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LAKE EASTEX NEEDS ANALYSIS AND ALTERNATIVES EVALUATION

United States Environmental Protection Agency

Dallas, Texas

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LAKE EASTEX
NEEDS ANALYSIS AND ALTERNATIVES EVALUATION

Prepared for

U.S. Environmental Protection Agency
Dallas, Texas

Prepared by

G.E.C., Inc.
9357 Interline Avenue
Baton Rouge, Louisiana 70809

Telephone: 225/612-3000 ❒ Fax: 225-612-3016

EXECUTIVE SUMMARY

Lake Eastex is a proposed 85,507 acre feet per year (AFY) water supply reservoir that would serve five East Texas counties (Angelina, Cherokee, Nacogdoches, Rusk, and Smith). Twenty entities (cities, water supply corporations, a manufacturer, and a county) are presently participating in the development of the lake, which would be built under the auspices of the Angelina & Neches River Authority (ANRA). A Clean Water Act Section 404 permit application for the reservoir has been submitted to the Fort Worth District Corps of Engineers. The Region 6 (Dallas) office of the U.S. Environmental Protection Agency (EPA) has a responsibility for reviewing the application pursuant to the 404(b)(1)Guidelines [40CFR Part 230] (Guidelines). One of EPA's primary regulatory review requirements under the Guidelines is whether there are any practicable, less environmentally damaging alternatives to the lake, including the no action alternative. This report provides background information to EPA with regard to an alternatives analysis.

The report discusses the purpose of the analysis, prior planning reports concerning Lake Eastex, information in the State Water Plan concerning water supply needs in the five-county region, and potential alternative water sources. Appendices contain information from the State Water Plan relevant to water supply needs in the five-county region and the engineering cost estimation worksheets for the various alternatives.

The needs analysis in this report is based on secondary data obtained from the East Texas Region report of the 2002 State Water Plan. The regional report covers 20 counties, including the five counties that would be served by Lake Eastex. The regional report provides supply, demand, and deficit figures for every city and category of use (e.g., steam electric power) in the five-county region that would sustain a deficit during at least one decennial year during the 50-year planning period from 2000 to 2050. The regional report analyzes alternatives and related costs for meeting those deficits and provides recommended strategies for meeting those deficits. No attempt was made to verify or enhance these data because they are recent and were generated by local water supply planners using state planning criteria.

According to the regional report, the 2050 deficit (which is the highest deficit) in the five-county region is 58,078 AFY. There are many cities and categories of use in the five-county region that will not have water supply deficits through 2050. Of those that do, there are many for which Lake Eastex is not the recommended strategy because nearby, reliable, lower-cost sources are readily available. Precision with respect to the entities and deficits for which Lake Eastex is the recommended strategy is not possible, primarily because water supply corporations (some of which would benefit from Lake Eastex) are lumped in a county-other category.

The highest estimated 2050 deficit for which Lake Eastex is the recommended strategy in the regional report is 20,908 AFY, and the most likely estimate is 19,778 AFY. Lake Eastex would meet about a third of the five-county deficit. Smith County has no deficits that would be met by Lake Eastex. The deficits for Rusk, Nacogdoches, and Angelina counties are negligible (509 AFY) and do not begin until 2050. Almost all of the deficits for which Lake Eastex is the recommended strategy occur in Cherokee County, and most of those deficits are sustained by a power company that is not an ANRA participant and whose plans are not firm.

Lake Eastex is not the recommended strategy for about half of the current Lake Eastex participants. Further, there are other existing sources of water for meeting the identified deficits. These alternatives are identified and costed out in the regional report and cumulatively would be less environmentally damaging than Lake Eastex because they would concentrate on the use of existing sources.

Alternatives for supplying the 85,507 AFY yield of Lake Eastex are analyzed in the present report. These analyses are essentially concerned with the practicality and costs of obtaining and transporting by pipeline from other sources to the Lake Eastex site the amount of water that would be yielded by Lake Eastex. Split distribution systems are also considered, mimicking the original planning reports on Lake Eastex that assume 60 percent distribution to a southern delivery point and 40 percent distribution to a northern delivery point (although there is no current basis for such an assumption). In addition, consideration is given to supplying from one source the 2050 deficit of 19,778 AFY recommended for satisfaction by Lake Eastex in the State Water Plan.

Proposed reservoirs are not considered because of their uncertainty. Groundwater was considered as a potential source but was rejected because of quantity and quality problems. B. A. Steinhagen Lake was considered but rejected because of its distance from the Lake Eastex site and because its use would involve complicated water rights issues. That left Toledo Bend Reservoir, Sam Rayburn Reservoir, and Lake Palestine as existing sources of additional water to be analyzed in this report.

Sam Rayburn Reservoir could supply the required amount of water. However, in order to obtain this water, it would be necessary to reallocate flood control storage in the reservoir to water supply storage. This would raise the lake level, disrupting existing facilities and usages and causing environmental damages, and would require an Act of Congress. Use of Sam Rayburn Reservoir to secure the yield of Lake Eastex is a possible, but not a practical, alternative.

Toledo Bend Reservoir could supply the required amount of water. The construction and operation and maintenance (O&M) cost for a pipeline from Toledo Bend Reservoir to the Lake Eastex site would be $176,030,440 and the total annual cost would be $19,204,570, providing the Lake Eastex yield at 69 cents per thousand gallons. The split-delivery version of this alternative would supply water to the region at a cost of 66 cents per thousand gallons. Both of these are viable alternatives and would be less environmentally damaging than Lake Eastex.

Lake Palestine could supply the required amount of water, but would require the purchase of water rights from an existing holder. The construction and O&M cost for a pipeline from Lake Palestine to the Lake Eastex site would be $36,314,850 and the total annual cost would be $10,396,016, providing the Lake Eastex yield at a cost of 37 cents per thousand gallons. The Lake Eastex yield would be available from Lake Palestine only if Dallas would be willing to sell its water rights. Because Dallas is currently developing plans to use these water rights, use of Lake Palestine to obtain the Lake Eastex yield is a possible, but not a practical, alternative.

Lake Palestine could supply the 2050 deficit of 19,778 AFY that the East Texas Region report recommends for satisfaction by Lake Eastex. The construction and O&M cost for this alternative would be $16,699,980 and the total annual cost would be $3,086,372, providing 21,000 AFY at a cost of 45 cents per thousand gallons. This alternative would require the acquisition of the portion of the City of Palestine's water rights in Lake Palestine that is presently not being used. Lake Palestine is a potential alternative for meeting the deficits for which Lake Eastex was the recommended strategy in the East Texas Region report, and this alternative would be less environmentally damaging than Lake Eastex. Cost estimates for all alternatives do not include compensatory mitigation costs because such costs are not known at this time.

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I. INTRODUCTION

LAKE EASTEX

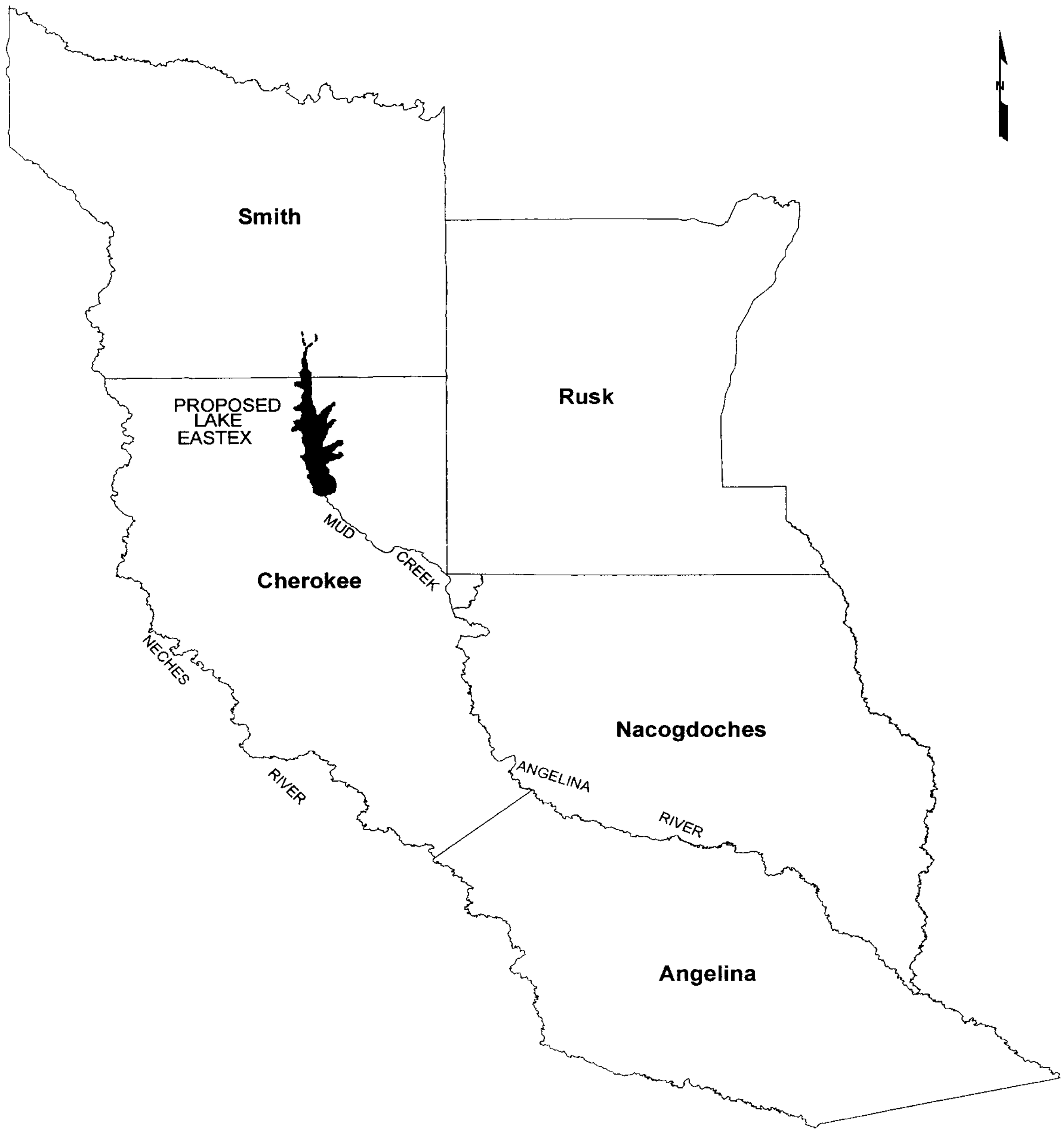
Lake Eastex (Figure 1) is a proposed lake that would be constructed under the auspices of the Angelina & Neches River Authority (ANRA). ANRA's webpage indicates that "The primary purpose of Lake Eastex is water supply. Lake Eastex is not a flood control reservoir nor is it envisioned to have any hydroelectric capabilities. The lake will be located in the Mud Creek floodplain, approximately 10 miles northeast of Jacksonville, Texas, primarily in Cherokee County, with the northern limits of the lake extending into Smith County. It will be 14 miles in length, 1.5 miles wide; cover 10,000 acres; contain 187,839 acre feet of water; and provide 85,507 acre feet of water per year to water supply customers."

Lake Eastex is envisioned as a water supply source for five counties in the 20-county East Texas Region water planning area, which is designated by the Texas Water Development Board (TWDB) as Region I. The five counties that are identified for servicing by the lake are Angelina, Cherokee, Nacogdoches, Rusk, and Smith. The lake is not envisioned in any planning documents to meet all of the water supply needs in the five-county region. Entities that might use the lake for water supply include 20 that are presently participating with ANRA in the development of the project. The 20 entities are comprised of nine cities, nine water supply corporations (WSCs), one county, and one manufacturing facility. Other entities that might use the lake are identified in the East Texas Region report, which is an integral part of the 2002 State Water Plan.

PURPOSE OF THE ANALYSIS

ANRA submitted a 404 permit application for Lake Eastex to the Fort Worth District Corps of Engineers in October 2000. The Environmental Protection Agency (EPA) has a responsibility for reviewing the application. To assist in its review of the application, EPA contracted G.E.C., Inc. (GEC) to provide information on whether the lake is needed for water supply and whether there are any practical, less environmentally damaging alternatives. The environmental concern arises from the preliminary estimates that the lake would inundate about 4,500 acres of U. S. waters, including 3,800 acres of forested wetlands.

There are many different reasons why a lake might be needed, including such things as recreation. However, ANRA indicates (published information and personal communication) that the purpose of the lake is water supply. For a water supply lake, need is generally understood as water supply deficits projected over a 50-year project planning period, with justification provided by an explanation of how the lake would contribute to meeting those needs. Deficits for the five-county region and an explanation of how Lake Eastex could contribute to meeting those needs are presented in the East Texas Region report. As a consequence, the present analysis is largely concerned with a review of the existing information.



Source: G.E.C., Inc.

Figure 1. Lake Eastex Region

Alternatives to Lake Eastex have been analyzed in prior reports and are summarized in the 404 permit application. The analyses were directed toward a regional distribution system that would meet total projected deficits for the five-county region and used combinations of six sources and two delivery points corresponding to the distribution of total deficits in the five-county region and found that Lake Eastex was the least-cost alternative. The present analysis includes a similar dual delivery approach, but focuses on a simpler approach, which is to determine whether there are any sources that could provide the 85,507 acre feet per year (AFY) that would be yielded by Lake Eastex and to analyze the costs of transporting that water to the Lake Eastex site. The cost estimates for these alternatives will provide a ready comparison to the cost estimates for Lake Eastex once they have been developed in a final form.

II. PRIOR REPORTS

1991 LAKE EASTEX REPORT

The two-volume *Lake Eastex Regional Water Supply Planning Study* was prepared by Lockwood, Andrews & Newnam for ANRA in August 1991. Volume 1, the Engineering and Financial Analysis, is concerned with the project background, water supply alternatives for the five-county region, and the engineering and financial issues associated with the proposed Lake Eastex. Volume 2, Environmental Inventory and Issues, describes the baseline environment and potential environmental impacts.

The introduction indicates that Lake Eastex was conceived in 1978 by Cherokee County community leaders (primarily Jacksonville) in conjunction with ANRA to satisfy long-term municipal and industrial water supply needs and particularly to meet an immediate opportunity for the establishment of a lignite mine that would use between 20,000 and 30,000 AFY. Although the opportunity for the lignite mine soon disappeared, the idea of the lake as an important factor for county development did not; and it was assumed by ANRA that haste was required because of increasing difficulties in developing water projects.

Financial support for obtaining a permit from the Texas Water Commission was consolidated by ANRA from 1981 to 1983, at which time there were 14 project participants: the cities of Jacksonville and Rusk in Cherokee County; the City of Lufkin in Angelina County; the cities of New London, Overton, and Henderson in Rusk County; the cities of Arp and Troup in Smith County; Cherokee County; Reklaw WSC; Angelina County; Angelina County WSC; Texas Utility Services; and Leo Childs. Lake Eastex had developed into a regional project.

A permit application was submitted in September 1984 and approved in June 1985. When it became time to obtain financial commitments for project planning, Texas Utility Services and Angelina County withdrew, and the remaining 12 were joined by 11 new participants: the City of Nacogdoches in Nacogdoches County; Temple-Inland Forest Products in Angelina County; Blackjack WSC; Craft-Turney WSC; Jackson WSC; New Summerfield WSC; Redland WSC; Star Mountain WSC; Walnut Grove WSC; Woodlawn WSC; and Wright City WSC. The project had assumed its present five-county regional dimension.

Water demand projections are presented in the Lake Eastex report for the five-county region for the decennial years from 1990 to 2040. These projections are generally in keeping with Texas Water Development Board projections, using the high per capita use without additional conservation high population series (October 1989 draft). The major departure was the inclusion under industrial demand estimates of needs for industries not currently in the region or with plans to expand or locate in the region, which was done in recognition that surface water can be an economic development tool. A minimum regional demand for new industries of 10,000 AFY and a maximum regional demand of 20,000 AFY was projected for each decennial year, producing a minimum total demand in 2040 of 304,526 AFY and a maximum total demand of 314,526 AFY.

Groundwater problems are discussed in the Lake Eastex report. Groundwater use is projected to be 85,207 AFY at a minimum in 2040 and 104,338 AFY at a maximum, depending on availability assumptions. Surface water demand is defined as the portion of total water demand that cannot be met by groundwater sources, with the maximum surface water demand determined by subtracting the minimum groundwater use projection from the maximum total demand. This produces a minimum surface water demand of 200,188 AFY and a maximum demand of 229,319 AFY.

Reservoirs within or near the five-county region had the capacity at the time the report was developed to supply through permits or contracts 222,825 AFY to entities within the region. Although part of this water was not used, the study did not consider this unused water as available for use. As a consequence, the 2040 minimum demand that could be met by existing supplies (assuming minimum groundwater supply) was 118,006 AFY, and the maximum was 119,217 AFY. Subtracting these numbers from the minimum and maximum demands for 2040 for the five-county region produced a minimum surface water deficit of 82,182 AFY and a maximum deficit of 110,102 AFY.

Because of groundwater limitations, deficits of this magnitude could only be met by surface water according to the report, either through a new project such as Lake Eastex or other existing or proposed surface water sources. A thorough analysis was made of the availability of supplies in existing surface water sources. The results are presented in Table III.8 of the report and are re-presented here as Table 1.

Most of the existing sources are eliminated in the report because of prior commitments, and most of the proposed sources are eliminated because they are not currently being pursued, could not be developed within 10-15 years, or would produce unacceptable environmental damages. That leaves the existing sources of Toledo Bend Reservoir (375,000 AFY uncommitted), Sam Rayburn Reservoir by way of B. A. Steinhagen Lake (370,000 AFY uncommitted), and Lake Palestine (5,000 AFY uncommitted) and the proposed sources Lake

Table 1. Existing Surface Water Alternatives

Basin and Reservoir	Owner	Permitted Diversion (ac-ft/yr)	Uncommitted Water (ac-ft/yr)	Status/Comments
NECHES BASIN				
Sam Rayburn Reservoir/B.A. Steinhagen Lake	LNVA/COE	820,000	370,000	Available from LNVA via Lake Steinhagen
Lakes Jacksonville & Acker	City of Jacksonville	6,200	0	Committed to Jacksonville
Lake Nacogdoches	City of Nacogdoches	22,000	0	Committed to Nacogdoches
Lake Palestine	UNMWA	238,110	5,000	Available with approval of UNMWA
Lakes Tyler & Tyler East	City of Tyler	40,325	0	Committed to Tyler
Lake Athens	Athens MWA	8,500	0	Committed to Athens
Lake Striker	Angelina-Nacogdoches Cos. WCID #1	20,600	5,600	Not Available-TP&L & Champion have first options to buy
Lake Pinkston	City of Center	3,800	0	Committed to Center
Lake Kurth	Champion International Corp.	19,100	0	Committed to Champion
SABINE BASIN				
Lake Cherokee	Cherokee Water Company	62,400	0	Committed to Longview & SW Electric Co.
Lake Gladewater	City of Gladewater	1,679	0	Committed to Gladewater
Lake Martin	Texas Utilities Elec. Co.	25,000	0	Committed to TU Electric
Lake Tawakoni	SRA	230,750	N/A	Some small amount uncommitted but is reserved for local needs
Toledo Bend Reservoir	SRA	750,000	375,000	Available with approval from SRA
Lake Fork	SRA	164,940	0	Committed to Dallas, Longview, Tenneco, TUGO, and Phillips Coal
Lake Murvaul	Panola County FWSD	22,400	0	Committed to Carthage
TRINITY BASIN				
Cedar Creek Reservoir	Tarrant County WCID #1	175,000	N/A	Some amount uncommitted, but reserved for in-basin needs
Richland-Chambers Reservoir	Tarrant County WCID #1	210,000	N/A	Some amount uncommitted, but reserved for in-basin needs
Bardwell Lake	TRA/COE	9,600	0	Committed to Ennis, Flood Control
Benbrook Lake	City of Fort Worth/COE	2,371	0	Committed to Benbrook WSA & Fort Worth, Flood Control
Grapevine Lake	Grapevine, Dallas COE	161,250	0	Committed to Grapevine & Dallas, Flood Control
Joe Pool Lake	TRA/COE	17,000	0	Committed to local needs, Flood Control
Lavon Lake	Texas MWD/COE	104,000	0	Committed to Texas MWD, Flood Control
Lewisville Lake	Dallas and Denton/COE	598,900	0	Committed to Dallas & Denton, Flood Control
Navarro Mills Lake	TRA/COE	19,400	0	Committed to Dawson, Corsicana, Post Oak WSC, Texas Industries
Ray Roberts Lake	Dallas & Denton/COE	799,600	0	Committed to Dallas and Denton
Lake Brideport	Tarrant County WCID #1	93,000	0	Committed to Brideport, Texas Industries, Wise Co. WSD, West Wise Rural WSC, Gifford-Hill
Eagle Mountain	Tarrant County WCID #1	159,600	0	Committed to Tarrant Utility Co., Tarrant Co. MUD #1, Tesco, Lone Star Ind., Community WSC
Lake Livingston	TRA & City of Houston	1,254,000	0	Committed to TP&L & Houston
Mountain Creek Lake	TP&L	6,400	0	Committed to TP&L
Lake Ray Hubbard	City of Dallas	89,700	0	Committed to Dallas
Lake Worth	City of Fort Worth	13,393	0	Committed to General Dynamics
Houston County Reservoir	Houston County WCID #1	7,000	0	Committed to Crockett, Grapeland, Lovelady, Southwest Chemical & Consolidated WSC
Lake Fairfield	TP&L, DP&L, TESCO	14,150	0	Committed to Power Generation
Forest Grove	Texas Utilities Services	9,500	0	Committed to Texas Utilities for Power Generation

Source: Table III.8 in *Lake Eastex Regional Water Supply Planning Study*, Volume 1.

Eastex (85,507 AFY), Little Cypress Reservoir (40,000 AFY uncommited), and Sam Rayburn Reservoir through reallocation of flood storage to water supply storage.

