed varying degrees of skepticism.[75,76,77] In 1987, Johnson pointed out inherent flaws and some pitfalls involved in taking these models too seriously.[78] Ellis has written a good critique of Weir's and Prewitt's works.[79] Others have

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[67] Suhm, D.A. A Review of Central Texas Archeology. Bulletin of the Texas Archeological Society: Volume 29:63-108. 1960.

[68] Jelks, E. B. The Kyle Site: A Stratified Central Texas Aspect Site in Hill County, Texas. Department of Anthropology, Archeology Series 5. University of Texas at Austin. 1962.

[69] Johnson, L. Jr., D.A. Suhm and C. Tunnell. Salvage Archeology of Canyon Reservoir: The Wunderlich, Footbridge and Oblate sites. Texas Memorial Museum Bulletin 5. University of Texas at Austin. 1962.

[70] Sorrow, W.R., H.J. Shafer and R.E. Ross. Excavations at Stillhouse Hollow Reservoir. Papers of the Texas Archeological Salvage Project 18. University of Texas at Austin. 1967.

[71] Johnson, L. Jr. Toward a Statistical Overview of the Archaic Cultures of Central and Southwestern Texas. Texas Memorial Museum Bulletin 12. University of Texas at Austin. 1967.

[72] Weir, F.A. The Central Texas Archaic. Ph.D. Dissertation, Washington State University, Ann Arbor. 1976.

[73] Prewitt, E.R. Cultural Chronology in Central Texas. Bulletin of the Texas Archeological Society. Volume 53:65-89. 1981.

[74] Prewitt, E.R. From Circleville to Toyah, Comments on Central Texas Chronology. Bulletin of the Texas Archeological Society. Volume 54:201-238. 1985.

[75] McKinney, W.W. Holocene Adaptations in Central and Southwestern Texas: The Problems of the Paleoindian-Early Archaic Transition. Bulletin of the Texas Archeological Society. Volume 52: 91-120. 1981.

[76] Peter, D.E., D. Prikryl, O. McCormick and M.A. Demuynck. Archeological Investigations at the San Gabriel Reservoir Districts, Central Texas: Volume I:8-1 to 8-156. Edited by T. R. Hays, Archaeology Program, Institute of Applied Sciences, North Texas State University, Denton. 1982.

[77] Johnson, L. Jr. Early Archaic Life at the Sleeper Archaeological Site, 41BC65, of the Texas Hill Country. Blanco County, Texas. Texas Department of Transportation Publications in Archeology: Report Number 39. 1991.

[78] Johnson, L. Jr. A Plague of Phases. Bulletin of the Texas Archeological Society: Volume 57:1-26. 1986.

[79] Ellis, G.L. Archeological Overview and Theoretical Perspectives. Significance Standards for Prehistoric Cultural Resources: A Case Study for Fort Hood, Texas:41-99. G. L. Ellis, C. Lintz, W. N. Trierweiler, and J. M. Jackson. USACERL Technical Report CRC-94/04, Urbana, Illinois. 1994.

attempted to make revisions.[80,81,82] The debate over chronology will likely continue for some time. Just as models of dinosaurs in museums around the world are being reconstructed to conform with recent advances in the field of paleontology, these archeological models for Central Texas will continue to change as we take into account newer and better data. Meanwhile, the works of Johnson, Weir and Prewitt continue to be the context in which the debate rages. The divisions and dates presented below are based on currently popular interpretations of various chronologies proposed for the Central Texas area.

Paleo-Indian Period (*ca.* 11200-8000 B. P.)

Central Texas has been occupied by humans for more than 11,000 years. The earliest bands of people may have entered the area following migratory herds of big game, such as mammoths (*Mammuthus columbi*), giant bison (*Bison antiquus*), horses (*Equus mexicanus* and *Equus francisci*), and camels (*Camelops hesternus*). These people were at least semi-nomadic and their tools were much the same as those in use on the Great Plains to the north, from whence it is assumed they came. The Paleo-Indian Period is traditionally divided into an early and a late period. There is no conclusive proof for human habitation in central Texas before 11,200 to 10,900 B. P. (the estimated date of the Clovis Horizon).

The earliest Paleo-Indian projectile points are known as *Clovis* and can be reliably dated in Central Texas from 11200-10000 B. P. The *Clovis* point (discovered near Clovis, New Mexico) has also been used to define the cultures who armed themselves with this type of fluted dart point. This period is sometimes called the Clovis Horizon. At Miami, Texas in the 1930s, two of these points were found in a bone bed made up entirely of elephants.[83] Such associations at Paleo-Indian sites in the Southern Plains suggested a culture that relied heavily on the exploitation of these animals. The traditional view of these people is that their primary occupation was the hunting of

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[80] Collins, M. B.,T.R. Hester, D. Olmstead and P. J. Hedrick. Engraved Cobbles from Early Archeological Contexts in Central Texas. Current Research in the Pleistocene. Volume 8:13-15. 1991.

[81] Johnson, L. Jr. and GT. Good. A New Try at Dating and Characterizing Holocene Climates, as well as Archeological Periods, on the Edwards Plateau. Bulletin of the Texas Archeological Society. Volume 65:151. 1994.

[82] Rickets, R.A. and M. B. Collins. Archaic and Late Prehistoric Human Ecology in the Middle Onion Creek Valley, Hays County, Texas. TARL Studies in Archeology Number 19. University of Texas, Austin. 1994.

[83] Sellards, E. H. Early Man in America: A Study in Prehistory. Illustrated by Hal Story, Texas Memorial Museum. University of Texas Press, Austin. 1952.

now-extinct giant herbivores.[84,85] In the broadest terms this is true. There is no doubt that these people were hunting the largest mammals on the continent, and that they may have contributed significantly to their extinction. However, the archeological record suggests that the diet of these people was more catholic in nature than previously believed, and that big game hunting was only one of many adaptive strategies employed by them.

Early Paleo-Indian sites include kill sites, stone quarries and workshops, camps, caches, cemeteries, and locations of ritual practice. In addition to the lithics associated with the production of *Clovis* points, the artifact assemblage includes other sharp stone tools, bifacial, flake, and prismatic. These points are exquisite in both their workmanship and selection of materials. Engraved cobbles, dart points made of bone and ivory, a bone shaft straightener, stone bolas, and ochre have been reported. Intriguing evidence has come to light that suggests that the people who made *Clovis* points in Central Texas may have been slightly more sedentary than previously supposed. Caches suggest regular "rounds" being made by groups who returned over and over again to the same places. A semi-permanent base camp may have existed at Kincaid Rockshelter. There, more than two metric tons of stones were brought up from the nearby river bed, enough to create a ten square meter pavement on the floor of the shelter.[86] Trade networks may have been established at the time, given the wide distribution of such exotic stone as Alibates Dolomite. Another interpretation is that these people habitually traveled enormous distances to resupply themselves with high quality raw materials.

The next recognizable cultural horizon in the Early Paleo-Indian Period is known as the Folsom. This period is also associated with a fluted dart point that has lent its name to the cultures which produced it. It is named after the town of Folsom, New Mexico, near the site where this point was first identified.[87] It was recognized early that in some places *Clovis* points were found underneath strata containing *Folsom* points. It could be demonstrated by relative dating that the

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[84] Krieger, A.D. Certain Projectile Points of the Early American Hunters. Bulletin of the Texas Archeological and Paleontological Society. 18:7-27. 1947.

[85] Suhm, D.A., A.D. Krieger and E. B. Jelks. An Introductory Handbook of Texas Archeology. Bulletin of the Texas Archeological Society: Volume 25. 1954.

[86] Collins, M.B. Forty Years of Archeology in Central Texas. Bulletin of the Texas Archeological Society. Volume 66:361-400. 1995.

[87] Sellards, E. H. Early Man in America: A Study in Prehistory. Illustrated by Hal Story, Texas Memorial Museum. University of Texas Press, Austin. 1952.

Clovis points had been deposited on the landscape earlier than *Folsom* points. The people who produced *Folsom* points are less understood than those who produced *Clovis* points, because there has been more interest focused on the earlier time period. Bison hunting seems to have been much more important to these later people than it had been in the past. Identifiable site types in Central Texas from this time period include camps, lithic workshops, and kill sites. Their tools included *Folsom* fluted and sometimes *Midland* unfluted points, end scrapers, and large, thin bifaces.

The next projectile point style interval in the Paleo-Indian Period is typified by the *Plainview*, and related variants. It was named after its type-site, discovered in 1944 near Plainview, Texas.[88] It is less understood than the two previous cultural horizons. Problems with dating these points and even typing them are discussed by Collins.[89] Currently this period is considered a transitional phase between the Early and the Late Paleo-Indian periods.

The Late Paleo-Indian Period is divided by Collins into three projectile point style intervals, *Wilson, Golondrina-Barber*, and *St. Mary's Hall.* They are all found at the Wilson-Leonard site in Williamson County. *Wilson* dart points were found in association with features, a burial, artifacts and faunal remains that suggest a shift toward more Archaic-like adaptations. The Golondrina-Barber and St. Mary's Hall components also exhibit some Archaic style attributes. Burned rock features are present, but not anything to compare with the later burned rock middens of the Middle Archaic Period. The burial recovered at the Wilson Leonard site was dated at 9500-10,000 years old.[90]

Archaic Period (ca. 8000-1200 B. P.)

The Archaic Period has been traditionally divided by scholars into three sub-periods, Early (*ca.* 8,000-4600 B. P.), Middle (*ca* 4,600-2,250 B. P.), and Late (*ca.* 2,250-1,200 B. P.). There are cogent arguments at this time for at least two further divisions. This is not surprising, given that the Archaic Period encompasses almost 7,000 years of human prehistory. In 1981, Prewitt divided the Central Texas Archaic Period into four sub-periods and added several phases to Weir's earlier

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[88] Sellards, E.H., G.L. Evans, G.E. Meade and A.D. Krieger. Fossil Bison and Associated Artifacts From Plainview, Texas. Geological Society of America Bulletin. Volume 58: 927-954. 1947.

[89] Collins, M.B. Forty Years of Archeology in Central Texas. Bulletin of the Texas Archeological Society. Volume 66:361-400. 1995.

[90] Masson, M.A. and M.B. Collins. The Wilson Leonard Site (41WM235). Cultural Resources News and Views. Volume 7 Number 1:6-10. 1995.

model based on typing and dating (both relative and absolute) of projectile points as well as notation of temporally diagnostic features.[91] His Archaic phases include:

Early Archaic

1) Circleville - *Golondrina*, *Meserve*, and *Scottsbluff* points appear in the archeological record.
2) San Geronimo - *Gower*, *Hoxie* and *Wells* points appear.
3) Jarrell - *Bell*, *Andice*, *Martindale*, and *Uvalde* points appear.
4) Oakalla - *Baird* and *Taylor* points appear, as do burned rock middens.

Middle Archaic

1) Clear Fork - *Nolan* and *Travis* points appear. Burned rock middens continue.
2) Marshall Ford - *Bulverde* points appear. Burned rock middens continue.
3) Round Rock - *Pedernales* points appear. Burned rock middens continue.
4) San Marcos - *Marshall*, *Williams*, and *Lang* points appear. Burned Rock middens continue.

Late Archaic

1) Uvalde - *Marcos*, *Montel*, *Castroville*, *Frio*, and *Fairland* points appear.
2) Twin Sisters - *Ensor* points, *San Gabriel* bifaces, and *Erath* bifaces appear.
3) Driftwood - *Mahomet* points and *Hare* bifaces appear.

There was a general warming trend during the Archaic Period, which corresponds to the Early Holocene. During this period glaciers receded, and sea levels rose. A hotter and dryer climate led to the retreat of some species of trees. In Central Texas mixed deciduous woods were largely replaced by oak savanna.[92] This was a period when people adapted new subsistence strategies to cope with a rapidly changing environment. These new strategies relied on new tools and are thus reflected in the archeological record. Unlike earlier periods, there were usually two or more primary projectile point types in use over much of the area at the same time. This may reflect a larger and more diverse population. It may also point to increased territorial conflict. The Archaic Period in Central Texas is a success story. It covers around 7,000 years of successful

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[91] Prewitt, E.R Cultural Chronology in Central Texas. Bulletin of the Texas Archeological Society. Volume 53:65-89. 1981.

[92] Black, S.L. Central Texas Plateau Prairie. From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos Texas. Thomas H. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bemont. Arkansas Archeological Survey Research Series Number 33:17-38. Center for Archaeological Research at the University of Texas at San Antonio, Texas A & M University, and the Arkansas Archeological Survey. 1989.

adjustments to changing climatic conditions. As stated by Collins, "A priority in the investigation of the Archaic record is to better understand the fundamentals of that adaptation, and to determine the significance of the variations seen over time and across space.[93]

Archaic site types include open campsites, rock shelters, caves, sinkholes, caches, isolated burials, quarries, and lithic work shops. During the Middle Archaic burned rock middens became a common feature of the landscape west of the Balcones Escarpment. Neo-Archaic cemeteries have also been found in Central Texas.

Late Prehistoric Period (*ca.* 1200-300 B. P.)

Collins divides the Historic Period in Central Texas into three smaller sub-periods, early, middle and late. The early period (*ca.* 1700-1730 A.D.)is the period when Spanish and French explorers were active in Texas before the majority of Indians in Spanish Texas were confined to missions. The middle period (*ca* 1730-1800) could also be called the mission period and extends to the collapse of that system around 1800. The Late Historic Period (*ca.* 1800-1950) represents the westward expansion and replacement of the indigenous peoples by European settlers.

The beginning of this period in Central Texas is traditionally marked by the advent of two new technologies, the bow and arrow, and ceramics. No doubt other changes in the material culture occurred which are not preserved or which are poorly represented in the archeological record. These changes reflected new subsistence strategies. There seem to have been changes in settlement patterns and there may have been major human migrations in and out of the area. There is also some indication that population densities may have actually decreased during this period.[94]

Jelks[95] recognized that Kelley's[96] Central Texas Aspect (Neo-Late Prehistoric) could be divided into two. He called the earlier phase the Austin Focus and the latter the Toyah Focus.

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[93] Collins, M.B. Forty Years of Archeology in Central Texas. Bulletin of the Texas Archeological Society. Volume 66:361-400. 1995.

[94] Black, S.L. Central Texas Plateau Prairie. From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos Texas. Thomas H. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bemont. Arkansas Archeological Survey Research Series Number 33:17-38. Center for Archaeological Research at the University of Texas at San Antonio, Texas A & M University, and the Arkansas Archeological Survey. 1989.

[95] Jelks, E. B. The Kyle Site: A Stratified Central Texas Aspect Site in Hill County, Texas. Department of Anthropology, Archeology Series 5. University of Texas at Austin. 1962.

[96] Kelley, J.C. The Lehmann Rock Shelter: A Stratified Site of the Toyah, Uvalde, and Round Rock Foci. Bulletin of the Texas Archeological and Paleontological Society 18:115-128. 1947.

Jelks noticed that arrow points from the Austin Focus have expanding stems, while those of the Toyah Focus have contracting stems. These two terms are still generally accepted today, although they are now called phases. Prewitt prefers to use the term Neo-Archaic for this period, divided as follows.[97]

1) Austin - *Scallorn* and *Granbury* points, *Friday* bifaces appear, as do cemeteries.
2) Toyah - *Perdiz*, *Clifton*, *Covington* points, end scrapers, and bevel bifaces appear. Cemeteries continue. *Leon Plain* Ceramics appears.

Common site types of this period in Central Texas include open camp sites, quarries, lithic work shops, and cemeteries. The burned rock middens, ubiquitous during the Central Texas Middle Archaic, had disappeared. The earliest arrow points appeared in Central Texas 1,500 years ago. Corn cobs also appeared in Central Texas during this period. Prewitt has suggested that these occur in the record as a result of trade with Caddoan farmers rather than local agriculture.[98]

Historic Period (*ca.* 300-50 B.P.)

The Historic Period in Texas begins with the travels of Alvar Nunez Cabeza de Vaca from Galveston Island across the Rio Grande Valley to Mexico in the early Sixteenth Century. He never saw Central Texas. It would be almost two centuries before the Spaniards began to arrive in Central Texas. The founding of the first mission at San Antonio in 1718 marks the beginning of European settlement in the area; however, a few accounts from exploratory expeditions predating the establishment of Mission San Antonio Valero (the Alamo) are extant and available in English translation. The diaries of the priest Olivares (1709 and 1716) are good examples, giving us a glimpse at Native-American cultures living near the Colorado River a scant 30 years after the mission revolt that gained control of Spanish horse herds in New Mexico for Native-Americans. This event is generally considered by historians as the advent of the horse culture of the Plains Indians.

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[97] Prewitt, E.R. Cultural Chronology in Central Texas. Bulletin of the Texas Archeological Society. Volume 53:65-89. 1981.

[98] Ibid.

These men were not anthropologists and they did not comment on most of the things anthropologists might like to know about the peoples inhabiting the region before they were replaced by European settlers. Often the best information from Olivares is preceded by apologies such as, "this may seem a digression," or "I mention in passing..." nonetheless, the notes these European invaders left behind, however imperfect, are the only first-hand accounts we will ever have of the behavior of Texas Indians at the beginning of the Eighteenth Century. For example, Olivares wrote the following in 1709.

> The nuts are so abundant that throughout the land the natives gather them, using them for food the greater part of the year. For this purpose they make holes in the ground and bury them in large quantities. Not all the nuts are of the same quality, for there are different sizes and the shells of some are softer than others, but all of them are more tasty and palatable than those of Castile, though they are longer and thinner. The Indians are very skillful in shelling them, taking the kernels out whole. Sometimes they thread them on long strings, but ordinarily they keep a supply in small sacks made of leather for that purpose. Though the Indians are gluttons by nature they keep these from year to year.[99]

According to Olivares pecans were a very important part of the diet of Native-Americans living in Central Texas in 1709. Unfortunately, due to generally poor preservation of organic material in the alkaline Central Texas soils, it is unlikely that this can be either demonstrated or disproved through archeological investigation. This is a case where archival research provides a key clue about subsistence patterns of these people, one that archeology could probably never provide. This demonstrates a crucial difference between historic and prehistoric investigations. Understanding of historical sites can and must rely on a dual approach of field archeology and archival research.

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[99] Tous, G. Diary of Fray Isidro Felix de Espinosa. Preliminary Studies of the Texas Catholic Historical Society. Volume I Number 3:3-17. 1930.

Sites

Open Campsites

Most prehistoric sites in Texas fall into this category. These sites usually contain chipped stone, burned rock, and sometimes stone tools. When found in upland settings in Central Texas, they tend toward poor stratification and long periods of occupation, leaving a jumble of lithic debris which is difficult to study. When these campsites are located on active floodplains, such as the Colorado River and its tributaries, there is potential for them to be periodically buried, becoming deeply stratified over the years. A good example of this type of site is Loeve-Fox.[100] Of equal interest are single occupation sites buried on alluvial terraces. A high potential for significant studies exists at these locales. These tributary floodplain sites, such as recently-tested 41TV1631 at the New Austin Airport at Bergstrom on Onion Creek[101] and 41TV1625 downstream[102] should be more thoroughly documented and studied in the future. Limited testing at 41TV1631 revealed three discrete three burned rock features, all with fair to good charcoal preservation. Excavated profiles of these features suggested the remains of a campfire and two rock-earth ovens, based on the amount of charcoal and the deposit's shape in profile, as well as the configurations of the burned rocks.

Burned Rock Middens

Burned rock middens are large piles of fire-cracked rock, mostly limestone. They were constructed in much of Central Texas during the Middle Archaic and have always received a great deal of attention in Texas archeology. In 1976, Weir defined four types of burned rock middens.[103] Creel and Black and McGraw noted that the distribution of burned rock middens in Central Texas

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[100] Prewitt, E.R. Late Archaic Occupations at the Loeve-Fox Site, Williamson County, Texas. The San Marcos and Twin Sisters Phases. The Texas Archaic: A Symposium (67-82), Thomas R. Hester, editor. Special Report Number 2. Center for Archeological Research, University of Texas at San Antonio. 1976.

[101] Lohse, J.C., R.Moir, L. Litwinionek, J.T. Jones, C.S. Caran, L. Shaw and K. Gardner. Archeological Testing for the New Austin Airport, Travis County, Texas. Hicks and Company Draft Report. 1996.

[102] Davis, M.W., J.T. Jones and D. Anthony. Cultural Resource Survey and Assessment for the Garfield Transmission Substation and Related Transmission Lines, Travis and Bastrop Counties, Texas. Hicks & Company Inc. Archeology Series Number 21. 1993.

[103] Weir, F.A. The Central Texas Archaic. Ph. D. Dissertation, Washington State University, Ann Arbor. 1976.

corresponded to the range of the Oak Savanna. [104,105] They maintain that these people were processing acorns in communal ovens. There is no doubt a strong association between burned rock middens and a combination of limestone outcrops, water, and oak trees, as well as evidence of acorn processing. Peter maintains that many things were being cooked in these ovens.[106] In as yet unpublished work on investigations at the Honey Creek site in Mason County, Black again characterizes the cooking features as rock and earth ovens and the midden deposit as debris cleaned out from oven pits.[107] Collins recently noted the correlation between the frequency of burned rock features and dryer conditions which resulted in the presence of fewer or no bison in Central Texas much of the Archaic Period.[108]

Rockshelters

Rockshelters have long been recognized as the campsites of ancient people in Central Texas. These shelters, along with caves and sinkholes, sometimes provide conditions conducive to better archeological preservation than most open campsites. Notable examples include the Lehman rock shelter, Smith rock shelter, Kincaid rockshelter, and the Levi Rockshelter.[109,110,111,112,113]

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[104] Creel, D. A. Study of Prehistoric Burned Rock Middens in West Central Texas. Ph. D. Dissertation, University of Arizona. 1986.

[105] Black, S.L. and A. J. McGraw. The Panther Springs Creek Site: Cultural Change and Continuity Within the Upper Salado Creek Watershed, South-Central Texas. Center for Archaeological Research, The University of Texas at San Antonio, Archaeological Survey Report 100. 1985.

[106] Peter, D.E., D. Prikryl, O. McCormick and M.A. Demuynck. Archeological Investigations at the San Gabriel Reservoir Districts, Central Texas: Volume I:8-1 to 8-156. edited by T. R. Hays, Archaeology Program, Institute of Applied Sciences, North Texas State University, Denton. 1982.

[107] Black, S.L. Chapter 10: "Oven Cookery at the Honey Creek Site" in Black, Stephen L., Linda Wootan Ellis, Darrell G. Creel, and Glenn T. Goode, Hot Rock Cooking on the Greater Edwards Plateau: Four Burned Rock Midden Sites in West Central Texas. Review Draft manuscript prepared for the Texas Department of Transportation. Texas Archeological Research Laboratory. 1996.

[108] Collins, M.B. Forty Years of Archeology in Central Texas. Bulletin of the Texas Archeological Society. Volume 66:361-400. 1995.

[109] Kelley, J.C. The Lehmann Rock Shelter: A Stratified Site of the Toyah, Uvalde, and Round Rock Foci. Bulletin of the Texas Archeological and Paleontological Society. 18:115-128. 1947.

[110] Suhm, D.A. Excavations at the Smith Rockshelter, Travis County, Texas. The Texas Journal of Science. Volume IX 1:26-58. 1957.

[111] Collins, M. B., T.R. Hester, D. Olmstead and P. J. Hedrick. Engraved Cobbles from Early Archeological Contexts in Central Texas. Current Research in the Pleistocene. Volume 8:13-15. 1991.

[112] Collins, M. B. The Archeological Sequence at the Kincaid Rockshelter, Uvalde County, Texas. Transactions of the 25th Regional Archeological Symposium for Southeastern New Mexico and Western Texas: 25-33. Midland Archeological Society, Midland. 1990.

[113] Alexander. 1983.

Excavations at Cherry Tree Shelter in Travis County are a good example of the potential yield of valuable information from these types of sites, if they can be found relatively intact.[114]

Caves and Sinkholes

In areas containing karst topology, like most of Central Texas west of the Balcones Escarpment, caves and sinkholes have long been the sites of human activity. Both sometimes trap soils and therefore become the sites of buried cultural deposits. Unfortunately, treasure hunters and spelunkers have disturbed most known sites of this type. A few examples are Friesenhahn Cave, Hitzfelder Cave, and Brawley's Cave.[115,116,117,118] These sites have provided important information in the past. Individual burials and even cemeteries have been discovered in these sites.

Quarries and Lithic Workshops

These are the most common types of sites in the uplands of Central Texas and may be the least understood. What is known is that where chert is readily available on the ground surface, either in the form of stream-rolled cobbles or stone outcrops, there is often evidence of human activity in the ancient past. These sites cannot normally be studied in ways that archeologists rely upon for their most reliable data. There is rarely any meaningful stratigraphy at these sites. Typically they are found lying on a stable or eroded surface with no diagnostic points or tools present, and they cannot be dated. Most of these sites probably had been used for hundreds or thousands of years and there is really no way to tell. Artifacts found at quarries are usually limited to chipped stone. Workshop areas demonstrate denser lithic debris and a greater reduction of the raw materials than quarry sites.

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[114] Kotter, S.M. Cherry Tree Shelter: Excavations of a Stratified Late Archaic and Neo-Archaic Rockshelter, Travis County, Texas. Research Report 92. Texas Archeological Survey, University of Texas at Austin. 1985.

[115] Krieger. 1964.

[116] Givens, D. R. A Preliminary Report on Excavations at Hitzfelder Cave. Bulletin of the Texas Archeological Society. Volume 38:47-56. 1968.

[117] Collins, M.B. On the Peopling of Hitzfelder Cave. Bulletin of the Texas Archeological Society. Volume 4:301-304. 1970.

[118] Olds, D. L. Report on Materials for Brawley's Cave, Bosque County, Texas. Bulletin of the Texas Archeological Society. Volume 36:111-152: 47-83. 1965.

The largest and best data base for these sites in Central Texas comes from Fort Hood, where 571 prehistoric sites were investigated in the early.[119] Trieirweiler uses the term lithic resource procurement area (LRPG) to designate these types of sites. Some types of useful information can be gleaned from these sites. Technical studies on lithic reduction and intrasite spatial distribution can be useful, as well as mapping of the sites with a view toward eventual understanding where Edwards chert and other important lithic resources were gathered and whether or not they were traded in prehistoric times. If so, how did these trade networks operate?

Burials and Cemeteries

Prehistoric burials and even cemeteries are not uncommon in the archeological record of Central Texas.[120] Burials have been found in isolation, in association with open campsites, in caves, sinkholes, rock shelters, and rarely, in burned rock middens. Bone preservation is not generally good in Central Texas and only a few specimens could be classified as fairly well preserved.[121] While individual human burials often elude looters, cemeteries do not fare as well and it is rare to find one that has not been desecrated. An Austin Phase cemetery was thoroughly investigated at the Loeve-Fox.[122,123]

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[119] Trierweiler, W.N., J.T. Abbott, K. Callister, W. Doering, G.L. Ellis, C.D. Frederick, G.A. Goodfriend, K. Kleinbach, C. Lintz, D. Lynch, G. Mehalchic, P. Mires, F.M. Oglesby, P.L. O'Neill, J. Peck, C. Peterson, J.M. Quigg, C. Ringstaff, M.B. Tomka, A.C. Treece, J. Truesdale, and J. Turpin. Archeological Investigations on 571 Prehistoric Sites at Fort Hood, Bell and Coryell Counties, Texas. W. Nicholas Trierweiler, editor. United States Archeological Resource Management Series Research Report Number 31. 1994.

[120] Prewitt, E.R.. Archeological Investigations at the Loeve-Fox Site, Williamson County, Texas. TARL Research Report Number 49. University of Texas at Austin. 1974.

[121] Black, S.L. Central Texas Plateau Prairie. From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos Texas. Thomas H. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bemont. Arkansas Archeological Survey Research Series Number 33:17-38. Center for Archaeological Research at the University of Texas at San Antonio, Texas A & M University, and the Arkansas Archeological Survey. 1989.

[122] Prewitt, E.R. Archeological Investigations at the Loeve-Fox Site, Williamson County, Texas. TARL Research Report Number 49. University of Texas at Austin. 1974.

[123] Prewitt, E.R. Archeological Investigations at the Loeve-Fox and Loeve Tombstone Buff Sites in the Granger Lake District of Central Texas. Archeological Investigations at the San Gabriel Reservoir Districts, Central Texas, Volume 4. T. R. Hays editor. Institute of Applied Sciences, North Texas State University, Denton. 1982.

Kill Sites, Caches and Rock Art

All of these are rare items in Central Texas archeology. Such kill sites as may have been discovered in Central Texas involve bison. Storage caches are sometimes found in Central Texas, usually of lithic materials or shells.[124] These can be associated with larger sites or may be isolated from other cultural material. Rock art is rare in Central Texas, but by no means absent. It occurs in the form of pictographs and petroglyphs, usually found in caves and rock shelters and occasional decorated pebbles.

ENVIRONMENTAL EFFECTS SUMMARY

The water supply alternatives evaluated can all be considered to consist of a combination of three categories of activity:

1) Water budget alterations - demand reduction, recycling/reuse, water purchase or barter within existing service areas
2) Pipeline construction and operation
3) Reservoir construction and operation

Detailed background information on project engineering, costing, environmental setting, and potential impacts specific to each alternative is considered in the following report sections. Regional and county background environmental information, including tables of protected and important species, are presented first. This background information is followed by summaries and comparisons of environmental consequences of the water supply alternatives.

All alternatives that provide additional surface water for diversion and use, including demand reduction, or conservation (Alternatives L-9, L-21) and reuse (Alternatives L-5, L-8) alternatives, will result in reduced streamflows below the point of diversion. For example, reuse programs commonly employ consumptive uses (irrigation, cooling water) that reduce return flows and provide treated water available for additional users. While additional users can be served without increasing diversions, the use of return flows results in reduced streamflows.

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[124] Black, S.L. Central Texas Plateau Prairie. From the Gulf to the Rio Grande: Human Adaptation in Central, South, and Lower Pecos Texas. Thomas H. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bemont. Arkansas Archeological Survey Research Series Number 33:17-38. Center for Archaeological Research at the University of Texas at San Antonio, Texas A & M University, and the Arkansas Archeological Survey. 1989.

Water diverted from, and not returned to, the Colorado and Brazos Rivers and their tributaries (including diversions from impoundments) will affect streamflows below the diversion and be lost as inflow to their respective estuaries. These transfers will have the net result of decreasing estuary inflows by an amount equivalent to the additional use in the system. Changes to a particular system may include additional consumptive uses, increased seepage and evaporation loss, and transfer of return flows to another basin. While the total diversion of water from a given river system may be the same for diversions from impoundments or directly from the river, the former do not generally exhibit the instantaneous effects on streamflow that run of river diversions have, but occur just the same, as reductions in spills and releases.

Most of the alternatives evaluated in this report involve the construction of pipelines and other facilities to utilize existing water supplies, including surface water impoundments and groundwater. Since most of the alternatives studied involve previously authorized projects, the Trans-Texas environmental criteria for instream flows was not applied to these existing authorized sources. The lower Colorado River alternatives, likewise, were not subject to the criteria since there is an existing instream flow restriction for these stream segments. Impacts to streamflows are discussed in the environmental subsections for each alternative.

A summary and comparison of the environmental issues associated with each water supply alternative is presented in Table 3.1-3. To facilitate comparisons, the effects of each alternative on six environmental resource areas (endangered species, potential water quality changes, magnitude of interbasin transfer, instream flow effects, impacted woodlands, and inundation) have been identified and assigned a score on a scale of 0 to 3 according to the criteria listed in Table 3.1-4. Indices are employed to allow comparisons of overall environmental consequence to be made among alternatives that exhibit a variety of effects difficult or impossible to equate; such as, the comparison of the significance of disturbing 50 acres of Golden-cheeked warbler habitat be evaluated relative to the conversion of three miles of stream habitat to an impoundment. Indices were scaled relative to the alternatives included in the evaluations, with the largest observed effect assigned a score of 3, and no effect assigned a score of zero. It was assumed that implementation of any alternative would include compliance with state and federal regulations regarding the protection of environmental and cultural resources, that impacts to those resources would be avoided or mitigated to the extent possible, and that

Table 3.1-3
Summary of Effects of Water Supply Alternatives

Water Supply Alternatives	Endangered Species	Water Quality	Inter-basin transfers	Instream Flow Effects	Impacted Woods **	Inundated Land	Total Score
L-9 Conservation - Austin Service Area	0	0	0	1	0	0	1
L-21 Conservation - Williamson County	0	0	0	1	0	0	1
L-5 Reuse - Austin Service Area	1	1	0	1	0	0	3
L-8 Reuse - Williamson County	1	0	0	1	0	0	2
B-1 L. Stillhouse Hollow to L. Georgetown	1	1	0	2	1	0	5
B-6 L. Granger to L. Georgetown	1	1	0	1	2	0	5
B-7 L. Sommerville to Colorado River	1	2	1	3	1	0	8
B-8 Brushy Creek Diversion	1	2	0	1	1	0	5
B-9 South Fork Reservoir *	NA	NA	NA	NA	NA	NA	NA
C-2 Water from LCRA L. Travis Scenario 1	2	0	0	2	0	0	4
C-2 Water from LCRA L. Travis Scenario 2	2	1	1	2	0	0	6
C-2 Water from LCRA L. Travis Scenario 3	2	1	2	2	1	0	8
C-2 Water from LCRA L. Travis Scenario 4	3	1	2	3	1	0	10
C-2 Water from LCRA L. Travis Scenario 5	3	1	3	3	1	0	11
C-2 Water from LCRA L. Travis Scenario 6†	1	1	1	1	0	0	4
C-2 Water from LCRA L. Travis Scenario 7†	1	1	1	1	0	0	4
C-2 Water from LCRA L. Travis Scenario 8†	1	1	1	1	0	0	4
C-4 Water from LCRA to L. Georgetown A	0	2	1	3	2	0	8
C-4 Water from LCRA to L. Georgetown B	0	3	2	3	2	0	10
C-5 Off-Channel Storage A	1	0	0	3	3	3	10
C-5 Off-Channel Storage B	1	2	0	3	3	3	12
C-5 Off-Channel Storage C	1	0	0	3	3	3	10
C-5 Off-Channel Storage D	1	2	0	3	3	3	12
C-6 Austin Steam-Electric Water Rights	0	0	0	1	0	0	1
CZ-1 Carrizo-Wilcox to Colorado River A	1	1	0	3	1	0	6
CZ-1 Carrizo-Wilcox to Colorado River B	1	1	0	3	3	3	11
CZ-2 Carrizo-Wilcox to L. Georgetown	1	1	0	3	1	0	6
BC-1 System Operation of lakes *	NA	NA	NA	NA	NA	NA	NA
BC-2 Water from LCRA to L. Georgetown	3	1	2	2	3	0	11

*Engineering analysis concludes not feasible, environmental review not erformed.

**Based on a uniform 140 ft. construction corridor for study purposes.

† Assumes limited or no effect on endangered species due to site selection, small site size, and mitigation design criteria.

Table 3.1-4
Environmental Index Criteria

Endangered species

Based on distributions and known occurrences of endangered species near the alternative and the potential of impacting those species based on proposed construction.

0 = no endangered species likely to be encountered
1 = slight possibility of encountering endangered species
2 = endangered species likely to be encountered, moderate potential impact
3 = endangered species known to occur, high potential impact

Water Quality

Based on influx of nutrients, change in volume, and pre-alternative state of water bodies.

0 = no change in quality
1 = slight degradation, no expected impact on biota
2 = moderate degradation, possible impact on biota
3 = high degradation, likely impact on biota

Interbasin Transfer

Based on acft/ yr water transfer between river basins.

0 = no transfer
1 = 0-25,000 acft/yr
2 = 25,001- 50,000 acft/yr
3 = greater than 50,000 acft/yr

Instream Flow Effects

Based on increase or decrease in streamflow(s) resulting from alternative.

0 = no change
1 = 0-25,000 acft/yr
2 = 25,001- 50,000 acft/yr
3 = greater than 50,000 acft/yr or increase greater than 200% of current streamflow

Impacted Woods

Based on acres of woodlands impacted during construction.

0 = none
1 = 0 to 50 acres
2 = 50 to 100 acres
3 = greater than 100 acres

Submerged Land

Based on acreage submerged by reservoir in alternatives.

0 = none
1 = up to 2500 acres
2 = 2500 to 5000 acres
3 = greater than 5000

suitable compensation for unavoidable, significant impacts to protected resources would be accomplished. The individual scores are summed to give an overall score that is an index of potential environmental impact for each alternative.

The overall impact scores for the alternatives ranged in magnitude from 1 through 12. When alternatives are grouped into the three activity categories (water budget alterations, pipeline construction, new reservoirs), the conservation and reuse alternatives which would require the least construction have the lowest overall impact scores, ranging from 1 to 3, and averaging 1.6. The only new reservoir alternative evaluated, C-5, which includes four scenarios involving an impoundment on Cummins Creek, exhibited uniformly high potential impact scores, ranging from 10 to 12 (average=11).

The pipeline alternatives were the largest and most diverse group evaluated, all consisting of transfers of water from existing reservoirs to regional water treatment plants. Reflecting an order of magnitude range in the annual quantities of water to be transferred, potential environmental impact scores ranged from 3 to 11, and averaged 6.7.

With respect to Endangered and Threatened species, the alternatives exhibiting the greatest potential for significant effects are those involving construction in the area north of Lake Travis (Scenarios 1 through 5 of Alternative C-2). This situation is a result of the general spatial distributions of the species (Golden-cheeked warbler and several karst invertebrates) on the eastern margin of the Edwards Plateau. However, actual impacts depend to a large extent on facility siting and mitigation measures, and pipeline projects are generally sufficiently flexible that significant impacts can be avoided by careful selection of the treatment plant site and pipeline alignments. Potential impacts to endangered and threatened species, including federal and state listed species, species that are candidates for listing as endangered and threatened, and other resources of concern (e.g. TOES species) are addressed in the environmental issues subsections of each of the alternative discussions.

Where avoidance and minimization of impacts do not result in sufficient mitigation, compensation for the residual, unavoidable impacts may be required, where it is practical. Compensation for unavoidable impacts to wetland and terrestrial wildlife habitats may be requested during permit application processes by U.S. Fish and Wildlife Service or Texas Parks and Wildlife Department, depending on the permit involved. However, decisions on the actual extent of required mitigation are made by the respective permitting agencies, the Texas Water Commission 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, Section 10 of the Rivers and Harbors Act, and others.

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 to compensate for that lost as a result of reservoir construction and operation. Acreage requirements should be 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 a minimum of $5-10 per acre per year over the life of the project. Ownership and management responsibility for the mitigation site may be retained by the owner of the project or transferred to a resource agency (typically Texas Parks and Wildlife Department) agreeable to the parties involved.

3.2 Water Available from Austin's Existing Water Rights (C-7)

3.2.1 Description of Austin's Existing Water Rights

The City of Austin's water source is the Colorado River and Austin holds run-of-river water diversion rights on the Colorado River for municipal, steam-electric, and irrigation uses. These diversion rights are governed by the Texas Natural Resource Conservation Commission. Austin's water supply is also affected by provisions of the 1987 Settlement Agreement[1] between the City of Austin and the Lower Colorado River Authority.

Austin's water diversions are limited by regulatory and physical constraints. Regulatory constraints include a maximum rate of diversion, prescribed uses for the water diverted, and requirements that more senior water right holders have first access to the water. The only significant water rights within the lower Colorado River Basin senior to the City of Austin's municipal rights are the Garwood Irrigation Company (168,000 acft/yr) and Pierce Ranch Limited (55,000 acft/yr). Physical limitations include the actual availability of water in the river at the point and at the time of desired diversion.

Previous Trans-Texas Water Program studies[2,3] have reported the estimated availability of water to the City of Austin's senior[4] water rights, based on computer simulations using LCRA's Daily Allocation Program (DAP) model. In this study, water availability has been evaluated in greater detail using an updated version of LCRA's Response Model. Specifically, these analyses included an examination of water availability to Austin's junior water rights. Additionally, two refinements to the model were performed including more accurately locating Austin's senior rights with respect to diversion location, as well as the locations of return flows in the model. These analyses have also included determining estimates of storage requirements in the Highland Lakes needed to meet the terms of the 1987 Settlement Agreement.

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[1] Comprehensive Water Settlement Agreement between City of Austin and Lower Colorado River Authority, December 10, 1987.

[2] HDR Engineering, Inc., et al., "Trans-Texas Water Program, Austin Study Area, Phase I Interim Report," Texas Water Development Board, August 1994.

[3] HDR Engineering, Inc., et al., "Trans-Texas Water Program, Corpus Christi Study Area, Phase II Report, Volume 2 - Technical Report," Texas Water Development Board, September 1995.

[4] The principle of "first in time, first in right" (otherwise known as the system of prior appropriation) determines priority among water rights holders. Hence, a "senior" water rights holder has established a first in time claim to a certain amount of water and other rights holders with a later priority date are "subordinated" to the senior right. With regards to the Highland Lakes, water rights existing prior to the lake permits (March 7, 1938 priority date) are said to have "senior" rights and water rights granted after the lake permit are "junior" rights.

Austin's Adjudicated Water Rights

The City of Austin's municipal and steam-electric water rights are set forth in Certificates of Adjudication 14-5471 and 14-5489 (CA 14-5471 and CA 14-5489). These rights are summarized in Table 3.2-1. Austin holds other minor rights for recreational and irrigation purposes. Austin currently has the right to divert up to 292,703 acft/yr for municipal use and up to 40,156 acft/yr for steam-electric use, subject to limitations described previously. Figure 3.2-1 is a schematic of the Colorado River in the Austin area showing the relative location of the Colorado River, Lake Austin, Town Lake, and the municipal and steam-electric diversion points.

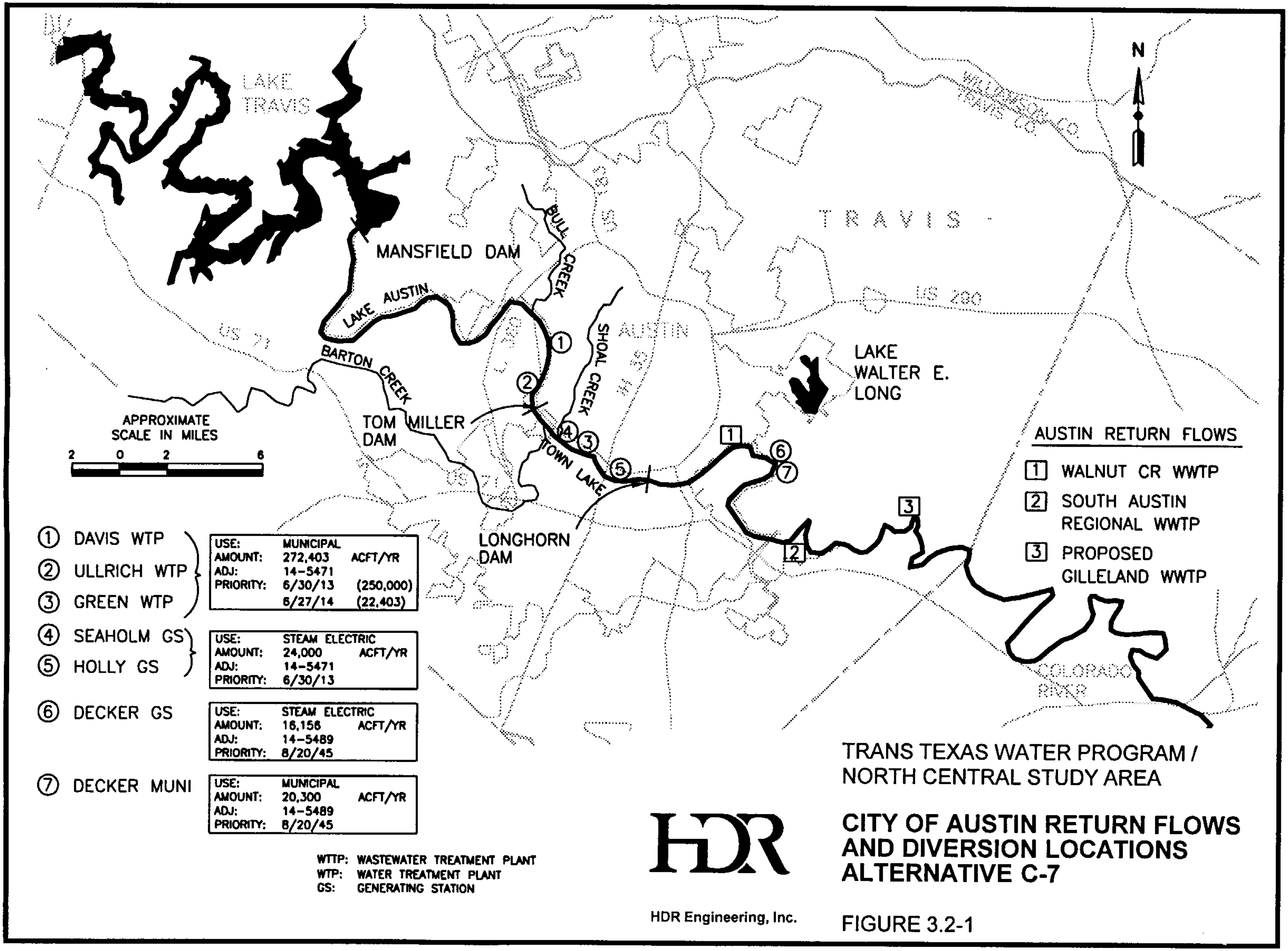
Table 3.2-1
City of Austin Existing Run-of-River Water Rights

Permitted Use	Certificate of Adjudication	Priority Date	Permit Right (acft/yr)	Amount[1] Backed Up By Highland Lakes Storage (acft/yr)
Municipal	14-5471	June 30, 1913	250,000[2]	250,000[3]
	14-5471	June 27, 1914	22,403	
	14-5489	August 20, 1945	20,300	
Total			292,703	
Steam-Electric	14-5471	June 30, 1913	24,000	24,000
	14-5489	February 23, 1965	16,156	16,156
Total			40,156[4]	40,156

[1] Pursuant to the 1987 Settlement Agreement between the City of Austin and the Lower Colorado River Authority.
[2] Includes 1,000 acft/yr of water temporarily allocated for irrigation. Temporary allocation expires after December 31, 2011, and use returns to municipal as shown.
[3] Amount backed up by Highland Lakes storage is not tied to any single water right held by the City of Austin.
[4] Permit limits consumptive use to quantity shown. There is no limit on diversion rate of pass-through diversions.
Note: Highland Lakes priority date is 1938.

Austin's senior municipal rights include 250,000 acft/yr and 22,403 acft/yr for diversion anywhere along the perimeter of Lake Austin and Town Lake (CA 14-5471). Although the 22,403 acft/yr portion of this right is not as dependable as the first 250,000 acft, it is a significant right. These rights are utilized by Austin for water diversion to the Davis and Ullrich water treatment plants located on Lake Austin, and diversion at Town Lake to the Green Water Treatment Plant.

Austin's 20,300 acft/yr municipal right (priority date 1945) is described under Certificate of Adjudication 14-5489. This right is junior to the Highland Lakes and is, therefore, limited to withdrawal of spills from the Highland Lakes and inflows to the Colorado River which occur between the Highland Lakes and the point of diversion that are not required by more senior rights holders. Water availability under this right is substantially less than that under the former two,



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CITY OF AUSTIN RETURN FLOWS AND DIVERSION LOCATIONS ALTERNATIVE C-7

FIGURE 3.2-1

particularly during periods of drought and often during the summer irrigation season. CA 14-5489 specifies a separate diversion location for the steam-electric and municipal portions of this right, and both diversion locations are downstream of Longhorn Dam. The diversion locations are indicated on Figure 3.2-1. Because the diversion locations are located downstream of the Walnut Creek WTP discharge, river flows available for diversion under this right include a portion of Austin's return flows.

Austin currently has 40,156 acft/yr of water rights for consumptive use associated with steam-electric power generation. Under the steam-electric rights, Austin may divert any quantity available in the river for pass-through cooling without limit provided that consumptive use for forced evaporation does not exceed 40,156 acft/yr. The most senior steam-electric right is for 24,000 acft/yr and has a priority date of June 30, 1913. This right may be diverted anywhere along the perimeter of Lake Austin or Town Lake. It has historically been utilized by the Seaholm and Holly Street Power Plants. The remaining right is for 16,156 acft/yr and has a priority date of August 20, 1945. This water is permitted to be diverted at a point downstream of Longhorn Dam and has historically been utilized to augment natural inflows to Lake Walter E. Long (Decker Lake) to keep the lake level within acceptable operating ranges for the Decker power plant.

Settlement Agreement

In 1987, the City of Austin and the Lower Colorado River Authority entered into a settlement agreement pertaining to the adjudication of water rights on the Colorado River. In the agreement, LCRA agreed to supply stored water from reservoirs (i.e., the Highland Lakes), as necessary, to firm a supply up to 150,000 acft/yr for municipal use at no cost. Further, LCRA agreed to firm a supply of up to an additional 100,000 acft/yr of stored water for municipal use for a payment. This results in 250,000 acft/yr of firm water supply being available to Austin for municipal use. The remaining 42,703 acft/yr of Austin's municipal rights are not backed up from storage.

Also under the terms of the Settlement Agreement, LCRA agreed to supply stored water as necessary to firm up Austin's steam-electric rights of up to 40,156 acft/yr of consumptive use for no payment. Under the terms of the agreement, municipal diversions by Austin in excess of 150,000 acft/yr, and diversions other than municipal and steam-electric are to be charged

LCRA's current rate for stored water regardless of whether stored water has to be released to satisfy the diversion. The current rate for firm water from storage is $105 per acft.

3.2.2 Availability of Austin's Existing Rights

Modeling Methods and Assumptions

Water availability to the City of Austin's run-of-river rights in the Lower Colorado River Basin was evaluated using LCRA's Response Model. The Response Model was developed by LCRA and applied to Trans-Texas studies by LCRA staff at HDR's direction with participation from LCRA staff. The Response Model estimates water availability to major diverters in the basin on a daily basis, and produces a monthly simulation of Highland Lakes operations for the period of 1941 to 1965. This period includes the drought of record in the Lower Colorado River Basin. Modeling was performed with all major diverters attempting to divert their full permitted rights. Major water rights included in the model are listed in Table 3.2-2.

For modeling purposes, Austin's daily water demand pattern is based upon historical use from 1976 to 1985, and return flows are distributed monthly according to the historical pattern from 1978 to 1987. Austin's return flows are modeled as 55 percent return of the annual municipal demand. In recent years, return flows have actually exceeded 55 percent in 13 of the past 16 years as shown in Figure 3.2-2. Higher return flows are generally attributable to infiltrated rainfall. During a critical period, return flows would be expected to be lower than the average return flows due to lower than average rainfall. Previous studies have shown that lower return flows reduce availability under Austin's water rights.[5] Therefore, the use of 55 percent is a reasonable assumption.

Modeling Limitations

A major assumption of the Response Model involves the daily simulation of water right diversions. Run-of-river water rights are issued subject to specified maximum annual and instantaneous diversion rates. For the significant water rights on the Lower Colorado River, in

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[5] HDR Engineering, Inc., "Trans-Texas Water Program, Austin Study Area, Phase I Interim Report," City of Austin, August, 1994.

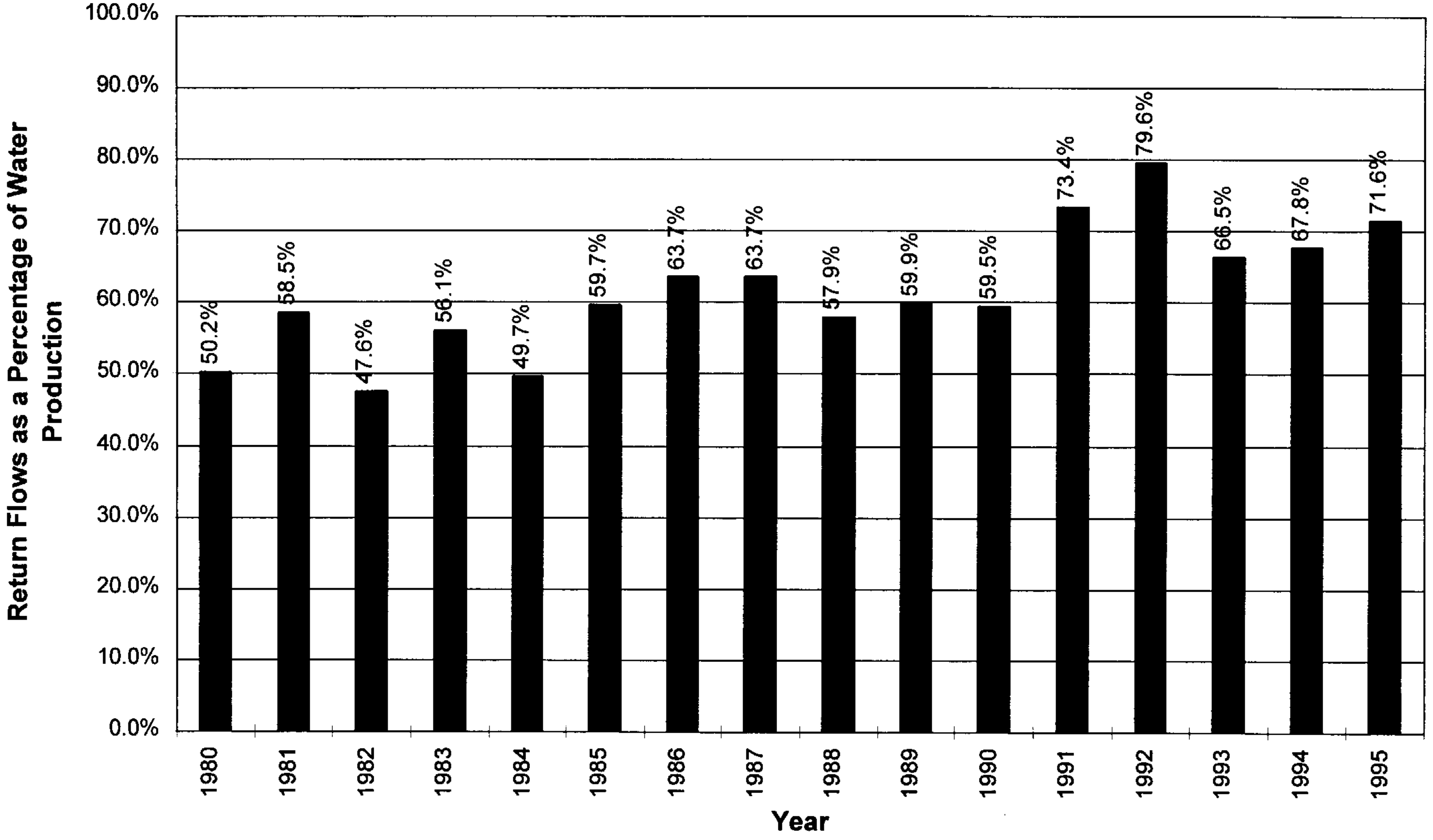
Table 3.2-2
Major Water Rights in the Lower Colorado River Basin

Water Right Holder	Model Parameters		
	Priority[1] Date	Demand Distribution for Modeling	Diversion Right (acft/yr)
LCRA Lakeside Irrigation Division			
a) Junior	11/01/87	agricultural	78,750
b) Senior (subordinated to COA[2])	01/04/01[2]	agricultural	52,500
Total			131,250
Garwood Irrigation Company			
a) agricultural	11/01/00	agricultural	133,000
b) municipal	11/02/00	uniform	35,000
Total			168,000
Pierce Ranch Irrigation Company	09/01/07	agricultural	55,000
LCRA Pierce Ranch[2] - Irrigation Division	09/01/07[2]	uniform	55,000
LCRA Gulf Coast Irrigation Division			
a) Junior	11/01/87	agriculture	33,930
b) Senior (subordinated to COA[2])	12/01/00[2]	agriculture	228,570
Total			262,500
City of Austin Municipal			
a) Junior	08/20/45	municipal	20,300
b) Senior (firmed from storage)	06/30/13	municipal	250,000
c) Senior	06/27/14	municipal	22,403
Total			292,703
City of Austin Steam-Electric			
a) Junior	02/23/65	municipal	16,156
b) Senior	06/30/13	municipal	24,000
Total			40,156

[1] Highland Lakes priority date is 1938.

[2] This portion of water right to be subordinated to the City of Austin Senior municipal rights under Certificate of Adjudication 14-5471, but not to other rights.

actual practice there are no restrictions (other than the maximum pumping rate) as to when (within the year) water may be diverted. This situation is very flexible which makes it difficult to model. In the Response model, this situation is simplified by assigning each right a fixed diversion amount for each day of the year. The total of these daily diversion assignments is the total annual right. If any portion of the assigned daily diversion amount cannot be met from run-of-river flows, the model does not allow for that deficit to be recovered at a later date. In actual practice, a diverter possibly could make up for the lack of availability by pumping on some later day if water becomes



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CITY OF AUSTIN
HISTORICAL RETURN FLOWS
ALTERNATIVE C-7

FIGURE 3.2-2

available. Therefore, the assumptions inherent in this modeling procedure result in underestimation of water potentially available to the more senior rights such as the City of Austin and Garwood Irrigation Company.

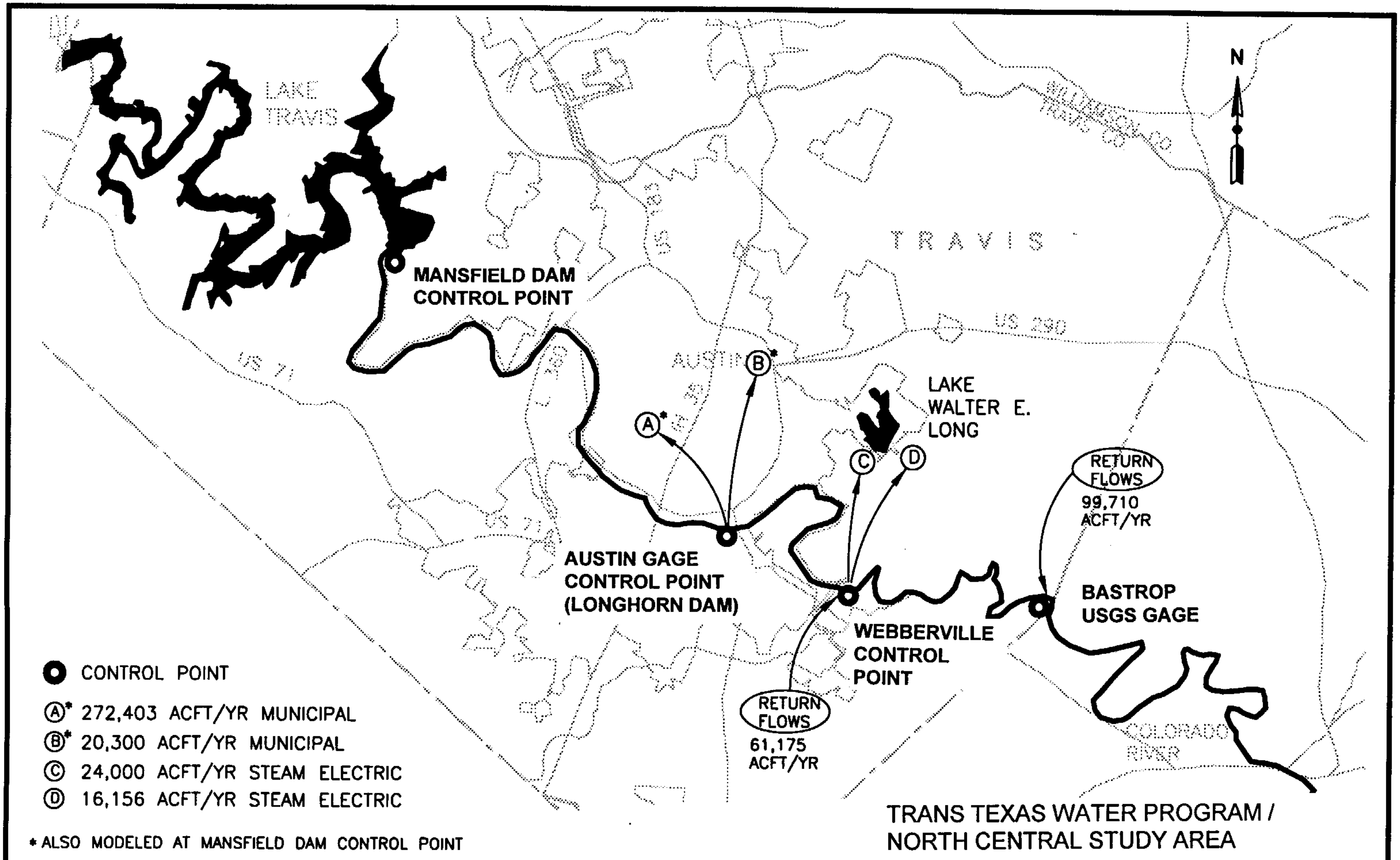
Another limitation of the Response Model is the aggregation of inflows and demands at control points. This limitation is common for basin models. Generally, control points are located at river gaging sites and they are the accounting points where inflows and diversions to the river are accounted. There are four control points where accounting is handled for Austin's diversions and return flows. These control point locations are shown on Figure 3.2-3.

The City of Austin's major municipal diversions occur in the model at Mansfield Dam; however, in reality the diversions are from Lake Austin and Town Lake which lie between the Mansfield and Austin control points. Intervening flows such as inflows from Bull Creek and Bee Creek which contribute to Lake Austin, and Barton Creek which contributes to Town Lake, are not available to the Mansfield control point but are available at the Austin control point. Therefore, assigning Austin's diversion to the Mansfield control point underestimates water availability. Similarly, assigning Austin's divisions to the Austin gage control point overestimates water availability at Davis and Ullrich water treatment plants on Lake Austin which do not have access to Barton Creek inflows contributing to Town Lake. The effect of control point location on estimated water availability was evaluated in this study.

Finally, the Response Model does not incorporate return flows from the agricultural uses in the lower basin or natural inflows below the Columbus, Texas USGS gage. Although these limitations may not significantly impact estimation of water availability to diverters, they do underestimate inflows to Matagorda Bay.

Estimated Availability

The availability of Austin's run-of-river rights identified in Table 3.2-1 were evaluated by LCRA using the Response Model. The two municipal rights under CA 14-5471 were aggregated in the analyses. The availability of water when the senior municipal rights are diverted at both Town Lake (Austin gage control point) and Mansfield Dam are summarized in Table 3.2-3 for average, 1954 to 1956 critical drought, and minimum year availability along with the requirement for stored water from the Highland Lakes. Since the municipal diversions are physically taken at both Lake Austin and Town Lake, actual availability would be more closely



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LOCATIONS OF CITY OF AUSTIN WATER RIGHTS IN DAILY ALLOCATION MODEL (DAP) ALTERNATIVE C-7

FIGURE 3.2-3

estimated with the diversions modeled at the Austin gage control point (Table 3.2-4). Previous studies have assumed that all of Austin's rights are located at the Austin gage control point. For both of these model scenarios, the steam-electric demands and the junior municipal right (CA 14-5489) are diverted at the Austin gage control point.

The impact of the diversion location to Austin's senior and junior municipal water availability is illustrated in Figure 3.2-4. It shows that availability is particularly increased in drought years for the modeled diversion location at the Austin gage control point. Additionally, the increase in municipal water availability due to diversion from Town Lake corresponds to a minor decrease in availability of Austin's more junior rights. The impact of the diversion location to Austin's total municipal water availability is illustrated side-by-side in Figure 3.2-5.

Modeling of water availability under Austin's municipal run-of-river diversion rights indicates that estimated water availability is significantly affected by the control point to which the diversion rights are assigned. When diversion rights are assigned to the Mansfield Dam control point at the upper-end of Lake Austin, estimated water availability is lower than when the diversion rights are assigned at the Austin gage control point. When assigned to the Austin gage control point, estimated water availability is increased because intervening inflows from Bull Creek, Bee Creek, Barton Creek, and other Austin area watersheds contribute to meeting the modeled diversions.

For minimum year conditions (i.e., 1954), water availability under Austin's municipal rights assigned to the Mansfield Dam control point is about 48,700 acft/yr (Table 3.2-4). When assigned to the Austin gage control point, municipal water availability almost doubles to 95,400 acft/yr. For the 1954 to 1956 critical drought period, estimated average annual municipal water availability for the Mansfield control point is 82,100 acft/yr (Table 3.2-4) and increases to 128,200 acft/yr (Table 3.2-3) when modeled at the Austin gage control point. However, Austin's diversion structures are located between these two model control points, and the estimated water availability reported in Tables 3.2-3 and 3.2-4 represent the high and low conditions. Actual water availability will be somewhere between the values reported in the tables, but generally closer to those at the Austin control point.

The effect of the location of municipal diversions on Austin's steam-electric water rights is to lower availability when municipal diversions are modeled at the Austin gage control point. This is shown in Figure 3.2-6. Since the steam-electric diversion rights are actually located near

Table 3.2-3
Water Availability with Senior Municipal Diversion at the Austin Gage Control Point

Water Right (priority date)	Diversion Right (acft/yr)	Water Availability[1] (acft/yr)		
		Minimum Year	*1954-1956 Drought*	*1941-1965 Average*
City of Austin Municipal				
Senior CA 14-5471(1913 & 1914)	272,403	89,400	121,500	191,100
Junior CA 14-5489 (1945)	20,300	6,000	6,700	8,800
Subtotal Run-of-River rights	292,703	95,400	128,200	199,900
From Highland Lakes[2]		154,600	121,800	50,100
Total Austin Municipal	292,703	250,000	250,000	250,000
City of Austin Steam-Electric				
Seaholm/Holly CA 14-5471 (1913)	24,000	2,000	3,600	10,400
Decker CA 14-5489 (1965)	16,156	4,500	5,200	6,900
Subtotal Run-of-River rights	40,156	6,500	8,800	17,300
From Highland Lakes[2]		33,656	31,356	22,856
Total Austin Steam-Electric	40,156	40,156	40,156	40,156
City of Austin Total	332,859	290,156	290,156	290,156

[1] All senior rights are modeled attempting to divert their full permitted amounts.

[2] Per 1987 Settlement Agreement, stored water from Highland Lakes required to firm a total municipal demand of 250,000 acft/yr and 40,156 acft/yr steam-electric demands.

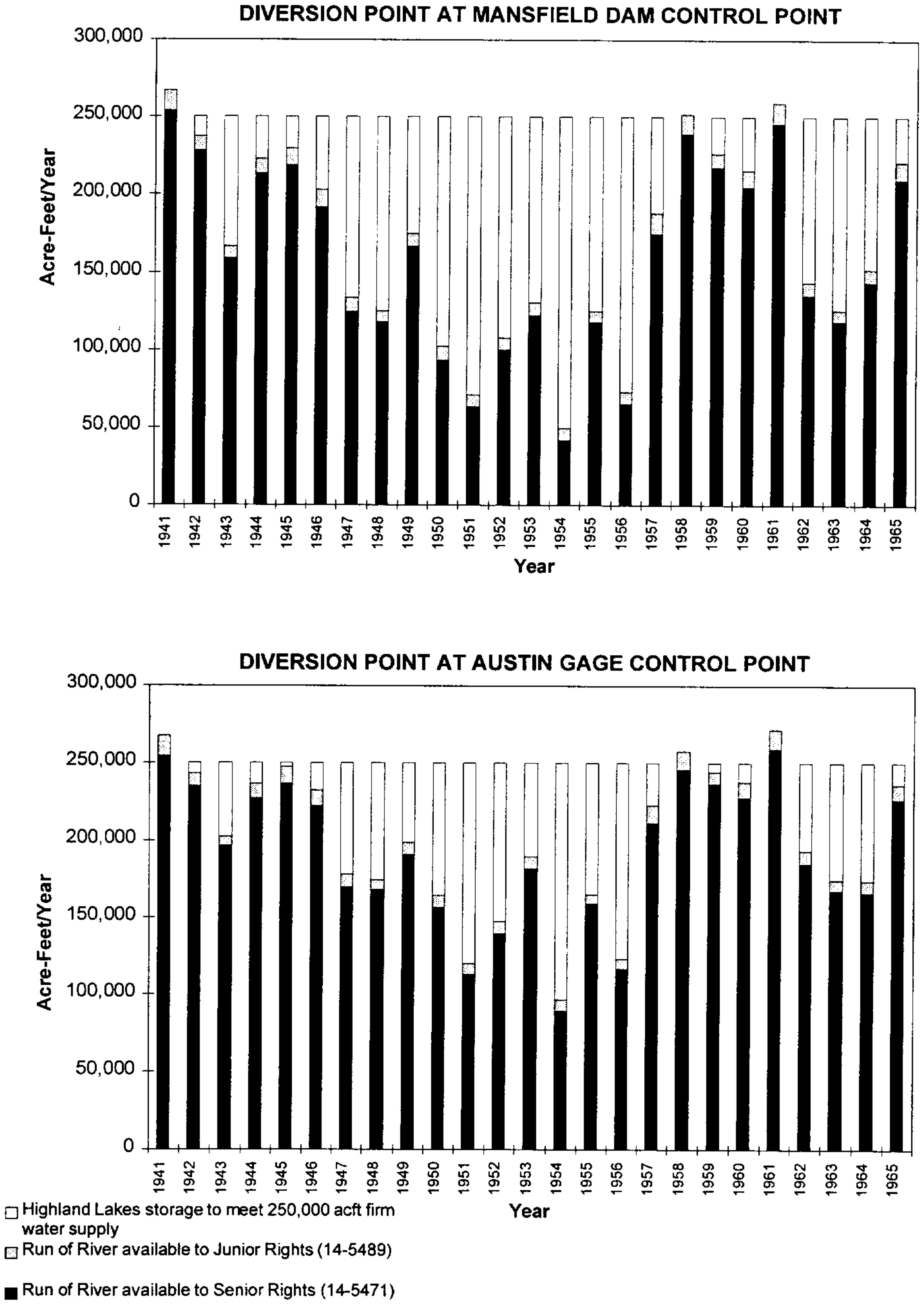
Table 3.2-4
Water Availability with Senior Municipal Diversion at the Mansfield Dam Control Point

Water Right (priority date)	Diversion Right (acft/yr)	Water Availability[1] (acft/yr)		
		Minimum Year	*1954-1956 Drought*	*1941-1965 Average*
City of Austin Municipal				
Senior CA 14-5471 (1913 & 1914)	272,403	41,600	74,800	158,600
Junior CA 14-5489 (1945)	20,300	7,100	7,300	9,500
Subtotal Run-of-River rights	292,703	48,700	82,100	168,100
From Highland Lakes[2]		201,300	167,900	81,900
Total Austin Municipal	292,703	250,000	250,000	250,000
City of Austin Steam-Electric[3]				
Seaholm/Holly CA 14-5471 (1913)	24,000	8,100	8,900	12,800
Decker CA 14-5489 (1965)	16,156	5,500	5,800	7,500
Subtotal Run-of-River rights	40,156	13,600	14,700	20,300
From Highland Lakes[2]		26,556	25,456	19,856
Total Austin Steam-Electric	40,156	40,156	40,156	40,156
City of Austin Total	332,859	290,156	290,156	290,156

[1] All senior rights are modeled attempting to divert their full permitted amounts.

[2] Per 1987 Settlement Agreement, stored water from Highland Lakes required to firm a total municipal demand of 250,000 acft/yr and 40,156 acft/yr steam-electric demands.

[3] Steam-electric diversions are located near the Austin gage control point and were not modeled at Mansfield Dam, but maintained at the Austin gage.



DIVERSION POINT AT MANSFIELD DAM CONTROL POINT

DIVERSION POINT AT AUSTIN GAGE CONTROL POINT

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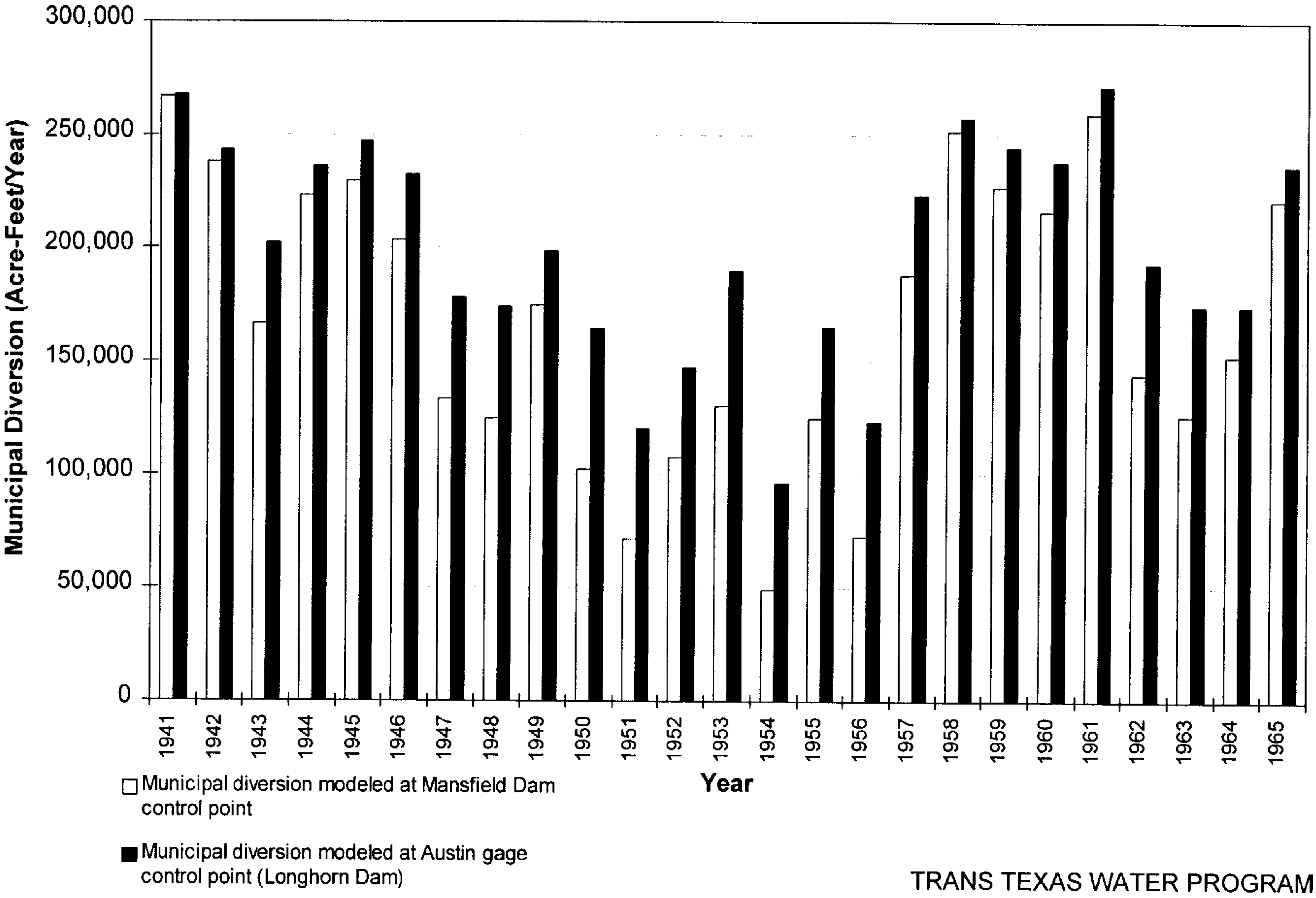
WATER AVAILABILITY UNDER AUSTIN'S MUNICIPAL RIGHTS ALTERNATIVE C-7

FIGURE 3.2-4



Note: Water availability estimated for
Junior (CA 14-5489) and
Senior (CA 14-5471) rights.

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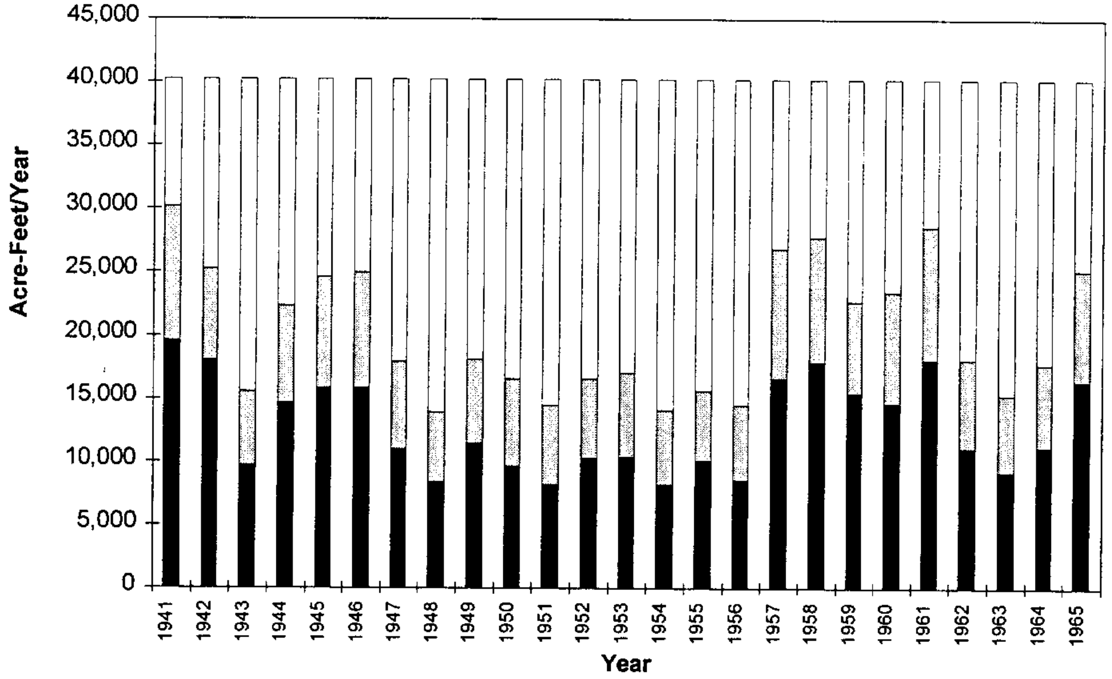
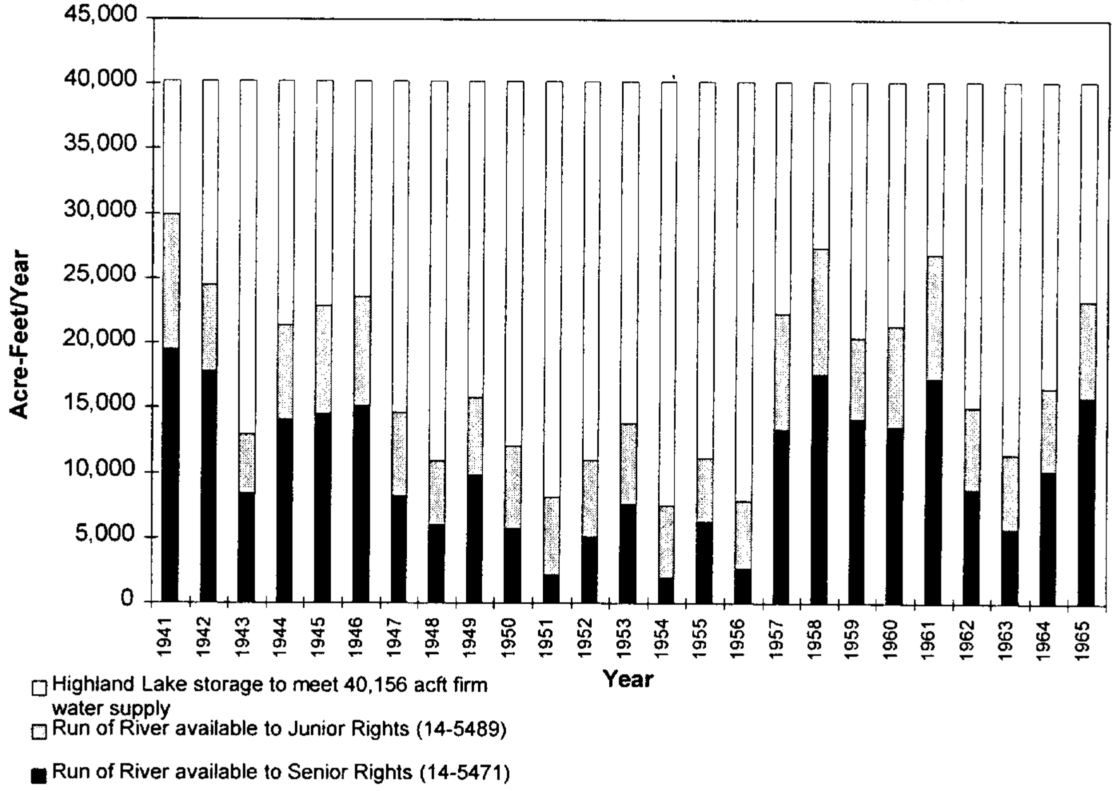
COMPARISON OF WATER AVAILABILITY UNDER AUSTIN'S MUNICIPAL RIGHTS - ALT. C-7

FIGURE 3.2-5

DIVERSION POINT AT MANSFIELD DAM CONTROL POINT



DIVERSION POINT AT AUSTIN GAGE CONTROL POINT



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WATER AVAILABILITY UNDER AUSTIN'S STEAM ELECTRIC RIGHTS ALTERNATIVE C-7

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FIGURE 3.2-6

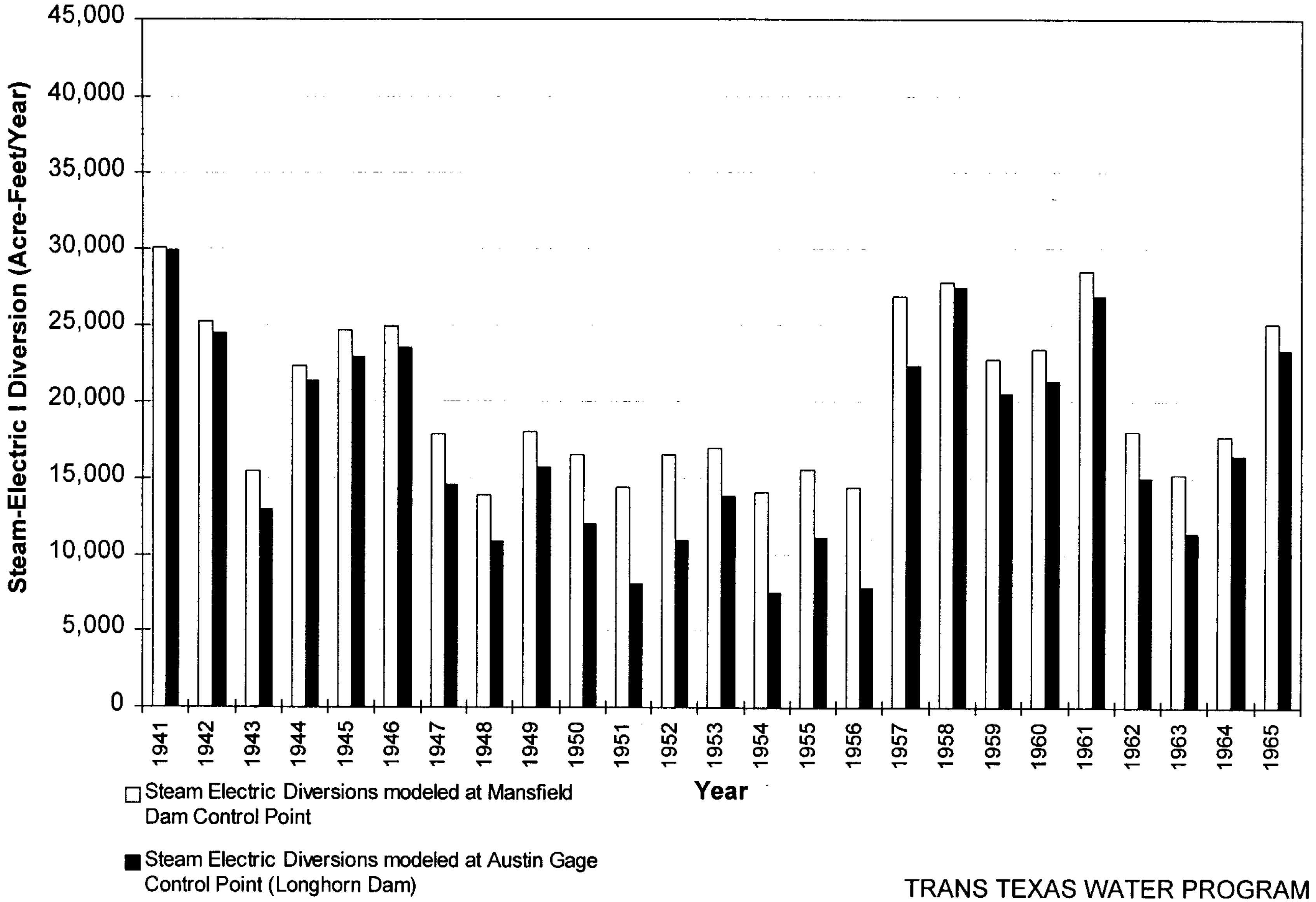
the Austin gage control point, these rights are always modeled at this control point. When the municipal diversions are modeled at the Mansfield Dam control point, the steam-electric rights have higher availability due to the intervening inflows between the control points. As modeled in the Response Model, with all diversion rights assigned at the Austin gage, the municipal rights are given precedence over the steam-electric rights, even though some of the rights have the same priority date. The impact of the diversion location to Austin's total steam-electric water availability is illustrated side-by-side in Figure 3.2-7.

For minimum year conditions, estimated water availability under Austin's steam-electric rights is 13,600 acft/yr (Table 3.2-4) with municipal diversions modeled at Mansfield control point. Estimated availability to the steam-electric rights is reduced to 6,500 acft/yr (Table 3.2-3) when the municipal diversions are modeled at the Austin gage control point. For the 1954 to 1956 critical drought period, estimated steam-electric water availability drops from 14,700 acft/yr (Table 3.2-4) with municipal diversions modeled at Mansfield to 8,800 acft/yr (Table 3.2-3) for all diversions at the Austin gage control point.

The estimated total water available to Austin under it's run-of-river rights is the sum of municipal and steam-electric diversions. For minimum year conditions, total water availability is estimated to be 62,300 acft/yr when municipal diversions are modeled at the Mansfield control point. When municipal diversions are modeled at the Austin gage control point, estimated water availability under all rights increases to 101,900 acft/yr. For the 1954 to 1956 critical drought period, total water availability is estimated to average 96,800 acft/yr when municipal diversions are modeled at the Mansfield control point. When municipal diversions are modeled at the Austin gage control point, average water availability under all rights increases to 137,000 acft/yr for this 3-year period.

Potential Increased Availability at Lake Austin Diversions

Austin currently diverts about 15 percent of its municipal water supply from Town Lake through the Green WTP, with the remainder being diverted from Lake Austin. Because of these diversion locations, Austin's actual water availability is more closely estimated by the results reported for the Mansfield Dam control point (i.e., drought average water availability is up to 29 percent lower for diversion only at Lake Austin). However, water availability to diversion on Lake Austin could be increased up to the values reported for the Austin gage control point by



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COMPARISON OF WATER AVAILABILITY UNDER AUSTIN'S STEAM-ELECTRIC RIGHTS-ALT. C-7

FIGURE 3.2-7

either pumping more water from Town Lake or by transferring water from Town Lake upstream to Lake Austin, thereby giving the Lake Austin diversion access to watersheds flowing into Town Lake.

Regardless of the quantity of water Austin can divert under its run-of-river diversion rights, under the terms of the City of Austin – LCRA Settlement Agreement, LCRA will supply stored water as necessary to firm a supply of 250,000 acft/yr for municipal use and 40,156 acft/yr for steam-electric use.

Impact on Lake Travis

The impact of diversion location to the availability of City of Austin's water rights is slight because of the firming provisions of the Settlement Agreement which makes the same amount of water available to Austin regardless of whether the diversion point is on Lake Austin or Lake Travis. However, the impacts to the Highland Lakes are more noteworthy. On average, the difference in storage required from the Highland Lakes, to firm up Austin's rights as set forth in the 1987 Settlement Agreement, is 31,800 acft/yr more if Austin's senior municipal water rights are modeled at Lake Travis (Mansfield Dam control point) rather than at Town Lake (Austin gage control point).

3.2.3 Environmental Issues

This alternative presents the results of a computer model evaluation of the availability of water for diversion from the Colorado River under the City of Austin's water rights, and the terms of the 1987 Settlement Agreement between the Lower Colorado River Authority and the City of Austin. The model showed differences in the amount of water available for diversion depending on the location (control point) used in accounting for diversions and return flows, and the seniority of the water right. However, releases from the Highland Lakes pursuant to the Settlement Agreement would make no more than 290,156 acft available for diversion in the driest year in the period of record, regardless of control point or seniority of right (Tables 3.2-3 and 3.2-4).

The model showed that since inflows from significant tributaries (e.g., Bull Creek, Barton Creek) are available at the more downstream control point (Austin gage) than at Mansfield Dam, use of that more upstream location for modeling diversions resulted in substantially greater demands on water stored in the Highland Lakes. Table 3.2-3 indicates that 72,956 acft/yr (50,100 acft/yr municipal and 22,856 acft/yr steam-electric) will have to be released from storage under average conditions to meet the terms of the Settlement Agreement with Austin's demands modeled at the Austin gage control point. When modeled at Mansfield Dam, the required release from storage increases to 101,756 acft/yr (Table 3.2-4: 81,900 acft/yr municipal and 19,856 acft/yr steam-electric), or an increase of 28,800 acft/yr. For minimum year conditions, the required release from storage increases from 188,256 acft/yr when modeled at the Austin gage control point, to 227,856 acft/yr when modeled at Mansfield Dam, or an increase of 39,600 acft/yr. Colorado River flows below Austin were the same regardless of the control point used in the model.

The City of Austin's actual diversion sites are located on Lake Austin and Town Lake, between the two control points used in the modeling study, so the actual mix of run-of-river water and that released from the Highland Lakes for the period of record will be intermediate between the values given in the tables and figures of Section 3.2.2. Therefore, if Austin's diversion sites were physically moved to the vicinity of Mansfield Dam, the increase in releases from the Highland Lakes to satisfy the terms of the Settlement Agreement would be less than the modeled 1941 to 1965 average increase of 28,800 acft/yr (39,600 acft during the maximum drought year).

The direct effect of additional releases would be an increase in the fluctuation of the water surface elevations in Lakes Travis and Buchanan. Because of the sizes and existing variability of Lakes Travis and Buchanan (whose water levels are allowed to vary, while the other Highland Lakes are typically held at constant elevations), the additional releases necessary for a Mansfield Dam diversion point would have no significant impact on water levels, or on the rate of change in water levels in those impoundments under normal and wet climatic conditions. Some additional drawdown can be expected during extreme drought years when the additional releases would be a larger proportion of the water remaining in storage when the elevations of Lakes Travis and Buchanan are low. At historic low levels, the additional releases would require 5 percent of the capacity of the two lakes.

Potential biological effects of increased water level fluctuations include disruption of nesting in fish species that utilize shallow littoral areas and stranding of beds of rooted aquatic vegetation. The significance of the impact is strongly dependent on the amount, rate, and timing of changes in water level. The four bottom nesting fish found in Lake Buchanan are the bluegill sunfish, the largemouth bass, the Guadalupe bass, and the longear sunfish ranked in order of abundance.[6] To impair reproductive success in these species, drawdowns must be: (1) sufficiently severe to strand active nests (more than 3 feet for bluegill and 5 feet for largemouth bass[7]); (2) sufficiently rapid that newly established nests are stranded prior to development of a free swimming stage (typically a period of 10 days for bluegill, and 14 days for largemouth bass[8]); and (3) changes in water level must continue to occur throughout a significant portion of the reproductive season (March through September for bluegill sunfish, and December through May for largemouth bass[9]). Additional drawdowns of a few inches spread over an annual cycle cannot be expected to result in significant changes in fish populations.

Rooted aquatic vegetation is typically restricted by rocky substrates, steeply sloping shorelines, and fluctuating water levels[10] in Edwards Plateau reservoirs with Lake Travis being typical of this situation. Lake Buchanan tends to have more extensive shallows than the other Highland Lakes,[11] but many of these result from recently deposited sediments that are relatively unstable and by resuspending contribute to the turbidity of the water column, which restricts the growth of rooted vegetation.[12] The slight changes in water levels in normal to wet years are not expected to significantly affect rooted vegetation, while during extreme drought periods established vegetation beds are already stranded. Large drawdowns in these two reservoirs do not generally last long enough to allow the establishment of substantial stands of aquatic vegetation, so the lowering of water levels attributable to the additional releases necessary for a Mansfield Dam diversion site is not expected to have significant impacts.

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[6] Terre, David R., and Stephan J. Magnelia. "Survey Report for Buchanan Reservoir," 1993, Statewide Freshwater Fisheries Monitoring and Management Program, Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department, Austin, Texas.

[7] Ibid.

[8] Ibid.

[9] Carlander, Kenneth D. 1977. "Handbook of Freshwater Fishery Biology: Life History Data on Centrarchid Fishes of the United States and Canada, Volume Two." Iowa State University Press, Ames, Iowa.

[10] Wetzel, Robert G. 1983. "Limnology," second edition. Saunders College Publishing, Fort Worth, Texas.

[11] Terre, David R., and Stephan J. Magnelia. 1994. "Survey Report for Buchanan Reservoir," 1993, Statewide Freshwater Fisheries Monitoring and Management Program, Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department, Austin, Texas.

[12] Reimer, Donald N. 1984. "Introduction to Freshwater Vegetation." AVI Publishing Company, Inc., Westport, Connecticut.

3.2.4 Water Quality and Treatability

The City of Austin will continue diverting under its water rights to their existing water treatment plants, therefore, raw water quality should remain the same as that currently experienced by the City. The only exception to this may be if Thomas C. Green WTP is retired and the new Water Treatment Plant No. 4 on Lake Travis is brought on-line. Table 3.2-5 summarizes the water quality characteristics at each of the current and potential WTP locations.

Table 3.2-5
Conventional Water Quality Constituents at Existing and Potential City of Austin's WTPs[1]

Constituent	Lake Travis	Lake Austin	Town Lake
Dissolved Oxygen (mg/l)	8.04	7.07	8.05
pH (su)	8.23	7.88	7.66
TDS (mg/l)	467.36	482.75	482.52
Fecal Coliforms (No./100 ml)	41.07	47.42	94.50
Chloride (mg/l)	110.30	104.31	108.33
Sulfate (mg/l)	83.75	79.21	84.50
Total Phosphorus (mg/l)	0.04	0.02	0.03
Total Nitrogen[2] (mg/l)	0.13	0.19	0.16

[1] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.
[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Although the conventional water quality characteristics of the three water sources are similar, synthetic organics (SOCs) and trace metals in the sediments are a concern in Town Lake. Substantial rainfall events on the heavily urbanized watershed results in non-point source pollution including SOCs, pesticides, nutrients, sediment, metals, and fecal coliforms.[13] Elevated levels of chlordane in the sediments and fish population resulted in a fish consumption advisory by the Texas Department of Health in 1990.[14] All three lakes exhibit oligotrophic (under-nourished) characteristics; however, during periods when water is not being released from Lake Travis for downstream irrigation purposes (mid-October to mid-March), Town Lake has experienced algae blooms that have caused voluntary WTP shut-downs for taste and odor concerns and increased treatment costs.[15]

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[13] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.
[14] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.
[15] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.

Lake Travis and Lake Austin are protected by TNRCC's Chapter 311, Water Protection, which prohibits discharge of pollutants into the reservoirs' water quality area unless sufficient treatment is applied so that the existing water quality is maintained.[16] The City of Austin is participating in the Clean Lakes Program to monitor and implement innovative pollution control measures for Town Lake.[17] With TNRCC's anti-degradation policy and the strong awareness of the City and local Austin community to the effects associated with increased urbanization, the water quality of the reservoirs is expected to remain relatively constant. However, increased population and development in the Lake Travis and Lake Austin watersheds could eventually lead to future water quality problems from non-point source pollution. All three reservoirs have experienced natural fluctuations in chlorides, sulfates, and TDS caused by hypersaline flows from upstream areas, but most notably from spills at Natural Dam Lake.

The City of Austin currently employs a conventional treatment scheme (rapid mix, flocculation, sedimentation, filtration, and disinfection) to produce potable water with additional hardness removal, and taste and odor control measures to improve the water's aesthetic quality. These treatment processes should continue to be adequate for treating the additional raw water diverted from the three lakes under the City's existing water rights pending any significant modifications to the state's drinking water standards.

3.2.5 Engineering and Costing

At present, the City of Austin diverts water under its run-of-river water rights at three locations: Ullrich WTP (Lake Austin), Davis WTP (Lake Austin), and Green WTP (Town Lake). The combined peak day capacity of these three treatment plants is 225 mgd. Presently, average daily water use is about 120 mgd, or about 135,000 acft/yr (max day peak factor of 1.87). Water supplies in excess of current diversion and treatment capacity, (whether the supplies come from existing water rights or from new supplies potentially available from other sources) could be diverted and treated by the City of Austin at an expansion of an existing facility, or by construction of WTP No. 4 on Lake Travis.

WTP No. 4 will allow Austin to utilize water from Lake Travis and will significantly increase Austin's diversion and treatment capacity. Diversions to WTP No. 4 could originate

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[16] Texas Administrative Code, Title 31, Chapter 311.

[17] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.

from Austin's rights under the 1987 Settlement Agreement,[18] or from new sources of water made available in Lake Travis by implementation of one or more alternatives in the Trans-Texas Water Program. WTP No. 4 is a major capital expenditure of the City of Austin and the timing of implementation will be dependent on a number of demand and financing factors. Prior to implementation of WTP No. 4, some additional diversion and treatment capacity can be obtained by expansion of existing facilities, thereby allowing use of water supplies originating from this or other alternatives. Expansion of existing facilities would be the more economical method for utilizing water supplies originating from this alternative. The following subsection provides information on the expected cost to divert and treat quantities of water through facility expansion. Section 3.12 (Purchase of Water from LCRA at Lake Travis) discusses diversion of larger quantities of water from Lake Travis, and the associated costs for WTP No. 4 and conveyance facilities.

Expansion of Existing Facilities

Ullrich WTP is the only existing plant that has site area for capacity expansion. Austin's long-range planning[19] anticipates two phases of improvements associated with Ullrich WTP. Improvements prior to year 2000 consist of transmission pipeline and pump station improvements. Some of the facilities recommended prior to 2000 are currently being implemented. Improvements in the next phase, which are planned to be implemented prior to year 2010, include a 40 mgd water treatment capacity expansion, pump station, ground storage tanks, and several transmission mains. Cost information from the Long-Range Planning Guide for expansion of the Ullrich WTP and associated transmission facilities has been used to estimate annual unit costs for water supplies diverted through an expansion of City of Austin facilities. In addition to this alternative, these unit costs are also used for Alternative C-6 (Potential Use of Austin Steam-Electric Generation Water Rights for Municipal Use).

Table 3.2-6 summarizes the estimated capital and annual costs for expansion of existing City of Austin facilities to utilize water diverted under existing water rights. The annual unit cost to divert and treat water under Austin's run-of-river water rights through an expansion of the

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[18] Comprehensive Water Settlement Agreement between City of Austin and Lower Colorado River Authority, December 10, 1987.

[19] City of Austin, "Water Distribution System Long-Range Planning Guide", February, 1994.

existing treatment and distribution system is estimated to be $275/acft or about $0.84 per 1,000 gallons for the additional volume of water.

Table 3.2-6
Cost Estimate Summary for Expansion of Ullrich WTP and Transmission Facilities

Item	Cost
Capital Costs[1]	
Ullrich WTP Upgrade (40 mgd expansion)	$21,540,000
Transmission Pipelines	5,218,000
Pump Station	582,000
Reservoir	2,454,000
Total Capital Costs	$29,794,000
Engineering, Contingency, and Legal	*Included*
Land Acquisition	*in*
Environmental Studies and Mitigation	*Above*
Interest During Construction	*Costs*
Total Project Costs	$29,794,000
Annual Costs	
Annual Debt Service (8% @ 25 years)	$2,792,000
Annual Operation and Maintenance (excluding power)	2,736,000
Power	630,000
Purchase Raw Water from LCRA[2]	420,000
Total Annual Cost	$6,578,000
Annual Project Yield[3]	23,960
Annual Unit Cost of Treated Water	
($ per acft)	$275
($ per 1,000 gal)	$0.84

[1] Source: City of Austin, "Water Distribution System Long-Range Planning Guide", Table S-2, Cost Estimate for CIP Improvements Recommended Between 2000 and 2010. Capital costs escalated 7.7%.

[2] For deliveries to City of Austin in excess of 150,000 acft/yr, cost of water from LCRA is $105 per acft. Under this expansion, it is assumed that average water use will be about 154,000 acft/yr, which will result in the purchase of 4,000 acft/yr.

[3] Incremental treatment plant capacity is 40 mgd; for max day peak factor of 1.87, annual project yield is 21.4 mgd (23,960 acft/yr).

3.2.6 Implementation Issues

This section has described refinements in the hydrologic modeling used to estimate availability of water to Austin's existing run-of-river water rights. As such, no "alternative" is to be implemented and no implementation issues are anticipated.

This section has also described some of the terms of the 1987 Settlement Agreement between the City of Austin and LCRA. The 1987 agreement allows the City of Austin to divert water from Lake Travis, as well as Lake Austin and Town Lake. However, diversions from Lake Travis are limited to 170,000 acft/yr and the raw water pumping rate is limited to 150 mgd. With construction of Water Treatment Plant No. 4 (WTP4) by the City of Austin, the annual limitation will probably be adequate through the planning horizon. Projected demands to be met by WTP4 for various scenarios and planning dates are described in Section 3.12. However, the withdrawal rate limitation is not adequate to meet peak day demands at WTP4 through the planning horizon and amendment of the Settlement Agreement will probably be necessary.

Conservation and Reuse Alternatives

3.3 Accelerated and Additional Municipal Water Conservation for the Austin Service Area (L-9)

3.3.1 General Description of Alternative

A major public policy objective is to increase water use efficiency through water conservation without adversely affecting population and economic growth potentials. In an operational sense, the objective can be expressed in terms of reducing the quantity of water used per person per day (per capita water use) for a large proportion of the population served. Methods to accomplish this objective include water conservation programs that reduce loss of water through leakage, replace high volume plumbing fixtures with low-flow fixtures, and modification of landscapes to reduce the quantity of water used for landscape irrigation. The City of Austin has a water conservation program that is operating to accomplish the objectives mentioned above. In this analysis, the present program is recognized as the baseline condition and attention is given to estimating the potential water conservation that might be achieved if the City's present program were accelerated to be accomplished in a shorter timeframe (i.e., by the year 2010 instead of 2020). Also, additional types of water conservation measures are identified and evaluated as to potential water savings and costs.

The quantity of water used within a typical city or water supply service area is usually expressed in terms of gallons per person per day (per capita water use). It is important to note that the municipal per capita water use within the home is for drinking, toilet flushing, bathing, food preparation, dish washing, laundry, and cleaning; outdoor uses at the home include landscape irrigation, car washing, outside cleaning, and, in some cases, air conditioning. In addition to water used at homes, the per capita water use statistic includes a person's share of water used in the workplace for toilet flushing, drinking, cleaning, showers, and lawn irrigation of office and commercial complexes, as well as a person's share of water used in commercial establishments such as restaurants, laundries, car washes, and lawn and garden centers.

The per capita water use statistic also includes a person's share of water used in institutions such as schools, churches, and recreation centers, and water used by the city for fire protection, sanitation, and public recreation, including irrigation of city parks and scenic places as well as unaccounted for water from leaks in the distribution system. Thus, in order for water conservation efforts to achieve the maximum effectiveness in reducing per capita water use, such efforts will need to be focused at both private residences, and the commercial and workplaces where people also use water. For example, in the Austin service area in 1990, 59 percent of water use was in homes, 20 percent was in commercial establishments, 9 percent was for public purposes, 7 percent was for industry, and 5 percent was unaccounted for (Table 3.3-1).

Municipal water conservation can be accomplished by using plumbing fixtures such as toilets, shower heads, and faucets that 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 that require less water; by repair of plumbing and water-using appliances to reduce leaks; and by modifying personal behavior which controls the use of plumbing fixtures, appliances, and lawn watering methods.

Table 3.3-1[1]
Water Use Statistics for the Austin Service Area -- 1990

Sector	**Use Percent**	**Place of Use**		**Outdoor Peak Factor**
		% Indoor	**% Outdoor**	
Single Family Homes	46	64	36	2.96
Multi-Family Homes	13	76	24	2.37
Commercial	20	62	38	3.22
Public	9	67	33	2.98
Industrial	7	75	25	2.36
Unaccounted For	5	NA	NA	Overall = 2.93
TOTAL	100	NA	NA	NA

[1] From Report for Water Conservation Plan, City of Austin, Texas, Montgomery Watson, March 1993
City changed plumbing code effective July 1, 1991.

An effective method to reduce per capita water demand for indoor uses is through the use of low-flow plumbing fixtures, primarily toilets and shower heads. In 1991, the Texas Legislature enacted legislation which established minimum standards for plumbing fixtures sold in Texas.[1] The legislation became effective on January 1, 1992, and allowed until January 1, 1993, for suppliers to clear existing inventories of pre-standard plumbing fixtures. The Texas Water Development Board (TWDB) estimates that the effect of the low flow plumbing fixtures will be to reduce per capita demand by about 11.7 gpcd by the year 2020, and 19.5 gpcd by 2050 (Table 3.3-2).

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

Table 3.3-2[1]
Projected Per Capita Water Demand for City of Austin Service Area
Below Normal Precipitation with Average Water Conservation

Year	Projected Per Capita Water Use (gpcd)
1990	170 (Actual)
2000	204
2010	195
2020	188
2030	185
2040	184
2050	182

[1] Computed from Texas Water Development Board, Municipal Water Demand Projections, most likely case.

In the following analyses, estimates are made of water conservation through an expansion of the City's existing water conservation program. In addition, other measures that have potential for water conservation are analyzed. Two types of water conservation are considered. The first type of conservation measure aims at improving efficiency of existing facilities. Audits, retrofitting, and xeriscape rebates are examples of this type. For these programs, an estimate is made of the potential water conservation based on information from the City's present program. Estimates are made of both the quantities of municipal water demand reductions and the costs of water conservation measures to achieve the estimated demand reductions. The second type of conservation measure is that which is on-going from year to year, such as conservation water rates and ordinances which apply to new construction.

3.3.2 Estimated Yield and Costs of Conservation Measures

The City's existing water conservation program consists of the following conservation measures:

- Public information,
- Residential audits — indoor,
- Residential audits — outdoor,
- Xeriscaping,
- Large landscape audits,
- Residential retrofitting,
- Commercial landscape ordinance,
- Commercial audits,

- Commercial and municipal toilet replacement,
- Commercial/industrial rebates,
- Waterless urinal rebate,
- Peak day public education program,
- Circulating pool filters,
- Leak detection and repair, and
- Water conservation rebates.

Additional possible measures are:

- Residential/landscape ordinance,
- Rain collection systems — public information, and
- Horizontal axis washing machine rebates.

The present program which addresses each of the measures listed above has an annual budget of $1.7 million and the program goal is to reduce water use by 0.7 mgd, or 784 acft/yr., through public information, water audits, xeriscape landscapes, and some plumbing retrofit. The cost per acre-foot of demand reduction is $203 at eight percent interest and 25 year amortigation schedule (Table 3.3-3).

Estimates of demand reduction potentials and costs of each water conservation measure listed above are presented in Table 3.3-3 for an accelerated water conservation program to accomplish water conservation potentials by year 2010 instead of 2050, as is estimated to be the date at which low flow plumbing fixtures are expected to be phased in through replacement and repair.

Public Information

Public information programs are generally regarded as essential water conservation an established practice in the thinking of the public, but are difficult to assess for direct effects. Although the City estimates that there are some water conservation effects due to the "Peak Day" Public Education Program, no additional reductions in daily water use are included for the public information program.

Table 3.3-3
Summary of Estimated Water Demand Reduction and Costs for Accelerated and Additional Water Conservation in the Austin Service Area

	Conservation Measure	Total Cost ($1,000)	Peak Reduction (MGD)	Average Annual Reduction (acft)	Cost per acft ($/acft)
	Present Program	$1,700	0.70	784	
	Accelerated Measures				
1	Public Information:	NA*	NA	NA	NA
2	Indoor Residential Audits	$830	0.23	240	$324
3	Outdoor Residential Audits	$1,200	1.30	500	$225
4	Residential Xeriscape	$31,625	5.70	2,100	$1,411
5	Commercial Landscape Audit	$458[1]	2.10	790	$54
6	Plumbing Retrofit	$64,320	13.20	5,080[2]	$949
7	Commercial Landscape Ordinance	NA[3]	0.16	63	- -
8	Commercial Audit	$250	0.94	70	$335

*NA means not applicable.

[1] With a cost outlay of $6.03 million per year ($64,320,000 amortized), there is an estimated savings to water customers of $6.97 million annually through reduced water billing. Thus, this program would more than pay for itself.

[2] Maximum annual reduction is in year 2010 and is estimated at 7,760 acft/yr.

[3] This applies only to new structures, and is based upon the assumption that the cost of installation of water efficient landscaping is no greater than that of previously used types. Thus, there is no cost estimate associated with this conservation measure.

Indoor Residential Audits

Indoor audits consist of inspection for leaks in pipes, toilets and faucets, replacement of showerheads, and an evaluation of the water-savings potential of replacing existing toilets with types that use only 1.6 gallons per flush.[2]

If the top 50 percent water users are offered audits, it is estimated that 20 percent of them will accept,[3] and savings of 8 gallons per capita per day (gpcd) can be achieved.[4] The City has performed 955 audits. Completion of the remaining audits, together with replacement of plumbing fixtures, as needed, is estimated to have a total cost of $830,000, and would conserve 240 acft/yr. (Table 3.3-3). The peak reduction would be expected to be about 0.23 mgd (Table 3.3-3).

Outdoor Residential Audits

Like the indoor audits, outdoor residential audits would be directed at the top 50 percent outdoor water users. Note that they are not necessarily the same as the top 50 percent indoor users. Outdoor water use may be distinguished from indoor water use by analysis of monthly water use. Substantially higher use through the summer months indicate high outdoor water use.

Outdoor audits consist primarily of determining an efficient watering schedule, as well as an inspection of the irrigation system for leaks and inefficiencies. Homeowners are made aware of the benefits of low water use landscapes. Reductions in outdoor water use are estimated at 15 percent.[5] Applied to the 20 percent who are estimated to accept audits, this yields a total water use reduction of 560 acft/yr. The unit cost is estimated at $2,400 acft/yr, so the annual cost is $120,000. The effect on peak day demand is estimated at 2.9 times the average day demand, and is therefore about 1.3 mgd. However, the City has already achieved about 10 percent of this, leaving a potential water conservation effect of this program of about 500 acft/yr. The estimated total cost of outdoor residential audits is $1,200,000. (Table 3.3-3).

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[2] Report for Water Conservation Plan, City of Austin, Texas, Mongomery Watson, March 1993.
[3] Ibid.
[4] Ibid.
[5] Ibid.

Residential Xeriscape

It is understood that the most flexible area of residential water use, and that which is most responsible for high peak demands, is irrigation of high water-use grass such as St. Augustine. It is estimated that replacement of such grass with a more drought-tolerant species, such as Prairie Buffalo grass would save an average of 175 gpd per lawn (30 percent of water use).[6] If ultimately 10 percent of existing lawns were resodded with drought-tolerant grass, above the number the City has already achieved, it may expect an estimated peak day reduction in municipal water use of about 5.7 mgd and an annual reduction of 2,100 acft/yr. The cost of replacing grass is estimated at $2,875 for a 7,000 square-foot lawn. The estimated total cost to resod 11,000 lawns would be $31,625,000 (10 percent of the estimated number of lawns in Austin) (Table 3.3-3).

Commercial Landscape Audit

The City of Austin currently has an audit program that targets commercial landscapes.[7] Utility personnel inspect irrigation systems for inefficiencies, recommend improvements, and determine an optimum irrigation schedule based on site-specific conditions. The program includes an annual follow-up list. Since the program was begun in 1993, City Water Conservation Program personnel estimate that a reduction of 9 acft/yr has been achieved so far.[8] This report estimates that if the top 50 percent of water users are approached and 40 percent of them accept an audit,[9] the City may realize an additional decrease in demand of about 790 acft/yr. Applying the outdoor peak factor of 2.9 results in a peak day reduction of 2.1 mgd. Considering the cost for personnel training and publicity, the total cost to the City for auditing 40 percent of the top 50 percent of water users would be $458,000. (Table 3.3-3).

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[6] Xeriscape: Promises and Pitfalls, City of Austin, Texas, December 1994

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

[8] Tony Gregg, Water Conservation Program Manager, Unpublished Spreadsheet, July 1996.

[9] Higher than usual 20% acceptance rate; Assumes audits mandatory for public properties.

Plumbing Retrofit

Retrofitting existing homes with low-flow toilets and showerheads would achieve most of the indoor water conservation potential (i.e., retrofitting is expected to result in an average per capita reduction of 22 gpd[10]).

At the time of adoption of the low-flow plumbing fixtures act in 1993, it is estimated that about 536,000 people lived in the Austin service area.[11] The estimated cost of retrofitting all structures that existed in the Austin service area at the time the plumbing fixture act became effective is $120 per person, which includes cost of fixtures and labor.[12] Thus, the estimated cost of plumbing retrofit in the service area would be approximately $64.32 million ($120 x 536,000). The water conservation potential through retrofitting residences, commercial establishments, workplaces, public places, and motel and hotel rooms that existed at the time the plumbing fixture act became effective is estimated at 13,208 acft/yr or 11.8 mgd. If an accelerated rate of plumbing retrofit were established to begin in 1999 with a schedule to accomplish complete plumbing retrofit of structures that existed at the time the plumbing fixtures act went into effect, at a uniform annual rate by the end of 2010 (11 years), the average annual water demand reduction for the period 1999 through 2050 would be 5,080 acft. If the program were financed for a period of 25 years at an interest rate of 8 percent, the annual cost would be $6.03 million. The estimated savings to water customers that would be realized through the 5080 acft/yr of reduced use would be $6.97 million per year at Austin's present rate of approximately $2.00 per thousand gallons for water and $3.58 per 1,000 gallons of wastewater treatment.

Commercial Landscape Ordinance

The City's existing commercial landscape ordinance applies to new construction of multi-family, commercial, and industrial and public sector properties. A reduction rate of 20 percent is applied to the estimated new annual outdoor water use of each sector.[13] Estimated annual reduction is 63 acft/yr, while the annual peak day reduction is 0.16 mgd. At this rate, by the year 2020 a demand reduction of nearly 1,600 acft/yr (4 mgd peak) would be realized (Table 3.3-3).

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[10] TWDB unpublished planning data, 1995.

[11] TWDB Projections for the Most Likely case;

[12] Structures built since the low flow plumbing fixtures act became effective will have been equipped with low flow plumbing fixtures.

[13] Non-Residential Water Conservation, Ploeser, et al, California Water Resources Dept., 10/92.

The cost of installing an efficient landscape is assumed to equal that of other landscapes, so, other than the cost of enforcement, there is no cost of the program. Requiring fully xeriscaped landscapes would increase savings from 20 to 30 percent,[14] a factor of 1.5, saving nearly 100 acft/yr and reducing the peak day demand by 0.24 mgd/yr.

Commercial Audits

Commercial audits involve an inspection of both interior and exterior water use practices at commercial, industrial, and public facilities. A report is made of the efficiency of the irrigation system, indoor piping, cooling tower operation, and recommendations to eliminate waste. Water savings are estimated for the top 50 percent water users in these sectors. Based on the literature for audit acceptance rates and overall water conservation per sector, it is estimated that about 700 acft/yr could be saved.[15,16] Total cost is estimated at $250,000, with an annual reduction of 70 acft/yr. Because most of the savings from these audits is expected to be indoors, a peak factor of 1.5 is estimated, yielding a peak day reduction of 0.94 mgd when all audits have been completed (Table 3.3-3).

Other Conservation Methods

Other potential water conservation methods available to the City of Austin include (1) Toilet replacement in commercial and public places; (2) circulating pool filters; (3) water conservation rates; (4) Residential landscape ordinance; (5) Rebates to industrial customers; and (6) Rain collection systems.[17] However due to lack of information, it is not possible to include estimates of water conservation and costs per acre-foot of waters saved by these methods.

Summary of Water Conservation and Cost Estimates

It is estimated that the City of Austin's present water conservation program, which is budgeted at $1.7 million annually, is resulting in a permanent reduction of demand of about 784 acft/yr, at a cost of $203 per acre-foot. At this rate of effort, the present program is estimated to

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[14] Xeriscape: Promises and Pitfalls, COO, Texas, December 1994

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

[16] TWDB Projections

[17] Leak detection and repair is not included here, since Austin's unaccounted for water is less than 10 percent, and it is unlikely that increased effort at this activity would be cost effective.

reduce demands by 11,000 acre-feet in about 15 years. An accelerated program of indoor and outdoor residential audits, commercial landscape audits, and plumbing retrofits to replace plumbing fixtures in structures that existed in 1993 (date at which the state's low flow plumbing fixture act became effective) by 2010 instead of over the next 50 years through ordinary repair and replacement, would reduce annual water demands by an additional 6,610 acft/yr, at a cost of approximately $947 per acre-foot.

3.3.3 Environmental Issues

The potential environmental effects of additional and accelerated water conservation in the Travis County service area can be categorized as follows:

- Effects on streamflows resulting from changes in return flows.
- Effects on urban landscapes.

The following discussion deals with expediting water conservation measures already in place, and considers measures for additional water conservation. Wastewater reuse is considered separately in Alternatives L-5 and L-8 (Sections 3.5 and 3.6 respectively).

Because the City of Austin already has an aggressive water conservation plan, the potential benefits of accelerated and additional conservation measures relative to the overall conservation effort are somewhat limited compared to communities in which there has not been as much interest in water conservation. An indirect effect of accelerated and additional conservation measures may be to delay new water supply projects which would postpone the environmental affects (either harmful or beneficial) of implementing such projects. However, as long as the trend is toward increased water use, the need for additional water supplies would only be postponed, not eliminated.

Because treated wastewater can be an important component of streamflow, the potential effects of conservation measures on return flows should be considered. The redistribution of water to uses that result in reduced return flows will reduce streamflows. The potential effects of such changes would depend on the magnitude of changes in return flows and size of the stream in question. For example, reduced return flow in a small creek would be expected to have a greater impact on fish than a similar reduction in a larger river. On the other hand, conservation measures that promote more efficient usage of water without disproportionately reducing return flows would be expected to enhance streamflows.

Travis County wastewater treatment plants and water treatment plants are all located on either major tributaries or the main body of the Colorado River, not on smaller tributaries and creeks. Fortunately, any impacts to wildlife from reduced streamflows will be less in a larger river than in the smaller creeks. Conservation measures that would reduce streamflow in the Colorado River and its tributaries are not likely to impact the majority of endangered, threatened or TOES watch list species in Travis County (Environmental Overview, Section 3.1-3).

None of the troglobitic species will be affected by the conservation efforts, nor will the plant or spring species. Three aquatic species present in Travis County are potentially affected by reduced streamflow. These include the blue sucker (*Cycleptus elongatus*), Guadalupe bass (*Micropterus treculi)*, and smalleye shiner (*Notropis buccula*). The smalleye shiner and Guadalupe bass prefer the habitat of creeks and small rivers. The lack of facilities on small creeks suggests it is unlikely that these species will be negatively affected by small reductions in streamflow of the Colorado River. If conservation practices increase, the reduced outfall from the wastewater treatment plants and water treatment plants of Travis County could cause this type of small streamflow reduction. In contrast to the other three species, the blue sucker prefers deep chutes (1 to 2.5 m) and main channels of medium to large rivers. Reduced streamflows will fortunately be less noticeable in a larger river as the reduction is a smaller percentage of total flow. Reduced streamflows may have some impact on the habitat of the blue sucker but due to the small percentage of change in total river flow, the impact should be minimal to non-existent.

Some conservation measures may result in changes to urban landscapes. These changes may be in the form of less luxuriant landscapes, or in the landscaping practices used. Altering urban landscapes would affect animals associated with such habitats; however, these effects would not be expected to be significant.

3.3.4 Water Quality and Treatability

Water quality is not an issue with conservation as no new sources of water developed.

3.3.5 Implementation Issues

Major issues involving accelerated municipal water conservation include public acceptance and willingness to:

- Replace plumbing fixtures in their homes, workplaces, and institutions;
- Change landscaping at home and public places, including recreational areas;
- Respond to a conservation-oriented water rate structure; and
- Become more conscious of and directly involved with management of personal water using functions.

The replacement of plumbing fixtures would be a temporary inconvenience, the most significant of which would be the removal and replacement of commodes within homes. Water conservation landscaping could result in views of different types of grasses and plants, and during dry times more brown and less green lawns in public places. A conservation-oriented rate structure could mean higher costs for the same or lower quantities of water.

3.4 Accelerated and Additional Municipal Water Conservation for Williamson County Area (L-21)[1]

3.4.1 Description of Alternative

A major public policy objective is to increase water use efficiency through water conservation without adversely affecting population and economic growth potentials. The general methods to accomplish this objective in the North Central Trans-Texas Study area are to: (1) Reduce per capita water use in the municipal water use category; and (2) Recycle and reuse municipal and industrial wastewater for non-potable purposes in the study area. Specific methods of water conservation for municipal purposes, together with conservation potentials and estimates of costs of water conservation methods are presented below.

The quantity of water used within a typical city or water supply service area is usually expressed in terms of number of gallons per person per day (gpcd). It is important to note that the per capita municipal water use statistic includes water use within the home for drinking, toilet flushing, bathing, food preparation, dishwashing, laundry, and cleaning, and in some case air conditioning. In addition to the water used at homes, the per capita water use statistic includes a person's share of water used in the workplace for toilet flushing, drinking, cleaning, showers, and lawn irrigation of office and commercial complexes, as well as a person's share of water used in commercial establishments such as restaurants, laundries, carwashes, and lawn and garden centers. The per capita water use statistic also includes a person's share of water used in institutions such as schools, churches, and recreation centers, and water used by the city for fire protection, sanitation, and public recreation, including the irrigation of city parks and scenic places as well as unaccounted for water from leaks in the distribution system.

Municipal water conservation can be accomplished by using plumbing fixtures such as toilets and shower heads, 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

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[1] Actions to accomplish the water conservation potential of low flow plumbing fixtures at an earlier date than has been assumed by the TWDB in the municipal water demand projections of Section 2.0 of this report, plus additional water conservation potentials through modifications to landscaping and lawn irrigation methods, and water rate structures.

modification of personal behavior which controls use of plumbing fixtures, appliances, and lawn watering methods.

With respect to plumbing fixtures, in 1991 the Texas Legislature enacted legislation which established minimum standards for plumbing fixtures sold within Texas.[2] The bill became effective on January 1, 1992, and allowed until January 1, 1993, for suppliers to clear existing inventories of pre-standards plumbing fixtures.

The potential effect of low flow plumbing fixtures on municipal water demand in Williamson County is estimated by the TWDB to reduce county average per capita demand by 6.5 gallons per person per day (gpcd) by 2000, 13 gpcd by 2010, and ultimately 19.5 gpcd by 2040, as new homes and businesses are built and equipped with the low flow fixtures, and as fixtures of existing structures are replaced with low flow fixtures, through normally expected schedules of remodeling and repairs. The estimated conservation effects are included in the water demand projections of Section 2.0, for each city of the county. One of the purposes of this report is to estimate the amount of water demand reduction that might be accomplished by accelerating the rate of replacement of plumbing fixtures as compared to the rate realized through normal replacements and repairs. In addition, the potentials and costs of other water conservation measures will be evaluated. The principal benefit of reducing the rate of growth in water demand in Williamson County is to delay the need for new investments in water treatment facilities, and additional water supplies.

3.4.2 Public Information

A public information program is also a necessary part of any community water conservation effort in order to inform the public about the program and to communicate its importance to large numbers of participants. Public information programs about water conservation typically include the distribution of water conservation brochures, water conservation tips enclosed in monthly water bills, public service announcements by local radio and TV stations, newspaper articles, presentations to clubs and civic organizations, and water conservation literature for school children. Public information about water conservation works in two ways to accomplish water conservation goals. One way is to inform water users of ways

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[2] Senate Bill 587, Texas Legislature, 1991, Austin, Texas.

to manage and operate existing and new fixtures and appliances so that less water is used, such as washing full loads of clothes and dishes, or using a pail of water instead of a flowing hose to wash automobiles. 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 lawn and shrubbery watering where regulations allow it, and to take advantage of water conservation incentives where available.

The population of Williamson County in 1998 is estimated at 209,000, of which about 62 percent (129,000) live in the service areas of Round Rock, Georgetown, Cedar Park, Taylor, and Brushy Creek, and about 38 percent (80,000) live in smaller communities throughout the county. At the present time each of the cities of the county has a public information program about water conservation. It is estimated that the programs cost about $0.50 per person per year, and reduce water use about 1.5 gallons per person per day.[3] The estimates of annual demand reduction due to public education are shown in Table 3.4-1.

Round Rock's demand reduction from a public information program is estimated at 86 acft/yr for the City's existing population, at a cost of about $25,000 annually, or $27/acft at 8 percent interest over a 25-year period.

Georgetown has a fairly new program and the estimated effect of a public information program is estimated to be 47 acft/yr for the present population at a cost of $14,000, or $27/acft at 8 percent interest over a 25-year period.

The City of Cedar Park has established a diverse public information program over several years. Its demand reduction is estimated at 39 acft/yr at a cost of $11,700 annually or $27/acft at 8 percent interest over 25 years.

Taylor could reasonably expect to reduce demand by about 28 acft/yr for its existing population, at a cost of $8,600 annually ($27/acft).

A water conservation public education at Brushy Creek MUD is estimated to reduce water demand 16 acft/yr at an annual cost of $4,800, or $27/acft.

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

Service Area	Population (1998)	Demand Reduction (acft/yr)	Annual Cost
Round Rock	51,000	86	$25,500
Georgetown	28,000	47	14,000
Cedar Park	23,000	39	11,700
Taylor	17,000	28	8,600
Brushy Creek	10,000	16	4,800
Other Williamson County	80,000	134	40,000
TOTAL	209,000	350	$104,600

Table 3.4-1
Population, Demand Reduction, and Costs of Public Information

[1] 1.5 gpcd, "Hays County Water and Wastewater Study," Hays County Water Development Board, San Marcos, Texas, 1989.

The potential water conservation for the remainder of Williamson County that might be realized through public education is estimated at 134 acft/yr for the existing population at an annual cost of $40,000 ($27 acft). However, since this population is widely dispersed throughout the county, achieving this estimate would require several water conservation public information programs.

If all of Williamson County has an effective water conservation public information program, it is estimated that water demand could be reduced by about 350 acft/yr for the present population. The cost of the program is estimated at $104,000 or $27/acft if these costs are amortized at 8 percent over a 25-year period.

3.4.3 Plumbing Retrofit Program

The Low Flow Plumbing Fixtures Act which became effective in 1993 will result in the installation of low flow plumbing fixtures in new homes, office buildings, commercial establishments, and public buildings, and in remodeling and repairs of structures that existed in 1993. Thus, the potential effects of low flow plumbing fixtures upon per capita water use of 22 gallons per person per day will apply to that segment of the population which occupies and/or uses new homes and new commercial and business establishments; (i.e., an equivalent to population and other growth of the area subsequent to 1993). However, that segment of the population and economy that existed in 1993 at the time the Low Flow Plumbing Fixtures Act became effective will still be using the facilities that existed in 1993 until they are replaced. It is estimated that replacement of plumbing fixtures will occur at a relatively uniform rate over the next 50 years through remodeling and repair of structures that existed in 1993. Therefore, at the normal rate of replacement, the full potential of low flow plumbing fixtures upon per capita water use will not be realized for several decades. Therefore, it may be desirable to implement plumbing retrofit programs to replace plumbing fixtures in structures that existed in 1993 at an accelerated pace. The costs and estimated water demand reductions from plumbing retrofit for Round Rock, Cedar Park, and Georgetown are presented below.

At the time of adoption of the low flow plumbing fixtures act in 1993 it is estimated that about 38,000 people lived in the Round Rock service area. Therefore, with a water conservation effect of 22 gallons per person per day, the water conservation potential through retrofitting residences, commercial establishments, workplaces, public places and motel and hotel rooms that existed in Round Rock in 1993 is estimated at 936 acft/yr, or 0.8 mgd.[4] TWDB estimates of average reductions in per capita water use by that segment of the population to which the plumbing retrofit is applied, (i.e., 38,000 population of Round Rock at the time the Low Flow Plumbing Fixtures Act went into effect). The estimated cost of retrofitting all structures that existed in the Round Rock service area at the time the plumbing fixtures act became effective is $120 per person, which includes cost of fixtures and labor. Thus, the estimated cost of plumbing retrofit in the Round Rock service area would be approximately $4.6 million ($120 x 38,000). If a plumbing retrofit program were established to begin in 1998 and accomplish complete plumbing retrofit at a uniform annual rate by the end of 2010 (12 years), which is 40 years earlier than complete plumbing fixtures replacement would occur through regular replacements via remodeling and repairs to existing structures. the average annual water demand reduction for the period 1998 through 2050, due to accelerated plumbing retrofit, would be 360 acft. If the program were financed for a period of 25 years at an interest rate of 8 percent, the cost per acre-foot of water saved would be $1,197. The estimated savings to water customers that would be realized through the 360 acft/yr of reduced use would be $307,930 per year at Round Rock's present rate of $1.76 per thousand gallons for water and $1.73 per 1,000 gallons of wastewater collection and treatment.

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[4] TWDB estimates average reductions in per capita water use by that segment of the population to which the plumbing retrofit is applied (i.e., 38,000 population of Round Rock at the time the Low Flow Plumbing Fixtures Act went into effect).

It is estimated that about 15,000 people lived in the Cedar Park service area in 1993. Therefore, the water conservation potential through retrofitting all residences, commercial establishments, workplaces, public places and motel and hotel rooms is estimated at 370 acft/yr, or 0.36 mgd. The estimated cost of retrofitting all structures that existed in the Cedar Park service area at the time the plumbing fixtures act became effective is $120 per person, which includes cost of fixtures and labor. Thus, the estimated cost of plumbing retrofit in the Cedar Park service area would be approximately $1.82 million ($120 x 15,000). If a plumbing retrofit program were established to begin in 1998 and accomplish complete plumbing retrofit at a uniform annual rate by the end of 2010 (12 years), instead of 2050, as is estimated to be the date at which plumbing fixtures would be fully replaced under normal repairs and remodeling schedules, the average annual water demand reduction for the period 1998 through 2050 would be 142 acft. If the program were financed for a period of 25 years at an interest rate of 8 percent, the cost per acre foot of water saved would be $1,200. The estimated savings to water customers that would be realized through the 142 acft/yr of reduced use would be $244,039 per year at Cedar Park's present rate of $2.40 per thousand gallons of water and $2,30 per thousand gallons of wastewater.

In 1993, it is estimated that about 21,000 people lived in the Georgetown service area. Therefore, the water conservation potential through retrofitting all residences, commercial establishments, workplaces, public places and motel and hotel rooms is estimated at 518 acft/yr, or 0.46 mgd. The estimated cost of retrofitting all structures that existed in the Round Rock service area at the time the plumbing fixtures act became effective is $120 per person, which includes cost of fixtures and labor. Thus, the estimated cost of plumbing retrofit in the Georgetown service area would be approximately $2.53 million ($120 x 21,000). If a plumbing retrofit program were established to begin in 1998 and accomplish complete plumbing retrofit at a uniform annual rate by the end of 2010 (12 years), the average annual water demand reduction for the period 1998 through 2050 would be 249 acft. If the program were financed for a period of 25 years at an interest rate of 8 percent, the cost per acre foot of water saved would be $952. The estimated savings to water customers that would be realized through the 249 acft/yr of reduced use would be $270,831 per year at Georgetown's present rate of $1.95 per thousand gallons for water, and $2.70 per thousand gallons for wastewater collection and treatment

3.4.4 Water Conservation Rates

Although it is generally understood that per capita water use decreases as water rates increase, when other things such as personal income remain unchanged, information is not available with which to estimate the water conservation effects of increased water rates in Williamson County. However, it is important to note that the study area cities and water districts of the county charge a base monthly rate with either a flat rate per thousand gallons of water used or an increasing rate per thousand gallons used as quantities increase. In addition, some study area participants also have a higher summer rate for the larger increments of water use. Thus, Williamson County study participants are using conservation oriented rate structures, but data are not available at the present time with which to estimate the quantitative effects of the rates upon water demands.

3.4.5 Leak Detection and Repair

A major potential for water conservation is often in the distribution system itself. It is not uncommon for older distribution systems to lose 30 percent or more of the water they transport. Fixing leaks can usually improve a system's efficiency up to about 90 percent (i.e, 10 percent loss).

Costs for leak detection and repair are based on the estimated number of crews required to reduce a system's loss rate to 10 percent. Estimated annual reductions and costs are shown in Table 3.4-2.

Table 3.4-2
Leak Detection and Repair
Demand Reductions and Costs

Service Area	Demand Reduction[1] (acft/yr)	Total Project Cost	Unit Cost ($/acft)
Round Rock	2,780	$ 700,000	$250
Georgetown	540	200,000	370
Cedar Park	440	200,000	450
Taylor	340	150,000	440
Brushy Creek	190	80,000	420
Other Williamson County	1,500	600,000	400
TOTALS	5,790	$1,930,000	$332 Average

[1] Estimated loss rate is 20 percent.

Round Rock's current loss rate is about 32 percent.[5] Cutting this to 10 percent is estimated to save 2,780 acft/yr throughout the service area. The annual cost of additional crews is estimated at $700,000, so the unit cost is $250 per acft/yr. Georgetown's loss rate was 18 percent in 1995.[6] To reduce this to 10 percent, the estimated cost to the City is $200,000 per year and would save about 540 acft/yr. The unit cost is $370 per acft/yr. Cedar Park's loss rate is between 18 percent and 23 percent.[7] To improve the system to a 10 percent loss rate would save about 400 acft/yr. The annual cost of additional crews is about $200,000, so the unit cost of water is $450 per acft/yr. A typical estimate of Taylor's loss rate is 20 percent. To reduce losses to 10 percent would result in savings of 340 acft/yr. The cost would be about $150,000 for a unit cost of $440. If Brushy Creek's distribution system loses 20 percent of its flow, a 10 percent reduction would save 190 acft/yr. The annual cost to maintain this efficiency is about $80,000 at a unit cost of $420 per acft/yr. For the remaining portion of Williamson County, if the average loss rate is 20 percent, 1,500 acft/yr could be saved by cutting losses to 10 percent. The cost of this maintenance is estimated at $600,000 and the unit cost is $400 per acft/yr.

It is estimated that Williamson County could save 5,790 acft/yr by reducing distribution system losses to 10 percent. The overall annual cost of this program is estimated at about $1,930,000 and the average unit cost is $332 per acft/yr (Table 3.4-2).[8]

3.4.6 Summary of Water Conservation Potentials in Williamson County

Of the potential methods to accomplish water demand reduction through water conservation, the three that appear to be applicable in Williamson County are: (1) Public information; (2) Plumbing retrofit; and (3) Leak detection and repair. It is estimated that a public information program could reduce annual water demands in Williamson County by about 350 acft/yr at a cost of $27 per acft. An accelerated plumbing retrofit program in the three Williamson County cities of the study (Round Rock, Cedar Park, and Georgetown) that would accomplish replacement of plumbing that existed in 1993, at the date of the Low Plumbing Fixtures Act, by the year 2010, is estimated to reduce Williamson County water demands by

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[5] Personal Interview, Round Rock Water Utility staff.

[6] Georgetown Water Utility, Public Information, July, 1996.

[7] "Comprehensive Water Conservation Plan," City of Cedar Park, Texas, 1993.

about 780 acft/yr at a cost of $1,190 per acre-foot (Table 3.4-3). Leak detection and repair is estimated to reduce demands by 5,790 acft/yr at a cost of $332 per acre-foot (Table 3.4-3). The total demand reduction potential in Williamson County through public information, plumbing retrofit, and leak detection and repair is estimated at 6,920 acft/yr at an average cost of $413 per acre-foot. This quantity is about 15 percent of present levels of municipal water use, but would be about 5 percent of projected year 2050 levels of use, since the projected water demands already have average levels of water conservation factored into the per capita water demands.

Table 3.4-3
Water Conservation Potentials and Costs
Williamson County

Conservation Method	Water Demand Reduction (acft/yr)	Estimated Cost ($/acft)
Public Information	350	$27
Plumbing Retrofit*	780	1,190
Leak Detection and Repair	5,790	332
TOTALS	6,920	$413

*Includes potentials for water conservation through accelerated plumbing retrofit programs in Round Rock, Cedar Park, and Georgetown.

3.4.7 Environmental Issues

The potential environmental effects of additional and accelerated water conservation in the Travis County service area can be categorized as follows:

- Effects on streamflows resulting from changes in return flows.
- Effects on urban landscapes.

The environmental effects of additional and accelerated conservation in Williamson County are similar to those discussed above for Travis County (Alternative L-9). Wastewater reuse is considered in Alternatives L-5 and L-8 (Sections 3.5 and 3.6 respectively).

There are substantial benefits to be realized in communities without conservation plans. However, greater potential for change in water usage also has heightened potential for affecting environmental change. Wastewater return flow is not an indispensable contributor to water supply and streamflows. The contribution of return flows to nutrient levels, streamflows and flows into bays and estuaries should be considered in large-scale conservation plans involving reduced return flow. Assuming water usage remains constant or increases, conservation measures that reduce wastewater return flow may reduce streamflow. However, such conservation measures may reduce the rate at which new sources of water are needed.

As long as population growth and industrial development out-pace per capita savings in water consumption due to conservation, the demand for water will increase. Thus, an indirect effect of conservation may be to delay implementation of additional water supply projects and their concomitant environmental effects.

3.4.8 Implementation Issues

Major issue involving accelerated municipal water conservation include public acceptance and willingness to:

- Replace plumbing fixtures in their homes, workplaces, and institutions;
- Change landscaping at homes and public places, including recreational areas;
- Accept a conservation oriented water rate structure; and,
- Become more conscious of and directly involved with management of personal water using functions.

The replacement of plumbing fixtures would be a temporary inconvenience, the most significant of which would be the removal and replacement of commodes within homes. Water conservation landscaping would result in views of different types of grasses and plants, and during the times more brown and less green lawns and public places,

A conservation oriented rate structure could mean higher costs for the same or lower quantities of water ((i.e., the purpose of such rates is to reduce the quantity of water use through the pricing mechanism).

3.5 Reclaimed Water Reuse — Areas in the Colorado River Basin (L-5)

3.5.1 Description of Alternative

This alternative explores potential direct reuse of reclaimed water to meet a portion of water demand in the Austin metropolitan area. Reclaimed water reuse would directly benefit the regional water supply by meeting water demands with high quality treated wastewater that would otherwise be supplied by the potable water system. Implementation of reclaimed water reuse would reduce raw water diversions from the Colorado River. Potential applications for reclaimed water reuse include landscape irrigation, industrial process water, steam-electric cooling, cooling tower make-up, augmentation of raw water supplies, and sanitation uses.

The City of Austin is a leader in reclaimed water reuse programs, planning, and technology. The City operates reuse projects, has a master plan for substantial enlargement of the reuse program, and is aggressively pursuing increased wastewater treatment and reuse technology. The City's existing reuse program supplies reclaimed water from the South Austin Regional Wastewater Treatment Plant to Jimmy Clay Golf Course, Roy Kizer Golf Course, Bergstrom Golf Course, and Hornsby Bend Biosolids Management Plant. Reuse water to Bergstrom Golf Course began in 1991 and to Jimmy Clay Golf Course in 1993 as the City expanded the reuse system. Plans for potential further expansion of existing reuse projects are described in this section.

Potential reclaimed water reuse projects considered in this alternative are divided into three categories:

- Further implementation of the City of Austin reuse master plan,
- Make-up supply to Decker Lake (also known as Lake Walter E. Long) for steam-electric cooling, and
- On-site water reclamation and reuse at semiconductor manufacturing plants.

City of Austin Reuse Master Plan Projects

The City of Austin's reuse master plan identifies the following as viable reuse strategies:

> Urban Irrigation Systems to reduce the demand for potable water or provide lower-cost water for irrigation of golf courses, airport land, state-owned land, community gardens, and possibly park land.
>
> Industrial/Commercial Systems associated with the semiconductor manufacturing industry, specifically the Motorola plant in east Austin, Advanced Micro Devices and Sematech in southeast Austin, and the Samsung plant under construction in northeast Austin.

Recycled Water/Water Augmentation Systems which postpone, eliminate, or reduce the requirements for major water and/or wastewater system improvements.

A study completed in 1992 for the City of Austin[1] recommended three projects be considered for further study and possible implementation. The following paragraphs describe the projects and Figure 3.5-1 shows their location.

Central Reuse System and Water Supply Augmentation (L-5A). Using reclaimed water from the Walnut Creek WWTP, the proposed irrigation system would be extended from Morris Williams Golf Course to Mueller Airport,[2] Hancock Golf Course, Community Gardens, the State Land Complex, and Lions Golf Course. This system would also potentially serve Tracor and Motorola on Ed Bluestein Blvd. An option included in this project is the possible water supply augmentation of Lake Austin and Town Lake.

South Reuse System Extension (L-5B). Using reclaimed water from the South Austin Regional WWTP, the existing irrigation system could be extended to serve Advanced Micro Devices, Sematech, industrial business park areas along Ben White Blvd., Capitol Metro bus maintenance facilities on South IH-35, and ultimately to Onion Creek Golf Course. Although use of reclaimed water at the new Austin-Bergstrom International Airport for landscape irrigation and toilet flushing was studied by the Aviation Department, the Aviation Department chose not to participate in the South Reuse System.

Northwest Water Reclamation Plan (L-5C). This plan would locate a new wastewater treatment plant in northwest Austin to treat wastewater that otherwise would flow to the Walnut Creek WWTP or to the Brushy Creek Regional WWTP in Williamson County. Reclaimed water would be used to irrigate area golf courses, provide cooling or process water to industries such as Texas Instruments or 3M, and potentially service dual-distribution systems in new residential or commercial developments. Currently, the City of Austin allows Balcones Country Club to draw wastewater as needed from existing wastewater lines and treat the wastewater for golf course irrigation purposes.

In addition to the projects recommended in the 1992 study, the top 10 water users in 1994 are listed in Table 3.5-1. Of the major water users listed in Table 3.5-1, five are included in the City of Austin's Master Plan as potential participants. Texas Instruments has already implemented an

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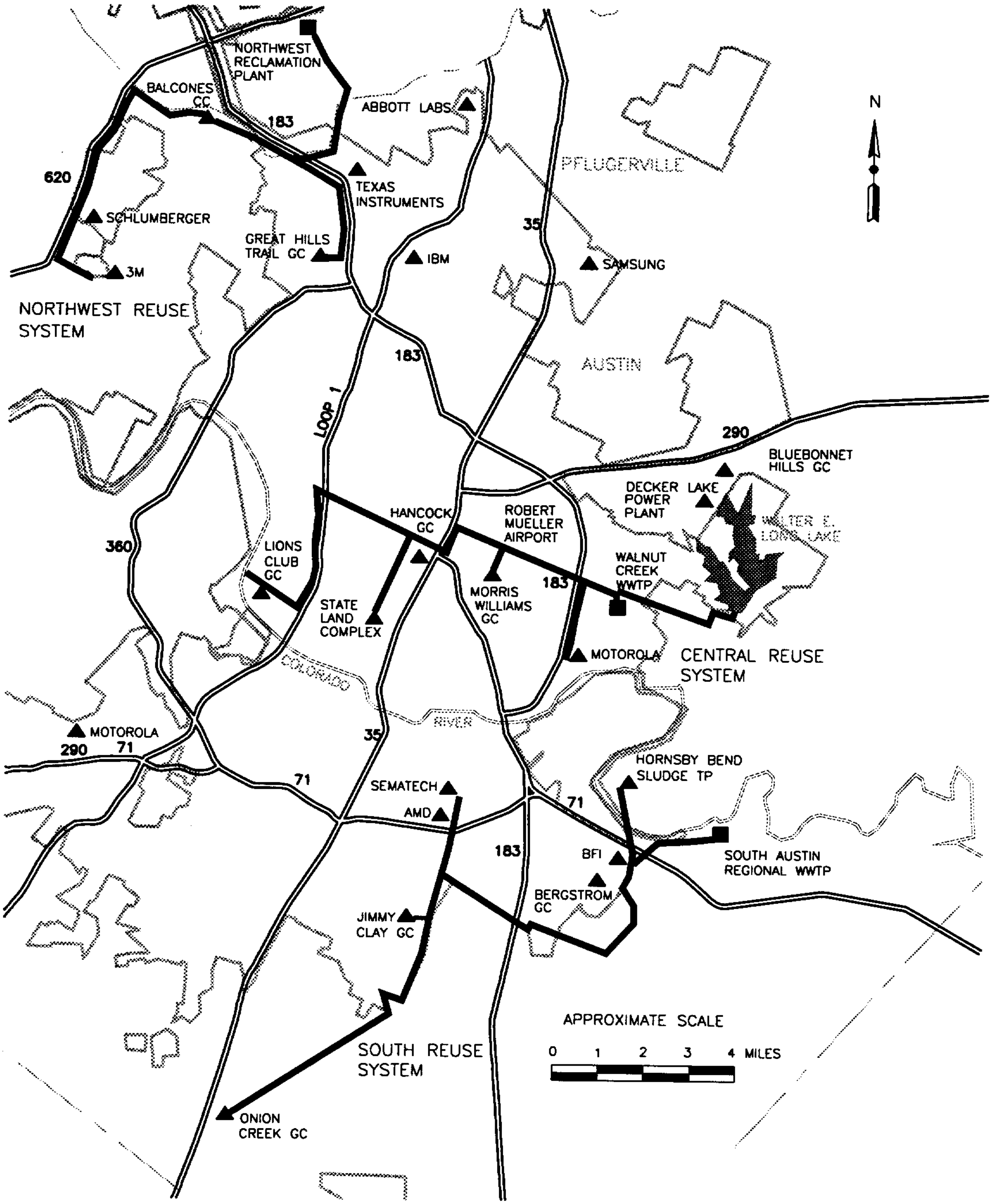
[1] CH2M-Hill, "Master Planning for Recycled Water", City of Austin, March, 1992.

[2] Mueller Airport currently uses little water for irrigation. Mueller will be closed when the new Austin-Bergstrom International Airport opens and the future use of the Mueller Airport site may require significantly more water for irrigation.



LEGEND

— PROPOSED SERVICE LINE

▲ POTENTIAL REUSE LOCATIONS

■ WWTP OR WRP

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

RECLAIMED WATER PROJECTS IN COLORADO RIVER BASIN ALTERNATIVE L-5

FIGURE 3.5-1

aggressive water reclamation program, and is not considered for participation in a future reuse project.

Table 3.5-1 Major Industrial Water Users in Austin Service Area[1]		
	Annual Demand	
User	mgd	acft/yr
Motorola, Ed Bluestein[2]	2.34	2623
Advanced Micro Devices[2]	1.86	2083
Motorola, Oak Hill	1.32	1481
IBM	0.91	1019
Abbott Labs	0.69	772
Sematech[2]	0.57	636
Texas Instruments[2]	0.30	336
Coca Cola	0.19	212
National Linen Service	0.18	204
3M[2]	0.11	118

[1] City of Austin industrial customers 1994.

[2] Identified as potential participant in 1992 City of Austin Master Plan for Recycled Water.

Of the major industrial water users not included in the Reuse Master Plan, Motorola's Oak Hill Plant, IBM, and Abbott Laboratories could potentially be considered for reuse opportunities, and based on surveys of several of the major industrial users, it is estimated that 40 percent of the annual demands can be replaced with reclaimed water for a total reuse potential of 3.53 mgd (3,939 acft/yr). Table 3.5-2 itemizes potential reuse quantities of selected major industrial water users. Figure 3.5-1 displays their locations.

Table 3.5-2 Potential Reuse Opportunities in Austin Service Area		
	Reuse Potential	
User[1]	mgd	acft/yr
Motorola, Oak Hill	0.53	592
Motorola, Ed Bluestein	1.36	1,518
Advanced Micro Devices	0.76	854
Sematech	0.23	255
IBM	0.37	410
Abbott Laboratories	0.28	310
TOTAL	3.53	3,939

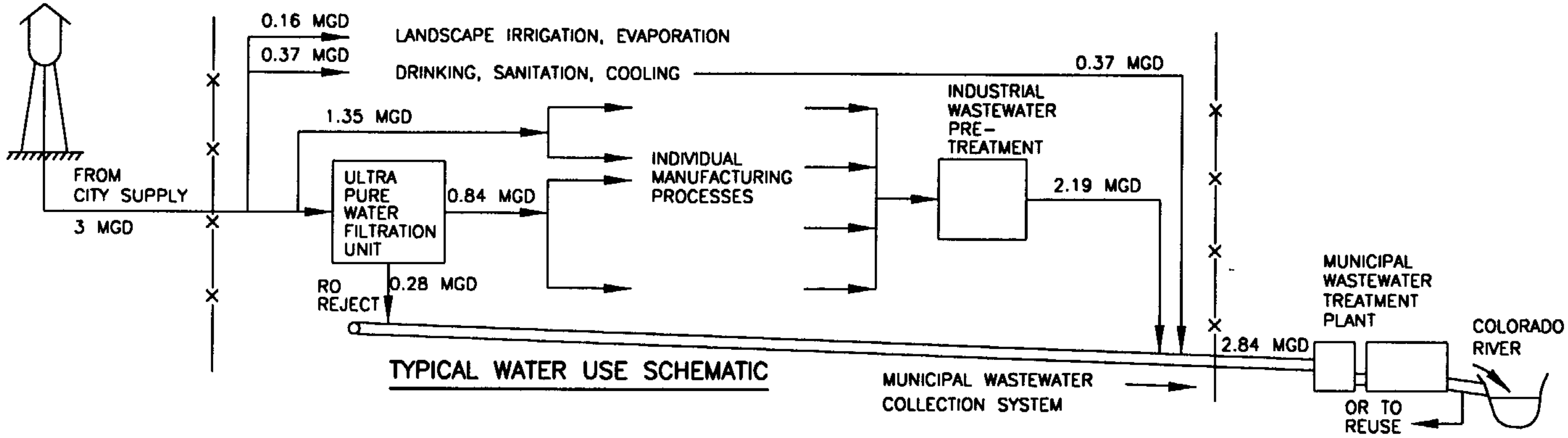
[1] City of Austin industrial customers 1994.

Decker Lake Make-up Water (L-5D)

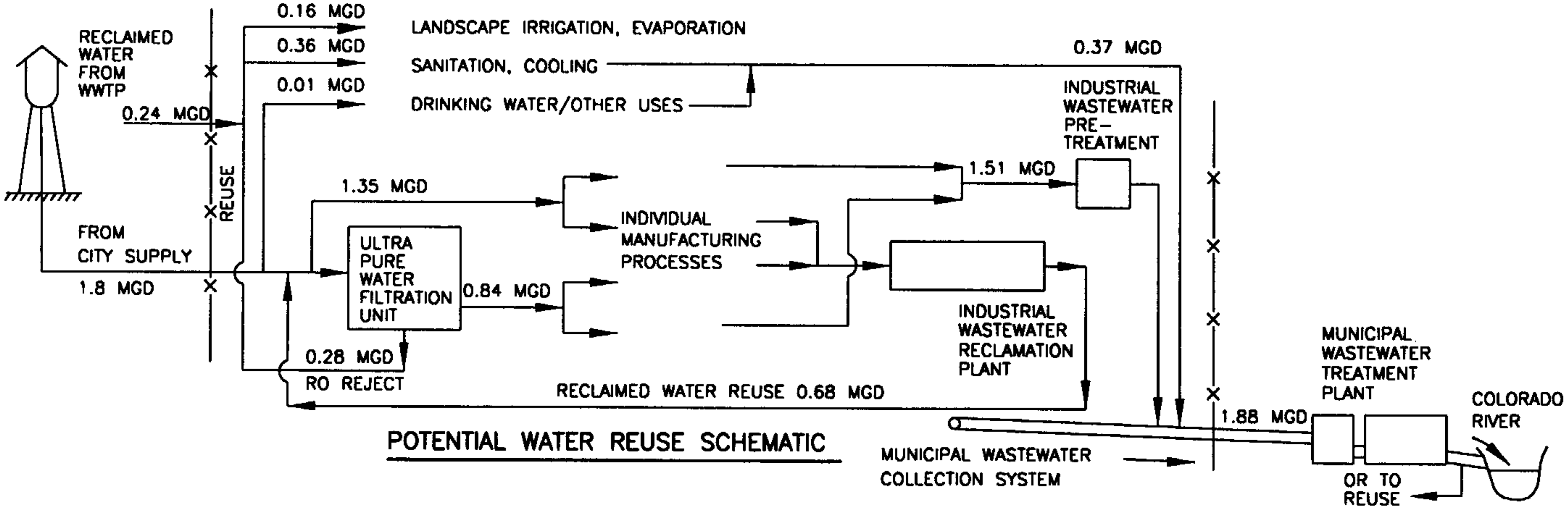
Decker Lake (also known as Lake Walter E. Long) is a cooling water reservoir for the Decker Electric Generating Station owned by the City of Austin. The reservoir is on Decker Creek and impounds runoff from the Decker watershed. However, inflows from Decker Creek are less than the demands of natural evaporation and forced evaporation to meet cooling needs; therefore, additional make-up water is required to keep the reservoir at operating level. Currently, the City of Austin obtains make-up water by pumping water from the Colorado River to Decker Lake. These diversions from the Colorado River are made under Austin's run-of-the-river water rights backed up by storage in the Highland Lakes. Diversions have ranged from 3,471 acft/yr to 6,173 acft/yr with an average of 4,247 acft/yr over the period from 1990 through 1995. The City of Austin has the right to divert up to 16,156 acft of water from the Colorado annually without any return to the river. If water from an alternate source, such as reclaimed water from Walnut Creek WWTP or from a semiconductor manufacturing plant (i.e., Motorola or Samsung) could be utilized as make-up water, then water currently diverted from the Colorado River is potentially available for municipal use, thereby increasing the overall water supply to the City. Bluebonnet Hills Golf Course could potentially fill irrigation needs with reclaimed water if made available to them through the Decker Lake reuse plan.

Water Reclamation and Reuse at Semiconductor Manufacturing Plants (L-5E)

Semiconductor manufacturing plants in the Austin area provide an excellent opportunity for water reclamation and reuse. Figure 3.5-2 provides a schematic diagram of typical water use in a semiconductor manufacturing plant and wastewater streams leaving the plant. Of the potable water entering the plant from the city water supply system, about 80 percent is diverted for use in industrial processes. From this point, water is either used directly or sent through an ultrapure water filtration unit. The ultrapure water unit is typically a reverse-osmosis filtration process that produces a by-product of water (RO reject water) containing a concentrate of the salts and minerals naturally occurring in the potable water supply. The RO reject water flow is typically about 25 percent of the input to the ultrapure unit. In some cases, the RO reject water is discharged to the municipal wastewater collection system; however, the RO reject water is of fairly high quality and, in some cases, direct discharge to surface streams is permitted. The



TYPICAL WATER USE SCHEMATIC



POTENTIAL WATER REUSE SCHEMATIC

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

SEMICONDUCTOR
MANUFACTURING PLANT
WATER USE SCHEMATIC

HDR Engineering, Inc.

FIGURE 3.5-2

ultrapure water (about 75 percent of the input to the ultrapure unit) is used to rinse the silicon wafers of various organic solutions, mild acids, and solvents. After use in manufacturing, the water (now termed industrial wastewater) is treated typically with sodium hydroxide to raise the pH, and then discharged to the municipal wastewater collection system. The remainder of the potable water entering the plant is used for drinking water, cooking and washing, sanitation, and cooling tower makeup.

The RO reject water and the industrial wastewater discharges both offer excellent opportunities for reuse at semiconductor plants. The RO reject water, which is of near-drinking water quality (see following section), has a number of possible uses at the manufacturing plant or at off-site locations near the plant. Possible uses in the manufacturing plants include cooling tower make-up, landscape irrigation, or sanitation (i.e., toilet flushing).

The industrial wastewater stream, blended from all of the various manufacturing processes, contains mild acids, organics, simple alcohols, and other compounds all of which can be removed with existing wastewater treatment technology. However, the newer semiconductor manufacturing plants have piping that allows segregating the wastewater streams from the various processes. By segregating the wastewater, the wastewater having characteristics most favorable for treatment and reuse could be directed to a water reclamation treatment plant in or near the manufacturing plant and the remainder of the industrial wastewater would be discharged to the municipal wastewater system following pretreatment as is currently done. Possible uses of the reclaimed industrial wastewater include feedwater to the ultrapure treatment unit, as well as the uses identified for the RO reject water. Figure 3.5-2 provides a schematic diagram of the potential reuse flow paths of RO reject and industrial wastewater at a semiconductor manufacturing plant.

Semiconductor manufacturing plants to be considered for reuse include Motorola-Ed Bluestein, Motorola-Oak Hill, Sematech, Advanced Micro Devices, and Samsung (under construction). The Texas Instruments plant in northwest Austin has already implemented wastewater reuse, and opportunities for additional reuse are too limited to be further considered.

3.5.2 Available Yield

The major sources of reclaimed water in the Austin area are Walnut Creek WWTP and South Austin Regional WWTP. Walnut Creek WWTP currently discharges an annual average of about 37 mgd (41,440 acft/yr),[3] and discharge is projected to increase to 67 mgd (75,040 acft/yr)[4] in the year 2040. South Austin Regional WWTP currently discharges an annual average of about 26 mgd (29,120 acft/yr),[5] and discharge is projected to increase to 84 mgd (94,080 acft/yr)[5] in the year 2040. Potentially, all of the discharge from these plants is available for reuse, but the quantity considered for reuse is considerably less than available because potential uses for all of the water have not been identified. The annual demands that might be met by reclaimed water for the uses identified are summarized in Table 3.5-3 and in the following paragraphs.

Central Reuse System and Water Supply Augmentation (L-5A)

The Central Reuse System would supply water to Motorola-Ed Bluestein, Morris Williams Golf Course, Hancock Golf Course, the State Land Complex and the Lions Club Golf Course.[6] As shown in Table 3.5-3, these five users have a potential demand for reclaimed water of about 2,600 acft/yr.

The Central Reuse System could be expanded to augment the raw water supply available from Lake Austin and Town Lake. A potential annual delivery from the reuse system to Lake Austin of 12,320 acft/yr (11 mgd) was studied. With augmentation of Lake Austin/Town Lake, the total potential benefit of the Central Reuse System is about 14,900 acft/yr (13.3 mgd).

South Reuse System Extension (L-5B)

By extending the South Reuse system to supply Browning-Ferris Industries, Advanced Micro Devices, Sematech, and Onion Creek Golf Course, 1.21 mgd (1,355 acft/yr) is available for reuse (Table 3.5-3). Reclamation demand Motorola's Oak Hill facility could potentially add an additional 0.53 mgd (592 acft/yr) of reuse (Table 3.5-3). In the report "Master Planning for Recycled Water,"[7] the reuse potential for the South Water Reuse System could be 1,938 acft/yr (1.7 mgd) with a maximum daily demand of 5.6 mgd (8.7 cfs). The demand estimates contained in the Master Plan were used for engineering and cost estimating.

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[3] City of Austin discharge records at Walnut Creek WWTP.

[4] Wastewater Collection System Long-Range Planning Guide, City of Austin, May 1994.

[5] City of Austin discharge records at South Austin Regional WWTP.

[6] Lions Golf Course currently irrigates with water from Town Lake. It is assumed that these demands will be filled by reclaimed water if made available.

[7] CH2M-Hill and Jones & Neuse, Inc., "Master Planning for Recycled Water," City of Austin, March 1992.

Table 3.5-3
Potential Reclaimed Water Reuse Projects in Austin Service Area

Project	Estimated Total Water Demand	Estimated Demand for Reclaimed Water
Central Reuse Project (L-5A)		
Morris Williams Golf Course	0.23 mgd (258 acft/yr)[1]	0.23 mgd (258 acft/yr)[2]
Motorola, Ed Bluestein	3.39 mgd (3796 acft/yr)[3]	1.36 mgd (1518 acft/yr)[4]
Motorola, RO Reject Blending[14]	n/a[5]	0.23 mgd (253 acft/yr)[6]
Hancock Golf Course	0.12 mgd (129 acft/yr)[1]	0.12 mgd (129 acft/yr)
State Land Complex	0.61 mgd (686 acft/yr)[7]	0.15 mgd (172 acft/yr)[7]
Lions Golf Course	0.23 mgd (258 acft/yr)[1]	0.23 mgd (258 acft/yr)[2]
TOTAL	**4.58 mgd (5,127 acft/yr)**	**2.32 mgd (2,588 acft/yr)**
Lake Austin/Town Lake Augmentation		11 mgd (12320 acft/yr)
TOTAL		**13.32 mgd (14,913 acft/yr)**
Decker Lake Makeup Water[8] (L-5D)	**4.0 mgd (4,505 acft/yr)[9]**	**4.0 mgd (4,505 acft/yr)[9]**
South Reuse System Extension[10] (L-5B)		
BFI	0.02 mgd (26 acft/yr)[7]	0.01 mgd (10 acft/yr)[7]
AMD	1.91 mgd (2136 acft/yr)[11]	0.76 mgd (854 acft/yr)[4]
Sematech	0.57 mgd (636 acft/yr)[11]	0.23 mgd (255 acft/yr)[4]
Onion Creek Golf Course	0.23 mgd (258 acft/yr)[1]	0.23 mgd (258 acft/yr)[2]
Motorola, Oak Hill[14]	1.32 mgd (1481 acft/yr)[11]	0.53 mgd (592 acft/yr)[4]
TOTAL[10]	**4.05 mgd (4536 acft/yr)**	**1.76 mgd (1969 acft/yr)**
Northwest Water Reclamation Plan[12] (L-5C)		
Samsung[14]	9 mgd (10080 acft/yr)[13]	3.0 mgd (3360 acft/yr)[13]
Schlumberger	0.02 mgd (20 acft/yr)[7]	0.01 mgd (8 acft/yr)[4]
3M	0.11 mgd (118 acft/yr)[11]	0.04 mgd (47.2 acft/yr)[4]
Great Hills Trail Golf Course	0.23 mgd (258 acft/yr)[1]	0.23 mgd (258 acft/yr)[2]
Abbott Laboratories[14]	0.69 mgd (772 acft/yr)[11]	0.28 mgd (310 acft/yr)[4]
IBM Corporation[14]	0.91 mgd (1019 acft/yr)[11]	0.37 mgd (410 acft/yr)[4]
TOTAL	**10.96 mgd (12275 acft/yr)**	**3.92 mgd (4394 acft/yr)**
TOTAL REUSE POTENTIAL		**23.0 mgd (25,781 acft/yr)**

[1] Based on 1992 City of Austin Reuse Master Plan estimates for golf course irrigation demands.
[2] All irrigation demands are replaceable with reclaimed water.
[3] Based on 1996 Self Monitoring Reports.
[4] Estimated as 40% of annual use.
[5] No current demand for RO blending.
[6] Based on reduction of TDS from 1100 ppm to 800 ppm.
[7] Based on 1992 City of Austin Reuse Master Plan estimates.
[8] Includes 258 acft/yr irrigation demand at Bluebonnet Hill Golf Course.
[9] Average annual make-up water diversions for natural and forced evaporation to Decker Lake for 1990 to 1995.
[10] Totals do not include existing reuse at Hornsby Bend Sludge Facility, Bergstrom Golf Course, and Jimmy Clay Golf Course.
[11] Based on 1994 City of Austin water records.
[12] Totals do not include existing reuse at Balcones Country Club.
[13] Based on City of Austin Projections
[14] Potential reuse added subsequent to 1992 City of Austin Reuse Master Plan.

Northwest Water Reclamation Plan (L-5C)

The total reuse potential in the Northwest region totals 3.92 mgd (4,394 acft/yr) (Table 3.5-3). Of this quantity, 3.65 mgd (4,080 acft/yr) would be obtained through reclamation at

Samsung, Abbott Laboratories, and IBM. In the reuse Master Plan report,[8] the reuse potential for the Northwest Water Reclamation Plant is estimated to be 1,000 acft/yr (0.9 mgd), with a maximum daily demand of 3.1 mgd (4.8 cfs). The demand estimates contained in the Master Plan were used for engineering and cost estimating.

Decker Lake Make-up Water (L-5D)

For the 1990 to 1995 time period, the average annual diversion of Colorado River water to Decker Lake was 4,247 acft/yr. This diversion quantity includes demands for natural evaporation as well as forced evaporation to meet steam-electric cooling needs. All make-up needs can be met from reclaimed water, therefore, the potential yield available for this alternative is 4,247 acft/yr. With the addition of the Bluebonnet Hills Golf Course, irrigation demand of 258 acft/yr, the total annual yield available from implementation of this alternative is 4,505 acft/yr.

Water Reclamation and Reuse at Semiconductor Manufacturing Plants (L-5E)

Potential reuse at the major semiconductor plants have been included as part of the regional reuse projects as indicated in Table 3.5-3. The combined potential reuse at the major semiconductor manufacturing plants (Advanced Micro Devices, both Motorola plants, Sematech, and Samsung) equals 6.1 mgd (6,832 acft/yr). These quantities mostly reflect water recycling performed at the manufacturing plants. Some municipal reclaimed water could also be needed for blending with RO reject (as listed in the Central Reuse Plan for Motorola) water to reduce TDS to acceptable levels for landscape irrigation or cooling tower makeup. Based on information provided by staff of several of the manufacturers, about 40 percent of the annual water demand could be met with reclaimed water. However, reuse potential will be very site-specific and a more detailed case-by-case evaluation would be needed to explore the exact reuse potential at each semiconductor manufacturing plant.

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[8] Ibid.

3.5.3 Environmental Issues

This alternative concerns the use of reclaimed water by commercial enterprises in the Austin area, cooling water at the Decker Lake Power Plant, and augmentation of Lake Travis/Lake Austin. Particular environmental concerns can be categorized as follows:

- Effects on water quality and streamflows resulting from the use of treated wastewater for landscape irrigation, and sanitation and cooling in manufacturing plants;
- Effects of augmentation on water quality and streamflows in the Colorado River, and on Decker Lake and Lake Travis/Lake Austin; and
- Effects resulting from the construction and operation distribution systems to transport treated wastewater to users.

Return flows from WWTPs into rivers are an indispensable part of streamflows which should be considered in the development of wastewater reuse projects. One factor relevant to the effects of wastewater reuse projects on streamflow is the relative contribution of wastewater to streamflow in the stream being considered as a source of water. The relative contribution of wastewater to streamflow is a function of the volume of raw water being diverted, and the volume of wastewater being returned. These are, in turn, related to the size of the water source and number of water users. Another factor to be considered is the efficiency of use (reuse) or the proportion of the raw water remaining as wastewater return flow. Typically, treated wastewater accounts for 40 to 50 percent of the water diverted for urban use. Some water uses, such as for irrigation and as cooling water for steam-electric plants, may have efficiencies (in terms of treated wastewater as a proportion of raw water diversion) at or near zero. However, even in cases where little or no water remains following use, it may be more desirable to use treated wastewater than raw water. All else being equal, replacing raw water use with an equal amount of treated wastewater would result in no net change in streamflow. Distributing water use in such a way that raw water is supplied to the most efficient uses and treated wastewater is supplied to the least efficient uses would tend to increase the overall efficiency of water use by minimizing raw water use and nutrient loading without affecting streamflow.

The projects considered (1) Alternative L-5 can be categorized according to the types of wastewater reuse as industrial reuse (e.g., such as for cooling tower make-up); (2) landscape irrigation; and (3) the augmentation of Lake Austin or Decker Lake.

The manufacture of semiconductors requires ultrapure water which is produced by the reverse osmosis (OR) of potable water as described above. Following reverse osmosis, about

75 percent of the water is ultrapure and appropriate for the manufacturing processes, and the remaining 25 percent is a high quality RO reject water which is discharged to municipal wastewater collection systems, or in some cases, directly to surface streams. Following use in the manufacturing process, the ultrapure water fraction is termed industrial wastewater. The industrial wastewater is slightly acidic and contains organic compounds which can be removed with available water treatment technology. Typically, the industrial wastewater is adjusted for pH and discharged into municipal wastewater collection systems. Thus, wastewater from these semiconductor plants is in the form of RO reject water and industrial wastewater. As noted above, in some manufacturing plants, industrial wastewater from various processes can be segregated which affords greater opportunity for reclaiming higher quality wastewater which could be used for cooling tower make-up, landscape irrigation, or sanitation.

With respect to landscape irrigation, substituting an equal amount of wastewater return flow for potable water would result in no significant change in streamflows; however, it is expected that the potable water saved would be supplied to other users. Thus, the combined use of treated wastewater with the use of the additional potable water will result in a net reduction of streamflow. Using wastewater for purposes resulting in minimal return flow and potable water for purposes resulting in greater return flow may be more efficient than using only potable water.

Environmental Consideration for Reuse at Decker Lake (L-5D)

Environmental issues associated with this alternative include: 1) effects on instream flows in the Colorado River, and 2) water quality impacts on Decker Lake, which may have secondary effects on recreational uses, operations of the Walter E. Long Steam Electric Generating Station, and on the biological community of the lake. With regard to instream flows, replacing the existing diversion with treated effluent that would otherwise be discharged to the river will result in no net change in Colorado River flows. However, any additional municipal diversions made possible by substitution of reclaimed water at Decker Lake will result in reduced flows in the Colorado River downstream of Austin.

A situation similar to the proposed reuse at Decker Lake has been in place at Lakes Braunig and Calaveras in San Antonio since 1962. Both lakes are constructed on small watersheds southeast of San Antonio, and are used to cool steam electric generating plants.

Although neither lake receives reclaimed water directly, their levels are maintained by diversions from the San Antonio River which is heavily dominated by discharges from multiple wastewater treatment facilities serving the City of San Antonio. Decker Lake, with a surface area of 1,269 acres and a normal storage capacity of 33,940 acft is intermediate in size between Lakes Braunig (1,350 acres, 26,500 acft) and Calvaras (3,450 acres, 61,800 acft), and has a similar basin shape, area-capacity relationship, and is located in a region of similar relief, vegetation and climate.[9] On average, Decker Lake has made up about 12.5 percent of its volume annually with diversions from the Colorado River, while Lakes Braunig and Calaveras have each year received about 20 percent (5,300 acft) and 31 percent (19,000 acft), respectively, of their volumes from the San Antonio River (make up volumes may increase by 50 percent or more during a dry year).[10]

Power plant operations on Lakes Braunig and Calaveras are not substantially different from other facilities employing once-through cooling systems.[11] Contact recreation, including water skiing and operation of personal watercraft is permitted on both reservoirs[12]. Both Lakes Braunig and Calaveras are highly productive, experiencing continuous high concentrations of phytoplankton, primarily blue-green algae (Cyanobacteria). Both reservoirs support diverse biological communities, including prolific sport fisheries for both native and exotic species, and they do not experience noxious surface algal blooms, or extensive fish kills.[13] The use of what is essentially treated wastewater, particularly during typical summers or in extended dry periods, has had no reported effect on electric generating facilities at these lakes. The minimal impacts can be attributed to the power plant cooling operations. Power plant cooling involves pumping the entire volume of the waterbody through the cooling system in a matter of a few weeks, resulting in a relatively high mixing energy that prevents long term stratification and discourages the proliferation of algal species that form surface mats or blooms in nutrient laden waters.

Given the similarities among the San Antonio reservoirs and Decker Lake, and the probable nutrient loading levels that would be realized; it is unlikely that adverse impacts to the electric generating facilities, the resident biological communities, or the present recreational uses

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[9] Dallas Morning News, "Texas Almanac", 1994-1995.

[10] Black and Veatch, "Water Management Plan using Braunig and Calaveras Lakes" Project No. 16598, February 1990.

[11] Joe Fulton, *pers. comm.*, City Public Service, San Antonio, Texas, July, 1996.

[12] James Blair, *pers. comm.*, San Antonio River Authority, San Antonio, Texas, July, 1996.

[13] Wes Dorset, *pers. comm.*, City Public Service, San Antonio, Texas, July 1996.

of the lake would result from implementation of the reuse alternative. It is, however, recommended that a mass balance study that includes nutrients and major inorganic ions (calcium, magnesium, sodium, carbonate, chloride, sulfate, etc.), together with consideration of the removal of synthetic organic chemicals and trihalomethane precursors (see the Lake Austin and Town Lake Augmentation alternative), be conducted prior to a final decision on the implementation of this alternative.

Augmentation of Lake Austin/Town Lake

Although anticipated nutrient removal processes will produce reclaimed water having substantially lower nutrient concentrations than conventional secondary treatment, phosphorus and nitrogen levels will still be excessive relative to the nutritional needs of aquatic plants and to existing nutrient loads in Lake Austin and Town Lake. For example, total phosphorus (T-P) and inorganic nitrogen ($InOrg\text{-}N=NO_3\text{-}N+NO_2\text{-}N+NH_3\text{-}N$) concentrations in water exiting Town Lake averaged 0.0219 mg/l and 0.3323 mg/l, respectively, during the period 1984 to 1993. Even the maximum macronutrient concentrations recorded, 0.184 mg/l T-P and 1.07mg/l InOr-N, were far less than the monthly average concentrations to be achieved by advanced wastewater treatment.[14]

Nutrient impacts on aquatic plant growth are now occurring in the Colorado River below Town Lake as a result of the existing wastewater discharges, and will continue to occur, although at levels reduced in proportion to achieved reductions in nutrient loading. Whether in stream or lake (reservoir) environments, the processes which remove and sequester nutrients (assimilation and growth, sedimentation and burial) are similar, but tend to be accelerated and concentrated in standing waters. This indicates that nutrient loading levels that might produce objectionable conditions (e.g., high densities of planktonic algae) in a lake or reservoir may have no observable 88substantial impact in a stream where flow is available to dilute and distribute the effects over long reaches, and where secondary physical properties related to water flow (increased turbidity, rapid change in light and temperature regime) can impact the growth of aquatic plant populations.

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[14] Patek, J., "Proposed New Segmentation for TNRCC Segments 1428 and 1402", Lower Colorado River Authority, 1994.

While discharge of reclaimed water into Lake Austin and Town Lake would likely result in changes to those reservoirs reflecting the increased nutrient load, in fact the load would only be moved upstream a few miles into an environment better suited to nutrient assimilation and trapping than the flowing waters of the Colorado River downstream. If sufficient nutrient load can be discharged into the upper reaches of Lake Austin, it is possible that the resulting planktonic algal growth would be sufficient to shade out the extensive stands of rooted vegetation now considered a significant nuisance in that lake, saving the city the necessity of conducting periodic winter drawdowns. Of course, the lakes would be green. In effect, the wastewater would be receiving additional "polishing" treatment in those reservoirs, in the area in which the water was diverted and used, instead of directly discharging the waste nutrients to the Colorado River for transport and eventual assimilation in downstream areas.

Reclaimed Water Distribution System

Travis and Williamson Counties are divided into the Central Texas Plateau: the Edwards Plateau in the west, and the Blackland Prairie in the east by the Balcones fault.[15],[16],[17] The terrain drops west to east from the Edwards Plateau to the Blackland Prairie. Elevations range from 1,200 to 425 feet mean sea level (msl) west to east. The western part of the counties are typified by thin, stony, gently sloping to sloping soils formed in limestone or limestone and marl. The western soils occur on broad ridges and in intervening long, shallow valleys of deeper soils. The soils in the central to eastern parts of the counties are deep to shallow clayey soils that formed in marine marls, ancient clayey alluvium, soft limestone and chalk. These soils occur in a series of level to gently sloping broad, ancient stream terraces and undulating uplands.[18,19,20] These vegetational areas are described in the Environmental Overview, Section 3.1.3.

Protected, candidate, and species of concern reported to occur in Travis and Williamson counties are presented in Section 3.1.3. Most of the bird species listed are migratory and not

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[15] Omerik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1): pp. 118-125.

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

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

[18] Soil Conservation Service. 1983. Williamson County. U.S. Department of Agriculture.

[19] Soil Conservation Service. 1974. Travis County. U.S. Department of Agriculture.

[20] Garner, L.E. and K.P. Young. 1976. Environmental Geology of the Austin Area: An Aid to Urban Planning. Report No. 86. Bureau of Economic Geology, University of Texas at Austin, Austin, Texas.

likely to be adversely affected by treatment plant or water transmission line construction. Although the proposed transmission pipeline routes for reclaimed water are primarily within urban areas, impacts to endangered species or important natural resources are possible and mitigation planning will be a required part of project planning and development. The likelihood of encountering endangered species is greatest with respect to the Northwest Area Reuse Alternative, which involves north central Travis County and south central Williamson County. This project area lies on the eastern margin of the Edwards Plateau, which supports a number of endangered species and unique habitats such as canyons, caves, and springs.

Numerous endangered, threatened, and sensitive species occurrences are reported on the Jollyville and Pflugerville West 7.5-minute quadrangle maps in the TNHP (Texas Natural Heritage Program) files. Vertebrates include the cave myotis bat (*Myotes velifer*), Black-capped Vireo (*Vireo atricapillus*), Golden-cheeked Warbler (*Dendroica chrysoparis*), Texas garter snake (*Thamnophis sirtalis*), and Guadalupe bass (*Micropterus treculi*). Of these species, the Golden-cheeked Warbler and Black-capped Vireo are listed as endangered both by the federal and state agencies. The cave myotis bat, Texas garter snake, and Guadalupe bass are listed as species of concern. Endangered invertebrates associated with karst features and reported in the TNHP files include the Tooth Cave ground beetle (*Rhadine persephone*), Kretschmarr Cave mold beetle (*Texamaurops reddelli*), Tooth Cave pseudoscorpion (*Tartarocreagris texana*), Tooth Cave spider (*Neoleptoneta myopica*), and Bone Cave harvestman (*Texella reyesi*). All of these species are afforded endangered status by the USFWS. The Tooth Cave blind rove beetle (*Cylindropsis* sp.) is listed from this area as a species of concern.

On the Austin East 7.5-minute quadrangle map, which covers the Central Reuse Area, TNHP lists the Texas garter snake (*Thamnophis sirtalis annecteus*), Guadalupe bass (*Micropterus treculi*), smalleye shiner (*Notropis buccula*), and the bracted twistflower (*Streptanthus bracteatus*) as species of concern.

The Golden-cheeked Warbler and Black-capped Vireo are categorized as endangered species and are afforded protection by USFWS. The Golden-cheeked Warbler inhabits mature, old-growth Ashe juniper-oak wood having between 40 and 85 percent Ashe juniper.[21,22,23,24,25]

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[21] Benson, R.H. 1990. Habitat Area Requirements of the Golden-cheeked Warbler on the Edwards Plateau. A Report to Texas Parks and Wildlife Department. Austin, TX.

The warbler requires strips of bark, which it gathers from mature Ashe juniper, for nest construction. Throughout most of its range, Texas oak is usually co-dominant with Ashe juniper, but other oaks may replace the Texas oak in some parts of its range. For example, at the northern extreme of the warbler's range, shin oak may dominate while in the southern extreme lacy oak (*Q. glaucoides*) increases in abundance.

The Black-capped Vireo inhabits dry limestone hilltops, ridges, and slopes on the eastern and southern portions of the Edwards Plateau, but its nesting range extends into the canyons of the Stockton Plateau to the west, and north into central Oklahoma.[26,27,28] Vegetation typical of Black-capped Vireo habitat may include oaks, mountain laurel (*Sophora secundiflora*), sumacs (*Rhus* sp.), redbud (*Cercis canadensis*), Texas persimmon, Ashe juniper, mesquite, and agarita. However, species composition appears to be less important than the structure of the vegetative habitat. This is characterized by an open overstory of larger trees (e.g., oak and juniper) and an understory of broad-leafed shrubs having dense foliage from the ground to about 6 feet high. Black-capped Vireo habitat is mid-successional and usually develops after a disturbance such as fire or clearing. Such habitat can be created and maintained using appropriate managment techniques. Nest parasitism by cowbirds (*Molothrus ater*) and the destruction of nestlings by fire ants (*Solenopsis invicta*) may have a greater impact on Vireo populations than habitat availability.

Cave adapted (troglobitic) invertebrates found in Edwards karst solution features include the Bee Creek Cave harvestman (*Texella reddelli*), Kretschmarr Cave mold beetle (*Texamaurops*

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[22] Campbell, L. 1995. Endangered and Threatened Animals of Texas. Resource Protection Division. Endangered Resources Branch. Texas Parks and Wildlife Dept. Austin, TX.

[23] Ladd, C.G. 1985. Nesting Habitat Requirements of the Golden-cheeked Warbler. Southwest Texas State University. Masters Thesis. San Marcos, TX.

[24] USFWS. 1994. Minimum Procedures for Determining the Presence/Absence of Golden-cheeked Warblers and Black-capped Vireos. U.S. Fish and Wildlife Service. Austin, TX.

[25] Wahl, R. D.D. Diamond and D. Shaw. 1990. The Golden-cheeked Warbler: A Status Review. A Final Report Submitted to Ecological Services. U.S. Fish and Wildlife Service, Fort Worth, TX.

[26] Campbell, L. 1995. Endangered and Threatened Animals of Texas. Resource Protection Division. Endangered Resources Branch. Texas Parks and Wildlife Dept. Austin, TX.

[27] Sexton, C.W. G.W. Lasley, J.A. Grybowski, and R.B. Clapp. 1989. Distribution and Status of the Black-capped Vireo in Texas. Unpublished Draft Report.

[28] TPWD. 1988. The Black-capped Vireo in Texas. Texas Parks and Wildlife Department. Austin, TX.

reddelli), Bone Cave harvestman (*Texella reyesi*) and Tooth Cave Ground Beetle (*Rhadine persephone*).[29],[30],[31],[32],[33],[34],[35],[36],[37],[38],[39]

The eastern Edwards Plateau is unique in that it is home to a diverse assemblage of over 40 highly adapted, aquatic and troglobitic species. Some species seem to have adapted from marine environments, and some may have originated from surface dwelling species that entered the aquifer through spring openings. It is possible that during the ice age, species such as the trogolobites entered the aquifer through springs and adapted to cave conditions to the extent that they are not able to survive outside of caves. Over the millennia, these species have evolved in cave environments that provide moisture, stable temperatures, darkness, and isolation. Their surface relatives have retreated to other regions because of climatic changes. The geologic complexities of this area enhanced this diversity by creating islands of karst separated by faulting and river downcutting. A prime example is the Jollyville Plateau, located in northwestern Travis County. It contains both Tooth Cave and Kretschmarr Cave in its 5-mile diameter island of

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[29] Longely, Glenn. 1986. The biota of the Edwards Aquifer and the implications for Paleozoogeography. in: Abbott, P.L. and C.M. Woodruff, Jr. eds. 1986. The Balcones Escarpment, Central Texas. Geological Society of America. pp 51-54.

[30] Elliott, W.R. and J.R. Reddell. 1989. The status and range of five endangered arthropods from caves in the Austin, Texas, region. 100 p. Austin Regional Habitat Conservation Plan. Reddell, J.R. 1991. Further study of the status and range of endangered arthropods from caves in the Austin, Texas, region. Draft Section 6 report on a study for Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service.

[31] Elliott, W.R. 1994. "The Cave Fauna of Texas" *in*: Elliott and G. Veni, eds, 1994. The Caves and Karst of Texas, Guidebook for the 1994 Convention of the National Speleological Society with Emphasis on the Southwestern Edwards Plateau, Texas Speleological Survey, Austin, Texas.

[32] Elliott, W.R. and J.R. Reddell. 1989. The status and range of five endangered arthropods from caves in the Austin, Texas, region. Austin Regional Habitat Conservation Plan.

[33] Elliot, W.R. 1994 . Community ecology of three caves in Williamson County, Texas: A three-year summary. Report to Simon Development Company, Inc. Texas Parks and Wildlife Dept.. and U.S. Fish and Wildlife Service.

[34] O'Donnell, L., W.R. Elliott, and R.A. Stanford. 1994. Recovery plan for endangered karst invertebrates in Travis and Williamson counties, Texas. U.S. Fish and Wildlife Service.

[35] Reddell, J.R. and W. R. Elliott. 1991. Distribution of endangered karst invertebrates in the Georgetown area, Williamson County, Texas. City of Georgetown, Texas.

[36] Reddell, J.R. 1991. Further study of the status and range of endangered arthropods from caves in the Austin, Texas, region. Draft Section 6 report on a study for Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service.

[37] Reddell, J.R. 1994. The cave fauna of Texas. pp 31-50 *in*: Elliott, W. R. and G. Veni (eds) 1994. The Caves and Karst of Texas. Convention Guidebook, National Speleological Society., Huntsville, Alabama.

[38] Elliott, W.R. 1994. Community ecology of three caves in Williamson County, Texas: A three-year summary. Report to Simon Development Co., Inc., Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service. 46 pp.
Reddell, J.R. and W.R. Elliott. 1991. Distribution of endangered karst invertebrates in the Georgetown area, Williamson County, Texas. City of Georgetown, Texas. 64 pp.