Eleven alternatives are evaluated for meeting the 110,102 AFY maximum 2040 deficit. Cost estimates were prepared for eight, with three eliminated from consideration because of obvious cost considerations. Most of the eight carried forward are combinations of sources because only Toledo Bend Reservoir and Sam Rayburn Reservoir (by way of B. A. Steinhagen Lake and by way of storage reallocation) have uncommited yields that could meet the maximum deficit. The alternatives are evaluated in terms of delivery of raw water by pipeline of 44,214 AFY to a northern delivery point west of New Summerfield at the lower end of the Lake Eastex site and 65,888 AFY to a southern delivery point near the Angelina River at U.S. 59.

Lake Eastex would not have a sufficient yield to meet the 110,102 AFY deficit by itself. The two alternatives involving Lake Eastex are the lowest-cost alternatives, largely because Lake Eastex would provide much of the water to the southern delivery point by way of the Angelina River (rather than by pipeline, as with the other alternatives). The least-cost alternative (10a) is Lake Eastex with Sam Rayburn Reservoir through storage reallocation, incorporating aspects of the Angelina County Regional Water Supply Plan, in which Lufkin would obtain water from Sam Rayburn and act as the distribution point for a portion of the southern delivery point. This alternative would deliver 110,102 AFY to the two delivery points at 51 cents per thousand gallons. The next lowest-cost alternative is 10 (Lake Eastex with Sam Rayburn Reservoir through storage reallocation), which would deliver water to the two delivery points at 53 cents per thousand gallons. Sam Rayburn Reservoir through storage reallocation alone would deliver water by pipeline at 70 cents per thousand gallons to the two delivery points, and Toledo Bend Reservoir alone would deliver water by pipeline at 96 cents per thousand gallons to the two delivery points. The report also points out (p. III-49) that if the regional deficit fell below the 85,507 AFY that could be supplied by Lake Eastex, Lake Eastex alone would be the least-cost alternative.

In considering the needs of the then-participants in the Lake Eastex project, the Lake Eastex report does not provide an analysis of deficits for each participant or attempt to demonstrate that Lake Eastex is the least-cost alternative for each participant. Rather, it presents a table of demands (rather than deficits) for the participants (Table IV.6, re-presented here as Table 2), develops four delivery systems for meeting those demands, and provides costs per thousand gallons for each participant so that the participants can make their own determinations as to whether Lake Eastex would be the least-cost alternative. Consequently, the report does not clarify whether the lake would satisfy any deficits or whether it would be used by anyone.

At the time of the analysis, the City of Nacogdoches with a 2040 demand of 15.5 MGD (one MGD is equal to about 1,120 AFY) accounted for one-third of the total 46.73 MGD demand for the 23 participants, which included a number of small WSCs. Other significant demands were registered by Temple-Inland (9.19 MGD), the City of Jacksonville (5.38 MGD), the City of Henderson (3.87 MGD), the City of Lufkin (3.79 MGD, which is the portion of this city's demand that would be supplied by Lake Eastex), Walnut Grove WSC (1.30 MGD), and the City of Rusk (1.00 MGD). The other 17 participants had demands of under 1.00 MGD, including Cherokee County with zero demand because it is not a water user or supplier. Sixteen participants were placed in a northern distribution system, four were placed in a southern system, and separate systems were developed for the City of Nacogdoches and Temple-Inland because of their geographic isolation from the clusters.

Table 2. Projected Demands for Project Participants
Average Day Projected Demands in MGD

Entity	Year				
	2000	**2010**	**2020**	**2030**	**2040**
Angelina WSC[3]	0	0	0.04	0.12	0.17
City of Arp	0.23	0.26	0.30	0.35	0.37
Blackjack WSC	0.10	0.10	0.11	0.12	0.12
Cherokee County[2]	0	0	0	0	0
Leo F. Childs	0.08	0.08	0.08	0.08	0.08
Craft-Turney WSC	0.50	0.54	0.59	0.62	0.64
City of Henderson	2.78	3.03	3.32	3.63	3.87
Jackson WSC	0.28	0.32	0.37	0.43	0.45
City of Jacksonville	4.26	4.70	4.95	5.24	5.38
City of Lufkin[1]	0	0	0.97	2.58	3.79
City of Nacogdoches	9.86	11.36	12.87	14.29	15.05
City of New London	0.42	0.45	0.53	0.62	0.66
New Summerfield WSC	0.13	0.14	0.16	0.17	0.17
City of Overton	0.50	0.54	0.60	0.66	0.70
Redland WSC[1]	0	0	0.03	0.08	0.12
Reklaw WSC	0.05	0.06	0.06	0.06	0.07
City of Rusk	0.79	0.87	0.92	0.97	1.00
Star Mountain WSC	0.22	0.25	0.29	0.34	0.36
Temple-Inland, Inc.	9.19	9.19	9.19	9.19	9.19
City of Troup	0.41	0.46	0.50	0.55	0.59
Walnut Grove WSC	0.79	0.91	1.05	1.22	1.30
Woodlawn WSC[3]	0	0	0.03	0.09	0.13
Wright City WSC	0.45	0.51	0.59	0.69	0.73
Subtotal	31.04	33.77	37.55	42.10	44.94
Other Angelina County Regional System Demands	0	0	0.43	1.13	1.79
Total Demand on Lake Eastex	31.04	33.77	37.98	43.23	46.73

1 As stated in Section IV.C.2., the delivery systems for the participants have been sized to convey all of the year 2040 demands. This approach was taken in order to provide a consistent basis for economic comparison between current sources and a Lake Eastex supply. Exceptions have been noted.

2 This participant is also a participant or is recommended to be a participant in the Angelina County Regional System. Demand which is shown is the portion of the total demand, which has been assumed as being supplied from Lake Eastex. Total 2040 demands which were used for sizing the Southern distribution system are as follows: Angelina WSC = 0.55 mgd; Lufkin = 11.81 mgd; Redland WSC = 0.37; and Woodlawn WSC = 0.40 mgd.

3 Cherokee County, as an entity, is not a water user and will not be diverting water out of Lake Eastex; therefore, no demand is shown.

Source: Table IV.6 in *Lake Eastex Regional Water Supply Planning Study*, Volume 1.

Construction cost estimates were prepared for Lake Eastex and for the delivery systems. Four alternative construction costs are presented for the lake, depending on mitigation cost assumptions and whether FM 2064 would be replaced or abandoned. These estimates range from $85,357,000 to $103,193,000 (in 1990 dollars). The least-cost alternative would produce raw water at a cost of 37 cents per 1,000 gallons. The highest-cost alternative would produce raw water at a cost of 45 cents per 1,000 gallons. The project financing plan was based on the assumption that 60 percent of the reservoir yield would be purchased by project participants and 40 percent by the State of Texas.

The second volume of the 1991 report contains an environmental inventory and discusses environmental impacts. Socioeconomic impacts of lake construction are summarized on page III-13:

1. The potential economic growth projected for the region cannot be achieved apart from the development of an adequate water supply.

2. Construction of the lake would provide a short-term boost to the local economy through construction employment and attendant housing, food, and service needs.

3. The lake would provide an opportunity for the attraction of manufacturers (particularly those that are water intensive), which if achieved would provide a large boost to the local and regional economy.

4. The only adverse impact would be a small short-term decrease in ad valorem tax income for Cherokee and Smith counties.

In addition, the report states that the lake would have a positive impact on housing development, recreational opportunities, and economic activities related to recreation.

1992 LAKE EASTEX REFORMULATION

In 1992, the alternatives were reformulated by Lockwood, Andrews & Newnam in the *Revised Surface Water Alternatives Analysis*. The reformulation looks at Lake Eastex as a stand-alone project rather than as a component of a regional water plan. Alternatives were identified and costed out for providing the 85,507 AFY that would be supplied by Lake Eastex rather than the originally identified deficit of 110,102 AFY. These were almost the same alternatives as those considered in the 1991 report. However, Alternative 10 (Lake Eastex with Sam Rayburn Reservoir with storage reallocation) was modified to Lake Eastex only. In addition, Alternative 10a (Lake Eastex with Sam Rayburn Reservoir through storage reallocation, incorporating aspects of the Angelina County Water Supply Plan), which was the least-cost alternative in the 1991 report, was excluded (p. 1) because "it is a variation on the utilization of a supplement to Lake Eastex." The same delivery points and pump stations were assumed.

As shown in Table 3, in most cases the revised estimates of the costs of delivered water are slightly higher than the original estimates (partly because the cost per thousand gallons delivered increases as the quantity delivered decreases). The cost figures for Alternative 10 are not comparable because they refer to two different projects. The revised costs for Alternative 10 exclude the original costs connected with the use of Sam Rayburn Reservoir, including the costs for reallocation, pumps, and a transmission line to the southern delivery point. The remaining costs (Table 4, which appear to be in 1991 dollars) provide an estimate of the construction cost for Lake Eastex (reflected in the raw water cost) and the cost of transmitting the water from the northern delivery point at Lake Eastex to the Angelina River. The Lake Eastex only alternative was found to be the least-cost alternative, delivering water to the regional system at 49 cents per thousand gallons (again, largely because a pipeline would not be needed for conveyance to the southern delivery point). The next lowest-cost alternative (at 72 cents per thousand gallons) was Sam Rayburn Reservoir with storage reallocation (Table 5 and Figure 2). The Toledo Bend Reservoir alternative (Table 6 and Figure 3) would provide water at 97 cents per thousand gallons.

Table 3. Cost of Delivered Water Comparisons
(cost per 1,000 gallons)

Alternative	1991	1992
1 Sam Rayburn Reservoir (via B. A. Steinhagen Lake)	1.1198	1.1266
2 Toledo Bend Reservoir	0.9608	0.9667
3 Toledo Bend Reservoir with Lake Palestine	0.9493	1.0079
4 Toledo Bend Reservoir with Lake Palestine and Little Cypress Reservoir	0.9134	0.9816
6 Sam Rayburn Reservoir via Storage Reallocation	0.7028	0.7166
7 Sam Rayburn Reservoir (via storage reallocation) with Lake Palestine and Little Cypress Reservoir	0.7216	0.7690
10 Lake Eastex with Sam Rayburn Reservoir/Lake Eastex Only	0.5286	0.4907

Source: *Revised Surface Water Alternatives Analysis*.

Table 4. Alternative 10: Lake Eastex

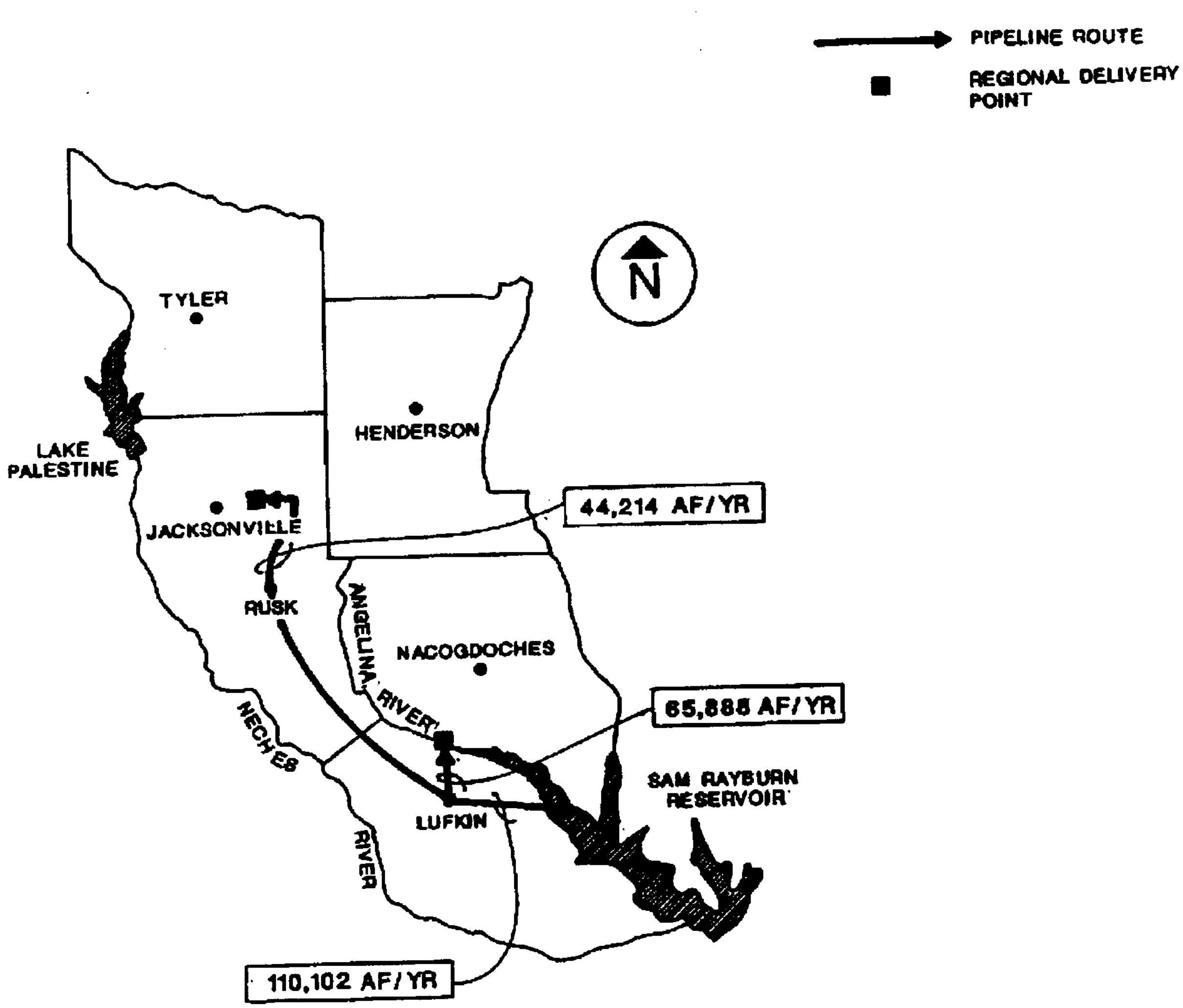
CAPITAL COSTS	
Intake/Pump Stations	$4,012,040
Intake – 1 @ 45.81 MGD	
Intake – 1 @ 30.54 MGD	
Transmission Line	
0.19 MI of 54”	$1,500,576
2 MI of 42”	
Subtotal	$5,512,616
Engineering and Contingency (25%)	$1,378,154
Total	$6,890,770
ANNUAL COSTS	
Raw Water ($0.45/1,000 Gal)	$12,537,289
O&M (5% of Capital Cost)	$344,539
Amortized Capital Cost (includes financing costs)	
Total	$13,671,179
COST PER 1,000 GALLONS	0.4907

Source: *Revised Surface Water Alternatives Analysis*.

Table 5. Alternative 6: Sam Rayburn Reservoir via Storage Reallocation

CAPITAL COSTS	
Intake/Pump Stations	$7,878,272
Intake – 1 @ 76.33 MGD	
Booster – 1 @ 76.33 MGD	
Booster – 3 @ 30.54 MGD	
Transmission Line	$74,289,600
21 MI of 66”	
10 MI of 54”	
57 MI of 42”	
Subtotal	$82,167,872
Engineering and Contingency (25%)	$20,541,968
Total	$102,709,840
ANNUAL COSTS	
Raw Water	
COE ($0.10/1,000 Gal)	$2,786,064
LNVA ($0.01/1,000 Gal)	$278,606
O&M (5% of Capital Cost)	$5,135,492
Amortized Capital Cost (includes financing costs)	$11,765,618
Total	$19,965,780
COST PER 1,000 GALLONS	0.7166

Source: *Revised Surface Water Alternatives Analysis*.



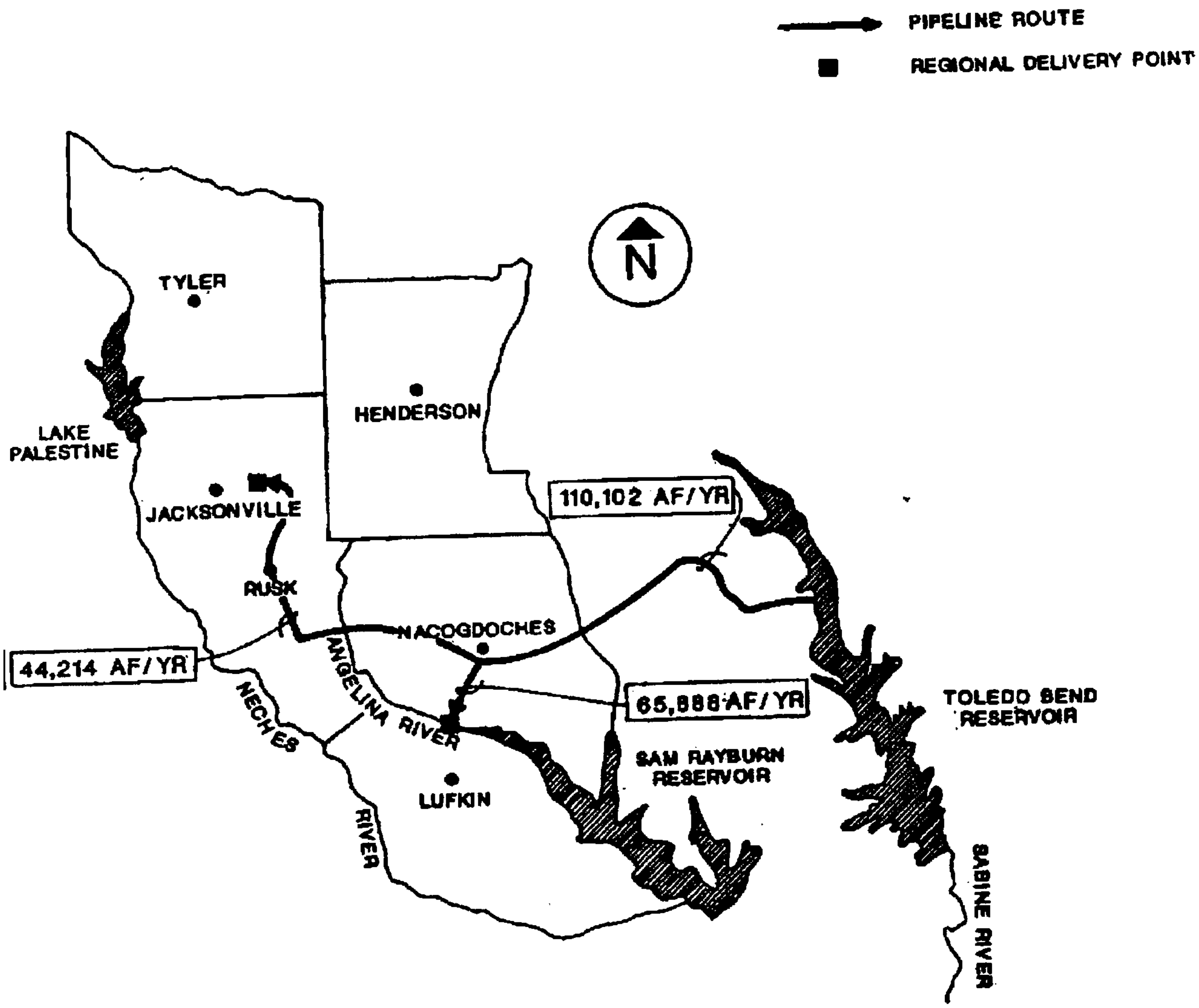
Source: Exhibit III.10 in *Lake Eastex Regional Water Supply Planning Study*, Volume 1.

Figure 2. Alternative 6: Sam Rayburn Reservoir via Storage Reallocation

Table 6. Alternative 2: Toledo Bend Reservoir

CAPITAL COSTS	
Intake/Pump Stations	$9,052,859
Intake – 1 @76.33 MGD	
Booster – 1 @ 76.33 MGD	
Booster – 2 30.54 MGD	
Transmission Line	$111,724,800
53 MI of 66”	
10 MI of 54”	
51 MI of 42”	
Subtotal	$120,777,659
Engineering and Contingency (25%)	$30,194,415
Total	$150,972,074
ANNUAL COSTS	
Raw Water ($0.075/1,000 Gal)	$2,089,548
O&M (5% of Capital Cost)	$7,548,604
Amortized Capital Cost (includes financing costs)	$17,294,153
Total	$26,932,305
COST PER 1,000 GALLONS	0.9667

Source: *Revised Surface Water Alternatives Analysis*.



Source: Exhibit III.7 in *Lake Eastex Regional Water Supply Planning Study*, Volume 1.

Figure 3. Alternative 2: Toledo Bend Reservoir

III. 404 PERMIT APPLICATION

A 404 permit application was submitted by ANRA to the Fort Worth District in October 2000. The purpose of Lake Eastex, according to the application, is "to supplement current and projected water supply demands in the region" (p. 1) or "to meet current and projected water supply demands within the adjacent five-county region" (p. 4). The latter wording occurs in the section on Proposed Project Purpose and is probably a better expression of purpose, as long as "meet" is understood to refer to partial rather than total fulfillment of demands.

The meaning of "demand" is unclear in the application and may refer to demand per se or to deficits (i.e., net demand). A demand table is not presented for the five-county region. The three tables that are presented as evidence of need (all on p. 6) are county population projections, water surplus/shortage, and water surplus/shortage as percent of demand. The textual reference to the two latter tables says that "The region is expected to experience increasing water demands, with water shortages projected for some counties by the year 2010 and becoming more widespread during the 50-year planning period 2000 to 2050." This suggests that the five-county deficit is considered to be the indicator of the need for the lake.

The surplus/shortage table (Table 4 in the permit application, which is re-presented here as Table 7) provides surplus and shortage figures for the decennial years from 2000 to 2050. The table shows a 2050 deficit of 46,492 AFY for the five-county region, constituted by a Smith County surplus of 10,316 AFY and deficits of 13,566 AFY in Angelina County, 18,703 AFY in Cherokee County, 10,944 AFY in Nacogdoches County, and 13,595 AFY in Rusk County. The cited source for this table is Shaumburg & Polk's 2000 *Regional Water Plan for East Texas Region I*, which was obviously an early draft of the East Texas Region report for the 2002 State Water Plan. It should be noted that these are general deficits rather than the surface water deficits presented in the 1991 report.

Table 7. Net Water Surplus/(Shortage) in Acre-Feet Per Year Based on the Regional Water Plan for East Texas Region I (Shaumburg & Polk *et al.*, 2000)

	Year					
County	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Angelina	8,220	5,048	1,447	(3,026)	(8,015)	(13,566)
Cherokee	345	(244)	(6,114)	(12,090)	(12,872)	(18,703)
Nacogdoches	14,762	12,270	9,499	(1,878)	(6,092)	(10,944)
Rusk	615	(3,789)	(8,377)	(13,444)	(13,476)	(13,595)
Smith	23,727	20,794	17,999	16,909	13,522	10,316
Total	**47,669**	**34,079**	**14,454**	**(13,529)**	**(40,455)**	**(46,492)**

Note: Shortages shown in parentheses.

Source: Table 4 in 404 permit application.

The East Texas Region report contains a surplus/shortage table (Table 4.4) for the 20 counties in the region. The figures for the five counties have been extracted and are re-presented here as Table 8. As can be seen from this table, the numbers for each county for each decennial year are different from those in Table 4 in the permit application (present Table 7). The most dramatic change is a move from a suplus to a deficit for Smith County. Such changes are not uncommon in water resources planning. The 2050 deficits for the five counties are 5,044 AFY for Angelina County, 18,395 AFY for Cherokee County, 12,315 AFY for Nacogdoches County, 16,912 AFY for Rusk County, and 5,412 AFY for Smith County. This produces a five-county 2050 deficit of 58,078. These are the figures that should appear in the permit application if it is updated.

Table 8. Net Water Surplus/(Shortage)
(acre-feet per year)

	Year					
County	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Angelina	16,742	13,570	9,969	5,496	507	(5,044)
Cherokee	446	(109)	(5,939)	(11,875)	(12,612)	(18,395)
Nacogdoches	13,391	10,899	8,128	(3,249)	(7,445)	(12,315)
Rusk	(2,673)	(7,082)	(11,676)	(16,749)	(16,786)	(16,912)
Smith	7,999	5,066	2,271	1,181	(2,206)	(5,412)
Total	**35,905**	**22,344**	**2,753**	**(25,196)**	**(38,542)**	**(58,078)**

Source: Table 4.4 in East Texas Region report.

The permit application does not attempt to show the part that Lake Eastex might play in meeting these deficits. Rather, a list of Lake Eastex participants is presented as Table 6 in the permit application and is re-presented here as Table 9. This list excludes some of the participants in 1991 and includes some new participants. The exclusions are Angelina WSC, Leo F. Childs, City of Henderson, City of Lufkin, City of Overton, Redland WSC, Star Mountain WSC, Walnut Grove WSC, Woodlawn WSC, and Wright City WSC. The inclusions are Afton Grove WSC, North Cherokee WSC, Rusk Rural WSC, Stryker Lake WSC, Caro WSC, City of Tyler, and City of Whitehouse. These exclusions and inclusions result in a list of 20 participants.

The table correctly indicates that Lake Eastex was not the recommended strategy in the draft East Texas Region plan for six of the listed entities. (Although not a water user, Cherokee County appears in the county-other category for Cherokee County in the regional plan, with Lake Eastex as the recommended strategy, which is why it is checked in the table.) No deficits appear in that plan by 2050 for the City of Jacksonville, the City of Troup, and the City of Arp; Lake Eastex is not the least-cost strategy for Jackson WSC and the City of Whitehouse; and the City of Tyler has plans to meet its deficits from a source other than Lake Eastex. The permit application points out that “these entities have elected to participate in the Lake Eastex project in order to secure an adequate water supply for the future,” apparently meaning as a contingency or after the 2050 planning period. A footnote to the table points out that the participants account for 66 percent of the Lake Eastex water rights.

Table 9. Participants in the Development of Lake Eastex

County	Participant	Senate Bill 1 Water User Group (WUG) Category	Lake Eastex is a Recommended Regional Water Planning Strategy
Current Participants			
Angelina	Temple Inland	Manufacturing	✔
Cherokee	Cherokee County	County-Other	✔
Cherokee	Craft Turney WSC	County-Other	✔
Cherokee	Afton Grove WSC	County-Other	✔
Cherokee	Blackjack WSC	County-Other	✔
Cherokee	North Cherokee WSC	County-Other	✔
Cherokee	Rusk Rural WSC	County-Other	✔
Cherokee	Reklaw WSC	County-Other	✔
Cherokee	Stryker Lake WSC	County-Other	✔
Cherokee	City of Jacksonville	Jacksonville	
Cherokee	City of New Summerfield	New Summerfield	✔
Cherokee	City of Rusk	Rusk	✔
Smith	City of Troup	Troup	
Nacogdoches	Caro WSC	County-Other	✔
Nacogdoches	City of Nacogdoches	Nacogdoches	✔
Rusk	City of New London	New London	✔
Smith	City of Arp	Arp	
Smith	Jackson WSC	County-Other	
Smith	City of Tyler	Tyler	
Smith	City of Whitehouse	Whitehouse	

Note: 1. Total Participation = 66 percent of Lake Eastex Water Rights.
2. Total ANRA Water Right for Lake Eastex = 85,507 acre-feet per year.

Source: Table 6 in 404 permit application.

The obvious course of action for showing a relationship between Lake Eastex and the needs expressed in the county deficit figures would be to present deficit projections for the Lake Eastex participants, as well as any other entities or categories of use that might benefit from the construction of the lake. These projections were available for presentation in the permit application. The only indications that there is relationship between need and Lake Eastex are the instances in Table 6 (present Table 9) where Lake Eastex is identified as the recommended strategy, the statement on page 8 that "Lake Eastex is recommended in the draft regional water plan as a water planning strategy for most of the 20 current Lake Eastex participants with ANRA," and the statement on page 11 that "Lake Eastex is a recommended strategy by the East Texas Water Planning Group for meeting future water shortages for the ANRA and many of its customers."

The permit application contains a section on alternatives to Lake Eastex. The information presented is a repetition of the information presented in the 1991 report and in the 1992 reformulation, without updating to costs that were current when the application was submitted. It is obvious from the information presented in the 404 permit application that Lake

Eastex is the least-cost alternative. However, the point is not made explicit and is not used as a justification for construction of the lake.

All of the alternatives are dismissed on the basis that they are not the recommended alternatives for Lake Eastex participants in the State Water Plan and that (p. 15) "Strategies that are not 'recommended' are not eligible for Texas Water Development Board funding." A secondary consideration, which applies only to the alternatives involving interbasin transfers, is that (p. 16) "Currently out-of-basin water rights are considered 'junior' by state law and are not considered reliable water sources and therefore are not a good risk for obtaining funding by selling of bonds."

IV. STATE WATER PLAN

The East Texas Region report is an integral part of the 2002 State Water Plan, which appears under the title *Water for Texas--2002*. The East Texas Region report is concerned with the 20 counties in Region I, including the five counties in the Lake Eastex service area. It was prepared by the East Texas Regional Water Planning Group with the assistance of Schaumburg & Polk as the lead engineering firm in keeping with Texas' newly instituted bottom-up water planning process.

The East Texas Region report presents strategies for meeting the water supply needs of every entity in the 20 counties that is expected to have a deficit by 2050 even with water conservation measures in place. The strategies for each entity are costed out, and the best strategies (that is, the least-cost strategies) for meeting the deficits are recommended. Lake Eastex is not presented as a strategy for meeting any of the deficits outside of the five-county service area.

Cities (over 1,000 population) are treated separately. WSCs are combined in a county-other category that makes it difficult to determine the situation of individual entities. Other categories of use include steam electric power, manufacturing, irrigation, mining, and livestock, the latter two of which are irrelevant to the present analysis. Water supply contracts that expire during the planning period are registered as deficits, as they are throughout the State Water Plan, and contract renewal is treated as an alternative for meeting deficits.

LAKE EASTEX PARTICIPANTS

Table 3.2 of the East Texas Region report contains a list of ANRA participants in the development of Lake Eastex, which is re-presented here as Table 10. The only difference between this list and the participant list in the permit application is that John Moore in Cherokee County replaces Craft-Turney WSC in Cherokee County. ANRA's webpage lists Craft-Turney WSC as a participant and does not list John Moore. However, the report states in the county-other analysis for Cherokee County on page 5-16 that John Moore has a contract with ANRA

Table 10. ANRA Participants in the Development of Lake Eastex

Participant	WUG	County	Percentage	Amount (ac-ft/yr)
Afton Grove WSC	County-Other	Cherokee	1.00%	855
City of Arp	Arp	Smith	0.05%	43
Blackjack WSC	County-Other	Cherokee	1.00%	855
Caro WSC	County-Other	Nacogdoches	1.50%	1,283
Cherokee County	County-Other	Cherokee	3.00%	2,565
Jackson WSC	County-Other	Smith	1.00%	855
City of Jacksonville	Jacksonville	Cherokee	5.00%	4,275
John Moore	County-Other	Cherokee	1.00%	855
City of Nacogdoches	Nacogdoches	Nacogdoches	10.00%	8,551
City of New London	New London	Rusk	1.00%	855
New Summerfield WSC	New Summerfield	Cherokee	1.00%	855
North Cherokee WSC	County-Other	Cherokee	1.00%	855
Reklaw WSC	County-Other	Cherokee	0.50%	428
City of Rusk	Rusk	Cherokee	1.00%	855
Rusk Rural WSC	County-Other	Cherokee	1.00%	855
Stryker Lake WSC	County-Other	Cherokee	0.50%	428
Temple Inland	Manufacturing	Angelina	10.00%	8,551
City of Troup	Troup	Smith	5.00%	4,275
City of Tyler	Tyler	Smith	10.00%	8,551
City of Whitehouse	Whitehouse	Smith	10.00%	8,551
Total Participation			64.55%	55,195
Total ANRA Water Right for Lake Eastex				85,507

Source: Table 3.2 in East Texas Region report.

with an option for water from Lake Eastex if developed and mentions Craft-Turney without that designation. ANRA (personal communication) indicates that the report was mistaken and that Craft-Turney rather than John Moore is the Lake Eastex participant.

The table is important because it shows the percentage of participation in the development of Lake Eastex and the allocated amount of the Lake Eastex yield that would be provided on the basis of the percentage of participation. These allocations are not water rights, but rather reflect the level of participation in the planning study and will need to be formalized by contracts in the future. The allocation numbers are important because they were used in the East Texas Region analysis of alternatives to meet deficits. In every case in which Lake Eastex is the recommended alternative, the recommended amount of water is the allocation amount rather than the amount that would be needed to meet the deficit.

Again, there are differences between the report and the webpage, with the latter indicating percentage of participation as 0.50 (rather than 0.05) for the City of Arp, 0.50 (rather than 1.50) for Caro WSC, 3.00 (rather than 1.00) for New Summerfield, and 2.00 (rather than 1.00) for North Cherokee WSC. ANRA (personal communication) indicates that the webpage is correct. However, the report numbers were the ones used in the strategies analysis. The total percentage participation is fairly close for the permit application (66 percent of the Lake Eastex yield), the report (64.55 percent), and the webpage (67 percent) and has no implications for the present analysis.

SHORTAGES

Table 4.6 in the East Texas Region report (Water Shortages During the Planning Period for East Texas Water User Groups) presents the 2000-2050 decennial shortages and surpluses for each city and category of use in the 20 counties that is expected to have a deficit at some time during the planning period. These numbers were derived from TWDB Table 7, which was the basis for planning throughout the state. Table 11 extracts the relevant numbers for the cities and categories in the five-county region and provides county and regional totals. This table does not include the Lake Eastex participants Jacksonville, Arp, and Troup because they did not have any expected deficits during the planning period.

These are almost the same deficit numbers that appear in the tables devoted to the analyses of each city and category of use. The exceptions are minor and occur in the 2050 deficit for manufacturing in Rusk County and for all decennial years in the steam electric power category for Rusk County. The exceptions have no relevance for the present analysis.

It should be noted that the deficits shown in the county and regional totals in Table 11 are higher than those shown in Table 8 presented in the previous section. This is because Table 11 excludes cities and use categories that registered surpluses throughout the planning period. Table 11 presents a much better perspective on the actual needs of the region, which tend to be depreciated in simple comparisons between surpluses and shortages.

Table 11 also contains two check lists. The first list shows whether the city is a Lake Eastex participant or whether the category contains Lake Eastex participants. The second list shows whether the report recommends Lake Eastex as the strategy for meeting the deficit. Both lists provide an overview of the role that Lake Eastex and its participants would play in meeting regional water needs. It should be noted that Lake Eastex is not the recommended strategy for meeting the deficits of most of the entities in the five-county service area (a generalization that remains true if the components of the county-other categories are disaggregated). This situation could, of couse, change in subsequent renditions of the State Water Plan.

Table 11. Water Shortages During the Planning Period (acre-feet per year)

County	Entity	Year 2000	2010	2020	2030	2040	2050	Lake Eastex Participant	Lake Eastex Recommended
Angelina	Lufkin	39	(747)	(1,673)	(2,995)	(4,544)	(5,949)		
	Huntington	137	99	66	28	(12)	(60)		
	Livestock	(1)	(22)	(46)	(75)	(108)	(146)		
	Manufacturing	14,519	12,229	9,642	6,701	3,381	(481)	✔	✔
	Mining	(14)	(18)	(23)	(29)	(35)	(42)		
	Total	14,680	11,541	7,966	3,630	(1,318)	(6,678)		
Cherokee	Alto	35	28	22	11	(2)	(16)		
	Bullard	(25)	(28)	(43)	(47)	(53)	(65)		
	New Summerfield	37	29	18	7	(6)	(21)	✔	✔
	Rusk	40	16	5	(54)	(96)	(134)	✔	✔
	Wells	(11)	(16)	(22)	(27)	(32)	(37)		
	County-Other	(1,542)	(2,000)	(3,076)	(4,068)	(4,459)	(4,800)	✔	✔(P)
	Irrigation	(1,312)	(1,312)	(1,312)	(1,312)	(1,312)	(1,312)	✔	✔(P)
	Mining	7	32	(183)	(485)	(629)	(799)		
	Steam Electric Power	343	343	(4,657)	(9,657)	(9,657)	(14,657)		✔
	Total	(2,428)	(2,908)	(9,248)	(15,632)	(16,246)	(21,841)		
Nacogdoches	Nacogdoches	13,725	11,872	9,844	7,079	3,938	(24)	✔	✔
	County-Other	(641)	(972)	(1,350)	(2,014)	(2,577)	(2,901)		
	Livestock	0	(287)	(621)	(1,008)	(1,457)	(1,978)		
	Mining	(41)	(60)	(92)	(125)	(158)	(195)		
	Steam Electric Power	0	0	0	(7,505)	(7,505)	(7,505)		
	Total	13,043	10,553	7,781	(3,573)	(7,759)	(12,603)		
Rusk	Henderson	(212)	(173)	(65)	9	23	(19)		
	New London	9	12	21	15	7	(4)	✔	✔
	Tatum	(13)	(6)	5	11	16	18		
	County-Other	(143)	(184)	(427)	(724)	(839)	(980)		
	Livestock	39	23	5	(16)	(41)	(69)		
	Steam Electric Power	(4,960)	(9,960)	(14,960)	(19,960)	(19,960)	(19,960)		
	Manufacturing	(47)	(52)	(58)	(64)	(69)	(35)		
	Irrigation	(62)	(62)	(62)	(62)	(62)	(62)		
	Total	(5,389)	(10,402)	(15,541)	(20,791)	(20,925)	(21,111)		
Smith	Lindale	3	(3)	(2)	(7)	(10)	(14)		
	Whitehouse	(22)	(236)	(378)	(403)	(386)	(382)	✔	
	Tyler	6,708	4,913	3,251	3,291	1,103	(866)	✔	
	County-Other	966	78	(901)	(1,996)	(3,198)	(4,422)	✔	
	Total	7,655	4,752	1,970	885	(2,491)	(5,684)		
GRAND TOTAL		27,561	8,784	(7,072)	(35,481)	(48,739)	(67,958)		

Note: P = partial (Lake Eastex would meet part of the deficit)

Source: Table 4.6 in East Texas Region report.

DEFICIT ANALYSIS

The following is a county-based summary of what the East Texas Region report says about the deficits for every entity or category of use for which Lake Eastex was considered a possible strategy for meeting a deficit, which includes Lake Eastex participants and potential users of Lake Eastex. The analysis concentrates on the features that are important for understanding the overall situation, rather than attempting to duplicate the complexity of the report's analysis. The report's full analysis for each entity or category of use is included as Appendix A.

Rusk County

The City of New London is a Lake Eastex participant at 855 AFY. New London, which uses groundwater, shows a deficit of 4 AFY beginning in 2050. New London could obtain water from Lake Eastex, Henderson, or Tyler. Lake Eastex is the least-cost strategy and the recommended strategy, with 885 AFY (apparently should be 855 AFY) as the recommended amount.

Nacogdoches County

The City of Nacogdoches is a Lake Eastex participant at 8,551 AFY. Nacogdoches, which uses ground and surface water (from Lake Nacogdoches), shows a deficit of 24 AFY beginning in 2050. Caro WSC is a Lake Eastex participant at 1,283 AFY. It is not analyzed as a separate entity in the report, but rather within the context of the alternatives for Nacogdoches. Nacogdoches could obtain water from Lake Eastex or Toledo Bend. Lake Eastex is the least-cost strategy and the recommended strategy, with 9,843 AFY (apparently Nacogdoches plus Caro) as the recommended amount.

Angelina County

The manufacturing category shows a deficit of 481 AFY beginning in 2050. The category includes the Lake Eastex participant (at 8,551 AFY) Temple-Inland, a forest products company in Diboll. However, the category also contains other entities that are not Lake Eastex participants, such as manufacturers that are supplied by the City of Lufkin. Consequently, it is uncertain whether the deficit is for Temple-Inland. It is probable that the deficit is not related to Temple-Inland, because this company indicated a static demand in the 1991 report (see Table 2), rather than an increasing demand that could result in a deficit. ANRA (personal communication) indicates that this interpretation is correct. Two strategies are recommended for meeting the deficit: (1) contract renewal with the City of Lufkin, which would supply 6,400 AFY; and (2) Lake Eastex, which would supply 8,551 AFY through Temple-Inland. It is uncertain which of the recommended strategies is meant to cover the deficit.

Smith County

The City of Whitehouse, which is a Lake Eastex participant at 8,551 AFY, receives 95 percent of its supply from Tyler and 5 percent from groundwater. Whitehouse shows a deficit beginning at 22 AFY in 2000 and rising to 382 AFY in 2050. Whitehouse could expand its contract with Tyler to meet the deficit or use Lake Eastex water. Lake Eastex is not the least-cost strategy and is not the recommended strategy.

Jackson WSC uses groundwater and is a Lake Eastex participant at 855 AFY. It is a component of the county-other category, which shows a deficit of 901 AFY in 2020, rising to 4,422 AFY in 2050. It is uncertain whether any portion of the total county-other deficit is sustained by Jackson WSC. The strategy for the total deficit is to obtain additional groundwater beginning at 160 AFY in 2020 and rising to 3,520 in 2050 and supplement these amounts by 885

AFY from Tyler. The 885 AFY could also be obtained from Lake Eastex through Jackson WSC. Lake Eastex is not the least-cost strategy and is not the recomended strategy.

The cities of Arp and Troup are Lake Eastex project participants at 43 AFY and 4,275 AFY, respectively. They do not appear in the Smith County analysis because they do not expect deficits through 2050. Tyler is a Lake Eastex project participant at 8,551 AFY with a deficit of 866 AFY beginning in 2050. Lake Eastex is not analyzed as an alternative for Tyler because Tyler is constructing a 30 MGD facilty to obtain water from Lake Palestine.

Cherokee County

The City of Rusk is a Lake Eastex participant at 855 AFY. Rusk shows a deficit beginning at 54 AFY in 2030 and rising to 134 AFY in 2050. The current supply is from groundwater and Rusk City Lake. Water could be obtained from Lake Eastex or the City of Jacksonville. Lake Eastex is the least-cost strategy and the recommended strategy, with 855 AFY as the recommended amount.

The City of New Summerfield is a Lake Eastex participant at 855 AFY. The city intends to use 787 AFY for resale to meet plant farm irrigation demands (as reflected in the analyis for that category). The current supplies for the city are from groundwater. New Summerfield shows a deficit of 6 AFY beginning in 2040 and rising to 21 AFY in 2050. Water can be obtained from Lake Eastex, Jacksonville, or Tyler. Lake Eastex is the least-cost strategy and the recommended strategy, with 855 AFY as the recommended amount.

The City of Jacksonville is a Lake Eastex participant at 4,275 AFY but is not included in the Cherokee County analysis because it does not expect any deficits through 2050.

The county-other category includes the Lake Eastex participants Afton Grove WSC, Blackjack WSC, North Cherokee WSC, Reklaw WSC, Rusk Rural WSC, Stryker Lake WSC, Craft-Turney (as corrected), and Cherokee County. These entities have a combined Lake Eastex allocation of 7,696 AFY. The category contains three WSCs that are not participants in the Lake Eastex project: John Moore (as corrected), Gum Creek, and West Jacksonville. Current supplies are from groundwater and Lake Jacksonville (through Jacksonville). The total deficit is 1,524 AFY in 2000, rising to 4,800 in 2050. Afton Grove WSC, Craft-Turney WSC, Gum Creek WSC, North Cherokee WSC, and West Jacksonville WSC could renew contracts with Jacksonville for water from Lake Jacksonville. There are two recommended strategies for meeting the 2050 deficit: (1) renew contracts with Jacksonville, with 1,130 AFY as the recommended amount; and (2) obtain water from Lake Eastex, with 7,696 AFY as the recommended amount. Because contract renewal would supply water at a lower cost than Lake Eastex, it is apparent that the 2050 deficit that would be met by Lake Eastex is 3,670 AFY (4,800 AFY minus 1,130 AFY). For the Lake Eastex participants that are presently using groundwater, expansion of groundwater supplies does not appear to be a viable long-term strategy. Blackjack WSC could obtain water from the City of Tyler; and Blackjack WSC, Stryker Lake WSC, and Rusk Rural WSC could obtain water from the City of Jacksonville, but the cost would be higher than the cost of water from Lake Eastex.