[39] O'Donnell, L., W.R. Elliott and R.A. Stanford. 1994. Recovery plan for endangered karst invertebrates in Travis and Williamson counties, Texas. U.S. Fish and Wildlife Service. 153.

Edwards formation. Tooth Cave is about 166 ft. long and 18 ft. deep and may contain 64 separate species; a high species diversity which is generally found in larger cave systems.[40]

Management guidelines for karst invertebrates involve the preservation of known caves, avoiding altering surface drainage patterns, preservation of native vegetation, prevention of groundwater contamination, restriction of human visitation, and fire ant control.[41] Out of these guidelines, changes in surface drainage patterns, clearing vegetation, and potential groundwater contamination appear to be most important with respect to Alternative L-5, Northwest Reuse and Reclamation area. Cave ecosystems and organisms are sensitive to changes in humidity and moisture levels on cave surfaces. Local drainage patterns play an important role in determining water dynamics within caves. Additionally, because photosynthesis does not occur in caves, nutrient dynamics in cave ecosystems are dependent on water inflow. Vegetation near caves influences nutrient dynamics in caves and reduces the potential for contamination and sedimentation.

Because of the unique geology, ecology, and biogeography of the area, the likelihood of encountering caves or caves harboring protected species during construction activities is relatively high. Pedestrian surveys of pipeline routes and other areas affected the implementation of Alternative L-5 will be conducted by qualified biologists and a mitigation plan will be developed in the planning stages before final design plans are approved. Mitigation planning involves avoiding, minimizing, and mitigating for unavoidable environmental impacts. Pedestrian surveys of proposed impact areas will assist in selecting project areas (e.g., pipeline routes) least likely to encounter unavoidable impacts. Advanced mitigation planning and coordination with the appropriate regulatory agencies also will minimize delays in the event karst features are encountered during construction. For example, cavities larger than about 1 foot across encountered during construction that appear to have airflow should be examined by a qualified karst biologist in consultation with USFWS. Qualified karst biologists have permits issued by USFWS that allow them to open and examine protected species habitat that may result in incidental "taking" or death of protected organisms. In order to minimize potential damage to endangered species habitat, construction at the site should cease and the opening should be

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[40] Elliott, W.R. 1990. Texas Endangered Species Endangered Caves *in*: National Speleological Society News. pp225-231. From a reprint provided by the author.
[41] Ibid.

covered to minimize drying. Methods to protect the karst habitat would be recommended and compliance would be coordinated with USFWS.

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.

3.5.4 Water Quality and Treatability

Water Quality Requirements for Landscape Irrigation

The TNRCC rules specify categories of use of reclaimed water with corresponding reclaimed water quality requirements.[42] For landscape irrigation with reclaimed water, the irrigated area is classified as restricted or unrestricted use. Most commonly, the landscapes to which reclaimed water is applied are parks, golf courses, and street medians. Public parks generally have unrestricted access and the water quality requirements for irrigation of public areas are as follows:[43]

BOD_5	5 mg/l
Turbidity	3 NTU
Fecal Coliform	75 CFU/100 ml

Golf courses and street medians are considered to have restricted access which allows irrigation at times when the public will not be exposed to the spray. The water quality requirements for restricted access are as follows:[44]

BOD_5	20 mg/l
Fecal Coliform (single grab)	800 CFU/100 ml
Fecal Coliform (geometric mean)*	200 CFU/100 ml
(no turbidity standard)	

* Draft rule revision to TNRCC Chapter 310.

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[42] TNRCC, Chapter 310: Use of Reclaimed Water.

[43] Texas Administrative Code, Title 31, Chapter 309.

[44] Ibid.

Unless the entity using the reclaimed water has a permit to discharge effluent, it must provide a storage pond for protection from accidental spillage. The pond must be capable of holding the maximum amount of reclaimed water which would accumulate in the event of a 25-year rainfall.

TNRCC rules permit use of reclaimed water in commercial and industrial application if the quality of the water meets these minimum requirements:

BOD_5 30-day average	20 mg/l
Fecal Coliform	200 CFU/100 ml
(no turbidity standard)	

Effluent at both Walnut Creek WWTP and South Austin Regional WWTP meet the unrestricted use criteria at current operation levels. Future discharge permits may require nutrient removal processes at both Walnut Creek WWTP and South Austin Regional WWTP. This will create a high quality effluent with a higher market value. Table 3.5-4 displays the current water quality criteria of the two WWTPs and the 1995 operation levels.

Table 3.5-4
Discharge Permit Requirements and 1995 Discharge Levels for Selected Austin Wastewater Treatment Plants[1]

Quality	Walnut Creek Regional WWTP		South Austin Regional WWTP	
Parameter	**Present[2]**	**1995 Levels[3]**	**Present[2]**	**1995 Levels[3]**
Carbonaceous BOD_5 (mg/l)	10.0	2.0	10.0	1.0
Total Suspended Solids (mg/l)	15.0	1.3	15.0	2.0
Ammonia Nitrogen (mg/l)	2.0	0.1	2.0	0.1
Total Nitrogen (mg/l)	None	22.7	None	7.7
Total Phosphorous (mg/l)	None	3.6	None	1.7
Turbidity	None	N/A	None	N/A

[1] Monthly Averages
[2] Wastewater Collection System Long-Range Planning, City of Austin, May 1994.
[3] City of Austin discharge records at Walnut Creek WWTP and South Austin Regional WWTP.

Water Quality Requirements for Augmentation of Lake Austin and Town Lake (L-5A)

Augmenting Lake Austin and/or Town Lake with reclaimed water would require compliance with TNRCC's anti-degradation policies.[45] It restricts all degradation of waters which exceed fishing/swimming quality unless necessary for important economic or social

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[45] Texas Administrative Code Title, Chapter 307.

development. Both Town Lake and Lake Austin are classified for contact recreational use, and aquatic life is considered high based on the Lower Colorado River Authority's 1994 water quality study.[46] High levels of toxic synthetic organics such as chlordane, DDT and its metabolites DDE and DDD have resulted in fishing bans in Town Lake. Increased nutrient loading and Lake Travis reservoir operations have also created eutrophication problems in Town Lake. Judging from Town Lake's current condition and the potentially troublesome nutrient loads from reclaimed water (discussed in Section 3.5.3), any reclaimed water used in augmenting either Lake Austin or Town Lake would be required to adhere to stringent water quality criteria. The treatment process at Walnut Creek WWTP already removes the soluble organics and organic solids to acceptable levels; however possible contamination from low-level synthetic organic chemicals (SOC), pesticides, and trihalomethane (THM) precursors in the WWTP effluent is a concern. Generally, an adsorptive process such as granular activated carbon (GAC) is used to remove taste- and odor-causing constituents as wells as the SOCs, pesticides, and THMs. To avoid any further degradation of Lake Austin and Town Lake, GAC treatment or other suitable treatment would be required for any reclaimed water used in water supply augmentation.

Water Quality Requirements for Reuse at Decker Lake (L-5D)

In order to summarize the water quality requirements at Decker Lake, the nutrient loads existing at Decker Lake are compared with nutrient loads expected with reclaimed water and the nutrient loads at Lakes Braunig and Calevaras. The average 1983 to 1993 recorded nutrient concentrations near the Decker Lake diversion point at the FM 973 crossing of the Colorado River are as follows:[47]

T-P	0.79 mg/l
Ammonia Nitrogen (mg/l)	0.39 mg/l
Nitrate Nitrogen (mg/l)	1.74 mg/l
Inorganic Nitrogen	2.13 mg/l

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[46] 1994 Water Quality Assessment of the Colorado River Basin, Lower Colorado River Authority, October, 1994.

[47] Patek, J., "Proposed New Segmentation for TNRCC Segments 1428 and 1402", Lower Colorado River Authority, 1994.

Using the averages at the FM 973 crossing, Colorado River diversions are adding about 4,150 kilograms (Kg) per year of total phosphorus and about 11,150 Kg of inorganic nitrogen annually to Decker Lake, giving area loading rates of 0.81 gm/m^2/year and 2.17 gm/m^2/year, respectively, in addition to that entering the lake from its watershed and from precipitation and dry deposition. Increases in electric generating capacity that would result in a need to divert the full 16,156 acft/yr consumptive water right would result in proportional increases in nutrient loading, assuming average Colorado River nutrient concentrations were unchanged (e.g., total phosphorus loading would increase to 3.1 gm/m^2/year, and inorganic nitrogen to 8.2 gm/m^2/year).

By way of comparison, using average concentrations of 2.6 mg/l for total phosphorus and 3.0 mg/l for inorganic nitrogen in the San Antonio River gives the following annual loading rates from make-up water:[48]

	KgT-P/year	gT-P/m^2/year	KgN/year	gN/m^2/year
Braunig	16,996	3.1	19,610	3.6
Calaveras	60,929	4.3	70,303	5.0

All of the loadings discussed above may be considered more than sufficient to support eutrophic conditions in these reservoirs, even without consideration of the sources within their own watersheds.[49]

If reclaimed water is substituted for Colorado River make-up water, Table 3.5-4 indicates that both phosphorus and nitrogen loadings would increase substantially at present treatment plant performance levels. If the projected treatment levels are achieved, total phosphorus loadings would not increase substantially, but inorganic nitrogen loadings would increase by a factor of about four. Although nitrogen would be expected to be limiting to algal growth because of the relatively low N:P ratios in the projected WWTP nutrient levels, in practice there is plenty of nutrients available for abundant algal growth, and nitrogen-fixing blue-green algae (Cyanobacteria) are typical constituents of summer algal communities in this region.

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[48] Black and Veatch, "Water Management Plan using Braunig and Calaveras Lakes" Project No. 16598, February 1990.

[49] Wetzel, R.G., "Limnology", Saunders College Pub., Philadelphia 1983.

As discussed above, substituting reclaimed water for raw water in Decker Lake would increase nutrient levels, especially nitrogen levels, in the lake. However, this does not appear to present a significant problem in terms of current recreational uses and aquatic life in Decker Lake. Comparisons with Lakes Braunig and Calaveras, which are similar to Decker Lake, indicate that high flow rates through Decker Lake will mitigate against algal blooms that might be expected in a low turnover situation. These comparisons indicate that Decker Lake would continue to support contact recreation and maintain the current quality of aquatic life.

Water Quality Requirements for Reuse at Semiconductor Plants (L-5E)

Water quality requirements inside a semiconductor plant depends on the source of reclaimed water and its intended application. There are three potential sources of reclaimed water for use at semiconductor plants:

- Reclaimed water from municipal WWTPs,
- Reclaimed industrial process water, and
- RO reject water.

The primary demand of reclaimed water from a municipal WWTP would be limited to blending it with RO reject for irrigation, sanitary flows (i.e., toilet flushing), and potential cooling tower makeup. Effluent from both Walnut Creek WWTP and South Austin Regional WWTP would be suitable for irrigation and toilet flushing. Another possible application of municipal reclaimed water would be incorporating it into the industrial process flows. The volumes and quality of this alternative would be contingent upon whether the plant has the capabilities to treat the municipal WWTP effluent to the appropriate manufacturing levels (assumed to be equal to drinking water standards).

Water quality of industrial wastewater is very process-specific. In general, TDS levels around 1,200 mg/l, BOD_5 of 60 mg/l, and pH readings ranging from 4 to 6 can be associated with these flows. The amount of total toxic organics (TTO) permitted at the sewer outfall is 2.0 mg/l.[50] For reuse in the plant, the most efficient procedure is to isolate and treat the industrial flows that are more readily treatable and release the remaining waste to the Publicly-Owned Treatment Works (POTW) as is currently done. Buffering of acidic waters, biological treatment

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[50] City of Austin Industrial Waste Discharge Permit.

of organics, and filtration to reduce turbidity would be required for internal reclamation to drinking water standards.

Typical RO reject water contains medium to high salts with TDS around 1,100 mg/l. With sulfates around 450 mg/l, chloride concentrations close to 270 mg/l, and fluoride levels around 1.0 mg/l, RO reject water is just about at drinking water standards. For irrigation purposes, the TDS should be around 800 mg/l to avoid salt build-up in soils and ultimate harm to irrigated vegetation. This would require blending with either reclaimed water from the WWTP or potable supplies. Assuming the TDS of blending waters to be around 350 mg/l, the blending would require a 1:1.5 mixing ratio (blending water to RO reject).

Reuse of either industrial wastewater or blended RO reject as cooling tower makeup would require a detailed cost/benefit analysis to find the optimum level of treatment needed for balancing the increased cooling tower maintenance costs versus the savings associated with decreases in potable water charges.

3.5.5 Engineering and Costs

City of Austin Reuse Master Plan Projects (L-5)

Central Reuse System and Water Supply Augmentation (Alt L-5A): Implementation of the Central Reuse System alternative would require construction of these facilities:

- Diversion structure at Walnut Creek WWTP,
- Pump station,
- Transmission pipeline,
- Connection to end-user distribution facilities,
- Control system,
- GAC treatment or other suitable treatment (for Lake Austin/Town Lake augmentation only), and
- Outfall structure (for Lake Austin/Town Lake augmentation only).

Reclaimed water would be diverted downstream of the filters at Walnut Creek WWTP at a new concrete diversion structure supplying the reclaimed water pump station. The pump station would have a peak pumping capacity of 6 cfs, discharging to a 16-inch transmission pipeline. The transmission pipeline route is shown in Figure 3.5-1. The capital and O&M cost estimates for this facility are contained in Table 3.5-5. Total project cost is estimated to be $8,780,000, resulting in annual debt service costs of $823,000. The total annual cost, including debt service, operation and maintenance, and power is estimated to be $940,000. For an annual project yield of 2,590 acft/yr, the resulting unit cost for this alternative is $363 per acft/yr (Table 3.5-5). A purchase price to obtain reclaimed water from the Austin wastewater utility is not included in the estimated cost for this alternative. The purchase price would reimburse the utility for costs to produce the reclaimed water including treatment and administration.[51]

Water Supply Augmentation of Lake Austin/Town Lake: For the option of augmenting water supplies at Lake Austin/Town Lake, facilities for treatment by granular activated carbon (GAC treatment) or other suitable treatment, would be needed at Walnut Creek WWTP to remove taste- and odor-causing constituents, THMs, and other constituents. The augmentation option would also require an outfall structure on Lake Austin. Reclaimed water would be diverted downstream of the filters at Walnut Creek WWTP at a new concrete diversion structure supplying the GAC treatment facility. The GAC treatment facility (or other suitable treatment) is estimated to cost $13,360,000 and have an annual O&M cost of $800,000. The reclaimed water treatment and pumping facilities would have a capacity of 22.7 cfs, discharging to a 30-inch transmission pipeline. The transmission pipeline route is shown in Figure 3.5-1.

The capital and O&M cost estimates for this facility are contained in Table 3.5-5. Total project cost is estimated to be $37,555,000, resulting in annual debt service costs of $3,518,000. The total annual cost, including debt service, operation and maintenance, and power is estimated to be $5,870,000. For an annual project yield of 14,900 acft/yr, the resulting unit cost for this alternative is $394 per acft/yr. A purchase price to obtain reclaimed water from the Austin wastewater utility is not included in the estimated cost for this alternative. The purchase price would reimburse the utility for costs to produce the reclaimed water including treatment and administration.[52]

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[51] The City of Austin has adopted a rate ordinance establishing the sales price for reclaimed water of $0.95 per 1,000 gal ($310 per acft). This price is intended to include all facilities and administrative costs needed to deliver reclaimed water to the user's facility and would double account for some costs if added as a cost to this project estimate. However, the $0.95 per 1,000 gal cost would include any additional treatment that may be needed such as nutrient removal.

[52] The City of Austin has adopted a rate ordinance establishing the sales price for reclaimed water of $0.95 per 1,000 gal ($310 per acft). This price is intended to include all facilities and administrative costs needed to deliver reclaimed water to the user's facility and would double account for some costs if added as a cost to this project estimate. However, the $0.95 per 1,000 gal cost would include any additional treatment that may be needed such as nutrient removal.

Table 3.5-5
Cost Estimate Summary for Central Reuse system and Water Supply Augmentation (Alt. L-5A)
(1st Quarter 1997 Dollars)

Item	Estimated Cost Central Reuse System (L-5A)	Estimated Cost Central Reuse System with Augmentation of Lake Austin/Town Lake (L-5A)
Capital Cost		
Diversion Structure and Pump Station	$ 465,000	$ 1,400,000
Transmission Pipeline	5,460,000	10,440,000
Interconnects and Controls	525,000	525,000
GAC Treatment	*	13,360,000
Outfall Structure	*	50,000
Subtotal	$6,450,000	$25,775,000
Engineering, Legal, and Contingency	1,810,000	8,330,000
Environmental Studies and Mitigation	150,000	650,000
Land Acquisition	0	0
Subtotal	$8,410,000	$34,755,000
Interest During Construction	370,000	2,800,000
Total Project Cost	$8,780,000	$37,555,000
Annual Costs		
Annual Debt Service	$823,000	$3,518,000
O&M	46,000	1,001,000
Annual Power Cost	71,000	1,351,000
Total Annual Cost	$940,000	$5,870,000
Available Project Yield	2,590 acft/yr	14,900 acft/yr
Annual Cost of Water	$363 per acft/yr $1.11 per 1,000 gal	$394 per acft/yr $1.21 per 1,000 gal

* Item not required.

South Reuse System Extension (Alt. L-5B)

Implementation of the South Reuse System Alternative would require the construction of these facilities:

- Diversion structure at South Austin Regional WWTP,
- Pump station,
- Transmission pipeline, and
- Connection to end-user distribution facilities.

Reclaimed water would be diverted from South Austin Regional WWTP at a new concrete diversion structure supplying the reclaimed water pump station. The pump station would have a peak pumping capacity[53] of 8.7 cfs, discharging to an 18-inch transmission pipeline. The transmission pipeline route is shown in Figure 3.5-1. The capital and O&M cost estimates for this facility are contained in Table 3.5-6. Total project cost is estimated to be $15,131,000 resulting in annual debt service costs of $1,417,000. The total annual cost, including debt service, operation and maintenance, and power is estimated to be $1,565,000. For an annual project yield of 1,938 acft/yr (Table 3.5-3). The resulting unit cost for this alternative is $807 per acft/yr (Table 3.5-6).

Northwest Water Reclamation Plan (Alt. L-5C)

Implementation of the Northwest Water Reclamation alternative would require construction of these facilities:

- New wastewater treatment plant in northwest Austin,
- Pump station,
- Transmission line, and
- Connection to end-user distribution facilities.

Reclaimed water would be used to irrigate area golf courses, provide cooling, or process water to industries. The system would have a capacity[54] of 5 cfs, discharging to a 14-inch transmission pipeline. The transmission pipeline route is shown in Figure 3.5-1. The capital and O&M cost estimates for this facility are contained in Table 3.5-7. Total project cost is estimated to be $28,211,000, resulting in annual debt service costs of $2,643,000. The total annual cost, including debt service, operation and maintenance, and power is estimated to be $3,105,000. For an annual project yield of 1,000 acft/yr (Table 3.5-3), the resulting unit cost for this alternative is $3,105 per acft/yr (Table 3.5-7).

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[53] CH2M-Hill and Jones & Neuse, "Master Planning for Recycled Water," City of Austin, March 1992.
[54] Ibid.

Table 3.5-6
Cost Estimate Summary for South Reuse System Extension (Alt. L-5B)
(1st Quarter 1997 Dollars)

Item	Estimated Cost[1]
Capital Cost	
Diversion Structure and Pump Station	$678,000
Transmission Pipeline	9,803,000
Subtotal	$10,481,000
Engineering, Legal, and Contingency	3,668,000
Environmental Studies and Mitigation	400,000
Subtotal	$14,549,000
Interest During Construction	582,000
Total Project Cost	$15,131,000
Annual Cost	
Annual Debt Service	$1,417,000
O&M	148,000
Total Annual Cost	$1,565,000
Available Project Yield	1,938 acft/yr
Annual Cost of Water	$807 per acft $2.48 per 1,000 gal

[1] Source: CH2M-Hill and Jones & Neuse, "Master Planning for Recycled Water," City of Austin, March 1992.

Reuse at Decker Lake (L-5D)

Use of reclaimed water at Decker Lake for steam-electric cooling would require construction of water conveyance facilities and, as identified in Section 3.5.4, nutrient removal is anticipated to be needed. The City of Austin's wastewater treatment master plan anticipates installation of nutrient removal at Walnut Creek WWTP although no implementation plan presently exists. The cost for this treatment is not considered as a capital cost for specific reuse alternatives at this time. However, the cost for nutrient removal is included as a unit cost for each acre-foot of reclaimed water provided for reuse.

Table 3.5-7
Cost Estimate Summary for Northwest Reuse System (Alt. L-5C)
(1st Quarter 1997 Dollars)

Item	Estimated Cost[1]
Capital Cost	
Water Reclamation Plant	$9,320,000
Diversion Structure and Pump Station	484,000
Transmission Pipeline	9,993,000
Subtotal	$19,797,000
Engineering, Legal, and Contingency	6,929,000
Environmental Studies and Mitigation	400,000
Subtotal	$27,126,000
Interest During Construction	1,085,000
Total Project Cost	$28,211,000
Annual Cost	
Annual Debt Service	$2,643,000
O&M	462,000
Total Annual Cost	$3,105,000
Available Project Yield	1,000 acft/yr
Annual Cost of Water	$3,105 per acft
	$9.53 per 1,000 gal

[1] Source: CH2M-Hill and Jones & Neuse, "Master Planning for Recycled Water," City of Austin, March 1992.

The major water conveyance facilities necessary to implement this alternative include:
- Diversion structure at Walnut Creek WWTP,
- Pump station,
- Transmission pipeline, and
- Outfall structure at Decker Lake.

Pumping data were studied for 6 years to determine the historic highest monthly diversion of raw water from the Colorado River to Decker Lake in order to estimate the required facility sizes and costs. The highest monthly diversion for the 1990 to 1995 period was 1,692 acft (27.6 cfs or 17.8 mgd). Reclaimed water would be diverted downstream of the filters at Walnut Creek WWTP at a new concrete diversion structure supplying the reclaimed water pump station. The pump station would have a peak firm pumping capacity of 27.6 cfs, discharging to a 30-inch transmission pipeline. The static pumping head to Decker Lake is about 125 feet. The capital and O&M cost estimates for this facility are contained in Table 3.5-8. Total project cost is estimated to be $3,850,000, resulting in annual debt service costs of $360,000. Total annual costs, including debt service, O&M, and power is estimated to be $490,000. For an annual project yield of 4,505 acft/yr, the resulting annual unit cost for this alternative is $109 per acft/yr (Table 3.5-8). A purchase price to obtain reclaimed water from the Austin wastewater utility is not included in the estimated cost for this alternative. The purchase price would reimburse the utility for costs to produce the reclaimed water including treatment and administration.[55]

Reuse at Semiconductor Manufacturing Plants (L-5E)

To estimate the net water supply benefit of a reclamation and reuse facility, a simple mass balance calculation was made for a typical semiconductor manufacturing facility. The water use mass balance calculation includes the following:

- Existing plant water use is a one-time, straight-through operation.
- Water demand of the manufacturing process is 1,000 gpm.
- Reuse rate is 40 percent (400 gpm) of process water demand.
- Ultrapure filtration unit is a reverse osmosis unit with a 4:1 feedwater to reject water ratio.
- With reuse, the RO unit feedwater to reject water ratio is assumed to need to be reduced to 3:1 due to higher TDS in reclaimed water.

Table 3.5-9 summarizes the water use mass balance calculation for 1,000 gpm of process water demand at a semiconductor manufacturing plant requiring ultrapure water. Benefits of the water reclamation and reuse system include: (1) 18 percent lower freshwater demand, (2) 40 percent lower wastewater production, and (3) a cost savings of $918,000 per year. This

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[55] The City of Austin has adopted a rate ordinance establishing the sales price for reclaimed water of $0.95 per 1,000 gal ($310 per acft). This price is intended to include all facilities and administrative costs needed to deliver reclaimed water to the user's facility and would double account for some costs if added as a cost to this project estimate. However, the $0.95 per 1,000 gal cost would include any additional treatment that may be needed such as nutrient removal.

Table 3.5-8
Cost Estimate Summary for Reclaimed Water Reuse at Decker Lake (Alt. L-5D)
(1st Quarter 1997 Dollars)

Item	Estimated Cost
Capital Costs	
Diversion Structure and Pump Station	$1,025,000
Transmission Pipeline and Crossings	1,500,000
Outfall Structure	70,000
Subtotal	$2,595,000
Engineering, Legal, and Contingency	$830,000
Environmental Studies and Mitigation	250,000
Land Easements	25,000
Subtotal	$3,700,000
Interest During Construction	$150,000
Total Project Cost	$3,850,000
Annual Costs	
Annual Debt Service	$360,000
Annual Operation and Maintenance	40,000
Annual Power Cost	90,000
Total Annual Cost	$490,000
Available Project Yield	4,505 acft/yr
Annual Cost of Water	$109 per acft/yr $0.33 per 1,000 gal

analysis assumes that the RO treatment unit would not require significant modification to handle the higher reject water rate, but maintain the same filtered water production rate.

Installation of a water reclamation plant located at, or near, a manufacturing plant would require the following facilities:

- Diversion piping, modified plant piping, valves, and controls;
- Water reclamation facility;
- Pump station;
- Modifications to the water pre-treatment facility (i.e., ultrapure water filtration facility, or other).

Table 3.5-9
Water Balance for Water Reclamation at Manufacturing Plant
(1st Quarter 1997 Dollars)

Item	Once-Through Operation	With Water Reclamation and Reuse
Freshwater Feed from City	1,333 gpm	1,100 gpm
Net Input to RO Unit	1,333 gpm	1,500 gpm
RO Reject Rate (feedwater: reject water)	4:1	3:1
RO Reject	333 gpm	500 gpm
Process Water Demand	1,000 gpm	1,000 gpm
Diversion to Water Reclamation Plant for Reuse	N/A	400 gpm
Reclaimed Water to be Blended with Freshwater Feed	N/A	400 gpm
Discharge to POTW⁽¹⁾	1,000 gpm	600 gpm
Annual Cost of Potable Water Purchase⁽²⁾	$1,488,000	$1,228,000
Annual Cost of Wastewater Treatment at POTW⁽³⁾	$1,645,000	$ 987,000
Sum of Water/ Wastewater Costs	$3,133,000	$2,215,000

(1) POTW: Publicly Owned Treatment Works (City of Austin)
(2) Based on City of Austin water volume charge of $2.13 per 1,000 gal for retail industrial customers.
(3) Based on City of Austin wastewater volume charge of $3.13 per 1,000 gal for retail industrial customers.

The water reclamation facility cost estimate is for biologic treatment to remove organic constituents typically found in semiconductor manufacturing processes. The treatment process would also include rapid sand filtration to reduce turbidity equal to drinking water standards. The cost of a 400 gpm (0.6 mgd) water reclamation treatment facility is estimated to be about $2,600,000 (Table 3.5-10). Piping modifications, pump station, and controls would be about $350,000. Total project cost for a 400 gpm facility are estimated to be $4,140,000, resulting in annual debt service costs of $390,000. Operation and maintenance costs are estimated to be about $400,000 per year. Total annual costs, including debt service, O&M, and power is estimated to be $790,000 (Table 3.5-10). For an annual project yield of 375 acft, the annual unit cost for this alternative is $2,106 per acft/yr. Implementation of this alternative would provide a benefit of avoided costs for potable water purchase and wastewater treatment payments of about

$918,000 per year or about $2,448 per acft/yr. Therefore, the cost benefit of this alternative to the manufacturing plant exceed the costs, resulting in a cost savings of about $128,000 per year.

Table 3.5-10
Cost Estimate Summary for Water Reclamation at Manufacturing Plants
(Alt. L-5E)
(1st Quarter 1997 Dollars)

Item	Estimated Cost
Capital Costs	
Plant Piping	$250,000
Water Reclamation Facility	2,600,000
Pump Station	100,000
Subtotal	$2,950,000
Engineering, Legal, and Contingency	$1,030,000
Subtotal	$4,140,000
Interest During Construction	$160,000
Total Project Cost	$3,980,000
Annual Costs	
Annual Debt Service	$390,000
Annual Operation and Maintenance	400,000
Total Annual Cost	$790,000
Available Project Yield	375 acft/yr
Annual Cost of Reclamation Facility	$2,106 per acft/yr
Annual Cost Savings	$918,000 $2,448 per acft/yr
Net Cost (Benefit) of Project	($341 per acft/yr) ($1.04 per 1,000 gal)

3.5.6 Implementation Issues

1. Permit Amendments: To change the use of reclaimed water that is currently discharged to surface streams (i.e., Walnut Creek WWTP and South Austin Regional WWTP) to other uses would require a permit amendment to a Chapter 309 permit (Use of Reclaimed Wastewater Without Sale) or to a Chapter 310 permit (Use of Reclaimed Water With Sale). For projects such as reuse at Decker Lake, a permit amendment adding a new discharge point would be required.

2. Treatment Plant Process Improvements: Current treatment plant process and discharge water quality is sufficient for reuse on unrestricted parkland. Treatment plant upgrades for nutrient removal would be required for implementation of these reuse projects: reuse at Decker Lake for steam-electric cooling; augmentation of Lake Austin/Town Lake water supply; reuse for industrial process water. Granular activated carbon treatment or

other suitable treatment would also be required if reuse for augmentation of Lake Austin or Town Lake is implemented.

3. Effect on Colorado Instream Flows: Implementation of significant reuse projects will reduce return flows to the Colorado River with the potential effect of requiring increased releases from the Highland Lakes to meet instream flow targets downstream of Austin. However, population growth will probably result in a net increase of return flows.

4. Permit Compliance: Increased monitoring of water quality above current discharge permit requirements may be required.

5. Public Information and Education: If deemed to be feasible, reuse projects will probably require public information programs to gain public acceptance.

6. Water Supply Augmentation: Augmentation of Lake Austin/Town Lake will require compliance with TNRCC's anti-degradation policy. Permitting will require extensive water quality modeling and monitoring. Compliance will potentially require treatment plant upgrades, including nutrient removal and GAC treatment.

7. Reuse at Decker Lake: With Decker Lake make-up water demands being met with reclaimed water, the existing run-of-the-river diversion rights on the Colorado River would be made available for municipal uses. To do this, the existing diversion permit must be amended to add municipal use to the current steam-electric permitted use. The permit would also have to be amended to add a second diversion point to allow use at the Ulrich or Davis water treatment plants.

3.6 Reclaimed Water Reuse — Areas in the Brazos River Basin (L-8)

3.6.1 Description of Alternative

This alternative considers the major sources of reclaimed water in the Williamson County region of the Brazos River Basin, and estimates the quantities which will be available in the years 2020 and 2050. Projected reclaimed water availability far exceeds the currently planned reuse projects and could potentially provide a significant water supply source for the Williamson County region. Potential uses of reclaimed water are numerous. In general, reuse alternatives can be categorized as: (1) urban irrigation, (2) agricultural irrigation, (3) industrial and commercial use, (4) water system augmentation, and (5) other specialized uses. The most common reuse alternatives are irrigation of public lands and reuse for industrial purposes.

Landscape irrigation with reclaimed water can be effective in urban areas, especially in situations where significant water usage is relatively concentrated. Public lands such as parks, golf courses, and road medians require large quantities of water and can usually be safely irrigated with reclaimed water. The City of Round Rock presently irrigates the Forest Creek Golf Course with reclaimed water and has plans to irrigate some park area, with projected annual consumption of reclaimed water of about 550 acft/yr. In the Georgetown area, the Sun City development plans to use all the reclaimed water generated by the development (about 1,600 acft/yr) to irrigate its golf course and properties by 2020,[1] and an additional 1,000 acft/yr from a future Georgetown wastewater treatment plant for a total of 2,600 acft/yr. Also, in Georgetown, Southwestern University has contracted with the City for up to 1 mgd of reclaimed water for irrigation (estimated to be 350 acft/yr, average annual demand). The expense of distributing reclaimed water to customers widely spread throughout the region tends to mitigate against the development of water reuse for urban irrigation. An easier and more cost-effective way to distribute large volumes of reclaimed water is to run isolated distribution mains to the region's largest water consumers.

The potential for reusing water for industrial purposes varies among industries and is affected by the quality of water required for particular uses. Some industries use large quantities of water for such processes as cooling, quenching, and washing. In many cases, reclaimed water could be used in these industrial processes. However, water quality requirements vary greatly

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[1] Design Report for Irrigation Transmission Line for the City of Georgetown, HDR Engineering, Inc., March, 1995.

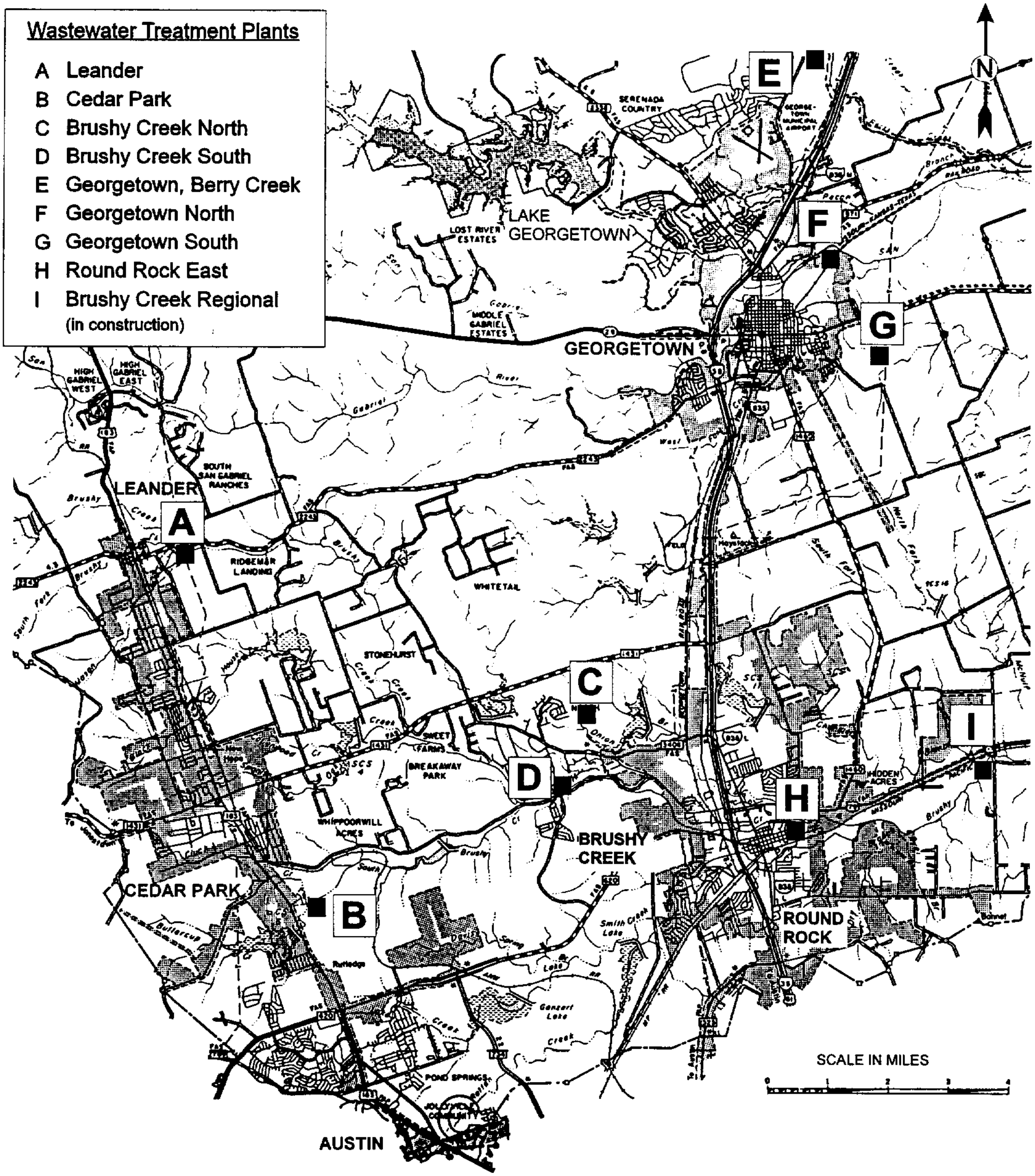
and some processes require additional treatment which would currently make the use of reclaimed water cost prohibitive. Reuse of reclaimed water for industry in Williamson County is possible as rapid expansion in the area continues, and large industry locates in the area. Water quality could potentially become a problem if reuse processes concentrate undesirable or harmful chemicals. Regulatory water quality standards and a trend toward stricter standards could limit the potential for industrial reclaimed water.

Augmentation projects involve using reclaimed water to postpone, eliminate, or reduce the need for new water supply sources. It is feasible to treat wastewater to potable standards, but the concept has proven unpopular with the public and usually meets strong opposition. This alternative may become more attractive as treatment technology, and the public's perception of it, improve. Finally, as the choice of additional supply sources dwindle or become more expensive, reuse of wastewater for municipal supply may become necessary.

The major sources of reclaimed water in the area studied are shown on Figure 3.6-1. The map shows the treatment plants of Round Rock, Georgetown, Cedar Park, Leander, and Brushy Creek, as well as the Brushy Creek Regional Treatment Plant. The two existing Round Rock plants (the West plant and the East plant) are to be retired and wastewater presently being treated at these plants will be rerouted to the Brushy Creek Regional Treatment Plant. The Regional Treatment Plant may also handle wastewater from Cedar Park, Brushy Creek, and that part of North Austin which lies in Williamson County. At the time of this writing, plans of the above-mentioned entities for participation in the regional plant were not known.

3.6.2 Available Yield

Wastewater discharge was determined from historical records of water use and reclaimed water discharge percentages for selected entities in Williamson County. Conservative projections of reclaimed water availability were made to provide dependable estimates for planning purposes for 2020 and 2050 conditions. Estimates of reclaimed water availability were made by assuming 50 percent of the low-month reclaimed water discharge would be available throughout the year. For the year 1990, this amount was determined as a percentage of water use and then projected to 2020 and 2050 based on respective water use projections. These amounts are shown in Table 3.6-1



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

HDR

HDR Engineering, Inc.

LOCATION OF WASTEWATER TREATMENT PLANTS IN CENTRAL WILLIAMSON COUNTY

FIGURE 3.6-1

Table 3.6-1
Projections of Water Use[1] and Reclaimed Water Availability
(acft/yr)

Service Area and Return Flow Percentage	Water Use			Wastewater Availability			
	Actual 1990[2]	Projected		Actual 1990[3]	Estimated Reclaimed Water Availability		
		2020	2050		2020	2050	% of Water Use
Georgetown (43%)	4,250	16,269	33,600	1,866	2,928	6,048	18
Round Rock (60%)	6,652	37,645	49,668	4,589	10,541	13,907	28
Brushy Creek MUD (50%)[4]	984	2,715	2,947	346	353	383	13
City of Austin (55%)[5]	494	3,783	6,073	272	567	911	15
Cedar Park (40%)	2,024	9,457	16,400	845	1,324	2,296	14
Leander (50%)[4]	871	3,986	7,934	197	558	1,111	14
Total	15,275	73,855	116,622	8,115	16,271	24,656	22

[1] TWDB Projections, April, 1996.
[2] 1990 Reported Water Use, TWDB.
[3] 1990 Reported Treated Wastewater Discharge, TNRCC.
[4] Estimated Return Flow Percentage.
[5] City of Austin service area in Williamson County.

Table 3.6-2 summarizes the total firm yield of reclaimed water, planned reuse, and the remaining available firm yield. The projected year 2020 total municipal and industrial water demand in Williamson County is 73,855 acft/yr (Table 2.2-4). Total estimated reclaimed water firm yield for that year is 16,271 acft/yr or 22 percent of the projected water use. Adjusting for existing reuse projects, 12,771 acft/yr is estimated to be available for use to offset water demand. For 2050, estimated reclaimed water firm yield is projected to be 24,656. Of this amount, 21,156 acft/yr is estimated to be available for use to offset water demand.

Table 3.6-2
Projections of Water Use and Availability of Reclaimed Water
(acft/yr)

	Projected Reclaimed Water Availability[1]		Currently Planned Reuse		Remaining Reclaimed Water Available	
Service Area	2020	2050	2020	2050	2020	2050
Georgetown	2,928	6,048	2,600	2,600	328	3,448
Round Rock	10,541	13,907	900	900	9,641	13,007
Brushy Creek	353	383	0	0	353	383
City of Austin	567	911	0	0	567	911
Cedar Park	1,324	2,296	0	0	1,324	2,296
Leander	558	1,111	0	0	558	1,111
Total	16,271	24,656	3,500	3,500	12,771	21,156

[1] Table 3.6-1

3.6.3 Environmental Issues.

Issues relevant to reclaimed water reuse can be categorized as follows:

- Effects of constructing and maintaining a distribution system for treated wastewater.
- Effects related to the use of wastewater on the terrestrial and aquatic environments.
- Reduced return flows to rivers, bays, and estuaries.

In general, reuse alternatives can be categorized as: (1) urban irrigation, (2) agricultural irrigation, (3) industrial and commercial use, (4) water supply augmentation, and (5) other specialized uses. Landscape irrigation with reuse water can be effective in urban areas, especially in situations where significant water usage is relatively concentrated. The expense of distributing reuse water, along with other problems associated with this distribution, to customers widely spread over a city tends to mitigate against the development of water reuse for urban irrigation. The identification of single large consumers of water makes it easier to provide easy, cost-effective use of large volumes of treated wastewater. Regulatory requirements for wastewater reuse as urban irrigation differ for unrestricted and restricted (legally or physically controlled access) landscapes.

Augmentation projects involve using treated wastewater to postpone, eliminate, or reduce the need for major water and/or wastewater system improvements. For example, augmentation could involve using treated wastewater to augment a water supply reservoir.

The potential for using treated wastewater for agricultural irrigation appears to be limited. Because agricultural irrigation is seasonal by nature, there are periods of limited water use which usually require the storage of a large volume of water to ensure a reliable supply. For this reason, projects involving the reuse of water for agricultural irrigation purposes may not be cost-effective. In addition, the construction of large water storage reservoirs have a high environmental impact in terms of acreage affected. Water quality standards for agricultural irrigation water vary according to these uses: (1) irrigation of food crops, (2) irrigation of fodder, (3) fiber and seed crops, and (4) irrigation of pastures for animals milked for human consumption.

The potential for reusing water for industrial purposes varies among industries and is affected by the quality of water required for particular uses. Some industries use large quantities of water and may represent significant potential users of treated wastewater. Water quality can decline when used in processes where reuse concentrates undesirable or harmful chemicals. A trend towards stricter regulatory water quality standards can limit the potential for industrial wastewater reuse, although new and more economical treatment technology mitigates these limitations.

The reuse of treated wastewater described in this report would require a system of transmission pipelines to distribute water from the wastewater treatment plants to the appropriate users. Although this alternative is preliminary and possible water transmission pipeline routes have not been determined, recent environmental studies for several water lines in the project area[2,3] provide general insights into the kinds of environmental issues associated with constructing water pipelines in the project area.

The Edwards Aquifer (and the Balcones Escarpment) forms the eastern boundary of the Edwards Plateau Ecoregion in Williamson County. Interstate Highway 35 between Georgetown and Round Rock (Figure 3.6-1) generally marks the boundary between the northern segment of the Edwards Aquifer to the West, and the Blackland Prairies ecoregion to the east. These ecoregions and the Edwards Aquifer are described in the Environmental Overview, Section 3.1.3.

A unique aspect of the eastern Edwards Plateau is that it is home to a diverse assemblage of over 40 highly adapted, aquatic and troglobitic species. Some species seem to have adapted from marine environments, and some may have originated from surface dwelling species that entered the aquifer through spring openings. It is possible that during the ice age, species such as the trogolobites entered the aquifer through springs and adapted to cave conditions to the extent that they are not able to survive outside of caves. Over the millennia, these species have evolved in cave environments that provide moisture, stable temperatures, darkness, and isolation. Their surface relatives have retreated to other regions because of climatic changes. The geologic complexities of this area enhanced this diversity by creating islands of karst separated by faulting and river downcutting. A prime example is the Jollyville Plateau, located in northwestern Travis County. It contains both Tooth Cave and Kretschmarr Cave, in its 5-mile diameter island of Edwards formation. Tooth Cave is about 166 ft. long and 18 ft. deep and may contain 64 separate species, a higher species diversity than is generally found in larger cave systems.[4]

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[2] Paul Price Associates, Inc. 1995. An Environmental Survey of the Proposed Sequoia Spur Water Approach Main, City of Georgetown. Georgetown, Williamson County, Texas.

[3] Paul Price Associates, Inc. 1995. An Environmental Survey of the Proposed West Loop Water Line, City of Georgetown. Georgetown, Williamson County, Texas.

[4] Elliott, W.R. 1990. Texas Endangered Species Endangered Caves *in*: National Speological Society News. pp 225-231. From a reprint provided by the author.

Management guidelines for karst invertebrates involve the preservation of known caves, avoiding altering surface drainage patterns, preservation of native vegetation, prevention of groundwater contamination, restriction of human visitation, and fire ant control.[5] Out of these guidelines, changes in surface drainage patterns, clearing vegetation, and potential groundwater contamination appear to be most important with respect to Alternative L-8. Cave ecosystems and organisms are sensitive to changes in humidity and moisture levels on cave surfaces. Local drainage patterns play an important role in determining water dynamics within caves. Additionally, because photosynthesis does not occur in caves, nutrient dynamics in cave ecosystems are dependent on water inflow. Vegetation near caves influences nutrient dynamics in caves and reduces the potential for contamination and sedimentation.

Return flows may constitute a substantial portion of the baseflow of creeks and rivers. The use of return flows that otherwise would be discharged to surface streams may reduce streamflow. The impact of reuse in terms of reduced streamflow would depend on the volume of reclaimed water diverted to reuse, the fate of the raw water being replaced by reclaimed water, the proportion of streamflows accounted for by reclaimed water, and the fate of the reclaimed water.

3.6.4 Water Quality

The TNRCC rules specify categories of use of reclaimed water with corresponding reclaimed water quality requirements.[6] For landscape irrigation with reclaimed water, the irrigated area is classified as restricted or unrestricted use. Most commonly the landscapes to which reclaimed water is applied are parks, golf courses, and street medians. Public parks generally have unrestricted access and the water quality requirements for irrigation of public areas are as follows:[7]

BOD_5	5 mg/l
Turbidity	3 NTU
Fecal Coliform	75 CFU/100 ml

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[5] Ibid.

[6] TNRCC, Chapter 310: Use of Reclaimed Water.

[7] Texas Administrative Code, Title 31, Chapter 309.

Golf courses and street medians are considered to have restricted access which allows irrigation at times when the public will not be exposed to the spray. The water quality requirements for restricted access are as follows:[8]

BOD_5	20 mg/l
Fecal Coliform (single grab)	800 CFU/100 ml
Fecal Coliform (geometric mean)*	200 CFU/100 ml
(no turbidity standard)	

* Draft rule revision to TNRCC Chapter 310.

Unless the entity using the reclaimed water has a permit to discharge effluent, it must provide protection from accidental spillage with a storage pond. The pond must be capable of holding the maximum amount of reclaimed water which would accumulate in the event of a 25-year rainfall. Typical costs for an irrigation system, including storage pond, can be found at the end of this section.

TNRCC rules permit use of reclaimed water in commercial and industrial application if the quality of the water meets these minimum requirements:

BOD_5 30-day average	20 mg/l
Fecal Coliform	200 CFU/100 ml
(no turbidity standard)	

Reclaimed water quality available at the Georgetown North WWTP, Cedar Park WWTP, and the Brushy Creek Regional WWTP (as defined by TNRCC discharge permit requirements) is reported in Table 3.6-3. Each of the current discharge permit requirements meet TNRCC quality requirements for BOD and TSS for irrigation of restricted access areas, and for commercial and industrial application. Only the Cedar Park WWTP discharge permit requirements are sufficient for irrigation of unrestricted access areas.

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[8] Ibid.

Table 3.6-3
Reclaimed Water Discharge Permit Requirements for Selected Williamson County Treatment Plants

Quality Parameter	Brushy Creek Regional WWTP	Georgetown North WWTP	Cedar Park WWTP
Carbonaceous BOD (mg/l)	10	10	5
Total Suspended Solids (mg/l)	15	15	5
Ammonia Nitrogen (mg/l)	3	3	2
Total Phosphorous (mg/l)	No Requirement	No Requirement	1
Turbidity	No Requirement	No Requirement	No Requirement

3.6.5 Engineering and Costing

The Georgetown plan for providing reclaimed water to the Sun City development is typical for required facilities and costs of reuse projects that could potentially be implemented at other treatment plants. The project is designed to provide reclaimed water from a wastewater treatment plant at a design flow of 3.62 mgd (peak month). The supply line is 16 inches in diameter and extends 17,200 feet from the treatment plant to the point of use. The estimated construction and associated costs for the irrigation line are given in Table 3.6-4.[9]

As indicated in Table 3.6-4 the cost for a reclaimed water reuse system for landscape irrigation in restricted use areas is about $263 per acft/yr ($0.81/1000 gal). To meet water quality requirements for irrigation of unrestricted access areas or for industrial process water, treatment levels above standard secondary wastewater treatment processes is required. The main processes of such a plant would include activated sludge with extended aeration to achieve nitrification, sedimentation, filtration, and disinfection.[10] Estimates of the annual cost of this treatment are about $280 per acft ($0.86/1,000 gal). Therefore, the total cost of a reclaimed water reuse system for industrial process or irrigation of public access areas is estimated to be about $543 per acft/yr ($1.67/1,000 gal).

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[9] Design Report for Irrigation Transmission Line for the City of Georgetown, HDR Engineering, Inc., March, 1995.

[10] CH2M-Hill, Master planning for Recycled Water, City of Austin, Texas, March, 1992.

Table 3.6-4
Cost Estimate for Typical Reclaimed Water Reuse System for Landscape Irrigation (Restricted Access)[1]
(1st Quarter 1996 dollars)

Item	Estimated Cost
Capital Cost	
Pipeline (16-inch)	$946,000
Pump Station	195,000
Storage Pond	2,280,000
Spray Irrigation System[2]	1,180,000
Subtotal	$4,601,000
Engineering, Legal, and Contingencies	1,576,000
Environmental Studies and Mitigation	32,000
Land Easements	32,000
Subtotal	$6,241,000
Interest During Construction	375,000
Total Project Cost	$6,616,000
Annual Cost	
Annual Debt Service	620,000
Annual Operation and Maintenance (Excluding Power)	41,000
Annual Power	27,000
Total Annual Cost	$684,000
Annual Reclaimed Water Use	2,600 acft/yr
Annual Cost of Reclaimed Water Use	$263 per acft/yr $0.81/1000 gal

Source: Design Report for Irrigation Transmission Line for the City of Georgetown, HDR Engineering, Inc., March, 1995.

[1] Restricted access means use of reclaimed water where incidental contact between the public and reclaimed water is unlikely.

3.6.6 Implementation Issues

Requirements Specific to Use of Reclaimed Water

1. Necessary Permits: Current direct discharge permits would need to be amended to a Chapter 309 permit (Use of Reclaimed Wastewater Without Sale) or to a Chapter 310 permit (Use of Reclaimed Wastewater With Sale).

2. Treatment Plant Process Improvements: To be able to discharge to unrestricted areas (such as park land), treatment plants discharging in excess of 5 mg/l BOD_5 would have to

retrofit to meet the more stringent requirements. Necessary retrofits would most likely include addition of filtration, as well as other improvements.

3. Although reuse of reclaimed water reduces return flows to Brushy Creek and the San Gabriel River, the expected growth in the area, along with new water supply projects (such as the Stillhouse Hollow Raw Waterline) will probably result in a net increase of return flows.

4. Increased monitoring of water quality above current discharge permit requirements may be required.

5. If deemed to be feasible, public education programs to gain public acceptance will likely be required.

Requirements Specific To Pipelines

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

Brazos River Basin Alternatives

3.7 Purchase of Water from Brazos River Authority at Lake Stillhouse Hollow Delivered to Lake Georgetown (B-1)

3.7.1 Description of Alternative

Lake Stillhouse Hollow, located in central Bell County about 5 miles southwest of the City of Belton, is one of 13 water supply reservoirs in the Brazos River Authority System. The reservoir is located on the Lampasas River, which is a tributary to the Little River. The Little River is a major tributary to the Brazos River and four other BRA water supply reservoirs are located in the Little River Basin: Lake Belton, Lake Proctor, Lake Georgetown, and Lake Stillhouse Hollow. The location of Lake Stillhouse Hollow is shown in Figure 3.7-1.

Lake Stillhouse Hollow was constructed by the U.S. Army Corps of Engineers (Corps) and is owned and operated by the Corps. The reservoir was built for flood control, conservation, and recreation. Construction of the reservoir began in 1968 and impoundment began in 1972. At the conservation pool, elevation of 622.0 ft-msl, the reservoir surface covers 6,430 acres and has a capacity of 226,063 acft.[1] At the top of the flood control pool, elevation 666 ft-msl, the reservoir surface area is 11,830 acres and stores 390,600 acft. The BRA has contracted with the Corps for the use of the water in the conservation storage space between reservoir elevations 622 ft-msl and 515 ft-msl. BRA directs the Corps on the operation of the reservoir within the conservation pool. The BRA holds the permit from the State of Texas for the right to impound water in the reservoir and divert water for municipal and other uses.[2] Diversions from Lake Stillhouse Hollow are also governed by the BRA System Operation Order.[3]

The system order permits the BRA to operate tributary reservoirs (i.e., Lake Stillhouse Hollow, Lake Granger, Lake Georgetown, and others) as elements of a system under which releases can be coordinated with releases from main stem reservoirs to achieve most effective conservation and beneficial use of available stored water. Also governing diversions at Lake Stillhouse Hollow is the Final Determinations document of the Brazos River Basin Adjudication. Of these three governing documents, the Final Determination limits maximum withdrawal from the lake to 67,768 acft/yr. Permitted uses for this water include municipal, industrial, agriculture, and mining.

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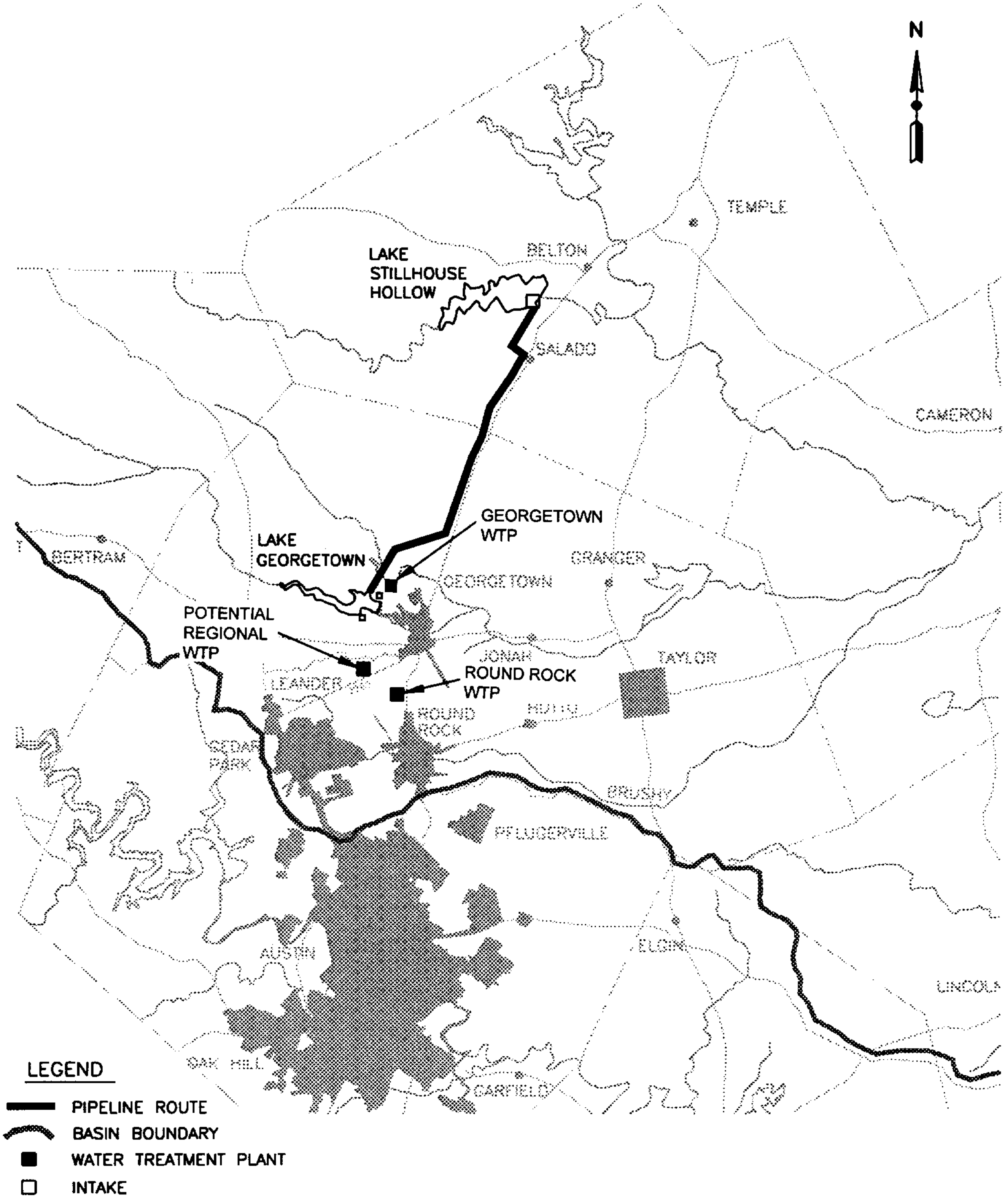
[1] TWDB, Hydrographic Survey Program, May, 1995.

[2] Permit No. 2109.

[3] System Operation Order, Texas Water Commission, July, 1964, as amended.



HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

WILIAMSON COUNTY
RAW WATERLINE
ALTERNATIVE B-1

FIGURE 3.7-1

Stored water from Lake Stillhouse Hollow is available to municipal and industrial users under long-term contract with the BRA. The BRA charges a uniform cost for purchase of water from system reservoirs. The system cost is set annually by the BRA Board of Directors to cover debt and operating expenses throughout the BRA system. The BRA system price for water in 1996 was $19.27 per acft, and is $20.01 per acft in 1998.

History of Alternative

In 1984, HDR Engineering completed a study for the BRA to consider the feasibility of a regional water transmission and treatment system using water from Lake Stillhouse Hollow.[4] The original study participants were City of Cedar Park, City of Georgetown, City of Round Rock, High Gabriel Water Supply Corporation, Jonah Special Utility District, City of Leander, SCB Development Corporation, and Salado Water Supply Corporation. The study concluded that the most economical plan was to:

- Utilize Lake Georgetown supplies until water demands exceeded the supply;
- When water demands exceeded the supply from Lake Georgetown, construct a raw water transmission pipeline from Lake Stillhouse Hollow to supplement the yield of Lake Georgetown;
- Set the raw water pumping rate and pipeline size to meet average annual needs of the participants, and use Lake Georgetown as an interim storage reservoir to meet peak demands;
- Construct water treatment and treated water distribution facilities in phases as needed to meet each participant's needs; and
- Distribute annual costs to participants on the basis of actual water used from the regional system on an annual basis with each participant required to use at least one-third of its peak daily water needs from the regional system.

As part of the definition of alternatives, the regional system was divided into three components: (1) Stillhouse Hollow raw water transmission pipeline; (2) water treatment facilities; and (3) treated water distribution facilities. Each component would be developed individually and participating entities could elect which components to participate in. One contract would cover participation in the raw water line, and other contracts would cover participation in treatment and distribution facilities. In 1985, a Phase II study was performed to consider possible economic advantages of purchasing existing facilities from Round Rock and/or

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[4] HDR Engineering, "Feasibility Study for Regional Treatment and Transmission System (RTTS) - Stillhouse Hollow", Brazos River Authority, September. 1984

Georgetown for incorporation into the regional system.[5] The 1985 study concluded that expansion of Round Rock treatment facilities was most economical for Cedar Park, Round Rock, High Gabriel, Jonah, and Leander, and expansion of Georgetown's facilities was most economical for Georgetown and SCB Development Corporation. At the conclusion of Phase II, Round Rock, Georgetown, and Jonah SUD elected to enter into a contract with BRA for the construction of a raw water pipeline from Lake Stillhouse Hollow to Lake Georgetown. The raw water transmission component of the project was named the Williamson County Raw Water Line project.

During the summer of 1996, Round Rock requested, under the terms of the raw water line contract, that implementation of the project begin. Following Round Rock's request, other water supply entities in Williamson and Bell counties have requested commitments of water supply from Lake Stillhouse Hollow. Table 3.7-1 summarizes long-term water supply commitments at Lake Stillhouse Hollow as of September 1996.

The earliest implementation date of this project, depending on the needs of the participants, indicates the increased supply at Lake Georgetown could be available as soon as December 1999. The water would be available for treatment at the City of Georgetown Treatment Plant, the City of Round Rock Treatment Plant, or at a potential regional water treatment plant. The location of these treatment facilities, Lake Stillhouse Hollow, Lake Georgetown, and the proposed conveyance route are shown in Figure 3.7-1.

This section presents information on the Williamson County Raw Water line project, including a brief discussion of the route, environmental and permitting issues, and cost estimates.

3.7.2 Available Yield

The firm yield of Lake Stillhouse Hollow was estimated for this study using the SIMYLD-II computer program. SIMYLD-II is designed to simulate the hydrologic operation of a system of reservoirs within a single river basin or a multi-basin water resource system.[6] The input to the model includes elevation-area-capacity curves for the reservoir, inflow data sets, reservoir operating criteria, evaporation rates, and water demand patterns. Using a monthly

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[5] HDR Engineering, "Phase II of the Feasibility Study for a Regional Treatment and Transmission System (RTTS) - Stillhouse Hollow", Brazos River Authority, October, 1985

[6] SIMYLD-II, River Basin Simulation Model, Texas Water Development Board

Table 3.7-1
Summary of Water Supply Commitments at Lake Stillhouse Hollow[1]

Entity	Water Supply Commitment (acft/yr)
Trans-Texas Water Program Participants	
Round Rock	18,134
Georgetown	15,448
Jonah SUD	2,439
Leander	2,700
Brushy Creek MUD	4,000
Subtotal	**42,721**
Other Entities	
Chisholm Trail WSC	1,600
Central Texas WSC	10,800
Belton	100
Harker Heights	3,200
Lampasas	3,500
Country Harvest	12
High Gabriel WSC	310
Kempner	3,400
Salado WSC	1,600
Trinity Materials	300
Lometa	200
Local Reserve	10
Subtotal	**25,032**
Grand Total	**67,753**
Permitted Annual Withdrawal	**67,768**

[1] Source: Brazos River Authority staff, September, 1996.

time step, SIMYLD-II estimates the firm yield of a reservoir, or system of reservoirs, by minimizing water shortages to an acceptable level through the period of lowest inflows (i.e., "critical period"). Usually, the acceptable amount of shortages is zero, resulting in a firm yield of the reservoir that can be sustained through a repeat of the critical period. Appendix A contains detailed hydrologic data used as the model input for estimation of the firm yield of Lake Stillhouse Hollow, as well as the 2050 firm yield runs for the critical drought period.

The firm yield of a reservoir will decrease with time as sediment from the reservoir catchment reduces the volume of the conservation pool. Table 3.7-2 contains the estimated firm yield of Lake Stillhouse Hollow for years 1995, 2020, and 2050 sediment conditions.

Table 3.7-2
Lake Stillhouse Hollow Firm Yield

	Year		
	1995	**2020**	**2050**
Firm Yield[1]	70,700 acft/yr	69,900 acft/yr	69,000 acft/yr

[1] Firm yield is based on a sedimentation rate of 0.27 acft/yr per square mile. See Appendix A for discussion of sedimentation rates and firm yield estimates.

The water rights permit for Lake Stillhouse Hollow currently limits annual municipal diversion to 67,768 acft/yr. Therefore, the diversion of the full firm yield is not allowed under the current permit.

The results of the reservoir operation studies show the critical period at Lake Stillhouse Hollow occurred from 1947 to 1957. Figure 3.7-2 contains a plot of the reservoir contents through the critical period had the reservoir been constructed and supplying firm yield demands during this period. The reservoir contents plot was estimated for the current commitments distributed on a typical municipal diversion pattern (i.e., a monthly peak factor of 1.4). On the upper portion of Figure 3.7-2 is a plot of reservoir spills that would have occurred prior to and following the critical period had the reservoir been in place.

Supply Available for Transfer

Current commitments[7] at Lake Stillhouse Hollow total 67,753 acft/yr. Of this amount, 42,721 acft/yr is committed to Williamson County entities in the Trans-Texas Water Program and 25,032 acft/yr is committed to other entities. Delivery of 42,721 acft/yr to Lake Georgetown for treatment and distribution by each of the participating entities could be made with a single 42-inch diameter pipeline, twin 33-inch diameter pipelines, or a combination of two different pipeline sizes. Cost estimates for a single pipeline and twin 33-inch diameter pipelines are presented in Section 3.7.5.

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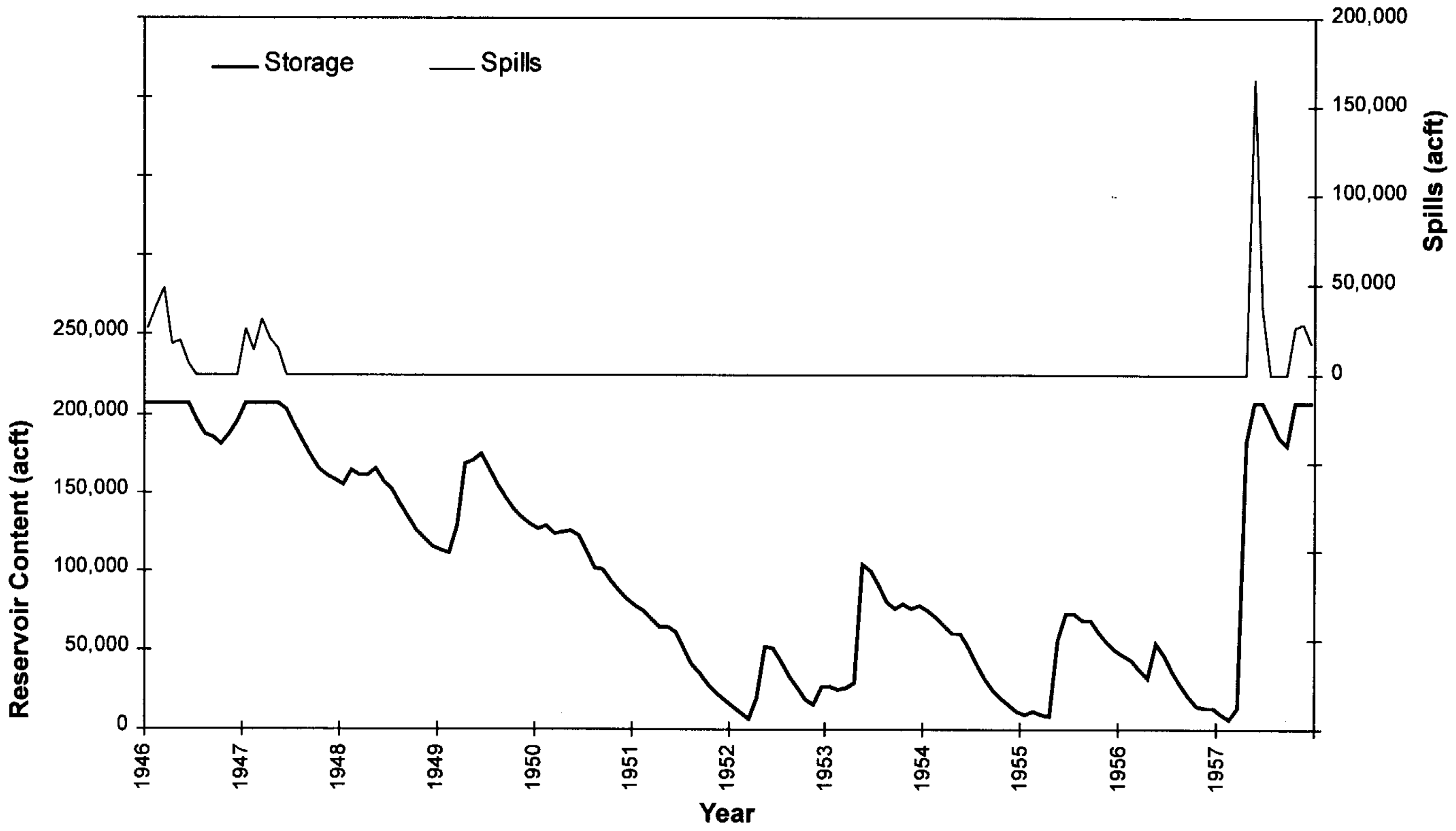
[7] Some commitments are pending BRA review of projected demands and the commitments may be adjusted.



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

RESERVOIR CONTENTS AND SPILLS AT LAKE STILLHOUSE HOLLOW 1946- 1957

HDR Engineering, Inc.

FIGURE 3.7-2

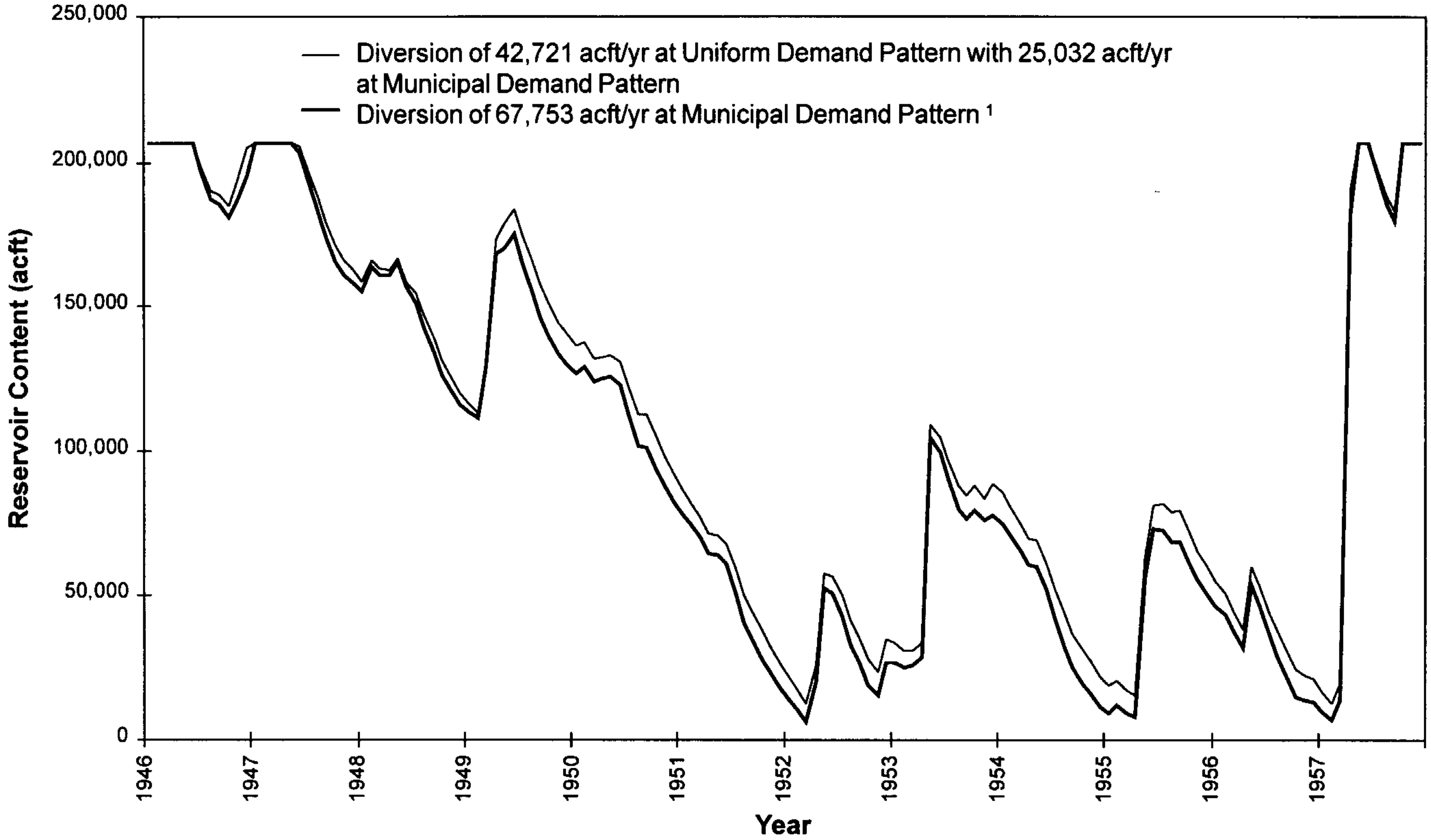
Effects of Project at Lake Stillhouse Hollow

Figures 3.7-3 and 3.7-4 present plots of the effect on Lake Stillhouse Hollow of the raw water line project. Figure 3.7-3 is a plot of reservoir contents while meeting current commitments had the reservoir been in place during the critical drought period. Figure 3.7-4 is very similar to Figure 3.7-3, but is a plot of reservoir water surface elevations during the critical drought period for the same demand conditions. The bold solid line in each plot represents reservoir contents (Figure 3.7-3) and reservoir level (Figure 3.7-4) for current commitments at a municipal demand pattern. The other line in each plot represents reservoir contents (Figure 3.7-3) and reservoir water surface elevations (Figure 3.7-4) for 42,721 acft/yr diverted to Williamson County at a uniform annual diversion rate and the remainder of the current commitments diverted at a municipal demand pattern. Figures 3.7-3 and 3.7-4 indicate that only a small change will occur at Lake Stillhouse Hollow for diversion of 42,271 acft/yr at a uniform demand pattern compared to diversion of the full current commitment at a municipal pattern. Appendix A contains a plot of the municipal monthly demand pattern and a uniform annual demand pattern used in the analyses.

Diversions of full contracted amounts (i.e., 67,768 acft/yr) from Lake Stillhouse Hollow are projected not to occur until the year 2020 or later. Prior to the year 2020, water diversions will be less than firm yield and lake levels will be higher than operations with full diversion amounts. Simulations were performed for two annual demands less than the full contracted amount to estimate the lake levels over an 80-year period (1905 to 1984) had the reservoir been in place. Table 3.7-3 summarizes the demand scenarios for 1995, 2005, 2015, and 2020.

Table 3.7-3
Estimated and Projected Demands on Lake Stillhouse Hollow Prior to Year 2020
(acft/yr)

Year	Williamson County Demands	Other Demands	Total Estimated or Projected Demands
1995	-0-	6,676	6,676
2005	16,234	13,600	29,834
2015	35,551	21,900	57,451
2020	42,721	25,032	67,753



[1] 67,753 acft/yr is current committment out of 67,768 acft/yr permitted

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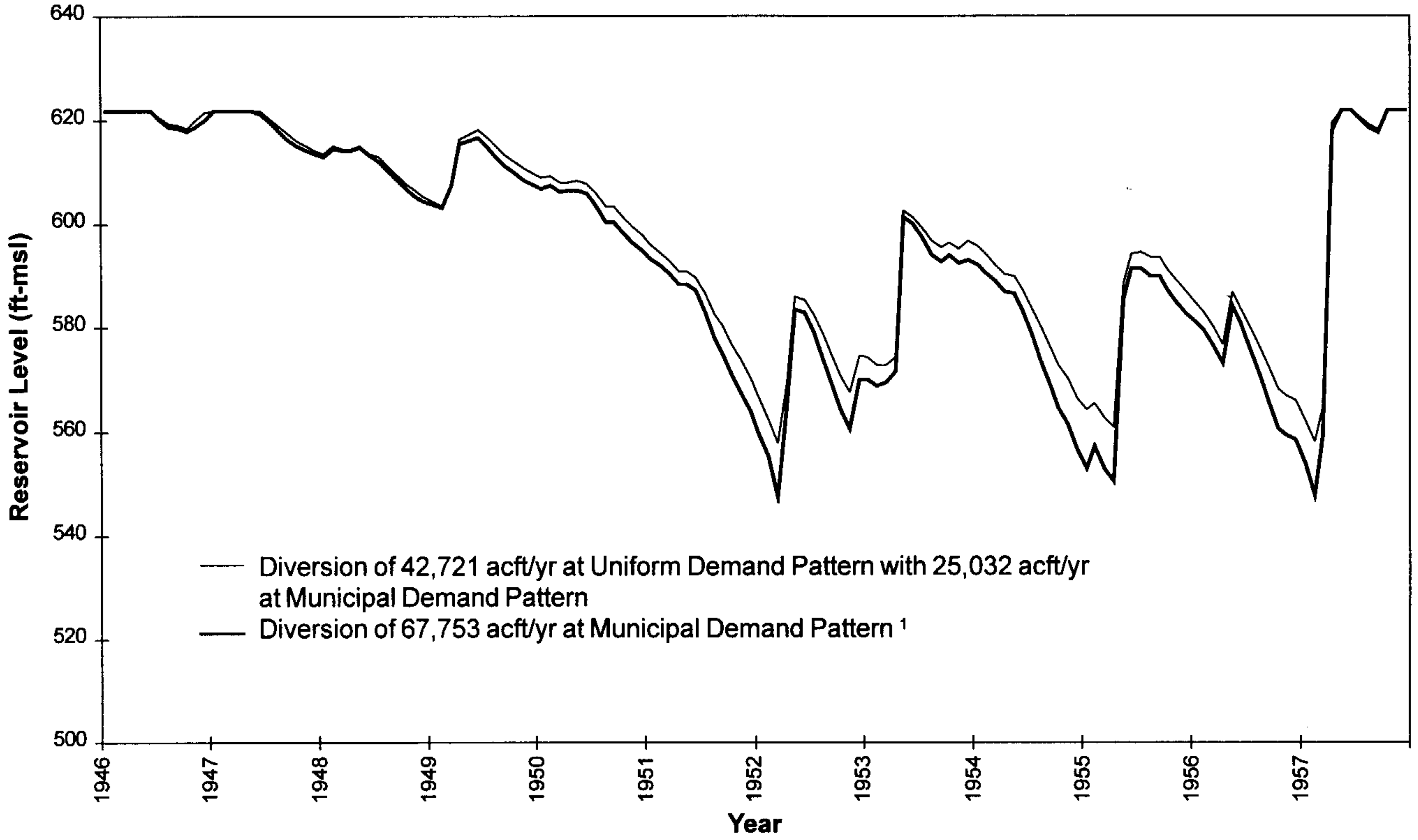
RESERVOIR CONTENTS AT LAKE STILLHOUSE HOLLOW FOR UNIFORM AND MUNICIPAL DEMAND PATTERNS

FIGURE 3.7-3



[1] 67,753 acft/yr is current committment out of 67,768 acft/yr permitted

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RESERVOIR LEVEL AT LAKE STILLHOUSE HOLLOW FOR UNIFORM AND MUNICIPAL DEMAND PATTERNS

FIGURE 3.7-4

Results of the reservoir operation simulations for each of the three future demand scenarios are contained in Figure 3.7-5. Analysis of these results indicates that the reservoir would not drop below elevation 600 feet (current elevation of Central Texas Water Supply Corporation[8] raw water intake) for the entire 80-year period under the year 2005 demand conditions. However, for diversion of either 2015 or full permitted conditions, the simulation results indicate the reservoir would drop below elevation 600 feet on an increasingly frequent basis. Table 3.7-4 summarizes the results of the reservoir simulation for three demand scenarios and how often the lake would be expected to drop below an elevation of 600 feet.

Table 3.7-4
Estimated Lake Level at Various Demands - Lake Stillhouse Hollow

Projected Demand (Year of Occurrence)	No. of Months Below Elevation 600 feet*	Percentage of Time Below Elevation 600 feet
6,676 acft/yr (1995)	-0- out of 960 months	0%
29,834 acft/yr (2005)	-0- out of 960 months	0%
57,451 acft/yr (2015)	96 out of 960 months	10%
67,753 acft/yr (2020)	142 out of 960 months	15%

* Elevation 600 feet is current level of Central Texas Water Supply Corporation raw water intake on Lake Stillhouse Hollow.

System Operation

Studies were performed to determine the potential to increase yield of Lakes Stillhouse Hollow and Georgetown resulting from system operation. These studies, described in Appendix A, included consideration of various delivery rates and target operating levels at Lake Georgetown. For diversion of Lake Stillhouse Hollow water at a uniform rate (i.e., most economical pipeline size and pumping conditions), simulations indicated that the highest water availability at Lake Georgetown occurs when the target operating level of Lake Georgetown is maintained at full condition. In other words, simulations show that highest water availability occurs when the pipeline from Lake Stillhouse Hollow is operated to keep Lake Georgetown as close to full condition as possible.

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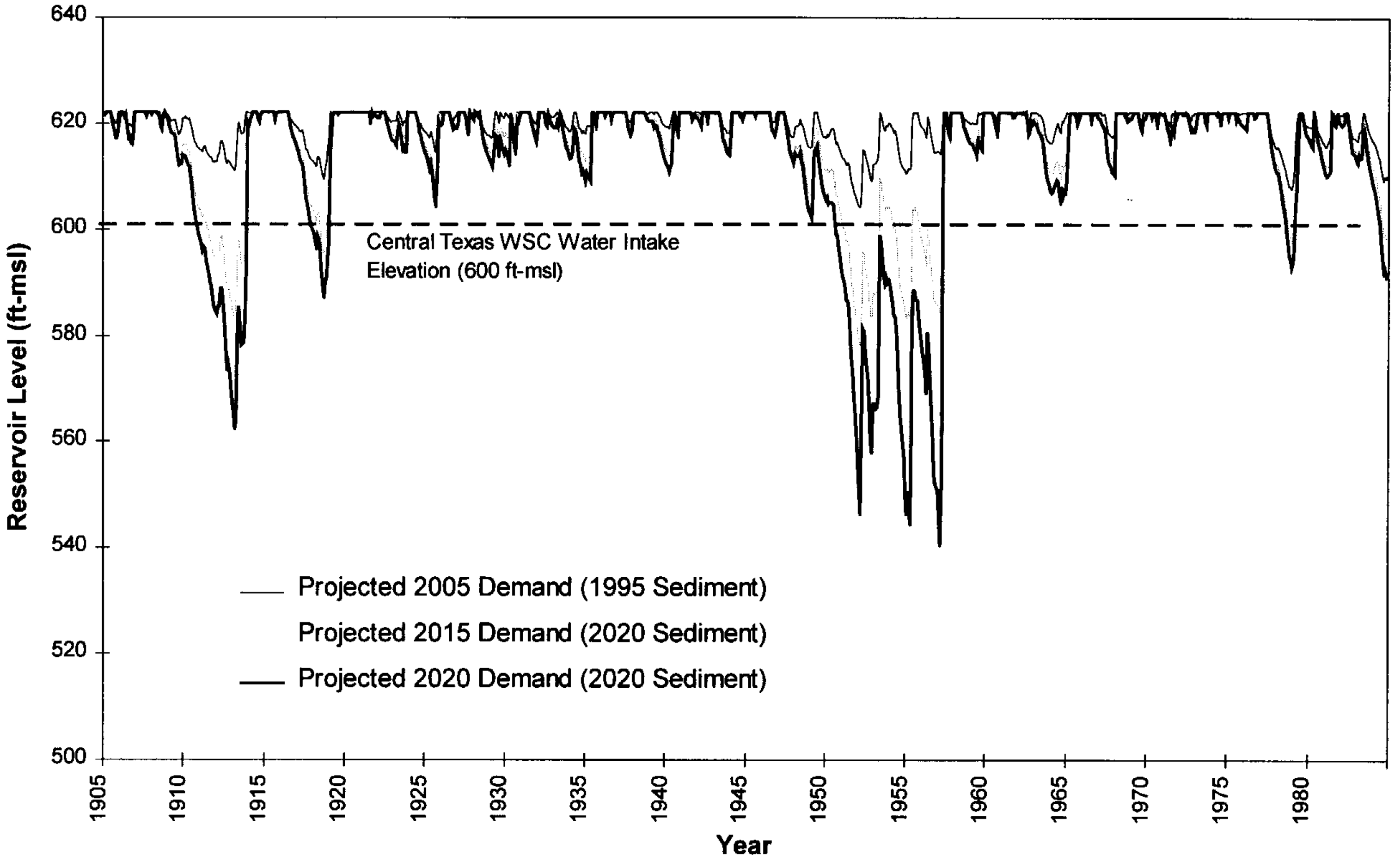
[8] Central Texas Water Supply Corporation raw water intake is located at the western end of Lake Stillhouse Hollow and can draw water down to elevation 600 feet. The Corporation has made provisions to draw water from a lower elevation through a secondary facility when needed during drought.



HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

LAKE STILLHOUSE HOLLOW SIMULATED RESERVOIR LEVEL AT VARIOUS DEMANDS FOR FULL PERIOD OF RECORD

FIGURE 3.7-5

Because the critical period of Lake Stillhouse Hollow and Lake Georgetown differ, there was a slight increase in yield created with the pipeline fully operational compared to the firm yield of the reservoirs operated independently without the pipeline. For diversion of 42,721 acft/yr from Lake Stillhouse Hollow to Lake Georgetown at a uniform transfer rate, the increased yield due to system operation is about 1,200 acft/yr, which is a 1.8 percent increase. Detailed examination of the hydrologic models shows this yield increase is a result of reduced spills and evaporation at Lake Georgetown. This "extra" water was not assigned for use at either reservoir, but would be available for future consideration.

3.7.3 Environmental Issues

The Williamson County Raw Waterline has been the subject of several studies, some of which have included the identification of environmental issues.[9,10,11] The proposed route for the water transmission line is presented in Figure 3.7-1. Environmental surveys were conducted in May 1988 for the purpose of mapping habitats, identifying possible endangered species habitat, and aiding in the selection of a pipeline easement resulting in minimum impact.

After studying recent aerial photography of the proposed pipeline route, it was determined that the land usage for this area has not significantly changed since the May 1988 survey was completed. Several species known to exist in the project area have been listed by USFWS for protection since the 1988 study. The following discussion combines results of the surveys previously presented in several reports[12,13] and from a variety of unpublished data files resulting from the earlier surveys.[14]

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[9] HDR Engineering, 1984. Feasibility Study for Regional Treatment and Transmission System (RTTS) - Stillhouse Hollow, Brazos River Authority.

[10] HDR Engineering, 1985. Phase II of the Feasibility Study for a Regional Treatment and Transmission System (RTTS)-Stillhouse Hollow", Brazos River Authority.

[11] HDR Engineering. 1994. Trans-Texas Water Program. Austin Study Area. Phase I Report. City of Austin and Texas Water Development Board.

[12] Ibid.

[13] a letter drafted by Paul Price Associates supporting the Brazos River Authority's request for authorization (pursuant to Section 404 of the Clean Water Act) to construct the Williamson County Raw Water Line under Nationwide Permit Nos. 12 (Backfill and bedding for utility lines, including outfall and intake structures) and, as appropriate, Regional General Permit No. SWF-87-DISTRICT-RGP-2.

[14] maintained at Paul Price Assoc., Inc.

Lake Stillhouse Hollow

Lake Stillhouse Hollow impounds the Lampasas River in its canyon on the eastern margin of the Edwards Plateau about 12 miles above its confluence with the Leon River in Bell County. The reservoir is generally characterized by a steep, rocky, well developed shoreline (58 miles, SDI 5.2); maximum depth is 107 feet and average depth is 37 feet. Lake Stillhouse Hollow comprises Segment 1216 of the Brazos River Basin. Designated uses within the segment are contact recreation, exceptional quality aquatic habitat, and public water supply.

Lake Stillhouse Hollow is a warm, monomictic reservoir exhibiting seasonal oxygen depletion in the hypolimnion. However, Texas Parks and Wildlife Department refers to this lake as being oligotrophic.[15] In the spring, oxygen concentrations can measure below 5.0 mg/l at depths of from 20 to 50 feet.[16] During the summer, dissolved oxygen levels can be less than 1.0 mg/l at depths ranging from 25 to 75 feet. Low dissolved oxygen concentrations appear to commonly occur below about 40 feet during May to October in this lake.

Texas Parks and Wildlife Department manages Lake Stillhouse Hollow for bass sport fishing. Abundant fish species in the reservoir include largemouth bass, spotted bass, longear sunfish, bluegill sunfish, redear sunfish, white crappie, gizzard shad, longnose gar, channel catfish, and common carp.[17,18,19] Fish populations and densities are lower than that of other lakes in the area due to the lack of woody cover, vegetative cover, and the rocky substrate. Recently, efforts have been made to increase densities of smallmouth bass and Florida largemouth bass by stocking (Texas Parks and Wildlife Department in 1993 and 1994).[20]

U.S. Geological Survey water quality records for Lake Stillhouse Hollow indicate a relatively sparse phytoplankton community dominated by numerous species of green algae

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[15] Texas Parks and Wildlife Department. 1987. Statewide Freshwater Fisheries Monitoring and Management Program, Federal Aid in Sport Fish Restoration Act Project F-30-R, Survey Report for Stillhouse Hollow Lake. TPWD, Austin, Texas.

[16] USGS. 1981, 1982, 1988, 1991, 1995. Water Resources Data. Texas.

[17] Texas Parks and Wildlife Department. 1987. Statewide Freshwater Fisheries Monitoring and Management Program, Federal Aid in Sport Fish Restoration Act Project F-30-R, Survey Report for Stillhouse Hollow Lake. TPWD, Austin, Texas.

[18] Texas Parks and Wildlife Department. 1989. Statewide Freshwater Fisheries Monitoring and Management Program, Federal Aid in Sport Fish Restoration Act Project F-30-R, Survey Report for Stillhouse Hollow Lake. TPWD, Austin, Texas.

[19] Mitchell, J.M. 1996. Survey Report for Stillhouse Hollow Reservoir, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas.

[20] Ibid.

(Chlorophyta).[21] A few taxa of diatoms (Bacillariophyta) and blue-green algae (Cyanobacteria) were present at high relative abundance at particular times and locations. Although macrophyte development has been limited historically by shoreline morphometry and lack of suitable substrates, during a 1995 survey, *Hydrilla* sp. covering 19.7 acres was observed for the first time in this reservoir.[22]

Lake Georgetown

Lake Georgetown impounds the North Fork San Gabriel River in Williamson County, which, like Lake Stillhouse Hollow, is located in an Edwards Plateau canyon. Like Stillhouse Hollow Reservoir, the lake shores are typically steep and rocky. The reservoir is deep (maximum depths of about 85 feet) and clear with no aquatic vegetation observed in 1995.[23] Designated uses in Segment 1249 (Lake Georgetown, also part of the Brazos River drainage) are contact recreation, high quality aquatic habitat, and public water supply. Fishery management recommendations noted a lack of nutrients and the need for more vegetational cover as limitations to sportfish production in both reservoirs.

Lake Georgetown is also a warm monomictic reservoir. An oxygen-depleted hypolimnion forms during the spring-summer season. In the April to May period, dissolved oxygen concentrations generally fall below 5 mg/l at depths exceeding about 30 feet. By August, oxygen concentrations at those depths are generally below 1 mg/l.[24]

During 1981 to 1982, phytoplankton assemblages in Lake Georgetown were similar to those reported from Lake Stillhouse Hollow. Total numbers were generally not high and the dominant algal groups included diatoms, greens and blue-greens at various times. During 1987, blue-green algae were the most abundant group in all collections (6) and dense (>200,000

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[21] USGS. 1981, 1982, 1988, 1991, 1995. Water Resources Data. Texas.

[22] Ibid.

[23] Terre, D.R. and S.J. Magnelia. 1996. Survey Report for Georgetown Reservoir, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas.

[24] USGS. 1981, 1982, 1988, 1991, 1995. Water Resources Data. Texas.

cells/ml) summer blooms were present at both sample stations.[25] Macrophytes are severely limited by a lack of shallow water and suitable substrates.[26]

Rocks and woody debris provide good habitat for white crappie, catfish (blue, channel, flathead), bass (largemouth, white, smallmouth), sunfish (bluegill, etc.), threadfin shad, and some gizzard shad. Stocking attempts have been made by the Texas Parks and Wildlife Department to increase the densities of sport fish such as channel catfish, hybrid striped bass, smallmouth bass, largemouth bass, and walleye.[27] Results from the creel survey showed that total angling pressure on the reservoir was 12.6 man-hours/acre and that anglers rated their fishing success compared to other places they fish as predominantly average (42 percent).[28]

Waterline Route

The proposed intake for the proposed Williamson County Raw Waterline would be located at Lake Stillhouse Hollow. The proposed pipeline corridor was surveyed on 26 May 1988. The corridor for the water transmission line would course east through Edwards Plateau Vegetational Area to the IH-35 ROW, southward along the highway through Blackland Prairies Vegetational Area to near the City of Florence, and westward to Lake Georgetown through the Edwards Plateau Vegetational Area. The Edwards Plateau and Blackland Prairies Vegetational Areas are described in the Environmental Overview (Section 3.1.3).

The land use and habitats in the area traversed by the Williamson County Raw Waterline reflect its location adjacent to the Balcones Escarpment, a topographic feature sharply demarking the eastern edge of the Edwards Plateau. This feature, a low-lying plateau underlain by Cretaceous limestones exhibits a physiography, soils, vegetation, and fauna more or less distinct from the Blackland prairies immediately to the east. The Balcones Escarpment marks a relatively sharp transition between the Central Texas Plateau and the Texas Blackland Prairie Ecoregions,[29] the Edwards Plateau and the Blackland Prairie Vegetational Aream,[30] and the Balconian and Texan Biotic Provinces.[31]

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[25] Ibid.

[26] Terre, D.R. and S.J. Magnelia. 1996. Survey Report for Georgetown Reservoir, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas.

[27] Ibid.

[28] Ibid.

[29] Omernik, James M. 1986. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, 77(1): pp.118-125.

Soils along the IH-35 corridor are moderately deep to very shallow, calcareous, clayey, cobbly, and stony soils formed over fractured limestone suited for rangeland, crops, and pastures.[32,33] Blackland Prairie 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 grazing lands remain. Little bluestem is the dominant grass of the native assemblage. Other important grasses include big bluestem, Indian grass, switchgrass, tall dropseed, silver bluestem, and Texas wintergrass. Under heavy grazing pressure, 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.

Most of the proposed pipeline right of way will traverse previously disturbed pasture and cropland. Wooded areas potentially affected are present only within the U.S. Army Corps of Engineers property at Lake Georgetown between the City of Georgetown WTP and the shoreline, along Salado Creek, and some of the other stream crossings.[34] Except for riparian strips at the stream crossings, all the woodlands within the pipeline corridor are upland juniper-oak associations, although they may have a substantial mesquite component. Woodlands on private ranchland (e.g., flanking FM 2338 between Berry Creek and the U.S. Corps of Engineers property around Lake Georgetown) tend to be composed of widely-spaced, small- to medium-sized cedar elms, Texas oaks and live oaks with little shrub growth, and a ground cover of improved pasture grasses. A single area near the southern margin of the corridor exhibited some deciduous brushland.[35] The existing alignment avoids this area.

Within the U.S. Corps of Engineers property at Lake Georgetown, vegetational coverage along the proposed pipeline route consists of grassland for about 150 m from the lake margin, and juniper-oak woodland to the private property line immediately north of the City of Georgetown's water treatment plant. This upland woodland appears to be the result of succession that has occurred since agricultural activity stopped on the federal land. More mature trees including live oak, Texas oak, shin oak , cedar elm, hackberry, and ashe juniper tend to

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[30] Gould, F.W. 1975. <u>The Grasses of Texas</u>. Texas A&M University Press, College Station, Texas.
[31] Blair, W.F. 1950. The Biotic Provinces of Texas. Texas Journal of Science, 2(1): pp. 93-117.
[32] Soil Conservation Service. 1983. Soil Survey of Williamson County Texas. U.S. Department of Agriculture.
[33] Soil Conservation Service. 1977. Bell County Texas. U.S. Department of Agriculture.
[34] EROS Data Center aerial photographs.
[35] HDR Engineering. 1994. Trans-Texas Water Program. Austin Study Area. Phase I Report. City of Austin and Texas Water Development Board.

dominate the overstory. Since the understory has not been maintained, it appears to have a denser and higher diversity shrub layer than the agricultural lands to the north. Dominant shrub species were yaupon, Texas persimmon, and many small individuals of overstory species, particularly elms and hackberries. A small area of dense woodland consisting of small (dbh <4-5") Ashe juniper is present in the vicinity of the City of Georgetowns' water treatment plant.

Approximately 20 stream crossings are within the pipeline corridor, but only two (Berry and Salado Creeks) are shown as perennial on USGS topographic maps. Aside from these two, only Dry Berry Creek is more than a small first- or second-order headwater in the reach to be crossed. The riparian cover of all these streams has been heavily disturbed.

Although Berry Creek is shown as perennial on USGS topographic maps, it was not flowing during the 1988 field survey. This stream typically consists of a series of elongated, rocky pools (often enlarged by building up the natural dam on the lower end) separated by boulder to gravel floored reaches that are only occasionally completely inundated. Although aquatic or wetland habitats in this reach of Berry Creek appeared to be restricted to the pools, the rainfall total that spring had been unusually low, and lotic habitats may develop during periods of higher rainfall. Actual stream crossing locations will be selected to (among other criteria) avoid springs or other particularly desirable aquatic habitats, archaeological sites (see below), and to minimize wetland impacts.

Protected species and candidate species for protection reported to occur in the project area are presented in the Environmental Overview (Section 3.1.3). A review of Texas Parks and Wildlife Department Natural Heritage Program files indicated the Edwards Plateau portion of the project area has numerous small springs, solution features, and associated species. These include the terrestrial invertebrates inhabiting shallow cavities in the areas of karst geology on the Edwards Plateau, and the salamanders found in the springs of the Balcones Escarpment. The Georgetown Salamander (*Eurycea sp. 5*) has been found in the project vicinity and other species could potentially occur in the project area.

The Golden-cheeked Warbler (*Dendroica chrysoparia*) and Black-capped Vireo (Vireo atricapillus), both listed as endangered by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife, nest both in the U.S. Corps of Engineers park at Lake Georgetown, and other areas with appropriate habitats. Both species are known to nest in Bell and Williamson counties.[36]

The Golden-cheeked Warbler inhabits mature, old-growth Ashe juniper-oak woods having between 40 and 85 percent Ashe juniper.[37,38,39,40,41] The warbler requires strips of bark, which it gathers from mature Ashe juniper, for nest construction. Throughout most of its range, Texas oak is usually co-dominant with Ashe juniper, but other oaks may replace the Texas oak in some parts of its range. For example, at the northern extreme of the warblers' range, shin oak may dominate while in the southern extreme, lacy oak (*Q. glaucoide*) increases in abundance.

The Black-capped Vireo is an inhabitant of well-drained bushy or thicket covered hills typical of many parts of the Edwards Plateau.[42] This species has become very rare in parts of its historic range, due to the heavy strain of brown-headed cowbird (*Molothrus ater*) nest parasitism, and land use practices (e.g., fire suppression, pasture maintenance) that reduce the availability of its successional nesting habitat.[43]

The bald eagle (*Haliaeetus leucocephalus*) is one of the largest birds of prey in North America, and is considered by U.S. Fish and Wildlife Service and Texas Parks and Wildlife to be threatened. The preferred habitat of the bald eagle can be described as large bodies of relatively clear water with nearby wooded areas containing tall trees.[44] Fish compose 50 to 90 percent of the bald eagle's diet, the balance of which consists of ducks, coots, other birds, rabbits, rodents, and carrion.[45]

Bald eagle breeding is mostly limited to the northern United States and to Canada; however, nesting rarely occurs at scattered localities in east Texas and at a number of sites on the

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[36] Texas Parks and Wildlife Department, Unpublished 1994. Data and map files of the Natural Heritage Program.

[37] Benson, R.H. 1990. Habitat Area Requirements of the Golden-cheeked Warbler on the Edwards Plateau. A Report to Texas Parks and Wildlife Department. Austin, TX.

[38] Campbell, L. 1995. Endangered and Threatened Animals of Texas. Resource Protection Division. Endangered Resources Branch. Texas Parks and Wildlife Dept. Austin, TX.

[39] Ladd, C.G. 1985. Nesting Habitat Requirements of the Golden-cheeked Warbler. Southwest Texas State University. Masters Thesis. San Marcos, TX.

[40] USFWS. 1994. Minimum Procedures for Determining the Presence/Absence of Golden-cheeked Warblers and Black-capped Vireos. U.S. Fish and Wildlife Service. Austin, TX.

[41] Wahl, R. D.D. Diamond and D. Shaw. 1990. The Golden-cheeked Warbler: A Status Review. A Final Report Submitted to Ecological Services. U.S. Fish and Wildlife Service, Fort Worth, TX.

[42] Oberholser, H.C. and E.B. Kincaid. 1974. The Bird Life of Texas. Univ. Texas Press. Austin, Texas.

[43] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Dept., Austin, Texas.

[44] Oberholser, H.C. and E.B. Kincaid. 1974. The Bird Life of Texas. Univ. Texas Press. Austin, Texas.

[45] Ibid.

central and upper Texas coastal plain.[46] As of 1994, Bald Eagle nests were known to occur in the Trans-Texas North Central counties of Bastrop and Fayette.[47] The bald eagle has become an increasingly common winter resident at numerous sites with good habitat in Texas and Oklahoma. Large bodies of water throughout Texas (especially in the eastern half) often support from one to several winter resident bald eagles. Bell and Williamson Counties are not reported by Campbell to support resident bald eagles.[48]

The peregrine falcon (*Falco peregrinus*) is a medium-to-large falconid whose populations were decimated largely due to the effects of environmental pollutants such as DDT.[49] The arctic peregrine falcon (*Falco peregrinus tundrius*), one of the two subspecies found in Texas, is considered by U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department to be threatened due to similarity of appearance to the protected species. The other subspecies, the American peregrine falcon (*Falco peregrinus anatum*), is listed by these agencies as endangered.[50]

The peregrine falcon is a swift raptor which feeds almost exclusively on birds ranging in size from that of small passerines to ducks.[51] Peregrine falcons occur only as migrants in north Texas. During this time, almost any area with trees or other perch structures and an adequate supply of prey might be considered potential habitat for this species. Thus, the importance of relatively small acreages considered individually in terms of peregrine falcon value is small.

The whooping crane (*Grus americana*) is listed by U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department as endangered, with critical habitat in Texas designated for this species. It is the tallest native avian inhabitant of Texas, where it is a winter resident of shallow wetland habitats of the Aransas National Wildlife Refuge and surrounding areas of the Gulf Coast.[52] Oberholser described the whooping crane as an omnivore that feeds on crabs, shrimp, frogs, crawfish, plant roots and tubers, acorns, and sorghum and other grains.[53]

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[46] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Dept., Austin, Texas

[47] Ibid.

[48] Ibid.

[49] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Dept., Austin, Texas

[50] Ibid.

[51] Ibid.

[52] Ibid.

[53] Oberholser, H.C. and E.B. Kincaid. 1974. The Bird Life of Texas. Univ. Texas Press. Austin, Texas.

Portions of north Texas, including Bell and Williamson Counties, lie within the migratory corridor that whooping cranes follow enroute to their nesting grounds in Wood Buffalo National Park, Canada.[54] However, in Texas there are no known regular migration stopover points such as are found in certain areas in Nebraska; in fact, there are only a few scattered confirmed ground sightings of whooping cranes anywhere in Texas other than on the wintering grounds on the coast.[55]

The interior least tern (*Sterna antillarum athalassas*) is a small member of the family Laridae which includes (among others) the gulls, terns, and skimmers. Like other members of the family, the interior least tern is an excellent flier, and is found in association with aquatic habitats and their margins, especially in coastal regions. It feeds by hovering above the water and then diving for small fish and invertebrates at or near the surface.[56]

Although there are three subspecies of least tern recognized, some biologists think that there is more interbreeding between the interior least tern and coastal subspecies than once believed.[57] The interior form breeds locally in the Missouri Valley along the larger streams from North Dakota south to the Brazos River system of North Texas. There it nests in pairs or small colonies on river sandbars or sandflats, but is otherwise similar in behavior to the coastal subspecies.[58] Nesting and/or summer occurrence has been confirmed for areas along the Red River between Texas and Oklahoma.[59] During winter, the interior least tern ranges from south Texas to Oaxaca, Mexico. Alterations in its preferred riverine habitat have apparently caused a decline in populations. This decline has led to the listing of the interior least tern by U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department as endangered.

The Texas horned lizard (*Phrynosoma cornutum*) and timber rattlesnake (*Crotalus horridus*), both listed as threatened by Texas Parks and Wildlife, could occur within areas that would be disturbed by construction activities. The Texas horned lizard is a denizen of open, well-drained habitats with sparse cover. Ants, spiders, and isopods are included in their diets.

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[54] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Dept., Austin, Texas

[55] Ibid.

[56] Oberholser, H.C. and E.B. Kincaid. 1974. The Bird Life of Texas. Univ. Texas Press. Austin, Texas.

[57] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Dept., Austin, Texas.

[58] Oberholser, H.C. and E.B. Kincaid. 1974. The Bird Life of Texas. Univ. Texas Press. Austin, Texas.

[59] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Texas Parks and Wildlife Dept., Austin, Texas.

The habitat requirements of this lizard species could be met on parts of the project area in both the Edwards Plateau and the Blackland Prairie regions. The timber rattlesnake is found in dense bottomland woodlands and extensive thickets in East Central to East Texas.[60] Wooded bottomlands in lower perennial streams may provide cover for this reclusive species. The project area is at the western edge of the timber rattlesnake's range. Widely distributed across the eastern third of Texas, this snake is generally uncommon near populated areas, nocturnal, and thinly distributed even in its preferred densely wooded habitat.[61]

The Texas garter snake (*Thamnophis sirtalis annectans*), a species of concern, prefers wet or moist habitats with an abundance of frogs and other aquatic-associated prey. Farm ponds and ephemeral pools could harbor individuals of this species. The Texas garter snakes' East Central Texas range includes habitats commonly found in the Blackland Prairie portion of the project area.[62,63]

Cultural Resources

In an attempt to focus the investigation toward the preservation of potentially significant resources, the proposed cultural resources inventory will proceed by dividing the project area into zones which have historically demonstrated a range of high and low site occurrence potential. The potential of any given zone will be assigned based on the analysis of current settlement patterns, the geomorphic context exhibited, and the results of archival research.

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[60] Ibid.

[61] Tennant, Alan. 1985. A Field Guide to Texas Snakes, Texas Monthly Field Guide Series. Texas Monthly Press, Austin, Texas.

[62] Tennant, Alan. 1985. A Field Guide to Texas Snakes, Texas Monthly Field Guide Series. Texas Monthly Press, Austin, Texas.

[63] Dixon, James R. 1987. Amphibians and Reptiles of Texas. Texas A&M University Press, College Station, Texas.

Black[64] and Collins[65] have presented excellent synopses regarding prehistoric settlement patterns of the region in question, while Anne Fox[66] has provided a similar report on historic resources. Most prehistoric sites are identified using a functional classification which corresponds to the inferred function of the various cultural features a particular site possesses. The functional classification of sites that occur within the project area can be grouped into one of several categories. These are: (1) open habitations, (2) lithic quarries and workstations, (3) burned rock middens, (4) kill sites, (5) rockshelters, (6) caves, and (7) sinkholes. Historic resources that may occur within the region include both 19th century farmsteads, ranches, and cemeteries and rarer 18th century sites such as missions and old town sites.

Because certain geomorphic elements of the regional landscape appear to correlate with the occurrence of potentially significant prehistoric resources, a data inquiry regarding the local geomorphology of the project area was conducted by examining published information contained on geologic maps, in soil surveys, and on aerial photographs. After the examination of this information, areas identified as possibly containing extensive Holocene deposits were assigned a high potential for site occurrence while those indicating a lack of Holocene deposition were considered to have a low probability of site occurrence. Holocene deposits are considered to be contemporaneous with human occupation of the New World. A general correlation was made between the local topography and the assignment of site occurrence potential. Upland areas were characterized by extensive outcrops of Cretaceous limestones, chalks, and marls while bottomland areas were found to contain some locally isolated Holocene sediment accumulations

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[64] Black, S.L. 1989. Central Texas Plateau Prairie. From the Gulf to the Rio Grande: Human Adaptation in Central, South and Lower Pecos Texas. Thomas H. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bemont. Arkansas Archeological Survey Research Series Number 33:17-38. Center for Archeological Research at the University of Texas at San Antonio, Texas, Texas A & M University, and the Arkansas Archeological Survey.

[65] Collins, M.B. 1995. Forty Years of Archeology in Central Texas. Bulletin of the Texas Archeological Society. Volume 66:361-400.

[66] Fox, A. 1989. Historic Analysis of European Exploration and Colonization. From the Gulf to the Rio Grande. Human Adaption in Central, South, and Lower Pecos Texas. Thomas H. Hester, Stephen L. Black, D. Gentry Steele, Ben W. Olive, Anne A. Fox, Karl J. Reinhard, and Leland C. Bemont. Arkansas Archeological Survey Research Series Number 33:85-92. Center for Archeological Research at the University of Texas at San Antonio, Texas, Texas A & M University, and the Arkansas Archeological Survey.

(Barnes[67], 1981; Huckabee et al.,[68]; Werchan and Coker,[69]). Based on these findings, upland areas were designated as having a low site occurrence potential, while bottomland areas were designated as possessing a high site occurrence potential. Specific areas identified as having high site occurrence potential were:

- The southeast slope of the Lake Stillhouse Hollow property,
- The Salado Creek crossing,
- The Dry Berry Creek crossing, and
- The northeast slope of the Lake Georgetown property.

Whether or not the Holocene deposits present at these locales are extensive enough to have potentially preserved any cultural resources could not be adequately determined from the examination of published data, and consequently will require ground truthing in the field. As a general procedure, all portions of the project alignment that intercept high potential areas will be targeted for intensive shovel testing on the order of one test every 30 meters. If the accumulation of Holocene sediment is determined to go beyond the depth capability of a normal shovel test (~ 80 cm), more invasive excavation means will be utilized (e.g., backhoe trenching, augering, etc.).

All portions of the project that cross low potential areas will be examined by conducting a pedestrian reconnaissance of the impact area. The subsurface testing procedures will performing shovel tests on a judgmental basis to identify and assess lithic procurement areas, caves, sinkholes, and historic remains. These types of features are generally visible along the surface and will only require testing in limited visibility areas such as those with dense vegetative cover.

An examination of archived documents at the Texas Archeological Research Laboratory in Austin revealed that the project area may potentially impact several previously-documented cultural resource sites. Each of these sites are addressed below.

41BL1050. This site was discovered during an intensive survey conducted by Dr. Peter Nichols. He described the site as a lithic scatter and recommended no further investigation.

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[67] Barnes, V.E. 1981 Geologic Atlas of Texas. Bureau of Economic Geology. The University of Texas at Austin.

[68] Huckabee, J.W. Jr., D.R. Thomson, J.C. Wyrick, and E.G. Pavlat. 1977. Soil Survey of Bell County, Texas. Soil Conservation Service, United States Department of Agriculture. In cooperation with the Texas Agricultural Experiment Station.

[69] Werchan, L.E. and J.L. Coker. 1983. Soil Survey of Williamson County, Texas. Soil Conservation Service, United States Department of Agriculture. In Cooperation with the Texas Agriculture Experiment Station.

41WM797. This site was recorded by Lone Star Archeological Services during a survey conducted at Sun City Georgetown. The site was reported as an historic cemetery (probably mid to late 19th century) containing several marked graves and a potential number of unmarked graves. No formal recommendation has been made. However, the burials at this site are protected by state and civil statues and cannot be removed unless the cemetery is abated as a nuisance.

41WM329 and 41WM362. Recorded by Texas A&M during their work at North Fork Reservoir (Lake Georgetown), sites 41WM329 and 41WM362 were reported to represent a lithic quarry and a lithic scatter, respectively. Texas A&M reported that they felt that no further work was warranted at either site. Note: the principal investigator at Paul Price Associates, Inc. has personally visited both of these sites during a previous investigation and determined that because of their lack of integrity, neither site presented any research value beyond their initial documentation. Concurrence with this finding was obtained from both the USCE and the Texas Historical Commission following formal consultation.

41WM331. This site was originally recorded by Texas A&M during their survey of Lake Georgetown in the 1970s. The site was reported as a large burned rock midden occupying an area 200 square meters in size. The archeological team noted that some areas of the site had been disturbed by looting activity. Further work was recommended for this site if it were subject to future disturbance.

During the proposed survey, all of these sites will be revisited to determine their potential for adverse impact by the project. If it is determined that a potential exists for direct site disturbance, then these sites will be re-evaluated using limited subsurface testing (shovel tests) to confirm their boundaries and present condition. Any applicable state site forms will be updated to reflect these re-evaluations.

Because documented information regarding the occurrence of cultural resources within the project area is incomplete, it is recommended that the entire impact area undergo a cultural resources inventory to both assess any potential impacts to cultural resources and determine appropriate mitigative measures. To accomplish this, a tailored survey strategy will be utilized which draws its rationale from current knowledge regarding the probability of site occurrence within the Edwards Escarpment area of Texas.

Construction Effects

Construction of the intake and outfall structures would affect a total of less than 0.15 acres of lake bottom in each reservoir. No substantial impacts to fish spawning, nursery, or feeding areas are expected. Both the intake structure and the outfall would be sited on parkland managed by the U.S. Army Corps of Engineers. No state- or federally-listed endangered or threatened species are known to occur in either impoundment or in their tailwaters, and no adverse effects on protected or other species are expected.

National Wetland Inventory Maps covering the water line corridor show predominately uplands dotted with farm ponds and traversed by perennial or intermittent streams with persistent pools[70.71.72.73.74.] Slightly more than one-third of stream-associated (palustrine) wetlands exhibit emergent vegetation and almost one-third consist of forested intermittent streambeds. The remaining wetlands are isolated, man-made farm ponds and a single, large perennial stream, Salado Creek.

The 80-foot pipeline construction easement will total about 240 acres, but the actual area disturbed during construction is expected to be less, between 90 and 200 acres. The proportion of habitats affected by the installation and operation of the water transmission line have been described as woodland/savannah (6 percent), pasture/cropland (79 percent), developed (12 percent), and wetland or water (3 percent).[75] Most of the water line corridor lies in previously disturbed pasture and cropland of the Blackland Prairie. Woodlands are located primarily within the U.S. Army Corps of Engineers properties surrounding both reservoirs, along Salado Creek, and the other minor creeks crossed by the corridor over the Edwards Plateau portion of the corridor. Woodlands generally consist of variable mixtures of liveoak, mesquite,

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[70] U.S. Fish and Wildlife Service. 1990. National Wetland Inventory Map Series, Belton Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

[71] _Salado Quadrangle. U. S. Department of the Interior, Albuquerque, NM.

[72] _Jarrell Quadrangle. U. S. Department of the Interior, Albuquerque, NM.

[73] _Cobbs Cavern Quadrangle. U. S. Department of the Interior, Albuquerque, NM.

[74] _Georgetown Quadrangle. U. S. Department of the Interior, Albuquerque, NM.

[75] HDR Engineering. 1994. Trans-Texas Water Program. Austin Study Area. Phase I Report. City of Austin and Texas Water Development Board.

and juniper. Woodlands on private ranchlands along FM 2338 between Berry Creek and the U.S. Army Corps of Engineers property at Lake Georgetown are generally sparse savannahs occupied by widely-spaced small- to medium-sized cedar elms, Texas oaks and live oaks with little shrub growth, and improved pasture grassland. Where the pipeline corridor crosses U.S. Army Corps of Engineers property at Lake Georgetown, the juniper-oak woodland consists of a mosaic of varying vegetational composition and ages. While some scattered, mature cedars are present, this is not an area of mature juniper-oak slope forest. Because several locations around Lake Georgetown have been characterized as Golden-cheeked Warbler habitat, Paul Price Associates surveyed the pipeline corridor for potential habitat requirements. The pipeline would traverse an area that can be characterized as marginal, that is, it might be used by the Golden-cheeked Warbler if prime habitat were nearby. Pipeline construction in this segment is not expected to disturb any warbler nesting habitat. A single area near the southern margin of the corridor exhibited some deciduous brushland. Before an easement on U.S. Corps of Engineer property is granted, USFWS and other regulatory agencies would be consulted.

Construction of the intake and discharge structures would affect a total of less than 0.15 acres of lake bottom in each reservoir, and will not involve the placement of loose fill or other actions that might result in siltation or other disturbance to either benthic or pelagic environments beyond the immediate work area. No substantial impacts to fish spawning, nursery, or feeding areas are expected from intake or discharge structure construction because of the limited area and time of disturbance.

Adverse impacts to endangered species discussed above, or to critical habitats or other resources required by those species, are not likely to result from construction and operation of this project. Project activities are not expected to have any effects on migratory or wintering individuals that might occur in the vicinity of the project area. Possible potential nesting habitat for the Black-capped Vireo was identified near the southern margin of a short segment of the proposed pipeline corridor. No disturbance of that area will occur as a result of project implementation.

The pipeline corridor extends through the area south of FM 2338 that exhibits a surface scatter of broken and/or worked flint. No archaeological survey has yet been made to determine the extent and significance of this material. Placement of this segment of the pipeline will require selection of suitable methodologies and a route that minimizes disturbance.

The stream crossings, particularly Salado Creek, will be selected to avoid disturbance to archaeological resources and significant natural features such as springs or marginal wetlands. The Salado Creek crossing will be upstream of an important recreational reach that contains substantial areas of gravel and cobble substrate, and large stands of rooted aquatic vegetation. Because dense turbidity plumes or siltation in that reach would be immediately evident to the numerous residents and visitors, procedures to minimize siltation during and following construction are included in the U.S. Corps of Engineers application.

Operational Effects

Effects of operation on the aquatic environment may result from changes in the frequency and extent of fluctuations in water surface elevations in both reservoirs (Figures 3.7-2 to 3.7-5), and in changes in streamflow in response to diversions from Stillhouse Hollow Reservoir. Hydrologic modeling that would show the effect of the proposed diversion on streamflows below Stillhouse Hollow Reservoir have not been performed. Because this alternative involves the sale of existing stored water, the instream flow provisions that presently govern the operation at Stillhouse Hollow Reservoir would appear to continue to apply. The flow regime below Lake Georgetown would not necessarily be affected by the implementation of this alternative.

Operational effects of the proposed project on terrestrial habitats will be limited to right-of-way maintenance. The permanent 30-foot pipeline easement will not require vegetation control except in wooded areas (the U.S. Army Corps of Engineers property at Lake Georgetown and adjacent to Salado Creek). Even in these areas, maintenance will be limited to preventing the establishment of trees on and immediately adjacent to the pipeline itself.

Potential effects on aquatic environments will be limited to intake and discharge effects within and downstream of the source and receiving reservoirs. In both reservoirs, alteration of the present water balance could result in changes in the timing and quantity of water released downstream, thereby altering the instream flows. Changes in the frequency and extent of fluctuation in water surface elevations could possibly affect fish nesting site success within the reservoirs. Potential impact routes restricted to one or another of the two reservoirs include, in the source (Stillhouse Hollow): entrainment and impingement of pelagic species or life stages, and in Lake Georgetown: segment standards/water quality changes, and transfers of aquatic organisms.

Adverse impacts to wetlands, endangered species, and cultural resource sites can largely be avoided or minimized by using field surveys to select final pipeline alignments and associated facility locations, and by choosing appropriate construction methods and schedules. Unavoidable impacts would have to be compensated for. This is generally accomplished by setting aside some appropriate acreage to be managed to regain the habitat values lost through project implementation. The project sponsor would be responsible for development of a management plan, and for providing funding to implement the management plan for the life of the project. The project sponsor may retain ownership of compensation lands, or they may be transferred to a mutually agreeable public agency (generally Texas Parks and Wildlife Department) for management.

3.7.4 Water Quality

Since Lake Stillhouse Hollow is consistently considered one the highest quality surface water supplies in Texas, pumping water from Stillhouse Hollow to Lake Georgetown should not have any detrimental effects on the water quality characteristics of Lake Georgetown. Both water supplies are considerd of very high quality as the constituent levels in Table 3.7-5 indicate. The low nutrient levels in Lake Stillhouse Hollow keep it ranked as one of Texas most oligotrophic (under nourished) reservoirs.[76] Since phosphorus is often the limiting nutrient in algal growth, mixing Lake Stillhouse Hollow water with Lake Georgetown should have little or no impact on algae growth in Lake Georgetown. Based on the levels reported in Table 3.7-5, the resulting mixture should have a lower total phosphorus concentration than the original water.

Total nitrogen concentrations in Lake Stillhouse Hollow water are about twice those measured in water sampled from Lake Georgetown. However, because phosphate concentrations are nearly equal in the two lakes, no adverse effects resulting from changes in nutrient

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[76] TNRCC, "Texas Water Quality, A Summary of River Basin Assessments," 1994.

Table 3.7-5
Water Quality Constituents
in Lake Stillhouse Hollow and Lake Georgetown[1]

Constituent	Lake Stillhouse Hollow	Lake Georgetown
Dissolved Oxygen (mg/l)	7.28	8.00
pH (su)	8.23	8.05
TDS (mg/l)	354.80	232.00
Fecal Coliforms (No./100 ml)	2.29	53.67
Chloride (mg/l)	66.00	13.00
Sulfate (mg/l)	24.44	18.38
Total Phosphorus (mg/l)	0.02	0.03
Total Nitrogen[2] (mg/l)	0.14	0.06

[1] TNRCC, "Texas State Water Quality Inventory," November, 1994
[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

concentrations and enhanced algal growth are expected. Although chloride levels in Lake Stillhouse Hollow are well below recommended maximum concentrations, the data presented below indicates that the water in Lake Stillhouse Hollow has a significantly higher chloride content than does Lake Georgetown. Water in Lake Georgetown is slightly harder than Lake Stillhouse Hollow, but less alkaline.[77,78] Both reservoirs stratify and experience low dissolved oxygen levels at about the same time, mid to late summer.[79]

Due to the exceptional high quality of Lake Stillhouse Hollow, much focus has been given to protecting and monitoring its upstream waters.[80] Therefore, the future water quality characteristics of Lake Stillhouse Hollow water are expected to remain the same. The conventional treatment already employed for public water supply on Lake Georgetown should be adequate to treat the blended Lake Stillhouse Hollow and Lake Georgetown water.

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[77] Ibid.

[78] U.S. Geological Service and Texas Water Commission. 1980-1991. Water Data for Water Years October 1989 to September 1990, Brazos River Basin , 08104050 Stillhouse Hollow Lake Near Belton, TX.; 082104650 Lake Georgetown near Georgetown, TX. Texas Water Commission, Austin, Texas.

[79] HDR Engineering, Inc. 1988. Williamson County Raw Water Line, Preliminary Engineering Report. Prepared for Brazos River Authority.

[80] Brazos River Authority, "Regional Assessment of Water Quality, Brazos River Basin including the Upper Oyster Creek Watershed," October, 1994.

3.7.5 Engineering and Costing

This section provides cost estimates for implementation of the Williamson County Raw Water line project. Cost estimates for two pipeline configurations are presented: (1) construction of a single 42-inch pipeline for delivery of 42,721 acft/yr as contracted for by entities in Williamson County; and, (2) construction of twin 33-inch diameter parallel pipelines, which could potentially be constructed in a phases. The capacity of the initial 33-inch pipeline would be about 21,000 acft/yr and with the final phase, the parallel 33-inch pipelines would have the capacity to deliver the full 42,271 acft/yr.

At Lake Georgetown, the Lake Stillhouse Hollow water will be blended with Lake Georgetown water and the combined amount could potentially be treated at either the Round Rock or Georgetown water treatment plants, or at a potential new regional water treatment plant. From the regional treatment plant, the water could potentially be distributed to project participants or other water supply entities.

Lake Stillhouse Hollow water would be diverted from a new intake structure to be located near the south end of the Stillhouse Hollow Dam. The water would be transported by pipeline to Lake Georgetown where an outfall structure would potentially be located off the north shore of Lake Georgetown sufficiently far away from the existing Georgetown water treatment plant intake to allow for blending of the Lake Stillhouse Hollow and Lake Georgetown waters. The length of the pipeline is 149,000 feet (28.2 miles) and requires a static lift of 280 ft.

The major facilities needed to implement this project are:

- Reservoir Intake and Pump Station,
- Raw Water Pipeline from Lake Stillhouse Hollow to Lake Georgetown,
- Increased intake and raw water pumping capacity for Round Rock and Georgetown,
- Expanded water treatment plant capacity for Round Rock and Georgetown,
- Expanded treated water distribution facilities,
- For a new regional treatment plant:
  - Lake Georgetown intake and pump station,
  - Raw water transmission pipeline,
  - Water treatment plant, and
  - Treated water transmission pipelines.

Pipeline Cost Estimate

The cost estimate for the single 42-inch pipeline option is summarized in Table 3.7-6 and Table 3.7-7 summarizes the estimate for twin 33-inch pipelines. The delivery rate to Lake Georgetown would be about 42 mgd (assuming 9 percent down time for outages and avoidance of summer peak electric charges), requiring a 42-inch diameter transmission pipeline or twin 33-inch diameter pipelines.

Table 3.7-6
Cost Estimate Summary for Williamson County Raw Water Pipeline
(Single 42-inch Diameter Pipeline) (B-1)
(1st Quarter 1997 Dollars)

Item	Cost
Capital Costs	
Intake and Pump Station	$ 4,440,000
Raw Water Pipeline	20,113,000
Water Treatment Plant	See following tables.
Total Capital Costs	$24,553,000
Engineering, Contingencies, and Legal	$ 6,680,000
Land Easements	-0-
Environmental Studies and Mitigation	200,000
Interest During Construction	1,250,000
Total Project Costs[1]	$32,683,000
Annual Costs	
Annual Debt Service	$ 3,062,000
Annual Operation and Maintenance (Excluding Power)	375,000
Annual Power	1,940,000
Purchase of Water from BRA[2]	823,000
Total Annual Cost	$ 6,200,000
Available Project Yield	42,721 acft/yr
Annual Unit Cost of Raw Water at Lake Georgetown	
($ per acft)	$145
($ per 1,000 gal)	$0.45

[1] Costs shown are estimated future costs and do not include approximately $1.5 million expended by Round Rock, Georgetown, and Jonah SUD for ROW acquisition and engineering.
[2] Based on purchase of 42,721 acft/yr at 1996 BRA system price of $19.27 per acft. BRA system price in 1998 is $20.01 acft.

For the single 42-inch diameter pipeline, the total cost of the intake, pipeline, and pump station for delivery from Lake Stillhouse Hollow to Lake Georgetown would be $24,553,000, and the total project cost would be $32,683,000 (Table 3.7-6). This cost does not include funds previously expended by Round Rock, Georgetown, and Jonah SUD for ROW acquisition and engineering. Financed at 8 percent annual interest for 25 years, the annual debt service on this amount would be $3,062,000 with total O&M costs estimated to be $2,315,000. Total annual cost would be $6,200,000, which includes the purchase of 42,271 acft/yr from BRA at a unit cost of $19.27 per acft. The resulting annual unit cost for the 42-inch diameter pipeline project with no treatment component would be $145 per acft ($0.45 per 1,000 gal).

Table 3.7-7
Cost Estimate Summary for Williamson County Raw Water Pipeline
(Twin 33-inch Diameter Pipelines) (B-1)
(1st Quarter 1997 Dollars)

Item	Phase I (One 33" φ Pipeline)	Phase II (Additional 33" φ Pipeline)
Capital Costs		
Intake and Pump Station	$ 3,054,000	$ 1,120,000
Raw Water Pipeline	13,833,000	13,713,000
Water Treatment Plant	See following tables.	See following tables.
Total Capital Costs	$16,887,000	$14,833,000
Engineering, Contingencies, and Legal	$ 4,570,000	$ 3,778,000
Land Easements	-0-	350,000
Environmental Studies and Mitigation	200,000	200,000
Interest During Construction	871,000	762,000
Total Project Costs[1]	$22,528,000	$19,923,000
Annual Costs		
Annual Debt Service	2,111,000	1,867,000
Annual Operation and Maintenance (Excluding Power)	266,000	201,000
Annual Power	1,205,000	1,205,000
Purchase of Water from BRA[2]	412,000	412,000
Total Annual Cost	$ 3,994,000	$ 3,685,000
Available Project Yield	21,360 acft/yr	21,360 acft/yr
Annual Unit Cost of Raw Water at Georgetown		
($ per acft)	$187	$173
($ per 1,000 gal)	$0.58	$0.53

[1] Costs shown are estimated future costs and do not include approximately $1.5 million expended by Round Rock, Georgetown, and Jonah SUD for ROW acquisition and engineering.

[2] Based on purchase of 42,721 acft/yr at 1996 BRA system price of $19.27 per acft. BRA system price in 1998 is $20.01 per acft.

For the twin 33-inch diameter pipeline option, Table 3.7-7 summarizes costs for construction of a first phase single pipeline (i.e., Phase I) to be followed by a second 33-inch pipeline parallel to the first pipeline (Phase II). Total project costs for Phase I would be $22,528,000. Phase I costs would include construction of an intake and pump station structure sufficient for Phase I and Phase II flows, resulting in higher costs for Phase I than Phase II. Phase II total project costs would be $19,923,000 (Table 3.7-7), which includes acquisition of additional right-of-way for the Phase II pipeline. These costs do not include funds previously expended by Round Rock, Georgetown, and Jonah SUD for ROW acquisition and engineering.

Total annual costs for Phase I, including debt service, O&M, power, and purchase of water would be about $3,994,000 (Table 3.7-7). For 21,360 acft/yr water availability for Phase I, the annual unit cost of water would be $187 per acft (or $0.58 per 1,000 gal). These costs include the purchase of water from BRA, but do not include treatment costs.

Total annual costs for Phase II, including debt service, O&M, power and purchase of water would be about $3,685,000 (about $309,000 per year less than Phase I costs). For the additional 21,360 acft produced by Phase II, the annual unit cost of water considering only Phase II costs would be about $173 per acft (or $0.53 per 1,000 gal). These costs include the purchase of water from BRA, but do not include treatment costs. The average unit cost of raw water considering both Phases would be $180 per acft or $0.55 per 1,000 gal.

Costs for Treated Water Delivered to the City of Georgetown

The City of Georgetown has contracted to purchase 15,448 acft/yr from Lake Stillhouse Hollow. Additionally, Jonah SUD has purchased 2,439 acft/yr which will potentially be treated by the City of Georgetown and delivered to Jonah SUD. For a combined annual delivery of 17,887 acft/yr, using a peak day to average annual day peak factor of 2.0, the treatment capacity needed for this annual quantity is 32 mgd. Because this additional treatment capacity needed by Georgetown is relatively large compared to their existing plant capacity at Lake Georgetown (5.3 mgd), virtually all the components of a new treatment facility would be required for the upgrade. Therefore, the cost of treatment capacity is conservatively estimated to be about the same as for construction of a new treatment plant. The raw water intake and transmission pipeline to the treatment plant would be sized to deliver 32 mgd, requiring a 42-inch diameter pipeline. The raw water line length from Lake Georgetown to the Georgetown treatment plant is about .5 miles (2,700-ft). The cost of 32 mgd of new or additional water treatment capacity is estimated to be $21,000,000. Table 3.7-8 summarizes the cost estimate for 32 mgd of treatment capacity at Georgetown.

Table 3.7-8
Cost Estimate Summary for Delivery of Treated Water from Lake Stillhouse Hollow to Georgetown
(1st Quarter 1997 Dollars)

Item	Cost
Capital Costs	
Intake and Raw Water Pipeline	$ 2,460,000
Water Treatment Plant	21,000,000
Total Capital Costs	$ 23,460,000
Engineering, Contingencies, and Legal	$ 8,211,000
Land Easements	40,000
Environmental Studies and Mitigation	40,000
Interest During Construction	1,270,000
Total Project Costs	$ 33,021,000
Annual Costs	
Annual Debt Service	$ 3,094,000
Annual Operation and Maintenance (Excluding Power)	2,434,000
Annual Power	95,000
Total Annual Cost of Treatment	$ 5,623,000
Total Annual Delivery to Georgetown	17,887 acft/yr
Annual Unit Costs of Treatment	
($ per acft)	$314
($ per 1,000 gal)	$0.96

Table 3.7-9 summarizes the cost estimates for participation by Georgetown in the 42-inch raw water line and treatment in an expansion of Georgetown's water treatment plant. The annual unit cost of the raw water line component at full utilization would be about $145 per acft and the treatment component would be about $314 per acft. The estimated total annual cost of the raw water line and treatment would be about $459 per acft ($1.41 per 1,000 gal) for the 42-inch diameter pipeline option with full utilization of the project capacity.

Table 3.7-9
Cost Estimate Summary for 42-inch Pipeline and Treatment at Georgetown
(1st Quarter 1997 Dollars)

Item	Cost
Annual Cost of Raw Water Delivered to Lake Georgetown (single 42-inch pipeline) (see Table 3.7-6) ($ per acft)	$145
Annual Cost of Treatment ($ per acft) (see Table 3.7-8)	314
Total Annual Unit Cost of Treated Water	
($ per acft)	$459
($ per 1,000 gal)	$1.41

Table 3.7-10 summarizes the cost estimates for participation by Georgetown in Phase II of the twin 33-inch pipeline project, with treatment in an expansion of Georgetown's water treatment plant. The annual unit cost of the raw water line component would be about $173 per acft. The estimated total annual cost of the raw water line and treatment would be about $487 per acft ($1.49 per 1,000 gal) for Phase II of 33-inch diameter pipeline option with full utilization of the project capacity. Although the 33-inch diameter pipeline option is slightly more expensive, it provides the opportunity to defer almost all capital expenditures until Phase II is implemented, at which time the facility would be more highly utilized than if the full-size 42-inch diameter pipeline is constructed.

Table 3.7-10
Cost Estimate Summary for 33-inch Pipeline and Treatment at Georgetown
(1st Quarter 1997 Dollars)

Item	Cost
Annual Cost of Raw Water Delivered to Lake Georgetown (twin 33-inch pipelines) (Phase II) (see Table 3.7-7) ($ per acft)	$173
Annual Cost of Treatment ($ per acft) (see Table 3.7-8)	314
Total Annual Unit Cost of Treated Water	
($ per acft)	$487
($ per 1,000 gal)	$1.49

Costs for Treated Water Delivered to the City of Round Rock

The City of Round Rock has contracted to purchase 18,134 acft/yr from Lake Stillhouse Hollow. Using a peak day to average annual peak factor of 2.0, the treatment capacity needed is

32 mgd. Because this additional treatment capacity needed by Round Rock is relatively large compared to their existing plant capacity (21 mgd capacity), virtually all the components of a new treatment facility would be required for the upgrade. Therefore, the cost of treatment capacity is conservatively estimated to be about the same as for construction of a new treatment plant. The raw water intake and transmission pipeline to the treatment plant would be sized to deliver 32 mgd, requiring a 42-inch pipeline. The raw water line length from Lake Georgetown to the Round Rock treatment plant is about 8 miles (44,400 feet). The cost of 32 mgd of new or additional water treatment capacity is estimated to be $21,000,000. Table 3.7-11 summarizes the cost estimate for delivery of treated water to Round Rock.

Table 3.7-11
Cost Estimate Summary for Delivery of Treated Water from Lake Stillhouse Hollow to Round Rock
(1st Quarter 1997 Dollars)

Item	Cost
Capital Costs	
Intake and Raw Water Pipeline	$ 9,966,000
Water Treatment Plant	21,000,000
Total Capital Costs	$ 30,966,000
Engineering, Contingencies, and Legal	$ 10,340,000
Land Easements	135,000
Environmental Studies and Mitigation	135,000
Interest During Construction	1,663,000
Total Project Costs	$ 43,239,000
Annual Costs	
Annual Debt Service	$ 4,051,000
Annual Operation and Maintenance (Excluding Power)	2,441,000
Annual Power	175,000
Total Annual Cost	$ 6,667,000
Annual Water Delivery	18,134 acft/yr
Annual Unit Cost of Treatment	
($ per acft)	$368
($ per 1,000 gal)	$1.12

Table 3.7-12 summarizes the cost estimate for Round Rock to participate in the 42-inch diameter raw water line and treatment at an expansion of Round Rock's water treatment plant. The annual unit cost of the raw water line component would be about $145 per acft, and the treatment component would be about $368 per acft. The estimated total annual cost would be about $513 per acft ($1.57 per 1,000 gal) with full utilization of the project capacity.

Table 3.7-12
Cost Estimate Summary for 42-inch Pipeline and Treatment at Round Rock
(1st Quarter 1997 Dollars)

Item	Cost
Annual Cost of Raw Water Delivered to Lake Georgetown	
(single 42-inch pipeline) (see Table 3.7-6) ($ per acft)	$145
Annual Cost of Treatment ($ per acft)	368
Total Annual Unit Cost of Treated Water	
($ per acft)	$513
($ per 1,000 gal)	$1.57

Table 3.7-13 summarizes the cost estimate for Round Rock to participate in the first phase of the twin 33-inch diameter raw water line option with treatment at an expansion of Round Rock's water treatment plant. The annual unit cost of the raw water line component would be about $187 per acft, and the treatment component would be $368 per acft. The estimated total annual unit cost would be about $555 per acft ($1.70 per 1,000 gal) with full utilization of the project capacity.

Table 3.7-13
Cost Estimate Summary for 33-inch Pipeline and Treatment at Round Rock
(1st Quarter 1997 Dollars)

Annual Cost of Raw Water Delivered to Lake Georgetown	
(single 33-inch pipeline)	$187
Annual Cost of Treatment ($ per acft)	368
Total Annual Unit Cost of Treated Water	
($ per acft)	$555
($ per 1,000 gal)	$1.70

Costs for Treated Water Delivered at Potential New Regional Water Treatment Plant

A potential new regional water treatment plant could be constructed to treat raw water from Lake Georgetown, including the water delivered from Lake Stillhouse Hollow. Possible participants for a plant supplied with a raw water intake on Lake Georgetown include Brushy Creek Municipal Utility District, Leander, Round Rock, Georgetown, and Jonah Special Utility District. With additional raw water supplies from other sources, other Williamson County water supply entities could potentially participate in a regional treatment plant.

Although a siting study for a regional treatment plant was not performed, a favorable location appears to be south of Lake Georgetown near FM 2243. A site near FM 2243 would be centrally located for delivery of treated water to Round Rock, Georgetown, and Leander. Treated water could then be supplied to Jonah SUD through Georgetown's distribution system and Brushy Creek could receive service through Round Rock's distribution system, or through a new water transmission pipeline.

Using a year 2010 planning horizon for a potential first phase, the combined peak day water demand of Round Rock, Georgetown, Jonah, Brushy Creek, and Leander is 86 mgd. Current total treatment capacity, including groundwater, for these entities is about 40 mgd. Therefore, a possible first phase regional treatment plant capacity is 46 mgd (i.e., 86 mgd demand - 40 mgd current capacity = 46 mgd required capacity).

For 46 mgd treatment capacity, the raw water pipeline would be 54-inch diameter and the length would be about 20,000 feet if the plant is located on FM 2243. The cost of a 46 mgd conventional water treatment plant is estimated to be $26,400,000. Table 3.7-14 contains the cost estimate summary for the regional treatment plant. The total project cost would be $47,360,000 and the total annual cost would be $8,190,000 including debt service, O&M, and power. For a peak day to average annual factor of 2.0, the 46 mgd plant would have an average annual delivery of about 23 mgd or about 25,760 acft/yr. The resulting annual unit cost for the average annual delivery is $318 per acft ($0.98 per 1,000 gal), not including the cost of raw water delivered from Lake Stillhouse Hollow.

Table 3.7-15 summarizes the cost estimate for participation in the regional plant and the 42-inch diameter raw water pipeline. The annual unit cost of the raw water line component would be about $145 per acft and the treatment component would be $318 per acft. The estimated total annual unit cost would be about $463 per acft ($1.42 per 1,000 gal) with full utilization of the project capacity.

Table 3.7-14
Cost Estimate Summary for Stillhouse Hollow Water Treated at a Potential New Regional Water Treatment Plant
(1st Quarter 1997 dollars)

Item	Cost
Capital Costs	
Intake and Raw Water Pipeline	$ 7,500,000
Water Treatment Plant	26,400,000
Total Capital Costs	$ 33,900,000
Engineering, Contingencies, and Legal	$ 11,490,000
Land Easements	75,000
Environmental Studies and Mitigation	75,000
Interest During Construction	1,820,000
Total Project Costs	$ 47,360,000
Annual Costs	
Annual Debt Service	$ 4,440,000
Annual Operation and Maintenance (Excluding Power)	3,532,000
Annual Power	218,000
Total Annual Cost of Treatment	$ 8,190,000
Total Annual Delivery[1]	25,760 acft/yr
Annual Unit Costs of Treatment	
($ per acft)	$318
($ per 1,000 gal)	$0.98

[1] Total annual water delivery based on plant capacity of 46 mgd and peak factor of 2.0 (i.e., 46 mgd ÷ 2 = 23 mgd annual average, or 25,760 acft/yr).

3.7.6 Implementation Issues

TNRCC approval must be obtained to change the point of diversion of the BRA water rights at Lake Stillhouse Hollow. TNRCC permit amendments will be needed to add a point of diversion at Lake Georgetown (regional treatment plant option only) and for increased diversion for municipal use.

Table 3.7-15
Cost Estimate Summary for 42-inch Pipeline and Treatment at New Regional WTP
(1st Quarter 1997 dollars)

Item	Cost
Annual Cost of Raw Water Delivered to Lake Georgetown (single 42-inch pipeline) (see Table 3.7-6) ($ per acft)	$145
Annual Cost of Treatment ($ per acft)	318
Total Annual Unit Cost of Treated Water	
($ per acft)	$463
($ per 1,000 gal)	$1.42

Requirements Specific to Pipelines

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 404 dredge and fill permit for stream crossings and lake intakes.
    b. GLO Sand and Gravel Removal permits.
    c. 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

Requirements Specific to Treatment and Distribution

1. Study is needed of the cost to integrate potential new supply into each participant's distribution system.
2. Necessary permits:
    a. Local construction permit
    b. No permit to treat and distribute water; however, the design must be approved by TNRCC and there are standards which must be met for water quality.

3.8 Purchase of Water from Brazos River Authority at Lake Granger Delivered to Lake Georgetown (B-6)

3.8.1 Description of Alternative

Lake Granger, located in eastern Williamson County, is one of 13 water supply reservoirs in the Brazos River Authority system. The reservoir is located on the San Gabriel River, tributary to the Little River. The Little River is a major tributary to the Brazos River and four other BRA water supply reservoirs are located in the Little River Basin: Lake Belton, Lake Proctor, Lake Stillhouse Hollow, and Lake Georgetown. The location of Lake Granger is shown in Figure 3.8-1.

Lake Granger was constructed by the U.S. Army Corps of Engineers (Corps), and is owned and operated by the Corps. The project was constructed for flood control and water supply purposes. Construction of the reservoir began in 1972 and impoundment started in 1980. At the conservation pool elevation of 504.0 ft-msl, the reservoir surface covers 4,400 acres and has a capacity[1] of 54,280 acft. At the top of the flood control pool, elevation of 528.0 ft, the reservoir surface area is 11,040 acres and stores 244,200 acft. The BRA has contracted with the Corps for the use of the water in the conservation storage space between elevations 504 ft-msl and 440 ft-msl. BRA directs the Corps on the operation of the reservoir within the conservation pool. The BRA holds the permit from the State of Texas for the right to impound water in the reservoir and divert water for municipal and other uses.[2] Diversions from Lake Granger are also governed by the BRA System Operation Order.[3]

The system order permits the BRA to operate tributary reservoirs (i.e., Lake Stillhouse Hollow, Lake Granger, Lake Georgetown, and others) as elements of a system under which releases can be coordinated with releases from main stem reservoirs to achieve most effective conservation and beneficial use of available stored water. Also governing diversions at Lake Granger is the Final Determinations document of the Brazos River Basin Adjudication. Of these three governing documents, the Final Determination limits maximum withdrawal from the lake to 19,840 acft/yr. Permitted uses for this water include municipal, industrial, agriculture, and mining.

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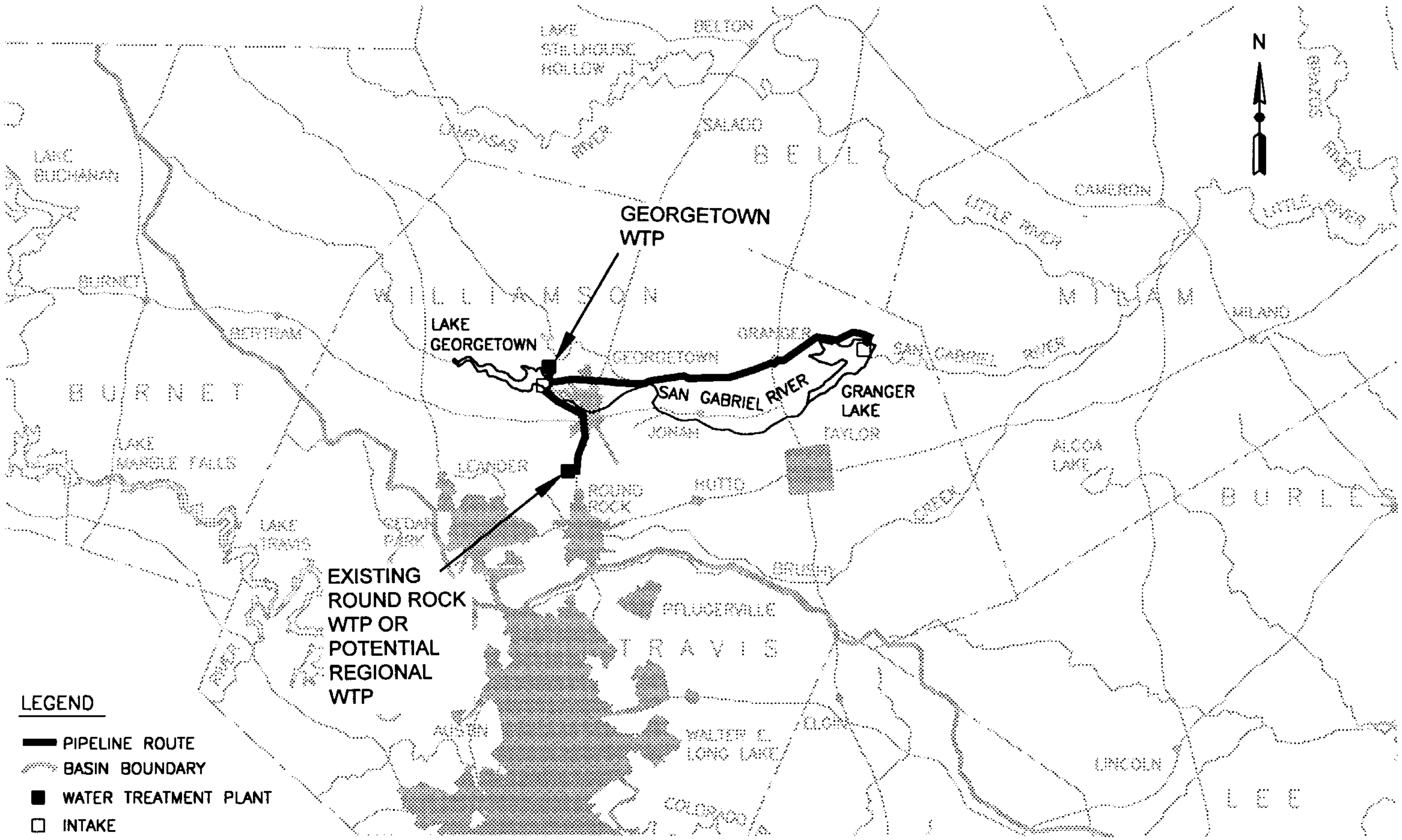
[1] Texas Water Development Board, Hydrographic Survey Program, May 1995.

[2] Permit No. 2366.

[3] System Operation Order, Texas Water Commission, July, 1964, as amended.



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**LAKE GRANGER
TO LAKE GEORGETOWN
ALTERNATIVE B-6**

FIGURE 3.8-1

Stored water from Lake Granger is available to municipal and industrial users under long-term contract with the BRA. The BRA charges a uniform cost for purchase of water from system reservoirs. The system cost is set annually by the BRA Board of Directors to cover debt and operating expenses throughout the BRA system. The BRA system price for water in 1996 is $19.27 per acft/yr.

This alternative involves consideration of the purchase and diversion of the uncommitted firm yield of Lake Granger to Lake Georgetown. The diversion would be made at a uniform annual rate. The augmented water supply at Lake Georgetown could then be treated and distributed in one of three ways: (1) at the City of Georgetown's Lake Treatment Plant, (2) at the Round Rock Water Treatment Plant, or (3) at a potential new regional water treatment plant. The location of Lake Granger and Lake Georgetown along with the proposed conveyance route are shown in Figure 3.8-1. The uncommitted firm yield at Lake Granger would be obtained by purchasing the water from the BRA at the system price.

3.8.2 Available Yield

The firm yield of Lake Granger was estimated for this study using the SIMYLD-II computer program. SIMYLD-II is designed to simulate the hydrologic operation of a system of reservoirs within a single river basin, or a multi-basin water resource system.[4] The input to the model includes elevation-area-capacity curves for the reservoir, inflow data sets, reservoir operating criteria, evaporation rates, and water demand patterns. Using a monthly time step, SIMYLD-II estimates the firm yield of a reservoir, or system of reservoirs, by minimizing water shortages to an acceptable level through the period of lowest inflows (i.e., "critical period"). Usually, the acceptable amount of shortages is zero, resulting in a firm yield of the reservoir that can be sustained through a repeat of the critical period. Appendix A contains the detailed hydrologic data used as model input for estimation of the firm yield of Lake Granger, as well as the 2050 firm yield runs for the critical drought period.

The firm yield of a reservoir will decrease with time as sediment from the reservoir catchment reduces the volume of the conservation pool. Table 3.8-1 contains the estimated firm yield of Lake Granger for years 1995, 2020, and 2050 sediment conditions.

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[4] SIMYLD-II, River Basin Simulation Model, Texas Water Development Board

Table 3.8-1 Lake Granger Firm Yield			
	Year		
	1995	2020	2050
Firm Yield[1]	20,600 acft/yr	18,500 acft/yr	15,800 acft/yr
[1] Firm yield is based on a sedimentation rate of 0.6 acft/yr/sq mi. See Appendix A for discussion of sedimentation rates and firm yield estimates.			

The critical period at Lake Granger occurred from 1954 to 1957. Figure 3.8-2 contains a plot of the reservoir contents through the critical period had the reservoir been constructed and supplying firm yield demands during this period. The reservoir contents plot was estimated for firm yield demands distributed on a typical municipal diversion pattern (i.e., a peak factor of 1.4). The upper portion of Figure 3.8-2 is a plot of reservoir spills that would have occurred during the critical period had the reservoir been in place.

Current Commitments

Presently, there are two long-term contracts for water from Lake Granger. The City of Taylor has a long-term contract for 6,721 acft/yr, and Del Webb-Sun City[5] has a contract for 15 acft/yr. Alcoa Aluminum Company holds a long term contract with BRA for purchase of 5,000 acft/yr at a diversion point on the Little River near Cameron. The Alcoa contract does not specify which BRA system reservoir is to supply this demand. The BRA could release water from any of the five reservoirs on the Little River to supply the Alcoa contract. However, the firm yield of Stillhouse Hollow Reservoir, Lake Georgetown, and Lake Belton is fully committed to meeting other long-term contracts. Lake Proctor, in Comanche County, is a local-use lake and does not supply water to BRA system contracts. Therefore, under current conditions, the only source of firm water remaining to satisfy the Alcoa contract is Lake Granger. The sum of long-term contracts committed to be supplied from Lake Granger totals 11,736 acft/yr.

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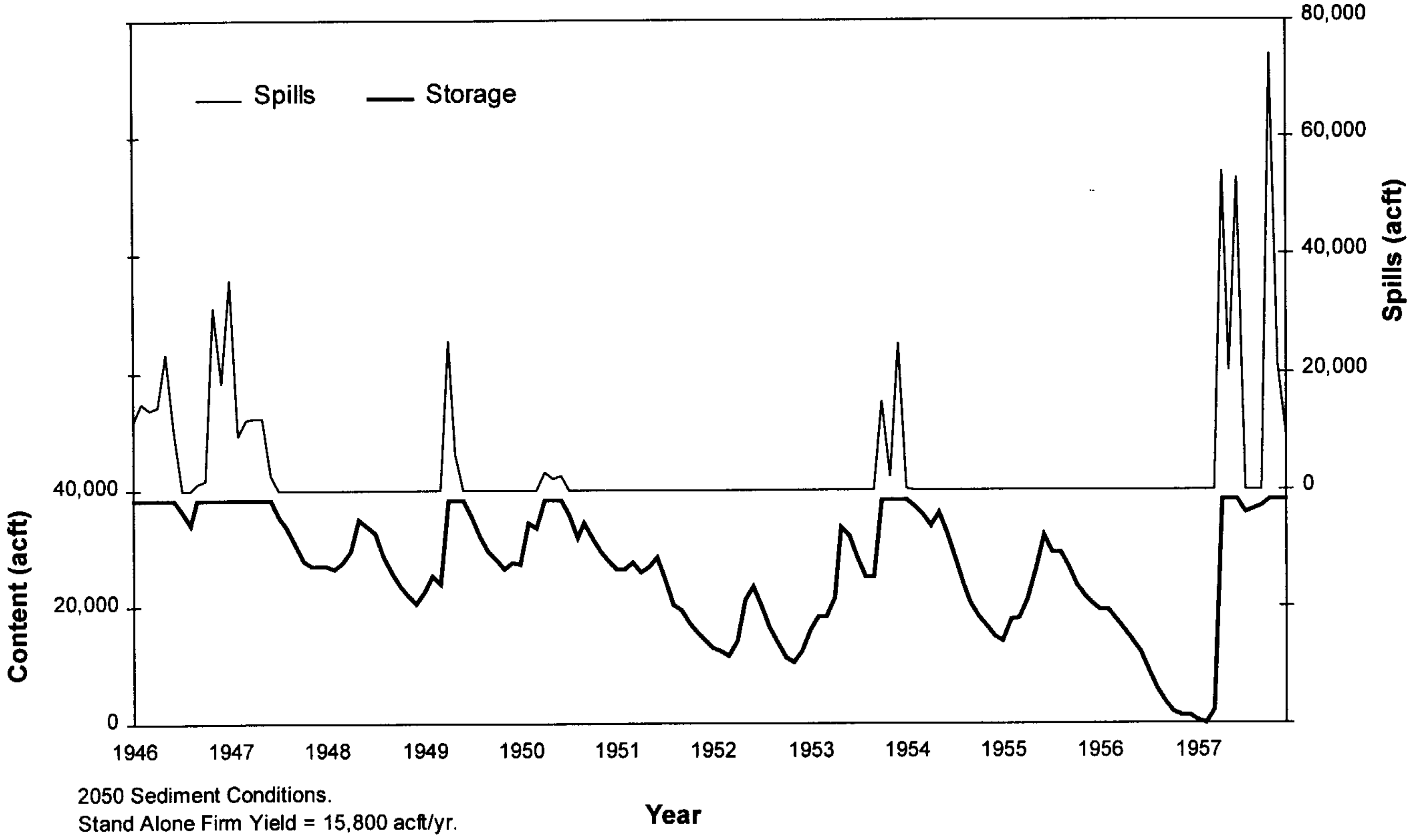
[5] Purchase contract is for Lake Granger yield reduction caused by impoundment in the Lake Granger watershed at Lake Granger.



2050 Sediment Conditions.
Stand Alone Firm Yield = 15,800 acft/yr.

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RESERVOIR CONTENTS AND SPILLS AT LAKE GRANGER 1946 - 1957

FIGURE 3.8-2

Supply Available for Transfer

The firm yield in Lake Granger in 2050 is estimated to be 15,800 acft/yr (Table 3.8-1). After meeting current commitments of 11,736 acft/yr, the remaining amount of water in Lake Granger available to augment supplies at Lake Georgetown in 2050 is approximately 4,060 acft/yr. Delivery of this quantity of water to Lake Georgetown at a uniform annual rate could be made with a 16-inch pipeline. Figure 3.8-3 indicates the small change in reservoir contents that diversion of 4,060 acft/yr from Lake Granger at a uniform annual rate will have compared to diversion at a municipal demand pattern.[6] The solid line in Figure 3.8-3 represents reservoir contents for firm yield demands at a municipal demand pattern (same plot as lower portion of Figure 3.8-2), and the dashed line is for delivery of 4,060 acft/yr at a uniform annual diversion rate with the remainder of the firm yield diverted at a municipal demand pattern.

System Operation

Prior to any potential use of water from Lake Granger, the Williamson County Raw Waterline will be in-place and will augment the supply of Lake Georgetown with water from Stillhouse Hollow Reservoir (see Alternative B-1, Section 3.7). Any consideration of use of Lake Granger water at Lake Georgetown should assume that the Stillhouse Hollow waterline is in place. Because a possible benefit of system operation (i.e., increased yield over standalone operation) could exist, a study was performed to determine potential benefits for system operation of Lake Granger, Lake Georgetown, and Lake Stillhouse Hollow. Results of this study show no increase in the firm yield of Lake Georgetown above its standalone yield. However, it should be noted that the inflow data sets used to simulate operation of Lake Granger and Lake Georgetown were derived from the same river gage. It is possible that refinements to inflows sets based on variations in local precipitation might provide opportunities for increased system yield. For instance, during September 1996, significant rainfall fell in the Lake Granger catchment which caused the lake to spill, while at the same time, Lake Georgetown had no significant inflow and remained below 50 percent capacity. Had a diversion from Lake Granger to Lake Georgetown been in place, a portion of the downstream spills could have been captured and stored in Lake Georgetown.

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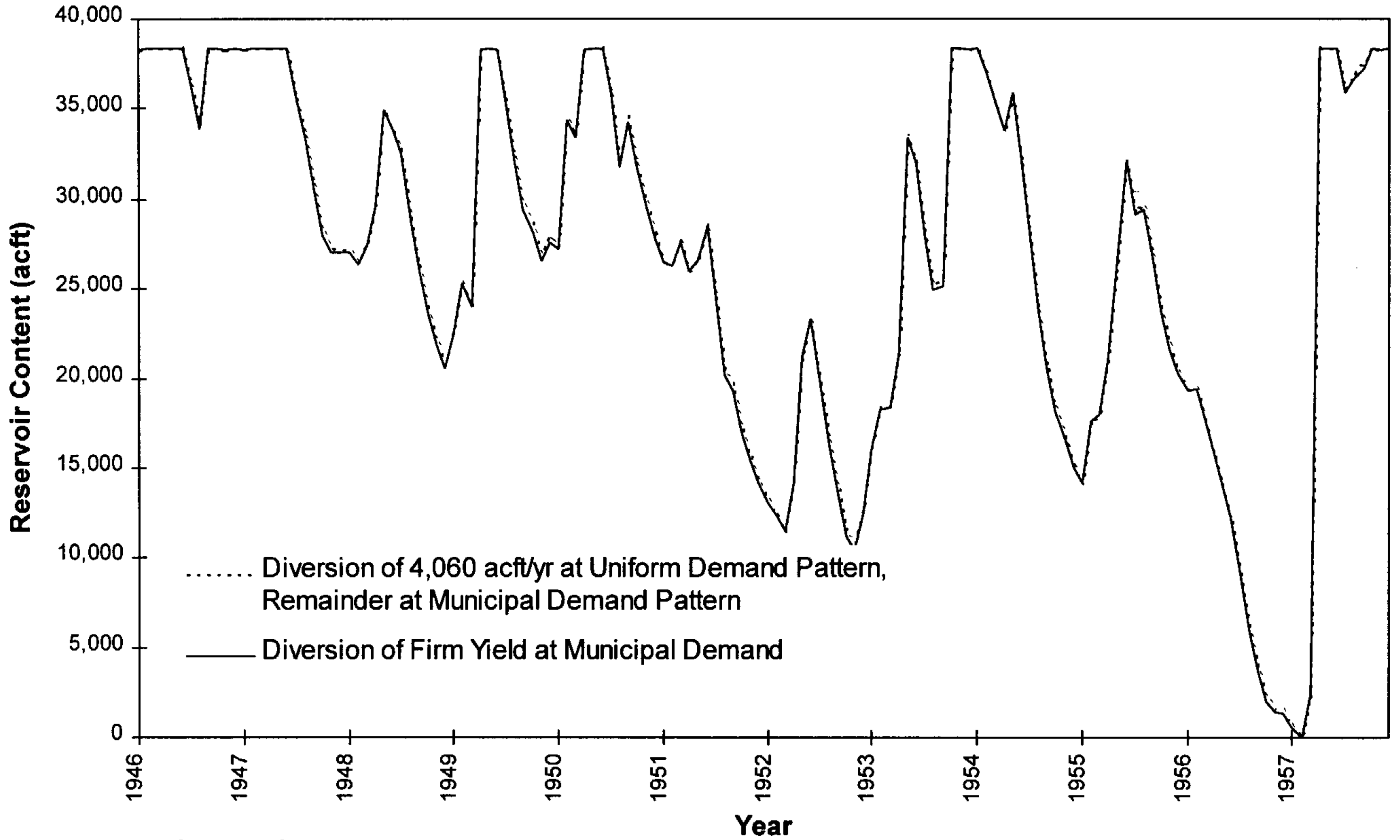
[6] Appendix A contains a plot of a typical municipal monthly demand pattern and a uniform annual demand pattern.



2050 Sediment Conditions.
Municipal Pattern has Summer Peak Factor of 1.4.
2050 Firm Yield is 15,800 acft/yr.

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DIVERSION FROM LAKE GRANGER AT UNIFORM AND MUNICIPAL DIVERSION PATTERNS

FIGURE 3.8-3

Conclusion

Because the amount of water available for transfer from Lake Granger is only 4,060 acft/yr, the unit cost of this project on a standalone basis will be higher than if a larger quantity of water were available. Lake Granger is a significant water resource in Williamson County and combining the water available at Lake Granger with other sources should be considered in order to create a larger project and possible economy of scale savings. Potential sources of water to augment the remaining Lake Granger uncommitted yield include diversion of water from Brushy Creek (see Alternative B-8, Section 3.10) and the Carrizo-Wilcox Aquifer (see Alternative CZ-2, Section 3.17).

3.8.3 Environmental

Environmental issues relevant to the diversion of water from Lake Granger to Lake Georgetown, both on the San Gabriel River, can be categorized as follows:

- Operational effects of transferring water from Lake Granger to Lake Georgetown.
- Effects of the construction and maintenance of a water transmission pipeline, and associated infrastructure from Lake Granger to Lake Georgetown.

Location, Water Quality, and Flow

Lake Granger is located downstream of Lake Georgetown on the San Gabriel River which is a tributary of the Brazos River. This alternative involves augmenting Lake Georgetown with water diverted from Lake Granger. As noted in Section 3.8.2, the projected amount of available water (considering BRA's permitted diversion, existing long-term commitments, and sedimentation rates) from Lake Granger is 13,104 acft in 2020 and 10,908 acft in 2050. Average discharge of the San Gabriel River at Laneport, Texas, downstream from Lake Granger was 148,500 acft/yr for the water years 1980 to 1990.[7] Because this alternative considers diverting water from Lake Granger under existing permits, resulting changes in reservoir operation and instream flow were not estimated as part of the Trans-Texas North Central Phase II Study. However, streamflow in the San Gabriel River below Lake Granger would be expected to decrease by the volume of water diverted from Lake Granger minus the additional volume of

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[7] USGS. 1990. Water Resources Data, Texas, Water Year 1990. Vol. 2. USGS Water-Data Report TX-90-2, Austin, TX.

treated wastewater returned to the river upstream from the lake as a result of implementing this alternative. Instream flows upstream from Lake Granger would increase by the volume of treated wastewater added as a result of this alternative. Obtaining permits to discharge water from Lake Granger into Lake Georgetown will require an investigation and analysis of water quality issues.

Existing nutrient loading rates into Lake Granger appear to be more than sufficient to ensure that eutrophic conditions are present there now.[8] Lake Granger inflows have averaged 271 cfs (196,195 acft/yr) and concentrations of total phosphorus and total inorganic nitrogen (nitrate + nitrite + ammonia) have averaged 0.6 and 0.46 mg/l, respectively over the period of record. However, Lake Granger is a broad, shallow, warm monomictic impoundment that is likely capable of sustaining higher than average rates of primary production without development of adverse consequences (i.e., algae bloom problems or excessive macrophyte growth, extensive areas of anoxic water and sediments, hydrogen sulfide formation, fish or waterfowl kills), at least during normal years when inflows may be sufficient to replace the whole volume of the lake four times. The lake will be more susceptible to these effects during dry periods when natural inflows are low and wastewater nutrient loadings continue to enter the reservoir at rates much higher than that expected from natural, dry weather flows.

In Lake Georgetown, annual phosphorus loading rates are already within the range commonly observed in eutrophic impoundments, but nitrogen inputs appear to be low enough to limit productivity to the mesotrophic range. Lake Georgetown is known to exhibit an anoxic summer hypolimnion, while this is a defining characteristic of eutrophic lakes in the northern temperate zones, high background phosphorus loads and anoxic summer bottom waters are common in Texas reservoirs of this size. The additional phosphorus loadings from Brushy Creek and Lake Granger will increase the probability that adverse environmental conditions could result from increased biological productivity in Lake Georgetown.

This alternative considers uniform and summer-peaking diversion scenarios. Generally, stream flow is lowest in summer when the demands placed on water supplies are the greatest. Thus, the summer-peaking diversion scenario might be expected to have a greater affect on lake fluctuation and instream flows downstream from the reservoir.

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[8] Wetzel, RG (1983): Limnology. Second ed. Saunders College Publishing, Philadelphia. 753 pages.

Land and Habitat

The majority of the pipeline route is in the Blackland Prairies Vegetational Area except for the section between Interstate 35 near the City of Georgetown and Lake Georgetown which is in the Edwards Plateau Vegetational Area. Descriptions of Lake Granger, Lake Georgetown, the Blackland Prairies, and Edwards Plateau are presented in the Environmental Overview (Section 3.1.3). Vegetational types crossed by the proposed pipeline have been described from east to west as cropland, silver bluestem-Texas wintergrass (*Bothrichloa saccharoides-Stipa leucotricha*), and oak-mesquite-juniper parks and woodlands. The majority of the proposed pipeline route courses through agricultural lands following existing ROWs.

Soils traversed by the proposed pipeline route include Branyon-Houston Black-Burlson, Austin-Houston Black-Castephen, Oakalla-Sunev, and Eckrant-Georgetown soils.[9] Branyon-Houston Black-Burlson soils are deep calcareous and noncalcareous, clayey soils formed in clayey alluvium, and marine clays and shales on ancient stream terraces and uplands. Oakalla-Sunev soils are deep calcareous, loamy soils formed in alluvium on bottom lands and stream terraces. These soils are found in the Blackland Prairies where the principal land use is for crop production, whereas the Eckrant Georgetown soils are located in the Edwards Plateau region. Eckrant-Georgetown soils are very shallow to moderately deep, calcareous and noncalcareous, stony, cobbly, and loamy soils formed in indurated fractured limestone on uplands.

Endangered and Threatened Species

Protected species and candidate species for protection reported to occur in Williamson County are presented in the Environmental Overview (Section 3.1.3). Several of the avian species listed are migratory birds which would be unlikely to be impacted by implementation of this alternative. These migratory species include the arctic peregrine falcon (*Falco peregrinus tundris*), American bald eagle (*Haliaeetus leucoecephalus*), interior least tern (*Sterna antillarum athalassas*), white-faced ibis (*Plegadis chihi*), whooping crane (*Grus americana*) and wood stork (*Mycteria americana*). These bird species are generally found near water. The American bald eagle, a species listed as threatened by both the USFWS and TPWD, is usually observed fishing

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[9] Soil Conservation Service. 1983. Soil Survey of Williamson County, Texas. USDA, SCS in cooperation with the Texas Agricultural Experiment Station.

from high perches near large bodies of water. Wading bird species include the whooping crane, a federal and state endangered species, and the white-faced ibis and wood stork are species listed as threatened by the State. These birds have a diet which is largely composed of small fish, frogs, and other aquatic species. Large river sandbars are frequent nesting sites for the interior least tern, while the arctic peregrine falcon is generally found in open areas near water. Both the arctic peregrine falcon and interior least tern are listed as endangered species by the federal government. Other bird species which need to be considered are the Golden-cheeked Warbler, and Black-capped Vireo both listed as endangered species.

The Golden-cheeked Warbler inhabits mature, old-growth Ashe juniper-oak wood having between 40 and 85 percent Ashe juniper.[10,11,12,13,14] The warbler requires strips of bark, which it gathers from mature Ashe juniper, for nest construction. Throughout most of its range, Texas oak is usually co-dominant with Ashe juniper, but other oaks may replace the Texas oak in some parts of its range. For example, at the northern extreme of the warbler's range, shin oak may dominate while in the southern extreme lacy oak increases in abundance.

The Black-capped Vireo, inhabits dry limestone hilltops, ridges, and slopes on the eastern and southern portions of the Edwards Plateau, but its nesting range extends into the canyons of the Stockman Plateau to the west, and north into central Oklahoma.[15,16,17] Vegetation typical of Black-capped Vireo habitat may include oaks, mountain laurel sumacs, redbud, Texas persimmon, Ashe juniper, mesquite, and agarita. However, species composition appears to be less important than the structure of the vegetative habitat. This is characterized by an open overstory of larger trees (e.g., oak and juniper) and an understory of broad-leaved shrubs having

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[10] Benson, R.H. 1990. Habitat Area Requirements of the Golden-cheeked Warbler on the Edwards Plateau. A Report to Texas Parks and Wildlife Department. Austin, TX.

[11] Campbell, L. 1995. Endangered and Threatened Animals of Texas. Resource Protection Division. Endangered Resources Branch. Texas Parks and Wildlife Dept. Austin, TX.

[12] Ladd, C.G. 1985. Nesting Habitat Requirements of the Golden-cheeked Warbler. Southwest Texas State University. Masters Thesis. San Marcos, TX.

[13] USFWS. 1994. Minimum Procedures for Determining the Presence/Absence of Golden-cheeked Warblers and Black-capped Vireos. U.S. Fish and Wildlife Service. Austin, TX.

[14] Wahl, R. D.D. Diamond and D. Shaw. 1990. The Golden-cheeked Warbler: A Status Review. A Final Report Submitted to Ecological Services. U.S. Fish and Wildlife Service, Fort Worth, TX.

[15] Campbell, L. 1995. Endangered and Threatened Animals of Texas. Resource Protection Division. Endangered Resources Branch. Texas Parks and Wildlife Dept. Austin, TX.

[16] Sexton, C.W. G.W. Lasley, J.A. Grybowski, and R.B. Clapp. 1989. Distribution and Status of the Black-capped Vireo in Texas. Unpublished Draft Report.

[17] TPWD. 1988. The Black-capped Vireo in Texas. Texas Parks and Wildlife Department. Austin, TX.

dense foliage from the ground to about 6 feet high. Black-capped Vireo habitat is mid-successional and usually develops after a disturbance such as fire or clearing. Such habitat can be created and maintained using appropriate management techniques. Nest parasitism by cowbirds and the destruction of nestlings by fire ants may have a greater impact on vireo populations than habitat availability.

Reptiles to be considered include the Texas horned lizard (*Phrynosoma cornutm*), Texas garter snake (*Thamnophis sirtalis annectens*), and Timber rattlesnake (*Crotalis horridus*). The Texas horned lizard is a species inhabiting arid and semi-arid regions having patchy, sparse vegetation. It is classified by both the Texas Parks and Wildlife Department and the Texas Organization for Endangered Species as a threatened species. The Texas garter snake is a species of concern found near water, wet meadows, marshes, and irrigation and drainage ditches. The Texas garter snake is active during the day and is most frequently seen amid moist vegetation where it searches for frogs, toads, salamanders, and earthworms.[18] A snake of the bottomland woodlands, the Timber rattlesnake, is often found in unsettled swampy areas and canebrake thickets. Their prey include squirrels, mice, and small birds.[19] The timber rattlesnake is listed as threatened by the State.

Files of the Texas Biological and Conservation Data System report an occurrence of the mountain plover (*Charadrinus montanus*) on the USGS Granger 7.5 minute quadrant map. The mountain plover inhabits shortgrass prairie, overgrazed pasture, plowed fields, and deserts.[20] It is a rare transient throughout Texas except in the eastern quarter of the state, and a rare winter resident in the southern-half of Texas. The mountain plover breeds in dry western great plains from southern Canada to western Texas and winters in California, Arizona, Texas, and northern Mexico. It is reported to nest in the vicinity of Granger Lake.[21] The mountain plover is classified as a species of concern by TPWD and TOES, and a candidate for listing by the USFWS. Also reported on the Granger map are Granger Wildlife Management Area (Texas Parks and Wildlife Department), Willis Creek Park (U.S. Army Corps of Engineers), and Taylor Park (U.S. Army Corps of Engineers).

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[18] Behler, J.L. F.W. King. 1979 The Audubon Society Field Guide to North American Reptiles and Amphibians

[19] Ibid

[20] Rappole, J.H. and G.W. Blacklock. 1994. A Field Guide. Birds of Texas. Texas A&M University. College Station, TX.

[21] Kutac, E.A. and S.C. Caran. 1994. Birds and Other Wildlife of South Central Texas. University of Texas Press, Austin, Texas.

Although there were no records of sensitive species or other features reported on the Weir 7.5 minute quadrant, numerous site records for sensitive species are reported on the Georgetown 7.5 minute quadrant map. The endangered species reported include troglobitic (cave adapted) arthropods. Two species listed are the Bone Cave harvestman *(Texella reyesi)* and Bee Creek Cave harvestman *(Texella reddelli),* both daddy long-legs. In addition to these two species, the Coffin Cave mold beetle *(Batrisodes texanus)* , Kretschmarr Cave mold beetle *(Texamaurops reddelli)* and Tooth Cave ground beetle *(Rhadine persephone)* are assigned endangered species status by USFWS. The Bone Cave harvestman inhabits the Temples of Thor, Flat Rock, Lair, Crevice, Sore-pea, Texella, Waterfall Canyon and Wolf's Rattlesnake Caves on the Georgetown quadrant map. The Coffin Cave mold beetle is known to inhabit Red Crevice Cave. These arthropod species are associated with Karst formations of the Balcones Escarpment. Issues involving endangered cave invertebrates are presented in Alternative L-8 (Section 3.6.3).

The Georgetown salamander (*Eurycea* sp.5), a species of concern, has been found in several sites along the San Gabriel River and its tributaries. This species also inhabits Cowan Spring Cave. Other *Eurycea* sp. of concern have been mapped at Bat Well Cave near Lake Georgetown.

A bat cave is reported on the Georgetown 7.5 minute quadrangle map as is the Guadalupe bass (*Micropterus treculi*). The Guadalupe bass is reported to occur in the San Gabriel River and is listed as a species of concern. Although the Guadalupe bass may occur in Lake Granger and/or Lake Georgetown it is better adapted to moving water and spawns in stream riffles.

Cultural Resources

A general discussion dealing with cultural resources of the Trans-Texas North Central Project Area is presented in the Environmental Overview (Section 3.1.3). 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.

Construction and Operation Effects of this alternative

Assuming a 140 foot wide construction ROW, the proposed water transmission pipeline of 27.9 miles in length would affect a total of 474 acres including 232 acres of crop (49 percent), 19 acres of grass (4 percent), 5 acres of brush (1 percent), 95 acres of park (20 percent), 57 acres of wood (12 percent), and 66 acres developed (14 percent). A ROW 40 feet wide maintained free of woody vegetation for the life of the project would affect a total of 135 acres including 66 acres of crop, 19 acres of grass, 1 acre of brush, 27 acres park, 16 acres of woods and 19 acres developed. Cropland and grassland could be returned to their original condition shortly after construction. Brushlands outside the maintenance ROW that are disturbed during construction would be expected to be reinvaded with brush if left undisturbed. Long-term effects of the construction ROW would be manifested primarily in the possible removal of parks or woodlands which tend to be limited to thin riparian strips.

In addition to wetland impacts resulting from the installation and operation of the intake and outfall, the proposed pipeline route crosses Willis Creek, Yankee Branch of Willis Creek, Opossum Creek, Berry Creek, Pecan Branch of the San Gabriel River, Weir Branch of the San Gabriel River, Mileham Branch of the San Gabriel River, the San Gabriel River and some small unnamed drainages and stock ponds. Most of these creeks are temporary and seasonally flooded.[22] However, Berry Creek, South Fork San Gabriel River and North Fork San Gabriel River are classified as riverine, lower perennial and having open water.[23] Total wetland acreage within the proposed water pipeline ROW would not be expected to exceed five acres including an acre each for the intake and outfall. A delineation of jurisdictional wetlands would be required to determine the actual acreage of wetlands impacted.

The proposed route of the water transmission line involves property owned by the U.S. Army Corps of Engineers, some of which is managed by Texas Parks and Wildlife Department. Additional requirements for pipeline construction on corps land include a Pollution Prevention Plan (PPP) prepared in accordance with the National Pollution Discharge Elimination System (NPDES) for the entire project.[24] The portion addressing the line on government fee land will

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[22] National Wetland Inventory maps.

[23] Ibid.

[24] Paul Price Associates, Inc. 1994. An Environmental Survey of the Proposed Lake Georgetown Raw Waterline Corridor. City of Round Rock. Round Rock, Texas. Appendix A. is a letter involving coordination with the USCOE on projects involving corps property.

require submission to the reservoir manager for approval. An inventory of all major vegetative resources will be necessary for use in restoring the area and/or mitigation of lost resources. A centerline description, or a metes and bounds description of the line, will have to be submitted to become an exhibit to the easement.

3.8.4 Water Quality

Since a significant portion of the water in Lake Granger comes from Lake Georgetown via the North Fork of the San Gabriel River, the water quality characteristics of the water are very similar. Table 3.8-2 compares some of the conventional water quality constituents in each reservoir. Although the TNRCC identifies chloride and sulfate levels as possible concerns in both reservoirs, they are well below the secondary drinking water standard of 300 mg/l for each.[25,26] A potential area of concern is the higher nutrient levels associated with the Lake Granger water. Since phosphorus is often the limiting nutrient in algal growth, augmenting Lake Georgetown with Lake Granger phosphorus levels could lead to increased algae growth in Lake Georgetown. Taste and odor problems as well as increased waste volumes from water treatment facilities are synonymous with higher algae densities.

Another possible concern with diverting Lake Granger water back upstream to Lake Georgetown is the potential for accumulating toxic constituents that previously would have been transported downstream for dilution or assimilation. Sparse data exists on the amount of toxic organics and metals in the two reservoirs, but traces of synthetic organic chemicals and metals such as zinc, copper, and lead have been measured in surrounding waters.[27] Also as the population grows in the area, possible increases in non-point source pollution associated with increases in population densities could occur. This could lead to detrimental affects on the local ecosystem as well as higher treatment costs.

Both sources are currently being used for public water supply and employ conventional surface water treatment methods (rapid chemical mix, flocculation, sedimentation, filtration, and disinfection). There is no indication that conventional treatment already employed for public water supply on Lake Georgetown would not be adequate to treat the Lake Granger and Lake

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[25] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.
[26] TNRCC, Chapter 290: Water Hygiene.
[27] Brazos River Authority, "Regional Assessment of Water Quality, Brazos River Basin including the Upper Oyster Creek Watershed," October, 1994.

Georgetown mixture. However, a detailed study of the water compatibility and future water quality should be undertaken before augmentation of Lake Georgetown with Lake Granger water is initiated.

Table 3.8-2
Conventional Water Quality Constituents in Lake Georgetown and Lake Granger[1]

Constituent	Lake Georgetown	Lake Granger
Dissolved Oxygen (mg/l)	8.00	8.08
pH (su)	8.05	7.92
TDS (mg/l)	232.00	245.90
Fecal Coliforms (No./100 ml)	53.67	65.62
Chloride (mg/l)	13.00	23.52
Sulfate (mg/l)	18.38	25.29
Total Phosphorus (mg/l)	0.03	0.06
Total Nitrogen[2] (mg/l)	0.06	0.46

[1] TNRCC, "Texas State Water Quality Inventory," November, 1994
[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

3.8.5 Engineering and Costing

This alternative considers the diversion of water from Lake Granger and transmission by pipeline to Lake Georgetown as shown in Figure 3.8-1. At Lake Georgetown the Lake Granger water could potentially be treated at either the Round Rock or Georgetown water treatment plants (Alternatives B-6A, B-6B), or at a regional treatment plant (Alternatives B-6C). From the regional treatment plant, the water could potentially be distributed to several water supply entities.

Water would be diverted from a new intake on the north shore of Lake Granger near the dam. The outfall would potentially be located off the north shore of Lake Georgetown sufficiently far away from the existing Georgetown water treatment plant intake to allow for blending of the Lake Granger and Lake Georgetown waters. The length of the pipeline is 147,500 ft (27.9 miles) and requires a static lift of 279 ft. The treatment capacity required for the 4,060 acft/yr is 7.3 mgd for a peak factor of 2.0 times the average day demand.

The major facilities to implement this project are:

- Reservoir Intake and Pump Station,
- Raw Water Pipeline from Lake Granger to Lake Georgetown,
- Increased intake and raw water pumping capacity for Round Rock and Georgetown,
- Expanded water treatment plant capacity for Round Rock and Georgetown,

- For a new regional treatment plant:
  - Lake Georgetown intake and pump station,
  - Raw water transmission pipeline,
  - Water treatment plant,
  - Treated water transmission pipeline.

Cost estimates are summarized in Table 3.8-3. The cost of adding 7.3 mgd of treatment capacity to one of the existing plants is conservatively estimated to be about the same as for construction of a new 7.3 mgd water treatment plant.

Table 3.8-3
Cost Estimate Summary for Purchase of Lake Granger Water Delivered to Lake Georgetown (B-6)
(1st Quarter 1997 dollars)

Item	Treatment at Expanded Georgetown WTP (B-6A)	Treatment at Expanded Round Rock WTP (B-6B) or Potential Regional WTP (B-6C)
Capital Costs		
Intake and Raw Water Pipeline	$ 7,520,000	$ 7,520,000
Pump Stations	1,210,000	1,210,000
Water Treatment Plant	7,890,000	11,480,000
Total Capital Costs	$ 16,620,000	$ 20,210,000
Engineering, Contingencies, and Legal	$ 5,470,000	$ 6,280,000
Land Easements	350,000	470,000
Environmental Studies and Mitigation	350,000	470,000
Interest During Construction	1,820,000	2,190,000
Total Project Costs	$ 24,610,000	$ 29,550,000
Annual Costs		
Annual Debt Service	$ 2,310,000	$ 2,770,000
Annual Operation and Maintenance (Excluding Power)	830,000	870,000
Annual Power	250,000	260,000
Purchase of Water from BRA	80,000	80,000
Total Annual Cost	$ 3,470,000	$ 3,980,000
Annual Project Yield	4,060 acft/yr	4,060 acft/yr
Annual Unit Cost of Treated Water		
($/acft)	$854	$980
($ per 1,000 gal)	$2.62	$3.01

Treatment at Expanded Georgetown Water Treatment Plant (B-6A)

For a uniform annual diversion, the delivery rate to Lake Georgetown would be about 3.8 mgd (assuming 5 percent down time for outages), requiring an 16-inch diameter transmission pipeline. The combined cost of the intake, pipeline and pump stations for delivery from Lake Granger to Lake Georgetown is $8,730,000. Using a peak day to average annual peak factor of 2.0, the raw water intake and transmission pipeline to the treatment plant would be sized to deliver 7.6 mgd, requiring a 24-inch pipeline. The raw waterline length from Lake Georgetown to the Georgetown treatment plant is about one-half mile (2,700-ft). The cost of 7.3 mgd of new or additional water treatment capacity is estimated to be $7,890,000. Total capital cost for the overall project would be $16,620,000 and the total project cost is $24,610,000. Financed at 8 percent for 25 years the annual debt service on this amount would be $2,310,000 with total O&M estimated to be $1,080,000. Total annual cost would be $3,470,000 which includes the purchase of 4,060 acft/yr from BRA at a unit cost of $19.27 per acft. The resulting annual unit cost for the overall project would be $854 per acft ($2.62 per 1,000 gal). It is instructive to note that this cost is divided roughly evenly between transmission cost and treatment cost.

Treatment at Expanded Round Rock Water Treatment Plant (B-6B) or Potential New Regional Water Treatment Plant (B-6C)

For a uniform annual diversion, the delivery rate to Lake Georgetown would be about 3.8 mgd (assuming 5 percent down time for outages), requiring an 16-inch diameter transmission pipeline. The combined cost of the intake, pipeline and pump stations for delivery from Lake Granger to Lake Georgetown is $8,730,000. Using a peak day to average annual peak factor of 2.0, the raw water intake and transmission pipeline to the treatment plant would be sized to deliver 7.6 mgd, requiring a 24-inch pipeline. The raw waterline length from Lake Georgetown to the Round Rock treatment plant is about 8 miles (44,000 feet). The cost of a raw waterline to the potential new regional water treatment plant was estimated to be the same as to the existing Round Rock treatment plant. The cost of 7.3 mgd of new or additional water treatment capacity is estimated to be $11,480,000. The total capital cost would be $20,210,000 and the total project cost is $29,550,000. Financed at 8 percent for 25 years the annual debt service on this amount would be $2,770,000 with total O&M estimated to be $1,130,000. Total annual cost would be $3,980,000 which includes the purchase of 4,060 acft/yr from BRA at a unit cost of $19.27 per acft. The resulting annual unit cost for the overall project would be $980 per acft ($3.01 per 1,000 gal). It is instructive to note that this cost is divided roughly evenly between transmission cost and treatment cost.