The irrigation category shows a deficit of 1,312 AFY beginning in 2000 and remaining at that level through 2050. Current supplies are from groundwater and are used for plant farms in the New Summerfield area. More than 90 percent of the irrigation shortage is attributed to plant farm demand. It is assumed that 40 percent of the deficit can be met by additional groundwater and 60 percent from Lake Eastex. Two strategies are recommended for meeting the deficit: (1) obtain additional water from aquifer, with 565 AFY as the recommended amount; and (2) obtain water from Lake Eastex through the New Summerfield allocation of 855 AFY, with 787 AFY as the recommended amount. The Lake Eastex water is more costly than the groundwater because it is treated water through New Summerfield. The portion of the deficit that would met by Lake Eastex is 787 AFY (i.e., 60 percent of the 2050 total irrigation deficit of 1,312 AFY).

The steam-electric power category shows a deficit of 4,657 AFY beginning in 2020 and rising to 14,657 AFY in 2050. The deficit is based on a constant supply from 2000 to 2050 of 5,343 AFY and a current demand of 5,000 AFY, rising to 10,000 AFY in 2020 and 20,000 AFY in 2050. Although a facility is not named, the 2000 demand is 5,000 AFY, the 2000 supply is 5,343, and the water source is groundwater and Striker Creek Lake. This indicates that the current demand and the constant supply refers to Texas Utilities, which is located on the west side of Striker Creek Lake, has a permit for the withdrawal of 5,000 AFY from the lake, and uses 343 AFY of groundwater. Texas Utilities is not a Lake Eastex participant. The source of the increased demand is not identified. Subsequent contacts with ANRA indicate that the source of the increased demand is a power company (a foreign enterprise) whose plans are not firm. The 14,657 AFY deficit in 2050 can be met by Lake Eastex or by a combination of alternatives (increased withdrawals of 5,600 AFY from Striker Creek Lake and reuse of wastewater from Jacksonville and Tyler). Lake Eastex is lower in cost (65 cents per thousand gallons) than the combination of alternatives, but shows the same cost as Stryker Creek Lake (which could not supply all of the 2050 deficit).

DEFICIT SUMMARY

Table 12 shows the deficits by decennial year for the cases in which Lake Eastex is a recommended solution, with the year 2000 left blank because Lake Eastex was not expected to come online until 2010. The numbers are acquired from the respective tables for each city and category of use contained in Appendix A. There are two problematic cases.

Two strategies are recommended for covering the manufacturing deficit in Angelina County (Lake Eastex through Temple-Inland and renewal of contracts with Lufkin). It is possible that the deficit would be met by Temple-Inland because the water that would be available from Lake Eastex through Temple-Inland is less costly ($1.14 per thousand gallons) than the water that would be available through Lufkin ($1.98 per thousand gallons). This is because the water that would be available through Lufkin to meet the deficit is treated water.

Table 12. Deficits for which Lake Eastex is the Recommended Solution (acre-feet per year)

County	Entity	Year					
		2000	2010	2020	2030	2040	2050
Angelina	Manufacturing	--	0	0	0	0	(481)
Cherokee	New Summerfield	--	-	-	-	(6)	(21)
	Rusk	--	0	0	(54)	(96)	(134)
	County-Other	--	(2,000) [2,000]	(2,514) [3,076]	(2,938) [4,068]	(3,326) [4,459]	(3,670) [4,800]
	Irrigation	--	(787)	(787)	(787)	(787)	(787)
	Steam Electric Power	--	0	(4,657)	(9,657)	(9,657)	(14,657)
Nacogdoches	Nacogdoches	--	0	0	0	0	(24)
Rusk	New London	--	0	0	0	0	(4)
Smith	--	--	0	0	0	0	0
TOTAL			(2,787) [2,787]	(7,958) [8,520]	(13,382) [14,512]	(13,872) [15,005]	(19,778) [20,908]

Source: County analytical tables in East Texas Region report.

The county-other category for Cherokee County does not provide a disaggregated analysis for its various components. Two strategies are recommended for meeting the deficit (Lake Eastex and contract renewal with Jacksonville). Contract renewal with Jacksonville does not have the capacity to meet all of the deficit. However, it is lower in cost ($1.48 per thousand gallons) than Lake Eastex ($1.61 per thousand gallons). This suggests that the portion of the deficit that would be met by Lake Eastex can be computed by subtracting the recommended amounts for contract renewal from the total deficits for each decennial year. The reduced amounts are presented in the table, with the full deficits underneath in brackets for comparison.

It should also be noted that the numbers for the irrigation category in Cherokee County have been adjusted to reflect the 60 percent portion of the deficit that would be met by Lake Eastex.

ALTERNATIVES

For every case in which Lake Eastex was the recommended strategy, at least one alternative strategy was presented and costed out. Lake Eastex was the recommended strategy because it was found to be the least-cost strategy. This means that alternatives to Lake Eastex do not need to be sought outside the confines of the report. These alternatives are presented in the analytical tables for each entity in Appendix A.

The City of Rusk in Cherokee County, which is a Lake Eastex participant at 855 AFY, may be used as an example. Tables 13 and 14 present the analytical tables for Rusk, which presently uses groundwater. The first table shows that Rusk is expected to have a deficit of 54 AFY in 2030, increasing to 96 AFY in 2040 and 134 AFY in 2050. Lake Eastex is the recommended strategy, and the amount recommended (855 AFY) is Rusk's allocation from Lake

Eastex. The second table shows that obtaining water from Jacksonville was considered as an alternative, but that it was not recommended because it was more costly than Lake Eastex. It should be noted that the cost analyses for the alternatives are based on the provision of the Lake Eastex allocation amount rather than the deficit amounts in the first table.

Table 13. Rusk Deficit and Recommendation

Category	Year					
	2000	2010	2020	2030	2040	2050
Population	4,645	4,945	5,237	5,651	5,952	6,182
Water Demand (ac-ft/year)	1,051	1,075	1,086	1,145	1,187	1,225
Current Supply (ac-ft/year)	1,091	1,091	1,091	1,091	1,091	1,091
Supply (+)-Demand (-) (ac-ft/yr)	40	16	5	-54	-96	-134
Recommended Strategy RU-1 (ac-ft/yr): Obtain water from Lake Eastex				855	855	855

Source: Page 5-15 in East Texas Region report.

Table 14. Rusk Alternatives

Strategy	Firm Yield (ac-ft/yr)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/ac-ft)	Unit Cost ($/1,000 gal)
RU-1: Obtain water from Lake Eastex	855	$5,630,000	$518,985	$607	$1.86
RU-2: Obtain water from City of Jacksonville	855	$4,915,000	$940,500	$1,100	$3.36

Source: Page 5-15 in East Texas Region report.

V. ALTERNATIVE WATER SOURCES

POTENTIAL ALTERNATIVES

The 1991 Lake Eastex report projected a 2040 surface water deficit of 110,102 AFY for the five-county region and identified and costed out alternatives to Lake Eastex that would transport from various sources 60 percent of the required amount of water (sustained by Angelina and Nacogdoches counties) to a southern delivery point north of Lufkin on the Angelina River and 40 percent (sustained by Cherokee, Rusk, and Smith counties) to a northern delivery point west of New Summerfield at the Lake Eastex site. The required amount was reduced in 1992 to 85,507 AFY on the basis that if 110,102 AFY of surface water was projected in 1991 to be needed in 2040, it was not unreasonable to assume in 1992 that at least 85,507 AFY would be needed. The same alternative delineations and delivery points were used, but the costs changed because lesser amounts were delivered and pipe and pump sizes were reduced.

The costs per thousand gallons of delivered water through these alternatives were carried forward in the 404 permit application as a basis for comparison to the cost of Lake Eastex water. However, the projected deficits for 2040 and even 2050 for the five-county region in the East Texas Region report (see present Table 8) are substantially below those of the 1991 Lake Eastex report (particularly in light of the fact that they contain deficits that are not surface water deficits); and the regional distribution of the deficits has changed dramatically, with Angelina and Nacogdoches counties now accounting for only 30 percent of the projected deficits. As a consequence, the costs per thousand gallons of delivered water for the alternatives in the permit application do not offer a valid comparison to Lake Eastex in the current planning context.

Performance of a surface water deficit analysis like the one conducted in 1991 would not demonstrate that there is need for an 85,507 AFY reservoir. The regional deficit numbers in the East Texas Region report are only partly correlated with a need for Lake Eastex (that is, in those cases where Lake Eastex is the recommended strategy). Insofar as they are correlated, they are heavily concentrated in Cherokee County and do not provide a context for the transport of large volumes of water in a regional system. The present allocations for Lake Eastex could be used to design alternatives, but this would decouple the alternatives from need and would not demonstrate that the yield of Lake Eastex is needed. More importantly, the participants are expected to change to some degree (ANRA, personal communication). Indeed, participation might change significantly once the current participants are required to sign contracts for the purchase of water, with the East Texas Region report indicating (p. 3-4) that current commitments extend only through the completion of the 404 permit process. Consequently, there is no reasonable basis for reanalyzing the previous alternatives with their weighted delivery points.

Nevertheless, alternatives assuming a 60 percent south/40 percent north delivery system are included in the present analysis in order to maintain continuity with the previous reports, whose results have been incorporated into the 404 permit application. It should be noted that the pipeline routes for the alternatives that use two delivery points are not the same as those in the previous reports. In addition, the delivery points differ to some degree because of hydrologic and efficiency considerations. The present analysis uses Henderson for the northern delivery point rather than the Lake Eastex site as in the previous reports and Rusk in one alternative rather than the Angelina River north of Lufkin.

The present analysis also uses an approach that was not included in the previous reports. This approach does not attempt to demonstrate that 85,507 AFY of surface water are needed in the five-county region. Rather, it asks if such an amount is needed whether there are alternative sources that could supply that amount and at what cost.

Groundwater as a potential source is analyzed in this report. The only surface water sources within the East Texas Region that could supply 85,507 AFY of water are Toledo Bend Reservoir, Sam Rayburn Reservoir, Lake Palestine, and B. A. Steinhagen Lake. Only Toledo Bend Reservoir is free of complications. All of Sam Rayburn Reservoir has already been allocated to various purposes, and to obtain the required amount, it would be necessary to reallocate flood control storage to water supply. Most of the water in Lake Palestine is already permitted, but much of the permitted water is not currently being used. Acquisition of that water would require a willing seller.

Toledo Bend Reservoir, Sam Rayburn Reservoir, and Lake Palestine are analyzed in this report, but B. A. Steinhagen Lake is not. B. A. Steinhagen Lake is downstream of Sam Rayburn Reservoir, from which it receives its water. Because of its location, B. A. Steinhagen Lake was the most costly of the alternatives considered in the 1991 Lake Eastex report, and acquisition of the required amount would involve complicated water rights issues.

Potential reservoirs are not analyzed in this report because they are uncertain and because the determination of the practical availability of water from such sources is complex. According to the East Texas Region report, there are 13 sites in Region I with features that make them desirable for reservoir construction, but only Lake Eastex is recommended as a strategy at this time. Little Cypress Reservoir, which was the only proposed reservoir considered in the 1991 Lake Eastex report, is listed in the North East Texas Region report as one of 14 potential reservoir sites in the region. However, only Marvin Nichols I on the Sulphur River is recommended, and it is too distant from the five-county Lake Eastex region to merit analysis.

COST ESTIMATES

Preliminary analysis indicated that groundwater was not a feasible alternative to Lake Eastex. As a consequence, this report develops costs for obtaining and transporting (by pipeline) 85,500 AFY from Toledo Bend Reservoir, Sam Rayburn Reservoir, and Lake Palestine and a lesser amount from Lake Palestine. These costs include raw water costs for Toledo Bend and Lake Palestine, water rights purchase costs for Lake Palestine, reallocation costs for Sam Rayburn, construction and operations and maintenance (O&M) costs for the pipelines, and other costs such as those associated with environmental effects.

Alignments were largely delineated in-field, using primarily highway rights-of-way (but also pipeline and railroad rights-of-way), which was the same procedure used in the 1991 Lake Eastex report. The developed raw water costs are costs of delivered (and therefore ready to use) water at the Lake Eastex site. A storage facility at the site is not assumed, which is the same procedure that was used in the 1991 Lake Eastex report to delineate the two delivery points. The raw water costs should not be compared to any numbers in the current 404 permit application, but rather to the raw water costs for Lake Eastex that will appear in the preliminary design and cost analysis that is presently being prepared for ANRA.

The construction and O&M cost estimates are based on cost data furnished by material and equipment suppliers, published cost data, and construction experience. Concrete pressure pipe is used throughout at dimensions ranging from 36 to 66 inches. Booster pump stations are placed at various locations along the pipelines to maintain system pressure. Use of existing rights-of-way reduces costs and interference with traffic and lowers gradients where pipelines cross over hills. Steel casings are used beneath all railroad and major highway crossings. Disrupted pavement surfaces are replaced in-kind. The construction and O&M cost estimates include a 25 percent escalation for engineering and contingencies and 5 percent for O&M.

Annual costs were determiend by calculating: (1) the annual amortiziation of total construction cost at 5.875 percent (the current discounting rate for Federal projects) over a 50-year project life; (2) annual operation and maintenance cost, including labor and materials at 5 percent of total construction cost, and annual power cost; (3) raw water cost where purchased from Toledo Bend Reservoir and Lake Palestine; (4) environmental mitigation costs associated with pipeline construction; (5) reallocation cost (Sam Rayburn); and (6) water rights purchase cost (Lake Palestine). All appropriate annual costs were totaled for each alternative. The annual yield in acre-feet was multiplied by 325.851 to convert water volumes to thousand gallon increments. The total annual cost of each alternative was divided by the yield of each alternative to provide an estimate of the cost per 1,000 gallon.

Mitigation costs were developed on the basis of a review of topographic maps and therefore are estimates, with $5,000 per acre assumed as the value. Because they are estimates, the mitigation costs include costs for wetland delineation studies.

TOLEDO BEND RESERVOIR

Two alternatives are considered for the use of Toledo Bend Reservoir water. The first involves a line directly from Toledo Bend to the Lake Eastex site. The second involves the use of northern and southern delivery points. The costs for both of these alternatives involve construction and O&M costs and raw water costs.

Direct Line

This alternative (Figure 4) would involve a concrete pressure pipeline running in a generally westerly direction that would transport 85,500 AFY from an intake structure at Toledo Bend Reservoir to the Lake Eastex site and would include pump stations at the intake structure and two booster stations along the line.

The line would begin at Toledo Bend Reservoir and would run westwardly parallel to State Route (SR) 2694 for 14 miles to Shelbyville, thence northwestwardly parallel to SR 87 for 22 miles to Timpson, thence westwardly parallel to U. S. 84 for 35 miles to its intersection with SR 204, thence northwardly along SR 204 and SR 110 for 10.7 miles to a point about two miles south of New Summerfield, thence west across country 4.7 miles to the Lake Eastex site.

The total length of the pipeline is 86.4 miles. Booster pump stations would be located at Timpson and on U.S. 84 about 6.5 miles northeast of Reklaw. The intake structure and both pump stations would each have four pumps, two of which are rated at 16,800 gallons per minute (GPM) and two at 10,000 GPM. A diesel generator for standby power in the event of power failure is included in the pump station estimates. The estimated construction and O&M cost of

Source: G.E.C., Inc.

Figure 4. Toledo Bend Reservoir Direct Line

this alternative is $176,030,440. A detailed construction and O&M cost estimate is included as Appendix B.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 15. The raw water cost was obtained (written communication) from the Sabine River Authority of Texas, which has jurisdiction over the Texas portion of Toledo Bend Reservoir. The total annual cost for this alternative is $19,204,570, providing 85,500 AFY at a cost of 69 cents per thousand gallons.

Table 15. Cost Summary for Toledo Bend Reservoir Direct Line (85,500 AFY)

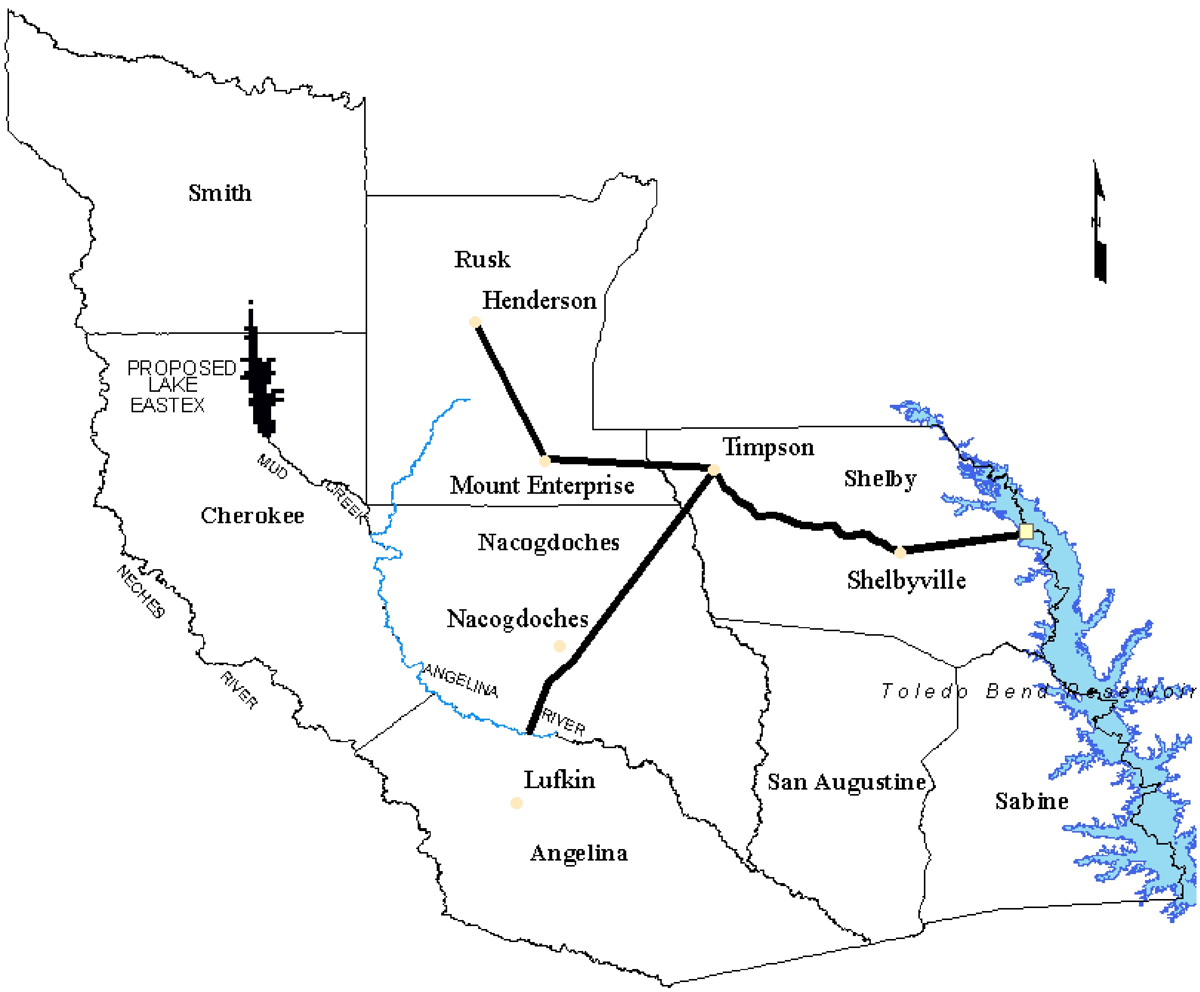
Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Toledo Bend to Pump Station No. 1	$83,178,940
Pump Station No. 1	$2,153,570
Pipeline, Pump Station No. 1 to Pump Station No. 2	$55,947,880
Pump Station No. 2	$2,153,570
Pipeline, Pump Station No. 2 to Lake Eastex Site	$29,988,380
Total Construction and O&M Cost	**$176,030,440**
Environmental Mitigation Cost	**$100,000**
Annual Cost	
Ammortized Construction Cost	$10,973,739
Operation and Maintenance Cost	$6,022,630
Raw Water Cost (@ $0.079/1,000 gallons)	$2,201,967
Environmental Mitigation	$6,234
Total Annual Cost	**$19,204,570**
Cost Per 1,000 Gallons	$0.69

Sources: G.E.C., Inc.

Split Delivery

This alternative (Figure 5) involves a line from Toledo Bend Reservoir that would split at Timpson, with 40 percent of the 85,500 AFY delivered to Henderson and 60 percent delivered to a point on the Angelina River north of Rusk.

The route of this pipeline begins at the same location on Toledo Bend Reservoir and follows the same route for 36 miles to the booster pump station at Timpson. It is sized to deliver85,500 AFY to this point. The intake structure at the reservoir and the booster pump



Source: G.E.C., Inc.

Figure 5. Toledo Bend Reservoir Split Delivery

station at Timpson have four pumps each, two rated at 16,800 GPM and two rated at 10,000 GPM.

From Timpson, a pipeline extends southwardly for 37.4 miles to a delivery point on U.S. 59 where it crosses the Angelina River. The route of this pipeline follows the route of an existing gas transmission pipeline from Timpson to SR 21 east of Nacogdoches. It then follows the 224 Loop around the south side of Nacogdoches to U.S. 59. From there, it runs south along U.S. 59 to the delivery point. No booster pump station is required for this pipeline. This pipeline delivers 51,300 AFY to the southern delivery point.

A second pipeline begins at the booster pump station at Timpson and extends westwardly along U.S. 84 to a booster pump station at Mt. Enterprise near the intersection of U.S. 259, a distance of 17.6 miles. This booster pump station has two pumps, each rated at 12,500 GPM. From this point, it runs northwardly along U.S. 259 a distance of 20.5 miles to a delivery point at Henderson. This pipeline delivers 34,200 AFY to the northern delivery point and is 38.1 miles long.

The intake structure and both booster pump stations have provision for standby power in the event of a power failure. The estimated construction and O&M cost of this alternative is $181,952,810. A detailed construction and O&M cost estimate is included as Appendix C.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 16. The total annual cost for this alternative is $18,370,098, providing 85,500 AFY at a cost of 66 cents per thousand gallons.

SAM RAYBURN RESERVOIR

Two alternatives are considered for the use of Sam Rayburn Reservoir water. The first involves a line directly from Sam Rayburn to the Lake Eastex site. The second involves the use of northern and southern delivery points. The costs for both of these alternatives involve construction and O&M costs and reallocation costs.