3.8.6 Implementation Issues

TNRCC approval must be obtained to change the point of diversion of the BRA water rights at Lake Granger. TNRCC permit amendments will be needed to add a point of diversion at Lake Georgetown (regional treatment plant option only) and for increased diversion for municipal use.

Requirements Specific to Pipelines

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 404 dredge and fill permits for stream crossings and lake intakes.
    b. GLO Sand and Gravel Removal permits.
    c. 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

Requirements Specific to Treatment and Distribution

1. Study is needed of the cost to integrate potential new supply into each participant's distribution system.
2. Necessary permits:
    a. Local construction permit
    b. No permit to treat and distribute water, however, the design must be approved by TNRCC and there are standards which must be met for water quality.

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3.9 Purchase and Transfer of Yield from Lake Somerville in the Brazos River Basin to the Colorado River (B-7)

3.9.1 Description of Alternative

This alternative considers the benefit of purchasing the uncommitted firm yield of Lake Somerville from the Brazos River Authority and diverting it to Cummins Creek, a tributary to the Colorado River near Columbus, Texas. This augmentation of the lower Colorado River Basin with water purchased from BRA would reduce the releases of inflows to the Highland Lakes that are required to meet senior downstream rights. Under the plan presented here, the diversion would be made during the months of the rice farming season generally April through September. This alternative would benefit study participants located near the Highland Lakes by lessening the Highland Lakes yield reduction associated with honoring downstream senior rights. The result is to increase the potential uncommitted yield of the Highland Lakes. This alternative would also benefit downstream diverters by increasing the availability of water to their run-of-river diversion rights. Both upstream and downstream interests would benefit from the reduction in losses and improved scheduling that can be achieved by providing additional supply closer to the major demands.

Lake Somerville is bounded by Washington, Burleson, and Lee Counties and is 1 of 13 water supply reservoirs in the Brazos River Authority system. The reservoir is located on Yegua Creek, a tributary to the Brazos River. The location of Lake Somerville and the proposed conveyance route are shown in Figure 3.9-1.

Lake Somerville was authorized by the Federal Flood Control Act and the Public Works Appropriation Act. The reservoir is owned and operated by the U.S. Corps of Engineers. The project was constructed for water supply and recreation purposes. Construction of the reservoir began in 1962 and impoundment started in 1967. At the conservation pool elevation of 238.0 ft-msl, the reservoir covers 11,456 acres and has a capacity[1] of 155,062 acft. The BRA holds a permit from the State of Texas for the right to impound water in the reservoir and divert water for

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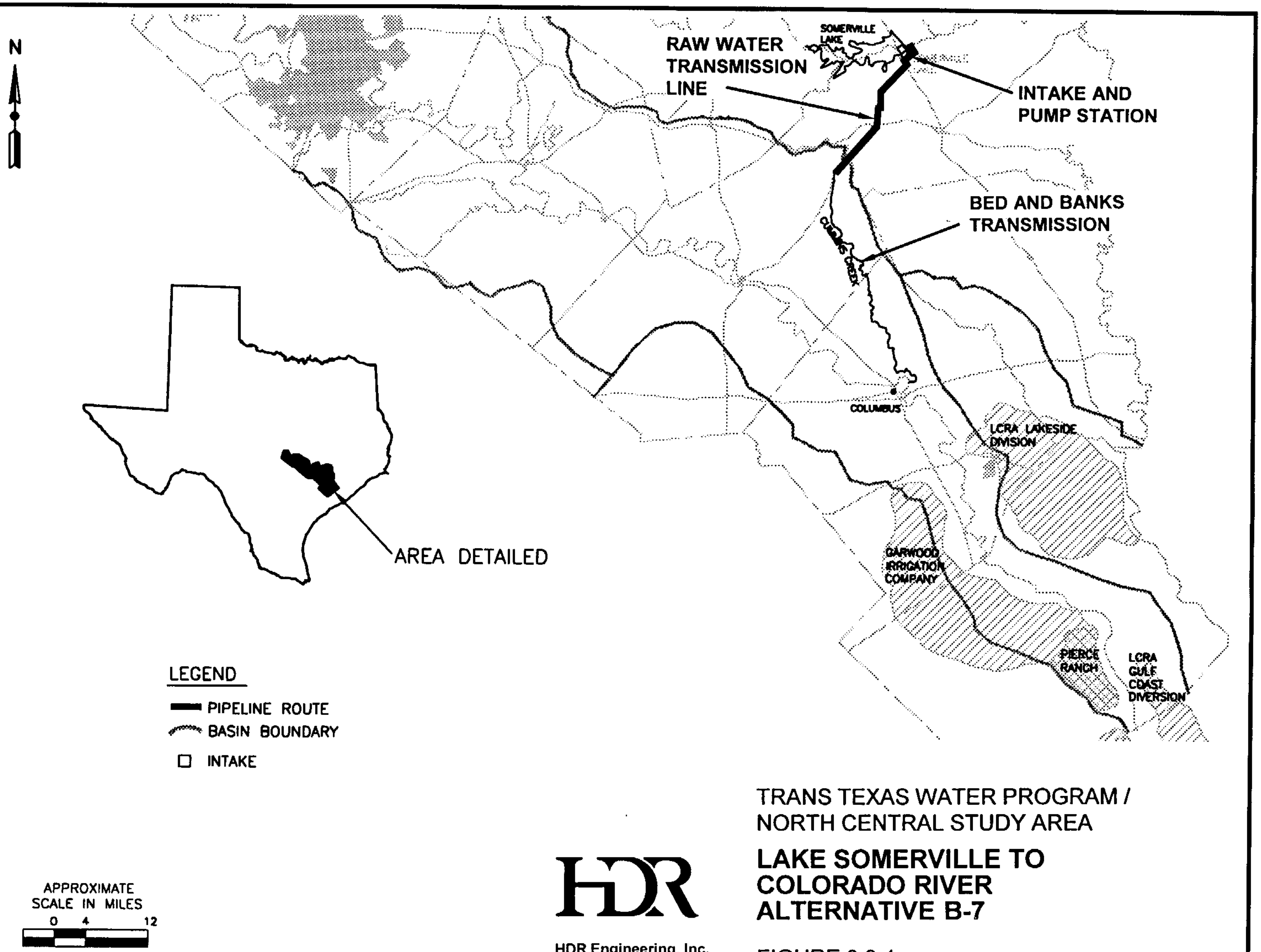
[1] Texas Water Development Board, Hydrographic Survey Program, November 1995.



HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

**LAKE SOMERVILLE TO
COLORADO RIVER
ALTERNATIVE B-7**

FIGURE 3.9-1

municipal and other uses.[2] Diversions from Lake Somerville are also governed by the BRA System Operation Order.[3]

The system order permits the BRA to operate tributary reservoirs as elements of a system under which releases can be coordinated with releases from main stem reservoirs to achieve the most effective conservation and beneficial use of available stored water. Also governing diversions at Lake Somerville is the Final Determinations document of the Brazos River Basin Adjudication. The Final Determination limits maximum withdrawal from the lake to 48,000 acft/yr. Permitted uses for this water include municipal, industrial, agriculture, irrigation, and mining.

Stored water from Lake Somerville is available to municipal and industrial users under long-term contract with the BRA. The BRA charges a uniform cost for purchase of water from system reservoirs. The system cost is set annually by the BRA Board of Directors to cover debt and operating expenses throughout the BRA system. The BRA system price for water in 1997 is $20.21 per acft/yr.

3.9.2 Water Availability

The benefit of augmenting the Colorado River with water diverted from Lake Somerville was investigated using the LCRA Response model to determine changes in water availability. The modeling was performed by LCRA staff at the direction of HDR. Details of this model are presented in Section 3.2. The yield of Lake Somerville in 2050 is estimated to be 35,100 acft/yr.[4] Currently, existing commitments from Lake Somerville total 4,619 acft/yr. These commitments are summarized in Table 3.9-1. The water available for diversion from Lake Somerville is, therefore, the remaining uncommitted legal withdrawal of 30,481 acft/yr. Under this alternative, the remaining uncommitted yield would be purchased from the BRA and would be pumped at a uniform rate from April through September of 84 cfs to Cummins Creek, a tributary of the Colorado River.

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[2] Permit to Appropriate Public Waters of the State of Texas, Amendment No. 2110B.

[3] System Operation Order, Texas Water Commission, July, 1964, as amended.

[4] Brazos River Authority, Long Term Planning Guide, March, 1996.

Table 3.9-1 Lake Somerville Summary of Water Supply Commitments and Supply	
Estimated 2050 firm yield	**35,100 acft/yr**
Commitments	
City of Brenham	4,484 acft/yr
City of Brenham - SWSA	135 acft/yr
Local Reserve	<1 acft/yr
Total Commitments	4,619 acft/yr
Uncommitted Yield Available	**30,481 acft/yr**

Based on an average diversion of 84 cfs (for 6 months), channel losses for Cummins Creek are estimated to be 0.65 percent per mile.[5] This loss rate is based on channel loss data for several streams of varying size and location in Central Texas. Soil maps for the Cummins Creek area indicate that the area is predominantly overlain with clay. Therefore, low losses from infiltration would be expected. A loss rate of 0.65 percent per mile is believed to be somewhat conservative (high) considering this information. Total losses over the approximate 34-mile creek route would therefore be about 22 percent or 6,710 acft/yr. The amount of water reaching the Colorado River would then be about 65 cfs (for 6 months) or 23,700 acft/yr.

Water made available by the delivery of Lake Somerville water to the Colorado River was evaluated over the 10-year critical period for the Highland Lakes of 1947 to 1956. Water made available to the Highland Lakes by this operation is estimated to be 10,000 acft/yr. Similarly, additional water would be made available to the senior downstream rights and the City of Austin of 13,400 acft/yr and 5,700 acft/yr, respectively. The total potential benefit is therefore 29,100 acft/yr. Table 3.9-2 compares the water availability in the basin both with and without the diversion project.

The increased yield available from this project and the quantity used for calculation of the unit cost of water is the sum of the benefits to Austin's run-of-river rights, Highland Lakes yield, and to other senior water rights. This total benefit is 29,000 acft/yr (Table 3.9-2).

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[5] HDR Engineering, Inc., "Recharge Enhancement Study, Guadalupe-San Antonio River Basin, Technical Report, Vol. II," Edwards Underground Water District, September, 1993.

Table 3.9-2
Water Availability in the Colorado River Basin with Augmentation from Lake Somerville
Averages for the Period of 1947-1956 in acft/yr

Diverter	Without Delivery From Somerville	With Delivery From Somerville	Water Made Available
City of Austin	166,900	172,600	5,700
Other Senior Rights	286,900	300,300	13,400
Highland Lakes Yield	445,300	455,300	10,000
Total	899,100	928,200	29,100
Flow to Matagorda Bay	*279,800*	*282,000*	*2,200*

3.9.3 Environmental Issues

This section discusses the environmental issues relevant to the purchase of uncommitted firm yield from Lake Somerville and diverting the water, via pipeline, to a tributary of the Colorado River. The environmental concerns of this project are associated with the potential effects listed below.

- Effects of the construction and maintenance of a pipeline from Lake Somerville to the outfall in the Colorado River Basin.
- Effects related to the transfer of water from the Brazos River Basin to the Colorado River Basin.
- Effects related to diverting water from Lake Somerville, including effects on the lake, downstream tributaries, and the Brazos River estuary.
- Effects related to increased flow in Cummins Creek, the Colorado River, and the Lavaca-Matagorda Bay estuary.

General Description of the Environment of Washington and Fayette Counties

Burleson, Washington, and Fayette Counties lie within the South Central climate of Texas.[6] The climate has a uniform seasonal pattern of rainfall with slight maximums occuring in May and September. Due to the proximity to the coast and its warm air masses, temperatures do not range greatly. Temperatures can be expected to reach 100°F in the summer. Winter temperatures rarely fall below 10°F and some freezes can be expected each winter. Approximately 68 percent to 86 percent of the year is freeze-free.

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[6] Natural Fibers Information Center in cooperation with the Office of the State Climatologist. 1987. The Climates of Texas Counties. Bureau of Business Research, Graduate School of Business, the University of Texas at Austin, Austin, Texas.

The northwestern halves of Fayette and Washington Counties lie within the Post Oak Savannah, while the southeastern halves of Fayette and Washington Counties lie within a band of the Blackland Prairie vegetational area.[7] Lake Somerville is located in the Post Oak Savannah ecoregion along the Burleson-Washington County line in northwest Washington County (Figure 3.9-1). The transmission pipeline from Lake Somerville traverses western Washington County and northeast Fayette County before it reaches Cummins Creek. The transmission pipeline lies within the transition zone between the Post Oak Savannah to the northwest and the Blackland Prairie to the southeast[8].

Topography of the Post Oak Savannah is gently rolling to hilly. Soils on the uplands 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 in native or improved pastures, but small farms are common. Climax grasses include little bluestem (*Schizachyrium scoparium* var. *frequens*), Indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), purpletop (*Tridens flavus*), silver bluestem (*Bothriochloa saccharoides* var. *torreyana*), Texas wintergrass (*Stipa leucotricha*), and narrowleaf woodoats (*Chasmanthium sessiliflorum*). The overstory is primarily post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*). Many other brush and weedy species are also common. Some invading plants are red lovegrass (*Eragrostis oxylepis*), broomsedge (*Andropogon virginicus*), splitbeard bluestem (*Andropogon ternarius*), yankeeweed (*Eupatorium compositifolium*), bullnettle (*Cnidoscolus texanus*), greenbrier (*Smilax* sp.), yaupon (*Ilex vomitoria*), smutgrass (*Sporoboulus indicus*), and western ragweed (*Ambrosia trifida*).

The Blackland Prairie vegetational area is considered a true prairie with little bluestem as a climax dominant. Other important grasses include big bluestem (*Andropogon gerardii*), Indian grass, switchgrass, sideoats grama (*Bouteloua curtipendula*), hairy grama, (*Bouteloua hirsuta*), tall dropseed (*Sporoboulus asper*), silver bluestem, and Texas wintergrass. Under heavy grazing, Texas wintergrass, buffalograss (*Buchloe dactyloides*), Texas grama (*Bouteloua rigidiseta*), smutgrass, and many annuals increase or invade these areas. Mesquite also has invaded hardland sites of the southern portion of the Blackland Prairies. Post oak and blackjack oak increase on

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

[8] McMahan, C.A., R.G. Frye and K.L. Brown. 1984. The Vegetation Types of Texas Including Cropland. TPWD, Austin, Texas.

the medium-to-light-textured soils. Although classified as a true prairie, the Blackland Prairie has substantial amounts of timber, especially along the streams that traverse it. Common tree species include a variety of oaks, pecan (*Carya illinioensis*), cedar elm (*Ulmus crassifolia*), bois d'arc (*Maclura pomifera*), and mesquite (*Hilaria berlangeri*).

Soils along the pipeline route in Washington County are classified as mostly "well drained and somewhat poorly drained, loamy soils, on uplands and terraces" between Lake Somerville and the City of Burton, and "well drained and moderately well drained clayey and loamy soils on uplands" between Burton and the terminus of the water transmission pipeline.[9] More specifically, the soils between Lake Somerville and the City of Burton were classified as Falba-Burlewash soils which are moderately deep, gently sloping and sloping, strongly acid and very strongly acid, loamy soils.[10] The soils between the City of Burton and the Washington County line are represented by Carbengel-Freisburg-Renish (deep, gently sloping to strongly sloping, moderately alkaline, clayey soils) and Freisburg-Latium (deep to very shallow, gently sloping and strongly sloping, moderately alkaline, loamy and clayey soils) soil associations.[11]

The four bodies of water affected by this alternative are Lake Somerville, the Brazos River Basin downstream of Yegua Creek, Cummins Creek, and the Colorado River Basin. Lake Somerville reservoir is a 155,062 acft capacity impoundment on Yegua Creek in Burleson, Lee, and Washington Counties located south of Somerville, Texas. At 238 ft-msl, the 11,456-acre impoundment was built in 1972 by the U.S. Army Corps of Engineers for the purpose of municipal water use, irrigation, and flood control. Recreational facilities operated by the U.S. Army Corps of Engineers provided swimming areas, boat ramps, picnicking, and camp sites for over 15 million visitor hours in 1994.[12] Drainage area above Lake Somerville reservoir is 1,006 square miles.[13]

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[9] Natural Resources Conservation Service. 1981. Soil Survey of Washington County, Texas. U.S. Department of Agriculture, Natural Resources Conservation Service in cooperation with the Texas Agricultural Experiment Station, College Station, Texas.

[10] Ibid.

[11] Ibid.

[12] Ramos, Mary G. (ed.). 1995. 1996-1997 Texas Almanac. Dallas Morning News, Inc., Communications Center. Dallas, Texas.

[13] Webb, M.A and J.C. Henson. 1995. Survey Report for Lake Somerville, 1994. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas.

The Brazos River Basin is bounded on the north by the Red River Basin, on the east by the Trinity and San Jacinto river Basins and the San Jacinto-Brazos Coastal Basin, and on the south and west by the Colorado River Basin and the Brazos-Colorado Coastal Basin. Major population centers in the Brazos River Basin include the Cities of Lubbock, Abilene, Waco, Temple-Killeen, Bryan-College Station, Round Rock, Georgetown-Cedar Park-Leander, Sugarland-Richmond-Rosenburg and the Brazos port area. There are 33 major water supply reservoirs in the Brazos River Basin. Water is also imported from the Canadian and Colorado Basins. The BRA owns, operates, or has acquired storage in 13 of the reservoirs as part of its basin-wide water system to supply water for in-basin uses and exports to the Trinity and San Jacinto-Brazos Basins.

Cummins Creek is a heavily wooded second-order tributary of the Colorado River that flows through Lee, Fayette and Colorado counties. It consists of intermittent headwaters in its upper reaches, becoming perennial in Fayette County.[14] The confluence of Cummins Creek and the Colorado River is near Columbus, Texas in Colorado County.

The Colorado River Basin is bounded on the north and east by the Brazos River Basin, on the south and west by the Lavaca, Guadalupe, Nueces, and Rio Grande Basins. The Colorado River Basin has 26 major water supply reservoirs. Major water suppliers in the basin are the Colorado River Municipal Water District, Lower Colorado River Authority (LCRA), and irrigation companies in the lower part of the basin. The LCRA and irrigation companies export water to areas in the Brazos-Colorado, Colorado-Lavaca, and Lavaca Basins.

Construction Effects

Portions of the aquatic ecosystem of Lake Somerville can be expected to be impacted by implementation of this alternative. Floating and emergent aquatic vegetation covering about 85 acres was observed by TPWD in 1994 in Lake Somerville.[15] Lake Somerville tends to have extensive shallows.[16] Changes in water levels during extreme drought periods already strand established vegetation beds, diversions from April to September would exacerbate these conditions.

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[14] USGS. 1954. 1:250,000 Scale Topographic Map, Austin Sheet, NH 14-6. USGS, Reston, Virginia, revised 1974.
[15] USGS. 1954. 1:250,000 Scale Topographic Map, Austin Sheet, NH 14-6. USGS, Reston, Virginia, revised 1974.
[16] Ibid.

Hybrid striped bass, white bass, largemouth bass, blue catfish, channel catfish, and flathead catfish are important to the fishery of Lake Somerville.[17] Other fish species reported by TPWD include spotted gar, longnose gar, gizzard shad, threadfin shad, inland silverside, blacktail shiner, common carp, smallmouth buffalo, bluegill, longear sunfish, largemouth bass, yellow bass, and freshwater drum.[18]

The proposed route for the water transmission line would mostly follow existing state and county roads, and would be about 22.4 miles long. A worse case 140 foot wide construction corridor the length of the pipeline would affect a total of 380.3 acres including 195.5 acres of cropland (51.4 percent), 93.9 acres of woods (24.7 percent), 46.0 acres of park (12.1 percent), 3.4 acres of grass (0.9 percent), 31.9 acres developed (8.4 percent), and 9.5 acres of wetland (2.5 percent). A 40-foot wide ROW maintained free of woody vegetation would affect 108.7 acres, classified as described in Table 3.9-3. Impacts of grass and crops may be negligable. Good construction techniques return topsoil to the surface and restablish preconstruction contours. The depth of the line is sufficient to return to the corridor to agricultural uses. Clauses in construction easement agreements could support a return of pasture and crop land to previous use.

Table 3.9-3
Physiognomic Classification of the Transmission Pipeline ROW

Vegetation Classifications	Raw Data Units	% Coverage	Acres
Developed	210	5.9	6.4
Asphalt	90	2.5	2.7
Grass	30	0.9	1.0
Crops	1825	51.4	55.8
Park	430	12.1	13.1
Woods	875	24.7	26.8
Water	90	2.5	2.7
Total	3550	100.0	108.7
Total Area Calculations	108.7 total acres in pipeline ROW		

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[17] Ibid.
[18] Ibid.

Endangered and threatened species that may be encountered in Burleson, Washington, and Fayette Counties are listed in the Environmental Overview (Section 3.1.3). Within the dense riparian forests lining the rivers and creeks, two species are of concern: the timber rattlesnake and the interior least tern. The State-threatened timber rattlesnake is normally found in dense cover bottomland woodlands. The numerous depositional midstream bars visible on Cummins Creek in the aerial photographs provide potential nesting habitat for the endangered interior least tern if the bars are composed of sand.

The blue sucker, a State-threatened fish species, and the smalleye shiner, a fish species of concern, should not be present in Lake Somerville or Cummins Creek but could inhabit the Colorado River. As fish that prefer faster water and larger rivers, increased flows would not adversely affect these species.

The Navasota Ladies'-tresses is an orchid found in parts of the Post Oak Savanna associated with the Navasota and Brazos Rivers.[19] This orchid prefers the slightly eroded, moist sandy soils[20] of small openings along wooded intermittent streams.[21] The Navasota Ladies'-tresses is endangered due to habitat loss, degradation associated with development and road construction, its limited range, and its low numbers of individuals.[22] Should this alternative be recommended for further study, a pedestrian survey of the pipeline routes by a biologist familiar with the Navasota Ladies'-tresses habitat is highly recommended while it is flowering (mid-October to mid-November[23]) to ensure identification and protection in Washington County.

The Houston toad (*Bufo houstonensis*) habitat is known to occur in Washington County. The current alignment of the transmission pipeline should not enter the sandy uplands typical of the Houston toad habitat.[24] The sandy loams of Washington County are found more than 5 miles to the east of the current alignment. For a more detailed discussion of the Houston toad and its preferred habitat, see sections 3.16.3 and 3.17.3.

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[19] Arroyo, Brian. 1992. Threatened and Endangered Species of Texas. U.S. Fish and Wildlife Service, Texas State Office, Austin, Texas.
[20] Ibid.
[21] Poole, Jackie M. and David H. Riskind. 1987. Endangered, Threatened, or Protected Native Plants of Texas. Texas Parks and Wildlife Department, Austin, Texas.
[22] Arroyo, Brian. 1992. Threatened and Endangered Species of Texas. U.S. Fish and Wildlife Service, Texas State Office, Austin, Texas.
[23] Ibid.
[24] Campbell, L. 1995. Endangered and threatened Animals o Texas. Their Life History and Management. TPWD. Austin, Texas.

The water transmission pipeline would follow a course roughly along the border of the Post Oak Savannah and Blackland Prairies Vegetational Areas from Lake Somerville near the Burleson-Washington County line to Cummins Creek in Fayette County. Vegetational habitats potentially affected by construction and operation of a water transmission pipeline along the proposed route have been reported as post oak woods and forests, post oak woods, forests and grassland mosaic, and other natural and/or introduced grasses.[25] Due to the diversity of habitat encountered in the transmission ROW, the land use proportions reported in Table 3.9-3 will vary considerably depending upon final selection of the pipeline route.

Operational Effects

With implementation of this alternative, Lake Somerville will be expected to have 30,481 acft/yr available for purchase by the year 2050. This quantity would be pumped from Lake Somerville at the proposed constant rate of 84 cfs from April through September. The total diversion is approximately 20 percent of the total capacity of Lake Somerville at conservation pool elevation of 238.0 ft-msl (155,062 acft).[26] Monthly diversions of 5,080 acft/mo would remove 2 percent of the water from the lake. Lake Somerville is a warm monomictic lake with a mean depth of 11 feet and a maximum depth of 38 feet.[27]

Fish populations may be affected by the diversions if their spawning habitats are significantly affected. There should be no effect on either major sport game fish in this lake, the hybrid striped bass or the white bass,[28] since the hybrid striped bass are reproductively unsuccessful and the white bass spawn in the tributary streams during the spring floods from February through April.[29] Potential biological effects of increased water level fluctuations include disruption of nesting in fish species that utilize shallow littoral areas. The significance of the impact is strongly dependent on the amount, rate, and timing of the change in water level.

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[25] McMahan, C.A., R.G. Frye and K.L. Brown. 1984. The Vegetation Types of Texas Including Cropland. TPWD, Austin, Texas.

[26] Texas Water Development Board, Hydrographic Survey Program, November 1995.

[27] Webb, M.A and J.C. Henson. 1995. Survey Report for Lake Somerville, 1994. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas.

[28] Ibid.

[29] Tinsley, Russell. 1988. Fishing Texas: an Angler's Guide. Shearer Publishing, Fredricksburg, Texas.

The five bottom nesting fish found in Lake Somerville[30] are white crappie, black crappie, bluegill, longear sunfish, and largemouth bass.[31] To impair reproductive success in these species, drawdowns must be: (1) sufficiently severe to strand active nests, (2) sufficiently rapid that newly established nests are stranded prior to development of a free swimming stage, and (3) changes in water level must continue to occur throughout a significant portion of the reproductive season. Table 3.9-4 shows the particular restrictions associated with each species.

Table 3.9-4

Descriptions of Spawning Nests of Bottom Nest Spawners[32] Found in Lake Somerville

	White Crappie	Black Crappie	Bluegill	Longear Sunfish	Largemouth Bass
Maximum nest depth	6 feet	18 feet	3 feet	2 feet	5 feet
Maximum length of nesting cycle per nest	8 days	8 days	10 days	14 days	14 days
Reproductive season in Texas reservoirs	late March to early May	late March to early May	March to September	May to mid-August	December to May

The spawning periods of white crappie, black crappie, and largemouth bass would overlap the period of diversion only during the months of spring flooding. For this reason, it is not likely that these species' spawning would be affected by diversion withdrawals from the reservoir. Both bluegill and longear sunfish exhibit extended spawning periods roughly coinciding with the diversion period (April to September). As long as the drawdowns do not cause lake levels to fall faster than 2 feet in 14 days for extended periods, at least some bluegill and longear sunfish nesting would be successful.

The largemouth bass populations should be unaffected by this alternative. The majority of their spawning season does not occur within the months of proposed diversions and the 2 months that do overlap are during spring flooding events when diversions should least impact the Lake Somerville aquatic ecosystem.

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[30] Webb, M.A and J.C. Henson. 1995. Survey Report for Lake Somerville, 1994. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas.

[31] Carlander, Kenneth. 1977. Handbook of Freshwater Fishery Biology, Volume 2. Iowa State University Press, Ames, Iowa.

[32] Carlander, Kenneth. 1977. Handbook of Freshwater Fishery Biology, Volume 2. Iowa State University Press, Ames, Iowa.

Implementation of this alternative would decrease flows to the Brazos River Basin. Comparing the diversion to the average annual discharge (3,733,000 acft/yr[33]) measured at the USGS gage on the Brazos River below the confluence of Yegua Creek, diverting 30,000 acft/yr from the Brazos River would decrease the Brazos River's average annual discharge by 1 percent and thus, would not have a measurable effect on the aquatic organisms of the Brazos River or the Gulf of Mexico.

Increased Flows to Cummins Creek and the Colorado River Basin

There is currently no flow data available for Cummins Creek. It is difficult to adequately analyze the environmental impacts to this stream without knowing whether the diversion will increase streamflow by 2 percent or 200 percent. Additional studies of Cummins Creek are recommended if this alternative is given further consideration.

The LCRA has existing criteria for minimum instream flows and interim criteria for minimum bay and estuary inflows.[34] Two separate environmental instream flow criteria, critical flows and target flows, have been established in the Colorado River below Austin based on fisheries habitat needs in segments designated on the basis of studies conducted by LCRA staff. Critical flows (Table 3.9-5) are maintained by releasing inflows or stored water from the Highland lakes as needed to maintain daily river flow at the Bastrop gage to be no less than the established critical instream flow in all years.

Target flows (Table 3.9-5) which vary monthly have been established for three points in the basin including the Austin gage, Bastrop gage, and Columbus gage. In wetter years when water supplies for the four major irrigation districts are not curtailed, inflows to the Highland Lakes are released on a daily basis to maintain river flows at the target instream flow.

The bay and estuary interim criteria is to maintain a minimum annual inflow of 272,000 acft to Matagorda Bay, a minimum seasonal inflow of 375 cfs, and a minimum mean monthly inflow of 200 cfs. Flow criteria are summarized in Table 3.9-5.

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[33] USGS. 1996. Water Resources Data, Texas Water Year 1995, Volume 2. Austin, Texas. USGS Water-Data Report TX-95-2. Average annual discharge over 17 years (1965-1983) at gage #08110200 was 3,733,000 acft/yr.

[34] Lower Colorado River Authority, Water Management Plan for the Lower Colorado River Basin, 1993.

Table 3.9-5

Natural Resource Flow Criteria for the Lower Colorado River[35]

	Colorado River Instream Flows		
Critical Flows	15 April to 31 May - 500 cfs minimum at Bastrop gage	All Other Times - 120 cfs minimum at Bastrop gage	To be met at all times with inflows or stored water from highland lakes
Target Flows	Established at 3 gages (Austin, Bastrop and Columbus)	Flow targets vary monthly	To be met with highland lakes inflows during years when there is no curtailment of downstream irrigators
	Matagorda Bay and Estuary Inflows		
Minimum Annual Inflow	272,000 acft/year		
Mean (Min) Seasonal Inflow	375 cfs		
Mean (Min) Monthly Inflow	200 cfs		

Figures 3.9-2 through 3.9-4 present summaries of the hydrologic effects of this alternative at three locations on the lower Colorado River: the Bastrop and Columbus gages, and inflows to Matagorda Bay. Each figure contains two bar graphs, one showing median monthly streamflows, the other showing total annual streamflows sorted into deciles (a decile is an interval or range of flows that amounts to 10 percent of the total range of annual flows for the period of record). Each bar graph depicts hydrologic statistics for a Base Case, or "without project," condition that is constant across all alternatives and scenarios, and a "with project" condition based on the same period of record. The "without project" or Base Case condition is represented by current basin conditions with full permitted diversions. Changes in median streamflow and Matagorda Bay inflow expected to result from implementation of the alternative are shown in Figure 3.9-5.

For evaluation of environmental effects of the variations of this alternative, the "without project" or Base Case condition is represented by current basin conditions with full permitted diversions. For the Base Case, the daily critical flow would not be met at the Bastrop gage for

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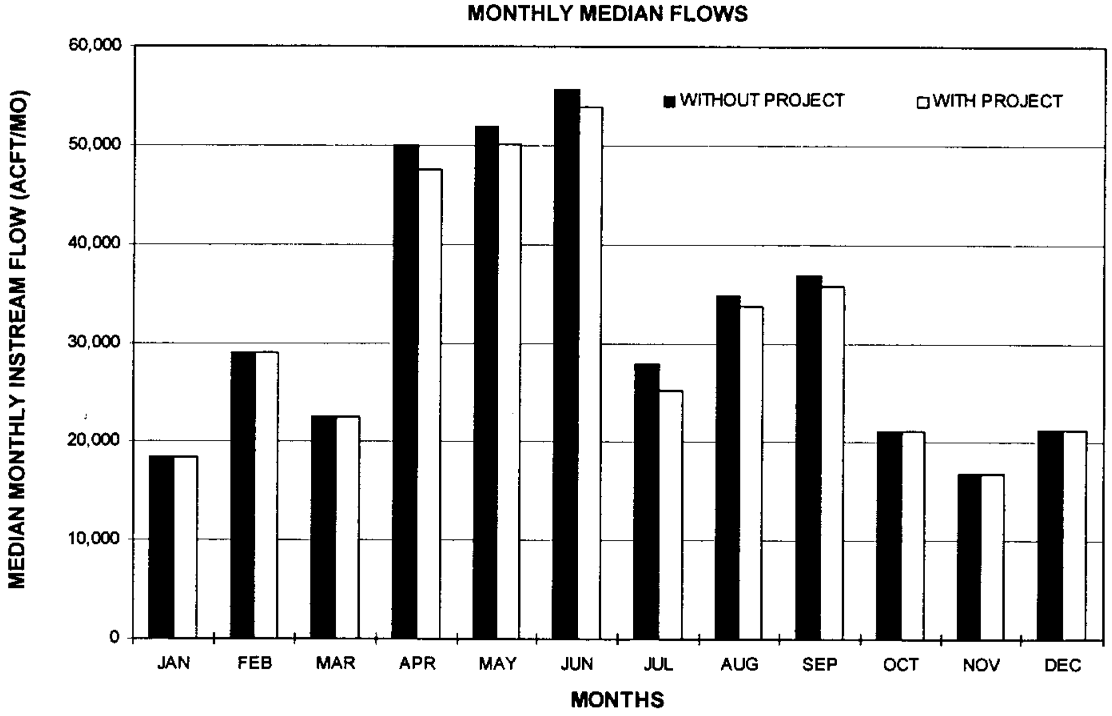
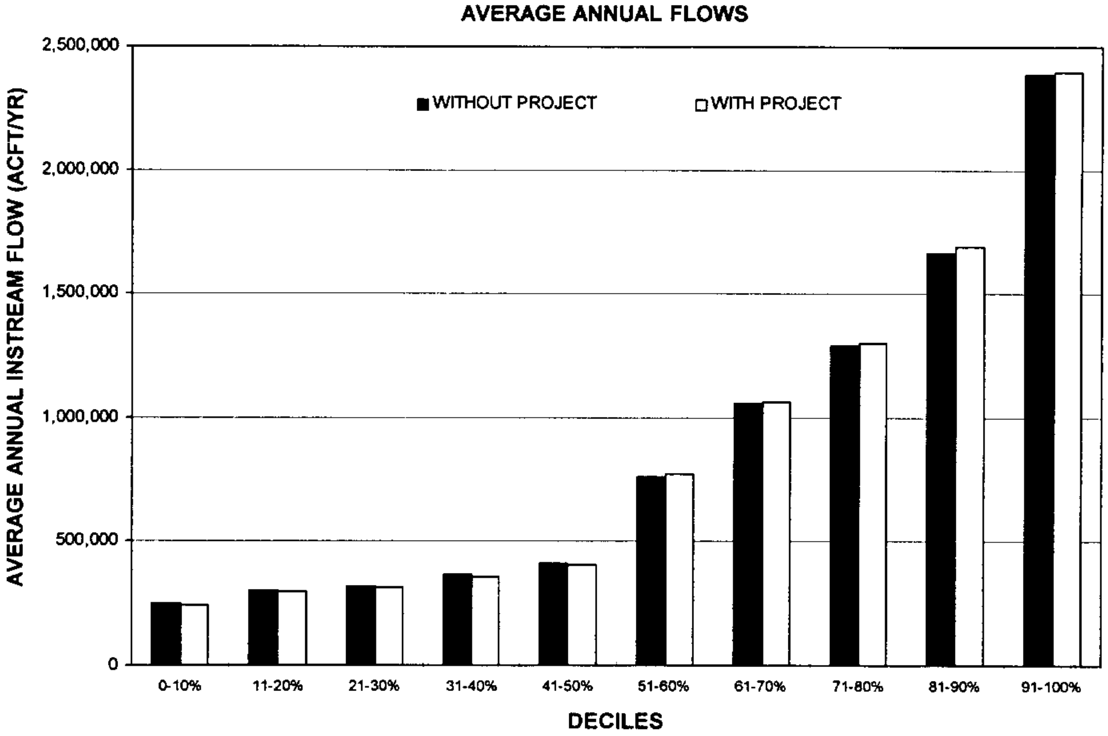
[35] Lower Colorado River Authority, Water Management Plan for the Lower Colorado River Basin, 1993





NOTES:

1. "WITHOUT PROJECT" IS THE BASE CONDITION WITH ALL EXISTING WATER RIGHTS ATTEMPTING TO DIVERT FULL AUTHORIZED AMOUNTS.
2. "WITH PROJECT" INCLUDES DIVERSION OF 30,481 ACFT OVER SIX MONTHS TO MEET LOWER BASIN IRRIGATION DEMAND.

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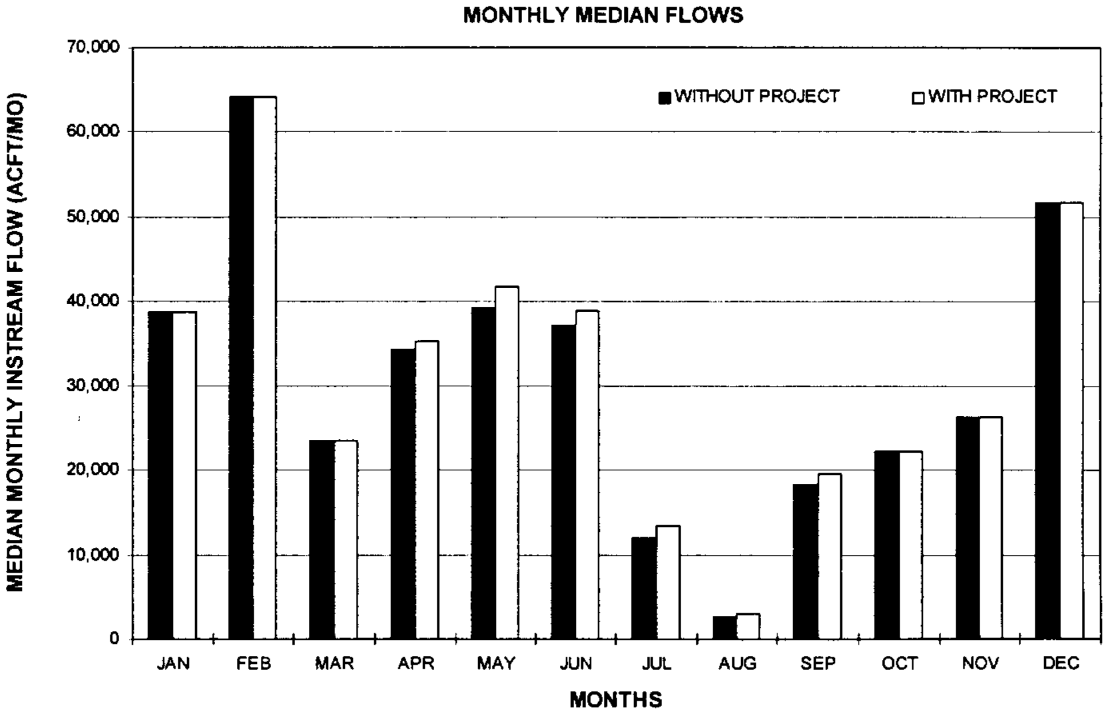
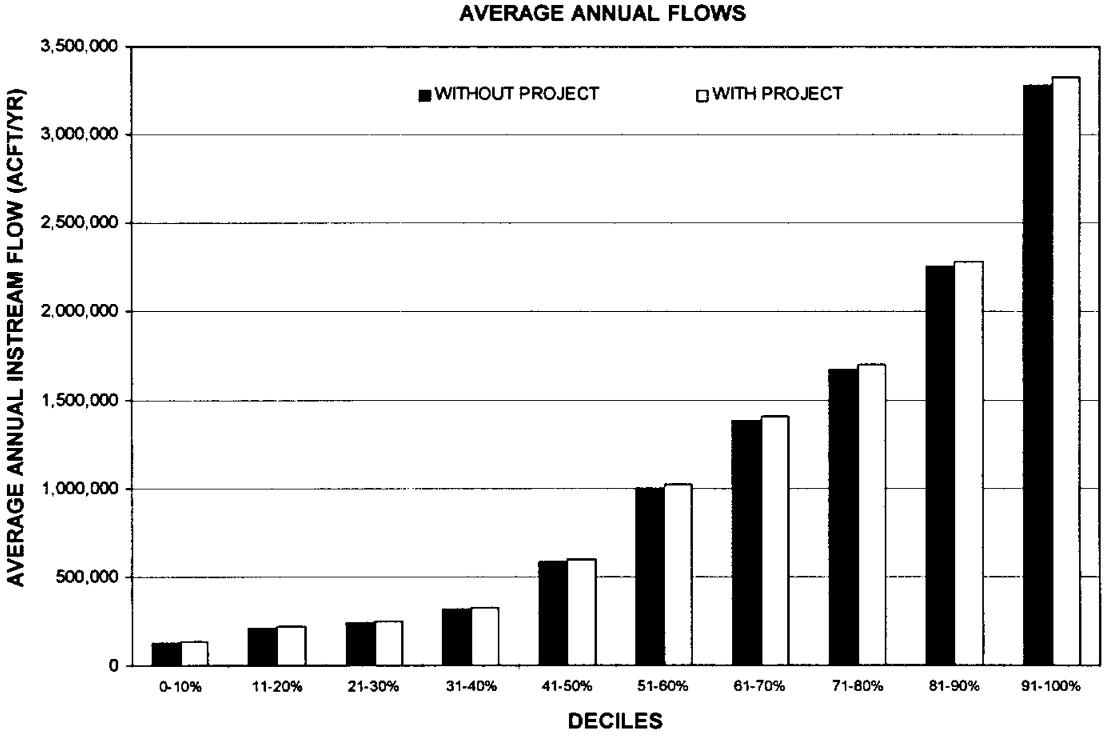
TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

CHANGES IN COLORADO RIVER
FLOWS AT BASTROP
ALTERNATIVE B-7

FIGURE 3.9-2





NOTES:

1. "WITHOUT PROJECT" IS THE BASE CONDITION WITH ALL EXISTING WATER RIGHTS ATTEMPTING TO DIVERT FULL AUTHORIZED AMOUNTS.
2. "WITH PROJECT" INCLUDES DIVERSION OF 30,481 ACFT OVER SIX MONTHS TO MEET LOWER BASIN IRRIGATION DEMAND.

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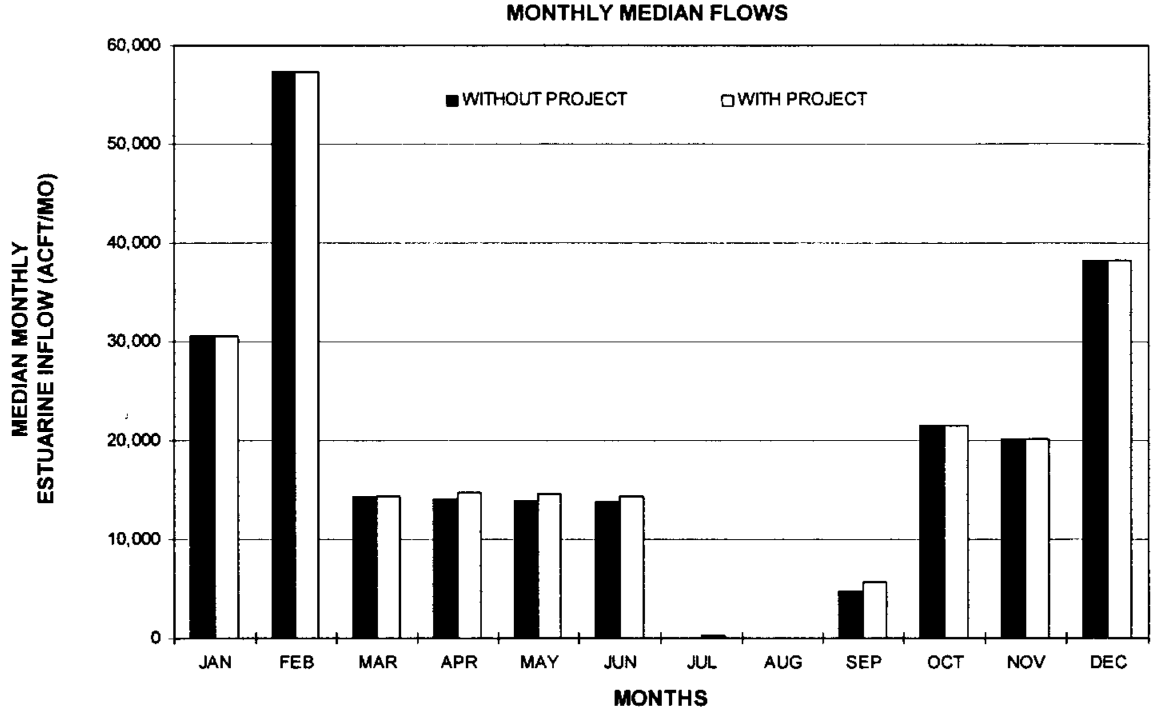
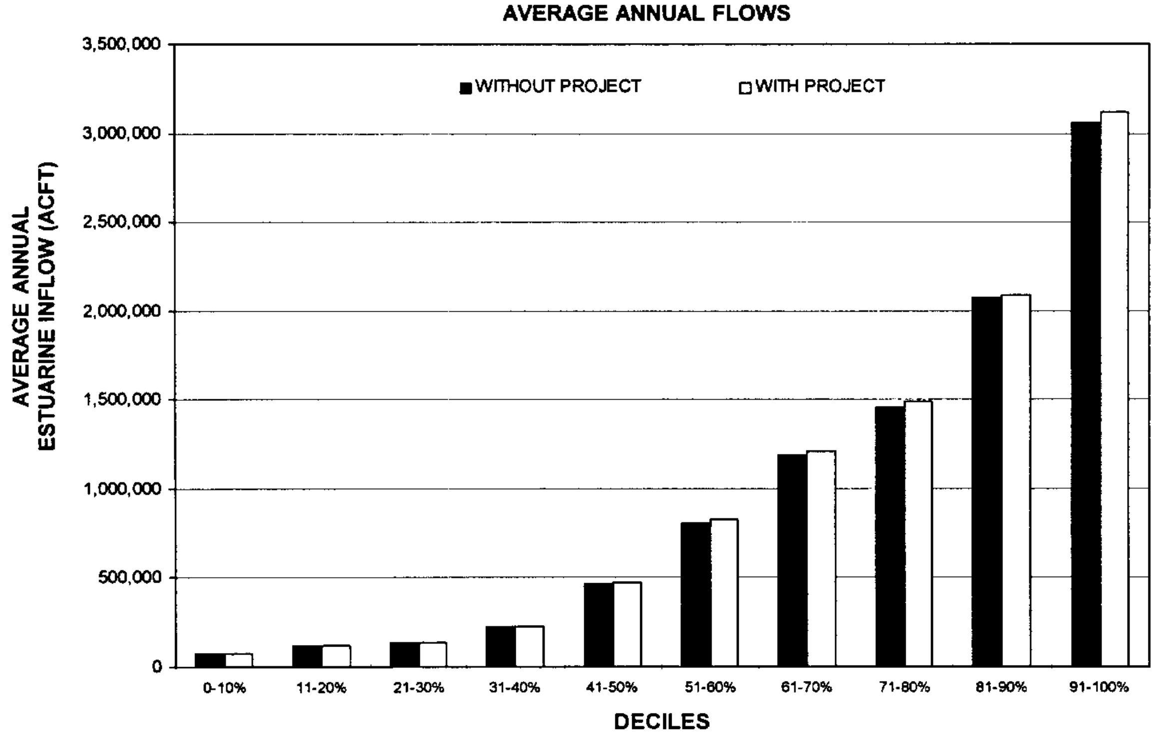
CHANGES IN COLORADO RIVER FLOWS AT COLUMBUS ALTERNATIVE B-7

FIGURE 3.9-3





NOTES:

1. "WITHOUT PROJECT" IS THE BASE CONDITION WITH ALL EXISTING WATER RIGHTS ATTEMPTING TO DIVERT FULL AUTHORIZED AMOUNTS.
2. "WITH PROJECT" INCLUDES DIVERSION OF 30,481 ACFT OVER SIX MONTHS TO MEET LOWER BASIN IRRIGATION DEMAND.

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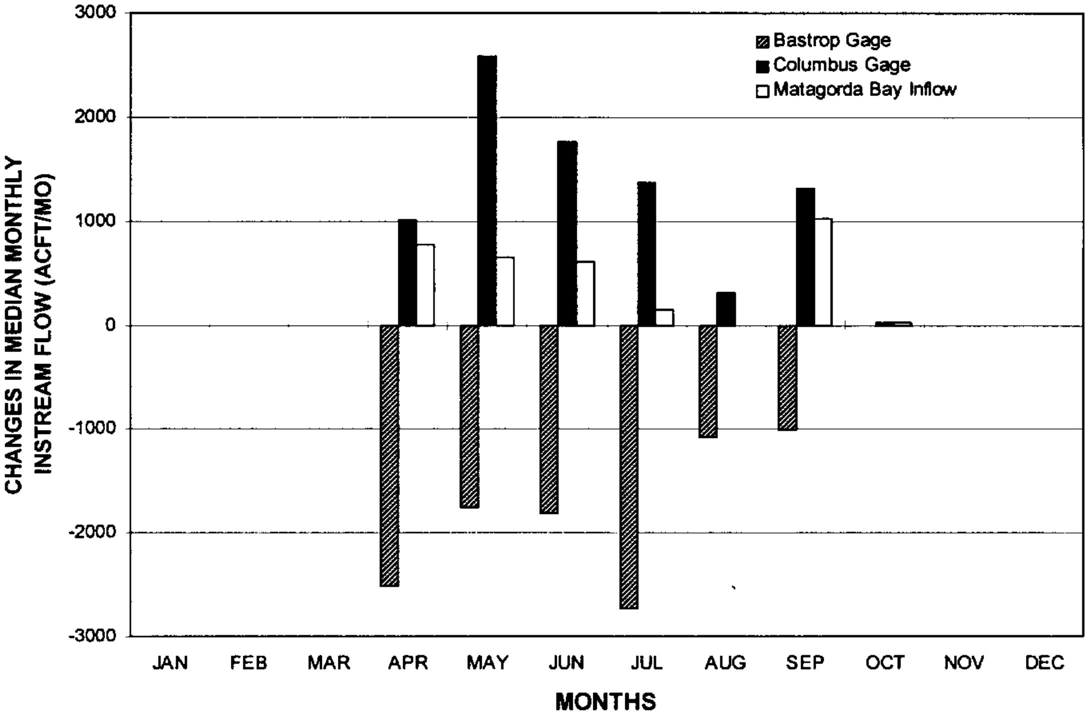
CHANGES IN MATAGORDA BAY INFLOWS
ALTERNATIVE B-7

FIGURE 3.9-4



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EFFECTS OF RELEASE OF 65 CFS INTO THE COLORADO RIVER BASIN ALTERNATIVE B-7

FIGURE 3.9-5

80 days during the 10-year drought period of 1947 to 1956, or 2.2 percent of the time. On these days, the reserved storage in Lake Travis, which has been specifically set aside for this purpose, would be released to maintain the critical flow. A release of 7,500 acft is estimated to be needed over the 10-year period for augmentation of streamflows to the critical flow criteria at the Bastrop location. Critical and target flows at Bastrop, Columbus, and for Matagorda Bay inflow under Base Case and with project conditions are summarized in Table 3.9-6.

Table 3.9-6
Hydrologic Effects of Lower Colorado Basin Alternatives

	Instream Flows			**Estuary Inflows (acft)**		
Alternative	**Critical Flows[1]**	**Required Release[2]**	**Target Flows[3]**	**Annual Mean[4]**	**Drought Mean[5]**	**Minimum Year**
Base Case	2.2% (80)	7,500	47.2% (1725) 75.4% (2755)	925,400	279,820	46,600
B-7	0.3% (12)	900	1.2% (43)	940,000	282,100	46,900

[1] Percent of time (days) critical flows not met at Bastrop gage during 10-year drought of record (1947-1956)
[2] Release from storage to meet critical flows during 10-year drought of record (1947-1956)
[3] Percent of time (days) target flows not met at Bastrop and Columbus gages during 10-year drought of record (1947-1956)
[4] Average for period of record provided by HDR Engineering, Inc.
[5] Average 1947-1956

Implementation of this alternative will result in decreased monthly median flows at Bastrop during the April to September irrigation season, and increases in those flows at Columbus and Matagorda Bay (Figure 3.9-2 through Figure 3.9-5). These hydrologic changes do not appear to be substantial even if predicted to occur in a pristine river and estuary exhibiting the flows and variability of this one. However, this river and estuary are not pristine environments; the lower Colorado River is highly regulated with the Highland Lakes system, and heavily utilized for agricultural production. Consequently, it has an annual hydrograph far different from its natural flow regime. Matagorda Bay, likewise, has experienced the near total loss and subsequent restoration of Colorado River inflows during the past century, and is presently in a transitional state following modifications of the delta completed by the U.S. Army Corps of Engineers in the early 1990s. Judgments concerning the significance of hydrologic changes to biological communities or to particular, important species in the highly regulated Colorado River will require additional study.

The transfer of organisms from the Brazos River Basin to the Colorado River Basin does not appear to present a significant ecological concern for several reasons. First, the Brazos River Basin and the Colorado River Basin are adjacent to each other and the distances between their respective feeder streams are short. Second, common aquatic organisms tend to be broadly adapted, widely distributed, and river basin divides are unlikely to present significant barriers to their dispersal. Uncommon organisms tend to be narrowly adapted and to have specific niche requirements, not basin divides, which limit their distribution. Organisms transferred to environments for which they are not adapted or are poorly adapted are unlikely to survive and compete successfully. Third, the distribution of most species of fish in Texas is determined by life zones or biotic provinces similar to the situation for terrestrial vertebrates.[36] The basic factors affecting fish distribution appear to be geography and climate which determine properties of the water.

3.9.4 Water Quality and Treatability

Implementation of this alternative would increase the availability of water in Lake Travis to be committed for municipal use in the study area. No new or outside sources of water would be introduced to Lake Travis, consequently, this section needs only to consider Lake Travis water quality.

Lake Travis is considered one of the highest quality surface water supplies in the state. Table 3.9-7 summarizes some of the conventional water quality constituents in Lake Travis. It is characterized by low nutrient levels and moderate levels of chlorides and sulfates. Nutrient concentrations in Lake Travis are usually below levels at which algae blooms are significant; however, inflows from stormwater runoff have been known to create elevated nutrient levels resulting in isolated periods of algal growth.[37] Hypersaline flows at Natural Dam Lake caused chloride, sulfate, and TDS levels in Lake Travis to increase considerably in 1988.[38]

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[36] Hubbs, Clark. 1957. Distributional patterns of Texas fresh-water fishes. The Southwestern Naturalist 2:89-104

[37] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.

[38] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.

Table 3.9-7
Conventional Water Quality Constituents in Lake Travis[1]

Constituent	Lake Travis
Dissolved Oxygen (mg/l)	8.04
pH (su)	8.23
TDS (mg/l)	467.36
Fecal Coliforms (No./100 ml)	41.07
Chloride (mg/l)	110.30
Sulfate (mg/l)	83.75
Total Phosphorus (mg/l)	0.04
Total Nitrogen[2] (mg/l)	0.13

[1] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.

[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Lake Travis is protected by TNRCC's Chapter 311, Water Protection, which prohibits discharge of pollutants into the reservoir's water quality area unless sufficient treatment is applied so that the lake's existing water quality is maintained.[39] With TNRCC's anti-degradation policy, the water quality of the reservoir is expected to remain relatively constant. However, increased population and development in the Lake Travis watershed could eventually lead to extended periods of algal growth or other water quality problems from non-point source pollution.

Conventional treatment including rapid mix, flocculation, sedimentation, filtration, and disinfection as currently used by the City of Austin and the City of Cedar Park should continue to be adequate for treating the additional raw water diverted from Lake Travis pending any significant modifications to the state drinking water standards. Additional taste and odor control measures may need to be applied to increase the aesthetic quality of the water when necessary.

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[39] Texas Administrative Code, Title 31, Chapter 311.

3.9.5 Engineering and Costing

For this alternative, a raw water intake and pump station would be built on Lake Somerville near the dam (Figure 3.9-1). A pipeline would traverse about 20.3 miles, mainly along existing roads, to the headwater of Rocky Creek, a tributary to Cummins Creek. The water would then flow in natural stream channels about 34 miles to the Colorado River near Columbus. The major items necessary to implement this alternative are:

- Raw water intake on Lake Somerville,
- Pump station, and
- Raw water transmission pipeline.

The uncommitted firm yield of Lake Somerville is 30,481 acft/yr.[40] This water would be pumped at a uniform rate to Cummins Creek over a 6-month period during the irrigation season. The pumping rate would, therefore, be about 84 cfs (5,080 acft/month), requiring a 54-inch diameter pipeline. The pipeline would be about 20.3 miles long and would require a static lift of about 254 feet.

Table 3.9-8 contains a summary of the cost estimate for this alternative. Total capital cost for the intake, pump station, and pipeline are estimated to be $22,160,000. The total project cost would be about $30,130,000. Financed at 8 percent for 25 years, the annual debt service would be about $2,820,000. With O&M, power, and the purchase of raw water, the total annual cost is estimated to be $4,956,000. For a project yield of 29,100 acft/yr, the unit cost for increased raw water supply is, therefore, $170 per acft.

Increased water supply at Lake Travis made available under this alternative could be diverted and treated through one or more existing, or proposed, water treatment plants on Lake Travis. Diversion through the planned City of Austin WTP No. 4 could potentially benefit the Austin service area, Pflugerville, and others. Entities in Williamson County including Leander, Cedar Park, Round Rock, and Brushy Creek MUD could potentially benefit from this alternative with diversion near Cedar Park and expansion of Cedar Park's WTP facilities or construction of a regional water treatment plant.

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[40] Brazos River Authority, "BRA Long Term Planning Guide," March, 1996.

Table 3.9-8
Cost Estimate Summary for Lake Somerville Water Delivered to the Colorado River (B-7)
(1st Quarter 1997 dollars)

Item	Cost
Capital Costs	
Intake	$ 320,000
Pump Station	5,120,000
Raw Water Pipeline and Crossings	$16,720,000
Total Capital Costs	$22,160,000
Engineering, Contingency, and Legal	$ 6,920,000
Land Acquisition and Easements	230,000
Environmental Studies and Mitigation	230,000
Interest During Construction	590,000
Total Project Costs	$30,130,000
Annual Costs	
Annual Debt Service	$ 2,820,000
Annual Operation and Maintenance (Excluding Power)	170,000
Annual Power[1]	1,350,000
Purchase Raw Water from BRA[2]	616,000
Total Annual Cost	$4,956,000
Annual Project Yield	29,100 acft/yr
Annual Unit Cost for Raw Water	$170 per acft

[1] Based on delivery of purchased amount in six months (84 cfs delivery rate).

[2] Based on annual purchase of 30,481 acft from BRA at system price of $20.21 per acft.

Table 3.9-9 summarizes the estimated unit costs for development of additional raw water supplies in Lake Travis, as well as potential treatment costs for several entities that could benefit from implementation of this alternative.

3.9.6 Implementation Issues

The transfer of water from Lake Somerville to the Colorado River Basin would constitute an interbasin transfer and require a permit from the TNRCC. TNRCC permit amendments could be needed to add a point of diversion at Lake Somerville. Agreements between LCRA and BRA would be necessary to account for the transferred water. A TNRCC permit would also be needed for use of a natural waterway to convey water from the point of discharge on Cummins Creek to the point of use.

Table 3.9-9
Treated Water Unit Costs for Alternative B-7

Entity	Cost Item (Source)	Unit Cost ($/acft)
Austin Service Area	Raw Water (Table 3.9-9)	$170
	Austin CIP Facilities (Table 3.12-17)	549
	Treated Water Cost	$719
Pflugerville	Raw Water (Table 3.9-9)	$170
	Austin CIP Facilities (Table 3.12-17)	549
	Other Delivery Facilities (Table 3.12-18)	36
	Treated Water Cost	$755
Round Rock	Raw Water (Table 3.9-9)	$170
	Div/Treatment Facilities (BC-2)[1]	391
	Treated Water Cost	$561
Brushy Creek MUD	Raw Water (Table 3.9-9)	$170
	Div/Treatment Facilities (C-2) (Table 3.12-32)	442
	Other Delivery Facilities (Table 3.12-19)	90
	Treated Water Cost	$702
Cedar Park	Raw Water (Table 3.9-9)	$170
	Div/Treatment Facilities (C-2) (Table 3.12-30)	321
	Other Delivery Facilities (Table 3.12-30)	41
	Treated Water Cost	$532
Leander	Raw Water (Table 3.9-9)	$170
	Div/Treatment Facilities (C-2) (Table 3.12-30)	321
	Other Delivery Facilities (Table 3.12-30)	63
	Treated Water Cost	$554

[1] Includes cost of $134 per acft for intake, pump station and pipeline from Alt. BC-2, Table 3.19-2, not including purchase cost of raw water from LCRA. Includes cost of $257 per acft for treatment at expansion of Round Rock WTP, Table 3.19-4.

Requirements Specific to Pipelines

1. Necessary permits:
   a. U.S. Army Corps of Engineers Section 404 dredge and fill permit for stream crossings and lake intake,
   b. GLO Sand and Gravel Removal permits, and
   c. 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, and
   c. Other utilities.

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3.10 Water Availability From Little River or Brushy Creek (B-8)

3.10.1 Description of Alternative

The Little River is one of seven major tributaries to the Brazos River. The Little River begins at the confluence of the Leon River and the Lampasas River just south of Temple, Texas, and ends where it joins the Brazos River east of Cameron, Texas (Figure 3.10-1). Tributaries to the Little River include the San Gabriel River, Salado Creek, and Brushy Creek. The total drainage area of the Little River and its tributaries is 7,687 square miles where it joins the Brazos River.[1] Of this area, 5,581 square miles are controlled by five major reservoirs. These five reservoirs have a combined conservation storage of 676,000 acft and flood control storage of 1,622,000 acft. The remaining 2,106 square miles, or about 27 percent of the watershed, drains into the Little River downstream of the lakes and flows uncontrolled to the Brazos River. Williamson County covers 1,136 square miles, almost all of which is in the Little River watershed.

This alternative considers the diversion of water from two locations in the Little River watershed. The first diversion location is directly from the Little River at a point near Cameron and the second diversion point is located on Brushy Creek at a point south of Taylor as shown in Figure 3.10-1. The potential sources of water which were evaluated from the Little River include: unappropriated streamflow and the purchase of under-utilized senior water rights. The potential source of water evaluated from Brushy Creek included only return flows.

Each potential diversion location is in close proximity to Lake Granger, and diverted water would first be conveyed and discharged to Lake Granger for temporary storage and blending. The water quantities considered in this alternative would then be combined with the uncommitted 2050 firm yield of Lake Granger, currently about 4,060 acft/yr, for conveyance to Lake Georgetown by pipeline. The augmented supply at Lake Georgetown would then be available for treatment at an expanded City of Georgetown WTP, City of Round Rock WTP, or at a potential new regional WTP. The potential diversion locations, pipeline routes, reservoirs, and streams are shown in Figure 3.10-1.

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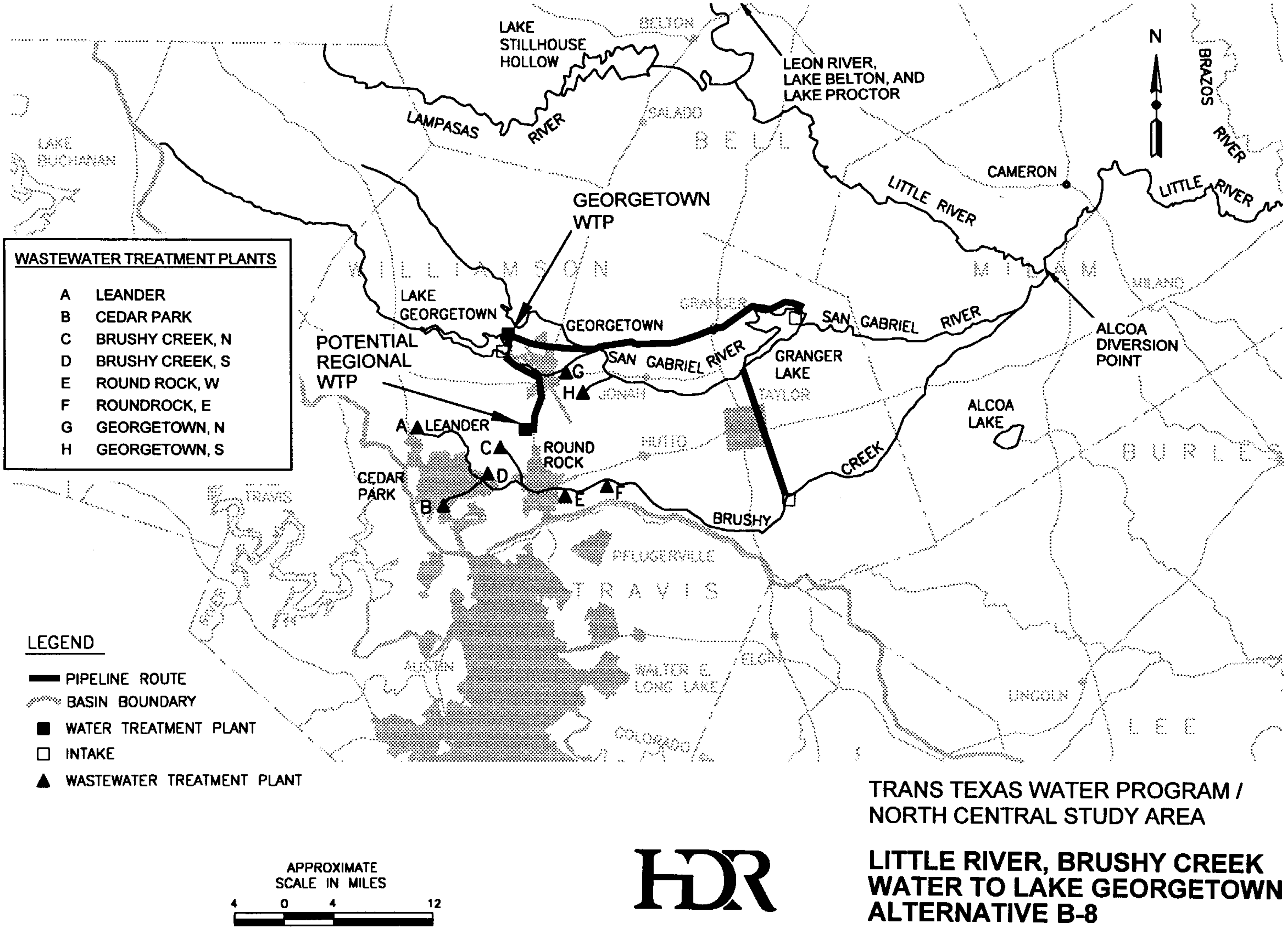
[1] Revised Interim Report of Water Availability in the Brazos River Basin, Texas, Texas Water Commission, February, 1987.



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

LITTLE RIVER, BRUSHY CREEK WATER TO LAKE GEORGETOWN ALTERNATIVE B-8

FIGURE 3.10-1

HDR

HDR Engineering, Inc.

3.10.2 Available Yield

Diversion from Little River

Two potential sources of water from the Little River were considered for this alternative: (1) unappropriated streamflows, and (2) senior water rights which are under-utilized and could possibly be purchased. Unappropriated streamflow is water that is periodically available in excess of demands by downstream water rights. Use of unappropriated streamflow for municipal purposes would require a permit from the TNRCC to divert the water. The Texas Water Commission (TWC), a predecessor of the TNRCC, made estimates of unappropriated water for many areas of the state.[2] Estimates of unappropriated water were made by the TWC for the period from 1940 to 1976, which includes the critical drought period for this area. These estimates were made for water rights existing as of June 1986, and no significant water rights are known to have been granted in the intervening period. The minimum unappropriated availability was 52 acft/yr, which occurred in 1951 (Figure 3.10-2). Therefore, without storage, there is virtually no firm yield remaining in the Little River at this location. The drought-average unappropriated availability was 3,805 acft/yr over the 3-year period from 1954 to 1956. Application of Trans-Texas instream flow requirements for a new diversion right at this location would further reduce water availability.

The other potential water source considered on the Little River was the potential purchase of under-utilized water rights. Because of the significant storage reservoirs existing in the watershed (i.e., Lake Stillhouse Hollow on the Lampasas River, 12/16/63 priority date; Lake Granger on the San Gabriel River, 02/12/68 priority date; and Lake Georgetown on the San Gabriel River, 02/12/68 priority date), only a water right with a priority date senior to these reservoirs would have a yield available during drought. Two significant water rights were found on the Little River with priority dates senior to all of the above reservoirs. One is held by the City of Cameron for 2,792 acft/yr, but the unutilized portion is only about 1,300 acft/yr.[3] This is a small amount and it is likely that the City will need the remainder for future growth. The second right is for 18,000 acft/yr and is owned by the Aluminum Company of America (Alcoa).[4] Alcoa uses the water for cooling purposes at its steam-electric power plant near Rockdale. Alcoa

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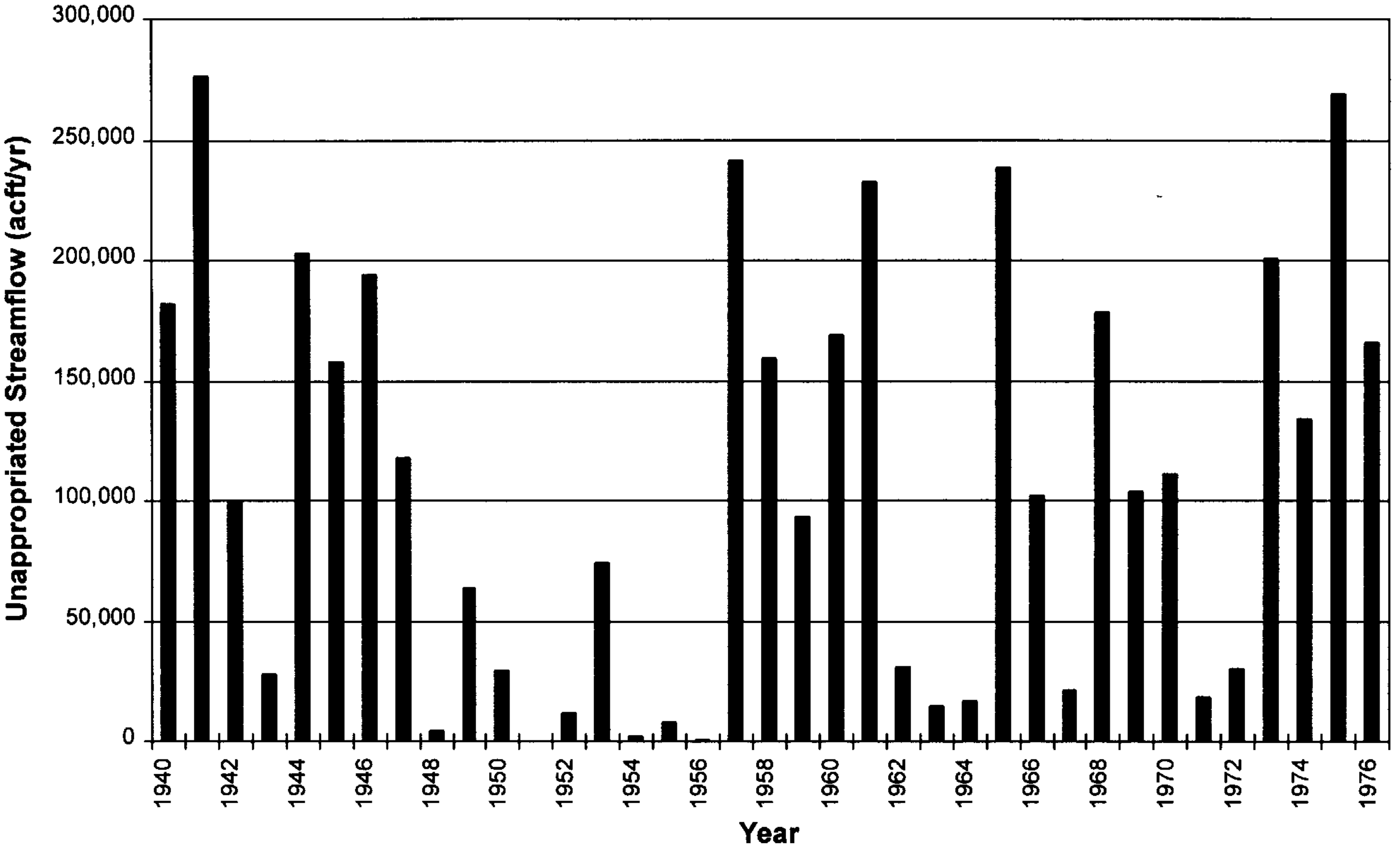
[2] Ibid.

[3] Water Use Records, Certificate 3761, TNRCC, 1970 to 1995.

[4] Water Use Records, Certificate 3758A, TNRCC 1970 to 1994.



Source: "Revised Interim Report of Water Availability in the Brazos River Basin, Texas," TWC, Feb., 1987.

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

UNAPPROPRIATED STREAMFLOW
LITTLE RIVER AT CAMERON
ALTERNATIVE B-8

FIGURE 3.10-2

estimates their long-term need to be 14,000 acft/yr, and Alcoa might be willing to sell a portion of their water right for municipal purposes.[5] However, the Alcoa right is subject to instream flow restrictions. The primary instream flow restriction is for the period from May 15 to September 15 each year when a flow of 690 cfs as measured at the Bryan gage on the main stem of the Brazos River is required before diversion can occur. In 1996, this instream flow requirement would have prevented diversions for much of the summer.[6]

From the above information, it was concluded that a diversion on the Little River would yield only a small quantity of firm water. Therefore, no conveyance system was costed as the cost of such a system would not be economical. Instead, attention was given to the more promising possibility of diversion of return flow from Brushy Creek as discussed below.

Brushy Creek

As the population and water use increase in the Brushy Creek watershed, return flows to the creek will increase and will be a potentially significant water supply source. All return flows to Brushy Creek have their source from outside the watershed (i.e., Highland Lakes, Edwards Aquifer, and the San Gabriel River), consequently, all return flows in Brushy Creek are in excess of natural flows. The potential exists to utilize return flows by diverting the flow from a point on Brushy Creek into Lake Granger. The Brushy Creek diversion would be blended with Lake Granger water, stored in Lake Granger for a short period of time (probably less than 1 month) and then diverted and pumped through a pipeline to Lake Georgetown where this water would then be available for treatment at either the City of Georgetown WTP, the Round Rock WTP, or a potential new regional WTP.

Use of return flows to augment the Lake Granger/Lake Georgetown yield would require a permit from the TNRCC to transfer the return flow from the various points of discharge in the upper Brushy Creek watershed to the diversion point near Lake Granger. Use of return flows to augment surface water sources has been permitted by the TNRCC at two locations. In 1986, the North Texas Municipal Water District was permitted by the TNRCC to increase their right to divert surface water from Lake Lavon (northeast of Dallas) by the amount of return flow

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[5] Pers. Comm., Alcoa, August, 1996.

[6] Ibid.

discharged from the Wilson Creek WTP, upstream of the lake. The supply obtained from return flows is about 9,000 acft/yr. Currently, North Texas Municipal Water District is in the process of amending their diversion permit to increase the use of return flows for municipal supply. In 1995, the TRA was granted a permit by the TNRCC to divert 3,696 acft/yr from Bardwell Reservoir originating from the City of Ennis WTP.

For this alternative, return flows from treatment plants located in the Brushy Creek and San Gabriel River watersheds would be combined with the remaining uncommitted yield available in Lake Granger. Return flows in the Brushy Creek watershed would need to be diverted from the creek southeast of Taylor and transferred by pipeline to Lake Granger (Figure 3.10-1). Lake Granger presently receives return flow from the Georgetown treatment plants via the San Gabriel River. From Lake Granger, the combined return flows plus uncommitted yield from Lake Granger would be transferred by a second pipeline to Lake Georgetown. This water would augment the yield of Lake Georgetown, and would then be treated and distributed to area demand centers in Williamson County.

Wastewater return flows amount to about 44 percent of total water use as indicated in Table 3.10-1. This value is conservatively estimated by using the ratio of the historical average minimum month of wastewater discharge to the average month of water use for the 1987 to 1994 period. However, in order to estimate how much of this water could potentially be available for reuse, the following adjustment factors were considered: (1) current reuse, (2) channel losses, and (3) instream flow requirements. Current reuse in Williamson County is about 3,500 acft/yr.[7] Channel losses are estimated to be about 19 percent of net return flow[8] (return flow minus reuse). Potential instream flow requirements for Brushy Creek were estimated to be the low flow water quality standard, which in this case is the 7-day 2-year return frequency low flow (7Q2). The instream flow requirement applied was 4 cfs or about 2,900 acft/yr.[9] For year 2020 conditions, total adjustments or deductions are estimated at 10,700 acft/yr or about 40 percent of total 2020 return flows. Therefore, the total return flow available for diversion in 2020 is conservatively estimated at 15,100 acft/yr (13.5 mgd). This includes 14,000 acft/yr from Brushy Creek and

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[7] Section 3.6 of this report (Alternative L-8).

[8] Hydrologic Effects of Flood Water Retarding Structures on Garza Little Elm Reservoir, Texas, USGS, September 1969.

[9] TNRCC, Part IX, Chapter 307.

1,100 acft/yr from Georgetown via the San Gabriel River. Table 3.10-1 summarizes these estimates.

Table 3.10-1
Year 2020 Return Flows Available For Diversion From Brushy Creek and Lake Georgetown
(all values are shown in acft/yr)

Origin	Projected 2020 Water Demand	Return Flow (% of total water demand)	Projected Return Flow	Deductions[1]	Available Return Flow
Brushy Creek[2]	45,300	45	20,300	6,300	14,000
Georgetown	13,800	40	5,500	4,400	1,100
TOTAL	59,144	43.7	25,800	10,700	15,100

[1] Includes channel losses, current reuse, and potential in-stream flow requirements.
[2] Includes Leander, Cedar Park, Brushy Creek MUD, Round Rock.

An approximation of available return flows for the system is represented by the following equation.

$$ARF = (0.44 \times WU - 3{,}500) \times E\% - 2{,}900$$

Where:

ARF = available return flow (acft/yr)
0.44 = gross return flow as percentage of water use (WU)
WU = total water use for all entities contributing to system (acft/yr)
3,500 = current reuse (acft/yr)
E% = efficiency (100% - channel loss %), (= 81% for 2020 projections)
2,900 = instream flow requirements (acft/yr)

Estimates of available return flow in 1995 are 3,100 acft/yr (2.8 mgd), and for the year 2050 are 21,700 acft/yr (19.4 mgd), assuming no increase in current reuse.

At Lake Granger, the 14,000 acft/yr return flow from Brushy Creek (Table 3.10-1) would join with the 1,100 acft/yr from Georgetown, and the 4,060 acft/yr uncommitted yield of Lake Granger (Section 3.8) to make up to 19,160 acft/yr available to be diverted to Lake Georgetown.

3.10.3 Environmental Issues

Environmental issues relevant to the diversion of water from Brushy Creek to Granger Lake, then to Lake Georgetown, can be categorized as follows:

- Effects of the construction of pipelines and associated infrastructure from Brushy Creek to Lake Granger and to Lake Georgetown.

- Effects arising from operation of the proposed system, including pipeline ROW maintenance, water quality in the two reservoirs, and instream flows in Brushy Creek and the San Gabriel River below Lake Granger.

The upper San Gabriel River and Brushy Creek arise on the Edwards Plateau, flow eastward through the cities of Georgetown and Round Rock (respectively), then traverse portions of the Grand and Blackland Prairies vegetational areas prior to their confluence below Lake Granger. These vegetational areas are discussed in detail within the environmental overview (Section 3.1.3). The lower reaches of these waters have an alternating pool and riffle morphology and perennial flows which are augmented at present by treated wastewater return flows. While low turbidity and hard substrates ranging from gravel to limestone bedrock dominate the upper portions of these streams, turbidity tends to increase and substrates become finer as the streams traverse the Blackland Prairies .

The North Fork San Gabriel River was impounded in 1980 to create Lake Georgetown. Located west of Georgetown, Lake Georgetown has a capacity of 37,010 acft and covers 1,297 surface acres in a relatively deep, narrow canyon on the eastern margin of the Edwards Plateau. Its average annual inflow is 73.3 cfs (53,066.8 acft/yr.), based on water years 1980 to 1995.[10] Nutrient concentrations in Lake Georgetown were averaged over the most complete recent period of nitrite and nitrate sampling, 1995. The average nutrient concentrations were 0.03 mg/l P and 0.14 mg/l N.

The San Gabriel River below the confluence of its north and south forks was impounded in 1980 to form Lake Granger. This reservoir, located downstream of the City of Georgetown, has a capacity of 54,280 acft and a surface area of 4,009 acres. The average depth and maximum depth are reported to be 9 feet and 60 feet respectively.[11] Lake Granger had an average inflow of 250 cfs (180,992 acft/yr)[12] over the water years 1980 to 1995 and exhibited average concentrations of total phosphorus of 0.04 mg/l P and concentrations of total nitrogen of 0.79 mg/l N during the drought year 1996[13].

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[10] USGS. 1996. Water Resources Data, Texas Water Year 1995, Volume 2.

[11] Terre, D. R. and S.J. Magnelia. 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Survey Report for Granger Reservoir, 1994. TPWD, Austin, TX.

[12] USGS. 1996. Water Resources Data, Texas Water Year 1995.

[13] TNRCC. 1997. Water Quality Database.

Brushy Creek lies to the south of the San Gabriel River in Williamson and Milam Counties where it joins with the San Gabriel River downstream of Lake Granger. Return flows from wastewater treatment facilities contribute significantly to instream flows in Brushy Creek. This is reflected in total phosphorous concentrations of 2.4 mg/l and total nitrogen concentrations of 4.66 mg/l.

For comparison, total phosphate concentrations in Lakes Granger and Georgetown are 0.06 mg/l and 0.03 mg/l respectively. Total nitrogen concentrations for Lakes Granger and Georgetown are 0.46 and 0.06 respectively.

The area encompassed by this alternative is located in the Blackland Prairies vegetational area, with the exception of a section in the Edwards Plateau vegetational area between Interstate 35 and Lake Georgetown. Descriptions of Lake Granger, Lake Georgetown, the Blackland Prairies, and Edwards Plateau are presented in the Environmental Overview (Section 3.1.3).

The pipeline route between Lake Granger and Lake Georgetown considered here is the same as that described in Alternative B-6 (Section 3.8), where vegetation and soil types crossed by the proposed Granger-Georgetown pipeline are described. The Brushy Creek-Lake Granger pipeline will follow FM 619, primarily through cropland, to the vicinity of the mouth of the San Gabriel River into Lake Granger (Figure 3.10-1).[14]

Soils traversed by the proposed pipeline route include Branyon-Houston Black-Burlson, Austin-Houston Black-Castephen, Oakalla-Sunev, and Eckrant-Georgetown soils.[15] Branyon-Houston Black-Burlson soils are deep calcareous and noncalcareous, clayey soils formed in clayey alluvium, and marine clays and shales on ancient stream terraces and uplands. Oakalla-Sunev soils are deep calcareous, loamy soils formed in alluvium on bottom lands and stream terraces.

Species listed as endangered or threatened by U.S. Fish and Wildlife Service or the State of Texas, and species of concern reported to occur in Williamson and Milam counties are presented in the Environmental Overview (Section 3.1.3). Several of the species presented are migratory birds, but others are potential residents with possible habitat within the area of the

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[14] McMahan, C.A., R.G. Frye and K.L. Brown. 1984. The vegetation types of Texas Including cropland. TPWD, Austin, Texas.

[15] Soil Conservation Service. 1983. Soil Survey of Williamson County, Texas. USDA, SCS in cooperation with the Texas Agricultural Experiment Station.

project. These include the Golden-cheeked Warbler, Black-capped Vireo, mountain plover, Texas horned lizard, and several species of troglobitic invertebrates. All of these species, except the Mountain Plover and Texas horned lizard, are primarily inhabitants of the Edwards Plateau. Their occurrence and habitat needs are discussed under Alternative B-6 in Section 3.8.3.

The Texas horned lizard (*Phrynosoma cornutm*) inhabits arid and semi-arid regions having patchy, sparse vegetation. It is a federal species of concern and is classified by Texas Parks and Wildlife Department as a threatened species.

Texas Natural Heritage Program files report an occurrence of the Mountain Plover (*Charadrinus montanus*) on the Granger 7.5 minute quadrangle map, this species has been reported to nest in the vicinity of Granger Lake.[16] The Mountain Plover inhabits shortgrass prairie, overgrazed pasture, plowed fields, and deserts.[17] It is a rare transient throughout Texas, except in the eastern quarter of the state, and a rare winter resident in the southern half of Texas. The mountain plover breeds in the dry western great plains from southern Canada to western Texas and winters in California, Arizona, Texas, and northern Mexico. The mountain plover is considered a species of concern.

Texas Natural Heritage Program files report the Guadalupe bass, a species of concern, occurs in the San Gabriel River where it has been introduced.[18] Although it may be present in Lakes Georgetown or Granger, nest building and spawning takes place in slow riffle and run habitats in streams.

Also present within the project area are two U.S. Army Corps of Engineers parks (Willis Creek and Taylor Park), and other public lands surrounding Lake Granger, including Granger Wildlife Management Area, which is located on U.S. Army Corps of Engineers' property but managed by the Texas Parks and Wildlife Department. Lake Georgetown is also a U.S. Army Corps of Engineers lake, and also has extensive park and other public land surrounding it.

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[16] Kutac, E.A. and S.C. Caran. 1994. Birds and Other Wildlife of South Central Texas. University of Texas Press, Austin, Texas.

[17] Rappole, J.H. and G.W. Blacklock. 1994. A Field Guide. Birds of Texas. Texas A&M University. College Station, TX.

[18] USFWS. 1994. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species. Federal Register, November 15, 1994.

Construction Effects

The pipeline route between Lake Granger and Lake Georgetown considered here is the same as that described in Alternative B-6, and is considered to have the same construction and operation impacts as outlined in Section 3.8.3

A 140 foot wide construction ROW between Lake Granger and Lake Georgetown would be 27.9 miles long, and would affect a total of 474 acres including 232 acres crop (49 percent), 19 acres grass (4 percent), 5 acres brush (1 percent), 95 acres park (20 percent), 57 acres wood (12 percent), and 66 acres developed (14 percent). A ROW 40 feet wide maintained free of woody vegetation for the life of the project would affect a total of 135 acres including 66 acres crop, 19 acres grass, 1 acre brush, 27 acres park, 16 acres woods, and 19 acres developed.

Installation and operation of the intake and outfall in the two reservoirs will result in less than 1 acre of wetland disturbance. Other wetlands affected include the stream channels at crossings of Willis Creek, Yankee Branch of Willis Creek, Opossum Creek, Berry Creek, Pecan Branch of the San Gabriel River, Weir Branch of the San Gabriel River, Mileham Branch of the San Gabriel River, the San Gabriel River, and some small unnamed drainages. Most of these creeks are temporary and seasonally flooded.[19] However, Berry Creek and the San Gabriel River are classified as riverine, lower perennial, and as having open water.[20] Total wetland acreage within the proposed water pipeline ROW would not be expected to exceed five acres including the intake and outfall.

The proposed route of the Lake Granger-Lake Georgetown water transmission line involves property owned by the U.S. Army Corps of Engineers, some of which is managed by the Texas Parks and Wildlife Department. Additional requirements for pipeline construction on the U.S. Army Corps of Engineers' land include a Pollution Prevention Plan (PPP) prepared in accordance with the National Pollution Discharge Elimination System (NPDES) for the entire project.[21] The portion addressing the line on government fee land will require submission to the reservoir manager for approval. An inventory of all major vegetative resources will be necessary for use in restoring the area and/or mitigation of lost resources. A centerline description, or a

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[19] National Wetland Inventory maps.

[20] Ibid.

[21] Paul Price Associates, Inc. 1994. An Environmental Survey of the Proposed Lake Georgetown Raw Waterline Corridor. City of Round Rock. Round Rock, Texas. Appendix A. is a letter involving coordination with the USCOE on projects involving corps property.

metes and bounds description of the line, will have to be submitted to become an exhibit to the easement.

With respect to the Brushy Creek diversion to Lake Granger, pipeline installation, assuming a 140 foot wide construction corridor along FM 619, would affect 176.8 acres total including 161.2 acres crop (91 percent), 14.7 acres wood (8.3 percent), and 0.8 acres wetland (0.5 percent). A ROW 40 feet wide maintained free of woody vegetation for the life of the project would affect 46.1 acres of crop, 4.2 acres of wood, and 0.2 acres of wetland.

Cropland and grassland affected by pipeline installation could be returned to their original condition shortly after construction. Brushlands outside the maintenance ROW that are disturbed during construction would be expected to be reinvaded with brush if left undisturbed. Long-term effects of the construction ROW would be manifested primarily in the possible removal of parks or woodlands, which tend to be limited to thin riparian strips in this area. Vegetative and endangered species surveys may be needed in the vicinity of Granger Lake in order to avoid or minimize adverse impacts, or determine mitigation liabilities where impacts are unavoidable.

A discussion dealing with cultural resources of the Trans-Texas North Central Project Area is presented in the Environmental Overview (Section 3.1.3). 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.

Operational Effects

Available statistics concerning the physical and chemical characteristics of Lake Granger, Lake Georgetown, and Brushy Creek were used to estimate the potential effects of implementing this alternative on nutrient loadings in Lake Granger and Lake Georgetown. For this analysis, it was assumed that total phosphorus and total nitrogen concentrations reported from Lakes Granger and Georgetown represent typical nutrient concentrations throughout their respective basins. Data from the TNRCC Water Quality Database is shown in Table 3.10-2 and

Table 3.10-3 that supports the assumption that the two lakes have fairly even distributions of total nitrogen and total phosphorus.

Table 3.10-2
Lake Granger Total Nitrogen and Total Phosphorus Values

Station	Date	00610 Total Ammonia (mg/l as N)	00630 Nitrite plus Nitrate (mg/l as N)	Total N (Calculated as 00610+00630)	00665 Total P (mg/l as P)
12095	Feb 96	0.01	1.15	1.16	0.04
12096	Feb 96	0.01	1.46	1.47	0.04
12097	Feb 96	0.01	1.19	1.2	0.05
12095	Aug 96	0.01	0.32	0.33	0.03
12096	Aug 96	0.01	0.33	0.34	0.04
12097	Aug 96	0.01	0.22	0.23	0.05

Station 12095 - Lake Granger near dam
Station 12096 - Lake Granger in San Gabriel River arm near headquarters
Station 12097 - Lake Granger in Willis Creek arm

Table 3.10-3
Lake Georgetown Total Nitrogen and Total Phosphorus Values

Station	Date	00610 Total Ammonia (mg/l as N)	00630 Nitrite plus Nitrate (mg/l as N)	Total N (Calculated as 00610+00630)	00665 Total P (mg/l as P)
12111	Feb 95	0.01	0.21	0.22	0.01
12113	Feb 95	0.02	0.19	0.21	0.04
12111	Aug 95	0.05	0.02	0.07	0.02
12113	Aug 95	0.03	0.01	0.04	0.03

Station 12111 - Lake Georgetown near dam
Station 12113 - Lake Granger in north San Gabriel River arm near headquarters

The nutrient loading analysis assumed a diversion of 14,000 acft/yr of water from Brushy Creek with an average total phosphorus concentration of 1.58 mg/l P and a total nitrogen concentration of 1.81 mg/l N.[22] The value used for total phosphorus is the average of all total phosphorus values (storet code 00665) collected on Brushy Creek during the drought year 1996 at the TNRCC station closest to the potential intake site south of Taylor, station 14944. The value used for total nitrogen is the average of the most complete record of nitrite and nitrate sampling (November 9, 1994 to September 28, 1995) for a Brushy Creek station east of the Round Rock wastewater treatment facility and west of the proposed intake site (station 12062).

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[22] TNRCC. 1997. Water Quality Database.

The calculated total nutrient loads of the 14.000 acft annual diversion of water from Brushy Creek were 27.282.7 KgP and 31,254.3 KgN.

Based on these statistics, annual loading rates for Lake Granger without implementation of this alternative and with implementation of the Brushy Creek Alternative were as follows:

Lake Granger	KgP/y	$gP/m^2/y$	KgN/y	$gN/m^2/y$
w/o Brushy	89,294	5.50	176,355	10.9
with Brushy	116,577	7.19	207,609	12.8

The calculated loadings increased 31 percent for total phosphorus and 18 percent for total nitrogen with implementation of the Brushy Creek Alternative. Areal loadings from Brushy Creek alone were 1.7 $gP/m^2/y$ and 1.9 $gN/m^2/y$. Existing nutrient loading rates into Lake Granger appear to be more than sufficient to ensure that eutrophic conditions are present there now.[23] The average total phosphorus concentration of 0.04 mg/l indicates at least near eutrophic conditions. A fish kill at Willis Creek Park on Lake Granger, April 1, 1991, was attributed to low dissolved oxygen caused by an algal bloom.[24] However, Lake Granger is a broad, shallow, warm, monomictic impoundment that is likely capable of sustaining higher than average rates of primary production without the development of adverse consequences (i.e., pervasive algae bloom problems, or excessive macrophyte growth, extensive areas of anoxic water and sediments, hydrogen sulfide formation, fish or waterfowl kills), at least during normal years when inflows may be sufficient to replace the whole volume of the lake four times.

The lake will be most susceptible to eutrophication and its potentially detrimental effects during dry periods when natural inflows are low and wastewater nutrient loadings continue to enter the reservoir at rates much higher than those expected from natural dry weather flows.

Following mixing in Lake Granger 14,000 acft/yr would be diverted to Lake Georgetown. In addition to simple mixing, other physical and biological processes within Lake Granger would be expected to alter the concentration of nutrients. For example, bacteria, algae, and other vegetation would assimilate both phosphorus and nitrogen, while the alkalinity of the water may

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[23] Wetzel, R.G. 1983. Limnology. Second ed. Saunders College Publishing, Philadelphia.

[24] TPWD. 1991. Fish Kill/Pollution Detailed Complaint Report. Resource Protection Division, Kills and Spills Team, Texas Parks and Wildlife Department.

cause some phosphorus precipitation into the substrate. However, for these preliminary analyses, it was conservatively assumed that only simple mixing would affect concentrations of phosphorus and nitrogen entering Lake Granger. Therefore, the 14,000 acft diverted from Lake Granger was calculated to carry concentrations of 0.48 mg/l P and 0.86 mg/l N to result in loadings of 8,288 KgP and 14,850 KgN into Lake Georgetown.

Areal loading rates based on average concentrations in the diversion water and in Lake Georgetown were as follows:

Lake Georgetown	KgP/y	$gP/m^2/y$	KgN/y	$gN/m^2/y$
w/o Brushy	1,964	0.37	9,163	1.75
with Brushy	10,252	1.95	20,013	3.81

The calculated loadings increased 422 percent for total phosphorus and 118 percent for total nitrogen with implementation of the Brushy Creek Alternative. In Lake Georgetown, annual phosphorus loading rates are already within the range commonly observed in eutrophic impoundments, but nitrogen inputs appear to be low enough to limit productivity to the mesotrophic range. Although Lake Georgetown has been referred to as an oligotrophic reservoir, it exhibits an anoxic hypolimnion during the summer, a defining characteristic of eutrophic lakes in northern temperate zones. However, high background phosphorus loads and anoxic summer bottom waters are common in Texas reservoirs of this size. The additional phosphorus loadings from Brushy Creek and Lake Granger will increase the probability that adverse environmental conditions could result from increased biological productivity in Lake Georgetown.

Because treated wastewater comprises such a large component of Brushy Creek inflow even after diverting 14,000 acft/yr, Brushy Creek flows will still exceed those expected naturally (without wastewater return and diversions). However, flows downstream of the diversion would be reduced by the volume diverted and not returned with implementation of Alternative B-8. Estimating inflow changes in Brushy Creek resulting from implementation of this alternative will require instream flow analyses in a later study phase.

3.10.4 Water Quality and Treatability

Table 3.10-4 presents water quality measurements for Brushy Creek, Lake Georgetown, and Lake Granger. Water quality characteristics of Lake Granger are similar to those of Lake Georgetown. Water quality characteristics of Brushy Creek water are considerably different from those encountered in Lake Granger and Lake Georgetown. TDS and nutrient levels in the two lakes are considerably lower than those found in Brushy Creek, as are chloride and sulfate levels.[25] None of these constituents in any of the bodies of water exceeds the drinking water standards set forth by the TNRCC.[26] Although little data exists on toxic organics and metals, trace amounts of copper, lead, nickel, selenium, and zinc have been measured.[27]

Table 3.10-4
Conventional Water Quality Constituents in Brushy Creek, Lake Georgetown, and Lake Granger[1]

Constituent	Brushy Creek	Lake Granger	Lake Georgetown
Dissolved Oxygen (mg/l)	9.05	8.08	8.00
pH (su)	7.99	7.92	8.05
TDS (mg/l)	592.57	245.90	232.00
Fecal Coliforms (No./100 ml)	215.39	65.62	53.67
Chloride (mg/l)	106.77	23.52	13.00
Sulfate (mg/l)	59.92	25.29	18.38
Total Phosphorus (mg/l)	2.40	0.06	0.03
Total Nitrogen[2] (mg/l)	4.66	0.46	0.06

[1] TNRCC, "Texas State Water Quality Inventory," November 1994.
[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Conventional treatment methods including chemical mixing, sedimentation, filtration, and disinfection are probably adequate for drinking water treatment of the final water mixture in Lake Georgetown. However, the effects of the lower quality Brushy Creek water on both Lake Granger and Lake Georgetown should be investigated in greater detail before implementation of the proposed alternative. Issues to be addressed include the ability of Lake Granger and Lake Georgetown to assimilate additional nutrient loads from Brushy Creek, the mixing capability of both reservoirs, the effects on aquatic life, and the possible increase in drinking water treatment costs.

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[25] Texas State Water Quality Inventory, TNRCC, November 1994.
[26] Chapter 290: Water Hygiene, TNRCC.
[27] Regional Assessment of Water Quality, Brazos River Basin including the Upper Oyster Creek Watershed, Brazos River Authority, October 1994.

3.10.5 Engineering and Costing

For this alternative, available return flow from Brushy Creek would be pumped to Lake Granger. This return flow, plus return flow from Georgetown and available yield from Lake Granger, would then be transferred from Lake Granger by pipeline to Lake Georgetown to augment its yield. This new water supply would then be treated at an expanded existing WTP or at a potential new regional WTP and distributed to area demand centers. The major facilities required to implement this alternative are:

- Brushy Creek channel dam, intake and pump station;
- Raw water pipeline to Lake Granger;
- Lake Granger intake and pump station;
- Raw water booster pump station;
- Lake Georgetown intake and pump station;
- Raw water pipeline to treatment plant; and
- Expanded existing water treatment plant or potential new regional water treatment plant.

A 30-inch pipeline was selected to carry the estimated 2020 available return flow of 14,000 acft/yr from Brushy Creek to Lake Granger. The pipeline traverses 10 miles of rural land from southeast of Taylor, north along County Road 619, to the southeast arm of Lake Granger (Figure 3.10-1). The pipeline would deliver a uniform rate of 13.2 mgd (14,000 acft/yr with 5 percent down time).

At Lake Granger, these 14,000 acft/yr would join the 1,100 acft/yr return flow from Georgetown, and the 4,060 acft/yr uncommitted yield of Lake Granger to make up to 19,160 acft/yr (17.1 mgd) available to be diverted to Lake Georgetown. This water would then be pumped 28 miles east to Lake Georgetown through a 36-inch water transmission pipeline. The static lift from Lake Granger to Lake Georgetown is 279 feet, and one booster station would be required. This 19,160 acft/yr of additional yield in Lake Georgetown would then be available to withdraw for treatment at either a new or expanded plant on the north shore of Lake Georgetown, or at a new or expanded plant in Round Rock. The treatment capacity required for this new yield is 34 mgd (for a summer peak factor of 2.0).

Costs were estimated for the total project with treatment at an expanded Georgetown water treatment plant and with treatment at an expanded Round Rock WTP (Table 3.10-5). The only difference between the two cases is the longer raw water pipeline needed for the Round Rock treatment plant; all other items are the same.

Table 3.10-5
Cost Estimate Summary of Diversion from Brushy Creek and Lake Granger, Delivered to Lake Georgetown (B-8)
(1st Quarter 1997 dollars)

Item	Treatment at City of Georgetown WTP	Treatment at Round Rock WTP or Regional WTP
Capital Costs		
Intake and Raw Water Pipeline	$ 19,800,000	$ 19,800,000
Pump Stations	5,160,000	5,160,000
Water treatment plant	25,240,000	33,220,000
Total Capital Costs	50,200,000	58,180,000
Engineering, Contingencies, and Legal	16,580,000	19,370,000
Land Easements	480,000	560,000
Environmental Studies and Mitigation	480,000	560,000
Interest During Construction	5,420,000	6,290,000
Total Project Costs	73,150,000	84,970,000
Annual Costs		
Annual Debt Service	6,850,000	7,960,000
Annual Operation and Maintenance (Excluding Power)	2,840,000	2,930,000
Annual Power	1,260,000	1,250,000
Purchase of Water from BRA	89,300	89,300
Total Annual Cost	11,050,000	12,220,000
Annual Project Yield	19,160 acft/yr	19,160 acft/yr
Annual Unit Cost of Treated Water		
($ per acft)	$576	$637
($ per 1,000 gal)	$1.77	$1.96

For treatment at an expanded Georgetown WTP, the cost of the transmission systems with pumping and intakes is $24,960,000. The expanded WTP is estimated to cost $25,240,000. Engineering, contingencies, and all other capital costs are about $22,960,000 to make a total project cost of $73,150,000. Financed at 8 percent for 25 years, the annual debt service is $6,850,000. With O&M costs, the total annual cost is $11,050,000. For the 19,160 acft/yr additional yield, the unit cost would be $576 per acft ($1.77 per 1,000 gal).

For treatment at an expanded Round Rock WTP, the cost of the transmission system with pumping and intakes is $24,960,000. The expanded water treatment plant with intake and pipeline is estimated to cost $33,220,000. The higher cost in this case is due to the roughly 8-mile route to the treatment plant which requires trenching in rock. The total project cost would be $84,970,000. The annual debt service is $7,960,000 and total annual costs are $12,220,000. For the additional yield of 19,160 acft/yr, the unit cost with treatment in Round Rock is $637 per acft ($1.96 per 1,000 gal).

3.10.6 Implementation Issues

Requirements Specific to Diversion of Return Flows From Brushy Creek

1. Necessary permits:
   a. TNRCC permit to divert wastewater from Brushy Creek.
   b. TNRCC permit to discharge to Lake Granger.
   c. U.S. Army Corps of Engineers (USCE) 404 dredge and fill permit for the intake and outfall structure.
2. Permitting may require these studies:
   a. Instream flow study.
   b. Compatibility study of Brushy Creek water blended with Lake Granger water.
3. Approval from Brazos River Authority (BRA) to use Lake Granger as temporary storage of Brushy Creek water.
4. Agreements with USCE and BRA to construct and operate an intake and pump station at Lake Granger.

Requirements Specific to Diversion of Water From Lake Granger

1. Necessary permits:
   a. TNRCC permit to divert Brushy Creek return flows discharged at Lake Granger.
   b. TNRCC permit to divert return flows from Lake Granger which originate from the Georgetown area.
   c. Permit to discharge water to Lake Georgetown.
   d. USCE 404 dredge and fill permit for the intake and outfall structure.
2. Permitting may require these studies:
   a. Compatibility study of Lake Granger water blended with Lake Georgetown water.
3. Agreements with USCE and BRA to construct and operate an intake and pump station at Lake Granger.

Requirements Specific to Diversion of Water from Lake Georgetown

1. Necessary permits:
   a. TNRCC permit to discharge to and to divert additional water supply from Lake Georgetown.
   b. USCE 404 dredge and fill permit for the intake structure.
2. Agreement with USCE and BRA to construct and operate an expanded or new intake structure and pump station at Lake Georgetown.

3. Approval from BRA and USCE to discharge to and withdraw additional water from Lake Georgetown.

Requirements Specific to Pipelines

1. Necessary permits:
   a. U.S. Army Corps of Engineers 404 dredge and fill permit for stream crossings.
   b. GLO Sand and Gravel Removal permits.
   c. 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.

3.11 South Fork Reservoir (B-9)

3.11.1 Description of Alternative

In 1962, a site on the South Fork of the San Gabriel River was studied by the U.S. Army Corps of Engineers for a possible new reservoir.[1] The South Fork Reservoir was to be the third of a system of reservoirs which included Lake Granger and Lake Georgetown. The system was authorized by the Flood Control Act of 1962. The dam for the South Fork Reservoir would be located at river mile 4.7, which is approximately 2 miles west of Interstate Highway 35. The capacity of the reservoir was to be 138,500 acft which included both flood control and water supply storage. Its operation would result in the reallocation of some flood control storage from Lake Granger. In 1967, consultation with local sponsors of the project resulted in a substantially scaled-down version of the original design, and in 1986 an additional reevaluation of the project found the reservoir unfavorable as a water supply alternative and recommended that further study be deferred indefinitely.[2] This alternative considers a much smaller potential reservoir for water supply only. Water supplied from this project would be delivered at a potential new regional water treatment plant. The reservoir site and a possible location of the water treatment plant are shown on Figure 3.11-1.

3.11.2 Available Yield

Preliminary reservoir operation studies were performed for the site to determine the optimum conservation pool capacity and to estimate the yield. Because operation of a reservoir on the South Fork would affect flows to Lake Granger, the yield reduction there was also estimated. The result of the analysis suggests that the approximate optimum conservation pool capacity for the South Fork Reservoir is 25,000 acft, which provides an estimated areal yield of 7,000 acft/yr (6.3 mgd)[3] without adjusting for water rights or environmental release criteria. The elevation of the conservation pool at 25,000 acft would be about 800 ft-MSL, and would have a surface area of about 980 acres. Estimates of the effects of the South Fork Reservoir on the yield of Lake Granger indicate a yield reduction of 3,250 acft/yr (2.9 mgd). This amount of firm yield

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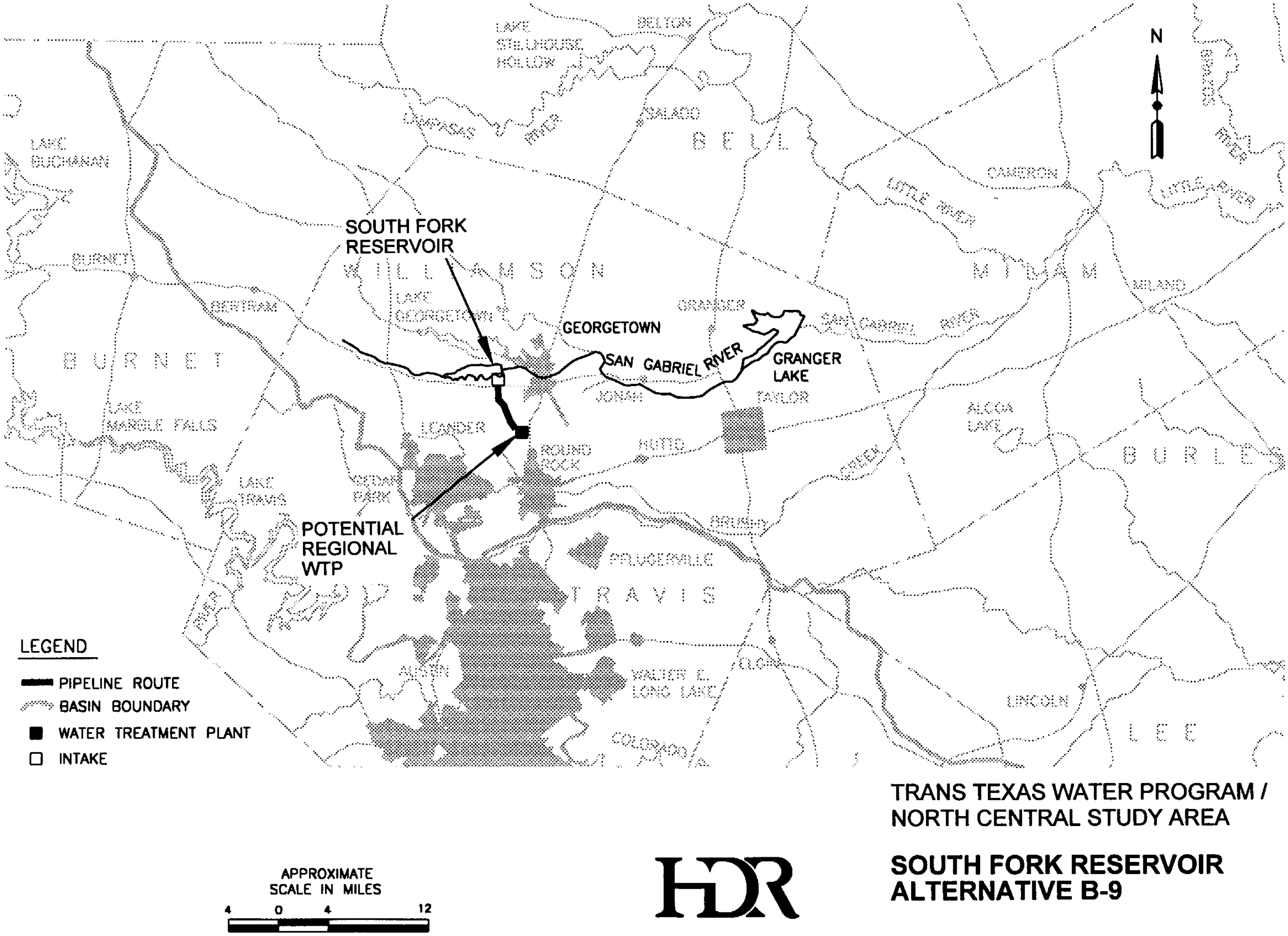
[1] South Fork Lake Reevaluation Report, Brazos River Basin, Texas, Corps of Engineers, October, 1986.

[2] Ibid.

[3] Preliminary Analysis of Potential Alternatives to Enhance Round Rock's Water Supply Capabilities, HDR Engineering, Inc., March, 1989.



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

SOUTH FORK RESERVOIR
ALTERNATIVE B-9

HDR Engineering, Inc.

FIGURE 3.11-1

is currently uncommitted in Lake Granger and would potentially have to be transferred to the South Fork Reservoir and purchased from the Brazos River Authority (BRA). A right to divert the remaining 3,750 acft/yr (3.4 mgd) from the South Fork of the San Gabriel would have to be acquired from the TNRCC. It is assumed that the full 7,000 acft/yr would be subject to the Trans-Texas environmental criteria for new reservoirs. Reducing the 7,000 acft/yr diversion right by an estimated environmental criteria factor of 15 percent leaves a net yield of 5,950 acft/yr. Because Lake Granger would capture any water released under the environmental criteria, the net yield reduction of Lake Granger would be reduced by the released amount. Therefore the net impact on the yield of Lake Granger would be reduced to 2,200 acft/yr (i.e., 3,250 acft/yr – 1,050 acft/yr).

3.11.3 Environmental Issues

Because this alternative is not reasonably cost effective (see Section 3.11.5), no environmental analysis was performed.

3.11.4 Water Quality and Treatability

From Table 3.11-1, both the North Fork and South Fork of the San Gabriel River have very similar water quality characteristics. Given these similarities and the geographic proximity of Lake Georgetown and the South Fork Reservoir, the South Fork Reservoir should share the high water quality characteristics found in Lake Georgetown.

Table 3.11-1
Conventional Water Quality Constituents
in the San Gabriel River, and Lake Georgetown[1]

Constituent	South Fork[2]	North Fork[3]	Lake Georgetown
Dissolved Oxygen (mg/l)	10.10	8.53	8.00
pH	7.99	7.87	8.05
TDS (mg/l)	274.21	299.73	232.00
Fecal Coliforms (No./100 ml)	21.00	29.62	53.67
Chloride (mg/l)	17.62	14.46	13.00
Sulfate (mg/l)	27.56	29.65	18.38
Total Phosphorus (mg/l)	0.01	0.01	0.03
Total Nitrogen[4] (mg/l)	0.77	0.13	0.06

[1] TNRCC, "Texas State Water Quality Inventory," November, 1994.
[2] Segment 1250 of the Brazos River Basin.
[3] Segment 1251 of the Brazos River Basin.
[4] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Conventional surface water treatment including rapid chemical mix, flocculation, sedimentation, filtration and disinfection would be adequate for treating impounded waters of the South Fork of the San Gabriel River to drinking water standards.

3.11.5 Engineering and Costing

The major items required to implement the South Fork Reservoir are:

- Dam and Reservoir
- Intake and Pump Station
- Raw Water Transmission Line to the Treatment Plant
- Conventional Surface Water Treatment Plant

The South Fork Reservoir would have a conservation pool capacity of 25,000 acft. Top of conservation pool occurs at approximately 800 ft-MSL, and the surface area at this elevation is about 980 acres. The estimated yield of the reservoir is 5,950 acft/yr (5.31 mgd). This yield requires conventional raw water treatment capacity of 10.6 mgd.[4] A 4.3 mile pipeline would deliver water to the treatment plant located at the tentative site of the potential regional plant, near the existing Round Rock water treatment plant. The pipeline was sized for a design flow of 11.2 mgd, which accommodates a 2.0 peak factor and 5 percent down time. This flow requires a 30-inch pipeline and a single pump station at the intake.

The cost estimate summary for this project is shown in Table 3.11-2. The combined cost of the dam and reservoir is $14,580,000. The estimated cost of a new 11 mgd treatment plant with raw water intake, pump station, and pipeline is $13,710,000. Land acquisition and environmental mitigation for the reservoir and dam areas is a major cost in this project, estimated at $52,870,000. The total project cost is $98,360,000. Financed at 8 percent for 25 years, the annual debt service for the South Fork Reservoir project would be $9,220,000. The total annual cost including operation and maintenance would be about $10,874,000. For the project yield of 5,950 acft/yr, the unit cost of water would be $1,830 per acft ($5.60 per 1,000 gal).

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[4] Assumes 2.0 peak factor.

Table 3.11-2
Cost Estimate Summary for The South Fork Reservoir with Treatment at a Potential New Treatment Plant (B-9)
(1st Quarter 1997 dollars)

Item	Cost
Capital Costs	
Dam	$ 12,890,000
Reservoir	1,690,000
Transmission System	3,310,000
Treatment Plant	10,400,000
Total Capital Costs	$ 28,290,000
Engineering, Contingency, and Legal	9,800,000
Land Acquisition and Damages[1]	52,870,000
Environmental Studies and Mitigation[2]	110,000
Interest During Construction	7,290,000
Total Project Cost	$ 98,360,000
Annual Costs	
Annual Debt Service	9,220,000
Purchase of Raw Water from BRA from Granger Reservoir	114,000
Annual Operations & Maintenance (Excluding Power)	1,460,000
Annual Power	80,000
Total Annual Cost	$ 10,874,000
Annual Project Yield	5,950 acft/yr
Annual Cost of Treated Water	
($ per acft)	$1,830
($ per 1,000 gal)	$5.60

[1] Land and damages costs from "South Fork Lake Reevaluation Report, U.S. Army Corps of Engineers, October, 1986. Calculated as $130,000,000 x (980 acres/3,200 acres) x 1.326. (1.326 is CCI ratio). Includes environmental mitigation for the dam and reservoir area.

[2] For water treatment plant and pipeline only.

3.11.6 Implementation Issues

Implementation Issues Specific to the South Fork Reservoir

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.
    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. Habitat mitigation plan.
    b. Environmental study of potential impact on endangered species.
    c. Cultural resource studies.
    d. Study of potential impact on karst geology organisms.
    e. Other environmental studies.
3. Relocations for the reservoir include:
    a. Affected utilities.
4. Land will need to be acquired either through negotiations or condemnation.

Requirements Specific to Pipelines

1. Necessary permits:
    a. U.S. Army Corps of Engineers 404 dredge and fill permit for stream crossings.
    b. GLO Sand and Gravel Removal permits.
    c. 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

Colorado River Basin Alternatives

3.12 Purchase of Uncommitted Stored Water from LCRA for Diversion at Lake Travis (C-2)

3.12.1 Description of Alternative

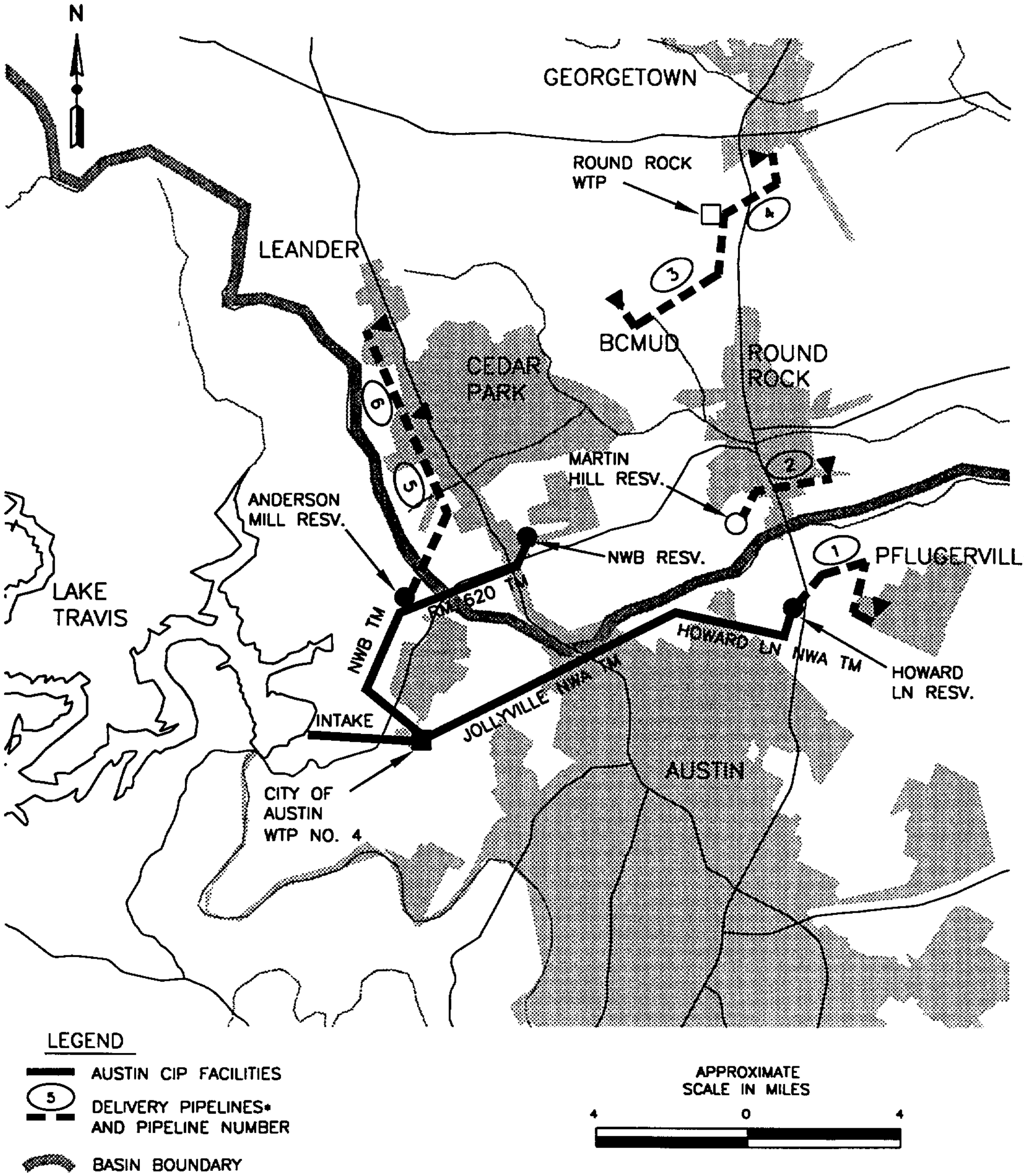
This alternative evaluates the use of stored water diverted at Lake Travis to meet demands in the study area. The stored water considered for diversion could come from the uncommitted portion of the combined firm yield of Lake Buchanan and Lake Travis, or from supplemental sources. Lakes Buchanan and Travis are part of the Highland Lakes system on the Colorado River and are owned and operated by LCRA. Lake Travis, from which the water would be withdrawn, is located in western Travis County, about 4 miles west of Austin. Lake Travis and portions of the study area are shown in Figure 3.12-1.

Water demands potentially met by facilities evaluated in this alternative exceed the amount of uncommitted firm yield available for purchase from LCRA (see Section 3.12.2) and supplemental supplies would be needed for some of the demand scenarios evaluated. Other supply alternatives in this report that could potentially augment supplies in Lake Travis include: Purchase of Water from Brazos River Authority at Lake Somerville for Transfer to Colorado River (Section 3.9, Alt B-7); Purchase Irrigation Rights in the Lower Colorado River Basin with Off-Channel Storage Near Columbus (Section 3.14, Alt C-5); and Use of Carrizo-Wilcox Aquifer to Augment Colorado River Flows (Section 3.16, Alt CZ-1).

Treatment Options

To meet the projected water demands of the study participants, consideration has been given to diversion and treatment of Lake Travis water at any of three treatment plants or a combination of them. The diversion locations and treatment plants considered are the City of Austin Water Treatment Plant 4 (WTP4), an expanded or additional Cedar Park Water Treatment Plant, or a potential regional water treatment plant located near the site of the existing Round Rock Treatment Plant.

WTP4 is a proposed project being considered by the City of Austin to serve a large portion of its future water treatment needs. Its location near Lake Travis is shown in Figure 3.12-1. It is possible that WTP4 would someday serve parts of the City currently being served



* DELIVERY FACILITIES NEEDED TO CONVEY TREATED WATER FROM WTP 4 TO POTENTIAL PARTICIPANTS

TRANS TEXAS WATER PROGRAM /
WEST CENTRAL STUDY AREA

WTP 4 AND CONVEYANCE FACILITIES - SCENARIOS 1-5 ALTERNATIVE C-2

HDR

HDR Engineering, Inc.

FIGURE 3.12-1

by the Davis, Green, and Ullrich treatment plants. Initial[1] capacity of WTP4 would probably be 100 mgd and ultimate capacity is most likely to be 160 mgd but could be as large as 356 mgd in the largest configuration considered for this alternative (year 2050 conditions). WTP4 is also conveniently located to serve parts of Williamson County, which is evaluated in some of the scenarios in this alternative.

The Cedar Park Treatment Plant, located on the Sandy Creek Arm of Lake Travis, is currently being expanded from 9 mgd to 15 mgd. A current capacity of 15 mgd was used for this report. Though the current site is only expandable to 21 mgd, with acquisition of additional land, future expansions could occur in the same general location.

A potential regional treatment plant in Williamson County is also being considered. Although no siting study or investigations have been made, the plant is tentatively located at the site of the existing Round Rock Treatment Plant, on the north edge of Round Rock near IH 35. The present capacity of the existing Round Rock Treatment Plant is 15 mgd and is currently being expanded to 21 mgd.

Delivery Scenarios

The entities who would potentially receive delivery of water from implementation of this alternative are the City of Austin, Pflugerville, Round Rock, Brushy Creek MUD, Georgetown, Cedar Park, and Leander. The point of delivery for each of these entities is summarized in Table 3.12-1. It may be possible for other entities to participate in this alternative by an interconnection with one of the participants.

Eight scenarios of treatment plant location and delivery location have been studied. For 5 of the 8 scenarios, projected water demands in years 2030 and 2050 have also been considered, resulting in 13 treatment/delivery/demand combinations.

The eight scenarios can be grouped into two categories. Scenarios 1 through 5 involve diversion and treatment at Austin's proposed Water Treatment Plant 4. Some of these scenarios would deliver treated water to entities in Williamson County.

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[1] City of Austin, "Water Distribution System, Long Range Planning Guide," February 1994.

Table 3.12-1
Delivery Locations for Entities (Alt C-2)

Entity	Delivery Location
Austin	Anderson Mill Reservoir, Martin Hill Reservoir, Howard Lane Reservoir.
Round Rock	New Storage Tank (near Dell Computer)
Pflugerville	Middle School Storage Tank
Georgetown	Rabbit Hill Storage Tank
Brushy Creek MUD	FM 1431 Storage Tank
Cedar Park	Webster Storage Tank
Leander	High School Storage Tank.

The second group, Scenarios 6 through 8, involve diversion on the Sandy Creek arm of Lake Travis near the existing Cedar Park WTP and treatment at either an expansion of the Cedar Park Water Treatment Plant, or a new regional facility near Round Rock. Scenarios 6 through 8 would only provide treated water to entities in Williamson County. Table 3.12-2 summarizes the grouping of the eight basic scenarios.

Table 3.12-2
Definition of Scenarios
Purchase of Water from LCRA for Diversion at Lake Travis (C-2)

Scenario	Diversion and WTP Location	Delivery Locations
1, 2, 3, 4, 5	Austin WTP4	Various - See Table 3.12-3
6	Expanded Cedar Park WTP or similar location	Cedar Park, Leander
7	Expanded Cedar Park WTP or similar location	Cedar Park, Leander, Round Rock
8	Diversion near Cedar Park WTP and Regional WTP near Round Rock	Round Rock

Scenarios 1 through 5 - Treatment at Austin's WTP4

Scenarios 1 through 5 provide for treatment at the proposed WTP4 and delivery to the City of Austin and one or more entities in Travis and Williamson Counties as summarized in Table 3.12-3. Scenario 1 would provide treated water only to the City of Austin. Scenario 2 would provide treated water to Austin, Pflugerville, and Round Rock. Scenario 3 would provide treated water to Austin, Pflugerville, Round Rock, and Brushy Creek MUD. Scenario 4 would provide service to Austin, Pflugerville, Round Rock, Brushy Creek MUD, Cedar Park, and Leander. Scenario 5 would provide service to Austin, Pflugerville, Round Rock, Brushy Creek, Cedar Park, Leander, and Georgetown.

Table 3.12-3
Delivery Locations for Scenarios Involving WTP4

Demand Center	Scenario				
	1	2	3	4	5
Austin	✓	✓	✓	✓	✓
Pflugerville		✓	✓	✓	✓
Round Rock		✓	✓	✓	✓
Brushy Creek MUD			✓	✓	✓
Cedar Park				✓	✓
Leander				✓	✓
Georgetown					✓

It is anticipated that increased demand for water in the Austin service area will be met by constructing WTP4 and expansion of Ullrich WTP (see Section 3.15.5). Other capital expenditures for pump stations, reservoirs, and transmission pipelines will be necessary to deliver new treated water supplies to the Austin service area and potential customers in Travis and Williamson Counties. WTP4 will supply projected growth in the northern portions of the Austin service area, primarily in the Northwest-A (NW-A), Northwest-B (NW-B), and North pressure zones. Capital facilities, along with cost estimates for those facilities, have been estimated for the NW-A and NW-B pressure zones for each scenario.

Demands for Scenarios 1, 3, 4, and 5 use projected demands for years 2030 and 2050 as presented in Tables 3.12-4a and 3.12-4b. In Scenario 2, the demands for Pflugerville and Round Rock are their 1996 supply contracts with the City of Austin (i.e., Pflugerville, 10 mgd and Round Rock, 4.8 mgd). The projected demands for the City of Austin represent incremental increases above 1990 demands. Demands for the North pressure zone are included for the NW-A pressure zone. For all other entities the demands reflect projected demands less current supplies.

However, contracts that Williamson County entities have for water from Lake Stillhouse Hollow were not included in estimates of demand and supply, thereby allowing comparison between Alternative C-2 (this alternative), and Alternative B-1 (use of Lake Stillhouse Hollow [see Section 3.7]).

Scenarios 6 through 8 - Treatment at Expanded Cedar Park WTP

In Scenarios 6, 7, and 8, facilities were sized to meet projected shortages as summarized in Table 3.12-4c. Scenario 6 would provide treated water to Cedar Park and Leander to meet projected year 2030 shortages. Leander's contract to purchase water from Lake Stillhouse Hollow (for 2,700 acft/yr) is not included as a supply, as it is assumed they would cancel the contract if participating in a Lake Travis water supply project. Scenario 7 would provide treated water to Cedar Park, Leander, and Round Rock to meet projected year 2030 shortages. Round Rock's contract to purchase water from Lake Stillhouse Hollow (18,134 acft/yr) is not included as a supply to Round Rock. However, Leander's purchase contract for Lake Stillhouse Hollow is not included as a supply source. Scenario 8 is closely patterned to a water supply alternative recently studied by LCRA[2] to provide treated water from Lake Travis to southern Williamson County. Projected shortages in the southern Williamson County region in year 2020 were estimated to be 19,000 acft/yr. Deliveries to the City of Round Rock were not specified and for comparison purposes are shown in Table 3.12-4c, the same as for Scenario 7 (11,458 cuft/yr).

Scenarios 1 to 5

Scenarios 1 to 5 all involve treatment and delivery from WTP4 in Austin to the participants. Scenario 1 involves delivery to Austin only. Scenario 2 involves delivery to Austin, Pflugerville, and Round Rock under existing supply contracts. Scenario 3 involves delivery to Austin, Pflugerville, Round Rock, and Brushy Creek MUD to meet projected demands. Scenario 4 involves delivery to the same participants as Scenario 3 plus Cedar Park

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[2] Espey, Huston & Associates, Inc., "Technical Memorandum, Equivalent Cost Boundary, Williamson County Water Supply Study," Lower Colorado River Authority, March 1996.

Table 3.12-4a
Projected Shortages for Year 2030 [1]
Scenarios 1 to 5 (Alt C-2)

Demand Center		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Northwest-A Pressure Zone						
Austin NW-A [2]	Annual (acft/yr) Peak (mgd)	72,590 111.5	72,590 111.5	72,590 111.5	72,590 111.5	72,590 111.5
Pflugerville	Annual (acft/yr) Peak (mgd)	—	11,200 [3] 10.0	12,362 22.1	12,362 22.1	12,362 22.1
Round Rock	Annual (acft/yr) Peak (mgd)	—	6,160 [3] 5.5	21,458 38.3	21,458 38.3	21,458 38.3
Brushy Creek MUD	Annual (acft/yr) Peak (mgd)	—	—	2,754 4.9	2,754 4.9	2,754 4.9
Georgetown	Annual (acft/yr) Peak (mgd)	—	—	—	—	5,369 9.6
Total NW-A	Annual (acft/yr) Peak (mgd)	72,590 111.5	89,950 127.0	109,164 176.8	109,164 176.8	114,533 186.4
Northwest-B Pressure Zone						
Austin NW-B	Annual (acft/yr) Peak (mgd)	28,140 45.0	28,140 45.0	28,140 45.0	28,140 45.0	28,140 45.0
Cedar Park	Annual (acft/yr) Peak (mgd)	—	—	—	7,983 14.3	7,983 14.3
Leander	Annual (acft/yr) Peak (mgd)	—	—	—	5,182 9.3	5,182 9.3
Total NW-B	Annual (acft/yr) Peak (mgd)	28,140 45.0	28,140 45.0	28,140 45.0	41,305 68.6	41,305 68.6
Grand Total	Annual (acft/yr) Peak (mgd)	100,370 156.5	118,090 172.0	137,304 221.8	150,469 245.4	155,838 255.0

1. Demands for Austin areas represent incremental increases above 1990 demands. Demands for all other entities represent projected shortages without Lake Stillhouse Hollow or Austin supply contracts. Peak factor source for Austin: City of Austin, "Water Utility Long Range Planning Guide," February, 1994. Peak factor for all others is 2.0.
2. Includes demands for North pressure zone.
3. Supply contract with City of Austin.

Source: Trans-Texas Water Program, North Central Study Area, "Population, Water Demand, and Supply Projections"; May 21, 1996.

Table 3.12-4b
Projected Shortages for Year 2050 [1]
Scenarios 1 to 5 (Alt C-2)

Demand Center		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
			Northwest-A Pressure Zone			
Austin NW-A [2]	Annual (acft/yr) Peak (mgd)	105,159 154.1	105,159 154.1	105,159 154.1	105,159 154.1	105,159 154.1
Pflugerville	Annual (acft/yr) Peak (mgd)	—	11,200 [3] 10.0	14,541 26.0	14,541 26.0	14,541 26.0
Round Rock	Annual (acft/yr) Peak (mgd)	—	6,160 [3] 5.5	29,774 53.2	29,774 53.2	29,774 53.2
Brushy Creek MUD	Annual (acft/yr) Peak (mgd)	—	—	2,835 5.1	2,835 5.1	2,835 5.1
Georgetown	Annual (acft/yr) Peak (mgd)	—	—	—	—	18,072 32.3
Total NW-A	Annual (acft/yr) Peak (mgd)	105,159 154.1	122,519 169.6	152,309 238.4	152,309 238.4	170,381 270.7
			Northwest-B Pressure Zone			
Austin NW-B	Annual (acft/yr) Peak (mgd)	34,455 52.9	34,455 52.9	34,455 52.9	34,455 52.9	34,455 52.9
Cedar Park	Annual (acft/yr) Peak (mgd)	—	—	—	10,436 18.6	10,436 18.6
Leander	Annual (acft/yr) Peak (mgd)	—	—	—	7,934 14.2	7,934 14.2
Total NW-B	Annual (acft/yr) Peak (mgd)	34,455 52.9	34,455 52.9	34,455 52.9	52,825 85.7	52,825 85.7
Grand Total	Annual (acft/yr) Peak (mgd)	139,614 207.0	156,190 221.8	186,764 291.3	205,134 324.1	223,206 356.4

1. Demands for Austin areas represent incremental increases above 1990 demands. Demands for all other entities represent projected shortages without Lake Stillhouse Hollow or Austin supply contracts. Peak factor source for Austin: City of Austin, "Water Utility Long Range Planning Guide," February, 1994. Peak factor for all others is 2.0.
2. Includes demands for North pressure zone.
3. Supply contract with City of Austin.

Source: Trans-Texas Water Program, North Central Study Area, "Population, Water Demand, and Supply Projections"; May 21, 1996.

Table 3.12-4c
Projected Shortages
Scenarios 6 to 8 (Alt C-2)

Demand Center		**Scenario 6 (Year 2030)**	**Scenario 7 (Year 2030)**	**Scenario 8 (Year 2020)**
Cedar Park	Annual (acft/yr) Peak (mgd)	8,816 15.7	8,816 15.7	—
Leander[1]	Annual (acft/yr) Peak (mgd)	5,182 9.3	5,182 9.3	—
Round Rock[2]	Annual (acft/yr) Peak (mgd)	—	11,458 20.5	11,458 20.5
Total	Annual (acft/yr) Peak (mgd)	13,998 25.0	25,456 45.5	19,000[3] 34.0

1. Contract for Lake Stillhouse Hollow water not included.
2. Contract for Lake Stillhouse Hollow water is included. Peak factor = 2.0.
3. Projected year 2020 shortage from "Technical Memorandum, Equivalent Cost Boundary, Williamson County Water Supply Study," LCRA, March 1996. Projected shortages for City of Round Rock only are same as Scenario 7 for comparison purposes. Total projected shortage includes demands for Round Rock and other entities in southern Williamson County.

Source: Trans-Texas Water Program, North Central Study Area, "Population, Water Demand, and Supply Projections"; May 21, 1996.

Figure 3.12-1 shows the routes of the major facilities required for Scenarios 1 through 5. These scenarios are dependent on planned expansions to Austin's NW-A and NW-B pressure zones[3]. The cost of service the Austin water utility experiences can vary by pressure zone depending on required capital improvements and energy costs. Therefore, costs are estimated by pressure zone and the following list indicates which pressure zones potentially would provide water to purchasers.

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[3] City of Austin, "Water Distribution System Long Range Planning Guide," February, 1994.

NW-A Pressure Zone

Austin NW-A
Austin North
Pflugerville
Round Rock
Brushy Creek MUD
Georgetown

NW-B Pressure Zone

Austin NW-B
Cedar Park
Leander

The following Austin CIP facilities are required for Scenarios 1 through 5. Most of these facilities are shown in Figure 3.12-1. The City of Austin CIP facilities necessary to implement Scenarios 1 through 5 are:

- Water Treatment Plant 4 (serves both pressure zones)
- **NW-A Pressure Zone**

  NW-A Pump Station
  Jollyville NW-A Transmission Main
  Martin Hill Transmission Main
  Howard Lane Transmission Main
  Howard Lane NW-A Pressure Control Station
  Jollyville Flow Control Station

- **NW-B Pressure Zone**

  NW-B Pump Station
  NW-B Discharge Transmission Main
  RM 620 Transmission Main
  NW-B Reservoir
  Four Points Flow Control Station

Water Treatment Plant 4 would serve the North, NW-A, and NW-B pressure zone. The plant includes an intake on Lake Travis and a raw water pipeline from the lake to the plant (Figure 3.12-1). Current planning by the City of Austin is to construct WTP4 by year 2017.[4] The cost of

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[4] City of Austin, "Water Distribution System Long-Range Planning Guide," February, 1994.

WTP4 is allocated to the pressure zones according to the projected deliveries to each pressure zone. Construction could be implemented earlier if water demands or purchase contracts with entities in Williamson County warrant.

Transmission Facilities from Austin to Other Entities

There are six potential transmission pipelines needed for delivery under the eight scenarios. The potential transmission pipelines are numbered 1 through 6 and are shown in Figure 3.12-1. The sizes of pipelines, their associated pump stations and storage facilities vary with demand and are summarized in Section 3.12.5. Scenarios 3, 4, and 5 require transmission facilities to deliver treated water from the Austin distribution system to Williamson County participants.[5]

Scenarios 6 and 7

Scenarios 6 and 7 involve treating water at an expanded or additional Cedar Park Water Treatment Plant. Water could be purchased from LCRA for diversion at Cedar Park's existing intake, or at a new intake site located on the north shore of Lake Travis. The participants involved in these scenarios are Cedar Park, Leander, and Round Rock. Treatment and delivery was evaluated for 2030 projected shortages as summarized in Table 3.12-4c. The major items necessary to implement these scenarios are:

- Intake and pump station on Lake Travis,
- Raw water transmission pipeline to the water treatment plant,
- New or expanded water treatment plant,
- Transmission pipeline from treatment plant to Webster storage tank,
- Pump station and distribution main from Webster storage tank to Leander storage tank (Line 6).

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[5] For Scenario 2 the facilities linking Pflugerville and Round Rock to the Austin distribution system are either in design or already in place and are not included in this cost evaluation. In the near-term, Pflugerville will receive North pressure zone water. For potential increased deliveries above the current contract, (Scenarios 3, 4, and 5) Pflugerville would convert to the NW-A pressure zone and deliver to Pflugerville's Middle School storage tank.

Scenario 7 also includes the following facilities:

- Transmission main from treatment plant to new storage tank in south Round Rock.

These facilities are shown in Figures 3.12-2 and 3.12-3.

Scenario 8

Scenario 8 is closely patterned to a water supply alternative recently studied by LCRA.[6] In the LCRA work, the study area was limited to the high growth areas in Williamson County south of the San Gabriel River where the estimated aggregate water shortage in year 2020 is about 19,000 acft/yr. To supply the projected shortage, LCRA studied a raw water supply from Lake Travis to a regional treatment plant potentially to be located north of Round Rock. The intake, pumping, and transmission facilities would be sized to deliver peak day demands to the regional treatment plant.

Scenario 8 involves diverting water from Lake Travis at a new intake and transporting it to a potential new regional water treatment plant near the existing Round Rock treatment plant. The necessary facilities to implement this scenario are shown in Figure 3.12-4 and are listed below.

- Intake and pump station on Lake Travis;
- Raw water transmission pipeline to the water treatment plant;
- New regional water treatment plant;
- Distribution main to new storage tank;
- New storage tank.

3.12.2 Available Yield

Lake Travis is located in western Travis County, about 4 miles west of the City of Austin. It is one of six reservoirs known as the Highland Lakes constructed on the Lower Colorado River. The location of Lake Travis is shown on Figure 3.12-1. The LCRA holds the permit from the State of Texas for the right to impound water in Lake Travis and divert water for municipal and other uses.[7]

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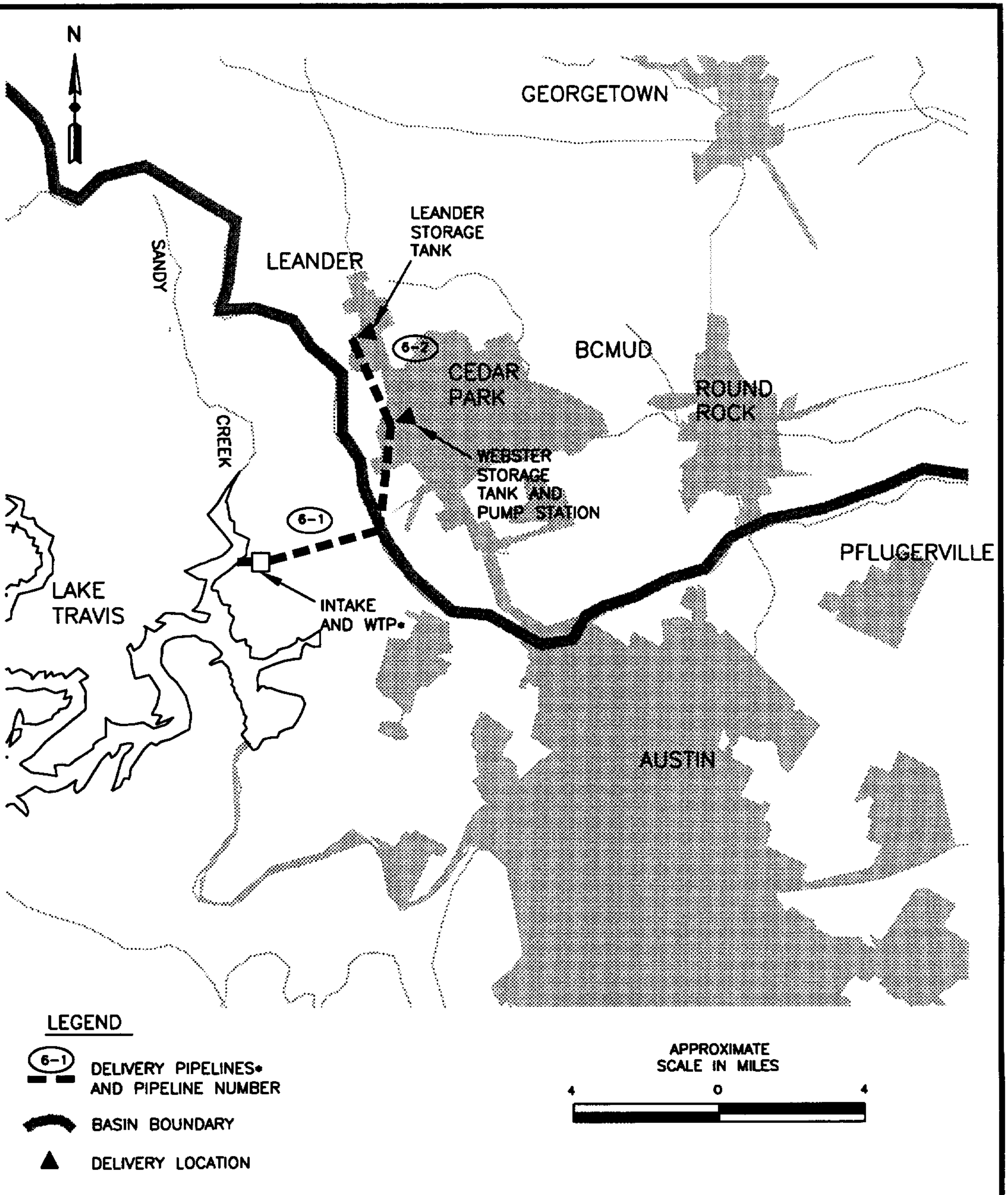
[6] Espey, Huston & Associates, Inc., "Technical Memorandum, Equivalent Cost Boundary, Williamson County Water Supply Study," Lower Colorado River Authority, March 1996.

[7] Permit No. 1260.



• INTAKE AND WTP LOCATION IS ADJACENT TO EXISTING CEDAR PARK WTP.

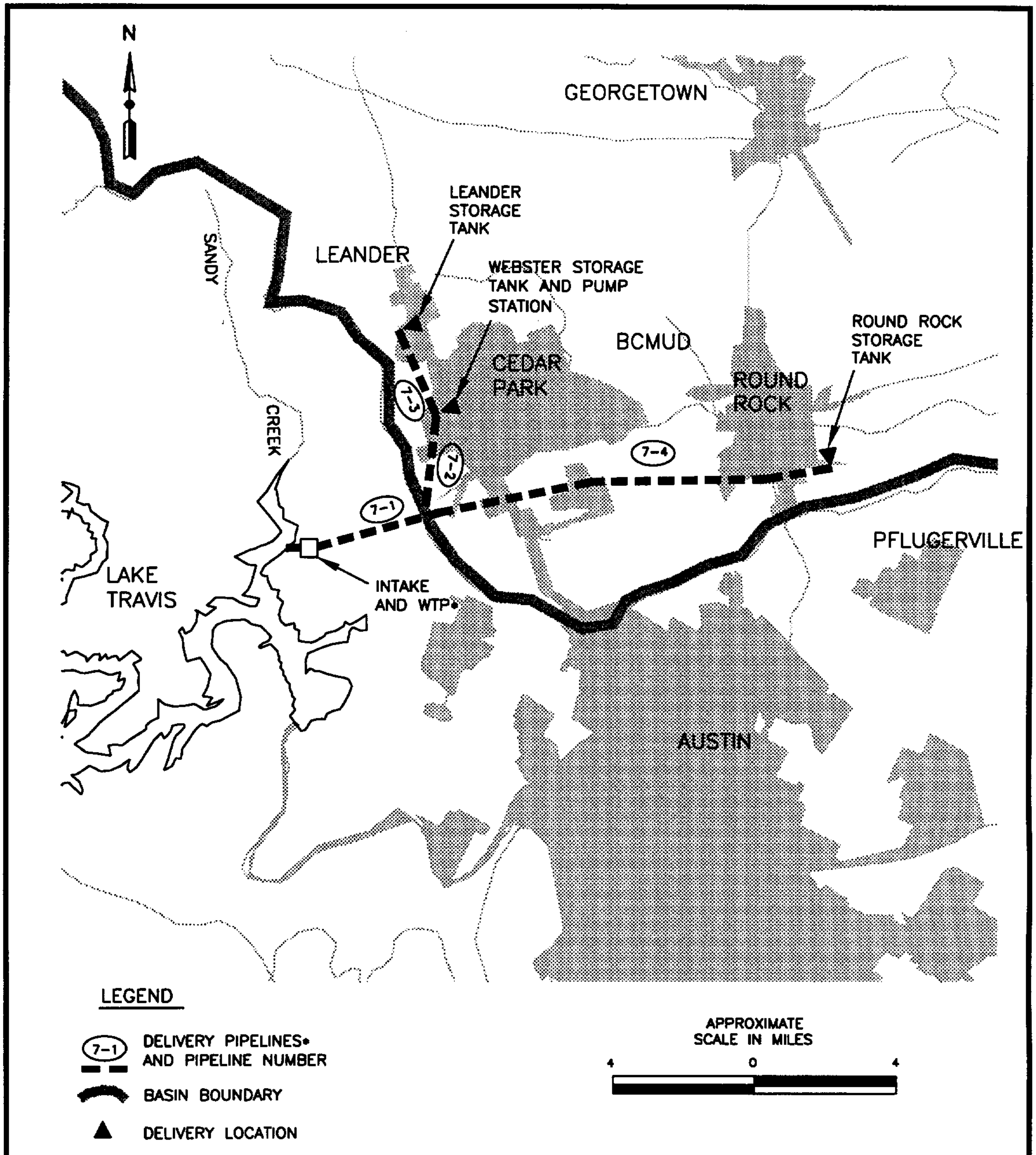
TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

LAKE TRAVIS DIVERSION AT CEDAR PARK - SCENARIO 6 ALTERNATIVE C-2

HDR

HDR Engineering, Inc.

FIGURE 3.12-2



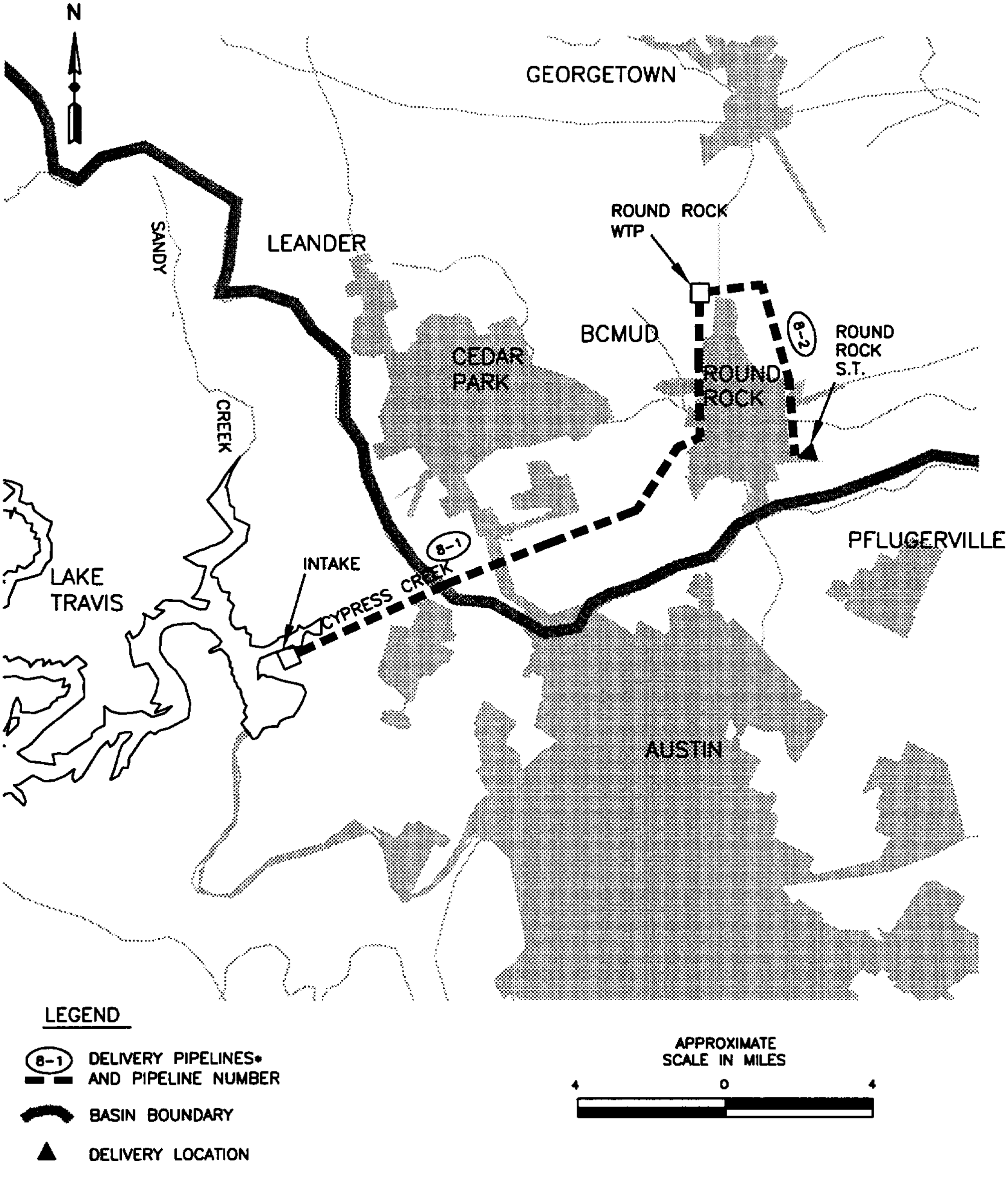
• INTAKE AND WTP LOCATION IS ADJACENT TO EXISTING CEDAR PARK WTP.

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

LAKE TRAVIS DIVERSION AT CEDAR PARK - SCENARIO 7 ALTERNATIVE C-2

FIGURE 3.12-3



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

LAKE TRAVIS DIVERSION AT CYPRESS CREEK - SCENARIO 8 ALTERNATIVE C-2

HDR

HDR Engineering, Inc.

FIGURE 3.12-4

The yield of the Highland Lakes after accounting for O. H. Ivey Reservoir is 689,609 acft/yr. Of this total, the yield is reduced by 392,643 acft to honor senior downstream water rights and commitments to the City of Austin, and 160,199 acft/yr is currently committed to water sale contracts and electric utilities. Of the remaining yield, 31,800 acft/yr has been reserved to provide instream flows and flows to the bay. The remaining 104,967 acft/yr of water is currently uncommitted.[8] The scenarios in this alternative are not limited to diverting this amount from Lake Travis as other alternatives in this report look at options for increasing the availability of water from the Highland Lakes (refer to Sections 3.2 and 3.14).

3.12.3 Environmental Issues

The eight scenarios in this alternative all require the installation of an intake structure in Lake Travis, water delivery systems and one of three potential regional water treatment plant options (Table 3.12-5). Scenarios 1 through 5 would utilize Water Treatment Plant 4 (WTP4) at the existing City of Austin parcel. Scenarios 6 and 7 would deliver raw water to a regional water treatment plant near Cedar Park for treatment before distribution. Scenario 8 would utilize a regional water treatment plant near to the existing Round Rock Treatment Plant (Figure 3.12-4).

The area potentially affected by this alternative are located in northern Travis and southern Williamson counties. Environmental considerations include:

- Potential effects on endangered and threatened terrestrial, aquatic and karstic species.
- Potential long term effects to the terrestrial environment along the water transmission line rights-of-way (ROW) and treatment facility properties.
- Impacts to the instream flows of the Brazos River below the Georgetown wastewater treatment facility outfall and the Matagorda Bay and estuary system.
- Impacts of interbasin water transfers between the Colorado and Brazos River Basins.

The description of the study area, below, is followed by text discussing the individual environmental considerations pertinent to the three potential water treatment plant facilities, associated raw water transmission main ROWs and the six dedicated delivery systems that comprise the eight alternative service scenarios.

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[8] Lower Colorado River Authority, Water Management Plan, 1993, and list of current water supply contracts.

Table 3.12-5

Eight Scenarios Proposed in the North-Central Trans-Texas Water Program C-2 Alternative.

Scenario	1	2	3	4	5	6	7	8
Municipality Supplied	Austin	Austin Pflugerville Round Rock	Austin Pflugerville Round Rock Brushy Creek	Austin Pflugerville Round Rock Brushy Creek Cedar Park Leander	Austin Pflugerville Round Rock Georgetown Brushy Creek Cedar Park Leander	Cedar Park Leander	Cedar Park Leander Round Rock	Round Rock
Water Source	Lake Travis							
Raw Water Line	12,100 feet tunneled	12,100 feet tunneled	12,100 feet tunneled	12,100 feet tunneled	12,100 feet tunneled	42,240 feet	42,240 feet	82,468 feet
WTP	WTP4	WTP4	WTP4 and Round Rock WTP	WTP4 and Round Rock WTP	WTP4 and Round Rock WTP	New or Expanded Cedar Park WTP	New or Expanded Cedar Park WTP	New or Expanded Round Rock WTP
Acreage for WTP Construction	240.4 (138 set aside for habitat)	240.4 (138 set aside for habitat)	240.4 (138 set aside for habitat)	240.4 (138 set aside for habitat)	240.4 (138 set aside for habitat)	9 (Habitat Mitigation to be Determined)	20 (Habitat Mitigation to be Determined)	17 (Habitat Mitigation to be Determined)
2030 Peak Production (mgd)	157	172	222	245	255	25	45.5	34
2030 Annual Production (acft/yr)	100,730	117,306	137,304	150,469	155,838	19,180	25,456	19,000

Table 3.12-5
Eight Scenarios Proposed in the North-Central Trans-Texas Water Program C-2 Alternative (Concluded)

Scenario	1	2	3	4	5	6	7	8
Proposed CIP Transmission Mains	NWA Jollyville NWA Transmission Main Howard Lane NWA Transmission Main Martin Hill Transmission Main		NW-B Discharge Transmission Main RM 620 Transmission Main			WTP to Webster Storage Tank Webster Storage Tank to Leander Storage Tank	WTP to Proposed New Storage Tank Round Rock WTP to Webster Storage Tank Transmission Main from Webster Storage Tank to Leander	Proposed New Storage Tank in South Round Rock
Dedicated Pipelines *	None Required	None Required	Line 1 Line 2 Line 3	Line 1 Line 2 Line 3 Line 5 Line 6	Line 1 Line 2 Line 3 Line 4 Line 5 Line 6	None Required	None Required	None Required
Storage	Existing Austin Storage Facilities New NW-B Storage Reservoir	Existing Austin Storage Facilities New NW-B Storage Reservoir	Existing Austin Pflugerville and Brushy Creek Storage Facilities New Storage Tank in South Round Rock	Existing Austin Pflugerville Brushy Creek Cedar Park and Leander Storage Facilities	Existing Austin Pflugerville Georgetown Brushy Creek Cedar Park and Leander Storage Facilities	Existing Cedar Park and Leander Storage Tanks	Existing Cedar Park and Leander Storage Tanks New Storage Tank in South Round Rock	New Storage Tank in South Round Rock

* Table 3.12-6 and 3.12-7 presents the details on the six dedicated water pipelines proposed in C-2 Scenarios 3-5.

Land and Habitat

The study area includes the eastern edge of the Edwards Plateau, the Balcones Escarpment, the Balcones Fault and parts of the Edwards aquifer recharge zone. The Balcones Escarpment is a distinct area of transition between the southern Blackland Prairies region to the east and the Edward's or Central Texas Plateau region to the west.[9,10,11,12,13]

The Edwards Plateau is underlain by horizontally bedded hard to soft dolomitic limestone and marl from shallow, marine Cretaceous sediments. Extensive faulting throughout the Edwards formation is an important feature in the development of local physiographic features, groundwater aquifers and springs. In the Balcones Fault and Edwards Aquifer recharge zone, groundwater sources are the basal Cretaceous Trinity sands and the Edwards Formation. Edwards Aquifer development occurred within rocks of the Edwards Limestone and equivalent limestones. Solution, or karst, features, including sinkholes, caves and smaller cavities along bedding planes and fractures are found throughout the Edwards formation, and springs commonly occur at its base. The eastern margin of the Edwards Plateau is dissected into deep, steep-walled canyons occupied by primarily spring fed streams that flow east or southeast. Recharge occurs in streambeds, faults and solution features underlain with cavernous limestone and on low-relief, plateau uplands underlain by karstic limestone.[14]

Soils of the Edwards Plateau are typically thin, stony and formed in limestone and marl on long ridges and steep slopes; deeper soils tend to occur in stream valleys. The Balcones Escarpment soils are moderately deep to very shallow, calcareous, clayey, cobbly and stony soils formed over Cretaceous Austin Chalk, Eagle Ford, Buda, Del Rio Clay and Georgetown formations. In the Balcones Fault and Edwards Aquifer recharge zone, soils are calcareous clays developed in marine chalk, marl and shale under prairie vegetation of mid and tall grasses.

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[9] Omernik, J.M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77:118-125.

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

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

[12] Blair, W.F. 1950. The Biotic Provinces of Texas. Texas Journal of Science. 2:93-117.

[13] Dice, L.R. 1943. The Biotic Provinces of North America. University of Michigan Press, Ann Arbor, Michigan.

[14] Woodruff, C.M., Jr. and P.L. Abbott. 1979. Drainage-basin Evolution and Aquifer Development in a Karstic limestone Terrain, South-Central Texas, USA. Earth Surface Processes, 4(4): pp. 319-334.

Omernik's classification of the ecoregions of the conterminuous United States place the study in an area of transition between the Texas Blackland Prairies and the Central Texas Plateau.[15] Omernik defined ecoregions based on the hypothesis that ecosystems and their components display regional patterns that are reflected in spatially variable combinations of causal factors such as climate, soils and geology, vegetation and physiography. His brief discussion of the vegetation describes the area as being a transition between irregular grassland plains and tablelands and plains with high hills of juniper/oak savannah and mesquite/oak savannah. The potential forms of wildlife of this area can be expected to also have representatives from both ecological regions.

With respect to the terrestrial vertebrates, the study area is in the transition between the Austroriparian and Texan biotic provinces to the east and the Balconian biotic province to the west.[16,17] Blair describes the Texan biotic province as a transition from eastern forested regions to western grassland regions. The eastern fauna mixed with important species from the Great Plains contributes to the large number of snakes. Herpetofauna are, to some extent, restricted to particular vegetation communities, soil types or water resources.

Wetlands

Wetlands in the study area were reviewed using the National Wetland Inventory maps. Generally, wetlands in the western (Edwards Plateau) portion of the project area are intermittent or lower perennial streams that are seasonally flooded. In the east, the streams are predominantly upper perennial with permanent water. Many streams in the project area, including Lime Creek, Cypress Creek and Bull Creek, are forested with seasonal pools occurring within the stream bed. Some of these streams also have perennial pools that support emergent vegetation.[18,19,20,21,22]

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[15] Omernik, J.M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77:118-125.

[16] Blair, W.F. 1950. The Biotic Provinces of Texas. Texas Journal of Science. 2:93-117.

[17] Dice, L.R. 1943. The Biotic Provinces of North America. University of Michigan Press, Ann Arbor, Michigan.

[18] U.S. Fish and Wildlife Service. 1993. National Wetland Inventory Map Series, Jollyville Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

[19] U.S. Fish and Wildlife Service. 1993. National Wetland Inventory Map Series, Leander Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

[20] U.S. Fish and Wildlife Service. 1993. National Wetland Inventory Map Series, Mansfield Dam Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

Potential facility sites and pipeline corridors will need to be surveyed for potential wetland disturbances and mitigation possibilities.

Endangered and Threatened Species

The Environmental Overview (Sec. 3.1.3) lists the federal or state protected, endangered and threatened species, and other sensitive species reported to occur in Travis and Williamson counties. Species on the Texas Organization for Endangered Species (TOES) watch list reported to occur within the study area have also been included in these tables. Species of concern to each individual facility or pipeline route are discussed within their respective sections.

Treatment Options

To meet the projected water demands of the study participants, consideration has been given to diversion and treatment of Lake Travis water at any of three treatment plants or a combination of them. The diversion locations and treatment plants considered are the City of Austin WTP4, an expanded or additional Cedar Park Water Treatment Plant, and a potential regional water treatment plant at the site of the existing Round Rock Treatment Plant.

Regional Treatment at Water Treatment Plant 4

The City of Austin WTP4 was originally planned to serve the northwestern portion of Austin but is now considered for use in Scenarios 1-5 to serve northern Travis and southern Williamson counties. This plant is well positioned to serve parts of Williamson County and to serve areas currently served by Green or Ullrich treatment plants. Development plans for WTP4 have been processed through Austin's subdivision and zoning review. Approximately 138 acres of native plateau live oak - little bluestem community was set aside for habitat management leaving about 102 acres of the total 240.4 acres for WTP facility construction and plant site campus. The 240.4 acre plant campus is located on River Place Boulevard on the Jollyville

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[21] U.S. Fish and Wildlife Service. Draft from 1982 Aerial Photography, Prepared in 1984-1985. National Wetland Inventory Map Series, Pflugerville West Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

[22] U.S. Fish and Wildlife Service. 1993. National Wetland Inventory Map Series, Round Rock Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

Plateau[23] upland above Bull Creek, and the plant would be connected to the Lake Travis intake site by a tunnel. The capitol improvement plan (CIP) designed by CH2MHill and Black and Veatch for the City of Austin in 1986[24] proposed phased development of water treatment facilities on the plateau site. The plateau live oak- little bluestem vegetation community would be preserved on the site slopes in the 138 acre habitat management area. Although the facilities plan and site engineering are now outdated, the City of Austin is committed to a habitat management zone should development proceed.[25] Other regional plants considered have not been subject to this level of examination. WTP4 site acreage may be exaggerated when compared to the other potential water treatment plant acreages as a result of WTP4's particular site purchase and development history.

Soils in the proposed buildable zone are Tarrant Series soils which developed under tall grass and open canopy of trees over limestone. Steeper areas are Tarrant soils with rock outcrop and Volente complex soils. Volente soils dominate in the Bull Creek valley and developed under mid and tall grass and scattered trees over limestone.

The Jollyville Plateau is habitat for numerous endangered or threatened species as well as unique and protected karst associated species. Numerous caves with protected species have been identified on the Jollyville Plateau. Edwards associated springs and seeps with salamanders have been identified in the Bull Creek drainage near the proposed site. This is also an area where Black-capped Vireos and Gold-cheeked Warblers have been known to nest.[26,27]

Regardless of the alternative plans considered in this alternative, a WTP4 may be developed to replace existing capacity or to provide water treatment to an increasing Austin population. Construction would trigger city development review procedures. An estimated 102 acres would be converted to water treatment plant and associated facilities.

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[23] Bureau of Economic Geology. 1974. Geologic Atlas of Texas, Austin Sheet. The University of Texas at Austin, Second Printing, June 1981. Austin, Texas.

[24] City of Austin. 1986.C.I.P. No. 227951 Contract 2, Water Treatment Plant No.4, Water Treatment Facilities, prepared by CH2MHill Austin and Black and Veatch Austin, Texas.

[25] City of Austin. 1986. C14-86-124 zoning case; Program Management Committee, March 1994, Waller Creek Center, Austin Texas.

[26] Soil Conservation Service. 1974. Soil Survey of Travis County, Texas. U.S. Department of Agriculture; SCS now named Natural Resource Conservation Service.

[27] Texas Parks and Wildlife Department. 1997, February, unpublished mapped data. Natural Heritage Inventory. Austin, Texas.

Regional Williamson County Treatment Plant at Cedar Park

The Cedar Park regional water treatment plant is located on the dissected eastern margin of the Edwards Plateau near the Balcones Escarpment. Scenarios 6 and 7 would utilize a site adjacent to the existing Cedar Park plant, located on the Sandy Creek arm of Lake Travis. Based on the potential yield, approximately 9 acres of plant site would be required for Scenario 6, and 20 acres with Scenario 7. Actual development and engineering requirements may require additional land for site buffer zones, mitigation lands either on or off-site for each scenario depending on the location selection and site restrictions.

The Sandy Creek branch of Lake Travis is located in a canyon exhibiting the terraced slopes of alternating resistive and recessive layers characteristic of upper Glen Rose limestones.[28] Soils are thin and stony Brackett and Tarrant series, either rolling or steep with rock outcrops. Ashe junipers dominate on the slopes and plateaus with Texas oaks and live oaks in an open savanna. Texas oaks spring from marly layers between resistant limestones of the upper Glen Rose formation.[29] In this region there are few caves in the upper Glen Rose Formation. Most caves are small and recently formed and karst associated species are not reported from the area. Plateau live oak occur in clumps in a mid-grass savanna on rolling rangeland. Ashe juniper-oak savanna can be excellent habitat for nesting Golden-cheeked Warblers and Black-capped Vireos. Prior to a regional plant development, the potential site would be evaluated for nesting habitat for Golden-cheeked Warblers and Black-capped Vireos.

Regional Williamson County Treatment Plant at Round Rock

The existing Round Rock Water Treatment Plant is located east of Cedar Park off IH-35 and Westinghouse Road. In Scenario 8, a raw water line from Sandy Creek would generally follow Trails End Road to FM 1431 east to the Round Rock regional plant site. The WTP site is drained by Chandler Branch, an intermittent creek flowing to the southeast. The surface geology of the site is dominated by Cretaceous age limestone bedrock of the Edwards Formation.[30] Extremely

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[28] Austin Sheet

[29] S.C.S. 1974. Travis County Soils Report. U.S. Department of Agriculture, Natural Resource Conservation Service (formerly Soil Conservation Service).

[30] Barnes, Virgil E. 1981. Geologic Atlas of Texas, Austin Sheet. Buruea of Economic Geology, The University of Texas at Austin.

stony clay soils of the Eckrant series ranging in depth from 5 to 20 inches are found in the area.[31] To the south is the Westinghouse facility, Texas Crushed Stone quarries are to the North, and the IH-35 corridor is to the east.

The existing water treatment plant site is located in an area formerly known as the Heart of Texas Ranch. The expansion site tract is within a karst zone favorable for solution features.[32] The closest mapped cave feature is the Great Mud Cave discovered in 1968 by geotechnical testing for the Westinghouse facility foundation south of Chandler Branch close to IH-35. The approximately 1,200-foot long cave was intersected by the test boring at a depth of about 60 feet. Inner Space Cave, formerly Laubach Cave, is approximately 2 miles north of Great Mud Cave. This large cave is generally oriented north-south, consists of large passages, and is one of the leading Pleistocene paleontological sites in Texas. Several entrances to Inner Space were open to the surface 13,000-25,000 years ago as evidenced by the remains of extinct mammoth, saber-toothed cat, camel, ground sloth, and other species. Karst associated species, including two endangered species, Bone Cave harvestman and Coffin Cave mold beetle, are present.[33] Numerous smaller caves associated with Onion Branch and Chandler Branch are known to contain these karstic species as well as others.[34]

The vegetational community found on the potential regional water treatment site consists of a live oak-Ashe juniper community that is mostly disturbed by quarry activities and ranching.[35] The habitat most likely to be important to site development is the underground environment and cave assemblage.[36] A karst survey associated with geotechnical testing and construction monitoring would be necessary to insure that protected species are not affected by construction at this potential site.

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[31] SCS. 1983. Soil Survey of Williamson County, Texas. U.S. Department of Agriculture, Soil Conservation Service.

[32] Texas Speleological Survey. 1995. Unpublished database of the TSS maintained in Williamson Co. by Mike Warton.

[33] Elliott, W.R.

[34] Natural Heritage Program. Unpublished data files and maps. September, 1996

[35] NAPP photo

[36] Natural Heritage Program. Unpublished data files and maps. September, 1996.

Construction Effects of Intake Structure

Implementation of any of the scenarios considered as part of this alternative would require either the installation of a new intake structure in Lake Travis or the expansion of the existing intake structure for the Cedar Park water treatment plant. The construction of a new intake structure will result in the disturbance of substantially less than 1 acre of aquatic and riparian habitat in Lake Travis. A small area of land surrounding the facility will be permanently maintained with groundcover similar to that found prior to the disturbance.

General Construction Effects of the Water Transmission Pipelines

Implementation of this alternative would require the construction of numerous water transmission pipelines linking Lake Travis to the new or expanded water treatment plant and then used for water distribution to the various dedicated water system tanks. Environmental issues arise from the construction of diversion facilities, pump stations and installation and maintenance of the pipeline. The proposed pipeline routes will follow land that is already largely in managed cover, either existing road and utility right-of-ways, pasture, crop or urban land. Adverse impacts to wetlands, endangered species and cultural resource sites can largely be avoided or minimized by using field surveys to select final pipeline alignments and associated facility locations, and by choosing appropriate construction methods and schedules. For example, the facilities needed to transfer raw water to the proposed WTP4 from the intake structure will be tunneled in order to minimize the potential impacts to wildlife habitats in general, and to those critical for any endangered and threatened species. Unavoidable impacts would have to be compensated for. Compensation is generally accomplished by setting aside appropriate acreage to be managed to regain the habitat values lost through project implementation. The project sponsor would be responsible for development and implementation of a management plan for the life of the project. The project sponsor may retain ownership of compensation lands, or they maybe transferred to a mutually agreeable public agency (generally TPWD) for management.

CIP Water Transmission Pipelines

The CIP Water transmission pipelines and storage facilities are presented in Table 3.12-5 as a part of the information provided for each of the potential eight scenarios. With the exception of sections of the Jollyville transmission main, Forest Ridge tunnel and the RM 620 transmission main, all transmission mains will be placed in or adjacent to existing road and utility ROWs. Approximately 14,000 feet of the 24,000 foot Jollyville transmission, the 4,000 feet Forest Ridge tunnel and approximately 2,000 feet of the 22,000 foot RM 620 transmission main will be tunneled to reduce construction effects to areas which are not maintained as road or utility ROWs.

Alternative C-2 Water Supply Scenarios

The six dedicated delivery lines would be used to supply the cities of Pflugerville, Round Rock, Brushy Creek MUD, Georgetown, Cedar Park, and Leander in Scenarios 3 through 5. Tables 3.12-6 and 3.12-7 provide comparisons among the water lines, routes and individual pipelines are discussed below. Physiognomic classifications presented in Table 3.12-7 are based upon the use of a 140 foot temporary construction ROW and a 40 foot permanent ROW maintained free of woody vegetation. Following construction, areas currently in grass can be revegetated and returned to their original use (see the section above dealing with General Construction Effects of the Water Transmission Pipelines). Brush can be expected to reinvade areas outside the maintenance ROW in about 10 years.

Dedicated Delivery Line 1

Water Line 1 would be dedicated to the City of Pflugerville (Scenarios 3, 4, and 5 only) and would connect to the Austin distribution system at the planned Howard Lane NW-A transmission main and run approximately 18,000 feet to the existing storage tank located south of the Pflugerville middle school. No pump station facilities are required because the head on the Howard Lane transmission main is sufficient to fill the Pflugerville storage tank.

Table 3.12-6
Comparison of Features and Facilities of Dedicated Pipelines[1]

Dedicated Pipeline	1	2[2]	3	4	5	6
Scenario	3, 4, 5	3, 4, 5	3, 4, 5	3, 4, 5	3, 4, 5	3, 4, 5
Municipality Supplied	Pflugerville	Round Rock Brushy Creek Georgetown	Brushy Creek	Georgetown	Cedar Park	Leander
Origin	Howard Lane NW-A Transmission Main	Martin Hill Reservoir	Round Rock Treatment Plant	Round Rock Treatment Plant	Anderson Mill Reservoir	Cedar Park Webster Storage Tank
Destination	Pflugerville Existing Water Storage Tank	Proposed Water Storage Round Rock	Brushy Creek Storage Tank	Georgetown Rabbit Hill Reservoir	Cedar Park Webster Storage Tank	Leander Storage Tank
Facility Expansion Area (acres)	WTP4 - 240.4 (138 Set Aside for Habitat)					
Pipeline						
Construction Area (ac)	57.9	83.6	61.1	31.5	106.1	11.1
Maintenance Area (ac)	16.5	23.9	17.4	9.0	30.3	3.2
Geologic Formations[3]	Austin Chalk	Austin Chalk Eagle Ford Buda Formation Del Rio Clay and Georgetown Formation	Austin Chalk	Eagle Ford Buda Formation Edwards Formation Del Rio Clay and Georgetown Formation	Edwards Formation Comanche Peak Kiamichi	Kiamichi Comanche Peak
Known Protected Species Habitat Within Corridor	-	Invertebrate & Karst Species Cavernous Limestone	Invertebrate & Karst Species Cavernous Limestone	Cavernous Limestone	Ash juniper - Oak Series Invertebrate & Karst Species Cavernous Limestone Wildlife Preserves - Golden Cheek Warbler and Black Cappped Vireo Habitat	Cavernous Limestone

[1] Facilities and pipelines are presented in Figure 3.12-1

[2] Water trade assumes construction of Austin WTP4.

[3] Bureau of Economic Geology. 1974. Geologic Atlas of Texas: Austin Sheet, Bureau of Economic Geology, the University of Texas at Austin, Austin, Texas.

Table 3.12-7
Comparison of Land and Habitat Acreages of the Dedicated Pipelines

Pipeline	1		2		3		4		5		6	
Physiognomic Category	140' Const. Corridor	40' Maint. Corridor	140' Const. Corridor	40' Maint. Corridor	140' Const. Corridor	40' Maint. Corridor	140' Const. Corridor	40' Maint. Corridor	140' Const. Corridor	40' Maint. Corridor	140' Const. Corridor	40' Maint. Corridor
Developed	35.2	10.0	16.7	4.8	0.5	0.2			7.8	2.2	2.6	0.8
Asphalt	0.9	0.2	1.1	0.3	0.5	0.2	2.9	0.8			1.0	0.3
Grass	21.8	6.2	65.8	18.8	16.5	4.7	1.0	0.3				
Crops							24.2	6.9	15.3	4.4	14.2	4.1
Brush					19.7	5.6			11.9	3.4		
Park					13.2	3.8	1.0	0.3	65.1	18.6	11.0	3.2
Woods					10.6	3.0	2.4	0.7				
Palustrine	0.01	0.04	0.01									
Intermittent	0.02	0.06	0.02		0.03	0.1	0.03	0.1	0.04	0.1	0.03	0.1
Total Wetlands	0.03	0.1	0.03	0.1	0.03	0.1	0.03	0.1	0.04	0.1	0.03	0.1
Total	57.93	16.5	83.63	24.0	61.03	17.6	31.53	9.1	106.04	30.4	28.83	8.5

Soils in this proposed pipeline ROW are from the Austin-Eddy Map Unit, Houston Black series, Stephen series and the Frio series.[37] All Soils in the Austin-Eddy Map Unit are typically very shallow to moderately deep, well drained, silty clay and gravelly loams. The Houston Black Series consists of deep, moderately well drained clay soils developed in calcareous marls, and alluvial clays. The Stephen Series consists of shallow, well drained, silty clay loam soils. All the above soils in the proposed pipeline ROW have developed under prairie vegetation of mid and tall grasses. The Frio Series is the only lowland soil and typically consists of deep, friable, nearly level soils on bottom lands along major streams. These are developed over chalk, and under tall grasses and scattered trees. All soils within this proposed pipeline ROW have developed over the Cretaceous Austin Chalk formation.[38]

Although numerous endangered and threatened species are found in Travis and Williamson Counties, TPWD Natural Heritage Program files do not indicate any known sightings within one mile of the proposed pipeline ROW.

National Wetland Inventory (NWI) maps covering this proposed pipeline route area indicate the pipeline is expected to cross three streams.[39] One of these crossings is over Wells Branch Creek and is classified as a deciduous broad-leaved forested temporary palustrine stream. The other two crossings are over small intermittent streams which were not described by the NWI map.

Assuming a uniform maximum corridor width of 140 feet, construction would affect 57.9 total acres of predominantly developed area (60.8 percent). A mowed ROW with a width of 40 feet maintained for the life of the project would affect 16.4 total acres (Table 3.12-7).

Dedicated Delivery Line 2

Water Line 2 would be dedicated to the Cities of Round Rock, Brushy Creek and Georgetown and would require a pump station and new storage tank. This water line would run

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[37] Soil Conservation Service. 1974. Soil Survey of Travis County, Texas. U.S. Department of Agriculture; SCS now named Natural Resource Conservation Service.

[38] Bureau of Economic Geology. 1974. Geologic Atlas of Texas, Austin Sheet. The University of Texas at Austin, Second Printing, June 1981. Austin, Texas

[39] U.S. Fish and Wildlife Service. Draft from 1982 Aerial Photography, Prepared in 1984-1985. National Wetland Inventory Map Series, Pflugerville West Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

from the Martin Hill reservoir about 26,000 feet to a potential new reservoir in south Round Rock off of FM 1325. The new pump station would be located at the site of the existing Martin Hill reservoir. Dedicated delivery line 2 is only needed for Scenarios 3, 4, and 5.

Soils in this proposed pipeline ROW are from the Austin-Houston Black-Castephen Map Unit, Denton-Eckrant-Doss Map Unit, Ferris-Heiden complex and the Tarrant and Speck soils.[40,41] Soils in the Austin-Houston Black-Castephen Map Unit are typically deep to shallow, calcareous clayey soils found on uplands and formed in marine chalk, marl, shale, and clays. The Castephen soils are typically found on ridges, the Austin soils on the middle slopes, and the Houston Black soils found on the lower areas. Soils from the Denton-Eckrant-Doss Map Unit are typically found on uplands and are moderately deep to very shallow, calcareous, clayey, cobbly and stony soils formed in indurated fractured limestone or limey earths. The Denton soils are typically found in the valleys and the Eckrant soils on the steeper hills and ridges with the Doss soils on the broad ridges and side slopes. The soils in the Ferris-Heiden complex are typically sloping to moderately steep, deep, calcareous, shaly clay, well drained soils found in uplands. When dry, these soils will form extensive cracks where the water can enter rapidly. However, when they are wet, water enters the soil very slowly, erosion is a hazard and these soils can develop large gullies. The Tarrant and Speck soils consist of an undifferentiated group of typically stony, shallow to very shallow, well-drained, clayey soils found on narrow to broad and irregular areas on upland ridges. The soils within this proposed pipeline ROW have developed over the Cretaceous Austin Chalk formation, Del Rio (Grayson Marl) and Georgetown formations and the Eagle Ford and Buda formations.[42]

Although numerous endangered and threatened species are found in Travis and Williamson counties, TPWD Natural Heritage Program files indicate only the presence of an invertebrate cave (McNeil Quarry Cave) within one mile of the proposed pipeline corridor. Although the presence of this cave presents the possibility of endangered or threatened

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[40] Soil Conservation Service. 1974. Soil Survey of Travis County, Texas. U.S. Department of Agriculture; SCS now named Natural Resource Conservation Service.

[41] Soil Conservation Service. 1983. Soil Survey of Williamson County, Texas. U.S. Department of Agriculture; SCS now named Natural Resource Conservation Service.

[42] Bureau of Economic Geology. 1974. Geologic Atlas of Texas, Austin Sheet. The University of Texas at Austin, Second Printing, June 1981. Austin, Texas.

invertebrate cave species, it is located to the west of the existing Martin Hill reservoir, opposite the direction in which the proposed pipeline ROW would head. Pipeline construction would not have any adverse effects on this cave or its inhabitants.

National Wetland Inventory (NWI) maps covering this proposed pipeline route area indicate this pipeline is expected to cross three streams.[43] One of these crossings is over a first order tributary of Rattan Creek and is classified as a temporary palustrine stream with persistent emergent vegetation. The other two crossings are over small intermittent first order headwater tributaries of Dry Branch and are not described by the NWI map. However, the streams and drainages in the area are typically intermittent with temporarily flooded flows and tend to dry in summer months with some maintaining isolated pools within their streambeds. It is likely that the undescribed streams are similar in nature.

Assuming a uniform maximum corridor width of 140 feet, construction would affect 83.6 total acres of predominantly grass (78.7 percent). A mowed ROW with a width of 40 feet maintained for the life of the project would affect 23.9 total acres (Table 3.12-7).

Dedicated Delivery Line 3

Water line 3 will be dedicated to the Brushy Creek MUD. The 19,000 foot pipeline will run from the existing Round Rock treatment plant to the Brushy Creek storage tank on FM 1431. No new treatment facilities or storage tanks will be required for this water line.

Soils in this proposed pipeline ROW have formed over Cretaceous Edwards limestone of the Fredericksburg Group[44] and are all from the Eckrant-Georgetown Map Unit.[45] These soils are typically found on uplands and are very shallow to moderately deep, calcareous and noncalcareous stony, cobbly and loamy soils formed in indurated fractured limestones. The Eckrant soils typically are found on the more sloping areas on ridges and hills while the Georgetown soils are found on broad ridges and gentle side slopes. These soils are typically well

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[43] U.S. Fish and Wildlife Service. Draft from 1982 Aerial Photography, Prepared in 1984-1985. National Wetland Inventory Map Series, Pflugerville West Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

[44] Bureau of Economic Geology. 1974. Geologic Atlas of Texas, Austin Sheet. The University of Texas at Austin, Second Printing, June 1981. Austin, Texas.

[45] Soil Conservation Service. 1983. Soil Survey of Williamson County, Texas. U.S. Department of Agriculture; SCS now named Natural Resource Conservation Service.

National Wetland Inventory (NWI) maps covering this proposed pipeline route area indicate the pipeline is expected to cross three streams.[56] These appear to be small, intermittent headwater streams but are not characterized by the NWI maps. The streams and drainages in the area are mostly intermittent, carrying brief flood flows and tending to dry in summer months, although many maintain isolated perennial pools within their streambeds.

Assuming a uniform maximum corridor width of 140 feet, construction would affect 31.5 total acres of predominantly cropland (76.9 percent). A mowed ROW with a width of 40 feet maintained for the life of the project would affect 9.0 total acres (Table 3.12-7).

Dedicated Delivery Line 5

Water line 5 will be dedicated to the Cities of Cedar Park and Leander. The 33,000 foot pipeline will run from the existing Austin NW-B Anderson Mill Reservoir to Cedar Park's Webster storage tank, and would require a new pump station. The service to Leander would be facilitated by delivery line 6, which is discussed in the next sub-section.

The soils along this pipeline route are all from the Denton-Eckrant-Doss soil map unit.[57] These soils are found on uplands, and are moderately deep to shallow and very shallow, calcareous, clayey, cobbly and stony soils formed in indurated fractured limestone or limey earths from the Cretaceous Fredericksburg Group along the Balcones fault zone.

Nineteen TPWD Natural Heritage Program listings for endangered and threatened species are found within one mile of the proposed pipeline route. Three of these listings are for sightings of the Golden-cheeked Warbler (*Dendroica chrysoparia*) and the rest are for observations of invertebrate caves and cave dwelling species. The route for this pipeline passes through an area in which particularly dense concentrations of caves are found near Buttercup Creek. This area also has the potential to contain Golden-cheeked Warbler habit that might be affected by pipeline

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[56] U.S. Fish and Wildlife Service. Draft from 1982 Aerial Photography, Prepared in 1984-1985. National Wetland Inventory Map Series, Pflugerville West Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

[57] Soil Conservation Service. 1983. Soil Survey of Williamson County, Texas. U.S. Department of Agriculture; SCS now named Natural Resource Conservation Service.

construction. Environmental and geologic surveys will be needed to determine a route which minimizes potential effects to this endangered species habitat.

Dedicated pipeline 5 is expected to disturb wetland habitat at four small intermittent headwater tributaries of Buttercup Creek and Cluck Creek. Although the NWI map does not give a characterization for these streams, the streams and drainages in the area are mostly intermittent, carrying brief flood flows and tending to dry out in summer months. Some of these streams may contain isolated perennial pools within their streambeds. It is possible that the unclassified streams are similar to the typical intermittent streams described above.

Assuming a uniform maximum corridor width of 140 feet, construction would affect 106.0 total acres of predominantly wooded area (61.4 percent). A mowed ROW with a width of 40 feet maintained for the life of the project would affect 30.3 total acres (Table 3.12-7).

Dedicated Delivery Line 6

Water line 6 will be dedicated to Leander. The 9,000 foot pipeline will run from the Cedar Park's Webster storage tank to Leander's storage located on Bagdad Road. Approximately 3,600 feet of pipeline already exists to deliver water from Cedar Park to Leander's storage tank.

The soils along this pipeline route are all from the Denton-Eckrant-Doss soil map unit.[58] These soils are found on uplands and are moderately deep, shallow and very shallow, calcareous, clayey, cobbly and stony soils formed in indurated fractured limestone or limey earths from the Cretaceous Fredericksburg Group along the Balcones fault zone.

A review of the TPWD Natural Heritage files revealed no records of endangered or protected species within one mile of the proposed pipeline route. However, as in pipeline route 5, the area surrounding this pipeline route has the potential to contain Golden-cheeked Warbler habitat and karst solution features. Environmental and geologic surveys will be needed to determine the presence, if any, of endangered species habitat.

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[58] Soil Conservation Service. 1983. Soil Survey of Williamson County, Texas. U.S. Department of Agriculture; SCS now named Natural Resource Conservation Service.

Dedicated pipeline 6 is expected to disturb wetland habitat at 3 small intermittent headwater tributaries of Block House Creek. The northernmost of these small tributaries follows the Bagdad Road embankment southward until it meets with another tributary and then crosses the proposed pipeline route. Although the NWI map does not give a characterization for these streams, the streams and drainages in the area are mostly intermittent carrying brief flood flows, tending to dry in summer months, some of which may contain isolated perennial pools within their streambeds. These unclassified streams can be expected to be similar to the intermittent streams described above.

Assuming a uniform maximum corridor width of 140 feet, construction would affect 28.8 total acres of predominantly crops (49.1 percent). A mowed ROW with a width of 40 feet maintained for the life of the project would affect 8.4 total acres (Table 3.12-7).

Impacts to Instream Flow of the Brazos River and the Matagorda Bay and Estuary System

This alternative involves the potential transfer of water from the Colorado River Basin to the Brazos River Basin. Table 3.12-4a shows that under Scenarios 1 through 5, an additional 100,370 acft/yr would need to be diverted from Lake Travis to satisfy demands in Austin's Northwest A and B Pressure Zones, and about 12,000 acft/yr would be delivered to Pflugerville under Scenarios 2 through 5. Presumably all the return flows from Austin and Pflugerville would be returned to the Colorado River. Scenarios 2 through 5, in addition, include transfers to Williamson County entities from which return flows would be discharged to tributaries (Brushy Creek, San Gabriel River) of the Brazos River. Interbasin diversifications under 2030 conditions to southern Williamson County will range from 5376 acft/yr under scenario 2 to 37,377 acft/yr under Scenarios 4 and 5, from which return flows would be discharged to Brushy Creek. Diversions to Georgetown (Scenario 5) would total 5,369 acft/yr, and return flows would be discharged into the San Gabriel River.

Scenarios 6, 7 and 8 involve diversions from the Sandy Creek Arm of Lake Travis to supply southern Williamson County entities that all discharge their treated waste water into Brushy Creek. If implemented, these diversions would range from 13,998 acft/yr in Scenario 6 to 25,456 acft/yr under Scenario 7.

Assuming 50 percent of diverted water is discharged as treated effluent in the respective receiving basins, net withdrawals from Lake Travis and the Colorado River are projected to range from 13,998 acft/yr (Scenario 6) to 113,362 acft/yr (Scenario 5) under 2030 conditions. Under 2050 conditions (Table 3.12-4b), the largest net diversion would amount to 146,128 acft/yr under Scenario 5.

Although hydrologic modeling of these scenarios has not been done, these are large net diversions that can be expected to have substantial effects on Highland Lake levels and streamflows in the Colorado River under current conditions. Water stored in the Highland Lakes is eventually either spilled or released downstream, diverted, or is lost through seepage and evaporation. Increased diversions come partly from water that would have been spilled or released under present conditions, reducing Colorado River streamflows.

The LCRA has existing criteria for minimum instream flows and interim criteria for minimum bay and estuary inflows.[59] Two separate environmental instream flow criteria; critical flows and target flows, have been established in the Colorado River below Austin based on fisheries habitat needs in segments designated on the basis of studies conducted by LCRA staff. Critical flows (Table 3.14-7) are maintained by releasing inflows or stored water from the Highland Lakes as needed to maintain daily river flow at the Bastrop gage to be no less than the established critical instream flow in all years.

Target flows (Table 3.14-7) which vary monthly have been established for three points in the basin; at the Bastrop, Columbus, and Wharton USGS gages. In wetter years when water supplies for the four major irrigation districts are not curtailed, inflows to the Highland Lakes are released on a daily basis to maintain river flows at the target instream flow.

If established critical streamflows for the Colorado River continue to maintained, some effect on target flows, and on the frequency and severity of low flows during dry periods, relative to current conditions, can be expected to result from the proposed diversion. For example, diverting 100,000 acre feet/year would require the continuous withdrawal of water at a constant rate of 138 cfs. This is a substantial flow when compared to median monthly flows under the

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[59] Lower Colorado River Authority, Waste Management Plan for the Lower Coloradio River Basin, 1993

base condition which range from about 300 to over 900 cfs at Bastrop, and is very large when drought period flows are considered.

Under this alternative, raw water from Lake Travis would be diverted through the water treatment systems of municipalities in the north Travis County - southern Williamson County area which discharge wastewater into Brushy Creek, a tributary of the San Gabriel River. Implementation of the various scenarios of this alternative will increase streamflows in Brushy Creek by amounts ranging from 2,688 acft/yr (Scenario 2) to 18,688 acft/yr (Scenario 5), if we assume that 50 percent of the water diverted from Lake Travis would be released from the respective municipal wastewater systems as treated effluent. While the effluent from Scenario 2 would amount would amount to only 3.7 cfs on a continuous basis, that from Scenario 5 would equal a flow of about 26 cfs. While an additional 3.7 cfs is not likely to have much effect on a stream already augmented and enriched by wastewater discharges, a constant, additional 26 cfs would be a significant increase and may be expected to elicit a biological response. The additional 9036 acft/yr of treated wastewater that would be added to the San Gabriel River under Scenario 5, 2050 conditions, and a 50 percent return flow (Table 3.12-4A) would be equivalent to a continuous flow of 12.5 cfs, about 5 percent of the average annual flow of that river below Georgetown.

The affected reaches of Brushy Creek and the San Gabriel River downstream of the wastewater outfalls would have enhanced, stabilized base flows. Stable base flows will tend to encourage the development of aquatic vegetation where substrates permit, enhancing physical habitat diversity, cover and the variety of food sources available following the initial period of channel adjustment. This can be expected to eventually increase the diversity and alter the composition of the aquatic community as resident species and new migrants from perennial habitats are able to respond to the altered hydrologic regime.

However, the high nutrient loading from the effluent can be expected to encourage algal and rooted plant growth where suitable habitats occur. When the streams traverse the Blackland Prairies, their channels tend to be constrained within steep banks of cohesive material with a closed riparian canopy shading, relatively deep, narrow runs and pools, largely habitats that will not support much plant growth even in the presence of excess nutrients.

Increased loading of Lake Granger from treated wastewater discharged into the San Gabriel River may have some stimulating effect on planktonic algal growth in that reservoir. The less cohesive soils of the Post Oak Savannah, traversed by lower Brushy Creek and the San Gabriel and Little Rivers, tend to produce a broader, shallower channel and less continuous riparian cover. These reaches may experience growth of aquatic vegetation as a consequence of increased nutrient loading and a more constant water supply.

The frequency and intensity of bankfull and greater flood events may be increased to some extent in Brushy Creek or the San Gabriel River. Additional modeling and field hydrologic study would be required to determine the significance of the increased frequency, and the likelihood that substantiated channel adjustments would result, even in the case where Brushy Creek would receive all the transferred water (see Section 3.4).

The Brazos River is expected to be less affected by implementation of this alternative than Brushy Creek or the San Gabriel River because the transferred water will be a smaller proportion of streamflow and substantial nutrient assimilation and loss will have occurred.

Given the current annual flow of the Brazos River of approximately 1,700,000 acft/yr[60], and the streamflow losses in the Brushy Creek-San Gabriel-Little River system due to seepage and evaporation, the increase in river flows would be insignificant during normal and wet years and slight during drought periods. Since the primary effect on the Brazos River would be small enhancement in flows during low flow periods, there should be no measurable adverse effects on the river and the estuarine or neretic systems in the Freeport area. Should this alternative be adopted, additional analysis of the water demand, operational regimes, nutrient loading and streamflow effects on the Colorado River are expected to be much greater and additional study of those waters is recommended.

Due to limited proportional increase to the Brazos River annual flow and the small enhancement expected during low flow periods, there should be no measurable adverse effects on estuarine or neretic systems in the Freeport area. Should this alternative be adopted,

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[60] USGSS. "Water Resources Data, Water Years 1995". USGS, Austin, Texas. USGS gage #08108700 at SH21 near Bryan, Texas., annual mean flow 1993-1994 was 2344 cfs (1,698,140 acft/yr). 1996.

additional analysis of the water demand, operational regimes, nutrient loading and streamflow effects of receiving waters is recommended.

Impacts of Interbasin Transfers Between Colorado and Brazos Basins

Interbasin transfer of biological organisms appears unlikely to have substantial impacts in the Brazos Basin because organism exchange between these adjacent basins is a historic and ongoing process. Fish, although they have a low interbasin vagility compared to algae, higher plants and most aquatic invertebrates, tend to be broadly adapted to water quality and physical habitat parameters, and to be widely distributed across areas of similar physiography and climate. Most fish species have distributions that correspond to Blair's Biotic Provinces, which were defined on the basis of the distributions of terrestrial vertebrates, rather than having distributions that follow basin divides.[61] The fish species known from the two basins are nearly identical, varying by only a few species.[62]

Freshwater plants and invertebrates generally have resting stages that are resistant to drying and many possess other mechanisms that facilitate dispersal across terrestrial environments. The headwaters of the Brazos and Colorado basins are closely interdigitated along the Calahan divide, facilitating interbasin exchange of taxa. It is noteworthy that the asiatic clam, an invasive exotic species, is abundant in both basins in spite of a poor capability for overland transport relative to most invertebrates. Adult aquatic insects, for example, can usually fly, while dissemules of aquatic plants, protozoans and other small invertebrates are commonly transported between water bodies by terrestrial organisms, including birds, mammals and insects, particularly the larger aquatic taxa (e.g. dragonflies).

3.12.4 Water Quality and Treatability

Implementation of this alternative would increase the availability of water in Lake Travis to be committed for municipal use in the study area. No new or outside sources of water would

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[61] Blair, W.F. 1950. The Biotic Provinces of Texas. Texas Journal of Science. 2:93-117.

[62] Hubbs, Clark. 1957. Distributional patterns of Texas fresh-water fishes. The Southwestern Naturalist 2:89-104.

be introduced to Lake Travis, consequently, this section needs only to consider Lake Travis water quality.

Lake Travis is considered one of the highest quality surface water supplies in the state. Table 3.12-8 summarizes some of the conventional water quality constituents in Lake Travis. It is characterized by low nutrient levels and moderate levels of chlorides and sulfates. Nutrient concentrations in Lake Travis are usually below levels at which algae blooms are significant, however inflows from stormwater runoff have been known to create elevated nutrient levels resulting in isolated periods of algal growth.[63] Hypersaline flows at Natural Dam Lake caused chloride, sulfate, and TDS levels in Lake Travis to increase considerably in 1988.[64]

Table 3.12-8
Conventional Water Quality Constituents in Lake Travis[1]

Constituent	Lake Travis
Dissolved Oxygen (mg/l)	8.04
pH (su)	8.23
TDS (mg/l)	467.36
Fecal Coliforms (No./100 ml)	41.07
Chloride (mg/l)	110.30
Sulfate (mg/l)	83.75
Total Phosphorus (mg/l)	0.04
Total Nitrogen[2] (mg/l)	0.13

[1] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.

[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Lake Travis is protected by TNRCC's Chapter 311, Water Protection, which prohibits discharge of pollutants into the reservoir's water quality area unless sufficient treatment is applied so that the lakes' existing water quality is maintained.[65] With TNRCC's anti-degradation policy, the water quality of the reservoir is expected to remain relatively constant. However,

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[63] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.

[64] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.

[65] Texas Administrative Code, Title 31, Chapter 311.

increased population and development in the Lake Travis watershed could eventually lead to extended periods of algal growth or other water quality problems from non-point source pollution.

Conventional treatment including rapid mix, flocculation, sedimentation, filtration, and disinfection is currently used by the City of Austin and the City of Cedar Park to produce potable water. These treatment processes should continue to be adequate for treating the additional raw water diverted from Lake Travis pending any significant modifications to the state drinking water standards. Additional taste and odor control measures are applied to increase the aesthetic quality of the water when necessary.

3.12.5 Engineering and Costing

Engineering and costing evaluations were performed for Scenarios 1 through 8. Entities receiving water in each scenario are listed in Section 3.12.1.

Scenarios 1 to 5 — WTP4 to Austin and Others

These five scenarios are dependent on implementation of City of Austin CIP facilities to deliver water from Lake Travis through WTP4 to the NW-A and NW-B pressure zones in Austin. These facilities are described in Section 3.12.1. Entities potentially receiving water under Scenarios 1 through 5 would interconnect to one of these two pressure zones and potential delivery locations are listed in Table 3.12-1. Projected shortages to be met for each potential entity (annual and peak day) are provided in Table 3.12-4a and 3.12-4b.

Presentation of Costs

Cost estimates for each scenario are presented in a three part format, with costs for each part summarized in a separate table. The three parts are:

Part 1: Costs for City of Austin CIP facilities, including WTP4 and transmission facilities.
Part 2: Costs for interconnection facilities from Austin to receiving entities.
Part 3: Summary Table with unit costs from Parts 1 and 2.

Within Part 1, costs for Austin CIP facilities are assigned to the respective pressure zone that would be served by the facility. Costs for WTP4 are allocated on a pro-rata basis to the pressure zones according to the water to be provided to each zone.

City of Austin CIP Facilities

Austin's capital improvement program, as defined in the Long Range Planning Guide,[66] provides a description of the framework to move water from WTP4 into Austin's service area to meet needs through year 2037. Using the Trans-Texas Water Program water demand projections,[67] the City of Austin staff reviewed the water transmission system requirements for projected demands in year 2030 and 2050. After verifying facilities needed to meet Austin service area needs (Scenario 1), the Water Utility planning staff then used their system model to estimate facility sizes potentially needed to supply water for Scenarios 2 through 5 for years 2030 and 2050. The sizes and capacities for each major facility resulting from these analyses are presented in Table 3.12-9.

Water Treatment Plant 4

WTP4 was designed in the early 1980's and a several hundred acre site near the intersection of RM 2222 and RM 620 was purchased. Because of the aesthetic quality of the Lake Travis area and the environmental sensitivity of the proposed plant site (the site is surrounded by Balcones Canyonland preserve), the treatment plant was designed to minimize impacts. Some of the design features necessary to reduce impacts, such as a raw water tunnel intake under Lake Travis, have significant cost associated with them. For evaluation of alternatives involving WTP4, the cost estimates for the treatment plant are based on the plant site remaining at the purchased site, and on the cost estimates prepared for the original intake tunnel, raw water pump station, and treatment plant. Costs from the original design work have been revised to account for inflation, changes in treatment capacity, and additional cost estimates performed for the City of Austin. Treatment plant capacities evaluated for this alternative range

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[66] City of Austin, "Water Utility Long Range Planning Guide," February, 1994.

[67] TWDB 1996 Consensus Water Plan Projections.

from 157 mgd (Scenario 1, year 2030 conditions) to 356 mgd (Scenario 5, year 2050 conditions). Total project costs for WTP4 in fourth quarter 1996 dollars (including intake, raw water pump station, treatment units, and engineering/legal/contingency) for these various capacities range from $190,000,000 (157 mgd, Scenario 1) to $517,000,000 (356 mgd, Scenario 5).

Table 3.12-9
Sizes of Austin CIP Facilities for Scenarios 1 to 5 (Alt C-2)

		Scenario									
		1		**2**		**3**		**4**		**5**	
Item	**Unit**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**	**2030**	**2050**
Water Treatment Plant 4	mgd	157	206	172	222	222	291	245	323	255	356
NWA Pressure Zone											
Pump Station	mgd	157	206	172	222	222	303	245	313	250	356
Jollyville TM	inch	90	108	96	114	114	126	120	126	120	2@96 138
Martin Hill TM	inch	72	84	72	90	102	114	102	114	102	126
Forest Ridge TM	inch	48	48	48	48	48	48	48	48	48	48
Howard Lane TM	inch	48	48	48	48	48	48	48	48	48	48
Howard Lane Pressure Control Station	mgd	27	53	27	53	27	53	27	53	27	53
Jollyville Flow Control Station	each	1	1	1	1	1	1	1	1	1	1
NWB Pressure Zone											
Pump Station	mgd	18	18	18	18	18	18	29	36	29	36
Discharge TM	inch	36	36	36	36	36	36	48	54	48	54
RM 620 TM	inch	48	48	48	48	48	48	48	48	48	48
NW-B Reservoir	mg	4	6	4	6	4	6	4	6	4	6
Four Points Flow Control Station	each	1	1	1	1	1	1	1	1	1	1

NW-A Pressure Zone Facilities

The Jollyville transmission main is proposed to extend 24,000 feet from WTP4 to the intersection of Spicewood Springs Road and US 183. The pipeline would supply water to the Jollyville reservoir and the NW-A system. About 14,000 feet of this pipeline is planned to be tunneled. The Martin Hill transmission main is proposed to run 24,000 feet from the interconnection with the Jollyville transmission main along McNeil Road to FM1325 where it would supply the Martin Hill Reservoir. Where the Jollyville transmission main meets the Martin Hill transmission main a flow control station would be necessary (Jollyville FCS). From the end of the Martin Hill transmission main at FM1325 the Howard Lane transmission main would continue 5,000 feet along Howard Lane to the existing Howard Lane reservoir in northeast Austin. Through existing distribution mains the Howard Lane reservoir would serve Austin's North pressure zone. For this reason the demands for the North pressure zone are included in the demands for the NW-A pressure zone. To facilitate delivery of NW-A pressure zone water from WTP4 to the lower North pressure zone, a pressure control station would be necessary (Howard Lane PCS). The Forest Ridge tunnel is proposed to run 4,000 feet south from WTP4 to connect to the existing distribution system at McNeil Drive to supply water to the Forest Ridge reservoir and the NW-A pressure zone. At the site of WTP4 pump stations are proposed to serve the NW-A and NW-B pressure zones (NW-A Pump Station, NW-B Pump Station). The NW-A pump station is sized with the same capacity as WTP4 in all scenarios.

NW-B Pressure Zone Facilities

A NW-B pump station would be located at the WTP4 site as shown in Figure 3.12-1. The proposed NW-B pressure zone would connect WTP4 to existing distribution mains in the NW-B pressure zone along RM 620. The line is proposed to be 22,000 feet long, 2,000 of which would need to be tunneled. The proposed RM 620 transmission main would run 9,000 feet to connect WTP4 to a new NW-B reservoir. A new NW-B reservoir is proposed in the Lake Creek area near the intersection of RM 620 and US 183.

Transmission Facilities from Austin to Other Entities

Line 1 (needed for Scenarios 3, 4, and 5) would deliver water from Austin NW-A pressure zone to Pflugerville (see Figure 3.12-1). The line would connect to the Austin distribution system at the Howard Lane transmission main and run approximately 18,000 feet to an existing storage tank located south of the middle school. Line 1 would not require a pump station as the head at the Howard Lane transmission main is sufficient to fill the storage tank.

Line 2 (needed for Scenarios 3, 4, and 5) would deliver water from Austin's NW-A pressure zone to Round Rock, Brushy Creek, and possibly to Georgetown (see Figure 3.12-1).

Line 2 would run about 26,000 feet from the Martin Hill reservoir in the Austin NW-A pressure zone to a potential new storage tank in south Round Rock (Figure 3.12-1). Line 2 would require a pump station and new storage tank. For the engineering evaluation this storage tank was assumed to have an overflow elevation of 971 ft-msl. The head range of the NW-A system (980 feet to 1,015 feet) could potentially supply the new tank without a pump station. Without a detailed hydraulic study, the pump station cost has been included. The storage tank was sized for 2,000,000 gallons for the year 2030, and at 3,000,000 gallons for the year 2050, based on projected population growth in Round Rock.

For Scenarios 3, 4, and 5, the delivery capacity of Line 2 would be increased to meet the respective demands of Round Rock, Brushy Creek MUD, and Georgetown. However, instead of proposing the installation of additional transmission pipelines through Round Rock to deliver Austin water directly to Brushy Creek MUD or Georgetown, a "water trade" would be more economical. The water trade would involve meeting the water demands of Georgetown and/or Brushy Creek MUD from the existing Round Rock WTP (i.e., the raw water source for Georgetown and/or Brushy Creek would actually be Lake Georgetown). To make up the Round Rock WTP capacity that would now be dedicated to Georgetown or Brushy Creek, the equivalent amount of water would be purchased from Austin's WTP4 and delivered through Line 2 to south Round Rock. This additional supply of water into south Round Rock would be distributed into Round Rock's distribution system to meet demands previously supplied by the Round Rock WTP. This water trade would meet Brushy Creek or Georgetown's demands from a treatment plant much nearer to them than Austin's facilities and also has the advantage of distributing additional supplies into the south Round Rock distribution system where high growth rates are requiring system upgrades.

Line 3 would be a part of the water trade and would deliver treated water from the Round Rock WTP to Brushy Creek (see Figure 3.12-1). The line would run about 19,000 feet from the Round Rock treatment plant to Brushy Creek's storage tank on FM1431. Pumping requirements were assumed to be accommodated by the existing pump station at the treatment plant.

Line 4 would be a part of the water trade and would deliver treated water from the Round Rock WTP to Georgetown as shown on Figure 3.12-1. The line would run about 9,800 feet from the Round Rock treatment plant to Georgetown's Rabbit Hill storage tank. Pumping requirements would be met by the high service pump station at the treatment plant.

Line 5 would deliver treated water from Austin to Cedar Park as shown on Figure 3.12-1. Line 5 would connect to the Austin NW-B pressure zone at the Anderson Mill reservoir. This line would require a pump station to deliver water about 33,000 feet to Cedar Park's Webster storage tank. Leander would receive its supply from this tank by an additional pipeline, Line 6. Line 6 would require a pump station to deliver water about 9,000 feet from the Webster storage tank in Cedar Park to Lender's storage tank located on Bagdad Road across from the high school. There already exists about 3,600 feet of 24-inch waterline to deliver water from Cedar Park to Leander's storage tank. The capacity of this line was taken into account in the engineering evaluation here.

Transmission Facilities from Austin to Other Entities

Scenarios 3, 4, and 5 require transmission facilities to deliver treated water from the Austin distribution system to Williamson County participants.[68] The six potential transmission pipelines are numbered 1 through 6 and are discussed here and shown in Figure 3.12-1. The sizes of pipelines, their associated pump stations and storage facilities vary with demand and are summarized in Table 3.12-10.

Table 3.12-10
Diameters of Pipelines Dedicated to Williamson County Supply (Alt C-2)

Pipeline No.	**Scenario (dimensions shown in inches diameter)**					
	3		**4**		**5**	
	2030	**2050**	**2030**	**2050**	**2030**	**2050**
1	36	42	36	42	36	42
2	54	60	54	60	54	72
3	18	18	18	18	18	18
4			36	42	36	42
5			24	30(5400′) 16(3600′)	24	30(5400′) 16(3600′)
6					24	42

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[68] For Scenario 2, the facilities linking Pflugerville and Round Rock to the Austin distribution system are either in design or already in place and are not included in this cost evaluation. In the near-term, Pflugerville will receive North Pressure Zone water. For potential increased deliveries above the current contract (Scenarios 3, 4, and 5), Pflugerville would connect to the NW-A pressure zone and deliver to Pflugerville's Middle School storage tank.

Scenario 1 — WTP4 to Austin Service Area

Scenario 1 involves treatment and delivery from WTP4 to the NW-A, NW-B, and North pressure zones of the Austin service area (Figure 3.12-1). Water for the North pressure zone would be delivered through the NW-A pressure zone, and its demand is included with the demand for the NW-A pressure zone. The water demands for these areas are listed in Table 3.12-4. The projected shortage for the 2030 case is 100,730 acft/yr (157 mgd peak), and is 139,614 acft/yr (206 mgd peak) for the 2050 case.

Scenario 1 — 2030 Conditions

Required sizes of Austin CIP facilities are summarized in Table 3.12-9. Under Scenario 1 WTP4 would require a capacity of 157 mgd, as would the NW-A pump station. The Jollyville transmission main would be 90 inches diameter, and the Martin Hill transmission main would be 72 inches diameter. The NW-B discharge main would be 36 inches diameter, and the NW-B reservoir would need a capacity of 4 million gallons.

A summary of the costs for Scenario 1 is provided in Table 3.12-11. The total cost of WTP4 for this scenario is estimated to be $190,150,000 for 2030 conditions. The NW-A pressure zone would receive 72 percent of the water delivered and is allocated that portion of the cost, or $137,030,000. The balance of $53,120,000 is allocated to the NW-B pressure zone. Total project cost for the NW-A pressure zone is estimated at $204,311,972. Financed at 8 percent for 25 years, the annual debt service would be $19,144,032, and with O&M and power the total annual cost would be $39,378,755. For an annual delivery of 72,590 acft/yr the unit cost is $542 per acft (not including purchase price of raw water from LCRA). Total project cost for the NW-B pressure zone would be $72,173,745. The annual debt service would be $6,762,680, and with O&M and power the total annual cost would be $14,606,806. For an annual delivery of 28,140 acft/yr the unit cost is $519 per acft (not including purchase price of raw water from LCRA).

The unit costs for Scenario 1 are summarized in Table 3.12-12. The unit cost of water in the NW-A pressure zone would be $542 per acft (Table 3.12-11) plus $105 per acft for purchase of raw water from LCRA, for a total of $647 per acft ($1.99 per 1,000 gal). For the NW-B

Table 3.12-11
Cost Estimate Summary for Scenario 1 (Alt C-2)
WTP4 to Austin Service Area
(1st Quarter 1997 dollars)

	Year 2030		**Year 2050**	
Item	**NW-A**	**NW-B**	**NW-A**	**NW-B**
Capital Costs				
Water Treatment Plant 4	$137,029,569	$53,120,431	$183,557,869	$60,142,131
Pump Stations	5,019,109	1,613,421	6,153,217	1,613,421
Transmission and Storage	35,153,000	8,871,359	46,401,420	9,672,616
Subtotal	$177,201,678	$63,605,211	$236,112,506	$71,428,168
Engineering, Contingencies, Legal	$12,302,588	$3,226,105	$16,074,052	$3,466,482
Land Acquisition	2,161,918	838,082	2,259,637	740,363
Environmental Studies and Mitigation	1,080,959	419,041	1,129,819	370,181
Interest During Construction	11,564,829	4,085,306	15,334,561	4,560,312
Total Project Cost	$204,311,972	$72,173,745	$270,910,575	$80,565,506
Annual Costs				
Debt Service	$19,144,032	$6,762,680	$25,384,321	$7,548,988
Annual O&M(1)	17,784,550	6,894,300	25,763,955	8,441,475
Annual Power	2,450,174	949,826	3,389,456	1,110,544
Total Annual Cost	$39,378,755	$14,606,806	$54,537,732	$17,101,007
Annual Project Yield	72,590 acft/yr	28,140 acft/yr	105,159 acft/yr	34,455 acft/yr
Annual Unit Cost				
$ per acft	$542	$519	$519	$496
$ per 1,000 gal	$1.66	$1.59	$1.59	$1.52

(1) Annual O&M costs for City of Austin CIP facilities include water utility administration and management costs.

Table 3.12-12
Estimated Unit Costs for Scenario 1 — WTP4 to Austin Service Area

Pressure Zone	**Item**	**Cost ($ per acft)**	
		Year 2030	**Year 2050**
Austin NW-A	CIP facilities	$542	$519
	Raw Water Purchase from LCRA	$105	$105
	Total Unit Cost	$647	$624
Austin NW-B	CIP facilities	$519	$496
	Raw Water	$105	$105
	Total Cost	$624	$601

pressure zone, the unit cost of water would be $519 per acft (Table 3.12-11), plus $105 per acft for purchase of raw water from LCRA for a total of $624 per acft ($1.92 per 1,000 gal).

Scenario 1 — 2050 Conditions

Required sizes of Austin CIP facilities for Scenario 1 under 2050 demand conditions are summarized in Table 3.12-9. WTP4 would require a capacity of 206 mgd, as would the NW-A pump station. The Jollyville transmission main would be 108 inches diameter, and the Martin Hill transmission main would be 84 inches diameter. The NW-B discharge main would be 36 inches diameter, and the NW-B reservoir would need a capacity of 6,000,000 gallons.

A summary of costs for Scenario 1 is provided in Table 3.12-11. The total cost of WTP4 for this scenario is estimated to be $243,700,000. The NW-A pressure zone would receive 75 percent of the water delivered, and is allocated that portion of the cost, or $183,560,000. The balance of 60,140,000 is allocated to the NW-B pressure zone. Total project cost for the NW-A pressure zone would be $270,910,575 (Table 3-12.11). Financed at 8 percent for 25 years, the annual debt service would be $25,384,321, and with O&M and power the total annual cost would be $54,537,732. For an annual delivery of 105,159 acft/yr the unit cost is $519 per acft (not including purchase price of raw water from LCRA). Total project cost for the NW-B pressure zone would be $80,565,506. Financed at 8 percent for 25 years, the annual debt service would be $7,548,988, and with O&M and power the total annual cost would be $17,101,007. For an annual delivery of 34,455 acft/yr the unit cost is $496 per acft (not including purchase price of raw water from LCRA).

The unit costs for Scenario 1 under 2050 conditions are summarized in Table 3.12-12. The unit cost of water in the NW-A pressure zone would be $519 per acft (Table 3.12-11) plus $105 per acft for purchase of raw water from LCRA, for a total of $624 per acft ($1.92 per 1,000 gal). For the NW-B pressure zone, the unit cost of water would be $496 per acft (Table 3.12-11), plus $105 per acft for purchase of raw water from LCRA for a total of $601 per acft ($1.84 per 1,000 gal).

Scenario 2 — to Austin Service Area, Pflugerville, and Round Rock (1996 Contracts)

Scenario 2 is similar to Scenario 1 with the addition of current water supply contracts with Pflugerville[69] and Round Rock,[70] both of which are served from Austin's NW-A pressure zone. The demands are summarized in Table 3.12-4. Pflugerville's supply would be provided from a planned interconnection into the NW-A distribution system. This increased demand would be supplied through the Howard Lane NW-A transmission main. Round Rock would be supplied from an existing interconnection with the NW-A system near the Martin Hill reservoir. The facilities dedicated to supplying Pflugerville and Round Rock are either in design or already in place and are not included in the engineering and costing evaluation here. Under the current contract, Pflugerville will receive North pressure zone water. For potential increased deliveries in Scenarios 3, 4, and 5, Pflugerville would connect to the NW-A pressure zone.

Scenario 2 — 2030 Conditions

For the 2030 projected needs of north Austin, Pflugerville, and Round Rock, WTP4 would need a capacity of 172 mgd. Required sizes of Austin CIP facilities are summarized in Table 3.12-11 and facility upsizing for each scenario can be determined. In the NW-A pressure zone, the Jollyville transmission main would be upsized by 6 inches to 96 inches diameter and the Martin Hill transmission main would remain at 72 inches diameter. The sizes of all other facilities remain the same as Scenario 1.

A summary of the costs of the Austin CIP facilities for Scenario 2 is provided in Table 3.12-13. WTP4 is estimated to have a total cost of $207,400,000. Of this amount, 76 percent would be to supply demands in the NW-A pressure zone, and that fraction of the cost, or $157,650,000 is allocated to NW-A. The balance of $49,750,000 is allocated to the NW-B pressure zone. The total project cost for the NW-A pressure zone is estimated to be $230,791,197 (Table 3-12.13). Financed at 8 percent for 25 years, the annual cost, with debt service, O&M, and power would be about $46,283,000. For an annual delivery of 89,950 acft/yr, the unit cost for the NW-A pressure zone is $514 per acft. The total project cost

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[69] Supply contract from City of Austin for 5.5 mgd.

[70] Supply contract from City of Austin for 10 mgd.

for the NW-B pressure zone is estimated to be $68,415,164. The total annual cost, with O&M and power would be about $14,200,000. For an annual delivery of 28,140 acft/yr, the unit cost for the NW-A pressure zone is $504 per acft.

Table 3.12-13
Cost Estimate Summary for Scenario 2 (Alt C-2)
WTP4 to Austin Service Area, Round Rock, and Pflugerville
(1st Quarter 1997 dollars)

Item	Year 2030		Year 2050	
	NW-A	**NW-B**	**NW-A**	**NW-B**
Capital Costs				
Water Treatment Plant 4	$157,647,762	$49,752,238	$203,346,319	$57,553,681
Pump Stations	5,374,625	1,613,421	6,508,285	1,613,421
Transmission and Storage	38,002,710	8,871,359	51,027,420	9,672,616
Subtotal	$201,025,097	$60,237,018	$260,882,024	$68,839,718
Engineering, Contingencies, Legal	$13,281,932	$3,226,105	$17,586,126	$3,466,482
Land Acquisition	2,280,344	719,656	2,338,210	661,790
Environmental Studies and Mitigation	1,140,172	359,828	1,169,105	330,895
Interest During Construction	13,063,653	3,872,556	16,918,528	4,397,933
Total Project Cost	$230,791,197	$68,415,164	$298,893,992	$77,696,819
Annual Costs				
Debt Service	$21,625,135	$6,410,501	$28,006,367	$7,280,192
Annual O&M[1]	21,845,670	6,894,300	29,829,075	8,441,475
Annual Power	2,812,424	887,576	3,741,136	1,058,864
Total Annual Cost	$46,283,229	$14,192,377	$61,572,578	$16,780,531
Annual Project Yield	89,950 acft/yr	28,140 acft/yr	122,519 acft/yr	34,455 acft/yr
Annual Unit Cost				
$ per acft	$514	$504	$503	$487
$ per 1,000 gal	$1.58	$1.55	$1.54	$1.49

(1) Annual O&M costs for City of Austin CIP facilities include water utility administration and management costs.

The unit costs for Scenario 2 are summarized in Table 3.12-14. The unit cost of water in the NW-A pressure zone would be $514 per acft (Table 3.12-13) plus $105 per acft for purchase of raw water from LCRA, for a total unit cost of $619 per acft ($1.92 per 1,000 gal). The total unit cost of water for the NW-B pressure zone would be $504 per acft (Table 3.12-13) plus $105 per acft for purchase of raw water from LCRA, or $609 per acft ($1.87 per 1,000 gal).

Table 3.12-14
Estimated Unit Costs for Scenario 2 — WTP4 to Austin Service Area, Round Rock, and Pflugerville

Pressure Zone	Item	Cost ($ per acft)	
		Year 2030	Year 2050
Austin NW-A	CIP facilities - NW-A Pressure Zone Raw Water Total Cost	$514 $105 $619	$503 $105 $608
Austin NW-B	CIP facilities - NW-B Pressure Zone Raw Water Total Cost	$504 $105 $609	$487 $105 $592

Scenario 2 — 2050 Conditions

For the 2050 projected needs of north Austin, Pflugerville, and Round Rock, WTP4 would require a capacity of 222 mgd. As indicated in Table 3.12-9, in the NW-A pressure zone, the Jollyville transmission main would be upsized to 114 inches diameter and the Martin Hill transmission main would be upsized to 90 inches diameter. The size of other facilities remain the same as Scenario 1.

The estimated costs of the Austin CIP facilities for Scenario 2 are summarized in Table 3.12-13. WTP4 is estimated to have a total cost of $260,900,000. Of this amount 78 percent is to supply demands in the NW-A pressure zone, and that fraction of the cost, or $203,346,319 is allocated to NW-A. The balance of $57,553,681 is allocated to the NW-B pressure zone. The total project cost for the NW-A pressure zone is estimated to be $298,893,992 (Table 3.12-13). Financed at 8 percent for 25 years, the annual cost, with debt service, O&M, and power would be about $61,570,000. For an annual delivery of 122,519 acft/yr, the unit cost for the NW-A pressure zone would be about $503 per acft. The total project cost for the NW-B pressure zone is estimated to be $77,696,819. The total annual cost, with debt service, O&M, and power would be about $16,780,000. For an annual delivery of 34,455 acft/yr, the unit cost for the NW-A pressure zone would be about $487 per acft.

The unit costs for Scenario 2 are summarized in Table 3.12-14. The unit cost of water in the NW-A pressure zone would be $503 per acft plus $105 per acft for purchase of raw water from LCRA, for a total unit cost of $608 per acft ($1.87 per 1,000 gal). The unit cost of water for the NW-B pressure zone would be about $487 per acft plus $105 per acft for purchase of raw water from LCRA, for a total unit cost of $592 per acft ($1.82 per 1,000 gal; Table 3.12-14).

Scenario 3 — WTP4 to Austin Service Area, Pflugerville, Round Rock, and Brushy Creek

The entities involved in Scenario 3 are the City of Austin, Pflugerville, Round Rock, and Brushy Creek MUD. As in previous scenarios, the CIP facilities to be implemented by the City of Austin provide treated water from WTP4 to the NW-A and NW-B pressure zones. Pflugerville, Round Rock, and Brushy Creek would all be served from the NW-A pressure zone. The demands for 2030 and 2050 are summarized in Table 3.12-4.

The facilities necessary to implement this scenario are:

- City of Austin CIP facilities (Table 3.12-9);
- Line 1: Transmission main from Howard Lane transmission main to Pflugerville (Figure 3.12-1);
- Line 2: Transmission main and pump station from Martin Hill Reservoir to new storage tank in Round Rock (Figure 3.12-1);
- New storage tank in south Round Rock (Figure 3.12-1); and
- Line 3: Transmission main from Round Rock treatment plant to Brushy Creek storage tank (Figure 3.12-1).

This scenario has some similarities with Scenario 2. Austin's demands in the NW-A and NW-B pressure zones are the same, and service is provided from the NW-A pressure zone to Pflugerville and Round Rock. However, in this scenario, projected shortages for Pflugerville and Round Rock are estimated without supply contracts for water from Austin or Lake Stillhouse Hollow (BRA). Also, Scenario 3 provides a supply to meet projected shortages of Brushy Creek MUD. Brushy Creek is located north-west of Round Rock in the vicinity of Round Rock's water treatment plant, which is several miles from the NW-A interconnect at Martin Hill. For this reason, instead of evaluating a dedicated transmission pipeline to supply Brushy Creek's needs, it was considered advantageous to include Brushy Creek's shortages with Round Rock's, and deliver both quantities to the potential new storage tank in south Round Rock. To meet Brushy Creek's needs, water would be delivered from the Round Rock treatment plant through a much shorter dedicated pipeline, shown in Figure 3.12-1 as Line 3. The advantage to this "water trade" is a reduced cost to Brushy Creek for a dedicated pipeline, and a more balanced distribution by relocating some of Round Rock's supply to the south, alleviating demand on the treatment plant and transmission system from the north. For equity, Brushy Creek would also share in the cost of Line 2 with Round Rock.

Scenario 3 — 2030 Conditions

The City of Austin CIP facilities necessary to implement this scenario are shown in Table 3.12-9. WTP4 was sized with a capacity of 222 mgd. The Jollyville transmission main would be 114 inches diameter, and the Martin Hill transmission main would be 102 inches diameter. The NW-B discharge main would require a diameter of 36 inches and the NW-B reservoir is sized for 4.0 million gallons.

The sizes of the pipeline facilities needed to supply Williamson County entities are summarized in Table 3.12-10. Line 1 would require a diameter of 36 inches to provide a flow of 22.1 mgd to Pflugerville. Line 2 would require a diameter of 54 inches to supply the combined flow of 43.2 mgd to Round Rock, including 4.9 mgd for Brushy Creek. Line 3, sized at 18 inches diameter, is dedicated to supply the Brushy Creek storage tank with 4.9 mgd from the Round Rock treatment plant.

Costs of the City of Austin CIP facilities are summarized in Table 3.12-15. The cost of WTP4 is $260,900,000. Of this amount 80 percent, or $207,429,409 is allocated to the NW-A pressure zone according to its fraction of the total demand. The remaining $53,470,591 is allocated to the NW-B pressure zone. The unit cost for the Austin CIP facilities in the NW-A pressure zone is $549 per acft, and that of the NW-B pressure zone is $520 per acft (Table 3.12-15).

Costs for the facilities dedicated to Williamson County entities are shown in Table 3.12-16. Line 1, dedicated to Pflugerville, is estimated to have a total project cost of $4,409,000, and have a total annual cost of $449,000 if financed at 8 percent for 25 years. For an annual delivery of 12,362 acft/yr, its unit cost is about $36 per acft. Line 2 which was sized to supply both Round Rock and Brushy Creek is estimated to have a total project cost of $12,418,000, and a total annual cost of $1,514,000. For an annual delivery of 24,212 acft/yr the unit cost is about $63 per acft. Line 3 is dedicated to supply Brushy Creek from the Round Rock treatment plant, and is estimated to have a total project cost of $2,415,000. The total annual cost would be about $247,000, and for an annual delivery of 2,754 acft/yr, the unit cost would be about $90 per acft.

Table 3.12-15
Cost Estimate Summary for Austin CIP Facilities for Scenario 3 (Alt C-2)
WTP4 to Austin Service Area, Pflugerville, Round Rock, and Brushy Creek
(1st Quarter 1997 dollars)

Item	Year 2030		Year 2050	
	NW-A	NW-B	NW-A	NW-B
Capital Costs				
Water Treatment Plant 4	$207,429,409	$53,470,591	$270,751,258	$61,248,742
Pump Stations	8,233,331	1,613,421	10,396,636	1,613,421
Transmission and Storage	57,004,710	8,871,359	65,947,420	9,672,616
Subtotal	$272,667,450	$63,955,371	$347,095,314	$72,534,779
Engineering, Contingencies, Legal	$19,983,079	$3,226,105	$23,423,049	$3,466,482
Land Acquisition	2,385,160	614,840	2,446,548	553,452
Environmental Studies and Mitigation	1,192,580	307,420	1,223,274	276,726
Interest During Construction	17,773,696	4,086,224	22,451,291	4,609,886
Total Project Cost	$314,001,965	$72,189,960	$396,639,475	$81,441,326
Annual Costs				
Debt Service	$29,421,984	$6,764,199	$37,165,119	$7,631,052
Annual O&M[1]	26,745,180	6,894,300	37,315,705	8,441,475
Annual Power	3,816,256	983,744	5,137,750	1,162,250
Total Annual Cost	$59,983,420	$14,642,243	$79,618,574	$17,234,777
Annual Project Yield	109,164 acft/yr	28,140 acft/yr	152,309 acft/yr	34,455 acft/yr
Annual Unit Cost				
$ per acft	$549	$520	$523	$500
$ per 1,000 gal	$1.69	$1.60	$1.60	$1.54

[1] Annual O&M costs for City of Austin CIP facilities include water utility administration and management costs.

Unit costs for all facilities including the cost for Austin's facilities and the purchase of raw water from LCRA are summarized and totaled for each entity in Table 3.12-17. Total unit cost for the Austin NW-A pressure zone is the sum of the unit cost for the Austin CIP facilities ($549 per acft) plus the raw water purchase cost from LCRA of $105 per acft, resulting in a total cost of $654 per acft ($2.01 per 1,000 gal), and for the NW-B pressure zone the sum of the unit

Table 3.12-16
Cost Estimate Summary for Non-CIP Facilities for Scenario 3 (Alt C-2) WTP4 to Austin Service Area, Pflugerville, Round Rock, and Brushy Creek

(1st Quarter 1997 Dollars)

Item	Cost ($)					
	Year 2030			Year 2050		
	Line 1 (Pflugerville)	Line 2 (RR/BCMUD)	Line 3 (BCMUD)	Line 1 (Pflugerville)	Line 2 (RR/BCMUD)	Line 3 (BCMUD)
Capitol Costs						
Pipeline	$3,221,000	$6,469,000	$1,748,000	$3,863,000	$7,328,000	$1,748,000
Pump Station	0	1,602,000	0	0	2,102,000	0
Storage Tank	0	960,000	0	0	1,290,000	0
Subtotal	$3,221,000	$9,031,000	$1,748,000	$3,863,000	$10,720,000	$1,748,000
Engineering, Contingencies, Legal	$966,000	$2,837,000	$524,000	$1,159,000	$3,386,000	$524,000
Environmental Studies and Mitigation	52,000	72,000	50,000	52,000	72,000	50,000
Interest During Construction	170,000	478,000	93,000	203,000	567,000	93,000
Total Project Cost	$4,409,000	$12,418,000	$2,415,000	$5,277,000	$14,745,000	$2,415,000
Annual Costs						
Annual Debt Service	$413,000	$1,164,000	$226,000	$494,000	$1,382,000	$226,000
Annual O&M	36,000	120,000	21,000	43,000	145,000	21,000
Annual Power	0	230,000	0	0	311,000	0
Total Annual Cost	$449,000	$1,514,000	$247,000	$537,000	$1,838,000	$247,000
Annual Delivery (acft/yr)	12,362	24,212	2,754	14,541	32,609	2,835
Annual Unit Costs						
$ per acft	$36	$63	Section 3-12 $90	$37	$56	$87
$ per 1,000 gal	$0.11	$0.19	$0.28	$0.11	$0.17	$0.27

Table 3.12-17 Total Estimated Unit Costs for Scenario 3 WTP4 to Austin Service Area, Pflugerville, Round Rock, and Brushy Creek			
		Cost ($ per acft)	
Entity	**Item**	**Year 2030**	**Year 2050**
Austin NW-A	Austin CIP Facilities - NW-A Pressure Zone	$549	$523
	Raw Water Purchase from LCRA	105	105
	Total	$654	$628
Austin NW-B	Austin CIP Facilities - NW-B Pressure Zone	$520	$500
	Raw Water Purchase from LCRA	105	105
	Total	$625	$605
Pflugerville	Austin CIP Facilities - NW-A Pressure Zone	$549	$523
	Line 1 (Dedicated Pipeline to Pflugerville)	36	37
	Raw Water	105	105
	Total	$690	$665
Round Rock	Austin CIP Facilities - NW-A Pressure Zone	$549	$523
	Line 2 (Dedicated Pipeline to Round Rock)	63	56
	Raw Water	105	105
	Total	$717	$684
Brushy Creek	Austin CIP Facilities - NW-A Pressure Zone	$549	$523
	Line 2 (Dedicated Pipeline, Austin/Round Rock)	63	56
	Line 3 (Dedicated Pipeline to Brushy Creek)	90	87
	Raw Water	105	105
	Total	$807	$771

cost for the CIP facilities ($520 per acft) plus the $105 per acft raw water cost, resulting in a total cost of $625 per acft ($1.92 per 1,000 gal). For Pflugerville, the sum of unit costs for the NW-A pressure zone, Line 1, and raw water is $690 per acft ($2.12 per 1,000 gal). For Round Rock the sum of unit costs for the NW-A pressure zone, Line 2, and raw water is $717 per acft ($2.21 per 1,000 gal). For Brushy Creek the sum of unit costs for the NW-A pressure zone, Line 2, and Line 3, and raw water is $807 per acft ($2.48 per 1,000 gal).

Scenario 3 — 2050 Conditions

The City of Austin CIP facilities necessary to implement this scenario are shown in Table 3.12-9. WTP4 has a capacity of 291 mgd, the Jollyville transmission main would need to be 126 inches diameter, and the Martin Hill transmission main would need to be 114 inches diameter. The sizes of all other Austin facilities remain the same as in Scenarios 1 and 2.

The sizes of the facilities needed to supply Williamson County entities are summarized in Table 3.12-10. Line 1 would require a diameter of 42 inches to provide a flow of 26 mgd to Pflugerville. Line 2 would require a diameter of 60 inches to supply the combined flow of 58.3 mgd to Round Rock, which includes 5.1 mgd for Brushy Creek. Line 3 is sized at 18 inches to supply the Brushy Creek storage tank with 5.1 mgd from the Round Rock treatment plant.

Costs of the Austin CIP facilities are summarized in Table 3.12-15. The total cost of WTP4 is estimated to be $332,000,000. Of this amount 82 percent, or $270,751,258 is allocated to the NW-A pressure zone according to its demand. The remaining $61,248,742 is allocated to the NW-B pressure zone. The unit cost for the CIP facilities in the NW-A pressure zone is $523 per acft, and that of the NW-B pressure zone is $500 per acft (Table 3.12-17).

Costs for the facilities dedicated to Williamson County supply are shown in Table 3.12-16. Line 1, dedicated to Pflugerville, is estimated to have a total project cost of $5,277,000, and have a total annual cost of $537,000 if financed at 8 percent for 25 years. For an annual delivery of 14,541 acft/yr, its unit cost is about $37 per acft. Line 2 which was sized to supply both Round Rock and Brushy Creek is estimated to have a total project cost of $14,745,000, and a total annual cost of $1,838,000. For an annual delivery of 32,609 acft/yr the unit cost is about $56 per acft. Line 3 is dedicated to supply Brushy Creek from the Round Rock treatment plant, and is estimated to have a total project cost of $2,415,000. The total annual cost would be about $247,000, and for an annual delivery of 2,835 acft/yr, the unit cost would be about $87 per acft.

Unit costs for all facilities including the cost for Austin's facilities and the purchase of raw water from LCRA at $105 per acft are summarized for each entity in Table 3.12-17. Total unit cost for the Austin NW-A pressure zone is estimated to be $628 per acft ($1.93 per 1,000 gal), and for the NW-B pressure zone is estimated to be $605 per acft ($1.86 per 1,000 gal). For Pflugerville the sum of unit costs for the NW-A pressure zone, Line 1, and raw water is $665 per acft ($2.05 per 1,000 gal). For Round Rock the sum of unit costs for the NW-A pressure zone, Line 2, and raw water is $684 per acft ($2.10 per 1,000 gal). For Brushy Creek the sum of unit costs for the NW-A pressure zone, Line 2 equity costs, Line 3, and raw water is $771 per acft ($2.37 per 1,000 gal).

Scenario 4 — WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, and Leander

Scenario 4 would deliver water to the Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, and Leander. Cedar Park and Leander would receive service through Austin's NW-B pressure zone. The water demands from each entity to be met by this alternative are summarized in Table 3.12-4.

The facilities necessary to implement this scenario are:

- Austin CIP facilities (Table 3.12-9);
- Line 1: Transmission main from Howard Lane transmission main to Pflugerville (Figure 3.12-1);
- Line 2: Transmission main and pump station from Martin Hill reservoir to new storage tank in Round Rock (Figure 3.12-1);
- New storage tank in south Round Rock;
- Line 3: Transmission main from Round Rock treatment plant to Brushy Creek storage tank (Figure 3.12-1).
- Line 5: Pump station and transmission main from Anderson Mill reservoir to Cedar Park's Webster storage tank (Figure 3.12-1);
- Line 6: Pump station and transmission main from Webster storage tank to Leander storage tank (Figure 3.12-1).

In this scenario water is supplied to the Cities of Cedar Park and Leander through the Anderson Mill Reservoir in Austin's NW-B pressure zone, as shown in Figure 3.12-1. From the Anderson Mill Reservoir, water for both Cedar Park and Leander would be delivered about 33,000 feet through Line 5 to Cedar Park's Webster storage tank. Line 5 would require a pump station to lift the water from elevation 1,095 feet at Anderson Mill Reservoir to the overflow elevation of 1,119 feet at the Webster tank. From the Webster tank, Leander's supply would be delivered through Line 6 to their storage tank on Bagdad Road across from the high school. Line 6 would be about 9,000 feet long and would require a pump station to deliver from Webster's minimum elevation of about 1,079 ft-msl to Leander's storage tank (elevation

1,050-ft msl). Leander is currently receiving water from Cedar Park through a 24-inch pipeline which extends about 3,600 feet from the Cedar Park System to the Leander storage tank. The capacity of the existing pipeline was included in the engineering evaluation to estimate the necessary additional facilities for this scenario.

Scenario 4 — 2030 Conditions

The City of Austin CIP facilities necessary to implement this scenario are shown in Table 3.12-9. WTP4 is sized with a capacity of 245 mgd and the Jollyville transmission main is sized at 120 inches. All remaining NW-A CIP facilities are sized the same as in Scenario 3. The NW-B pressure zone requires an upsized discharge main with a diameter of 48 inches with the remaining facilities sized the same as in Scenario 3.

The sizes of the facilities needed to supply the Williamson County entities are summarized in Table 3.12-10. Facilities supplying Pflugerville, Round Rock, and Brushy Creek are the same as Scenario 3. Line 5 which supplies Cedar Park and Leander would require a diameter of 36 inches to supply the combined flow of 23.6 mgd to the Webster storage tank, including 14.3 mgd for Cedar Park and 9.3 mgd for Leander. Line 6 would require a diameter of 24 inches. This is the same diameter as the existing pipe to Leander, so only 5,400 feet of new 24-inch line would be necessary. Both pipelines require pump stations.

Costs of the Austin CIP facilities are summarized in Table 3.12-18. The cost of WTP4 is $285,000,000. Of this amount 73 percent, or $206,765,114 is allocated to the NW-A pressure zone according to its fraction of the total demand. The remaining $78,234,886 is allocated to the NW-B pressure zone which includes service for Cedar Park and Leander. The unit cost, not including purchase of raw water from LCRA, for the Austin CIP facilities in the NW-A pressure zone is $551 per acft, and that of the NW-B pressure zone is $513 per acft (Table 3.12-18).

Costs for facilities for Williamson County entities are shown in Table 3.12-19. The costs of Lines 1, 2, and 3 to NW-A recipients are the same as Scenario 3. Line 5 which was sized to supply both Cedar Park and Leander is estimated to have a total project cost of $9,495,000, and a total annual cost of $1,092,000. For an annual delivery of 13,165 acft/yr the unit cost is about $83 per acft. Line 6 is dedicated to supply Leander from the Webster storage tank, and is estimated to have a total project cost of $1,107,000 for the portion which is not currently

Table 3.12-18
Cost Estimate Summary for Austin CIP Facilities for Scenario 4 (Alt C-2) WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, and Leander
(1st Quarter 1997 dollars)

Item	Year 2030		Year 2050	
	NW-A	NW-B	NW-A	NW-B
Capital Costs				
Water Treatment Plant 4	$206,765,114	$78,234,886	$272,492,142	$94,507,858
Pump Stations	8,865,136	2,307,235	10,652,931	2,713,440
Transmission and Storage	57,896,710	10,791,359	65,947,420	12,792,616
Subtotal	$273,526,960	$91,333,480	$349,092,493	$110,013,914
Engineering, Contingencies, Legal	$20,471,811	$4,044,940	$23,512,752	$4,787,489
Land Acquisition	2,176,475	823,525	2,227,456	772,544
Environmental Studies and Mitigation	1,088,237	411,763	1,113,728	386,272
Interest During Construction	17,835,809	5,796,822	22,556,786	6,957,613
Total Project Cost	$315,099,292	$102,410,530	$398,503,215	$122,917,832
ANNUAL COSTS				
Debt Service	$29,524,804	$9,595,867	$37,339,751	$11,517,401
Annual O&M(1)	26,745,180	10,119,725	37,315,705	12,942,125
Annual Power	3,845,106	1,454,894	5,197,398	1,802,602
Total Annual Cost	$60,115,089	$21,170,486	$79,852,854	$26,262,128
Annual Project Yield	109,164 acft/yr	41,305 acft/yr	152,309 acft/yr	52,825 acft/yr
Annual Unit Cost				
$ per acft	$551	$513	$524	$497
$ per 1,000 gal	$1.69	$1.57	$1.61	$1.53

(1) Annual O&M costs for City of Austin CIP facilities include water utility administration and management costs.

Table 3.12-19
Cost Estimate Summary for Williamson County Facilities for Scenario 4, 2030 Conditions (Alt C-2)
WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, and Leander

(1st Quarter 1997 dollars)

Item	Line 1 (Pflugerville)	Line 2 (Round Rock)	Line 3 (BCMUD)	Line 5 (CP/Leander)	Line 6 (Leander)
Capital Costs					
Pipeline	$3,221,000	$6,469,000	$1,748,000	$5,745,000	$609,000
Pump Station	0	1,602,000	0	1,170,000	187,000
Storage Tank	0	960,000	0	0	0
Subtotal	$3,221,000	$9,031,000	$1,748,000	$6,915,000	$796,000
Engineering, Contingencies, Legal	$ 966,000	$ 2,837,000	$ 524,000	$2,133,000	$ 248,000
Environmental Studies and Mitigation	52,000	72,000	50,000	82,000	20,000
Interest During Construction	170,000	478,000	93,000	365,000	43,000
Total Project Cost	$4,409,000	$12,418,000	$2,415,000	$9,495,000	$1,107,000
Annual Costs					
Annual Debt Service	$413,000	$1,164,000	$226,000	$890,000	$104,000
Annual O&M	36,000	130,000	21,000	99,000	10,000
Annual Power	0	230,000	0	103,000	1,000
Total Annual Cost	$449,000	$1,514,000	$247,000	$1,092,000	$115,000
Annual Delivery (acft/yr)	12,362	24,212	2,754	13,165	5,182
Annual Unit Costs					
$ per acft	$36	$63	$90	$83	$22
$ per 1,000 gal	$0.11	$0.19	$0.28	$0.25	$0.07

installed. The total annual cost for this line would be about $115,000, which includes O&M for the whole line. For an annual delivery of 5,182 acft/yr, the unit cost would be about $22 per acft.

Unit costs for all facilities, including both City of Austin facilities and the purchase of raw water from LCRA, are summarized and totaled for each participant in Table 3.12-21. Total unit cost for the Austin NW-A pressure zone is the sum of the unit cost for the Austin CIP facilities ($551 per acft) plus the raw water purchase cost from LCRA of $105 per acft, resulting in a total cost of $656 per acft ($2.02 per 1,000 gal). For Austin NW-B pressure zone, the total cost, including raw water costs, is $618 per acft. For Pflugerville, the sum of unit costs for the NW-A pressure zone, Line 1, and raw water is $692 per acft ($2.13 per 1,000 gal). For Round Rock, the sum of unit costs for the NW-A pressure zone, Line 2, and raw water is $719 per acft ($2.21 per 1,000 gal). For Brushy Creek the sum of unit costs for the NW-A pressure zone, Line 2 equity cost, Line 3, and raw water is $809 per acft ($2.49 per 1,000 gal). For Cedar Park the sum of unit costs for the NW-B pressure zone, Line 5, and raw water is $701 per acft ($2.16 per 1,000 gal). For Leander, the sum of unit costs for the NW-A pressure zone, Line 5, Line 6, and raw water is $723 per acft ($2.22 per 1,000 gal).

Scenario 4 — 2050 Conditions

The City of Austin CIP facilities necessary to implement this scenario are shown in Table 3.12-9. WTP4 was sized with a capacity of 323 mgd and the remaining NW-A CIP facilities are sized the same as the 2050 case for Scenario 3. The NW-B pump station would need to be upsized to 36 mgd and the discharge main would require upsizing to a diameter of 54 inches. All other facilities would be sized the same as for Scenario 3 for 2050 conditions.

The sizes of the facilities dedicated to the Williamson County entities are summarized in Table 3.12-10. Those supplying Pflugerville, Round Rock, and Brushy Creek are the same as Scenario 3. Line 5 would require a diameter of 42 inches to supply the combined flow of 32.8 mgd to the Webster storage tank, including 18.6 mgd for Cedar Park and 14.2 mgd for Leander. Line 6 would require a new line with a diameter of 30 inches for about 5,400 feet, and about 3,600 feet of 16-inch line would need to be installed along the existing 24-inch line. Both Lines 5 and 6 require pump stations.

Costs of the Austin CIP facilities are summarized in Table 3.12-18. The cost of WTP4 is $367,000,000. Of this amount 74 percent, or $272,492,142 is allocated to the NW-A pressure zone according to its fraction of the total demand. The remaining $94,507,858 is allocated to the NW-B pressure zone which includes service for Cedar Park and Leander. The unit cost for the Austin CIP facilities in the NW-A pressure zone is $524 per acft, and that of the NW-B pressure zone is $497 per acft (Table 3.12-18).

Costs for the facilities dedicated to Williamson County supply are shown in Table 3.12-20. The costs of Lines 1, 2, and 3 to NW-A recipients are the same as for the 2050 case of Scenario 3. Line 5 which was sized to supply both Cedar Park and Leander is estimated to have a total project cost of $11,553,000, and a total annual cost of $1,343,000. For an annual delivery of 18,370 acft/yr the unit cost is about $73 per acft. Line 6 is dedicated to supply Leander from the Webster storage tank, and is estimated to have a total project cost of $1,846,000 for the portion which is not currently in the ground. The total annual cost for this line would be about $194,000, and for an annual delivery of 7,934 acft/yr, the unit cost would be about $24 per acft.

Unit costs for all facilities plus the purchase of raw water from LCRA are summarized for each participant in Table 3.12-21. Total unit cost, including purchase of raw water from LCRA, for the Austin NW-A pressure zone is estimated to be $629 per acft ($1.94 per 1,000 gal) and for the Austin NW-B pressure zone is estimated to be $602 per acft ($1.85 per 1,000 gal). For Pflugerville, the sum of unit costs for the NW-A pressure zone, Line 1, and purchase of raw water from LCRA is $666 per acft ($2.05 per 1,000 gal). For Round Rock the sum of unit costs for the NW-A pressure zone, Line 2, and purchase of raw water is $685 per acft ($2.11 per 1,000 gal). For Brushy Creek the sum of unit costs for the NW-A pressure zone, Line 2 and Line 3, and purchase of raw water from LCRA is $772 per acft ($2.38 per 1,000 gal). For Cedar Park the sum of unit costs for the NW-B pressure zone, Line 5, and purchase of raw water from LCRA is $675 per acft ($2.08 per 1,000 gal). For Leander the sum of unit costs for the NW-B pressure zone, Line 5 and Line 6, and purchase of raw water from LCRA is $699 per acft ($2.15 per 1,000 gal).

Table 3.12-20
Cost Estimate Summary for Non-CIP Facilities for Scenario 4, 2050 Conditions (Alt C-2)
WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, and Leander
(1st Quarter 1997 dollars)

Item	Line 1 (Pflugerville)	Line 2 (Round Rock)	Line 3 (BCMUD)	Line 5 (CP/Leander)	Line 6 (Leander)
Capital Costs					
Pipeline	$3,863,000	$ 7,328,000	$1,748,000	$6,962,000	$1,071,000
Pump Station	0	2,102,000	0	1,464,000	258,000
Storage Tank	0	1,290,000	0	0	0
Subtotal	$3,863,000	$10,720,000	$1,748,000	$8,426,000	$1,329,000
Engineering, Contingencies, Legal	$1,159,000	$ 3,386,000	$ 524,000	$ 2,601,000	$ 412,000
Environmental Studies and Mitigation	52,000	72,000	50,000	82,000	34,000
Interest During Construction	203,000	567,000	93,000	444,000	71,000
Total Project Cost	$5,277,000	$14,745,000	$2,415,000	$11,553,000	$1,846,000
Annual Costs					
Annual Debt Service	$494,000	$1,382,000	$226,000	$1,083,000	$173,000
Annual O&M	43,000	145,000	21,000	121,000	20,000
Annual Power	0	311,000	0	139,000	1,000
Total Annual Cost	$537,000	$1,838,000	$247,000	$1,343,000	$194,000
Annual Delivery (acft/yr)	14,541	32,609	2,835	18,370	7,934
Annual Unit Costs					
$ per acft	$37	$56	$87	$73	$24
$ per 1,000 gal	$0.11	$0.17	$0.27	$0.22	$0.08

Table 3.12-21
Total Estimated Unit Costs for Scenario 4
WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, and Leander

Participant	Item	Cost ($ per acft)	
		Year 2030	Year 2050
Austin NW-A	CIP Facilities NW-A Pressure Zone	$551	$524
	Raw Water Purchase from LCRA	105	105
	Total	$656	$629
Austin NW-B	CIP Facilities NW-B Pressure Zone	$513	$497
	Raw Water Purchase from LCRA	105	105
	Total	$618	$602
Pflugerville	CIP Facilities - NW-A Pressure Zone	$551	$524
	Line 1 (dedicated pipeline to Pflugerville)	36	37
	Raw Water Purchase from LCRA	105	105
	Total	$692	$666
Round Rock	CIP Facilities - NW-A Pressure Zone	$551	$524
	Line 2 (dedicated pipeline to Round Rock)	63	56
	Raw Water Purchase from LCRA	105	105
	Total	$719	$685
Brushy Creek	CIP Facilities - NW-A Pressure Zone	$551	$524
	Line 2 (dedicated pipeline for RR/BCMUD)	63	56
	Line 3 (dedicated pipeline to BCMUD)	90	87
	Raw Water Purchase from LCRA	105	105
	Total	$809	$772
Cedar Park	CIP Facilities - NW-B Pressure Zone	$513	$497
	Line 5 (dedicated pipeline for CP/Leander)	83	73
	Raw Purchase from LCRA	105	105
	Total	$701	$675
Leander	CIP Facilities - NW-B Pressure Zone	$513	$497
	Line 5 (dedicated pipeline for CP/Leander)	83	73
	Line 6 (dedicated pipeline to Leander)	22	24
	Raw Water Purchase from LCRA	105	105
	Total	$723	$699

Scenario 5 — WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, Leander, and Georgetown

Scenario 5 would deliver water to the Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, Leander and Georgetown. Cedar Park and Leander would receive service through Austin's NW-B pressure zone and the remainder of the participants would receive service through the NW-A pressure zone. Requirements for Lines 5 and 6 which serve Cedar Park and Leander, and Line 3 which serve Brushy Creek are unchanged from Scenario 4.

The facilities necessary to implement this scenario are:

- City of Austin CIP facilities (Table 3.12-9);
- Line 1: Transmission main from Howard Lane transmission main to Pflugerville (Figure 3.12-1);
- Line 2: Transmission main and pump station from Martin Hill reservoir to new storage tank in Round Rock (Figure 3.12-1);
- New storage tank in south Round Rock;
- Line 3: Transmission main from Round Rock treatment plant to Brushy Creek storage tank (Figure 3.12-1);
- Line 4: Transmission main from Round Rock treatment plant to Georgetown's storage tank (Figure 3.12-1);
- Line 5: Pump station and transmission main from Anderson Mill reservoir to Cedar Park's Webster storage tank (Figure 3.12-1);
- Line 6: Pump station and transmission main from Webster storage tank to Leander storage tank (Figure 3.12-1).

As with Brushy Creek in Scenarios 3 and 4, the Georgetown demand center is located near the Round Rock treatment plant and a "water trade" was considered the most economic solution to providing Georgetown with water from Austin. In this scenario, Line 2 from the Martin Hill Reservoir would deliver all the supply for Round Rock, Brushy Creek, and Georgetown to a potential new storage tank in south Round Rock. A dedicated transmission line, Line 4, would be added from Round Rock's treatment plant to Georgetown's Rabbit Hill storage tank, as shown in Figure 3.12-1. This configuration considerably reduces the amount of pipe, and is logistically much simpler than installing a pipeline through Round Rock.

Scenario 5 — 2030 Conditions

The City of Austin CIP facilities necessary to implement this scenario are shown in Table 3.12-9. WTP4 is sized with a capacity of 255 mgd and Austin's NW-A pump station is upsized to 250 mgd. All other facilities are sized the same as the 2030 case for Scenario 4.

The sizes of the facilities dedicated to the Williamson County entities are summarized in Table 3.12-10. The pipelines supplying Pflugerville, Cedar Park and Leander are the same as Scenario 4. For 2030 conditions Line 2 would still require a diameter of 54 inches to supply the combined flow of 52.8 mgd to the potential new storage tank in south Round Rock. This line includes capacity for 38.3 mgd for Round Rock, 4.9 mgd for Brushy Creek, and 9.6 mgd for Georgetown. Line 4 to Georgetown would require a diameter of 36 inches. Like Line 3 to Brushy Creek, it was also assumed here that pumping requirements would be provided by the Round Rock treatment plant, and no separate pump stations were included.

Costs of the Austin CIP facilities are summarized in Table 3.12-22. The cost of WTP4 is estimated to be $295,000,000. Of this amount 74 percent, or $216,809,989 is allocated to the NW-A pressure zone according to its fraction of the total demand. The remaining $78,190,011 is allocated to the NW-B pressure zone. The unit cost for the CIP facilities in the NW-A pressure zone is $547 per acft, and that of the NW-B pressure zone is $512 per acft (Table 3.12-22).

Costs for the facilities dedicated to Williamson County supply for 2030 conditions are summarized in Table 3.12-23. The costs of Lines 5 and 6 to Cedar Park and Leander are the same as for the 2030 case of Scenario 4, as is the cost of Line 3 to Brushy Creek. Line 2 which was sized to supply Round Rock, Brushy Creek, and Georgetown is estimated to have a total project cost of $13,119,000, and a total annual cost of $1,657,000. For an annual delivery of 29,581 acft/yr the unit cost is about $56 per acft. Line 4 is dedicated to supply Georgetown from the Round Rock treatment plant, and is estimated to have a total project cost of $1,691,000. The total annual cost for this line would be about $174,000. For an annual delivery of 5,369 acft/yr, the unit cost would be about $32 per acft.

Unit costs for all facilities plus the purchase of raw water from LCRA are summarized and totaled for each participant in Table 3.12-25. Total unit cost for the Austin NW-A pressure zone is estimated to be $656 per acft ($2.02 per 1,000 gal) and for the Austin NW-B pressure

Table 3.12-22
Cost Estimate Summary for Austin CIP Facilities for Scenario 5 (Alt C-2) WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, Leander, Georgetown

(1st Quarter 1997 dollars)

Item	Year 2030		Year 2050	
	NW-A	NW-B	NW-A	NW-B
Capital Costs				
Water Treatment Plant 4	$216,809,989	$78,190,011	$394,644,306	$122,355,694
Pump Stations	9,000,484	2,307,235	11,732,710	2,713,440
Transmission and Storage	57,896,710	10,791,359	78,123,420	12,974,616
Subtotal	$283,707,183	$91,288,605	$484,500,436	$138,043,750
Engineering, Contingencies, Legal	$20,519,182	$4,044,940	$27,543,475	$4,842,089
Land Acquisition	2,204,847	795,153	2,290,006	709,994
Environmental Studies and Mitigation	1,102,424	397,576	1,145,003	354,997
Interest During Construction	18,452,018	5,791,576	30,928,735	8,637,050
Total Project Cost:	$325,985,654	$102,317,851	$546,407,654	$152,587,880
Annual Costs				
Debt Service	$30,544,856	$ 9,587,183	$51,198,397	$14,297,484
Annual O&M(1)	28,060,585	10,119,725	41,743,345	12,942,125
Annual Power	4,042,220	4,457,780	5,877,681	1,822,319
Total Annual Cost	$62,647,661	$21,164,687	$98,819,423	$29,061,928
Annual Project Yield	114,533 acft/yr	41,305 acft/yr	170,381 acft/yr	52,825 acft/yr
Annual Unit Cost				
$ per acft	$547	$512	$580	$550
$ per 1,000 gal	$1.68	$1.57	$1.78	$1.69

(1) Annual O&M costs for City of Austin CIP facilities include water utility administration and management costs.

Table 3.12-23
Cost Summary for Non-CIP Facilities for Scenario 5, 2030 Conditions (Alt C-2)
WTP4 to Austin Service Area, Pflugerville, Round Rock, Georgetown, Brushy Creek, Cedar Park, and Leander

(1st Quarter 1997 Dollars)

	Line 1 (Pflugerville)	Line 2 (Round Rock)	Line 3 (BCMUD)	Line 4 (Georgetown)	Line 5 (CP/Leander)	Line 6 (Leander)
Capital Costs						
Pipeline	$3,221,000	$6,469,000	$1,748,000	$1,227,000	$5,745,000	$609,000
Pump Station	0	2,101,000	0	0	1,170,000	187,000
Storage Tank	0	960,000	0	0	0	0
Subtotal	$3,221,000	$9,530,000	$1,748,000	$1,227,000	$6,915,000	$796,000
Engineering, Contingencies, Legal	$966,000	$3,012,000	$524,000	$368,000	$2,133,000	$248,000
Environmental Studies and Mitigation	52,000	72,000	50,000	31,000	82,000	20,000
Interest During Construction	170,000	505,000	93,000	65,000	365,000	43,000
Total Project Cost	$4,409,000	$13,119,000	$2,415,000	$1,691,000	$9,495,000	$1,107,000
Annual Costs						
Annual Debt Service	$413,000	$1,229,000	$226,000	$158,000	$890,000	$104,000
Annual O&M	36,000	135,000	21,000	16,000	99,000	10,000
Annual Power	0	293,000	0	0	103,000	1,000
Total Annual Cost	$449,000	$1,657,000	$247,000	$174,000	$1,092,000	$115,000
Annual Delivery (acft/yr)	12,362	29,581	2,754	5,369	13,165	5,182
Annual Unit Costs						
$ per acft	$36	$56	$90	$32	$83	$22
$ per 1,000 gal	$0.11	$0.17	$0.28	$0.10	$0.25	$0.07

Table 3.12-24
Cost Estimate Summary for Non-CIP Facilities for Scenario 5, 2050 Conditions (Alt C-2)
WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, Leander, and Georgetown

(1st Quarter 1997 Dollars)

	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Capital Costs						
Pipeline	$3,863,000	$10,490,000	$1,748,000	$2,393,000	$6,962,000	$1,071,000
Pump Station	0	2,956,000	0	0	1,464,000	258,000
Storage Tank	0	1,290,000	0	0	0	0
Subtotal	$3,863,000	$14,736,000	$1,748,000	$2,393,000	$8,426,000	$1,329,000
Engineering, Contingencies, Legal	$1,159,000	$4,633,000	$ 524,000	$ 718,000	$ 2,601,000	$ 412,000
Environmental Studies and Mitigation	52,000	72,000	50,000	31,000	82,000	34,000
Interest During Construction	203,000	778,000	93,000	126,000	444,000	71,000
Total Project Cost	$5,277,000	$20,219,000	$2,415,000	$3,268,000	$11,553,000	$1,846,000
Annual Costs						
Annual Debt Service	$494,000	$1,895,000	$226,000	$306,000	$1,083,000	$173,000
Annual O&M	43,000	205,000	21,000	30,000	121,000	20,000
Annual Power	0	481,000	0	0	139,000	1,000
Total Annual Cost	$537,000	$2,581,000	$247,000	$336,000	$1,343,000	$194,000
Annual Delivery (acft/yr)	14,541	50,681	2,835	18,072	18,370	7,934
Annual Unit Costs						
$ per acft	$37	$51	$87	$19	$73	$24
$ per 1,000 gal	0.11	0.17	0.28	0.10	0.25	0.07

Table 3.12-25
Total Estimated Unit Costs for Scenario 5
WTP4 to Austin Service Area, Pflugerville, Round Rock, Brushy Creek, Cedar Park, Leander, and Georgetown

Participant	Description of Cost Item	Cost ($ per acft)	
		Year 2030	**Year 2050**
Austin NW-A	CIP Facilities NW-A Pressure Zone	$547	$580
	Purchase of Raw Water from LCRA	105	105
	Total	$656	$685
Austin NW-B	CIP Facilities NW-B Pressure Zone	$512	$550
	Purchase of Raw Water from LCRA	105	105
	Total	$617	$655
Pflugerville	CIP facilities - NW-A Pressure Zone	$547	$580
	Line 1 (dedicated pipeline to Pflugerville)	36	37
	Raw Water Purchase from LCRA	105	105
	Total	$688	$722
Round Rock	CIP facilities - NW-A Pressure Zone	$547	$580
	Line 2 (dedicated pipeline to Round Rock)	56	51
	Raw Water Purchase from LCRA	105	105
	Total	$708	$736
Brushy Creek	CIP facilities - NW-A Pressure Zone	$547	$580
	Line 2 (dedicated pipeline to RR/BCMUD)	56	51
	Line 3 (dedicated pipeline to BCMUD)	90	87
	Raw Water Purchase from LCRA	105	105
	Total	$798	$823
Cedar Park	CIP facilities - NW-B Pressure Zone	$512	$550
	Line 5 (dedicated pipeline to CP/Leander)	83	73
	Raw Water Purchase from LCRA	105	105
	Total	$700	$728
Leander	CIP facilities - NW-B Pressure Zone	$512	$550
	Line 5 (dedicated pipeline to CP/Leander)	83	73
	Line 6 (dedicated pipeline to Leander)	22	24
	Raw Water Purchase from LCRA	105	105
	Total	$722	$752
Georgetown	CIP facilities - NW-A Pressure Zone	$547	$580
	Line 2 (dedicated pipeline to RR/BCMUD/ Georgetown)	56	51
	Line 4 (dedicated pipeline to Georgetown)	32	19
	Raw Water Purchase from LCRA	105	105
	Total	$740	$755

zone is estimated to be $617 per acft ($1.90 per 1,000 gal). For Pflugerville, the sum of unit costs for the NW-A pressure zone, Line 1, and purchase of raw water is $688 per acft ($2.12 per 1,000 gal). For Round Rock, the sum of unit costs for the NW-A pressure zone, Line 2, and purchase of raw water is $708 per acft ($2.18 per 1,000 gal). For Brushy Creek, the sum of unit costs for the NW-A pressure zone, Line 2, Line 3, and purchase of raw water is $798 per acft ($2.46 per 1,000 gal). For Cedar Park the sum of unit costs for the NW-B pressure zone, Line 5, and purchase of raw water from LCRA is $700 per acft ($2.15 per 1,000 gal). For Leander the sum of unit costs for the NW-A pressure zone, Line 5 and Line 6, and purchase of raw water from LCRA is $722 per acft ($2.22 per 1,000 gal). For Georgetown, the sum of unit costs for the NW-A pressure zone, Line 2, Line 4, and purchase of raw water from LCRA is $740 per acft ($2.28 per 1,000 gal).

Scenario 5 — 2050 Conditions

The City of Austin CIP facilities necessary to implement this scenario are shown in Table 3.12-9. WTP4 is sized with a capacity of 356 mgd. In the NW-A pressure zone the NW-A pump station would be upsized to 356 mgd and the Jollyville transmission main from WTP4 would be upsized to two parallel 96-inch diameter pipelines, with the tunnel portion requiring a single 138-inch diameter pipe. The Martin Hill transmission main would be upsized to a diameter of 126 inches. All other facilities are sized the same as the 2050 case for Scenario 4.

The sizes of the facilities dedicated to the Williamson County entities are summarized in Table 3.12-10. The pipelines supplying Pflugerville, Cedar Park and Leander are the same as Scenario 4. Line 2 would require an upsized diameter of 72 inches to supply the combined flow of 90.9 mgd to the potential new storage tank in south Round Rock. This line includes capacity for 53.2 mgd for Round Rock, 5.1 mgd for Brushy Creek, and 32.3 mgd for Georgetown. Line 4 to Georgetown would still require a diameter of 42 inches. Like Line 3 to Brushy Creek, it was also assumed here that pumping requirements would be provided by the Round Rock treatment plant, and no separate pump stations were included.

Costs of the Austin CIP facilities, are summarized in Table 3.12-22. The cost of WTP4 for the 2050 case is estimated to be $517,000,000. Of this amount 76 percent, or $394,644,306 is allocated to the NW-A pressure zone according to its fraction of the total demand. The remaining $122,355,694 is allocated to the NW-B pressure zone. The unit cost for the CIP facilities in the NW-A pressure zone is $580 per acft, and that of the NW-B pressure zone is $550 per acft (Table 3.12-22).

Costs for the facilities dedicated to Williamson County supply for 2050 conditions are shown in Table 3.12-24. The costs of Lines 5 and 6 to the Cedar Park and Leander are the same as for the 2050 case of Scenario 4, as is the cost of Line 3 to Brushy Creek. Line 2 which was sized to supply Round Rock, Brushy Creek, and Georgetown is estimated to have a total project cost of $20,219,000, and a total annual cost of $2,581,000. For an annual delivery of 50,681 acft/yr the unit cost is about $51 per acft. Line 4 is dedicated to supply Georgetown from the Round Rock treatment plant, and is estimated to have a total project cost of $3,268,000. The total annual cost for this line would be about $336,000. For an annual delivery of 18,072 acft/yr, the unit cost would be about $19 per acft.

Unit costs for all facilities plus the purchase of raw water from LCRA are summarized for each participant in Table 3.12-25. Total unit cost for the Austin NW-A pressure zone is estimated to be $685 per acft ($2.11 per 1,000 gal) and total unit cost for the Austin NW-B pressure zone is estimated at $655 per acft ($2.02 per 1,000 gal). For Pflugerville, the sum of unit costs for the NW-A pressure zone, Line 1, and purchase of raw water is $722 per acft ($2.22 per 1,000 gal). For Round Rock, the sum of unit costs for the NW-A pressure zone, Line 2, and purchase of raw water is $736 per acft ($2.26 per 1,000 gal). For Brushy Creek, the sum of unit costs for the NW-A pressure zone, Line 2, Line 3, and purchase of raw water is $823 per acft ($2.53 per 1,000 gal). For Cedar Park the sum of unit costs for the NW-B pressure zone, Line 5, and purchase of raw water is $728 per acft ($2.24 per 1,000 gal). For Leander, the sum of unit costs for the NW-A pressure zone, Line 5, Line 6, and purchase of raw water is $752 per acft ($2.31 per 1,000 gal). For Georgetown, the sum of unit costs for the NW-A pressure zone, Line 2, Line 4, and purchase of raw water is $755 per acft ($2.32 per 1,000 gal).

Scenarios 6 and 7

Scenarios 6 and 7 consider diverting water from Lake Travis and treating it at a new or expanded Cedar Park treatment plant, and then delivering it to the entities. Potential entities evaluated for Scenario 6 include Cedar Park and Leander. Potential participants for Scenario 7 include Cedar Park, Leander, and Round Rock. Delivery scenarios were evaluated for 2030 projected shortages as summarized in Table 3.12-4c. The projected shortages include existing water supply contracts for Cedar Park and Round Rock, however, Leander's contract for water from Lake Stillhouse Hollow is not included in these scenarios.

Scenario 6 — New or Expanded WTP at Cedar Park for Delivery to Cedar Park and Leander

Scenario 6 considers treatment of Lake Travis water at a new or expanded Cedar Park treatment plant, for delivery to Cedar Park and Leander to meet their 2030 projected shortages. Cedar Park's projected shortage is 8,816 acft/yr (15.9 mgd peak), and Leander's is 5,182 acft/yr (9.3 mgd peak). Their combined demands are 13,998 acft/yr (25.0 mgd peak) in year 2030.

The facilities necessary to implement this scenario are:

- Intake and pump station on Lake Travis;
- Raw water pipeline from Lake Travis to the treatment plant;
- New or expanded Cedar Park water treatment plant;
- Transmission pipeline from the treatment plant to Webster storage tank;
- Transmission pipeline from Webster storage tank to Leander;

Transmission facilities for this scenario involves two pipelines, Line 6-1 and Line 6-2, as shown in Figure 3.12-2. Line 6-1 would convey water for both Cedar Park and Leander from the WTP to the Webster storage tank in Cedar Park. All facilities were sized for the combined demand of 25.0 mgd. The pipelines (raw and treated) would be 36 inches diameter.

Line 6-2 would deliver water from the Webster storage tank to a Leander storage tank on Bagdad Road near the high school. Line 6-2 was sized for a capacity of 9.3 mgd and would require a diameter of 24 inches. There exists about 3,600 feet of 24-inch waterline delivering water from the existing Cedar Park distribution system to Leander's storage tank, and an additional 5,400 feet would need to be installed from the Webster storage tank to the 24-inch Leander transmission pipeline.

A summary of the costs for Scenario 6 is provided in Table 3.12-26. The cost of a new 25 mgd water treatment plant is estimated to cost $18,000,000. With intake, transmission and pumping facilities, the total capital cost would be about $25,719,000. With other project costs the total project cost is estimated to be $36,007,000. Financed at 8 percent for 25 years, the annual debt service would be about $3,374,000, and with O&M and power the total annual cost would be about $5,608,000. For an annual delivery of 13,998, the unit cost would therefore be $401 per acft ($1.23 per 1,000 gal).

Table 3.12-26
Cost Estimate Summary for Treatment and Delivery Facilities (Alt C-2)
Scenario 6 —New or Expanded Cedar Park WTP Delivery to Cedar Park and Leander
(1st Quarter 1997 dollars)

Item	Line 6-1 (Cedar Park & Leander)	Line 6-2 (Leander)
Capital Costs		
Cedar Park Water Treatment Plant	$18,000,000	$ 0
Transmission	6,103,000	609,000
Pump Station	1,616,000	187,000
Subtotal	$25,719,000	$ 796,000
Engineering, Contingencies, Legal	$8,697,000	$ 248,000
Land Acquisition	56,000	0
Environmental Studies and Mitigation	150,000	20,000
Interest During Construction	1,385,000	43,000
Total Project Cost	$36,007,000	$1,107,000
Annual Costs		
Debt Service	$ 3,374,000	$ 104,000
Operations & Maintenance	2,015,000	10,000
Transmission Power	219,000	1,000
Total Annual Cost	$ 5,608,000	$ 115,000
Annual Project Yield	13,998	5,182
Annual Unit Cost		
$ per acft	$401	$22
$ per 1,000 gal	$1.23	$0.07

Line 6-2 consists of transmission and pumping facilities which are estimated to cost about $796,000. With other project costs, the total project cost would be about $1,107,000 and annual debt service would be about $104,000. With annual O&M and power the total annual cost would be about $115,000. For an annual delivery of 5,182 acft/yr, the unit cost would be $22 per acft ($0.07 per 1,000 gal).

A summary of unit costs is provided in Table 3.12-27. Cedar Park's unit cost for Scenario 6 would be $401 for treatment and transmission and $105 for purchase of raw water from LCRA, for a total unit cost of $506 per acft ($1.55 per 1,000 gal). Leander's unit cost for Scenario 6 would be $401 for intake, treatment, and Line 6-1, $22 for Line 6-2, and $105 for purchase of raw water from LCRA, for a total unit cost of $528 per acft ($1.62 per 1,000 gal).

Table 3.12-27
Summary of Unit Costs
Scenario 6 — New or Expanded Cedar Park WTP Delivery to Cedar Park and Leander (Alt C-2)
(1st Quarter 1997 dollars)

Entity	Item	Unit Cost ($/acft)
Cedar Park	Treatment and Delivery Facilities (from Table 3.12-28)	$401
	Raw Water Purchase from LCRA	105
	Total	$506
Leander	Treatment and Delivery Facilities (from Table 3.12-28)	
	Line 6-1	$401
	Line 6-2	22
	Raw Water Purchase from LCRA	105
	Total	$528

Scenario 7 - New or Expanded WTP at Cedar Park for Delivery to Cedar Park, Leander, and Round Rock

Scenario 7 evaluates treatment of Lake Travis water at a new or expanded Cedar Park treatment plant, and delivered to Cedar Park, Leander, and Round Rock to meet their 2030 projected shortages. Shortages to be met at Cedar Park and Leander are the same as Scenario 6. Round Rock's projected 2030 shortages, including their contract for water from Lake Stillhouse Hollow, is 11,458 acft/yr (20.5 mgd peak).[71] Their combined demands are 25,456 acft/yr (45.5 mgd peak). Transmission facilities for this scenario involves four pipelines, Line 7-1 to 7-4, as shown in Figure 3.12-3.

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[71] Projected 2030 demand of 41,352 acft/yr, minus supply contracts of 6,720 acft/yr from Lake Georgetown; 18,134 acft/yr from Lake Stillhouse Hollow; 5,040 acft/yr groundwater.

The facilities necessary to implement this scenario are:

- Intake and pump station on Lake Travis;
- Raw water pipeline from Lake Travis to the treatment plant;
- New or expanded Cedar Park water treatment plant;
- Transmission main from the treatment plant to a junction with transmission mains;
- Transmission mains from the junction to Cedar Park and Round Rock;
- New storage tank in south Round Rock;
- Transmission main from the Webster storage tank to Leander.

Line 7-1 includes an intake and pump station on Lake Travis, a raw water pipeline to the treatment plant, a new or expanded treatment plant, and a 16,000 foot long (3.0 mile) transmission main to a junction with Lines 7-2 and 7-4 near the Dies pump station. Line 7-1 would carry supply for all participants. All facilities were sized for the combined demand of 45.5 mgd, and the pipelines (raw and treated) would be 48 inches diameter.

Line 7-2 would deliver supply for Cedar Park and Leander about 21,000 feet to the Webster storage tank in Cedar Park. Line 7-2 was sized for a demand of 25.0 mgd and would require a diameter of 36 inches. Line 7-3 would be dedicated to Leander and is the same as Line 6-2 in scenario 6. Line 7-3 would be about 9,000 feet long and was sized for a demand of 9.3 mgd, and would require a diameter of 24 inches. As in Scenario 6, the existing 24-inch line could be used, and only 5,400 feet of new 24-inch pipeline would be needed. Line 7-4 would be dedicated to Round Rock, and would run from the junction with Line 7-1 to a potential new storage tank in south Round Rock. Line 7-4 would be about 77,000 feet long (14.6 miles) and would require a diameter of 36 inches to carry a peak demand of 20.5 mgd.

A summary of the costs for Scenario 7 is provided in Table 3.12-28. The cost of a new 45.5 mgd water treatment plant is estimated to cost $26,400,000. With intake, transmission and pumping facilities, the total capital cost would be about $33,778,000. With other project costs the total project cost is estimated to be $47,457,000. Financed at 8 percent for 25 years, the annual debt service would be about $4,447,000, and with O&M and power the total annual cost would be about $8,160,000. For an annual delivery of 25,456, the unit cost would therefore be $321 per acft ($0.98 per 1,000 gal). Line 7-2 is estimated to have a total project cost of

$5,555,000 and a total annual cost of $567,000. For an annual delivery of 13,998 acft/yr, the unit cost is $41 ($0.13 per 1,000 gal).

Table 3.12-28
Cost Estimate Summary for Treatment and Delivery Facilities (Alt C-2)
Scenario 7 — New or Expanded Cedar Park WTP Delivery to Cedar Park, Leander, and Round Rock (2030 Projected Shortages)
(1st Quarter 1997 dollars)

Item	Line 7-1 (CP/Lndr/RR)	Line 7-2 (CP/Leander)	Line 7-3 (Leander)	Line 7-4 (Round Rock)
Capital Costs				
Cedar Park Water Treatment Plant	$26,400,000	$ 0	$ 0	$ 0
Transmission and Storage	4,639,000	4,064,000	609,000	16,929,000
Pump Station	2,739,000	0	187,000	0
Subtotal	$33,778,000	$4,064,000	$796,000	$16,929,000
Engineering, Contingencies, Legal	$11,590,000	$1,219,000	$ 248,000	$ 5,127,000
Land Acquisition	100,000	0	0	170,000
Environmental Studies and Mitigation	164,000	58,000	20,000	181,000
Interest During Construction	1,825,000	214,000	43,000	896,000
Total Project Cost	$47,457,000	$5,555,000	$1,107,000	$23,303,000
Annual Costs				
Debt Service	$4,447,000	$521,000	$104,000	$2,183,000
Operations & Maintenance	3,420,000	46,000	10,000	182,000
Transmission Power	293,000	0	1,000	0
Total Annual Cost	$8,160,000	$567,000	$115,000	$2,365,000
Annual Project Yield (acft/yr)	25,456	13,998	5,182	11,458
Annual Unit Cost				
$ per acft	$321	$41	$22	$206
$ per 1,000 gal	0.98	0.13	0.07	0.63

Line 7-3 consists of transmission and pumping facilities which are estimated to cost about $796,000 (Table 3.12-28). With other capital items, the total capital cost would be about $1,107,000. Financed as above, the annual debt service would be about $104,000. With other annual costs, the total annual cost would be about $115,000. For an annual delivery of 5,182 acft/yr, the unit cost is $22 per acft ($0.07 per 1,000 gal). Line 7-4 is estimated to have a total project cost of $23,303,000 and a total annual cost of $2,365,000. For an annual delivery of 11,458 acft/yr, the unit cost is $206 ($0.63 per 1,000 gal).

A summary of unit costs is provided in Table 3.12-29. Cedar Park's unit cost for Scenario 7 would be $321 for intake, WTP, and Line 7-1, $41 for Line 7-2, and $105 for purchase of raw water from LCRA, for a total unit cost of $467 per acft ($1.43 per 1,000 gal). Leander's unit cost for Scenario 7 would be $321 for Line 7-1, $41 for Line 7-2, $22 for Line 7-3, and $105 for purchase of raw water from LCRA, for a total unit cost of $489 per acft ($1.50 per 1,000 gal). Round Rock's unit cost for Scenario 7 would be $321 for Line 7-1, $206 for Line 7-4, and $105 for purchase of raw water from LCRA, for a total unit cost of $632 per acft ($1.94 per 1,000 gal).

Table 3.12-29
Summary of Unit Costs
Scenario 7 — New or Expanded Cedar Park WTP Delivery to Cedar Park, Leander, and Round Rock (Alt C-2)
(1st Quarter 1997 Dollars)

Entity	**Item**	**Unit Cost ($/acft)**
Cedar Park	Line 7-1 (from Table 3.12-30)	$321
	Line 7-2 (from Table 3.12-30)	41
	Raw Water Purchase from LCRA	105
	Total	$467
Leander	Line 7-1 (from Table 3.12-30)	$321
	Line 7-2 (from Table 3.12-30)	41
	Line 7-3 (from Table 3.12-30)	22
	Raw Water Purchase from LCRA	105
	Total	$489
Round Rock	Line 7-1 (from Table 3.12-30)	$321
	Line 7-4 (from Table 3.12-30)	206
	Raw Water Purchase from LCRA	105
	Total	$632

Scenario 8 — Regional Water Treatment Plant and Delivery to Round Rock

Scenario 8, patterned after a delivery system studied by LCRA,[72] evaluates the diversion of raw water from the Cypress Creek arm of Lake Travis delivered for treatment at a potential new regional water treatment plant in central Williamson County. The main facilities necessary to implement this scenario are listed below and shown on Figure 3.12-4.

- Intake and pump station on Lake Travis;
- Raw water transmission main from Lake Travis to a potential new regional treatment plant near the existing Round Rock WTP;
- New regional water treatment plant;
- Distribution main from treatment plant to potential new storage tank in south Round Rock;
- New storage tank on the south side of Round Rock.

Line 8-1 consists of an intake and pump station on Lake Travis, and a raw water pipeline to a potential new regional treatment plant. These facilities were sized to accommodate an annual delivery of 19,000 acft/yr with a peak factor of 2.0, or about 34 mgd. Line 8-2 would be a treated water transmission pipeline to deliver water to a potential new storage tank located on the south side of Round Rock. Cost estimates for Line 8-2 were included to allow direct comparison of costs between Scenario 7 and Scenario 8 for delivery of water to the same location.

Line 8-1 from Lake Travis to the treatment plant would be about 19 miles long and require a diameter of 42 inches. Line 8-2 would require a diameter of 36 inches to deliver 20.5 mgd about 10 miles to a new storage tank. The new storage tank was sized to hold 2 million gallons.

A summary of the costs for Scenario 8 is provided in Table 3.12-30. The cost of the intake, pump station, and transmission main from Lake Travis to the treatment plant is estimated to total $16,465,000 . The cost of a new 34 mgd water treatment plant is estimated to cost $21,600,000 and with other project costs the total project cost is estimated at $53,927,200. Total annual cost with O&M and power would be about $8,389,000. For an annual delivery of 19,000

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[72] Espey, Huston & Associates, Inc., "Technical Memorandum, Equivalent Cost Boundary, Williamson County Water Supply Study," for LCRA, March 1996.

acft/yr the unit cost would be $442 per acft. The total project cost for the distribution main and storage tank are estimated to be $7,350,000. The total annual cost with O&M and power would be about $967,870. For an annual delivery of 11,458 acft/yr the unit cost would be about $84 per acft ($0.26 per 1,000 gal).

Table 3.12-30
Cost Estimate Summary for Treatment and Delivery Facilities (Alt C-2)
Scenario 8 — Regional Water Treatment Plant and Delivery to Round Rock
(1st Quarter 1997 Dollars)

Item	Cost ($)	
	Raw Water Transmission and WTP	**Treated Water Transmission and Storage**
Capital Costs		
Regional Water Treatment Plant	$21,600,000	$ 0
Transmission and Storage	10,875,000	7,350,000
Intake and Pump Station	5,590,000	0
Subtotal	$38,065,000	$7,350,000
Engineering, Contingencies, Legal	$12,266,000	$ 2,572,500
Land Acquisition	954,000	0
Environmental Studies and Mitigation	249,000	10,000
Interest During Construction	2,393,200	397,000
Total Project Cost	$53,927,200	$10,329,500
Annual Costs		
Debt Service	$5,052,979	$967,870
Operations & Maintenance	2,789,000	0
Transmission Power	547,000	0
Total Annual Cost	$8,388,979	$967,870
Annual Project Yield (acft/yr)	19,000	11,458
Annual Unit Cost		
$ per acft	$442	$84
$ per 1,000 gal	1.35	0.26

A summary of unit costs is provided in Table 3.12-31. The total unit cost for this scenario with purchase of raw water from LCRA would be about $631 per acft ($1.94 per 1,000 gal).

Table 3.12-31
Summary of Unit Costs for Scenario 8
Regional Water Treatment Plant and Delivery to Round Rock

Entity	**Description of Item**	**Unit Cost ($/acft)**
Round Rock	Intake, Line 8-1, WTP	$442
	Line 8-2	84
	Raw Water Purchase	105
	Total Unit Cost	$631
		$1.94 per 1,000 gal

Unit Cost Summary

A comparison of unit costs and water delivery capacities to each entity for all scenarios is contained in Tables 3.12-30, 3.12-31, and 3.12-32. Unit costs for Scenarios 1 through 5 for year 2030 are summarized in Table 3.12-32. Unit costs for Scenarios 1 through 5 for year 2050 are summarized in Table 3.12-31. Unit costs for Scenarios 6, 7, and 8 are summarized in Table 3.12-32. A review of these tables indicates:

- Unit costs to customers in City of Austin service areas stay about the same when water deliveries are made to Williamson County entities (Table 3.12-30, $647 [Scenario 1], compared to $654 [Scenario 3]).
- Unit costs to Round Rock, Leander, and Cedar Park are lower to build dedicated facilities from Lake Travis than to participate in WTP4.
- Unit costs to Leander and Cedar Park are about 10 percent lower to build a regional water treatment plant (i.e., Scenario 7) as compared to a smaller plant (i.e., Scenario 6).

Table 3.12-32
Comparison of Unit Cost and Delivery Capacity for Scenarios 1 through 5, Year 2030
Alternative C-2

Entity	Scenario 1 Unit Cost[1] (Del. Cap.[2])	Scenario 2 Unit Cost[1] (Del. Cap.[2])	Scenario 3 Unit Cost[1] (Del. Cap.[2])	Scenario 4 Unit Cost[1] (Del. Cap.[2])	Scenario 5 Unit Cost[1] (Del. Cap.[2])
Austin (NW-A)	\$647 (72,590)	\$624 (72,590)	\$654 (72,590)	\$656 (72,590)	\$656 (72,590)
Austin (NW-B)					
Pflugerville	—	\$624 (11,200)	\$690 (12,362)	\$692 (12,362)	\$688 (12,362)
Round Rock	—	\$624 (6,160)	\$717 (21,458)	\$719 (21,458)	\$708 (21,458)
Brushy Creek MUD	—	—	\$807 (2,754)	\$809 (2,754)	\$798 (2,754)
Cedar Park	—	—	—	\$701 (7,983)	\$700 (7,983)
Leander	—	—	—	\$723 (5,182)	\$722 (5,182)
Georgetown	—	—	—	—	\$740 (5,369)

(1) Unit cost is in units of \$ per acft/yr. Includes raw water purchase from LCRA.

(2) Delivery capacity is in units of acft/yr.

Table 3.12-33
Comparison of Unit Cost and Delivery Capacity for Scenarios 1 through 5, Year 2050
Alternative C-2

	Scenario				
	1	2	3	4	5
Entity	Unit Cost[1] (Del. Cap.[2])	Unit Cost[1] (Del. Cap.[2])	Unit Cost[1] (Del. Cap.[2])	Unit Cost[1] (Del. Cap.[2])	Unit Cost[1] (Del. Cap.[2])
Austin (NW-A)	$624 (105,159)	$611 (105,159)	$628 (105,159)	$629 (105,159)	$685 (105,159)
Austin (NW-B)	$601 (34,455)	$592 (34,455)	$605 (34,455)	$602 (34,455)	$655 (34,455)
Pflugerville	—	$611 (11,200)	$665 (14,541)	$666 (14,541)	$722 (14,541)
Round Rock	—	$611 (5,376)	$684 (29,774)	$685 (29,774)	$736 (29,774)
Brushy Creek MUD	—	—	$771 (2,835)	$772 (2,835)	$823 (2,835)
Cedar Park	—	—	—	$675 (10,436)	$728 (10,436)
Leander	—	—	—	$699 (7,934)	$752 (7,934)
Georgetown	—	—	—	—	$755 (18,072)

(1) Unit cost is in units of $ per acft/yr. Includes raw water purchase from LCRA.

(2) Delivery capacity is in units of acft/yr.

Table 3.12-34
Comparison of Unit Cost and Delivery Capacity for Scenarios 6, 7, and 8
Alternative C-2

Entity	Scenario 6 Unit Cost[1] (Del. Cap.[2])	Scenario 7 Unit Cost[1] (Del. Cap.[2])	Scenario 8 Unit Cost[1] (Del. Cap.[2])
Cedar Park	\$506 (8,816)	\$467 (8,816)	—
Leander	\$528 (5,182)	\$489 (5,182)	—
Round Rock	—	\$632 (11,458)	\$631 (11,458)

(1) Unit cost is in units of \$ per acft/yr. Includes raw water purchase from LCRA.
(2) Delivery capacity is in units of acft/yr.

3.12.6 Implementation Issues

The transfer of water from Lake Travis to Williamson County or Lake Georgetown would constitute an interbasin transfer and would require a permit from TNRCC. Under Senate Bill 1 (1997 Texas Legislature), a permit must be obtained to divert state water from one river basin to another (SB 1, Section 11.085(a)). However, Senate Bill 1 provides an exemption (Section 11.085(v)) from most of the requirements of Section 11.085 for water transfer to another river basin when a portion of the county or municipality receiving the water is in the basin of origin. Because a small portion of Williamson County is in the Colorado River Basin, the exemptions allowed in Senate Bill 1 will probably apply. Additionally, a TNRCC permit amendment would potentially be needed to add a point of diversion at Lake Travis.

Requirements Specific to Pipelines

1. Necessary permits:
   a. U.S. Army Corps of Engineers Section 404 dredge and fill permit for stream crossings and lake intake.
   b. GLO Sand and Gravel Removal permits.
   c. 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.

Requirements Specific to Discharges to Lake Georgetown (Scenario 8)

1. Study of the environmental effects on mixing Lake Travis water in Lake Georgetown would be needed.
2. Once quantities to be discharged to Lake Georgetown are known, the study of the hydrologic effects of the discharges on Lake Georgetown would be needed.

Requirements Specific to Treatment and Distribution

1. Local construction permit needed.
2. Design of treatment plant must be approved by TNRCC and there are standards which must be met for water quality.

SB 1879,[73] passed by the 75th Texas Legislature, authorizes LCRA to sell raw water to entities in the Brazos River Basin, including Leander and Cedar Park. However, an interbasin transfer permit from TNRCC may still be required.

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[73] Senate Bill No. 1, 75th Texas Legislature, 1997.

3.13 Purchase of Uncommitted Stored Water from LCRA Diverted at Lake Buchanan and Delivered to Lake Georgetown (C-4)

3.13.1 Description of Alternative

Lake Buchanan is located on the Colorado River in eastern Llano and western Burnet Counties and is about 8 miles west of the City of Burnet. It is one of the group of reservoirs known as the Highland Lakes. The location of Lake Buchanan is shown in Figure 3.13-1.

Lake Buchanan was constructed by the U.S. Bureau of Reclamation, and is owned and operated by the Lower Colorado River Authority (LCRA). Construction of the reservoir, built for water supply and recreation, began in 1931 and impoundment began in 1937. At the conservation pool, elevation of 1,020.3 ft-msl, the reservoir covers 22,795 acres and has a capacity of 918,777 acft.[1] The LCRA holds the permit from the State of Texas for the right to impound water in Lake Buchanan and divert water for municipal and other uses.[2]

The yield of the Highland Lakes after accounting for O. H. Ivey Reservoir is 689,609 acft/yr. Of this total, yield is reduced by 392,643 acft/yr to honor senior downstream water rights, and 153,940 acft/yr is currently committed to water sale contracts and electric utilities. Of the remaining yield, 31,800 acft/yr has been reserved to provide instream flows and flows to the bay. The remaining 111,226 acft/yr of water is currently uncommitted.[3]

This alternative involves consideration of the purchase and diversion of either 21,500 acft/yr or 47,700 acft/yr of uncommitted firm yield from Lake Buchanan to augment the water supply available at Lake Georgetown. The diversion would be made at a uniform annual rate. The augmented water supply at Lake Georgetown could then be treated and distributed from the City of Georgetown's water treatment plant, the City of Round Rock's water treatment plant, or at a potential regional treatment plant. The location of Lake Buchanan and Lake Georgetown, along with the treatment plants and the proposed conveyance routes, are shown in Figure 3.13-1.

The source of the raw water would be Lake Buchanan, located about 35 miles west of Lake Georgetown. This alternative takes advantage of Lake Buchanan's proximity to Russell Fork, a tributary of the San Gabriel River on which Lake Georgetown is located. A pipeline would be routed from an intake near the dam at Lake Buchanan along Highway 29, then north of

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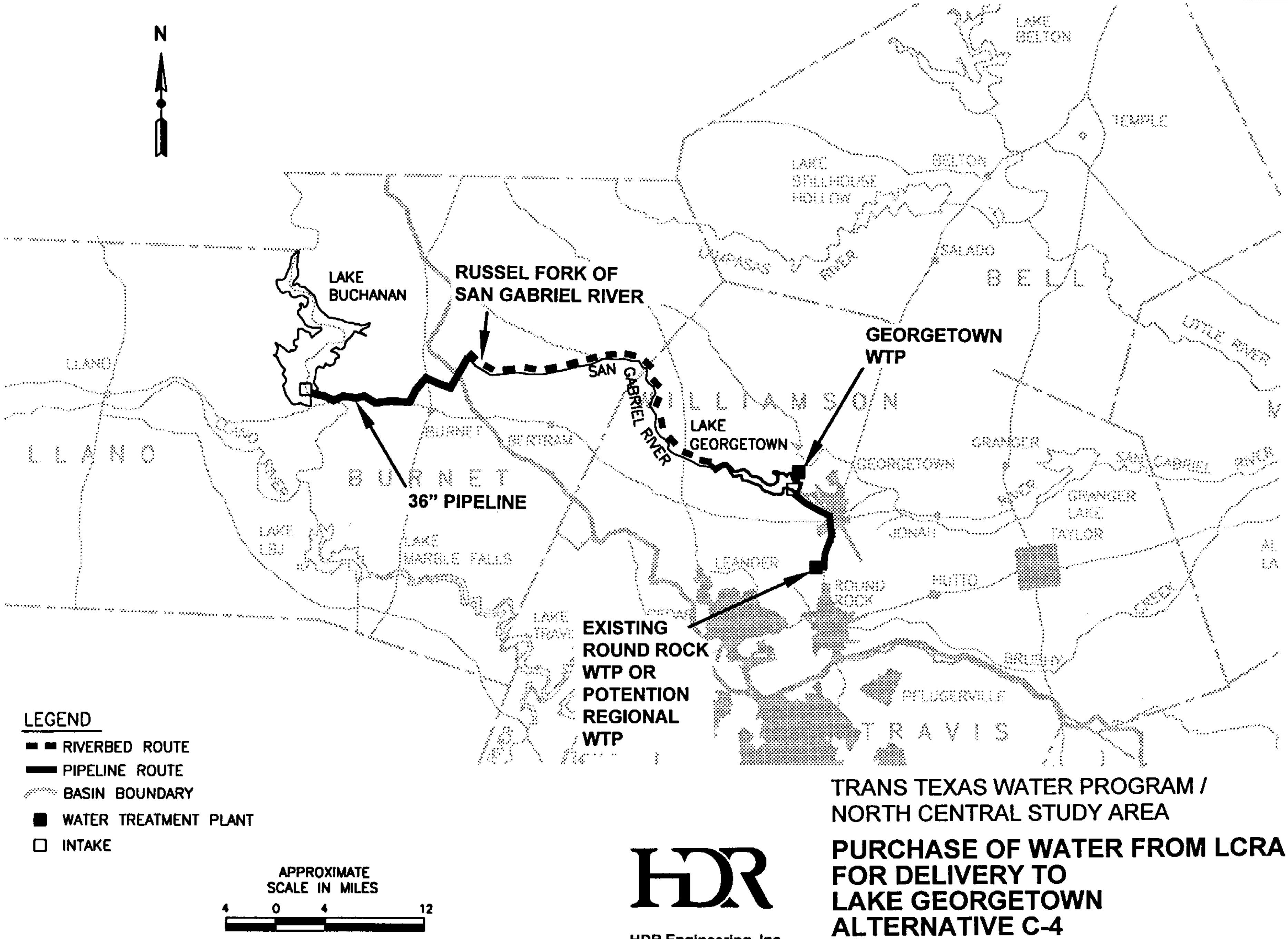
[1] LCRA, "LCRA Water Management Plan for the Lower Colorado River," Vol. II, Appendices, 1993.

[2] Texas Water Commission Certificate of Adjudication Permit No. 1259 (1938).

[3] LCFA



HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

PURCHASE OF WATER FROM LCRA FOR DELIVERY TO LAKE GEORGETOWN ALTERNATIVE C-4

FIGURE 3.13-1

Burnet to Russell Fork. At Russell Fork, the water would be discharged into the tributary where it would flow about 30 river miles to Lake Georgetown. The uncommitted firm yield at Lake Buchanan would be obtained by purchasing the water from the LCRA at the system price for stored water, which currently is $105 per acft.

3.13.2 Available Yield

Two previous studies which considered this alternative were reviewed.[4,5] In 1989, HDR considered delivery of 20,000 acft/yr from Lake Buchanan to Lake Georgetown. In 1996, LCRA commissioned a study for delivery of 19,000 acft/yr to Lake Georgetown.

This study investigates options which will increase the firm yield of Lake Georgetown by either 19,000 acft/yr or 42,000 acft/yr to augment municipal supply. Channel losses in the stream are estimated at 12 percent of the amount discharged from Lake Buchanan. This loss rate was determined from soil surveys, channel loss studies for similar areas, and mean July evaporation.[6] This loss rate indicates that in order to increase the yield of Lake Georgetown by 19,000 acft/yr, approximately 21,500 acft/yr would need to be purchased and diverted from Lake Buchanan. To increase its yield by 42,000 acft/yr, about 47,700 acft/yr would have to be diverted from Lake Buchanan.

3.13.3 Environmental Issues

This alternative would transfer water from Lake Buchanan to Lake Georgetown. An intake structure would be constructed on Lake Buchanan for pipeline transport that would utilize a pipeline route following FM 690 to SH 29 through Burnet to FM 963 from Burnet to the Russell Fork. The water would be discharged to flow down Russell Fork and the North Fork of the San Gabriel River to Lake Georgetown (Figure 3.13-1). Final distribution of water from Lake Georgetown to the cities of Georgetown and Round Rock water treatment plant would utilize the existing raw pipelines.

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[4] HDR Engineering, Inc., "Preliminary Analysis of Potential Alternatives to Enhance Round Rock's Water Supply Capabilities," City of Round Rock, March, 1989.

[5] Espey, Huston and Associates, Inc., "Williamson County Water Supply Study, Technical Memorandum," LCRA, March, 1996.

[6] Ibid.

Environmental considerations relevant to the construction of facilities and transportation of water through the bed and banks of Russell Fork, and the North Fork of the San Gabriel River to Lake Georgetown can be categorized as follows:

- Effects of construction and maintenance of an intake structure on Lake Buchanan and pipeline to the discharge point on the San Gabriel River,
- Effects of increased flows in the San Gabriel River,
- Effects on instream flows in the Colorado River Basin and in the Brazos River Basin,
- Effects of the interbasin transfer of water from the Colorado River Basin to the Brazos River Basin, and
- Water quality effects in Lake Georgetown.

Land and Habitat

The project area of this alternative lies within Burnet and Williamson Counties on the Edwards Plateau, west of the Balcones Escarpment, from the eastern edge of the Llano Uplift, across the Llano crossplain to the eastern margin of the Edwards Plateau.[7] The western pipeline corridor is on loamy shallow Keese-Nebgen soils in rolling hills, and ridges of granite and sandstone. The eastern-most third of the piepline is on shallow loamy, clayey, and cobbly soils. Hensley soils are on gentle sloping hills while reddish brown stoney Eckrant soils are found on steep slopes; both soil associations are over limestone bedrock.[8]

The climatic vegetational community of the eastern Edwards Plateau is an open grassland savannah with oak motts and associated brush and herbaceous species. Oak-mesquite-juniper parks; live oak-mesquite parks; and live oak-Ashe juniper parks characterize the vegetation of the project area.[9]

Spring-fed rivers of the Edwards Plateau have cut canyons which form unique niches for a variety of plant species. Endemic ferns, as well as many of the flowering plants are primarily lithophilous ("rock-loving"), and are represented primarily by various species of lipferns (*Cheilanthes* spp.), cloak-ferns (*Notholaena* spp.), and cliff brakes (*Pellaea* spp.). Columbine (*Aquilegia canadensis*) and endemic species such as anemone *(Anemone edwardsianas)* and wand butterfly-bush (*Buddlega racemosa*) are sometimes found together with other species on

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[7] Ferguson, W.K. 1986. The Geographic Provinces of Texas. Austin.

[8] Soil Conservation Service. 1979. Soil Survey of Blanco and Burnet Counties. prepared with Texas Agriculture Experimental Station. Issued by the Natural Resource Conservation Service, formerly the SCS.

[9] McMahan, C.A., R.G. Frye and K.L. Brown. 1984. The Vegetation Types of Texas Including Cropland. TPWD, Austin, TX.

large boulders in shaded ravines along with such species as mock-orange (*Philadelphus* spp.), American smoke-tree (*Cotinus americana*), spicebush (*Benzoin aestivale*), and the endemic silver bells (*Styrax platanifolia* and *S. texana*).

The most important climax grasses of the Plateau include switchgrass, several species of bluestems and grammas, Indian grass, Canada wild-rye (*Elymus canadensis*), curly mesquite (*Hilaria berlangeri*), and buffalograss (*Buchloe dactyloides*). The rough, rocky areas typically support a tall or mid-grass understory and a brush overstory complex consisting primarily of live oak (*Quercus virginiana*), Texas oak (*Q. buckleyi*), shinnery oak (*Q. havardii*), Ashe juniper (*Juniperus ashei*), and mesquite (*Prosopis glandulosa*). Throughout the region, the brush species are generally considered "invaders" with grassland or open savannah climax communities. The steeper canyon slopes historically supported a dense oak-Ashe juniper thicket.

In Burnet and Williamson counties, the approximately 30 miles of the Russell Fork and North Fork of the San Gabriel River, used for transporting water to Lake Georgetown, traverses live oak-mesquite parks, live oak-mesquite-Ashe juniper parks, and live oak-Ashe juniper parks.[10]

Aquatic Habitats

Lake Buchanan, constructed in 1937, is the upper-most and largest (surface area 23,060 acres) of the chain of lakes on the Colorado River operated by the LCRA for electric power generation and flood control. These lakes form a 150-mile long, nearly continuous series of impoundments from Lake Buchanan in Burnet County to Town Lake in Travis County. Lake Buchanan impounds an approximate 172-mile reach of the Colorado River through the Lampasas Cut Plains below Owen Ivey Reservoir, giving it a drainage area of approximately 31,250 square miles of which about 38 percent (11,900 square miles) is probably non-contributing.[11]

The North Fork of the San Gabriel River is a small tributary to the Little River in the Brazos River Basin. It rises in springs from the Glen Rose limestone of the Trinity group and seasonal rainfall in Burnet County. Lake Georgetown was constructed for flood control on the

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[10] Ibid.

[11] Lower Colorado River Authority. 1992. Instream Flows for the Lower Colorado River: Reconciling Traditional Beneficial Uses With the Ecological Requirements of the Native Aquatic Community. prepared by D.T. Mosier and R.T. Ray. Lower Colorado River Authority, Austin, Texas.

North Fork of the San Gabriel River by the U.S. Army Corps of Engineers in 1980. It is just upstream from the City of Georgetown in Williamson County. The lake occupies about 1,310 surface acres with normal pool impoundment capacity of approximately 37,100 acft.[12] Its average annual inflow is 73.3 cfs (53,066.8 acft/yr) for water years 1980 to 1995.[13] The drainage area above Lake Georgetown reservoir is 246 square miles, all located within the Edwards Plateau vegetational area.[14]

Lake Georgetown is a warm monomictic reservoir with an oxygen-depleted hypolimnion that forms during the spring-summer season. In the April to May period, dissolved oxygen concentrations generally fall below 5 mg/l at depths exceeding about 30 feet. By August, oxygen concentrations at those depths are generally below 1 mg/l.[15]

During 1981 to 1982, phytoplankton assemblages in Lake Georgetown were relatively sparse.[16] Total numbers were generally not high and the dominant algal groups included diatoms (Bacillariophyta), greens (Chlorophyta), and blue-greens (Cyanobacteria) at various times. During 1987, blue-green algae were the most abundant group in all collections (6) and dense (>200,000 cells/ml) summer blooms were present at both sample stations.[17] Macrophytes are severely limited by a lack of shallow water and suitable substrates.[18]

Rocks and woody debris provide good habitat for white crappie; catfish (blue, channel, flathead); bass (largemouth, white, smallmouth); sunfish (bluegill, etc.); threadfin shad; and some gizzard shad. Stocking attempts have been made by Texas Parks and Wildlife Department to increase the densities of sport fish such as channel catfish, hybrid striped bass, smallmouth bass, largemouth bass, and walleye.[19] Results from the creel survey showed that total angling pressure on the reservoir was 12.6 man-hours/acre and that anglers rated their fishing success

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[12] Brazos River Authority. 1996. 1996 Final Report Regional Assessment of Water Quality Brazos River Basin Including the Upper Oyster Creek Watershed. prepared with Texas Natural Resource Conservation Commission under the authorization of the Clean Rivers Act. Brazos River Authority, Waco, Texas.

[13] USGS. 1996. Water Resources Data, Texas Water Year 1995, Volume 2.

[14] Terre, D.R. and S.J. Magnelia. 1996. Survey Report for Georgetown Reservoir, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas.

[15] USGS. 1981, 1982, 1988, 1991, 1995. Water Resources Data. Texas.

[16] USGS. 1981, 1982, 1988, 1991, 1995. Water Resources Data. Texas.

[17] USGS. 1981, 1982, 1988, 1991, 1995. Water Resources Data. Texas.

[18] Terre, D.R. and S.J. Magnelia. 1996. Survey Report for Georgetown Reservoir, 1995. Statewide Freshwater Fisheries Monitoring and Management Program Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department. Austin, Texas.

[19] Ibid.

compared to other places they fish as predominantly average (42 percent).[20] Fish sampling studies are routinely conducted by TPWD on Lake Georgetown reservoir using electrofishing, gill netting, and frame netting.[21] In addition, a creel survey was conducted by TPWD from March to May 1995 to assess angler use and catch.[22]

There are no USGS gages on Russell Fork or North Fork San Gabriel River available for estimating flow changes expected with implementation of the project. However, streamflows in Russell Fork can be estimated using drainage area and climatological data. The drainage area of Russell Fork is 19 percent of the drainage area of the North Fork San Gabriel River. Streamflows into Lake Georgetown have been estimated using climatological data and information from other streams in the area.[23] Although these statistics are not actual data, they can be used to qualitatively evaluate the potential affects of increased flows with implementation of this alternative.

Average annual streamflows in the North Fork San Gabriel River, prior to construction of Lake Georgetown and the lake's regulation of streamflows, were 63,830[24] acft/yr as recorded at a USGS gage 5,000 m downstream of the current location of the Lake Georgetown Dam. Annual streamflows over an 11-year period, from 1969 to 1979, were averaged to obtain the average annual streamflow. Russell Fork accounts for approximately 19 percent of the drainage area of the North Fork San Gabriel River. Assuming the streamflows from Russell Fork contribute the same 19 percent to the annual streamflow of the North Fork San Gabriel River, it can be estimated that the average annual streamflow of Russell Fork is approximately 12,128 acft/yr. Monthly streamflows vary considerably, but May is generally the wettest month with heavy spring rains contributing to streamflows approximately 30 percent to 40 percent higher than the typically driest month of August.

Endangered and Threatened Species

Endangered and threatened species, and species of concern that may be present in the project area are presented in of the Environmental Overview (Section 3.1.3). Similarity in

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[20] Ibid.

[21] Ibid.

[22] Ibid.

[23] Wurbs, et. al. 1988. Hydrologic and Institutional Water Availability in the Brazos Basin, August, 1988.

[24] USGS. 1996. Water Resources Data, Texas Water Year 1995, Volume 2.

habitat for both Llano County and Burnet County has led us to include those species reported in either county. Plant species of concern which may occur along the pipeline route, include the basin bellflower (*Campanula reverchonii*), Edwards Plateau cornsalad (*Valerianella texana*),[25] and rock quillwort (*Isoetes lithophilia*).[26]

Mammals of concern that may occur in the pipeline route area include the cave myotis, a colonial bat which prefers caves or abandoned buildings for its roosting activities. The Llano pocket gopher inhabits deep, brown loamy sands or gravely sandy loams like those found along the proposed pipeline route.

The majority of the rare birds are migratory. The woodlands and parks found in the pipeline corridor may include nesting sites for the endangered Golden-cheeked Warbler (*Dendroica chrysoparia*) and Black-capped Vireo (*Vireo atricapillus*).

Two species of reptiles, the Texas garter snake (*Thamnophis sirtalis annectens*) a species of concern, and the Texas horned lizard (*Phrynosoma cornutum*), listed as threatened by the state, could possibly occur in the project area. The garter snake is found near water in wet meadows, marshes, irrigation, and drainage ditches. Living in open county with loose soil supporting grass, mesquite, and cactus, the Texas horned lizard's habitat requirements could be met in the open areas of the pipeline route.

The Guadalupe bass (*Micropterus treculi*) and the blue sucker (*Cycleptus elongatus*) are two species of fish of concern that may occur in the project area. The Guadalupe bass is found in streams and reservoirs of south-central Texas, and the blue sucker is generally found in strong currents in deep chutes and main channels of medium-to-large rivers over bedrock, sand, and gravel.

Wetlands

National Wetland Inventory Maps covering the water line corridor show predominantly uplands dotted with diked semipermanent and permanently flooded farm ponds. Typical of the

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[25] Texas Organization for Endangered Species. 1993. Endangered, Threatened and Watch Lists of Texas Plants. Texas Organization for Endangered Species. Austin, TX .

[26] Texas Biological and Conservation Data System. Texas Parks and Wildlife Department, Endangered Resources Branch. County lists of Texas' special species. (Burnet and Llano Counties revised January 13, 1997)

Edwards Plateau, most of the streams are intermittent throughout the project area.[27,28,29] The proposed pipeline corridor involves 18 stream crossings, all of which are intermittent. Jurisdictional wetlands at the stream crossings generally consist of only the stream channel, the wooded riparian corridors usually being dominated by upland vegetation.

Construction Effects

Environmental issues arise from the disturbance of vegetation and natural habitats (and cultural resources) during the construction of diversion facilities, pump stations, and installation and maintenance of the pipeline. Implementation of this alternative would require the installation of an intake in Lake Buchanan, the construction of which would disturb less than an acre of shoreline and reservoir bottom. If constructed within the conditions of USCE Regional General Permit No. 2, no significant effects on Lake Buchanan biological communities are expected.

Implementation of this alternative would require the construction of a water transmission pipeline from an intake on Lake Buchanan to an outfall on Russell Fork, northeast of the City of Burnet. The proposed route of the water transmission line follows existing roads: FM 960 from Lake Buchanan to SH 29 to the City of Burnet and FM 963 from Burnet to Russell Fork, but would probably not be built in existing right-of-ways.

The length of the proposed waterline would be 13.1 miles. Assuming uniform construction corridor width of 140 feet, construction would affect 222.3 acres total (Table 3.13-1) including grass (6.4 acres, 2.9 percent); crop (31.6 acres, 14.2 percent); developed (31.1 acres, 14.0 percent); brush (6.4 acres, 2.9 percent); park (57.3 acres, 25.8 percent); woods (85.6 acres, 38.5 percent); and wetland (2.2 acres, 1.0 percent). A mowed ROW with a width of 40 feet maintained for the life of the project would affect 63.5 acres including grass (1.8 acres), crop (9.0 acres), developed (8.9 acres), brush (1.8 acres), park (16.4 acres), woods (38.5 acres), and wetland (0.6 acres). If topsoils are conserved during construction, areas currently in grass and

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[27] U.S. Fish and Wildlife Service. 1992. National Wetland Inventory Map Series, Lake Buchanan Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

[28] U.S. Fish and Wildlife Service. 1992. National Wetland Inventory Map Series, Council Creek Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

[29] U.S. Fish and Wildlife Service. 1992. National Wetland Inventory Map Series, Burnet Quadrangle. U.S. Department of the Interior, Albuquerque, NM.

crop can be re-seeded and returned to their original use. Brush can be expected to reinvade areas outside the maintenance ROW in about 10 years. The removal of trees would have long-term effects.

Table 3.13-1

Physiognomic Categories and Areas Within the Construction and Maintenance Corridors

Physiognomic Category	Percent Coverage in Construction Corridor	Acreage in 140' Construction Corridor	Acreage in 40' Maintenance Corridor
Developed	14.0	31.1	8.9
Asphalt	0.7	1.6	0.4
Grass	2.9	6.4	1.8
Crop	14.2	31.6	9.0
Brush	2.9	6.4	1.8
Park	25.8	57.3	16.4
Wood	38.5	85.6	24.5
Wetland	1.0	2.2	0.6
Total	100	222.3	63.5

Potential adverse impacts to wetlands, woods and cultural resource sites could be avoided or minimized by using field surveys to select final pipeline alignments and associated facility locations, and by choosing appropriate construction methods and schedules. Compensation would have to be made for unavoidable impacts. This alternative alignments may reduce the impacts to woodlands.

Operational Effects

This alternative would involve the transfer of water from the Colorado River Basin to the Brazos River Basin. A diversion of 29.7 cfs at a constant rate of withdrawal (Section 3.13.2) may affect instream flows in the Colorado River. Spills from Lake Buchanan would be reduced by 29.7 cfs, but during periods when downstream flows are controlled by releases, this will not necessarily be the case.

Water transported from Lake Buchanan into Russell Fork would increase average annual streamflow of that stream by about 72 percent, and of the North Fork San Gabriel River by about 33 percent. Monthly flow increases would range from 15 percent during the wettest months, to 187 percent during the driest months in the latter stream, with the most significant increases in flow occurring during the driest years and months. Streamflows would be continuously elevated during dry periods, and a base flow provided during droughts as long as pumping is continued.

Implementation of this alternative would have a marked affect on streamflows in Russell Fork. Releasing water at a rate of 21,500 acft/yr into Russell Fork would increase average annual flow by about 175 percent. At a uniform release rate, monthly flow increases would range from 80 percent in the wettest months to 983 percent in the driest months. Naturalized annual flows in Russell Creek exceeded 21,500 acft/yr, the diversion volume, in only 10 out of 85 years. Based on the period of record, the maximum annual flows in Russell Fork were estimated to be about 29,000 acft/yr. Assuming a uniform rate of release, the monthly volume of the proposed diversion exceeds modeled historical volumes in all months but April and May.

This additional water will profoundly change the hydrologic and habitat conditions in Russell Fork, and significantly affect them in the North Fork San Gabriel River. The affected reaches of both streams will have substantial, stable base flows as in spring-fed streams, as long as water transfers are uninterrupted. Stable base flows will tend to encourage the development of aquatic vegetation where substrates permit which will enhance physical habitat diversity, cover, and the variety of food sources available following the initial period of channel adjustment. This can be expected to eventually increase the diversity and alter the composition of the aquatic community as resident species and new migrants from perennial habitats are able to respond to the altered hydrologic regime.

The frequency and intensity of bankfull and greater flood events will be substantially increased in the lower reach of Russell Fork, which can be expected to result in adjustments in the channel to accommodate the increased flows. Channel adjustment will include an initial period of scour and redeposition as the channel degrades and widens, and a tendency for coarser substrates to become proportionally more common as the increased base flows and initially higher current velocities prevent clay and silt deposition in most areas. The lack of suspended solids in the Lake Buchanan water will increase its competence, resulting in enhanced erosion in the reach below the outfall. Channel adjustment may lead to the loss of some riparian cover to bank erosion in the affected reach of Russell Fork, and aquatic populations are likely to be adversely affected during the period of channel adjustment. Over the longer term, however, the enhancements in diversity and productivity mentioned above are expected to develop as the channel achieves equilibrium with the new flow regime. Given the relative volume and competence of the Lake Buchanan water, intermittent, rather than constant, operation of the diversion can be expected to result in adverse impacts to Russell Fork for the life of the project.

The North Fork San Gabriel River is expected to be less affected by implementation of This alternative than Russell Fork because the transferred water will be a smaller proportion of streamflow, its suspended and bed loads will be at equilibrium, and it already has substantial perennial habitat. Some channel adjustment will occur, particularly in the vicinity of the confluence of Russell Fork, but the major changes (both adverse and beneficial) anticipated in the latter stream are not expected in the North Fork San Gabriel River. Likewise, intermittent operation of the diversion could be expected to have adverse effects in the North Fork San Gabriel River, but not to the extent expected in Russell Fork.

Lake Georgetown (Segment 1249) and the upper North Fork San Gabriel River (Segment 1251) have numerical criteria for chloride of 20 and 35 mg/l, respectively, for sulfate of 20 and 30 mg/l, and for total dissolved solids (TDS) of 280 and 330 mg/l. Lake Buchanan, in contrast, has numerical criteria for these materials that are far higher: Chloride - 145 mg/l, sulfate - 95 mg/l, and TDS - 525 mg/l (TAC 307.10, Appendix A). Water quality data collected by the U.S. Geological Survey and Texas Natural Resource Conservation Commission in Lake Georgetown extending from 1981 through 1996 indicates that actual concentrations of these dissolved materials remains consistently and substantially below the criteria. Similar data for the reach of the Colorado River above Lake Buchanan shows that concentrations of these constituents, even discounting the elevated chloride levels of the early 1990s, are commonly three to five times the numerical criteria for Lake Georgetown. This indicates that violations of segments standards in the North Fork San Gabriel River and Lake Georgetown are a likely result of implementation of this alternative, particularly under dry climatic conditions when natural inflows are reduced.

Interbasin transfer of biological organisms appears unlikely to have substantial impacts in the Brazos Basin because organism exchange between these adjacent basins is a historic and ongoing process. Fish, although they have a low interbasin vagility compared to algae higher plants and most aquatic invertebrates, tend to be broadly adapted to water quality and physical habitat parameters, and to be widely distributed across areas of similar physiography and climate. Most fish species have distributions that correspond to Blair's Biotic Provinces, which were defined on the basis of the distributions of terrestrial vertebrates, rather than having distributions that follow basin divides.[30] The fish species known from the two basins are nearly identical, varying by only a few species.[31]

Freshwater plants and invertebrates generally have resting stages that are resistant to drying and many possess other mechanisms that facilitate dispersal across terrestrial environments. The headwaters of the Brazos and Colorado basins are closely interdigitated along the Calahan divide, facilitating interbasin exchange of taxa. It is noteworthy that the asiatic clam, an invasive exotic species, is abundant in both basins in spite of a poor capability for overland transport relative to most invertebrates. Adult aquatic insects, for example, can usually fly, while dissemules of aquatic plants, protozoans and other small invertebrates are commonly transported between water bodies by terrestrial vertebrates (especially birds).

3.13.4 Water Quality and Treatability

Table 3.13-2 provides a comparison of the major water quality constituents in Lake Buchanan, the North Fork of the San Gabriel River, and Lake Georgetown. The most significant difference between the waters is the elevated dissolved solids associated with Lake Buchanan water. These are the result of the saline inflows to the upper Colorado River. Another possible concern with mixing the water, is the higher nutrient levels in Lake Buchanan. Since phosphorus is usually the limiting nutrient in algae growth, higher phosphorus loads from Lake Buchanan water could lead to an increase in the algae population in Lake Georgetown. Residence time in the North Fork of the San Gabriel River should provide pretreatment of the Lake Buchanan water by assimilating some of the nutrients before they ultimately reach Lake Georgetown.

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[30] Hubbs, Clark. 1957. Distributional patterns of Texas fresh-water fishes. The Southwestern Naturalist 2:89-104.
Blair, Frank. 1950.

[31] Connor and Suttkus. 19??. Zoogeography ...?
Hubbs, Clark. 1957

Table 3.13-2
Conventional Water Quality Constituents
in Lake Buchanan, the San Gabriel River, and Lake Georgetown[1]

Constituent	*Lake Buchanan*	*North Fork[2]*	*Lake Georgetown*
Dissolved Oxygen (mg/l)	7.53	8.53	8.00
pH (su)	8.06	7.87	8.05
TDS (mg/l)	574.43	299.73	232.00
Fecal Coliforms (No./100 ml)	12.50	29.62	53.67
Chloride (mg/l)	147.75	14.46	13.00
Sulfate (mg/l)	115.67	29.65	18.38
Total Phosphorus (mg/l)	0.05	0.01	0.03
Total Nitrogen[3] (mg/l)	0.20	0.13	0.06

[1] TNRCC, "Texas State Water Quality Inventory," November, 1994.
[2] Segment 1251 of the Brazos River Basin.
[3] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Lake Buchanan is protected by TNRCC's Chapter 311, Water Protection, which prohibits discharge of pollutants into the reservoir water quality area unless sufficient treatment is applied to ensure that the existing water quality of the lake is maintained.[32] With TNRCC's anti-degradation policy in place, the water quality of Lake Buchanan is expected to remain relatively constant. However, Lake Buchanan experienced substantial increases in chlorides, sulfates, and TDS when heavy rains caused hypersaline overflows located at Natural Dam Lake in 1986 and 1987. The salinity problems were eliminated by the record floods of 1992.[33]

Although there is little indication that the waters from Lake Buchanan and Lake Georgetown would be incompatible, a more detailed water quality study should be conducted to address any effects that Lake Buchanan water might have on the North Fork of the San Gabriel River and Lake Georgetown, and determine if the mixture would require any additional treatment. Conventional treatment already employed for public water supply on Lake Georgetown should be adequate to treat the Lake Buchanan and Lake Georgetown mixture pending any significant modifications to the state's drinking water standards.

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[32] Texas Administrative Code, Title 31, Chapter 311.
[33] TNRCC, "Texas State Water Quality Inventory," November, 1994.

3.13.5 Engineering and Costing

This alternative considers the diversion of water from Lake Buchanan to Lake Georgetown. From Lake Georgetown, the water could be treated at either an expanded Georgetown treatment plant located just north of Lake Georgetown, at the existing Round Rock treatment plant, or at a potential regional treatment plant. From the regional plant, water could potentially be distributed to several water supply entities.

Water would be diverted from Lake Buchanan from a new intake at the southeast portion of the reservoir near the dam. This water would be pumped at a uniform annual rate into the Brazos River Basin and discharged into Russell Fork, a tributary to the San Gabriel River north of the town of Burnet. The pipeline would be about 86,000 feet long (16 miles) and require a static lift of 420 feet from Lake Buchanan's normal pool elevation of 1,020 ft-msl. From Russell Fork, the water would flow in the river bed about 30 river miles to Lake Georgetown. Locating the intake at Inks Lake rather than Lake Buchanan was also considered because the length of pipe could be reduced by about 17,000 feet. However, the normal pool elevation of Inks Lake is 888 ft-msl, which is 132 feet below Lake Buchanan's normal pool elevation of 1,020 ft-msl. The additional head would make a second pump station necessary and, with the additional capital and power costs, this option could be more expensive than the diversion from Lake Buchanan. If this option is pursued in the future, a more detailed cost comparison analyses should be performed.

Requirements for treatment include a new or expanded intake and pump station, as well as a pipeline to the treatment plant. The major facilities to implement this alternative are:

- Raw water intake and pump station at Lake Buchanan;
- Raw water pipeline to Russell Fork in the Brazos River Basin;
- Expanded raw water intake and pumping capacity at Lake Georgetown; and
- Expanded treatment and distribution capacity at Georgetown or Round Rock water treatment plant, or a new regional treatment plant. For a new regional treatment plant the following items would need to be implemented:
  - Raw water intake and pump station at Lake Georgetown,
  - Raw water pipeline line,
  - Water treatment plant, and
  - Treated water transmission pipeline.

A summary of the cost estimates for the various alternatives which provide 19,000 acft/yr of treated water are shown in Table 3.13-3. Also included are the costs for options which provide 42,000 acft/yr both with and without treatment.

Table 3.13-3
Cost Estimate Summary for Diversion of Water from Lake Buchanan to Lake Georgetown with Treatment at Georgetown, Round Rock, or a Potential New Treatment Plant
(1st Quarter 1997 Dollars)

	19,000 acft/yr		42,000 acft/yr	
Item	**Treatment at Georgetown WTP**	**Treatment at Round Rock or Regional WTP**	**No Treatment**	**With Treatment**
Capital Costs				
Pipelines, Intakes, Crossings	$ 11,720,000	$ 19,620,000	$ 17,378,000	$ 7,500,000
Pump Stations	5,760,000	5,780,000	5,243,000	0
Treatment Plant	22,400,000	22,400,000	0	26,400,000[5]
Total Capital Cost	$ 39,880,000	$ 47,800,000	$ 22,621,000	$ 33,900,000
Engineering, Contingency, Legal	$ 13,370,000	$ 15,750,000	$ 7,048,450	$ 11,490,000
Land Easements	290,000	390,000	190,000	75,000
Environmental Studies & Mitigation	290,000	390,000	190,000	75,000
Interest During Construction	2,150,000	2,570,000	1,210,978	1,820,000
Total Project Cost	$ 55,980,000	$ 66,900,000	$ 31,251,428	$ 47,360,000
Annual Costs				
Annual Debt Service	$ 5,250,000	$ 6,270,000	$ 2,928,000	$ 4,440,000
Annual Operations & Maintenance (Excluding Power)	2,910,000	2,910,000	350,000	3,400,000
Annual Power	900,000[1]	900,000[1]	1,556,000	218,000
Purchase of Raw Water from LCRA	2,260,000[2]	2,260,000[2]	5,009,000	0
Total Annual Cost	$ 11,320,000	$ 12,340,000	$ 9,843,000	$ 8,058,000
Total Project Yield	19,000 acft/yr	19,000 acft/yr	42,000 acft/yr	25,760[5] acft/yr
Annual Unit Costs of Treated Water				
$ per acft	$596	$649	$234	$312
$ per 1,000 gal	$1.83	$1.99		

[1] Based on annual pumpage of 21,500 acft.

[2] Based on purchase of 21,500 acft/yr at current LCRA system price of $105 per acft.

[3] Based on annual pumpage of 47,700 acft/yr.

[4] Based on purchase of 47,700 acft/yr at current LCRA system price of $105 per acft.

[5] Based on projected regional treatment need of 46 mgd and peak factor of 2.0, i.e., 46 mgd ÷ 2 = 23 mgd annual average, or 25,760 acft/yr.

Treatment at an Expanded Georgetown Water Treatment Plant

Uniform annual diversion of 21,500 acft/yr from Lake Buchanan to Russell Fork would require a raw water intake, a pump station, and a raw water transmission line. The transmission line would be about 16 miles long and 36 inches in diameter. The intake, pump station, and pipeline at Lake Georgetown was sized for 34 mgd peak capacity, with a peak factor of 2.0. The pipeline to the Georgetown water treatment plant would be 2,700 feet long, 48 inches in diameter, and require a static lift of about 70 feet. Facilities at Georgetown's existing treatment plant would likely be inadequate to support 34 mgd of additional capacity. Therefore, the cost of expanding the plant by 34 mgd is conservatively estimated to be the same as that for a new plant, or about $22,400,000. Total capital cost is estimated at $39,880,000, and the total project cost would be about $55,980,000. The annual debt service for this project financed at 8 percent for 25 years would be about $5,250,000. With annual operations and maintenance, power, and purchase of 21,500 acft/yr from LCRA at the system price of $105 per acft, the total annual cost would be $11,300,000. For a net yield of 19,000 acft/yr, the unit cost with treatment at Georgetown would be $596 per acft ($1.83 per 1,000 gal).

Treatment at an Existing Round Rock Water Treatment Plant

The costs for the intake, pump station, and pipeline from Lake Buchanan to Russell Fork are the same for the Round Rock option, as discussed above. The intake, pump station, and transmission line to an expanded Round Rock water treatment plant, or at a potential new regional treatment plant were sized for 34 mgd peak capacity, with a peak factor of 2.0. The transmission line to the treatment plant would be about 8.4 miles long and 48 inches in diameter. The elevation of the treatment plant is at about the same elevation as Lake Georgetown's normal pool elevation (791 ft-msl). The cost of 34 mgd of new treatment capacity is estimated at $22,400,000. The total capital cost of this project would be $47,800,000, and the total project cost is estimated at $66,900,000. Financed at 8 percent for 25 years, the annual debt service would be $6,270,000. With operations and maintenance, power, and the cost of raw water from LCRA at $105 per acft, the total annual cost of this alternative would be about $12,330,000. For an annual yield of 19,000 acft/yr, the unit cost would be about $649 per acft ($1.99 per 1,000 gal). The reason this alternative is more expensive than that with treatment at Georgetown is the longer raw water transmission pipeline from Lake Georgetown to the treatment plant. Treatment costs account for roughly two-thirds of the cost of this alternative.

Treatment at a Potential New Regional Water Treatment Plant

For comparison with the Williamson County Raw Water Line, the intake, pump station, and pipeline from Lake Buchanan to Russell Fork were sized to increase the yield of Lake Georgetown by 42,000 acft/yr. Considering the estimated 12 percent losses, the diverted amount would suffer in the San Gabriel River, it would be necessary to divert about 47,700 acft/yr from Lake Buchanan. The raw water pipeline to Russell Fork would need to have a diameter of 54 inches. The intake, pump station, and transmission line from Lake Georgetown to the treatment plant were sized for an annual delivery of 25,760 acft/yr with a peak factor of 2.0 or a 46 mgd peak capacity. For this case, the treatment plant would be located on FM 2243 south of Lake Georgetown, and the transmission line to the plant would be about 20,000 feet long and 54 inches in diameter. At this location, the treatment plant would be at an elevation of about 890 ft-msl or about 100 feet above Lake Georgetown's normal pool elevation of 791 ft-msl.

The capital cost of the transmission facilities from Lake Buchanan to Russell Fork is estimated to be $22,620,000, and the total project cost is estimated at about $31,250,000. Financed at 8 percent for 25 years, the debt service would be about $2,928,000. With annual operation and maintenance, power, and the cost of raw water from LCRA at $105 per acft, the total annual cost would be about $9,244,000. For an annual delivery of 42,000 acft/yr, the unit cost for raw water would be $234 per acft ($0.72 per 1,000 gal). The cost of 46 mgd of new treatment capacity is described in Section 3.7 of this report, and the costs are summarized in the right-hand column of Table 3.13-4. The unit cost of treatment would be about $312 per acft ($0.96 per 1,000 gal). The total unit cost for treated water from this system would, therefore, be about $546 per acft ($1.68 per 1,000 gal).

3.13.6 Implementation Issues

A permit would need to be obtained from the TNRCC to divert water from the Colorado River and make an interbasin transfer to the Brazos River Basin. An NPDES discharge permit may also be needed to discharge into Russell Fork. Also, a bed-and-banks transfer permit must be obtained from the TNRCC to maintain ownership of the water while in the San Gabriel River.

A TNRCC permit amendment must be obtained to add a point of diversion at Lake Georgetown for the regional treatment plant option. A permit amendment would need to be obtained to increase diversions from the lake for municipal use.

Additional studies would also be necessary to more accurately assess channel losses along Russell Fork and the North San Gabriel River.

Requirements Specific to Pipelines

1. Necessary permits:
    a) TNRCC Interbasin Transfer Permit including provisions for use of the bed-and-banks of San Gabriel River and its tributaries.
    b) EPA NPDES discharge permit at Russell Fork (possible).
    c) U.S. Army Corps of Engineers Sections 404 dredge and fill permits for stream crossings and lake intakes.
    d) GLO Sand and Gravel Removal permits.
    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.

Requirements Specific to Treatment and Distribution

1. Study is needed of the cost to integrate potential new supply into each participant's distribution system.
2. Necessary permits:
    a) Local construction permit
    b) No permit to treat and distribute water, however, the design must be approved by TNRCC and there are standards which must be met for water quality.

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3.14 Purchase of Irrigation Rights in Lower Colorado River Basin with Off-Channel Storage (C-5)

3.14.1 Description of Alternative

This alternative investigates the water supply potentially made available by constructing an off-channel reservoir in the Lower Colorado River Basin. An off-channel reservoir could benefit water supply in the study area by reducing pass throughs of Highland Lakes water needed to honor downstream senior rights, thereby increasing the uncommitted yield of the Highland Lakes. An off-channel reservoir would need to be constructed on a tributary of the Colorado River where both tributary inflows and water pumped from the Colorado River could be stored for later use. While this alternative investigates the potential benefits of an off-channel storage reservoir located near Columbus, Texas, other sites could be considered with potentially similar results. Benefits of a reservoir to water supply in the North Central planning area are investigated both with and without purchase of underutilized water rights in the lower basin. Finally, incidental benefits to areas outside the North Central planning area are summarized.

Four project configurations have been considered for this alternative:

Alternative C-5A —	Construction of an off-channel reservoir utilizing only tributary watershed inflows,
Alternative C-5B —	Construction of an off-channel reservoir and diversion facilities on the Colorado River to divert unappropriated flows,
Alternative C-5C —	Construction of an off-channel reservoir and purchase of 75,000 acft/yr of irrigation water rights, and
Alternative C-5D —	Construction of an off-channel reservoir and diversion facilities on the Colorado River to divert unappropriated flows with purchase of 75,000 acft/yr of irrigation rights.

A schematic representation of the lower Colorado River Basin and the four options which were investigated are shown in Figure 3.14-1.

Previous studies of constructing additional storage in the Colorado River Basin have investigated both on-channel[1,2] and off-channel storage reservoirs. Construction and operation of on-channel reservoirs is more involved than off-channel reservoirs because of the substantial

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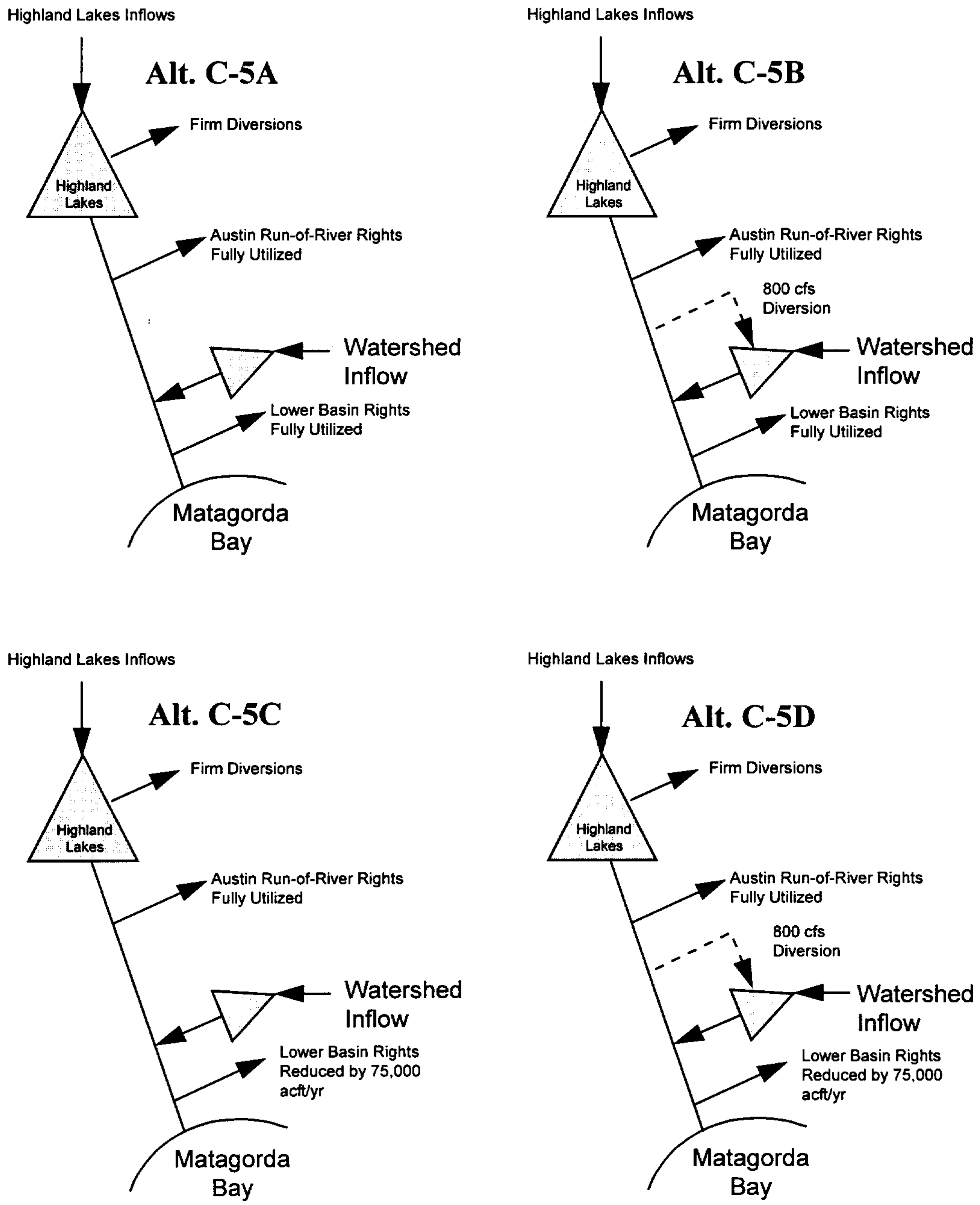
[1] U.S. Bureau of Reclamation, Colorado Coastal Plains Project, Shaws Bend Reservoir, March 1985.

[2] U.S. Bureau of Reclamation, Columbus Bend Project, 1961.



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LOWER COLORADO RIVER BASIN
SCHEMATIC
ALTERNATIVE C-5

HDR Engineering, Inc.

FIGURE 3.14-1

spillway requirements, land requirements, and permitting issues associated with the high flows experienced on the Colorado River. While this investigation considers the potential of storage constructed on Cummins Creek near Columbus, Texas, it should be representative of any off-channel site of similar size in the area. The Cummins Creek reservoir has been investigated in prior studies.[3] The location of this off-channel reservoir is shown in relation to the study area and the major downstream diverters in Figure 3.14-2. The conservation pool elevation would be 256-ft msl and would extend 12 miles upstream. The conservation storage capacity of the reservoir as configured here would be 132,700 acft and have a surface area of 6,600 acres.

The operation of an off-channel reservoir located downstream of the Highland Lakes could be used to store unappropriated streamflow, when available, and to release water to supply lower basin demands when needed. This operation would reduce the releases of inflows to the Highland Lakes that are required to meet senior downstream rights by making more efficient use of natural inflows and return flows below the Highland Lakes. The operation would benefit water supply in the study area by reducing pass throughs of Highland Lakes inflows committed to honoring downstream senior rights thereby increasing the uncommitted yield of the Highland Lakes. This would also benefit downstream interests by increasing the availability of water to senior water rights holders. An additional benefit to the basin results from the reduction in water losses and improved water delivery scheduling that can be achieved by making releases for irrigation from a reservoir that is significantly closer to the major diverters than the Highland Lakes.

3.14.2 Water Availability

Modeling and Reservoir Operation Methodology

The operation of an off-channel reservoir was modeled in conjunction with the Colorado River Basin using LCRA's Response Model to determine water availability. The modeling was performed by LCRA staff at the direction of HDR. Details of the Response Model are presented in Section 3.2. Water available for storage by the reservoir included both unappropriated water from its watershed as well as water diverted from the Colorado River. The contributing

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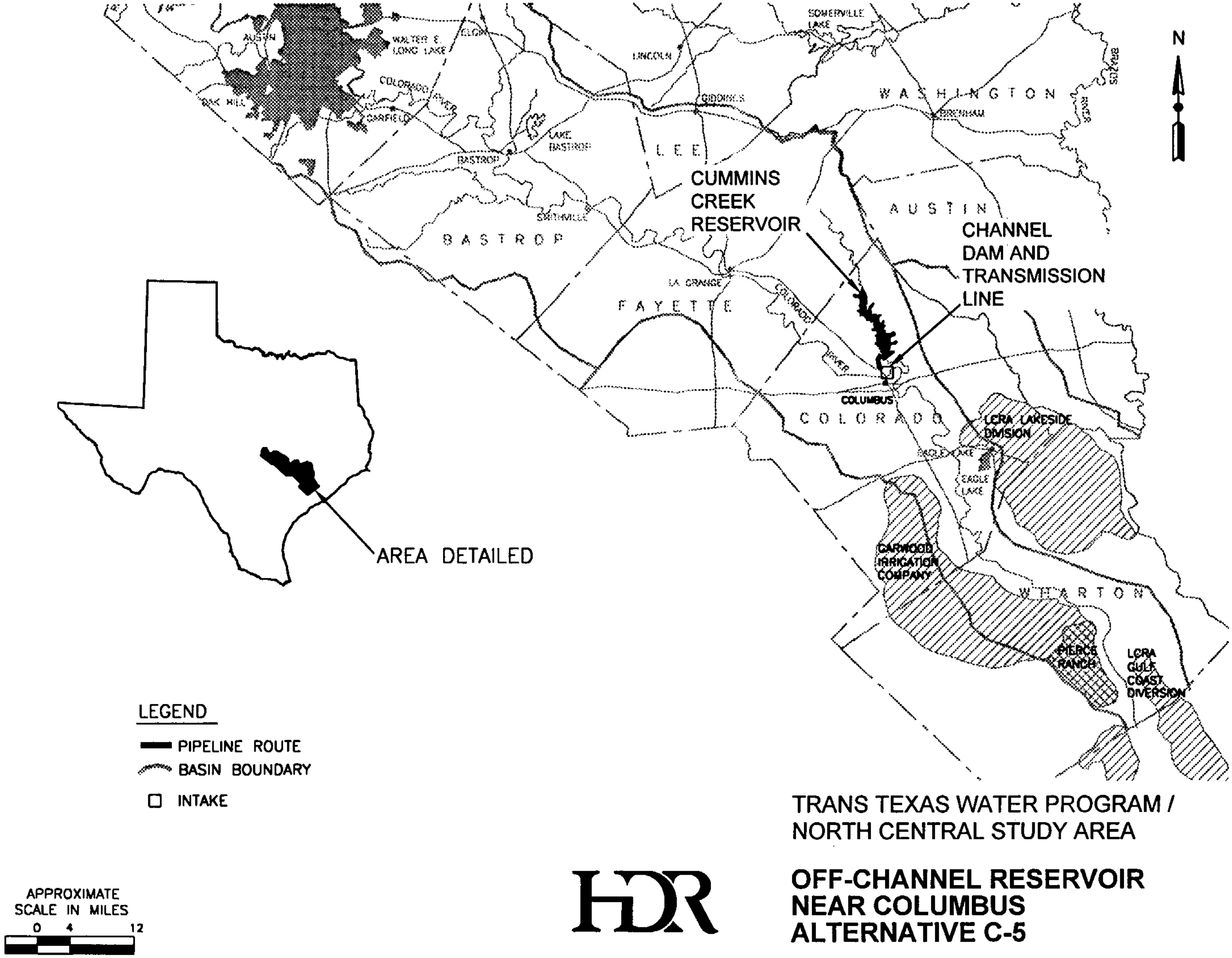
[3] U.S. Bureau of Reclamation, Colorado Coastal Plains Project, September, 1977.



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NORTH CENTRAL STUDY AREA

**OFF-CHANNEL RESERVOIR
NEAR COLUMBUS
ALTERNATIVE C-5**

FIGURE 3.14-2

watershed area of the Cummins Creek reservoir is estimated to be 293 square miles. Unappropriated flows in the Colorado River basin would be diverted by pumping from the river at a site near Columbus to the off-channel storage.

For modeling purposes, diversions from the Colorado River were limited by both the availability of unappropriated water and the assumed capacity of the diversion facility. Operation of a diversion facility to provide for possible environmental criteria such as minimum flows could reduce the water made available below these estimates. Therefore, water made available by these diversions generally represents the upper limit of what could be obtained. Several different diversion facility sizes were investigated.

The yield of the Highland Lakes after accounting for the impact of O. H. Ivey Reservoir is 689,609 acft/yr (Figure 3.14-3). This yield is further reduced by 392,643 acft to honor senior downstream water rights and 160,199 acft/yr is currently committed to water sale contracts and electric utilities. Of the remaining yield, 31,800 acft/yr has been reserved to help ensure adequate instream flows and inflows to Matagorda Bay. These commitments are shown in Figure 3.14-3. The remaining 104,967 acft/yr of water is currently uncommitted.[4]

In general, the off-channel reservoir would fill during the winter months when agricultural demands are minimal. Then in the spring when agricultural demands increase, the reservoir would begin satisfying demands when needed. Inflows to the Highland Lakes would be passed downstream to meet downstream demands for senior water rights only when the off-channel storage is empty. A simulated off-channel reservoir content is shown with unappropriated diversions from the Colorado River of up to 800 cfs in Figure 3.14-4.

A. Off-Channel Reservoir with Natural Inflow — Alt C-5A

In this study, changes in water availability were evaluated at the Highland Lakes, the City of Austin, to other senior diverters, and to inflows into Matagorda Bay. The operation of the off-channel reservoir was modeled to allow management of demands in the lower basin and inflows to the Highland Lakes. By providing water from the off-channel storage reservoir when flows below the Highland Lakes is insufficient to meet downstream demands, the off-channel reservoir

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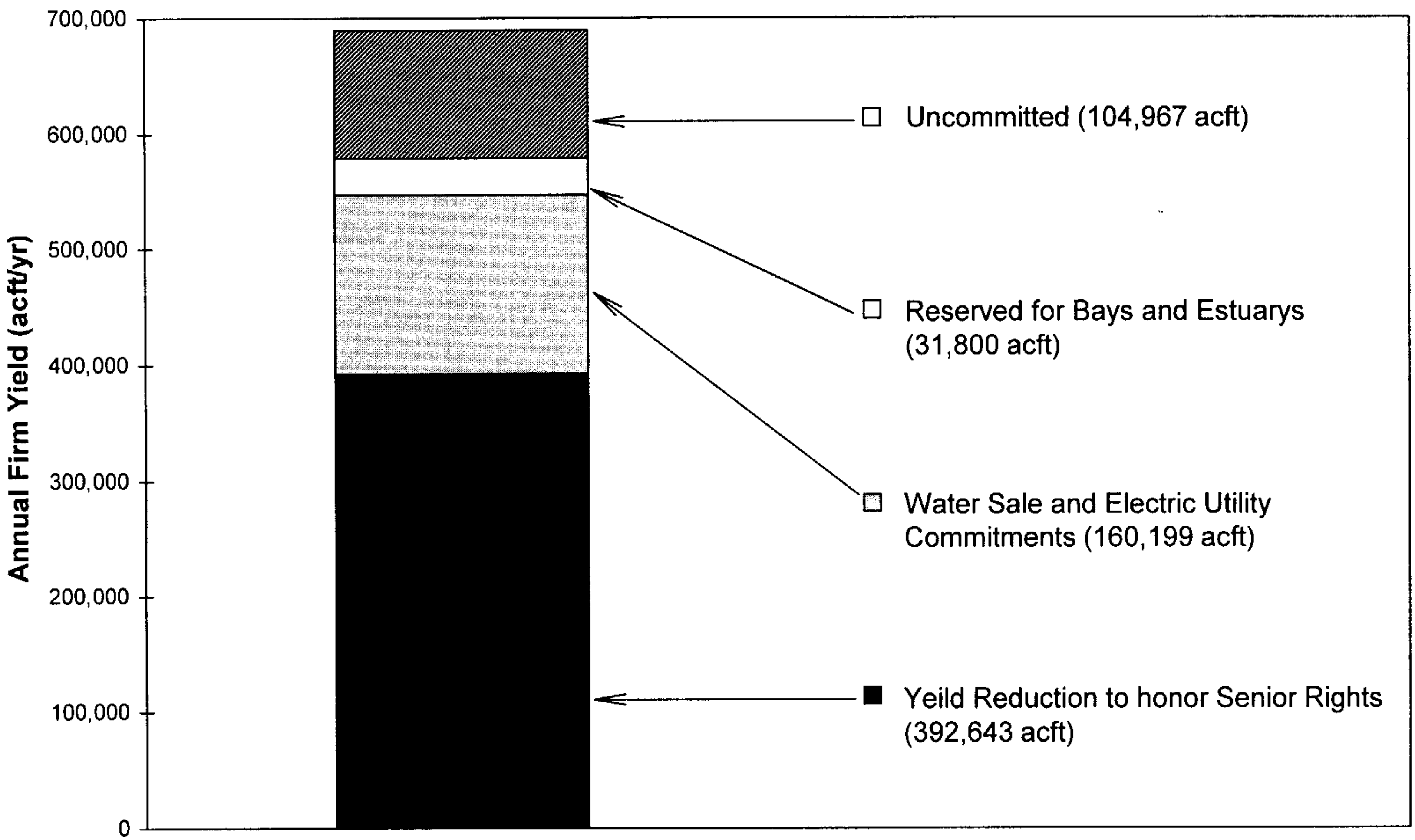
[4] Lower Colorado River Authority, Water Management Plan, 1993, and list of current water supply contracts.



Highland Lakes Yield Commitments after yield reduction due to construction of O. H. Ivey Reservoir.

Source: LCRA, Water Management Plan, 1993

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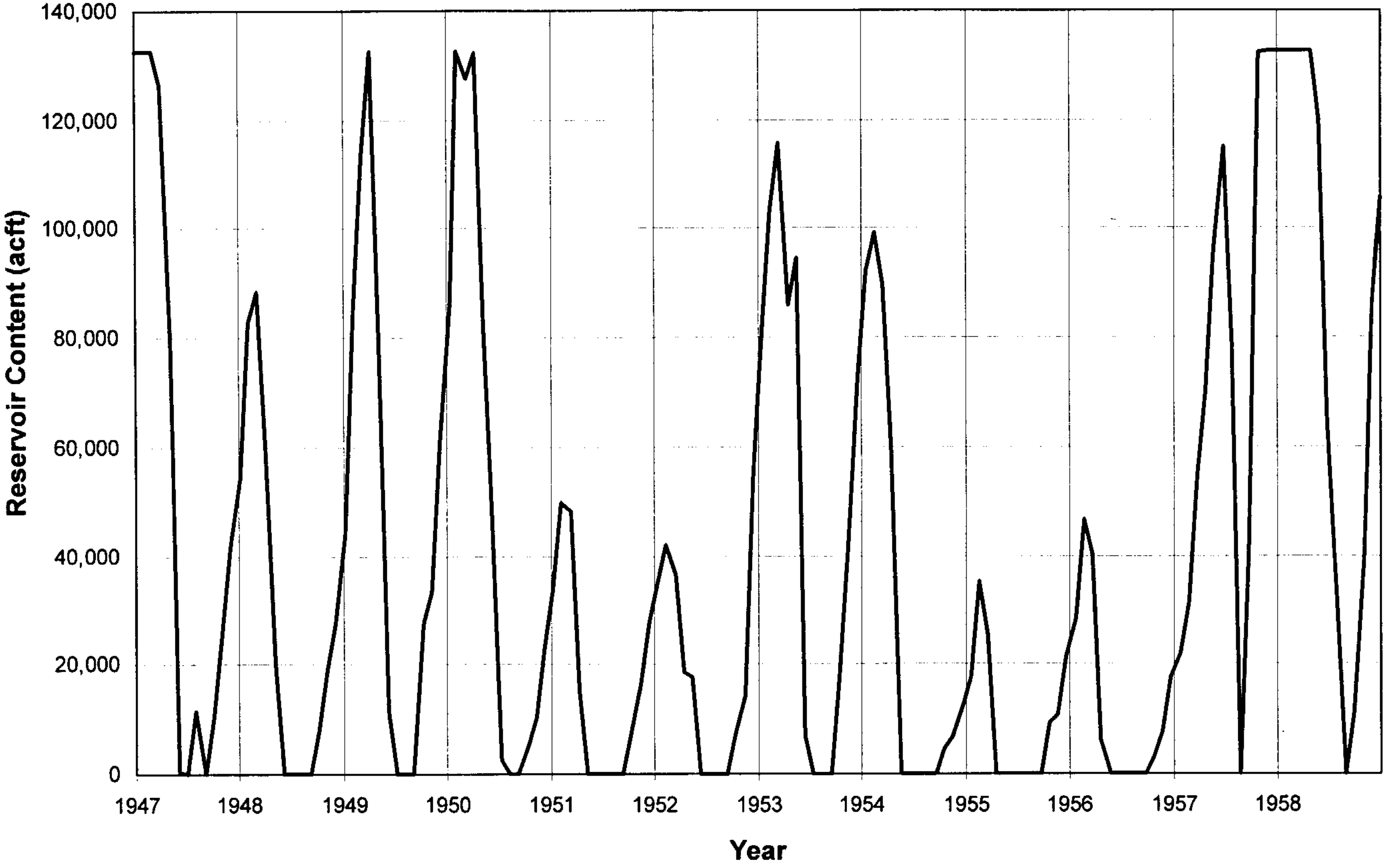
HIGHLAND LAKES YIELD COMMITMENTS ALTERNATIVE C-5

FIGURE 3.14-3



NOTES:

1. Estimated by Response Model simulation with all senior water rights attempting to divert at permitted rate.
2. Unappropriated flows in Colorado River diverted at 800 cfs to off-channel reservoir.

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NORTH CENTRAL STUDY AREA

OFF-CHANNEL RESERVOIR CONTENT WITH DIVERSION OF UNAPPROPRIATED FLOWS ALTERNATIVE C-5

FIGURE 3.14-4

can reduce the pass through of inflows to the Highland Lakes. This operation also eliminates some of the losses that occur in the river during the 5-day travel from the Highland Lakes to the major diverters in the lower basin.

Water made available by the construction of new off-channel storage was evaluated over the 10-year critical period for the Highland Lakes of 1947 to 1956. Table 3.14-1 compares the water availability in the basin both with and without the off-channel storage reservoir. By storing only unappropriated water occurring in the watershed of the off-channel reservoir, water available to the City of Austin's run-of-river diversions increased by 1,400 acft/yr, water available to other major rights increased by 19,600 acft/yr, and the firm yield of Lake Travis increased by 42,400 acft/yr. The sum of increased water availability to water rights holders totals 63,400 acft/yr. This increase in availability results in a decrease to the flows into Matagorda Bay by an average of 26,800 acft/yr for a net water supply increase of 36,600 acft/yr. The 36,600 acft/yr difference is attributed to the reduction in losses due to improved basin management made possible by the off-channel reservoir.

Table 3.14-1
Water Availability with Off-Channel Reservoir Capturing Only Unappropriated Water in its Watershed — Alt C-5A
Averages for the Period of 1947-1956 (acft/yr)

Diverter	Base Case	With Off-channel Reservoir	Water Made Available
City of Austin	166,900	168,300	1,400
Other Major Rights	286,900	306,500	19,600
Highland Lakes Yield	445,300	487,700	42,400
Total	899,100	962,500	63,400
Flow to Matagorda Bay	279,800	253,000	(26,800)

B. Off-Channel Reservoir with Diversion of Unappropriated Flow — Alt C-5B

The quantity of water made available by operation of an off-channel reservoir can be significantly increased by diverting unappropriated water from the Colorado River into the reservoir. The construction and operation of an 800 cfs diversion facility would approximately double the water made available under the previous scenarios (Table 3.14-2). Increased water availability to the City of Austin run-of-river diversions would be approximately 3,700 acft/yr, to other major rights it would be 82,000 acft/yr, and to the firm yield of the Highland Lakes it would be 82,300 acft/yr. The sum of increased water availability to water rights holders totals 168,000 acft/yr. This increase in availability results in a decrease in the inflows to the Matagorda Bay of an average of 100,700 acft/yr for a net water supply increase to the basin of 67,300 acft/yr (168,000 acft/yr - 100,700 acft/yr = 67,300 acft/yr). The difference, or 67,300 acft/yr, is attributable to reductions in losses due to improved basin management. Water made available with other diversion rates, as well as the resulting reductions to inflows to Matagorda Bay, are shown in Figure 3.14-5.

Table 3.14-2
Water Availability with Off-Channel Reservoir with Diversion of 800 cfs of Unappropriated Colorado River Flow — Alt C-5B
Averages for the Period of 1947-1956 (acft/yr)

Diverter	Base Case	With Off-channel Reservoir	Water Made Available
City of Austin	166,900	170,600	3,700
Other Major Rights	286,900	368,900	82,000
Highland Lakes Yield	445,300	527,600	82,300
Total	899,100	1,067,100	168,000
Flow to Matagorda Bay	279,800	179,100	(100,700)

C. Off-Channel Reservoir with Purchase of Under-Utilized Water Rights — Alt C-5C

The benefit of purchasing under-utilized water rights in conjunction with operation of off-channel storage was investigated. In previous studies, it was found that a total of 75,000 acft/yr of existing water rights can be classified as under-utilized[5] (i.e., not used in the 10-year period from 1984 to 1993). The under-utilized rights were determined to be 20,000 acft/yr of the Gulf Coast Supply Co. right and 55,000 acft/yr of the Pierce Ranch right. Currently, both of these under-utilized rights are owned by LCRA.

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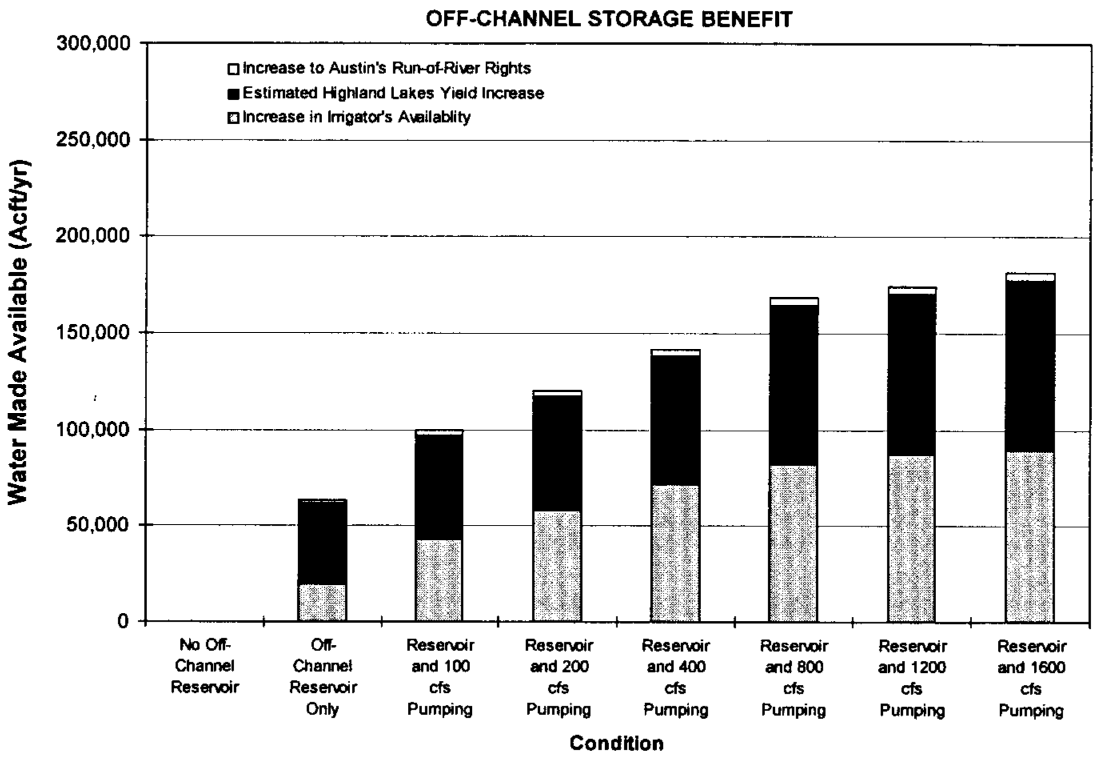
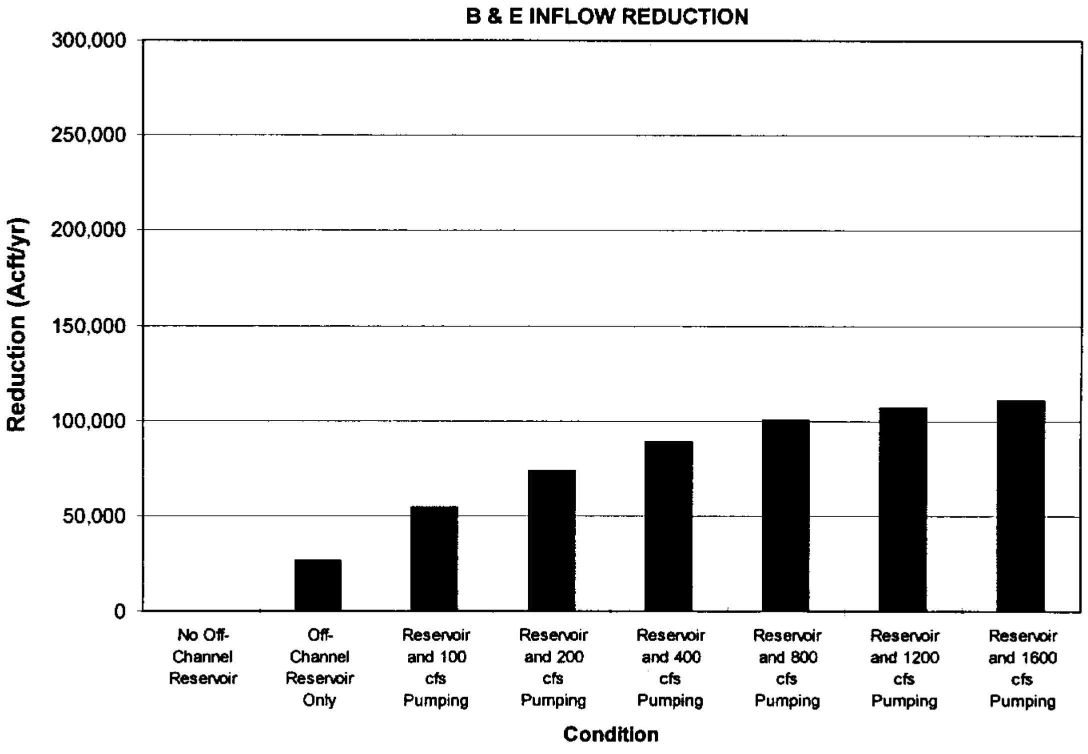
[5] HDR Engineering, Inc., et al., Texas Water Development Board Trans-Texas Program, Austin Study Area, Phase I-Interim Report, August, 1994.





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EFFECTS OF OFF-CHANNEL STORAGE IN THE LOWER COLORADO BASIN WITH DIVERSION OF UNAPPROPRIATED FLOW ALTERNATIVE C-5B

FIGURE 3.14-5

With no off-channel storage, the purchase and retirement of the 75,000 acft/yr of under-utilized rights increases the 10-year drought flow to Matagorda Bay by an estimated 26,300 acft/yr, or roughly one-third of the purchase quantity. Increased water availability to the City of Austin diversions would be about 1,000 acft/yr and the increased yield of the Highland Lakes is estimated to be 3,600 acft/yr. Simulations show that significant additional water would not become available to other major rights.

The benefit of off-channel storage after purchase of these under-utilized rights was first evaluated without diversions of unappropriated flow from the Colorado River. Water availability under this scenario is summarized in Table 3.14-3. Water made available includes 46,700 acft/yr of increased firm yield to the Highland Lakes. Increases in the City of Austin's run-of-river availability was 2,800 acft/yr. This increase in availability results in a decrease in the inflows to Matagorda Bay of an average of only 3,400 acft/yr. Water availability increases to other major water rights holders cannot be determined directly because the rights have been reduced from the base case. Compared to Alternative C-5A, the purchase of under-utilized rights increases water availability at the Highland Lakes by an additional 4,300 acft/yr and reduces impacts to Matagorda Bay by 23,400 acft/yr with the net flow reductions to the Bay totaling only 3,400 acft/yr.

Table 3.14-3
Water Availability with Off-Channel Reservoir and Purchase of Under-utilized Irrigation Rights — Alt C-5C
Averages for the Period of 1947-1956 (acft/yr)

Diverter	Base Case	With Off-Channel Reservoir & Diversion*	Water Made Available
City of Austin	166,900	169,700	2,800
Other Major Rights*	256,100*	277,400	21,300
Highland Lakes Yield	445,300	492,700	46,700
Total	868,300	939,100	70,800
Flow to Matagorda Bay	279,800	276,400	(3,400)

*Base case for this alternative includes purchase and retirement of 75,000 acft/yr of senior water rights and the resulting reduction in water diversions.

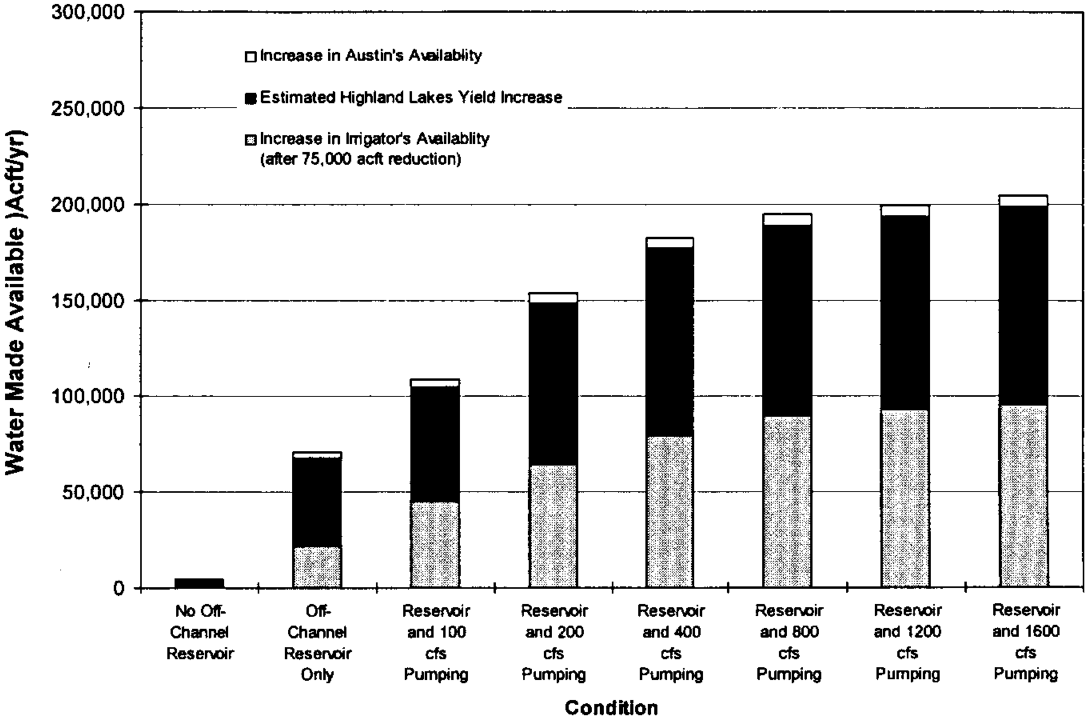
D. Off-Channel Reservoir with Purchase of Under-utilized Rights and Diversion of Unappropriated Flow Alt C-5D

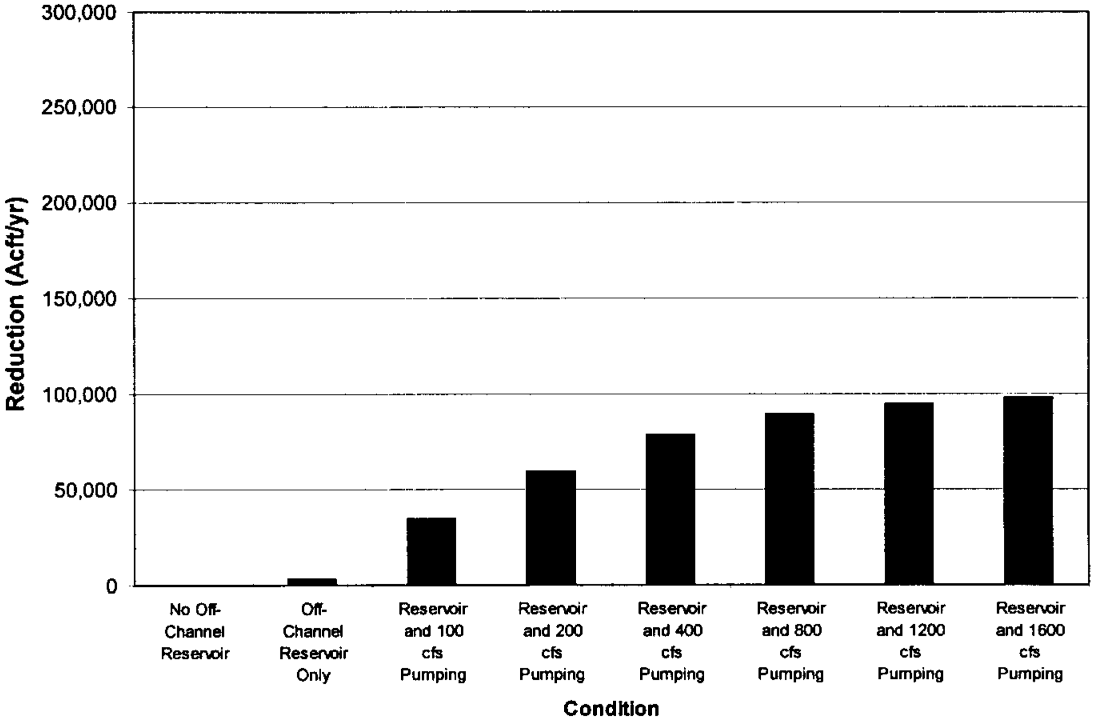
Finally, the benefit of purchasing under-utilized senior water rights in conjunction with operation of off-channel storage and diversion of 800 cfs of unappropriated flows from the Colorado River was investigated. Water availability under this scenario is summarized in Table 3.14-4. Water made available with a diversion rate of 800 cfs resulted in 99,000 acft/yr of increased firm yield to the Highland Lakes. Increases in the City of Austin's run-of-river availability was 5,700 acft/yr. Water availability increases to other major water rights holders cannot be determined directly because the rights have been reduced from the base case. This increase in availability results in a decrease in the inflows to Matagorda Bay of an average of 89,100 acft/yr for a net water supply increase of 74,000 acft/yr. Compared to Alternative C-5B, the purchase of under-utilized rights increases water availability at the Highland Lakes by 16,700 acft/yr and reduces impacts to Matagorda Bay by 11,600 acft/yr with the net flow reduction to the Bay totaling 89,100 acft/yr. Water made available with other diversion rates and the resulting reduction to flows into Matagorda Bay is shown in Figure 3.14-6.

Table 3.14-4
Water Availability with Off-Channel Reservoir, Purchase of Under-utilized Irrigation Rights, and Diversion of Unappropriated Colorado River Flow — Alt C-5D
Averages for the Period of 1947-1956 (acft/yr)

Diverter	Base Case	With Off-channel Reservoir & Diversion*	Water Made Available
City of Austin	166,900	172,600	5,700
Other Major Rights*	256,100*	345,700	89,600
Highland Lakes Yield	445,300	544,300	99,000
Total	868,300	1,062,600	194,300
Flow to Matagorda Bay	279,800	190,700	(89,100)

*Base case for this alternative includes purchase and retirement of 75,000 acft/yr of senior rights and the resulting reduction in water diversions.