Direct Line

This alternative (Figure 6) involves a concrete pressure pipeline running in a westerly and northerly direction that would transport 85,500 AFY from an intake structure at Sam Rayburn Reservoir to the Lake Eastex site and would include pump stations at the intake structure and two booster stations along the line.

The line begins at the Sam Rayburn Reservoir near Etoile and runs in a westerly direction paralleling SR 103 for 13.4 miles to the 287 Loop around Lufkin, thence northwestwardly around Lufkin to U.S. 59 and northwardly along U.S. 59 a distance of 16.1 miles to a booster pump station at Nacogdoches. From that point, it runs northwardly 23.7 miles along U.S. 59/259 and SR 204 to a second booster pump station located about one mile west of Cushing on SR 204, thence northwestwardly 17.7 miles along SR 204/110 to a point

Table 16. Cost Summary for Toledo Bend Reservoir Split Delivery (85,500 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Toledo Bend to Pump Station No. 1	$83,178,940
Pump Station No. 1	$2,153,570
Pipeline, Pump Station No. 1 to Angelina River	$52,249,630
Pipeline, Pump Station No. 1 to Pump Station No. 2	$18,899,250
Pump Station No. 2	$979,690
Pipeline to Henderson	$21,883,630
Total Construction and O&M Cost	**$181,952,810**
Environmental Mitigation Cost	**$150,000**
Annual Cost	
Ammortized Construction	$11,342,940
Operation and Maintenance Cost	$4,815,840
Raw Water Cost (@$0.079/1,000 gallons)	$2,201,967
Environmental Mitigation Cost	$9,351
Total Annual Cost	**$18,370,098**
Cost Per 1,000 Gallons	**$0.66**

Source: G.E.C., Inc.

Source: G.E.C., Inc.

Figure 6. Sam Rayburn Reservoir Direct LIne

about two miles south of New Summerfield, thence west across country 4.7 miles to the Lake Eastex site.

The total length of the pipeline is 75.6 miles. The intake structure and both pump stations would each have four pumps, two of which are rated at 16,800 GPM and two at 10,000 GPM. A diesel generator for stanby power in the event of power failure is included in the pump station estimates. The estimated construction and O&M cost of this alternative is $144,448,040. A detailed construction and O&M cost estimate is included as Appendix D.

Sam Rayburn Reservoir contains three pools. The lower pool is the sedimentation pool, which is allocated for the storage of sediment. The middle pool is the conservation pool, which stores water for use, including water supply. Most of the water supply is used downriver by the Lower Neches Valley Authority for distribution to customers by way of B. A. Steinhagen Lake. The upper pool is the flood control pool, essentially an empty area that is available for the storage of flood waters as needed.

In order to secure additional water supply from the reservoir, it would be necessary to reallocate a portion of the flood storage capacity to water supply. Securing 85,500 AFY of additional water supply from the reservoir would require raising the lake level about one foot. A lake raise of this amount would affect the contiguous shoreline, environment, facilities, and cultural resources and would require mitigation, replacement, relocation, and real estate acquisition. These are reallocation costs, which, as initial costs, may be thought of as similar to raw water costs.

An analysis of reallocation costs is far beyond the scope of the present analysis. To compute a reallocation cost, the cost designated as "COE raw water cost" in the 1991 Lake Eastex report was updated to current price levels.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 17. The total annual cost for this alternative is $17,961,572, providing 85,500 AFY at a cost of 64 cents per thousand gallons.

Reallocations involving water level changes are generally difficult to achieve because of the disruptions they would cause to existing facilities and usages. Raising the water level on Sam Rayburn Reservoir would involve such problems, the dimensions of which are reflected to some degree in the high estimated cost of reallocation. To this should be added the difficulties that would be involved in pursuing a reallocation, including a need for an Act of Congress. Most importantly, the quality of the habitat that would be inundated is higher than the quality of the habitat that would be destroyed through the creation of Lake Eastex. Consequently, use of Sam Rayburn Reservoir to secure the yield of Lake Eastex is a possible, but not a practical, alternative.

Table 17. Cost Summary for Sam Rayburn Reservoir Direct Line (85,500 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Sam Rayburn to Pump Station No. 1	$63,858,320
Pump Station No. 1	$2,153,570
Pipeline, Pump Station No. 1 to Pump Station No. 2	$40,316,350
Pump Station No. 2	$2,153,570
Pipeline to Lake Eastex Site	$33,358,130
Total Construction and O&M Cost	**$144,448,040**
Environmental Mitigation Cost	**$100,000**
Annual Cost	
Ammortized Construction Cost	$9,004,892
Operation and Maintenance Cost	$5,105,730
Reallocation Cost (COE @ $0.138/1,000 gallons)	$3,844,716
Environmental Mitigation Cost	$6,234
Total Annual Cost	**$17,961,572**
Cost Per 1,000 Gallons	**$0.64**

Source: G.E.C., Inc.

Split Delivery

The route of this pipeline (Figure 7) begins at the same location on Sam Rayburn Reservoir and follows the same route for 29.5 miles to the booster pump station at Nacogdoches. This pipeline is sized to deliver 85,500 AFY to Lufkin, where 51,300 AFY is conveyed to a southern delivery point. From this delivery point, it is sized to deliver 34,200 AFY to Henderson. The intake structure and the first booster pump station each have four pumps, two rated at 16,800 GPM and two rated at 10,000 GPM. From here, a pipeline extends northwardly along U.S. 59 and 259 a distance of 21.3 miles to a second booster pump station about 3.5 miles south of Mt. Enterprise. This pump station has two pumps rated at 12,500 GPM each. From here, it continues along U.S. 259 for 22.3 miles to Henderson, where 34,200 AFY is delivered. The estimated construction and O&M cost of this alternative is $100,626,100. A detailed construction and O&M cost estimate is included as Appendix E.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 18. The total annual cost for this alternative is $13,246,499, providing 85,500 AFY at a cost of 48 cents per thousand gallons.

Source: G.E.C., Inc.

Figure 7. Sam Rayburn Reservoir Split Delivery

Table 18. Cost Summary for Sam Rayburn Reservoir Split Delivery (85,500 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Sam Rayburn to Pump Station No. 1	$48,034,570
Pump Station No. 1	$979,690
Pipeline, Pump Station No. 1 to Pump Station No. 2	$24,053,980
Pump Station No. 2	$979,690
Pipeline to Henderson	$23,970,070
Total Construction and O&M Cost	**$100,626,100**
Environmental Mitigation Cost	**$150,000**
Annual Cost	
Ammortized Construction Cost	$6,273,032
Operation and Maintenance Cost	$3,119,400
Reallocation Cost (COD @ $0.138/1,000 gallons)	$3,844,716
Environmental Mitigation Cost	$9,351
Total Annual Cost	**$13,246,499**
Cost Per 1,000 Gallons	**$0.48**

Source: G.E.C., Inc.

The objections to this alternative are the same as those enumerated for the direct delivery of Sam Rayburn Reservoir water.

LAKE PALESTINE

Lake Palestine is about 17 miles from the Lake Eastex site. According to the East Texas Region report, Lake Palestine has a yield of 238,110 AFY, of which 600 AFY is allocated for irrigation, 23,000 AFY for industrial use, and 214,510 for municipal use. The irrigation and industrial allocations are currently being used. Almost all of the municipal allocation has been permitted. The City of Dallas has acquired rights to 114,337 AFY, the City of Tyler to 67,200 AFY, and the City of Palestine to 28,000 AFY, for a total of 209,537 AFY, leaving only 4,973 AFY unpermitted.

Appendix C of the report indicates that only 3,045 AFY of the municipal allocation was being used in 1995, suggesting that large quantities of unused water are available from Lake Palestine. The report also indicates that Tyler is presently constructing a 30 MGD (33,600 AFY) facility to make use of its Lake Palestine water, which would still leave a substantial quantity of unused water.

Lake Palestine would be able to supply the required 85,500 AFY only if Dallas would be willing to sell its water. Costs are developed for this “Full Amount” alternative. Costs are also developed for a “Reduced Amount” alternative, which assumes that an amount less than 85,500 AFY would be available from other permittees. The costs for both of these alternatives include construction and O&M costs, water rights costs, and raw water costs.

Full Amount

This alternative (Figure 8) involves a concrete pressure pipeline running in an easterly direction that would transport 85,500 AFY from an intake structure at Lake Palestine to the Lake Eastex site.

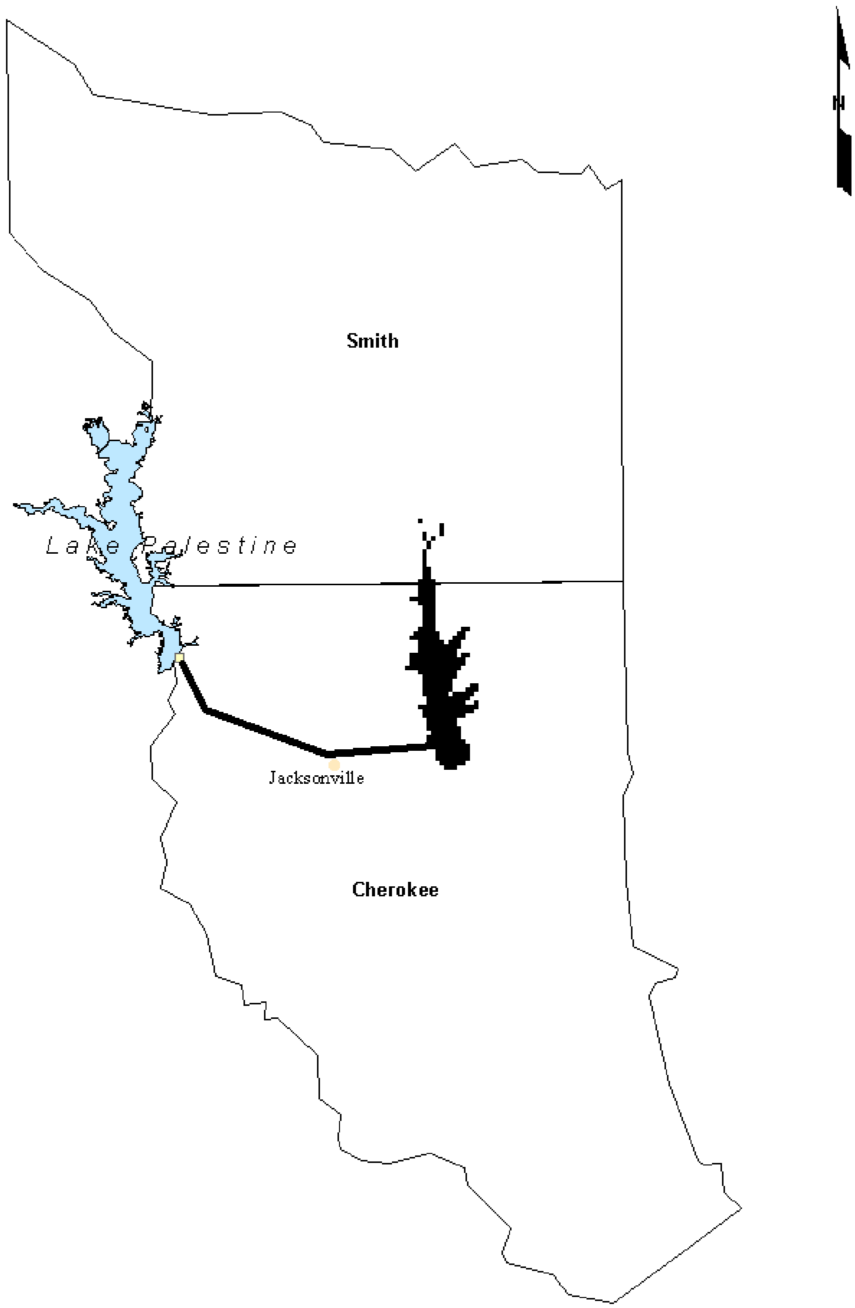
The pipeline begins at an intake structure at Cherokee Landing on the east side of Lake Palestine approximately one-half mile northeast of the dam and runs southeastwardly about three miles to a pipeline right-of-way, thence southeastwardly along the north side of the pipeline right-of-way for about four miles to an electric transmission line right-of-way, thence southeastwardly along the north side of the power line right-of-way for about five miles to near an electric substation in the northeast corner of Jacksonville, thence east along the north side of the power line right-of-way for about five miles to the Lake Eastex site.

The intake structure has four pumps, two rated at 16,800 GPM and two at 10,000 GPM, with provision for standby power in the event of power failure. The estimated construction and O&M cost of this alternative is $36,314,850. A detailed construction and O&M cost estimate is included as Appendix F.

The cost of water under this alternative would also depend on the price for which it could be purchased from Dallas Water Utilities. The Utility paid $10,000,000 for its Lake Palestine water rights in the 1970s. This price equals $87.46 per acre foot, or $5.48 per acre foot per year based on a 50-year project life and 6 percent interest, or 1.7 cents per thousand gallons.

Information on water rights transactions in East Texas is not readily available. In March 2002, the Georgia Water Planning and Policy Center published *The Sale and Leasing of Water Rights in Western States: An Overview for the Period 1990-2001*. According to the data presented in this report, water rights transactions in Texas have concentrated in the Rio Grande Valley and in the San Antonio region. Statewide, the average sales price of water is $442 per acre foot, and the average lease price is $45 per acre foot per year. Based on a 50-year project life at 6 percent interest, the annual cost of water purchased for $442 per acre foot is $28 per acre foot per year, or 8.6 cents per thousand gallons.

The San Antonio Water System has been a consistent purchaser of water rights in Texas and is the nearest major purchaser to Lake Palestine. Municipal water systems are generally able to pay more for water than industrial users or agricultural users. The San Antonio Water System paid $700 per acre foot for water rights to the Edwards aquifer in 1999, which equals $46 per acre foot per year, or approximately 14 cents per thousand gallons. The City of Laredo purchased



Source: G.E.C., Inc.

Figure 8. Lake Palestine Full Amount

surface water rights during the past 10 years for amounts ranging from $288 to $600 per acre foot, which equals approximately 6 to 12 cents per thousand gallons.

Because Dallas Water Utilities is not offering its Lake Palestine water for sale or lease, a hypotethical sales price of 12 cents per thousand gallons is assumed, which is the highest price that has been paid for surface water in Texas during the past ten years.

The cost of this alternative would also depend on the cost of raw water from Lake Palestine, which is under the jurisdiction of the Upper Neches River Municipal Water Authority. Information on the cost of raw water from Lake Palestine is not readily available. It was 7.67 cents per thousand gallons in 1991, when Toledo Bend water was selling for 7.5 cents per thousand gallons. Because the current price of Toledo Bend water is 7.9 cents per thousand gallons, 8 cents per thousand gallons is a reasonable estimate for the current price of Lake Palestine raw water.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 19. The total annual cost for this alternative is $10,396,016, providing 85,500 AFY at a cost of 37 cents per thousand gallons.

Table 19. Cost Summary for Lake Palestine Full Amount (85,500 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$2,608,100
Pipeline, Lake Palestine to Lake Eastex Site	$33,706,750
Total Construction and O&M	**$36,314,850**
Environmental Mitigation Cost	**$50,000**
Water Allocation Purchase Cost (@ $700 per acre foot)	**$59,850,000**
Annual Cost	
Ammortized Construction Cost	$2,263,868
Operation and Maintenance Cost	$2,169,160
Water Rights Purchase Cost (@ $0.12/1,000 gallons)	$3,731,050
Raw Water Cost (@ $0.08/1,000 gallons)	$2,228,821
Environmental Mitigation Cost	$3,117
Total Annual Cost	**$10,396,016**
Cost Per 1,000 Gallons	**$0.37**

Source: G.E.C., Inc.

The Region D report for the State Water Plan indicates (p. 5.36) that Dallas Water Utilities plans to develop facilities to connect its Lake Palestine water supply to its system at a cost of $300 million by 2020 as part of a plan to meet a 2050 demand of 855,485 AFY. Contact with Dallas Water Utilities indicates that an additional $200 million will be invested in a treatment plant, that rights-of-way are currently being obtained, that the pipeline will be constructed by 2015, and that the probability of construction is 100 percent. Consequently, purchase of Lake Palestine water from Dallas Water Utilities might be considered a theoretical possibility until the pipeline is actually built, but it is not a practical alternative.

Reduced Amount

The City of Tyler and the City of Palestine combined have permits for 95,200 AFY from Lake Palestine.

Tyler has a permit for 67,200 AFY from Lake Palestine. The East Texas Region report indicates that Tyler is constructing a 30 MGD (33,600 AFY) facility to obtain half of its water from Lake Palestine. Contact with the Tyler Water Utilities indicates that the city intends to use its remaining half in 2020-2025 based on projected demand. Consequently, this water is not practically available.

Palestine has a permit for 28,000 AFY from Lake Palestine. Palestine's webpage indicates that it withdraws 3.25 MGD (3,640 AFY) from the Neches River below the Lake Palestine dam, with a 6 MGD maximum withdrawal. Contact with the City of Palestine Utilities indicates that Palestine uses an average of 5 MGD (5,600 AFY), with an 8 MGD maximum withdrawal, that municipal demand is not expected to increase, and that the remaining water might be used for industry, including a prospective power plant whose plans are not firm. It should also be kept in mind that there is 4,973 AFY of uncommitted water in Lake Palestine.

There is sufficient water in Lake Palestine potentially available for use that could meet the 2050 deficit of 19,778 AFY that the East Texas Region report recommends for satisfaction by Lake Eastex. A residual (21,000 AFY) of Palestine's permitted usage (28,000 AFY) will be used for the costing of the "Reduced Amount" alternative.

This alternative involves a 36-inch concrete pressure pipeline running in an easterly direction that would transport 21,000 AFY from an intake structure at Lake Palestine to the Lake Eastex site. The pipeline route would be the same as that for the "Full Amount" scenario, as shown in Figure 8. The intake structure has two pumps rated at 13,000 GPM, with provision for standby power in the event of power failure. The estimated construction and O&M cost of this alternative is $16,699,980. A detailed construction and O&M cost estimate is included as Appendix G.

The construction and O&M costs, environmental mitigation costs, annual costs, and costs per thousand gallons of water for this alternative are shown in Table 20. The total annual cost for this alternative is $3,086,372, providing 21,000 AFY at a cost of 45 cents per thousand gallons.

Table 20. Cost Summary for Lake Palestine Reduced Amount (21,000 AFY)

Construction and O&M Cost	
Intake Structure and Pump Station	$1,519,230
Pipeline to Lake Eastex Site	$15,180,750
Total Construction and O&M Cost	**$16,699,980**
Environmental Mitigation Cost	**$50,000**
Annual Cost	
Ammortized Construction Cost	$1,041,077
Operation and Maintenance Cost	$578,350
Water Rights Purchase Cost (@ $0.12/1,000 gallons)	$916,398
Raw Water Cost (@ $0.08/1,000 gallons)	$547,430
Environmental Mitigation Cost	$3,117
Total Annual Cost	**$3,086,372**
Cost Per 1,000 Gallons	**$0.45**

Source: G.E.C., Inc.

GROUNDWATER

In 1991, TWDB published an *An Evaluation of Ground Water Resources in the Vicinity of the Cities of Henderson, Jacksonville, Kilgore, Lufkin, Nacogdoches, Rusk and Tyler in East Texas*, which deals with historic groundwater usage in six counties, including the five counties in the Lake Eastex service area. The present analysis of groundwater as an alternative to Lake Eastex is based on this report.

There are three principal groundwater aquifers in the six-county area. The shallowest is the Sparta, with an estimated annual recharge rate of 31,000 acre-feet. At greater depth is the Queen City with an estimated annual recharge rate of 208,000 acre-feet; and at even greater depth is the Carrizo-Wilcox with an estimated annual recharge rate of 105,000 acre-feet.

Most of the groundwater that has been used is from the Carrizo-Wilcox aquifer, because the quality of its water is higher than that of the water in the Sparta and Queen City aquifers. Generally, the water quality of all three aquifers is well within the recommended limits for concentrations of primary and secondary constituents for drinking water. However, quality deteriorates with depth. In the Sparta and Queen City aquifers, this is significant and may occur just below their outcrops. These two aquifers rarely contain fresh water below depths of 600 to 700 feet, whereas in the Carrizo-Wilcox aquifer fresh water occurs in depths of up to 3,000 feet. Although the water quality in all three aquifers is generally good, low well yields and high concentrations of iron and dissolved solids in the upper aquifers result in much higher production costs because of the number of wells required to achieve the volume desired and the required treatment process.

The six-county area has experienced significant historic groundwater level declines because of long-term heavy pumpage and insufficient well spacing. This is particularly true in the vicinity of Tyler, Nacogdoches, and Lufkin. In these areas, the drop of water levels in many wells has exceeded 300 to 400 feet and, in some instances, as much as 500 feet. The areas of significant water level decline are characterized by long-term pumping of high-capacity wells that are spaced too close together. However, there has been a leveling-off and/or reduction of annual water level decline rates in the Lufkin-Nacogdoches area since Nacogdoches began using surface water from Lake Nacogdoches as a major source of its water supply in 1979.

According to the report, relatively large amounts of groundwater are recoverable from the underlying aquifers, but much of this water is not economical or dependable for recovery in the large amounts required for the projected demand, particularly from the Sparta and Queen City aquifers. The Sparta aquifer has a maximum thickness of about 200 feet and averages about 100 feet in thickness. Also, it has a significant threat of surface pollution because it is very close to the ground surface. The Queen City aquifer has a maximum thickness of about 600 feet and an average thickness in the range of 300 to 400 feet.

The reason that these aquifers are not dependable and economical sources of water supply is that a large number of small-capacity wells would be required to meet the projected demand. In addition, the high concentration of iron and dissolved solids would require a more expensive degree of treatment. There is still a significant amount of water available from the Carrizo-Wilcox aquifer, but not in the vicinity of the population centers. The larger cities would have to supplement their water supply from surface sources because of the cost of well spacing and hudraulic problems associated with conveying groundwater from remote areas, where water is available, to their treatment facilities.

In 1985, the total groundwater usage in the six-county area was 74,618 acre-feet, of which 91 percent (68,029 acre-feet) was from the Carrizo-Wilcox aquifer. The annual recharge for this aquifer is 105,000 acre-feet, leaving 36,971 acre-feet for future use. In 1991, the projected usage for the area in 2010 was 135,425 acre-feet. The volume recovered from the Carrizo-Wilcox aquifer has averaged in the range of 63 percent to 66 percent. Assuming that 60 percent of the 2010 demand is groundwater, the total usage from this source is 81,255 acre-feet, leaving 23,745 acre-feet available for future use.