OFF-CHANNEL STORAGE BENEFIT


B & E INFLOW REDUCTION

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EFFECTS OF OFF-CHANNEL STORAGE, DIV. OF UNAPPROPRIATED WATER, AND PURCHASE OF 75,000 ACFT OF UNDERUTILIZED RIGHTS - ALT.C-5D

FIGURE 3.14-6

3.14.3 Environmental Issues

This alternative investigates the water supply potentially available for diversion from the Highland Lakes as a result of construction of an off-channel reservoir near Columbus, Colorado County, Texas. This reservoir would capture and store water to be released for use by downstream water rights holders who could otherwise call for releases from the Highland Lakes to fulfill their senior run-of-river rights. Previous studies have already investigated the feasibility, costs, and potential environmental effects of constructing a reservoir on Cummins Creek.

Some scenarios of this alternative also involve the purchase of irrigation rights in the Lower Colorado River in conjunction with the operation of the off-channel storage facility near Columbus. The off-channel reservoir site used to characterize yields and estimate environmental impacts is the Cummins Creek Reservoir site, selected because hydrologic, engineering, and environmental information about the site is available from prior studies.[6] Cummins Creek also has the largest drainage area of the Colorado River tributaries in the region, and the dam site provides the largest yield among potential regional reservoir sites.

Major issues relevant to the purchase of irrigation rights, and construction and operation of an off-channel reservoir in the Lower Colorado River Basin are listed below and each will be addressed individually.

- Potential effects on terrestrial and aquatic species (including endangered species) associated with Cummins Creek and surrounding habitat potentially inundated by construction and operation of the off-channel reservoir.
- Impacts to the instream flow of Cummins Creek, the Colorado River, and Matagorda Bay and estuary system below the potential project area.

General Description of the Environment of Colorado County

The project construction area lies within Colorado County. Winters in the region are typically mild with considerably cloudy mornings. Stalled cold fronts typically bring cool,

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[6] U.S. Bureau of Reclamation, Colorado Coastal Plains Project, September, 1977.

drizzly weather followed by clear skies, crisp, cool nights and mild, sunny days.[7] Mean daily maximum temperatures average 80°F while minimum temperatures average 56°F. The average growing season is 280 days and mean annual precipitation averages about 41 inches with May and September typically the wettest months.[8,9]

The economy of Colorado County is primarily supported by oil and gas production, mineral processing, and farming. Rice is the major crop.[10]

There are three major types of soils in Colorado County. Depending on the final location of the reservoir, supporting facilities and pipelines, some or all of these soil types may be encountered during the course of the project. The floodplains will typically consist of a clayey and loamy, moderately to well-drained soil represented by the Brazoria-Norwood soil association. The Brazoria-Norwood soil association consists of nearly level soils that are very slowly to moderately permeable. This association consists of about 35 percent Brazoria, 30 percent Norwood, and 35 percent other soils. Brazoria soils have a thick reddish-brown clay surface layer over a red clay subsoil. Norwood soils have a thick reddish brown silt loam surface layer over a pink to light reddish-brown silt loam subsoil.

The uplands will consist of one of two types of soils that are sandy and loamy, ranging from somewhat poorly-drained to moderately well-drained soils: the Tremona-Straber soil association or the Wilson-Crockett soil association. The Tremona-Straber soil association has nearly level to sloping soils that are slowly to very slowly permeable soils. This association consists of about 50 percent Tremona, 25 percent Straber, and 25 percent other soils. Tremora soils have a thick pale-brown loamy fine sand surface layer over a gray sandy clay subsoil. Straber soils have a thick pale brown loamy fine sand surface over a light yellowish brown, light gray and red mottled clay. The second sandy upland soil is the Wilson-Crockett soil association, which has nearly level to sloping soils that are very slowly permeable. This association consists of about 40 percent Wilson, 25 percent Crockett, and 35 percent other soils. Wilson soils have a

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[7] National Fibers Information Center. 1987. The Climates of Texas Counties. Bureau of Business Research. The University of Texas. Austin, Texas.
[8] Ibid.
[9] Dallas Morning News. 1995. 1996-1997 Texas Almanac.
[10] National Fibers Information Center. 1987. The Climates of Texas Counties. Bureau of Business Research. The University of Texas. Austin, Texas.

thin, very dark gray silt loam surface layer over a gray silty clay subsoil. Crockett soils have a thin, dark-brown fine sandy loam surface layer over an olive, yellow, and brown mottled clay subsoil.

Most of Colorado County lies within the Post Oak Savannah vegetation area, with the Blackland Prairies bordering the northwest county line, and the Gulf Prairies and Marshes adjacent on the southeast county line.[11] Ecologically, the project area lies within an area classified as a post oak savannah[12] within the South Central Plains.[13] This area is described as an oak-hickory forest with some cropland and pasture on irregular plains.[14] The dominant overstory vegetation of this community are post oak (*Quercus stellata*), blackjack oak (*Q. emoryi*), live oak (*Q. virginiana*), sandjack oak *(Q. incana*), eastern red cedar (*Juniperus virginiana*), mesquite (*Prosopis glandulosa*), cedar elm (*Ulmus crassifolia*), black hickory (*Carya texana*), and hackberry (*Celtis laevigata*).[15] Typical understory vegetation includes yaupon (*Ilex* spp.), poison oak (*Toxicodendron radicans*), american beautyberry (*Callicarpa americana*), hawthorn (*Cretageus* spp.), supplejack (*Berchemia scandens*), trumpet creeper (*Campsis radicans*), dewberry (*Rubrus* spp.), coral-berry (*Symphoricarpos orbiculatus*), little bluestem (*Schizachyrium scoparium*), silver bluestem (*Bothriochloa laguroides*), sand lovegrass (*Eragrostis trichodes*), beaked panicum (*Panicum anceps*), three-awn (*Aristida* spp.), sprangle-grass (*Leptochloa* spp.), and tickclover (*Desmodium* spp.).[16]

Aerial photos and topographic quadrangles[17] show the Cummins Creek reservoir area to be densely forested with some cleared pastures. The Cummins Creek reservoir was examined for land use and Table 3.14-5 contains the results.

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

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

[13] Omernik, J.M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77:118-125.

[14] Omernik, J.M. 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers. 77:118-125.

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

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

[17] USGS. 1953. Western Unites States topographic quadrangle, Seguin, Texas sheet, NH 14-9 Series V502, Denver, Colorado, revised 1975.

Table 3.14-5 Physiognomic Classification of the Cummins Creek Reservoir site			
Vegetation classifications	**Raw Data Units**	**% Coverage**	**Acres**
Developed	30	0.2	10.9
Asphalt	35	0.3	16.4
Grass	5405	39.6	2162.2
Brush	385	2.8	152.9
Park	1045	7.6	415.0
Woods	6410	47.0	2566.2
Water	340	2.5	136.5
Total	13650	100.0	5460.1
Total Area Calculations	5460 total acres in reservoir		

Potential Effects of Reservoir Construction and Operation

The Cummins Creek reservoir site is typical of the region, consisting of a densely wooded, but narrow, riparian corridor dominated by a sugar hackberry-elm overstory and embedded in primarily grassland uplands that have been substantially modified by agricultural activity. This landscape is typical of both the Blackland Prairie and the Post Oak Savannah vegetational areas. Table 3.14-5, which lists the vegetation and land use types within the footprint of Cummins Creek Reservoir, also represents the composition and relative proportions of vegetation and land use types that can be expected to occur at any reservoir site in the region.

Endangered and threatened species that may be encountered in Colorado County are listed in the Environmental Overview (Section 3.1.3). The protected species of greatest concern are Attwater's Greater Prairie-Chicken, smooth green snake, and White-Tailed Hawk. The endangered Attwater's Greater Prairie-Chicken preserve is in northeast Colorado County, remote from the Cummins Creek site or any other practical reservoir site. The preserve is actively managing for Attwater's Greater Prairie-Chicken habitat: open prairies with a sparse herbaceous vegetation and patches of bare ground, but dominated by thick, tall grasses.[18] The Cummins Creek reservoir does not contain any native prairie habitat, the grasslands within the reservoir site being heavily grazed native and improved pastures which do not provide prairie chicken habitat.

Two state-threatened species, the smooth green snake and White-Tailed Hawk prefer the open grasslands of the southeast Colorado County coastal prairies. Topographic relief in this area appears to be insufficient to support a suitable reservoir site.

Within the dense riparian forests lining the rivers and creeks in Colorado County two species are of concern: the timber rattlesnake and the interior least tern. The state threatened timber rattlesnake is normally found in dense cover bottomland woodlands and may be present in any reservoir site in the region. The endangered interior least tern typically nests on sandbars in large river habitats. Sandbars are present in lower Cummins Creek and in numerous other regional streams, including the Colorado River, and use of these areas by interior least terns would have to be investigated during the permitting process for any regional reservoir site.

Most of the 13 soil types found in the project area of Cummins Creek reservoir are upland sandy soils, which are common throughout the region, and which may be expected to occur on other potential reservoir sites.[19] These areas of sandy soil are the most likely habitat of the endangered Houston toad and the Texas asaphomyian tabanid fly, a species of concern. The endangered Houston toad (*Bufo houstonensis*) is a terrestrial toad, similar in size and appearance to the common Woodhouse's toad (*Bufo woodhousei*), that is now restricted to deep sandy soils within the Post Oak Savannah vegetational area of east central Texas.[20] Extant populations inhabit pine or oak woodland, or savannah with native bunchgrasses and forbs present in open areas. Plants typically present in Houston toad habitat include loblolly pine (*Pinus taeda*), post oak, bluejack or sandjack oak, yaupon, and little bluestem.

Houston toads deposit and fertilize their eggs in still or slowly flowing water that persists for at least 30 days in which tadpole development takes place. Temporary and permanent pools

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[18] Arroyo, B. 1992. Threatened and Endangered Species of Texas. U.S. Fish and Wildlife Service, Texas State Office, Austin, Texas.

[19] Natural Resources Conservation Service. 1997. Personal communication with soil scientists in Colorado County.

[20] Campbell, L. 1995. Endangered and Threatened Animals of Texas. Their Life History and Management. TPWD. Austin, TX.

within three quarters of a mile of the toad's hibernation and foraging habitats serve as breeding sites.[21] The eggs hatch within 7 days and the tadpoles metamorphose into small toads in 15 to 100 days, depending on water temperature. The small toadlets emerge from the pools and begin foraging for insects and other invertebrates.

A variety of factors may have affected the decline of the Houston toad. These include the loss of wetlands, the conversion of temporary pools to permanent ponds inhabited by predators, land uses and ranching practices that eliminate sandy soils and bunchgrass habitats, roads and pipelines that mitigate against migration by eliminating native vegetation, and the invasion of the red imported fire ant. Any or all of these factors may jeopardize the survival of the Houston toad.[22] The management guidelines for the Houston toad recommend the protection of wetland habitat, the conservation and management of existing post oak or loblolly pine woodland and savannah and their associated native plant communities, and the reduction of habitat loss due to pasture establishment.[23] With respect to the reduction of habitat loss due to pasture establishment, it is recommended that potential habitat (rangeland in the Post Oak Savannah region) should be managed as native rangeland pasture for the production of native bunchgrasses and forbs.[24] Any reservoir site in Colorado County must be concerned with the project's potential impact on the endangered Houston toad.

One of the most significant effects of construction of the off-channel reservoir and its associated facilities will be to cultural resources the new reservoir will potentially submerge. There are two types of cultural resources: prehistoric and historic. Prehistoric sites are most likely to be found along natural drainages, while historic sites can be found in any setting, including the uplands. The first task in analysis of the cultural resources that may exist on the project site will be to perform an identification survey. Each site discovered will then be determined to be significant or not. Significant sites will be considered potentially eligible for the National Register of Historic Places. Sites potentially eligible for the National Register must

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[21] Ibid.

[22] Ibid.

[23] Ibid.

[24] Campbell, L. 1995. Endangered and Threatened Animals of Texas. Their Life History and Management. TPWD. Austin, TX.

either be avoided or undergo National Register testing to determine their eligibility status. If they are found to be eligible for inclusion in the National Register of Historic Places, then mitigation ensues. Mitigation entails either avoiding the site or subjecting it to scientific data recovery. All cultural resources issues are negotiated through the State Historic Preservation Office.

The LCRA has existing criteria for minimum instream flows and interim criteria for minimum bay and estuary inflows.[25] Two separate environmental instream flow criteria, critical flows and target flows, have been established in the Colorado River below Austin. These were based on fisheries habitat needs in segments designated on the basis of studies conducted by LCRA staff. Critical flows (Table 3.14-6) are maintained by releasing inflows or stored water from the Highland Lakes, as needed, to maintain daily river flow at the Bastrop gage which should be no less than the established critical instream flow in all years.

Table 3.14-6
Natural Resource Flow Criteria for the Lower Colorado River

	Colorado River Instream Flows		
Critical Flows	15 April to 31 May - 500 cfs minimum at Bastrop gage	All Other Times - 120 cfs minimum at Bastrop gage	To be met at all times with inflows or stored water from highland lakes
Target Flows	Established at 3 gages (Austin, Bastrop and Columbus)	Flow targets vary monthly	To be met with highland lakes inflows during years when there is no curtailment of downstream irrigators
	Matagorda Bay and Estuary Inflows		
Minimum Annual Inflow	272,000 acft/year		
Mean (Min) Seasonal Inflow	375 cfs		
Mean (Min) Monthly Inflow	200 cfs		

SOURCE: Lower Colorado River Authority, Water Management Plan for the Lower Colorado River Basin, 1993

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[25] Lower Colorado River Authority, Water Management Plan for the Lower Colorado River Basin, 1993.

Target flows (Table 3.14-6) which vary monthly have been established for three points in the basin including the Austin gage, Bastrop gage, and Columbus gage. In wetter years when water supplies for the four major irrigation districts are not curtailed, inflows to the Highland Lakes are released on a daily basis to maintain river flows at the target instream flow.

The bay and estuary interim criteria is to maintain a minimum annual inflow of 272,000 acft to Matagorda Bay, a minimum seasonal inflow of 375 cfs, and a minimum mean monthly inflow of 200 cfs. Flow criteria are summarized in Table 3.14-6.

Table 3.14-7 summarizes hydrologic statistics for the four scenarios of this alternative discussed in Section 3.14.2. Median monthly streamflows and flow deciles, with and without each of the four scenarios, are shown for the Bastrop and Columbus gages, and for inflows to Matagorda Bay in Figures 3.14-7 through 3.14-20. This information is presented in a more condensed format in Figures 3.14-19 and 3.14-20, which show the changes in median monthly streamflow (and Matagorda Bay inflow) expected to result from implementation of the four C-5 scenarios.

For evaluation of environmental effects of the variations of this alternative, the without project, or Base Case condition, is represented by current basin conditions with full permitted diversions. Table 3.14-8 shows that for the base case, the daily critical flow would not be met at the Bastrop gage for 80 days during the 10-year drought period of 1947 to 1956, or 2.2 percent of the time. On these days, the reserved storage in Lake Travis which has been specifically set aside for this purpose would be released to maintain the critical flow. A release of 7,500 acft is estimated to be needed over the 10-year period for augmentation of streamflows to the critical flow criteria at the Bastrop location.

The daily target flows at the Bastrop Gage would not be met on 2,755 days or 75.4 percent of the drought period. At Matagorda Bay, the average annual inflow for the simulated period is 925,400 acft during the 10-year drought period is 279,800 acft, and in the minimum year is 46,600 acft.

Table 3.14-7
Hydrologic Effects of Lower Colorado Basin Alternatives

	Instream Flows			Estuary Inflows (acre feet)		
Alternative	Critical Flows[1]	Required Release[2]	Target Flows[3]	Annual Mean[4]	Drought Mean[5]	Minimum Year
Base Case	2.2% (80)	7,500	47.2% (1725) 75.4% (2755)	925,400	279,820	46,600
C5-Natural Drainage	2.6% (94)	10,400	47.5% (1734) 76% (2759)	989,270	253,000	43,600
C5-800 cfs Diversion	2.8% (101)	11,700	48.0 % (1753) 86.7% (3166)	964,600	179,100	600
C5-Under Used Irrigation	2.8% (104)	12,500	47.5% (1735) 72.7% (2656)	1,039,750	276,400	65,700
C5-800 cfs & Under Used Irr	3.1% (113)	13,300	48.3% (1763) 86.6% (3162)	1,007,180	190,700	900

[1] Percent of time (days) critical flows not met at Bastrop gage during 10 year drought of record (1947-1956)

[2] Release from storage to meet critical flows during 10 year drought of record (1947-1956)

[3] Percent of time (days) target flows not met at Bastrop and Columbus gages during 10 year drought of record (1947-1956)

[4] Average for period of record provided by HDR Engineering, Inc.

[5] Average 1947-1956

Table 3.14-8
Hydrologic Effects of Lower Colorado Basin Alternatives

Instream Flows				Estuary inflows (acre feet)		
Alternative	Critical Flows[1]	Required Release[2]	Target Flows[3]	Annual Mean[4]	Drought Mean[5]	Minimum Year
Base Case	2.2% (80)	7,500	47.2% (1725) 75.4% (2755)	925,400	279,820	46,600
C5-Natural Drainage	2.6% (94)	10,400	47.5% (1734) 76% (2759)	989,270	253,000	43,600
C5-800 cfs Diversion	2.8% (101)	11,700	48.0% (1753) 86.7% (3166)	964,600	179,100	600
C5-Under Used Irrigation	2.8% (104)	12,500	47.5% (1735) 72.7% (2656)	1,039,750	276,400	65,700
C5-800 cfs & Under Used Irr	3.1% (113)	13,300	48.3% (1763) 86.6% (3162)	1,007,180	190,700	900

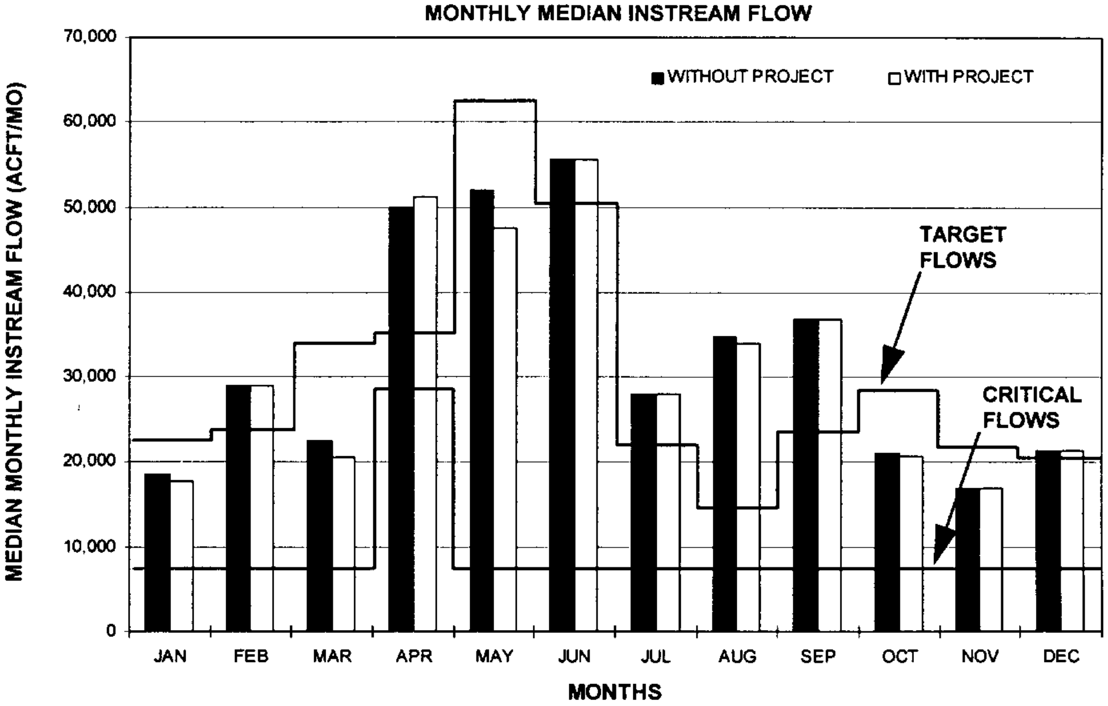
[1] Percent of time (days) critical flows not met at Bastrop gage during 10 year drought of record (1947-1956)

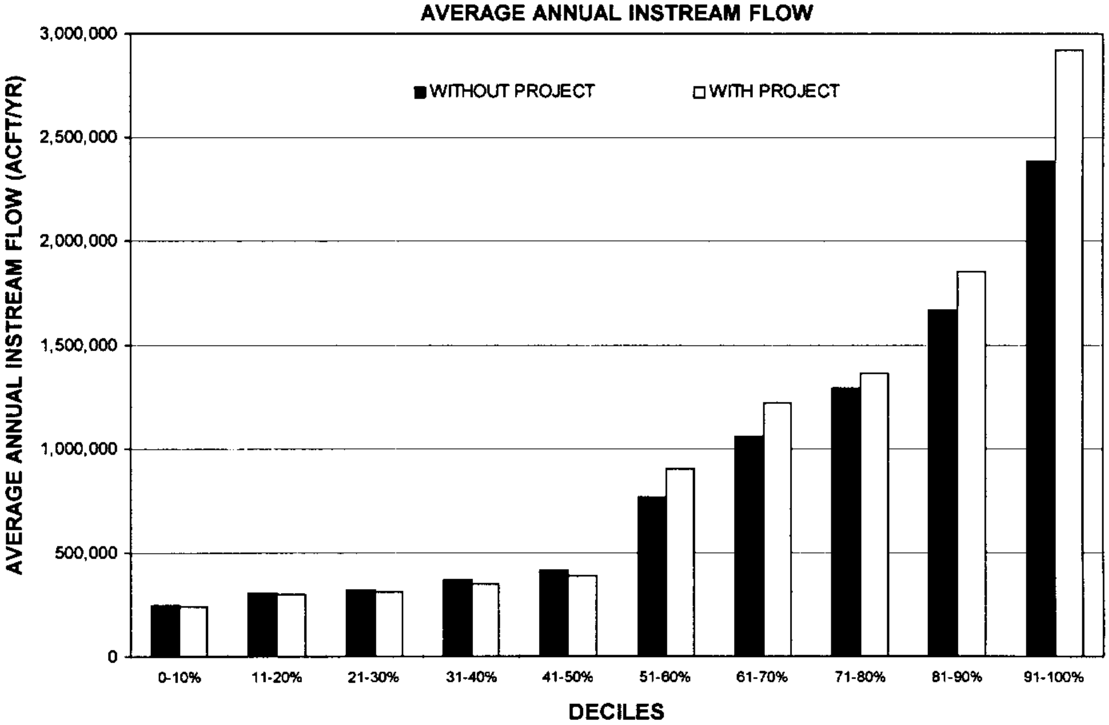
[2] Release from storage to meet critical flows during 10 year drught of record (1947 - 1956)

[3] Percent of time (days) target flows not met at Bastrop and Columbus gages during 10 year drought of record (1947-956)

[4] Average for period of record provided by HDR Engineering, Inc.

[5] Average 1947-1956





NOTES:

1. "WITHOUT PROJECT" IS THE BASE CONDITION WITH ALL EXISTING WATER RIGHTS ATTEMPTING TO DIVERT FULL AUTHORIZED AMOUNTS.
2. "WITH PROJECT" INCLUDES AN OFF-CHANNEL RESERVOIR ON CUMMINS CREEK OPERATED TO MEET LOWER BASIN IRRIGATION DEMAND.

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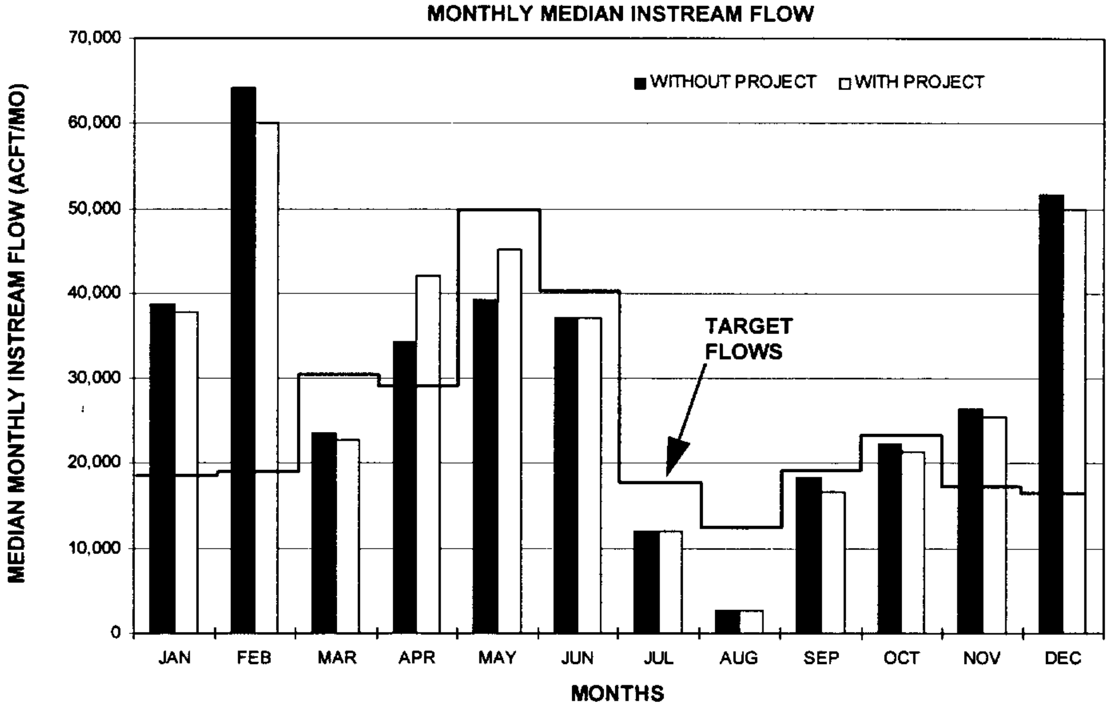
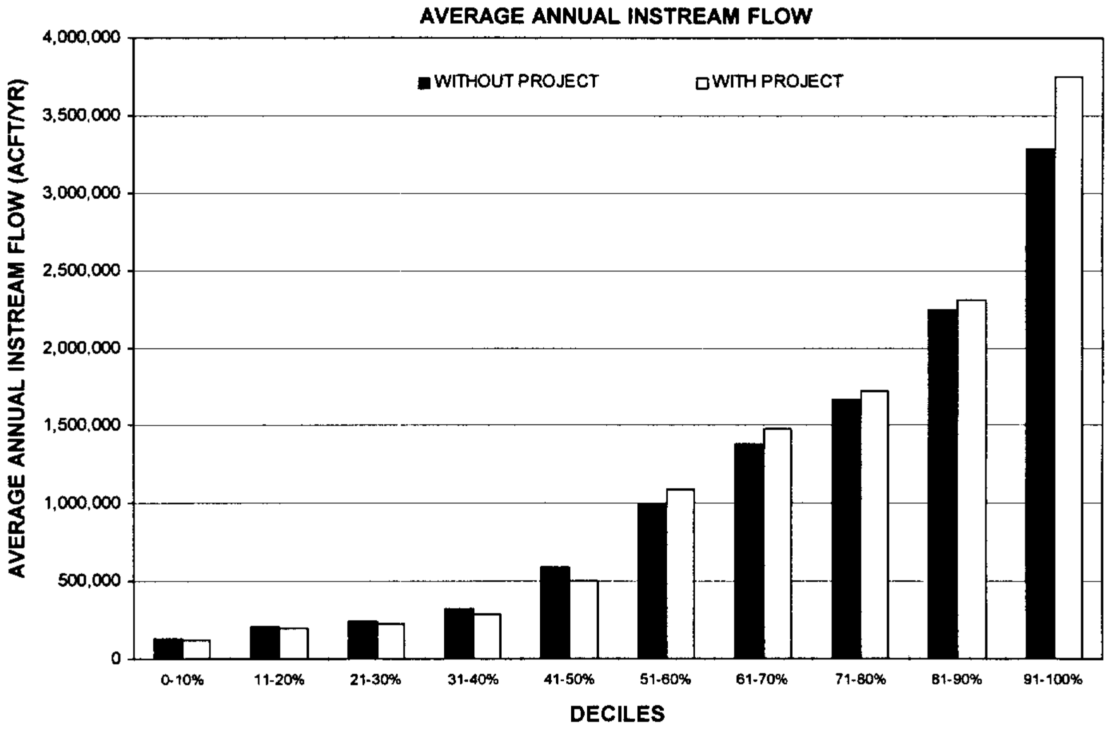
CHANGES IN COLORADO RIVER FLOWS AT BASTROP WITH OFF-CHANNEL RESERVOIR ALTERNATIVE C-5A

FIGURE 3.14-7





NOTES:

1. "WITHOUT PROJECT" IS THE BASE CONDITION WITH ALL EXISTING WATER RIGHTS ATTEMPTING TO DIVERT FULL AUTHORIZED AMOUNTS.
2. "WITH PROJECT" INCLUDES AN OFF-CHANNEL RESERVOIR ON CUMMINS CREEK OPERATED TO MEET LOWER BASIN IRRIGATION DEMAND.

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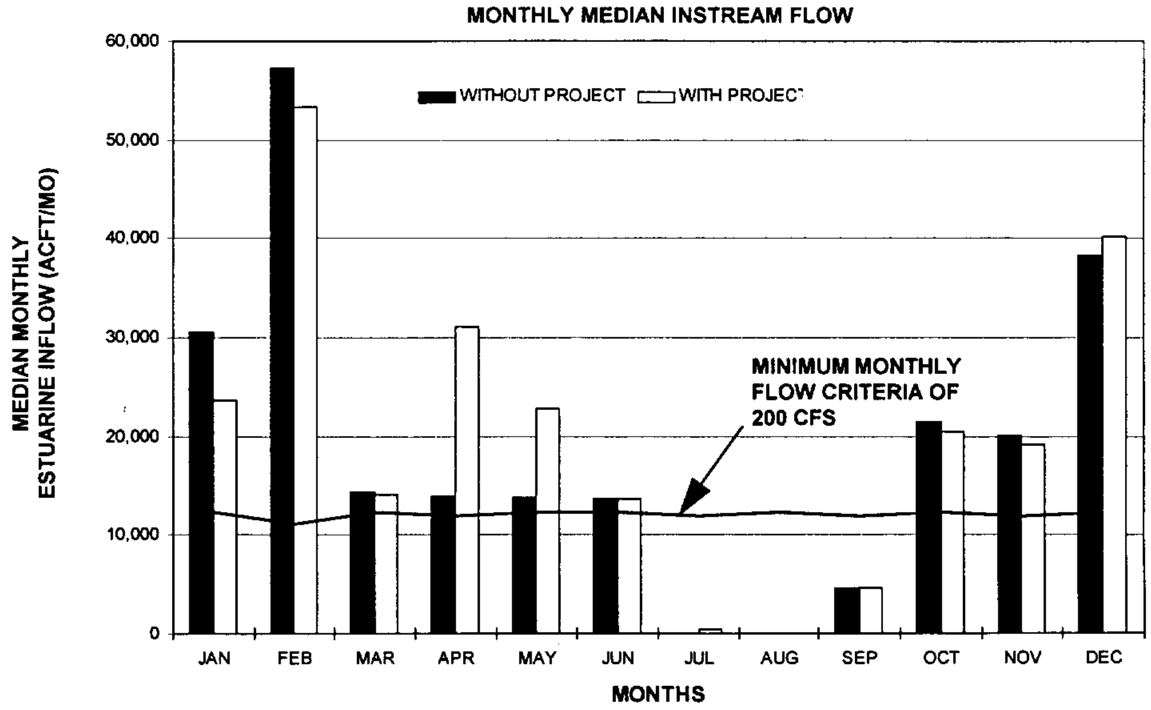
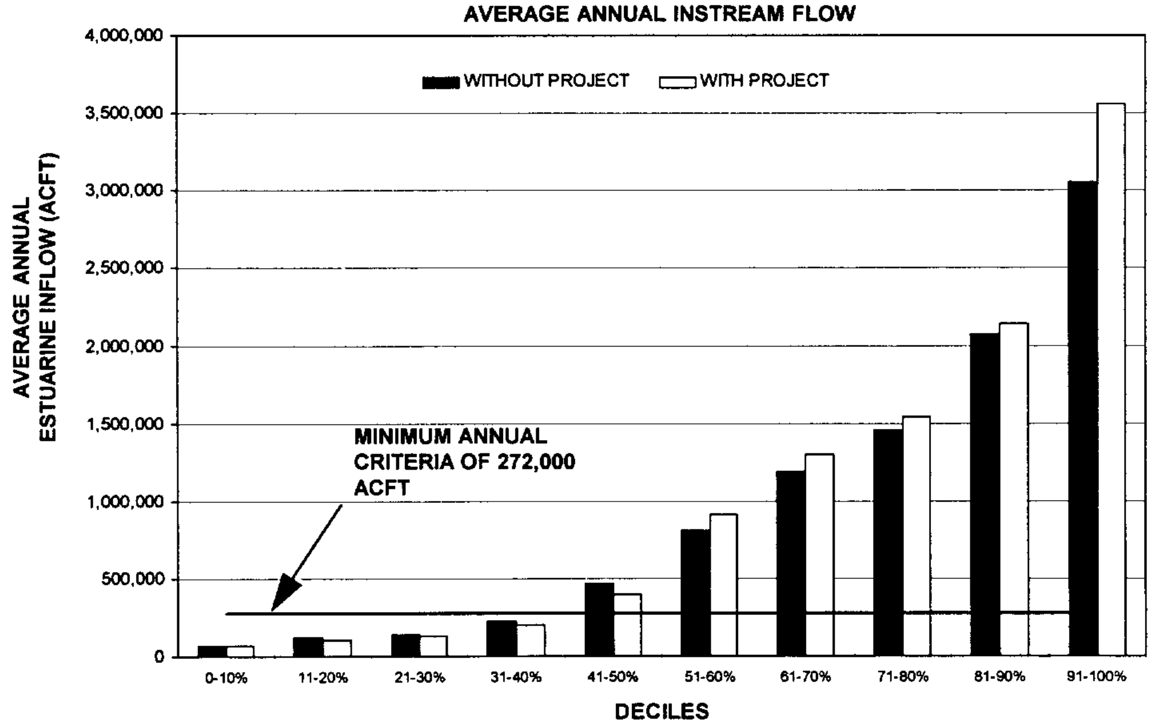
CHANGES IN COLORADO RIVER FLOWS AT COLUMBUS WITH OFF-CHANNEL RESERVOIR ALTERNATIVE C-5A

FIGURE 3.14-8





NOTES:

1. "WITHOUT PROJECT" IS THE BASE CONDITION WITH ALL EXISTING WATER RIGHTS ATTEMPTING TO DIVERT FULL AUTHORIZED AMOUNTS.
2. "WITH PROJECT" INCLUDES AN OFF-CHANNEL RESERVOIR ON CUMMINS CREEK OPERATED TO MEET LOWER BASIN IRRIGATION DEMAND.

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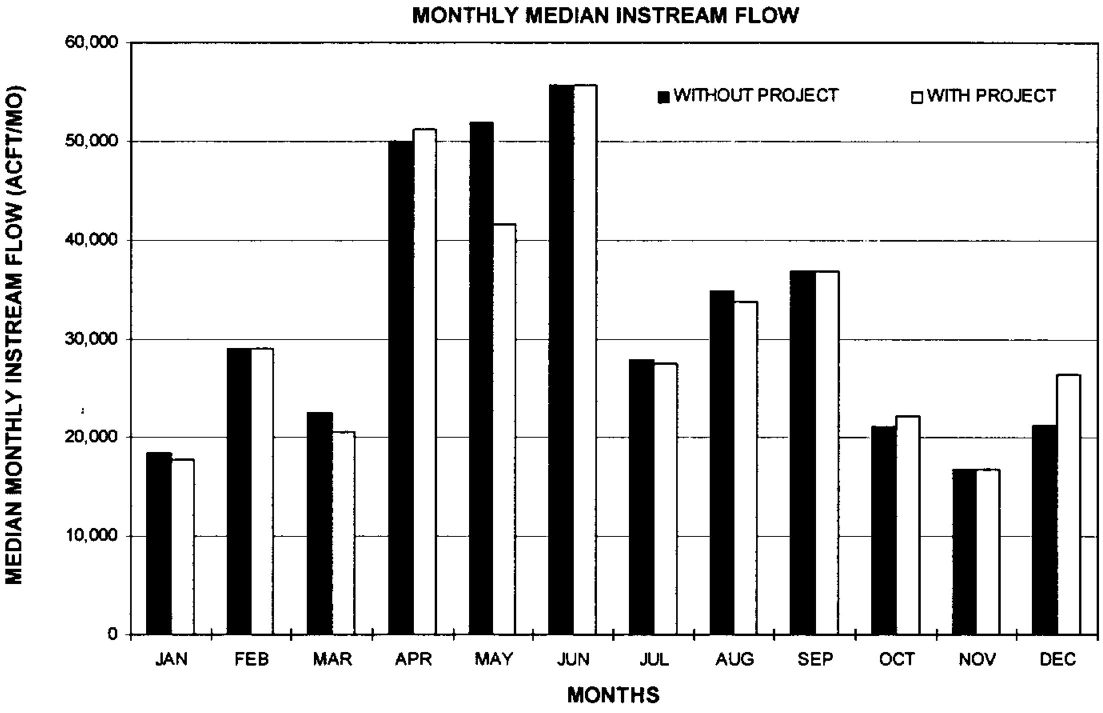
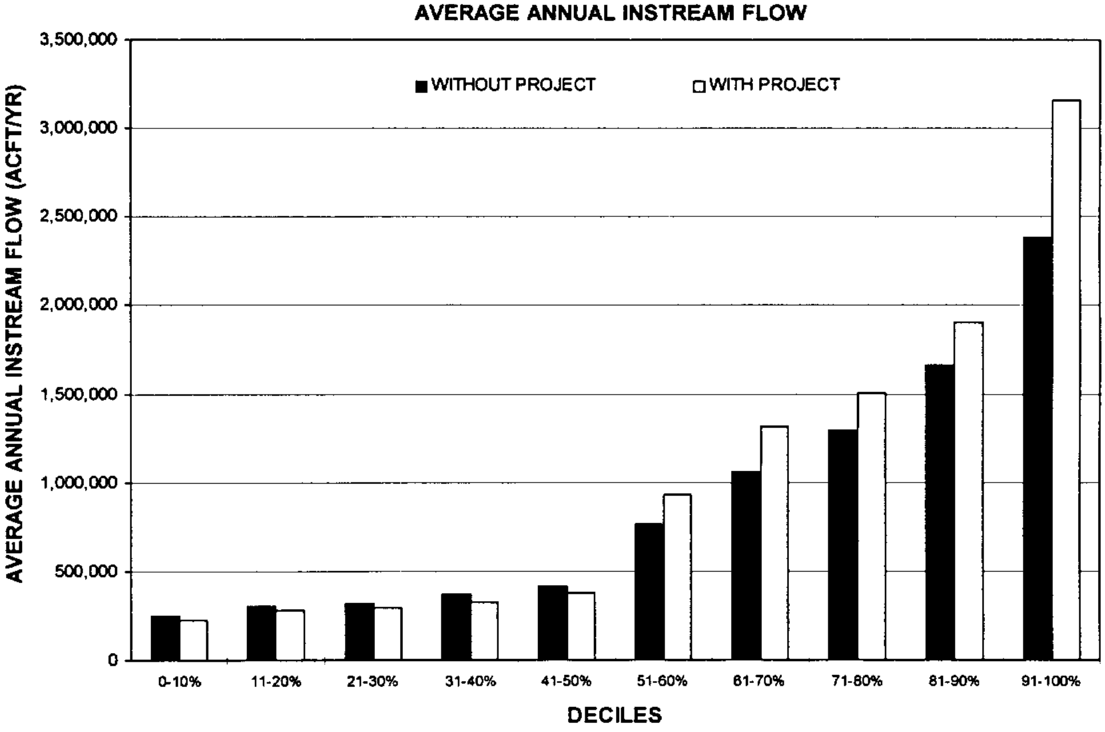
CHANGES IN MATAGORDA BAY INFLOWS WITH OFF-CHANNEL RESERVOIR - ALTERNATIVE C-5A

FIGURE 3.14-9


MONTHLY MEDIAN INSTREAM FLOW


AVERAGE ANNUAL INSTREAM FLOW

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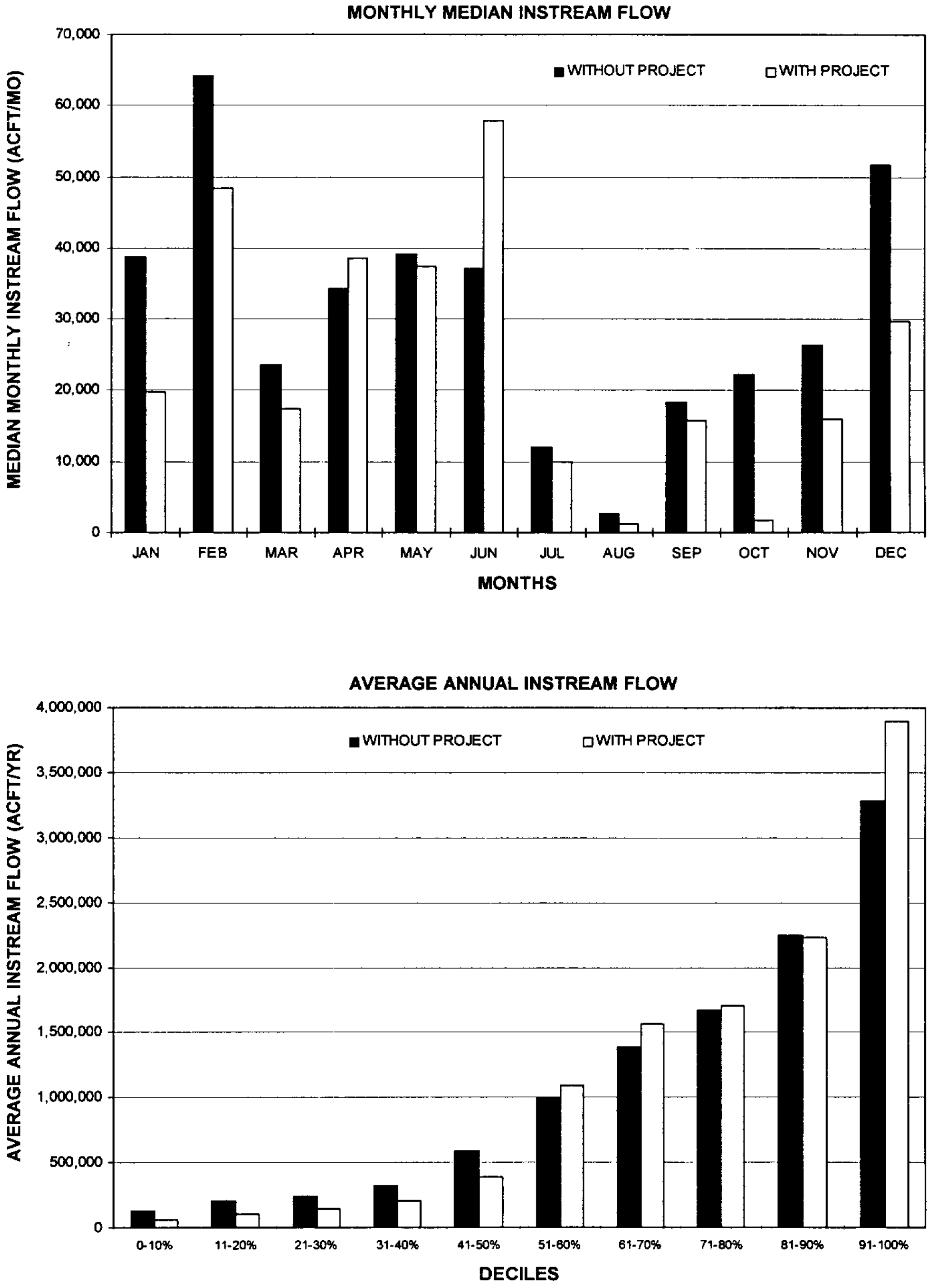
CHANGES IN COLORADO RIVER FLOWS AT BASTROP WITH OFF-CHANNEL RESERVOIR AND 800 CFS DIVERSION - ALTERNATIVE C-5B

FIGURE 3.14-10



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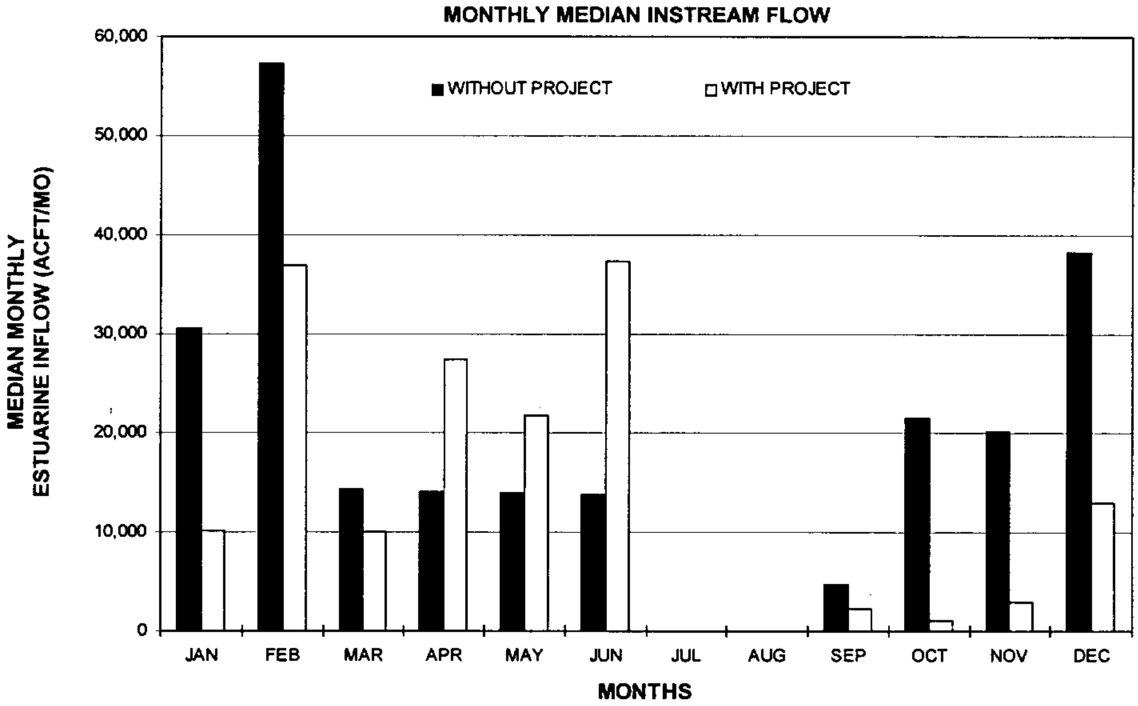
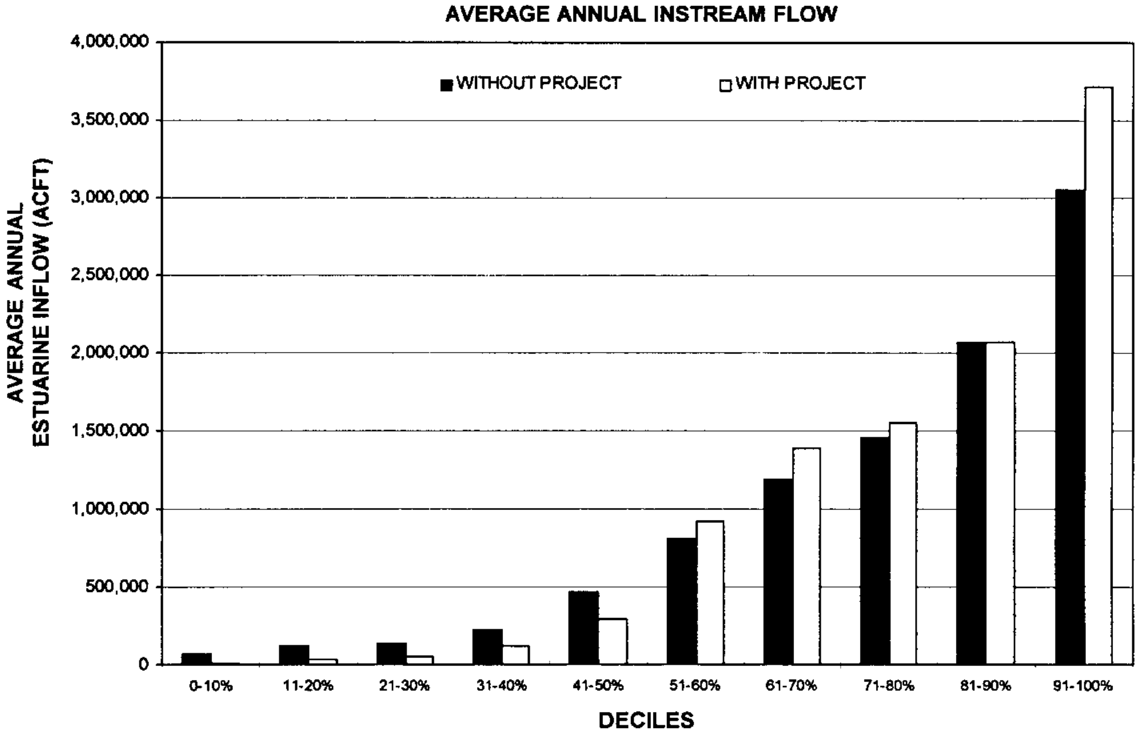
CHANGES IN COLORADO RIVER FLOWS AT COLUMBUS WITH OFF-CHANNEL RESERVOIR AND 800 CFS DIVERSION - ALTERNATIVE C-5B

FIGURE 3.14-11





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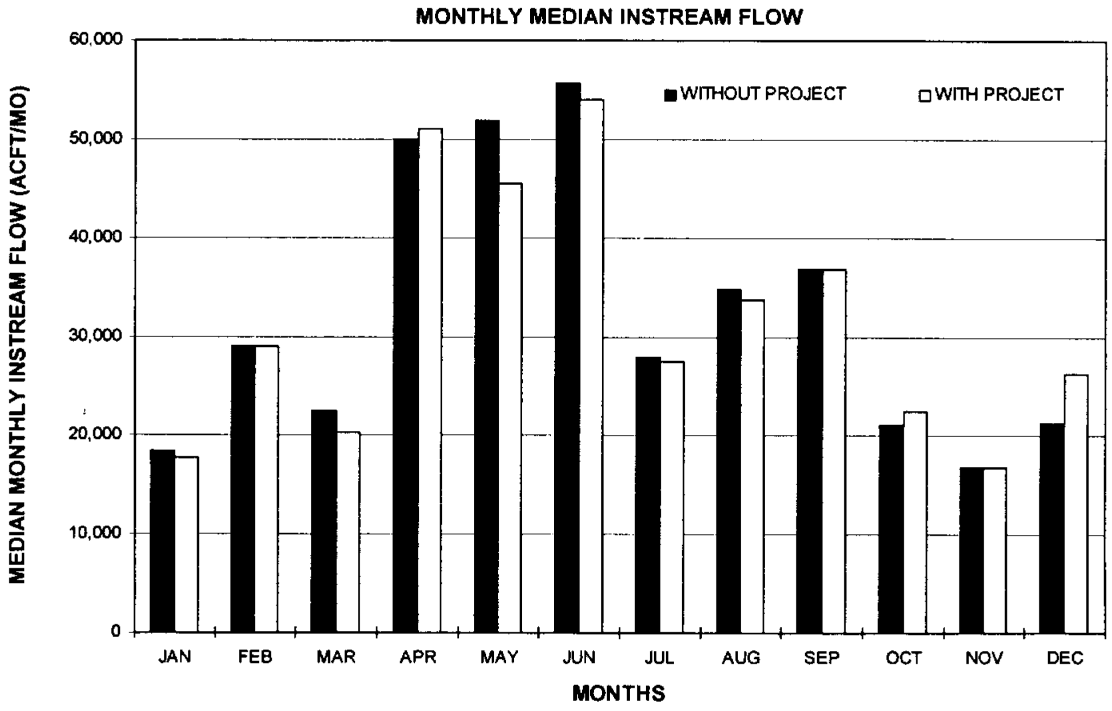
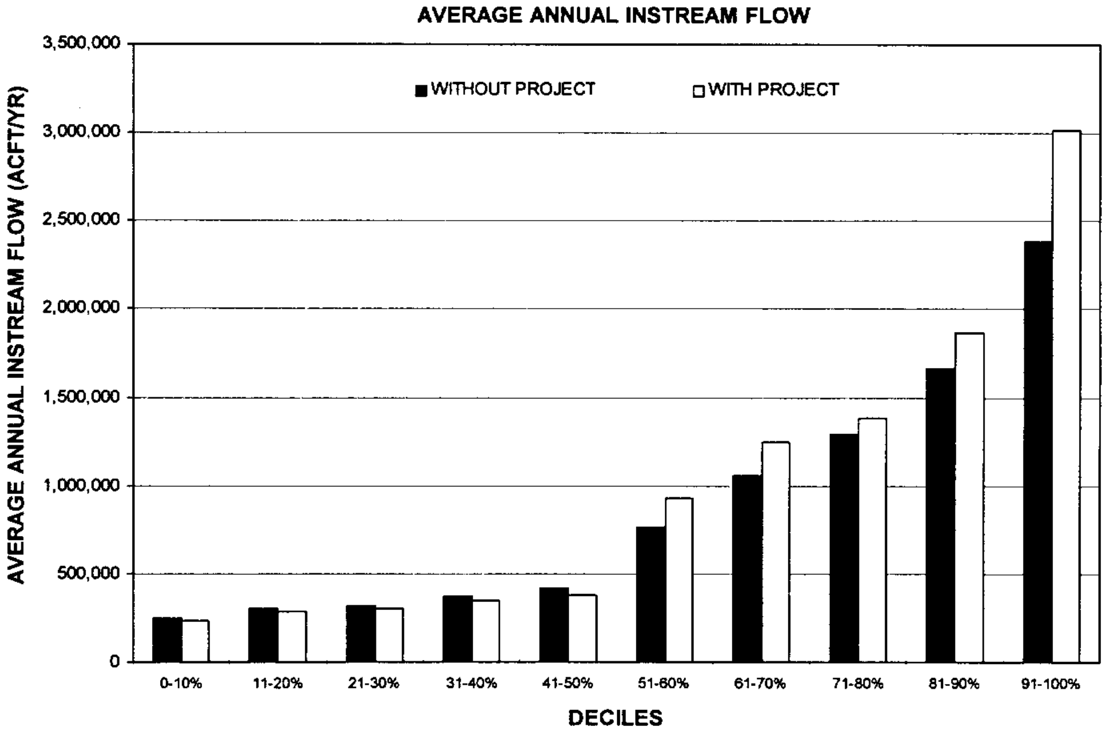
CHANGES IN MATAGORDA BAY INFLOWS WITH OFF CHANNEL STORAGE AND 800 CFS DIVERSION ALTERNATIVE C-5B

FIGURE 3.14-12





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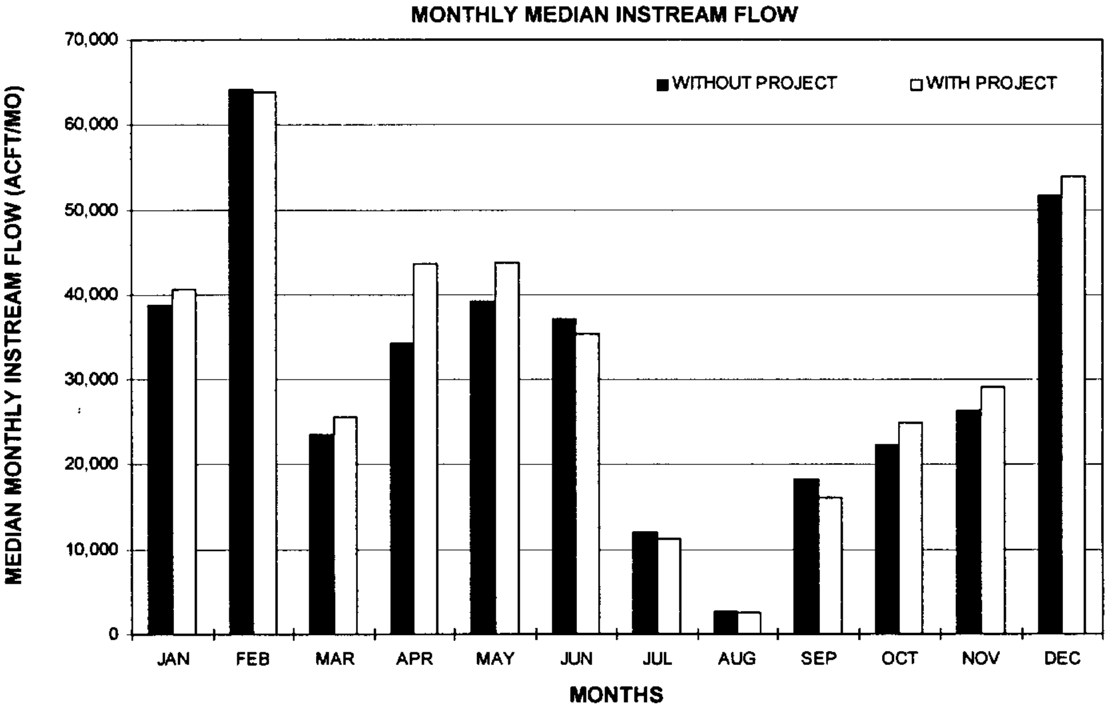
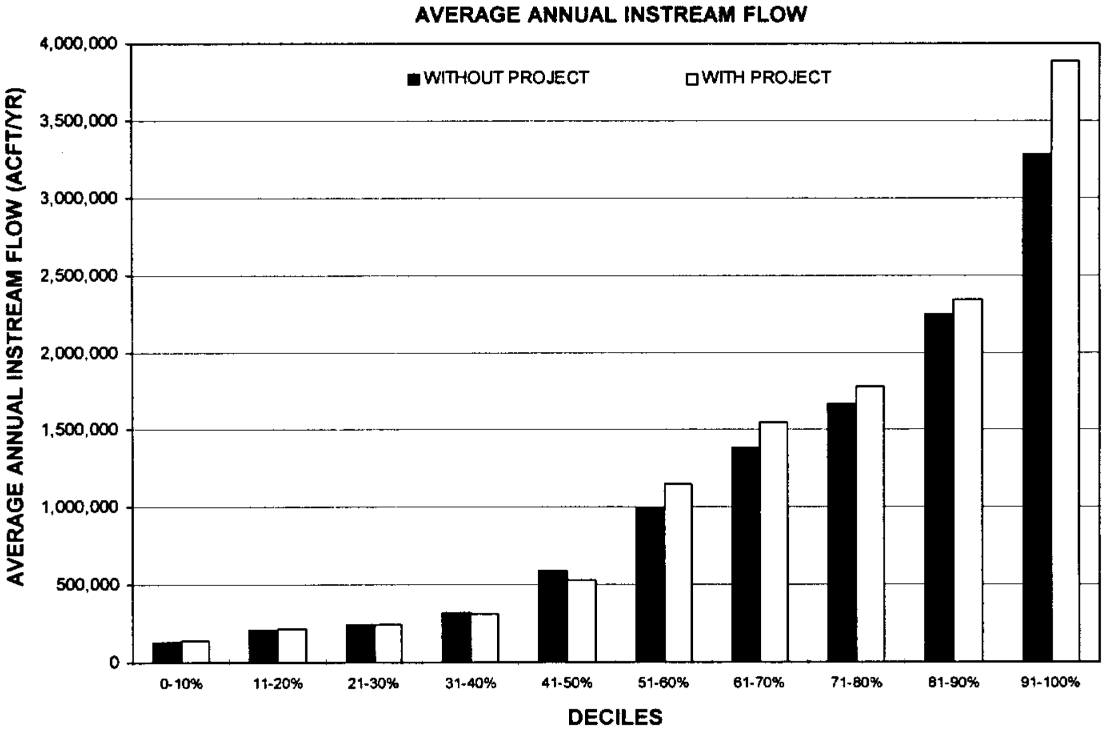
CHANGES IN COLORADO RIVER FLOWS AT BASTROP WITH OFF-CHANNEL RESERVOIR AND 75,000 ACFT PURCHASE ALTERNATIVE C-5C

FIGURE 3.14-13





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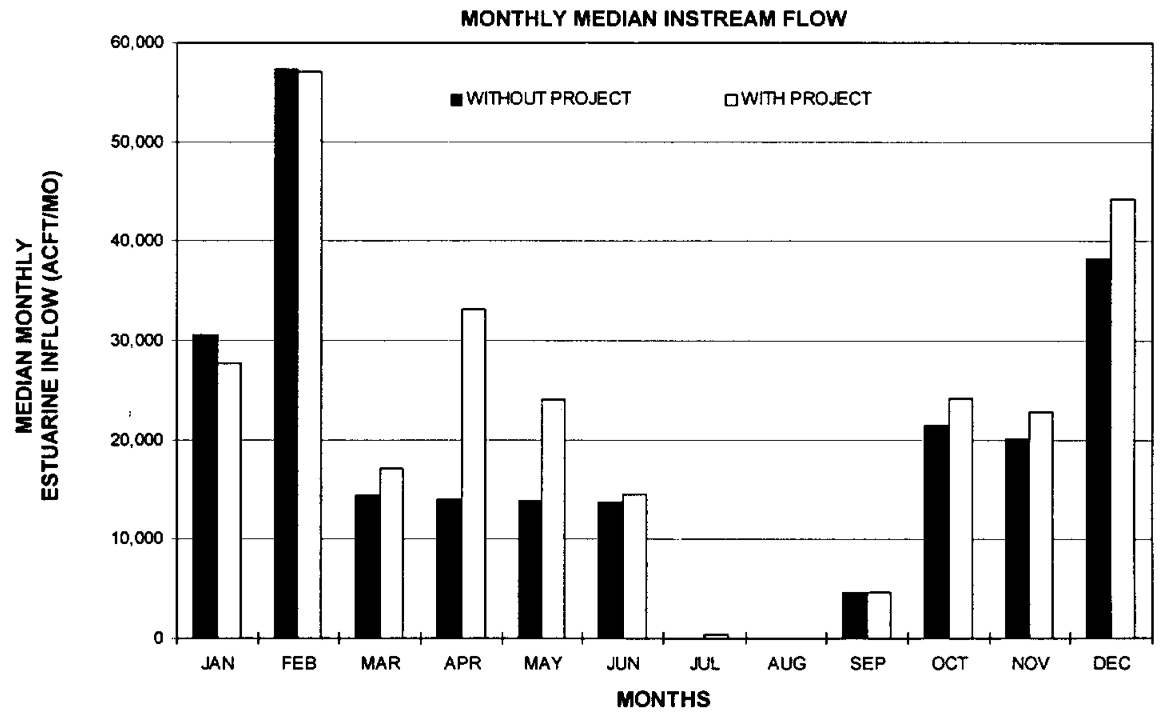
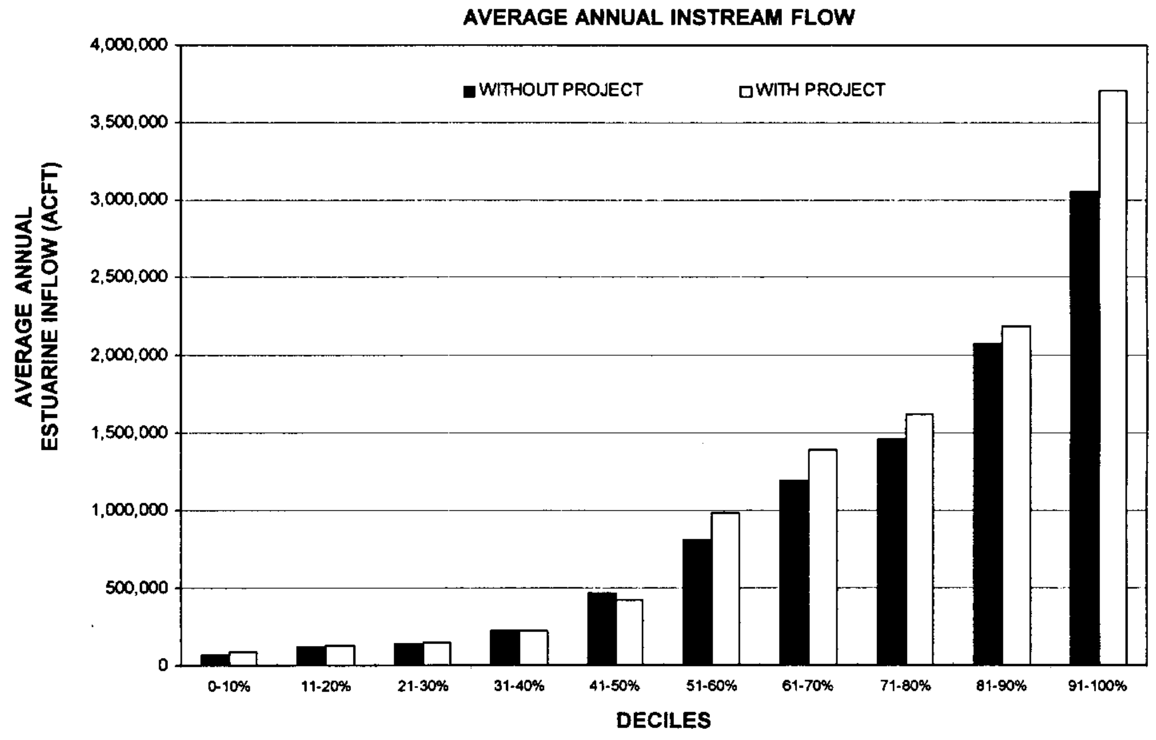
CHANGES IN COLORADO RIVER FLOWS AT COLUMBUS WITH OFF-CHANNEL RESERVOIR AND 75,000 ACFT PURCHASE ALTERNATIVE C-5C

FIGURE 3.14-14





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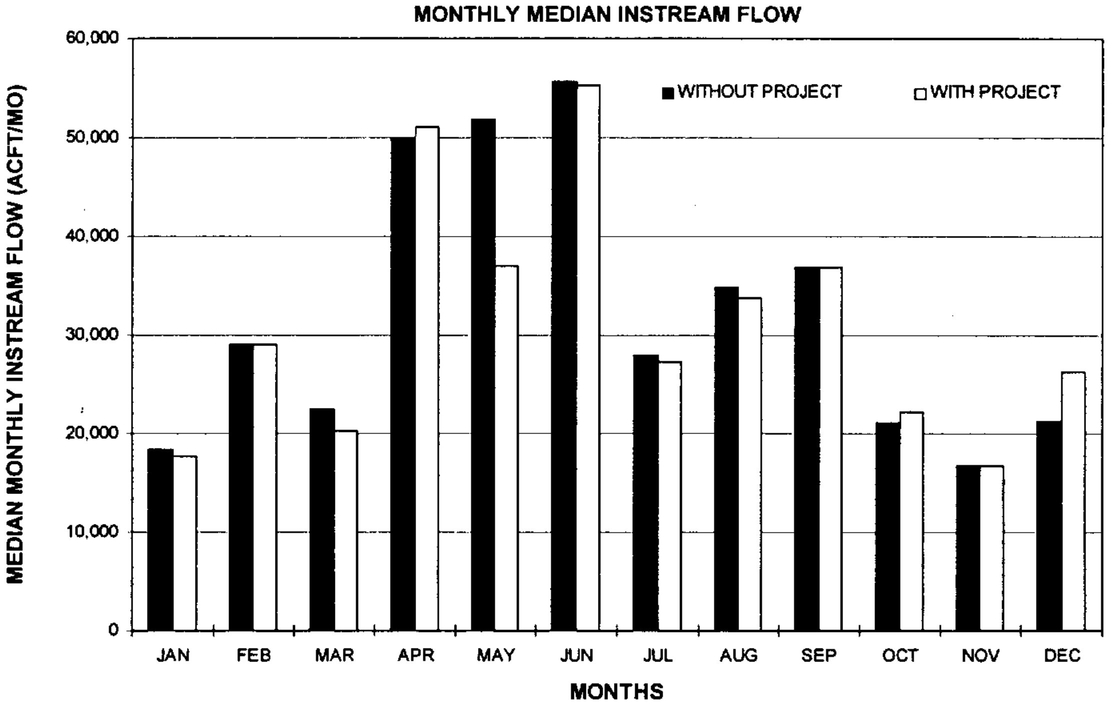
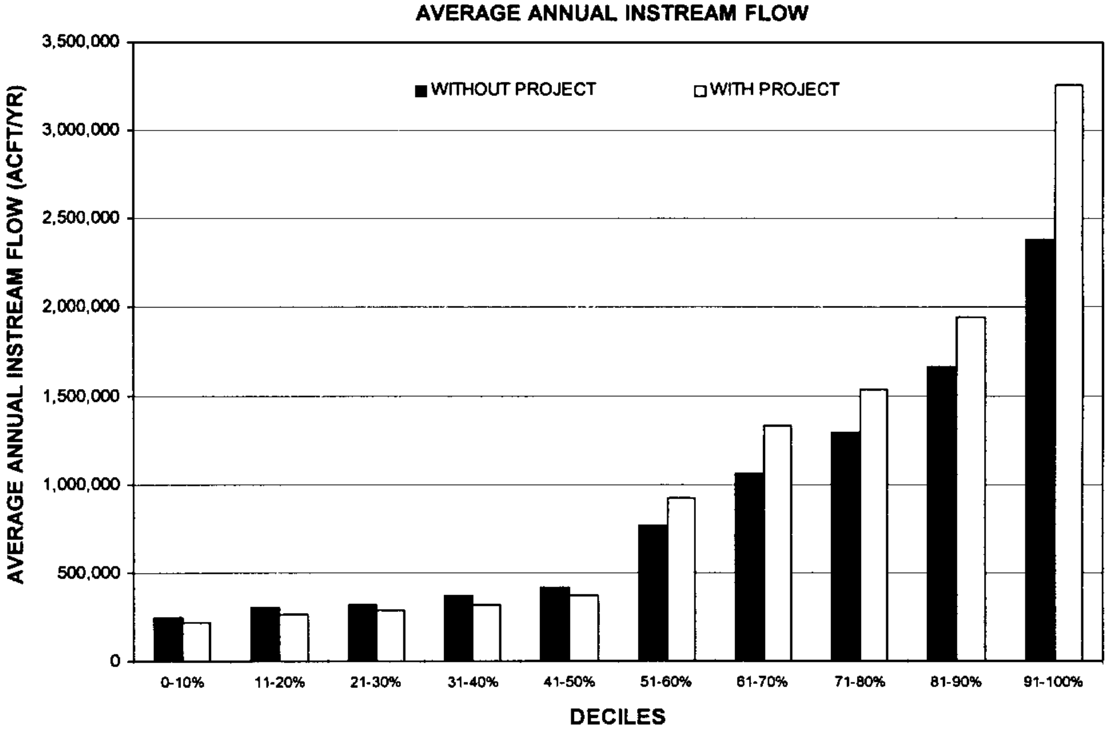
CHANGES IN MATAGORDA BAY INFLOWS WITH OFF-CHANNEL RESERVOIR AND 75,000 ACFT PURCHASE - ALTERNATIVE C-5C

FIGURE 3.14-15





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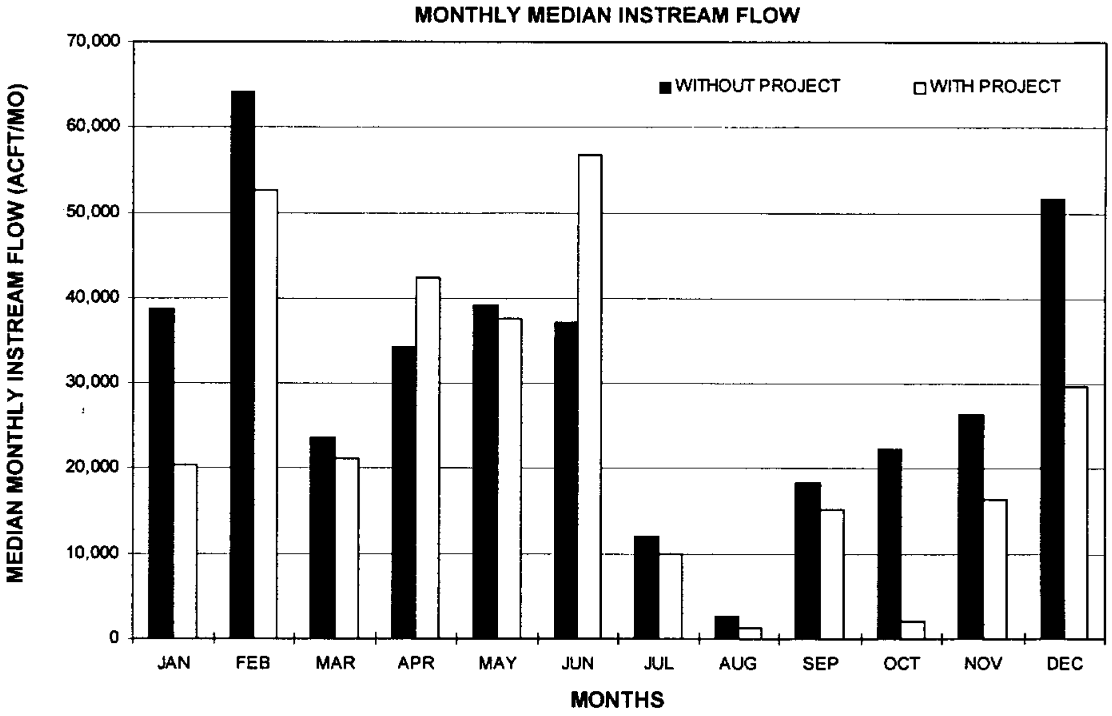
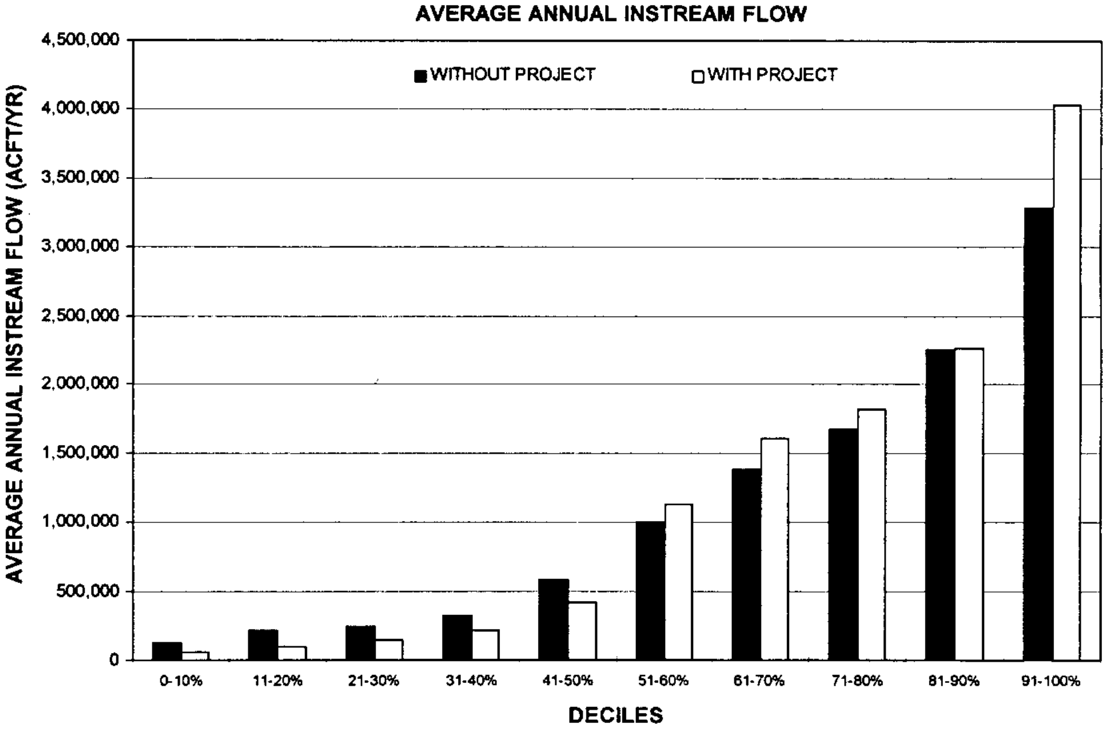
CHANGES IN COLORADO RIVER FLOWS AT BASTROP WITH OFF-CHANNEL RESERVOIR, 800 CFS DIVERSION AND 75,000 ACFT PURCHASE - ALTERNATIVE C-5D

FIGURE 3.14-16





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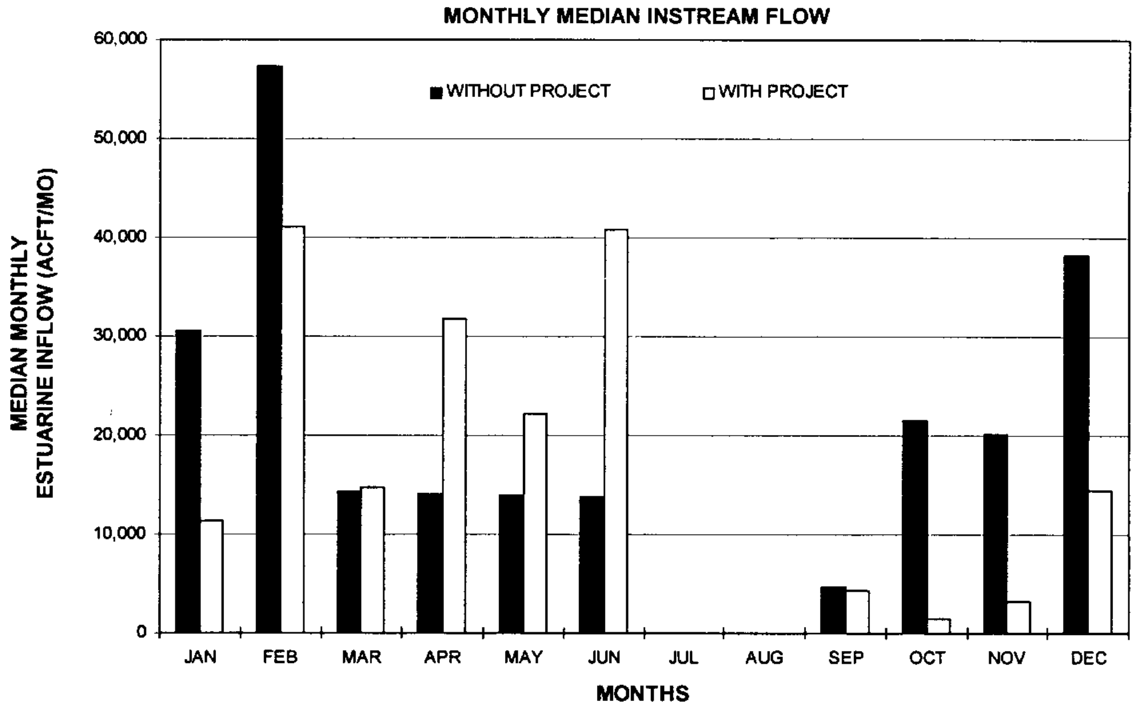
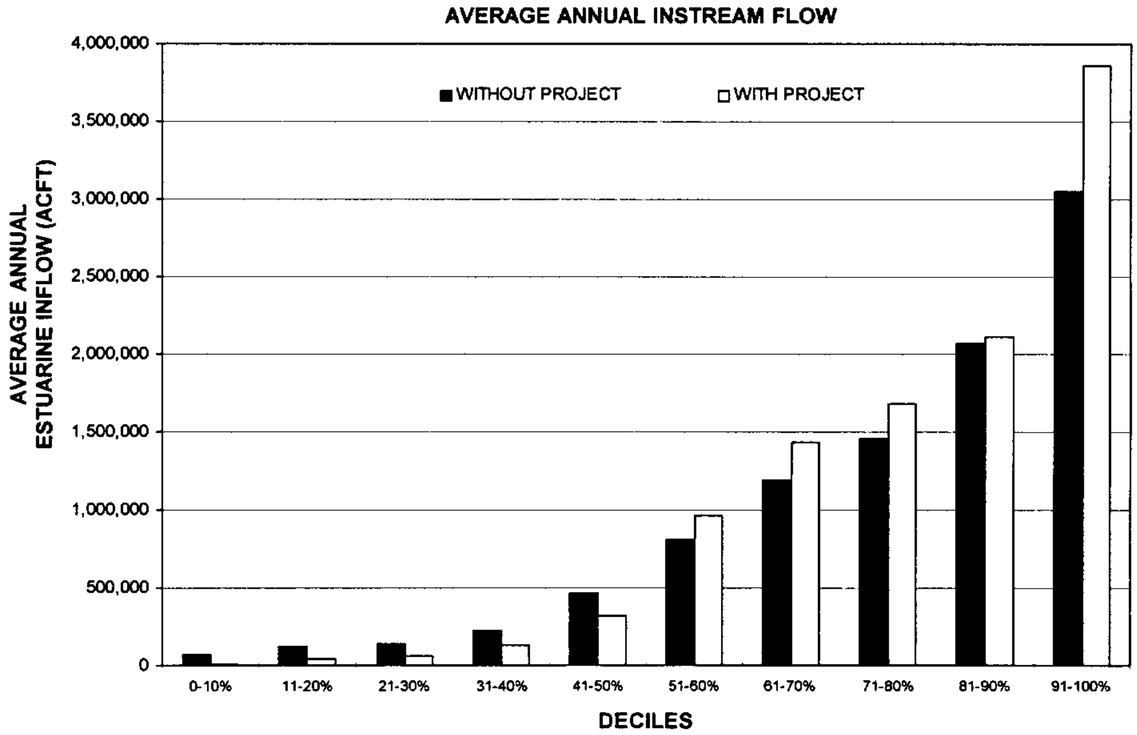
CHANGES IN COLORADO RIVER FLOWS AT COLUMBUS WITH OFF-CHANNEL RESERVOIR, 800 CFS DIVERSION AND 75,000 ACFT PURCHASE - ALTERNATIVE C-5D

FIGURE 3.14-17





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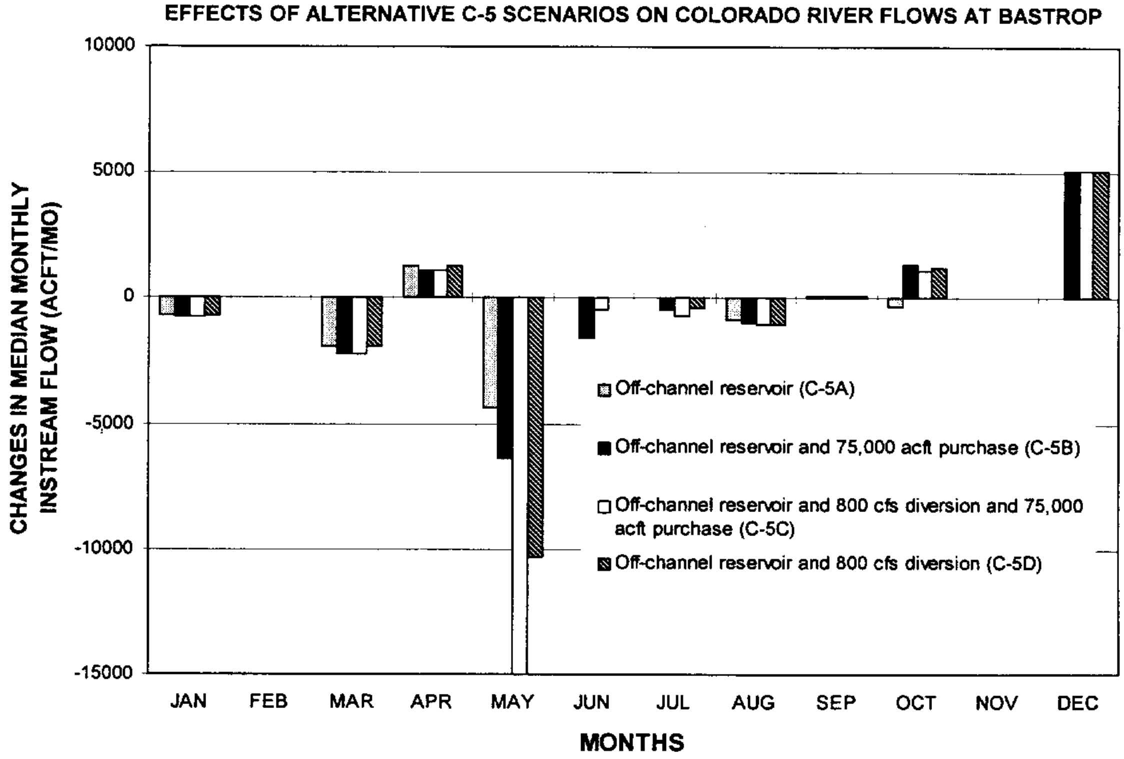
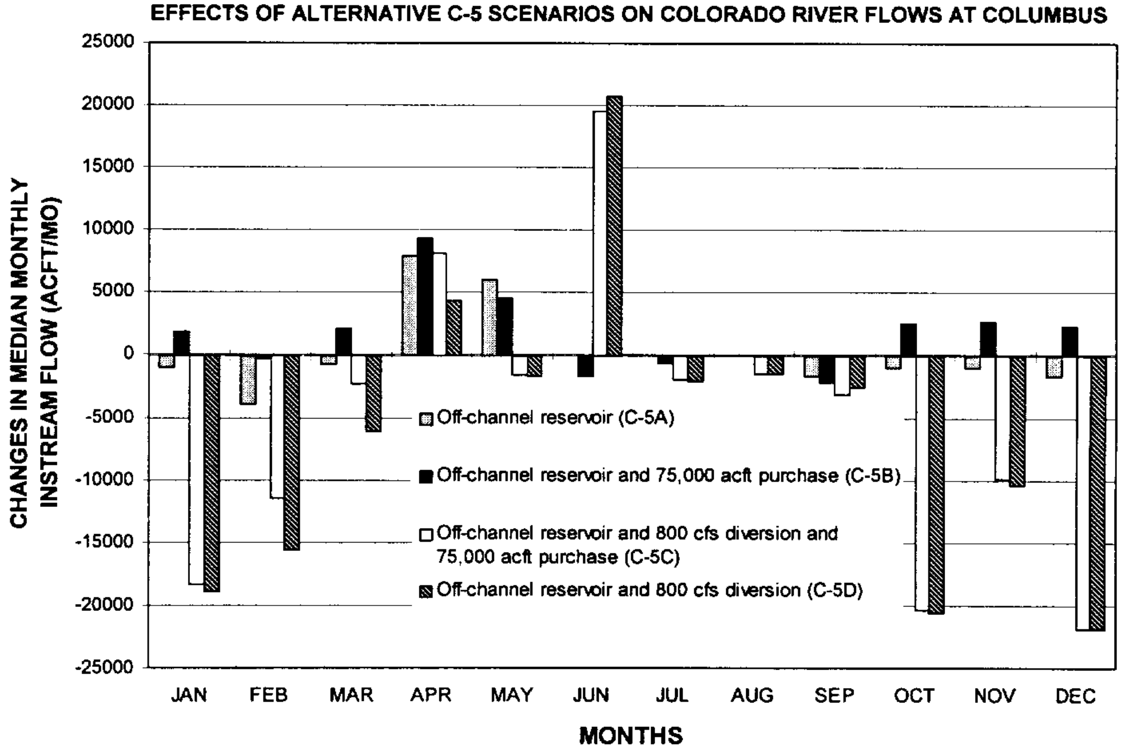
CHANGES IN MATAGORDA BAY INFLOWS WITH OFF-CHANNEL RESERVOIR, 800 CFS DIVERSION, AND 75,000 ACFT PURCHASE ALTERNATIVE C-5D

FIGURE 3.14-18



EFFECTS OF ALTERNATIVE C-5 SCENARIOS ON COLORADO RIVER FLOWS AT BASTROP



EFFECTS OF ALTERNATIVE C-5 SCENARIOS ON COLORADO RIVER FLOWS AT COLUMBUS

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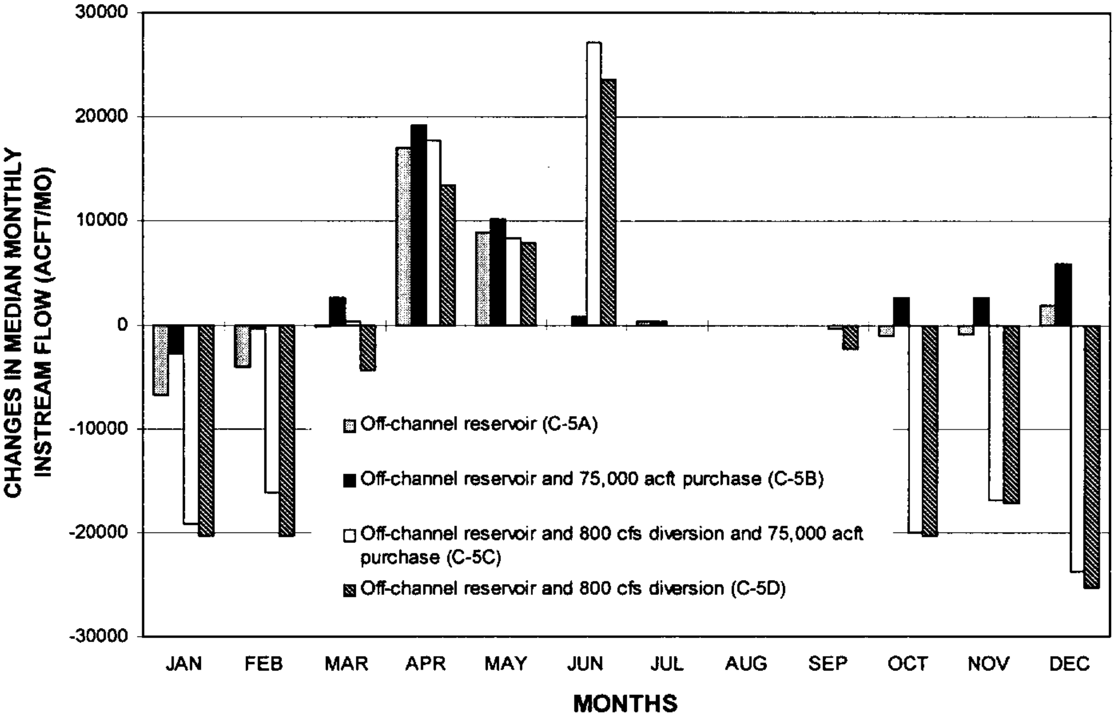
CHANGES IN COLORADO RIVER FLOWS AT BASTROP AND COLUMBUS ALTERNATIVE C-5

FIGURE 3.14-19

EFFECTS OF ALTERNATIVE C-5 SCENARIOS ON MATAGORDA BAY INFLOWS



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CHANGES IN MATAGORDA BAY INFLOWS ALTERNATIVE C-5

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FIGURE 3.14-20

Inspection of Table 3.14-8 shows that, compared to the Base Case, none of the four scenarios have substantial impact on the frequency at which critical or target flows at the Bastrop gage go unmet during the drought of record. At the Columbus gage, the purchase of 75,000 acft/yr of under-utilized irrigation rights results in a decrease in the frequency of unmet target flows, while the two scenarios that include diversion of up to 800 cfs of run-of-river water result in large increases (about 15 percent) in the number of days that target flows are not achieved. These latter two scenarios have the most adverse effects on drought mean and minimum year inflows to Matagorda Bay, while all scenarios result in higher overall mean inflows relative to the Base Case.

The predicted effects of implementation of this alternative on median monthly streamflows and on average flow distributions vary substantially among scenarios and gauging stations (Figures 3.14-6 through 3.14-20). Changes in median monthly flows as a result of all four scenarios tended to be small (less than 10 percent) and to include both increases and decreases. Simulation modeling shows some scenarios, particularly those involving diversion from the Colorado River, to result in large changes in the median flows of particular months (Figures 3.14-13, and 3.14-18 through 3.14-20). Larger changes are predicted to occur more frequently at Columbus and Matagorda Bay than at the Bastrop gage, which reflects conditions in the reach containing the breeding habitat for the blue sucker (Figures 3.14-18 through 3.14-20).

All scenarios are predicted to result in a flow distribution with increased proportions of higher flows relative to the Base Case (i.e., larger average annual flows in the deciles above 50 percent; Figure 3.14-6 et seq.). The two scenarios that include 800 cfs diversions would also reduce average annual flows in the lower (less than 50 percent) deciles. This effect is particularly pronounced at Matagorda Bay (Figure 3.14-14), and reflect the more extreme changes in drought period inflows noted in Table 3.14-8.

These hydrologic changes would appear to be substantial if predicted to occur in a pristine river and estuary; however, this river and estuary are not pristine environments. The lower Colorado River is highly regulated with the Highland Lakes system and heavily utilized for agricultural production, consequently it has an annual hydrograph far different from its natural flow regime. Matagorda Bay, likewise, has experienced the near total loss and subsequent restoration of Colorado River inflows during the past century, and is presently in a transitional state following the modifications of the delta completed by the U.S. Army Corps of Engineers in the early 1990s. While the two 800 cfs diversion scenarios tend to result in the largest hydrologic changes relative to the base case, judgments concerning the significance of those changes to biological communities or to particular, important species will require additional study.

3.14.4 Water Quality and Treatability

Implementation of this alternative would increase the availability of water in Lake Travis to be committed for municipal use in the study area. No new or outside sources of water would be introduced to Lake Travis, consequently, this section needs only to consider Lake Travis water quality.

Lake Travis is considered one of the highest quality surface water supplies in the state. Table 3.14-9 summarizes some of the conventional water quality constituents in Lake Travis. It is characterized by low nutrient levels and moderate levels of chlorides and sulfates. Nutrient concentrations in Lake Travis are usually below levels at which algae blooms are significant; however, inflows from stormwater runoff have been known to create elevated nutrient levels resulting in isolated periods of algal growth.[26] Hypersaline flows at Natural Dam Lake caused chloride, sulfate, and TDS levels in Lake Travis to increase considerably in 1988.[27]

Lake Travis is protected by TNRCC's Chapter 311, Water Protection, which prohibits discharge of pollutants into the reservoir's water quality area unless sufficient treatment is applied so that the lake's existing water quality is maintained.[28] With TNRCC's anti-degradation policy, the water quality of the reservoir is expected to remain relatively constant. However, increased population and development in the Lake Travis watershed could eventually lead to extended periods of algal growth or other water quality problems from non-point source pollution.

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[26] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.
[27] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.
[28] Texas Administrative Code, Title 31, Chapter 311.

Table 3.14-9
Conventional Water Quality Constituents in Lake Travis[1]

Constituent	Lake Travis
Dissolved Oxygen (mg/l)	8.04
pH (su)	8.23
TDS (mg/l)	467.36
Fecal Coliforms (No./100 ml)	41.07
Chloride (mg/l)	110.30
Sulfate (mg/l)	83.75
Total Phosphorus (mg/l)	0.04
Total Nitrogen[2] (mg/l)	0.13

[1] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.
[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Conventional treatment including rapid mix, flocculation, sedimentation, filtration, and disinfection as currently used by the City of Austin and the City of Cedar Park should continue to be adequate for treating the additional raw water diverted from Lake Travis pending any significant modifications to the state drinking water standards. Additional taste and odor control measures may need to be applied to increase the aesthetic quality of the water when necessary.

3.14.5 Engineering and Costing

<u>A. Off-Channel Reservoir Only — Alt C-5A</u>

For this alternative, an off-channel reservoir would be built on Cummins Creek. A previous study[29] was utilized as a basis for determining cost estimates. The earlier cost estimates were adjusted to fourth-quarter 1996 market conditions. Cost estimates for the reservoir and dam are summarized in Column A of Table 3.14-10.

---

[29] U.S. Bureau of Reclamation, Colorado Coastal Plains Project, 1977.

Table 3.14-10
Cost Estimate Summary for Off-Channel Storage and Diversion Facilities of Colorado River Water
(1st Quarter 199 Dollars)

Item	Column A Reservoir Only (Alt C-5A)	Column B Reservoir with Diversion (Alt C-5B)
Capital Costs		
Channel Dam	$ 0	$ 3,660,000
Intake and Pump Station	0	7,960,000
Pipeline and Crossings	0	19,920,000
Dam and Reservoir	45,890,000	45,890,000
Total Capital Costs	$ 45,890,000	$ 77,430,000
Engineering, Contingencies, and Legal	$ 16,060,000	$ 26,110,000
Land Easements	30,800,000	30,840,000
Environmental Studies and Mitigation	19,080,000	21,090,000
Interest During Construction	5,960,000	6,830,000
Total Project Costs	$117,790,000	$162,300,000
Annual Costs		
Annual Debt Service	$ 11,040,000	$ 15,210,000
Annual Operation and Maintenance (Excluding Power)	690,000	1,110,000
Annual Power	0	1,080,000
Total Annual Cost	$ 11,730,000	$ 17,400,000
Annual Project Yield*	36,600 acft/yr*	67,300 acft/yr*
Annual Unit Cost for Raw Water	$320 per acft	$259 per acft

* Net benefit to COA, Lake Travis firm yield, and senior rights with mitigation for reduced freshwater inflows to Matagorda Bay. See Tables 3.14-1 and 3.14-2.

The capital cost of the dam and reservoir is estimated to be $45,890,000 not including land acquisition, environmental studies, and mitigation. Total project cost including engineering, permitting, land acquisition, environmental studies, and mitigation is estimated to be $117,790,000. Financed at 8 percent interest for 25 years, annual debt service would be

$11,040,000. Annual operation and maintenance cost for the dam and reservoir is estimated to be $690,000 for a total annual cost of $11,730,000.

Benefits at Lake Travis, expressed in terms of increases in firm yield is 42,400 acft/yr (Table 3.14-1). For a total annual cost of $11,730,000, the annual unit cost of the increased raw water supply at Lake Travis is $277 per acft.

This alternative would also provide additional water to be made available to City of Austin water rights (1,400 acft/yr) and to lower basin senior water rights (19,600 acft/yr). The total increased water supply to all rights holders made available by this alternative would be 63,400 acft/yr (Table 3.14-1). However, freshwater inflows to Matagorda Bay would be reduced by about 26,800 acft/yr with implementation of this alternative. By mitigating the reduced freshwater inflows with water made available from this alternative, the net water supply benefit from this alternative is about 36,600 acft/yr.[30]

The resulting annual unit cost for increased raw water supply of this alternative, considering water supply benefits to all users and mitigating the reduced inflows to Matagorda Bay, increases to $320 per acft as shown in Table 3.14-10 ($11,730,000 annual cost divided by 36,600 acft/yr increased water supply).

B. Off-Channel Reservoir and Diversion Facilities on Colorado River — Alt C-5B

For this alternative, unappropriated run-of-river water would be pumped from the Colorado River and stored in an off-channel reservoir on Cummins Creek near Columbus. In addition to Colorado River water, the reservoir would also store water from the Cummins Creek watershed. The benefit of the project is increased water availability both to users of the Highland Lakes and to downstream water rights holders.

The major facilities required to implement this alternative are:

- Channel Dam on Colorado River,
- Intake and pump station,
- Raw water pipeline to off-channel reservoir on Cummins Creek, and
- Off-channel reservoir and dam.

---

[30] 63,400 acft/yr of increased water supply to all users minus 26,800 acft/yr reduced freshwater inflows.

The intake and pump station were sized to pump raw water at a maximum rate of 800 cfs. The pipeline consists of two 120-inch diameter pipes which would traverse roughly 20,000 feet to the reservoir with a static lift of about 76 feet. This pumping capacity would be necessary to capture unappropriated flows in the river which are typically available only a few months out of the year. Costs of the project are summarized in Column B, Table 3.14-10.

Considering the cost of diversion facilities on the Colorado River, the total project cost is estimated at $162,300,000. Financed at 8 percent for 25 years, annual debt service would be $15,210,000, and with operation and maintenance and power costs, the total annual cost is $17,400,000.

Benefits at Lake Travis, expressed in terms of increased firm yield, is 82,300 acft/yr (Table 3.14-2). For a total annual cost of $17,400,000, the annual unit cost of the increased raw water supply at Lake Travis is $211 per acft.

This alternative would also provide additional water to be made available to City of Austin water rights (3,700 acft/yr) and to lower basin senior water rights (82,000 acft/yr). The total increased water supply to all water rights made available by this alternative would be 168,000 acft/yr (Table 3.14-2). However, freshwater inflows to Matagorda Bay would be reduced by about 100,700 acft/yr. By mitigating the reduced freshwater inflows with water made available from this alternative, the net water supply benefit from this alternative is about 67,300 acft/yr.[31]

The resulting annual unit cost for increased raw water supply of this alternative considering water supply benefits to all users and mitigating the reduced inflows to Matagorda Bay increases to $259 per acft ($17,400,000 annual cost divided by 67,300 acft/yr net increased water supply).

C. Off-Channel Reservoir and Purchase of Under-utilized Water Rights — Alt C-5C

The capital costs for this alternative would be the same as for Alt C-5A, as described earlier. However, payments for purchase of 75,000 acft/yr of under-utilized water rights must be

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[31] 168,000 acft/yr of increased water supply to all users minus 100,700 acft/yr reduced freshwater inflows.

added to estimate the complete cost of this alternative. The under-utilized water rights are run-of-river rights and the full 75,000 acft is not available every year for diversion under these rights. Analyses of these rights indicate that during the worst 10-year drought period about 35 percent of the full 75,000 acft is available on the average. The value of these rights is estimated to be roughly equivalent to 35 percent of the purchase price for the Garwood water rights being purchased by the City of Corpus Christi. This would result in a purchase price of about $150 per acft or $11,250,000 for 75,000 acft.

Benefits at Lake Travis resulting from this alternative, expressed in terms of increased firm yield, is 46,700 acft/yr (Table 3.14-3). For an adjusted total annual cost of $12,784,000 (includes $1,054,000 per year for purchase of irrigation rights), the annual unit cost of the increased raw water supply at Lake Travis is $274 per acft.

This alternative would also provide additional water to be made available to City of Austin water rights (2,800 acft/yr) and to lower basin senior water rights (21,300 acft/yr). The total increased water supply to all rights holders made available by this alternative would be 70,800 acft/yr (Table 3.14-3). However, freshwater inflows to Matagorda Bay would be reduced by about 3,400 acft/yr with implementation of this alternative. By mitigating the reduced freshwater inflows with water made available from this alternative, the net water supply benefit from this alternative is 67,400 acft/yr.[32]

The resulting annual unit cost for increased raw water supply of this alternative, considering water supply benefits to all users and mitigating the reduced inflows to Matagorda Bay, decreases to $190 per acft ($12,784,000 annual cost divided by 67,400 acft/yr net increased water supply).

D. Off Channel Reservoir, Purchase of Under-utilized Water Rights, and Diversion of Unappropriated Flows — Alt C-5D

The capital costs for this alternative would be the same as for Alt C-5B as described earlier. However, payments for purchase of 75,000 acft/yr of under-utilized water rights must be added to estimate the complete cost of this alternative. The under-utilized water rights are run-

---

[32] 70,800 acft/yr of increased water supply to all users minus 3,400 acft/yr reduced freshwater inflows.

of-river rights and the full 75,000 acft is not available every year for diversion under these rights. The value of these rights is estimated to be $150 per acft or $11,250,000 as indicated for Alternative C-5C.

Benefits at Lake Travis resulting from this alternative, expressed in terms of increased firm yield, is 99,000 acft/yr (Table 3.14-4). For a total annual cost of $18,454,000 (includes $1,054,000 for purchases of irrigation rights), the annual unit cost of the increased raw water supply at Lake Travis is $186 per acft.

This alternative would also provide additional water to be made available to City of Austin water rights (5,700 acft/yr) and to lower basin senior water rights (89,600 acft/yr). The total increased water supply to all rights holders made available by this alternative would be 194,300 acft/yr (Table 3.14-4). However, freshwater inflows to Matagorda Bay would be reduced by about 89,100 acft/yr with implementation of this alternative. By mitigating the reduced freshwater inflows with water made available from this alternative, the net water supply benefit from this alternative is 105,200 acft/yr.[33]

The resulting annual unit cost for increased raw water supply of this alternative, considering water supply benefits to all users and mitigating the reduced inflows to Matagorda Bay, decreases to $175 per acft ($18,454,000 annual cost divided by 105,200 acft/yr net increased water supply).

E. Cost Estimate Summary

A comparison of water availability and the unit cost for all four alternatives is shown in Table 3.14-11. A review of this table indicates that the most economical water supply alternative is Alternative C-5D which results in a net increase in water availability of about 105,200 acft/yr at a cost of $175 per acft.

Increased water supply at Lake Travis made available under this alternative could be diverted and treated through one or more existing or proposed water treatment plants on Lake Travis. Diversion through the planned City of Austin WTP No. 4 could potentially benefit the Austin service area, Pflugerville, and others. Entities in Williamson County including Leander,

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[33] 194,300 acft/yr of increased water supply to all users minus 89,100 acft/yr reduced freshwater inflows.

Cedar Park, Round Rock, and Brushy Creek MUD could potentially benefit from this alternative with diversion near Cedar Park and expansion of Cedar Park's WTP facilities or construction of a regional water treatment plant.

Table 3.14-11
Comparison of Water Availability and Unit Costs of Raw Water for Alternative C-5

Alternative	Maximum Firm Yield Increase @ Lake Travis (acft/yr)	Unit Cost of Increased Lake Travis Yield ($/acft)	Net Water Supply Increase (acft/yr)	Unit Cost of Increased Net Raw Water Supply ($/acft)
Alt C-5A (Off-Channel Reservoir only)	42,400	$277	36,600	$320
Alt C-5B (Off-Channel Reservoir w/ Unappropriated Diversion)	82,300	$211	67,300	$259
Alt C-5C (Off-Channel Reservoir w/ Purchase of Irrigation Rights)	46,700	$274	67,400	$190
Alt C-5D (Off-Channel Reservoir, Purchase of Irrigation Rights, and Unappropriated Diversion)	99,000	$186	105,200	$175

Table 3.14-12 summarizes the estimated unit costs for development of additional raw water supplies in Lake Travis, as well as potential treatment costs for several entities that could benefit from implementation of this alternative.

3.14.6 Implementation Issues

Requirements Specific To Reservoirs

1. Necessary permits for the off-channel storage reservoir could include:
   a) TNRCC Water Right and Storage permits.

Table 3.14-12
Treated Water Unit Costs for Alternative C-5

Entity	Cost Item (Source)	Unit Cost ($/acft)
Austin Service Area	Raw Water (Table 3.14-11)	$175
	Austin CIP Facilities (Table 3.12-17)	549
	Treated Water Cost	$724
Pflugerville	Raw Water (Table 3.14-11)	$175
	Austin CIP Facilities (Table 3.12-17)	549
	Other Delivery Facilities (Table 3.12-18)	36
	Treated Water Cost	$760
Round Rock	Raw Water (Table 3.14-11)	$175
	Div./Treatment Facilities (BC-2)[1]	391
	Treated Water Cost	$566
Brushy Creek MUD	Raw Water (Table 3.14-11)	$175
	Div./Treatment Facilities (C-2) (Table 3.12-32)	442
	Other Delivery Facilities (Table 3.12-19)	90
	Treated Water Cost	$607
Cedar Park	Raw Water (Table 3.14-11)	$175
	Div./Treatment Facilities (C-2) (Table 3.12-30)	321
	Other Delivery Facilities (Table 3.12-30)	41
	Treated Water Cost	$537
Leander	Raw Water (Table 3.14-11)	$175
	Div./Treatment Facilities (C-2) (Table 3.12-30)	321
	Other Delivery Facilities (Table 3.12-30)	63
	Treated Water Cost	$559

[1] Includes cost of $134 per acft for intake, pump station and pipeline from Alt. BC-2, Table 3.19-2, not including purchase cost of raw water from LCRA. Includes cost of $257 per acft for treatment at expansion of Round Rock WTP, Table 3.19-4.

b) U.S. Army Corps of Engineers Sections 10 and 404 dredge and fill permits for the reservoir.
c) GLO Sand and Gravel Removal permit.
d) GLO Easement for use of state-owned land (if any).
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 must be acquired through either negotiations or condemnation.
4. Relocations for the reservoir potentially include:
   a) Highways and local roads.
   b) Gas and oil field pipelines and facilities.
   c) Other utilities if applicable.

Requirements Specific to Pipelines

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 local roads.
   b) Other utilities if applicable.

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3.15 Potential Use of Austin Steam-Electric Generation Water Rights for Municipal Use (C-6)

3.15.1 Description of Alternative

The City of Austin holds diversion rights for 40,156 acft/yr of water from the Colorado River to be used for steam-electric generating purposes. Historically, Austin has used no more than 7,000 acft/yr. Projections[1] indicate that the long-term steam-electric water demand in the North Central Study Area could be about 13,500 acft/yr, leaving about 26,656 acft/yr potentially available for other uses. This alternative investigates the opportunity to amend a portion of Austin's steam-electric water rights to include municipal use for the purpose of increasing Austin's municipal water supply.

In mid-1997, the City of Austin made application to the TNRCC to amend a portion of one of its steam-electric water diversion permits.[2] Austin is seeking a permit amendment to transfer the point of diversion for 15,000 acft/yr from Town Lake to the Fayette Power Project (located downstream of Austin in Fayette County). The Fayette Power Project currently obtains all of its cooling water under contract from LCRA and a portion of the firm yield of the Highland Lakes is dedicated by LCRA to meet this demand. If a portion of the Fayette Power Project demand is met from Austin run-of-river steam electric rights, then stored water in the Highland Lakes would become available for other uses.

3.15.2 Water Availability

The City of Austin's 40,156 acft/yr of diversion rights for steam-electric use are described in Section 3.2 and are listed in Table 3.2-1. Water availability under these rights during a repeat of the drought of record is estimated to be about 6,500 acft/yr and 17,300 acft/yr under average conditions.[3] Table 3.2-3 in Section 3.2 summarizes water availability under each specific diversion right. During a drought year, any steam-electric diversion requirement in excess of run-of-river availability would be supplied from storage in the Highland Lakes, up to the full right as established in the 1987 Settlement Agreement[4].

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[1] Texas Water Development Board, 1996 Consensus Water Plan Projections.

[2] CA 14-5471 permits diversion of up to 24,000 acft/yr for steam-electric use, and also allows diversion of additional amounts for other uses.

[3] See description of model methods and results, Section 3.2.

[4] Comprehensive Water Settlement Agreement between City of Austin and Lower Colorado River Authority, December 10, 1987.

Issues to be considered when making a change in use include determination that sufficient rights are maintained for steam-electric uses to insure sufficient cooling water is available in the future under critical conditions, the acceptance of regulatory authorities, the effect of the 1987 Settlement Agreement, and environmental effects.

Combined consumptive steam-electric demands under highest demand conditions for Decker power plant which diverts from Walter E. Long Lake (Decker Lake) under provisions of CA 14-5489 and Holly power plant which diverts from Town Lake under provisions of CA 14-5471 are estimated to be 7,500 acft/yr. These diversion locations are shown on Figure 3.2-1. Additionally, natural evaporation from Decker Lake, which is an off-channel impoundment, is approximately 6,500 acft/yr under drought conditions. This natural evaporation would probably need to be made up from diversions under the steam-electric right, but this requirement is not clear in the Settlement Agreement. For Town Lake, which is an on-channel impoundment that provides cooling water to the Holly Street and Seaholm Power Plants, LCRA has agreed to provide sufficient water to maintain the level no lower than five feet below the crest of the dam. Colorado flows required to meet natural evaporation demands from Town Lake are not counted against the City's permitted supply. Therefore, total current steam-electric water demands are about 13,500 acft/yr, including the natural evaporation component at Decker Lake. This demand is greater than the run-of-river availability in the minimum year under existing rights. Projected water demands for steam-electric use in the Austin area through year 2050 are for 13,500 acft/yr.

The water rights permits potentially affected by this alternative (CA 14-5471 and CA 14-5489) only allow water for steam-electric generation. A change of use would require approval by the Texas Natural Resource Conservation Commission.

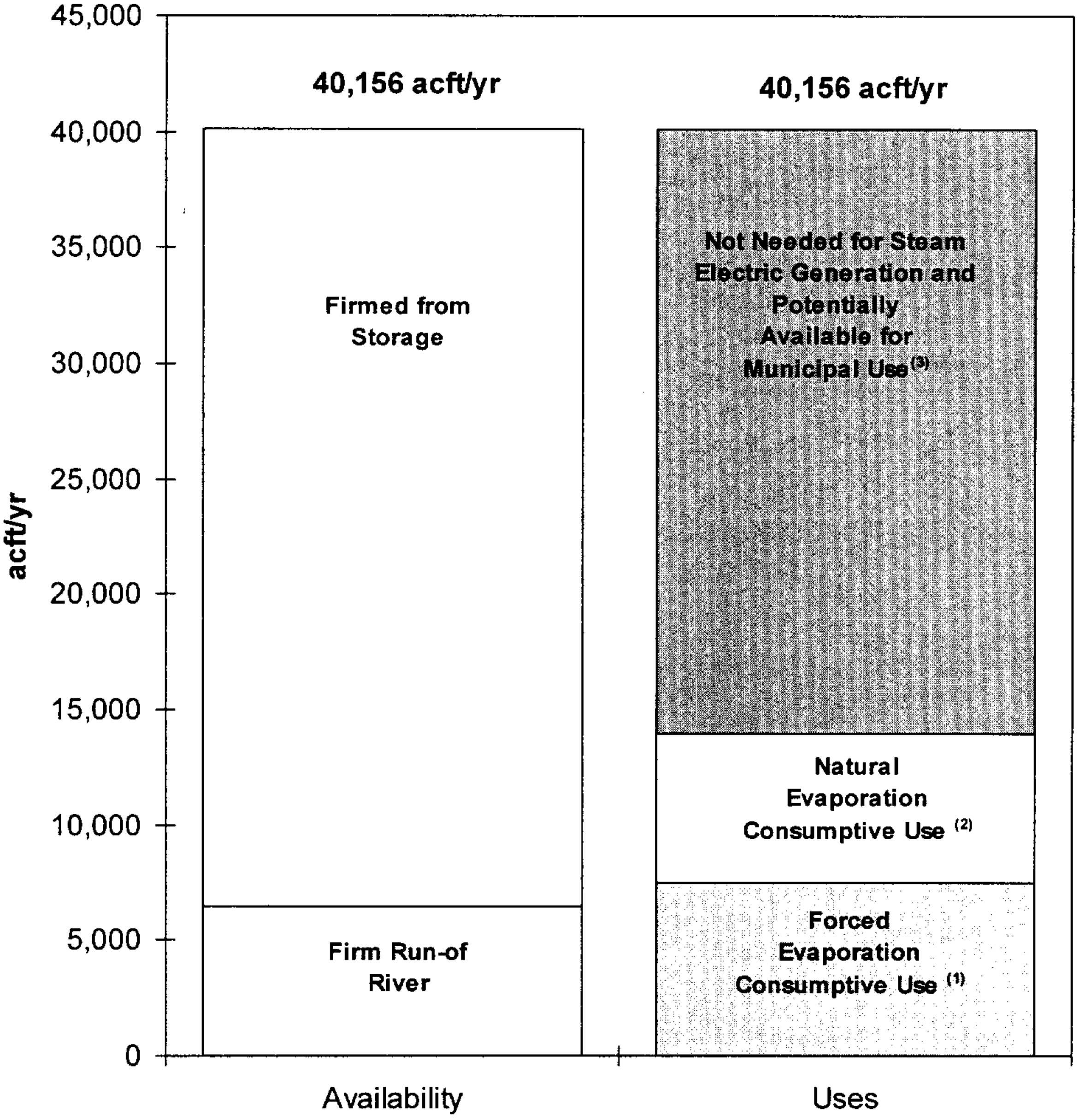
The 1987 Settlement Agreement between the Lower Colorado River Authority and the City of Austin does not explicitly address amending the type of use. Currently, the Settlement Agreement provides for firm annual deliveries up to the full amount of the water rights. Diversion patterns for municipal use would be similar to steam-electric diversions. Actual net consumption under municipal use would be less than an equivalent annual volume for steam-electric use, as municipal use results in about 55 percent return flows and steam-electric use has no return flow. If the Settlement Agreement provision to firm the steam-electric diversions does not transfer with the change in use, it appears that the run-of-river availability of the right would only meet estimated steam-electric needs and would not yield any additional municipal water availability. Provided that the firming provision of the Settlement Agreement transfers with the change in use, potential firm water availability is approximately 26,656 acft/yr. This availability is shown in Figure 3.15-1. However, with the pending transfer of 15,000 acft/yr to the Fayette Power Project, potential availability is reduced to 11,656 acft/yr.

Dual purpose use of the City of Austin's steam-electric cooling water rights for municipal use as well as steam-electric cooling would allow for the most flexibility in water planning for the City of Austin. However, utilization of the steam-electric cooling water rights for municipal use is intended to make full use of the City's current water rights without causing a shortfall in water available for cooling water for electric power generation by the City's Electric Utility. Should unanticipated expansion of the generating facility at Decker Lake occur, or should the City of Austin permanently utilize a portion of its steam-electric cooling water right at the Fayette Power Plant downstream of Austin, then the City of Austin would need to secure additional future municipal water from the other recommended alternatives.

3.15.3 Environmental Issues

Implementation of this alternative would potentially allow the use of up to 26,656 acft/yr for municipal supply purposes of water currently not needed for steam-electric cooling out of the City of Austin's 40,156 acft/yr steam-electric water right. For this alternative to be practical, it must be assumed that anticipated population growth and resulting demand for electric power will be met from generating stations with sufficient water supplies (i.e., existing plants with water rights or contracts, or generating stations in other basins), or from electric generating technologies using less water for cooling.

Diverting this amount of water would have the effect of slightly increasing the fluctuations in water surface elevations in Lakes Travis and Buchanan, and possibly increasing flows through Lake Austin to the existing City of Austin intakes. A municipal diversion of this water would be mitigated to some extent by return flows of treated wastewater, slightly increasing instream flow in the lower Colorado, while use of the 26,656 acft/yr for power plant cooling would not be expected to result in any return flows.



(1) Includes Decker Generating Station and Holly Generating Station.

(2) Only includes natural evaporation from Decker Lake which must be met with make-up water pumped from the Colorado River.

(3) Potential transfer of 15,000 acft/yr to Fayette Power Project not included.

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CITY OF AUSTIN STEAM-ELECTRIC WATER RIGHTS USES AND AVAILABILITY

FIGURE 3.15-1

3.15.4 Water Quality and Treatability

Since additional water made available from the City of Austin's steam-electric water rights will be diverted at the City's existing WTPs, raw water quality should remain the same as that currently experienced by the City . The only exception to this will be if Thomas C. Green WTP is eventually retired and the new Water Treatment Plant No. 4 on Lake Travis is brought on-line. Table 3.15-1 summarizes the water quality characteristics at each of the current and potential WTP locations. The water quality of Lake Austin and Town Lake are the direct result of the high quality water found in Lake Travis.

Table 3.15-1
Conventional Water Quality Constituents at Existing and Potential City of Austin's WTP's[1]

Constituent	*Lake Travis*	*Lake Austin*	*Town Lake*
Dissolved Oxygen (mg/l)	8.04	7.07	8.05
pH (su)	8.23	7.88	7.66
TDS (mg/l)	467.36	482.75	482.52
Fecal Coliforms (No./100 ml)	41.07	47.42	94.50
Chloride (mg/l)	110.30	104.31	108.33
Sulfate (mg/l)	83.75	79.21	84.50
Total Phosphorus (mg/l)	0.04	0.02	0.03
Total Nitrogen[2] (mg/l)	0.13	0.19	0.16

[1] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.
[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Although the conventional water quality characteristics of the three water sources are similar, synthetic organics (SOCs) and trace metals in the sediments are a concern in Town Lake. Substantial rainfall events on Town Lake's heavily urbanized watershed result in excessive non-point source pollution including SOCs, pesticides, nutrients, sediment, metals, and fecal coliforms.[5] Elevated levels of chlordane in the sediments and fish population resulted in a fish consumption advisory by the Texas Department of Health in 1990.[6] All three lakes exhibit oligotrophic (under-nourished) characteristics; however, during periods when water is not being released from Lake Travis for downstream irrigation purposes (mid-October to mid-March), Town Lake has experienced significant algae blooms that have caused WTP shut-downs and increased treatment costs.[7]

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[5] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.
[6] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.
[7] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.

Lake Travis and Lake Austin are protected by TNRCC's Chapter 311, Water Protection, which prohibits discharge of pollutants into the reservoirs' water quality area unless sufficient treatment is applied so that the lakes' existing water quality is maintained.[8] The City of Austin is participating in the Clean Lakes Program to monitor and implement innovative pollution control measures for Town Lake.[9] With TNRCC's anti-degradation policy and the strong awareness of the City and local Austin community to the effects associated with increased urbanization, the water quality of the reservoirs is expected to remain relatively constant. However, increased population and development in the Lake Travis and Lake Austin watersheds could eventually lead to future water quality problems from non-point source pollution. All three reservoirs have experienced natural fluctuations in chlorides, sulfates, and TDS caused by hypersaline flows from upstream areas but most notably from spills at Natural Dam Lake.

The City of Austin currently employs conventional treatment (rapid mix, flocculation, sedimentation, filtration, and disinfection) to produce potable water with additional hardness removal and taste and odor control measures to improve the water's aesthetic quality. These treatment processes should continue to be adequate for treating the additional raw water diverted from the three lakes under the City's existing steam-electric water rights pending any significant modifications to the state's drinking water standards.

3.15.5 Engineering and Costing

At present, the City of Austin diverts water under its run-of-river water rights at three locations: Ullrich WTP (Lake Austin), Davis WTP (Lake Austin), and Green WTP (Town Lake). The combined peak day capacity of these three treatment plants is 225 mgd. Average annual water use is about 135,000 acft/yr or about 120 mgd (max day peak factor of 1.87). Water supplies in excess of current diversion and treatment capacity, (whether the supplies come from existing water rights or from new supplies potentially available from other sources) could be diverted and treated by the City of Austin at an expansion of an existing facility, or by construction of WTP No. 4 on Lake Travis.

WTP No. 4 will allow Austin to utilize water from Lake Travis and will significantly increase Austin's diversion and treatment capacity. Diversions to WTP No. 4 could originate

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[8] Texas Administrative Code, Title 31, Chapter 311.

[9] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.

from Austin's rights under the 1987 Settlement Agreement,[10] or from new sources of water made available in Lake Travis by implementation of one or more alternatives in the Trans-Texas Water Program. WTP No. 4 is a major capital expenditure of the City of Austin and the timing of implementation will be dependent on a number of demand and financing factors. Prior to implementation of WTP No. 4, some additional diversion and treatment capacity can be obtained by expansion of existing facilities, thereby allowing use of water supplies originating from this or other alternatives. Expansion of existing facilities would be the more economical method for utilizing water supplies originating from this alternative. The following subsection provides information on the expected cost to divert and treat quantities of water through facility expansion. Section 3.12 (Purchase of Water from LCRA at Lake Travis) discusses diversion of larger quantities of water from Lake Travis and the associated costs for WTP No. 4 and conveyance facilities.

Expansion of Existing Facilities

Ullrich WTP is the only existing plant that has site area for capacity expansion. Austin's long-range planning[11] anticipates two phases of improvements associated with Ullrich WTP. Improvements prior to year 2000 consist of transmission pipeline and pump station improvements. Some of the facilities recommended prior to 2000 are currently being implemented. Improvements in the next phase, which is planned to be implemented prior to year 2010 includes a 40 mgd water treatment capacity expansion, pump station, ground storage tanks, and several transmission mains. Cost information from the Long-Range Planning Guide for expansion of the Ullrich WTP and associated transmission facilities has been used to estimate annual unit costs for water supplies diverted through an expansion of City of Austin facilities. In addition to this alternative, these unit costs are also used for Alternative C-7 (Water Available From Austin's Existing Water Rights).

Table 3.15-2 summarizes the estimated capital and annual costs for expansion of existing City of Austin facilities to utilize water diverted under existing water rights. The annual unit cost to divert and treat water under Austin's run-of-river water rights through an expansion of the

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[10] Comprehensive Water Settlement Agreement between City of Austin and Lower Colorado River Authority, December 10, 1987.

[11] City of Austin, "Water Distribution System Long-Range Planning Guide", February, 1994.

existing treatment and distribution system is estimated to be $275/acft or about $0.84 per 1,000 gallons for the additional volume of water.

Table 3.15-2
Cost Estimate Summary for Expansion of Ullrich WTP and Transmission Facilities

Item	Cost
Capital Costs[1]	
Ullrich WTP Upgrade (40 mgd expansion)	$21,540,000
Transmission Pipelines	5,218,000
Pump Station	582,000
Reservoir	2,454,000
Total Capital Costs	$29,794,000
Engineering, Contingency, and Legal	*Included*
Land Acquisition	*in*
Environmental Studies and Mitigation	*Above*
Interest During Construction	*Costs*
Total Project Costs	$29,794,000
Annual Costs	
Annual Debt Service	$2,792,000
Annual Operation and Maintenance (excluding power)	2,736,000
Power	630,000
Purchase Raw Water from LCRA[2]	420,000
Total Annual Cost	$6,578,000
Annual Project Yield[3]	23,960
Annual Unit Cost of Treated Water	
($ per acft)	$275
($ per 1,000 gal)	$0.84

[1] Source: City of Austin, "Water Distribution System Long-Range Planning Guide", Table S-2. Cost Estimate for CIP Improvements Recommended Between 2000 and 2010. Capital costs escalated 7.7%.

[2] For deliveries to City of Austin in excess of 150,000 acft/yr, cost of water from LCRA is $105 per acft. Under this expansion it is assumed that average annual water use will be about 154,000 acft/yr which will result in the purchase of 4,000 acft/yr.

[3] Incremental treatment plant capacity is 40 mgd; for max day peak factor of 1.87, annual project yield is 21.4 mgd (23,960 acft/yr).

3.15.6 Implementation Issues

Amendment of the existing City of Austin steam-electric diversion rights to include municipal use would probably require approval by the Austin electric utility. To obtain this approval, the electric utility would need to confirm current estimates of projected water demands for steam-electric use.

Dual purpose use of the City of Austin's steam-electric cooling water rights for municipal use as well as steam-electric cooling would allow for the most flexibility in water planning for the City of Austin. However, utilization of the steam-electric cooling water rights for municipal use is intended to make full use of the City's current water rights without causing a shortfall in water available for cooling water for electric power generation by the City's Electric Utility. Should unanticipated expansion of the generating facility at Decker Lake occur, or should the City of Austin permanently utilize a portion of its steam-electric cooling water right at the Fayette Power Plant downstream of Austin, then the City of Austin would need to secure additional future municipal water from the other recommended alternatives.

Amendment of current steam-electric diversion permits would require hydrologic studies indicating the effect on in-stream flows, including potential increases in return flows, and studies indicating the effect (if any) on commitments of stored water in the Highland Lakes. It would be most advantageous for the City to obtain TNRCC authorization to use this water for both steam-electric use and municipal use. This authorization would provide the City the greatest flexibility in the use of this resource.

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3.16 Use of Carrizo-Wilcox Aquifer to Augment Colorado River Flows (CZ-1)

3.16.1 Description of the Alternative

This alternative considers augmenting the flows in the Colorado River below Columbus, Texas with groundwater from the Carrizo-Wilcox Aquifer to supply a portion of the demands of senior water rights holders. The augmentation of the lower Colorado River with groundwater would reduce the releases of inflows to the Highland Lakes that are required to meet senior downstream rights. The operation would benefit study participants located near the Highland Lakes by lessening the Highland Lakes yield reduction associated with honoring downstream senior rights. The result would be to increase the potential uncommitted yield of the Highland Lakes. Both upstream and downstream interests would benefit from the reduction in losses and improved scheduling that can be achieved by providing additional supply closer to the major demands.

The Carrizo-Wilcox Aquifer is one of the most extensive aquifers in Texas, providing high quality groundwater to a large area including portions of the Brazos, Colorado, Guadalupe, and Trinity River Basins. In the vicinity of the North Central study area, the Carrizo-Wilcox Aquifer crosses the far eastern corner of Williamson County, and parts of Lee, Milam and Bastrop Counties. In this region it is estimated that large quantities of ground water are available for development as a dependable water supply. Well water from the Carrizo-Wilcox aquifer would be pumped directly to the lower Colorado River as shown on Figure 3.16-1 or to a tributary of the Colorado River such as Cummins Creek as shown on Figure 3.16-2.

3.16.2 Water Availability

Groundwater availability from the Carrizo-Wilcox aquifer is from two principal water-bearing formations, the Carrizo and Simsboro sand layers. At the well field site shown on Figure 3.16-1, the Carrizo layer extends from 300 to 2,000 feet below the surface, and the Simsboro layer extends from 1,700 to 4,000 feet below the surface. Yields in the Carrizo-Wilcox aquifer for continuously operated wells range from 100 to 2,500 gpm with the higher yields being more typical of these formations.[1] Pumpage rates from the aquifer can be higher if not operated continuously.

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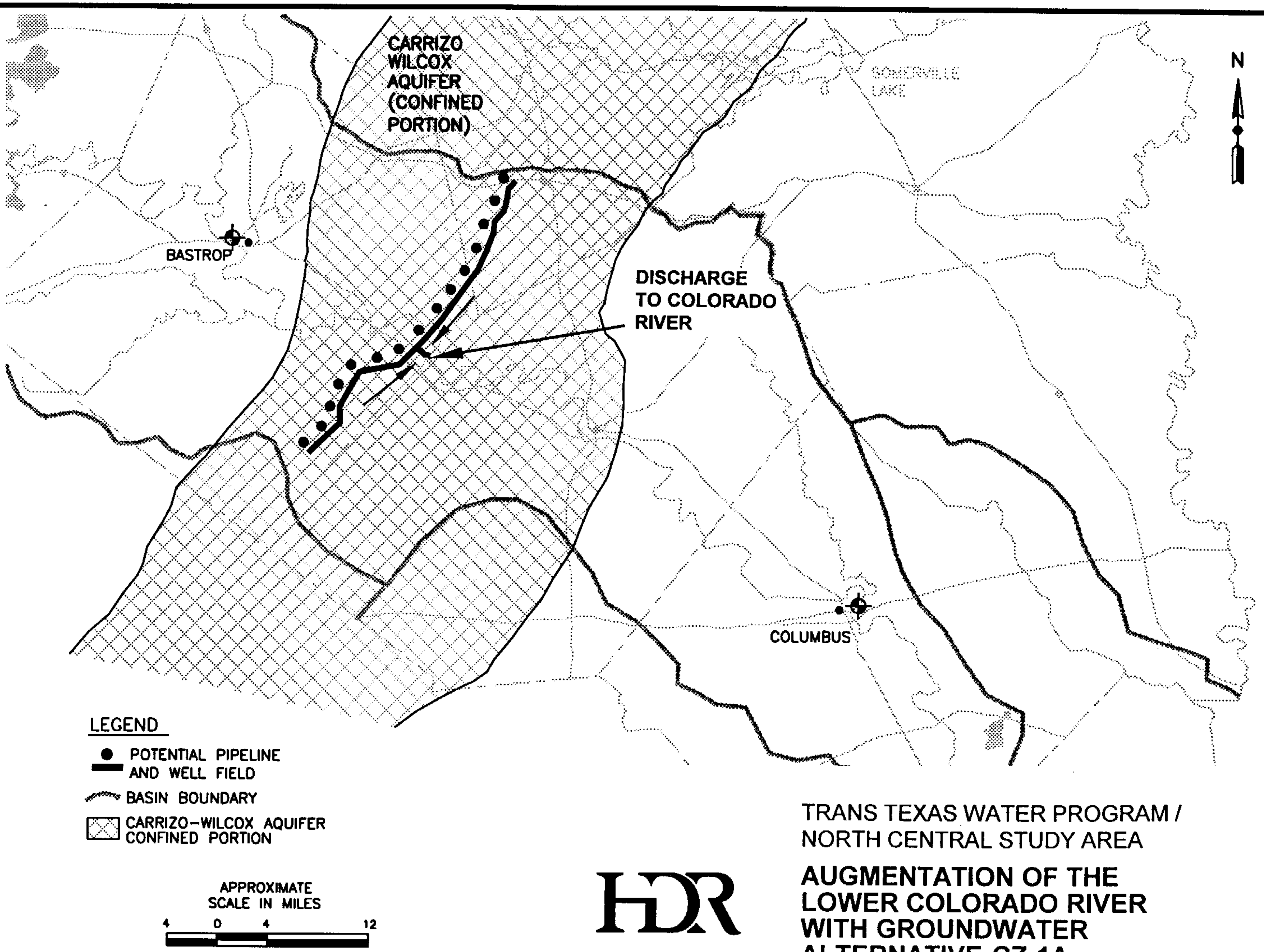
[1] TWDB, "Groundwater Resources of the Carrizo-Wilcox Aquifer in the Central Texas Region", Report R332, September, 1991.



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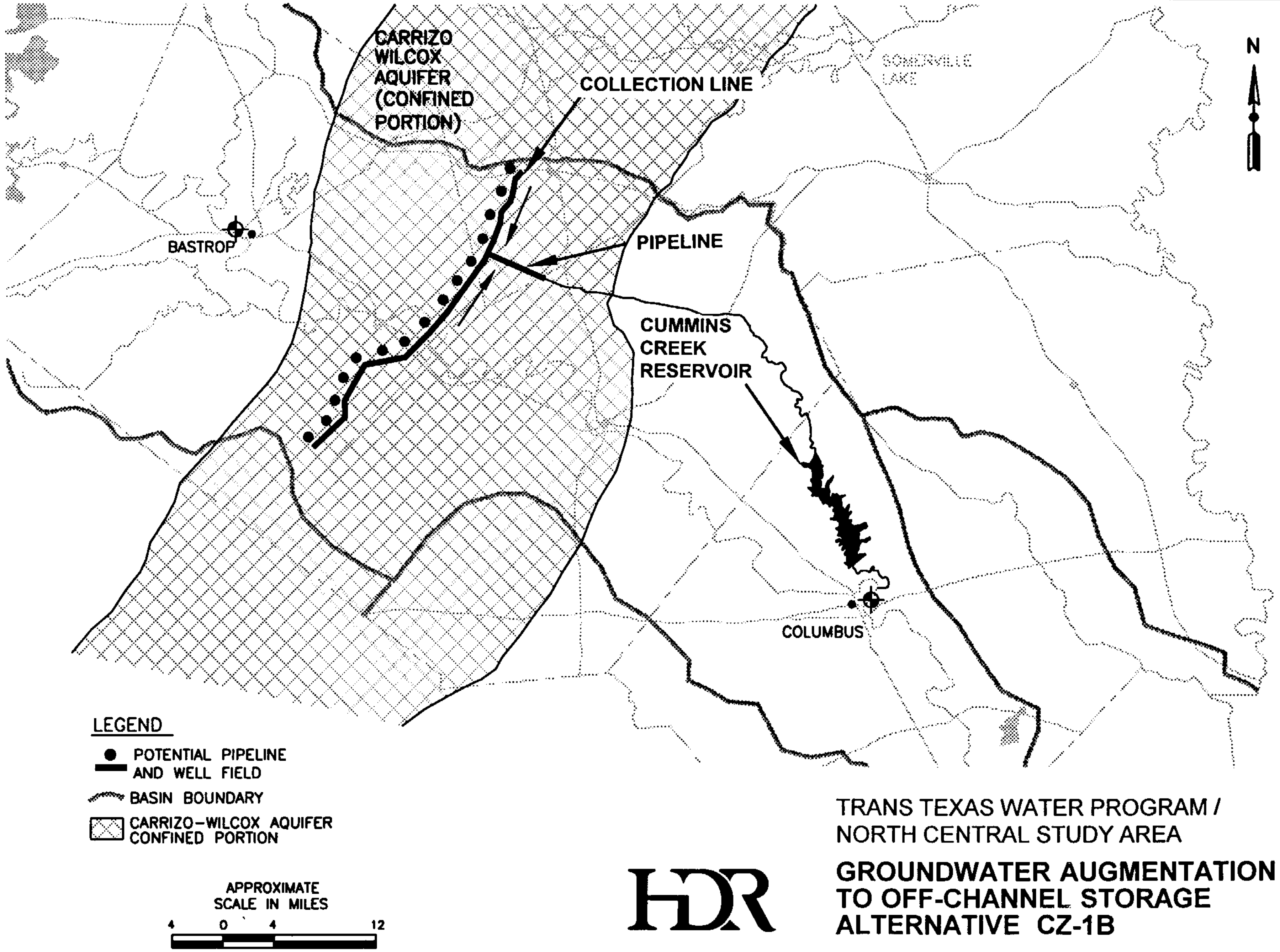
AUGMENTATION OF THE LOWER COLORADO RIVER WITH GROUNDWATER ALTERNATIVE CZ-1A

FIGURE 3.16-1



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GROUNDWATER AUGMENTATION
TO OFF-CHANNEL STORAGE
ALTERNATIVE CZ-1B

FIGURE 3.16-2

Recharge to the Carrizo and Simsboro formations is from excess precipitation in the recharge zone, percolation from streams in the recharge zone, and leakage from overlying formations.[2] The amount pumped from the aquifer in the study area has historically been very low compared to the recharge it receives. This has resulted in the aquifer being nearly full in the study area and indications are that it discharges water to overlying formations and to rivers crossing the recharge zone, as well as rejecting some recharge available to the aquifer.[3]

Study of the aquifer's hydrologic properties supports the conclusion that recharge to the aquifer would be significantly increased if more water were pumped from it (i.e., available recharge water which is currently being rejected because the aquifer is full).[4] The Carrizo-Wilcox Aquifer within the Colorado River Basin is located in Bastrop County and the southern portion of Lee County. Estimated potential sustainable yield from the Carrizo-Wilcox aquifer within the Colorado River Basin is approximately 56,830 acft/yr and is summarized in Table 3.16-1.

Table 3.16-1
Estimated Potential Sustainable Yield from the Carrizo-Wilcox Aquifer within the Colorado River Basin

Area	Estimated Potential Sustainable Yield (acft/yr)	Estimated Aquifer Pumpage in 1990 (acft/yr)	Groundwater Available for Development (acft/yr)
Southern Lee County	6,800[1]	1,870[2]	4,930
Bastrop County	60,000[3]	8,100[3]	51,900
Total	66,800	9,970	56,830

[1] Based on areal yield from within Brazos River Basin assuming homogeneous aquifer properties. See Section 3.17
[2] Texas Water Development Board, reported 1990 water use in Lee County within the Colorado River Basin.
[3] LBG-Guyton Associates, "Trans-Texas Water Program, Phase I Evaluation of Carrizo-Wilcox Aquifer, West-Central Study Area," January 1994.

Based on this estimate, an annual volume of 56,830 acft/yr was considered for aquifer pumping and transfer by pipeline to a tributary of the river or to an off-channel storage reservoir near Columbus, Texas. Figure 3.16-1 indicates potential well field locations within Bastrop and Lee counties and a potential water transmission line route to the off-channel reservoir site.

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[2] Ibid.

[3] LBG-Guyton Associates, "Phase I Evaluation, Carrizo-Wilcox Aquifer, West Central Study Area, Trans-Texas Water Program," January, 1994.

[4] TWDB, "A Digital Model of the Carrizo-Wilcox Aquifer within the Colorado River Basin of Texas", Report LP-208, January, 1989.

Direct Augmentation of Colorado River

The benefits of augmenting the Colorado River with water diverted from the Carrizo-Wilcox aquifer were investigated using LCRA's Response Model to determine changes in water availability. The modeling was performed by LCRA staff at the direction of HDR. Details of this model are presented in Section 3.2. Without an off-channel storage reservoir, aquifer water would be pumped at a uniform rate of 160 cfs from April through September to the Colorado River. Greatest water demands in the lower Colorado River basin are typically during the rice growing season from April to September. Senior water rights were modeled attempting to divert their full permitted water rights. To produce 56,830 acft of groundwater within a 6-month period would require approximately 15 wells producing 5,400 gpm each and allowing for 10 percent downtime.

Table 3.16-2 summarizes water potentially made available by this alternative to the Highland Lakes and other rights holders. Water made available to the Highland Lakes by this operation through the 10-year critical period of 1947 to 1956 is estimated to be 22,000 acft/yr. Similarly, additional water would be made available to the senior downstream rights and the City of Austin in the amounts of 33,000 acft/yr and 14,100 acft/yr respectively. The total potential benefit not including increased inflow to Matagorda Bay is, therefore, 69,100 acft/yr. The water made available is greater than the amount pumped from the aquifer due to reduced losses in the Colorado Basin since the augmentation supply is located closer to the demands. Increased inflow to Matagorda Bay averages 5,500 acft/yr for the drought period.

Table 3.16-2
Water Availability in the Colorado River Basin With Augmentation From the Carrizo-Wilcox Aquifer
Averages for the Period of 1947-1956 in acft/yr

Diverter	Without Augmentation	With Augmentation from Carrizo-Wilcox	Water Made Available
City of Austin	166,900	181,000	14,100
Other Senior Rights	286,900	319,900	33,000
Highland Lakes yield	445,300	467,300	22,000
Total	899,100	968,200	69,100
Flow to Matagorda Bay	*279,800*	*285,300*	*5,500*

Augmentation Routed through Off-Channel Reservoir

The water made available by utilizing groundwater from the Carrizo-Wilcox in conjunction with operation of an off-channel reservoir was also investigated. Modeling methods and investigation of off-channel reservoir benefits without augmentation are presented in Section 3.14.2.

To produce 56,830 acft of groundwater over a 12-month period would require approximately 15 wells at 2,700 gpm each and allowing for 10 percent downtime. The discharge to Cummins Creek would be 80 cfs and channel losses are estimated to be 0.65 percent per mile.[5] This loss rate is based on channel loss data for several streams of varying size and location in Central Texas. Soil maps[6] for the Cummins Creek area indicate that the area is predominately overlain with clay. Therefore, low losses from infiltration would be expected. Total losses over the approximate 30-mile creek route to the off-channel storage would therefore be about 19.5 percent, or 11,080 acft/yr. The amount of water reaching the off-channel reservoir would then be about 64 cfs, or 45,750 acft/yr.

Table 3.16-3 summarizes water potentially made available to the Highland Lakes and other rights holders with augmentation supplied to an off-channel reservoir. Operation of an off-channel reservoir capturing natural drainage and diversion of groundwater for storage in the reservoir would potentially make available 105,400 acft/yr. The increased water availability to the City of Austin diversions would be approximately 8,600 acft/yr, to other diverters would be 42,900 acft/yr, and to the firm yield of the Highland Lakes would be 53,900 acft/yr. This increase in availability corresponds to a decrease in Matagorda Bay flows of 15,000 acft/yr on the average. If decreases in inflows to Matagorda Bay were mitigated by releasing a portion of the developed water, the net yield increase would be about 90,400 acft/yr.

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[5] HDR Engineering, Inc., "Recharge Enhancement Study, Guadalupe-San Antonio River Basin, Technical Report, Vol. II," Edwards Underground Water District, September, 1993.

[6] USSCS, Soil Surveys of Colorado and Fayette Counties.

Table 3.16-3
Water Availability in the Colorado River Basin With Augmentation From the Carrizo-Wilcox Aquifer and Off-Channel Storage Averages for the Period of 1947-1956 in acft/yr

Diverter	Without Off-channel Reservoir and Augmentation	With Off-channel Reservoir and Augmentation	Water Made Available
City of Austin	166,900	175,500	8,600
Other Senior Rights	286,900	329,800	42,900
Highland Lakes Yield	445,300	499,200	53,900
Total	899,100	1,004,500	105,400
Flow to Matagorda Bay	*279,800*	*264,800*	*(15,000)*

3.16.3 Environmental Issues

This alternative would transfer water from the Carrizo-Wilcox Aquifer wells located in Bastrop and Lee Counties by pipeline either directly to the Colorado River near Smithville or to Cummins Creek, a tributary of the Colorado River. Environmental considerations relevant to water pumped from the Carrizo-Wilcox Aquifer focus on the operational effects of lowering the water table over Carrizo-Wilcox outcrop and potentially capturing more surface run-off. Other considerations are:

- Construction and operational effects of the well field and pipeline;
- Construction and operational effects of Cummins Creek, a tributary reservoir; and
- The system operational effects on the Colorado River and Estuary downstream from the project.

Construction effects of a reservoir potentially to be located on Cummins Creek have been addressed in Section 3.14 which also considers the effects of the reservoir operation on the Colorado River and Matagorda Bay.

Affected Environment

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. The aquifer outcrops in a southwest-northeast trending crescent 15 to 20 miles in width near the inland margin of the Gulf Coastal Plain and dipping downward toward the coast (Figure 3.16-1). The project area extends from Bastrop

County northeast to Lee County entirely within underground water quality management area 4 of the Carrizo-Wilcox Aquifer.[7]

Carrizo-Wilcox Aquifer recharge occurs over the general surface of the outcrop area, with seepage from streams or lakes being of importance in a few particular locations.[8] Effective recharge (the proportion of precipitation actually entering the aquifer) is determined by local factors, including topography, vegetation and soil characteristics on the outcrop. Surface topography exerts significant influence on water movement within the aquifer as recharge water moves down gradient either into the aquifer or to topographic lows where it may discharge to marshes, ponds, creeks and rivers. The aquifer is believed to be full and spilling in the project area, resulting in discharges to area streams where they cross the outcrop. The extent to which ponding of surface water over the Carrizo Sands is influenced by water levels in the aquifer is presently unknown but is possibly significant.

The project area in Bastrop and Lee Counties lies primarily in the Post Oak Woods and Pine-Hardwood Forest vegetational areas.[9] The Post Oak Woods, or Post Oak Savannah, as Gould[10] described the area, consists of rolling hills of light-colored upland soils of acid sandy loams or sands. Bottomland soils are light-brown to dark-gray and acid, ranging in texture from sandy loams to clays. The area receives 35 to 45 inches of rain annually with much of that falling in May and June.[11]

Much of the project area has experienced agricultural or silvacultural development so use for cropland or pastures of native and introduced grasses is typical of cleared land.[12] Although most of the Post Oak Savannah is in native or improved pastures, small farms are common. Climax grasses include little bluestem, Indian grass, switchgrass, purpletop (*Tridens flavus*), silver bluestem, Texas wintergrass, and narrowleaf woodoats (*Chasmanthium sessiliflorum*).[13] The overstory is primarily post oak (*Quercus stellata*) and blackjack oak (*Quercus*

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[7] Chapter 294: Underground Water Management Areas. TNRCC.

[8] 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.

[9] McMahan, C.A., R.G. Frye and K.L. Brown. 1984. The Vegetation Types of Texas Including Cropland. TPWD, Austin, TX.

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

[11] Ibid.

[12] Ibid.

[13] bid.

marilandica).[14] Many other brush and weedy species are also common. Some invading plants are red lovegrass (*Eragrostis oxylepis*), broomsedge (*Andropogon virginicus*), splitbeard bluestem *(Andropogon ternarius*), yankeeweed (*Eupatorium compositifolium*), bullnettle (*Cnidoscolus texanus*), greenbrier (*Smilax* sp.), yaupon (*Ilex vomitoria*), smutgrass, and western ragweed (*Ambrosia trifida*).[15]

A small area of Pine-Hardwood Forest exists east of Bastrop known as "The Lost Pines."[16] Depending on the final placement of the well line, the wells may or may not fall into this vegetational area, characterized by deep sands, and towering loblolly pines.

Table 3.16-4 summarizes some of the land use and vegetation characteristics of the project area. Acreages and the proportion of physiognomic categories affected during construction and operation are based on construction and maintenance requirements estimated by HDR Engineering, Inc. and applied to the general area. Actual vegetation or land use types affected would be very sensitive to siting considerations. Other than the farm ponds indicated, wetlands in the project area are limited to streams and their associated riparian zones. Most agricultural lands could be returned to previous productivity.

Table 3.16-4
Summary of Physiognomic Classification of Alternative CZ-1
Carrizo-Wilcox Aquifer Well Field

Physiognomic Category	Percent Coverage in Construction Corridor	Acreage in Well Field Construction Areas	Acreage in Maintenance Buffer
Developed	3.2	2.72	0.68
Crop	70.7	60.15	15.04
Park	10.6	9.02	2.26
Wood	12.8	10.89	2.72
Farm Ponds	2.69	2.30	0.58
Total	100	85.11	21.28

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[14] Ibid.

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

[16] McMahan, C.A., R.G. Frye and K.L. Brown. 1984. The Vegetation Types of Texas Including Cropland. TPWD, Austin, TX.

Endangered and Threatened Species

Plant and animal species in Bastrop or Lee Counties Texas which are listed by the USFWS and TPWD as endangered or threatened, and species listed by TOES as watch list species are presented in the Environmental Overview (Section 3.1.3). The species listed are likely to be encountered in the project area so care must be taken in selecting final pipeline and well fields. Any bald eagles present will probably be near the Colorado River and may be nesting in remote tall tree tops. The Texas garter snake prefers moist habitat, such as the wetlands surrounding the Colorado River.

Populations of the Houston toad have been found near shallow ponds in the vicinity of Bastrop State Park in the Lost Pines area. The Houston toad is a terrestrial amphibian associated with deep sandy soils within the Post Oak Savannah vegetational area of east central Texas. Because the Houston toad is a poor burrower it requires loose friable soils for burrowing and surface debris such as the soils and woody debris found in the Lost Pines area of Bastrop County. It inhabits pine or oak woodland or savannah that commonly includes loblolly pine, post oak, bluejack or sandjack oak, and yaupon with little bluestem and other native bunchgrasses and flowering plants present in open areas.

Like most amphibians, the Houston toad requires water for breeding and tadpole development. It requires still or slow-flowing water that persists for at least 30 days. Breeding and development may include ephemeral pools, flooded fields, drainage ditches, wet areas associated with seeps or springs, or more permanent ponds. Toads may migrate up to three quarters of a mile from their foraging habitat to suitable breeding areas. Male Houston toads may call from December through June but breeding generally takes place in February and March. The adults, and especially the first-year toadlets, are active year round when temperatures and moisture conditions are favorable.

Life history and habitat studies indicate that successful mating seasons are characterized by above average rainfall and temperatures preceding the breeding season, which is January through March. Warm temperatures, high humidity, rainfall, and dark phases of the moon appear to stimulate breeding activity.[17] The preferential use of temporary rain-pools for mating by the

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[17] Price, Andrew H. 1993. Final Report, Houston Toad (*Bufo houstonensis*) Status Survey. Job No. 8, Texas Project E-1-4. Texas Parks and Wildlife Department, Austin, Texas.

Houston toad is thought to reduce mating interference and competition with the more common Woodhouse's toad (*Bufo woodhousei).* Use of widely distributed temporary pools may also reduce the distance Houston toads must travel to mate and thereby reduce their exposure to predation.

Possible reasons for the decline of the Houston toad include the draining of wetlands, the conversion of ephemeral ponds to permanent ponds containing predatory fishes, the clearing of native vegetation near ponds or on uplands adjacent to ponds (reducing the quality of foraging habitat and cover), the conversion of grass cover from native grassland and woodland savannah to sod-forming grasses which form denser mats (reducing the area suitable for burrowing and aestivation), and barriers to migration such as roads, pipelines, and transmission lines between foraging and breeding habitats.

Construction and Operational Effects of Alternative CZ-1

The primary impact resulting from construction of this alternative would be the temporary disturbance to soils and habitat that will occur during construction of the well field and pipelines, and permanent conversion of a portion of that land to maintained pipeline rights of way, well sites, and access roads. Surveys for protected species or other biological resources of restricted distribution or other importance, should be coordinated as necessary with property (or easement) acquisition so as to avoid significant impacts to important species. The effects of constructing an off channel reservoir in the lower Colorado River basin (Alternative Scenario CZ-1B) are addressed in Section 3.14-3.

Potential operational impacts of this alternative arise from increased withdrawals from the Carrizo-Wilcox Aquifer and the discharge from that water into either the Colorado River or Cummins Creek. Because there are no known metazoan inhabitants of the Carrizo-Wilcox Aquifer, withdrawing water would not directly impact any endemic fauna as is the case in the Edwards Aquifer. However, aquifer withdrawals will be large enough to lower the water table in the outcrop area. It is intended (Section 3.16.2) that operation of the proposed well field will lower water levels in the outcrop portion of the aquifer so that additional storage space would be created, increasing the efficiency of capturing precipitation and surface-water runoff.[18] As a result, base flows of streams crossing the recharge zone may be reduced as the amount of water discharged from the presently full aquifer into stream channels declines. If the water table begins dropping below the levels of the streambeds, channel losses will occur where streams cross the outcrop. Because of limited groundwater storage capacity, the potential for significant losses of stream baseflow due to the loss of shallow groundwater resurgence alone is probably not a major concern, but combined with enhancement of seepage losses due to a general lowering of the water table in the outcrop area, extended low and zero flow episodes during drier periods may increase in area streams.

If the distribution, abundance and persistence of temporary pools is also substantially affected by the elevation of the water table in the recharge area, implementation of this alternative may have significant effects on Houston toad populations as additional breeding pools may be eliminated. The Texas garter snake is also a species of concern that utilizes low-lying moist wetlands that may be affected by declining water tables.

Discharge of Carrizo-Wilcox water directly into the Colorado River (Alternative Scenario CZ-1A), or to an off-channel reservoir near Columbus, will result in changes in Colorado River streamflows. The extent and temporal distribution of those changes varies with location on the river as releases from the highland lakes are curtailed while extra basin water is added at some point downstream for users who will attempt to divert it before it enters Matagorda Bay, the present estuary of the Colorado River.

The LCRA has existing criteria for minimum instream flows for the lower Colorado River and interim criteria for minimum bay and estuary inflows.[19] Two separate environmental instream flow criteria, critical flows and target flows, have been established in the Colorado River below Austin based on fisheries habitat needs in segments designated on the basis of studies conducted by LCRA staff. Critical flows (Table 3.16-5) are maintained by releasing inflows or stored water from the Highland lakes as needed to maintain daily river flow at the Bastrop gage to be no less than the established critical instream flow in all years.

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[18] 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.

[19] Lower Colorado River Authority, Water Management Plan for the Lower Colorado River Basin, 1993.

Target flows (Table 3.16-5) which vary monthly have been established for three points in the basin including the Austin gage, Bastrop gage, and Columbus gage. In wetter years when water supplies for the four major irrigation districts are not curtailed, inflows to the Highland lakes are released on a daily basis to maintain river flows at the target instream flow.

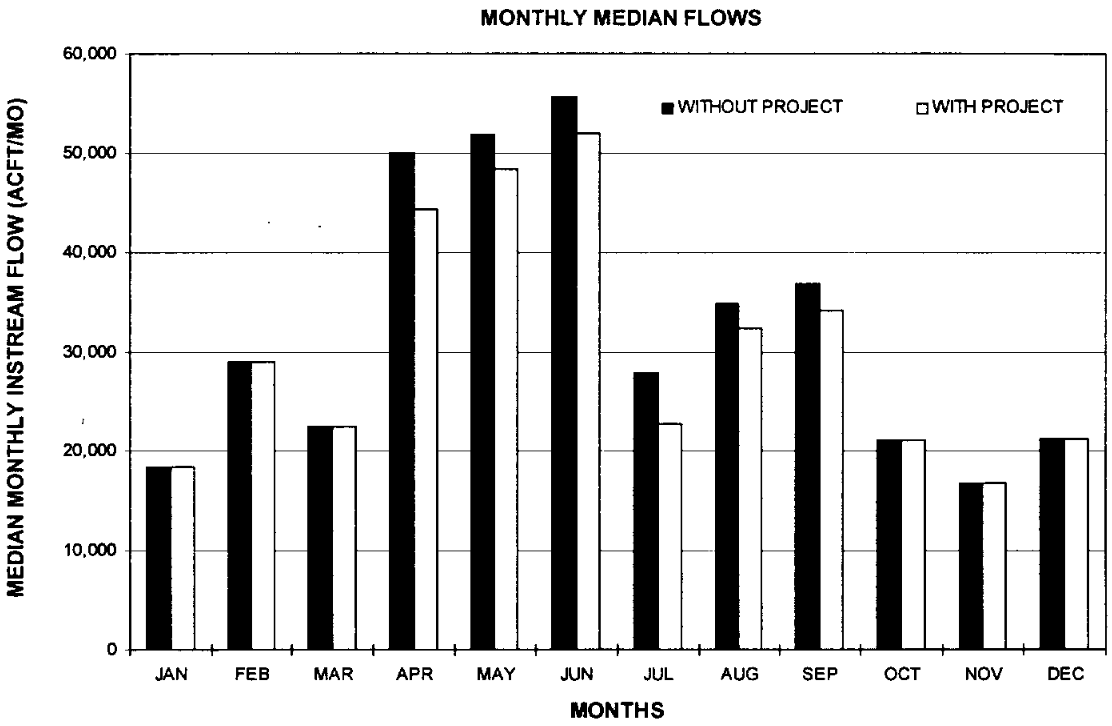
Table 3.16-5
Natural Resource Flow Criteria for the Lower Colorado River

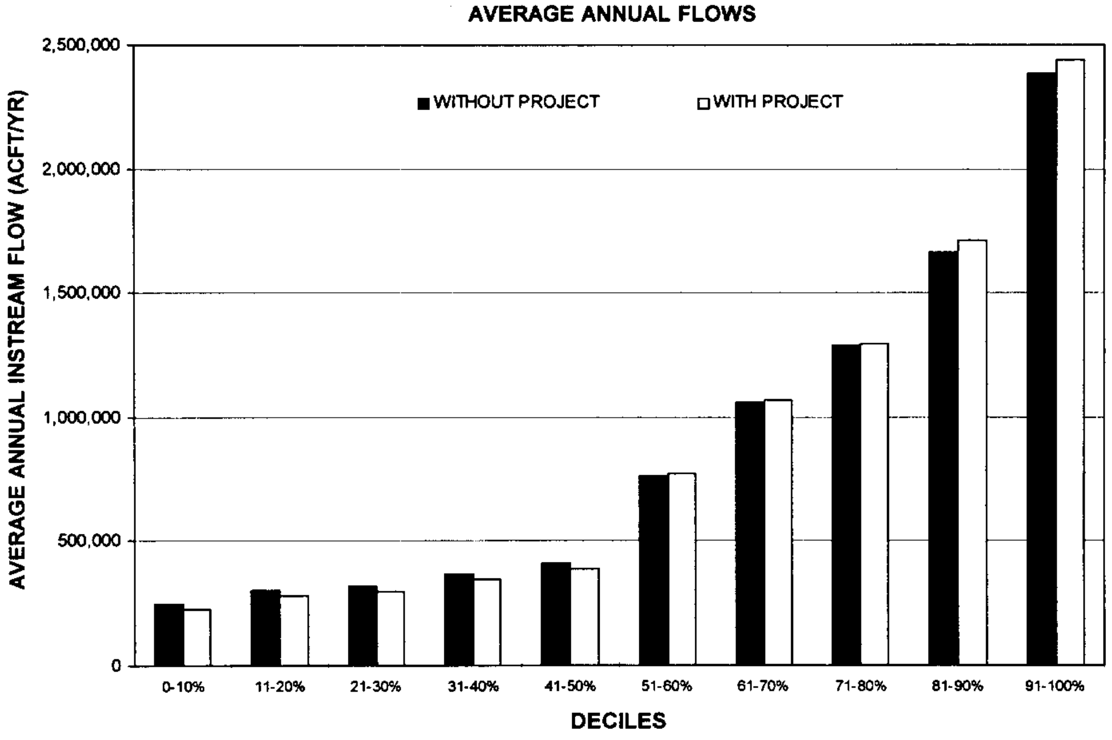
	COLORADO RIVER INSTREAM FLOWS		
Critical Flows	15 April to 31 May - 500 cfs minimum at Bastrop gage	All Other Times - 120 cfs minimum at Bastrop gage	To be met at all times with inflows or stored water from highland lakes
Target Flows	Established at 3 gages (Austin, Bastrop and Columbus)	Flow targets vary monthly	To be met with highland lakes inflows during years when there is no curtailment of downstream irrigators
	MATAGORDA BAY AND ESTUARY INFLOWS		
Minimum Annual Inflow	272,000 acft/year		
Mean (Min) Seasonal Inflow	375 cfs		
Mean (Min) Monthly Inflow	200 cfs		

Source: Lower Colorado River Authority, Water Management Plan for the Lower Colorado River Basin, 1993

The bay and estuary interim criteria are to maintain a minimum annual inflow of 272,000 acft to Matagorda Bay, a minimum seasonal inflow of 375 cfs, and a minimum mean monthly inflow of 200 cfs. Flow criteria are summarized in Table 3.16-5.

Figure 3.16-3 through 3.16-8 present summaries of the hydrologic effects of the two scenarios for this alternative addressed in this section at three locations on the lower Colorado River: the Bastrop and Columbus gages, and inflows to Matagorda Bay. Each figure contains two bar graphs, one showing median monthly streamflows, the other showing total annual





NOTES:

1. "WITHOUT PROJECT" IS THE BASE CONDITION WITH ALL EXISTING WATER RIGHTS ATTEMPTING TO DIVERT FULL AUTHORIZED AMOUNTS.
2. "WITH PROJECT" INCLUDES 56,830 ACFT/YR FROM CARRIZO-WILCOX AQUIFER OPERATED TO MEET LOWER BASIN IRRIGATION DEMAND.

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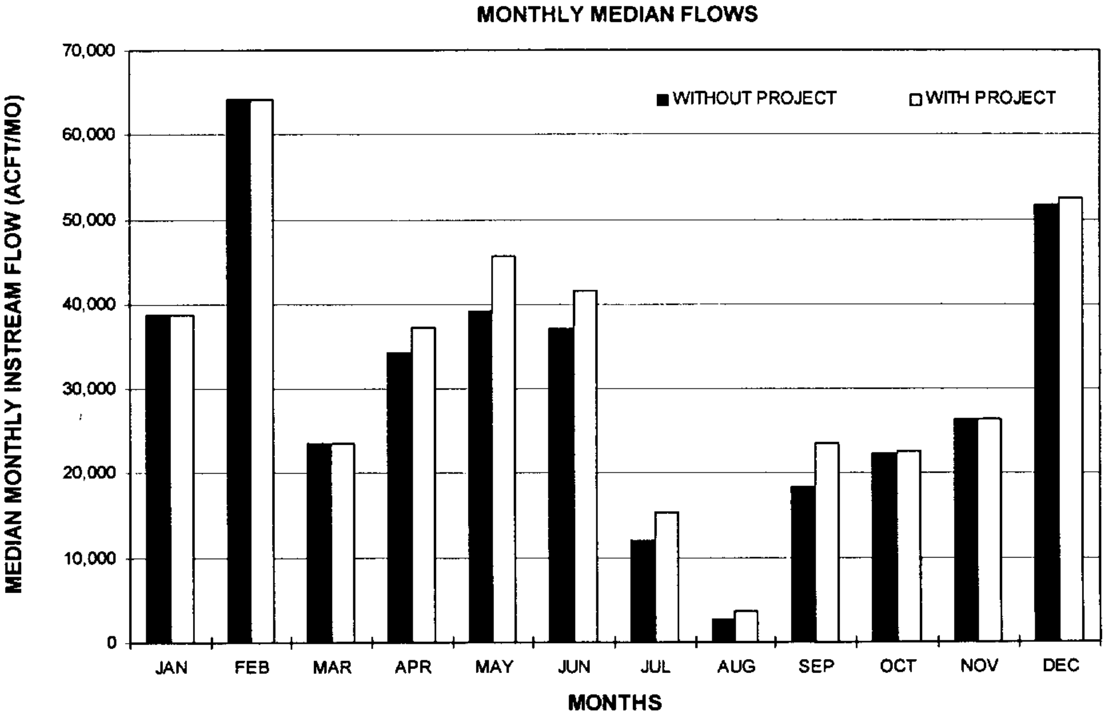
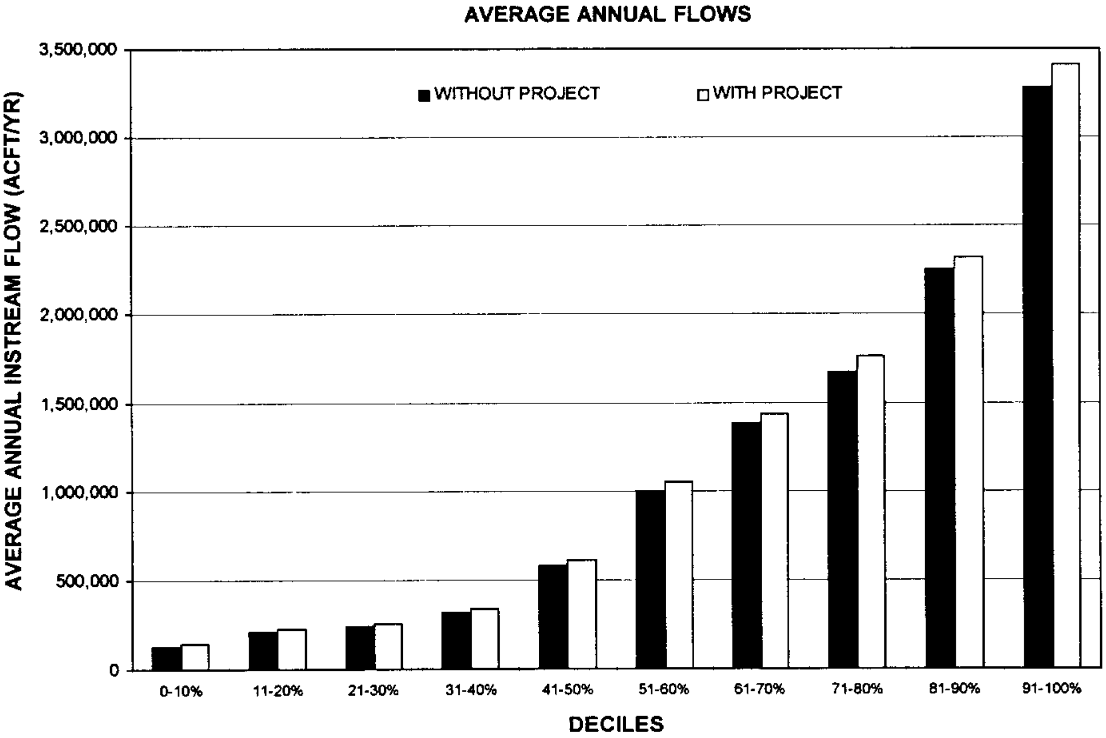
CHANGES IN COLORADO RIVER FLOW AT BASTROP WITH AUGMENTATION FROM CARRIZO-WILCOX - ALTERNATIVE CZ-1A

FIGURE 3.16-3





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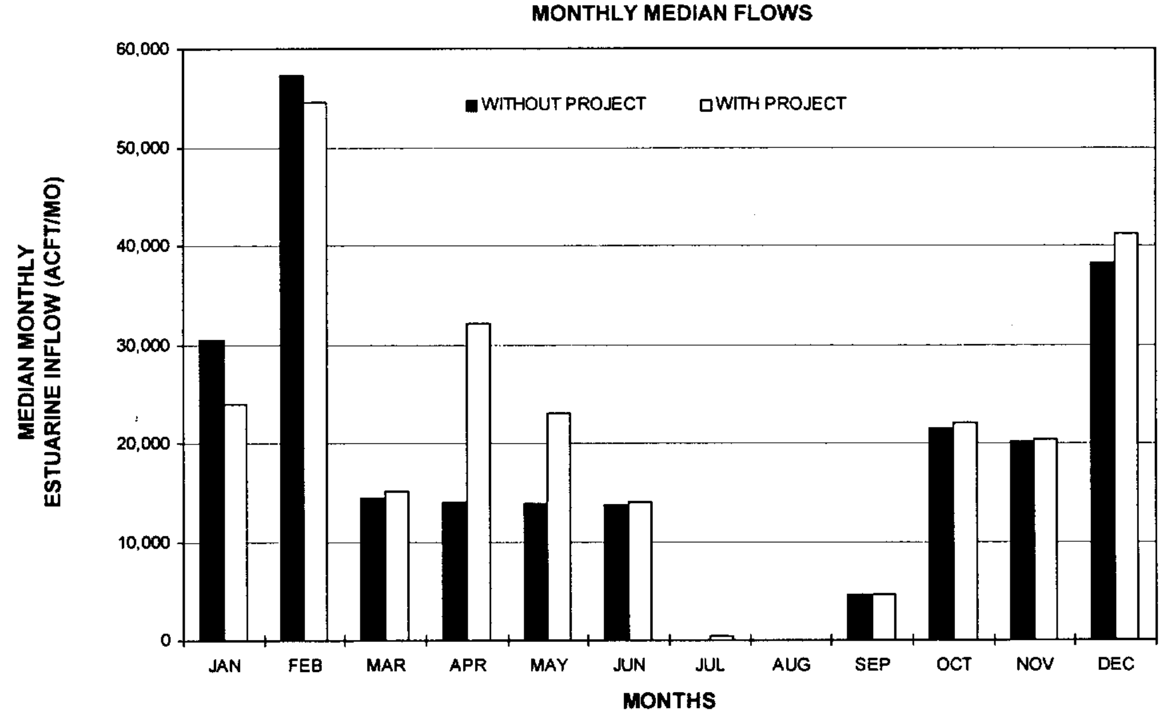
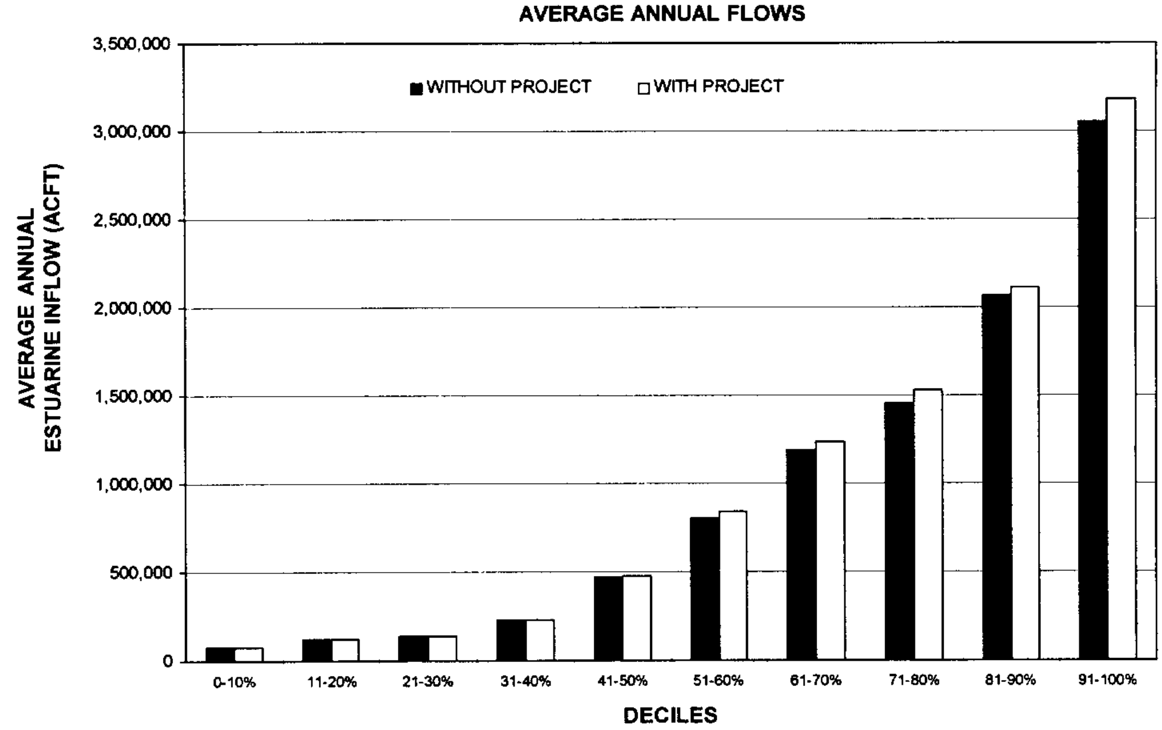
CHANGES IN COLORADO RIVER FLOW AT COLUMBUS WITH AUGMENTATION FROM CARRIZO-WILCOX - ALTERNATIVE CZ-1A

FIGURE 3.16-4





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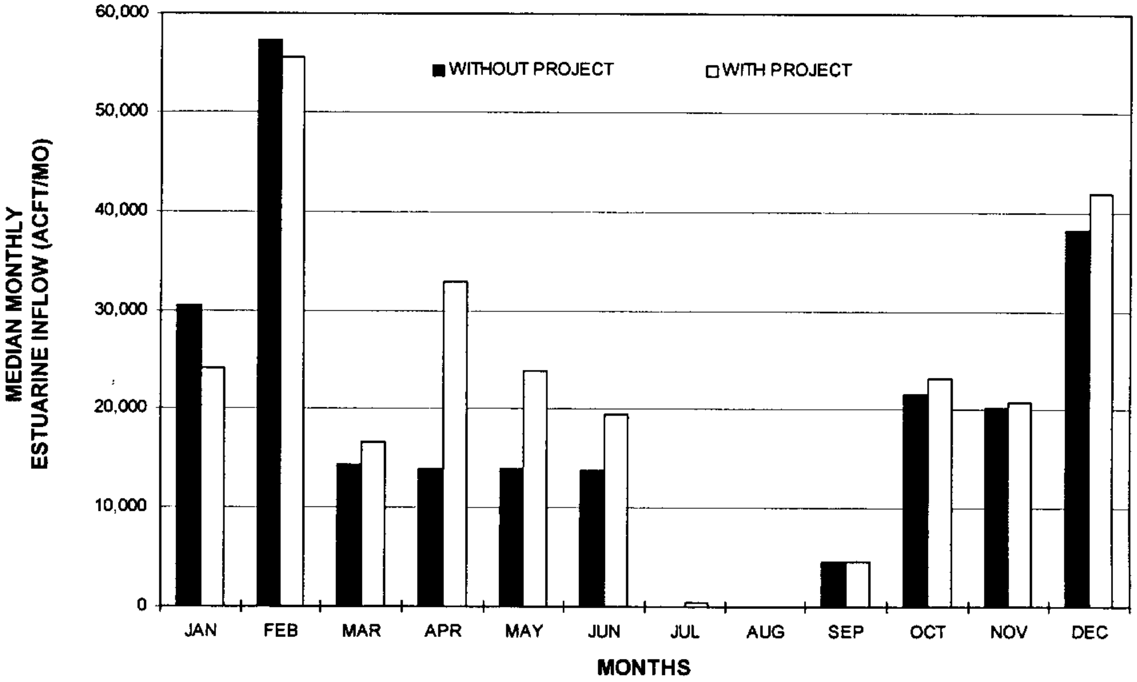
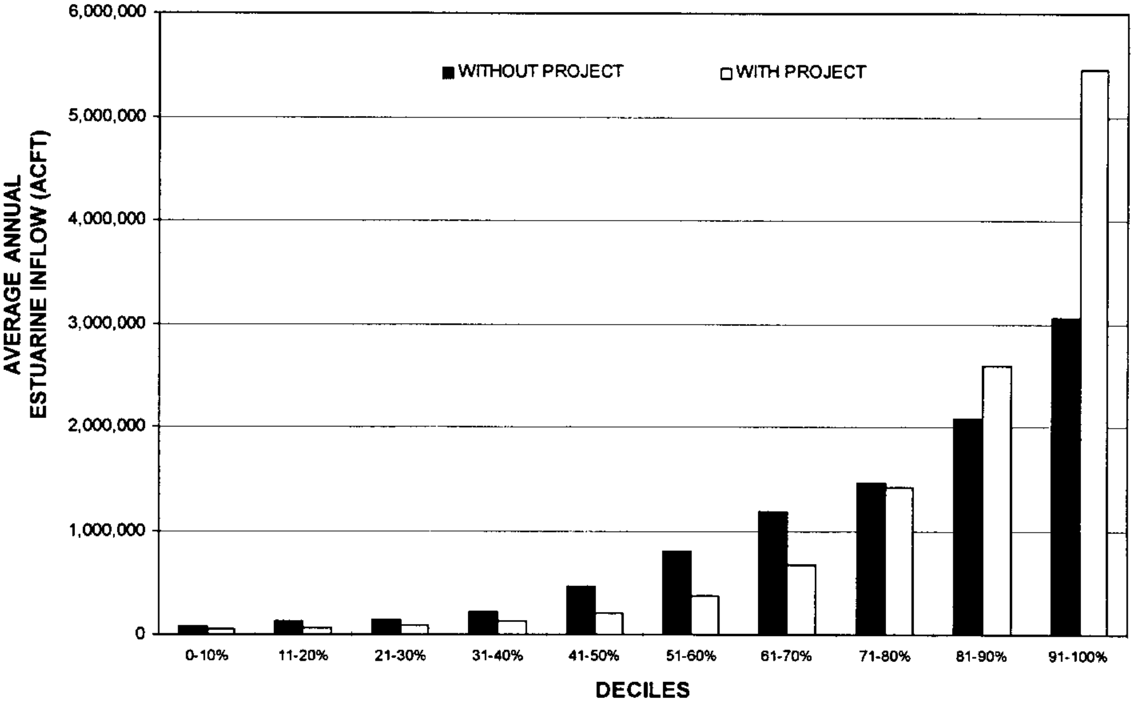
CHANGES IN MATAGORDA BAY INFLOWS WITH AUGMENTATION FROM GROUNDWATER ALTERNATIVE CZ-1A

FIGURE 3.16-5

MONTHLY MEDIAN FLOWS



AVERAGE ANNUAL FLOWS



NOTES:

1. "WITHOUT PROJECT" IS THE BASE CONDITION WITH ALL EXISTING WATER RIGHTS ATTEMPTING TO DIVERT FULL AUTHORIZED AMOUNTS.
2. "WITH PROJECT" INCLUDES AN OFF-CHANNEL RESERVOIR ON CUMMINS CREEK AND GROUNDWATER AUGMENTATION OPERATED TO MEET LOWER BASIN IRRIGATION DEMAND.

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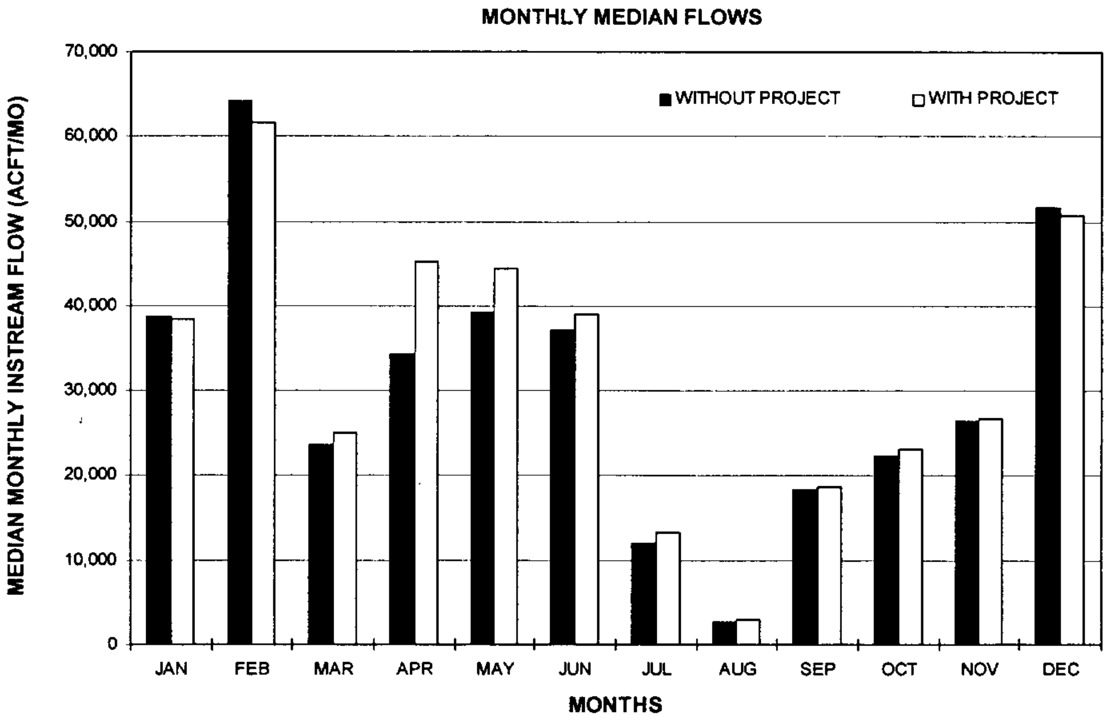
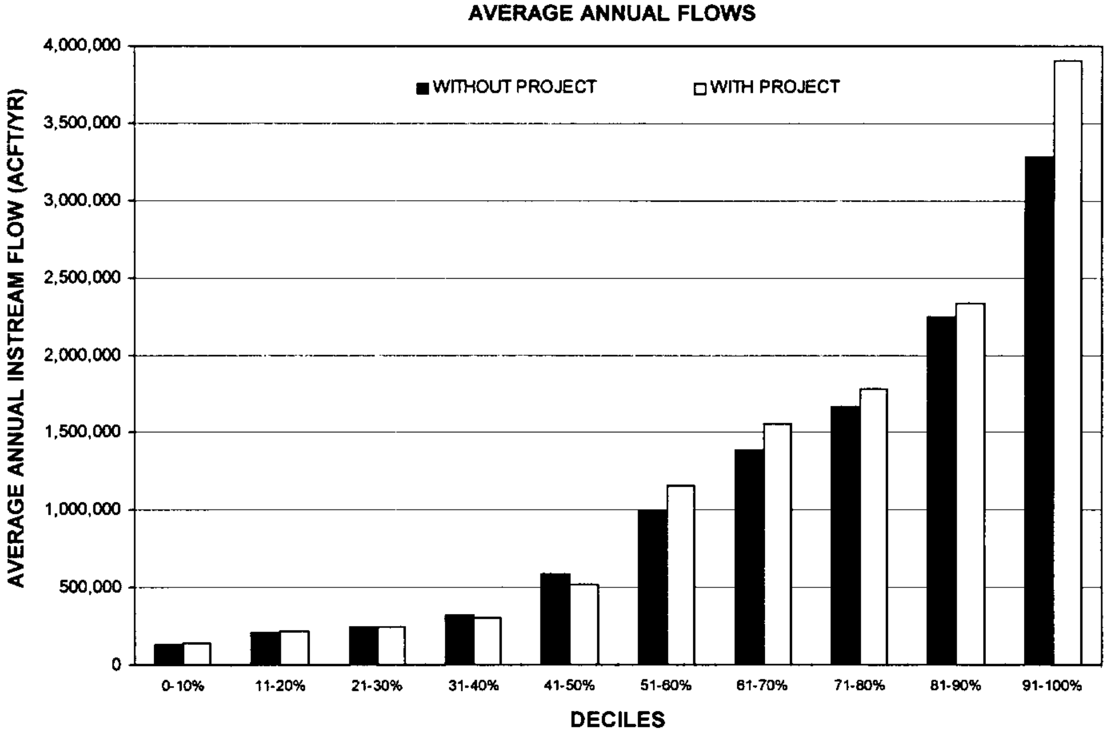
CHANGES IN MATAGORDA BAY INFLOWS WITH AUGMENTATION FROM GROUNDWATER AND OFF-CHANNEL STORAGE - ALTERNATIVE CZ-1B

FIGURE 3.16-6





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2. "WITH PROJECT" INCLUDES AN OFF-CHANNEL RESERVOIR ON CUMMINS CREEK AND AUGMENTATION FROM GROUNDWATER OPERATED TO MEET LOWER BASIN IRRIGATION DEMAND.