Additional large-volume wells in the vicinity of the population centers would severely lower groundwater levels, ruling this out as a source of future water supply in these areas. This additional capacity can be used in small population centers without affecting groundwater levels. Because there will be very little water available from the Carrizo-Wilcox aquifer and because of the problems associated with recovering water from the other aquifers, groundwater is not a viable alternative for the provision of the Lake Eastex yield.

LEGAL ISSUES

The 404 permit application states that there can be no practical alternatives to Lake Eastex because: (1) only the alternatives recommended in the State Water Plan for Lake Eastex participants and other potential users are eligible for state funding; and (2) any alternative involving interbasin transfers would encounter difficulties with respect to priority of water rights and therefore would be a bad risk for bond sales. If both of these statements are true, it is obvious that the present analysis of Toledo Bend Reservior, Sam Rayburn Reservoir, and Lake Palestine as alternatives to Lake Eastex is not viable. Sam Rayburn Reservoir and Lake Palestine would violate the first point, and Toledo Bend Reservoir would violate both points because it would involve an interbasin transfer.

With respect to the issue of state funding, Senate Bill 1, which was enacted in 1997 and established the procedures under which the regional plans were developed, indicates (Section 1.02 – Regional Water Plans) that projects are normally eligible for state funding only if they are compatible with the State Water Plan, but that a waiver may be granted. This directive and the waiver provision are reiterated on page 70 of *Water for Texas--2002*. In implementing this directive, TWDB as a practical matter is not funding projects that are not included in the State Water Plan (TWDB, personal communication). This is as it should be, for to do otherwise would subvert the whole intent of the state planning process.

However, the directive is not applicable to projects for which state funding is not sought. More importantly, the law does not say that only projects that appear in the 2002 State Water Plan are eligible for state funding. A new plan is developed every five years, and any alternatives described in the 1991 Lake Eastex report and in the present report could be included in future renditions. Taken at face value, the argument in the permit application suggests severe limitations on the inclusion of any new participants in the Lake Eastex project and, should the project not be built, that entities with needs currently recommended for satisfaction by Lake Eastex would never be eligible for state funding. Texas water law places no barriers to the type of formal analysis of alternatives presented in the 1991 Lake Eastex report and in the present report.

Texas water law authorizes the taking of water from one basin to another, but protects the interest of the source basin. Table 5-7 in *Water for Texas--2002* contains a list of 99 existing interbasin transfers in Texas, and Table 8-1 contains a list of major water conveyances proposed by the regional water planning groups, many of which involve interbasin transfers. Prior appropriation is a fundamental principle of Texas water law. During times of shortage, seniority with respect to water allocations is established by the order in time in which water rights were secured, with all subsequently established rights being junior in priority. Section 2.08 (Interbasin Transfers) of Senate Bill 1 provides that any new application for an interbasin transfer would be junior in relation to existing rights in the water source during times of shortage. This provision contributes to the practical (but not prohibitive) difficulties connected with interbasin transfers.

Texas water policy also protects the interests of the source basin. Permits for interbasin transfers are generally not granted if it is determined that the source basin has significant needs over 50 years that could be met by the source and that the granting of the permit would be detrimental to the satisfaction of those needs (TWDB, personal communication). However, even in these cases the law is not prohibitive because Senate Bill 1 contains provisions under Section 2.08 for compensation and mitigation if they are needed. The *Comprehensive Sabine Watershed Management Plan* shows a net 2050 surplus of 755,780 AFY for the 21 counties in its region, suggesting that there would be no difficulties in securing water from Toledo Bend.

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Appendix A

DEFICITS AND STRATEGIES

5.2.2 Angelina County

City of Lufkin

The City of Lufkin currently receives all of its supply from the Carrizo-Wilcox Aquifer. The City is currently planning construction of a surface water treatment plant on Sam Rayburn Reservoir (where it will contract with the LNVA for 28,000 acre-feet/year). The City's existing well field will continue to be operated at or near its current capacity, but the proposed surface water plant will be expanded in a series of phases to meet rising future demands. The most recent plans for the timing of the phased development is as follows:

Year	Capacity (ac-ft/yr)
2006	11,200
2015	16,800
2025	22,400
2035	28,000

It is proposed that the future expansions will enable the City to service additional surrounding county water suppliers and to meet increasing manufacturing demands.

The following is a summary of the demands and supply provided by the selected strategy. The selected strategy is to construct a proposed surface water plant and transfer line to supply water from Sam Rayburn Reservoir. The general location of the improvements is indicated on the county map.

	2000	2010	2020	2030	2040	2050
Population	36,684	44,281	53,452	64,521	77,883	94,013
Water Demand (ac-ft/year)	5,712	6,498	7,424	8,746	10,295	11,700
Current Supply (ac-ft/year)	5,751	5,751	5,751	5,751	5,751	5,751
Supply(+)-Demand(-) (ac-ft/yr)	39	-747	-1,673	-2,995	-4,544	-5,949
Recommended Strategy LU-1 (ac-ft/year); Construct conveyance pipeline to Rayburn Reservoir and associated water treatment plant.		5,600	6,384	6,272	7,560	7,560

The supplies provided by recommended strategy are cumulative totals based on construction of phases as discussed above and do not include quantities supplied to meet manufacturing needs.

Only one strategy was considered to meet the future water demands. Expansion of groundwater was not considered to be a realistic alternative due to the demand required. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
LU-1; Construct conveyance pipeline to Rayburn Reservoir and associated water treatment plant.	7,560	$50,409,000	$4,064,256	$648	$ 1.98

City of Huntington

The City of Huntington currently receives supplies from the Yegua aquifer. The shortage shown in the year 2040 and beyond is based on limiting current supply to 50% of the current well pumping capacity. The shortage can be most easily met by additional wells if needed.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	2,273	2,756	3,202	3,670	4,120	4,601
Water Demand (ac-ft/year)	298	336	369	407	447	495
Current Supply (ac-ft/year)	435	435	435	435	435	435
Supply(+)-Demand(-) (ac-ft/yr)	137	99	66	28	-12	-60
Recommended Strategy HU-1 (ac-ft/year): Expand current supplies					60	60

The existing wells, with proper management and maintenance, are expected to continue servicing the needs of the City.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
HU-1: Expand current supply	60	$176,773	$16,954	$283	$ 0.87

Livestock

Livestock is supplied from Queen City and Sparta and local supplies. The recommended strategy is to continue expansion of the current supplies.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	628	649	673	702	735	773
Current Supply (ac-ft/year)	627	627	627	627	627	627
Supply(+)-Demand(-) (ac-ft/yr)	-1	-22	-46	-75	-108	-146
Recommended Strategy HU-1 (ac-ft/year): Expand current supplies	49	49	49	98	147	147

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
ANL-1 (ac-ft/year): Expand current supplies	145	$66,570	$8,604	$69.49	$ 0.21

Manufacturing

Current supplies are from several sources with the following approximate distribution; 14,668 acre-feet/year from the Carrizo-Wilcox Aquifer, 851 acre-feet/year from the Yegua and 29,000 acre-feet/year from surface water sources. The City of Lufkin currently supplies approximately 12% of the current needs, however, it would be expected that the City's percentage of the supply would increase. The 19,000 acre-feet of surface water is controlled by a single manufacturing entity, Donohue. It is not expected that all of the growth will be limited to Donohue, which has the largest source of water supply. It is anticipated that growth will be supplied by the City of Lufkin and possibly Temple-Inland, which is currently under contract with ANRA for supply from Lake Eastex. It is expected that Temple-Inland would use the Lake Eastex supply as it became available.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	30,000	32,290	34,877	37,818	41,138	45,000
Current Supply (ac-ft/year)	44,519	44,519	44,519	44,519	44,519	44,519
Supply(+)-Demand(-) (ac-ft/yr)	14,519	12,229	9,642	6,701	3,381	-481
Recommended Strategy ANM-1 (ac-ft/year): Renew Contract with City of Lufkin.			2,006	4,947	6,400	6,400
Recommended Strategy ANM-2 (ac-ft/year): Obtain supply from Lake Eastex					8,551	8,551

The supply from the City of Lufkin is based on supplies available after meeting municipal demands by the City of Lufkin.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
ANM-1 (ac-ft/year): Renew Contract with City of Lufkin.	6,400	$42,944,000	$3,193,344	$648	$ 1.98
ANM-2 (ac-ft/year): Obtain supply From Lake Eastex	8,551	$32,992,000	$3,180,972	$372	$ 1.14

Note: Cost reflect treated water for ANM-1 and raw water for ANM-2. ANM-1 is industrial portion of cost of water from City of Lufkin.

Mining

Water for mining is supplied from the Carrizo-Wilcox. Water strategy would be to continue use of the Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	36	40	45	51	57	64
Current Supply (ac-ft/year)	22	22	22	22	22	22
Supply(+)-Demand(-) (ac-ft/yr)	-14	-18	-23	-29	-35	-42
Recommended Strategy ANN-1 (ac-ft/year): Increase supply from wells.	42	42	42	42	42	42

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
ANN-l: Increase supply from wells	42	$33,936	$4,081	$96.00	$ 0.29

5.2.3 Cherokee County

The Carrizo-Wilcox Aquifer is almost fully allocated in Cherokee County. There are substantial amounts of additional water available from the Queen City and Sparta Aquifers, but these aquifers do not cover the entire county. Where feasible, water from the Queen City or Sparta Aquifers may be substituted for Carrizo-Wilcox water in the following potential water management strategies. However, the ETRWPG has made a policy decision that water from the Queen City and Sparta Aquifers will be used primarily for Livestock and Irrigation uses because of the unreliable supply and quantity. No proposed management strategies for municipal water shortages involve the Queen City and Sparta Aquifers.

Water obtained from the Queen City Aquifer may be acidic and may have levels of iron and manganese greater than TNRCC secondary drinking water standards. Water obtained from the Sparta Aquifer may have levels of sulfates greater than the TNRCC secondary drinking water standards, especially in far southern Cherokee County. Water quality in the Sparta Aquifer is best on the outcrop.

Alto

The City of Alto's water supply is currently from groundwater wells in the Carrizo-Wilcox Aquifer. Future population growth is expected to increase the demand for water. The strategy selected to meet the future demands is to increase additional supplies from the Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	1,137	1,235	1,335	1,443	1,556	1,656
Water Demand (ac-ft/year)	205	212	218	229	242	256
Current Supply (ac-ft/year)	240	240	240	240	240	240
Supply(+)-Demand(-) (ac-ft/yr)	35	28	22	11	-2	-16
Recommended Strategy Al-1 (ac-ft/year): Increase supply from Carrizo-Wilcox					121	121

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Al-1: Increase supply from Carrizo-Wilcox	121	$201,025	$32,181	$266	$ 0.81

Bullard

The City of Bullard's water supply is currently from groundwater wells in the Carrizo-Wilcox Aquifer, with some of the wells in Smith County. Future population growth is expected to increase the demand for water. The strategy selected to meet the future demands is to increase additional supplies from the Carrizo-Wilcox in Smith County.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	661	737	875	942	1,033	1,130
Water Demand (ac-ft/year)	141	144	159	163	169	181
Current Supply (ac-ft/year)	116	116	116	116	116	116
Supply(+)-Demand(-) (ac-ft/yr)	-25	-28	-43	-47	-53	-65
Recommended Strategy BU-1 (ac-ft/year: Increase supply from Carrizo-Wilcox	121	121	121	121	121	121

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
BU-1 (ac-ft/year): Increase supply from Carrizo-Wilcox	121	$214,725	$35,126	$290	$ 0.89

New Summerfield

The City of New Summerfield currently obtains water supply from Carrizo-Wilcox Aquifer. Although near term needs are adequate, the City has a contract with ANRA for water from Lake Eastex, if it is developed. Development of plant farms in the New Summerfield area, with the City being the supplier of the water, will impact the City's need for new sources. The selected strategy is to obtain water from Lake Eastex. Improvements used in the evaluation of strategies are shown on the county map.

2000	2010	2020	2030	2040	2050

Population (number of persons)	604	681	767	864	974	1,097
Water Demand (ac-ft/year)	81	89	100	111	124	139
Current Supply (ac-ft/year)	118	118	118	118	118	118
Supply(+)-Demand(-) (ac-ft/yr)	37	29	18	7	-6	-21
Recommended Strategy SU-1 (ac-ft/year): Obtain water from Lake Eastex for support of local plant farm.		855	85 5	855	855	855

Most of the supply from Eastex (787 ac-ft/yr) is for resale to plant farm irrigation demands.

In addition to the recommended alternative, alternatives were also investigated for purchase of water through Cities of Jacksonville and Tyler. The evaluation of alternatives was based on providing a supply equal to the Lake Eastex contract amounts.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
SU-1: Obtain water from Lake Eastex	855	$5,630,000	$518,985	$607	$ 1.86
SU-2: Obtain water from City of Jacksonville	855	$4,267,441	$839,610	$982	$ 3.00
SU-3: Obtain water from City of Tyler	855	$1,280,394	$692,550	$810	$ 2.48

Rusk

Current supplies are obtained from Carrizo-Wilcox Aquifer and Rusk City Lake. The City presently has a contract with ANRA for water from Lake Eastex, if constructed. The selected strategy is to obtain water from Lake Eastex. Improvements used in the evaluation of strategies are shown on the county map.

	2000	2010	2020	2030	2040	2050
Population	4,645	4,945	5,237	5,651	5,952	6,182

Water Demand (ac-ft/year)	1,051	1,075	1,086	1,145	1,187	1,225
Current Supply (ac-ft/year)	1,091	1,091	1,091	1,091	1,091	1,091
Supply(+)-Demand(-) (ac-ft/yr)	40	16	5	-54	-96	-134
Recommended Strategy RU-1 (ac-ft/year): Obtain water from Lake Eastex				855	855	855

In addition to the selected alternatives, a supplementary alternative of strategy RU-2, will be to obtain water from the City of Jacksonville. The evaluation of alternatives were based on providing a supply equal to the Lake Eastex contract amounts

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
RU-1: Obtain water from Lake Eastex	855	$5,630,000	$518,985	$607	$ 1.86
RU-2: Obtain water from City of Jacksonville	855	$4,915,000	$940,500	$1,100	$ 3.36

Wells

Current supply is from Carrizo-Wilcox Aquifer. Due to the small quantity of projected future demand the selected strategy is to continue development of current supply.

	2000	2010	2020	2030	2040	2050
Population	824	874	929	976	1,026	1,078
Water Demand (ac-ft/year)	124	129	135	140	145	150
Current Supply (ac-ft/year)	113	113	113	113	113	113
Supply(+)-Demand(-) (ac-ft/yr)	-11	-16	-22	-27	-32	-37
Recommended Short Term Strategy WE-1 (ac-ft/year): Use additional water from Carrizo-Wilcox.	121	121	121	121	121	121

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
WE-1: Increase supply from Carrizo-Wilcox	121	$233,146	$35,090	$290	$ 0.89

County-Other

Current supplies are from Carrizo-Wilcox Aquifer, Queen City Aquifer, Sparta Aquifer and Lake Jacksonville. Afton Grove WSC, Craft-Turney WSC, Gum Creek WSC, North Cherokee WSC, and West Jacksonville WSC could potentially renew contracts with Jacksonville for water from Lake Jacksonville. Afton Grove WSC, Blackjack WSC, Cherokee County, John Moore, North Cherokee WSC, Reklaw WSC, Rusk Rural WSC, and the Stryker Lake WSC have existing contracts with ANRA with option for water from Lake Eastex if developed. These contracts are sufficient to meet remaining County-Other demands.

	2000	2010	2020	2030	2040	2050
Population	27,594	30,767	34,070	36,654	39,042	41,279
Water Demand (ac-ft/year)	5,441	5,917	6,431	6,855	7,246	7,587
Current Supply (ac-ft/year)	3,917	3,917	3,355	2,787	2,787	2,787
Supply(+)-Demand(-) (ac-ft/yr)	-1,524	-2,000	-3,076	-4,068	-4,459	-4,800
Recommended Strategy CHC-1 (ac-ft/year): Use additional water from Carrizo-Wilcox	404					
Recommended Strategy CHC-2 (ac-ft/year): Overdraft Carrizo-Wilcox until sustainable supply obtained	1,211					
Recommended Strategy CHC-3 (ac-ft/year): Renew contracts with City of Jacksonville			562	1,130	1,130	1,130
Recommended Strategy CHC-4 (ac-ft/year): Obtain water from Lake Eastex		7,696	7,696	7,696	7,696	7,696

In addition to the above recommended strategies evaluation was also made of supplies from the Cities of Jacksonville and Tyler. The evaluation of alternatives were based on providing a supply equal to the Lake Eastex contract amounts

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
CHC-1: Use additional water from Carrizo-Wilcox	404	$637,740	$107,968	$268	$ 0.82
CHC-2: Overdraft Carrizo-Wilcox until sustainable supply obtained	1,211	$1,913,200	$323,905	$268	$ 0.82

CHC-3: Renew contracts with City of Jacksonville	1,130	$0	$548,050	$485	$ 1.48
CHC-4: Obtain water from Lake Eastex	7,696	$44,680,000	$4,055,792	$527	$ 1.61
CHC-5: Obtain water from City of Jacksonville for certain Lake Eastex participants	1,283	$6,403,657	$1,259,906	$982	$ 3.00
CHC-6: Obtain water from City of Tyler for Lake Eastex participants	855	$1,280,394	$692,530	$810	$ 2.48
CHC-7: Obtain water from City of Jacksonville for certain Lake Eastex participants	855	$4,915,000	$940,500	$1,100	$ 3.36

Notes: Eastex participants in various alternatives as noted below:
CHC-5: New Summerfield, Blackjack WSC, Stryker Lake WSC
CHC-6: Blackjack WSC and New Summerfield on extension of line from Whitehouse and Troup.
CHC-7: City of Rusk and Rusk Rural WSC

Irrigation

Current supply is from Carrizo-Wilcox Aquifer, Queen City Aquifer, Sparta Aquifer and Irrigation Local Supply. More than 90% of the irrigation water shortage is attributable to plant farm demands. Based on conversation with Joe Daniels of Powell Brothers Plant Farm and geographical extent of the Queen City Aquifer, it is assumed that 40% of the shortage can be met using additional supply from the Queen City Aquifer. The remaining 60% of the shortage can be met with water from Lake Eastex. There appears to be sufficient water in the New Summerfield contract with ANRA, and much of the plant farm demand is centered around New Summerfield.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	1,753	1,753	1,753	1,753	1,753	1,753
Current Supply (ac-ft/year)	441	441	441	441	441	411
Supply(+)-Demand(-) (ac-ft/yr)	-1,312	-1,312	-1,312	-1,312	-1,312	-1,312
Recommended Strategy CHR-1 (ac-ft/year)						

Use additional water from the Queen City Aquifer	565	565	565	565	565	565
Recommended Strategy CHR-2 (ac-ft/year) Overdraft Carrizo-Wilcox Aquifer until sustainable supply obtained	807					
Recommended Strategy CHR-3 (ac-ft/year) Obtain water from Lake Eastex (from New Summerfield)		787	787	787	787	787

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
CHR-1: Use additional water from the Queen City Aquifer	565	$1,130,800	$155,026	$274	$ 0.84
CHR-2: Overdraft Carrizo-Wilcox Aquifer until sustainable supply obtained	807	$993,616	$92,866	$236	$ 0.72
CHR-3: Obtain water from Lake Eastex	787	$0	$468,265	$607	$ 1.86

NOTE: CHI-3 is treated water supplied thru New Summerfield.

Mining

Current supply is from Carrizo-Wilcox Aquifer and Mining Local Supply. Recommended strategy is to obtain water from the Queen City Aquifer.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	77	52	267	569	713	883
Current Supply (ac-ft/year)	84	84	84	84	84	84
Supply(+)-Demand(-) (ac-ft/yr)	7	32	-183	-485	-629	-799
Recommended Strategy CHN-1 (ac-ft/year): Use water from Queen City.			807	807	807	807

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
CHN-1: Use water from Queen City.	807	$1,723,838	$231,367	$287	$ 0.88

Steam Electric Power

Current supplies are from the Carrizo-Wilcox Aquifer and Striker Creek Lake. Construction of Lake Eastex could meet the entire future demand.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	5,000	5,000	10,000	15,000	15,000	20,000
Current Supply (ac-ft/year)	5,343	5,343	5,343	5,343	5,343	5,343
Supply(+)-Demand(-) (ac-ft/yr)	343	343	-5,657	-9,657	-9,657	-14,657
Recommended Strategy CHS-1 (ac-ft/year): Obtain water from Lake Eastex.		14,657	14,657	14,657	14,657	14,657

Besides Lake Eastex, no single alternative can provide the entire demand. A review of the supply from alternative strategies is as follows:

Alternative	Approx. Qty. (ac-ft/yr)
Lake Striker	5,600
Reuse of wastewater from Jacksonville	1,934
Reuse of wastewater from Tyler	7,123

The comparison of the alternatives is as follows:

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
CH1-S: Obtain water from Lake Eastex	14,657	$30,857,000	$3,136,598	$214	$ 0.65
CHS-2: Striker Creek Lake	5,600		$1,187,200	$212	$ 0.65
CHS-3: Reuse from City of Jacksonville	1,934	$4,618,000	$555,982	$302	$ 0.92
CHS-4: Reuse from City of Tyler, South	7,123	$15,689,000	$1,942,276	$497	$ 1.52
CHS-5: Reuse from City of Tyler, West	5,862	$26,855,000	$3,546,518	$605	$ 1.85

5.2.9 Nacogdoches County

City of Nacogdoches

The City of Nacogdoches obtains water from both ground and surface water sources. The City has eight water wells which tap the Carrizo-Wilcox Aquifer. The City also operates a surface water plant located on Lake Nacogdoches. The current water plant is rated for 6.75 mgd. Plans are currently in process to expand the surface water facility to a capacity of 15 to 18 MGD. In addition to its own demands, the City of Nacogdoches provides almost all manufacturing demands and provides water to surrounding water supply corporations.