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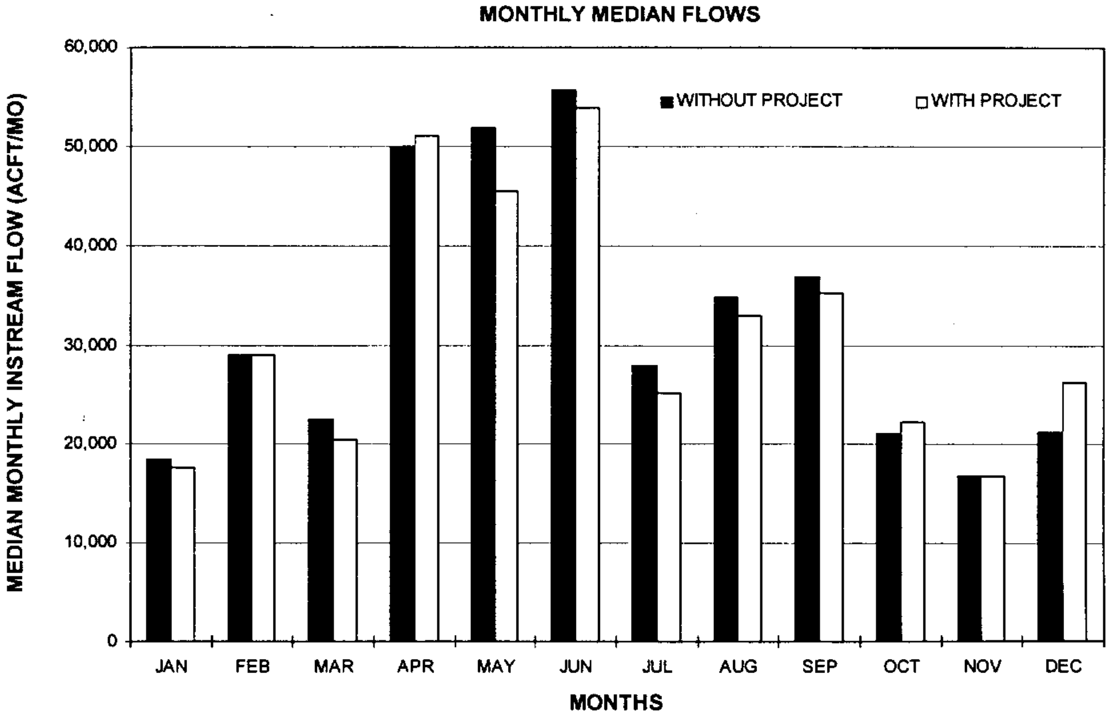
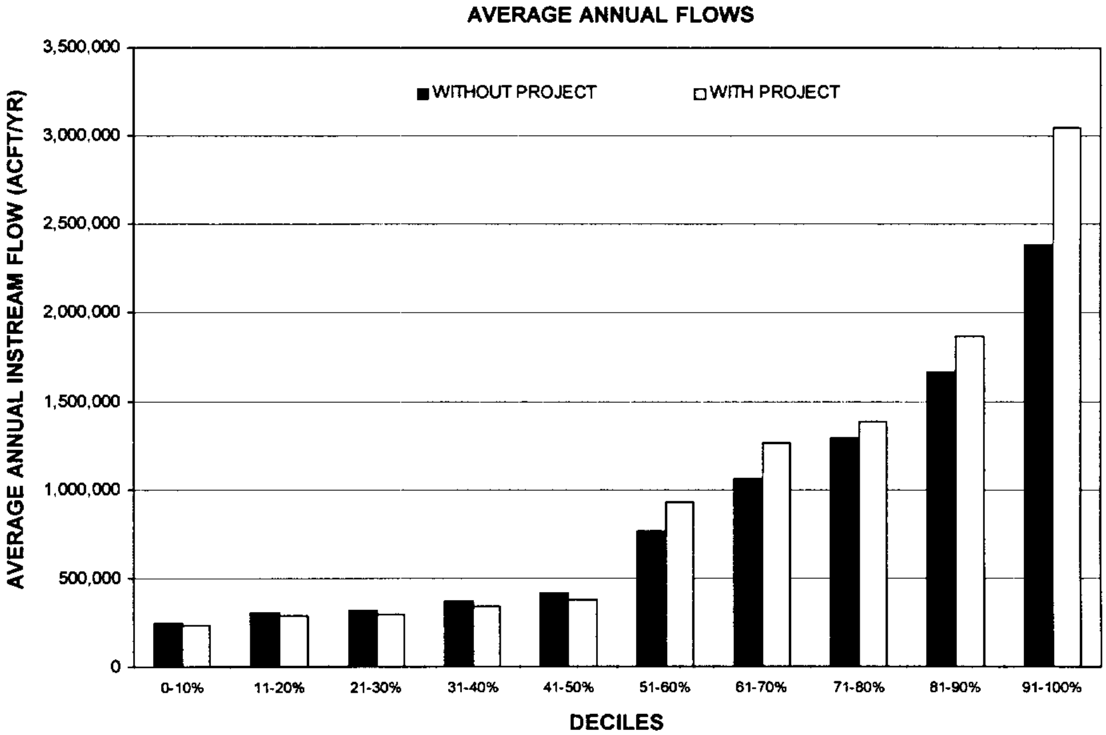
CHANGES IN COLORADO RIVER FLOW AT COLUMBUS WITH OFF-CHANNEL STORAGE AND AUGMENTATION FROM GROUNDWATER - ALTERNATIVE CZ-1B

FIGURE 3.16-7





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CHANGES IN COLORADO RIVER FLOW AT BASTROP WITH OFF-CHANNEL STORAGE AND AUGMENTATION FROM GROUNDWATER - ALTERNATIVE CZ-1B

FIGURE 3.16-8

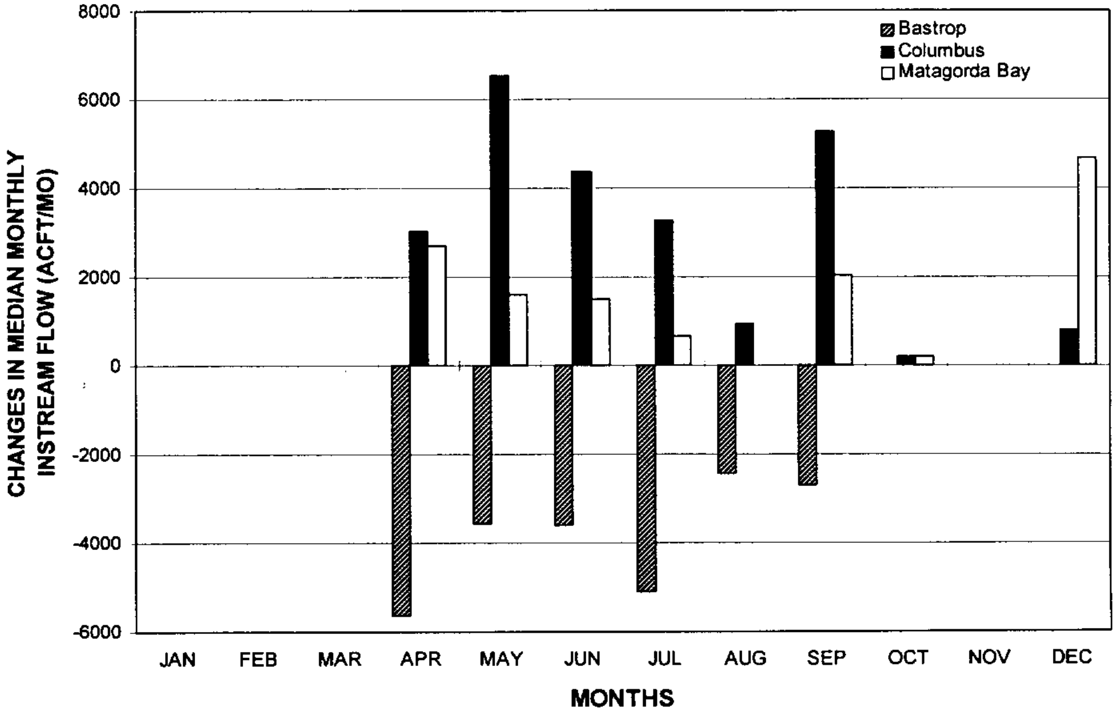
streamflows sorted into deciles (a decile is an interval or range of flows that amounts to 10 percent of the total range of annual flows for the period of record). Each bar graph depicts hydrologic statistics for a Base Case, or without project condition that is constant across all alternatives and scenarios, and a with project condition based on the same period of record. The without project, or Base Case condition is represented by current basin conditions with full permitted diversions.

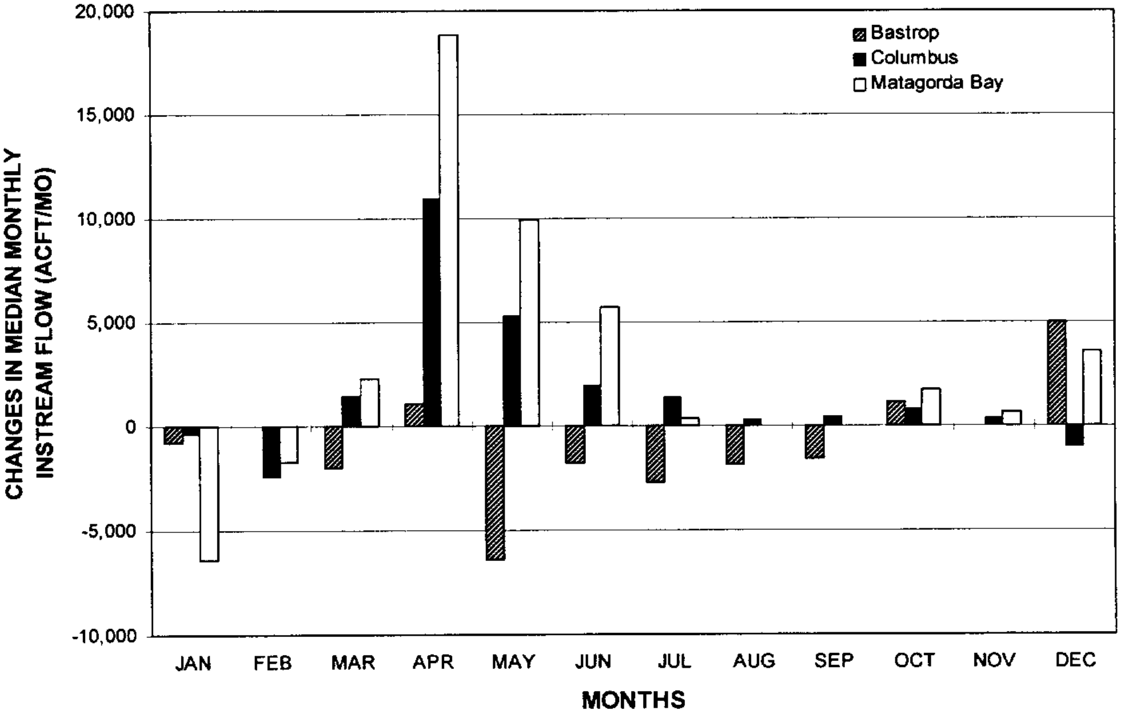
Figure 3.16-3 indicates that median monthly flows at Bastrop would be less than the Base Case for spring and summer (April to September) periods because fewer releases from the Highland Lakes would be required to satisfy senior downstream run-of-river rights. Decreases at the Bastrop gage amount to 10 percent or less for all months except July. The reductions will tend to occur in the lower range (less than 50 percentile flows) of annual flows, while increases will occur in the higher flow ranges (greater than 50 percentile). Increased flows reflect the increase in spills that will result from keeping more water in storage in the Highland Lakes.

Figures 3.16-4 and 3.16-5 show median monthly flows and annual flow deciles for the Columbus gage, and for modeled inflows to Matagorda Bay. All changes predicted at the Columbus gage reflect increased flows with implementation of this scenario (CZ-1A), with the largest changes (about 10 percent of the median) occurring during May-September as irrigation water is delivered to downstream users (Figure 3.16-4). At Matagorda Bay both increases and decreases in median monthly flows are predicted, while large proportional increases will occur in April and May, a substantial decrease in inflow is projected for January (Figure 3.16-5).

Although the details are different, the direction and magnitude of streamflow alterations in the Colorado River predicted to result from implementation of Alternative Scenario CZ-1B (use of an off-channel storage reservoir on Cummins Creek) at all three modeled locations is very similar to the effects of the preceding scenario (Figures 3.16-6 through 3.16-8). Modeled changes in median monthly streamflow are summarized for the two scenarios in Figures 3.16-9.

These hydrologic changes would appear to be substantial if predicted to occur in a pristine river and estuary; however, this river and estuary are not pristine environments. The lower Colorado River is highly regulated with the Highland Lakes system and heavily utilized for agricultural production, consequently it has an annual hydrograph far different from its


DIRECT AUGMENTATION OF 160 CFS TO COLORADO RIVER (ALT CZ-1A)


AUGMENTATION VIA THE PROPOSED CUMMINS CREEK RESERVOIR (ALT CZ-1B)

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CHANGES IN COLORADO RIVER FLOW WITH AUGMENTATION FROM GROUNDWATER ALTERNATIVE CZ-1

FIGURE 3.16-9

natural flow regime. Matagorda Bay, likewise, has experienced the near total loss and subsequent restoration of Colorado River inflows during the past century, and is presently in a transitional state following the modifications of the delta completed by the U.S. Army Corps of Engineers in the early 1990s. While the two 800 cfs diversion scenarios tend to result in the largest hydrologic changes relative to the base case, judgments concerning the significance of those changes to biological communities or to particular important species will require additional study.

3.16.4 Water Quality and Treatability

Implementation of this alternative would increase the availability of water in Lake Travis to be committed for municipal use in the study area. No new or outside sources of water would be introduced to Lake Travis, consequently, this section only considers Lake Travis water quality.

Lake Travis is considered one of the highest quality surface water supplies in the state. Table 3.16-6 summarizes some of the conventional water quality constituents in Lake Travis. It is characterized by low nutrient levels and moderate levels of chlorides and sulfates. Nutrient concentrations in Lake Travis are usually below levels at which algae blooms are significant, however inflows from stormwater runoff have been known to create elevated nutrient levels resulting in isolated periods of algal growth.[20] Hypersaline flows at Natural Dam Lake caused chloride, sulfate, and TDS levels in Lake Travis to increase considerably in 1988.[21]

Lake Travis is protected by TNRCC's Chapter 311, Water Protection, which prohibits discharge of pollutants into the reservoir's water quality area unless sufficient treatment is applied so that the lakes' existing water quality is maintained.[22] With TNRCC's anti-degradation policy, the water quality of the reservoir is expected to remain relatively constant. However, increased population and development in the Lake Travis watershed could eventually lead to extended periods of algal growth or other water quality problems from non-point source pollution.

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[20] Lower Colorado River Authority, "1994 Water Quality Assessment of the Colorado River Basin," October, 1994.
[21] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.
[22] Texas Administrative Code, Title 31, Chapter 311.

Conventional treatment including rapid mix, flocculation, sedimentation, filtration, and disinfection as currently used by the City of Austin and the City of Cedar Park should continue to be adequate for treating the additional raw water diverted from Lake Travis pending any significant modifications to the state drinking water standards. Additional taste and odor control measures may need to be applied to increase the aesthetic quality of the water when necessary.

Table 3.16-6
Conventional Water Quality Constituents in Lake Travis[1]

Constituent	Lake Travis
Dissolved Oxygen (mg/l)	8.04
pH (su)	8.23
TDS (mg/l)	467.36
Fecal Coliforms (No./100 ml)	41.07
Chloride (mg/l)	110.30
Sulfate (mg/l)	83.75
Total Phosphorus (mg/l)	0.04
Total Nitrogen[2] (mg/l)	0.13

[1] TNRCC, "The State of Texas Water Quality Inventory," November, 1994.

[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

3.16.5 Engineering and Costing

For this alternative, a well field in the Carrizo-Wilcox Aquifer would be developed in southern Lee County and Bastrop County. The well field would be located between the outcrop (recharge zone) and the bad water line (TDS greater than 3,000 ppm). The water withdrawn from the aquifer would be discharged into the Colorado River or transferred by pipeline to an off-channel reservoir for later use by downstream users.

Two methods of transferring water from the well field to the downstream users are presented. In each method, CZ-1A and CZ-1B, the annual delivery is 56,830 acft/yr. This is the amount estimated to be available from the Carrizo-Wilcox Aquifer in Lee and Bastrop counties within the Colorado River Basin (Table 3.16-1).

Direct Discharge to Colorado River During 6-month Irrigation Season (CZ-1A)

In this sub-alternative, a well field would be constructed as shown in Figure 3.16-1. The water from each well would be collected in a collection pipeline which would discharge to the Colorado River near the Bastrop County-Fayette County line. The well field would operate only during the 6-month irrigation season from April to September when needed by downstream users. The wells would not be operated during the rest of the year. The water made available to all users in the Colorado River basin under this alternative is estimated to be 69,100 acft/yr.

The major facilities required to implement this alternative are:

- Well Field,
- Collection Pipeline, and
- Discharge Structure in the Colorado River.

The well field would consist of 15 wells with capacities of 5,400 gpm (12.0 cfs), drilled to a depth of about 3,600 feet. This depth would be necessary to tap the full thickness of the two principle water-bearing formations of the Carrizo-Wilcox Aquifer. The width of the Colorado River Basin at the location selected for this report is about 30 miles. To tap the full width of the aquifer the 15 wells would be placed at uniform intervals of about 10,500 feet, linked by a collection line about 28 miles long. The diameter of the collection line would vary from 20 inches at the ends to 54 inches in the middle of the collection line where it would discharge to the Colorado River. A discharge structure would be installed to diffuse the energy of the water to reduce disturbance to the river bed.

A summary of costs for this alternative is shown in Table 3.16-7. The cost of the well field and collection line is estimated to be $39,200,000. The total project cost would be about $54,220,000. Annual debt service of the project financed at 8 percent for 25 years would be about $5,080,000. With annual operations and maintenance costs and payments for groundwater leases, the total annual cost would be about $6,597,000. For a project yield of 69,100 acft/yr the unit cost for increased raw water supply would be $95 per acft.

Pump at Uniform Annual Rate to a New Off-Channel Reservoir (CZ-1B)

In this sub-alternative the well field location is the same as in CZ-1A. The well-field collection line would discharge to a booster station located in southern Lee County, as shown in

Figure 3.16-2. This location provides the minimum length of pipeline from the well field to the point of discharge on Cummins Creek. The water made available with this method after considering mitigation for reduced inflows to Matagorda Bay is estimated to be 90,400 acft/yr.

Table 3.16-7
Cost Estimate Summary for Use of Carrizo-Wilcox Aquifer to Augment Colorado River Flows (Alt. CZ-1)
(1st Quarter 1997 dollars)

Item	Cost	
	CZ-1A	CZ-1B
	Pump Directly to Colorado River	Pump to Off-Channel Reservoir
Capital Costs		
Well Field	$ 39,200,000	$ 28,550,000
Transmission	0	11,280,000
Discharge Structure	100,000	70,000
Dam and Reservoir	$ 0	$ 45,890,000
Subtotal	$ 39,300,000	$ 85,790,000
Engineering, Contingency, Legal	$ 13,120,000	$ 29,010,000
Land Easements	370,000	31,340,000
Environmental Studies and Mitigation	370,000	19,630,000
Interest During Construction	$ 1,060,000	$ 6,990,000
Total Project Cost	$ 54,220,000	$ 172,760,000
Annual Costs		
Debt Service	$ 5,080,000	$ 16,190,000
Operations and Maintenance	130,000	350,000
Power	250,000	510,000
Groundwater Lease Payments[1]	1,137,000	1,137,000
Total Annual Cost	$ 6,597,000	$ 18,187,000
Annual Project Yield[2]	69,100 acft/yr	90,400 acft/yr
Annual Unit Cost for Raw Water	$95 per acft	$201 per acft

[1] Groundwater lease payments are estimated to be $20 per acft for pumping 56,830 acft/yr. This cost is equivalent to purchase of stored water from BRA at the current system price.

[2] Net benefit to City of Austin, Lake Travis firm yield, and other senior water rights with mitigation for reduced freshwater in-flows to Matagorda Bay. See Tables 3.16-2 and 3.16-3.

The major facilities required to implement this alternative are:

- Well Field,
- Collection Pipeline,
- Discharge Structure in Cummins Creek,
- Booster Pump Station, and
- Off-Channel Dam and Reservoir.

The well field would consist of 15 wells with capacities of 2,700 gpm (6.0 cfs), drilled to a depth of about 3,600 feet. The width of the Colorado River Basin at the location selected in this report is about 30 miles. To tap the full width of the aquifer the 15 wells would be placed uniformly at about 10,500-foot intervals, requiring a collection line about 28 miles long. The diameter of the collection line would vary from 16 inches at the ends to 54 inches where it would discharge to a booster station. The booster station would be necessary to transfer a flow of about 80 cfs through the 14-mile pipeline where it would discharge to Cummins Creek. The discharge line would have a diameter of 54 inches and require a static lift of about 30 feet. The location selected as the point of discharge on Cummins Creek is just downstream of USSCS Dam Number 2 on the West Fork of Cummins Creek (Figure 3.16-2). From there the water would flow about 30 miles in the channel to a new reservoir on Cummins Creek located just upstream of its confluence with the Colorado River near Columbus. Channel losses are estimated to be 19.5 percent of the delivery amount or 11,080 acft/yr. This leaves about 45,750 acft/yr inflow to the reservoir from the well fields. The reservoir would also catch natural drainage from the Cummins Creek watershed. The reservoir would have a normal pool elevation of 256 ft-msl, and extend about 12 miles upstream from the dam. The capacity of the reservoir would be about 132,700 acft, and the conservation pool surface area would be 6,600 acres. The water in the reservoir could be released to downstream users as needed.

A summary of costs for this alternative is shown in Table 3.16-7. The cost of the well field and transmission facilities is estimated to be $39,900,000. The cost of the dam and reservoir would be about $45,890,000. The total project cost is estimated to be $172,760,000. Land acquisition, and environmental studies and mitigation are substantial for the reservoir. Annual debt service of the project financed at 8 percent for 25 years would be about $16,190,000. With annual operations and maintenance costs and payments for groundwater leases the total annual cost would be about $18,187,000. For a project yield of 90,400 acft/yr the unit cost for increased raw water supply would be $201 per acft.

Cost of Treated Water to Entities in Travis and Williamson Counties

Increased water supply at Lake Travis made available under this alternative could be diverted and treated through one or more existing or proposed water treatment plants on Lake Travis. Diversion through the planned City of Austin WTP No. 4 could potentially benefit the Austin service area, Pflugerville, and others. Entities in Williamson County including Leander, Cedar Park, Round Rock, and Brushy Creek MUD could potentially benefit from this alternative with diversion near Cedar Park and expansion of Cedar Park's WTP facilities or construction of a regional water treatment plant.

Table 3.16-8 summarizes the estimated unit costs for development of additional raw water supplies in Lake Travis, as well as potential treatment costs for several entities that could benefit from implementation of this alternative.

3.16.6 Implementation Issues

A permit for discharging raw water to a creek or river would be required by the TNRCC, if the possibility exists that the water quality in the stream could be changed. However, because of the high quality of the aquifer water, a permit may not be required.[23] An institutional arrangement would be needed to implement projects including financing on a regional basis.

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[23] TNRCC, Personal Interview, June, 1996.

Table 3.16-8
Treated Water Unit Costs for Alternative CZ-1

Entity	Cost Item (Source)	Unit Cost ($/acft)
Austin Service Area	Raw Water (Table 3.16-8)	$ 95
	Austin CIP Facilities (Table 3.12-17)	549
	Treated Water Cost	$ 644
Pflugerville	Raw Water (Table 3.16-8)	$ 95
	Austin CIP Facilities (Table 3.12-17)	549
	Other Delivery Facilities (Table 3.12-18	36
	Treated Water Cost	$ 680
Round Rock	Raw Water (Table 3.16-8)	$ 95
	Div./Treatment Facilities (BC-2)(1)	391
	Treated Water Cost	$ 486
Brushy Creek MUD	Raw Water (Table 3.16-8)	$ 95
	Div./Treatment Facilities (C-2) (Table 3.12-32)	442
	Other Delivery Facilities (Table 3.12-19)	90
	Treated Water Cost	$ 627
Cedar Park	Raw Water (Table 3.16-8)	$ 95
	Div./Treatment Facilities (C-2) (Table 3.12-30)	321
	Other Delivery Facilities (Table 3.12-30)	41
	Treated Water Cost	$ 457
Leander	Raw Water (Table 3.16-8)	$ 95
	Div./Treatment Facilities (C-2) Table 3.12-30)	321
	Other Delivery Facilities (Table 3.12-30)	63
	Treated Water Cost	$ 479

(1) Includes cost of $134 per acft for intake, pump station and pipeline fro Alt. BC-2, Table 3.19-2, not including purchase cost of raw water from LCRA. Includes cost of $257 per acft for treatment at expansion of Round Rock WTP, Table 3.19-4/

Requirements Specific to a Well Field in Lee and Bastrop Counties

1. Easements for water well sites and water transmission pipelines.
2. For use of the Carrizo-Wilcox Aquifer as a long-term supply, 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, must be verified by a technical groundwater investigation. This investigation program would be used to determine the most efficient well completion, optimum pumping rate, pump setting, well spacing, and

water level drawdown impacts in the outcrop and within the area for development. Such an investigation should include:

- a. Hydrogeologic mapping
- b. Updated inventory of existing wells
- c. Test drilling
- d. Test pumping
- e. Computer modeling
- f. Chemical analysis

Requirements Specific to Pipelines

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

Requirements Specific to Use of Waterways

- I. Obtain TNRCC approval for:
  - A. The use of the bed and banks of Cummins Creek.
- II. Water rights sales and contracts must be approved by the TNRCC.

Requirements Specific To Reservoirs

- I. Necessary permits for the off-channel storage reservoir 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 San and Gravel Removal review.
  - D. GLO Easement for us of state-owned land.
  - E. Coastal Coordinating Council review.
  - F. TPWD Sand, Gravel, and Marl permit.

II. 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.

III. Land must be acquired through either negotiations or condemnation.

IV. Relocation's for the reservoir include:
   - A. Highways and local roads.
   - B. Gas and oil field pipelines and facilities.
   - C. Other utilities if applicable.

3.17 Use of Carrizo-Wilcox Aquifer to Augment Lake Georgetown Yield (CZ-2)

3.17.1 Description of Alternative

The Carrizo-Wilcox Aquifer is one of the most extensive aquifers in Texas, providing high quality groundwater to a large area from the Rio Grande to the northeast corner of the state. In the vicinity of the North Central study area, the Carrizo-Wilcox Aquifer crosses the far eastern corner of Williamson County, and parts of Lee, Milam and Bastrop Counties. In this region it is estimated that there are large quantities of ground water available for development as a dependable water supply.

For this alternative, a reconnaissance-level investigation was made of the potential development of the Carrizo-Wilcox Aquifer to augment the supply of Lake Georgetown. Based on estimates of potential sustainable yield, an annual volume of 25,000 acft/yr from the aquifer was considered for transfer by pipeline to Lake Georgetown for storage, either at a uniform rate or on a summer peak delivery rate. Figure 3.17-1 indicates a potential well field location, the confined portion of the aquifer, and a potential water transmission line route to Lake Georgetown. There are no underground water conservation districts in this region.

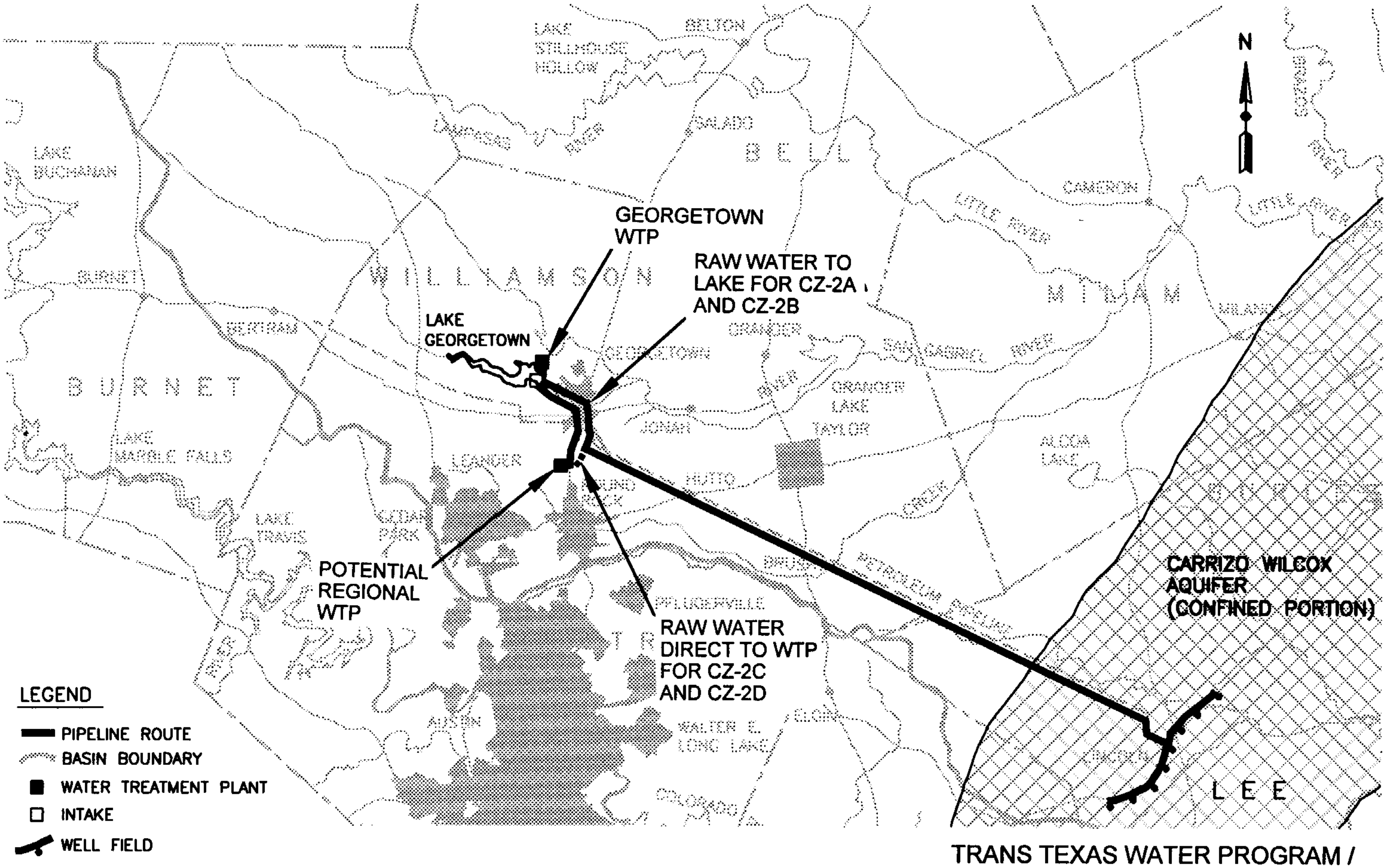
The increased water supply from the Carrizo-Wilcox Aquifer delivered to Lake Georgetown could be treated at either the existing City of Georgetown Water Treatment Plant, the City of Round Rock Water Treatment Plant, or a potential regional treatment plant. Four subalternatives of delivery rate and treatment plant location were considered as summarized in Table 3.17-1.

Table 3.17-1
Designation of Subalternatives for Carrizo Aquifer Augmentation of Lake Georgetown (CZ-2)

Delivery Rate From Carrizo Aquifer	Treatment Plant Location	
	Expansion of Lake Georgetown WTP	Expansion of Round Rock WTP or Potential New Regional WTP
Uniform Annual	CZ-2A	CZ-2B
Summer Peak[1]	CZ-2C	CZ-2D

[1] Delivery rate would be 2.0 times the annual average-day demand.

The principal water-bearing formations of the Carrizo-Wilcox Aquifer are the Carrizo and Simsboro sand layers. At the well field site shown on Figure 3.17-1, the Carrizo layer extends from 1,900 to 2,300 ft below the surface, and the Simsboro layer extends from 3,100 to 3,600 ft below the surface.



HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM / NORTH CENTRAL STUDY AREA

CARRIZO-WILCOX AQUIFER TO LAKE GEORGETOWN ALTERNATIVE CZ-2

FIGURE 3.17-1

Recharge to the Carrizo and Simsboro formations is from precipitation and leakage from overlying formations.[1] The amount pumped from the aquifer in the study area has historically been very low compared to the recharge it receives. This has resulted in the aquifer being nearly full in the study area and indications are that it discharges water to overlying formations and to rivers crossing the recharge zone, as well as rejecting some recharge available to the aquifer.[2]

Study of the aquifer's hydrologic properties supports the conclusion that recharge to the aquifer would be significantly increased if more water were pumped from it, i.e., available recharge water which is currently being rejected because the aquifer is full.[3] It is estimated that the sustainable yield of the aquifer in the Brazos River Basin is as much as four times current groundwater pumpage.

After mixing with surface water in Lake Georgetown, the blended groundwater and surface water would require conventional surface water treatment at a greater expense than that for groundwater alone. Alternatively, if the groundwater were to be kept separate, terminal storage near Georgetown or Round Rock would be needed and minimal treatment for removal of iron and/or hydrogen sulfide in addition to disinfection would be needed. For the summer peak delivery options where terminal storage in Lake Georgetown is not required, the water could be delivered directly to a treatment facility. The treatment process for Carrizo groundwater is described in Section 3.17.4 and would be simpler and less expensive than conventional treatment.

For uniform annual delivery, an alternative to lake storage, however, could be storage in the Edwards Aquifer from which much of the study area already gets a portion of its municipal supply. Because the Carrizo water that would be recharging the Edwards Aquifer is high quality, it would probably require no treatment before recharging it to the aquifer and upon withdrawal would require minimal treatment. If this alternative compares favorably with other water supply alternatives, further study of aquifer storage and recovery in the Edwards Aquifer would need to be considered.

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[1] TWDB, Groundwater Resources of the Carrizo-Wilcox Aquifer in the Central Texas Region, Report R332, September, 1991.

[2] "Phase I Evaluation, Carrizo-Wilcox Aquifer, West Central Study Area, Trans-Texas Water Program," LBG-Guyton Associates, January, 1994.

[3] TWDB, A Digital Model of the Carrizo-Wilcox Aquifer within the Colorado River Basin of Texas, Report LP-208, January, 1989.

In addition to the options listed above, the current dewatering operation at the Alcoa lignite mine in southern Milam County is being considered as a source of aquifer water for the study area. To facilitate mining in Milam County, Alcoa is pumping an estimated 25,000 acft/yr from the Simsboro formation. This water, which is suitable for municipal supply, is presently being discharged into Yegua Creek.[4] Preliminary discussions with staff at Alcoa indicate a willingness to consider an arrangement to make the water available for municipal supply.

3.17.2 Available Yield

The estimated quantity of water available for development in the Carrizo-Wilcox Aquifer for Lee, Milam, Burleson, and Bastrop Counties, which would not cause dewatering of the aquifer or deterioration in quality is 220,300 acft/yr (Table 3.17-2).[5]

Table 3.17-2
Water Available for Development in the Carrizo-Wilcox Aquifer

Area	Percent of Area of Carrizo-Wilcox Aquifer in Brazos Basin	Fraction of Estimated Sustainable Yield[1] (acft/yr)	Reported 1990 Pumpage (acft/yr)	Groundwater Available for Development (acft/yr)
Lee County	14.2	31,300	2,354[5]	29,800 (36,600)[6]
Milam County	11.4	25,100	28,300[2]	0
Burleson County	15.9	35,000	700	34,300
Subtotal	41.5	91,400	27,300[3]	64,100
Remaining Brazos Basin	58.5	128,900	---	---
Bastrop County	---	---	---	52,100[4]
Total	100	220,300	---	116,200

[1] Based on area of county in Brazos River Basin and in Carrizo-Wilcox Aquifer (CWA/BB).
[2] Mostly Alcoa lignite mine. This portion of aquifer may be overdrafted.
[3] Includes only 25,100 acft/yr sustainable for Milam County.
[4] Trans-Texas Water Program, West Central Study Area, Phase II, Table 3.34-1, HDR Engineering, Inc.
[5] Total for all of Lee County - 1,500 acft/yr in Brazos River Basin, assume 854 acft/yr in Colorado River Basin.
[6] All of Lee County; includes 6,800 acft/yr from portion in Colorado River Basin.

The quantity of water available for development in Lee County includes a proportional amount for the southern corner of the county which lies outside the Brazos River Basin. This analysis assumes that the properties of the aquifer are fairly uniform throughout each county; however,

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[4] Personal Interview, June, 1996.

[5] TWDB, Groundwater Resources of the Carrizo-Wilcox Aquifer in the Central Texas Region, September, 1991.

this would need to be verified by field studies if this alternative is chosen as a water supply option for the study area. Bastrop County is included in the table because of its proximity to the study area, should it be desirable to extend a well field south of Lee County.

The sustainable yield of the Carrizo-Wilcox Aquifer available for development in this four-county region is estimated to be up to 116,200 acft/yr (Table 3.17-2). Engineering and costing were performed for a potential initial phase project in Lee County only. The total water available for development in Lee County is currently estimated at 36,600 acft/yr. For purposes of this study, only 25,000 acft/yr was selected as the development quantity in Lee County, leaving over 11,000 acft/yr of remaining sustainable yield. Because the delivery rate to Lake Georgetown will generally not exceed diversions to the treatment plants, water would only be stored for a short time in the lake. Therefore, pumping from the aquifer would not cause a net increase in the volume or surface area of Lake Georgetown, avoiding increased evaporation losses.

3.17.3 Environmental

Issues relevant to augmenting Lake Georgetown yield with water pumped from the Carrizo-Wilcox Aquifer can be categorized as follows:

- Effects resulting from the construction of a well field and water transmission pipeline to the terminus at Lake Georgetown.
- Effects on the Carrizo-Wilcox Aquifer resulting from project operation.
- Effects on the water quality of Lake Georgetown and changes in instream flows on the San Gabriel River and Brazos River and Estuary downstream from the project.

The Carrizo-Wilcox aquifer (Figure 3.17-1) is one of the most extensive aquifers in Texas and has been the subject of previous Trans-Texas studies.[6] The hydrologically connected interbedded sands, clays, silts and discontinuous lignite beds of the Wilcox Group, and the overlying massive sands of the Carrizo which compose the Carrizo-Wilcox aquifer were deposited by large fluvial-deltaic river systems during the early Tertiary Period. These deposits were covered by the clays and interbedded sands of the Reklaw formation.

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[6] HDR Engineering, Inc. Trans-Texas Water Program. West Central Study Area, Phase I Interim Report. Volume 2. May, 1994.

The Carrizo-Wilcox aquifer is recharged by precipitation, and in some places by seepage from lakes, streams and rivers over the outcrop area. The amount of recharge is affected by topography, vegetative cover (type and density), soil characteristics, and the hydraulic conductivity of the exposed soils and rock in the outcrop. Recharge occurs in the outcrop and water moves down into the aquifer or discharges in low areas as springs and seeps in overlying river basins. In Bastrop County, immediately south of potential Carrizo well field, investigators[7,8] reported that the proportion of precipitation falling on the outcrop which to be transmitted to the downdip is approximately 3 percent of the average annual precipitation (about one inch per annum).

Infrastructure required to implement this alternative would be constructed in Lee and Williamson Counties. The proposed well field follows SH 21 between the City of Old Dime Box and the City of Manheim. The proposed pipeline route follows an existing pipeline ROW from SH 21 to I-35 south of the City of Georgetown, and northwest to Lake Georgetown (Fig. 3.17-1). The well field is located in Lee County, within the Post Oak Savannah Vegetational Area. The proposed pipeline route courses through Post Oak Savannah in Lee County, and Blackland Prairies in Williamson County. The western most extent of the pipeline route involves the and Edwards Plateau Vegetational Area. These vegetational areas are described in the Environmental Overview (Section 3.1.3). The vegetation types potentially affected by implementation of this alternative have been described as croplands, oak-mesquite-juniper parks and woods, post oak woods, forest and grassland mosaics, post oak woods and forest, silver bluestem-Texas wintergrass grasslands and other native and or introduced grasses.[9]

The potential effects of well field and pipeline construction and operation depend to a large degree on the siting of these structures. In general, critical habitats for endangered species are unique and localized, which usually makes avoidance a practical and preferable means of mitigation. The more ubiquitous habitats, which may be more important to wildlife in some areas, are more difficult to completely avoid. However, wells and buried water pipelines impact

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[7] Thorkildsen et al., cited in HDR Engineering, Inc. Trans-Texas Water Program. West Central Study Area, Phase I Interim Report. Volume 2. May, 1994.

[8] HDR Engineering, Inc. Trans-Texas Water Program. West Central Study Area, Phase I Interim Report. Volume 2. May, 1994.

[9] McMahan, C.A., R.G. Frye and K.L. Brown. 1984. The Vegetation Types of Texas Including Cropland. TPWD, Austin, TX.

limited areas, and in some cases may benefit certain species by breaking up habitat (e.g. breaking up dense brush may favor deer) or by providing edge habitat.

Endangered, threatened and candidate species are reported in Table XX, Section 3.1.3. Most of the protected species potentially occurring in the project county are migratory, highly mobile (e.g., bald eagle, whooping crane, interior least tern), and appear unlikely to be adversely affected by the proposed well field or pipeline construction and operation. The removal of large trees which could be used for perching often can be minimized or eliminated by field surveys and appropriate selection of the easements.

Endangered and threatened species inhabiting karst features in proposed construction areas in the vicinity of the City of Georgetown, on the Balcones Escarpment have been discussed previously in Sections 3.5 and 3.6. Habitat for the endangered Houston toad was reported on several 7.5 minute quadrangle maps of the Texas Natural Heritage Program database including Deanville, Tanglewood, Lincoln, Paige, Fedor, McDade, Lexington, Beaukiss. Critical habitat for the Houston toad is located in Bastrop and Burleson Counties adjacent to Lee County where it is presumed to occur.[10] Recent surveys have not reported breeding populations in Lee County.[11,12,13]

The Houston toad is a small toad, similar in appearance to the common Woodhouse's toad (*Bufo woodhousei*). It is a terrestrial amphibian associated with deep sandy soils within the Post Oak Savannah vegetational area of east central Texas. The Houston Toad is a poor burrower and requires loose friable soils for burrowing. It inhabits pine or oak woodland or savanna with native bunchgrasses and flowering plants present in open areas. Houston toad habitat commonly includes loblolly pine, post oak, bluejack or sandjack oak, yaupon, and little bluestem.

Like most amphibians, the Houston toad requires water for breeding and tadpole development. It requires still or slow-flowing water that persists for at least 30 days. Breeding

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[10] Arroyo, Bryan. 1992. Threatened and Endangered Species of Texas. U.S. Fish and Wildlife Service, Texas State Office, Austin, TX.

[11] Yantis, J.H. and A.H. Price. 1993. Houston Toad (*Bufo houstonensis*) Status Survey. Final Report. Texas Parks and Wildlife Dept., Austin, TX.

[12] Price, A.H. 1992. Houston Toad (*Bufo houstonensis*) Status Survey. Performance Report. Texas Parks and Wildlife Dept., Austin, TX.

[13] Price, A.H. 1990. Houston Toad Status Survey. Performance Report. Texas Parks and Wildlife Dept., Austin, TX.

and development may include ephemeral pools, flooded fields, drainage ditches, wet areas associated with seeps or springs, or more permanent ponds. The source of water used for breeding is general within three quarters of a mile from the toad's breeding and foraging habitat. Male Houston toads may call from December through June and breeding generally takes place in February and March. The adults, and especially the first-year toadlets are active year round when temperatures and moisture conditions are favorable.

Possible reasons for decline of the Houston toad potentially relevant to the implementation of this alternative include the draining of wetlands or the conversion of ephemeral ponds to permanent ponds containing predatory fishes, the clearing of native vegetation near ponds or on uplands adjacent to ponds which reduces the quality of foraging habitat and cover, conversion of grass cover from native grassland and woodland savanna to sod-forming grasses which form denser mats, barriers to migration such as roads, pipelines, and transmission lines between foraging and breeding habitats, especially where native grasses have been removed.

Suggested management guidelines pertinent to project implementation include avoiding or disturbing wet-weather ponds and other small pools within one-half mile of deep sandy soils which support post oak or loblolly pine woodland or savanna. Extensive removal of native vegetation and altering drainage patters should be avoided in and near ponds. Other management guidelines concern range management but may be relevant to pipeline ROWs. For example, native bunch grasses on sandy soils in potential Houston toad habitat would be preferable to sod-forming grasses such as bermuda grass and bahia grass.[14]

Construction Effects

Construction in brush/shrub habitat and maintenance activities could potentially impact the Texas tortoise and Texas horned lizard. Because the majority of the proposed well field and pipeline corridor consists of cropland, wildlife habitat tends to be limited, patchy, and of disproportionate value to local wildlife populations. However, construction impacts can generally be mitigated by avoidance of sensitive features by confining this to pastures, cropland

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[14] Campbell, Linda. 1995. Endangered and Threatened Animals of Texas. Their Life History and Management. Texas Parks and Wildlife Dept., Austin, TX.

and uplands when possible. Because riparian zones support wetlands and represent more valuable wildlife habitat, and may be more difficult to return on preconstruction condition, construction across rivers and streams should be minimized. Mitigation may be required for impacts associated with pump stations, wells and pipelines proposed for this alternative if sensitive ecological or cultural resources are identified in a future phase of this study. Expansion of the City of Georgetown or City of Round Rock Water Treatment Plants for regional supply would require additional detailed siting studies due to the density of endangered species habitats both above and below the surface at each location.

A general discussion dealing with cultural resources of the study area is presented in the Environmental Overview (Section 3.1.3). 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.

Operational Effects

No animal species have been reported to inhabit the Carrizo-Wilcox aquifer. Thus, the most significant environmental issues appear to be related to water quality effects on Lake Georgetown and possibly lowering the water table and affecting the water budgets of ponds and streams crossing the outcrop area. A search of water quality data collected from wells in Lee County in 1992 revealed seven wells reporting phosphate concentrations ranging between 0.01 mg/l and 0.35 mg/l.[15] These values are within the range of concentrations commonly reported in the surface waters of Texas, and it appears unlikely that 25,000 acft/yr of water from the Carrizo-Wilcox aquifer would significantly affect phosphate concentrations in Lake Georgetown. Nitrate concentrations in Carrizo-Wilcox water reported in section 3.17.4 are about three times those reported in Lake Georgetown. Because vegetative growth is usually limited by phosphate in freshwater systems, nitrogen concentrations are not likely to stimulate algae growth. Certain

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[15] Texas Water Development Board computer database searched October, 1996.

forms of nitrites may be a human health concern and may require consideration or analysis in a later study.

As noted above, the Carrizo-Wilcox aquifer currently appears to be full and it discharges water to overlying formations and to rivers crossing the recharge zone. Because the Carrizo-Wilcox aquifer is full, some water that might potentially recharge the aquifer passes through the recharge zone and contributes to instream flows. Pumping water from the aquifer may lower the water levels in the outcrop area and increase recharge by surface water runoff and seepage from ponds. As a result it is possible that channel losses could increase on the outcrop resulting in decreased instream flows downstream from the outcrop.

Lowering the Carrizo-Wilcox aquifer water table in the project area could impact possible Houston toad habitat or the Houston toad which depends on the saturated sands of the Carrizo aquifer to provide temporary pools during the breeding season. Other species inhabiting the moist sands of the project area include the Texas garter snake, lesser siren, and bracted twistflower. Determining the possible effects of withdrawing water from the Carrizo-Wilcox aquifer at a rate of 25,000 acft/yr on temporary pools and ponds would require hydrologic analyses to be conducted in a future phase of project development.

3.17.4 Water Quality and Treatability

The potential groundwater supplies from the Carrizo-Wilcox Aquifer have twice the dissolved solids and much greater levels of chloride and sulfate compared to Lake Georgetown (Table 3.17-3). All the listed constituents are well below the drinking water standards for public water supplies. More than 90 percent of the wells included in a TWDB study of the Carrizo-Wilcox Aquifer reported TDS levels under 1,000 mg/l, with the majority of wells reporting less the 500 mg/l.[16] Water directly from the Carrizo-Wilcox Aquifer is currently being used by municipalities and households in the area with little or no treatment.

Excessive iron concentrations and odor problems associated with hydrogen sulfide concentrations have been measured and reported in the Carrizo-Wilcox groundwater. Both constituents are common in groundwater supplies and can be easily treated with either aeration or an oxidizing chemical treatment if the mixing and aeration processes occurring during discharge

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[16] Ground-Water Resources of the Carrizo-Wilcox Aquifer in Central Texas Region, TWDB, September, 1991.

and blending in Lake Georgetown are not adequate. It is important to note that the City of Giddings, located near the potential well field discussed here, treats only for hydrogen sulfide.[17] However, the higher nitrate levels in the groundwater could potentially lead to excessive algae growth in Lake Georgetown if other limiting nutrients, such as phosphorus, are available.

Table 3.17-3
Water Quality Constituents
in Lake Georgetown[1] and the Carrizo-Wilcox Aquifer[2]

Constituent	Lake Georgetown	Carrizo-Wilcox Aquifer
pH (su)	8.05	7.60
TDS (mg/l)	232	464
Chloride (mg/l)	13	74
Sulfate (mg/l)	18	55
Nitrate (mg/l)	0.05	1.6

[1] Texas State Water Quality Inventory, TNRCC, November, 1994.
[2] Ground-Water Resources of the Carrizo-Wilcox Aquifer in the Central Texas Region., TWDB, September 1991.

Existing conventional treatment of surface waters should be adequate to produce drinking water supplies from the groundwater and Lake Georgetown water mixture. However, in order to alleviate any impacts to the Lake Georgetown ecosystem and any water compatibility problems, a more detailed analysis of the two waters would need to be conducted before implementation. For direct treatment of Carrizo Aquifer water with the summer peak delivery options, the treatment process would probably include application of chlorine dioxide for taste and odor control and addition of phosphate to sequester iron and manganese.

3.17.5 Engineering and Costing

For this alternative, a well field would be developed in Lee County half way between the outcrop of the aquifer and the bad water line (> 3,000 ppm TDS). A possible well field location is shown on Figure 3.17-1. More specific information about the local hydrogeology would be needed prior to determining the final well field location.

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[17] City of Giddings staff, pers. comm., June, 1996.

The major facilities required to implement this alternative are:

- Well field and collection lines;
- Raw water pipeline to Lake Georgetown;
- Raw water pipeline booster pump stations;
- Raw water intake expansion at Lake Georgetown;
- Raw water pipeline from Lake Georgetown to the water treatment plant;
- Conventional surface water treatment plant expansion at Lake Georgetown (uniform annual delivery); and,
- Groundwater treatment plant (summer peak delivery).

The well field, transmission pipelines, and water treatment facilities have been sized and costed for uniform and summer peak delivery rates. Both rates would deliver 25,000 acft/yr of water to the study area. However, the uniform delivery system would transfer a steady 2,083 acft/month (22.3 mgd) to Lake Georgetown where it would be blended and stored temporarily. Conventional water treatment capacity sufficient to meet summer peak demands would be required. The peak delivery system would be capable of delivering 4,166 acft/month (45 mgd) and the Carrizo Aquifer water would be delivered to the treatment facility. The treatment facility would be as described in Section 3.17.4 and be more economical than conventional treatment. Costing of the summer peak system is based on a typical municipal monthly water demand pattern. Another advantage of the summer peak delivery system is that the well field could be extended to pump up to a steady 4,166 acft/month without requiring additional transmission line capacity.

Alternative CZ-2A: Uniform Delivery Rate, Treatment at Expanded Lake Georgetown Water Treatment Plant

For this alternative, a well field would be developed to produce 25,000 acft/yr (2,083 acft/month). The well field would consist of six wells spaced about 14,000 ft apart. The collection line would be about 16.6 miles long, extending along Route 21 in Lee County, and would consist of pipe varying in diameter from 16 inches to 30 inches.

The average depth of the wells would be about 3,600 ft, providing access to the full thickness of both the Carrizo and Simsboro formations. The wells would have a 12-inch hole casing, underreamed and fully cemented, with stainless steel screens at the sand layers. The wells would have a capacity of 2,700 gpm, requiring 400 hp motors.

The transmission line from the well field to Lake Georgetown would be sized to deliver 2,083 acft/month at a constant rate. The line would be about 56 miles long, 42 inches in diameter, require two pump stations, and have a static lift of 460 ft.

A new raw water pipeline from Lake Georgetown to the Georgetown Water Treatment Plant would be needed. The raw water pipeline would be 2,700 ft long and 54 inches in diameter. The line would be sized for 50,000 acft/yr capacity and would have a static lift of 70 ft. The cost of the treatment plant is based on a design capacity of 45 mgd for conventional surface water treatment.

The total project cost of this alternative is $114,260,000 (Table 3.17-4). Financing at 8.0 percent annual interest rate for 25 years would require an annual debt service of $10,710,000. Operations and maintenance costs, including power costs, total $7,240,000, to result in a total annual cost of $17,950,000. For an annual yield of 25,000 acft/yr, the unit cost of water would be $718 per acft ($2.20 per 1,000 gal) (Table 3.17-3).

Alternative CZ-2B: Uniform Delivery Rate, Treatment at Expanded Round Rock Water Treatment Plant or New Regional Treatment Plant

For this alternative, treatment would occur at either an expanded Round Rock Water Treatment Plant or at a potential new regional water treatment plant. The cost for the treatment plant component would be about the same for either a major expansion of the Round Rock plant (current capacity is 21 mgd), or for construction of a potential new regional plant. The well field, transmission line to Lake Georgetown, and the treatment plant would be the same as those for Alternative CZ-2A. The intake pipeline from Lake Georgetown to the proposed regional treatment plant would be 8.4 miles long; 8 miles longer than the line to the Georgetown Water Treatment Plant. The pipeline would be 54 inches in diameter, with 50,000 acft/yr capacity, and a static lift of zero.

The total project cost of this alternative is $127,970,000 (Table 3.17-3). Financed at 8.0 percent annual interest rate for 25 years results in an annual debt service of $11,990,000. Operations and maintenance costs, with power, total $7,360,000, to result in a total annual cost of $19,420,000. For an annual yield of 25,000 acft/yr, the unit cost of water is $777 per acft ($2.38 per 1,000 gal) (Table 3.17-4).

Alternative CZ-2C: Summer Peak Delivery Rate, Treatment at Lake Georgetown Water Treatment Plant

For this alternative, a well field would be developed to produce 25,000 acft/yr, but each well would be sized to deliver water at a rate twice the annual well yield. A well field has been costed with six wells, with capacities of 5,400 gpm. The collection line would be about 16.6 miles long, as shown in Figure 3.17-1. The diameter of the line would vary from 24 inches to 42 inches, and be sized to deliver 45 mgd, according to a municipal demand pattern with a peak factor of 2.0.

Table 3.17-4
Cost Estimate Summary for Carrizo-Wilcox Aquifer Development to Augment Lake Georgetown Alternative (CZ-2)
(1st Quarter 1997 dollars)

Item	Uniform Delivery Rate		Summer Peak Delivery Rate	
	Alt. CZ-2A Treat at Lake Georgetown Plant	**Alt. CZ-2B Treat at Regional Plant**	**Alt. CZ-2C Treat at Lake Georgetown Plant**	**Alt. CZ-2D Treat at Regional Plant**
Capital Costs				
Well Field	$ 10,080,000	$ 10,080,000	$ 15,140,000	$ 15,140,000
Trans Lines, Pump Stations	41,230,000	50,830,000	51,790,000	45,316,000
Treatment Plant	27,000,000	27,000,000	6,100,000	6,100,000
Total Capital Cost	$ 78,310,000	$ 87,910,000	$ 73,030,000	$ 66,556,000
Engineering, Contingency, Legal	25,630,000	28,540,000	23,322,000	21,320,000
Land Acquisition	930,000	930,000	910,000	910,000
Environmental Studies and Mitigation	930,000	930,000	910,000	910,000
Interest During Construction	8,460,000	9,480,000	7,850,000	7,180,000
Total Project Cost	$114,260,000	$127,970,000	$106,022,000	$ 96,876,000
Annual Costs				
Annual Debt Service	10,710,000	11,990,000	9,930,000	9,080,000
Annual O&M	4,720,000	4,840,000	3,010,000	3,010,000
Annual Power	2,520,000	2,590,000	2,410,000	2,234,000
Total Annual Cost	$17,950,000	$19,420,000	$ 15,350,000	$ 14,324,000
Annual Project Yield	25,000 acft/yr	25,000 acft/yr	25,000 acft/yr	25,000 acft/yr
Annual Unit Costs				
($ per acft)	$ 718	$ 777	$ 614	$ 573
($ per 1,000 gal)	$2.20	$2.38	$1.88	$1.76

The transmission pipeline to the treatment plant would be sized for a maximum capacity of 45 mgd, and would follow the same route as the line for the uniform demand scenario discussed previously (CZ-2A). This line would require two booster pump stations and have a static lift of 460 ft. The treatment process would primarily be for taste and odor control as described in Section 3.17.4.

The total project cost of this alternative would be $106,022,000 (Table 3.17-3). Financing at 8.0 percent annual interest rate for 25 years requires an annual debt service of $9,930,000. Operations and maintenance costs, with power, total $5,420,000, to result in a total annual cost of $15,350,000. For an annual yield of 25,000 acft/yr, the unit cost of water would be $614 per acft ($1.88 per 1,000 gal) (Table 3.17-3).

Alternative CZ-2D: Summer Peak Delivery Rate, Treatment at Expanded Round Rock Water Treatment Plant or New Regional Treatment Plant

For this alternative, treatment would occur at either an expanded Round Rock Water Treatment Plant or at a potential new regional water treatment plant. The cost for the treatment plant component would be about the same for either a major expansion of the Round Rock plant (current capacity is 21 mgd), or for construction of a potential new regional plant. The well field and transmission line to the treatment plant would be sized to carry 50,000 acft/yr (45 mgd) and are identical to those in Alternative CZ-2C.

The total project cost of this alternative is $96,876,000 (Table 3.17-3). Financed at 8.0 percent annual interest rate for 25 years would result in an annual debt service of $9,080,000. Operations and maintenance costs, with power, total $5,244,000, to result in a total annual cost of $14,324,000. For an annual yield of 25,000 acft/yr, the unit cost of water would be $573 per acft ($1.76 per 1,000 gal) (Table 3.17-3).

3.17.6 Implementation

A permit for discharging raw water to a lake would be required by the TNRCC, if the possibility exists that the lake quality could be changed. However, because of the high quality of the aquifer water, a permit may not be required.[18]

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[18] TNRCC, Personal Interview, June, 1996.

Requirements Specific to a Well Field in Lee County

1. Easements for water well sites and water transmission pipelines.
2. For use of the Carrizo-Wilcox Aquifer as a long-term supply, 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, must be verified by a technical groundwater investigation. This investigation program would be used to determine the most efficient well completion, optimum pumping rate, pump setting, well spacing, water treatment requirements, and water level drawdown impacts in the outcrop and within the area for development. Such an investigation should include:
    a. hydrogeologic mapping
    b. updated inventory of existing wells
    c. test drilling
    d. test pumping
    e. computer modeling
    f. chemical analysis

Requirements Specific to Pipelines

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

3.18 System Operation of Lake Stillhouse Hollow and Lake Travis (BC-1)

3.18.1 Description of Alternative

This alternative considers methods to increase water availability from Lake Stillhouse Hollow and Lake Travis by operating the two reservoirs as a system. System operation could be implemented by constructing a one-way delivery system from Lake Stillhouse Hollow to Lake Travis, or by overdrafting/underdrafting the reservoirs. For either method, the goal is for the combined system yield to exceed the sum of the reservoir yields operated independently.

Lake Stillhouse Hollow, located in central Bell County about five miles southwest of the City of Belton, is one of 13 water supply reservoirs in the Brazos River Authority System. The reservoir is located on the Lampasas River, which is a tributary to the Little River. The Little River is a major tributary to the Brazos River. Lake Stillhouse Hollow is located about 45 miles northeast of Lake Travis and its location is shown on Figure 3.18-1.

Lake Stillhouse Hollow was constructed by the U.S. Army Corps of Engineers (Corps) and is owned and operated by the Corps. The reservoir was built for flood control, conservation and recreation. Construction of the reservoir began in 1968 and impoundment began in 1972. At the conservation pool elevation of 622.0 ft-msl, the reservoir covers 6,430 acres and has a capacity of 226,063 acft[1] At the top of the flood control pool, elevation 666 ft-msl, the reservoir covers 11,830 acres and stores 390,600 acft. The BRA has contracted with the Corps for the use of the water in the conservation storage space between reservoir elevations 622 ft-msl and 515 ft-msl. BRA directs the Corps on the operation of the reservoir within the conservation pool. The BRA holds the permit from the State of Texas for the right to impound water in the reservoir and divert water for municipal and other uses.[2] Diversions from Lake Stillhouse Hollow are also governed by the BRA System Operation Order.[3]

The system order permits the BRA to operate tributary reservoirs (i.e., Lake Stillhouse Hollow, Lake Granger, Lake Georgetown, and others) as elements of a system under which releases can be coordinated with releases from main stem reservoirs to achieve the most effective use of available stored water. Also governing diversions at Lake Stillhouse Hollow is the Final

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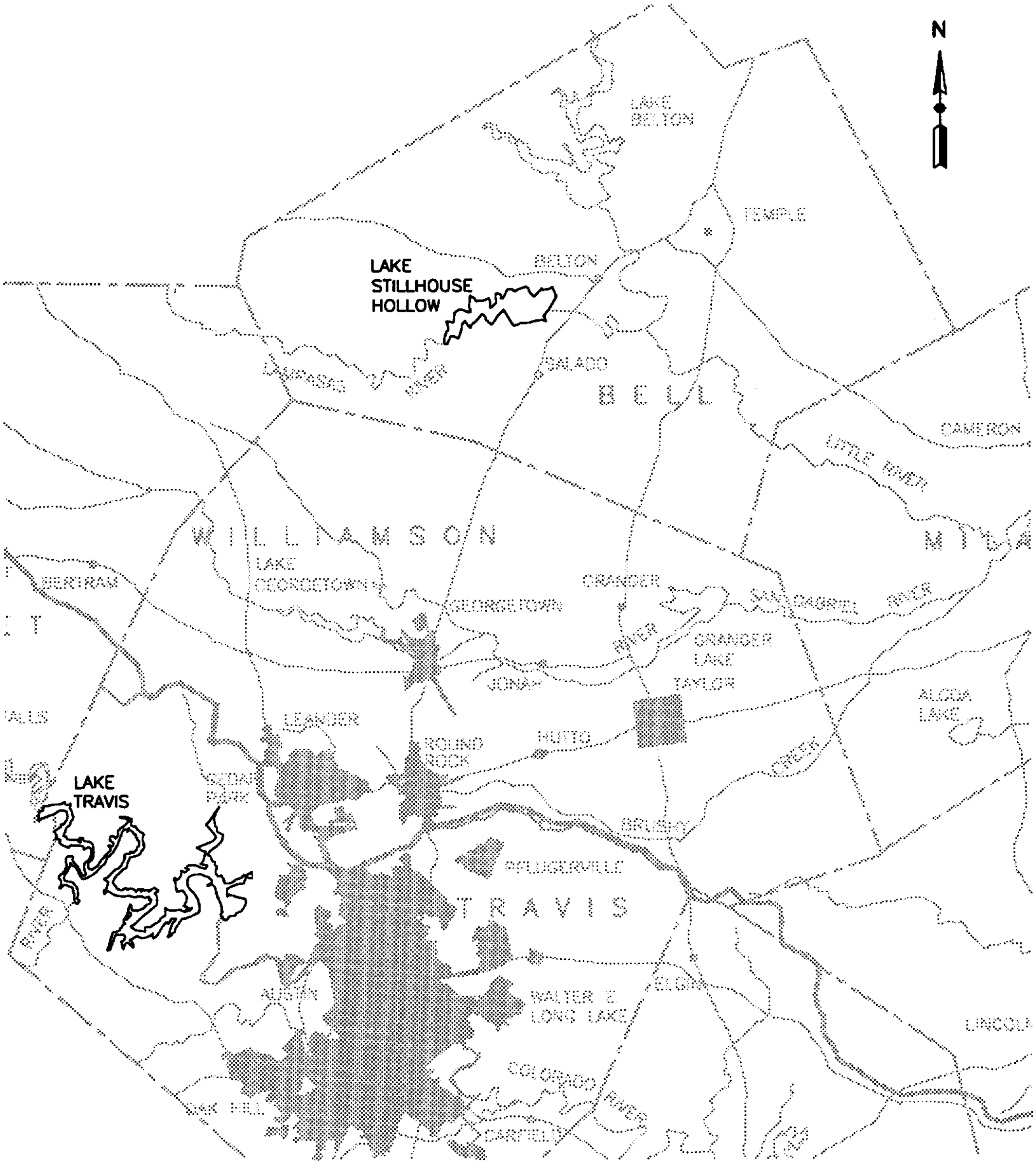
[1] TWDB, Hydrographic Survey Program, May, 1995.

[2] Permit No. 2109.

[3] System Operation Order, Texas Water Commission, July, 1964, as amended.



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**LAKE STILLHOUSE HOLLOW
AND LAKE TRAVIS
ALTERNATIVE BC-1**

FIGURE 3.18-1

Determination document of the Brazos River Basin Adjudication. Of these three governing documents, the Final Determination limits maximum withdrawal from the lake to 67,768 acft/yr. Permitted uses for this water include municipal, industrial, agriculture, and mining.

Lake Travis is located in western Travis County about four miles west of the City of Austin. It is one of six reservoirs known as the Highland Lakes constructed on the Lower Colorado River. Two of the Highland Lakes, Lakes Buchanan and Travis, are water supply reservoirs and have dedicated conservation storage. The other four reservoirs in the Highland Lakes are constant level lakes and are not considered water supply reservoirs. The location of Lake Travis is shown on Figure 3.18-1.

Lake Travis was constructed by the U.S. Bureau of Reclamation and is owned and operated by the Lower Colorado River Authority (LCRA). The reservoir was built for flood control, conservation and recreation. Construction of the reservoir began in 1937 and impoundment began in 1940. At the conservation pool elevation of 681.1 ft-msl, the reservoir covers 18,930 acres and has a capacity of 1,170,069 acft.[4] At the top of the flood control pool, elevation 714.1 ft-msl, the reservoir covers 29,000 acres and stores 1,951,000 acft. The LCRA holds the permit from the State of Texas for the right to impound water in Lake Travis and divert water for municipal and other uses.[5]

The yield of the Highland Lakes after accounting for O. H. Ivey Reservoir is 689,609 acft/yr. Of this total, yield is reduced by 392,643 acft to honor senior downstream water rights and 153,940 acft/yr is currently committed to water sale contracts and electric utilities. Of the remaining yield, 31,800 acft/yr has been reserved to provide instream flows and flows to the bay. The remaining 111,226 acft/yr of water is currently uncommitted.[6]

3.18.2 Available Yield

Benefits of systems operation of two or more reservoirs can potentially result from several conditions. The conditions studied for Lakes Stillhouse Hollow and Travis include differences in evaporation efficiencies and use of spills during non-concurrent critical periods.

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[4] LCRA Water Management Plan for the Lower Colorado River, LCRA, Volume II, Appendices, June 1993.

[5] Permit No. 1260.

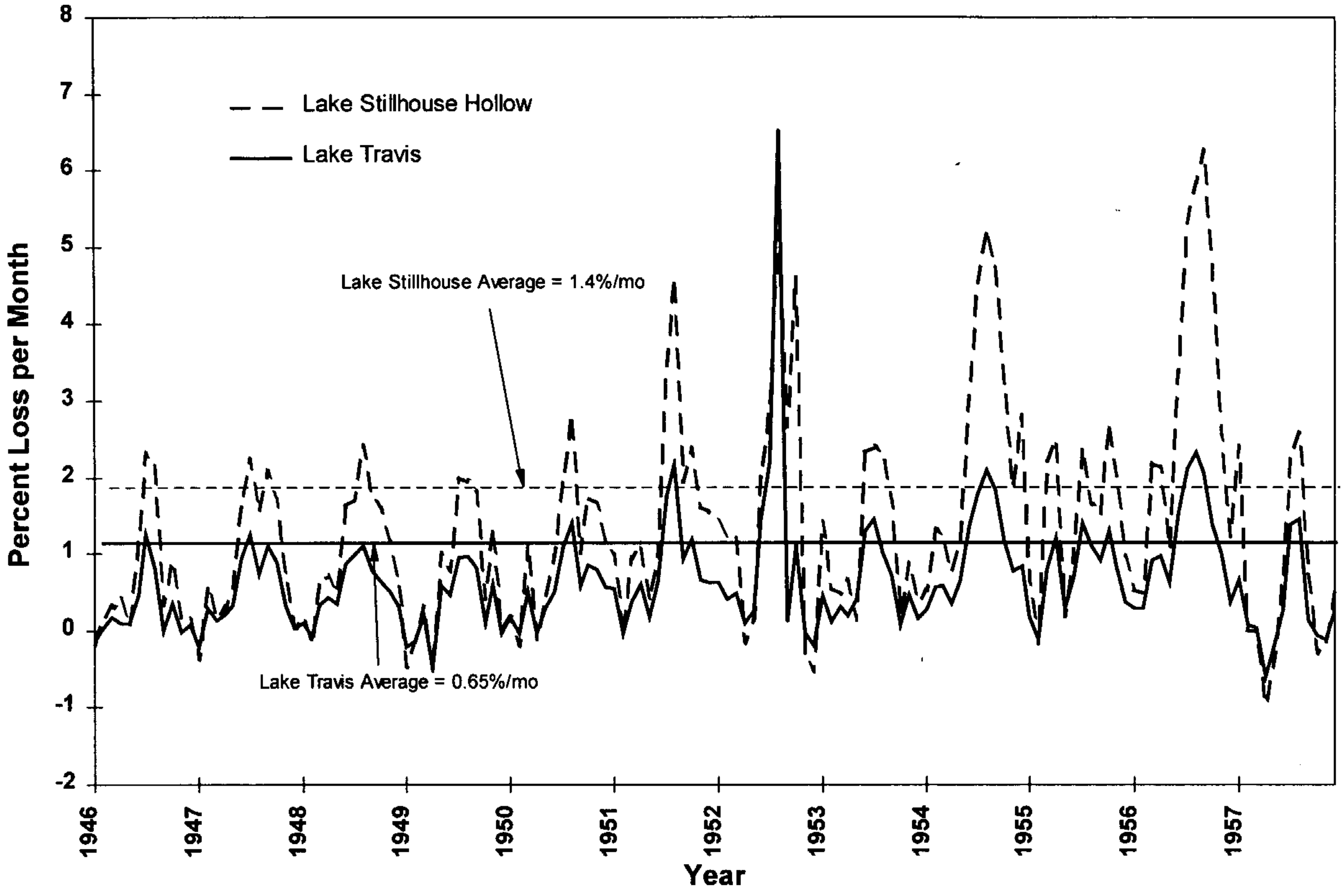
[6] Lower Colorado River Authority, Water Management Plan, 1993.

Evaporation Efficiencies

Evaporation losses can vary considerably, even within a relatively small area, depending on climate conditions and reservoir surface area. Because evaporation from reservoirs represents a significant amount of water, it is useful to examine systems operations which minimize these losses. A convenient method for comparing the evaporation efficiencies of reservoirs is to calculate the amount of water lost to evaporation divided by the amount of water in storage at that time. A high loss factor indicates poor efficiency. This loss factor, represented as a percent, is shown for both Lake Stillhouse Hollow and Lake Travis in Figure 3.18-2. The plot is of monthly data over the critical drought period from 1946 to 1957. As seen in the figure, the loss factor varies considerably with the season and can be negative, indicating more precipitation than evaporation. Of significance for this study is that the average loss rate of 1.4 percent per month for Lake Stillhouse Hollow is more than twice as high as the 0.65 percent per month for Lake Travis. This suggests that there is an opportunity to minimize evaporation by diverting as much water as possible from Lake Stillhouse Hollow to meet demands, thereby keeping more water in Lake Travis.

The difference in evaporation rates indicates that for every 1,000 acft diverted from Lake Stillhouse Hollow instead of Lake Travis, evaporation at Lake Stillhouse Hollow would be reduced by 14 acft/mo, while that amount left in Lake Travis would lose an additional 6.5 acft/mo. The net difference is a benefit of 7.5 acft/mo per 1,000 acft overdrafted at Lake Stillhouse Hollow. It is important to understand that this effect is cumulative; 1,000 acft overdrafted from Lake Stillhouse Hollow this month means a reduction in content of 1,000 acft, with the corresponding benefit of 7.5 acft. Continuing to overdraft at this rate through the next month means the content is reduced by an additional 1,000 acft , for a total of 2,000 acft, with the corresponding benefit of 15 acft for that month, and so on.

Annual water supply contracts to be met from Lake Stillhouse Hollow total 67,753 acft/yr. Of this amount, 25,032 acft/yr is supplied to local municipalities near the lake or to water supply corporations drawing from the lake. The remaining 42,721 acft/yr is committed to Williamson County entities. For the evaluation of system operations, the 25,032 acft/yr local demand is modeled at a municipal demand pattern and the demand is met at all times. The remaining 42,721 acft/yr can be diverted under various scenarios. Under one scenario this water



Notes:

1. Lake Stillhouse Hollow: firm yield delivery of 67,768 acft/yr and 1995 sediment conditions.
2. Lake Travis: combined firm yield delivery of 445,266 acft/yr from Highland Lakes and 1991 Sediment Conditions.

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PERCENT OF RESERVOIR CONTENT LOST TO EVAPORATION-LAKES STILLHOUSE HOLLOW AND TRAVIS ALTERNATIVE BC-1

FIGURE 3.18-2

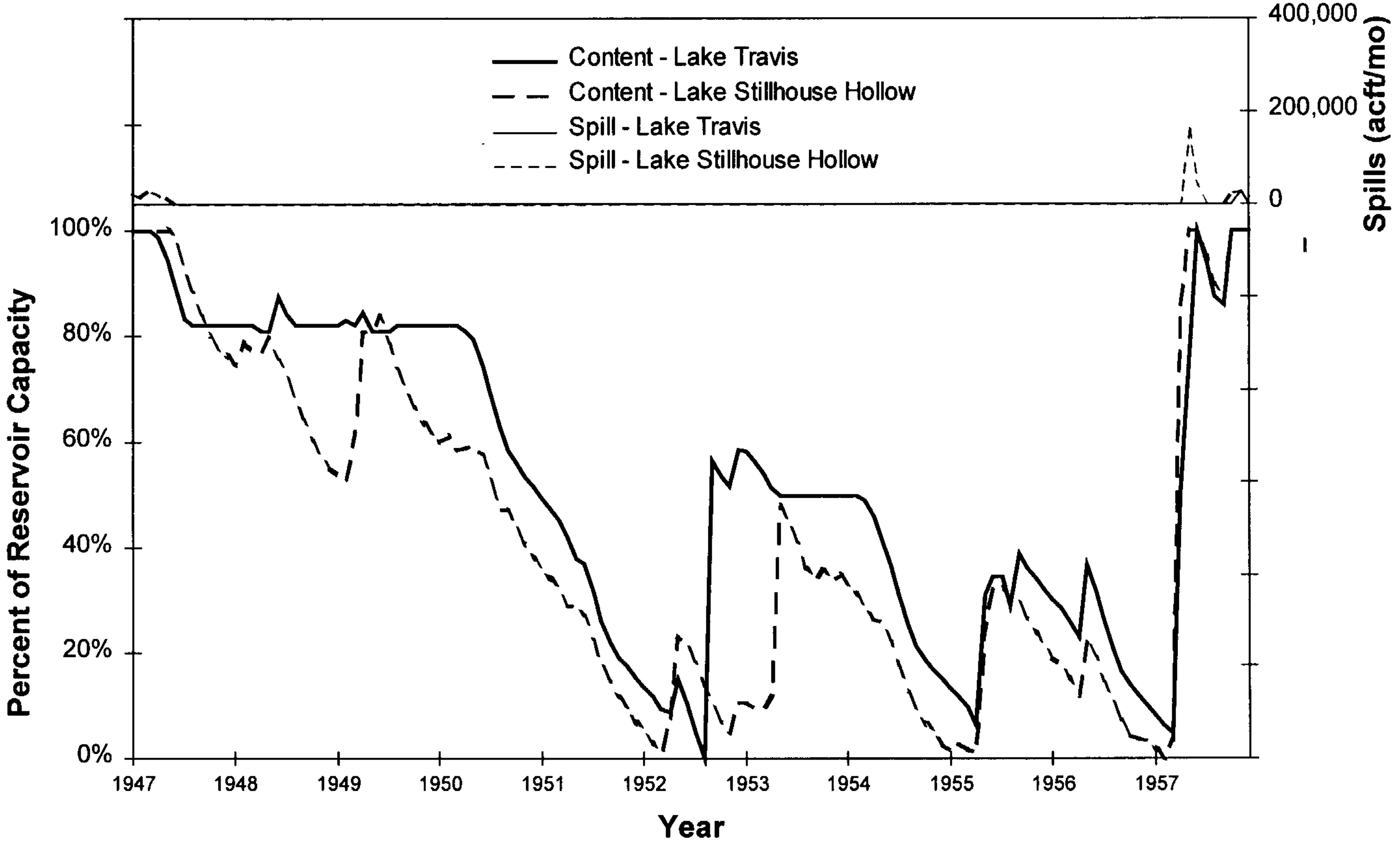
is diverted at a uniform annual rate of 3,560 acft/mo with independent operation of Lake Travis and Stillhouse Hollow. This is the base case scenario. Under an alternate scenario the diversion rate for the 42,721 acft is varied. This is referred to as the overdraft/underdraft scenario as indicated in the following example.

For the example considered here Lake Stillhouse Hollow would be overdrafted by 500 acft/mo, or 6,000 acft/yr (total diversion rate of 4,060 acft/mo). Modeling the reservoir through the critical period of 1946 to 1957 indicates that this overdrafting could be done for about 34 months, until March, 1950, at which time diversion would have to be reduced by 1,000 acft/mo (500 acft/mo underdraft) so that local commitments from Lake Stillhouse Hollow of 25,032 acft/yr are met for the remainder of the drought. To continue meeting water supply needs of the Williamson County entities, the reduction of 1,000 acft/mo would be made up by purchase of stored water from Lake Travis. The benefit from avoided evaporation for the 34 months from the beginning of the drought in June, 1947, would be about 2,200 acft. This amount distributed over the roughly 10-year drought period represents an increase in combined firm yield of the two reservoirs over the base case scenario of about 220 acft/yr. This diversion scenario is illustrated in Figure 3.18-3.

To accommodate overdrafting at this rate the Williamson County Raw Water Line would have to be oversized from a 42-inch diameter to a 48-inch diameter pipeline, at a cost of roughly $5,000,000. With financing at 8 percent for 25 years, the annual debt service would be about $470,000, which, for a benefit of 220 acft/yr, results in a unit cost of over $2,100 per acft, or about $6.50 per 1000 gal. Even before considering the transmission facilities needed from Lake Travis, the cost prohibits further study of this alternative.

Non-Concurrent Critical Periods

The critical period of a reservoir is the period of time in history, had the reservoir been constructed, during which the reservoir was last full, and the storage content would have been at a minimum while meeting firm yield water demands. If the critical period for two reservoirs are non-concurrent, it may be possible to increase the combined firm yield of the reservoirs by transferring water between them, or by switching demand from one supply source to the other. Figure 3.18-4 shows the content of Lake Travis and Lake Stillhouse Hollow for the period from



1. Lake Stillhouse Hollow: firm yield delivery of 67,768 acft/yr and 2050 sediment conditions.
2. Lake Travis: combined firm yield delivery of 445,266 acft/yr from Highland Lakes and 1991 sediment conditions.

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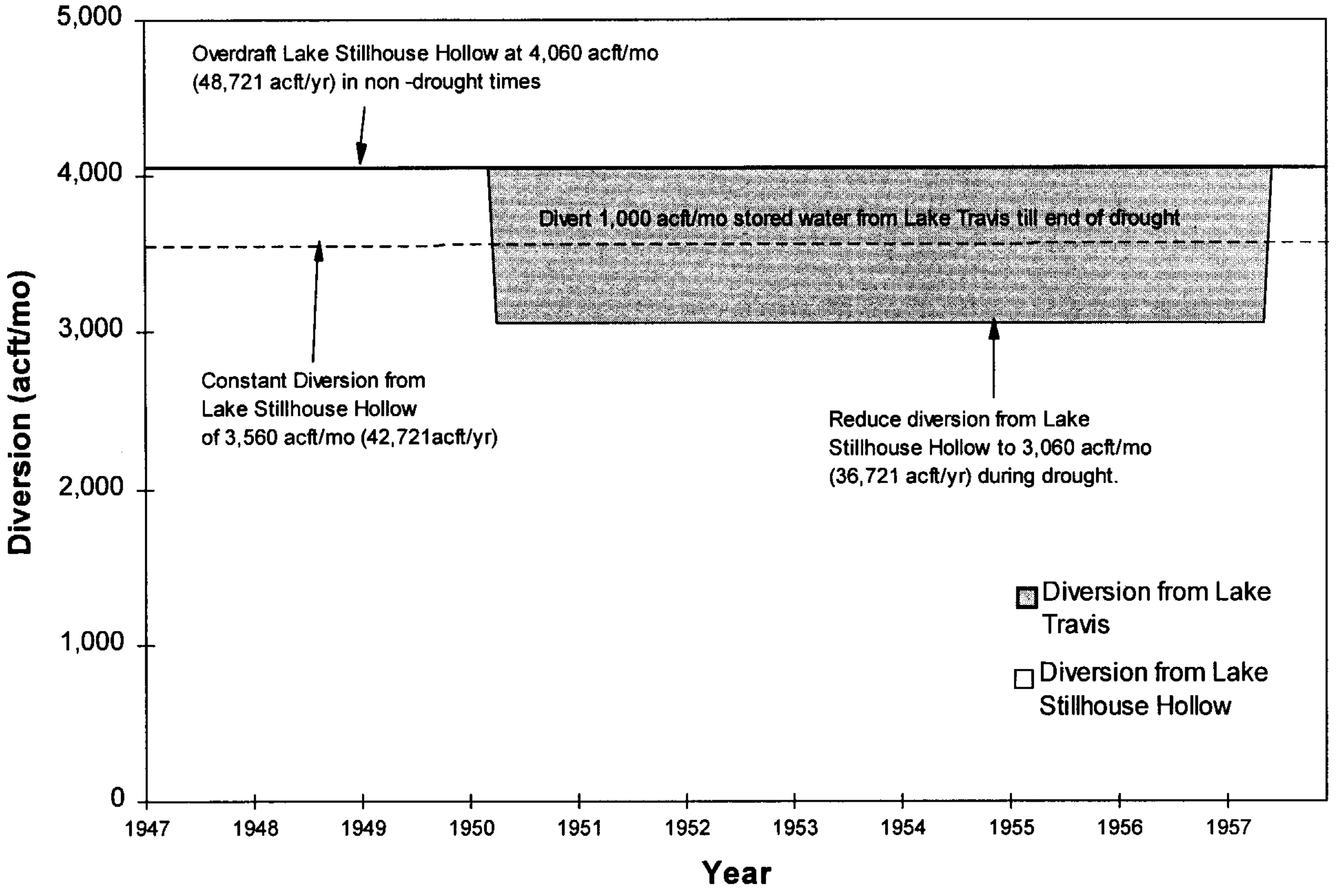
RESERVOIR CONTENT AND SPILL OF LAKE TRAVIS AND LAKE STILLHOUSE HOLLOW ALTERNATIVE BC-1

FIGURE 3.18-4



1. Lake Stillhouse Hollow: firm yield delivery of 67,768 acft/yr and 2050 sediment conditions.
2. Lake Travis: combined firm yield delivery of 445,266 acft/yr from Highland Lakes and 1991 sediment conditions.

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SYSTEM OPERATION SCENARIO WITH LAKE STILLHOUSE HOLLOW AND LAKE TRAVIS ALTERNATIVE BC-1

FIGURE 3.18-3

1946 to 1957. The figure shows the content of Lake Travis and monthly spills at Lake Stillhouse Hollow and Lake Travis from 1947 to 1957, which includes the historic critical periods for both lakes. This storage trace is produced by simulation with the reservoirs operated independently at firm yield withdrawals under current sediment conditions. The simulation reveals that Lake Stillhouse Hollow spills for about two months after Lake Travis begins to drop as it enters the drought in March, 1947. Analysis of simulation output finds that about 34,000 acft are spilled from Stillhouse Hollow during this time and that Lake Travis' capacity could accommodate about 29,000 acft of that water. However, because the spill occurs over a period of only two months, it is not feasible to build a pipeline which could carry all of the spill. A 60-inch pipeline could transfer about 6,000 acft/month, or 12,000 acft over the two-month period. This additional supply, distributed over the roughly 10-year drought period at Lake Stillhouse Hollow, represents an increase in firm yield of about 1,200 acft/yr. However, evaporation from Lake Travis at 0.65 percent per month over 10 years reduces the benefit to about 800 acft/yr. The cost of a 60-inch pipeline from Lake Stillhouse Hollow to Lake Travis for a benefit of 800 acft/yr makes this alternative clearly not economically avorable.

3.18.3 Environmental Issues

Because no reasonably cost-effective systems operation alternatives were found, no environmental analysis was performed.

3.18.4 Water Quality and Treatability

Because no reasonably cost-effective system operation alternatives were found, no water quality and treatability information was developed.

3.18.5 Engineering and Costing

Because no reasonably cost-effective systems operation alternatives were found, no engineering and costing were performed for any facilities.

3.18.6 Implementation Issues

Because no reasonably cost-effective systems operation alternatives were found, no implementation issues are discussed.

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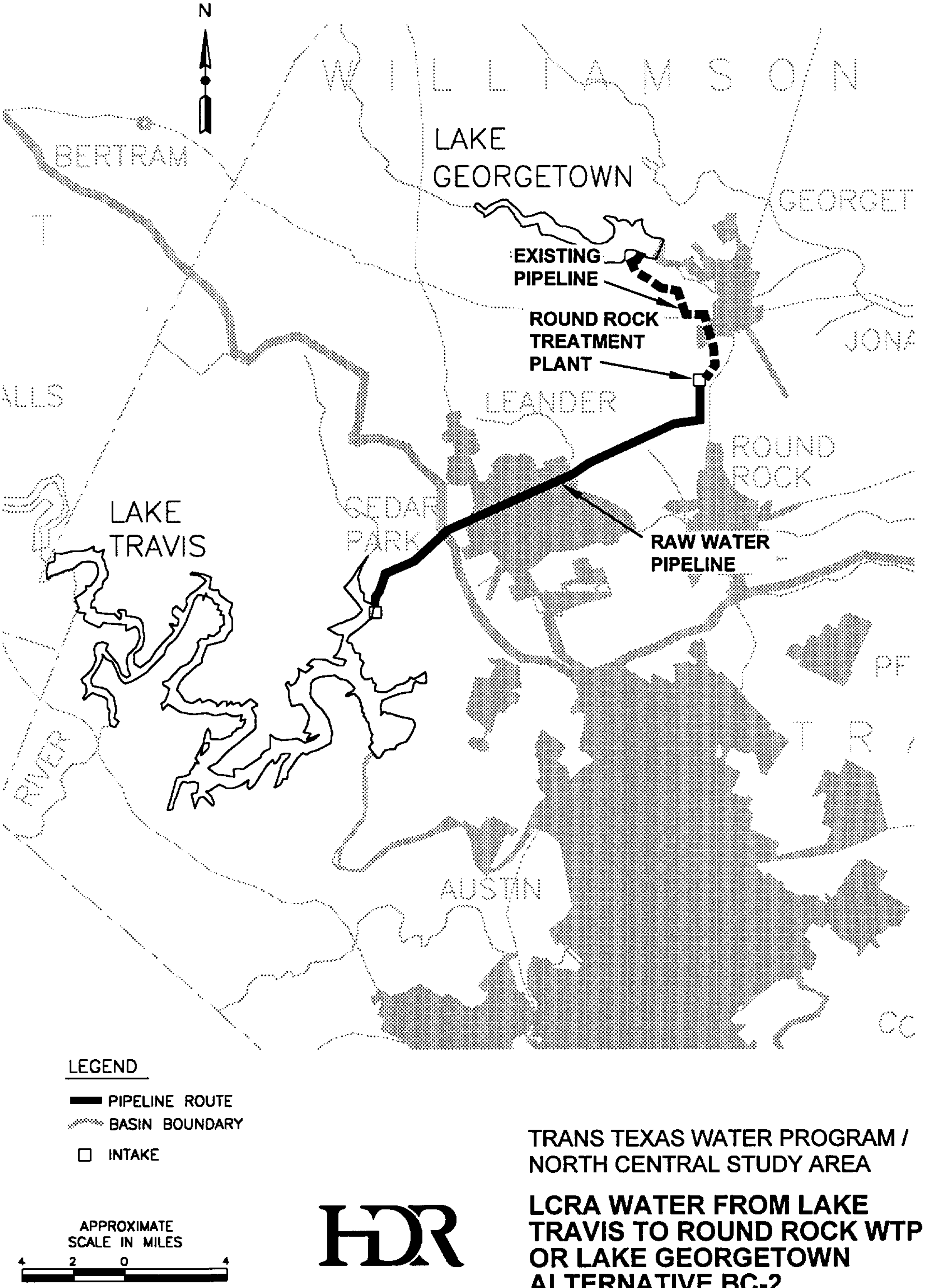
3.19 Purchase of Uncommitted Water Stored in Lake Travis to Augment Lake Georgetown (BC-2)

3.19.1 Description of Alternative

This alternative evaluates the diversion of 42,721 acft/yr of raw water from Lake Travis at an average annual rate for delivery to treatment facilities at, or near, the existing City of Round Rock Water Treatment Plant. Diversion facilities would be constructed on the Sandy Creek arm of Lake Travis near the existing City of Cedar Park intake and a raw water transmission pipeline would be constructed from Lake Travis to the Round Rock WTP. A portion of the raw water, sufficient to meet the combined needs of Round Rock and Brushy Creek MUD, would be delivered directly to a treatment facility and the remainder of the raw water would be pumped to Lake Georgetown for short-term storage to meet peak usage needs of Round Rock or eventual use by City of Georgetown and others. The treatment facility at Round Rock could either be an expansion of the existing Round Rock Water Treatment Plant, or a new regional facility. Potential cost savings are created in this alternative by diversion and pumping of raw water from Lake Travis at an average annual rate, rather than up-sizing raw water facilities to meet maximum day demands. Futher costs savings are created by conjunctive use of Round Rock's existing raw water transmission pipelines from Lake Georgetown to the treatment plant. The existing eight-mile long raw water pipelines from Lake Georgetown will be converted to allow reverse flow and a portion of the Lake Travis water will be conveyed to Lake Georgetown for storage. Conversion of the existing pipelines will save the cost of installation of eight miles of new pipeline. Figure 3.19-1 indicates the facility locations for this alternative.

Use of water from Lake Travis in the Austin metropolitan area and parts of Williamson County is also considered in Section 3.12 (Purchase of Uncommitted Stored Water from LCRA for Diversion at Lake Travis, Alt C-2). However, the delivery systems studied in that alternative are sized to meet maximum day demands of the end users, typically using a maximum day to average day peak factor of 2.0. Municipal supply systems must meet maximum day demands and the facilities required to meet these demands (such as the facilities costed in Alternative C-2) have unused capacity through much of the year. For long-distance supply facilities, such as water transmission pipelines, it is more economical to meet maximum day demands from storage



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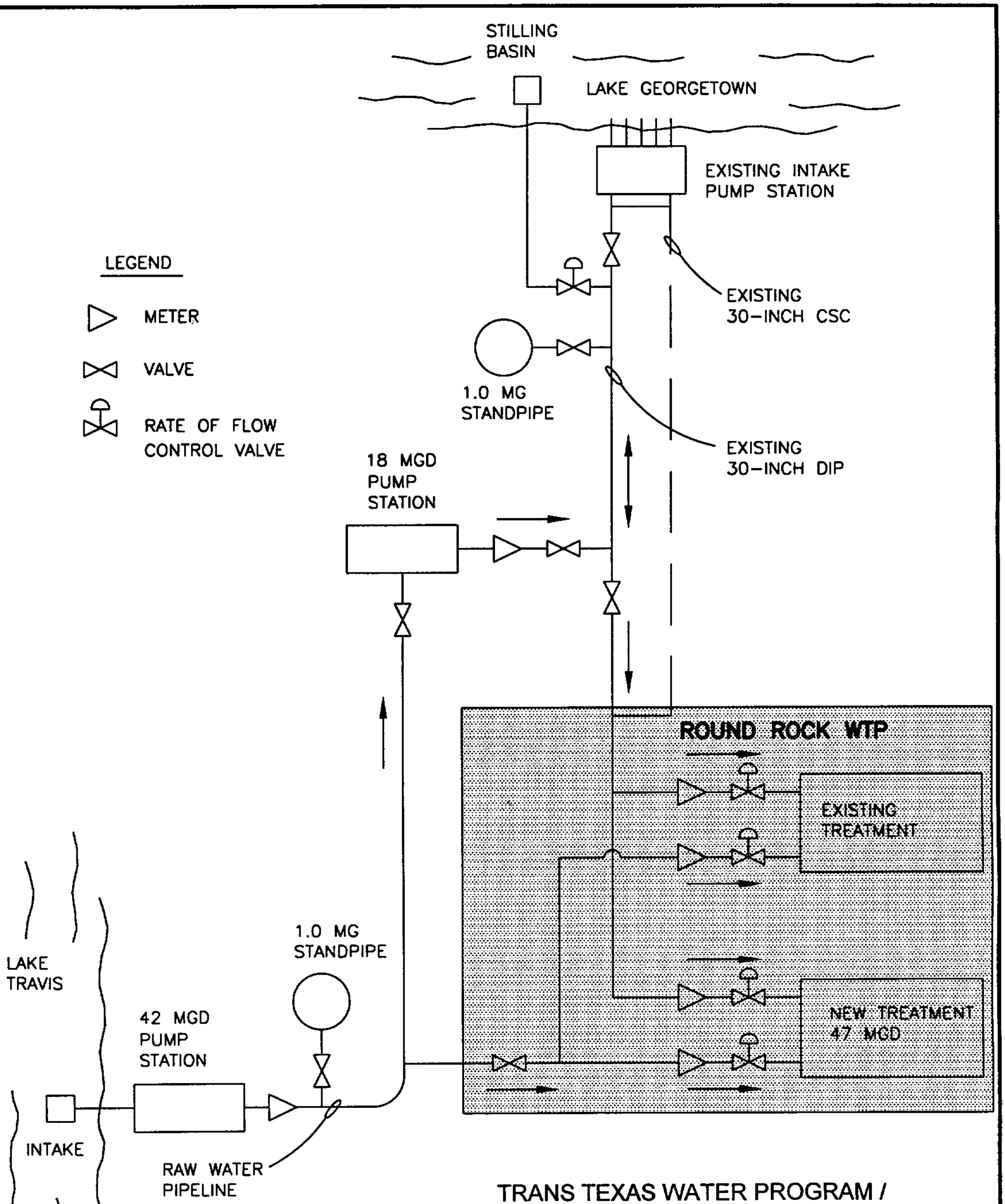
LCRA WATER FROM LAKE TRAVIS TO ROUND ROCK WTP OR LAKE GEORGETOWN ALTERNATIVE BC-2

FIGURE 3.19-1

close to the demand center and size the transmission facilities to deliver the average daily demands.

This alternative potentially reduces the cost of Lake Travis water delivered to Williamson County by sizing the major facilities to pump Lake Travis raw water at an average annual rate throughout the year and utilize storage space in Lake Georgetown to meet maximum day demands. By pumping water at the lower rate, the raw water pump station and transmission pipeline would be smaller and less expensive than for a treated water pipeline sized to delivery max day rates. For this particular alternative, further cost savings would be realized by using the existing raw water pipelines from Lake Georgetown to the Round Rock WTP. The new Lake Travis transmission pipeline would connect to the existing Round Rock pipelines just upstream of the Round Rock WTP headworks. The existing Round Rock raw water pipelines would be modified to receive the new raw water from Lake Travis. At times when the average day delivery rate from Lake Travis exceeds the water treatment plant's needs, the Lake Travis water would be diverted through the existing raw water pipeline to Lake Georgetown. In this situation, the flow in the existing raw water pipelines would be reversed and the Lake Travis water would be discharged into Lake Georgetown for temporary storage. Figure 3.19-2 is a schematic of the facilities that would be required to implement this alternative. As shown in the schematic, raw water from Lake Travis can be delivered to either the Round Rock Water Treatment Plant or to Lake Georgetown. The pumping conditions are significantly different for delivery to the Round Rock Water Treatment Plant compared to delivery to Lake Georgetown. Pumping head will be much higher to deliver to Lake Georgetown due to the additional eight miles of pipeline as well as the additional static lift. This hydraulic condition indicated that a booster pump station, located at the Round Rock Water Treatment Plant, would be needed to deliver water to Lake Georgetown.

In Section 3.7 (Purchase of Water from Brazos River Authority at Lake Stillhouse Hollow Delivered to Lake Georgetown, Alt. B-1), the system provides for delivery of 42,271 acft/yr to five entities in Williamson County holding water purchase contracts with BRA. Round Rock's contract (for 18,134 acft/yr) will provide sufficient water to meet their needs through about year 2010. With water trades among the participants, the aggregate needs of all five



TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

SCHEMATIC - LAKE TRAVIS WATER DELIVERED TO ROUND ROCK AND LAKE GEORGETOWN ALTERNATIVE BC-2

FIGURE 3.19-2

HDR Engineering, Inc.

entities can be met by the existing contracts through about year 2022. For direct comparison of options, this alternative is sized to deliver and equivalent amount of water (42,721 acft/yr).

3.19.2 Available Yield

Lake Travis is located in western Travis County about four miles west of the City of Austin. It is one of six reservoirs known as the Highland Lakes constructed on the Colorado River. Two of the Highland Lakes, Lakes Buchanan and Travis, are water supply reservoirs and have dedicated conservation storage. The other four reservoirs in the Highland Lakes are constant level lakes and are not considered water supply reservoirs. The location of Lake Travis is shown on Figure 3.19-1.

Lake Travis was constructed by the U.S. Bureau of Reclamation and is owned and operated by the Lower Colorado River Authority (LCRA). The reservoir was built for flood control, conservation and recreation. Construction of the reservoir began in 1937 and impoundment began in 1940. At the conservation pool elevation of 681.0 ft-msl, the reservoir surface covers 18,930 acres and has a capacity of 1,170,069 acft.[1] At the top of the flood control pool, elevation 714.1 ft-msl, the reservoir surface area is 29,000 acres and stores 1,951,000 acft. The LCRA holds the permit from the State of Texas for the right to impound water in Lake Travis and divert water for municipal and other uses.[2]

The yield of the Highland Lakes after accounting for O. H. Ivey Reservoir is 689,609 acft/yr. Of this total, yield is reduced by 392,643 acft to honor senior downstream water rights and 153,940 acft/yr is currently committed to water sale contracts and electric utilities. Of the remaining yield, 31,800 acft/yr has been reserved to provide instream flows and flows to the bay. The remaining 111,226 acft/yr of water is currently uncommitted.[3] The LCRA system price for stored water in 1996 was $105 per acft.

Treatment capacity and unit costs for treatment are based on the combined 2010 projected shortages for Round Rock and Brushy Creek MUD which are estimated to be 26,494 acft/yr.[4]

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[1] LCRA Water Management Plan for the Lower Colorado River, LCRA, Volume II, Appendices, June 1993.

[2] Permit No. 1260.

[3] Lower Colorado River Authority, Water Management Plan, 1993.

[4] Based on combined TWDB projected demand for Round Rock and Brushy Creek of 33,214 acft/yr with credit for Round Rock's current contract for 6,720 acft/yr from Lake Georgetown. Assumes that Round Rock and Brushy Creeks' current combined capacity of 5,152 acft/yr of groundwater would no longer be available.

Subtracting this amount from the annual delivery of 42,721 acft/yr would leave 16,227 acft/yr of raw water at the Round Rock Treatment Plant or in Lake Georgetown available to other users.

3.19.3 Environmental Issues

This alternative would divert water from Lake Travis to the City of Round Rock water treatment plant and to Lake Geoergetown to serve Round Rock, Brushy Creek Municipal Utility District and possibly others. A portion of the water would be stored in Lake Georgetown for either peak usage needs by the Round Rock system or for eventual use by City of Georgetown and others. Environmental issues include direct construction effects and instream flows.

Expansion of water treatment facilities for the City of Round Rock or for a regional treatment plant are assumed to be located at or near the existing water treatment plant site. The alternative would require construction of:

- An intake and pump station at Lake Travis;
- Raw water pipeline from Lake Travis to the City of Round Rock Water Treatment Plant;
- Expansion of Round Rock water treatment facilities including a booster pump station; and,
- An outfall structure at Lake Georgetown within a new easement through U.S. Corps of Engineers property.

The raw water pipeline from the intake to the treatment plant would have a construction right-of-way of up to 140 ft. and a permanent easement width of 40 ft. The estimated 15.5 mile transmission corridor leads from the intake site at Lake Travis to a potential regional water treatment plant site adjacent to the existing City of Round Rock Water Treatment Plant site. The intake site would affect less than one acre of lake bottom and shore. The potential regional water treatment plant site would be approximately 20 acres. The outfall structure at Lake Georgetown would be near the existing City of Round Rock intake site. This structure would likely require an additional easement from the U.S. Corps of Engineers in order to allow for mixing to occur prior to intake by the City of Round Rock intake structure. Treated wastewater resulting from use of water from this supply alternative would be discharged into Brushy Creek through the Brushy Creek Regional Wastewater Treatment Facility or into the San Gabriel River by the City of Georgetown wastewater treatment facility. Both are tributaries to the Little River in the Brazos River basin.

Environmental Setting

The environmental setting of Travis and Williamson counties has been addressed in several preceding sections including Sections 3.3, 3.4, 3.5, 3.6, 3.7, and the Environmental Overview Section 3.1.3. This alternative (BC-2) includes Northwestern Travis and Southwestern Williamson counties; from the Glen Rose limestone canyons of Lake Travis through cavernous-forming Edwards limestone in the Balcones Fault Zone and into the western edge of the Blackland Prairies.

Table 3.19-1
Physiognomic Categories and Areas Within the Pipeline, Intake and Outfall Construction and Maintenance Corridors

Physiognomic Category	Percent Coverage in Construction Corridor	Acreage in 140′ Construction Corridor	Acreage in 40′ Maintenance Corridor
Developed	6	16.6	4.8
Grass	8	20.3	5.8
Crop	4	10.4	3.0
Park	24	64.3	18.4
Wood	57	153.1	43.8
Intermittent	>1	0.9	>0.03
Lake	1	3.0	1.8
Total	100	268.6	77.6

The expanded water treatment plant site adjacent to the existing plant site is in rangeland and limestone quarry operations. For the purposes of this alternative, it is assumed that the expanded plant would occupy approximately 20 acres for the facility and buffer zone. If reclaimed quarry land would be suitable then the habitat impacts would be creation of a facility campus on the remaining disturbed quarry site. If adjacent rangeland is used, impacts would be similar to development of the existing plant site. Which would include replacement of rangeland with a campus park around treatment plant buildings, parking and associated facilities. Sensitive habitat considerations would include the potential impact to karst habitats.

Protected species and candidate species for protection reported to occur in Williamson and Travis Counties are presented in the Environmental Overview (Section 3.1.3). Seven endangered troglobithic arthopods known from Williamson and Travis counties are found in caves in the Edwards formations. Five of the cave invertebrates, Tooth Cave spider (*Neoleptoneta myopica*), Tooth Cave pseudoscorpion (*Tartarocreagis texana*), Bee Creek Cave harvestman (*Texella reddelli*), Tooth Cave ground beetle (*Rhadine persephone*), and Kretschmarr Cave mold beetle (*Texamaurops reddelli*) were listed in 1988 for protection. Later taxanomic studies revealed that the original populations described in the listings included two previously undescribed species and populations of another species, Bone Cave harvestman (*Texella reyesi*). The Bone Cave harvestman *Batrisodes* (*Excavodes*) *texana* were determined in 1993 to be properly considered endangered.[5,6] The Tooth Cave ground beetle, the Bone Cave harvestman, and the Bee Creek Cave harvestman have been found in caves in the vicinity of the Round Rock Water Treatment Plant and existing raw water pipelines from Lake Georgetown. Karst surveys and geotechnical investigations for building structures should identify subsurface cavern features prior to construction. If caves are encountered during construction, a qualified karst biologist should be called to investigate and provide recommendations for protection, if necessary.

The western most portion of the raw water pipeline from Lake Travis through Cedar Park and the proposed Lake Georgetown outfall would be near mapped nesting habitat of the Golden-cheeked Warbler and Black-capped Vireo. Both birds, listed as endangered by the U.S. Fish and Wildlife Service (USFWS), nest in Travis and Williamson counties.[7] A final pipeline alignment that would disturbance of bird habitat would be assumed through these areas.

Other species of concern include the Texas horned lizard. This lizard, once common and wide spread throughout the Williamson and Travis counties, could occur within open, well-

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[5] Elliott, W. R., and J. R. Reddell, "The status and range of five endangered arthropods from caves in the Austin, Texas, region." Austin Regional Habitat Conservation Plan. Reddell, J. R., 1989. Further study of the status and range of endangered arthropods from caves in the Austin, Texas, region. Draft Section 6, 1991, report on a study for Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service.

[6] O'Donnell, L., W. R. Elliott, and R. A. Stanford, "Recovery plan for endangered karst invertebrates in Travis and Williamson counties, Texas." U.S. Fish and Wildlife Service, 1994.

[7] Natural Heritage Program Files, 1994, unpublished mapped occurrences, Texas Parks and Wildlife Department, Austin, Texas, 1994.

drained habitats with sparse cover that would be disturbed by construction activities.[8] However, the species is less likely to be found in areas previously disturbed by development and construction activities. Areas within the potential construction area that are along roadways, through subdivisions and near the limestone quarry would not be good habitat. Disturbed habitat is not a deterrent to the fire ant (*Solenopsis invicta*). The decline of Texas horned lizard populations is associated with the invasion of fire ants, agricultural practices and urbanization. Conservation measures to restore this lizard include controlling the invading fire ant without broadcast chemicals and maintenance of native vegetation communities and corridors.[9]

Wetlands within the project area include the lake bottoms and shorelines of Lake Travis and Lake Georgetown, intermittent drainages and creeks within the pipeline corridors. Creek crossings include Spanish Oak, Dry Fork Brush Creek and Brushy Creek. Creek and drainages in western Travis and Williamson counties are characteristically intermittent with ponded areas within the channel. These creeks are fed by springs, seeps and rainfall. Except for the lake bottoms and shoreline where the intake and the outfall would be constructed, wetlands would be returned to their former contours and revegetated for erosion control.

Operational Effects

The diversion of 42,721 acft/yr of raw water from storage in Lakes Travis and Buchanan would slightly increase the frequency of fluctuation in water surface elevation in those reservoirs. Because of the sizes and existing variability of Lakes Travis and Buchanan (whose water levels are allowed to vary, while the other Highland Lakes are held at constant elevations for as long as possible into a drought), the additional diversion would have no discernable impact on water levels, or on the rate of change in water levels in those impoundments under normal and wet climatic conditions. Some additional drawdown can be expected during extreme drought years when the additional releases would be a larger proportion of the water remaining in storage when the elevations of Lakes Travis and Buchanan are low. At historic low levels, the additional releases would require about 5 percent of the remaining capacity of the two lakes.

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[8] Price, A., W. Donaldson, and J. Morse, "Final Report As Required by the Endangered Species Act, Section 6, Texas Project No. E-1-4," Texas Parks and Wildlife Department, Austin, Texas, 1993.

[9] Price, A., W. Donaldson, and J. Morse, "Final Report As Required by the Endangered Species Act, Section 6, Texas Project No. E-1-4," Texas Parks and Wildlife Department, Austin, Texas, 1993.

Potential biological effects of increased water level fluctuations include disruption of nesting in fish species that utilize shallow littoral areas and stranding of beds of rooted aquatic vegetation. The significance of the impact is strongly dependent on the amount, rate and timing of the change in water level. The four bottom nesting fish found in Lake Buchanan are the bluegill sunfish, the largemouth bass, the Guadalupe bass and the longear sunfish, ranked in order of abundance[10]. To impair reproductive success in these species, drawdowns must be: 1) sufficiently severe to strand active nests (more than 3 feet for bluegill and 5 feet for largemouth bass[11]), 2) sufficiently rapid that newly established nests are stranded prior to development of a free swimming stage (typically a period of 10 days for bluegill and 14 days for largemouth bass[12]), and 3) changes in water level must continue to occur throughout a significant portion of the reproductive season (March through September for bluegill sunfish and December through May for largemouth bass[13]). Additional drawdowns of a few inches spread over an annual cycle cannot be expected to result in significant changes in fish populations.

Rooted aquatic vegetation is typically restricted by rocky substrates, steeply sloping shorelines and fluctuating water levels[14] in Edwards Plateau reservoirs, with Lake Travis being typical of this situation. Lake Buchanan tends to have more extensive shallows than the other Highland Lakes[15], but much of this consists of recently deposited sediments that are relatively unstable and easily resuspended, contributing to the turbidity of the water column, which restricts the growth of rooted vegetation[16]. The slight changes in water levels in normal to wet years are not expected to significantly affect rooted vegetation, while during extreme drought periods established vegetation beds are already stranded. Large drawdowns in these two reservoirs do not generally last long enough to allow the establishment of substantial stands of aquatic

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[10] Terre, David R., and Stephan J. Magnelia, "Survey Report for Buchanan Reservoir," Statewide Freshwater Fisheries Monitoring and Management Program, Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department, Austin, Texas, 1993.

[11] Ibid.

[12] Ibid.

[13] Carlander, Kenneth D., "Handbook of Freshwater Fishery Biology: Life History Data on Centrarchid Fishes of the United States and Canada, Volume Two." Iowa State University Press, Ames, Iowa, 1977.

[14] Wetzel, Robert G., "Limnology," second edition. Saunders College Publishing, Fort Worth, Texas, 1983.

[15] Terre, David R. and Stephan J. Magnelia. 1994. Survey Report for Buchanan Reservoir, 1993, Statewide Freshwater Fisheries Monitoring and Management Program, Federal Aid in Sport Fish Restoration Act Project F-30-R. Texas Parks and Wildlife Department, Austin, Texas.

[16] Reimer, Donald N. 1984. Introduction to Freshwater Vegetation. AVI Publishing Company, Inc., Westport, Connecticut.

vegetation, so the lowering of water levels attributable to the additional releases necessary for a Mansfield Dam diversion site are not expected to have significant impacts.

Water stored in the Highland Lakes is eventually either spilled or released downstream, or is lost through diversion, seepage, or evaporation. The portion of the diverted water that would have been spilled or released under the without project, or base case, condition (see Section 3.14.3) would be lost to Colorado River streamflows. We assume that the established critical and target streamflows for the Colorado River will continue to be maintained, but some effect on instream flows in the Colorado River below the Highland Lakes can be expected to result from the proposed diversion. For example, diverting 42,721 acft/yr would require the continuous withdrawal of water at a constant rate of about 59 cfs, compared to median monthly flows under the base case condition which range from about 300 to to over 900 cfs at Bastrop, and from 49 to 1150 cfs at Columbus.

The City of Round Rock has constructed and now operates a regional wastewater treatment plant at the existing East Wastewater Treatment Plant site on Brushy Creek. The City and the Brushy Creek Water Control and Improvement District No. 1 have combined their permits after construction of the plant expansion from 3.6 million gallons per day (mgd) to 11.8 mgd in 1996. A discharge of 11.8 mgd is equivalent to about 18 cfs. If we assume the wastewater flow represents about 50 percent of the raw water diverted (36 cfs or 26,067 acre feet), the remainder of the 42,721 acft/yr to be diverted under this alternative (23 cfs or 16,654 acft/yr) would be stored in Lake Georgetown to be used for reginal municipal supply. Note that transfers to Lake Georgetown would be larger to the extent that water supplies other than the proposed transfer would be used in Round Rock.

The portion of transferred water used in Round Rock and vicinity would be discharged to Brushy Creek, eventually increasing its base flows up to 18 cfs with existing infastructure, or 59 cfs if all the transferred water were used..[17] Water transferred to Lake Georgetown would increase the frequency of spills, which, together with return flows from use of this water, will increase flows in the San Gabriel River. Flows in Brushy Creek are heavily influenced by existing wastewater discharges, primarily by the City of Round Rock, but other small

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[17] For 26,494 acft/yr delivered to Round Rock and return flow factor of 0.50.

municipalities and districts also use this stream for disposal. The north fork of the San Gabriel River is presently regulated by operation of Lake Georgetown

Mitigative Measures and Impacts Which Cannot Be Avoided

Mitigative measures will primarily address the effects of construction activity. The construction activity will be limited to the construction corridors. Good engineering and construction practices including erosion and sedimentation control and revegetation will be employed. Reclamation of quarried land with a regional WT Plant Campus would limit impacts to existing rangeland.

Impacts that cannot be avoided result from constrution activities. The habitats disrupted by construction activities include rangeland and woodland. Depending on the actual alignment chosen, woodland impacts may be significantly reduced. and impacts within developed areas may be larger than currently estimated. Alignments within existing developed easements have the least impact on wildlife habitats. The pipeline routes and facility expansion are all within urbanizing areas of Travis and Williamson counties. An easement through the U.S. Corps of Engineers property around Lake Georgetown would require careful alignment selection to avoid protected species habitat and avoid conflicts with recreational uses.

Areas within the temporary construction easement would be reshaped to their natural contour and reseeded. Given the geology of the eastern Balcones fault zone, there is some likelihood of encountering unknown caves with no surface expression. From the surface, it is often impossible to know whether karst features with federally listed species are actually present. Cavities intersected during construction should be evaluated by a qualified karst biologist in consultation with USFWS, in order to minimize potential damage to endangered species habitat.

3.19.4 Water Quality and Treatability

This alternative involves transferring water from Lake Travis to Lake Georgetown, although it does not estimate the quantity which might ultimately be stored in Lake Georgetown. Both lakes provide excellent quality water for municipal use.[18] Table 3.19-2 summarizes the

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[18] TNRCC, "Texas Water Quality, A Summary of River Basin Assessments," 1994.

conventional water quality characteristics of each reservoir. Based on the levels reported in Table 3.19-2, the resulting mixture would have slightly higher total phosphorus and nitrogen concentrations than the original water. This might have some impact on the growth of algae in Lake Georgetown. There are also significantly higher concentrations of TDS, chlorides, and sulfates in the Travis water.

Table 3.19-2
Conventional Water Quality Constituents in Lake Travis and Lake Georgetown[1]

Constituent	Lake Travis	Lake Georgetown
Dissolved Oxygen (mg/l)	8.04	8.00
pH (su)	8.23	8.05
TDS (mg/l)	467.36	232.00
Fecal Coliforms (No./100 ml)	41.07	53.67
Chloride (mg/l)	110.30	13.00
Sulfate (mg/l)	83.75	18.38
Total Phosphorus (mg/l)	0.04	0.03
Total Nitrogen[2] (mg/l)	0.13	0.06

[1] TNRCC, "Texas State Water Quality Inventory," November, 1994
[2] Total Nitrogen equals ammonia plus nitrite plus nitrate.

Conventional treatment facilities should be adequate to treat the Lake Travis and Lake Georgetown mixture. The variation in the quality of water diverted for treatment could present a challenge to plant operators in establishing a flexible chemical dosing regime which would produce a finished water of consistent quality. This concern has been expressed by treatment plant personnel. It is for this reason that the conceptual layout of the new treatment facility shown in Figure 3.19-2 allows the water from the two sources to be kept separate throughout the treatment process.

3.19.5 Engineering and Costing

This section provides cost estimates for implementation of a raw water line from Lake Travis to the Round Rock Treatment Plant. Cost estimates for two pipeline configurations are presented: (1) construction of a single 42-inch pipeline for delivery of 42,721 acft/yr and, (2) construction of twin 33-inch diameter parallel pipelines, which could potentially be constructed in phases. The capacity of the initial 33-inch pipeline would be about 21,000 acft/yr and with the final phase, the full 42,721 acft/yr would be delivered to the Round Rock Treatment Plant and/or Lake Georgetown.

Water would be diverted from a new intake structure located on the Sandy Creek arm of Lake Travis. The water would be transported by pipeline to the Round Rock Treatment Plant where it could be treated at the plant, or pumped to Lake Georgetown. An outfall structure would potentially be located along the south shore of Lake Georgetown sufficiently far away from the existing Georgetown water treatment plant intake to allow for blending of the Lake Travis and Lake Georgetown waters. The length of the pipeline would be about 83,000 ft (16 miles) and require a static lift of about 370 ft.

The major facilities needed to implement this project are:

- Intake and pump station at Lake Travis
- Raw water pipeline from Lake Travis to Round Rock Treatment Plant
- Booster pump station at Round Rock Treatment Plant
- Outfall structure and associated piping at Lake Georgetown
- Expanded water treatment plant capacity for Round Rock
- Associated valving and control equipment

Pipeline Cost Estimate

The cost estimate for the single 42-inch pipeline option is summarized in Table 3.19-3. Table 3.19-4 summarizes the estimate for twin 33-inch pipelines. The delivery rate to the Round Rock treatment plant would be about 42 mgd (assuming 9 percent down time for outages and avoidance of summer peak electric charges), requiring a 42-inch diameter transmission pipeline or twin 33-inch diameter pipelines. Up to 18 mgd of the raw water could be pumped from a new booster station at the treatment plant to Lake Georgetown through one of the existing 30-inch raw water intake lines. About 1,000 ft of new 30-inch pipe would tie into one of the existing raw water lines. New piping and valves at the Round Rock intake would divert water to a new outfall structure in Lake Georgetown as shown in Figure 3.19-2. The new 30-inch piping would facilitate diversion of water to be discharged to Lake Georgetown instead of going through Round Rock's existing intake structure.

For the single 42-inch diameter pipeline, the total capital cost of the intake, pump stations, pipeline and associated valves and control equipment is estimated to be $23,080,000.

The total project cost would be about $31,770,000 (Table 3.19-3). Financed at 8 percent for 25 years the annual debt service on this amount would be $2,980,000. With other annual costs the total annual cost would be about $10,190,000, which includes the purchase of 42,721 acft/yr from LCRA at a unit cost of $105 per acft. The resulting annual unit cost for the 42-inch diameter pipeline project with no treatment component would be $239 per acft ($0.73 per 1,000 gal).

Table 3.19-3
Cost Estimate Summary for Lake Travis Raw Water Pipeline
(Single 42-inch Diameter Pipeline) (Alt. BC-2)
(1st Quarter 1997 dollars)

Item	Cost
Capital Costs	
Intake and Pump Station	$ 4,810,000
Booster Pump Station at Round Rock WTP	1,610,000
Transmission Pipeline	16,150,000
Valves and Control Equipment	510,000
Total Capital Costs	$ 23,080,000
Engineering, Contingency, and Legal	6,460,000
Land Easements	800,000
Environmental Studies and Mitigation	210,000
Interest During Construction	1,220,000
Total Project Cost	$ 31,770,000
Annual Costs	
Debt Service	2,980,000
Operation & Maintenance	480,000
Power(1)	2,240,000
Purchase of Water From LCRA(2)	4,490,000
Total Annual Cost	$ 10,190,000
Annual Project Yield (acft/yr)	42,721
Annual Unit Costs	
$ per acft	$ 239
$ per 1,000 gal	$0.73

[1] Based on annual pumpage of 42,721 acft/yr.
[2] Based on purchase of 42,721 acft/yr at 1996 LCRA stored water cost of $105 per acft.

Table 3.19-4
Cost Estimate Summary for Lake Travis Raw Water Pipeline
(Twin 33-inch Diameter Pipelines) (Alt BC-2)
(1st Quarter 1997 dollars)

Item	**Phase I** (First 33″ Pipeline)	**Phase II** (Second 33″ Pipeline)
Capital Costs		
Intake and Pump Station	$ 3,520,000	$ 1,290,000
Booster Pumps at Round Rock WTP	1,610,000	0
Transmission Pipeline	12,060,000	10,630,000
Valves and Control Equipment	510,000	0
Total Capital Costs	$ 17,700,000	$ 11,920,000
Engineering, Contingency, and Legal	4,990,000	3,110,000
Land Easements	350,000	300,000
Environmental Studies and Mitigation	90,000	80,000
Interest During Construction	930,000	620,000
Total Project Cost	$ 24,060,000	$ 16,030,000
Annual Costs		
Debt Service	2,250,000	1,500,000
Operation & Maintenance	320,000	270,000
Power(1)	1,160,000	1,160,000
Purchase of Water From LCRA(2)	4,490,000	0
Total Annual Cost	$ 8,220,000	$ 2,930,000
Annual Project Yield (acft/yr)	21,360	21,360
Annual Unit Costs		
$ per acft	$ 385	$ 137
$ per 1,000 gal	$1.18	$0.42

[1] Based on annual pumpage of 42,721 acft/yr.
[2] Based on purchase of 42,721 acft/yr at 1996 LCRA stored water cost of $105 per acft.

For the twin 33-inch diameter pipeline option, Table 3.19-4 summarizes costs for construction of a first phase single pipeline (i.e., Phase I) to be followed by a second 33-inch pipeline parallel to the first (Phase II). Phase I costs would include construction of an intake and pump station structure sufficient for Phase I and Phase II flows, as well as an 18 mgd booster station and the piping and outfall structure at Lake Georgetown. Inclusion of these items in the Phase I results in substantially higher costs for Phase I than for Phase II. Total project costs for Phase I would be $24,060,000. Phase II total project costs would be about $16,030,000, which includes acquisition of additional right-of-way for the Phase II pipeline.

Total annual costs for Phase I, including debt service, O&M, power, and purchase of raw water would be about $8,220,000 (Table 3.19-4). For 21,360 acft/yr of water available for Phase I, the annual unit cost of water would then be $385 per acft (or $1.18 per 1,000 gal). These costs do not include treatment.

Total annual costs for Phase II, including debt service, O&M, power and purchase of raw water would be about $2,930,000 (about $5,290,000 per year less than Phase I costs). For the additional 21,360 acft produced by Phase II, the annual unit cost of water considering only Phase II costs would be about $137 per acft (or $0.42 per 1,000 gal). The average unit cost of water for Phases I and II would be about $260 per acft or $0.80 per 1,000 gal. These costs do not include treatment.

Costs for Water Treatment at a New Round Rock Treatment Facility

The combined 2010 projected shortages of Round Rock and Brushy Creek are estimated to be 26,494 acft/yr. Using a peak day to average day factor of 2.0, the treatment capacity needed would be about 47 mgd. Because this additional treatment capacity needed by Round Rock is large compared to their existing plant capacity (21 mgd), virtually all the components of a new treatment facility would be required for the upgrade. Therefore, the cost of treatment capacity is conservatively estimated to be the same as for construction of a new treatment plant. A new treatment system which could be operated independently would also facilitate treating waters from the two sources (Lake Travis and Lake Georgetown) separately. This would simplify operation with respect to chemical requirements, and would likely produce a finished water of more consistent quality.

Table 3.19-5 summarizes the cost estimate for construction and operation of a 47 mgd water treatment facility at Round Rock. The capital cost of 47 mgd of new water treatment capacity is estimated to be $26,800,000. The total project cost would be about $35,100,000.

Table 3.19-5
Cost Estimate Summary for Treatment of Lake Travis Water at Round Rock WTP (Alt. BC-2)
(1st Quarter 1997 dollars)

Item	Cost
Capital Costs	
Treatment Plant (47 mgd)	$ 26,800,000
Total Capital Costs	$ 26,800,000
Engineering, Contingency, and Legal	6,700,000
Land Easements	200,000
Environmental Studies and Mitigation	50,000
Interest During Construction	1,350,000
Total Project Cost	$ 35,100,000
Annual Costs	
Debt Service	3,290,000
Operations & Maintenance (Including Power)	3,530,000
Total Annual Costs	$ 6,820,000
Annual Treatment at Round Rock (acft/yr)	26,494
Annual Unit Costs	
$ per acft	$ 257
$ per 1,000 gal	$0.79

Total annual costs would be about $6,820,000, which consist of debt service, O&M and power at the plant. For annual treatment of 26,494 acft of water the unit cost would be $257 per acft ($0.79 per 1,000 gal).

Table 3.19-6 summarizes the cost estimate for Round Rock to participate in the 42-inch diameter raw water line and treatment at an expansion of Round Rock's water treatment plant. The annual unit cost of the raw water line component would be about $239 per acft, and the treatment component would be about $257 per acft. The estimated total annual cost would therefore be about $496 per acft ($1.52 per 1,000 gal).

Table 3.19-6
Cost Estimate Summary for 42-inch Pipeline and Treatment at Round Rock
(1st Quarter 1997 dollars)

Item	Cost
Annual Cost of Raw Water Delivered to Round Rock Treatment Plant(1)	
(42-inch pipeline)(see Table 3.19-3)($ per acft)	$ 239
Annual Cost of Treatment	
(see Table 3.19-5) ($ per acft)	257
Total Annual Unit Cost of Treated Water	
($ per acft)	$ 496
($ per 1,000 gal)	$1.52

[1] Includes purchase of raw water from LCRA.

Table 3.19-7 summarizes the cost estimate for Round Rock to participate in the first phase of the twin 33-inch diameter raw water line option with treatment at an expansion of Round Rock's water treatment plant. The annual unit cost of the raw water line component would be about $385 per acft, and the treatment component would be $257 per acft. The estimated total annual unit cost of treated water at the Round Rock Treatment Plant would therefore be about $536 per acft ($2.81 per 1,000 gal).

Table 3.19-7
Cost Estimate Summary for 33-inch Pipeline and Treatment at Round Rock
(1st Quarter 1997dollars)

Item	Cost
Annual Cost of Raw Water Delivered to Round Rock Treatment Plant(1)	
(33-inch pipeline)(see Table 3.19-4)($ per acft)	$ 385
Annual Cost of Treatment	
(see Table 3.19-5) ($ per acft)	257
Total Annual Unit Cost of Treated Water	
($ per acft)	$ 642
($ per 1,000 gal)	$1.97

[1] Includes purchase of raw water from LCRA.

3.19.6 Implementation Issues

The transfer of water from Lake Travis to Round Rock or Lake Georgetown would constitute an interbasin transfer and require a permit from the TNRCC. Under Senate Bill 1 (1997 Texas Legislature), a permit must be obtained to divert state water from one river basin to another (SB 1, Section 11.085 (a)). However, Senate Bill 1 provides an exemption (Section 11.085 (v)) from most of the requirements of Section 11.085 for water transfers to another river basin when a portion of the county or municipality receiving the water is in the basin of origin. Because a small portion of Williamson County is in the Colorado River Basin, the exemptions allowed in Senate Bill 1 will probably apply. TNRCC permit amendments could be needed to add a point of diversion at Lake Travis. Negotiations between LCRA and BRA would be necessary to facilitate accounting of the Lake Travis water discharged to Lake Georgetown.

Requirements Specific to Pipelines

1. Necessary permits:
    a. U.S. Army Corps of Engineers Sections 404 dredge and fill permit for stream crossings and lake intake.
    b. GLO Sand and Gravel Removal permits.
    c. 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

Requirements Specific to Discharges to Lake Georgetown

1. Study of the environmental effects on mixing Lake Travis water in Lake Georgetown would be needed.
2. Once quantities to be discharged to Lake Georgetown are known, the study of the hydrologic effects of the discharges on Lake Georgetown would be needed.

Requirements Specific to Treatment and Distribution

1. Study is required to evaluate the practical aspects or treating water from the two sources.
2. Necessary permits:
    a. Local construction permit
    b. No permit to treat and distribute water, however, the design must be approved by TBRCC and there are standards which must be met for water quality.

Appendix

APPENDIX A

Yield Hydrology of Brazos River Basin Reservoirs

APPENDIX A

YIELD HYDROLOGY: LOCAL BRAZOS RESERVOIRS

As part of the Trans-Texas alternative evaluations, baseline hydrology was established for Lake Stillhouse Hollow, Lake Georgetown, and Lake Granger. This included establishing, reservoir capacities, sedimentation, evaporation, inflow, typical monthly demand distribution, and finally firm yields for the years 1995, 2020, and 2050. Each of these items is discussed below.

A.1 Hydrologic Data

1995 Reservoir Capacity

In 1995 the Texas Water Development Board (TWDB) performed detailed hydrographic surveys on Lake Stillhouse Hollow, Lake Georgetown, and Lake Granger. These surveys provide the relationship between elevation, surface area, and capacity of a reservoir (EAC), which is essential to understanding their operation. The 1995 surveys also serve as a valid point from which to project future EAC relations as they are altered by sedimentation. The 1995 and projected surveys are provided in Tables A-1a, b, and c. These projections are discussed in the following section.

Sedimentation

Sedimentation is the process whereby silt suspended in flowing water is allowed to settle in a reservoir. This has the effect, over time, of reducing storage capacity in the reservoir which affects its operation.

Estimates of sedimentation rates were available from several sources. The Texas Department of Water Resources (TDWR), estimated rates for the three reservoirs in 1979.[1] The Brazos River Authority (BRA) also provided rates which were determined by previous consultants. The TWDB estimated sedimentation in the reservoirs by comparing initial EACs with the hydrographic surveys it performed in 1995. Comparison of estimated future reservoir capacities based on each of the three referenced sources are shown in Figures A-1a, b, and c. From the figures, it is evident that estimates vary widely.

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[1] Texas Department Water Resources, Erosion and Sedimentation by Water in Texas, Report 268, February, 1982.

Table A-1a
Elevation-Area-Capacity Table for Lake Stillhouse

Elevation (ft)	1995 (1) Area (acre)	1995 (1) Capacity (acft)	2020 (2) Area (acre)	2020 (2) Capacity (acft)	2050 (3) Area (acre)	2050 (3) Capacity (acft)
622	6,429	226,063	6,429	217,203	6,429	206,563
619	5,989	207,485	5,942	198,672	5,886	188,088
616	5,594	190,134	5,532	181,485	5,459	171,094
613	5,233	173,904	5,161	165,455	5,076	155,302
610	4,870	158,745	4,790	150,523	4,696	140,639
607	4,522	144,662	4,436	136,688	4,335	127,098
604	4,191	131,593	4,100	123,884	3,992	114,608
600	3,772	115,694	3,676	108,360	3,561	99,527
596	3,443	101,285	3,342	94,345	3,223	85,979
588	2,840	76,202	2,733	70,091	2,607	62,708
580	2,304	55,688	2,194	50,441	2,064	44,086
572	1,831	39,250	1,721	34,883	1,589	29,574
564	1,397	26,287	1,288	22,797	1,158	18,533
556	1,020	16,686	914	14,053	788	10,814
540	435	5,344	342	4,295	231	2,959
506	0	0	0	0	0	0

1. TWDB 1995 hydrographic survey.
2. 8,860 acft new sediment. TWDB rate of 354.5 acft/yr for 25 years.
3. 19,500 acft new sediment. TWDB rate of 354.5 acft/yr for 55 years.

Table A-1b
Elevation-Area-Capacity Table for Lake Georgetown

Elevation (ft)	1995 (1) Area (acre)	1995 (1) Capacity (acft)	2020 (2) Area (acre)	2020 (2) Capacity (acft)	2050 (3) Area (acre)	2050 (3) Capacity (acft)
791	1,297	37,010	1,297	36,870	1,297	36,711
789	1,238	34,483	1,237	34,344	1,236	34,185
787	1,188	32,056	1,187	31,920	1,185	31,764
785	1,137	29,729	1,135	29,596	1,133	29,444
783	1,083	27,508	1,081	27,378	1,079	27,230
780	998	24,388	996	24,264	994	24,123
777	919	21,513	917	21,396	914	21,262
774	849	18,864	847	18,754	844	18,628
771	786	16,410	784	16,307	781	16,189
768	707	14,174	704	14,078	702	13,969
765	636	12,166	633	12,078	631	11,977
760	538	9,237	535	9,162	532	9,076
755	441	6,800	438	6,738	435	6,667
750	363	4,789	360	4,739	358	4,683
735	150	973	148	958	145	941
714	0	0	0	0	0	0

1. TWDB 1995 hydrographic survey.
2. 140 ac-ft new sediment. TWDB rate of 5.43 ac-ft/yr for 25 years.
3. 300 ac-ft new sediment. TWDB rate of 5.43 ac-ft/yr for 55 years.

Table A-1c
Elevation-Area-Capacity Table for Lake Granger

Elevation (ft)	1995 (1)		2020 (2)		2050 (3)	
	Area (acre)	Capacity (acft)	Area (acre)	Capacity (acft)	Area (acre)	Capacity (acft)
504	4,009	54,280	4,009	47,031	4,009	38,330
503	3,786	50,417	3,674	43,205	3,527	34,553
501	3,466	43,159	3,295	36,228	3,072	27,944
499	3,087	36,643	2,883	30,086	2,617	22,291
497	2,770	30,790	2,544	24,662	2,248	17,429
495	2,428	25,585	2,187	19,924	1,871	13,303
493	2,114	21,049	1,862	15,881	1,532	9,906
491	1,843	17,100	1,584	12,443	1,246	7,136
489	1,599	13,660	1,337	9,523	994	4,898
487	1,375	10,688	1,113	7,076	769	3,138
485	1,149	8,166	889	5,076	548	1,822
483	955	6,073	700	3,499	365	920
481	801	4,321	553	2,250	229	330
479	608	2,904	370	1,318	59	33
475	284	1,234	76	539	0	0
465	0	0	0	0	0	0

1. TWDB 1995 hydrographic survey.
2. 7,249 ac-ft new sediment. BRA rate of 289.8 ac-ft/yr for 25 years.
3. 15,950 ac-ft new sediment. BRA rate of 289.8 ac-ft/yr for 55 years.

For Lake Stillhouse Hollow and Lake Georgetown, the TWDB rates were considered to be the most accurate. For Lake Stillhouse Hollow, the TWDB sedimentation rate is based on a period of 27 years which is substantial. Also, the U.S. Army Corps of Engineers (the Corps) has substantiated the TWDB rate there.[2] The low sedimentation rate determined by the TWDB for Lake Georgetown was confirmed by the TWDB in a second survey.[3]

Compared to Lakes Stillhouse Hollow and Georgetown, Lake Granger suffers from a much higher sedimentation rate. The TWDB rate which is based on a 15-year period suggests that the capacity of Lake Granger projected for 2050 would be reduced to about 20 percent of its original 1980 capacity. The BRA plans to perform a study addressing this issue in the near future and, if appropriate, to take steps to reduce sedimentation at Lake Granger. For this reason, the BRA rate was selected to be used for Lake Granger in this study.

Based on the sedimentation rates discussed above elevation-area-capacity (EAC) relations were calculated for years 2020 and 2050 from the 1995 EAC relations determined by the 1995

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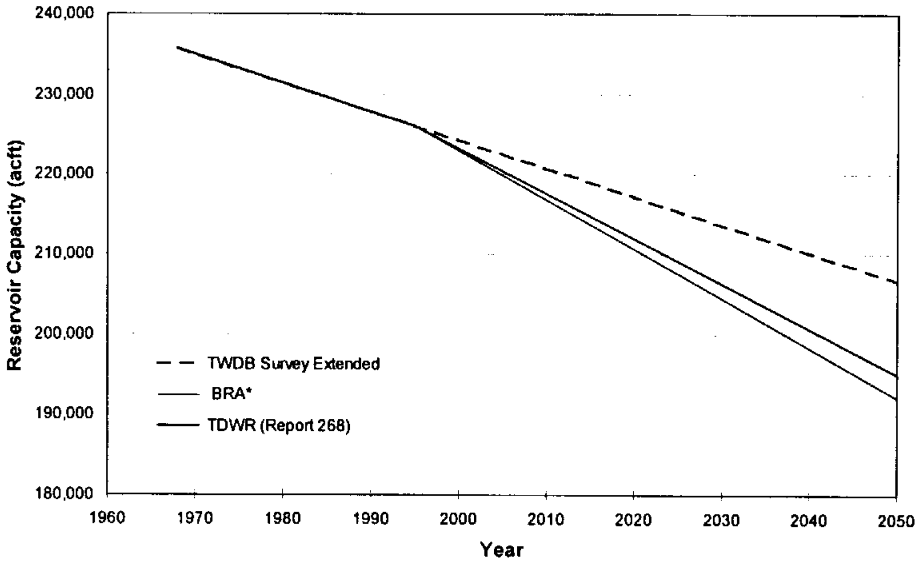
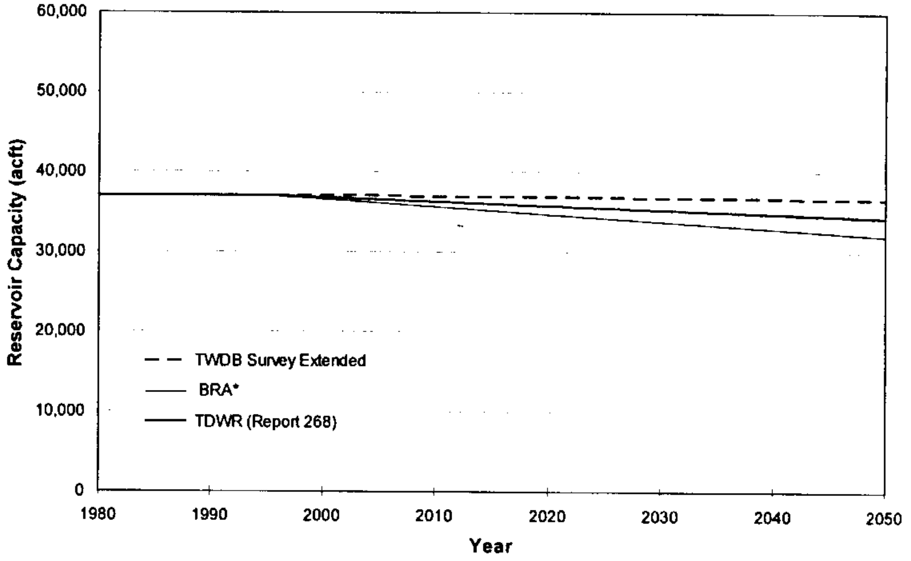
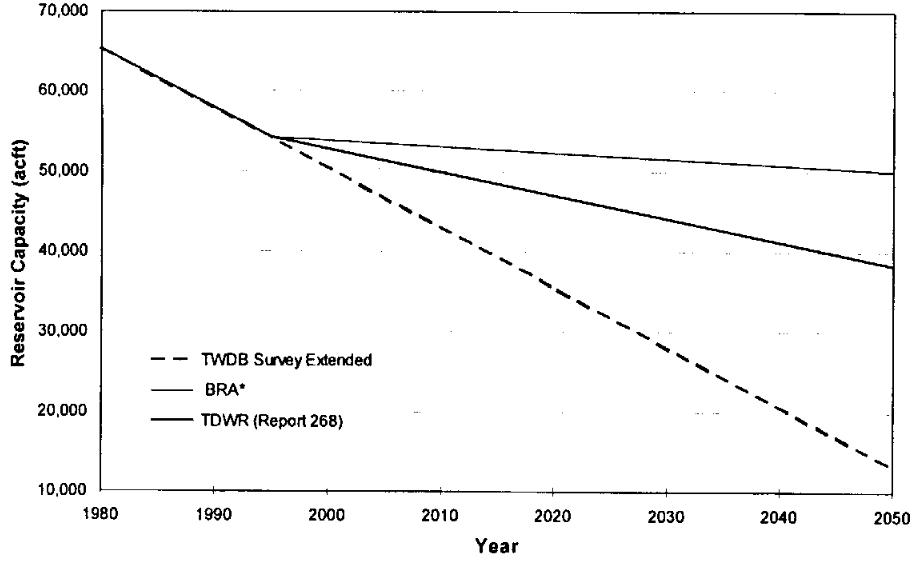
[2] BRA Staff, October, 1996.

[3] Ibid..


LAKE STILLHOUSE HOLLOW


LAKE GEORGETOWN


LAKE GRANGER

* Sedimentation rate provided by BRA staff from previous consultants reports.

HDR Engineering, Inc.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

DEPLETION OF CONSERVATION STORAGE FROM SEDIMENTATION

FIGURE A-1

TWDB surveys. These relations are given in Table A-2. Sediment was distributed in each reservoir as outlined by Borland.[4] The method first identifies the type of reservoir based on the input EAC information, and then distributes the sediment in the reservoir according to the shape of the bottom of the reservoir. This method is somewhat more sophisticated than assuming that all sediment deposits in the sediment reserve space in the lowest point of the lake.

Table A-2
Estimated Sedimentation Rates and Projected Reservoir Capacities

Reservoir	**Sedimentation Rate** (acft/yr/sq mi)	**Drainage Area** (sq mi)	**Annual Sedimentation** (acft/yr)	**Reservoir Conservation Pool Capacity** (acft)			
				Original (1)	**1995 (2)**	**2020 (3)**	**2050 (4)**
Lake Stillhouse Hollow	0.27	1313	355	235,700	226,060	217,200	206,563
Lake Georgetown	0.022	247	5.43	37,080	37,010	36,870	36,711
Lake Granger	0.60	483	290	65,510	54,280	47,031	38,330

1. Stillhouse 1968, Georgetown 1980, Granger 1980. U.S. Army Corps of Engineers, Water Resources Development in Texas, 1991.
2. TWDB Survey, May, 1995.
3. 1995 Capacity - [Sedimentation(acft/yr) x 25 yr.]
4. 1995 Capacity - [Sedimentation(acft/yr) x 55 yr.]

Evaporation

Monthly reservoir evaporation data for the historical period 1941 to 1965 were developed from reservoir-evaporation data available from the TWDB. Net evaporation (evaporation minus precipitation) was calculated based on weighted quantities reported at the four closest TWDB evaporation quadrants. Weighting was based on the distance from each quadrant to the respective reservoir site. The monthly evaporation data for the period 1940 through 1990 are shown in Tables A-3a, b, and c.

Inflows

Monthly inflow data for the three lakes are based on work performed by the Texas Water Resources Institute for TR-144.[5] These inflows were developed from naturalized streamflows obtained from the TNRCC using their water rights model for the Brazos Basin. These

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[4] Borland and Miller, Distribution of Sediment in Large Reservoirs, Journal of the Hydraulics Division, ASCE, April, 1958, Paper 1587.

[5] Wurbs, R.A., et al, Hydrologic and Institutional Water Availability in the Brazos River Basin, Technical Report 144, Texas Water Resources Institute, August, 1988.

Table A-3a
Net Evaporation in Feet - Lake Stillhouse

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	0.13	0.01	0.31	0.04	0.30	-0.13	0.48	0.66	0.65	0.36	-0.32	-0.06	2.43
1941	0.11	-0.12	-0.04	-0.06	0.03	0.01	0.42	0.59	0.56	0.09	0.17	0.12	1.88
1942	0.14	0.20	0.31	-0.33	-0.01	0.25	0.49	0.50	0.08	0.03	0.24	0.11	2.01
1943	0.15	0.29	0.16	0.34	0.17	0.49	0.46	0.79	0.27	0.41	0.23	0.00	3.76
1944	-0.18	-0.12	0.04	0.24	-0.23	0.50	0.73	0.61	0.49	0.46	-0.06	-0.10	2.38
1945	-0.01	-0.08	-0.03	-0.10	0.42	0.28	0.46	0.51	0.49	0.22	0.31	0.11	2.58
1946	-0.07	0.05	0.11	0.15	0.02	0.40	0.79	0.73	0.11	0.30	0.06	0.07	2.72
1947	-0.14	0.20	0.05	0.10	0.19	0.57	0.76	0.52	0.70	0.57	0.23	0.01	3.76
1948	0.05	-0.06	0.21	0.23	0.16	0.53	0.55	0.77	0.54	0.50	0.36	0.20	4.04
1949	-0.15	-0.05	0.10	-0.21	0.34	0.26	0.65	0.62	0.58	0.13	0.42	0.01	2.70
1950	0.05	-0.07	0.35	-0.04	0.13	0.30	0.58	0.82	0.30	0.50	0.47	0.32	3.71
1951	0.27	0.00	0.25	0.28	0.10	0.26	0.80	0.97	0.40	0.45	0.29	0.26	4.33
1952	0.23	0.17	0.15	-0.04	0.04	0.48	0.62	0.98	0.47	0.72	-0.05	-0.12	3.65
1953	0.27	0.10	0.09	0.13	0.05	0.67	0.65	0.59	0.45	0.05	0.23	0.10	3.38
1954	0.13	0.33	0.29	0.18	0.28	0.67	0.90	0.92	0.76	0.46	0.26	0.31	5.49
1955	0.07	-0.03	0.23	0.25	0.06	0.28	0.61	0.40	0.38	0.62	0.45	0.21	3.53
1956	0.11	0.10	0.41	0.37	0.29	0.69	0.94	0.92	0.84	0.51	0.32	0.15	5.65
1957	0.17	0.02	-0.01	-0.53	-0.16	0.25	0.77	0.87	0.26	-0.11	-0.06	0.17	1.64
1958	0.05	-0.11	0.08	0.04	0.16	0.38	0.70	0.63	0.15	0.17	0.22	0.15	2.62
1959	0.17	-0.03	0.32	0.05	0.18	0.15	0.37	0.26	0.43	-0.01	0.27	0.02	2.18
1960	0.04	0.07	0.14	0.19	0.33	0.34	0.51	0.45	0.56	-0.06	0.06	-0.18	2.45
1961	-0.08	-0.11	0.19	0.36	0.39	0.00	0.22	0.67	0.35	0.31	0.12	0.11	2.53
1962	0.15	0.17	0.27	0.03	0.40	0.14	0.73	0.84	0.32	0.24	0.19	0.08	3.56
1963	0.16	0.14	0.30	0.20	0.26	0.44	0.74	0.81	0.59	0.54	0.14	0.13	4.45
1964	0.02	0.07	0.08	0.14	0.25	0.33	0.73	0.63	0.11	0.38	0.08	0.16	2.98
1965	-0.01	-0.12	0.16	0.16	-0.40	0.38	0.62	0.64	0.44	0.19	0.03	-0.05	2.04
1966	-0.01	-0.02	0.21	0.05	0.05	0.39	0.61	0.46	0.18	0.39	0.34	0.16	2.81
1967	0.19	0.13	0.29	0.18	0.12	0.59	0.72	0.68	0.17	0.20	0.09	0.06	3.42
1968	-0.18	0.02	0.07	0.07	-0.07	0.25	0.52	0.71	0.24	0.39	0.14	0.16	2.32
1969	0.13	-0.02	0.04	-0.03	0.17	0.50	0.81	0.48	0.27	0.19	0.18	0.04	2.76
1970	0.11	-0.04	0.02	0.11	0.07	0.50	0.70	0.78	0.11	0.11	0.31	0.21	2.99
1971	0.27	0.21	0.40	0.29	0.36	0.57	0.63	0.22	0.33	0.14	0.20	0.00	3.62
1972	0.07	0.21	0.37	0.33	0.21	0.40	0.47	0.44	0.43	0.21	0.11	0.13	3.38
1973	-0.03	-0.03	0.13	0.06	0.33	0.21	0.41	0.67	0.23	0.05	0.26	0.26	2.55
1974	0.03	0.25	0.26	0.32	0.30	0.58	0.75	0.25	0.18	0.15	0.03	0.05	3.15
1975	0.10	0.03	0.20	0.15	0.04	0.30	0.46	0.48	0.34	0.36	0.33	0.13	2.92
1976	0.21	0.28	0.19	0.03	0.18	0.34	0.24	0.66	0.22	0.09	0.12	0.04	2.60
1977	-0.01	0.11	0.18	0.07	0.22	0.44	0.78	0.69	0.61	0.42	0.15	0.28	3.94
1978	0.09	-0.02	0.25	0.27	0.28	0.46	0.81	0.52	0.27	0.41	-0.01	0.10	3.43
1979	-0.01	-0.03	0.06	0.11	0.12	0.30	0.38	0.37	0.43	0.49	0.24	0.01	2.47
1980	0.05	0.11	0.19	0.26	0.13	0.59	0.87	0.75	0.32	0.36	0.11	0.09	3.83
1981	0.10	0.06	0.06	0.16	0.21	0.09	0.54	0.54	0.33	0.11	0.18	0.21	2.59
1982	0.09	0.06	0.12	0.10	0.13	0.29	0.64	0.70	0.55	0.32	0.08	0.08	3.16
1983	0.03	0.00	0.07	0.37	0.17	0.30	0.50	0.45	0.47	0.29	0.17	0.15	2.97
1984	0.10	0.21	0.20	0.47	0.45	0.49	0.63	0.70	0.53	0.02	0.12	-0.02	3.90
1985	0.05	0.04	0.09	0.17	0.31	0.34	0.55	0.78	0.38	0.13	0.11	0.12	3.07
1986	0.19	0.07	0.32	0.25	0.11	0.20	0.76	0.54	0.21	0.06	0.06	-0.07	2.70
1987	0.11	-0.03	0.16	0.36	0.12	0.12	0.50	0.70	0.35	0.48	0.05	0.06	2.98
1988	0.17	0.13	0.21	0.31	0.32	0.34	0.48	0.66	0.50	0.38	0.31	0.12	3.93
1989	-0.02	0.02	0.10	0.29	0.24	0.28	0.61	0.53	0.56	0.41	0.26	0.23	3.51
1990	0.09	0.05	0.03	0.11	0.30	0.66	0.45	0.59	0.31	0.30	0.11	0.13	3.13
Average	0.07	0.06	0.17	0.14	0.17	0.36	0.61	0.63	0.39	0.28	0.17	0.10	3.15

Soucre: TWDB Report 64, Quadrangles: 609 (17%), 610 (33%), 709 (17%), 710 (33%)

Table A-3b
Net Evaporation in Feet - Lake Georgetown

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	0.13	-0.01	0.29	0.04	0.27	-0.18	0.47	0.65	0.63	0.33	-0.32	-0.08	2.22
1941	0.10	-0.12	-0.06	-0.07	0.02	-0.01	0.39	0.61	0.53	0.08	0.17	0.11	1.75
1942	0.10	0.21	0.30	-0.29	-0.01	0.26	0.44	0.51	0.07	0.02	0.21	0.10	1.92
1943	0.14	0.27	0.15	0.33	0.18	0.48	0.43	0.78	0.24	0.40	0.20	0.00	3.60
1944	-0.20	-0.12	0.02	0.26	-0.22	0.47	0.72	0.57	0.45	0.44	-0.10	-0.11	2.18
1945	-0.02	-0.07	-0.01	-0.08	0.42	0.27	0.47	0.47	0.45	0.21	0.29	0.08	2.48
1946	-0.08	0.04	0.10	0.12	0.03	0.38	0.78	0.67	0.10	0.29	0.01	0.06	2.50
1947	-0.14	0.19	0.05	0.10	0.20	0.57	0.76	0.49	0.69	0.56	0.22	0.01	3.70
1948	0.05	-0.06	0.21	0.23	0.18	0.53	0.56	0.75	0.52	0.47	0.34	0.19	3.97
1949	-0.16	-0.06	0.10	-0.24	0.34	0.28	0.64	0.61	0.54	0.12	0.40	-0.02	2.55
1950	0.05	-0.05	0.33	-0.06	0.14	0.30	0.59	0.82	0.29	0.49	0.46	0.31	3.67
1951	0.27	-0.02	0.23	0.29	0.10	0.29	0.80	0.95	0.39	0.45	0.28	0.25	4.28
1952	0.22	0.16	0.15	-0.02	0.05	0.47	0.61	0.97	0.39	0.68	-0.04	-0.12	3.52
1953	0.27	0.08	0.10	0.11	0.09	0.68	0.69	0.59	0.44	0.03	0.22	0.08	3.38
1954	0.14	0.31	0.29	0.19	0.29	0.66	0.86	0.90	0.75	0.47	0.26	0.30	5.42
1955	0.06	-0.03	0.23	0.26	0.09	0.28	0.62	0.40	0.41	0.62	0.43	0.20	3.57
1956	0.11	0.10	0.40	0.37	0.30	0.68	0.92	0.92	0.81	0.50	0.32	0.14	5.57
1957	0.18	0.02	0.00	-0.52	-0.15	0.21	0.79	0.87	0.22	-0.11	-0.06	0.16	1.61
1958	0.04	-0.14	0.07	0.05	0.14	0.33	0.66	0.61	0.11	0.14	0.20	0.14	2.35
1959	0.16	-0.03	0.32	0.03	0.20	0.19	0.38	0.25	0.42	-0.03	0.23	0.01	2.13
1960	0.03	0.06	0.13	0.18	0.35	0.35	0.48	0.43	0.54	-0.11	0.05	-0.16	2.33
1961	-0.05	-0.11	0.19	0.34	0.38	-0.01	0.22	0.66	0.30	0.30	0.10	0.09	2.41
1962	0.13	0.18	0.28	0.03	0.41	0.15	0.74	0.82	0.29	0.22	0.19	0.07	3.51
1963	0.16	0.12	0.31	0.22	0.31	0.46	0.75	0.82	0.58	0.54	0.14	0.12	4.53
1964	0.03	0.07	0.10	0.15	0.26	0.35	0.74	0.62	0.10	0.38	0.10	0.15	3.05
1965	-0.01	-0.13	0.16	0.16	-0.36	0.39	0.60	0.65	0.44	0.18	0.05	-0.07	2.06
1966	0.00	-0.03	0.21	0.02	0.05	0.39	0.62	0.45	0.17	0.39	0.36	0.16	2.79
1967	0.18	0.12	0.28	0.18	0.11	0.60	0.74	0.68	0.16	0.22	0.06	0.05	3.38
1968	-0.22	0.03	0.08	0.07	-0.10	0.21	0.51	0.72	0.21	0.39	0.12	0.15	2.17
1969	0.13	-0.05	0.02	-0.02	0.15	0.48	0.79	0.49	0.28	0.15	0.18	0.02	2.62
1970	0.11	-0.06	0.01	0.12	0.04	0.50	0.72	0.79	0.11	0.12	0.34	0.23	3.03
1971	0.27	0.21	0.40	0.29	0.35	0.55	0.64	0.21	0.31	0.14	0.19	0.01	3.57
1972	0.07	0.21	0.36	0.33	0.18	0.39	0.47	0.42	0.44	0.22	0.11	0.13	3.33
1973	-0.03	-0.03	0.13	0.06	0.33	0.21	0.42	0.65	0.22	0.05	0.26	0.25	2.52
1974	0.03	0.25	0.25	0.32	0.28	0.56	0.73	0.23	0.20	0.16	0.02	0.05	3.08
1975	0.10	0.03	0.20	0.15	0.05	0.28	0.45	0.46	0.33	0.36	0.33	0.13	2.87
1976	0.20	0.27	0.19	0.03	0.18	0.34	0.24	0.65	0.23	0.10	0.12	0.04	2.59
1977	-0.01	0.11	0.18	0.07	0.22	0.43	0.77	0.70	0.57	0.41	0.14	0.28	3.87
1978	0.08	-0.02	0.25	0.26	0.27	0.43	0.79	0.50	0.23	0.40	-0.02	0.08	3.25
1979	-0.01	-0.03	0.06	0.10	0.12	0.30	0.35	0.38	0.42	0.50	0.23	0.01	2.43
1980	0.05	0.10	0.18	0.27	0.13	0.58	0.85	0.72	0.29	0.33	0.10	0.10	3.70
1981	0.09	0.06	0.06	0.16	0.20	0.07	0.52	0.53	0.32	0.11	0.18	0.21	2.51
1982	0.09	0.07	0.12	0.09	0.12	0.29	0.65	0.68	0.52	0.30	0.08	0.08	3.09
1983	0.02	-0.01	0.06	0.37	0.16	0.28	0.48	0.44	0.44	0.28	0.17	0.14	2.83
1984	0.10	0.21	0.21	0.47	0.45	0.48	0.62	0.69	0.53	0.01	0.13	-0.02	3.88
1985	0.04	0.04	0.09	0.16	0.31	0.34	0.54	0.77	0.37	0.13	0.11	0.12	3.02
1986	0.18	0.08	0.32	0.27	0.10	0.19	0.75	0.52	0.19	0.05	0.06	-0.08	2.63
1987	0.11	-0.03	0.17	0.36	0.11	0.11	0.47	0.68	0.34	0.47	0.05	0.07	2.91
1988	0.17	0.14	0.20	0.30	0.30	0.35	0.46	0.65	0.51	0.39	0.32	0.13	3.92
1989	-0.03	0.04	0.10	0.28	0.24	0.30	0.62	0.55	0.57	0.40	0.25	0.22	3.54
1990	0.08	0.05	0.02	0.10	0.29	0.65	0.44	0.59	0.31	0.30	0.10	0.12	3.05
Average	0.07	0.05	0.17	0.14	0.17	0.36	0.60	0.62	0.37	0.28	0.16	0.09	3.08

Soucre: TWDB Report 64, Quadrangles: 609 (15%), 610 (18%), 709 (22%), 710 (45%)

Table A-3c

Net Evaporation in Feet - Lake Granger

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	0.10	-0.04	0.25	0.00	0.19	-0.21	0.40	0.62	0.55	0.29	-0.37	-0.11	1.67
1941	0.07	-0.08	-0.05	-0.07	0.02	-0.07	0.27	0.58	0.48	0.03	0.19	0.07	1.44
1942	0.04	0.21	0.25	-0.29	-0.01	0.21	0.33	0.54	0.07	0.09	0.15	0.04	1.63
1943	0.09	0.23	0.11	0.28	0.15	0.41	0.35	0.69	0.28	0.33	0.17	-0.02	3.07
1944	-0.25	-0.13	-0.05	0.22	-0.21	0.41	0.64	0.49	0.42	0.43	-0.23	-0.16	1.58
1945	-0.04	-0.08	-0.09	-0.10	0.32	0.22	0.42	0.24	0.47	0.11	0.25	0.03	1.75
1946	-0.12	0.00	-0.02	0.07	-0.05	0.30	0.67	0.50	0.09	0.27	-0.14	0.03	1.60
1947	-0.13	0.17	-0.01	0.06	0.10	0.46	0.64	0.34	0.64	0.52	0.15	-0.03	2.91
1948	0.00	-0.10	0.18	0.20	0.14	0.46	0.49	0.71	0.49	0.45	0.29	0.18	3.49
1949	-0.23	-0.07	0.08	-0.21	0.36	0.23	0.54	0.53	0.46	0.02	0.39	-0.11	1.99
1950	0.03	-0.07	0.27	-0.11	0.12	0.20	0.51	0.72	0.22	0.44	0.41	0.28	3.02
1951	0.25	-0.04	0.20	0.31	0.15	0.29	0.80	0.89	0.27	0.43	0.24	0.22	4.01
1952	0.17	0.07	0.12	-0.05	0.05	0.48	0.57	0.87	0.55	0.63	-0.13	-0.15	3.18
1953	0.24	0.02	0.07	0.05	0.02	0.64	0.64	0.48	0.40	-0.03	0.17	-0.07	2.63
1954	0.10	0.28	0.29	0.17	0.26	0.65	0.76	0.82	0.74	0.39	0.23	0.28	4.97
1955	0.04	-0.10	0.18	0.18	0.09	0.27	0.55	0.35	0.41	0.61	0.40	0.16	3.14
1956	0.08	0.03	0.29	0.29	0.27	0.60	0.86	0.85	0.77	0.47	0.24	0.13	4.88
1957	0.18	0.00	-0.05	-0.56	-0.03	0.14	0.69	0.72	0.16	-0.18	-0.09	0.12	1.10
1958	0.03	-0.14	0.09	0.00	0.20	0.34	0.50	0.49	-0.03	0.13	0.17	0.10	1.88
1959	0.15	-0.07	0.26	-0.08	0.13	0.26	0.34	0.18	0.31	0.04	0.18	-0.02	1.68
1960	0.02	0.01	0.12	0.11	0.33	0.18	0.46	0.32	0.48	-0.21	0.00	-0.18	1.64
1961	-0.09	-0.10	0.15	0.28	0.34	-0.05	0.21	0.53	0.16	0.30	0.05	0.04	1.82
1962	0.07	0.15	0.25	0.02	0.37	0.08	0.67	0.71	0.19	0.17	0.13	0.03	2.84
1963	0.12	0.08	0.30	0.15	0.34	0.45	0.64	0.76	0.53	0.52	0.15	0.07	4.11
1964	0.04	0.06	0.10	0.18	0.25	0.31	0.67	0.58	0.00	0.38	0.10	0.13	2.80
1965	-0.04	-0.13	0.15	0.17	-0.31	0.39	0.58	0.63	0.38	0.24	-0.03	-0.11	1.92
1966	-0.01	-0.06	0.22	-0.04	0.00	0.42	0.64	0.37	0.13	0.39	0.38	0.18	2.62
1967	0.18	0.14	0.33	0.15	0.08	0.58	0.70	0.66	0.11	0.18	0.05	0.02	3.18
1968	-0.24	0.04	0.07	0.05	-0.09	0.10	0.44	0.65	0.16	0.38	0.04	0.11	1.71
1969	0.09	-0.10	0.00	-0.04	0.12	0.46	0.77	0.52	0.29	0.21	0.17	-0.04	2.45
1970	0.04	-0.10	-0.03	0.07	0.04	0.54	0.74	0.79	0.07	0.04	0.34	0.20	2.74
1971	0.27	0.19	0.38	0.29	0.30	0.51	0.63	0.24	0.32	0.16	0.17	-0.02	3.44
1972	0.06	0.20	0.32	0.30	0.17	0.36	0.41	0.43	0.40	0.20	0.06	0.09	3.00
1973	-0.04	-0.03	0.09	0.04	0.30	0.15	0.42	0.60	0.19	0.01	0.22	0.20	2.15
1974	-0.04	0.24	0.22	0.26	0.25	0.52	0.65	0.24	0.16	0.13	-0.01	0.04	2.66
1975	0.08	0.01	0.15	0.12	0.02	0.25	0.42	0.41	0.30	0.30	0.30	0.11	2.47
1976	0.18	0.23	0.13	0.01	0.13	0.30	0.22	0.60	0.19	0.08	0.09	0.00	2.16
1977	-0.03	0.06	0.16	0.08	0.23	0.42	0.74	0.67	0.48	0.41	0.13	0.25	3.60
1978	0.03	-0.03	0.23	0.22	0.25	0.39	0.72	0.56	0.21	0.39	-0.02	0.05	3.00
1979	-0.03	-0.05	0.04	0.07	0.08	0.32	0.27	0.39	0.31	0.45	0.20	-0.01	2.04
1980	0.03	0.08	0.14	0.22	0.12	0.58	0.81	0.72	0.31	0.33	0.07	0.11	3.52
1981	0.07	0.04	0.07	0.15	0.16	0.03	0.43	0.51	0.30	0.08	0.16	0.21	2.21
1982	0.09	0.08	0.09	0.05	0.11	0.29	0.61	0.66	0.50	0.23	0.02	0.05	2.78
1983	0.01	-0.04	0.05	0.37	0.15	0.27	0.43	0.34	0.35	0.26	0.14	0.11	2.44
1984	0.10	0.18	0.17	0.44	0.40	0.40	0.58	0.64	0.51	-0.01	0.14	-0.02	3.53
1985	0.05	0.04	0.06	0.14	0.28	0.31	0.51	0.75	0.37	0.13	0.07	0.12	2.83
1986	0.17	0.06	0.30	0.23	0.08	0.19	0.75	0.49	0.19	0.07	0.04	-0.08	2.49
1987	0.12	-0.04	0.17	0.37	0.09	0.11	0.44	0.69	0.33	0.46	0.05	0.05	2.84
1988	0.17	0.12	0.16	0.27	0.30	0.36	0.50	0.64	0.52	0.37	0.31	0.09	3.81
1989	-0.05	0.05	0.09	0.25	0.19	0.25	0.54	0.49	0.56	0.37	0.22	0.22	3.18
1990	0.09	0.04	0.01	0.08	0.27	0.61	0.41	0.59	0.29	0.30	0.10	0.13	2.92
Average	0.05	0.03	0.14	0.11	0.15	0.32	0.55	0.56	0.33	0.25	0.13	0.06	2.68

Soucre: TWDB Report 64, Quadrangles: 610 (15%), 611 (11%), 710 (59%), 711 (15%)

naturalized flows were then adjusted for senior water rights using the Texas A&M University Water Rights Analysis Program (TAMUWRAP). The resulting inflows include water available for impoundment at the reservoir site. These inflow data were developed as input to HEC-3 for reservoir simulations as part of the TR-144 effort. Flow data were available for the period from 1941 to 1965 and are included on this appendix as Tables A-4a, b, and c. To verify the reasonableness of these flows, comparisons were made of TR-144 flows with naturalized inflows developed by TNRCC, and with USGS gauged flows adjusted for differences in drainage area. Comparisons were made of cumulative inflows from these sources for the critical drought period of each reservoir. The results of these comparisons are shown for each reservoir in Figures A-2a, b, and c. These comparisons show that the TR-144 inflow sets overall track slightly below the gauged inflows sets, which is reasonable assuming senior water rights would be diverting water when available.

Demand Distribution

A municipal demand distribution was used for all baseline yield analyses (i.e., with reservoirs operated independently). This demand distribution was based on records from the City of Austin for the period 1980 to 1995, provided as part of this study. The peak months in the distribution are July and August, and the peak-to-average month ratio is about 1.4. The demand distributed is shown in Figure A-3. For yield analyses which included transfer of water between reservoirs through cross-country pipelines, a uniform monthly diversion pattern was used.

A.2 Firm Yield Analyses

Stand Alone Firm Yields

The firm yield of each of the three reservoirs was computed with the reservoirs operated independently for years 1995, 2020, and 2050 sediment conditions. These yield projections are shown in Figures A-4a, b, and c, along with the BRA's yields taken from their 1996 Long Term Planning Guide.[6] The new yield estimates for Lakes Stillhouse Hollow and Georgetown show a small increase in reservoir yields over previous estimates. Since in both cases the 1995 yields

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[6] BRA firm yields from the BRA Long-Term Planning Guide, March, 1996.

Table A-4a
Inflow Data to Lake Stillhouse Hollow
(ac-ft/mo)

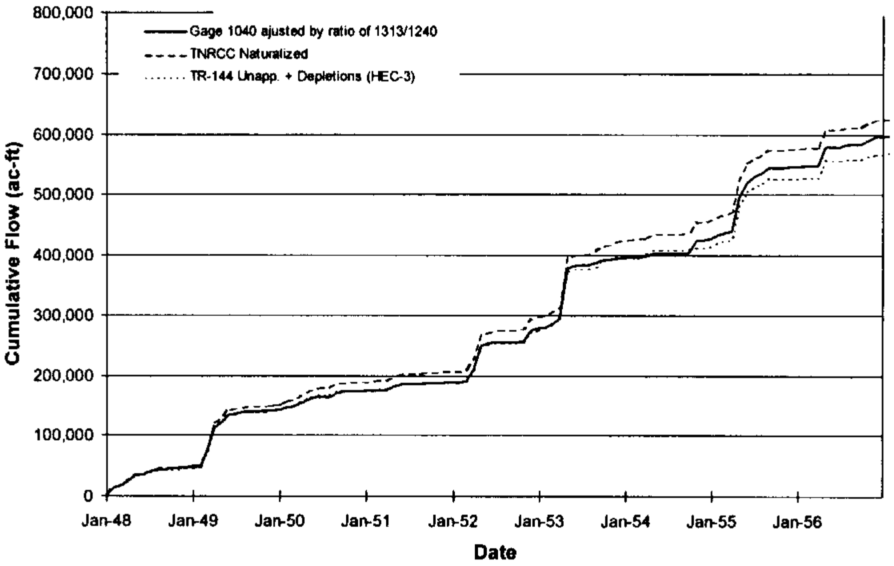
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	62,230	101,730	102,730	93,970	120,140	67,480	31,080	11,350	3,940	11,100	4,330	4,230	614,310
1942	3,370	2,780	2,530	78,550	83,210	93,160	9,570	5,040	21,880	19,130	13,050	10,860	343,130
1943	9,010	5,700	7,750	7,660	6,420	1,630	710	50	7,550	2,040	1,400	1,910	51,830
1944	24,180	66,750	63,280	28,710	269,260	91,310	13,330	9,200	9,310	5,610	8,650	42,150	631,740
1945	81,260	87,110	104,350	118,930	52,490	36,270	11,060	7,930	16,790	17,030	12,940	22,190	568,350
1946	29,110	41,690	53,490	23,220	24,700	14,230	3,050	2,990	5,150	3,520	10,750	13,480	225,380
1947	40,080	18,810	35,660	26,150	20,660	6,290	2,010	1,910	1,060	780	1,360	1,760	156,530
1948	1,630	12,340	3,090	6,620	10,540	600	5,020	3,090	320	190	540	1,070	45,050
1949	1,220	1,380	23,140	43,930	9,020	12,170	1,470	1,510	160	150	690	1,410	96,250
1950	880	5,970	1,330	6,010	6,610	4,610	440	0	6,970	220	380	450	33,870
1951	470	660	960	430	5,490	3,560	0	0	1,120	0	250	320	13,260
1952	280	300	860	18,950	37,710	5,570	1,600	20	0	0	980	16,160	82,430
1953	4,570	2,650	5,320	8,520	81,050	3,720	1,070	0	3,740	9,350	1,800	6,770	128,560
1954	1,560	840	480	760	5,610	0	10	40	40	1,010	1,790	300	12,440
1955	2,040	6,730	2,220	4,340	53,710	23,860	9,380	4,810	7,480	30	180	400	115,180
1956	410	1,120	30	0	28,020	250	0	1,630	0	680	3,910	4,130	40,180
1957	740	1,120	11,870	171,750	194,520	44,560	3,170	1,820	2,190	58,720	32,360	23,030	545,850
1958	17,560	83,560	66,700	26,190	58,950	34,860	5,350	2,600	4,620	2,770	2,530	2,170	307,860
1959	1,740	2,490	1,760	3,950	2,340	24,290	3,440	7,630	6,430	152,490	28,560	48,390	283,510
1960	71,970	49,030	30,990	17,030	8,790	4,000	4,970	3,310	4,350	73,960	23,110	83,850	375,360
1961	109,590	127,090	53,320	27,340	13,860	19,830	35,620	7,240	8,740	11,450	13,210	6,670	433,960
1962	5,860	5,270	6,100	7,300	6,940	11,230	2,660	260	10,180	19,250	4,200	6,920	86,170
1963	3,420	3,800	2,910	2,170	4,790	1,750	1,340	390	1,030	2,940	2,730	980	28,250
1964	1,450	5,450	9,820	9,900	8,230	7,230	1,000	4,040	17,600	3,020	9,230	4,330	81,300
1965	14,670	49,190	24,340	18,530	312,000	43,420	9,030	4,330	12,990	11,540	22,490	17,810	540,340
Average	19,572	27,342	24,601	30,036	57,002	22,235	6,255	3,248	6,146	16,279	8,057	12,870	233643.6
%Annual	8.4	11.7	10.5	12.9	24.4	9.5	2.7	1.4	2.6	7.0	3.4	5.5	100.0

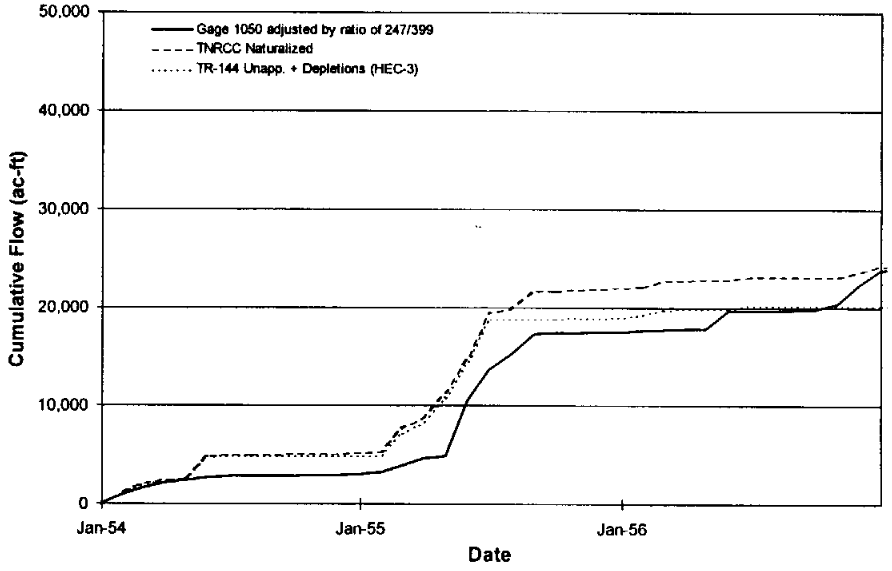
Table A-4b
Inflow Data to Lake Georgetown
(ac-ft/mo)

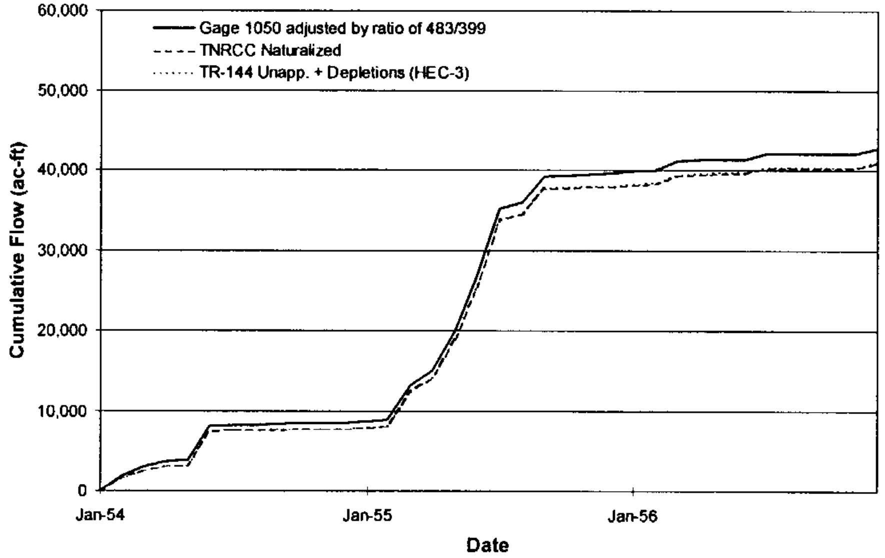
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	20,060	13,070	18,770	17,290	21,860	15,780	19,350	0	2,510	2,650	1,290	1,020	133,650
1942	1,330	1,170	1,180	6,490	9,080	13,270	2,380	610	17,480	3,970	5,630	5,120	67,710
1943	3,710	2,270	4,160	4,810	3,810	1,340	1,050	530	0	560	490	720	23,450
1944	7,620	8,440	15,200	1,150	30,500	18,830	2,630	0	4,180	1,070	4,030	10,890	104,540
1945	12,890	9,610	8,790	24,230	9,060	11,280	3,780	2,590	0	5,540	1,120	3,570	92,460
1946	7,520	10,170	9,890	9,930	15,100	8,650	2,200	1,120	0	2,700	17,910	12,150	97,340
1947	22,150	8,510	9,360	10,020	10,180	4,230	1,180	780	620	420	520	790	68,760
1948	870	0	1,720	2,450	4,000	1,220	1,290	200	10	190	100	170	12,220
1949	1,270	1,970	0	21,850	5,010	1,440	700	300	210	160	350	1,170	34,430
1950	570	4,440	910	4,940	2,090	2,690	840	240	2,590	340	160	230	20,040
1951	270	160	0	370	0	2,300	0	0	0	90	50	120	3,360
1952	140	230	340	2,170	4,680	2,720	0	0	0	0	10	1,610	11,900
1953	2,740	1,730	760	2,330	7,340	1,240	0	80	1,510	15,950	2,460	14,470	50,610
1954	1,200	750	420	60	2,290	60	0	0	0	0	0	0	4,780
1955	0	2,330	1,030	2,600	3,540	4,530	0	0	0	70	60	130	14,290
1956	130	590	80	10	0	330	0	0	0	0	10	10	1,160
1957	130	0	1,860	48,300	11,410	29,530	1,190	3,000	1,640	41,040	12,050	7,090	157,240
1958	5,780	29,060	12,280	6,380	15,250	7,160	3,450	0	7,000	2,730	2,200	1,600	92,890
1959	1,120	2,590	1,320	4,910	3,720	0	2,140	1,030	1,300	25,220	9,030	13,720	66,100
1960	13,950	12,250	6,420	4,430	3,120	1,970	1,280	900	460	20,920	11,110	25,990	102,800
1961	23,370	28,450	10,500	4,680	3,700	12,030	8,900	2,980	10,900	2,990	1,730	5,240	115,470
1962	3,010	2,930	2,170	4,890	2,710	6,890	2,360	500	980	1,970	4,730	4,950	38,090
1963	1,640	4,220	1,360	2,060	830	460	540	130	310	1,060	790	350	13,750
1964	350	1,570	2,430	770	2,120	320	1,230	0	0	860	3,110	2,200	14,960
1965	20,250	23,870	7,910	8,520	51,860	8,480	2,450	1,890	2,340	3,640	8,750	11,040	151,000
Average	6,083	6,815	4,754	7,826	8,930	6,270	2,358	675	2,162	5,366	3,508	4,974	59,720
	10.2	11.4	8.0	13.1	15.0	10.5	3.9	1.1	3.6	9.0	5.9	8.3	100.0

Table A-4c
Inflow Data to Lake Granger
(ac-ft/mo)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	32,780	20,550	31,310	29,190	37,700	26,480	33,350	0	3,370	3,860	1,670	2,240	222,500
1942	1,630	1,550	1,470	11,370	15,850	23,480	3,140	560	31,150	5,150	8,080	7,360	110,790
1943	4,680	2,760	6,650	8,120	6,380	1,940	1,500	660	230	750	560	900	35,130
1944	12,230	12,320	23,460	910	51,670	28,290	3,630	750	6,990	1,140	6,840	18,260	166,490
1945	20,660	14,150	11,780	41,050	12,700	19,130	5,750	3,890	0	9,560	1,700	5,740	146,110
1946	12,150	15,840	14,630	15,890	24,300	12,600	2,580	1,270	7,190	3,980	31,610	19,530	161,570
1947	36,260	10,890	12,980	13,740	14,070	5,820	1,410	1,020	790	480	630	1,020	99,110
1948	990	0	2,700	4,090	7,020	2,000	2,310	360	110	330	170	260	20,340
1949	2,260	3,590	0	40,380	8,830	2,270	1,070	420	340	260	640	1,820	61,880
1950	700	7,820	1,140	8,730	3,590	4,680	1,360	360	4,650	450	200	280	33,960
1951	320	700	3,040	510	2,360	4,200	180	30	1,180	170	80	160	12,930
1952	190	350	520	3,870	8,420	4,780	150	70	0	0	180	2,870	21,400
1953	4,990	3,220	1,420	4,330	13,480	2,140	0	180	2,780	29,640	4,070	25,640	91,890
1954	1,570	920	600	100	4,260	140	20	60	120	0	0	150	7,940
1955	170	4,240	1,830	4,780	6,550	8,400	710	3,220	80	100	90	190	30,360
1956	190	1,070	120	100	0	670	0	0	0	0	650	1,150	3,950
1957	210	270	3,440	89,880	21,250	54,970	2,280	5,380	2,620	76,070	21,880	10,880	289,130
1958	7,970	51,490	20,820	10,720	27,390	11,520	4,820	1,490	12,260	3,980	3,000	2,060	157,520
1959	1,530	4,400	2,220	8,690	6,520	0	3,510	1,500	2,030	46,160	15,320	23,200	115,080
1960	22,330	19,190	9,040	6,320	4,620	2,930	1,800	1,250	540	38,640	18,340	44,090	169,090
1961	38,340	47,820	15,570	6,720	5,380	21,260	15,770	4,580	18,950	4,250	2,410	8,360	189,410
1962	3,610	3,820	2,550	7,740	3,840	11,770	3,690	590	1,570	3,440	8,430	8,160	59,210
1963	2,140	7,210	1,880	3,260	1,040	620	940	220	580	1,970	1,350	480	21,690
1964	500	2,680	4,240	1,130	3,630	5,060	2,230	400	9,510	1,380	5,270	3,220	39,250
1965	36,350	41,680	10,700	12,850	93,590	12,180	5,180	3,190	5,090	5,850	14,170	16,870	257,700
Average	9,790	11,141	7,364	13,379	15,378	10,693	3,895	1,258	4,485	9,504	5,894	8,196	100,977
	9.7	11.0	7.3	13.2	15.2	10.6	3.9	1.2	4.4	9.4	5.8	8.1	100.0


LAKE STILLHOUSE HOLLOW


LAKE GEORGETOWN


LAKE GRANGER *

* Downstream of Lake Georgetown

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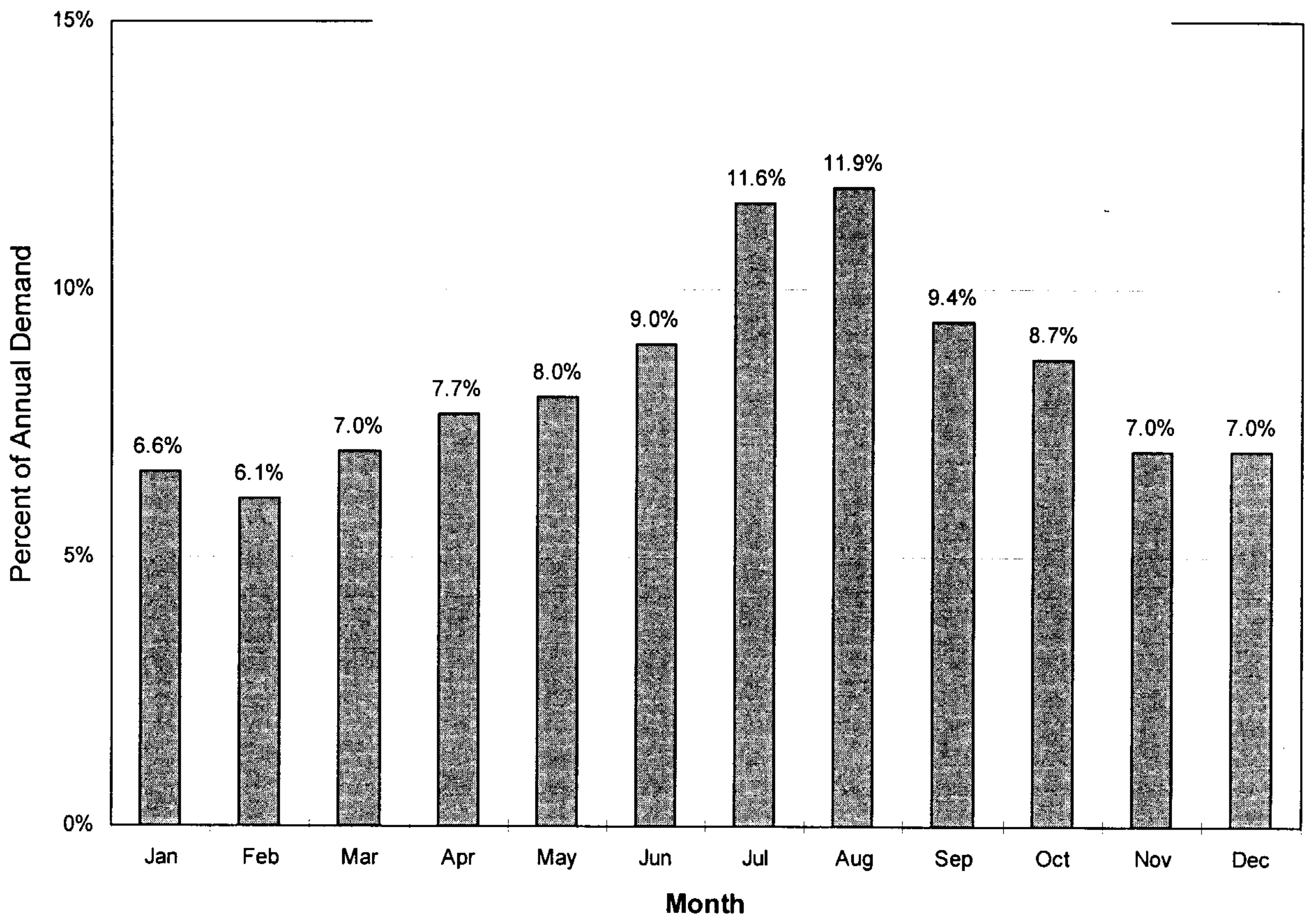
NORTH CENTRAL STUDY AREA

CUMULATIVE INFLOW FOR DROUGHT PERIOD

FIGURE A-2



City of Austin 1980-1995

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TYPICAL MUNICIPAL MONTHLY DEMAND PATTERN

HDR

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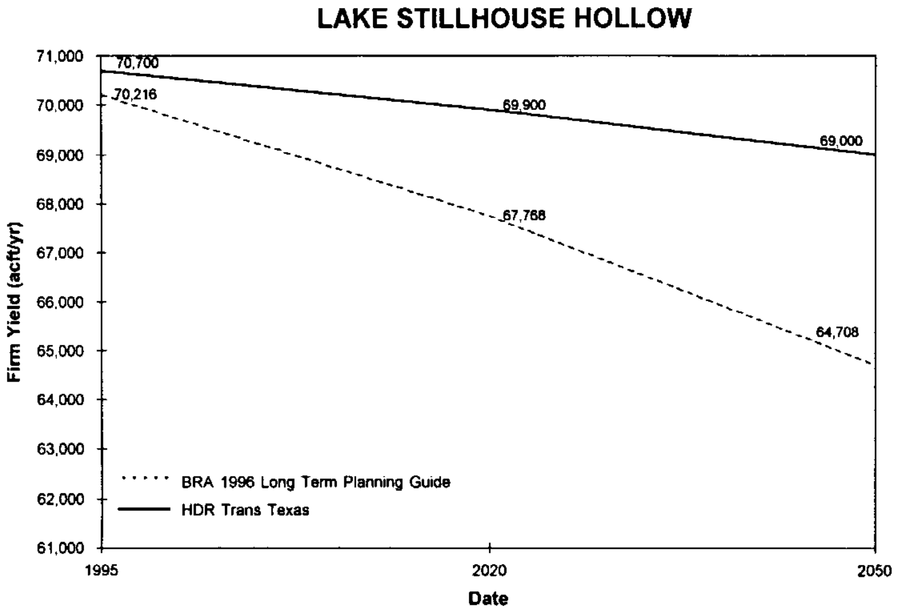
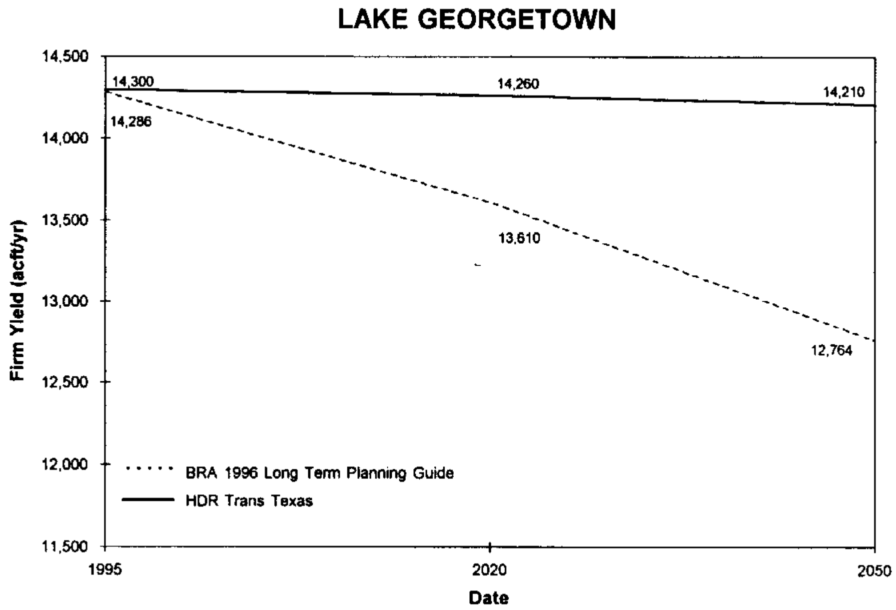
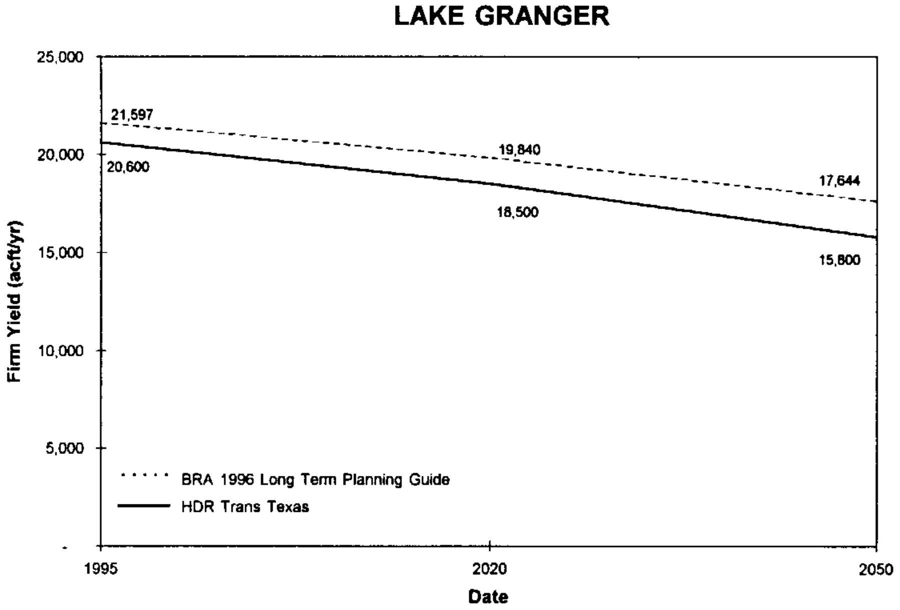
FIGURE A-3


LAKE STILLHOUSE HOLLOW


LAKE GEORGETOWN


LAKE GRANGER

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NORTH CENTRAL STUDY AREA

ESTIMATED FIRM YIELD

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FIGURE A-4

are very close, the difference can be explained by the lower sedimentation rates used in this study. For Lake Granger, the new estimates are lower than the previous ones for all years. The new estimates, though using the same sedimentation rate as the previous ones, are based on reservoir capacities extrapolated from the 1995 survey. The previous estimates, done before the 1995 survey, use larger reservoir capacities determined with a sedimentation rate which is lower than actual. Table A-5 compares the projected 2050 firm yield, the permitted diversion amount, current commitments,[7] and uncommitted supply for each reservoir (based on the 2050 firm yield). Table A-5 shows that, based on the new firm yield estimates, there is over 1,200 acft/yr of uncommitted yield in Lake Stillhouse Hollow, about 800 acft/yr of uncommitted yield in Lake Georgetown, and about 4,000 acft/yr of uncommitted yield in Lake Granger.[8]

Table A-5
Water Availability from Selected BRA Reservoirs (as of 9/23/96)

Reservoir	**Year 2050 Firm Yield** (acft/yr)		**Permitted Diversion** (acft/yr)	**Existing Commitments** (acft/yr)	**Uncommitted 2050 Supply** (acft/yr)
Lake Stillhouse Hollow	69,000	(1)	67,768	67,751	1,249
Lake Georgetown	14,210	(2)	13,610	13,440	770
Lake Granger	15,800	(3)	19,840	11,736	4,064
TOTAL	99,010		101,218	92,927	6,083

(1) Year 2050 projected firm yield using TWDB estimated sedimentation rate and TR-144 inflow data set.
(2) Year 2050 projected firm yield using TWDB estimated sedimentation rate and TR-144 inflow data set.
(3) Year 2050 projected firm yield using BRA estimated sedimentation rate and TR-144 inflow data set.