The numbers indicated in the supply table (TWDB Table 5) included all water rights to Lake Nacogdoches even though the City cannot currently treat the entire water rights. The City will need to construct wells and improve the water surface treatment plant to meet demands. The table does indicate the City should consider other sources of water, in addition to Lake Nacogdoches, in the later portions of the planning period. The selected strategy to obtain long-term water supplies is to obtain water from Lake Eastex. The current plant is to release water from Lake Eastex into the Angelina River and divert the flows from the Angelina River to Lake Nacogdoches.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	36,709	42,959	50,274	58,834	68,851	80,574
Water Demand (ac-ft/year)	9,033	10,551	12,264	14,622	17,366	20,780
Current Supply (ac-ft/year)	22,758	22,423	22,108	21,701	21,286	20,756
Supply(+)-Demand(-) (ac-ft/yr)	13,725	11,872	9,844	7,079	3,938	-24
Recommended Strategy NA-1 (ac-ft/year): Obtain supply from Lake Eastex						9,834

Note: Strategy NA-1 includes 1,283 ac-ft/yr for Caro WSC located just north of Nacogdoches

Other strategies evaluated included obtaining water from Toledo Bend with a regional treatment facility located at Center.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
NA-1 (ac-ft/year): Obtain supply from Lake Eastex	9,834	$121,727,275	$11,929,660	$853	$ 2.61
NA-2 (ac-ft/year): Obtain supply from Toledo Bend in conjunction with Center and San Augustine	9,834	$155,686,675	$15,188,457	$1,544.48	$ 4.72

NOTE: Strategy cost includes water treatment and transport cost to treat additional water from Lake Nacogdoches in addition to water from Lake Eastex.

<u>County-Other</u>

Appleby WSC, caro WSC, D&M WSC, Etoile WSC Libby WSC Lilbert-Looneyville WSC, Lilly Grove WSC, Melrose WSC, Sacul WSC, Swift WSC and Woden WSC obtain their groundwater from the Carrizo Wilcox Aquifer. The remaining supplies are from the Queen City, Sparta Sands, or other *undifferentiated* aquifers. The City of Nacogdoches provides wholesale water to D&M, Lilly Grove, Appleby, Woden, Timber Ridge Association, Woodland Hills and Central Heights, and Nacogdoches Count MUD. For the majority of the County-Other entities, the best means for supply is to continue use of groundwater and expansion of contracts with the City of Nacogdoches.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	24,923	28,622	32,635	37,904	42,717	45,337
Water Demand (ac-ft/year)	4,199	4,530	4,908	5,572	6,135	6,459
Current Supply (ac-ft/year)	3,558	3,558	3,558	3,558	3,558	3,558
Supply(+)-Demand(-) (ac-ft/yr)	-641	-972	-1,350	-2,014	-2,577	-2,901
Recommended Strategy NAC-1 (ac-ft/year): Use additional groundwater	780	1,040	1,300	1,820	2,340	2,600
Recommended Strategy NAC-2: Expand contract with City of Nacogdoches	77	116	162	241	309	343

Other strategies included for evaluation are determining the feasibility of developing surface water sources in the area (such as apply to State agencies for potable use of Lake Naconiche). Cost for this alternative was not developed. Caro WSC has an existing contract with ANRA with option from water for Lake Eastex if developed. The cost for Caro WSC was analyzed within the City of Nacogdoches water management strategies.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
NAC-1: Use additional Groundwater	2,600	$3,997,095	$204,100	$157	$ 0.48
NAC-2: Expand contract with City of Nacogdoches	348	$0.00	$227,923	$654.95	$ 2.00

Livestock

Supply is from the Carrizo-Wilcox, Sparta and Queen City Aquifers. Expansion of current supplies by drilling new wells and/or constructing ponds for livestock is the best strategy. Livestock producers that currently obtain water from public water suppliers (either as an emergency back-up or primary provider) should continue to renew their contracts.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	2,150	2,437	2,771	3,158	3,607	4,128
Current Supply (ac-ft/year)	2,150	2,150	2,150	2,150	2,150	2,150
Supply(+)-Demand(-) (ac-ft/yr)	0	-287	-621	-1,008	-1,457	-1,978
Recommended Strategy NAL-1 (ac-ft/year): Expand current supplies		287	861	1,148	1,722	2,009

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Strategy NAL-1: Expand current supplies	2,009	$481,058	$67,732	$59	$ 0.18

Mining

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	261	280	312	345	378	415
Current Supply (ac-ft/year)	220	220	220	220	220	220
Supply(+)-Demand(-) (ac-ft/yr)	-41	-60	-92	-125	-158	-195
Recommended Strategy NAN-1 (ac-ft/year): Increase groundwater usage	96	96	96	195	195	195

Only one strategy was considered to meet the future water demands. The cost of the strategy is presented in the following table.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
NAN-1: Increase groundwater Usage	195	$146,880	$10,176	$106	$ 0.32

Steam Electric Power

No current supply exists and no immediate need was identified. The largest and closets source of water is from Rayburn Reservoir.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	0	0	0	7,505	7,505	7,505
Current Supply (ac-ft/year)	0	0	0	0	0	0
Supply(+)-Demand(-) (ac-ft/yr)	0	0	0	-7,505	-7,505	-7,505
Recommended Strategy NAI-1: (ac-ft/year): Obtain water from Sam Rayburn				7,505	7,505	7,505

Alternative source of supply is for the construction of a pipeline form Toledo Bend Reservoir. However, transportation distance is farther than Sam Rayburn Reservoir.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
NAI-1: Obtain water from Sam Rayburn	7,505			$28.14	$ 0.09

Note: Unit cost include only estimate of cost for raw water supply.

5.2.14 Rusk County

Much of the supply is groundwater taken from the Carrizo-Wilcox. However, the City of Henderson is in the process of construction of a surface water treatment plant. Surface water is also used for Steam Electric Power.

County-Other

Current supply is from Carrizo-Wilcox with the exception of surface water from Upper Neches Municipal Water Authority provided to New Salem WSC and sales to Cross Roads WSC from the City of Kilgore. Development of groundwater from Carrizo Wilcox is favorable except in areas of existing well field development appears to be at a maximum. This area is around the Henderson, New London and Mount Enterprise areas. Well fields could be developed at further distances (3-10 miles) outside these developed areas. In addition, both the City of Kilgore and the City of Henderson are currently developing new surface water systems. This may be a potential source for new water.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	27,291	29,609	34,210	38,058	41,848	43,009
Water Demand (ac-ft/year)	3,362	3,403	3,646	3,943	4,058	4,199
Current Supply (ac-ft/year)	3,219	3,219	3,219	3,219	3,219	3,219
Supply(+)-Demand(-) (ac-ft/yr)	-143	-184	-427	-724	-839	-980
Recommended Strategy: RUC-1: Increase supplies from groundwater	350	350	350	500	500	640
Recommended Strategy: RUC-2 Expand services from Kilgore and Henderson	0	590	590	590	590	590

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Recommended Strategy: RUC-1: Increase supplies from groundwater	480	$718,494	$49,920	$156	$ 0.48
Recommended Strategy: RUC-2: Expand services from Kilgore and Henderson	590	$4,028,647	$698,560	$1,184	$ 3.62

City of Henderson

The City of Henderson is presently constructing a 3 mgd water treatment plant. Supply is taken from the Sabine River near Longview. The City shares a portion of the raw water supply line with the City of Kilgore. The City has a contract with the Sabine River Authority for a 4.5 mgd supply. This project will meet the demands for the City in the planning period.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	12,006	12,161	11,866	11,584	11,554	11,524
Water Demand (ac-ft/year)	2,461	2,384	2,233	2,115	2,058	2,053
Current Supply (ac-ft/year)	2,249	2,211	2,168	2,124	2,081	2,034
Supply(+)-Demand(-) (ac-ft/yr)	-212	-173	-65	9	23	-19
Recommended Strategy: HE-1 Construct transfer and treatment Facilities from Sabine River.	1680	1680	1680	1680	1680	1680

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Recommended Strategy HE-1 (ac-ft/year): Construct transfer and treatment facilities from Sabine River	1680	$19,300,000	$1,653,120	$984	$ 3.01

City of New London

Current supply is from Carrizo-Wilcox. The City has an existing contract with ANRA for water from Lake Eastex if developed. The recommended strategy is for the City to continue pursuit of supplies from Lake Eastex.

	2000	2010	2020	2030	2040	2050
Population	1,039	1,069	1,079	1,127	1,191	1,256
Water Demand (ac-ft/year)	233	230	221	227	235	246
Current Supply (ac-ft/year)	242	242	242	242	242	242
Supply(+)-Demand(-) (ac-ft/yr)	9	12	21	15	7	-4
Recommended Strategy NL-1 (ac-ft/year): Obtain water from Lake Eastex		885	885	885	885	885

Alternate strategies include obtaining treated supplies from the City of Henderson or Tyler. The financially feasibility will depend on the cost of treated water from these sources.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Strategy NL-1: Obtain water from Lake Eastex	885	$5,630,000	$537,195	$607	$ 1.86
Strategy NL-2: Obtain water From City of Henderson	885	$3,857,175	$867,546	$979	$ 2.99
Strategy NL-3 Obtain water from City of Tyler	885	$7,252,954	$1,115,815	$1322	$ 4.04

City of Tatum

Current supply is from Carrizo-Wilcox. Use additional water from Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	1,063	1,077	1,053	1,031	1,029	1,027
Water Demand (ac-ft/year)	141	134	123	117	112	110
Current Supply (ac-ft/year)	128	128	128	128	128	128
Supply(+)-Demand(-) (ac-ft/yr)	-13	-6	5	11	16	18
Recommended Strategy TA-1 (ac-ft/year): Increase supply from Carrizo-Wilcox	41	41	41	41	41	41

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
TA-1: Increase supply from Carrizo-Wilcox	30	$181,458	$11,820	$394	$ 1.21

Livestock

Current supply is groundwater and surface water. Use additional groundwater from Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	1,237	1,253	1,271	1,292	1,317	1,345
Current Supply (ac-ft/year)	1,276	1,276	1,276	1,276	1,276	1,276
Supply(+)-Demand(-) (ac-ft/yr)	39	23	5	-16	-41	-69
Recommended Strategy RUL-1 (ac-ft/year): Increase supply from Carrizo-Wilcox				41	41	82

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
RUL-1: Increase supply from Carrizo-Wilcox	82	$37,900	$6,068	$74	$ 0.23

Steam Electric Power

Current demands are being met by Lake Martin based on historical data. Immediate future demands are related to construction of the Tanaska/Coral plant in southern Rusk County which have expected water demands of 12,900 acre-feet/year. This demand will be met with construction of raw water line from Toledo Bend. Provide surface water from Toledo Bend.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	30,000	35,000	40,000	45,000	45,000	45,000
Current Supply (ac-ft/year)	25,179	25,179	25,179	25,179	25,179	25,179
Supply(+)-Demand(-) (ac-ft/yr)	-4,821	-9,821	-14,821	-19,821	-19,821	-19,821
Recommended Strategy RUI-1 (ac-ft/year): Surface water from Toledo Bend	4,960	9,960	14,960	19,960	19,960	19,960

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Surface water from Toledo Bend	19,960	$0.00	$638,720	$32	$ 0.10

NOTE: Cost does not include transportation cost of water.

Manufacturing

Supplies are from local surface water surfaces or the City of Henderson. With the construction of the new surface water plant, it would be expected that growth would occur in the Henderson area.

	2000	2010	2020	2030	2040	2050
Water Demand (ac-ft/year)	344	382	425	469	512	559
Current Supply (ac-ft/year)	297	330	367	405	443	483
Supply(+)-Demand(-) (ac-ft/yr)	-47	-52	-58	-64	-69	-76
Recommended Strategy RUM-1 (ac-ft/year): Increase groundwater supply	81	81	81	81	81	81

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
RUM-1: Increase groundwater Supplies	81	$51,323	$7,047	$87	$ 0.27

Irrigation

Water from the Neches Basin portion of the County has been used to meet needs in the Sabine portion of the County. It is assumed this will continue. The table shows a shortage in the Sabine Basin that can be adequately supplied by the Neches Basin. The selected strategy is to transfer surplus from the Neches to the Sabine Basin.

5.2.18 Smith County

With the exception of the City of Tyler, Resort Water Service, Inc and local sources for mining and livestock, water is supplied from the Carrizo-Wilcox. The City of Tyler currently utilizes groundwater to fulfill 15% of its needs. The City of Tyler also provides approximately 75% of the manufacturing demands. The City of Tyler currently has underway a project to supply treated water from Lake Palestine. The initial phase of construction will add approximately 30 mgd capacity.

County-Other

Most of the supply is from Carrizo-Wilcox with the exception of surface water provided to Resort Water Services by the Upper Neches Municipal Water Authority and some sales by the City of Tyler. Demands could be provided by increasing production from Carrizo-Wilcox or through water contracts with City of Tyler.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	51,862	60,338	69,524	79,568	89,431	99,531
Water Demand (ac-ft/year)	7,757	8,645	9,624	10,719	11,921	13,145
Current Supply (ac-ft/year)	8,723	8,723	8,723	8,723	8,723	8,723
Supply(+)-Demand(-) (ac-ft/yr)	966	78	-901	-1,996	-3,198	-4,422
Recommended Strategy SMC-1 (ac-ft/year): Use additional water from Carrizo-Wilcox			160	1,120	2,400	3,520
Recommended Strategy SMC-2 (ac-ft/year): Supply from City of Tyler			885	885	885	885

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
SMC-1: Use additional water from Carrizo-Wilcox	3520	$5,397,060	$496,800	$207	$ 0.63
Strategy SMC-2 (ac-ft/year): Obtain water from City of Tyler	885	$3,299,552	$489,405	$553.00	$ 1.69
Strategy SMC-3 (ac-ft/year): Obtain water from Lake Eastex.	885	$5,630,000	$525,690	$594.00	$ 1.82

City of Lindale

Supply is from Carrizo-Wilcox. Increase supply from Carrizo-Wilcox.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	1,372	1,490	1,565	1,625	1,676	1,709
Water Demand (ac-ft/year)	261	267	266	271	274	278
Current Supply (ac-ft/year)	264	264	264	264	264	264
Supply(+)-Demand(-) (ac-ft/yr)	3	-3	-2	-7	-10	-14
Recommended Strategy LI-1 (ac-ft/year): Increase supply from Carrizo-Wilcox			40	40	40	40

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
Strategy LI-1: Increase supply From Carrizo-Wilcox	40	$82,333	$8,160	$204	$ 0.62

City of Whitehouse

City of Whitehouse receives approximately 95% through City of Tyler and 5% through groundwater. Increase from City of Tyler supplies.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	7,230	9,535	11,289	11,724	11,806	11,889
Water Demand (ac-ft/year)	972	1,186	1,328	1,353	1,336	1,332
Current Supply (ac-ft/year)	950	950	950	950	950	950
Supply(+)-Demand(-) (ac-ft/yr)	-22	-236	-378	-403	-386	-382
Recommended Strategy WH-1 (ac-ft/year): Renew and expand contract with City of Tyler	22	236	378	403	386	382

Has a contract with ANRA for water from Lake Eastex, if developed.

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
WH-1 (ac-ft/year): Renew and Expand contract with City of Tyler	382	$0	$185,270	$485	$ 1.48
WH-2 (ac-ft/year): Obtain supply from Lake Eastex	8,551	$56,306,000	$5,087,845	$595	$ 1.82

City of Tyler

The City of Tyler currently has underway a project to supply treated water from Lake Palestine. The initial phase of construction will add approximately 30 mgd capacity.

	2000	2010	2020	2030	2040	2050
Population (number of persons)	86,694	98,647	111,146	123,995	136,968	149,806
Water Demand (ac-ft/year)	17,577	19,006	20,418	20,139	22,093	23,828
Current Supply (ac-ft/year)	24,285	23,919	23,669	23,430	23,196	22,962
Supply(+)-Demand(-) (ac-ft/yr)	6,708	4,913	3,251	3,291	1,103	-866
Recommended Strategy TY-1 (ac-ft/year): Increase supply from Lake Palestine		16,800	16,800	16,800	16,800	16,800

Strategy	Firm Yield (AF/Y)	Total Capital Cost	Total Annualized Cost	Unit Cost ($/AF)	Unit Cost ($/Thou. Gal.)
TY-1: Increase supply from Lake Palestine	16,800	$60,000,000	$7,089,600	$422	$ 1.29

Appendix B

TOLEDO BEND DIRECT

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Toledo Bend Reservoir to the proposed Eastex Reservoir site near New Summerfield, Texas.

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)

Eastex Reservoir New Summerfield	Toledo Bend Reservoir

85,500 acre-feet .

76.32 MGD (53,000 GPM)

Detailed Cost Worksheet – Toledo Bend Alternative

Reach ______1______
Demand Center __Pump Station No. 1__.
Water Source __Toledo Bend__.
Page ___1___ of ___13___

I. Intake Structure and Pump Station

A	Excavation		
	8,000 CY @ $8.11/CY		$ 64,880
B.	Concrete		
	350 CY @ $400/CY		$ 140,000
C.	Pumps		
	Total design head 461 ft. (200 psi)		
	Pump and motor	2 – 16,800 GPM @ $335,000 2 – 10,000 GPM @ $206,400	$1,082,800
D.	Valves		$ 174,000
E.	Pipework		$ 237,800
F.	Electrical Controls		$ 150,000
G.	Pump Building		
	600 Sq. Ft. @ $40/Sq. Ft.		$ 24,000
H.	Sluice Gates	2 Ea. @ $10,250	$ 20,500
I.	Standby Power (Diesel generator)		$ 32,500
J.	Dewatering		$ 115,000
K.	Miscellaneous (Handrails, ladders, plumbing, etc.)		$ 45,000
L.	Construction Cost (Items A-K)		$2,086,480
M.	Engineering and Contingencies (25% of Line K)		$ 521,620
N.	Total Construction Cost (Line L + Line M)		$2,608,100

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend .

O. Operation and Maintenance

1.	Labor and Materials (0.5% of Line N)	$ 13,100
2.	Annual Power Cost ($0.025/KWH)	$ 2,022,610

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend .
Page 3 of 15

II. Pipeline

A. Pipeline Design Information

1. From Toledo Bend to Pump Station No. 1 (Timpson)
2. Pipeline Capacity: 76.32_MGD (53,000 GPM)
3. Length: 191,000 feet
4. Diameter: 66 inch
5. Type of pipe: Concrete pressure_pipe_(200 psi)
6. Pump Station No. 1 Head

a. Static

	High point elevation	-	470 msl
	Intake water elevation	-	165 msl
	Static head	-	305 feet
b.	Friction head loss in pipe	-	155 feet
c.	Total pump head	-	461 feet (200 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe — $65,513,000

a. Concrete pressure pipe

191,000 L.F. 66" pipe @ $343/LF

2. Special Items

a. Clearing and grubbing — $ 335,400

78 acres @ $4,300/acre

b. Bored highway crossings — $ 184,000

96" steel pipe casing – 160 LF @ $1,150/LF

c. Bored Railroad Crossings — $ 100,000

96" steel pipe casing – 80 LF @ $1,250/LF

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1.
Water Source Toledo Bend

	d.	Highway and roadway crossings	$ 31,550
		Highway - 8 crossings @ $1,600 Ea. Roadway - 15 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 69,400
		Major crossings - 2 @ $25,600 Ea. Minor crossings - 7 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 87,500
		96" steel pipe casing – 140 LF @ $625/LF	
3.	Land for right-of-way- 78 acres @ $2,850/acre		$ 222,300
4.	Construction Cost (Items 1 – 3)		$66,543,150
5.	Engineering and Contingencies (25% of Line 4)		$16,635,790
6.	Total Construction Cost (Line 4 + Line 5)		$83,178,940
7.	Operation and Maintenance		
	a.	Labor and Materials (.5% of Line 6)	$ 415,900

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2
Demand Center Pump station No. 2 .
Water Source Toledo Bend ,
Page 5 of 13 .

III. Pump Station No. 1

A	Excavation	
	250 CY @ $15/CY	$ 3,750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$1,082,800
	Total design head 408 ft (177 psi).	
	Pump and motor 2 – 16,800 GPM @ $335,000 2- 10,000 GPM @ $206,400	
D.	Valves	$ 174,000
E.	Pipework	$ 237,800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Standby Power (Diesel generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$1, 722,850
K.	Engineering and Contingencies (25% 0f Line J)	$ 430,720
L.	Total Construction Cost (Line J + Line K)	$ 2,153,570

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2.
Demand Center Pump Station No. 2
Water Source Toledo Bend.
Page 6 of 11.

M. Operation and Maintenance

1.	Labor and Materials (0.5% of Line L)	$ 10,900
2.	Annual Power Cost ($0.025/KWH)	$ 1,790,080

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2
Demand Center Pump Station No. 2
Water Source Toledo Bend .
Page 7 of 13

IV. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 1 (Timpson) to Pump Station No. 2
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 159,000 feet
4. Diameter: 60-inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Pipeline Head

a. Static

High point elevation	- 590 msl
P. S. No. 1 elevation	- 389 msl
Static head	- 201 feet

b. Friction head loss in pipe - 207 feet

c. Total pump head - 408 feet (177 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $44,202,000

a. Concrete pressure pipe

159,000 L.F. 60" pipe @ $278/LF

2. Special Items

a. Clearing and grubbing $ 47,300

11 acres @ $4,300/acre

b. Bored highway crossings $ 374,000

84" steel pipe casing: 340 LF @ $1,100/LF

c. Highway and roadway crossings $ 26,250

Roadway – 21 crossings @ $1,250 Ea.