Figures A-5a, b, and c, show the monthly spills and reservoir contents of the three lakes when operated independently and drafted at their firm yields over the drought period from 1946 to 1957. While all the lakes are depleted in February, 1957, it is interesting to note that Lake Stillhouse Hollow becomes virtually depleted in 1952 and 1955 as well.

Corps of Engineers Contractual Limits

The contracts between the Corps of Engineers and the BRA for operation of each reservoir sets a minimum elevation to which each lake may be drawn down. In the cases of

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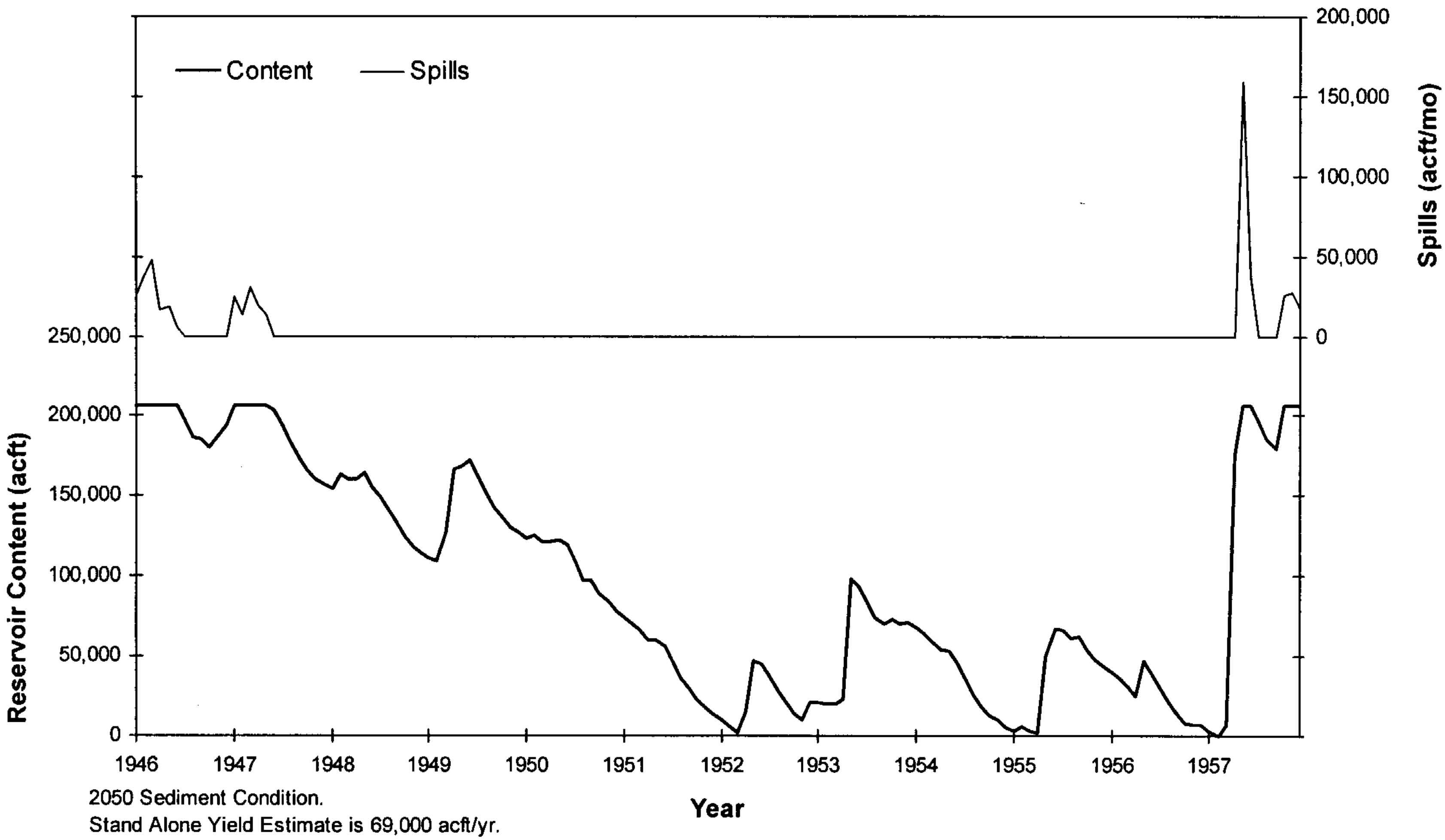
[7] Current commitments obtained from BRA staff, October, 1996.
[8] With the 5,000 acft/yr system commitment to Alcoa assigned to Lake Granger.



2050 Sediment Condition.
Stand Alone Yield Estimate is 69,000 acft/yr.
Summer Peak Factor = 1.4.

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NORTH CENTRAL STUDY AREA

RESERVOIR CONTENTS AND SPILLS AT LAKE STILLHOUSE HOLLOW 1946-1957

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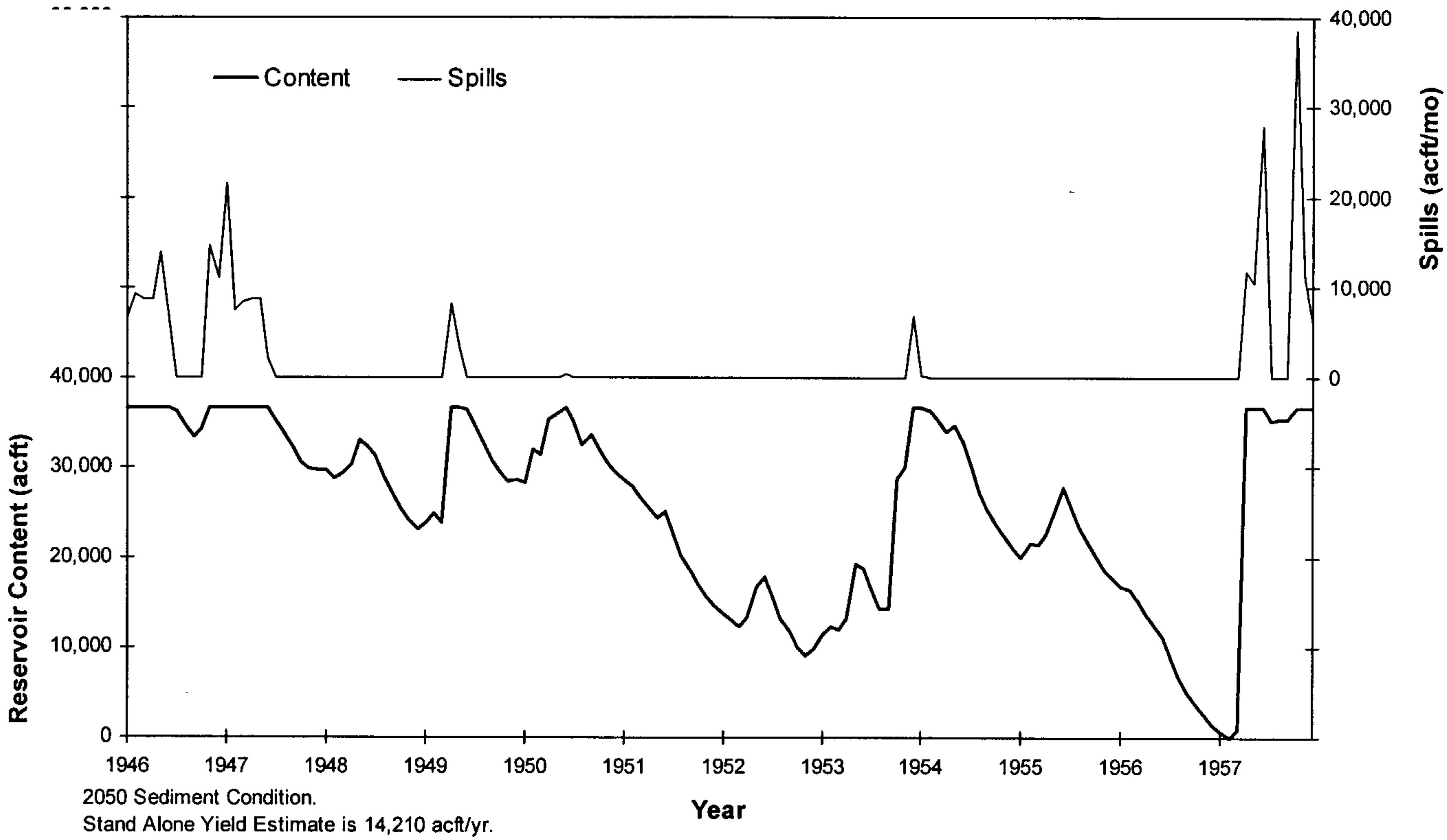
FIGURE A-5a



2050 Sediment Condition.
Stand Alone Yield Estimate is 14,210 acft/yr.
Summer Peak Factor = 1.4.

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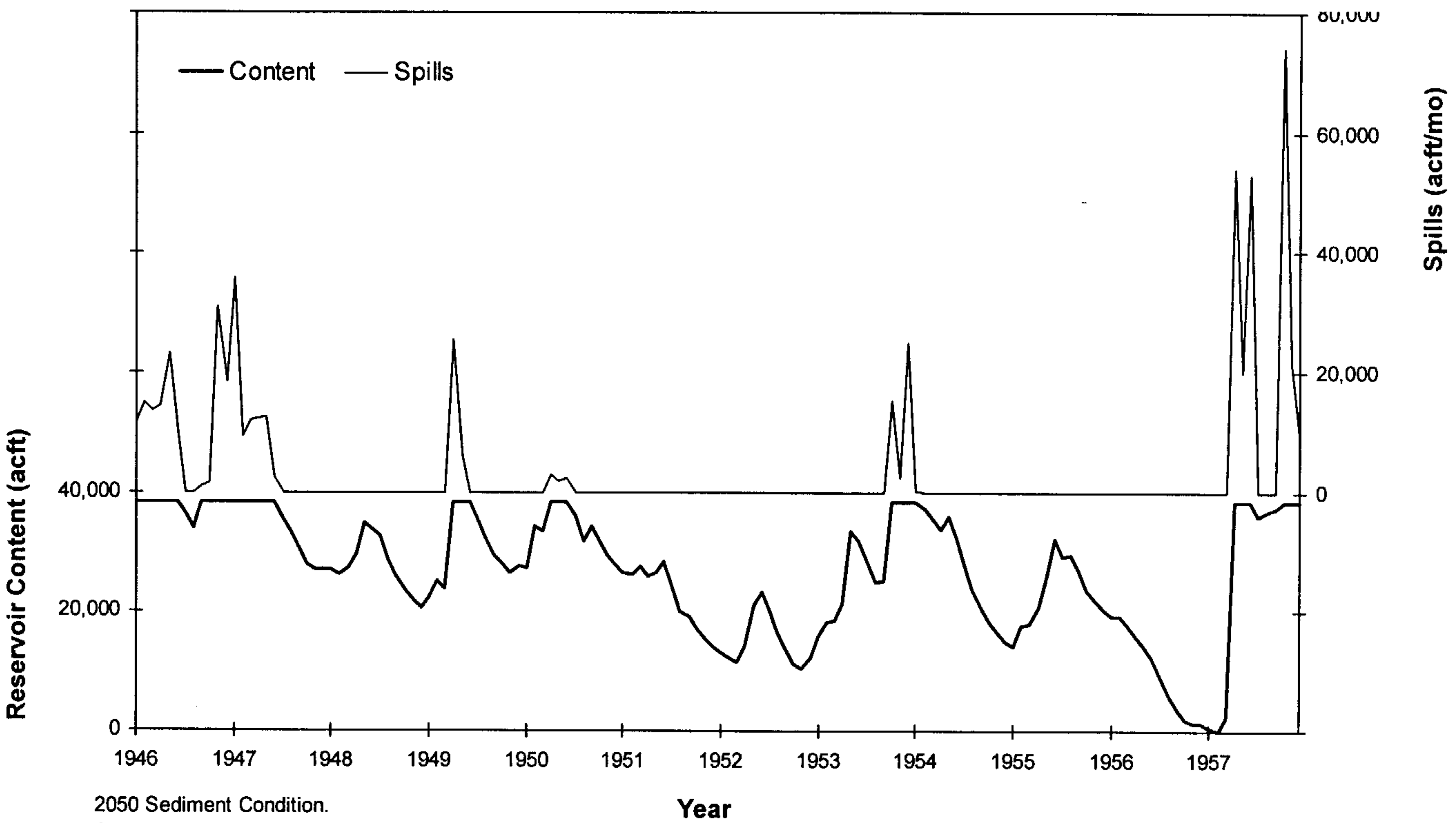
RESERVOIR CONTENTS AND SPILLS AT LAKE GEORGETOWN 1946-1957

FIGURE A-5b



2050 Sediment Condition.
Stand Alone Yield Estimate is 15,800 acft/yr.
Summer Peak Factor = 1.4.

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NORTH CENTRAL STUDY AREA

RESERVOIR CONTENTS AND SPILLS AT LAKE GRANGER 1946-1957

HDR Engineering, Inc.

FIGURE A-5c

Lakes Georgetown and Granger, that elevation is well below the bottom elevation of the lakes as determined by the 1995 hydrographic survey.[9] At Lake Stillhouse Hollow, the capacity below the minimum level is only 30 acft. Therefore, the contract limits have virtually no effect on the operation of these reservoirs.

TWDB's SIMYLD-II Model

Reservoir simulations to determine firm yields were computed with the SIMYLD-II model created by the TWDB. The model can be used to analyze a single reservoir or a system of reservoirs linked by streams or pipelines. The program requires monthly inflows and monthly evaporation for the period being simulated. Unique monthly demands may be input, or a typical monthly demand distribution can be specified as in the analyses performed for this report. The user is allowed to specify monthly target levels for each reservoir. Demands and reservoir levels are ranked by the user according to the desired priority. The program may be run in forward mode according to the demands and priorities defined, or in the firm yield mode to maximize the diversion at a single, user defined reservoir in the system.

Reservoir Efficiency

The storage efficiency of a lake can be represented be the percent of stored water lost to evaporation. This quantity was calculated for the three lakes from firm yield runs over the period from 1946 to 1957. A plot of the monthly values, as well as the average loss rates, are shown in Figure A-6. Negative values indicate that water gained from precipitation was greater than evaporation lost for that month. Figure A-6 illustrates that loss rates for Lake Stillhouse Hollow and Lake Georgetown track very closely over the period and their average loss rates are nearly the same at about 1.4 percent per month. This indicates that there is not much opportunity to benefit from differences in evaporation losses between the two lakes. In contrast, the average loss rate from Lake Granger is about 2.6 percent per month, or nearly double that of the other lakes. This suggests that there may be a significant opportunity to benefit from differences in evaporation loss rates through system operation of the lakes.

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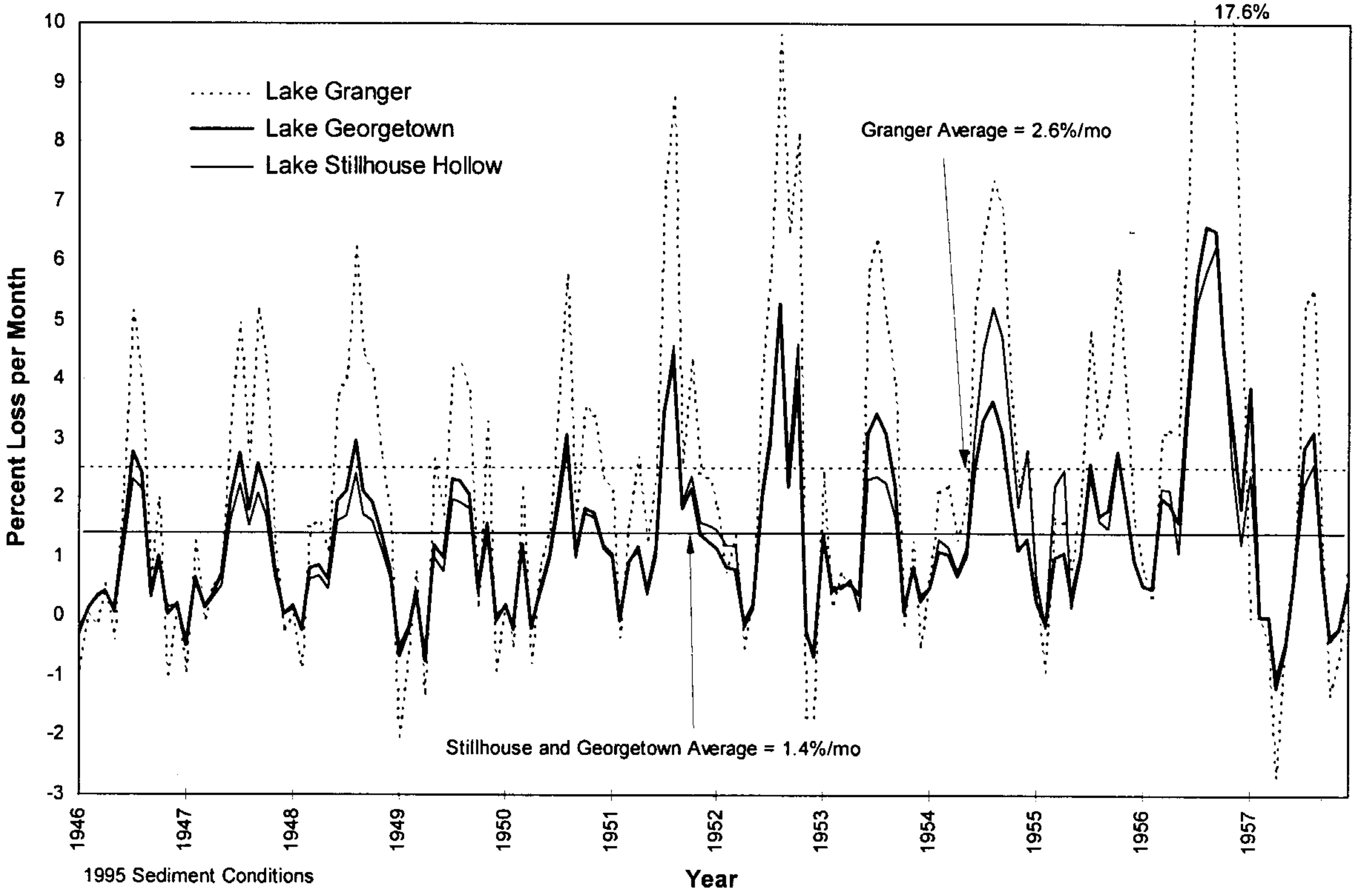
[9] Hydrographic Survey, June, 1995, TWDB.



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PERCENT OF STORED WATER LOST TO EVAPORATION 1946-1957

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FIGURE A-6

System Operation

It is sometimes possible to increase the combined firm yields of independent reservoirs by operating them as a system. For this report, various system operations involving Lake Stillhouse Hollow, Lake Georgetown, and Lake Granger were examined. Alternatives B-6 and B-8 of this report (Section 3.8 and 3.10, respectively) involve transferring water from Lake Granger by pipeline to Lake Georgetown, which is upstream of Lake Granger. Analysis of this system was performed with the SIMYLD-II model to see if the system yield could be increased above their combined individual yields.

For the individual yield simulations, all of Lake Granger's 15,800 acft/yr firm yield was diverted at a municipal demand pattern. For the system simulation, the current commitment of 11,736 acft/yr at Lake Granger was diverted at a municipal demand pattern and the remaining amount of 4,064 acft/yr was transferred at a uniform rate to Lake Georgetown. The resulting increased firm yield of Lake Georgetown was diverted according to a municipal demand pattern. In both cases, the combined firm yields were almost exactly equal, leading to the conclusion that there is no benefit from operating the two lakes as a system. Figure A-7a shows the spills and reservoir contents for both cases over the drought period. It can be seen that diversion of the full demand at a municipal pattern tends to draw down the lake more than at a uniform pattern, although, in this case, the difference is barely perceptible.

Lake Stillhouse Hollow and Lake Georgetown were also studied for system benefits. The permitted diversion from Lake Stillhouse Hollow is for 67,768 acft/yr.[10] For the system simulation, 42,721 acft/yr was transferred from Lake Stillhouse Hollow under a uniform monthly pattern to Lake Georgetown, and the remaining 25,047 acft/yr was diverted locally from Lake Stillhouse Hollow at a municipal pattern.[11] From Lake Georgetown the Lake Stillhouse Hollow water and the water stored in Lake Georgetown was diverted at a municipal demand pattern. The effect of the system operation was to increase the combined individual yields of the two lakes by about 1,200 acft/yr. The gain in system yield was realized by diverting water from Lake Georgetown at a higher rate during the summer months than flows were delivered from Lake Stillhouse Hollow. This provided additional storage in the reservoir allowing some of the water

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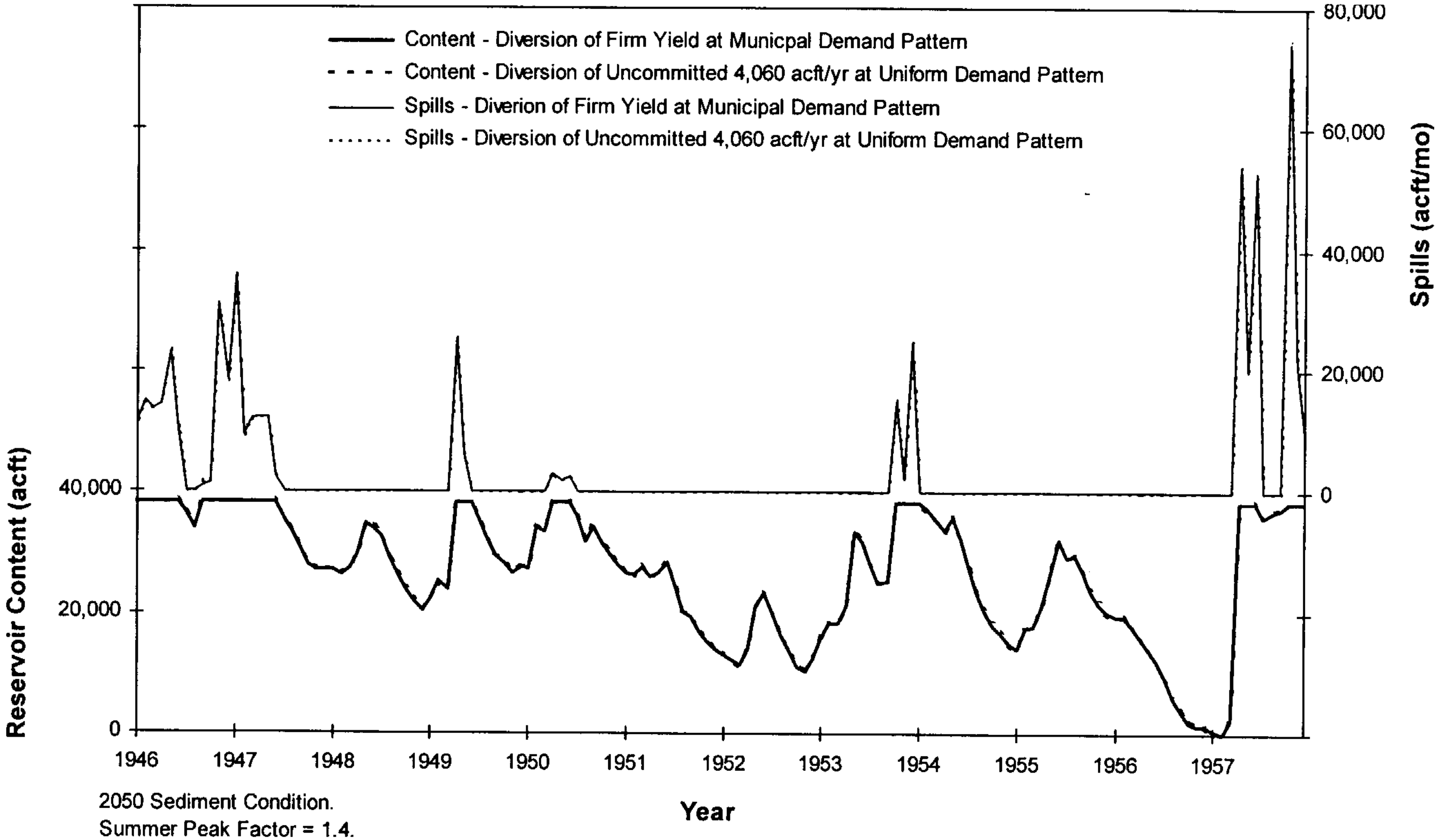
[10] BRA Long-Term Planning Guide, March, 1996.

[11] Permitted amount = 67,768 acft/yr, so the remainder is 25,047 acft/yr.



2050 Sediment Condition.
Summer Peak Factor = 1.4.

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NORTH CENTRAL STUDY AREA

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RESERVOIR CONTENTS AND SPILLS AT LAKE GRANGER 1946-1957

FIGURE A-7a

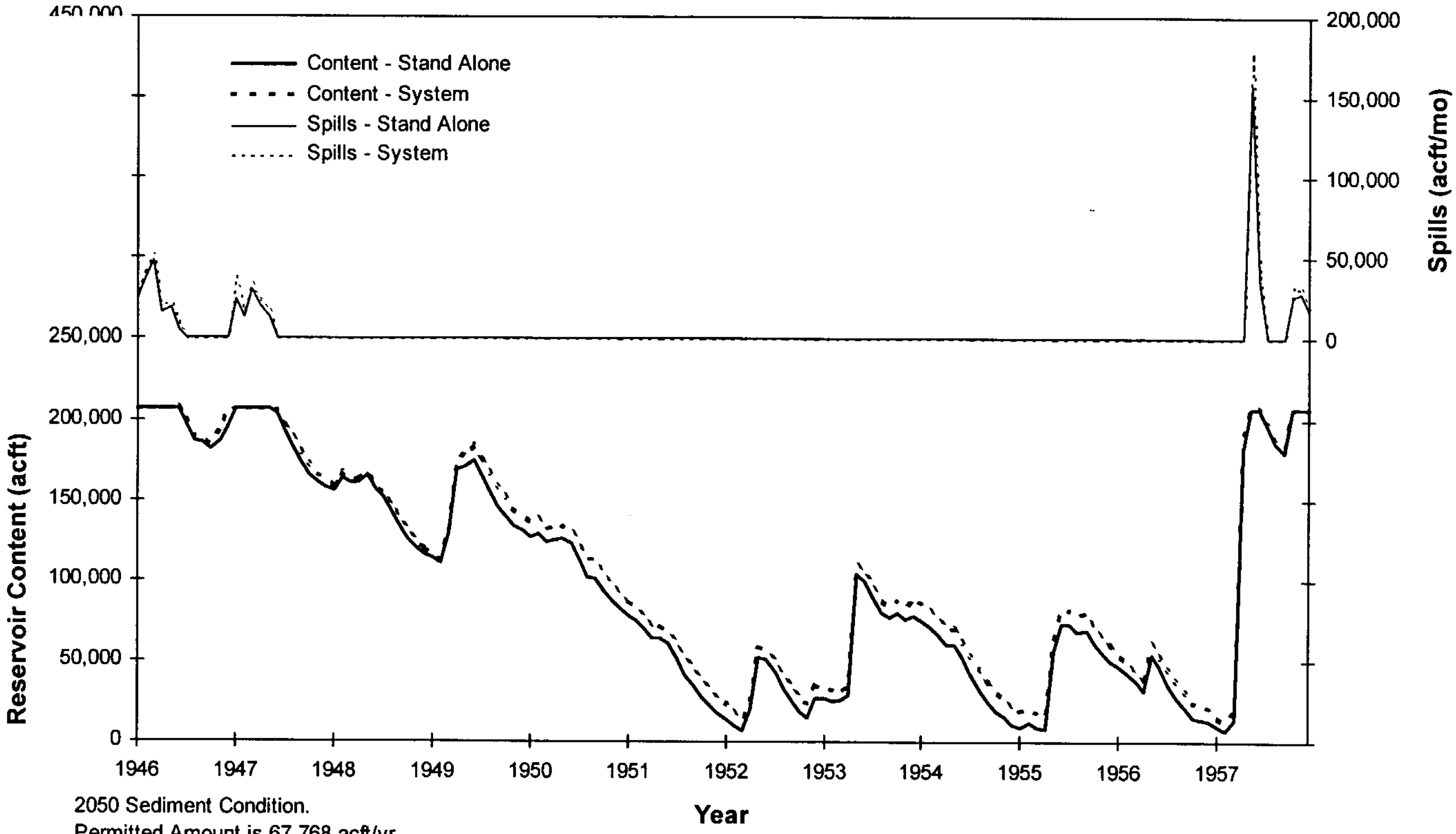
which spilled in the independent Lake Georgetown yield run to be captured, thereby increasing the yield. Figures A-7b and A-7c show comparisons of spills and reservoir contents for Lakes Stillhouse Hollow and Georgetown for both independent and system operating conditions.

To answer the concern that this system configuration would empty Lake Stillhouse Hollow to keep Lake Georgetown full, Figure A-8 was constructed to show content differences (as percent capacity) of the reservoirs during the simulation over the drought period. These figures show percent capacity of each reservoir under 2050 sediment conditions. The capacity of Lake Georgetown is 36,711 acft, which is about 18 percent of Lake Stillhouse Hollow's capacity of 206,565 acft. This means that each 1 percent of Lake Stillhouse Hollow's capacity transferred to Lake Georgetown represents an increase at Lake Georgetown of 5.6 percent of its capacity.

Because the diameter the Williamson County Raw Water Line has not yet been decided, increases in system yields were studied for a range of transmission capacities. At each transmission capacity Lake Georgetown's firm yield of 14,210 acft/yr was subtracted from the system yield to give the remaining yield at Lake Stillhouse Hollow. From the yield at Lake Stillhouse Hollow, the amount transferred to Lake Georgetown was subtracted with the remaining yield available for diversion at Lake Stillhouse. It can be seen in Figure A-9 that the system yield increases steadily with transmission capacity to a maximum of about 1,200 acft/yr, leveling off somewhat at the contracted amount of 42,721 acft/yr.

A.3 Yield Runs with SIMYLD-II Model

All yield analyses were performed with the TWDB's SIMYLD-II reservoir simulation model. Several of the model outputs are included in this Appendix and are listed in Table A-6.



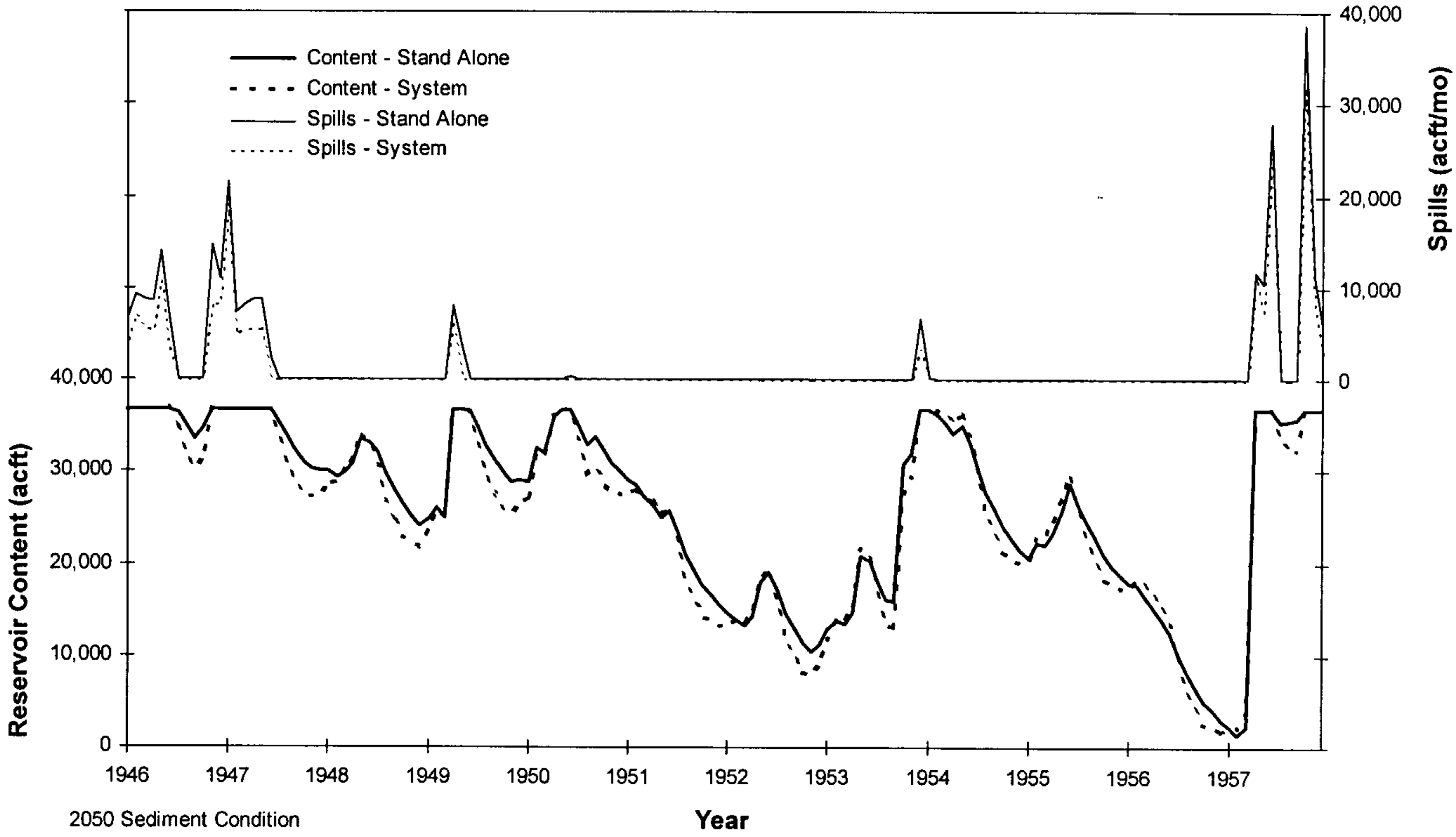
2050 Sediment Condition.
Permitted Amount is 67,768 acft/yr.
Summer Peak Factor = 1.4.

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

RESERVOIR CONTENTS AND SPILLS AT LAKE STILLHOUSE HOLLOW 1946-1957

HDR Engineering, Inc.

FIGURE A-7b



2050 Sediment Condition
Diverted at Permitted Amount of 13,610 acft/yr
Summer Peak Factor = 1.4.

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NORTH CENTRAL STUDY AREA

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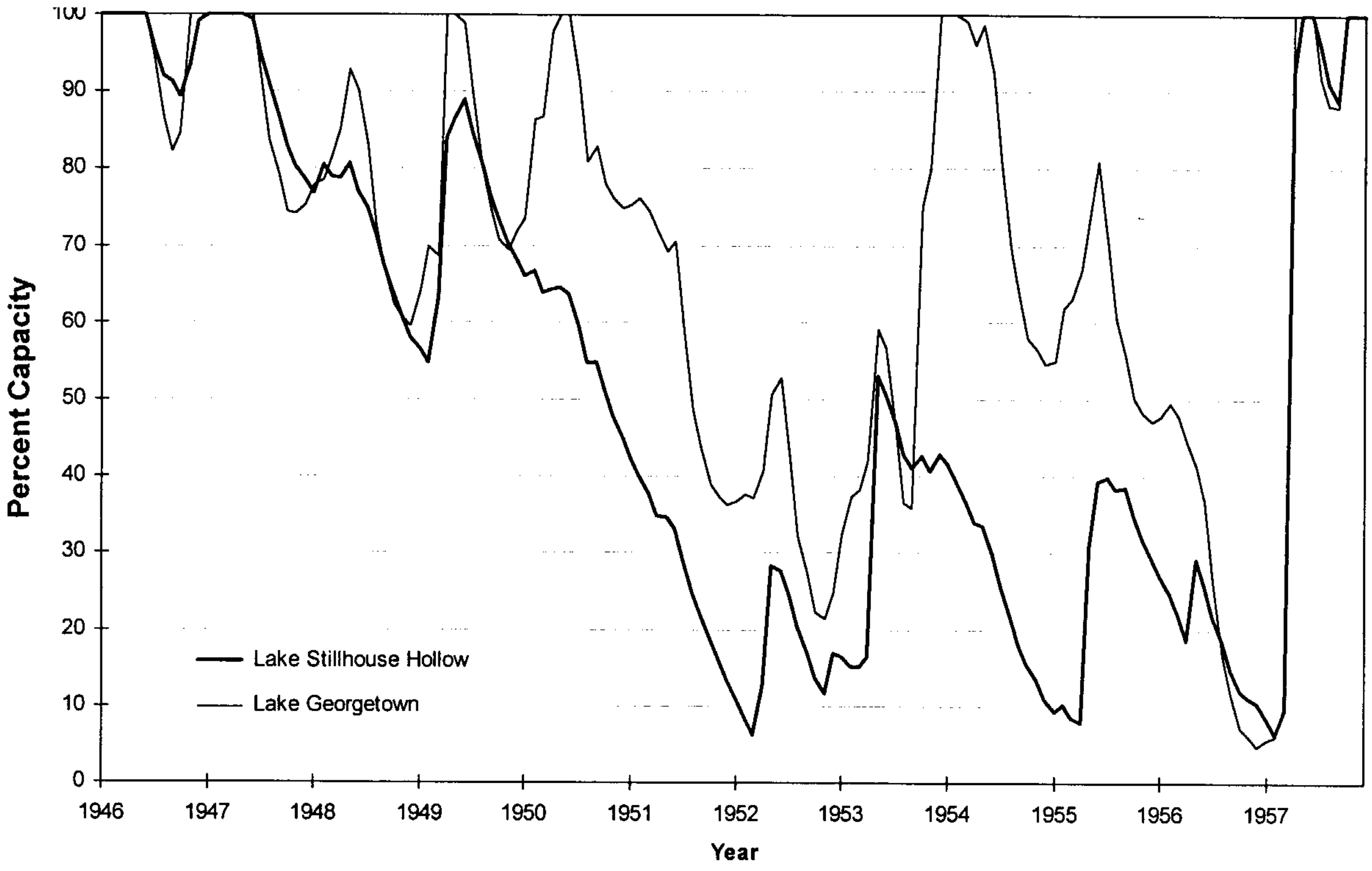
RESERVOIR CONTENTS AND SPILLS AT LAKE GEORGETOWN 1946-1957

FIGURE A-7c



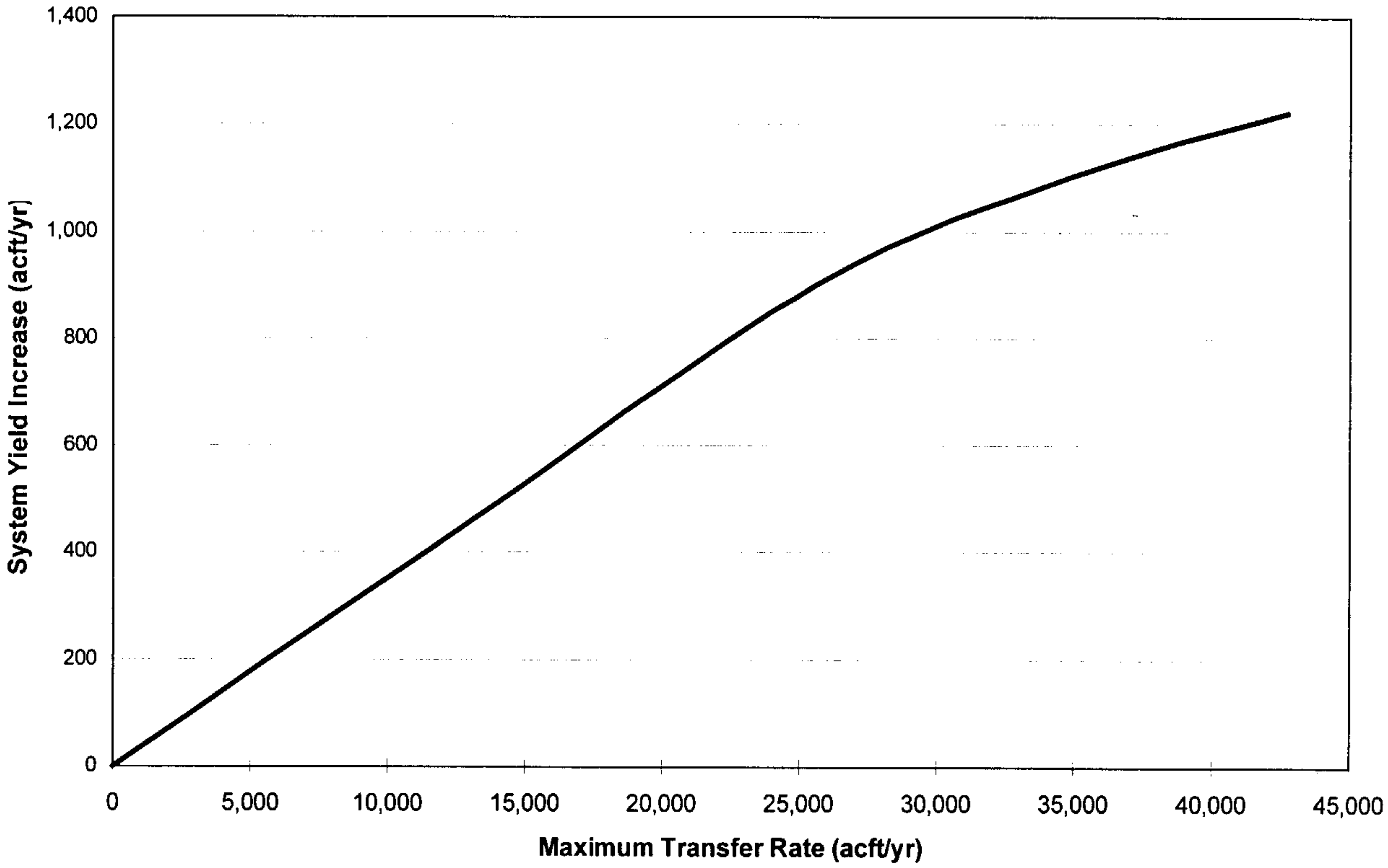
2050 Sediment Conditions.
Summer Peak Demand Factor=1.4.

Stillhouse Demand: 25,047 acft/yr Local, and 42,721 acft/yr to Georgetown.
Georgetown Demand is 56,331 acfr/yr (firm yield of 13,610 acft/yr plus 42,721 acft/yr)

TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

HDR Engineering, Inc.

PERCENT OF CAPACITY FOR LAKE STILLHOUSE HOLLOW AND LAKE GEORGETOWN AS A SYSTEM
1946-1957
FIGURE A-8



2050 Sediment Conditions.

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TRANS TEXAS WATER PROGRAM /
NORTH CENTRAL STUDY AREA

SYSTEM YIELD INCREASES ABOVE STAND-ALONE YIELDS WITH TRANSFER OF UP TO 42,721 ACFT/YR TO NCTT PARTICIPANTS
FIGURE A-9

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Table A-6
SIMYLD-II Runs Included in Appendix A

Entity(s)	Sediment Conditions (year)	Reservoir Capacity (acft)	Firm Yield (acft/yr)
Individual Firm Yield Runs			
Lake Stillhouse Hollow	1995	226,063	70,700 (1)
	2050	206,563	69,000 (1)
Lake Granger	1995	54,280	20,600 (2)
	2050	38,330	15,800 (2)
Lake Georgetown	1995	37,010	14,300 (3)
	2050	36,711	14,210 (3)
System Operation Runs			
Lakes Stillhouse Hollow and Georgetown	2050	as above	84,400 (4)
Lakes Granger and Georgetown	2050	as above	30,000 (5)

(1) Rounded down to nearest 100.

(2) Modeled with Lake Georgetown upstream with diversion at its permitted amount of 13,610 acft/yr.

(3) Rounded down to nearest 10 to show small difference between 1995 and 2050.

(4) Diversion from Lake Georgetown is firm yield of 14,210 acft/yr plus uniform delivery of 42,721 acft/yr from Lake Stillhouse Hollow, totaling 56,921 acft/yr. Diversion from Lake Stillhouse Hollow is remaining system yield of 27,590 acft/yr.

(5) Diversion from Lake Granger is current commitment of 11,736 acft/yr with remaining 4,064 acft/yr of firm yield of 15,800 acft/yr transferred uniformly to Lake Georgetown. Diversion from Lake Georgetown is remaining system yield of 18,280 acft/yr. System Firm Yield is rounded to nearest 100.

**Stillhouse
Hollow
1995**

```
1
        RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

                     NUMBER OF NODES =    1              NUMBER OF RESERVOIRS =  1

                     NUMBER OF LINKS =    0            NUMBER OF RIVER REACHES =  0

        CALENDAR YEAR OPERATION STARTS = 1941      NUMBER OF YEARS TO SIMULATE = 25

              NUMBER OF DEMAND NODES =    1             NUMBER OF SPILL NODES =  1

                          YIELD NODE =    0                       IMPORT NODE =  0


        NODE NO.   NODE NAME     --------- CAPACITIES ---------     YEARLY
                                  MAXIMUM   MINIMUM   STARTING      DEMAND

          1         STILLHSE       226063         0     226063       70700
1
        RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

        SYSTEM CONFIGURATION

        LINK NO.    FROM NODE     TO NODE     MAX. CAPACITY    MIN. CAPACITY


        LIST OF SPILL RESERVOIRS -      1

        YEARLY IMPORT QUANTITY =         0

        MONTHLY IMPORT DISTRIBUTION -   .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00

        SUB-SYSTEM OF RESERVOIRS      1

        'AVERAGE' DEFINED AS BETWEEN40.00, AND90.00 PERCENT FULL OF SUBSYSTEM


        FACTORS

            MULTIPLY LINK CAPACITIES BY     1.000

            MULTIPLY INFLOWS BY .......    10.00

            MULTIPLY DEMANDS BY .......     1.00
1
        RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

                                      MONTHLY DEMAND DISTRIBUTION
        NODE NO.         JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY   AUG.   SEPT   OCT.   NOV.   DEC.    * RANK *
                                                                                                            AVG DRY WET

          1             .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700     4   4   4
1
        RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

                                      DESIRED MONTHLY STORAGE LEVEL (PERCENT FULL)
        RESERVOIR NO.

          1   AVRG     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        99
              DRY      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        99
              WET      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        99
```

```
1
        RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

                TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

                                      RESERVOIRS AREA - CAPACITY TABLES

            RESERVOIR NO.  1    RESERVOIR NO.
   1              0        0
   2            150      590
   3            696     9896
   4           1020    16686
   5           1397    26287
   6           1831    39250
   7           2304    55688
   8           2840    76202
   9           3443   101285
  10           3772   115694
  11           4191   131593
  12           4522   144662
  13           4870   158745
  14           5233   173904
  15           5594   190134
  16           5989   207485
  17           6429   226063
  18              0        0
1
                TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

  SIMULATION YEAR  6     CALENDAR YEAR 1946

                 RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0         INITIAL    UREG   UPSTRM             SURFACE  EVAP     EVAP  DWNSTRM             PUMPED     PUMPED   SYSTEM END MO.      OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO        OUT     LOSS  CONTENT      RULE
    1     226063    29110       0      4242     6424   -.07     -449        0        0        0          0    25317   226063    226063
    2     226063    41690       0      4242     6429    .05      321        0        0        0          0    37127   226063    226063
    3     226063    53490       0      4949     6429    .11      707        0        0        0          0    47834   226063    226063
    4     226063    23220       0      5656     6429    .15      964        0        0        0          0    16600   226063    226063
    5     226063    24700       0      5656     6429    .02      129        0        0        0          0    18915   226063    226063
    6     226063    14230       0      6363     6429    .40     2572        0        0        0          0     5295   226063    226063
    7     226063     3050       0      8484     6306    .79     4982        0        0        0          0        0   215647    226063
    8     215647     2990       0      8484     6065    .73     4427        0        0        0          0        0   205726    226063
    9     205726     5150       0      6363     5928    .11      652        0        0        0          0        0   203861    226063
   10     203861     3520       0      6363     5854    .30     1756        0        0        0          0        0   199262    226063
   11     199262    10750       0      4949     5864    .06      352        0        0        0          0        0   204711    226063
   12     204711    13480       0      4949     6019    .07      421        0        0        0          0        0   212821    226063

    YEAR TOTALS   225380        0     70700                    16834        0        0        0          0   151088
1
                TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

  SIMULATION YEAR  7     CALENDAR YEAR 1947

                 RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0         INITIAL    UREG   UPSTRM             SURFACE  EVAP     EVAP  DWNSTRM             PUMPED     PUMPED   SYSTEM END MO.      OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO        OUT     LOSS  CONTENT      RULE
    1     212821    40080       0      4242     6262   -.14     -876        0        0        0          0    23473   226062    226063
    2     226062    18810       0      4242     6429    .20     1286        0        0        0          0    13281   226063    226063
    3     226063    35660       0      4949     6429    .05      321        0        0        0          0    30390   226063    226063
    4     226063    26150       0      5656     6429    .10      643        0        0        0          0    19851   226063    226063
    5     226063    20660       0      5656     6429    .19     1222        0        0        0          0    13782   226063    226063
    6     226063     6290       0      6363     6428    .57     3664        0        0        0          0        0   222326    226063
    7     222326     2010       0      8484     6208    .76     4718        0        0        0          0        0   211134    226063
    8     211134     1910       0      8484     5962    .52     3100        0        0        0          0        0   201460    226063
    9     201460     1060       0      6363     5746    .70     4022        0        0        0          0        0   192135    226063
   10     192135      780       0      6363     5541    .57     3158        0        0        0          0        0   183394    226063
   11     183394     1360       0      4949     5390    .23     1240        0        0        0          0        0   178565    226063
   12     178565     1760       0      4949     5301    .01       53        0        0        0          0        0   175323    226063

    YEAR TOTALS   156530        0     70700                    22551        0        0        0          0   100777
1
                TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

  SIMULATION YEAR  8     CALENDAR YEAR 1948

                 RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0         INITIAL    UREG   UPSTRM             SURFACE  EVAP     EVAP  DWNSTRM             PUMPED     PUMPED   SYSTEM END MO.      OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO        OUT     LOSS  CONTENT      RULE
    1     175323     1630       0      4242     5233    .05      262        0        0        0          0        0   172449    226063
    2     172449    12340       0      4242     5294   -.06     -317        0        0        0          0        0   180864    226063
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       3    180864     3090        0      4949     5355    .21    1125        0         0        0         0         0   177880   226063
       4    177880     6620        0      5656     5319    .23    1223        0         0        0         0         0   177621   226063
       5    177621    10540        0      5656     5360    .16     858        0         0        0         0         0   181647   226063
       6    181647      600        0      6363     5310    .53    2814        0         0        0         0         0   173070   226063
       7    173070     5020        0      8484     5138    .55    2826        0         0        0         0         0   166780   226063
       8    166780     3090        0      8484     4952    .77    3813        0         0        0         0         0   157573   226063
       9    157573      320        0      6363     4735    .54    2557        0         0        0         0         0   148973   226063
      10    148973      190        0      6363     4524    .50    2262        0         0        0         0         0   140538   226063
      11    140538      540        0      4949     4342    .36    1563        0         0        0         0         0   134566   226063
      12    134566     1070        0      4949     4206    .20     841        0         0        0         0         0   129846   226063

    YEAR TOTALS       45050        0     70700                   19827        0         0        0         0         0
1
                  TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

   SIMULATION YEAR  9     CALENDAR YEAR 1949

                      RESERVOIR NO  1  STILLHSE   MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM            SURFACE   EVAP    EVAP  DWNSTRM             PUMPED    PUMPED    SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT     RULE
       1    129846     1220        0      4242     4113   -.15    -616        0         0        0         0         0   127440   226063
       2    127440     1380        0      4242     4046   -.05    -201        0         0        0         0         0   124779   226063
       3    124779    23140        0      4949     4243    .10     424        0         0        0         0         0   142546   226063
       4    142546    43930        0      5656     4953   -.21   -1039        0         0        0         0         0   181859   226063
       5    181859     9020        0      5656     5427    .34    1845        0         0        0         0         0   183378   226063
       6    183378    12170        0      6363     5492    .26    1428        0         0        0         0         0   187757   226063
       7    187757     1470        0      8484     5424    .65    3526        0         0        0         0         0   177217   226063
       8    177217     1510        0      8484     5190    .62    3218        0         0        0         0         0   167025   226063
       9    167025      160        0      6363     4960    .58    2877        0         0        0         0         0   157945   226063
      10    157945      150        0      6363     4766    .13     620        0         0        0         0         0   151112   226063
      11    151112      690        0      4949     4605    .42    1934        0         0        0         0         0   144919   226063
      12    144919     1410        0      4949     4483    .01      45        0         0        0         0         0   141335   226063

    YEAR TOTALS       96250        0     70700                   14061        0         0        0         0         0
1
                  TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

   SIMULATION YEAR 10     CALENDAR YEAR 1950

                      RESERVOIR NO  1  STILLHSE   MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM            SURFACE   EVAP    EVAP  DWNSTRM             PUMPED    PUMPED    SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT     RULE
       1    141335      880        0      4242     4392    .05     220        0         0        0         0         0   137753   226063
       2    137753     5970        0      4242     4373   -.07    -305        0         0        0         0         0   139786   226063
       3    139786     1330        0      4949     4333    .35    1517        0         0        0         0         0   134650   226063
       4    134650     6010        0      5656     4275   -.04    -170        0         0        0         0         0   135174   226063
       5    135174     6610        0      5656     4287    .13     557        0         0        0         0         0   135571   226063
       6    135571     4610        0      6363     4253    .30    1276        0         0        0         0         0   132542   226063
       7    132542      440        0      8484     4079    .58    2366        0         0        0         0         0   122132   226063
       8    122132        0        0      8484     3789    .82    3107        0         0        0         0         0   110541   226063
       9    110541     6970        0      6363     3649    .30    1095        0         0        0         0         0   110053   226063
      10    110053      220        0      6363     3553    .50    1776        0         0        0         0         0   102134   226063
      11    102134      380        0      4949     3389    .47    1593        0         0        0         0         0    95972   226063
      12     95972      450        0      4949     3249    .32    1040        0         0        0         0         0    90433   226063

    YEAR TOTALS       33870        0     70700                   14072        0         0        0         0         0
1
                  TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

   SIMULATION YEAR 11     CALENDAR YEAR 1951

                      RESERVOIR NO  1  STILLHSE   MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM            SURFACE   EVAP    EVAP  DWNSTRM             PUMPED    PUMPED    SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT     RULE
       1     90433      470        0      4242     3127    .27     844        0         0        0         0         0    85817   226063
       2     85817      660        0      4242     3028    .00       0        0         0        0         0         0    82235   226063
       3     82235      960        0      4949     2928    .25     732        0         0        0         0         0    77514   226063
       4     77514      430        0      5656     2796    .28     783        0         0        0         0         0    71505   226063
       5     71505     5490        0      5656     2712    .10     271        0         0        0         0         0    71068   226063
       6     71068     3560        0      6363     2660    .26     692        0         0        0         0         0    67573   226063
       7     67573        0        0      8484     2478    .80    1982        0         0        0         0         0    57107   226063
       8     57107        0        0      8484     2192    .97    2126        0         0        0         0         0    46497   226063
       9     46497     1120        0      6363     1953    .40     781        0         0        0         0         0    40473   226063
      10     40473        0        0      6363     1752    .45     788        0         0        0         0         0    33322   226063
      11     33322      250        0      4949     1546    .29     448        0         0        0         0         0    28175   226063
      12     28175      320        0      4949     1373    .26     357        0         0        0         0         0    23189   226063

    YEAR TOTALS       13260        0     70700                    9804        0         0        0         0         0
1
                  TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

   SIMULATION YEAR 12     CALENDAR YEAR 1952
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                  RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0         INITIAL    UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.     OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA    RATE     LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT      RULE
    1      23189      280      0       4242      1192     .23      274       0        0        0         0         0    18953   226063
    2      18953      300      0       4242      1028     .17      175       0        0        0         0         0    14836   226063
    3      14836      860      0       4949       831     .15      125       0        0        0         0         0    10622   226063
    4      10622    18950      0       5656      1044    -.04      -41       0        0        0         0         0    23957   226063
    5      23957    37710      0       5656      1851     .04       74       0        0        0         0         0    55937   226063
    6      55937     5570      0       6363      2284     .48     1096       0        0        0         0         0    54048   226063
    7      54048     1600      0       8484      2139     .62     1326       0        0        0         0         0    45838   226063
    8      45838       20      0       8484      1872     .98     1835       0        0        0         0         0    35539   226063
    9      35539        0      0       6363      1588     .47      746       0        0        0         0         0    28430   226063
   10      28430        0      0       6363      1337     .72      963       0        0        0         0         0    21104   226063
   11      21104      980      0       4949      1117    -.05      -55       0        0        0         0         0    17190   226063
   12      17190    16160      0       4949      1263    -.12     -151       0        0        0         0         0    28552   226063

   YEAR TOTALS     82430       0     70700                        6367       0        0        0         0         0
1
                 TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

  SIMULATION YEAR 13     CALENDAR YEAR 1953

                  RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0         INITIAL    UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.     OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA    RATE     LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT      RULE
    1      28552     4570      0       4242      1472     .27      397       0        0        0         0         0    28483   226063
    2      28483     2650      0       4242      1441     .10      144       0        0        0         0         0    26747   226063
    3      26747     5320      0       4949      1416     .09      127       0        0        0         0         0    26991   226063
    4      26991     8520      0       5656      1465     .13      190       0        0        0         0         0    29665   226063
    5      29665    81050      0       5656      2607     .05      130       0        0        0         0         0   104929   226063
    6     104929     3720      0       6363      3469     .67     2324       0        0        0         0         0    99962   226063
    7      99962     1070      0       8484      3296     .65     2142       0        0        0         0         0    90406   226063
    8      90406        0      0       8484      3058     .59     1804       0        0        0         0         0    80118   226063
    9      80118     3740      0       6363      2887     .45     1299       0        0        0         0         0    76196   226063
   10      76196     9350      0       6363      2874     .05      144       0        0        0         0         0    79039   226063
   11      79039     1800      0       4949      2862     .23      658       0        0        0         0         0    75232   226063
   12      75232     6770      0       4949      2835     .10      283       0        0        0         0         0    76770   226063

   YEAR TOTALS    128560       0     70700                        9642       0        0        0         0         0
1
                 TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

  SIMULATION YEAR 14     CALENDAR YEAR 1954

                  RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0         INITIAL    UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.     OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA    RATE     LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT      RULE
    1      76770     1560      0       4242      2815     .13      366       0        0        0         0         0    73722   226063
    2      73722      840      0       4242      2719     .33      897       0        0        0         0         0    69423   226063
    3      69423      480      0       4949      2595     .29      753       0        0        0         0         0    64201   226063
    4      64201      760      0       5656      2457     .18      442       0        0        0         0         0    58863   226063
    5      58863     5610      0       5656      2378     .28      666       0        0        0         0         0    58151   226063
    6      58151        0      0       6363      2261     .67     1515       0        0        0         0         0    50273   226063
    7      50273       10      0       8484      2000     .90     1800       0        0        0         0         0    39999   226063
    8      39999       40      0       8484      1689     .92     1554       0        0        0         0         0    30001   226063
    9      30001       40      0       6363      1398     .76     1062       0        0        0         0         0    22616   226063
   10      22616     1010      0       6363      1137     .46      523       0        0        0         0         0    16740   226063
   11      16740     1790      0       4949       941     .26      245       0        0        0         0         0    13336   226063
   12      13336      300      0       4949       744     .31      231       0        0        0         0         0     8456   226063

   YEAR TOTALS     12440       0     70700                       10054       0        0        0         0         0
1
                 TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

  SIMULATION YEAR 15     CALENDAR YEAR 1955

                  RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL        0
0         INITIAL    UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.     OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA    RATE     LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT      RULE
    1       8456     2040      0       4242       546     .07       38       0        0        0         0         0     6216   226063
    2       6216     6730      0       4242       554    -.03      -16       0        0        0         0         0     8720   226063
    3       8720     2220      0       4949       543     .23      125       0        0        0         0         0     5866   226063
    4       5866     4340      0       5656       418     .25      104       0        0        0         0         0     4446   226063
    5       4446    53710      0       5656      1469     .06       88       0        0        0         0         0    52412   226063
    6      52412    23860      0       6363      2438     .28      683       0        0        0         0         0    69226   226063
    7      69226     9380      0       8484      2648     .61     1615       0        0        0         0         0    68507   226063
    8      68507     4810      0       8484      2577     .40     1031       0        0        0         0         0    63802   226063
    9      63802     7480      0       6363      2518     .38      957       0        0        0         0         0    63962   226063
   10      63962       30      0       6363      2418     .62     1499       0        0        0         0         0    56130   226063
   11      56130      180      0       4949      2234     .45     1005       0        0        0         0         0    50356   226063
   12      50356      400      0       4949      2079     .21      437       0        0        0         0         0    45370   226063

   YEAR TOTALS    115180       0     70700                        7566       0        0        0         0         0
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1
                    TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

  SIMULATION YEAR 16     CALENDAR YEAR 1956

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL       0
0         INITIAL    UREG   UPSTRM                                                                 
                                             SURFACE  EVAP     EVAP  DWNSTRM             PUMPED    PUMPED   SYSTEM END MO.    OPER.
 MONTH  STORAGE  INFLOWS  SPILLS   DEMAND    AREA   RATE     LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
   1      45370      410       0     4242    1949    .11      214       0        0        0         0        0    41324   226063
   2      41324     1120       0     4242    1843    .10      184       0        0        0         0        0    38018   226063
   3      38018       30       0     4949    1696    .41      695       0        0        0         0        0    32404   226063
   4      32404        0       0     5656    1498    .37      554       0        0        0         0        0    26194   226063
   5      26194    28020       0     5656    1760    .29      510       0        0        0         0        0    48048   226063
   6      48048      250       0     6363    1977    .69     1364       0        0        0         0        0    40571   226063
   7      40571        0       0     8484    1706    .94     1604       0        0        0         0        0    30483   226063
   8      30483     1630       0     8484    1401    .92     1289       0        0        0         0        0    22340   226063
   9      22340        0       0     6363    1099    .84      923       0        0        0         0        0    15054   226063
  10      15054      680       0     6363     797    .51      406       0        0        0         0        0     8965   226063
  11       8965     3910       0     4949     605    .32      194       0        0        0         0        0     7732   226063
  12       7732     4130       0     4949     543    .15       81       0        0        0         0        0     6832   226063

   YEAR TOTALS    40180       0    70700                     8018       0        0        0         0        0
1
                    TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

  SIMULATION YEAR 17     CALENDAR YEAR 1957

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  226063  MIN. OPERATING POOL       0
0         INITIAL    UREG   UPSTRM                                                                 
                                             SURFACE  EVAP     EVAP  DWNSTRM             PUMPED    PUMPED   SYSTEM END MO.    OPER.
 MONTH  STORAGE  INFLOWS  SPILLS   DEMAND    AREA   RATE     LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
   1       6832      740       0     4242     411    .17       70       0        0        0         0        0     3260   226063
   2       3260     1120       0     4242     215    .02        4       0        0        0         0        0      134   226063
   3        134    11870       0     4949     326   -.01       -2       0        0        0         0        0     7057   226063
   4       7057   171750       0     5656    3195   -.53    -1692       0        0        0         0        0   174843   226063
   5     174843   194520       0     5656    5818   -.16     -930       0        0        0         0        0   226061   226063
   6     226061    44560       0     6363    6429    .25     1607       0        0        0         0   138576   226063   226063
   7     226063     3170       0     8484    6309    .77     4858       0        0        0         0    36588   215891   226063
   8     215891     1820       0     8484    6047    .87     5261       0        0        0         0        0   203966   226063
   9     203966     2190       0     6363    5844    .26     1519       0        0        0         0        0   198274   226063
  10     198274    58720       0     6363    6092   -.11     -669       0        0        0         0        0   226062   226063
  11     226062    32360       0     4949    6424   -.06     -384       0        0        0         0    25238   226062   226063
  12     226062    23030       0     4949    6429    .17     1093       0        0        0         0    27795   226063   226063
                                                                                                 0    16987
   YEAR TOTALS   545850       0    70700                    10735       0        0        0         0   245184
1
                    TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions

                    SIMULATION PERIOD TOTAL SUMMARY BY NODE  1

 YEAR START. STRG.  UNREG. FLOW     DEMANDS   SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
   1      226063      614310       70700          0        12000       537513       220160
   2      220160      343130       70700          0        12753       253774       226063
   3      226063       51830       70700          0        22740         5171       179282
   4      179282      631740       70700          0        15433       498826       226063
   5      226063      568350       70700          0        16559       481091       226063
   6      226063      225380       70700          0        16834       151088       212821
   7      212821      156530       70700          0        22551       100777       175323
   8      175323       45050       70700          0        19827            0       129846
   9      129846       96250       70700          0        14061            0       141335
  10      141335       33870       70700          0        14072            0        90433
  11       90433       13260       70700          0         9804            0        23189
  12       23189       82430       70700          0         6367            0        28552
  13       28552      128560       70700          0         9642            0        76770
  14       76770       12440       70700          0        10054            0         8456
  15        8456      115180       70700          0         7566            0        45370
  16       45370       40180       70700          0         8018            0         6832
  17        6832      545850       70700          0        10735       245184       226063
  18      226063      307860       70700          0        16199       252853       194171
  19      194171      283510       70700          0        12298       168620       226063
  20      226063      375360       70700          0        15210       289452       226061
  21      226061      433960       70700          0        16156       347102       226063
  22      226063       86170       70700          0        22121         4136       215276
  23      215276       28250       70700          0        24202            0       148624
  24      148624       81300       70700          0        13717            0       145507
  25      145507      540340       70700          0        12960       376124       226063


  PERIOD TOTALS      5841090     1767500          0       361879      3711711


 PERIOD AVERAGES      233643       70700          0        14475       148468
1
                    TITLE CARD  Stillhouse Hollow 1995 Yield with Unappropriated + Stream Depletions
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              SIMULATION PERIOD TOTAL SUMMARY BY YEAR***

YEAR START. STRG.  UNREG. FLOW     DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
  1       226063       614310       70700            0        12000       537513       220160
  2       220160       343130       70700            0        12753       253774       226063
  3       226063        51830       70700            0        22740         5171       179282
  4       179282       631740       70700            0        15433       498826       226063
  5       226063       568350       70700            0        16559       481091       226063
  6       226063       225380       70700            0        16834       151088       212821
  7       212821       156530       70700            0        22551       100777       175323
  8       175323        45050       70700            0        19827            0       129846
  9       129846        96250       70700            0        14061            0       141335
 10       141335        33870       70700            0        14072            0        90433
 11        90433        13260       70700            0         9804            0        23189
 12        23189        82430       70700            0         6367            0        28552
 13        28552       128560       70700            0         9642            0        76770
 14        76770        12440       70700            0        10054            0         8456
 15         8456       115180       70700            0         7566            0        45370
 16        45370        40180       70700            0         8018            0         6832
 17         6832       545850       70700            0        10735       245184       226063
 18       226063       307860       70700            0        16199       252853       194171
 19       194171       283510       70700            0        12298       168620       226063
 20       226063       375360       70700            0        15210       289452       226061
 21       226061       433960       70700            0        16156       347102       226063
 22       226063        86170       70700            0        22121         4136       215276
 23       215276        28250       70700            0        24202            0       148624
 24       148624        81300       70700            0        13717            0       145507
 25       145507       540340       70700            0        12960       376124       226063


 PERIOD TOTALS             5841090     1767500            0       361879      3711711


PERIOD AVERAGES             233643       70700            0        14475       148468
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Stillhouse Hollow 2050

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1

      RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

                 NUMBER OF NODES =    1             NUMBER OF RESERVOIRS =  1

                 NUMBER OF LINKS =    0          NUMBER OF RIVER REACHES =  0

      CALENDAR YEAR OPERATION STARTS = 1941      NUMBER OF YEARS TO SIMULATE = 25

            NUMBER OF DEMAND NODES =    1           NUMBER OF SPILL NODES =  1

                      YIELD NODE =    0                     IMPORT NODE =  0


      NODE NO.   NODE NAME    --------- CAPACITIES ---------     YEARLY
                                MAXIMUM  MINIMUM   STARTING      DEMAND

        1        STILLHSE       206563        0     206563       69080
1

      RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

      SYSTEM CONFIGURATION

      LINK NO.    FROM NODE     TO NODE     MAX. CAPACITY    MIN. CAPACITY


      LIST OF SPILL RESERVOIRS -     1


      YEARLY IMPORT QUANTITY =        0

      MONTHLY IMPORT DISTRIBUTION -   .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00

      SUB-SYSTEM OF RESERVOIRS     1

      'AVERAGE' DEFINED AS BETWEEN40.00, AND90.00 PERCENT FULL OF SUBSYSTEM


      FACTORS

          MULTIPLY LINK CAPACITIES BY    1.000

          MULTIPLY INFLOWS BY .......    10.00

          MULTIPLY DEMANDS BY .......     1.00
1

      RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions


                                   MONTHLY DEMAND DISTRIBUTION
      NODE NO.          JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY   AUG.   SEPT   OCT.   NOV.   DEC.    * RANK *
                                                                                                             AVG DRY WET

        1              .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700    1   1   1
1

      RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions


                                   DESIRED MONTHLY STORAGE LEVEL (PERCENT FULL)
      RESERVOIR NO.

        1   AVRG     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        2
            DRY      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        2
            WET      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        2
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1
        RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

                                     RESERVOIRS AREA - CAPACITY TABLES

             RESERVOIR NO.  1   RESERVOIR NO.
    1            0        0
    2          231     2959
    3          788    10814
    4         1158    18533
    5         1589    29574
    6         2064    44086
    7         2607    62708
    8         3223    85979
    9         3561    99527
   10         3992   114608
   11         4335   127098
   12         4696   140639
   13         5076   155302
   14         5459   171094
   15         5886   188088
   16         6429   206563
   17            0        0
   18            0        0
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR  1     CALENDAR YEAR 1941

                      RESERVOIR NO  1  STILLHSE   MAX. CAPACITY  206563  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM              SURFACE  EVAP    EVAP  DWNSTRM            PUMPED    PUMPED   SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS SHORTAGE    INTO      OUT     LOSS  CONTENT     RULE
     1     206563    62230      0      4145      6429    .11     707       0        0       0        0    57378   206563   206563
     2     206563   101730      0      4145      6418   -.12    -769       0        0       0        0    98355   206562   206563
     3     206562   102730      0      4836      6425   -.04    -256       0        0       0        0    98149   206563   206563
     4     206563    93970      0      5526      6423   -.06    -384       0        0       0        0    88829   206562   206563
     5     206562   120140      0      5526      6429    .03     193       0        0       0        0   114420   206563   206563
     6     206563    67480      0      6217      6429    .01      64       0        0       0        0    61199   206563   206563
     7     206563    31080      0      8290      6429    .42    2700       0        0       0        0    20090   206563   206563
     8     206563    11350      0      8290      6429    .59    3793       0        0       0        0        0   205830   206563
     9     205830     3940      0      6217      6322    .56    3540       0        0       0        0        0   200013   206563
    10     200013    11100      0      6217      6308    .09     568       0        0       0        0        0   204328   206563
    11     204328     4330      0      4836      6340    .17    1078       0        0       0        0        0   202744   206563
    12     202744     4230      0      4836      6297    .12     756       0        0       0        0        0   201382   206563

     YEAR TOTALS  614310        0   69081                     11990       0        0       0        0   538420
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR  2     CALENDAR YEAR 1942

                      RESERVOIR NO  1  STILLHSE   MAX. CAPACITY  206563  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM              SURFACE  EVAP    EVAP  DWNSTRM            PUMPED    PUMPED   SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS SHORTAGE    INTO      OUT     LOSS  CONTENT     RULE
     1     201382     3370      0      4145      6252    .14     875       0        0       0        0        0   199732   206563
     2     199732     2780      0      4145      6190    .20    1238       0        0       0        0        0   197129   206563
     3     197129     2530      0      4836      6090    .31    1888       0        0       0        0        0   192935   206563
     4     192935    78550      0      5526      6229   -.33   -2055       0        0       0        0    61451   206563   206563
     5     206563    83210      0      5526      6428   -.01     -63       0        0       0        0    77747   206563   206563
     6     206563    93160      0      6217      6429    .25    1607       0        0       0        0    85336   206563   206563
     7     206563     9570      0      8290      6429    .49    3150       0        0       0        0        0   204693   206563
     8     204693     5040      0      8290      6280    .50    3140       0        0       0        0        0   198303   206563
     9     198303    21880      0      6217      6308    .08     505       0        0       0        0     6898   206563   206563
    10     206563    19130      0      6217      6429    .03     193       0        0       0        0    12720   206563   206563
    11     206563    13050      0      4836      6429    .24    1543       0        0       0        0     6671   206563   206563
    12     206563    10860      0      4836      6429    .11     707       0        0       0        0     5317   206563   206563

     YEAR TOTALS  343130        0   69081                     12728       0        0       0        0   256140
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR  3     CALENDAR YEAR 1943

                      RESERVOIR NO  1  STILLHSE   MAX. CAPACITY  206563  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM              SURFACE  EVAP    EVAP  DWNSTRM            PUMPED    PUMPED   SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS SHORTAGE    INTO      OUT     LOSS  CONTENT     RULE
     1     206563     9010      0      4145      6429    .15     964       0        0       0        0     3901   206563   206563
     2     206563     5700      0      4145      6429    .29    1864       0        0       0        0        0   206254   206563
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      3     206254     7750       0      4836      6424    .16     1028       0        0        0        0      1577   206563    206563
      4     206563     7660       0      5526      6429    .34     2186       0        0        0        0         0   206511    206563
      5     206511     6420       0      5526      6428    .17     1093       0        0        0        0         0   206312    206563
      6     206312     1630       0      6217      6309    .49     3091       0        0        0        0         0   198634    206563
      7     198634      710       0      8290      6044    .46     2780       0        0        0        0         0   188274    206563
      8     188274       50       0      8290      5730    .79     4527       0        0        0        0         0   175507    206563
      9     175507     7550       0      6217      5568    .27     1503       0        0        0        0         0   175337    206563
     10     175337     2040       0      6217      5485    .41     2249       0        0        0        0         0   168911    206563
     11     168911     1400       0      4836      5349    .23     1230       0        0        0        0         0   164245    206563
     12     164245     1910       0      4836      5257    .00        0       0        0        0        0         0   161319    206563

      YEAR TOTALS     51830       0     69081                    22515       0        0        0        0      5478
1
                  TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

    SIMULATION YEAR  4      CALENDAR YEAR 1944

                    RESERVOIR NO  1   STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0             INITIAL     UREG   UPSTRM             SURFACE   EVAP     EVAP  DWNSTRM             PUMPED     PUMPED     SYSTEM  END MO.     OPER.
    MONTH     STORAGE   INFLOWS  SPILLS    DEMAND     AREA    RATE     LOSS    SPILLS  SHORTAGE    INTO       OUT        LOSS   CONTENT     RULE
      1     161319    24180       0      4145      5477   -.18     -985       0        0        0        0         0   182339    206563
      2     182339    66750       0      4145      6062   -.12     -726       0        0        0        0     39109   206561    206563
      3     206561    63280       0      4836      6429    .04      257       0        0        0        0     58185   206563    206563
      4     206563    28710       0      5526      6429    .24     1543       0        0        0        0     21641   206563    206563
      5     206563   269260       0      5526      6407   -.23    -1473       0        0        0        0    265212   206558    206563
      6     206558    91310       0      6217      6429    .50     3214       0        0        0        0     81874   206563    206563
      7     206563    13330       0      8290      6429    .73     4693       0        0        0        0       347   206563    206563
      8     206563     9200       0      8290      6429    .61     3922       0        0        0        0         0   203551    206563
      9     203551     9310       0      6217      6385    .49     3129       0        0        0        0         0   203515    206563
     10     203515     5610       0      6217      6288    .46     2892       0        0        0        0         0   200016    206563
     11     200016     8650       0      4836      6293   -.06     -377       0        0        0        0         0   204207    206563
     12     204207    42150       0      4836      6385   -.10     -638       0        0        0        0     35596   206563    206563

      YEAR TOTALS    631740       0     69081                    15451       0        0        0        0    501964
1
                  TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

    SIMULATION YEAR  5      CALENDAR YEAR 1945

                    RESERVOIR NO  1   STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0             INITIAL     UREG   UPSTRM             SURFACE   EVAP     EVAP  DWNSTRM             PUMPED     PUMPED     SYSTEM  END MO.     OPER.
    MONTH     STORAGE   INFLOWS  SPILLS    DEMAND     AREA    RATE     LOSS    SPILLS  SHORTAGE    INTO       OUT        LOSS   CONTENT     RULE
      1     206563    81260       0      4145      6428   -.01      -63       0        0        0        0     77178   206563    206563
      2     206563    87110       0      4145      6421   -.08     -513       0        0        0        0     83478   206563    206563
      3     206563   104350       0      4836      6426   -.03     -192       0        0        0        0     99706   206563    206563
      4     206563   118930       0      5526      6420   -.10     -641       0        0        0        0    114046   206562    206563
      5     206562    52490       0      5526      6429    .42     2700       0        0        0        0     44263   206563    206563
      6     206563    36270       0      6217      6429    .28     1800       0        0        0        0     28253   206563    206563
      7     206563    11060       0      8290      6429    .46     2957       0        0        0        0         0   206376    206563
      8     206376     7930       0      8290      6418    .51     3273       0        0        0        0         0   202743    206563
      9     202743    16790       0      6217      6373    .49     3123       0        0        0        0      3630   206563    206563
     10     206563    17030       0      6217      6429    .22     1414       0        0        0        0      9399   206563    206563
     11     206563    12940       0      4836      6429    .31     1993       0        0        0        0      6111   206563    206563
     12     206563    22190       0      4836      6429    .11      707       0        0        0        0     16647   206563    206563

      YEAR TOTALS    568350       0     69081                    16558       0        0        0        0    482711
1
                  TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

    SIMULATION YEAR  6      CALENDAR YEAR 1946

                    RESERVOIR NO  1   STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0             INITIAL     UREG   UPSTRM             SURFACE   EVAP     EVAP  DWNSTRM             PUMPED     PUMPED     SYSTEM  END MO.     OPER.
    MONTH     STORAGE   INFLOWS  SPILLS    DEMAND     AREA    RATE     LOSS    SPILLS  SHORTAGE    INTO       OUT        LOSS   CONTENT     RULE
      1     206563    29110       0      4145      6422   -.07     -449       0        0        0        0     25414   206563    206563
      2     206563    41690       0      4145      6429    .05      321       0        0        0        0     37224   206563    206563
      3     206563    53490       0      4836      6429    .11      707       0        0        0        0     47947   206563    206563
      4     206563    23220       0      5526      6429    .15      964       0        0        0        0     16730   206563    206563
      5     206563    24700       0      5526      6429    .02      129       0        0        0        0     19045   206563    206563
      6     206563    14230       0      6217      6429    .40     2572       0        0        0        0      5441   206563    206563
      7     206563     3050       0      8290      6279    .79     4960       0        0        0        0         0   196363    206563
      8     196363     2990       0      8290      5987    .73     4371       0        0        0        0         0   186692    206563
      9     186692     5150       0      6217      5829    .11      641       0        0        0        0         0   184984    206563
     10     184984     3520       0      6217      5752    .30     1726       0        0        0        0         0   180561    206563
     11     180561    10750       0      4836      5767    .06      346       0        0        0        0         0   186129    206563
     12     186129    13480       0      4836      5949    .07      416       0        0        0        0         0   194357    206563

      YEAR TOTALS    225380       0     69081                    16704       0        0        0        0    151801
1
                  TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

    SIMULATION YEAR  7      CALENDAR YEAR 1947
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                       RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL         0
0          INITIAL       UREG   UPSTRM                SURFACE  EVAP      EVAP  DWNSTRM              PUMPED       PUMPED     SYSTEM END MO.      OPER.
  MONTH    STORAGE    INFLOWS   SPILLS     DEMAND      AREA    RATE      LOSS   SPILLS  SHORTAGE    INTO         OUT       LOSS   CONTENT      RULE
     1      194357      40080        0       4145      6237    -.14      -872        0         0       0           0      24603    206561    206563
     2      206561      18810        0       4145      6429     .20      1286        0         0       0           0      13377    206563    206563
     3      206563      35660        0       4836      6429     .05       321        0         0       0           0      30503    206563    206563
     4      206563      26150        0       5526      6429     .10       643        0         0       0           0      19981    206563    206563
     5      206563      20660        0       5526      6429     .19      1222        0         0       0           0      13912    206563    206563
     6      206563       6290        0       6217      6429     .57      3665        0         0       0           0          0    202971    206563
     7      202971       2010        0       8290      6162     .76      4683        0         0       0           0          0    192008    206563
     8      192008       1910        0       8290      5866     .52      3050        0         0       0           0          0    182578    206563
     9      182578       1060        0       6217      5633     .70      3943        0         0       0           0          0    173478    206563
    10      173478        780        0       6217      5413     .57      3085        0         0       0           0          0    164956    206563
    11      164956       1360        0       4836      5253     .23      1208        0         0       0           0          0    160272    206563
    12      160272       1760        0       4836      5159     .01        52        0         0       0           0          0    157144    206563

    YEAR TOTALS      156530        0      69081                         22286        0         0       0           0     102376
1
                     TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

  SIMULATION YEAR  8     CALENDAR YEAR 1948

                       RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL         0
0          INITIAL       UREG   UPSTRM                SURFACE  EVAP      EVAP  DWNSTRM              PUMPED       PUMPED     SYSTEM END MO.      OPER.
  MONTH    STORAGE    INFLOWS   SPILLS     DEMAND      AREA    RATE      LOSS   SPILLS  SHORTAGE    INTO         OUT       LOSS   CONTENT      RULE
     1      157144       1630        0       4145      5087     .05       254        0         0       0           0          0    154375    206563
     2      154375      12340        0       4145      5157    -.06      -308        0         0       0           0          0    162878    206563
     3      162878       3090        0       4836      5225     .21      1097        0         0       0           0          0    160035    206563
     4      160035       6620        0       5526      5190     .23      1194        0         0       0           0          0    159935    206563
     5      159935      10540        0       5526      5239     .16       838        0         0       0           0          0    164111    206563
     6      164111        600        0       6217      5188     .53      2750        0         0       0           0          0    155744    206563
     7      155744       5020        0       8290      5009     .55      2755        0         0       0           0          0    149719    206563
     8      149719       3090        0       8290      4816     .77      3708        0         0       0           0          0    140811    206563
     9      140811        320        0       6217      4589     .54      2478        0         0       0           0          0    132436    206563
    10      132436        190        0       6217      4368     .50      2184        0         0       0           0          0    124225    206563
    11      124225        540        0       4836      4176     .36      1503        0         0       0           0          0    118426    206563
    12      118426       1070        0       4836      4034     .20       807        0         0       0           0          0    113853    206563

    YEAR TOTALS       45050        0      69081                         19260        0         0       0           0          0
1
                     TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

  SIMULATION YEAR  9     CALENDAR YEAR 1949

                       RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL         0
0          INITIAL       UREG   UPSTRM                SURFACE  EVAP      EVAP  DWNSTRM              PUMPED       PUMPED     SYSTEM END MO.      OPER.
  MONTH    STORAGE    INFLOWS   SPILLS     DEMAND      AREA    RATE      LOSS   SPILLS  SHORTAGE    INTO         OUT       LOSS   CONTENT      RULE
     1      113853       1220        0       4145      3937    -.15      -590        0         0       0           0          0    111518    206563
     2      111518       1380        0       4145      3867    -.05      -192        0         0       0           0          0    108945    206563
     3      108945      23140        0       4836      4082     .10       408        0         0       0           0          0    126841    206563
     4      126841      43930        0       5526      4849    -.21     -1017        0         0       0           0          0    166262    206563
     5      166262       9020        0       5526      5362     .34      1823        0         0       0           0          0    167933    206563
     6      167933      12170        0       6217      5437     .26      1414        0         0       0           0          0    172472    206563
     7      172472       1470        0       8290      5367     .65      3489        0         0       0           0          0    162163    206563
     8      162163       1510        0       8290      5122     .62      3176        0         0       0           0          0    152207    206563
     9      152207        160        0       6217      4881     .58      2831        0         0       0           0          0    143319    206563
    10      143319        150        0       6217      4678     .13       608        0         0       0           0          0    136644    206563
    11      136644        690        0       4836      4509     .42      1894        0         0       0           0          0    130604    206563
    12      130604       1410        0       4836      4382     .01        44        0         0       0           0          0    127134    206563

    YEAR TOTALS       96250        0      69081                         13888        0         0       0           0          0
1
                     TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

  SIMULATION YEAR 10     CALENDAR YEAR 1950

                       RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL         0
0          INITIAL       UREG   UPSTRM                SURFACE  EVAP      EVAP  DWNSTRM              PUMPED       PUMPED     SYSTEM END MO.      OPER.
  MONTH    STORAGE    INFLOWS   SPILLS     DEMAND      AREA    RATE      LOSS   SPILLS  SHORTAGE    INTO         OUT       LOSS   CONTENT      RULE
     1      127134        880        0       4145      4288     .05       214        0         0       0           0          0    123655    206563
     2      123655       5970        0       4145      4270    -.07      -298        0         0       0           0          0    125778    206563
     3      125778       1330        0       4836      4230     .35      1480        0         0       0           0          0    120792    206563
     4      120792       6010        0       5526      4171    -.04      -166        0         0       0           0          0    121442    206563
     5      121442       6610        0       5526      4187     .13       544        0         0       0           0          0    121982    206563
     6      121982       4610        0       6217      4155     .30      1246        0         0       0           0          0    119129    206563
     7      119129        440        0       8290      3976     .58      2306        0         0       0           0          0    108973    206563
     8      108973          0        0       8290      3669     .82      3009        0         0       0           0          0     97674    206563
     9       97674       6970        0       6217      3511     .30      1053        0         0       0           0          0     97374    206563
    10       97374        220        0       6217      3411     .50      1705        0         0       0           0          0     89672    206563
    11       89672        380        0       4836      3241     .47      1523        0         0       0           0          0     83693    206563
    12       83693        450        0       4836      3091     .32       989        0         0       0           0          0     78318    206563

    YEAR TOTALS       33870        0      69081                         13605        0         0       0           0          0
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1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 11     CALENDAR YEAR 1951

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL     UREG    UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM              PUMPED      PUMPED    SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS    SPILLS     DEMAND      AREA     RATE     LOSS    SPILLS  SHORTAGE     INTO        OUT     LOSS   CONTENT     RULE
     1      78318       470        0       4145       2961      .27      799        0         0        0          0        0    73844    206563
     2      73844       660        0       4145       2856      .00        0        0         0        0          0        0    70359    206563
     3      70359       960        0       4836       2749      .25      687        0         0        0          0        0    65796    206563
     4      65796       430        0       5526       2612      .28      731        0         0        0          0        0    59969    206563
     5      59969      5490        0       5526       2523      .10      252        0         0        0          0        0    59681    206563
     6      59681      3560        0       6217       2471      .26      642        0         0        0          0        0    56382    206563
     7      56382         0        0       8290       2275      .80     1820        0         0        0          0        0    46272    206563
     8      46272         0        0       8290       1969      .97     1910        0         0        0          0        0    36072    206563
     9      36072      1120        0       6217       1707      .40      683        0         0        0          0        0    30292    206563
    10      30292         0        0       6217       1483      .45      667        0         0        0          0        0    23408    206563
    11      23408       250        0       4836       1252      .29      363        0         0        0          0        0    18459    206563
    12      18459       320        0       4836       1040      .26      270        0         0        0          0        0    13673    206563

    YEAR TOTALS     13260          0      69081                         8824        0         0        0          0        0
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 12     CALENDAR YEAR 1952

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL     UREG    UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM              PUMPED      PUMPED    SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS    SPILLS     DEMAND      AREA     RATE     LOSS    SPILLS  SHORTAGE     INTO        OUT     LOSS   CONTENT     RULE
     1      13673       280        0       4145        828      .23      190        0         0        0          0        0     9618    206563
     2       9618       300        0       4145        563      .17       96        0         0        0          0        0     5677    206563
     3       5677       860        0       4836        281      .15       42        0         0        0          0        0     1659    206563
     4       1659     18950        0       5526        616     -.04      -24        0         0        0          0        0    15107    206563
     5      15107     37710        0       5526       1641      .04       66        0         0        0          0        0    47225    206563
     6      47225      5570        0       6217       2131      .48     1023        0         0        0          0        0    45555    206563
     7      45555      1600        0       8290       1982      .62     1229        0         0        0          0        0    37636    206563
     8      37636        20        0       8290       1690      .98     1656        0         0        0          0        0    27710    206563
     9      27710         0        0       6217       1382      .47      650        0         0        0          0        0    20843    206563
    10      20843         0        0       6217       1101      .72      793        0         0        0          0        0    13833    206563
    11      13833       980        0       4836        841     -.05      -41        0         0        0          0        0    10018    206563
    12      10018     16160        0       4836       1024     -.12     -122        0         0        0          0        0    21464    206563

    YEAR TOTALS     82430          0      69081                         5558        0         0        0          0        0
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 13     CALENDAR YEAR 1953

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL     UREG    UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM              PUMPED      PUMPED    SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS    SPILLS     DEMAND      AREA     RATE     LOSS    SPILLS  SHORTAGE     INTO        OUT     LOSS   CONTENT     RULE
     1      21464      4570        0       4145       1274      .27      344        0         0        0          0        0    21545    206563
     2      21545      2650        0       4145       1244      .10      124        0         0        0          0        0    19926    206563
     3      19926      5320        0       4836       1220      .09      110        0         0        0          0        0    20300    206563
     4      20300      8520        0       5526       1282      .13      167        0         0        0          0        0    23127    206563
     5      23127     81050        0       5526       2552      .05      128        0         0        0          0        0    98523    206563
     6      98523      3720        0       6217       3476      .67     2329        0         0        0          0        0    93697    206563
     7      93697      1070        0       8290       3299      .65     2144        0         0        0          0        0    84333    206563
     8      84333         0        0       8290       3046      .59     1797        0         0        0          0        0    74246    206563
     9      74246      3740        0       6217       2863      .45     1288        0         0        0          0        0    70481    206563
    10      70481      9350        0       6217       2852      .05      143        0         0        0          0        0    73471    206563
    11      73471      1800        0       4836       2843      .23      654        0         0        0          0        0    69781    206563
    12      69781      6770        0       4836       2816      .10      282        0         0        0          0        0    71433    206563

    YEAR TOTALS    128560          0      69081                         9510        0         0        0          0        0
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 14     CALENDAR YEAR 1954

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL     UREG    UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM              PUMPED      PUMPED    SYSTEM END MO.     OPER.
   MONTH   STORAGE  INFLOWS    SPILLS     DEMAND      AREA     RATE     LOSS    SPILLS  SHORTAGE     INTO        OUT     LOSS   CONTENT     RULE
     1      71433      1560        0       4145       2799      .13      364        0         0        0          0        0    68484    206563
     2      68484       840        0       4145       2704      .33      892        0         0        0          0        0    64287    206563
     3      64287       480        0       4836       2579      .29      748        0         0        0          0        0    59183    206563
     4      59183       760        0       5526       2428      .18      437        0         0        0          0        0    53980    206563
     5      53980      5610        0       5526       2344      .28      656        0         0        0          0        0    53408    206563
     6      53408         0        0       6217       2223      .67     1489        0         0        0          0        0    45702    206563
     7      45702        10        0       8290       1953      .90     1758        0         0        0          0        0    35664    206563
     8      35664        40        0       8290       1629      .92     1499        0         0        0          0        0    25915    206563
     9      25915        40        0       6217       1306      .76      993        0         0        0          0        0    18745    206563
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      10    18745     1010       0     6217     1032   .46     475        0        0        0        0        0    13063   206563
      11    13063     1790       0     4836      818   .26     213        0        0        0        0        0     9804   206563
      12     9804      300       0     4836      549   .31     170        0        0        0        0        0     5098   206563

    YEAR TOTALS      12440       0    69081                    9694        0        0        0        0        0
1
                 TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 15     CALENDAR YEAR 1955

                 RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0        INITIAL     UREG  UPSTRM           SURFACE  EVAP    EVAP  DWNSTRM             PUMPED   PUMPED   SYSTEM  END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS   DEMAND     AREA  RATE    LOSS   SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
       1     5098     2040       0     4145      307   .07      21        0        0        0        0        0     2972   206563
       2     2972     6730       0     4145      324  -.03      -9        0        0        0        0        0     5566   206563
       3     5566     2220       0     4836      320   .23      74        0        0        0        0        0     2876   206563
       4     2876     4340       0     5526      176   .25      44        0        0        0        0        0     1646   206563
       5     1646    53710       0     5526     1438   .06      86        0        0        0        0        0    49744   206563
       6    49744    23860       0     6217     2476   .28     693        0        0        0        0        0    66694   206563
       7    66694     9380       0     8290     2705   .61    1650        0        0        0        0        0    66134   206563
       8    66134     4810       0     8290     2638   .40    1055        0        0        0        0        0    61599   206563
       9    61599     7480       0     6217     2579   .38     980        0        0        0        0        0    61882   206563
      10    61882       30       0     6217     2470   .62    1531        0        0        0        0        0    54164   206563
      11    54164      180       0     4836     2275   .45    1024        0        0        0        0        0    48484   206563
      12    48484      400       0     4836     2121   .21     445        0        0        0        0        0    43603   206563

    YEAR TOTALS     115180       0    69081                    7594        0        0        0        0        0
1
                 TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 16     CALENDAR YEAR 1956

                 RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0        INITIAL     UREG  UPSTRM           SURFACE  EVAP    EVAP  DWNSTRM             PUMPED   PUMPED   SYSTEM  END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS   DEMAND     AREA  RATE    LOSS   SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
       1    43603      410       0     4145     1983   .11     218        0        0        0        0        0    39650   206563
       2    39650     1120       0     4145     1866   .10     187        0        0        0        0        0    36438   206563
       3    36438       30       0     4836     1723   .41     706        0        0        0        0        0    30926   206563
       4    30926        0       0     5526     1523   .37     564        0        0        0        0        0    24836   206563
       5    24836    28020       0     5526     1793   .29     520        0        0        0        0        0    46810   206563
       6    46810      250       0     6217     2033   .69    1403        0        0        0        0        0    39440   206563
       7    39440        0       0     8290     1749   .94    1644        0        0        0        0        0    29506   206563
       8    29506     1630       0     8290     1431   .92    1317        0        0        0        0        0    21529   206563
       9    21529        0       0     6217     1130   .84     949        0        0        0        0        0    14363   206563
      10    14363      680       0     6217      815   .51     416        0        0        0        0        0     8410   206563
      11     8410     3910       0     4836      578   .32     185        0        0        0        0        0     7299   206563
      12     7299     4130       0     4836      511   .15      77        0        0        0        0        0     6516   206563

    YEAR TOTALS      40180       0    69081                    8186        0        0        0        0        0
1
                 TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 17     CALENDAR YEAR 1957

                 RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0        INITIAL     UREG  UPSTRM           SURFACE  EVAP    EVAP  DWNSTRM             PUMPED   PUMPED   SYSTEM  END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS   DEMAND     AREA  RATE    LOSS   SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
       1     6516      740       0     4145      360   .17      61        0        0        0        0        0     3050   206563
       2     3050     1120       0     4145      120   .02       2        0        0        0        0        0       23   206563
       3       23    11870       0     4836      272  -.01      -2        0        0        0        0        0     7059   206563
       4     7059   171750       0     5526     3350  -.53   -1775        0        0        0        0        0   175058   206563
       5   175058   194520       0     5526     5952  -.16    -951        0        0        0        0   158443   206560   206563
       6   206560    44560       0     6217     6429   .25    1607        0        0        0        0    36733   206563   206563
       7   206563     3170       0     8290     6283   .77    4838        0        0        0        0        0   196605   206563
       8   196605     1820       0     8290     5965   .87    5190        0        0        0        0        0   184945   206563
       9   184945     2190       0     6217     5738   .26    1492        0        0        0        0        0   179426   206563
      10   179426    58720       0     6217     6020  -.11    -661        0        0        0        0    26028   206562   206563
      11   206562    32360       0     4836     6423  -.06    -384        0        0        0        0    27908   206562   206563
      12   206562    23030       0     4836     6429   .17    1093        0        0        0        0    17100   206563   206563

    YEAR TOTALS     545850       0    69081                   10510        0        0        0        0   266212
1
                 TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 18     CALENDAR YEAR 1958

                 RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0        INITIAL     UREG  UPSTRM           SURFACE  EVAP    EVAP  DWNSTRM             PUMPED   PUMPED   SYSTEM  END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS   DEMAND     AREA  RATE    LOSS   SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
       1   206563    17560       0     4145     6429   .05     321        0        0        0        0    13094   206563   206563
       2   206563    83560       0     4145     6419  -.11    -705        0        0        0        0    80121   206562   206563
       3   206562    66700       0     4836     6429   .08     514        0        0        0        0    61349   206563   206563
       4   206563    26190       0     5526     6429   .04     257        0        0        0        0    20407   206563   206563
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      5     206563    58950       0     5526     6429    .16    1029       0        0       0        0    52395   206563   206563
      6     206563    34860       0     6217     6429    .38    2443       0        0       0        0    26200   206563   206563
      7     206563     5350       0     8290     6321    .70    4425       0        0       0        0        0   199198   206563
      8     199198     2600       0     8290     6073    .63    3826       0        0       0        0        0   189682   206563
      9     189682     4620       0     6217     5896    .15     884       0        0       0        0        0   187201   206563
     10     187201     2770       0     6217     5808    .17     987       0        0       0        0        0   182767   206563
     11     182767     2530       0     4836     5708    .22    1256       0        0       0        0        0   179205   206563
     12     179205     2170       0     4836     5619    .15     843       0        0       0        0        0   175696   206563

      YEAR TOTALS  307860         0    69081                   16080       0        0       0        0   253566
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 19     CALENDAR YEAR 1959

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL    UREG   UPSTRM            SURFACE  EVAP    EVAP  DWNSTRM              PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH   STORAGE  INFLOWS  SPILLS   DEMAND    AREA    RATE    LOSS   SPILLS SHORTAGE      INTO       OUT      LOSS  CONTENT     RULE
      1     175696     1740       0     4145     5533    .17     941       0        0       0        0        0   172350   206563
      2     172350     2490       0     4145     5472   -.03    -163       0        0       0        0        0   170858   206563
      3     170858     1760       0     4836     5395    .32    1726       0        0       0        0        0   166056   206563
      4     166056     3950       0     5526     5314    .05     266       0        0       0        0        0   164214   206563
      5     164214     2340       0     5526     5242    .18     944       0        0       0        0        0   160084   206563
      6     160084    24290       0     6217     5401    .15     810       0        0       0        0        0   177347   206563
      7     177347     3440       0     8290     5529    .37    2046       0        0       0        0        0   170451   206563
      8     170451     7630       0     8290     5418    .26    1409       0        0       0        0        0   168382   206563
      9     168382     6430       0     6217     5368    .43    2308       0        0       0        0        0   166287   206563
     10     166287   152490       0     6217     5843   -.01     -57       0        0       0        0   106054   206563   206563
     11     206563    28560       0     4836     6429    .27    1736       0        0       0        0    21988   206563   206563
     12     206563    48390       0     4836     6429    .02     129       0        0       0        0    43425   206563   206563

      YEAR TOTALS  283510         0    69081                   12095       0        0       0        0   171467
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 20     CALENDAR YEAR 1960

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL    UREG   UPSTRM            SURFACE  EVAP    EVAP  DWNSTRM              PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH   STORAGE  INFLOWS  SPILLS   DEMAND    AREA    RATE    LOSS   SPILLS SHORTAGE      INTO       OUT      LOSS  CONTENT     RULE
      1     206563    71970       0     4145     6429    .04     257       0        0       0        0    67568   206563   206563
      2     206563    49030       0     4145     6429    .07     450       0        0       0        0    44435   206563   206563
      3     206563    30990       0     4836     6429    .14     900       0        0       0        0    25254   206563   206563
      4     206563    17030       0     5526     6429    .19    1222       0        0       0        0    10282   206563   206563
      5     206563     8790       0     5526     6429    .33    2122       0        0       0        0     1142   206563   206563
      6     206563     4000       0     6217     6365    .34    2164       0        0       0        0        0   202182   206563
      7     202182     4970       0     8290     6205    .51    3165       0        0       0        0        0   195697   206563
      8     195697     3310       0     8290     5997    .45    2699       0        0       0        0        0   188018   206563
      9     188018     4350       0     6217     5820    .56    3259       0        0       0        0        0   182892   206563
     10     182892    73960       0     6217     6076   -.06    -364       0        0       0        0    44436   206563   206563
     11     206563    23110       0     4836     6429    .06     386       0        0       0        0    17888   206563   206563
     12     206563    83850       0     4836     6412   -.18   -1153       0        0       0        0    80170   206560   206563

      YEAR TOTALS  375360         0    69081                   15107       0        0       0        0   291175
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 21     CALENDAR YEAR 1961

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL    UREG   UPSTRM            SURFACE  EVAP    EVAP  DWNSTRM              PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH   STORAGE  INFLOWS  SPILLS   DEMAND    AREA    RATE    LOSS   SPILLS SHORTAGE      INTO       OUT      LOSS  CONTENT     RULE
      1     206560   109590       0     4145     6421   -.08    -513       0        0       0        0   105955   206563   206563
      2     206563   127090       0     4145     6419   -.11    -705       0        0       0        0   123651   206562   206563
      3     206562    53320       0     4836     6429    .19    1222       0        0       0        0    47261   206563   206563
      4     206563    27340       0     5526     6429    .36    2314       0        0       0        0    19500   206563   206563
      5     206563    13860       0     5526     6429    .39    2507       0        0       0        0     5827   206563   206563
      6     206563    19830       0     6217     6429    .00       0       0        0       0        0    13613   206563   206563
      7     206563    35620       0     8290     6429    .22    1414       0        0       0        0    25916   206563   206563
      8     206563     7240       0     8290     6351    .67    4255       0        0       0        0        0   201258   206563
      9     201258     8740       0     6217     6278    .35    2197       0        0       0        0        0   201584   206563
     10     201584    11450       0     6217     6356    .31    1970       0        0       0        0        0   204847   206563
     11     204847    13210       0     4836     6404    .12     768       0        0       0        0     5890   206563   206563
     12     206563     6670       0     4836     6429    .11     707       0        0       0        0     1127   206563   206563

      YEAR TOTALS  433960         0    69081                   16136       0        0       0        0   348740
1
                    TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

   SIMULATION YEAR 22     CALENDAR YEAR 1962

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL    UREG   UPSTRM            SURFACE  EVAP    EVAP  DWNSTRM              PUMPED     PUMPED   SYSTEM END MO.    OPER.
```

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 MONTH  STORAGE  INFLOWS   SPILLS   DEMAND     AREA     RATE     LOSS   SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
     1   206563     5860        0     4145     6429      .15      964        0        0        0        0      751   206563   206563
     2   206563     5270        0     4145     6429      .17     1093        0        0        0        0       32   206563   206563
     3   206563     6100        0     4836     6429      .27     1736        0        0        0        0        0   206091   206563
     4   206091     7300        0     5526     6422      .03      193        0        0        0        0     1109   206563   206563
     5   206563     6940        0     5526     6429      .40     2572        0        0        0        0        0   205405   206563
     6   205405    11230        0     6217     6412      .14      898        0        0        0        0     2957   206563   206563
     7   206563     2660        0     8290     6279      .73     4584        0        0        0        0        0   196349   206563
     8   196349      260        0     8290     5937      .84     4987        0        0        0        0        0   183332   206563
     9   183332    10180        0     6217     5793      .32     1854        0        0        0        0        0   185441   206563
    10   185441    19250        0     6217     5979      .24     1435        0        0        0        0        0   197039   206563
    11   197039     4200        0     4836     6123      .19     1163        0        0        0        0        0   195240   206563
    12   195240     6920        0     4836     6120      .08      490        0        0        0        0        0   196834   206563

  YEAR TOTALS      86170        0    69081                      21969        0        0        0        0     4849
1
                   TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

  SIMULATION YEAR 23     CALENDAR YEAR 1963

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL          0
0       INITIAL     UREG   UPSTRM            SURFACE     EVAP     EVAP  DWNSTRM             PUMPED   PUMPED   SYSTEM  END MO.    OPER.
 MONTH  STORAGE  INFLOWS   SPILLS   DEMAND     AREA     RATE     LOSS   SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
     1   196834     3420        0     4145     6118      .16      979        0        0        0        0        0   195130   206563
     2   195130     3800        0     4145     6075      .14      850        0        0        0        0        0   193935   206563
     3   193935     2910        0     4836     6003      .30     1801        0        0        0        0        0   190208   206563
     4   190208     2170        0     5526     5882      .20     1176        0        0        0        0        0   185676   206563
     5   185676     4790        0     5526     5797      .26     1507        0        0        0        0        0   183433   206563
     6   183433     1750        0     6217     5681      .44     2500        0        0        0        0        0   176466   206563
     7   176466     1340        0     8290     5456      .74     4037        0        0        0        0        0   165479   206563
     8   165479      390        0     8290     5176      .81     4193        0        0        0        0        0   153386   206563
     9   153386     1030        0     6217     4921      .59     2903        0        0        0        0        0   145296   206563
    10   145296     2940        0     6217     4741      .54     2560        0        0        0        0        0   139459   206563
    11   139459     2730        0     4836     4628      .14      648        0        0        0        0        0   136705   206563
    12   136705      980        0     4836     4532      .13      589        0        0        0        0        0   132260   206563

  YEAR TOTALS      28250        0    69081                      23743        0        0        0        0        0
1
                   TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

  SIMULATION YEAR 24     CALENDAR YEAR 1964

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL          0
0       INITIAL     UREG   UPSTRM            SURFACE     EVAP     EVAP  DWNSTRM             PUMPED   PUMPED   SYSTEM  END MO.    OPER.
 MONTH  STORAGE  INFLOWS   SPILLS   DEMAND     AREA     RATE     LOSS   SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
     1   132260     1450        0     4145     4435      .02       89        0        0        0        0        0   129476   206563
     2   129476     5450        0     4145     4412      .07      309        0        0        0        0        0   130472   206563
     3   130472     9820        0     4836     4487      .08      359        0        0        0        0        0   135097   206563
     4   135097     9900        0     5526     4598      .14      644        0        0        0        0        0   138827   206563
     5   138827     8230        0     5526     4668      .25     1167        0        0        0        0        0   140364   206563
     6   140364     7230        0     6217     4682      .33     1545        0        0        0        0        0   139832   206563
     7   139832     1000        0     8290     4533      .73     3309        0        0        0        0        0   129233   206563
     8   129233     4040        0     8290     4298      .63     2708        0        0        0        0        0   122275   206563
     9   122275    17600        0     6217     4352      .11      479        0        0        0        0        0   133179   206563
    10   133179     3020        0     6217     4432      .38     1684        0        0        0        0        0   128298   206563
    11   128298     9230        0     4836     4421      .08      354        0        0        0        0        0   132338   206563
    12   132338     4330        0     4836     4458      .16      713        0        0        0        0        0   131119   206563

  YEAR TOTALS      81300        0    69081                      13360        0        0        0        0        0
1
                   TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

  SIMULATION YEAR 25     CALENDAR YEAR 1965

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL          0
0       INITIAL     UREG   UPSTRM            SURFACE     EVAP     EVAP  DWNSTRM             PUMPED   PUMPED   SYSTEM  END MO.    OPER.
 MONTH  STORAGE  INFLOWS   SPILLS   DEMAND     AREA     RATE     LOSS   SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
     1   131119    14670        0     4145     4583     -.01      -45        0        0        0        0        0   141689   206563
     2   141689    49190        0     4145     5300     -.12     -635        0        0        0        0        0   187369   206563
     3   187369    24340        0     4836     6147      .16      984        0        0        0        0        0   205889   206563
     4   205889    18530        0     5526     6419      .16     1027        0        0        0        0    11303   206563   206563
     5   206563   312000        0     5526     6429     -.40    -2571        0        0        0        0   309045   206563   206563
     6   206563    43420        0     6217     6429      .38     2443        0        0        0        0    34760   206563   206563
     7   206563     9030        0     8290     6429      .62     3986        0        0        0        0        0   203317   206563
     8   203317     4330        0     8290     6217      .64     3979        0        0        0        0        0   195378   206563
     9   195378    12990        0     6217     6160      .44     2710        0        0        0        0        0   199441   206563
    10   199441    11540        0     6217     6298      .19     1197        0        0        0        0        0   203567   206563
    11   203567    22490        0     4836     6385      .03      192        0        0        0        0    14466   206563   206563
    12   206563    17810        0     4836     6424     -.05     -320        0        0        0        0    13294   206563   206563

  YEAR TOTALS     540340        0    69081                      12947        0        0        0        0   382868
1
                   TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions
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                SIMULATION PERIOD TOTAL SUMMARY BY NODE  1

 YEAR START. STRG.  UNREG. FLOW      DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
    1       206563       614310        69081            0        11990       538420       201382
    2       201382       343130        69081            0        12728       256140       206563
    3       206563        51830        69081            0        22515         5478       161319
    4       161319       631740        69081            0        15451       501964       206563
    5       206563       568350        69081            0        16558       482711       206563
    6       206563       225380        69081            0        16704       151801       194357
    7       194357       156530        69081            0        22286       102376       157144
    8       157144        45050        69081            0        19260            0       113853
    9       113853        96250        69081            0        13888            0       127134
   10       127134        33870        69081            0        13605            0        78318
   11        78318        13260        69081            0         8824            0        13673
   12        13673        82430        69081            0         5558            0        21464
   13        21464       128560        69081            0         9510            0        71433
   14        71433        12440        69081            0         9694            0         5098
   15         5098       115180        69081            0         7594            0        43603
   16        43603        40180        69081            0         8186            0         6516
   17         6516       545850        69081            0        10510       266212       206563
   18       206563       307860        69081            0        16080       253566       175696
   19       175696       283510        69081            0        12095       171467       206563
   20       206563       375360        69081            0        15107       291175       206560
   21       206560       433960        69081            0        16136       348740       206563
   22       206563        86170        69081            0        21969         4849       196834
   23       196834        28250        69081            0        23743            0       132260
   24       132260        81300        69081            0        13360            0       131119
   25       131119       540340        69081            0        12947       382868       206563


  PERIOD TOTALS        5841090      1727025            0       356298      3757767


PERIOD AVERAGES         233643        69081            0        14251       150310
1
                TITLE CARD  Stillhouse Hollow 2050 Sediment * Unappropriated + Stream Depletions

                SIMULATION PERIOD TOTAL SUMMARY BY YEAR***

 YEAR START. STRG.  UNREG. FLOW      DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
    1       206563       614310        69081            0        11990       538420       201382
    2       201382       343130        69081            0        12728       256140       206563
    3       206563        51830        69081            0        22515         5478       161319
    4       161319       631740        69081            0        15451       501964       206563
    5       206563       568350        69081            0        16558       482711       206563
    6       206563       225380        69081            0        16704       151801       194357
    7       194357       156530        69081            0        22286       102376       157144
    8       157144        45050        69081            0        19260            0       113853
    9       113853        96250        69081            0        13888            0       127134
   10       127134        33870        69081            0        13605            0        78318
   11        78318        13260        69081            0         8824            0        13673
   12        13673        82430        69081            0         5558            0        21464
   13        21464       128560        69081            0         9510            0        71433
   14        71433        12440        69081            0         9694            0         5098
   15         5098       115180        69081            0         7594            0        43603
   16        43603        40180        69081            0         8186            0         6516
   17         6516       545850        69081            0        10510       266212       206563
   18       206563       307860        69081            0        16080       253566       175696
   19       175696       283510        69081            0        12095       171467       206563
   20       206563       375360        69081            0        15107       291175       206560
   21       206560       433960        69081            0        16136       348740       206563
   22       206563        86170        69081            0        21969         4849       196834
   23       196834        28250        69081            0        23743            0       132260
   24       132260        81300        69081            0        13360            0       131119
   25       131119       540340        69081            0        12947       382868       206563


  PERIOD TOTALS        5841090      1727025            0       356298      3757767


PERIOD AVERAGES         233643        69081            0        14251       150310
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Granger
Yield
1995

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1

     RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

           TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

                NUMBER OF NODES =    2              NUMBER OF RESERVOIRS =  2

                NUMBER OF LINKS =    1           NUMBER OF RIVER REACHES =  1

     CALENDAR YEAR OPERATION STARTS = 1941     NUMBER OF YEARS TO SIMULATE = 25

         NUMBER OF DEMAND NODES =    2             NUMBER OF SPILL NODES =  2

                     YIELD NODE =    0                       IMPORT NODE =  0


     NODE NO.   NODE NAME    --------- CAPACITIES ---------    YEARLY
                               MAXIMUM  MINIMUM   STARTING    DEMAND

        1       GEORGETN        37010        0      37010      13610

        2       GRANGER         54280        0      54280      20600
1
     RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

           TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

     SYSTEM CONFIGURATION

     LINK NO.    FROM NODE     TO NODE     MAX. CAPACITY    MIN. CAPACITY

        1            1            2          999999999              0


     LIST OF SPILL RESERVOIRS -      1    2

     YEARLY IMPORT QUANTITY =         0

     MONTHLY IMPORT DISTRIBUTION -   .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00

     SUB-SYSTEM OF RESERVOIRS      1

     'AVERAGE' DEFINED AS BETWEEN40.00, AND99.00 PERCENT FULL OF SUBSYSTEM


     FACTORS

          MULTIPLY LINK CAPACITIES BY     1.000

          MULTIPLY INFLOWS BY .......     10.00

          MULTIPLY DEMANDS BY .......      1.00
1
     RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

           TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

                                   MONTHLY DEMAND DISTRIBUTION
     NODE NO.           JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY   AUG.   SEPT   OCT.   NOV.   DEC.    * RANK *
                                                                                                            AVG DRY WET

        1              .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700    1   1   1

        2              .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700    3   3   3
1
     RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

           TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm
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                                   DESIRED MONTHLY STORAGE LEVEL (PERCENT FULL)
       RESERVOIR NO.

            1  AVRG    1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        2
               DRY     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        2
               WET     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        2

            2  AVRG    1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        4
               DRY     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        4
               WET     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        4
1

       RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

             TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm


                                  RESERVOIRS AREA - CAPACITY TABLES


         RESERVOIR NO.  1   RESERVOIR NO.  2    RESERVOIR NO.
   1            0       0         0       0
   2          150     973       284    1234
   3          363    4789       608    2904
   4          441    6800       801    4321
   5          538    9237       955    6073
   6          636   12166      1149    8166
   7          707   14174      1375   10688
   8          786   16410      1599   13660
   9          849   18864      1843   17100
  10          919   21513      2114   21049
  11          998   24388      2428   25585
  12         1083   27500      2770   30790
  13         1137   29729      3087   36643
  14         1188   32056      3466   43159
  15         1238   34483      3786   50417
  16         1297   37010      4009   54280
  17            0       0         0       0
  18            0       0         0       0
1
             TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR  6     CALENDAR YEAR 1946

                    RESERVOIR NO  1  GEORGETN   MAX. CAPACITY   37010  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM              SURFACE  EVAP    EVAP  DWNSTRM              PUMPED    PUMPED   SYSTEM END MO.    OPER.
   MONTH   STORAGE INFLOWS   SPILLS     DEMAND    AREA   RATE    LOSS    SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
     1      37010    7520        0        817    1296   -.08    -103        0        0        0        0     6806    37010    37010
     2      37010   10170        0        817    1297    .04      52        0        0        0        0     9301    37010    37010
     3      37010    9890        0        953    1297    .10     130        0        0        0        0     8807    37010    37010
     4      37010    9930        0       1089    1297    .12     156        0        0        0        0     8685    37010    37010
     5      37010   15100        0       1089    1297    .03      39        0        0        0        0    13972    37010    37010
     6      37010    8650        0       1225    1297    .38     493        0        0        0        0     6932    37010    37010
     7      37010    2200        0       1633    1297    .78    1012        0        0        0        0        0    36565    37010
     8      36565    1120        0       1633    1271    .67     852        0        0        0        0        0    35200    37010
     9      35200       0        0       1225    1240    .10     124        0        0        0        0        0    33851    37010
    10      33851    2700        0       1225    1240    .29     360        0        0        0        0        0    34966    37010
    11      34966   17910        0        953    1273    .01      13        0        0        0        0    14900    37010    37010
    12      37010   12150        0        953    1297    .06      78        0        0        0        0    11119    37010    37010

    YEAR TOTALS    97340        0    13612                      3206        0        0        0        0    80522

                    RESERVOIR NO  2  GRANGER    MAX. CAPACITY   54280  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM              SURFACE  EVAP    EVAP  DWNSTRM              PUMPED    PUMPED   SYSTEM END MO.    OPER.
   MONTH   STORAGE INFLOWS   SPILLS     DEMAND    AREA   RATE    LOSS    SPILLS SHORTAGE     INTO      OUT     LOSS  CONTENT     RULE
     1      54280   12150        0       1236    3995   -.12    -478        0        0        0        0    11394    54278    54280
     2      54278   15840        0       1236    4009    .00       0        0        0        0        0    14602    54280    54280
     3      54280   14630        0       1442    4007   -.02     -79        0        0        0        0    13267    54280    54280
     4      54280   15890        0       1648    4009    .07     281        0        0        0        0    13961    54280    54280
     5      54280   24300        0       1648    4003   -.05    -199        0        0        0        0    22851    54280    54280
     6      54280   12600        0       1854    4009    .30    1203        0        0        0        0     9543    54280    54280
     7      54280    2580        0       2472    4009    .67    2686        0        0        0        0        0    51702    54280
     8      51702    1270        0       2472    3775    .50    1887        0        0        0        0        0    48613    54280
     9      48613    7190        0       1854    3836    .09     345        0        0        0        0        0    53604    54280
    10      53604    3980        0       1854    3989    .27    1077        0        0        0        0      373    54280    54280
    11      54280   31610        0       1442    3993   -.14    -558        0        0        0        0    30728    54278    54280
    12      54278   19530        0       1442    4009    .03     120        0        0        0        0    17966    54280    54280

    YEAR TOTALS   161570        0    20600                      6285        0        0        0        0   134685
1
             TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR  7     CALENDAR YEAR 1947
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                  RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL       0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP    EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.    OPER.
MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
    1     37010    22150       0       817     1295   -.14    -180        0        0        0         0    21514    37009    37010
    2     37009     8510       0       817     1297    .19     246        0        0        0         0     7446    37010    37010
    3     37010     9360       0       953     1297    .05      65        0        0        0         0     8342    37010    37010
    4     37010    10020       0      1089     1297    .10     130        0        0        0         0     8801    37010    37010
    5     37010    10180       0      1089     1297    .20     259        0        0        0         0     8832    37010    37010
    6     37010     4230       0      1225     1297    .57     739        0        0        0         0     2266    37010    37010
    7     37010     1180       0      1633     1292    .76     982        0        0        0         0        0    35575    37010
    8     35575      780       0      1633     1246    .49     611        0        0        0         0        0    34111    37010
    9     34111      620       0      1225     1215    .69     838        0        0        0         0        0    32668    37010
   10     32668      420       0      1225     1185    .56     664        0        0        0         0        0    31199    37010
   11     31199      520       0       953     1162    .22     256        0        0        0         0        0    30510    37010
   12     30510      790       0       953     1152    .01      12        0        0        0         0        0    30335    37010

  YEAR TOTALS      68760       0     13612                    4622        0        0        0         0    57201

                  RESERVOIR NO  2  GRANGER     MAX. CAPACITY   54280  MIN. OPERATING POOL       0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP    EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.    OPER.
MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
    1     54280    36260       0      1236     3994   -.13    -518        0        0        0         0    35544    54278    54280
    2     54278    10890       0      1236     4009    .17     682        0        0        0         0     8970    54280    54280
    3     54280    12980       0      1442     4008   -.01     -39        0        0        0         0    11577    54280    54280
    4     54280    13740       0      1648     4009    .06     241        0        0        0         0    11851    54280    54280
    5     54280    14070       0      1648     4009    .10     401        0        0        0         0    12021    54280    54280
    6     54280     5820       0      1854     4009    .46    1844        0        0        0         0     2122    54280    54280
    7     54280     1410       0      2472     3906    .64    2500        0        0        0         0        0    50718    54280
    8     50718     1020       0      2472     3739    .34    1271        0        0        0         0        0    47995    54280
    9     47995      790       0      1854     3605    .64    2307        0        0        0         0        0    44624    54280
   10     44624      480       0      1854     3459    .52    1799        0        0        0         0        0    41451    54280
   11     41451      630       0      1442     3328    .15     499        0        0        0         0        0    40140    54280
   12     40140     1020       0      1442     3281   -.03     -97        0        0        0         0        0    39815    54280

  YEAR TOTALS      99110       0     20600                   10890        0        0        0         0    82085
1
                  TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

 SIMULATION YEAR  8     CALENDAR YEAR 1948

                  RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL       0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP    EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.    OPER.
MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
    1     30335      870       0       817     1151    .05      58        0        0        0         0        0    30330    37010
    2     30330        0       0       817     1141   -.06     -67        0        0        0         0        0    29580    37010
    3     29580     1720       0       953     1139    .21     239        0        0        0         0        0    30108    37010
    4     30108     2450       0      1089     1157    .23     266        0        0        0         0        0    31203    37010
    5     31203     4000       0      1089     1200    .18     216        0        0        0         0        0    33898    37010
    6     33898     1220       0      1225     1219    .53     646        0        0        0         0        0    33247    37010
    7     33247     1290       0      1633     1202    .56     673        0        0        0         0        0    32231    37010
    8     32231      200       0      1633     1167    .75     875        0        0        0         0        0    29923    37010
    9     29923       10       0      1225     1120    .52     582        0        0        0         0        0    28126    37010
   10     28126      190       0      1225     1079    .47     507        0        0        0         0        0    26584    37010
   11     26584      100       0       953     1041    .34     354        0        0        0         0        0    25377    37010
   12     25377      170       0       953     1012    .19     192        0        0        0         0        0    24402    37010

  YEAR TOTALS      12220       0     13612                    4541        0        0        0         0        0

                  RESERVOIR NO  2  GRANGER     MAX. CAPACITY   54280  MIN. OPERATING POOL       0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP    EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.    OPER.
MONTH   STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
    1     39815      990       0      1236     3264    .00       0        0        0        0         0        0    39569    54280
    2     39569        0       0      1236     3231   -.10    -322        0        0        0         0        0    38655    54280
    3     38655     2700       0      1442     3224    .18     580        0        0        0         0        0    39333    54280
    4     39333     4090       0      1648     3295    .20     659        0        0        0         0        0    41116    54280
    5     41116     7020       0      1648     3484    .14     488        0        0        0         0        0    46000    54280
    6     46000     2000       0      1854     3558    .46    1637        0        0        0         0        0    44509    54280
    7     44509     2310       0      2472     3484    .49    1707        0        0        0         0        0    42640    54280
    8     42640      360       0      2472     3306    .71    2347        0        0        0         0        0    38181    54280
    9     38181      110       0      1854     3082    .49    1510        0        0        0         0        0    34927    54280
   10     34927      330       0      1854     2917    .45    1313        0        0        0         0        0    32090    54280
   11     32090      170       0      1442     2784    .29     807        0        0        0         0        0    30011    54280
   12     30011      260       0      1442     2664    .18     480        0        0        0         0        0    28349    54280

  YEAR TOTALS      20340       0     20600                   11206        0        0        0         0        0
1
                  TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

 SIMULATION YEAR  9     CALENDAR YEAR 1949

                  RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL       0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP    EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.    OPER.
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   MONTH STORAGE INFLOWS  SPILLS    DEMAND      AREA  RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
       1   24402    1270       0       817      1007  -.16    -160        0        0        0         0        0    25015    37010
       2   25015    1970       0       817      1032  -.06     -61        0        0        0         0        0    26229    37010
       3   26229       0       0       953      1034   .10     103        0        0        0         0        0    25173    37010
       4   25173   21850       0      1089      1164  -.24    -278        0        0        0         0     9203    37009    37010
       5   37009    5010       0      1089      1297   .34     441        0        0        0         0     3479    37010    37010
       6   37010    1440       0      1225      1297   .28     363        0        0        0         0        0    36862    37010
       7   36862     700       0      1633      1273   .64     815        0        0        0         0        0    35114    37010
       8   35114     300       0      1633      1229   .61     750        0        0        0         0        0    33031    37010
       9   33031     210       0      1225      1191   .54     643        0        0        0         0        0    31373    37010
      10   31373     160       0      1225      1160   .12     139        0        0        0         0        0    30169    37010
      11   30169     350       0       953      1135   .40     454        0        0        0         0        0    29112    37010
      12   29112    1170       0       953      1125  -.02     -22        0        0        0         0        0    29351    37010

     YEAR TOTALS   34430       0     13612                    3187        0        0        0         0    12682

                  RESERVOIR NO  2  GRANGER     MAX. CAPACITY    54280  MIN. OPERATING POOL        0
0        INITIAL    UREG  UPSTRM               SURFACE  EVAP    EVAP  DWNSTRM             PUMPED    PUMPED   SYSTEM  END MO.    OPER.
   MONTH STORAGE INFLOWS  SPILLS    DEMAND      AREA  RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
       1   28349    2260       0      1236      2663  -.23    -611        0        0        0         0        0    29984    54280
       2   29984    3590       0      1236      2795  -.07    -195        0        0        0         0        0    32533    54280
       3   32533       0       0      1442      2819   .08     226        0        0        0         0        0    30865    54280
       4   30865   40380       0      1648      3411  -.21    -715        0        0        0         0    16037    54275    54280
       5   54275    8830       0      1648      4009   .36    1443        0        0        0         0     5734    54280    54280
       6   54280    2270       0      1854      4009   .23     922        0        0        0         0        0    53774    54280
       7   53774    1070       0      2472      3879   .54    2095        0        0        0         0        0    50277    54280
       8   50277     420       0      2472      3691   .53    1956        0        0        0         0        0    46269    54280
       9   46269     340       0      1854      3534   .46    1626        0        0        0         0        0    43129    54280
      10   43129     260       0      1854      3416   .02      68        0        0        0         0        0    41467    54280
      11   41467     640       0      1442      3307   .39    1290        0        0        0         0        0    39375    54280
      12   39375    1820       0      1442      3267  -.11    -358        0        0        0         0        0    40111    54280

     YEAR TOTALS   61880       0     20600                    7747        0        0        0         0    21771
1
                  TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR 10     CALENDAR YEAR 1950

                  RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    37010  MIN. OPERATING POOL        0
0        INITIAL    UREG  UPSTRM               SURFACE  EVAP    EVAP  DWNSTRM             PUMPED    PUMPED   SYSTEM  END MO.    OPER.
   MONTH STORAGE INFLOWS  SPILLS    DEMAND      AREA  RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
       1   29351     570       0       817      1125   .05      56        0        0        0         0        0    29048    37010
       2   29048    4440       0       817      1162  -.05     -57        0        0        0         0        0    32728    37010
       3   32728     910       0       953      1197   .33     395        0        0        0         0        0    32290    37010
       4   32290    4940       0      1089      1232  -.06     -73        0        0        0         0        0    36214    37010
       5   36214    2090       0      1089      1288   .14     180       25        0        0         0        0    37010    37010
       6   37010    2690       0      1225      1297   .30     389        0        0        0         0     1076    37010    37010
       7   37010     840       0      1633      1288   .59     760        0        0        0         0        0    35457    37010
       8   35457     240       0      1633      1233   .82    1011        0        0        0         0        0    33053    37010
       9   33053    2590       0      1225      1219   .29     354        0        0        0         0        0    34064    37010
      10   34064     340       0      1225      1214   .49     595        0        0        0         0        0    32584    37010
      11   32584     160       0       953      1185   .46     545        0        0        0         0        0    31246    37010
      12   31246     230       0       953      1158   .31     359        0        0        0         0        0    30164    37010

     YEAR TOTALS   20040       0     13612                    4514       25        0        0         0     1076

                  RESERVOIR NO  2  GRANGER     MAX. CAPACITY    54280  MIN. OPERATING POOL        0
0        INITIAL    UREG  UPSTRM               SURFACE  EVAP    EVAP  DWNSTRM             PUMPED    PUMPED   SYSTEM  END MO.    OPER.
   MONTH STORAGE INFLOWS  SPILLS    DEMAND      AREA  RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
       1   40111     700       0      1236      3270   .03      98        0        0        0         0        0    39477    54280
       2   39477    7820       0      1236      3450  -.07    -241        0        0        0         0        0    46302    54280
       3   46302    1140       0      1442      3577   .27     966        0        0        0         0        0    45034    54280
       4   45034    8730       0      1648      3705  -.11    -407        0        0        0         0        0    52523    54280
       5   52523    3590      25      1648      3958   .12     475        0        0        0         0        0    54015    54280
       6   54015    4680       0      1854      4001   .20     800        0        0        0         0     1761    54280    54280
       7   54280    1360       0      2472      3919   .51    1999        0        0        0         0        0    51169    54280
       8   51169     360       0      2472      3714   .72    2674        0        0        0         0        0    46383    54280
       9   46383    4650       0      1854      3652   .22     803        0        0        0         0        0    48376    54280
      10   48376     450       0      1854      3630   .44    1597        0        0        0         0        0    45375    54280
      11   45375     200       0      1442      3505   .41    1437        0        0        0         0        0    42696    54280
      12   42696     280       0      1442      3378   .28     946        0        0        0         0        0    40588    54280

     YEAR TOTALS   33960      25     20600                   11147        0        0        0         0     1761
1
                  TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR 11     CALENDAR YEAR 1951

                  RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    37010  MIN. OPERATING POOL        0
0        INITIAL    UREG  UPSTRM               SURFACE  EVAP    EVAP  DWNSTRM             PUMPED    PUMPED   SYSTEM  END MO.    OPER.
   MONTH STORAGE INFLOWS  SPILLS    DEMAND      AREA  RATE    LOSS   SPILLS SHORTAGE     INTO       OUT     LOSS  CONTENT     RULE
       1   30164     270       0       817      1137   .27     307        0        0        0         0        0    29310    37010
       2   29310     160       0       817      1119  -.02     -21        0        0        0         0        0    28674    37010
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        3    28674      0        0      953     1097    .23     252        0        0        0        0        0    27469    37010
        4    27469    370        0     1089     1068    .29     310        0        0        0        0        0    26440    37010
        5    26440      0        0     1089     1038    .10     104        0        0        0        0        0    25247    37010
        6    25247   2300        0     1225     1032    .29     299        0        0        0        0        0    26023    37010
        7    26023      0        0     1633     1009    .80     807        0        0        0        0        0    23583    37010
        8    23583      0        0     1633      941    .95     894        0        0        0        0        0    21056    37010
        9    21056      0        0     1225      886    .39     346        0        0        0        0        0    19485    37010
       10    19485     90        0     1225      845    .45     380        0        0        0        0        0    17970    37010
       11    17970     50        0      953      812    .28     227        0        0        0        0        0    16840    37010
       12    16840    120        0      953      783    .25     196        0        0        0        0        0    15811    37010

        YEAR TOTALS    3360        0    13612                    4101        0        0        0        0        0

                   RESERVOIR NO  2   GRANGER     MAX. CAPACITY    54280  MIN. OPERATING POOL         0
0           INITIAL    UREG   UPSTRM            SURFACE  EVAP      EVAP  DWNSTRM           PUMPED      PUMPED     SYSTEM END MO.     OPER.
       MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE      LOSS   SPILLS SHORTAGE    INTO        OUT       LOSS  CONTENT     RULE
        1    40588    320        0     1236     3266    .25     816        0        0        0        0        0    38856    54280
        2    38856    700        0     1236     3204   -.04    -127        0        0        0        0        0    38447    54280
        3    38447   3040        0     1442     3219    .20     644        0        0        0        0        0    39401    54280
        4    39401    510        0     1648     3186    .31     988        0        0        0        0        0    37275    54280
        5    37275   2360        0     1648     3131    .15     470        0        0        0        0        0    37517    54280
        6    37517   4200        0     1854     3179    .29     922        0        0        0        0        0    38941    54280
        7    38941    180        0     2472     3083    .80    2466        0        0        0        0        0    34183    54280
        8    34183     30        0     2472     2820    .89    2510        0        0        0        0        0    29231    54280
        9    29231   1180        0     1854     2622    .27     708        0        0        0        0        0    27849    54280
       10    27849    170        0     1854     2486    .43    1069        0        0        0        0        0    25096    54280
       11    25096     80        0     1442     2327    .24     558        0        0        0        0        0    23176    54280
       12    23176    160        0     1442     2200    .22     484        0        0        0        0        0    21410    54280

        YEAR TOTALS   12930        0    20600                   11508        0        0        0        0        0
1
                  TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

       SIMULATION YEAR 12     CALENDAR YEAR 1952

                   RESERVOIR NO  1   GEORGETN    MAX. CAPACITY    37010  MIN. OPERATING POOL         0
0           INITIAL    UREG   UPSTRM            SURFACE  EVAP      EVAP  DWNSTRM           PUMPED      PUMPED     SYSTEM END MO.     OPER.
       MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE      LOSS   SPILLS SHORTAGE    INTO        OUT       LOSS  CONTENT     RULE
        1    15811    140        0      817      750    .22     165        0        0        0        0        0    14969    37010
        2    14969    230        0      817      723    .16     116        0        0        0        0        0    14266    37010
        3    14266    340        0      953      698    .15     105        0        0        0        0        0    13548    37010
        4    13548   2170        0     1089      704   -.02     -13        0        0        0        0        0    14642    37010
        5    14642   4680        0     1089      786    .05      39        0        0        0        0        0    18194    37010
        6    18194   2720        0     1225      846    .47     398        0        0        0        0        0    19291    37010
        7    19291      0        0     1633      832    .61     508        0        0        0        0        0    17150    37010
        8    17150      0        0     1633      770    .97     747        0        0        0        0        0    14770    37010
        9    14770      0        0     1225      702    .39     274        0        0        0        0        0    13271    37010
       10    13271      0        0     1225      646    .68     439        0        0        0        0        0    11607    37010
       11    11607     10        0      953      602   -.04     -23        0        0        0        0        0    10687    37010
       12    10687   1610        0      953      599   -.12     -71        0        0        0        0        0    11415    37010

        YEAR TOTALS   11900        0    13612                    2684        0        0        0        0        0

                   RESERVOIR NO  2   GRANGER     MAX. CAPACITY    54280  MIN. OPERATING POOL         0
0           INITIAL    UREG   UPSTRM            SURFACE  EVAP      EVAP  DWNSTRM           PUMPED      PUMPED     SYSTEM END MO.     OPER.
       MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE      LOSS   SPILLS SHORTAGE    INTO        OUT       LOSS  CONTENT     RULE
        1    21410    190        0     1236     2091    .17     355        0        0        0        0        0    20009    54280
        2    20009    350        0     1236     2007    .07     140        0        0        0        0        0    18983    54280
        3    18983    520        0     1442     1933    .12     232        0        0        0        0        0    17829    54280
        4    17829   3870        0     1648     1973   -.05     -98        0        0        0        0        0    20149    54280
        5    20149   8420        0     1648     2282    .05     114        0        0        0        0        0    26807    54280
        6    26807   4780        0     1854     2564    .48    1231        0        0        0        0        0    28502    54280
        7    28502    150        0     2472     2497    .57    1423        0        0        0        0        0    24757    54280
        8    24757     70        0     2472     2221    .87    1932        0        0        0        0        0    20423    54280
        9    20423      0        0     1854     1970    .55    1083        0        0        0        0        0    17486    54280
       10    17486      0        0     1854     1765    .63    1112        0        0        0        0        0    14520    54280
       11    14520    180        0     1442     1623   -.13    -210        0        0        0        0        0    13468    54280
       12    13468   2870        0     1442     1645   -.15    -246        0        0        0        0        0    15142    54280

        YEAR TOTALS   21400        0    20600                    7068        0        0        0        0        0
1
                  TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

       SIMULATION YEAR 13     CALENDAR YEAR 1953

                   RESERVOIR NO  1   GEORGETN    MAX. CAPACITY    37010  MIN. OPERATING POOL         0
0           INITIAL    UREG   UPSTRM            SURFACE  EVAP      EVAP  DWNSTRM           PUMPED      PUMPED     SYSTEM END MO.     OPER.
       MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE      LOSS   SPILLS SHORTAGE    INTO        OUT       LOSS  CONTENT     RULE
        1    11415   2740        0      817      640    .27     173        0        0        0        0        0    13165    37010
        2    13165   1730        0      817      686    .08      55        0        0        0        0        0    14023    37010
        3    14023    760        0      953      697    .10      70        0        0        0        0        0    13760    37010
        4    13760   2330        0     1089      713    .11      78        0        0        0        0        0    14923    37010
        5    14923   7340        0     1089      827    .09      74        0        0        0        0        0    21100    37010
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       6    21100     1240        0       1225      900    .68      612        0        0         0         0         0    20503     37010
       7    20503        0        0       1633      863    .69      595        0        0         0         0         0    18275     37010
       8    18275       80        0       1633      808    .59      477        0        0         0         0         0    16245     37010
       9    16245     1510        0       1225      779    .44      343        0        0         0         0         0    16187     37010
      10    16187    15950        0       1225      975    .03       29        0        0         0         0         0    30883     37010
      11    30883     2460        0        953     1176    .22      259        0        0         0         0         0    32131     37010
      12    32131    14470        0        953     1240    .08       99        0        0         0         0      8539    37010     37010

      YEAR TOTALS    50610        0      13612                     2864        0        0         0         0      8539

                      RESERVOIR NO  2  GRANGER     MAX. CAPACITY    54280  MIN. OPERATING POOL        0
0         INITIAL     UREG   UPSTRM              SURFACE   EVAP     EVAP  DWNSTRM              PUMPED    PUMPED    SYSTEM  END MO.     OPER.
   MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE      INTO       OUT      LOSS  CONTENT      RULE
       1    15142     4990        0       1236     1822    .24      437        0        0         0         0         0    18459     54280
       2    18459     3220        0       1236     2003    .02       40        0        0         0         0         0    20403     54280
       3    20403     1420        0       1442     2064    .07      144        0        0         0         0         0    20237     54280
       4    20237     4330        0       1648     2147    .05      107        0        0         0         0         0    22812     54280
       5    22812    13480        0       1648     2633    .02       53        0        0         0         0         0    34591     54280
       6    34591     2140        0       1854     2933    .64     1877        0        0         0         0         0    33000     54280
       7    33000        0        0       2472     2775    .64     1776        0        0         0         0         0    28752     54280
       8    28752      180        0       2472     2521    .48     1210        0        0         0         0         0    25250     54280
       9    25250     2780        0       1854     2404    .40      962        0        0         0         0         0    25214     54280
      10    25214    29640        0       1854     3230   -.03      -96        0        0         0         0         0    53096     54280
      11    53096     4070        0       1442     3975    .17      676        0        0         0         0       768    54280     54280
      12    54280    25640        0       1442     4001   -.07     -279        0        0         0         0     24478    54279     54280

      YEAR TOTALS    91890        0      20600                     6907        0        0         0         0     25246
1
                      TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR 14     CALENDAR YEAR 1954

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    37010  MIN. OPERATING POOL        0
0         INITIAL     UREG   UPSTRM              SURFACE   EVAP     EVAP  DWNSTRM              PUMPED    PUMPED    SYSTEM  END MO.     OPER.
   MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE      INTO       OUT      LOSS  CONTENT      RULE
       1    37010     1200        0        817     1297    .14      182       68        0         0         0       133    37010     37010
       2    37010      750        0        817     1296    .31      402        0        0         0         0         0    36541     37010
       3    36541      420        0        953     1280    .29      371        0        0         0         0         0    35637     37010
       4    35637       60        0       1089     1253    .19      238        0        0         0         0         0    34370     37010
       5    34370     2290        0       1089     1249    .29      362        0        0         0         0         0    35209     37010
       6    35209       60        0       1225     1233    .66      814        0        0         0         0         0    33230     37010
       7    33230        0        0       1633     1185    .86     1019        0        0         0         0         0    30578     37010
       8    30578        0        0       1633     1126    .90     1013        0        0         0         0         0    27932     37010
       9    27932        0        0       1225     1067    .75      800        0        0         0         0         0    25907     37010
      10    25907        0        0       1225     1016    .47      478        0        0         0         0         0    24204     37010
      11    24204        0        0        953      976    .26      254        0        0         0         0         0    22997     37010
      12    22997        0        0        953      943    .30      283        0        0         0         0         0    21761     37010

      YEAR TOTALS     4780        0      13612                     6216       68        0         0         0       133

                      RESERVOIR NO  2  GRANGER     MAX. CAPACITY    54280  MIN. OPERATING POOL        0
0         INITIAL     UREG   UPSTRM              SURFACE   EVAP     EVAP  DWNSTRM              PUMPED    PUMPED    SYSTEM  END MO.     OPER.
   MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE      INTO       OUT      LOSS  CONTENT      RULE
       1    54279     1570       68       1236     4009    .10      401        0        0         0         0         0    54280     54280
       2    54280      920        0       1236     4000    .28     1120        0        0         0         0         0    52844     54280
       3    52844      600        0       1442     3869    .29     1122        0        0         0         0         0    50880     54280
       4    50880      100        0       1648     3758    .17      639        0        0         0         0         0    48693     54280
       5    48693     4260        0       1648     3746    .26      974        0        0         0         0         0    50331     54280
       6    50331      140        0       1854     3692    .65     2400        0        0         0         0         0    46217     54280
       7    46217       20        0       2472     3488    .76     2651        0        0         0         0         0    41114     54280
       8    41114       60        0       2472     3201    .82     2625        0        0         0         0         0    36077     54280
       9    36077      120        0       1854     2950    .74     2183        0        0         0         0         0    32160     54280
      10    32160        0        0       1854     2764    .39     1078        0        0         0         0         0    29228     54280
      11    29228        0        0       1442     2600    .23      598        0        0         0         0         0    27188     54280
      12    27188      150        0       1442     2468    .28      691        0        0         0         0         0    25205     54280

      YEAR TOTALS     7940       68      20600                    16482        0        0         0         0         0
1
                      TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR 15     CALENDAR YEAR 1955

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    37010  MIN. OPERATING POOL        0
0         INITIAL     UREG   UPSTRM              SURFACE   EVAP     EVAP  DWNSTRM              PUMPED    PUMPED    SYSTEM  END MO.     OPER.
   MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE      INTO       OUT      LOSS  CONTENT      RULE
       1    21761        0        0        817      914    .06       55        0        0         0         0         0    20889     37010
       2    20889     2330        0        817      923   -.03      -27        0        0         0         0         0    22429     37010
       3    22429     1030        0        953      942    .23      217        0        0         0         0         0    22289     37010
       4    22289     2600        0       1089      958    .26      249        0        0         0         0         0    23551     37010
       5    23551     3540        0       1089     1007    .09       91        0        0         0         0         0    25911     37010
       6    25911     4530        0       1225     1081    .28      303        0        0         0         0         0    28913     37010
       7    28913        0        0       1633     1089    .62      675        0        0         0         0         0    26605     37010
       8    26605        0        0       1633     1031    .40      412        0        0         0         0         0    24560     37010
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      9     24560         0         0      1225       980    .41       402         0         0         0         0         0     22933     37010
     10     22933        70         0      1225       934    .62       579         0         0         0         0         0     21199     37010
     11     21199        60         0       953       894    .43       384         0         0         0         0         0     19922     37010
     12     19922       130         0       953       864    .20       173         0         0         0         0         0     18926     37010

      YEAR TOTALS    14290         0     13612                        3513         0         0         0         0         0

                   RESERVOIR NO  2   GRANGER      MAX. CAPACITY     54280  MIN. OPERATING POOL        0
0         INITIAL      UREG    UPSTRM             SURFACE   EVAP      EVAP   DWNSTRM               PUMPED    PUMPED    SYSTEM  END MO.      OPER.
    MONTH STORAGE   INFLOWS    SPILLS    DEMAND      AREA   RATE      LOSS    SPILLS  SHORTAGE      INTO       OUT      LOSS  CONTENT      RULE
      1     25205       170         0      1236      2361    .04        94         0         0         0         0         0     24045     54280
      2     24045      4230         0      1236      2433   -.10      -242         0         0         0         0         0     27281     54280
      3     27281      1830         0      1442      2537    .18       457         0         0         0         0         0     27212     54280
      4     27212      4780         0      1648      2622    .18       472         0         0         0         0         0     29872     54280
      5     29872      6550         0      1648      2846    .09       256         0         0         0         0         0     34518     54280
      6     34518      8400         0      1854      3129    .27       845         0         0         0         0         0     40219     54280
      7     40219       710         0      2472      3193    .55      1756         0         0         0         0         0     36701     54280
      8     36701      3220         0      2472      3081    .35      1078         0         0         0         0         0     36371     54280
      9     36371        80         0      1854      2991    .41      1226         0         0         0         0         0     33371     54280
     10     33371       100         0      1854      2816    .61      1718         0         0         0         0         0     29899     54280
     11     29899        90         0      1442      2632    .40      1053         0         0         0         0         0     27494     54280
     12     27494       190         0      1442      2499    .16       400         0         0         0         0         0     25842     54280

      YEAR TOTALS    30350         0     20600                        9113         0         0         0         0         0
1
                  TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

    SIMULATION YEAR 16     CALENDAR YEAR 1956

                   RESERVOIR NO  1   GEORGETN     MAX. CAPACITY     37010  MIN. OPERATING POOL        0
0         INITIAL      UREG    UPSTRM             SURFACE   EVAP      EVAP   DWNSTRM               PUMPED    PUMPED    SYSTEM  END MO.      OPER.
    MONTH STORAGE   INFLOWS    SPILLS    DEMAND      AREA   RATE      LOSS    SPILLS  SHORTAGE      INTO       OUT      LOSS  CONTENT      RULE
      1     18926       130         0       817       841    .11        93         0         0         0         0         0     18146     37010
      2     18146       590         0       817       827    .10        83         0         0         0         0         0     17836     37010
      3     17836        80         0       953       807    .40       323         0         0         0         0         0     16640     37010
      4     16640        10         0      1089       770    .37       285         0         0         0         0         0     15276     37010
      5     15276         0         0      1089       723    .30       217         0         0         0         0         0     13970     37010
      6     13970       330         0      1225       676    .68       460         0         0         0         0         0     12615     37010
      7     12615         0         0      1633       614    .92       565         0         0         0         0         0     10417     37010
      8     10417         0         0      1633       542    .92       499         0         0         0         0         0      8285     37010
      9      8285         0         0      1225       468    .81       379         0         0         0         0         0      6681     37010
     10      6681         0         0      1225       409    .50       204         0         0         0         0         0      5252     37010
     11      5252        10         0       953       359    .32       115         0         0         0         0         0      4194     37010
     12      4194        10         0       953       302    .14        42         0         0         0         0         0      3209     37010

      YEAR TOTALS     1160         0     13612                        3265         0         0         0         0         0

                   RESERVOIR NO  2   GRANGER      MAX. CAPACITY     54280  MIN. OPERATING POOL        0
0         INITIAL      UREG    UPSTRM             SURFACE   EVAP      EVAP   DWNSTRM               PUMPED    PUMPED    SYSTEM  END MO.      OPER.
    MONTH STORAGE   INFLOWS    SPILLS    DEMAND      AREA   RATE      LOSS    SPILLS  SHORTAGE      INTO       OUT      LOSS  CONTENT      RULE
      1     25842       190         0      1236      2403    .08       192         0         0         0         0         0     24604     54280
      2     24604      1070         0      1236      2352    .03        71         0         0         0         0         0     24367     54280
      3     24367       120         0      1442      2275    .29       660         0         0         0         0         0     22385     54280
      4     22385       100         0      1648      2131    .29       618         0         0         0         0         0     20219     54280
      5     20219         0         0      1648      1982    .27       535         0         0         0         0         0     18036     54280
      6     18036       670         0      1854      1828    .60      1097         0         0         0         0         0     15755     54280
      7     15755         0         0      2472      1611    .86      1385         0         0         0         0         0     11898     54280
      8     11898         0         0      2472      1322    .85      1124         0         0         0         0         0      8302     54280
      9      8302         0         0      1854      1039    .77       800         0         0         0         0         0      5648     54280
     10      5648         0         0      1854       819    .47       385         0         0         0         0         0      3409     54280
     11      3409       650         0      1442       612    .24       147         0         0         0         0         0      2470     54280
     12      2470      1150         0      1442       489    .13        64         0         0         0         0         0      2114     54280

      YEAR TOTALS     3950         0     20600                        7078         0         0         0         0         0
1
                  TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

    SIMULATION YEAR 17     CALENDAR YEAR 1957

                   RESERVOIR NO  1   GEORGETN     MAX. CAPACITY     37010  MIN. OPERATING POOL        0
0         INITIAL      UREG    UPSTRM             SURFACE   EVAP      EVAP   DWNSTRM               PUMPED    PUMPED    SYSTEM  END MO.      OPER.
    MONTH STORAGE   INFLOWS    SPILLS    DEMAND      AREA   RATE      LOSS    SPILLS  SHORTAGE      INTO       OUT      LOSS  CONTENT      RULE
      1      3209       130         0       817       254    .18        46         0         0         0         0         0      2476     37010
      2      2476         0         0       817       211    .02         4         0         0         0         0         0      1655     37010
      3      1655      1860         0       953       213    .00         0         0         0         0         0         0      2562     37010
      4      2562     48300         0      1089       867   -.52      -450         0         0         0         0     13216     37007     37010
      5     37007     11410         0      1089      1295   -.15      -193         0         0         0         0     10512     37009     37010
      6     37009     29530         0      1225      1297    .21       272         0         0         0         0     28032     37010     37010
      7     37010      1190         0      1633      1292    .79      1021         0         0         0         0         0     35546     37010
      8     35546      3000         0      1633      1279    .87      1113         0         0         0         0         0     35800     37010
      9     35800      1640         0      1225      1274    .22       280         0         0         0         0         0     35935     37010
     10     35935     41040         0      1225      1283   -.11      -140         0         0         0         0     38880     37010     37010
     11     37010     12050         0       953      1296   -.06       -77         0         0         0         0     11174     37010     37010
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       12     37010     7090        0       953      1297     .16      208        0         0         0         0     5929    37010     37010

        YEAR TOTALS   157240        0     13612                         2084        0         0         0         0   107743

                        RESERVOIR NO  2   GRANGER       MAX. CAPACITY    54280  MIN. OPERATING POOL         0
0             INITIAL     UREG    UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM             PUMPED     PUMPED    SYSTEM  END MO.     OPER.
      MONTH   STORAGE   INFLOWS   SPILLS     DEMAND       AREA    RATE     LOSS    SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT      RULE
        1      2114       210        0        1236        349     .18       63        0         0         0         0        0     1025     54280
        2      1025       270        0        1236        125     .00        0        0         0         0         0        0       59     54280
        3        59      3440        0        1442        245    -.05      -11        0         0         0         0        0     2068     54280
        4      2068     89880        0        1648       2598    -.56    -1454        0         0         0         0    37474    54280     54280
        5     54280     21250        0        1648       4006    -.03     -119        0         0         0         0    19721    54280     54280
        6     54280     54970        0        1854       4009     .14      561        0         0         0         0    52555    54280     54280
        7     54280      2280        0        2472       4003     .69     2762        0         0         0         0        0    51326     54280
        8     51326      5380        0        2472       3922     .72     2824        0         0         0         0        0    51410     54280
        9     51410      2620        0        1854       3848     .16      616        0         0         0         0        0    51560     54280
       10     51560     76070        0        1854       3910    -.18     -703        0         0         0         0    72202    54277     54280
       11     54277     21880        0        1442       3998    -.09     -359        0         0         0         0    20795    54279     54280
       12     54279     10880        0        1442       4009     .12      481        0         0         0         0     8956    54280     54280

        YEAR TOTALS   289130        0     20600                         4661        0         0         0         0   211703
1
                   TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

                   SIMULATION PERIOD TOTAL SUMMARY BY NODE  1

        YEAR START. STRG.  UNREG. FLOW     DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
          1        37010       133650        13612            0         2227       118228        36593
          2        36593        67710        13612            0         2481        50976        37010
          3        37010        23450        13612            0         4510        12607        29731
          4        29731       104540        13612            0         2824        80735        37009
          5        37009        92460        13612            0         3207        75640        37010
          6        37010        97340        13612            0         3206        80522        37010
          7        37010        68760        13612            0         4622        57201        30335
          8        30335        12220        13612            0         4541            0        24402
          9        24402        34430        13612            0         3187        12682        29351
         10        29351        20040        13612            0         4514         1076        30164
         11        30164         3360        13612            0         4101            0        15811
         12        15811        11900        13612            0         2684            0        11415
         13        11415        50610        13612            0         2864         8539        37010
         14        37010         4780        13612            0         6216          133        21761
         15        21761        14290        13612            0         3513            0        18926
         16        18926         1160        13612            0         3265            0         3209
         17         3209       157240        13612            0         2084       107743        37010
         18        37010        92890        13612            0         3031        76247        37010
         19        37010        66100        13612            0         2716        49677        37010
         20        37010       102800        13612            0         2975        86214        37009
         21        37009       115470        13612            0         3129        98711        37010
         22        37010        38090        13612            0         4490        19988        37010
         23        37010        13750        13612            0         5464         4548        27131
         24        27131        14960        13612            0         3186            0        25293
         25        25293       151000        13612            0         2677       122994        37010


         PERIOD TOTALS         1493000       340300            0        87714      1064461


        PERIOD AVERAGES          59720        13612            0         3508        42578
1
                   TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

                   SIMULATION PERIOD TOTAL SUMMARY BY NODE  2

        YEAR START. STRG.  UNREG. FLOW     DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
          1        54280       222500        20600            0         5515       199457        51208
          2        51208       110790        20600            0         6388        80954        54280
          3        54280        35130        20600            0        11602        17932        39276
          4        39276       166490        20600            0         6292       124687        54278
          5        54278       146110        20600            0         6960       118548        54280
          6        54280       161570        20600            0         6285       134685        54280
          7        54280        99110        20600            0        10890        82085        39815
          8        39815        20340        20600            0        11206            0        28349
          9        28349        61880        20600            0         7747        21771        40111
         10        40111        33960        20600            0        11147         1761        40588
         11        40588        12930        20600            0        11508            0        21410
         12        21410        21400        20600            0         7068            0        15142
         13        15142        91890        20600            0         6907        25246        54279
         14        54279         7940        20600            0        16482            0        25205
         15        25205        30350        20600            0         9113            0        25842
         16        25842         3950        20600            0         7078            0         2114
         17         2114       289130        20600            0         4661       211703        54280
         18        54280       157520        20600            0         7502       129418        54280
         19        54280       115080        20600            0         6524        88051        54280
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    20        54280       169090        20600          0        6369       142125       54276
    21        54276       189410        20600          0        7301       161522       54280
    22        54280        59210        20600          0       11085        27525       54280
    23        54280        21690        20600          0       14624         6330       34421
    24        34421        39250        20600          0        8856            0       44215
    25        44215       257700        20600          0        7698       219338       54279


   PERIOD TOTALS              2524420       515000          0      216808      1793138


 PERIOD AVERAGES               100976        20600          0        8672        71725
1
                    TITLE CARD  Granger Yield * 1995 Sediment * Georgetown 13,610 acft/yr firm

                    SIMULATION PERIOD TOTAL SUMMARY BY YEAR***

  YEAR START. STRG.  UNREG. FLOW      DEMANDS   SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
     1        91290       356150        34212          0        7742       317685       87801
     2        87801       178500        34212          0        8869       131930       91290
     3        91290        58580        34212          0       16112        30539       69007
     4        69007       271030        34212          0        9116       205422       91287
     5        91287       238570        34212          0       10167       194188       91290
     6        91290       258910        34212          0        9491       215207       91290
     7        91290       167870        34212          0       15512       139286       70150
     8        70150        32560        34212          0       15747            0       52751
     9        52751        96310        34212          0       10934        34453       69462
    10        69462        54000        34212          0       15661         2837       70752
    11        70752        16290        34212          0       15609            0       37221
    12        37221        33300        34212          0        9752            0       26557
    13        26557       142500        34212          0        9771        33785       91289
    14        91289        12720        34212          0       22698          133       46966
    15        46966        44640        34212          0       12626            0       44768
    16        44768         5110        34212          0       10343            0        5323
    17         5323       446370        34212          0        6745       319446       91290
    18        91290       250410        34212          0       10533       205665       91290
    19        91290       181180        34212          0        9240       137728       91290
    20        91290       271890        34212          0        9344       228339       91285
    21        91285       304880        34212          0       10430       260233       91290
    22        91290        97300        34212          0       15575        47513       91290
    23        91290        35440        34212          0       20088        10878       61552
    24        61552        54210        34212          0       12042            0       69508
    25        69508       408700        34212          0       10375       342332       91289


   PERIOD TOTALS              4017420       855300          0      304522      2857599


 PERIOD AVERAGES               160696        34212          0       12180       114303
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**Granger
Yield
2050**

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1
          RIVER BASIN SIMULATION PROGRAM  -           TEXAS WATER DEVELOPMENT BOARD

                   TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

                       NUMBER OF NODES =    2              NUMBER OF RESERVOIRS =  2

                       NUMBER OF LINKS =    1           NUMBER OF RIVER REACHES =  1

          CALENDAR YEAR OPERATION STARTS = 1941     NUMBER OF YEARS TO SIMULATE = 25

                NUMBER OF DEMAND NODES =    2              NUMBER OF SPILL NODES =  2

                            YIELD NODE =    0                        IMPORT NODE =  0


          NODE NO.   NODE NAME    --------- CAPACITIES ---------     YEARLY
                                    MAXIMUM  MINIMUM   STARTING      DEMAND

            1        GEORGETN        36711        0      36711        13610

            2        GRANGER         38330        0      38330        15800
1
          RIVER BASIN SIMULATION PROGRAM  -           TEXAS WATER DEVELOPMENT BOARD

                   TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

          SYSTEM CONFIGURATION

          LINK NO.    FROM NODE     TO NODE     MAX. CAPACITY    MIN. CAPACITY

             1            1            2          999999999               0


          LIST OF SPILL RESERVOIRS -     1    2

          YEARLY IMPORT QUANTITY =         0

          MONTHLY IMPORT DISTRIBUTION -   .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00

          SUB-SYSTEM OF RESERVOIRS      1

          'AVERAGE' DEFINED AS BETWEEN40.00, AND99.00 PERCENT FULL OF SUBSYSTEM


          FACTORS

               MULTIPLY LINK CAPACITIES BY     1.000

               MULTIPLY INFLOWS BY .......     10.00

               MULTIPLY DEMANDS BY .......      1.00
1
          RIVER BASIN SIMULATION PROGRAM  -           TEXAS WATER DEVELOPMENT BOARD

                   TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

                                            MONTHLY DEMAND DISTRIBUTION
          NODE NO.          JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY   AUG.   SEPT   OCT.   NOV.   DEC.    * RANK *
                                                                                                                 AVG DRY WET

             1             .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700    1   1   1

             2             .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700    3   3   3
1
          RIVER BASIN SIMULATION PROGRAM  -           TEXAS WATER DEVELOPMENT BOARD

                   TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm
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                                   DESIRED MONTHLY STORAGE LEVEL (PERCENT FULL)
      RESERVOIR NO.

          1  AVRG   1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       2
             DRY    1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       2
             WET    1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       2

          2  AVRG   1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       4
             DRY    1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       4
             WET    1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       4
1

      RIVER BASIN SIMULATION PROGRAM  -           TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm


                                  RESERVOIRS AREA - CAPACITY TABLES


          RESERVOIR NO.  1    RESERVOIR NO.  2    RESERVOIR NO.
   1         0        0         0        0
   2       145      941         0        0
   3       358     4683        59       33
   4       435     6667       229      330
   5       532     9076       365      920
   6       631    11977       548     1822
   7       702    13969       769     3138
   8       781    16189       994     4898
   9       844    18628      1246     7136
  10       914    21262      1532     9906
  11       994    24123      1871    13303
  12      1079    27230      2248    17429
  13      1133    29444      2617    22291
  14      1185    31764      3072    27944
  15      1236    34185      3527    34553
  16      1297    36711      4009    38330
  17         0        0         0        0
  18         0        0         0        0
1
              TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR  6     CALENDAR YEAR 1946

                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL        0
0        INITIAL     UREG   UPSTRM               SURFACE  EVAP     EVAP  DWNSTRM           PUMPED      PUMPED   SYSTEM END MO.    OPER.
  MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE    INTO        OUT     LOSS  CONTENT     RULE
    1     36711     7520        0        817      1296   -.08     -103        0        0       0          0     6806    36711    36711
    2     36711    10170        0        817      1297    .04       52        0        0       0          0     9301    36711    36711
    3     36711     9890        0        953      1297    .10      130        0        0       0          0     8807    36711    36711
    4     36711     9930        0       1089      1297    .12      156        0        0       0          0     8685    36711    36711
    5     36711    15100        0       1089      1297    .03       39        0        0       0          0    13972    36711    36711
    6     36711     8650        0       1225      1297    .38      493        0        0       0          0     6932    36711    36711
    7     36711     2200        0       1633      1297    .78     1012        0        0       0          0        0    36266    36711
    8     36266     1120        0       1633      1270    .67      851        0        0       0          0        0    34902    36711
    9     34902        0        0       1225      1239    .10      124        0        0       0          0        0    33553    36711
   10     33553     2700        0       1225      1234    .29      358        0        0       0          0        0    34670    36711
   11     34670    17910        0        953      1272    .01       13        0        0       0          0    14903    36711    36711
   12     36711    12150        0        953      1297    .06       78        0        0       0          0    11119    36711    36711

    YEAR TOTALS    97340        0      13612                      3203        0        0       0          0    80525

                    RESERVOIR NO  2  GRANGER     MAX. CAPACITY    38330  MIN. OPERATING POOL        0
0        INITIAL     UREG   UPSTRM               SURFACE  EVAP     EVAP  DWNSTRM           PUMPED      PUMPED   SYSTEM END MO.    OPER.
  MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE    INTO        OUT     LOSS  CONTENT     RULE
    1     38330    12150        0        948      3978   -.12     -476        0        0       0          0    11682    38326    38330
    2     38326    15840        0        948      4009    .00        0        0        0       0          0    14888    38330    38330
    3     38330    14630        0       1106      4004   -.02      -79        0        0       0          0    13603    38330    38330
    4     38330    15890        0       1264      4009    .07      281        0        0       0          0    14345    38330    38330
    5     38330    24300        0       1264      3996   -.05     -199        0        0       0          0    23235    38330    38330
    6     38330    12600        0       1422      4009    .30     1203        0        0       0          0     9975    38330    38330
    7     38330     2580        0       1896      4009    .67     2686        0        0       0          0        0    36328    38330
    8     36328     1270        0       1896      3599    .50     1799        0        0       0          0        0    33903    38330
    9     33903     7190        0       1422      3726    .09      335        0        0       0          0     1006    38330    38330
   10     38330     3980        0       1422      4009    .27     1082        0        0       0          0     1476    38330    38330
   11     38330    31610        0       1106      3973   -.14     -555        0        0       0          0    31064    38325    38330
   12     38325    19530        0       1106      4009    .03      120        0        0       0          0    18299    38330    38330

    YEAR TOTALS   161570        0      15800                      6197        0        0       0          0   139573
1
              TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR  7     CALENDAR YEAR 1947
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                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL          0
0          INITIAL     UREG    UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM                PUMPED    PUMPED    SYSTEM END MO.      OPER.
   MONTH   STORAGE  INFLOWS    SPILLS    DEMAND      AREA    RATE     LOSS    SPILLS  SHORTAGE     INTO       OUT      LOSS   CONTENT      RULE
     1      36711     22150        0        817      1295    -.14     -180       0         0          0         0    21514    36710     36711
     2      36710      8510        0        817      1297     .19      246       0         0          0         0     7446    36711     36711
     3      36711      9360        0        953      1297     .05       65       0         0          0         0     8342    36711     36711
     4      36711     10020        0       1089      1297     .10      130       0         0          0         0     8801    36711     36711
     5      36711     10180        0       1089      1297     .20      259       0         0          0         0     8832    36711     36711
     6      36711      4230        0       1225      1297     .57      739       0         0          0         0     2266    36711     36711
     7      36711      1180        0       1633      1292     .76      982       0         0          0         0        0    35276     36711
     8      35276       780        0       1633      1245     .49      610       0         0          0         0        0    33813     36711
     9      33813       620        0       1225      1213     .69      837       0         0          0         0        0    32371     36711
    10      32371       420        0       1225      1182     .56      662       0         0          0         0        0    30904     36711
    11      30904       520        0        953      1158     .22      255       0         0          0         0        0    30216     36711
    12      30216       790        0        953      1148     .01       11       0         0          0         0        0    30042     36711

    YEAR TOTALS     68760         0     13612                       4616         0         0          0         0    57201

                      RESERVOIR NO  2  GRANGER     MAX. CAPACITY    38330  MIN. OPERATING POOL          0
0          INITIAL     UREG    UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM                PUMPED    PUMPED    SYSTEM END MO.      OPER.
   MONTH   STORAGE  INFLOWS    SPILLS    DEMAND      AREA    RATE     LOSS    SPILLS  SHORTAGE     INTO       OUT      LOSS   CONTENT      RULE
     1      38330     36260        0        948      3976    -.13     -516       0         0          0         0    35832    38326     38330
     2      38326     10890        0        948      4009     .17      682       0         0          0         0     9256    38330     38330
     3      38330     12980        0       1106      4006    -.01      -39       0         0          0         0    11913    38330     38330
     4      38330     13740        0       1264      4009     .06      241       0         0          0         0    12235    38330     38330
     5      38330     14070        0       1264      4009     .10      401       0         0          0         0    12405    38330     38330
     6      38330      5820        0       1422      4009     .46     1844       0         0          0         0     2554    38330     38330
     7      38330      1410        0       1896      3822     .64     2446       0         0          0         0        0    35398     38330
     8      35398      1020        0       1896      3514     .34     1195       0         0          0         0        0    33327     38330
     9      33327       790        0       1422      3347     .64     2142       0         0          0         0        0    30553     38330
    10      30553       480        0       1422      3163     .52     1645       0         0          0         0        0    27966     38330
    11      27966       630        0       1106      3036     .15      455       0         0          0         0        0    27035     38330
    12      27035      1020        0       1106      2999    -.03      -89       0         0          0         0        0    27038     38330

    YEAR TOTALS     99110         0     15800                      10407         0         0          0         0    84195
1
                    TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

  SIMULATION YEAR  8     CALENDAR YEAR 1948

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL          0
0          INITIAL     UREG    UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM                PUMPED    PUMPED    SYSTEM END MO.      OPER.
   MONTH   STORAGE  INFLOWS    SPILLS    DEMAND      AREA    RATE     LOSS    SPILLS  SHORTAGE     INTO       OUT      LOSS   CONTENT      RULE
     1      30042       870        0        817      1147     .05       57       0         0          0         0        0    30038     36711
     2      30038         0        0        817      1137    -.06      -67       0         0          0         0        0    29288     36711
     3      29288      1720        0        953      1135     .21      238       0         0          0         0        0    29817     36711
     4      29817      2450        0       1089      1154     .23      265       0         0          0         0        0    30913     36711
     5      30913      4000        0       1089      1198     .18      216       0         0          0         0        0    33608     36711
     6      33608      1220        0       1225      1217     .53      645       0         0          0         0        0    32958     36711
     7      32958      1290        0       1633      1199     .56      671       0         0          0         0        0    31944     36711
     8      31944       200        0       1633      1163     .75      872       0         0          0         0        0    29639     36711
     9      29639        10        0       1225      1116     .52      580       0         0          0         0        0    27844     36711
    10      27844       190        0       1225      1075     .47      505       0         0          0         0        0    26304     36711
    11      26304       100        0        953      1037     .34      353       0         0          0         0        0    25098     36711
    12      25098       170        0        953      1007     .19      191       0         0          0         0        0    24124     36711

    YEAR TOTALS     12220         0     13612                       4526         0         0          0         0        0

                      RESERVOIR NO  2  GRANGER     MAX. CAPACITY    38330  MIN. OPERATING POOL          0
0          INITIAL     UREG    UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM                PUMPED    PUMPED    SYSTEM END MO.      OPER.
   MONTH   STORAGE  INFLOWS    SPILLS    DEMAND      AREA    RATE     LOSS    SPILLS  SHORTAGE     INTO       OUT      LOSS   CONTENT      RULE
     1      27038       990        0        948      3001     .00        0       0         0          0         0        0    27080     38330
     2      27080         0        0        948      2976    -.10     -297       0         0          0         0        0    26429     38330
     3      26429      2700        0       1106      2992     .18      539       0         0          0         0        0    27484     38330
     4      27484      4090        0       1264      3116     .20      623       0         0          0         0        0    29687     38330
     5      29687      7020        0       1264      3374     .14      472       0         0          0         0        0    34971     38330
     6      34971      2000        0       1422      3520     .46     1619       0         0          0         0        0    33930     38330
     7      33930      2310        0       1896      3440     .49     1686       0         0          0         0        0    32658     38330
     8      32658       360        0       1896      3264     .71     2317       0         0          0         0        0    28805     38330
     9      28805       110        0       1422      3029     .49     1484       0         0          0         0        0    26009     38330
    10      26009       330        0       1422      2821     .45     1269       0         0          0         0        0    23648     38330
    11      23648       170        0       1106      2657     .29      771       0         0          0         0        0    21941     38330
    12      21941       260        0       1106      2541     .18      457       0         0          0         0        0    20638     38330

    YEAR TOTALS     20340         0     15800                      10940         0         0          0         0        0
1
                    TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

  SIMULATION YEAR  9     CALENDAR YEAR 1949

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL          0
0          INITIAL     UREG    UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM                PUMPED    PUMPED    SYSTEM END MO.      OPER.
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MONTH    STORAGE  INFLOWS   SPILLS    DEMAND        AREA  RATE     LOSS   SPILLS SHORTAGE     INTO        OUT     LOSS  CONTENT     RULE
    1      24124     1270        0       817        1002  -.16     -159        0        0        0          0        0    24736    36711
    2      24736     1970        0       817        1027  -.06      -61        0        0        0          0        0    25950    36711
    3      25950        0        0       953        1030   .10      103        0        0        0          0        0    24894    36711
    4      24894    21850        0      1089        1160  -.24     -277        0        0        0          0     9222    36710    36711
    5      36710     5010        0      1089        1297   .34      441        0        0        0          0     3479    36711    36711
    6      36711     1440        0      1225        1297   .28      363        0        0        0          0        0    36563    36711
    7      36563      700        0      1633        1272   .64      814        0        0        0          0        0    34816    36711
    8      34816      300        0      1633        1227   .61      748        0        0        0          0        0    32735    36711
    9      32735      210        0      1225        1188   .54      642        0        0        0          0        0    31078    36711
   10      31078      160        0      1225        1156   .12      139        0        0        0          0        0    29874    36711
   11      29874      350        0       953        1131   .40      452        0        0        0          0        0    28819    36711
   12      28819     1170        0       953        1120  -.02      -21        0        0        0          0        0    29057    36711

  YEAR TOTALS    34430        0    13612                     3184        0        0        0          0    12701

                    RESERVOIR NO  2  GRANGER     MAX. CAPACITY   38330  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM             PUMPED     PUMPED   SYSTEM END MO.    OPER.
MONTH    STORAGE  INFLOWS   SPILLS    DEMAND        AREA  RATE     LOSS   SPILLS SHORTAGE     INTO        OUT     LOSS  CONTENT     RULE
    1      20638     2260        0       948        2564  -.23     -589        0        0        0          0        0    22539    38330
    2      22539     3590        0       948        2751  -.07     -192        0        0        0          0        0    25373    38330
    3      25373        0        0      1106        2811   .08      225        0        0        0          0        0    24042    38330
    4      24042    40380        0      1264        3271  -.21     -686        0        0        0          0    25519    38325    38330
    5      38325     8830        0      1264        4009   .36     1443        0        0        0          0     6118    38330    38330
    6      38330     2270        0      1422        4009   .23      922        0        0        0          0        0    38256    38330
    7      38256     1070        0      1896        3815   .54     2060        0        0        0          0        0    35370    38330
    8      35370      420        0      1896        3469   .53     1839        0        0        0          0        0    32055    38330
    9      32055      340        0      1422        3266   .46     1502        0        0        0          0        0    29471    38330
   10      29471      260        0      1422        3135   .02       63        0        0        0          0        0    28246    38330
   11      28246      640        0      1106        3030   .39     1182        0        0        0          0        0    26598    38330
   12      26598     1820        0      1106        3006  -.11     -330        0        0        0          0        0    27642    38330

  YEAR TOTALS    61880        0    15800                     7439        0        0        0          0    31637
1
                    TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

SIMULATION YEAR 10     CALENDAR YEAR 1950

                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM             PUMPED     PUMPED   SYSTEM END MO.    OPER.
MONTH    STORAGE  INFLOWS   SPILLS    DEMAND        AREA  RATE     LOSS   SPILLS SHORTAGE     INTO        OUT     LOSS  CONTENT     RULE
    1      29057      570        0       817        1121   .05       56        0        0        0          0        0    28754    36711
    2      28754     4440        0       817        1158  -.05      -57        0        0        0          0        0    32434    36711
    3      32434      910        0       953        1194   .33      394        0        0        0          0        0    31997    36711
    4      31997     4940        0      1089        1230  -.06      -73        0        0        0          0        0    35921    36711
    5      35921     2090        0      1089        1287   .14      180        0        0        0          0       31    36711    36711
    6      36711     2690        0      1225        1297   .30      389        0        0        0          0     1076    36711    36711
    7      36711      840        0      1633        1278   .59      754        0        0        0          0        0    35164    36711
    8      35164      240        0      1633        1231   .82     1009        0        0        0          0        0    32762    36711
    9      32762     2590        0      1225        1217   .29      353        0        0        0          0        0    33774    36711
   10      33774      340        0      1225        1212   .49      594        0        0        0          0        0    32295    36711
   11      32295      160        0       953        1182   .46      544        0        0        0          0        0    30958    36711
   12      30958      230        0       953        1155   .31      358        0        0        0          0        0    29877    36711

  YEAR TOTALS    20040        0    13612                     4501        0        0        0          0     1107

                    RESERVOIR NO  2  GRANGER     MAX. CAPACITY   38330  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM             PUMPED     PUMPED   SYSTEM END MO.    OPER.
MONTH    STORAGE  INFLOWS   SPILLS    DEMAND        AREA  RATE     LOSS   SPILLS SHORTAGE     INTO        OUT     LOSS  CONTENT     RULE
    1      27642      700        0       948        3034   .03       91        0        0        0          0        0    27303    38330
    2      27303     7820        0       948        3272  -.07     -228        0        0        0          0        0    34403    38330
    3      34403     1140        0      1106        3485   .27      941        0        0        0          0        0    33496    38330
    4      33496     8730        0      1264        3675  -.11     -403        0        0        0          0     3038    38327    38330
    5      38327     3590        0      1264        4009   .12      481        0        0        0          0     1842    38330    38330
    6      38330     4680        0      1422        4009   .20      802        0        0        0          0     2456    38330    38330
    7      38330     1360        0      1896        3850   .51     1963        0        0        0          0        0    35831    38330
    8      35831      360        0      1896        3476   .72     2503        0        0        0          0        0    31792    38330
    9      31792     4650        0      1422        3422   .22      753        0        0        0          0        0    34267    38330
   10      34267      450        0      1422        3422   .44     1506        0        0        0          0        0    31789    38330
   11      31789      200        0      1106        3259   .41     1336        0        0        0          0        0    29547    38330
   12      29547      280        0      1106        3124   .28      875        0        0        0          0        0    27846    38330

  YEAR TOTALS    33960        0    15800                    10620        0        0        0          0     7336
1
                    TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

SIMULATION YEAR 11     CALENDAR YEAR 1951

                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM                 SURFACE  EVAP     EVAP  DWNSTRM             PUMPED     PUMPED   SYSTEM END MO.    OPER.
MONTH    STORAGE  INFLOWS   SPILLS    DEMAND        AREA  RATE     LOSS   SPILLS SHORTAGE     INTO        OUT     LOSS  CONTENT     RULE
    1      29877      270        0       817        1133   .27      306        0        0        0          0        0    29024    36711
    2      29024      160        0       817        1115  -.02      -21        0        0        0          0        0    28388    36711
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      3    28388        0       0       953     1093   .23      251        0        0        0         0         0    27184     36711
      4    27184      370       0      1089     1064   .29      309        0        0        0         0         0    26156     36711
      5    26156        0       0      1089     1033   .10      103        0        0        0         0         0    24964     36711
      6    24964     2300       0      1225     1028   .29      298        0        0        0         0         0    25741     36711
      7    25741        0       0      1633     1005   .80      804        0        0        0         0         0    23304     36711
      8    23304        0       0      1633      936   .95      889        0        0        0         0         0    20782     36711
      9    20782        0       0      1225      880   .39      343        0        0        0         0         0    19214     36711
     10    19214       90       0      1225      840   .45      378        0        0        0         0         0    17701     36711
     11    17701       50       0       953      805   .28      225        0        0        0         0         0    16573     36711
     12    16573      120       0       953      776   .25      194        0        0        0         0         0    15546     36711

   YEAR TOTALS     3360        0   13612                        4079        0        0        0         0         0

                       RESERVOIR NO  2  GRANGER     MAX. CAPACITY   38330  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.     OPER.
    MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO        OUT      LOSS  CONTENT      RULE
      1    27846      320       0       948     3008   .25      752        0        0        0         0         0    26466     38330
      2    26466      700       0       948     2948  -.04     -117        0        0        0         0         0    26335     38330
      3    26335     3040       0      1106     2996   .20      599        0        0        0         0         0    27670     38330
      4    27670      510       0      1264     2982   .31      924        0        0        0         0         0    25992     38330
      5    25992     2360       0      1264     2941   .15      441        0        0        0         0         0    26647     38330
      6    26647     4200       0      1422     3044   .29      883        0        0        0         0         0    28542     38330
      7    28542      180       0      1896     2956   .80     2365        0        0        0         0         0    24461     38330
      8    24461       30       0      1896     2623   .89     2334        0        0        0         0         0    20261     38330
      9    20261     1180       0      1422     2429   .27      656        0        0        0         0         0    19363     38330
     10    19363      170       0      1422     2310   .43      993        0        0        0         0         0    17118     38330
     11    17118       80       0      1106     2149   .24      516        0        0        0         0         0    15576     38330
     12    15576      160       0      1106     2015   .22      443        0        0        0         0         0    14187     38330

   YEAR TOTALS    12930        0   15800                       10789        0        0        0         0         0
1
                   TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

  SIMULATION YEAR 12     CALENDAR YEAR 1952

                       RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.     OPER.
    MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO        OUT      LOSS  CONTENT      RULE
      1    15546      140       0       817      743   .22      163        0        0        0         0         0    14706     36711
      2    14706      230       0       817      716   .16      115        0        0        0         0         0    14004     36711
      3    14004      340       0       953      690   .15      103        0        0        0         0         0    13288     36711
      4    13288     2170       0      1089      697  -.02      -13        0        0        0         0         0    14382     36711
      5    14382     4680       0      1089      780   .05       39        0        0        0         0         0    17934     36711
      6    17934     2720       0      1225      840   .47      395        0        0        0         0         0    19034     36711
      7    19034        0       0      1633      827   .61      504        0        0        0         0         0    16897     36711
      8    16897        0       0      1633      764   .97      741        0        0        0         0         0    14523     36711
      9    14523        0       0      1225      695   .39      271        0        0        0         0         0    13027     36711
     10    13027        0       0      1225      639   .68      435        0        0        0         0         0    11367     36711
     11    11367       10       0       953      594  -.04      -23        0        0        0         0         0    10447     36711
     12    10447     1610       0       953      591  -.12      -70        0        0        0         0         0    11174     36711

   YEAR TOTALS    11900        0   13612                        2660        0        0        0         0         0

                       RESERVOIR NO  2  GRANGER     MAX. CAPACITY   38330  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.     OPER.
    MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO        OUT      LOSS  CONTENT      RULE
      1    14187      190       0       948     1902   .17      323        0        0        0         0         0    13106     38330
      2    13106      350       0       948     1815   .07      127        0        0        0         0         0    12381     38330
      3    12381      520       0      1106     1739   .12      209        0        0        0         0         0    11586     38330
      4    11586     3870       0      1264     1834  -.05      -91        0        0        0         0         0    14283     38330
      5    14283     8420       0      1264     2276   .05      114        0        0        0         0         0    21325     38330
      6    21325     4780       0      1422     2624   .48     1260        0        0        0         0         0    23423     38330
      7    23423      150       0      1896     2581   .57     1471        0        0        0         0         0    20206     38330
      8    20206       70       0      1896     2313   .87     2012        0        0        0         0         0    16368     38330
      9    16368        0       0      1422     2035   .55     1119        0        0        0         0         0    13827     38330
     10    13827        0       0      1422     1796   .63     1131        0        0        0         0         0    11274     38330
     11    11274      180       0      1106     1633  -.13     -211        0        0        0         0         0    10559     38330
     12    10559     2870       0      1106     1698  -.15     -254        0        0        0         0         0    12577     38330

   YEAR TOTALS    21400        0   15800                        7210        0        0        0         0         0
1
                   TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

  SIMULATION YEAR 13     CALENDAR YEAR 1953

                       RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0          INITIAL    UREG   UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.     OPER.
    MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO        OUT      LOSS  CONTENT      RULE
      1    11174     2740       0       817      634   .27      171        0        0        0         0         0    12926     36711
      2    12926     1730       0       817      680   .08       54        0        0        0         0         0    13785     36711
      3    13785      760       0       953      691   .10       69        0        0        0         0         0    13523     36711
      4    13523     2330       0      1089      707   .11       78        0        0        0         0         0    14686     36711
      5    14686     7340       0      1089      822   .09       74        0        0        0         0         0    20863     36711
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      6     20863     1240        0      1225      895    .68     609        0         0        0         0        0   20269     36711
      7     20269        0        0      1633      858    .69     592        0         0        0         0        0   18044     36711
      8     18044       80        0      1633      803    .59     474        0         0        0         0        0   16017     36711
      9     16017     1510        0      1225      774    .44     341        0         0        0         0        0   15961     36711
     10     15961    15950        0      1225      972    .03      29        0         0        0         0        0   30657     36711
     11     30657     2460        0       953     1174    .22     258        0         0        0         0        0   31906     36711
     12     31906    14470        0       953     1239    .08      99        0         0        0         0     8613   36711     36711

    YEAR TOTALS     50610        0     13612                    2848        0         0        0         0     8613

                  RESERVOIR NO  2  GRANGER      MAX. CAPACITY   38330  MIN. OPERATING POOL          0
0         INITIAL    UREG   UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED     SYSTEM END MO.     OPER.
   MONTH  STORAGE  INFLOWS  SPILLS     DEMAND     AREA    RATE     LOSS   SPILLS  SHORTAGE    INTO        OUT       LOSS  CONTENT     RULE
      1     12577     4990        0       948     1968    .24     472        0         0        0         0        0   16147     38330
      2     16147     3220        0       948     2233    .02      45        0         0        0         0        0   18374     38330
      3     18374     1420        0      1106     2325    .07     163        0         0        0         0        0   18525     38330
      4     18525     4330        0      1264     2443    .05     122        0         0        0         0        0   21469     38330
      5     21469    13480        0      1264     3042    .02      61        0         0        0         0        0   33624     38330
      6     33624     2140        0      1422     3413    .64    2184        0         0        0         0        0   32158     38330
      7     32158        0        0      1896     3226    .64    2065        0         0        0         0        0   28197     38330
      8     28197      180        0      1896     2966    .48    1424        0         0        0         0        0   25057     38330
      9     25057     2780        0      1422     2848    .40    1139        0         0        0         0        0   25276     38330
     10     25276    29640        0      1422     3334   -.03     -99        0         0        0         0    15263   38330     38330
     11     38330     4070        0      1106     4009    .17     682        0         0        0         0     2282   38330     38330
     12     38330    25640        0      1106     3991   -.07    -278        0         0        0         0    24814   38328     38330

    YEAR TOTALS     91890        0     15800                    7980        0         0        0         0    42359
1
                  TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR 14     CALENDAR YEAR 1954

                  RESERVOIR NO  1  GEORGETN     MAX. CAPACITY   36711  MIN. OPERATING POOL          0
0         INITIAL    UREG   UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED     SYSTEM END MO.     OPER.
   MONTH  STORAGE  INFLOWS  SPILLS     DEMAND     AREA    RATE     LOSS   SPILLS  SHORTAGE    INTO        OUT       LOSS  CONTENT     RULE
      1     36711     1200        0       817     1297    .14     182        0         0        0         0      201   36711     36711
      2     36711      750        0       817     1296    .31     402        0         0        0         0        0   36242     36711
      3     36242      420        0       953     1279    .29     371        0         0        0         0        0   35338     36711
      4     35338       60        0      1089     1251    .19     238        0         0        0         0        0   34071     36711
      5     34071     2290        0      1089     1248    .29     362        0         0        0         0        0   34910     36711
      6     34910       60        0      1225     1230    .66     812        0         0        0         0        0   32933     36711
      7     32933        0        0      1633     1182    .86    1017        0         0        0         0        0   30283     36711
      8     30283        0        0      1633     1121    .90    1009        0         0        0         0        0   27641     36711
      9     27641        0        0      1225     1063    .75     797        0         0        0         0        0   25619     36711
     10     25619        0        0      1225     1012    .47     476        0         0        0         0        0   23918     36711
     11     23918        0        0       953      971    .26     252        0         0        0         0        0   22713     36711
     12     22713        0        0       953      937    .30     281        0         0        0         0        0   21479     36711

    YEAR TOTALS      4780        0     13612                    6199        0         0        0         0      201

                  RESERVOIR NO  2  GRANGER      MAX. CAPACITY   38330  MIN. OPERATING POOL          0
0         INITIAL    UREG   UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED     SYSTEM END MO.     OPER.
   MONTH  STORAGE  INFLOWS  SPILLS     DEMAND     AREA    RATE     LOSS   SPILLS  SHORTAGE    INTO        OUT       LOSS  CONTENT     RULE
      1     38328     1570        0       948     4009    .10     401        0         0        0         0      219   38330     38330
      2     38330      920        0       948     4007    .28    1122        0         0        0         0        0   37180     38330
      3     37180      600        0      1106     3760    .29    1090        0         0        0         0        0   35584     38330
      4     35584      100        0      1264     3546    .17     603        0         0        0         0        0   33817     38330
      5     33817     4260        0      1264     3565    .26     927        0         0        0         0        0   35886     38330
      6     35886      140        0      1422     3496    .65    2272        0         0        0         0        0   32332     38330
      7     32332       20        0      1896     3225    .76    2451        0         0        0         0        0   28005     38330
      8     28005       60        0      1896     2907    .82    2384        0         0        0         0        0   23785     38330
      9     23785      120        0      1422     2608    .74    1930        0         0        0         0        0   20553     38330
     10     20553        0        0      1422     2396    .39     934        0         0        0         0        0   18197     38330
     11     18197        0        0      1106     2244    .23     516        0         0        0         0        0   16575     38330
     12     16575      150        0      1106     2099    .28     588        0         0        0         0        0   15031     38330

    YEAR TOTALS      7940        0     15800                   15218        0         0        0         0      219
1
                  TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR 15     CALENDAR YEAR 1955

                  RESERVOIR NO  1  GEORGETN     MAX. CAPACITY   36711  MIN. OPERATING POOL          0
0         INITIAL    UREG   UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED     SYSTEM END MO.     OPER.
   MONTH  STORAGE  INFLOWS  SPILLS     DEMAND     AREA    RATE     LOSS   SPILLS  SHORTAGE    INTO        OUT       LOSS  CONTENT     RULE
      1     21479        0        0       817      908    .06      54        0         0        0         0        0   20608     36711
      2     20608     2330        0       817      917   -.03     -27        0         0        0         0        0   22148     36711
      3     22148     1030        0       953      937    .23     216        0         0        0         0        0   22009     36711
      4     22009     2600        0      1089      953    .26     248        0         0        0         0        0   23272     36711
      5     23272     3540        0      1089     1003    .09      90        0         0        0         0        0   25633     36711
      6     25633     4530        0      1225     1076    .28     301        0         0        0         0        0   28637     36711
      7     28637        0        0      1633     1085    .62     673        0         0        0         0        0   26331     36711
      8     26331        0        0      1633     1026    .40     410        0         0        0         0        0   24288     36711
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     9    24288        0       0      1225      976    .41      400        0        0       0          0         0    22663     36711
    10    22663       70       0      1225      929    .62      576        0        0       0          0         0    20932     36711
    11    20932       60       0       953      888    .43      382        0        0       0          0         0    19657     36711
    12    19657      130       0       953      858    .20      172        0        0       0          0         0    18662     36711

    YEAR TOTALS    14290       0     13612                     3495        0        0       0          0         0

                      RESERVOIR NO  2  GRANGER     MAX. CAPACITY   38330  MIN. OPERATING POOL        0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP     EVAP  DWNSTRM           PUMPED     PUMPED    SYSTEM  END MO.     OPER.
 MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE    INTO        OUT      LOSS  CONTENT      RULE
     1    15031      170       0       948     1990    .04       80        0        0       0          0         0    14173     38330
     2    14173     4230       0       948     2110   -.10     -210        0        0       0          0         0    17665     38330
     3    17665     1830       0      1106     2278    .18      410        0        0       0          0         0    17979     38330
     4    17979     4780       0      1264     2407    .18      433        0        0       0          0         0    21062     38330
     5    21062     6550       0      1264     2721    .09      245        0        0       0          0         0    26103     38330
     6    26103     8400       0      1422     3156    .27      852        0        0       0          0         0    32229     38330
     7    32229      710       0      1896     3264    .55     1795        0        0       0          0         0    29248     38330
     8    29248     3220       0      1896     3169    .35     1109        0        0       0          0         0    29463     38330
     9    29463       80       0      1422     3087    .41     1266        0        0       0          0         0    26855     38330
    10    26855      100       0      1422     2861    .61     1745        0        0       0          0         0    23788     38330
    11    23788       90       0      1106     2654    .40     1062        0        0       0          0         0    21710     38330
    12    21710      190       0      1106     2523    .16      404        0        0       0          0         0    20390     38330

    YEAR TOTALS    30350       0     15800                     9191        0        0       0          0         0
1
                    TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR 16     CALENDAR YEAR 1956

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP     EVAP  DWNSTRM           PUMPED     PUMPED    SYSTEM  END MO.     OPER.
 MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE    INTO        OUT      LOSS  CONTENT      RULE
     1    18662      130       0       817      835    .11       92        0        0       0          0         0    17883     36711
     2    17883      590       0       817      821    .10       82        0        0       0          0         0    17574     36711
     3    17574       80       0       953      801    .40      320        0        0       0          0         0    16381     36711
     4    16381       10       0      1089      764    .37      283        0        0       0          0         0    15019     36711
     5    15019        0       0      1089      716    .30      215        0        0       0          0         0    13715     36711
     6    13715      330       0      1225      669    .68      455        0        0       0          0         0    12365     36711
     7    12365        0       0      1633      607    .92      558        0        0       0          0         0    10174     36711
     8    10174        0       0      1633      533    .92      490        0        0       0          0         0     8051     36711
     9     8051        0       0      1225      459    .81      372        0        0       0          0         0     6454     36711
    10     6454        0       0      1225      399    .50      199        0        0       0          0         0     5030     36711
    11     5030       10       0       953      348    .32      111        0        0       0          0         0     3976     36711
    12     3976       10       0       953      290    .14       41        0        0       0          0         0     2992     36711

    YEAR TOTALS     1160       0     13612                     3218        0        0       0          0         0

                      RESERVOIR NO  2  GRANGER     MAX. CAPACITY   38330  MIN. OPERATING POOL        0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP     EVAP  DWNSTRM           PUMPED     PUMPED    SYSTEM  END MO.     OPER.
 MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE    INTO        OUT      LOSS  CONTENT      RULE
     1    20390      190       0       948     2436    .08      195        0        0       0          0         0    19437     38330
     2    19437     1070       0       948     2402    .03       72        0        0       0          0         0    19487     38330
     3    19487      120       0      1106     2341    .29      679        0        0       0          0         0    17822     38330
     4    17822      100       0      1264     2201    .29      638        0        0       0          0         0    16020     38330
     5    16020        0       0      1264     2036    .27      550        0        0       0          0         0    14206     38330
     6    14206      670       0      1422     1868    .60     1121        0        0       0          0         0    12333     38330
     7    12333        0       0      1896     1611    .86     1385        0        0       0          0         0     9052     38330
     8     9052        0       0      1896     1289    .85     1096        0        0       0          0         0     6060     38330
     9     6060        0       0      1422     1001    .77      771        0        0       0          0         0     3867     38330
    10     3867        0       0      1422      743    .47      349        0        0       0          0         0     2096     38330
    11     2096      650       0      1106      544    .24      131        0        0       0          0         0     1509     38330
    12     1509     1150       0      1106      482    .13       63        0        0       0          0         0     1490     38330

    YEAR TOTALS     3950       0     15800                     7050        0        0       0          0         0
1
                    TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

   SIMULATION YEAR 17     CALENDAR YEAR 1957

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0       INITIAL     UREG  UPSTRM            SURFACE   EVAP     EVAP  DWNSTRM           PUMPED     PUMPED    SYSTEM  END MO.     OPER.
 MONTH  STORAGE  INFLOWS  SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE    INTO        OUT      LOSS  CONTENT      RULE
     1     2992      130       0       817      241    .18       43        0        0       0          0         0     2262     36711
     2     2262        0       0       817      197    .02        4        0        0       0          0         0     1441     36711
     3     1441     1860       0       953      199    .00        0        0        0       0          0         0     2348     36711
     4     2348    48300       0      1089      862   -.52     -447        0        0       0          0     13298    36708     36711
     5    36708    11410       0      1089     1295   -.15     -193        0        0       0          0     10512    36710     36711
     6    36710    29530       0      1225     1297    .21      272        0        0       0          0     28032    36711     36711
     7    36711     1190       0      1633     1292    .79     1021        0        0       0          0         0    35247     36711
     8    35247     3000       0      1633     1278    .87     1112        0        0       0          0         0    35502     36711
     9    35502     1640       0      1225     1273    .22      280        0        0       0          0         0    35637     36711
    10    35637    41040       0      1225     1282   -.11     -140        0        0       0          0     38881    36711     36711
    11    36711    12050       0       953     1296   -.06      -77        0        0       0          0     11174    36711     36711
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    12    36711    7090        0      953     1297    .16     208        0         0         0         0     5929    36711    36711

     YEAR TOTALS   157240        0    13612                    2083        0         0         0         0   107826

                        RESERVOIR NO  2  GRANGER    MAX. CAPACITY   38330  MIN. OPERATING POOL       0
0            INITIAL     UREG    UPSTRM             SURFACE  EVAP     EVAP  DWNSTRM             PUMPED     PUMPED    SYSTEM END MO.     OPER.
    MONTH    STORAGE  INFLOWS    SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT     RULE
     1         1490      210        0       948      398    .18       72        0         0         0         0        0      680    38330
     2          680      270        0       948      232    .00        0        0         0         0         0        0        2    38330
     3            2     3440        0      1106      418   -.05      -20        0         0         0         0        0     2356    38330
     4         2356    89880        0      1264     2469   -.56    -1382        0         0         0         0    54024    38330    38330
     5        38330    21250        0      1264     4001   -.03     -119        0         0         0         0    20105    38330    38330
     6        38330    54970        0      1422     4009    .14      561        0         0         0         0    52987    38330    38330
     7        38330     2280        0      1896     4009    .69     2766        0         0         0         0        0    35948    38330
     8        35948     5380        0      1896     3857    .72     2777        0         0         0         0        0    36655    38330
     9        36655     2620        0      1422     3872    .16      620        0         0         0         0        0    37233    38330
    10        37233    76070        0      1422     3939   -.18     -708        0         0         0         0    74259    38330    38330
    11        38330    21880        0      1106     3986   -.09     -358        0         0         0         0    21134    38328    38330
    12        38328    10880        0      1106     4009    .12      481        0         0         0         0     9291    38330    38330

     YEAR TOTALS   289130        0    15800                    4690        0         0         0         0   231800
1
                    TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

                    SIMULATION PERIOD TOTAL SUMMARY BY NODE  1

     YEAR START. STRG.  UNREG. FLOW      DEMANDS     SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
        1        36711       133650        13612           0         2225       118228       36296
        2        36296        67710        13612           0         2481        51073       36711
        3        36711        23450        13612           0         4505        12607       29437
        4        29437       104540        13612           0         2824        80768       36710
        5        36710        92460        13612           0         3207        75640       36711
        6        36711        97340        13612           0         3203        80525       36711
        7        36711        68760        13612           0         4616        57201       30042
        8        30042        12220        13612           0         4526            0       24124
        9        24124        34430        13612           0         3184        12701       29057
       10        29057        20040        13612           0         4501         1107       29877
       11        29877         3360        13612           0         4079            0       15546
       12        15546        11900        13612           0         2660            0       11174
       13        11174        50610        13612           0         2848         8613       36711
       14        36711         4780        13612           0         6199          201       21479
       15        21479        14290        13612           0         3495            0       18662
       16        18662         1160        13612           0         3218            0        2992
       17         2992       157240        13612           0         2083       107826       36711
       18        36711        92890        13612           0         3029        76249       36711
       19        36711        66100        13612           0         2715        49754       36711
       20        36711       102800        13612           0         2974        86215       36710
       21        36710       115470        13612           0         3129        98728       36711
       22        36711        38090        13612           0         4488        19990       36711
       23        36711        13750        13612           0         5454         4548       26842
       24        26842        14960        13612           0         3173            0       25017
       25        25017       151000        13612           0         2677       123017       36711


      PERIOD TOTALS            1493000       340300           0        87493      1064991


    PERIOD AVERAGES              59720        13612           0         3499        42599
1
                    TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

                    SIMULATION PERIOD TOTAL SUMMARY BY NODE  2

     YEAR START. STRG.  UNREG. FLOW      DEMANDS     SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
        1        38330       222500        15800           0         5337       202142       37551
        2        37551       110790        15800           0         6411        87929       38330
        3        38330        35130        15800           0        11207        19612       26841
        4        26841       166490        15800           0         6245       133019       38330
        5        38330       146110        15800           0         6906       123404       38330
        6        38330       161570        15800           0         6197       139573       38330
        7        38330        99110        15800           0        10407        84195       27038
        8        27038        20340        15800           0        10940            0       20638
        9        20638        61880        15800           0         7439        31637       27642
       10        27642        33960        15800           0        10620         7336       27846
       11        27846        12930        15800           0        10789            0       14187
       12        14187        21400        15800           0         7210            0       12577
       13        12577        91890        15800           0         7980        42359       38328
       14        38328         7940        15800           0        15218          219       15031
       15        15031        30350        15800           0         9191            0       20390
       16        20390         3950        15800           0         7050            0        1490
       17         1490       289130        15800           0         4690       231800       38330
       18        38330       157520        15800           0         7476       134244       38330
       19        38330       115080        15800           0         6400        92899       38330
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     20          38330        169090         15800              0          6269       147021          38330
     21          38330        189410         15800              0          7304       166306          38330
     22          38330         59210         15800              0         10896        32514          38330
     23          38330         21690         15800              0         13761         7627          22837
     24          22837         39250         15800              0          8804            0          37483
     25          37483        257700         15800              0          7682       233374          38327


  PERIOD TOTALS              2524420        395000              0        212429      1917210


 PERIOD AVERAGES              100976         15800              0          8497        76688
1
                 TITLE CARD  Granger Yield * 2050 Sediment * Georgetown 13,610 acft/yr firm

                 SIMULATION PERIOD TOTAL SUMMARY BY YEAR***

 YEAR START. STRG.  UNREG. FLOW      DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
     1         75041       356150        29412          0          7562       320370         73847
     2         73847       178500        29412          0          8892       139002         75041
     3         75041        58580        29412          0         15712        32219         56278
     4         56278       271030        29412          0          9069       213787         75040
     5         75040       238570        29412          0         10113       199044         75041
     6         75041       258910        29412          0          9400       220098         75041
     7         75041       167870        29412          0         15023       141396         57080
     8         57080        32560        29412          0         15466            0         44762
     9         44762        96310        29412          0         10623        44338         56699
    10         56699        54000        29412          0         15121         8443         57723
    11         57723        16290        29412          0         14868            0         29733
    12         29733        33300        29412          0          9870            0         23751
    13         23751       142500        29412          0         10828        50972         75039
    14         75039        12720        29412          0         21417          420         36510
    15         36510        44640        29412          0         12686            0         39052
    16         39052         5110        29412          0         10268            0          4482
    17          4482       446370        29412          0          6773       339626         75041
    18         75041       250410        29412          0         10505       210493         75041
    19         75041       181180        29412          0          9115       142653         75041
    20         75041       271890        29412          0          9243       233236         75040
    21         75040       304880        29412          0         10433       265034         75041
    22         75041        97300        29412          0         15384        52504         75041
    23         75041        35440        29412          0         19215        12175         49679
    24         49679        54210        29412          0         11977            0         62500
    25         62500       408700        29412          0         10359       356391         75038


  PERIOD TOTALS              4017420        735300              0        299922      2982201


 PERIOD AVERAGES              160696         29412              0         11996       119288
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Lake
Georgetown
1995

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1

     RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

          TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

               NUMBER OF NODES =    1              NUMBER OF RESERVOIRS =  1

               NUMBER OF LINKS =    0            NUMBER OF RIVER REACHES =  0

     CALENDAR YEAR OPERATION STARTS = 1941      NUMBER OF YEARS TO SIMULATE = 25

          NUMBER OF DEMAND NODES =    1              NUMBER OF SPILL NODES =  1

                    YIELD NODE =    0                      IMPORT NODE =  0


     NODE NO.   NODE NAME     --------- CAPACITIES ---------     YEARLY
                                MAXIMUM  MINIMUM   STARTING      DEMAND

        1        GEORGETN        37010        0      37010        14310
1

     RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

          TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

     SYSTEM CONFIGURATION

     LINK NO.    FROM NODE    TO NODE     MAX. CAPACITY    MIN. CAPACITY


     LIST OF SPILL RESERVOIRS -      1


     YEARLY IMPORT QUANTITY =         0

     MONTHLY IMPORT DISTRIBUTION -   .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00

     SUB-SYSTEM OF RESERVOIRS      1

     'AVERAGE' DEFINED AS BETWEEN40.00, AND90.00 PERCENT FULL OF SUBSYSTEM


     FACTORS

          MULTIPLY LINK CAPACITIES BY     1.000

          MULTIPLY INFLOWS BY .......     10.00

          MULTIPLY DEMANDS BY .......      1.00
1

     RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

          TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions


                                     MONTHLY DEMAND DISTRIBUTION
     NODE NO.           JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY   AUG.   SEPT   OCT.   NOV.   DEC.    * RANK *
                                                                                                           AVG DRY WET

        1              .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700     4   4   4
1

     RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

          TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions


                                  DESIRED MONTHLY STORAGE LEVEL (PERCENT FULL)
     RESERVOIR NO.

        1    AVRG     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       5
             DRY      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       5
             WET      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       5
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1
        RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                 TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

                                        RESERVOIRS AREA - CAPACITY TABLES

              RESERVOIR NO.  1    RESERVOIR NO.
      1            0        0
      2          150      973
      3          363     4789
      4          441     6800
      5          538     9237
      6          636    12166
      7          707    14174
      8          786    16410
      9          849    18864
     10          919    21513
     11          998    24388
     12         1083    27500
     13         1137    29729
     14         1188    32056
     15         1238    34483
     16         1297    37010
     17            0        0
     18            0        0
1
                 TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR  6     CALENDAR YEAR 1946

                 RESERVOIR NO  1  GEORGETN   MAX. CAPACITY   37010  MIN. OPERATING POOL        0
0          INITIAL   UREG   UPSTRM             SURFACE  EVAP    EVAP  DWNSTRM            PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS    DEMAND    AREA    RATE    LOSS   SPILLS SHORTAGE   INTO       OUT      LOSS  CONTENT    RULE
     1     37010     7520      0       859     1296    -.08    -103      0        0        0         0      6764   37010   37010
     2     37010    10170      0       859     1297     .04      52      0        0        0         0      9259   37010   37010
     3     37010     9890      0      1002     1297     .10     130      0        0        0         0      8758   37010   37010
     4     37010     9930      0      1145     1297     .12     156      0        0        0         0      8629   37010   37010
     5     37010    15100      0      1145     1297     .03      39      0        0        0         0     13916   37010   37010
     6     37010     8650      0      1288     1297     .38     493      0        0        0         0      6869   37010   37010
     7     37010     2200      0      1717     1297     .78    1012      0        0        0         0         0   36481   37010
     8     36481     1120      0      1717     1268     .67     850      0        0        0         0         0   35034   37010
     9     35034        0      0      1288     1236     .10     124      0        0        0         0         0   33622   37010
    10     33622     2700      0      1288     1231     .29     357      0        0        0         0         0   34677   37010
    11     34677    17910      0      1002     1270     .01      13      0        0        0         0     14562   37010   37010
    12     37010    12150      0      1002     1297     .06      78      0        0        0         0     11070   37010   37010

    YEAR TOTALS     97340      0     14312                      3201      0        0        0         0     79827
1
                 TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR  7     CALENDAR YEAR 1947

                 RESERVOIR NO  1  GEORGETN   MAX. CAPACITY   37010  MIN. OPERATING POOL        0
0          INITIAL   UREG   UPSTRM             SURFACE  EVAP    EVAP  DWNSTRM            PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS    DEMAND    AREA    RATE    LOSS   SPILLS SHORTAGE   INTO       OUT      LOSS  CONTENT    RULE
     1     37010    22150      0       859     1295    -.14    -180      0        0        0         0     21472   37009   37010
     2     37009     8510      0       859     1297     .19     246      0        0        0         0      7404   37010   37010
     3     37010     9360      0      1002     1297     .05      65      0        0        0         0      8293   37010   37010
     4     37010    10020      0      1145     1297     .10     130      0        0        0         0      8745   37010   37010
     5     37010    10180      0      1145     1297     .20     259      0        0        0         0      8776   37010   37010
     6     37010     4230      0      1288     1297     .57     739      0        0        0         0      2203   37010   37010
     7     37010     1180      0      1717     1291     .76     981      0        0        0         0         0   35492   37010
     8     35492      780      0      1717     1243     .49     609      0        0        0         0         0   33946   37010
     9     33946      620      0      1288     1211     .69     836      0        0        0         0         0   32442   37010
    10     32442      420      0      1288     1180     .56     661      0        0        0         0         0   30913   37010
    11     30913      520      0      1002     1155     .22     254      0        0        0         0         0   30177   37010
    12     30177      790      0      1002     1144     .01      11      0        0        0         0         0   29954   37010

    YEAR TOTALS     68760      0     14312                      4611      0        0        0         0     56893
1
                 TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR  8     CALENDAR YEAR 1948

                 RESERVOIR NO  1  GEORGETN   MAX. CAPACITY   37010  MIN. OPERATING POOL        0
0          INITIAL   UREG   UPSTRM             SURFACE  EVAP    EVAP  DWNSTRM            PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS    DEMAND    AREA    RATE    LOSS   SPILLS SHORTAGE   INTO       OUT      LOSS  CONTENT    RULE
     1     29954      870      0       859     1142     .05      57      0        0        0         0         0   29908   37010
     2     29908        0      0       859     1131    -.06     -67      0        0        0         0         0   29116   37010
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      3      29116     1720        0     1002     1128   .21     237      0       0       0       0       0    29597    37010
      4      29597     2450        0     1145     1146   .23     264      0       0       0       0       0    30638    37010
      5      30638     4000        0     1145     1186   .18     213      0       0       0       0       0    33280    37010
      6      33280     1220        0     1288     1206   .53     639      0       0       0       0       0    32573    37010
      7      32573     1290        0     1717     1187   .56     665      0       0       0       0       0    31481    37010
      8      31481      200        0     1717     1149   .75     862      0       0       0       0       0    29102    37010
      9      29102       10        0     1288     1099   .52     571      0       0       0       0       0    27253    37010
     10      27253      190        0     1288     1054   .47     495      0       0       0       0       0    25660    37010
     11      25660      100        0     1002     1016   .34     345      0       0       0       0       0    24413    37010
     12      24413      170        0     1002      985   .19     187      0       0       0       0       0    23394    37010

     YEAR TOTALS     12220       0    14312                    4468      0       0       0       0       0
1
                      TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR  9     CALENDAR YEAR 1949

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL        0
0           INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH    STORAGE  INFLOWS   SPILLS    DEMAND     AREA    RATE     LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT     RULE
      1      23394     1270        0      859      978  -.16    -155      0       0       0       0       0    23960    37010
      2      23960     1970        0      859     1002  -.06     -59      0       0       0       0       0    25130    37010
      3      25130        0        0     1002     1003   .10     100      0       0       0       0       0    24028    37010
      4      24028    21850        0     1145     1151  -.24    -275      0       0       0       0    7999    37009    37010
      5      37009     5010        0     1145     1297   .34     441      0       0       0       0    3423    37010    37010
      6      37010     1440        0     1288     1297   .28     363      0       0       0       0       0    36799    37010
      7      36799      700        0     1717     1271   .64     813      0       0       0       0       0    34969    37010
      8      34969      300        0     1717     1226   .61     748      0       0       0       0       0    32804    37010
      9      32804      210        0     1288     1186   .54     640      0       0       0       0       0    31086    37010
     10      31086      160        0     1288     1153   .12     138      0       0       0       0       0    29820    37010
     11      29820      350        0     1002     1126   .40     450      0       0       0       0       0    28718    37010
     12      28718     1170        0     1002     1115  -.02     -21      0       0       0       0       0    28907    37010

     YEAR TOTALS     34430       0    14312                    3183      0       0       0       0   11422
1
                      TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR 10     CALENDAR YEAR 1950

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL        0
0           INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH    STORAGE  INFLOWS   SPILLS    DEMAND     AREA    RATE     LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT     RULE
      1      28907      570        0      859     1114   .05      56      0       0       0       0       0    28562    37010
      2      28562     4440        0      859     1151  -.05     -57      0       0       0       0       0    32200    37010
      3      32200      910        0     1002     1186   .33     391      0       0       0       0       0    31717    37010
      4      31717     4940        0     1145     1220  -.06     -72      0       0       0       0       0    35584    37010
      5      35584     2090        0     1145     1275   .14     178      0       0       0       0       0    36351    37010
      6      36351     2690        0     1288     1289   .30     387      0       0       0       0       0    37010    37010
      7      37010      840        0     1717     1278   .59     754      0       0       0       0     356    37010    37010
      8      35379      240        0     1717     1231   .82    1009      0       0       0       0       0    35379    37010
      9      32893     2590        0     1288     1215   .29     352      0       0       0       0       0    32893    37010
     10      33843      340        0     1288     1209   .49     592      0       0       0       0       0    33843    37010
     11      32303      160        0     1002     1178   .46     542      0       0       0       0       0    32303    37010
     12      30919      230        0     1002     1151   .31     357      0       0       0       0       0    30919    37010
                                                                                                                  29790    37010
     YEAR TOTALS     20040       0    14312                    4489      0       0       0       0     356
1
                      TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR 11     CALENDAR YEAR 1951

                      RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL        0
0           INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED   SYSTEM END MO.    OPER.
   MONTH    STORAGE  INFLOWS   SPILLS    DEMAND     AREA    RATE     LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT     RULE
      1      29790      270        0      859     1128   .27     305      0       0       0       0       0    28896    37010
      2      28896      160        0      859     1108  -.02     -21      0       0       0       0       0    28218    37010
      3      28218        0        0     1002     1085   .23     250      0       0       0       0       0    26966    37010
      4      26966      370        0     1145     1054   .29     306      0       0       0       0       0    25885    37010
      5      25885        0        0     1145     1022   .10     102      0       0       0       0       0    24638    37010
      6      24638     2300        0     1288     1015   .29     294      0       0       0       0       0    25356    37010
      7      25356        0        0     1717      990   .80     792      0       0       0       0       0    22847    37010
      8      22847        0        0     1717      920   .95     874      0       0       0       0       0    20256    37010
      9      20256        0        0     1288      864   .39     337      0       0       0       0       0    18631    37010
     10      18631       90        0     1288      823   .45     370      0       0       0       0       0    17063    37010
     11      17063       50        0     1002      788   .28     221      0       0       0       0       0    15890    37010
     12      15890      120        0     1002      749   .25     187      0       0       0       0       0    14821    37010

     YEAR TOTALS      3360       0    14312                    4017      0       0       0       0       0
1
                      TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR 12     CALENDAR YEAR 1952
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                        RESERVOIR NO  1   GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL          0
0          INITIAL      UREG    UPSTRM              SURFACE  EVAP      EVAP  DWNSTRM             PUMPED       PUMPED     SYSTEM END MO.     OPER.
    MONTH  STORAGE   INFLOWS    SPILLS     DEMAND     AREA   RATE      LOSS   SPILLS SHORTAGE      INTO         OUT       LOSS  CONTENT      RULE
       1     14821       140         0        859      714    .22       157        0        0         0           0          0    13945     37010
       2     13945       230         0        859      686    .16       110        0        0         0           0          0    13206     37010
       3     13206       340         0       1002      659    .15        99        0        0         0           0          0    12445     37010
       4     12445      2170         0       1145      664   -.02       -12        0        0         0           0          0    13482     37010
       5     13482      4680         0       1145      744    .05        37        0        0         0           0          0    16980     37010
       6     16980      2720         0       1288      814    .47       383        0        0         0           0          0    18029     37010
       7     18029         0         0       1717      799    .61       487        0        0         0           0          0    15825     37010
       8     15825         0         0       1717      723    .97       701        0        0         0           0          0    13407     37010
       9     13407         0         0       1288      653    .39       255        0        0         0           0          0    11864     37010
      10     11864         0         0       1288      597    .68       406        0        0         0           0          0    10170     37010
      11     10170        10         0       1002      553   -.04       -21        0        0         0           0          0     9199     37010
      12      9199      1610         0       1002      548   -.12       -65        0        0         0           0          0     9872     37010

      YEAR TOTALS      11900         0      14312                      2537        0        0         0           0          0
1
                   TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR 13     CALENDAR YEAR 1953

                        RESERVOIR NO  1   GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL          0
0          INITIAL      UREG    UPSTRM              SURFACE  EVAP      EVAP  DWNSTRM             PUMPED       PUMPED     SYSTEM END MO.     OPER.
    MONTH  STORAGE   INFLOWS    SPILLS     DEMAND     AREA   RATE      LOSS   SPILLS SHORTAGE      INTO         OUT       LOSS  CONTENT      RULE
       1      9872      2740         0        859      588    .27       159        0        0         0           0          0    11594     37010
       2     11594      1730         0        859      631    .08        50        0        0         0           0          0    12415     37010
       3     12415       760         0       1002      639    .10        64        0        0         0           0          0    12109     37010
       4     12109      2330         0       1145      654    .11        72        0        0         0           0          0    13222     37010
       5     13222      7340         0       1145      782    .09        70        0        0         0           0          0    19347     37010
       6     19347      1240         0       1288      853    .68       580        0        0         0           0          0    18719     37010
       7     18719         0         0       1717      816    .69       563        0        0         0           0          0    16439     37010
       8     16439        80         0       1717      750    .59       442        0        0         0           0          0    14360     37010
       9     14360      1510         0       1288      712    .44       313        0        0         0           0          0    14269     37010
      10     14269     15950         0       1288      921    .03        28        0        0         0           0          0    28903     37010
      11     28903      2460         0       1002     1132    .22       249        0        0         0           0          0    30112     37010
      12     30112     14470         0       1002     1219    .08        98        0        0         0           0       6472    37010     37010

      YEAR TOTALS      50610         0      14312                      2688        0        0         0           0       6472
1
                   TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR 14     CALENDAR YEAR 1954

                        RESERVOIR NO  1   GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL          0
0          INITIAL      UREG    UPSTRM              SURFACE  EVAP      EVAP  DWNSTRM             PUMPED       PUMPED     SYSTEM END MO.     OPER.
    MONTH  STORAGE   INFLOWS    SPILLS     DEMAND     AREA   RATE      LOSS   SPILLS SHORTAGE      INTO         OUT       LOSS  CONTENT      RULE
       1     37010      1200         0        859     1297    .14       182        0        0         0           0        159    37010     37010
       2     37010       750         0        859     1296    .31       402        0        0         0           0          0    36499     37010
       3     36499       420         0       1002     1278    .29       371        0        0         0           0          0    35546     37010
       4     35546        60         0       1145     1247    .19       237        0        0         0           0          0    34224     37010
       5     34224      2290         0       1145     1241    .29       360        0        0         0           0          0    35009     37010
       6     35009        60         0       1288     1228    .66       810        0        0         0           0          0    32971     37010
       7     32971         0         0       1717     1178    .86      1013        0        0         0           0          0    30241     37010
       8     30241         0         0       1717     1116    .90      1004        0        0         0           0          0    27520     37010
       9     27520         0         0       1288     1055    .75       791        0        0         0           0          0    25441     37010
      10     25441         0         0       1288     1003    .47       471        0        0         0           0          0    23682     37010
      11     23682         0         0       1002      961    .26       250        0        0         0           0          0    22430     37010
      12     22430         0         0       1002      927    .30       278        0        0         0           0          0    21150     37010

      YEAR TOTALS       4780         0      14312                      6169        0        0         0           0        159
1
                   TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR 15     CALENDAR YEAR 1955

                        RESERVOIR NO  1   GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL          0
0          INITIAL      UREG    UPSTRM              SURFACE  EVAP      EVAP  DWNSTRM             PUMPED       PUMPED     SYSTEM END MO.     OPER.
    MONTH  STORAGE   INFLOWS    SPILLS     DEMAND     AREA   RATE      LOSS   SPILLS SHORTAGE      INTO         OUT       LOSS  CONTENT      RULE
       1     21150         0         0        859      897    .06        54        0        0         0           0          0    20237     37010
       2     20237      2330         0        859      905   -.03       -26        0        0         0           0          0    21734     37010
       3     21734      1030         0       1002      923    .23       212        0        0         0           0          0    21550     37010
       4     21550      2600         0       1145      937    .26       244        0        0         0           0          0    22761     37010
       5     22761      3540         0       1145      985    .09        89        0        0         0           0          0    25067     37010
       6     25067      4530         0       1288     1057    .28       296        0        0         0           0          0    28013     37010
       7     28013         0         0       1717     1065    .62       660        0        0         0           0          0    25636     37010
       8     25636         0         0       1717     1003    .40       401        0        0         0           0          0    23518     37010
       9     23518         0         0       1288      951    .41       390        0        0         0           0          0    21840     37010
      10     21840        70         0       1288      904    .62       560        0        0         0           0          0    20062     37010
      11     20062        60         0       1002      863    .43       371        0        0         0           0          0    18749     37010
      12     18749       130         0       1002      833    .20       167        0        0         0           0          0    17710     37010

      YEAR TOTALS      14290         0      14312                      3418        0        0         0           0          0
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1
                  TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR 16     CALENDAR YEAR 1956

                        RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL        0
0             INITIAL     UREG   UPSTRM               SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.     OPER.
   MONTH  STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS  SHORTAGE    INTO        OUT      LOSS   CONTENT     RULE
      1     17710      130        0       859      809    .11       89        0        0        0          0        0    16892    37010
      2     16892      590        0       859      794    .10       79        0        0        0          0        0    16544    37010
      3     16544       80        0      1002      769    .40      308        0        0        0          0        0    15314    37010
      4     15314       10        0      1145      722    .37      267        0        0        0          0        0    13912    37010
      5     13912        0        0      1145      674    .30      202        0        0        0          0        0    12565    37010
      6     12565      330        0      1288      626    .68      426        0        0        0          0        0    11181    37010
      7     11181        0        0      1717      566    .92      521        0        0        0          0        0     8943    37010
      8      8943        0        0      1717      483    .92      444        0        0        0          0        0     6782    37010
      9      6782        0        0      1288      409    .81      331        0        0        0          0        0     5163    37010
     10      5163        0        0      1288      343    .50      171        0        0        0          0        0     3704    37010
     11      3704       10        0      1002      272    .32       87        0        0        0          0        0     2625    37010
     12      2625       10        0      1002      214    .14       30        0        0        0          0        0     1603    37010

    YEAR TOTALS      1160        0     14312                     2955        0        0        0          0        0
1
                  TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

   SIMULATION YEAR 17     CALENDAR YEAR 1957

                        RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   37010  MIN. OPERATING POOL        0
0             INITIAL     UREG   UPSTRM               SURFACE  EVAP     EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.     OPER.
   MONTH  STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS  SHORTAGE    INTO        OUT      LOSS   CONTENT     RULE
      1      1603      130        0       859      164    .18       30        0        0        0          0        0      844    37010
      2       844        0        0       859       65    .02        1        0       16        0          0        0        0    37010
      3         0     1860        0      1002       66    .00        0        0        0        0          0        0      858    37010
      4       858    48300        0      1145      845   -.52     -438        0        0        0          0    11445    37006    37010
      5     37006    11410        0      1145     1295   -.15     -193        0        0        0          0    10455    37009    37010
      6     37009    29530        0      1288     1297    .21      272        0        0        0          0    27969    37010    37010
      7     37010     1190        0      1717     1291    .79     1020        0        0        0          0        0    35463    37010
      8     35463     3000        0      1717     1276    .87     1110        0        0        0          0        0    35636    37010
      9     35636     1640        0      1288     1269    .22      279        0        0        0          0        0    35709    37010
     10     35709    41040        0      1288     1280   -.11     -140        0        0        0          0    38591    37010    37010
     11     37010    12050        0      1002     1296   -.06      -77        0        0        0          0    11125    37010    37010
     12     37010     7090        0      1002     1297    .16      208        0        0        0          0     5880    37010    37010

    YEAR TOTALS    157240        0     14312                     2072        0       16        0          0   105465
1
                  TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions

                  SIMULATION PERIOD TOTAL SUMMARY BY NODE  1

    YEAR START. STRG.  UNREG. FLOW     DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
      1       37010        133650       14312           0         2222       117836       36290
      2       36290         67710       14312           0         2479        50199       37010
      3       37010         23450       14312           0         4496        12362       29290
      4       29290        104540       14312           0         2825        79684       37009
      5       37009         92460       14312           0         3207        74940       37010
      6       37010         97340       14312           0         3201        79827       37010
      7       37010         68760       14312           0         4611        56893       29954
      8       29954         12220       14312           0         4468            0       23394
      9       23394         34430       14312           0         3183        11422       28907
     10       28907         20040       14312           0         4489          356       29790
     11       29790          3360       14312           0         4017            0       14821
     12       14821         11900       14312           0         2537            0        9872
     13        9872         50610       14312           0         2688         6472       37010
     14       37010          4780       14312           0         6169          159       21150
     15       21150         14290       14312           0         3418            0       17710
     16       17710          1160       14312           0         2955            0        1603
     17        1603        157240       14312          16         2072       105465       37010
     18       37010         92890       14312           0         3029        75549       37010
     19       37010         66100       14312           0         2711        49077       37010
     20       37010        102800       14312           0         2970        85519       37009
     21       37009        115470       14312           0         3129        98028       37010
     22       37010         38090       14312           0         4485        19293       37010
     23       37010         13750       14312           0         5445         4364       26639
     24       26639         14960       14312           0         3119            0       24168
     25       24168        151000       14312           0         2675       121171       37010


     PERIOD TOTALS        1493000      357800          16        86600      1048616


   PERIOD AVERAGES          59720       14312           0         3464        41944
1
                  TITLE CARD  Lake Georgetown 1995 Yield with Unappropriated & Stream Depletions
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                 SIMULATION PERIOD TOTAL SUMMARY BY YEAR***

YEAR START. STRG.  UNREG. FLOW      DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
  1        37010       133650        14312           0         2222       117836       36290
  2        36290        67710        14312           0         2479        50199       37010
  3        37010        23450        14312           0         4496        12362       29290
  4        29290       104540        14312           0         2825        79684       37009
  5        37009        92460        14312           0         3207        74940       37010
  6        37010        97340        14312           0         3201        79827       37010
  7        37010        68760        14312           0         4611        56893       29954
  8        29954        12220        14312           0         4468            0       23394
  9        23394        34430        14312           0         3183        11422       28907
 10        28907        20040        14312           0         4489          356       29790
 11        29790         3360        14312           0         4017            0       14821
 12        14821        11900        14312           0         2537            0        9872
 13         9872        50610        14312           0         2688         6472       37010
 14        37010         4780        14312           0         6169          159       21150
 15        21150        14290        14312           0         3418            0       17710
 16        17710         1160        14312           0         2955            0        1603
 17         1603       157240        14312          16         2072       105465       37010
 18        37010        92890        14312           0         3029        75549       37010
 19        37010        66100        14312           0         2711        49077       37010
 20        37010       102800        14312           0         2970        85519       37009
 21        37009       115470        14312           0         3129        98028       37010
 22        37010        38090        14312           0         4485        19293       37010
 23        37010        13750        14312           0         5445         4364       26639
 24        26639        14960        14312           0         3119            0       24168
 25        24168       151000        14312           0         2675       121171       37010


 PERIOD TOTALS           1493000       357800          16        86600      1048616


PERIOD AVERAGES            59720        14312           0         3464        41944
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**Lake
Georgetown
2050**

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1
      RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

                   NUMBER OF NODES =    1           NUMBER OF RESERVOIRS =  1

                   NUMBER OF LINKS =    0         NUMBER OF RIVER REACHES =  0

      CALENDAR YEAR OPERATION STARTS = 1941     NUMBER OF YEARS TO SIMULATE = 25

            NUMBER OF DEMAND NODES =    1          NUMBER OF SPILL NODES =  1

                        YIELD NODE =    0                    IMPORT NODE =  0


      NODE NO.   NODE NAME    --------- CAPACITIES ---------    YEARLY
                                MAXIMUM   MINIMUM   STARTING    DEMAND

        1        GEORGETN        36711        0       36711      14220
1
      RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

      SYSTEM CONFIGURATION

      LINK NO.    FROM NODE     TO NODE     MAX. CAPACITY    MIN. CAPACITY


      LIST OF SPILL RESERVOIRS -      1


      YEARLY IMPORT QUANTITY =         0

      MONTHLY IMPORT DISTRIBUTION -   .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00

      SUB-SYSTEM OF RESERVOIRS      1

      'AVERAGE' DEFINED AS BETWEEN40.00, AND90.00 PERCENT FULL OF SUBSYSTEM


      FACTORS

          MULTIPLY LINK CAPACITIES BY    1.000

          MULTIPLY INFLOWS BY .......    10.00

          MULTIPLY DEMANDS BY .......     1.00
1
      RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions


                                   MONTHLY DEMAND DISTRIBUTION
      NODE NO.           JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY   AUG.   SEPT   OCT.   NOV.   DEC.    * RANK *
                                                                                                            AVG DRY WET

        1              .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700    1   1   1
1
      RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

              TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions


                               DESIRED MONTHLY STORAGE LEVEL (PERCENT FULL)
      RESERVOIR NO.

        1   AVRG    1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       2
            DRY     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       2
            WET     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000       2
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1
        RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

                  TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

                                        RESERVOIRS AREA - CAPACITY TABLES

               RESERVOIR NO.  1    RESERVOIR NO.
     1              0        0
     2            145      941
     3            358     4683
     4            435     6667
     5            532     9076
     6            631    11977
     7            702    13969
     8            781    16189
     9            844    18628
    10            914    21262
    11            994    24123
    12           1079    27230
    13           1133    29444
    14           1185    31764
    15           1236    34185
    16           1297    36711
    17              0        0
    18              0        0
1
                  TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

   SIMULATION YEAR  6     CALENDAR YEAR 1946

                     RESERVOIR NO  1   GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM               SURFACE  EVAP    EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.    OPER.
   MONTH STORAGE  INFLOWS   SPILLS     DEMAND     AREA    RATE    LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT     RULE
     1    36711     7520       0         853      1296    -.08    -103       0        0        0         0     6770    36711    36711
     2    36711    10170       0         853      1297     .04      52       0        0        0         0     9265    36711    36711
     3    36711     9890       0         995      1297     .10     130       0        0        0         0     8765    36711    36711
     4    36711     9930       0        1138      1297     .12     156       0        0        0         0     8636    36711    36711
     5    36711    15100       0        1138      1297     .03      39       0        0        0         0    13923    36711    36711
     6    36711     8650       0        1280      1297     .38     493       0        0        0         0     6877    36711    36711
     7    36711     2200       0        1706      1297     .78    1012       0        0        0         0        0    36193    36711
     8    36193     1120       0        1706      1267     .67     849       0        0        0         0        0    34758    36711
     9    34758        0       0        1280      1235     .10     123       0        0        0         0        0    33355    36711
    10    33355     2700       0        1280      1230     .29     357       0        0        0         0        0    34418    36711
    11    34418    17910       0         995      1269     .01      13       0        0        0         0    14609    36711    36711
    12    36711    12150       0         995      1297     .06      78       0        0        0         0    11077    36711    36711

    YEAR TOTALS    97340       0       14219                       3199       0        0        0         0    79922
1
                  TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

   SIMULATION YEAR  7     CALENDAR YEAR 1947

                     RESERVOIR NO  1   GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM               SURFACE  EVAP    EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.    OPER.
   MONTH STORAGE  INFLOWS   SPILLS     DEMAND     AREA    RATE    LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT     RULE
     1    36711    22150       0         853      1295    -.14    -180       0        0        0         0    21478    36710    36711
     2    36710     8510       0         853      1297     .19     246       0        0        0         0     7410    36711    36711
     3    36711     9360       0         995      1297     .05      65       0        0        0         0     8300    36711    36711
     4    36711    10020       0        1138      1297     .10     130       0        0        0         0     8752    36711    36711
     5    36711    10180       0        1138      1297     .20     259       0        0        0         0     8783    36711    36711
     6    36711     4230       0        1280      1297     .57     739       0        0        0         0     2211    36711    36711
     7    36711     1180       0        1706      1291     .76     981       0        0        0         0        0    35204    36711
     8    35204      780       0        1706      1242     .49     609       0        0        0         0        0    33669    36711
     9    33669      620       0        1280      1209     .69     834       0        0        0         0        0    32175    36711
    10    32175      420       0        1280      1177     .56     659       0        0        0         0        0    30656    36711
    11    30656      520       0         995      1152     .22     253       0        0        0         0        0    29928    36711
    12    29928      790       0         995      1142     .01      11       0        0        0         0        0    29712    36711

    YEAR TOTALS    68760       0       14219                       4606       0        0        0         0    56934
1
                  TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

   SIMULATION YEAR  8     CALENDAR YEAR 1948

                     RESERVOIR NO  1   GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM               SURFACE  EVAP    EVAP  DWNSTRM            PUMPED     PUMPED    SYSTEM END MO.    OPER.
   MONTH STORAGE  INFLOWS   SPILLS     DEMAND     AREA    RATE    LOSS   SPILLS SHORTAGE    INTO       OUT      LOSS  CONTENT     RULE
     1    29712      870       0         853      1139     .05      57       0        0        0         0        0    29672    36711
     2    29672        0       0         853      1128    -.06     -67       0        0        0         0        0    28886    36711
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    3    28886     1720       0      995     1125    .21     236       0        0        0        0        0    29375    36711
    4    29375     2450       0     1138     1143    .23     263       0        0        0        0        0    30424    36711
    5    30424     4000       0     1138     1185    .18     213       0        0        0        0        0    33073    36711
    6    33073     1220       0     1280     1205    .53     639       0        0        0        0        0    32374    36711
    7    32374     1290       0     1706     1186    .56     664       0        0        0        0        0    31294    36711
    8    31294      200       0     1706     1148    .75     861       0        0        0        0        0    28927    36711
    9    28927       10       0     1280     1098    .52     571       0        0        0        0        0    27086    36711
   10    27086      190       0     1280     1053    .47     495       0        0        0        0        0    25501    36711
   11    25501      100       0      995     1015    .34     345       0        0        0        0        0    24261    36711
   12    24261      170       0      995      984    .19     187       0        0        0        0        0    23249    36711

    YEAR TOTALS   12220       0    14219                   4464       0        0        0        0        0
1
                  TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

  SIMULATION YEAR  9     CALENDAR YEAR 1949

                  RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL         0
0          INITIAL    UREG   UPSTRM             SURFACE  EVAP    EVAP  DWNSTRM           PUMPED    PUMPED    SYSTEM END MO.     OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND    AREA    RATE    LOSS    SPILLS SHORTAGE   INTO      OUT      LOSS   CONTENT     RULE
    1     23249     1270       0      853      978    -.16    -155       0        0        0        0        0    23821    36711
    2     23821     1970       0      853     1002    -.06     -59       0        0        0        0        0    24997    36711
    3     24997        0       0      995     1003     .10     100       0        0        0        0        0    23902    36711
    4     23902    21850       0     1138     1149    -.24    -275       0        0        0        0     8178    36711    36711
    5     36711     5010       0     1138     1297     .34     441       0        0        0        0     3431    36711    36711
    6     36711     1440       0     1280     1297     .28     363       0        0        0        0        0    36508    36711
    7     36508      700       0     1706     1270     .64     813       0        0        0        0        0    34689    36711
    8     34689      300       0     1706     1224     .61     747       0        0        0        0        0    32536    36711
    9     32536      210       0     1280     1183     .54     639       0        0        0        0        0    30827    36711
   10     30827      160       0     1280     1150     .12     138       0        0        0        0        0    29569    36711
   11     29569      350       0      995     1123     .40     449       0        0        0        0        0    28475    36711
   12     28475     1170       0      995     1111    -.02     -21       0        0        0        0        0    28671    36711

    YEAR TOTALS   34430       0    14219                   3180       0        0        0        0    11609
1
                  TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

  SIMULATION YEAR 10     CALENDAR YEAR 1950

                  RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL         0
0          INITIAL    UREG   UPSTRM             SURFACE  EVAP    EVAP  DWNSTRM           PUMPED    PUMPED    SYSTEM END MO.     OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND    AREA    RATE    LOSS    SPILLS SHORTAGE   INTO      OUT      LOSS   CONTENT     RULE
    1     28671      570       0      853     1111     .05      56       0        0        0        0        0    28332    36711
    2     28332     4440       0      853     1148    -.05     -56       0        0        0        0        0    31975    36711
    3     31975      910       0      995     1184     .33     391       0        0        0        0        0    31499    36711
    4     31499     4940       0     1138     1219    -.06     -72       0        0        0        0        0    35373    36711
    5     35373     2090       0     1138     1276     .14     179       0        0        0        0        0    36146    36711
    6     36146     2690       0     1280     1290     .30     387       0        0        0        0      458    36711    36711
    7     36711      840       0     1706     1277     .59     753       0        0        0        0        0    35092    36711
    8     35092      240       0     1706     1229     .82    1008       0        0        0        0        0    32618    36711
    9     32618     2590       0     1280     1213     .29     352       0        0        0        0        0    33576    36711
   10     33576      340       0     1280     1207     .49     591       0        0        0        0        0    32045    36711
   11     32045      160       0      995     1176     .46     541       0        0        0        0        0    30669    36711
   12     30669      230       0      995     1148     .31     356       0        0        0        0        0    29548    36711

    YEAR TOTALS   20040       0    14219                   4486       0        0        0        0      458
1
                  TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

  SIMULATION YEAR 11     CALENDAR YEAR 1951

                  RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL         0
0          INITIAL    UREG   UPSTRM             SURFACE  EVAP    EVAP  DWNSTRM           PUMPED    PUMPED    SYSTEM END MO.     OPER.
  MONTH   STORAGE  INFLOWS  SPILLS    DEMAND    AREA    RATE    LOSS    SPILLS SHORTAGE   INTO      OUT      LOSS   CONTENT     RULE
    1     29548      270       0      853     1125     .27     304       0        0        0        0        0    28661    36711
    2     28661      160       0      853     1105    -.02     -21       0        0        0        0        0    27989    36711
    3     27989        0       0      995     1082     .23     249       0        0        0        0        0    26745    36711
    4     26745      370       0     1138     1051     .29     305       0        0        0        0        0    25672    36711
    5     25672        0       0     1138     1019     .10     102       0        0        0        0        0    24432    36711
    6     24432     2300       0     1280     1012     .29     293       0        0        0        0        0    25159    36711
    7     25159        0       0     1706      988     .80     790       0        0        0        0        0    22663    36711
    8     22663        0       0     1706      917     .95     871       0        0        0        0        0    20086    36711
    9     20086        0       0     1280      861     .39     336       0        0        0        0        0    18470    36711
   10     18470       90       0     1280      820     .45     369       0        0        0        0        0    16911    36711
   11     16911       50       0      995      785     .28     220       0        0        0        0        0    15746    36711
   12     15746      120       0      995      746     .25     186       0        0        0        0        0    14685    36711

    YEAR TOTALS    3360       0    14219                   4004       0        0        0        0        0
1
                  TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

  SIMULATION YEAR 12     CALENDAR YEAR 1952
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                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM              PUMPED      PUMPED    SYSTEM  END MO.      OPER.
   MONTH   STORAGE  INFLOWS   SPILLS     DEMAND     AREA     RATE     LOSS   SPILLS  SHORTAGE     INTO        OUT      LOSS   CONTENT     RULE
     1       14685      140        0        853      712      .22      157        0         0        0          0         0    13815    36711
     2       13815      230        0        853      683      .16      109        0         0        0          0         0    13083    36711
     3       13083      340        0        995      657      .15       99        0         0        0          0         0    12329    36711
     4       12329     2170        0       1138      662     -.02      -12        0         0        0          0         0    13373    36711
     5       13373     4680        0       1138      743      .05       37        0         0        0          0         0    16878    36711
     6       16878     2720        0       1280      812      .47      382        0         0        0          0         0    17936    36711
     7       17936        0        0       1706      798      .61      487        0         0        0          0         0    15743    36711
     8       15743        0        0       1706      722      .97      700        0         0        0          0         0    13337    36711
     9       13337        0        0       1280      652      .39      254        0         0        0          0         0    11803    36711
    10       11803        0        0       1280      596      .68      405        0         0        0          0         0    10118    36711
    11       10118       10        0        995      551     -.04      -21        0         0        0          0         0     9154    36711
    12        9154     1610        0        995      546     -.12      -65        0         0        0          0         0     9834    36711

     YEAR TOTALS     11900        0     14219                         2532        0         0        0          0         0
1
                   TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

   SIMULATION YEAR 13     CALENDAR YEAR 1953

                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM              PUMPED      PUMPED    SYSTEM  END MO.      OPER.
   MONTH   STORAGE  INFLOWS   SPILLS     DEMAND     AREA     RATE     LOSS   SPILLS  SHORTAGE     INTO        OUT      LOSS   CONTENT     RULE
     1        9834     2740        0        853      587      .27      158        0         0        0          0         0    11563    36711
     2       11563     1730        0        853      631      .08       50        0         0        0          0         0    12390    36711
     3       12390      760        0        995      640      .10       64        0         0        0          0         0    12091    36711
     4       12091     2330        0       1138      655      .11       72        0         0        0          0         0    13211    36711
     5       13211     7340        0       1138      783      .09       70        0         0        0          0         0    19343    36711
     6       19343     1240        0       1280      855      .68      581        0         0        0          0         0    18722    36711
     7       18722        0        0       1706      817      .69      564        0         0        0          0         0    16452    36711
     8       16452       80        0       1706      753      .59      444        0         0        0          0         0    14382    36711
     9       14382     1510        0       1280      715      .44      315        0         0        0          0         0    14297    36711
    10       14297    15950        0       1280      924      .03       28        0         0        0          0         0    28939    36711
    11       28939     2460        0        995     1135      .22      250        0         0        0          0         0    30154    36711
    12       30154    14470        0        995     1220      .08       98        0         0        0          0      6820    36711    36711

     YEAR TOTALS     50610        0     14219                         2694        0         0        0          0      6820
1
                   TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

   SIMULATION YEAR 14     CALENDAR YEAR 1954

                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM              PUMPED      PUMPED    SYSTEM  END MO.      OPER.
   MONTH   STORAGE  INFLOWS   SPILLS     DEMAND     AREA     RATE     LOSS   SPILLS  SHORTAGE     INTO        OUT      LOSS   CONTENT     RULE
     1       36711     1200        0        853     1297      .14      182        0         0        0          0       165    36711    36711
     2       36711      750        0        853     1296      .31      402        0         0        0          0         0    36206    36711
     3       36206      420        0        995     1278      .29      371        0         0        0          0         0    35260    36711
     4       35260       60        0       1138     1246      .19      237        0         0        0          0         0    33945    36711
     5       33945     2290        0       1138     1240      .29      360        0         0        0          0         0    34737    36711
     6       34737       60        0       1280     1226      .66      809        0         0        0          0         0    32708    36711
     7       32708        0        0       1706     1176      .86     1011        0         0        0          0         0    29991    36711
     8       29991        0        0       1706     1113      .90     1002        0         0        0          0         0    27283    36711
     9       27283        0        0       1280     1052      .75      789        0         0        0          0         0    25214    36711
    10       25214        0        0       1280     1000      .47      470        0         0        0          0         0    23464    36711
    11       23464        0        0        995      958      .26      249        0         0        0          0         0    22220    36711
    12       22220        0        0        995      923      .30      277        0         0        0          0         0    20948    36711

     YEAR TOTALS      4780        0     14219                         6159        0         0        0          0       165
1
                   TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

   SIMULATION YEAR 15     CALENDAR YEAR 1955

                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM                SURFACE   EVAP     EVAP  DWNSTRM              PUMPED      PUMPED    SYSTEM  END MO.      OPER.
   MONTH   STORAGE  INFLOWS   SPILLS     DEMAND     AREA     RATE     LOSS   SPILLS  SHORTAGE     INTO        OUT      LOSS   CONTENT     RULE
     1       20948        0        0        853      894      .06       54        0         0        0          0         0    20041    36711
     2       20041     2330        0        853      902     -.03      -26        0         0        0          0         0    21544    36711
     3       21544     1030        0        995      919      .23      211        0         0        0          0         0    21368    36711
     4       21368     2600        0       1138      934      .26      243        0         0        0          0         0    22587    36711
     5       22587     3540        0       1138      983      .09       88        0         0        0          0         0    24901    36711
     6       24901     4530        0       1280     1056      .28      296        0         0        0          0         0    27855    36711
     7       27855        0        0       1706     1064      .62      660        0         0        0          0         0    25489    36711
     8       25489        0        0       1706     1003      .40      401        0         0        0          0         0    23382    36711
     9       23382        0        0       1280      950      .41      389        0         0        0          0         0    21713    36711
    10       21713       70        0       1280      902      .62      559        0         0        0          0         0    19944    36711
    11       19944       60        0        995      862      .43      371        0         0        0          0         0    18638    36711
    12       18638      130        0        995      831      .20      166        0         0        0          0         0    17607    36711

     YEAR TOTALS     14290        0     14219                         3412        0         0        0          0         0
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                 TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

  SIMULATION YEAR 16     CALENDAR YEAR 1956

                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0        INITIAL     UREG   UPSTRM             SURFACE  EVAP    EVAP  DWNSTRM             PUMPED    PUMPED    SYSTEM END MO.    OPER.
  MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA  RATE    LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT    RULE
     1     17607      130        0        853      807   .11      89        0         0        0         0         0    16795   36711
     2     16795      590        0        853      792   .10      79        0         0        0         0         0    16453   36711
     3     16453       80        0        995      769   .40     308        0         0        0         0         0    15230   36711
     4     15230       10        0       1138      722   .37     267        0         0        0         0         0    13835   36711
     5     13835        0        0       1138      673   .30     202        0         0        0         0         0    12495   36711
     6     12495      330        0       1280      625   .68     425        0         0        0         0         0    11120   36711
     7     11120        0        0       1706      564   .92     519        0         0        0         0         0     8895   36711
     8      8895        0        0       1706      481   .92     443        0         0        0         0         0     6746   36711
     9      6746        0        0       1280      407   .81     330        0         0        0         0         0     5136   36711
    10      5136        0        0       1280      342   .50     171        0         0        0         0         0     3685   36711
    11      3685       10        0        995      271   .32      87        0         0        0         0         0     2613   36711
    12      2613       10        0        995      211   .14      30        0         0        0         0         0     1598   36711

    YEAR TOTALS      1160        0    14219                     2950        0         0        0         0         0
1
                 TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

  SIMULATION YEAR 17     CALENDAR YEAR 1957

                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0        INITIAL     UREG   UPSTRM             SURFACE  EVAP    EVAP  DWNSTRM             PUMPED    PUMPED    SYSTEM END MO.    OPER.
  MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA  RATE    LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT    RULE
     1      1598      130        0        853      161   .18      29        0         0        0         0         0      846   36711
     2       846        0        0        853       65   .02       1        0         8        0         0         0        0   36711
     3         0     1860        0        995       67   .00       0        0         0        0         0         0      865   36711
     4       865    48300        0       1138      842  -.52    -437        0         0        0         0     11756    36708   36711
     5     36708    11410        0       1138     1295  -.15    -193        0         0        0         0     10463    36710   36711
     6     36710    29530        0       1280     1297   .21     272        0         0        0         0     27977    36711   36711
     7     36711     1190        0       1706     1291   .79    1020        0         0        0         0         0    35175   36711
     8     35175     3000        0       1706     1276   .87    1110        0         0        0         0         0    35359   36711
     9     35359     1640        0       1280     1269   .22     279        0         0        0         0         0    35440   36711
    10     35440    41040        0       1280     1280  -.11    -140        0         0        0         0     38629    36711   36711
    11     36711    12050        0        995     1296  -.06     -77        0         0        0         0     11132    36711   36711
    12     36711     7090        0        995     1297   .16     208        0         0        0         0      5887    36711   36711

    YEAR TOTALS    157240        0    14219                     2072        0         8        0         0    105844
1
                 TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions

                 SIMULATION PERIOD TOTAL SUMMARY BY NODE  1

    YEAR START. STRG.  UNREG. FLOW     DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
      1         36711       133650       14219            0         2221       117888        36033
      2         36033        67710       14219            0         2481        50332        36711
      3         36711        23450       14219            0         4494        12395        29053
      4         29053       104540       14219            0         2824        79840        36710
      5         36710        92460       14219            0         3207        75033        36711
      6         36711        97340       14219            0         3199        79922        36711
      7         36711        68760       14219            0         4606        56934        29712
      8         29712        12220       14219            0         4464            0        23249
      9         23249        34430       14219            0         3180        11609        28671
     10         28671        20040       14219            0         4486          458        29548
     11         29548         3360       14219            0         4004            0        14685
     12         14685        11900       14219            0         2532            0         9834
     13          9834        50610       14219            0         2694         6820        36711
     14         36711         4780       14219            0         6159          165        20948
     15         20948        14290       14219            0         3412            0        17607
     16         17607         1160       14219            0         2950            0         1598
     17          1598       157240       14219            8         2072       105844        36711
     18         36711        92890       14219            0         3029        75642        36711
     19         36711        66100       14219            0         2711        49170        36711
     20         36711       102800       14219            0         2970        85612        36710
     21         36710       115470       14219            0         3129        98121        36711
     22         36711        38090       14219            0         4484        19387        36711
     23         36711        13750       14219            0         5436         4390        26416
     24         26416        14960       14219            0         3115            0        24042
     25         24042       151000       14219            0         2676       121436        36711


     PERIOD TOTALS             1493000      355475            8        86535      1050998


   PERIOD AVERAGES               59720       14219            0         3461        42039
1
                 TITLE CARD  Lake Georgetown 2050 Sediment * Unappropriated & Stream Depletions
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                SIMULATION PERIOD TOTAL SUMMARY BY YEAR***

YEAR START. STRG.  UNREG. FLOW     DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
   1       36711       133650       14219           0         2221       117888        36033
   2       36033        67710       14219           0         2481        50332        36711
   3       36711        23450       14219           0         4494        12395        29053
   4       29053       104540       14219           0         2824        79840        36710
   5       36710        92460       14219           0         3207        75033        36711
   6       36711        97340       14219           0         3199        79922        36711
   7       36711        68760       14219           0         4606        56934        29712
   8       29712        12220       14219           0         4464            0        23249
   9       23249        34430       14219           0         3180        11609        28671
  10       28671        20040       14219           0         4486          458        29548
  11       29548         3360       14219           0         4004            0        14685
  12       14685        11900       14219           0         2532            0         9834
  13        9834        50610       14219           0         2694         6820        36711
  14       36711         4780       14219           0         6159          165        20948
  15       20948        14290       14219           0         3412            0        17607
  16       17607         1160       14219           0         2950            0         1598
  17        1598       157240       14219           8         2072       105844        36711
  18       36711        92890       14219           0         3029        75642        36711
  19       36711        66100       14219           0         2711        49170        36711
  20       36711       102800       14219           0         2970        85612        36710
  21       36710       115470       14219           0         3129        98121        36711
  22       36711        38090       14219           0         4484        19387        36711
  23       36711        13750       14219           0         5436         4390        26416
  24       26416        14960       14219           0         3115            0        24042
  25       24042       151000       14219           0         2676       121436        36711


 PERIOD TOTALS        1493000      355475           8        86535      1050998


PERIOD AVERAGES         59720       14219           0         3461        42039
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Stillhouse-
Georgetown
2050

```
1
         RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

                 TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

                     NUMBER OF NODES =    2              NUMBER OF RESERVOIRS =  2

                     NUMBER OF LINKS =    1          NUMBER OF RIVER REACHES =  0

         CALENDAR YEAR OPERATION STARTS = 1941      NUMBER OF YEARS TO SIMULATE = 25

                NUMBER OF DEMAND NODES =    2           NUMBER OF SPILL NODES =  2

                          YIELD NODE =    0                      IMPORT NODE =  0


         NODE NO.   NODE NAME    --------- CAPACITIES ---------     YEARLY
                                   MAXIMUM   MINIMUM   STARTING     DEMAND

            1        STILLHSE       206563         0     206563      27580

            2        GEORGETN        36711         0      36711      56931
1
         RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

                 TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

         SYSTEM CONFIGURATION

         LINK NO.    FROM NODE     TO NODE     MAX. CAPACITY    MIN. CAPACITY

            1            1            2              3560               0


         LIST OF SPILL RESERVOIRS -      1    2

         YEARLY IMPORT QUANTITY =          0

         MONTHLY IMPORT DISTRIBUTION -   .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00

         SUB-SYSTEM OF RESERVOIRS      2

         'AVERAGE' DEFINED AS BETWEEN40.00, AND99.00 PERCENT FULL OF SUBSYSTEM


         FACTORS

             MULTIPLY LINK CAPACITIES BY     1.000

             MULTIPLY INFLOWS BY .......    10.00

             MULTIPLY DEMANDS BY .......     1.00
1
         RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

                 TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

                                   MONTHLY DEMAND DISTRIBUTION
         NODE NO.          JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY   AUG.   SEPT   OCT.   NOV.   DEC.     * RANK *
                                                                                                               AVG DRY WET

            1             .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700     2   2   2

            2             .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700     1   1   1
1
         RIVER BASIN SIMULATION PROGRAM  -          TEXAS WATER DEVELOPMENT BOARD

                 TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.
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                                        DESIRED MONTHLY STORAGE LEVEL (PERCENT FULL)
       RESERVOIR NO.

            1   AVRG     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        4
                DRY      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        4
                WET      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        4

            2   AVRG     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        3
                DRY      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        3
                WET      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000        3
1

       RIVER BASIN SIMULATION PROGRAM  -           TEXAS WATER DEVELOPMENT BOARD

                TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.


                                        RESERVOIRS AREA - CAPACITY TABLES


           RESERVOIR NO.  1     RESERVOIR NO.  2     RESERVOIR NO.
   1            0        0          0        0
   2          231     2959        145      941
   3          788    10814        358     4683
   4         1158    18533        435     6667
   5         1589    29574        532     9076
   6         2064    44086        631    11977
   7         2607    62708        702    13969
   8         3223    85979        781    16189
   9         3561    99527        844    18628
  10         3992   114608        914    21262
  11         4335   127098        994    24123
  12         4696   140639       1079    27230
  13         5076   155302       1133    29444
  14         5459   171094       1185    31764
  15         5886   188088       1236    34185
  16         6429   206563       1297    36711
  17            0        0          0        0
  18            0        0          0        0
1
                TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

   SIMULATION YEAR  6     CALENDAR YEAR 1946

                  RESERVOIR NO  1  STILLHSE   MAX. CAPACITY  206563  MIN. OPERATING POOL       0
0         INITIAL    UREG   UPSTRM              SURFACE  EVAP      EVAP  DWNSTRM             PUMPED     PUMPED    SYSTEM END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS    DEMAND      AREA   RATE      LOSS   SPILLS SHORTAGE      INTO        OUT      LOSS  CONTENT     RULE
     1     206563    29110       0      1655      6422   -.07      -449        0        0         0          0     27904   206563   206563
     2     206563    41690       0      1655      6429    .05       321        0        0         0          0     39714   206563   206563
     3     206563    53490       0      1931      6429    .11       707        0        0         0          0     50852   206563   206563
     4     206563    23220       0      2206      6429    .15       964        0        0         0          0     20050   206563   206563
     5     206563    24700       0      2206      6429    .02       129        0        0         0          0     22365   206563   206563
     6     206563    14230       0      2482      6429    .40      2572        0        0         0          0      9176   206563   206563
     7     206563     3050       0      3310      6300    .79      4977        0        0         0       3560         0   197766   206563
     8     197766     2990       0      3310      6049    .73      4416        0        0         0       3560         0   189470   206563
     9     189470     5150       0      2482      5904    .11       649        0        0         0       3560         0   187929   206563
    10     187929     3520       0      2482      5828    .30      1748        0        0         0       3560         0   183659   206563
    11     183659    10750       0      1931      5881    .06       353        0        0         0          0         0   192125   206563
    12     192125    13480       0      1931      6174    .07       432        0        0         0          0         0   203242   206563

    YEAR TOTALS   225380        0   27581                        16819        0        0         0    14240    170061

                  RESERVOIR NO  2  GEORGETN   MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0         INITIAL    UREG   UPSTRM              SURFACE  EVAP      EVAP  DWNSTRM             PUMPED     PUMPED    SYSTEM END MO.    OPER.
   MONTH  STORAGE  INFLOWS  SPILLS    DEMAND      AREA   RATE      LOSS   SPILLS SHORTAGE      INTO        OUT      LOSS  CONTENT     RULE
     1      36711     7520       0      3416      1296   -.08      -103        0        0         0          0      4207    36711    36711
     2      36711    10170       0      3416      1297    .04        52        0        0         0          0      6702    36711    36711
     3      36711     9890       0      3985      1297    .10       130        0        0         0          0      5775    36711    36711
     4      36711     9930       0      4554      1297    .12       156        0        0         0          0      5220    36711    36711
     5      36711    15100       0      4554      1297    .03        39        0        0         0          0     10507    36711    36711
     6      36711     8650       0      5124      1297    .38       493        0        0         0          0      3033    36711    36711
     7      36711     2200       0      6832      1272    .78       992        0        0      3560          0         0    34647    36711
     8      34647     1120       0      6832      1214    .67       813        0        0      3560          0         0    31682    36711
     9      31682        0       0      5124      1164    .10       116        0        0      3560          0         0    30002    36711
    10      30002     2700       0      5124      1154    .29       335        0        0      3560          0         0    30803    36711
    11      30803    17910       0      3985      1227    .01        12        0        0         0          0      8005    36711    36711
    12      36711    12150       0      3985      1297    .06        78        0        0         0          0      8087    36711    36711

    YEAR TOTALS    97340        0   56931                         3113        0        0     14240          0     51536
1
                TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

   SIMULATION YEAR  7     CALENDAR YEAR 1947
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                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL         0
0         INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM               PUMPED    PUMPED   SYSTEM  END MO.    OPER.
   MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS  SHORTAGE      INTO       OUT     LOSS  CONTENT     RULE
     1     203242    40080        0       1655     6367   -.14     -890        0         0         0         0    35996   206561   206563
     2     206561    18810        0       1655     6429    .20     1286        0         0         0         0    15867   206563   206563
     3     206563    35660        0       1931     6429    .05      321        0         0         0         0    33408   206563   206563
     4     206563    26150        0       2206     6429    .10      643        0         0         0         0    23301   206563   206563
     5     206563    20660        0       2206     6429    .19     1222        0         0         0         0    17232   206563   206563
     6     206563     6290        0       2482     6429    .57     3665        0         0         0      1633        0   205073   206563
     7     205073     2010        0       3310     6244    .76     4745        0         0         0      3560        0   195468   206563
     8     195468     1910        0       3310     5984    .52     3112        0         0         0      3560        0   187396   206563
     9     187396     1060        0       2482     5755    .70     4028        0         0         0      3560        0   178386   206563
    10     178386      780        0       2482     5536    .57     3156        0         0         0      3560        0   169968   206563
    11     169968     1360        0       1931     5367    .23     1234        0         0         0      3560        0   164603   206563
    12     164603     1760        0       1931     5256    .01       53        0         0         0      3560        0   160819   206563

    YEAR TOTALS    156530        0      27581                     22575        0         0         0     22993   125804

                    RESERVOIR NO  2  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL         0
0         INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM               PUMPED    PUMPED   SYSTEM  END MO.    OPER.
   MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS  SHORTAGE      INTO       OUT     LOSS  CONTENT     RULE
     1      36711    22150        0       3416     1295   -.14     -180        0         0         0         0    18915    36710    36711
     2      36710     8510        0       3416     1297    .19      246        0         0         0         0     4847    36711    36711
     3      36711     9360        0       3985     1297    .05       65        0         0         0         0     5310    36711    36711
     4      36711    10020        0       4554     1297    .10      130        0         0         0         0     5336    36711    36711
     5      36711    10180        0       4554     1297    .20      259        0         0         0         0     5367    36711    36711
     6      36711     4230        0       5124     1297    .57      739        0         0      1633         0        0    36711    36711
     7      36711     1180        0       6832     1260    .76      958        0         0      3560         0        0    33661    36711
     8      33661      780        0       6832     1192    .49      584        0         0      3560         0        0    30585    36711
     9      30585      620        0       5124     1139    .69      786        0         0      3560         0        0    28855    36711
    10      28855      420        0       5124     1097    .56      614        0         0      3560         0        0    27097    36711
    11      27097      520        0       3985     1073    .22      236        0         0      3560         0        0    26956    36711
    12      26956      790        0       3985     1076    .01       11        0         0      3560         0        0    27310    36711

    YEAR TOTALS     68760        0      56931                      4448        0         0     22993         0    39775
1
                TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

   SIMULATION YEAR  8     CALENDAR YEAR 1948

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL         0
0         INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM               PUMPED    PUMPED   SYSTEM  END MO.    OPER.
   MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS  SHORTAGE      INTO       OUT     LOSS  CONTENT     RULE
     1     160819     1630        0       1655     5163    .05      258        0         0         0      3560        0   156976   206563
     2     156976    12340        0       1655     5207   -.06     -311        0         0         0      3560        0   164412   206563
     3     164412     3090        0       1931     5254    .21     1103        0         0         0      3560        0   160908   206563
     4     160908     6620        0       2206     5208    .23     1198        0         0         0      3560        0   160564   206563
     5     160564    10540        0       2206     5251    .16      840        0         0         0      3560        0   164498   206563
     6     164498      600        0       2482     5200    .53     2756        0         0         0      3560        0   156300   206563
     7     156300     5020        0       3310     5042    .55     2773        0         0         0      3560        0   151677   206563
     8     151677     3090        0       3310     4884    .77     3761        0         0         0      3560        0   144136   206563
     9     144136      320        0       2482     4679    .54     2527        0         0         0      3560        0   135887   206563
    10     135887      190        0       2482     4462    .50     2231        0         0         0      3560        0   127804   206563
    11     127804      540        0       1931     4265    .36     1535        0         0         0      3560        0   121318   206563
    12     121318     1070        0       1931     4104    .20      821        0         0         0      3560        0   116076   206563

    YEAR TOTALS     45050        0      27581                     19492        0         0         0     42720        0

                    RESERVOIR NO  2  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL         0
0         INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM               PUMPED    PUMPED   SYSTEM  END MO.    OPER.
   MONTH  STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS  SHORTAGE      INTO       OUT     LOSS  CONTENT     RULE
     1      27310      870        0       3416     1093    .05       55        0         0      3560         0        0    28269    36711
     2      28269        0        0       3416     1107   -.06      -65        0         0      3560         0        0    28478    36711
     3      28478     1720        0       3985     1122    .21      236        0         0      3560         0        0    29537    36711
     4      29537     2450        0       4554     1148    .23      264        0         0      3560         0        0    30729    36711
     5      30729     4000        0       4554     1193    .18      215        0         0      3560         0        0    33520    36711
     6      33520     1220        0       5124     1212    .53      642        0         0      3560         0        0    32534    36711
     7      32534     1290        0       6832     1173    .56      657        0         0      3560         0        0    29895    36711
     8      29895      200        0       6832     1096    .75      822        0         0      3560         0        0    26001    36711
     9      26001       10        0       5124     1017    .52      529        0         0      3560         0        0    23918    36711
    10      23918      190        0       5124      963    .47      453        0         0      3560         0        0    22091    36711
    11      22091      100        0       3985      928    .34      316        0         0      3560         0        0    21450    36711
    12      21450      170        0       3985      913    .19      173        0         0      3560         0        0    21022    36711

    YEAR TOTALS     12220        0      56931                      4297        0         0     42720         0        0
1
                TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

   SIMULATION YEAR  9     CALENDAR YEAR 1949

                    RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL         0
0         INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM               PUMPED    PUMPED   SYSTEM  END MO.    OPER.
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  MONTH  STORAGE  INFLOWS   SPILLS    DEMAND      AREA   RATE     LOSS    SPILLS SHORTAGE     INTO      OUT     LOSS   CONTENT      RULE
    1     116076     1220        0      1655      3985   -.15     -597         0        0        0     3560        0    112678    206563
    2     112678     1380        0      1655      3885   -.05     -193         0        0        0     3560        0    109036    206563
    3     109036    23140        0      1931      4076    .10      408         0        0        0     3560        0    126277    206563
    4     126277    43930        0      2206      4878   -.21    -1023         0        0        0        0        0    169024    206563
    5     169024     9020        0      2206      5469    .34     1859         0        0        0        0        0    173979    206563
    6     173979    12170        0      2482      5590    .26     1453         0        0        0     3560        0    178654    206563
    7     178654     1470        0      3310      5536    .65     3598         0        0        0     3560        0    169656    206563
    8     169656     1510        0      3310      5319    .62     3298         0        0        0     3560        0    160998    206563
    9     160998      160        0      2482      5107    .58     2962         0        0        0     3560        0    152154    206563
   10     152154      150        0      2482      4910    .13      638         0        0        0     3560        0    145624    206563
   11     145624      690        0      1931      4737    .42     1990         0        0        0     3560        0    138833    206563
   12     138833     1410        0      1931      4593    .01       46         0        0        0     3560        0    134706    206563

  YEAR TOTALS       96250        0     27581                    14439         0        0        0    35600        0

                         RESERVOIR NO  2  GEORGETN     MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM               SURFACE   EVAP     EVAP   DWNSTRM             PUMPED   PUMPED   SYSTEM   END MO.     OPER.
  MONTH  STORAGE  INFLOWS   SPILLS    DEMAND      AREA   RATE     LOSS    SPILLS SHORTAGE     INTO      OUT     LOSS   CONTENT      RULE
    1      21022     1270        0      3416       929   -.16     -148         0        0     3560        0        0     22584     36711
    2      22584     1970        0      3416       981   -.06      -58         0        0     3560        0        0     24756     36711
    3      24756        0        0      3985      1004    .10      100         0        0     3560        0        0     24231     36711
    4      24231    21850        0      4554      1153   -.24     -276         0        0        0        0     5092     36711     36711
    5      36711     5010        0      4554      1297    .34      441         0        0        0        0       15     36711     36711
    6      36711     1440        0      5124      1296    .28      363         0        0     3560        0        0     36224     36711
    7      36224      700        0      6832      1245    .64      797         0        0     3560        0        0     32855     36711
    8      32855      300        0      6832      1168    .61      712         0        0     3560        0        0     29171     36711
    9      29171      210        0      5124      1103    .54      596         0        0     3560        0        0     27221     36711
   10      27221      160        0      5124      1058    .12      127         0        0     3560        0        0     25690     36711
   11      25690      350        0      3985      1030    .40      412         0        0     3560        0        0     25203     36711
   12      25203     1170        0      3985      1034   -.02      -20         0        0     3560        0        0     25968     36711

  YEAR TOTALS       34430        0     56931                     3046         0        0    35600        0     5107
1
                     TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

  SIMULATION YEAR 10     CALENDAR YEAR 1950

                         RESERVOIR NO  1  STILLHSE     MAX. CAPACITY  206563  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM               SURFACE   EVAP     EVAP   DWNSTRM             PUMPED   PUMPED   SYSTEM   END MO.     OPER.
  MONTH  STORAGE  INFLOWS   SPILLS    DEMAND      AREA   RATE     LOSS    SPILLS SHORTAGE     INTO      OUT     LOSS   CONTENT      RULE
    1     134706      880        0      1655      4477    .05      224         0        0        0     3560        0    130147    206563
    2     130147     5970        0      1655      4430   -.07     -309         0        0        0     3560        0    131211    206563
    3     131211     1330        0      1931      4369    .35     1529         0        0        0     3560        0    125521    206563
    4     125521     6010        0      2206      4297   -.04     -171         0        0        0     3560        0    125936    206563
    5     125936     6610        0      2206      4307    .13      560         0        0        0     3560        0    126220    206563
    6     126220     4610        0      2482      4278    .30     1283         0        0        0     3233        0    123832    206563
    7     123832      440        0      3310      4124    .58     2392         0        0        0     3560        0    115010    206563
    8     115010        0        0      3310      3860    .82     3165         0        0        0     3560        0    104975    206563
    9     104975     6970        0      2482      3714    .30     1114         0        0        0     3560        0    104789    206563
   10     104789      220        0      2482      3602    .50     1801         0        0        0     3560        0     97166    206563
   11      97166      380        0      1931      3418    .47     1606         0        0        0     3560        0     90449    206563
   12      90449      450        0      1931      3259    .32     1043         0        0        0     3560        0     84365    206563

  YEAR TOTALS       33870        0     27581                    14237         0        0        0    42393        0

                         RESERVOIR NO  2  GEORGETN     MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM               SURFACE   EVAP     EVAP   DWNSTRM             PUMPED   PUMPED   SYSTEM   END MO.     OPER.
  MONTH  STORAGE  INFLOWS   SPILLS    DEMAND      AREA   RATE     LOSS    SPILLS SHORTAGE     INTO      OUT     LOSS   CONTENT      RULE
    1      25968      570        0      3416      1054    .05       53         0        0     3560        0        0     26629     36711
    2      26629     4440        0      3416      1120   -.05      -55         0        0     3560        0        0     31268     36711
    3      31268      910        0      3985      1175    .33      388         0        0     3560        0        0     31365     36711
    4      31365     4940        0      4554      1218   -.06      -72         0        0     3560        0        0     35383     36711
    5      35383     2090        0      4554      1278    .14      179         0        0     3560        0        0     36300     36711
    6      36300     2690        0      5124      1292    .30      388         0        0     3233        0        0     36711     36711
    7      36711      840        0      6832      1259    .59      743         0        0     3560        0        0     33536     36711
    8      33536      240        0      6832      1180    .82      968         0        0     3560        0        0     29536     36711
    9      29536     2590        0      5124      1143    .29      331         0        0     3560        0        0     30231     36711
   10      30231      340        0      5124      1130    .49      554         0        0     3560        0        0     28453     36711
   11      28453      160        0      3985      1099    .46      506         0        0     3560        0        0     27682     36711
   12      27682      230        0      3985      1084    .31      336         0        0     3560        0        0     27151     36711

  YEAR TOTALS       20040        0     56931                     4319         0        0    42393        0        0
1
                     TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

  SIMULATION YEAR 11     CALENDAR YEAR 1951

                         RESERVOIR NO  1  STILLHSE     MAX. CAPACITY  206563  MIN. OPERATING POOL       0
0        INITIAL     UREG   UPSTRM               SURFACE   EVAP     EVAP   DWNSTRM             PUMPED   PUMPED   SYSTEM   END MO.     OPER.
  MONTH  STORAGE  INFLOWS   SPILLS    DEMAND      AREA   RATE     LOSS    SPILLS SHORTAGE     INTO      OUT     LOSS   CONTENT      RULE
    1      84365      470        0      1655      3106    .27      839         0        0        0     3560        0     78781    206563
    2      78781      660        0      1655      2972    .00        0         0        0        0     3560        0     74226    206563
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    3      74226      960        0       1931     2842    .25      710        0        0        0       3560        0    68985    206563
    4      68985      430        0       2206     2692    .28      754        0        0        0       3560        0    62895    206563
    5      62895     5490        0       2206     2605    .10      260        0        0        0       3560        0    62359    206563
    6      62359     3560        0       2482     2551    .26      663        0        0        0       3560        0    59214    206563
    7      59214        0        0       3310     2377    .80     1902        0        0        0       3560        0    50442    206563
    8      50442        0        0       3310     2119    .97     2055        0        0        0       3560        0    41517    206563
    9      41517     1120        0       2482     1887    .40      755        0        0        0       3560        0    35840    206563
   10      35840        0        0       2482     1683    .45      757        0        0        0       3560        0    29041    206563
   11      29041      250        0       1931     1458    .29      423        0        0        0       3560        0    23377    206563
   12      23377      320        0       1931     1240    .26      322        0        0        0       3560        0    17884    206563

   YEAR TOTALS    13260        0    27581                        9440        0        0        0  42720          0

                      RESERVOIR NO  2  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.      OPER.
 MONTH    STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE      INTO        OUT     LOSS  CONTENT       RULE
    1      27151      270        0       3416     1078    .27      291        0        0      3560          0        0    27274     36711
    2      27274      160        0       3416     1084   -.02      -21        0        0      3560          0        0    27599     36711
    3      27599        0        0       3985     1080    .23      248        0        0      3560          0        0    26926     36711
    4      26926      370        0       4554     1058    .29      307        0        0      3560          0        0    25995     36711
    5      25995        0        0       4554     1030    .10      103        0        0      3560          0        0    24898     36711
    6      24898     2300        0       5124     1021    .29      296        0        0      3560          0        0    25338     36711
    7      25338        0        0       6832      971    .80      777        0        0      3560          0        0    21289     36711
    8      21289        0        0       6832      860    .95      817        0        0      3560          0        0    17200     36711
    9      17200        0        0       5124      783    .39      305        0        0      3560          0        0    15331     36711
   10      15331       90        0       5124      718    .45      323        0        0      3560          0        0    13534     36711
   11      13534       50        0       3985      676    .28      189        0        0      3560          0        0    12970     36711
   12      12970      120        0       3985      658    .25      164        0        0      3560          0        0    12501     36711

   YEAR TOTALS     3360        0    56931                        3799        0        0  42720          0        0
1
                    TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

  SIMULATION YEAR 12     CALENDAR YEAR 1952

                      RESERVOIR NO  1  STILLHSE    MAX. CAPACITY   206563  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.      OPER.
 MONTH    STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE      INTO        OUT     LOSS  CONTENT       RULE
    1      17884      280        0       1655     1003    .23      231        0        0         0       3560        0    12718    206563
    2      12718      300        0       1655      744    .17      126        0        0         0       3560        0     7677    206563
    3       7677      860        0       1931      399    .15       60        0        0         0       3560        0     2986    206563
    4       2986    18950        0       2206      701   -.04      -27        0        0         0       3560        0    16197    206563
    5      16197    37710        0       2206     1673    .04       67        0        0         0       3560        0    48074    206563
    6      48074     5570        0       2482     2158    .48     1036        0        0         0       3560        0    46566    206563
    7      46566     1600        0       3310     2038    .62     1264        0        0         0       3560        0    40032    206563
    8      40032       20        0       3310     1790    .98     1754        0        0         0       3560        0    31428    206563
    9      31428        0        0       2482     1529    .47      719        0        0         0       3560        0    24667    206563
   10      24667        0        0       2482     1262    .72      909        0        0         0       3560        0    17716    206563
   11      17716      980        0       1931     1012   -.05      -50        0        0         0       3560        0    13255    206563
   12      13255    16160        0       1931     1163   -.12     -139        0        0         0       3560        0    24063    206563

   YEAR TOTALS    82430        0    27581                        5950        0        0        0  42720          0

                      RESERVOIR NO  2  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.      OPER.
 MONTH    STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE      INTO        OUT     LOSS  CONTENT       RULE
    1      12501      140        0       3416      652    .22      143        0        0      3560          0        0    12642     36711
    2      12642      230        0       3416      659    .16      105        0        0      3560          0        0    12911     36711
    3      12911      340        0       3985      661    .15       99        0        0      3560          0        0    12727     36711
    4      12727     2170        0       4554      679   -.02      -13        0        0      3560          0        0    13916     36711
    5      13916     4680        0       4554      765    .05       38        0        0      3560          0        0    17564     36711
    6      17564     2720        0       5124      826    .47      388        0        0      3560          0        0    18332     36711
    7      18332        0        0       6832      788    .61      481        0        0      3560          0        0    14579     36711
    8      14579        0        0       6832      654    .97      634        0        0      3560          0        0    10673     36711
    9      10673        0        0       5124      556    .39      217        0        0      3560          0        0     8892     36711
   10       8892        0        0       5124      486    .68      330        0        0      3560          0        0     6998     36711
   11       6998       10        0       3985      440   -.04      -17        0        0      3560          0        0     6600     36711
   12       6600     1610        0       3985      457   -.12      -54        0        0      3560          0        0     7839     36711

   YEAR TOTALS    11900        0    56931                        2351        0        0  42720          0        0
1
                    TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

  SIMULATION YEAR 13     CALENDAR YEAR 1953

                      RESERVOIR NO  1  STILLHSE    MAX. CAPACITY   206563  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM              SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.      OPER.
 MONTH    STORAGE  INFLOWS   SPILLS     DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE      INTO        OUT     LOSS  CONTENT       RULE
    1      24063     4570        0       1655     1354    .27      366        0        0         0       3560        0    23052    206563
    2      23052     2650        0       1655     1282    .10      128        0        0         0       3560        0    20359    206563
    3      20359     5320        0       1931     1224    .09      110        0        0         0       3560        0    20078    206563
    4      20078     8520        0       2206     1269    .13      165        0        0         0       3560        0    22667    206563
    5      22667    81050        0       2206     2535    .05      127        0        0         0       3560        0    97824    206563
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     6     97824      3720        0      2482     3461    .67     2319        0         0        0      3560        0     93183    206563
     7     93183      1070        0      3310     3304    .65     2148        0         0        0      3560        0     85235    206563
     8     85235         0        0      3310     3088    .59     1822        0         0        0      3560        0     76543    206563
     9     76543      3740        0      2482     2925    .45     1316        0         0        0      3560        0     72925    206563
    10     72925      9350        0      2482     2919    .05      146        0         0        0      3560        0     76087    206563
    11     76087      1800        0      1931     2903    .23      668        0         0        0      3560        0     71728    206563
    12     71728      6770        0      1931     2906    .10      291        0         0        0         0        0     76276    206563

     YEAR TOTALS    128560        0     27581                      9606        0         0        0     39160        0

                    RESERVOIR NO  2   GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL         0
0         INITIAL     UREG    UPSTRM                SURFACE  EVAP      EVAP  DWNSTRM              PUMPED      PUMPED     SYSTEM  END MO.     OPER.
  MONTH   STORAGE   INFLOWS   SPILLS     DEMAND      AREA    RATE      LOSS   SPILLS  SHORTAGE     INTO        OUT       LOSS   CONTENT     RULE
     1      7839      2740        0      3416      536     .27      145        0         0      3560         0        0     10578     36711
     2     10578      1730        0      3416      614     .08       49        0         0      3560         0        0     12403     36711
     3     12403       760        0      3985      651     .10       65        0         0      3560         0        0     12673     36711
     4     12673      2330        0      4554      678     .11       75        0         0      3560         0        0     13934     36711
     5     13934      7340        0      4554      804     .09       72        0         0      3560         0        0     20208     36711
     6     20208      1240        0      5124      874     .68      594        0         0      3560         0        0     19290     36711
     7     19290         0        0      6832      812     .69      560        0         0      3560         0        0     15458     36711
     8     15458        80        0      6832      691     .59      408        0         0      3560         0        0     11858     36711
     9     11858      1510        0      5124      621     .44      273        0         0      3560         0        0     11531     36711
    10     11531     15950        0      5124      847     .03       25        0         0      3560         0        0     25892     36711
    11     25892      2460        0      3985     1067     .22      235        0         0      3560         0        0     27692     36711
    12     27692     14470        0      3985     1194     .08       96        0         0         0         0     1370     36711     36711

     YEAR TOTALS     50610        0     56931                      2597        0         0     39160         0     1370
1
                   TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

  SIMULATION YEAR 14     CALENDAR YEAR 1954

                    RESERVOIR NO  1   STILLHSE    MAX. CAPACITY   206563  MIN. OPERATING POOL         0
0         INITIAL     UREG    UPSTRM                SURFACE  EVAP      EVAP  DWNSTRM              PUMPED      PUMPED     SYSTEM  END MO.     OPER.
  MONTH   STORAGE   INFLOWS   SPILLS     DEMAND      AREA    RATE      LOSS   SPILLS  SHORTAGE     INTO        OUT       LOSS   CONTENT     RULE
     1     76276      1560        0      1655     2928     .13      381        0         0         0      2398        0     73402    206563
     2     73402       840        0      1655     2826     .33      933        0         0         0      3068        0     68586    206563
     3     68586       480        0      1931     2686     .29      779        0         0         0      3560        0     62796    206563
     4     62796       760        0      2206     2530     .18      455        0         0         0      3560        0     57335    206563
     5     57335      5610        0      2206     2438     .28      683        0         0         0      3560        0     56496    206563
     6     56496         0        0      2482     2315     .67     1551        0         0         0      3560        0     48903    206563
     7     48903        10        0      3310     2077     .90     1869        0         0         0      3560        0     40174    206563
     8     40174        40        0      3310     1797     .92     1653        0         0         0      3560        0     31691    206563
     9     31691        40        0      2482     1532     .76     1164        0         0         0      3560        0     24525    206563
    10     24525      1010        0      2482     1282     .46      590        0         0         0      3560        0     18903    206563
    11     18903      1790        0      1931     1080     .26      281        0         0         0      3560        0     14921    206563
    12     14921       300        0      1931      854     .31      265        0         0         0      3560        0      9465    206563

     YEAR TOTALS     12440        0     27581                     10604        0         0        0     41066        0

                    RESERVOIR NO  2   GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL         0
0         INITIAL     UREG    UPSTRM                SURFACE  EVAP      EVAP  DWNSTRM              PUMPED      PUMPED     SYSTEM  END MO.     OPER.
  MONTH   STORAGE   INFLOWS   SPILLS     DEMAND      AREA    RATE      LOSS   SPILLS  SHORTAGE     INTO        OUT       LOSS   CONTENT     RULE
     1     36711      1200        0      3416     1297     .14      182        0         0      2398         0        0     36711     36711
     2     36711       750        0      3416     1297     .31      402        0         0      3068         0        0     36711     36711
     3     36711       420        0      3985     1297     .29      376        0         0      3560         0        0     36330     36711
     4     36330        60        0      4554     1277     .19      243        0         0      3560         0        0     35153     36711
     5     35153      2290        0      4554     1275     .29      370        0         0      3560         0        0     36079     36711
     6     36079        60        0      5124     1254     .66      828        0         0      3560         0        0     33747     36711
     7     33747         0        0      6832     1181     .86     1016        0         0      3560         0        0     29459     36711
     8     29459         0        0      6832     1082     .90      974        0         0      3560         0        0     25213     36711
     9     25213         0        0      5124      992     .75      744        0         0      3560         0        0     22905     36711
    10     22905         0        0      5124      932     .47      438        0         0      3560         0        0     20903     36711
    11     20903         0        0      3985      896     .26      233        0         0      3560         0        0     20245     36711
    12     20245         0        0      3985      878     .30      263        0         0      3560         0        0     19557     36711

     YEAR TOTALS      4780        0     56931                      6069        0         0     41066         0        0
1
                   TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

  SIMULATION YEAR 15     CALENDAR YEAR 1955

                    RESERVOIR NO  1   STILLHSE    MAX. CAPACITY   206563  MIN. OPERATING POOL         0
0         INITIAL     UREG    UPSTRM                SURFACE  EVAP      EVAP  DWNSTRM              PUMPED      PUMPED     SYSTEM  END MO.     OPER.
  MONTH   STORAGE   INFLOWS   SPILLS     DEMAND      AREA    RATE      LOSS   SPILLS  SHORTAGE     INTO        OUT       LOSS   CONTENT     RULE
     1      9465      2040        0      1655      578     .07       40        0         0         0      3560        0      6250    206563
     2      6250      6730        0      1655      519    -.03      -15        0         0         0      3560        0      7780    206563
     3      7780      2220        0      1931      453     .23      104        0         0         0      3560        0      4405    206563
     4      4405      4340        0      2206      280     .25       70        0         0         0      3560        0      2909    206563
     5      2909     53710        0      2206     1482     .06       89        0         0         0      3560        0     50764    206563
     6     50764     23860        0      2482     2508     .28      702        0         0         0      3560        0     67880    206563
     7     67880      9380        0      3310     2755     .61     1681        0         0         0      3560        0     68709    206563
     8     68709      4810        0      3310     2724     .40     1090        0         0         0      3560        0     65559    206563
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     9       65559     7480        0      2482     2688    .38     1021        0        0        0      3560         0    65976     206563
    10       65976       30        0      2482     2591    .62     1606        0        0        0      3560         0    58358     206563
    11       58358      180        0      1931     2387    .45     1074        0        0        0      3560         0    51973     206563
    12       51973      400        0      1931     2213    .21      465        0        0        0      3560         0    46417     206563

  YEAR TOTALS       115180        0     27581                      7927        0        0        0     42720         0

                   RESERVOIR NO  2  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM            SURFACE   EVAP     EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.      OPER.
 MONTH     STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO       OUT      LOSS  CONTENT       RULE
     1       19557        0        0      3416      870    .06       52        0        0     3560         0         0    19649      36711
     2       19649     2330        0      3416      904   -.03      -26        0        0     3560         0         0    22149      36711
     3       22149     1030        0      3985      944    .23      217        0        0     3560         0         0    22537      36711
     4       22537     2600        0      4554      969    .26      252        0        0     3560         0         0    23891      36711
     5       23891     3540        0      4554     1021    .09       92        0        0     3560         0         0    26345      36711
     6       26345     4530        0      5124     1090    .28      305        0        0     3560         0         0    29006      36711
     7       29006        0        0      6832     1074    .62      666        0        0     3560         0         0    25068      36711
     8       25068        0        0      6832      969    .40      388        0        0     3560         0         0    21408      36711
     9       21408        0        0      5124      892    .41      366        0        0     3560         0         0    19478      36711
    10       19478       70        0      5124      840    .62      521        0        0     3560         0         0    17463      36711
    11       17463       60        0      3985      805    .43      346        0        0     3560         0         0    16752      36711
    12       16752      130        0      3985      790    .20      158        0        0     3560         0         0    16299      36711

  YEAR TOTALS        14290        0     56931                      3337        0        0    42720         0         0
1
                   TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

  SIMULATION YEAR 16     CALENDAR YEAR 1956

                   RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM            SURFACE   EVAP     EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.      OPER.
 MONTH     STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO       OUT      LOSS  CONTENT       RULE
     1       46417      410        0      1655     2058    .11      226        0        0        0      3560         0    41386     206563
     2       41386     1120        0      1655     1905    .10      190        0        0        0      3560         0    37101     206563
     3       37101       30        0      1931     1734    .41      711        0        0        0      3560         0    30929     206563
     4       30929        0        0      2206     1518    .37      562        0        0        0      3560         0    24601     206563
     5       24601    28020        0      2206     1782    .29      517        0        0        0      3560         0    46338     206563
     6       46338      250        0      2482     2020    .69     1394        0        0        0      3560         0    39152     206563
     7       39152        0        0      3310     1763    .94     1657        0        0        0      3560         0    30625     206563
     8       30625     1630        0      3310     1501    .92     1381        0        0        0      3560         0    24004     206563
     9       24004        0        0      2482     1233    .84     1036        0        0        0      3560         0    16926     206563
    10       16926      680        0      2482      941    .51      480        0        0        0      3560         0    11084     206563
    11       11084     3910        0      1931      743    .32      238        0        0        0      3560         0     9265     206563
    12        9265     4130        0      1931      627    .15       94        0        0        0      3560         0     7810     206563

  YEAR TOTALS        40180        0     27581                      8486        0        0        0     42720         0

                   RESERVOIR NO  2  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM            SURFACE   EVAP     EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.      OPER.
 MONTH     STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO       OUT      LOSS  CONTENT       RULE
     1       16299      130        0      3416      786    .11       86        0        0     3560         0         0    16487      36711
     2       16487      590        0      3416      797    .10       80        0        0     3560         0         0    17141      36711
     3       17141       80        0      3985      797    .40      319        0        0     3560         0         0    16477      36711
     4       16477       10        0      4554      769    .37      285        0        0     3560         0         0    15208      36711
     5       15208        0        0      4554      724    .30      217        0        0     3560         0         0    13997      36711
     6       13997      330        0      5124      673    .68      458        0        0     3560         0         0    12305      36711
     7       12305        0        0      6832      577    .92      531        0        0     3560         0         0     8502      36711
     8        8502        0        0      6832      435    .92      400        0        0     3560         0         0     4830      36711
     9        4830        0        0      5124      315    .81      255        0        0     3560         0         0     3011      36711
    10        3011        0        0      5124      215    .50      107        0        0     3560         0         0     1340      36711
    11        1340       10        0      3985      154    .32       49        0        0     3560         0         0      876      36711
    12         876       10        0      3985      102    .14       14        0        0     3560         0         0      447      36711

  YEAR TOTALS         1160        0     56931                      2801        0        0    42720         0         0
1
                   TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

  SIMULATION YEAR 17     CALENDAR YEAR 1957

                   RESERVOIR NO  1  STILLHSE    MAX. CAPACITY  206563  MIN. OPERATING POOL        0
0          INITIAL     UREG   UPSTRM            SURFACE   EVAP     EVAP  DWNSTRM            PUMPED    PUMPED    SYSTEM END MO.      OPER.
 MONTH     STORAGE  INFLOWS   SPILLS    DEMAND     AREA   RATE     LOSS   SPILLS SHORTAGE     INTO       OUT      LOSS  CONTENT       RULE
     1        7810      740        0      1655      414    .17       70        0        0        0      3560         0     3265     206563
     2        3265     1120        0      1655      127    .02        3        0        0        0      2727         0        0     206563
     3           0    11870        0      1931      247   -.01       -1        0        0        0      3560         0     6380     206563
     4        6380   171750        0      2206     3374   -.53    -1787        0        0        0         0         0   177711     206563
     5      177711   194520        0      2206     5991   -.16     -958        0        0        0         0    164422   206561     206563
     6      206561    44560        0      2482     6429    .25     1607        0        0        0         0     40469   206563     206563
     7      206563     3170        0      3310     6303    .77     4853        0        0        0      3560         0   198010     206563
     8      198010     1820        0      3310     6026    .87     5243        0        0        0      3560         0   187717     206563
     9      187717     2190        0      2482     5809    .26     1510        0        0        0      3560         0   182355     206563
    10      182355    58720        0      2482     6063   -.11     -666        0        0        0         0     32697   206562     206563
    11      206562    32360        0      1931     6423   -.06     -384        0        0        0         0     30813   206562     206563
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    12   206562   23030       0     1931    6429   .17   1093       0        0       0       0   20005   206563   206563

   YEAR TOTALS   545850       0    27581                10583       0        0       0   20527  288406

                    RESERVOIR NO  2  GEORGETN   MAX. CAPACITY   36711  MIN. OPERATING POOL       0
0          INITIAL    UREG  UPSTRM             SURFACE  EVAP   EVAP  DWNSTRM           PUMPED  PUMPED  SYSTEM END MO.     OPER.
   MONTH   STORAGE INFLOWS  SPILLS   DEMAND       AREA  RATE   LOSS   SPILLS SHORTAGE    INTO     OUT    LOSS  CONTENT     RULE
     1         447     130       0     3416         89   .18     16        0        0    3560       0       0      705    36711
     2         705       0       0     3416         55   .02      1        0        0    2727       0       0       15    36711
     3          15    1860       0     3985        113   .00      0        0        0    3560       0       0     1450    36711
     4        1450   48300       0     4554        850  -.52   -441        0        0       0       0    8929    36708    36711
     5       36708   11410       0     4554       1295  -.15   -193        0        0       0       0    7047    36710    36711
     6       36710   29530       0     5124       1297   .21    272        0        0       0       0   24133    36711    36711
     7       36711    1190       0     6832       1260   .79    995        0        0    3560       0       0    33634    36711
     8       33634    3000       0     6832       1210   .87   1053        0        0    3560       0       0    32309    36711
     9       32309    1640       0     5124       1194   .22    263        0        0    3560       0       0    32122    36711
    10       32122   41040       0     5124       1240  -.11   -135        0        0       0       0   31463    36710    36711
    11       36710   12050       0     3985       1296  -.06    -77        0        0       0       0    8141    36711    36711
    12       36711    7090       0     3985       1297   .16    208        0        0       0       0    2897    36711    36711

   YEAR TOTALS   157240       0    56931                 1962       0        0   20527       0   82610
1
                   TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

                   SIMULATION PERIOD TOTAL SUMMARY BY NODE  1

    YEAR START. STRG.  UNREG. FLOW     DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
      1        206563       614310       27581            0        12010       562347       201135
      2        201135       343130       27581            0        12744       279524       206563
      3        206563        51830       27581            0        22660        17086       163481
      4        163481       631740       27581            0        15472       520686       206562
      5        206562       568350       27581            0        16575       506396       206563
      6        206563       225380       27581            0        16819       170061       203242
      7        203242       156530       27581            0        22575       125804       160819
      8        160819        45050       27581            0        19492            0       116076
      9        116076        96250       27581            0        14439            0       134706
     10        134706        33870       27581            0        14237            0        84365
     11         84365        13260       27581            0         9440            0        17884
     12         17884        82430       27581            0         5950            0        24063
     13         24063       128560       27581            0         9606            0        76276
     14         76276        12440       27581            0        10604            0         9465
     15          9465       115180       27581            0         7927            0        46417
     16         46417        40180       27581            0         8486            0         7810
     17          7810       545850       27581            0        10583       288406       206563
     18        206563       307860       27581            0        16214       271826       181533
     19        181533       283510       27581            0        12668       196526       206563
     20        206563       375360       27581            0        15193       316104       206560
     21        206560       433960       27581            0        16247       379999       206563
     22        206563        86170       27581            0        22105        17259       200707
     23        200707        28250       27581            0        24668            0       140438
     24        140438        81300       27581            0        13854            0       137583
     25        137583       540340       27581            0        13035       416504       206563


     PERIOD TOTALS            5841090      689525            0       363603      4068528


   PERIOD AVERAGES             233643       27581            0        14544       162741
1
                   TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

                   SIMULATION PERIOD TOTAL SUMMARY BY NODE  2

    YEAR START. STRG.  UNREG. FLOW     DEMANDS    SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
      1         36711       133650       56931            0         2177        93970        35083
      2         35083        67710       56931            0         2444        24560        36711
      3         36711        23450       56931            0         4364          112        26339
      4         26339       104540       56931            0         2728        59430        36710
      5         36710        92460       56931            0         3180        50145        36711
      6         36711        97340       56931            0         3113        51536        36711
      7         36711        68760       56931            0         4448        39775        27310
      8         27310        12220       56931            0         4297            0        21022
      9         21022        34430       56931            0         3046         5107      . 25968
     10         25968        20040       56931            0         4319            0        27151
     11         27151         3360       56931            0         3799            0        12501
     12         12501        11900       56931            0         2351            0         7839
     13          7839        50610       56931            0         2597         1370        36711
     14         36711         4780       56931            0         6069            0        19557
     15         19557        14290       56931            0         3337            0        16299
     16         16299         1160       56931            0         2801            0          447
     17           447       157240       56931            0         1962        82610        36711
     18         36711        92890       56931            0         3005        50223        36711
     19         36711        66100       56931            0         2653        28221        36711
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      20          36711        102800        56931             0          2900         59455          36710
      21          36710        115470        56931             0          3122         65546          36711
      22          36711         38090        56931             0          4372          1868          36711
      23          36711         13750        56931             0          5255           648          23897
      24          23897         14960        56931             0          2998             0          21648
      25          21648        151000        56931             0          2579         90667          36711


    PERIOD TOTALS             1493000      1423275             0         83916        705243


  PERIOD AVERAGES               59720        56931             0          3356         28209
1
                         TITLE CARD  Stillhouse - Georgetown System with 2050 Sediment Conditions.

                         SIMULATION PERIOD TOTAL SUMMARY BY YEAR***

  YEAR START. STRG.  UNREG. FLOW       DEMANDS     SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
      1        243274        747960        84512             0         14187        656317         236218
      2        236218        410840        84512             0         15188        304084         243274
      3        243274         75280        84512             0         27024         17198         189820
      4        189820        736280        84512             0         18200        580116         243272
      5        243272        660810        84512             0         19755        556541         243274
      6        243274        322720        84512             0         19932        221597         239953
      7        239953        225290        84512             0         27023        165579         188129
      8        188129         57270        84512             0         23789             0         137098
      9        137098        130680        84512             0         17485          5107         160674
     10        160674         53910        84512             0         18556             0         111516
     11        111516         16620        84512             0         13239             0          30385
     12         30385         94330        84512             0          8301             0          31902
     13         31902        179170        84512             0         12203          1370         112987
     14        112987         17220        84512             0         16673             0          29022
     15         29022        129470        84512             0         11264             0          62716
     16         62716         41340        84512             0         11287             0           8257
     17          8257        703090        84512             0         12545        371016         243274
     18        243274        400750        84512             0         19219        322049         218244
     19        218244        349610        84512             0         15321        224747         243274
     20        243274        478160        84512             0         18093        375559         243270
     21        243270        549430        84512             0         19369        445545         243274
     22        243274        124260        84512             0         26477         19127         237418
     23        237418         42000        84512             0         29923           648         164335
     24        164335         96260        84512             0         16852             0         159231
     25        159231        691340        84512             0         15614        507171         243274


    PERIOD TOTALS             7334090      2112800             0        447519       4773771


  PERIOD AVERAGES              293363        84512             0         17900        190950
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1
          RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

                       NUMBER OF NODES =    2              NUMBER OF RESERVOIRS =  2

                       NUMBER OF LINKS =    2            NUMBER OF RIVER REACHES =  1

          CALENDAR YEAR OPERATION STARTS = 1941       NUMBER OF YEARS TO SIMULATE = 25

                NUMBER OF DEMAND NODES =    2               NUMBER OF SPILL NODES =  2

                            YIELD NODE =    0                         IMPORT NODE =  0


          NODE NO.   NODE NAME     --------- CAPACITIES ---------     YEARLY
                                     MAXIMUM  MINIMUM   STARTING      DEMAND

            1        GEORGETN         36711         0      36711       18280

            2        GRANGER          38330         0      38330       11736
1
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Granger-Georgetown

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          RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

          SYSTEM CONFIGURATION

          LINK NO.   FROM NODE    TO NODE    MAX. CAPACITY    MIN. CAPACITY

             1           1           2         999999999                0

             2           2           1               340                0


          LIST OF SPILL RESERVOIRS -     1    2

          YEARLY IMPORT QUANTITY =        0

          MONTHLY IMPORT DISTRIBUTION -  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00  .00

          SUB-SYSTEM OF RESERVOIRS      1

          'AVERAGE' DEFINED AS BETWEEN40.00, AND99.00 PERCENT FULL OF SUBSYSTEM


          FACTORS

              MULTIPLY LINK CAPACITIES BY    1.000

              MULTIPLY INFLOWS BY .......    10.00

              MULTIPLY DEMANDS BY .......     1.00
1
          RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

                                         MONTHLY DEMAND DISTRIBUTION
          NODE NO.          JAN.   FEB.   MAR.   APR.   MAY    JUNE   JULY   AUG.   SEPT   OCT.   NOV.   DEC.   * RANK *
                                                                                                             AVG DRY WET

            1              .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700    2   2   2

            2              .0600  .0600  .0700  .0800  .0800  .0900  .1200  .1200  .0900  .0900  .0700  .0700    1   1   1
1
          RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.
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                                             DESIRED MONTHLY STORAGE LEVEL (PERCENT FULL)
          RESERVOIR NO.

              1   AVRG     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000          3
                  DRY      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000          3
                  WET      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000          3

              2   AVRG     1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000          4
                  DRY      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000          4
                  WET      1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000 1.0000          4
1

          RIVER BASIN SIMULATION PROGRAM  -            TEXAS WATER DEVELOPMENT BOARD

                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.


                                             RESERVOIRS AREA - CAPACITY TABLES


               RESERVOIR NO.  1     RESERVOIR NO.  2     RESERVOIR NO.
      1             0        0         0        0
      2           145      941         0        0
      3           358     4683        59       33
      4           435     6667       229      330
      5           532     9076       365      920
      6           631    11977       548     1822
      7           702    13969       769     3138
      8           781    16189       994     4898
      9           844    18628      1246     7136
     10           914    21262      1532     9906
     11           994    24123      1871    13303
     12          1079    27230      2248    17429
     13          1133    29444      2617    22291
     14          1185    31764      3072    27944
     15          1236    34185      3527    34553
     16          1297    36711      4009    38330
     17             0        0         0        0
     18             0        0         0        0
1
                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

   SIMULATION YEAR 14      CALENDAR YEAR 1954

                            RESERVOIR NO  1   GEORGETN     MAX. CAPACITY    36711  MIN. OPERATING POOL        0
0          INITIAL     UREG    UPSTRM                   SURFACE  EVAP     EVAP  DWNSTRM                                                    
   MONTH   STORAGE  INFLOWS    SPILLS     DEMAND     AREA   RATE     LOSS    SPILLS SHORTAGE    PUMPED      PUMPED    SYSTEM END MO.     OPER.
                                                                                                  INTO        OUT      LOSS  CONTENT      RULE
     1       36711     1200         0       1097     1297    .14      182         0        0       340          0       261    36711     36711
     2       36711      750         0       1097     1297    .31      402         0        0       340          0         0    36302     36711
     3       36302      420         0       1280     1281    .29      371         0        0       340          0         0    35411     36711
     4       35411       60         0       1462     1253    .19      238         0        0       340          0         0    34111     36711
     5       34111     2290         0       1462     1248    .29      362         0        0       340          0         0    34917     36711
     6       34917       60         0       1645     1230    .66      812         0        0       340          0         0    32860     36711
     7       32860        0         0       2194     1177    .86     1012         0        0       340          0         0    29994     36711
     8       29994        0         0       2194     1112    .90     1001         0        0       340          0         0    27139     36711
     9       27139        0         0       1645     1048    .75      786         0        0       340          0         0    25048     36711
    10       25048        0         0       1645      995    .47      468         0        0       340          0         0    23275     36711
    11       23275        0         0       1280      954    .26      248         0        0       340          0         0    22087     36711
    12       22087        0         0       1280      920    .30      276         0        0       340          0         0    20871     36711

    YEAR TOTALS       4780         0    18281                        6158         0        0      4080          0       261

                            RESERVOIR NO  2   GRANGER      MAX. CAPACITY    38330  MIN. OPERATING POOL        0
0          INITIAL     UREG    UPSTRM                   SURFACE  EVAP     EVAP  DWNSTRM                                                    
   MONTH   STORAGE  INFLOWS    SPILLS     DEMAND     AREA   RATE     LOSS    SPILLS SHORTAGE    PUMPED      PUMPED    SYSTEM END MO.     OPER.
                                                                                                  INTO        OUT      LOSS  CONTENT      RULE
     1       38328     1570         0        704     4009    .10      401         0        0         0        340       123    38330     38330
     2       38330      920         0        704     4001    .28     1120         0        0         0        340         0    37086     38330
     3       37086      600         0        822     3745    .29     1086         0        0         0        340         0    35438     38330
     4       35438      100         0        939     3527    .17      600         0        0         0        340         0    33659     38330
     5       33659     4260         0        939     3544    .26      921         0        0         0        340         0    35719     38330
     6       35719      140         0       1056     3486    .65     2266         0        0         0        340         0    32197     38330
     7       32197       20         0       1408     3221    .76     2448         0        0         0        340         0    28021     38330
     8       28021       60         0       1408     2914    .82     2389         0        0         0        340         0    23944     38330
     9       23944      120         0       1056     2621    .74     1940         0        0         0        340         0    20728     38330
    10       20728        0         0       1056     2410    .39      940         0        0         0        340         0    18392     38330
    11       18392        0         0        822     2257    .23      519         0        0         0        340         0    16711     38330
    12       16711      150         0        822     2109    .28      591         0        0         0        340         0    15108     38330

    YEAR TOTALS       7940         0    11736                       15221         0        0         0       4080       123
1
                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.
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     SIMULATION YEAR 15      CALENDAR YEAR 1955

                         RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL         0
0            INITIAL      UREG    UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.      OPER.
      MONTH  STORAGE   INFLOWS    SPILLS     DEMAND      AREA    RATE     LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT      RULE
        1     20871         0         0       1097        893     .06       54       0         0      340         0         0    20060     36711
        2     20060      2330         0       1097        903   -.03      -26        0         0      340         0         0    21659     36711
        3     21659      1030         0       1280        923     .23      212        0         0      340         0         0    21537     36711
        4     21537      2600         0       1462        939     .26      244        0         0      340         0         0    22771     36711
        5     22771      3540         0       1462        989     .09       89        0         0      340         0         0    25100     36711
        6     25100      4530         0       1645       1061     .28      297        0         0      340         0         0    28028     36711
        7     28028         0         0       2194       1066     .62      661        0         0      340         0         0    25513     36711
        8     25513         0         0       2194       1001     .40      400        0         0      340         0         0    23259     36711
        9     23259         0         0       1645        946     .41      388        0         0      340         0         0    21566     36711
       10     21566        70         0       1645        898     .62      557        0         0      340         0         0    19774     36711
       11     19774        60         0       1280        858     .43      369        0         0      340         0         0    18525     36711
       12     18525       130         0       1280        829     .20      166        0         0      340         0         0    17549     36711

      YEAR TOTALS     14290         0      18281                          3411        0         0     4080         0         0

                         RESERVOIR NO  2  GRANGER     MAX. CAPACITY    38330  MIN. OPERATING POOL         0
0            INITIAL      UREG    UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.      OPER.
      MONTH  STORAGE   INFLOWS    SPILLS     DEMAND      AREA    RATE     LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT      RULE
        1     15108       170         0        704       1992     .04       80       0         0        0       340         0    14154     38330
        2     14154      4230         0        704       2104   -.10     -209        0         0        0       340         0    17549     38330
        3     17549      1830         0        822       2267     .18      408        0         0        0       340         0    17809     38330
        4     17809      4780         0        939       2393     .18      431        0         0        0       340         0    20879     38330
        5     20879      6550         0        939       2706     .09      244        0         0        0       340         0    25906     38330
        6     25906      8400         0       1056       3144     .27      849        0         0        0       340         0    32061     38330
        7     32061       710         0       1408       3258     .55     1792        0         0        0       340         0    29231     38330
        8     29231      3220         0       1408       3173     .35     1111        0         0        0       340         0    29592     38330
        9     29592        80         0       1056       3096     .41     1269        0         0        0       340         0    27007     38330
       10     27007       100         0       1056       2874     .61     1753        0         0        0       340         0    23958     38330
       11     23958        90         0        822       2665     .40     1066        0         0        0       340         0    21820     38330
       12     21820       190         0        822       2529     .16      405        0         0        0       340         0    20443     38330

      YEAR TOTALS     30350         0      11736                          9199        0         0        0      4080         0
1
                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

     SIMULATION YEAR 16      CALENDAR YEAR 1956

                         RESERVOIR NO  1  GEORGETN    MAX. CAPACITY    36711  MIN. OPERATING POOL         0
0            INITIAL      UREG    UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.      OPER.
      MONTH  STORAGE   INFLOWS    SPILLS     DEMAND      AREA    RATE     LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT      RULE
        1     17549       130         0       1097        807     .11       89       0         0      340         0         0    16833     36711
        2     16833       590         0       1097        794     .10       79       0         0      340         0         0    16587     36711
        3     16587        80         0       1280        774     .40      310       0         0      340         0         0    15417     36711
        4     15417        10         0       1462        729     .37      270       0         0      340         0         0    14035     36711
        5     14035         0         0       1462        681     .30      204       0         0      340         0         0    12709     36711
        6     12709       330         0       1645        632     .68      430       0         0      340         0         0    11304     36711
        7     11304         0         0       2194        567     .92      522       0         0      340         0         0     8928     36711
        8      8928         0         0       2194        480     .92      442       0         0      340         0         0     6632     36711
        9      6632         0         0       1645        402     .81      326       0         0      340         0         0     5001     36711
       10      5001         0         0       1645        334     .50      167       0         0      340         0         0     3529     36711
       11      3529        10         0       1280        263     .32       84       0         0      340         0         0     2515     36711
       12      2515        10         0       1280        207     .14       29       0         0      340         0         0     1556     36711

      YEAR TOTALS      1160         0      18281                          2952        0         0     4080         0         0

                         RESERVOIR NO  2  GRANGER     MAX. CAPACITY    38330  MIN. OPERATING POOL         0
0            INITIAL      UREG    UPSTRM                SURFACE  EVAP     EVAP  DWNSTRM              PUMPED     PUMPED    SYSTEM END MO.      OPER.
      MONTH  STORAGE   INFLOWS    SPILLS     DEMAND      AREA    RATE     LOSS   SPILLS  SHORTAGE     INTO       OUT      LOSS  CONTENT      RULE
        1     20443       190         0        704       2437     .08      195       0         0        0       340         0    19394     38330
        2     19394      1070         0        704       2395     .03       72       0         0        0       340         0    19348     38330
        3     19348       120         0        822       2328     .29      675       0         0        0       340         0    17631     38330
        4     17631       100         0        939       2184     .29      633       0         0        0       340         0    15819     38330
        5     15819         0         0        939       2017     .27      545       0         0        0       340         0    13995     38330
        6     13995       670         0       1056       1848     .60     1109       0         0        0       340         0    12160     38330
        7     12160         0         0       1408       1601     .86     1377       0         0        0       340         0     9035     38330
        8      9035         0         0       1408       1295     .85     1101       0         0        0       340         0     6186     38330
        9      6186         0         0       1056       1016     .77      782       0         0        0       340         0     4008     38330
       10      4008         0         0       1056        767     .47      360       0         0        0       340         0     2252     38330
       11      2252       650         0        822        565     .24      136       0         0        0       340         0     1604     38330
       12      1604      1150         0        822        496     .13       64       0         0        0       340         0     1528     38330

      YEAR TOTALS      3950         0      11736                          7049        0         0        0      4080         0

                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

     SIMULATION YEAR 17      CALENDAR YEAR 1957
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```
0                    RESERVOIR NO  1  GEORGETN    MAX. CAPACITY   36711  MIN. OPERATING POOL         0
          INITIAL     UREG    UPSTRM            SURFACE  EVAP     EVAP  DWNSTRM                 PUMPED    PUMPED    SYSTEM  END MO.     OPER.
   MONTH  STORAGE  INFLOWS    SPILLS    DEMAND     AREA  RATE     LOSS   SPILLS SHORTAGE     INTO       OUT      LOSS  CONTENT     RULE
     1       1556      130         0      1097      161   .18       29        0        0      340         0         0      900    36711
     2        900        0         0      1097       69   .02        1        0        9      189         0         0        0    36711
     3          0     1860         0      1280       71   .00        0        0        0      340         0         0      920    36711
     4        920    48300         0      1462      843  -.52     -437        0        0      340         0     11827    36708    36711
     5      36708    11410         0      1462     1295  -.15     -193        0        0      340         0     10479    36710    36711
     6      36710    29530         0      1645     1297   .21      272        0        0      340         0     27952    36711    36711
     7      36711     1190         0      2194     1277   .79     1009        0        0      340         0         0    35038    36711
     8      35038     3000         0      2194     1257   .87     1094        0        0      340         0         0    35090    36711
     9      35090     1640         0      1645     1262   .22      278        0        0      340         0         0    35147    36711
    10      35147    41040         0      1645     1276  -.11     -139        0        0      340         0     38311    36710    36711
    11      36710    12050         0      1280     1296  -.06      -77        0        0      340         0     11186    36711    36711
    12      36711     7090         0      1280     1297   .16      208        0        0      340         0      5942    36711    36711

    YEAR TOTALS   157240         0     18281                      2045        0        9     3929         0    105697

0                    RESERVOIR NO  2  GRANGER     MAX. CAPACITY   38330  MIN. OPERATING POOL         0
          INITIAL     UREG    UPSTRM            SURFACE  EVAP     EVAP  DWNSTRM                 PUMPED    PUMPED    SYSTEM  END MO.     OPER.
   MONTH  STORAGE  INFLOWS    SPILLS    DEMAND     AREA  RATE     LOSS   SPILLS SHORTAGE     INTO       OUT      LOSS  CONTENT     RULE
     1       1528      210         0       704      396   .18       71        0        0        0       340         0      623    38330
     2        623      270         0       704      218   .00        0        0        0        0       189         0        0    38330
     3          0     3440         0       822      411  -.05      -20        0        0        0       340         0     2298    38330
     4       2298    89880         0       939     2467  -.56    -1381        0        0        0       340     53950    38330    38330
     5      38330    21250         0       939     4001  -.03     -119        0        0        0       340     20090    38330    38330
     6      38330    54970         0      1056     4009   .14      561        0        0        0       340     53013    38330    38330
     7      38330     2280         0      1408     4009   .69     2766        0        0        0       340         0    36096    38330
     8      36096     5380         0      1408     3866   .72     2784        0        0        0       340         0    36944    38330
     9      36944     2620         0      1056     3910   .16      626        0        0        0       340         0    37542    38330
    10      37542    76070         0      1056     3959  -.18     -712        0        0        0       340     74598    38330    38330
    11      38330    21880         0       822     3986  -.09     -358        0        0        0       340     21078    38328    38330
    12      38328    10880         0       822     4009   .12      481        0        0        0       340      9235    38330    38330

    YEAR TOTALS   289130         0     11736                      4699        0        0        0      3929    231964
1
                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

                  SIMULATION PERIOD TOTAL SUMMARY BY NODE  1

    YEAR START. STRG.  UNREG. FLOW      DEMANDS     SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
      1         36711       133650        18281             0         2218       117994        35948
      2         35948        67710        18281             0         2477        50269        36711
      3         36711        23450        18281             0         4481        12674        28805
      4         28805       104540        18281             0         2818        79616        36710
      5         36710        92460        18281             0         3206        75052        36711
      6         36711        97340        18281             0         3194        79945        36711
      7         36711        68760        18281             0         4584        57188        29498
      8         29498        12220        18281             0         4450            0        23067
      9         23067        34430        18281             0         3168        11706        28422
     10         28422        20040        18281             0         4471          464        29326
     11         29326         3360        18281             0         3987            0        14498
     12         14498        11900        18281             0         2519            0         9678
     13          9678        50610        18281             0         2690         6686        36711
     14         36711         4780        18281             0         6158          261        20871
     15         20871        14290        18281             0         3411            0        17549
     16         17549         1160        18281             0         2952            0         1556
     17          1556       157240        18281             9         2045       105697        36711
     18         36711        92890        18281             0         3028        75661        36711
     19         36711        66100        18281             0         2702        49082        36711
     20         36711       102800        18281             0         2963        85637        36710
     21         36710       115470        18281             0         3129        98139        36711
     22         36711        38090        18281             0         4474        19415        36711
     23         36711        13750        18281             0         5421         4635        26186
     24         26186        14960        18281             0         3105            0        23840
     25         23840       151000        18281             0         2670       121258        36711


    PERIOD TOTALS          1493000       457025             9        86321      1051379


   PERIOD AVERAGES           59720        18281             0         3452        42055

                  TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

                  SIMULATION PERIOD TOTAL SUMMARY BY NODE  2

    YEAR START. STRG.  UNREG. FLOW      DEMANDS     SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
      1         38330       222500        11736             0         5353       202038        37623
      2         37623       110790        11736             0         6413        87854        38330
      3         38330        35130        11736             0        11240        19334        27070
      4         27070       166490        11736             0         6260       133154        38330
      5         38330       146110        11736             0         6908       123386        38330
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   6        38330       161570       11736           0         6213       139541        38330
   7        38330        99110       11736           0        10445        83943        27236
   8        27236        20340       11736           0        10973            0        20787
   9        20787        61880       11736           0         7470        31509        27872
  10        27872        33960       11736           0        10661         7314        28041
  11        28041        12930       11736           0        10823            0        14332
  12        14332        21400       11736           0         7232            0        12684
  13        12684        91890       11736           0         7979        42451        38328
  14        38328         7940       11736           0        15221          123        15108
  15        15108        30350       11736           0         9199            0        20443
  16        20443         3950       11736           0         7049            0         1528
  17         1528       289130       11736           0         4699       231964        38330
  18        38330       157520       11736           0         7481       134223        38330
  19        38330       115080       11736           0         6425        92954        38330
  20        38330       169090       11736           0         6287       146987        38330
  21        38330       189410       11736           0         7304       166290        38330
  22        38330        59210       11736           0        10926        32468        38330
  23        38330        21690       11736           0        13806         7377        23039
  24        23039        39250       11736           0         8820            0        37653
  25        37653       257700       11736           0         7686       233524        38327


  PERIOD TOTALS      2524420      293400           0       212873      1916434


PERIOD AVERAGES       100976       11736           0         8514        76657
1
                TITLE CARD  Granger delivers 4,060 acft/yr to augment Georgetown's 13,610 FY.

                SIMULATION PERIOD TOTAL SUMMARY BY YEAR***

YEAR START. STRG.  UNREG. FLOW     DEMANDS   SHORTAGES  EVAPORATION  SYSTEM LOSS ENDING STRG.
   1        75041       356150       30017           0         7571       320032        73571
   2        73571       178500       30017           0         8890       138123        75041
   3        75041        58580       30017           0        15721        32008        55875
   4        55875       271030       30017           0         9078       212770        75040
   5        75040       238570       30017           0        10114       198438        75041
   6        75041       258910       30017           0         9407       219486        75041
   7        75041       167870       30017           0        15029       141131        56734
   8        56734        32560       30017           0        15423            0        43854
   9        43854        96310       30017           0        10638        43215        56294
  10        56294        54000       30017           0        15132         7778        57367
  11        57367        16290       30017           0        14810            0        28830
  12        28830        33300       30017           0         9751            0        22362
  13        22362       142500       30017           0        10669        49137        75039
  14        75039        12720       30017           0        21379          384        35979
  15        35979        44640       30017           0        12610            0        37992
  16        37992         5110       30017           0        10001            0         3084
  17         3084       446370       30017           9         6744       337661        75041
  18        75041       250410       30017           0        10509       209884        75041
  19        75041       181180       30017           0         9127       142036        75041
  20        75041       271890       30017           0         9250       232624        75040
  21        75040       304880       30017           0        10433       264429        75041
  22        75041        97300       30017           0        15400        51883        75041
  23        75041        35440       30017           0        19227        12012        49225
  24        49225        54210       30017           0        11925            0        61493
  25        61493       408700       30017           0        10356       354782        75038


  PERIOD TOTALS      4017420      750425           9       299194      2967813


PERIOD AVERAGES       160696       30017           0        11967       118712
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APPENDIX B

Comment Letters and Responses

G,

TEXAS WATER DEVELOPMENT BOARD

William B. Madden, *Chairman*
Charles W. Jenness, *Member*
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Craig D. Pedersen
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BRAZOS RIVER AUTHORITY
'96 NOV 6 AM 10 14

November 4, 1996

Mr. Tom Ray, P.E.
Brazos River Authority
P. O. Box 7555
Waco, Texas 76714-7555

Dear Mr. Ray:

The staff of the Texas Water Development Board have reviewed the Preliminary Sections (3.1.3, 3.7, 3.8, 3.10, and 3.17) on Brazos River Alternatives of the Phase II Report and offer the following comments:

Section 3.1.3: Environmental Overview

1. Based on the numbering scheme, it is assumed that the section containing the Environmental Overview (section 3.1.3) will precede the other sections currently being reviewed. Hopefully, that is the case. To help orient the reader, this section should appear prior to the sections discussing each option, rather than at the end where it may be confusing.

2. An overview of the environmental impacts or a quantitative comparison of the various alternatives would be helpful in selecting the preferred alternative.

3. Beginning with page 22, the section number is listed as 3.0. The Cultural Resources of Central Texas section should be section 3.1.3 or 3.1.X to either be included in the Environmental Overview section or to follow it.

4. The report states that the U.S. Fish and Wildlife Department's 1989-1990 lists of endangered, threatened, and candidate species were used in this assessment. Those lists are badly out of date, having been updated numerous times in the Federal Register and by consolidated reports of federally listed species in Texas, 1995 and 1996 (copy attached). The Texas Parks and Wildlife Department list is not dated, so it is impossible to determine whether the current state list is being used. The Texas Organization for Endangered Species (TOES) lists were not considered. TOES is one of the state's leading authorities on rare species and communities.

Our Mission
Exercise leadership in the conservation and responsible development of water resources for the benefit of the citizens, economy, and environment of Texas.
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Section 3.7: Purchase of Water from Brazos River Authority at Lake Stillhouse Hollow Delivered to Lake Georgetown (B-1)

5. A nice addition to this table would be the current permitted maximum withdrawal (67,768 ac ft/yr) which when compared to the "Grand Total" would emphasize the high percentage of water that is committed.

6. On page 12, a more complete discussion of the various delivery rates and operating levels would be very informative. The only option discussed is the "uniform rate/Lake Georgetown at full" which was found to provide the highest water availability. What other options were simulated? The final statement concerning "extra" water is very intriguing, but would this water actually be available for municipal use?

7. On page 13, the report states that "surveys focusing on sensitive areas such as the Salado Creek crossing and potential karst features....are **planned** .....the environmental surveys are **nearly complete.**" This seems contradictory. It is not clear if the surveys are in the planning stage or if they are nearing completion. Will survey information for the Salado Creek crossing and the potential karst features be available in an upcoming draft of the study?

8. In accordance with the "List of Common and Scientific Names of Fishes," published by the American Fisheries Society, there are two misspellings on page 14: **long ear** sunfish should be spelled as one word, **longear** sunfish; and **red ear** sunfish should also be spelled as one word, **redear** sunfish.

9. In discussion of the black-capped vireo habitat on page 17, more discussion is necessary to clarify the source of the recommendation that "the pipeline avoid the location." The Phase I Report for the Austin Study Area is referenced, but it is unclear if there was a particular recommendation within the report. Similarly, on page 24, the discussion of the golden-cheeked warbler habitat refers to a "biologist familiar with the warbler and its habitat requirements" but does not identify the biologist. Without naming the expert providing the consultation service, the statement lacks credibility.

10. "Approximately 20 stream crossings are within the pipeline corridor (page 17)," the impacts of which can be mitigated by numerous strategies, such as avoiding dredge and fill operations during periods that fish are spawning, using erosion barriers, re-vegetating disturbed streambank, etc. It would seem appropriate to mention these in general, and indicate any specific techniques that might be recommended. Although Berry Creek, one of the perennial streams that would be crossed by the pipeline, was not flowing during the survey, the severe drought conditions during the study period were not mentioned.

11. The inventory of locations of recorded historic and prehistoric sites within the proposed project area (page 22) found eight sites occurring within the 100-year flood pool of Lake Georgetown. On page 24, the report states that the majority of the 80-foot pipeline

easement will occur in Blackland Prairie habitat outside the floodplain. It is not clear if the historic and prehistoric site inventory included areas outside the floodplain.

12. Two major impacts of the operational effects discussed on pages 25-27 are not covered in the study. First, changes in the timing and quantity of water released downstream will alter instream flows, which are not covered in the report. Also, changes in the frequency and extent of fluctuations in water surface elevations can affect fish nesting site success which is also not considered in this study.

13. The reference on page 27 to Lake Stillhouse Hollow as "Texas' **most** oligotrophic (under nourished) **reservoirs**" should read "**one of the** most oligotrophic reservoirs in the state" or "Texas' most oligotrophic **reservoir.**"

14. An incorrect assessment is made about the effect upon nutrient dynamics resulting from the mixing of Lake Stillhouse Hollow water with that of Lake Georgetown as mentioned on page 27. While phosphorous is the most limiting nutrient in most freshwater ecosystems, it is not the only limiting factor. For instance, mixing water of higher alkalinity, as would occur in this case, usually increases algae production significantly.

15. Pages 29 - 31 discuss the cost of two options for delivery of **raw** water. To emphasize that these costs do not include treatment and to ensure that readers do not mistake a raw water delivery cost figure for a treated water delivery cost figure, the last line of the third paragraph on page 31 should read "The average unit cost of **raw** water considering both Phases would be $180 per ac.ft. or $0.55 per 1,000 gal."

16. The remainder of section 3.7.5 discusses the cost of delivery of treated water to Georgetown, Round Rock, and the potential new Regional Treatment Plant. How much will it cost to deliver treated water to the other cities in the study area?

17. Table 3.7-11 provides the cost estimate of treating the water from Lake Stillhouse Hollow at the Round Rock facility. The final item in the table should be labeled "Annual Unit Cost of **Treatment**", <u>not</u> "Annual Unit Cost of **Treated Water.**" The dollar figures given do not include the cost of the raw water. (Tables 3.7-12 and -13 provide the "Total Annual Unit Cost of <u>Treated Water</u>.") Table 3.7-11 should use wording similar to that in Table 3.7-8, "Cost Estimate Summary for Delivery of Treated Water from Lake Stillhouse Hollow to Georgetown."

Section 3.8: Purchase of Water from Brazos River Authority at Lake Granger Delivered to Lake Georgetown (B-6)

18. To facilitate comparison of options, it would be helpful if each section of the report provided comparable information. Specifically, tables similar to 3.7-6 and 3.7-8 in section 3.7 providing the annual unit costs of raw water would be very helpful.

Section 3.10: Water Availability From Little River or Brushy Creek (B-8)

19. The analysis of the operational effects on page 14 assume that total phosphate and total nitrogen concentrations existing in Lake Granger and Lake Georgetown were at equilibrium with those of inflows to these lakes. This assumption is highly significant on the estimate of the loading rate, and therefore algae production. Therefore, this assumption needs to be justified. Furthermore, the Lake Granger inflows are based on an old period of record, 1968-1979. More recent water quality data and gage records should be used or the reason for using the older data identified.

20. Table 3.10-3 on page 15 shows that nutrient loading from Brushy Creek into Lake Granger will be significant. The report assess this loading rate as being helpful to "insure that eutrophic conditions are present." This is a poor interpretation of the data, since eutrophication is a deleterious process in lakes. While initially resulting in high productivity in fish, it eventually causes water quality problems.

Section 3.11: South Fork Reservoir (B-9)

21. See comment #18.

Section 3.17: Use of Carrizo-Wilcox Aquifer to Augment Lake Georgetown Yield (CZ-2)

22. There are two interesting options mentioned briefly on pages 2 and 3: Aquifer Storage and Recovery in the Edwards Aquifer, and availability of water from the Alcoa dewatering operation. More information on each of these options, including costs and implementation issues, should be included.

23. Potential impacts on the aquifer in Lee County from both the North Central and West Central options need to be more fully identified.

If you have any questions, please call Cindy Yates at (512) 463-1061.

Sincerely,

Tommy R. Knowles
Deputy Executive Administrator,
Office of Planning

FEDERALLY LISTED
THREATENED AND ENDANGERED
SPECIES OF TEXAS
- October 1996 -

MAMMALS:

black-footed ferret	E	*Mustela nigripes*
jaguar	P/E	*Panthera onca*
jaguarundi	E	*Felis yagouaroundi cacomitli*
Louisiana black bear	T	*Ursus americanus luteolus*
Mexican [=greater] long-nosed bat	E	*Leptonycteris nivalis*
Mexican gray wolf	E	*Canis lupus baileyi*
ocelot	E	*Felis pardalis*
West Indian [=Florida] manatee	E	*Trichechus manatus*

BIRDS:

American peregrine falcon	E	*Falco peregrinus anatum*
Arctic peregrine falcon	T(S/A)	*Falco peregrinus tundrius*
(northern) aplomado falcon	E	*Falco femoralis septentrionalis*
Attwater's greater prairie-chicken	E	*Tympanuchus cupido attwateri*
bald eagle	T	*Haliaeetus leucocephalus*
black-capped vireo	E	*Vireo atricapillus*
brown pelican	E	*Pelecanus occidentalis*
cactus ferruginous pygmy-owl	P/T	*Glaucidium brasilianum cactorum*
golden-cheeked warbler	E	*Dendroica chrysoparia*
interior least tern	E	*Sterna antillarum*
Mexican spotted owl	T	*Strix occidentalis lucida*
piping plover	T	*Charadrius melodus*
red-cockaded woodpecker	E	*Picoides borealis*
southwestern willow flycatcher	E	*Empidonax traillii extimus*
whooping crane	E/CH	*Grus americana*

REPTILES:

American alligator	T(S/A)	*Alligator mississippiensis*
Concho water snake	T/CH	*Nerodia paucimaculata* (= harteri p.)
green sea turtle	T	*Chelonia mydas*
hawksbill sea turtle	E	*Eretmochelys imbricata*
Kemp's ridley sea turtle	E	*Lepidochelys kempii*
leatherback sea turtle	E	*Dermochelys coriacea*
loggerhead sea turtle	T	*Caretta caretta*

AMPHIBIANS:

Houston toad	E/CH	*Bufo houstonensis*
San Marcos salamander	T/CH	*Eurycea nana*
Texas blind salamander	E	*Typhlomolge rathbuni*

FISHES:

Arkansas River shiner	P/E	*Notropis girardi*
Big Bend gambusia	E	*Gambusia gaigei*
Clear Creek gambusia	E	*Gambusia heterochir*
Comanche Springs pupfish	E	*Cyprinodon elegans*
fountain darter	E/CH	*Etheostoma fonticola*
Leon Springs pupfish	E/CH	*Cyprinodon bovinus*
Pecos gambusia	E	*Gambusia nobilis*
San Marcos gambusia	E/CH	*Gambusia georgei*

(continued)

G. Letter from Texas Water Development Board, November 4, 1996.

1. The Environmental Overview will precede the sections discussing individual supply alternatives.

2. A quantitative comparison of the alternative is provided in Table 3.1-2.

3. The Cultural Resources section has been incorporated into the Environmental Overview.

4. The lists of endangered species have been updated.

5. Permitted annual withdrawal added to table.

6. Appendix A describes the various delivery rates and operating scenarios studied for systems operation. The increase in yield due to systems operation is firm yield that could be permitted for municipal use.

7. The status of the environmental surveys has been classified in the text.

8. Text revised per comment.

9. Text revised per comment.

10. Erosion control and revegetation recommendations must be based on site specific information. General discussion of these techniques is not consistent with the scope of this report. Climatic conditions during surveys have been added to the text.

11. A majority of the pipeline corridor has not been surveyed for cultural resources. Text has been revised to resolve the comment.

12. Text revised to resolve comment.

13. Text revised per comment.

14. We are unaware of any support in the biological literature for the statement that "...mixing water of higher alkalinity,..., usually increases algal production significantly." Although carbon limited production in aquatic systems was claimed to be a widespread phenomenon by the detergent industry during the period of controversy about the phosphorus content of detergents, it was never considered to be so by reputable biologists.

    We are aware that in acid softwater systems, photosynthesis may be limited by the rate of molecular diffusion of carbon dioxide through the air-water interface. Adding sufficient water with significant alkalinity to such a system would result in raising the pH to alkaline levels, selecting for plants which prefer pH to the above 7, and providing a carbon source ($HC0_3$) immediately and abundantly available, compared to CO_2 alone, all having the effect of in creasing algal production. Lake Georgetown water has sufficient carbonate alkalinity to insure that production is seldom, if ever, limited by the availability of carbon. Discussions of these relationships can be found in: Ruttner, F. 1963. Fundamentals of Limnology, 3rd ed. University of Toronto Press, Toronto.

15. Text revised per comment.

16. Costs for treated water have been estimated at five water treatment plant locations (Round Rock WTP, Georgetown WTP, Cedar Park WTP, Austin WTP No. 4, and a potential Williamson County regional water treatment plant). Costs for delivery of treated water to other entities will be developed in the integrated supply plan only for selected alternatives. Regarding this specific alternative, all of the Lake Stillhouse Hollow yield is committed, therefore no water is available for consideration of delivery to other entities.

17. Text revised per comment.

18. The additional detail provided in Section 3.7 (Alternatives B-1, Lake Stillhouse Hollow) was necessary because the total raw water quantity delivered to Lake Georgetown exceeds the delivery quantities to the individual treatment plants, thereby making a straightforward unit cost calculation of treated water unit costs difficult. For most of the other alternatives, a combined cost estimate of raw water and treatment costs is provided in a single table.

19. Text revised per comment.

20. Text revised per comment.

21. See response to #18.

22. Aquifer storage and recovery (ASR) in the Edwards Aquifer or underlying formations could be an important management option. Resources to more fully consider ASR have not been allocated in this study. However, if use of the Carrizo-Wilcox water compares favorably with other water supply alternatives, further study of ASR should be pursued. Excess groundwater from the Alcoa lignite mine is available for purchase. For several reasons, use of the Alcoa water was not considered directly. These reasons include: (1) the mine owners were not prepared to estimate a purchase price until further study is performed: (2) being an economic enterprise, the wise operation is subject to a number of regulatory and economic forces that may cause it to cease operation, and, therefore, cannot be considered a permanent source of water for municipal use; and (3) the aquifer depressurization occurring at the mine is a much more intense development of the aquifer than would be implemented for a municipal water source. The concepts and cost estimates presented in Section 3.17 for use of the Carrizo Aquifer are compatible with consideration of use of the excess Alcoa water and the facility sizes and delivery rates were chose accordingly.

23. If use of the Carrizo-Wilcox Aquifer compares favorably with other water supply alternatives, then further study of potential impacts (particularly cumulative impacts resulting from other Trans-Texas study area alternatives) must be made.

H,

City of Austin
Founded by Congress, Republic of Texas, 1839
Municipal Building, Eighth at Colorado, P.O. Box 1088, Austin, Texas 78767 Telephone 512/499-200

September 22, 1997

Mr. Dale Pahmiyer, Planning Administrator
Brazos River Authority
P.O. Box 7555
Waco, Texas 76714-7555

RE: Comments on Draft Report

Dear Mr. Pahmiyer,

Attached are comments on the Colorado River Basin Alternatives Draft Report dated July 31, 1997. These comments are being sent also to HDR Engineering to allow the to evaluate the comments. If you have any questions regarding any of the comments please do not hesitate to call me at 512-322-2965.

Sincerely,

Joe A. Cadwell

Joe A. Cadwell, P.E.
Water and Wastewater Utility
City of Austin

xc: David Wheelock, P.E., HDR Engineering

Section 3.12 Purchase of Uncommitted Stored Water from LCRA for Diversion at Lake Travis (C-2) Report Draft Review

On the Figure 3.12-1 Map, on the tables, including 3.12-5 and 3.12-8, and in the text it would be helpful to rename the Jollyville and Howard Lane TM projects to the Jollyville <u>NWA</u> TM and Howard Lane <u>NWA</u> TM. There are other City of Austin existing CIP water transmission main projects referred to as the Jollyville TM and the Howard Lane TM.

2 The small Forest Ridge NWA TM is missing from the Figure 3.12-1 Map, the NWA project listing on Section 3.12, Page 10, Table 3.12-5, and some of the text. We can not tell if this City of Austin CIP project is included in the cost analysis since the cost figures are different than the early crude numbers in the original tables.

3 In the first line on the top of Section 3.12, page 3, the word Green should be inserted after Davis.

4 On the Table 3.12-4a, the Austin NW-A peak demand should be 111.5 MGD for all scenarios. This changes the total NW-A amounts for Scenarios 1 - 5 and the Grand total for Scenarios 2 - 5, only. With these changed grand totals, the Year 2030 WTP 4 sizing numbers make more sense. The annual acft/yr. for the NW-A, the total NWA, and the Grand total also change accordingly.

Minor: Use 5.5 MGD instead of 4.8 MGD for contract supply amount for Round Rock.

6 Section 3.12, Page 10, third line from the bottom of the page, insert "(and North)" after "NW-A".

7 In Footnote 5 Section 3.12, page 11, we agree for Scenario 2 (1996 Contract Amounts) that the facilities linking Round Rock to the Austin Distribution system are already in place. But for Pflugerville, the facilities are in the planning stage. They are not existing. There are facilities planned, to be constructed by Pflugerville, to link Pflugerville to the existing North Pressure Zone 48-inch Howard Lane TM on West Dessau Rd. east of I35.

8 There is a bit of an inconsistency between current Pflugerville planning and the Trans-Texas planning. They are currently working toward connecting to the COA North Zone facilities, while in the Trans-Texas work we have them extending NWA water to their Middle School Storage Tank. This is ok for these early planning stages.

9 On Table 3.12-11, the NWA flow control station should be labeled as the Jollyville Flow Control Station. The NWA Pressure Control station should be labeled the Howard Lane Pressure control Station. The NWA PZ flow control station should be labeled the Four Points Flow Control Station.

10 In Section 3.12, Page 50, middle of page, second sentence under NW-A Pressure Zone Facilities Heading should read: "The pipeline would supply water to the Jollyville Reservoir and the NW-A system."

1 In Section 3.12, Page 50, last paragraph, 5 lines from the bottom of the page, the sentence should read: "To facilitate delivery of NW-A Pressure Zone water from WTP 4 to the lower North pressure zone, a pressure control station would be necessary (Howard Lane PCS)."

2 In Section 3.12, Page 50, last line, "and the NW-A Pressure Zone" should be inserted after "Forest Ridge Reservoir".

3 Section 3.12, Page 51, The second paragraph on the page needs a heading. Suggest: "Transmission Facilities from Austin to Other Entities". Also clarify that Lines 1 and 2 are needed for Scenarios 3, 4, and 5 only.

4 It is unclear why a pump station at Martin Hill, in the third paragraph of Section 3.12 page 51, associated with Lane 2, is needed. Depending on the line size, of course, the head range of the NWA system (roughly 980 to 1015) appears to potentially be sufficient without additional boosting if the tank being supplied has an overflow of 971 ft.

5 Section 3.12, Page 32 and 35, it would be helpful here to clarify that Lines 1 and 2 are needed only for Scenarios 3, 4, and 5.

6 Section 3.12, Page 32, Dedicated Delivery Line 1: It is helpful, especially here, to clarify that the plan is to connect to the Howard Lane NWA TM, not the Howard Lane TM (which implies the existing North Pressure Zone 48-inch TM).

7 The $ is missing from the number 53,120,000 in Section 3.12, page 54, second paragraph.

8 Section 3.12, Page 57, first paragraph, There is no existing interconnection between the COA's North Pressure Zone 48-inch Howard Lane TM and Pflugerville, that we are aware of. One is planned. Round Rock would be supplied from an existing interconnection with the NW-A system near the Martin Hill Reservoir.

9 The last sentence of Section 3.12, page 57, first paragraph, should be more like: For Scenario 2 (1996 contract amount) the facilities linking Round Rock to the Austin NWA Pressure Zone Distribution system, are already in place and are not included in the engineering and cost evaluation here. The facilities for Scenario 2 (1996 contract amount) linking Pflugerville to the Austin North Pressure Zone distribution system are already planned by Pflugerville and are also not included in the engineering and cost evaluation.

10 In Section 3.12, Page 67, middle of page, the low HGL number for Anderson Mill Reservoir should be 1,095 ft., not 1,090 ft.

11 Two of the Transmission Facilities From Austin to Other Entities, Line 2 and Line 5, include pump stations. The text indicates that the pump stations should be sited at the Martin Hill Reservoir for Line 2 and the Anderson Mill Reservoir for Line 5. It is too early to indicate

that the existing sites can accommodate these proposed pump stations. Therefore, planning for these pump stations should include acquisition of additional land near these reservoirs to accommodate siting.

2 It would be helpful if the unit cost summary would go into some of the reasons why the unit cost indicate these three findings, for example, why are the unit costs to Round Rock, Leander, and Cedar Park lower to build dedicated facilities from Lake Travis than to participate in WTP 4?

Section 3.15 Potential Use of Austin Steam-Electric Generation Water Rights for Municipal Use (C6)

3 The City of Austin is currently seeking to amend the Steam Electric cooling water right on Lake Austin of 24,000 acre-feet to allow for the use of approximately 15,000 acre feet of this right at the Fayette Power Plant. This would most likely be a temporary transfer of a portion of this right for approximately 20 years with the potential for extension. This could potentially limit the opportunity to utilize this right for municipal use in the future. Mention should be made of this and how this could impact the use of this right for municipal use in the future.

Section 3.14, page 9

4 In the second paragraph the number 67,300 is used twice. The difference between 100,700 acre feet and 67,300 acre feet would equal 33,400 acre feet.

Additionally there are a few typographical errors which will be passed along in a marked up copy at a later date.

Travis - Texas Water Program
North Central Study Area

H. Letter from City of Austin, September 22, 1997.

1. Figure and tables revised per comment.

2. Although not specifically identified in the tables or on the map, the cost for the Forest Ridge TM is included in the estimates.

3. Text revised per comment.

4. Revisions made as noted.

5. Tables revised with new contract amount.

6. Text revised per comment.

7. Footnote revised per comment.

8. Footnote expanded per comment.

9. Table revised per comment.

10. Text revised per comment.

11. Text revised per comment.

12. Text revised per comment.

13. Text revised per comment.

14. Because the minimum HGL of NW-A (980') is close to the proposed tank overflow, the cost of a pump station has conservatively been included. A hydraulic analysis may show the pump station is not needed. The text is revised to state this.

15. Text revised per comment.

Travis - Texas Water Program
North Central Study Area

16. Text revised per comment.

17. Text revised per comment.

18. Text revised per comment.

19. Text revised similar to suggested phrase.

20. Revision made.

21. Comment noted.

22. The primary reasons the unit costs for WTP4 supplying Williamson County entities exceed costs for dedicated facilities are:

    (a) WTP4 is substantially more expensive (on a unit cost basis) than the type of plant costed for the dedicated facilities. The Williamson County WTP cost estimates are for a modular conventional process plant with steel tankage. The cost estimate includes a floating intake.

    (b) Alternatives sourced from the City of Austin as a regional provider include an administration and management cost (similar to the $105/acft cost charged by LCRA) to reimburse the City of Austin for costs associated with running the utility, but not directly associated with the CIP facilities costed here. The administration and management cost is $245/acft ($0.75/1000 gal).

    (c) The cost of installing major transmission mains in an urban area to service existing Austin areas is higher on a unit cost basis than installing pipelines to the Williamson County entities in a more rural setting.

23. Section revised to incorporate pending water right amendment.

24. A parenthetical note has been added to clarify. The values stated were correct, but not clear.

I,

City of Austin
Founded by Congress, Republic of Texas, 1839
Municipal Building, Eighth at Colorado, P.O. Box 1088, Austin, Texas 78767 Telephone 512/499-2000

September 29, 1997

Mr. Dale Pahmiyer, Planning Administrator
Brazos River Authority
P.O. Box 7555
Waco, Texas 76714-7555

RE: Comments on Draft Report

Dear Mr. Pahmiyer,

Attached are additional comments on the Colorado River Basin Alternatives Draft Report dated July 31, 1997 that I just received from staff at the Electric Utility. These comments are also being sent also to HDR Engineering to allow the to evaluate the comments. If you have any questions regarding any of the comments please do not hesitate to call me at 512-322-2965.

Sincerely,

Joe A. Cadwell

Joe A. Cadwell, P.E.
Water and Wastewater Utility
City of Austin

xc: David Wheelock, P.E., HDR Engineering

Section 3.15 Potential Use of Austin Steam-Electric Generation Water Rights for Municipal Use (C6)

3.15.1 & .2 page 1 : The report mentions 7,000 acft/yr as historical usage of steam electric cooling use and 7,500 acft/yr consumptive steam-electric demands for Decker Power Plant and Holly power plant. Should both of these numbers be the same?

2 3.15.2 page 2 : The report says "total current steam-electric water demands are about 14,000 acft/yr, including the natural evaporation component..." and also says "Projected water demands for steam electric use in the Austin area through year 2050 are for 13,500 acft/yr." Are both of these numbers representing the same demand, and if so, should they be the same? If they are not the same, does the 13,500 acft/yr include natural evaporation from Decker Lake?

3 3.15.2 page 2 : "A change of use would require approval by the Texas Natural Resource Conservation Commission" and would also require amending the 1987 Settlement Agreement to include Municipal Use of the steam electric cooling water right in the Settlement Agreement. It may be appropriate to include a short description of steam electric cooling and consumptive use of the cooling water.

#4
3.15.2 & .3 page 2 : These sections generally use several numbers to represent both the steam electric demands and water potentially available for municipal use which are different, presumably because of rounding. And example is the numbers 26,600 acft/yr in section 3.15.2 and 26,156 acft/yr in 3.15.3. They appear to represent the same water usage.

#5 A general comment needs to be made that whatever the plan for the steam electric cooling water rights, it needs to fit with the future plans of the electric utility's generating needs as well as what fits best with the growth needs of the citizens of Austin.

Travis - Texas Water Program
North Central Study Area

I. Letter from City of Austin, September 29, 1997.

1. Yes, the values have been revised.
2. Yes, the values have been revised.
3. Comment noted.
4. Yes, the values have been revised to be consistent.
5. Comment added to text.

Ⓐ

DAVID WHEELOCK

Hwg

RECEIVED
MAY 2 1996

May 23, 1996

Mr. Tom Ray, P.E.
Brazos River Authority
P.O. Box 7555
Waco, Texas 76714-7555

Re: North Central Area Study - Trans Texas Study
Comments on Population, Water Demand and Supply Projections

Dear Tom:

Following are the City's comments on the draft population and water supply projections presented at the PMC meeting in Round Rock last Tuesday:

1. The population and demand projections for Cedar Park are not consistent with where we are currently and where we are forecasting we will be in the future (Table 2.2-3 says we used 2,680 ac-ft in 1995 whereas in actuality we purchased 3,590 ac-ft from LCRA during calendar year 1995 and Table 2.2-1 says we had 15,098 population in our service area in 1995 whereas we had approximately 20,500, excluding employment). Please see the attached forecasts as prepared by our planning dept. and a real estate market analysis consultant (Capital Market Research). For water demand forecasting purposes, the public works department converted the employment estimates to a household population equivalent by assuming that one employee uses 0.5 times the amount of water a household resident does. This conversion factor was determined in a study done by the City of Austin for use in their long term water and wastewater plans. We then added this employment equivalent to the household estimate to result in a total population equivalent.

   In review of the actual growth in our system for the past 4 years versus what would in most cases be relatively aggressive growth rates for the future (i.e., 7% per year), we feel strongly that the attached population equivalent estimates when applied to the per capita demand projections will result in a more realistic projections of the water demands for this area.

   The demand projections for Cedar Park if revised using the attached population equivalents applied to the per capita usage also need to be increased by the contractual amounts we are obligated to supply Leander according to the schedule on page 8 of the water supply agreement with them (copy attached).

600 N. BELL BLVD. • CEDAR PARK, TEXAS 78613 • (512) 258-4121
P.O. BOX 1090 • 78630 • FAX: (512) 258-6083

2. The summary of the status of Cedar Park's water supply contract with LCRA in Section 2.2.3.3 is not entirely correct. Please refer to the attached amendment to the Cedar Park/LCRA contract for clarification.

   In the event the contract with Leander is terminated, the authorization for the additional 2,400 ac-ft terminates. So the assumption that the 2,400 ac-ft reverts back to Cedar Park is incorrect. On page 8 of the Cedar Park-Leander Agreement (copy attached) is a schedule of quantities of water per year through year 2000 that Cedar Park is committed to. The 2,400 ac-ft was derived from an assumption that in year 2000 Leander could and would purchase 2.18 mgd (=2,442 ac-ft annually) from Cedar Park and that this could potentially continue through the term of the contract which expires in year 2021. Based on this, I would recommend that it be assumed that Cedar Parks supply is 9,400 ac-ft per year in 1996 tapering to 7,000 ac-ft in year 2000 (decreasing by the increase in the Leander supply) and continuing thereafter.

3. The water demand versus supply graphs/summaries for affected cities (i.e., Round Rock and Georgetown) assume the Still House Hollow line is in place. Do we want to do this?

Please let me know if you have any questions or comments.

Sincerely,

Sam P. Roberts, P.E.
Director Public Works

cc: David Wheelock, HDR (with attachments)

City of Cedar Park
Population & Employment Estimates & Forecasts
For Total Utility Service Area (excluding Leander)

Year	Household Population	% Growth	Employment Population	Employment Pop Equivalent (see note 1)	Total Population Equivalent
1970 Census	687 (city limits)				
1980 Census	3474 (city limits)				
1989	11081	3% actual			
1990 Census	5161 (city limits)				
1990	11,534	4% actual	1,849	925	12,459
1991	12,271	6% actual	1,871	936	13,207
1992	13,322	9% actual	1,893	947	14,269
1993	15,615	17% actual	1,914	957	16,572
1994	17,599	13% actual	1,937	969	18,568
1995	20,547	17% actual	2,022	1,011	21,558
1996	21,330	7%	2,189	1,095	22,425
1997	22,809	7%	2,357	1,179	23,988
1998	24,289	7%	2,525	1,263	25,552
1999	25,768	6%	2,693	1,347	27,115
2000	27,249	6%	2,861	1,431	28,680
2001	29,110	7%	3,093	1,547	30,657
2002	30,970	6%	3,325	1,663	32,633
2003	32,833	6%	3,557	1,779	34,612
2004	34,695	6%	3,789	1,895	36,590
2005	36,556	5%	4,021	2,011	38,567
2010	48,404		8,330	4,165	52,569
2015	55,173		11,166	5,583	60,756
2020	61,941		14,002	7,001	68,942
2025	69,124		17,313	8,657	77,781
2030	76,306		20,623	10,312	86,618
2035	79,882		23,536	11,768	91,650
2040	83,458		26,449	13,225	96,683

Prepared by Cedar Park Public Works Department
Sources: Cedar Park Planning Dept. & Capital Market Research, Inc.(except emp pop equivalent)
Updated 5/21/96

Note 1: Employment population equivalent assumed to be 0.5 to 1

Trans-Texas Water Program
North Central Study Area

Response to comment letter

A. Letter from City of Cedar park, May 23, 1996.

1. Revisions to the Cedar Park projections have been made in consultation with the City of Cedar Park. The revisions included the addition of water in the manufacturing use category to handle the needs of the work force mentioned in the comments.

2. The Cedar Park water supply discussion has been revised in accordance with the comment.

3. Entities that have supply contracts in place (i.e., Cedar Park-LCRA Lake Travis supply; and Georgetown/Round Rock-BRA Stillhouse Hollow Reservoir Supply) are credited with these supplies, regardless of whether delivery facilities are in place.

B

City of Austin
Founded by Congress, Republic of Texas, 1839
Municipal Building, Eighth at Colorado, P.O. Box 1088, Austin, Texas 78767 Telephone 512/499-2000

June 6, 1996

Mr. Tom Ray, P.E.
Planning and Environmental Division Manager
P.O. Box 7555
Waco, Texas 76714

RE: Comments on Population, Water Demand, and Water Supply Projections

Dear Tom,

The following are comments on the draft population, water demand, and water supply projections presented in the HDR draft dated May 21, 1996.

1. Table 2.1-5 : City of Austin municipal and industrial water use for 1990 was 111,918 acft of which approximately 9%-12% was for industrial purposes. In 1995 municipal and industrial water use for the City of Austin was 119,363 acft, also of which approximately 9%-12% of that amount was for industrial purposes.

2. Table 2.1-2 : The gpcd numbers for the Austin Service Area listed in this table probably already includes industrial demand. To add industrial demand on top of these gpcd demands may have the effect of doubling projected industrial demands.

3. Page 2-6 : The first sentence of the last paragraph should read as follows: "Steam-electric power use in 1990 was 3,139 acft/yr and is <u>currently</u> projected to remain constant at 13,500 acft/yr from 2000 to 2050."

4. Table 2.1-5 : Under the City of Austin-Steam Electric section of the table, the Natural Evap (Lake Long only) amount for water use reported in 1990 and 1995 was included in the amount reported for "forced evaporation" for those years.

5. Page 2-14 : The sentence "In the case of City of Austin steam-electric power generation water demands..." should be revised to read as follows: "In the case of City of Austin steam-electric power generation water demands, the future demands for the time period from 2000-2050 are still undecided, because the City is still in the process of making generation planning decisions for that time period. Current estimated demands are not projected to increase above 13,500 acft/yr. The City's supply available for these purposes is 40,156 acft/yr which

suggests under current projections a surplus supply of steam-electric power generation water of 26,656 acft/yr. (Table 2.1-5)

6. Page 2-14 : Footnote no. 7 should be deleted entirely.

Thank you for the opportunity to comment. Let me know if you have any questions.

Joe R. Cadwell

Joe Cadwell P.E.
City of Austin

B. Letter from City of Austin, June 6, 1996.

1. The review draft projections were adjusted in response to this comment.

2. According to the Texas Water Development Board's data processing procedures, any industrial water use was deleted from the total water use reported by the City prior to computation of the per capita rates shown in Table 2.1-2. Thus, the procedure used in this study should not result in double counting of industrial demands. It is noted, however, that the per capita rates of Table 2.1-2 are for dry conditions and may appear to be high enough to include industrial demands.

3. The water demand tables were corrected to properly account for forced evaporation and natural evaporation from the cooling lake surface. The result agrees with the comment.

4. The tables were changed to show forced evaporation and natural evaporation, as suggested in the comment.

5. This suggestion was adopted.

6. This suggestion was adopted and is consistent with #5 above.

TEXAS WATER DEVELOPMENT BOARD

William B. Madden, *Chairman*
Charles W. Jenness, *Member*
Lynwood Sanders, *Member*

Craig D. Pedersen
Executive Administrator

Noé Fernández, *Vice-Chairman*
Elaine M. Barrón, M.D., *Member*
Charles L. Geren, *Member*

June 10, 1996

Mr. Tom Ray, P.E.
Brazos River Authority
P. O. Box 7555
Waco, Texas 76714-7555

Dear ~~Mr. Ray:~~ Tom

The Texas Water Development Board (Board) staff has reviewed the North Central Study Area Population, Water Demand and Supply Projections and offer the following comments:

- In Table 1, the population and water demand projections for Travis County are 11 to 12 percent higher for each decade than the Board consensus projections. Board staff recommends that the county level consensus projections be used unless other data is presented that would justify an increase in the consensus projections.
- While the population and water demand projections presented in Table 2 for Williamson County are consistent with the Board's consensus projections at the county level, Board staff acknowledges that municipalities such as Cedar Park, Leander and Pflugerville are concerned that their service area projections may be low. Board staff also acknowledges that the population and demand projections are focused on service areas, and as such, has no objections to adjusting service area projections as long as the county totals remain consistent with the consensus projections. Board staff recommends that a meeting be held with all concerned parties, Board staff and HDR to resolve the concerns expressed by the study participants.

If you have any questions regarding the Board's comments, please contact Dennis Crowley at (512) 463-7976 or Butch Bloodworth at (512) 936-0880.

Sincerely,

Tommy

Tommy R. Knowles
Deputy Executive Administrator
for Planning

Our Mission
Exercise leadership in the conservation and responsible development of water resources for the benefit of the citizens, economy, and environment of Texas.

P.O. Box 13231 • 1700 N. Congress Avenue • Austin, Texas 78711-3231
Telephone (512) 463-7847 • Telefax (512) 475-2053 • 1-800- RELAY TX (for the hearing impaired)
URL Address: http://www.twdb.state.tx.us • E-Mail Address: info@twdb.state.tx.us

Travis - Texas Water Program
North Central Study Area

C. *Letter from Texas Water Development Board, June 10, 1996.*

1. The procedures used to make projections of Table 1 were based upon trends in build-out rates of subdivisions served by Austin and were reviewed with TWDB staff members. The methods and data are documented in the report.

2. The procedure suggested was followed, and the TWDB Williamson County totals were used. It should be noted that TWDB increased its Williamson County projections, after local review, and the new projections for the County totals are those used in this study.

D.

TEXAS
PARKS AND WILDLIFE DEPARTMENT
4200 Smith School Road • Austin, Texas 78744 • 512-389-4800

ANDREW SANSOM
Executive Director

RECEIVED
BRAZOS RIVER AUTHORITY
'96 JUN 17 AM 9 33

June 12, 1996

Mr. Tom Ray, P.E.
Planning and Environmental Division Manager
P.O. Box 7555
Waco, Texas 76714

Dear ~~Mr. Ray~~: Tom

I have reviewed the document presenting population, water demand and supply projections distributed at the May 21 meeting of the Technical Advisory Committee. I have a few comments about population and demand projections presented in the document.

#1 Population projections for Travis County given in Table 2.1-1 are approximately 10% higher than the 1996 Consensus Water Plan (CWP) Projections. For example, Table 2.1-1 gives the projected total Travis County population for the year 2050 as 1,723,518, while the CWP revised projections for 2050 is 1,550,521. What is meant by the phrase "as modified" in the footnote for this table? It should be explained in the text. The population projections given for Williamson County in Table 2.21 are in agreement with revised CWP projections.

#2 The per capita water demand projections given in Table 2.1-2 need more background. It appears from the table that per capita consumption from 1990 to 2000 for Austin, Pflugerville, Manville WSC and the remainder of Travis County is expected to increase. Table 2.2-2 shows similar trends for parts of Williamson County. Is this apparent increase a result of comparing actual consumption in 1990 to projected consumption in 2000 and beyond? This could be made more clear by explaining how these gpcd projections were derived. For example, CWP high case gpcd estimates are equal to a city's highest annual consumption rate for the period 1987-1991, adjusted for projected conservation savings over time.

Sincerely,

Cindy Loeffler

Cindy Loeffler, P.E.
Inflow Implementation Coordinator,
Resource Protection Division

Post-it® Fax Note 7671

To DAVID WHEELOCK		Date 6-19-96	# of pages ▶ 1
Co./Dept.		From TOM RAY	
Phone #		Co. BRA	
Fax #		Phone # 817-776-1441	
		Fax # 817-772-578	

D. Letter from Texas Parks and Wildlife Department, June 12, 1996.

1. See response to Texas Water Development Board comment #1. The footnote has been revised to explain the meaning of the phrase, "as modified." The new footnote is "..., as modified by HDR Engineering to show Austin Service area projections by the service area pressure zones."

2. The comment contains an accurate descriptions of the data of Tables 2.1-2 and 2.2-2. The tables contain a footnote providing further explanation.

E.

THE STATE OF TEXAS

TEXAS WATER DEVELOPMENT BOARD

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RECEIVED
BRAZOS RIVER AUTHORITY
OCT 17 AM 10 02

October 10, 1996

Mr. Tom Ray, P.E.
Brazos River Authority
P. O. Box 7555
Waco, Texas 76714-7555

Dear ~~Mr. Ray~~ Tom

The staff of the Texas Water Development Board have reviewed the Preliminary Sections (3.3, 3.4, 3.5, and 3.6) of the Phase II Report and offer the following comments:

1. Table 3.3-1 lists the percentage of outdoor use in single family homes at 60%. According to the Montgomery Watson report of March of 1993, single family outdoor use is 118 gallons per day per dwelling and per capita indoor use is 77 gpcd (page 2-4 of the Montgomery Watson report). The Montgomery Watson report also gives a value of 2.68 people per household in single family dwellings. This means that the per-dwelling indoor use is 206.4 gallons per dwelling per day. This gives a total use of approximately 325 gallons per dwelling per day. Based on that figure, outdoor water use would be 36% of the total.

   As for total city use, outdoor use represents approximately 24% of total use. For comparison, Cedar Park's outdoor use is about 21% of total use and Georgetown's outdoor use is about 23%. These data are based on a comparison of 15 years of monthly data for these cities.

2. The figures given for the impact of plumbing fixtures on indoor water use do not reflect the current projections used by the TWDB. Using current assumptions, fixtures put in place after 1995 will result in a 21.7 gpcd reduction and it is further assumed that for all existing fixtures for the expected and advanced (accelerated) conservation cases, the following replacement schedules will be followed:

Our Mission
Exercise leadership in the conservation and responsible development of water resources for the benefit of the citizens, economy, and environment of Texas.

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PER CAPITA REDUCTIONS IN WATER USE DUE TO REPLACEMENT IN EXISTING HOMES

YEAR	EXPECTED CASE (gallons per person per day)	ADVANCED CASE (gallons per person per day)
2000	3.5	6.4
2010	7.8	13.0
2020	11.7	16.6
2030	15.6	18.5
2040	19.5	20.2
2050	19.5	21.7

3. Table 3.3-3 provides a summary of conservation measures and their related costs. Additional description in section 3.3.2 explaining the Total Cost category may be helpful in determining if the cost is borne by the city or the customer. For example, item 4 - Residential Xeriscape has a total cost of $5,500,000. By looking at the note attached to the Unit Cost for this item, it is apparent that only the city's rebate cost is included, but that is not clear from the Total Cost figure.

4. Sections 3.2.2.10, 3.2.2.11, 3.2.2.12, 3.2.2.13, 3.2.2.15, and 3.2.5 should be renumbered 3.3.2.10, 3.3.2.11, 3.3.2.12, 3.3.2.13, 3.3.2.15, and 3.3.5, respectively.

5. Section 3.4.5 details the current loss rate due to leakage within the distribution systems in the study. The cost for reducing losses from 20% to 10% in the Taylor system should be $150,000.

6. Gray water use for irrigation is addressed in section 3.4.7, however the discussion only includes retrofitting, it does not cover the cost of installing this type of system in new construction. Education of the public, specifically of the home builders and developers in the area, would be required, but could have positive impact on the decrease in outdoor water use demand.

7. In section 3.2.2.13, an Austin Residential Landscape Ordinance was discussed which includes the savings realized when xeriscaping is required for new lawns. The cost was considered to be the same as putting in a non-xeriscaped lawn, therefore a benefit of reduced water demand was realized without expenditure by the city. This should also be considered for at least the larger cities in the Williamson County area.

8. In the consideration of endangered and threatened species, relevant information from the Texas Organization for Endangered Species (TOES) Animal, Plant, Invertebrate, and Community lists should be included.

9. The first alternative reported in section 3.3.3 categorizes the most important potential environmental effect of accelerated and additional water conservation in the Austin service area as its effects on streamflows resulting from changes in return flows. This is an important consideration, since the streamflows have a major impact on the assimilation of Austin's wastewater effluent and the resulting downstream water quality, recreation, bay and estuary inflows, downstream water rights, and the LCRA's Water Management Plan. None of these important issues were evaluated in this assessment. The overlap created by a separate Colorado River Basin alternative, reported in section 3.5.3, does provide a brief description of the potential effects on water quality and streamflows resulting form the use of reclaimed water for landscape irrigation, sanitation, cooling and industrial processes. However, the brief description given is not a qualified assessment and is unsatisfactory for that purpose.

If you have any questions, please call Cindy Yates at (512) 463-1061.

Sincerely,

Tommy

Tommy R. Knowles
Deputy Executive Administrator,
Office of Planning

Trans-Texas Water Program
North Central Study Area

E. Letter from Texas Water Development Board, October 10, 1996.

1. Correction noted.

2. The per capita municipal water demand projections used for the City of Austin service area were computed from the TWDB Most Likely 1996 Consensus Water Plan, Dry Weather, Expected Case with Water Conservation for the City of Austin. However some adjustments were necessary in order to respond to City of Austin review which provided data from City of Austin records that varied from the computations based upon TWDB projections. For the advanced water conservation case, the analysis were based upon measures to accelerate the rate of plumbing fixtures to achieve the maximum potential by year 2020 instead of 2050, as shown in the comment.

3. The text was modified to clarify this point. However, it is important to note that although this measure is dismissed, due to the high cost, it was not included as a promising water conservation potential for the study area.

4. Sections were renumbered.

5. The cost for Taylor were corrected.

6. Comment noted.

7. The water conservation method of residential ordinances for cities of Williamson County was not given further consideration due to lack of information as to the potential for water conservation, and the practicality of this method for Williamson County cities.

8. List of T.O.E.S. species included.

9. Impacts to streamflow and bay and estuary inflows were not estimated for the various conservation and reuse alternatives. Implementation of these alternatives would

reduce return flows. However, these alternatives would also reduce diversions of raw water, thereby mitigating effects of reduced return flows. Effects of these alternatives on streamflows are expected to be small.

F.

City of Austin
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Municipal Building, Eighth at Colorado, P.O. Box 1088, Austin, Texas 78767 Telephone 512/499-200

BRAZOS RIVER AUTHORITY
'96 OCT 31 AM 10 56

October 28, 1996

Mr. Tom Ray, P.E.
Brazos River Authority
P.O. Box 7555
Waco, Texas 76714-7555

Dear Mr. Ray,

The following are comments relating to section 3.5 **Reclaimed Water Reuse-Areas in the Colorado River Basin (L-5)** for the North Central Study Area of the Trans-Texas Study. Some verbal and written comments on section 3.3 **Accelerated and Additional Municipal Water Conservation for the Austin Service Area (L9)** were transmitted earlier in a meeting with David Wheelock and Herb Grubb of HDR.

1. Page 1: The sentence in the middle of the page beginning "The City's existing reuse program supplies reclaimed water from South Austin Regional..." should read as follows: The City's existing reuse program supplies reclaimed water from South Austin Regional Wastewater Treatment Plant to Jimmy Clay Golf Course, Roy Kizer Golf Course, Bergstrom Golf Course, and Hornsby Bend Biosolids Management Plant.

2. Page 1: The word "expanded" is misspelled in the very next sentence.

3. Page 2: Under the paragraph titled South Reuse System Extension (L5B) the use of reclaimed water at the new Austin-Bergstrom International Airport was studied by the City's Aviation Department, not the airport authority.

4. Page 9: Under section titled Northwest Water Reclamation Plan verify numbers 3.28 mgd and 3,674 acft/yr. Table 3.5-3 shows 3.92 and 4394 respectively.

5. Page 19: Near the bottom of the page, the sentence that begins "Future discharge permits will require a more rigorous nutrient removal ..." should read as follows: Future discharge permits may require nutrient removal processes at both Walnut Creek WWTP and South Austin Regional WWTP.

6. Page 20: Leave out **Table 3.5-4** as well as the reference to it on page 19. Current testing of nutrient removal processes, or the need to remove nutrients at Walnut and South Austin Regional WWTPs is purely speculative

on the part of the City of Austin and does not imply that the processes will be implemented.

7. Page 20: The last sentence on the page should read: To avoid any further degradation of Lake Austin and Town Lake, GAC treatment or other suitable treatment would be required for any reclaimed water used in water supply augmentation. Also please make the same correction in the list at the top of page 24 to read . GAC or other suitable Treatment (for Lake Austin/Town Lake augmentation only)

8. Page 24: Reference to GAC treatment in second paragraph should also contain the statement "or other suitable treatment".

9. Page 24: There is question in the appropriateness of using the cost to acquire reclaimed water of $310 per acft or $0.95 per 1000 gal. The Utility's Finance group developed the rate of $0.95 per 1,000 gallons based on the current reuse system costs and projected costs of over a 30 year period. The reuse infrastructure improvements were SAR filtration and pump station improvements and then an annual allotment of reuse projects of approximately $1.0 million. The analysis also assumed Water and Wastewater Utility subsidy of over 60% in the first year with a goal to eliminate the subsidy over time. None of the numbers stated in the report were assumptions of the rate analysis. The project costs, debt service, and other costs stated in the draft do not correlate with the rate analysis that produced the $0.95 per 1,000 gallon rate. Also, the $0.95 rate did not assume any nutrient removal costs. I recommend we meet to discuss how to develop a more accurate rate for the reclaimed water.

10. Page 26: Second sentence in paragraph titled Reuse at Decker Lake (L-5D) should read as follows: The City of Austin's wastewater treatment master plan anticipates installation of nutrient removal at the Walnut Creek WWTP even though it is not planned at the present. The cost for this treatment is not considered as a capital cost for specific reuse alternatives at this time.

11. Page 30: Item 2 should once again refer to GAC or other suitable treatment.

If you have any questions regarding these comments please call me at 512-322-2965.

Joe

Joe Cadwell, P.E.
Water and Wastewater Utility

Travis - Texas Water Program
North Central Study Area

Response to Comment Letters

F. ***Letter from City of Austin, October 28, 1996.***

1. Text revised per comment.

2. Text revised per comment.

3. Text revised per comment.

4. Values in Table 3.5-3 were verified. Text revised to match table.

5. Text revised as noted.

6. The projected discharge permit requirements were removed from Table 3.5-4. Remainder of Table 3.5-4 was retained as it demonstrates the utilities' excellent record of producing reclaimed water for reuse purposes.

7. Text revised per comment.

8. Text revised per comment.

9. (revision to be made following discussion with CDM or GSG).

10. Text revised per comment.

11. Text revised per comment.