Detailed Cost Worksheet – Toledo Bend Alternative

	d.	Stream crossings	$ 13,000
		Minor crossings - 5 @ $2,600 Ea.	
	e.	Pipeline crossings	$ 64,400
		84" steel pipe casing – 140 LF @ $460/LF	
3.	Land for right-of-way - 11 acres @ $2,850/acre		$ 31,350
4.	Construction Cost (Items 1 - 3)		$44,758,300
5.	Engineering and Contingencies (25% 0f Line 4)		$11,189,580
6.	Total Construction Cost (Line 4 + Line 5)		$55,947,880
7.	Operation and Maintenance		
	Labor and Materials (0.5% of Line 6)		$ 279,740

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 3
Demand Center Lake Eastex
Water Source Toledo Bend

III. Pump Station No. 2

A Excavation

250 CY @ $15/CY — $ 3, 750

B. Concrete

20 CY @ $400/CY — $ 8,000

C. Pumps — $1,082,800

Total design head 303 ft. (132 psi)

Pump and motor cost 2 – 16,800 GPM @ $335,000
2 – 10,000 GPM @ $206,400

D. Valves — $ 174,000

E. Pipework — $ 237,800

F. Electrical Controls — $ 150,000

G. Pump Building

600 Sq. Ft. @ $40/Sq. Ft. — $ 24,000

H. Standby Power (Diesel Generator) — $ 32,500

I. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 10,000

J. Construction Cost (Items A-I) — $1,722,850

K. Engineering and Contingencies (25% of Line J) — $ 430,720

L. Total Construction Cost (Line J + Line K) — $2,153,570

Detailed Cost Worksheet – Toledo Bend Alternative

M. Operation and Maintenance

a.	Labor and Materials (0.5% of Line L)	$ 10,900
b.	Annual Power Cost	$ 1,329,400

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 3
Demand Center Lake Eastex .
Water Source Toledo Bend .

VI. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 2 to Lake Eastex near New Summerfield
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 106,000 feet
4. Diameter: 54 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Pump Station Head

a.	Static	
	High point elevation	- 545 msl
	Pump Sta. No. 2 elevation	- 470 msl
	Static head	- 75 feet
b.	Friction head loss in pipe	- 228 feet
c.	Total pump head	- 303 feet (132 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $23,532,000

a. Concrete pressure pipe

106,000 L.F. 54" pipe @ $222/LF

2. Special Items

a. Clearing and grubbing $ 47,300

11 acres @ $4,300/acre

b. Bored highway crossings $ 289,000

66" steel pipe casing: 340 LF @ $850/LF

c. Highway and roadway crossings $ 26,250

Roadway – 21 crossings @ $1,250 Ea.

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 4
Demand Center Lake Eastex
Water Source Toledo Bend

	d.	Stream crossings	$ 13,000
		Minor crossings – 5 @ $2,600 Ea.	
	e.	Pipeline crossings	$ 51,800
		66" steel pipe casing – 140 LF @ $370/LF	
3.		Land for right-of-way - 11 acres @ 2,850/acre	$ 31,350
4.		Construction Cost (Items 1 - 3)	$23,990,700
5.		Engineering and Contingencies (25% Of Line 4)	$ 5,997,680
6.		Total Construction Cost (Line 4 + Line 5)	$29,988,380
7.		Operation and Maintenance	
		Labor and Materials (0.5% of Line 6)	$ 150,000

Detailed CostWorksheet – Toledo Bend Alternative

Reach 1 – 3
Demand Center Lake Eastex
Water Source Toledo Bend

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$ 2,608,100	$ 162,589	$ 2,035,710	$ 2,198,299
II.	Pipeline Toledo Bend Bend to P.S. No. 1	$ 83,178,940	$ 5,185,376	$ 415,900	$ 5,601,276
III.	Pump Station No. 1	$ 2,153,570	$ 134,253	$ 1,800,980	$ 1,935,233
IV.	Pipeline P.S. No. 1 to P.S. No. 2	$ 55,947,880	$ 3,487,791	$ 279,740	$ 3,767,531
V.	Pump Station No. 2	$ 2,153,570	$ 134,254	$1,340,300	$ 1,474,554
VI.	Pipeline P.S. No. 2 to Lake Eastex Site	$ 29,988,380	$ 1,869,476	$ 150,000	$ 2,019,476
VIII.	Total	$176,030,440	$10,973,739	$6,022,630	$16,996,369

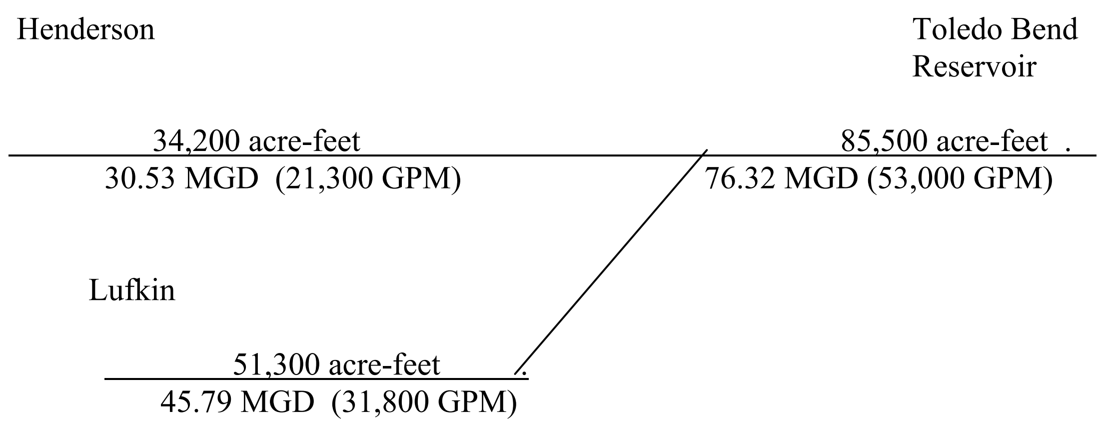
Appendix C

TOLEDO BEND SPLIT DELIVERY

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Toledo Bend Reservoir to delivery points near Lufkin (51,300 acre-feet) and Henderson (34,200 acre-feet).

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)



.Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No.1 .
Water Source Toledo Bend .
Page 1 of 15

I. Intake Structure and Pump Station

A	Excavation	
	8,000 CY @ $8.11/CY	$ 64,880
B.	Concrete	
	350 CY @ $400/CY	$ 140,000
C.	Pumps	
	Total design head 459 ft. (199)	
	Pump and motor 2 – 16,800 GPM @ $335,000 2 – 10,000 GPM @ $206,400	$1,082,800
D.	Valves	$ 174,000
E.	Pipework	$ 237,800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Sluice Gates 2 Ea. @ $10,250	$ 20,500
I.	Standby Power (Diesel generator)	$ 32,500
J.	Dewatering	$ 115,000
K.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 45,000
L.	Construction Cost (Items A-K)	$2,086,480
M.	Engineering and Contingencies (25% of Line K)	$ 521,620
N.	Total Construction Cost (Line L + Line M)	$2,608,100

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend .
Page 2 of 15 .

O. Operation and Maintenance

1.	Labor and Materials (0.5% of Line N)	$ 13,100
2.	Annual Power Cost ($0.025/KWH)	$ 2,013,840

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Toledo Bend .

II. Pipeline

A. Pipeline Design Information

1. From Toledo Bend to Pump Station No. 1 (Timpson)
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 191,000 feet
4. Diameter: 66 inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Pump Station No. 1 Head

a. Static

High point elevation	- 470 msl
Intake water elevation	- 165 msl
Static head	- 305 feet

b. Friction head loss in pipe - 154 feet

c. Total pump head - 459 feet (199 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $65,513,000

a. Concrete pressure pipe

191,000 L.F. 66" pipe @ $343/LF

2. Special Items

a. Clearing and grubbing $ 335,400

78 acres @ $4,300/acre

b. Bored highway crossings $ 184,000

96" steel pipe casing – 160 LF @ $1,150/LF

c. Bored Railroad Crossings $ 100,000

96" steel pipe casing – 80 LF @ $1,250/LF

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 1
Demand Center Pump Station No. 1.
Water Source Toledo Bend .

	d.	Highway and roadway crossings	$ 31,550
		Highway - 8 crossings @ $1,600 Ea. Roadway - 15 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 69,400
		Major crossings - 2 @ $25,600 Ea. Minor crossings - 7 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 87,500
		96" steel pipe casing – 140 LF @ $625/LF	
3.	Land - 78 acres @ $2,850/acre		$ 222,300
4.	Construction Cost (Items 1 – 3)		$66,543,150
5.	Engineering and Contingencies (25% of Line 4)		$16,635,790
6.	Total Construction Cost (Line 4 + Line 5)		$83,178,940
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 6)	$ 415,900

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2
Demand Center Angelina River/Henderson.
Water Source Toledo Bend .
Page 5 of 13 .

III. Pump Station No. 1

A. Excavation

250 CY @ $15/CY — $ 3,750

B. Concrete

20 CY @ $400/CY — $ 8,000

C. Pumps — $1,082,800

Total design head 338 ft. (146 psi)

Pump and motor 2 – 16,800 GPM @ $335,000
2 - 10,000 GPM @ $206,400

D. Valves — $ 174,000

E. Pipework — $ 237,800

F. Electrical Controls — $ 150,000

G. Pump Building

600 Sq. Ft. @ $40/Sq. Ft. — $ 24,000

H. Standby Power (Diesel generator) — $ 32,500

I. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 10,000

J. Construction Cost (Items A-I) — $1, 722,850

K. Engineering and Contingencies (25% 0f Line J) — $ 430,720

L. Total Construction Cost (Line J + Line K) — $ 2,153,570

Detailed Cost Worksheet – Toledo Bend Alternative

M. Operation and Maintenance

1.	Labor and Materials (0.5% of Line L)	$ 10,900
2.	Annual Power Cost ($0.025/KWH)	$ 1,482,960

Detailed Cost Worksheet - Toledo Bend Alternative

IV. Pipeline

A. Pipeline Design Information

1. From Timpson to delivery point at the Angelina River near Lufkin
2. Pipeline Capacity: 31.8 MGD (31,800 GPM)
3. Length: 60,000 feet of 48" & 137,500 feet of 54"
4. Diameter: 34 inch & 54 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Intake station pump head

a. Static

	High point elevation	- 510 msl
	Intake water elevation	- 389 msl
	Static head	- 121 feet
b.	Friction head loss in pipe	- 217 feet
c.	Total pump head	- 338 feet (146 psi)

B. Pipeline Construction Cost Data – Timpson to Angelina River

1. Transmission Pipe — $40,845,000

a. Concrete pressure pipe

60,000 L.F. 48" pipe @ $172/LF
137,500 L.F. 54" pipe @ $222/LF

2. Special Items

a. Clearing and grubbing — 468,700

109 acres @ $4,300/acre

b. Bored highway crossings — 95,000

84" steel pipe casing: 40 LF @ $1,100/LF
66" steel pipe casing: 60 LF @ $850/LF

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 2
Demand Center Angelina River
Water Source Toledo Bend

c.	Highway and roadway crossings		$ 25,150
		Highway - 4 crossings @ $1,600 Ea. Roadway - 15 crossings @ $1,250 Ea.	
	d.	Stream crossings	$ 25,600
		Major crossing - 1 @ $25,600 Ea.	
	f.	Pipeline crossings	$ 29,600
		66" steel pipe casing – 80 LF @ $370/LF	
3.	Land for right-of-way		$ 310,650
	109 acres @ $2,850/acre		
4.	Construction Cost (Items 1 – 2)		$ 41,799,700
5.	Construction Contingency (25% of Line 4)		$ 10,449,930
6.	Total Construction Cost (Line 4 + Line 5)		$52,249,630
7.	Operation and Maintenance		
	Labor and Materials (0.5% of Line 9)		$ 261,250

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 4
Demand Center Pump Station No. 2
Water Source Toledo Bend

V. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 1 (Timpson) to Pump Station No. 2
2. Pipeline Capacity: 30.53 MGD (21,200 GPM)
3. Length: 93,000 feet
4. Diameter: 42 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Intake station pump head

a. Static

High point elevation	- 590 msl
P. S. No. 1 elevation	- 389 msl
Static head	- 201 feet
b. Friction head loss in pipe	- 133 feet
c. Total pump head	- 334 feet (145 psi)

B. Pipeline Construction Cost Data – Toledo Bend to Timpson

1. Transmission Pipe $14,787,000

a. Concrete pressure pipe

93,000 L.F. 42" pipe @ $159/LF

2. Special Items

a. Clearing and grubbing $ 47,300

11 acres @ $4,300/acre

b. Bored highway crossings $ 170,000

66" steel pipe casing: 200 LF @ $850/LF

c. Highway and roadway crossings $ 13,750

Roadway – 11 crossings @ $1,250 Ea.

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 4
Demand Center Pump Station No. 2
Water Source Toledo Bend

	d.	Stream crossings	$ 18,200
		Minor crossings - 7 @ $2,600 Ea.	
	e.	Pipeline crossings	$ 51,800
		66" steel pipe casing – 140 LF @ $370/LF	
3.	Land - 11 acres @ 2,850/acre		$ 31,350
4.	Construction Cost (Items 1 - 3)		$15,119,400
5.	Engineering and Contingencies (25% Of Line 4)		$ 3,779,850
6.	Total Construction Cost (Line 4 + Line 5)		$18,899,250
7.	Operation and Maintenance		
	Labor and Materials (0.5% of Line 6)		$ 94,500

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 4
Demand Center Henderson
Water Source Toledo Bend

VI. Pump Station No. 2

A	Excavation	
	250 CY @ $15/CY	$ 3, 750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$ 516,000
	Total design head 233 ft. (101 psi)	
	Pump and motor cost 2 – 12,500 GPM @ $258,000	
D.	Valves	$ 90,000
E.	Pipework	$ 30,500
F.	Electrical Controls	$ 75,000
G.	Pump Building	
	450 Sq. Ft. @ $40/Sq. Ft.	$ 18,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$ 783,750
K.	Engineering and Contingencies (25% of Line J)	$ 195,140
L.	Total Construction Cost (Line J + Line K)	$ 979,690

Detailed Worksheet – Toledo Bend Alternative

Reach 3.
Demand Center Henderson.
Water Source Toledo Bend.

M. Operation and Maintenance

a. Labor and materials (0.5% of Line L) $ 5,030

b. Annual Power Cost $ 408,940

Detailed Cost Worksheet – Toledo Bend Alternative

Reach 4
Demand Center Henderson
Water Source Toledo Bend

VII. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 2 to delivery point at Henderson
2. Pipeline Capacity: 30.53 MGD (21,200 GPM)
3. Length: 108,000 feet
4. Diameter: 42 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Pump Station Head

a.	Static	
	High point elevation	- 558 msl
	Pump Sta. No. 2 elevation	- 480 msl
	Static head	- 78 feet
b.	Friction head loss in pipe	- 155 feet
c.	Total pump head	- 233 feet (101 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe — $17,172,000

   a. Concrete pressure pipe

   108,000 L.F. 42" pipe @ $159/LF

2. Special Items

   a. Clearing and grubbing — $ 47,300

   11 acres @ $4,300/acre

   b. Bored highway crossings — $ 221,000

   66" steel pipe casing: 260 LF @ $850/LF

   c. Highway and roadway crossings — $ 13,750

   Roadway – 11 crossings @ $1,250 Ea.

Detailed Cost Worksheet – Toledo Bend Alternative

	d.	Stream crossings	$ 10,400
		Minor crossings - 4 @ $2,600 Ea.	
	e.	Pipeline crossings	$ 11,100
		66" steel pipe casing – 30 LF @ $370/LF	
3.		Land for right-of-way - 11 acres @ 2,850/acre	$ 31,350
4.		Construction Cost (Items 1 - 3)	$17,506,900
5.		Engineering and Contingencies (25% Of Line 4)	$ 4,376,730
6.		Total Construction Cost (Line 4 + Line 5)	$21,883,630
7.		Operation and Maintenance	
		Labor and Materials (0.5% of Line 6)	$ 109,420

Detailed CostWorksheet – Toledo Bend Alternative

Reach 1 – 3
Demand Center Angelina River & Henderson
Water Source Toledo Bend

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$ 2,608,100	$ 162,589	$2,026,940	$ 2,189,529
II.	Pipeline Toledo Bend Bend to P.S. No. 1	$ 83,178,940	$ 5,185,376	$ 415,900	$ 5,601,276
III.	Pump Station No. 1	$ 2,153,570	$ 134,254	$ 1,493,860	$ 1,628,114
IV.	Pipeline P.S. No. 1 to Angelina River	$ 52,249,630	$ 3,257,242	$ 261,250	$ 3,518,492
V.	Pipeline P.S. No. 1 to P.S. No. 2	$ 18,899,250	$ 1,178,179	$ 94,500	$ 1,272,679
VI.	Pump Station No. 2	$ 979,690	$ 61,074	$ 413,970	$ 475,044
VII.	Pipeline to Henderson	$ 21,883,630	$ 1,364,226	$ 109,420	$ 1,473,646
VIII.	Total	$181,952,810	$11,342,940	$ 4,815,840	$16,158,780

Appendix D

SAM RAYBURN DIRECT

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Sam Rayburn Reservoir to the proposed Eastex Reservoir site near New Summerfield, Texas.

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)

Eastex Reservoir New Summerfield	Sam Rayburn Reservoir

85,500 acre-feet .

76.32 MGD (53,000 GPM

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Sam Rayburn .
Page 1 of 13

I. Intake Structure and Pump Station

A	Excavation	
	8,000 CY @ $8.11/CY	$ 64,880
B.	Concrete	
	350 CY @ $400/CY	$ 140,000
C.	Pumps	$1,082,800
	Total design head 342 ft. (142 psi)	
	Pump and motor 2 – 16,800 GPM @ $335,000 2 – 10,000 GPM @ $206,400	
D.	Valves	$ 174,000
E.	Pipework	$ 237,800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Sluice Gates 2 Ea. @ $10,250	$ 20,500
I.	Standby Power (Diesel Generator)	$ 32,500
J.	Dewatering	$ 115,000
K.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 45,000
L.	Construction Cost (Items A-K)	$ 2,086,480
M.	Engineering and Contingencies (25% of Line L)	$ 521,620

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1.
Demand Center Pump Station No. 1
Water Source Sam Rayburn.
Page 2 of 13.

N.	Total Construction Cost (Line L + Line M)	$ 2,608,100
O.	Operation and Maintenance	
	1. Labor and Materials (0.5% of Line O)	$ 13,100
	2. Annual Power Cost	$ 1,500,510

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No. 1.
Water Source Sam Rayburn .
Page 3 of 13

II. Pipeline

A. Pipeline Design Information

1. From Sam Rayburn to Pump Station No. 1
2. Pipeline Capacity: 76.32 MGD
3. Length: 155,700 feet
4. Diameter: 66 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Intake station pump head

a.	Static		
	High point elevation	-	380 msl
	Intake water elevation	-	164 msl
	Static head	-	216 feet
b.	Friction head loss in pipe	-	126 feet
c.	Total pump head	-	342 feet (148 psi)

B. Pipeline Construction Cost Data – Sam Rayburn to Pump Station No. 1

1. Transmission Pipe — $50,135,400

a. Concrete pressure pipe

155,700 L.F. 66" pipe @ $322/LF

2. Special Items

a. Clearing and grubbing — $ 335,400

78 acres @ $4,300/acre

b. Bored highway crossings — $ 126,500

96" steel pipe casing - 110 LF @ $1,150/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

	c.	Bored railroad crossings	$ 200,000
		96" steel pipe casing 160 LF @ $1,250/LF	
	d.	Highway and roadway crossings	$ 17,500
		Roadway - 14 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 30,800
		Major crossings - 1 @ $25,600 Ea. Minor crossings - 2 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 18,750
		96" steel pipe casing – 30 LF @ $625/LF	
3.	Land - 78 acres @ $2,850/acre		$ 222,300
4.	Construction Cost – (Items 1 – 3)		$51,086,650
5.	Engineering and Contingencies (25% of Line 4)		$12,771,670
6.	Total Construction Cost (Line 4 + Line 5)		$63,858,320
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 7)	$ 319,300

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 2

Demand Center Pump Station No. 2 .

Water Source Sam Rayburn .

Page 5 of 13 .

III. Pump Station No. 1

A	Excavation	
	250 CY @ $15/CY	$ 3, 750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$ 1,082,800
	Total design head 339 ft. (147 psi)	
	Pump and motor cost 2 – 16,800 GPM @ $335,000 2 – 10,000 GPM @ $206,400	
D.	Valves	$ 174,000
E.	Pipework	$ 237,800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$ 1,772,850
K.	Engineering and Contingencies (25% of Line I)	$ 430,720
L.	Total Construction Cost (Line J + Line K)	$ 2,153,570

Detailed Cost Worksheet – Sam Rayburn Alternative

M.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line L)	$ 10,960
	b.	Annual Power Cost	$1,461,020

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 2
Demand Center Pump Sta.No. 2
Water Source Sam Rayburn
Page 7 of 13

IV. Pipeline

A. Pipeline Design Information

1. Pipeline from Pump Station No. 1 to Pump Station No. 2
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 125,300 feet
4. Diameter: 60 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Booster pump station head

a. Static

High point elevation	-	558 msl
Low point elevation	-	380 msl
Static head	-	178 feet

b. Friction head loss in pipe - 161 feet

c. Total pump head - 339 feet (147 psi)

z

B. Pipeline Construction Cost Data

1. Transmission Pipe $30,698,500

a. Concrete pressure pipe

125,300 L.F. 60" pipe @ $245/LF

2. Special Items

a. Clearing and grubbing $ 120,400

28 acres @ $4,300/acre

b. Bored highway crossings $ 308 000

84" steel pipe casing - 280 LF @ $1,100/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

	c.	Bored railroad crossings	$ 72,000
		84" steel pipe casing 60 LF @ $1,200/LF	
	d.	Highway and roadway crossings	$ 18,550
		Highway - 3 crossings @ $1,600 Ea. Roadway - 11 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 105,000
		Major crossings - 4 @ $25,600 Ea. Minor crossings – 1 @ $ 2,600 Ea.	
	f.	Pipeline crossings	$ 22,200
		66" steel pipe casing – 60 LF @ $370/LF	
	g.	Asphalt street removed and replaced	$ 828,630
		40,500 Sq. Yds. @ 20.46/Sq. Yd.	
3.	Land - 28 acres $ $2,850/acre		$ 79,800
4.	Construction Cost (Items 1 – 3)		$32,253,080
5.	Engineering and Contingencies (25% of Line 4)		$ 8,063,270
6.	Total Construction Cost (Line 4 + Line 5)		$40,316,350
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 6)	$ 201,600

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 3
Demand Center Lake Eastex
Water Source Sam Rayburn

V. Pump Station No. 2

A	Excavation	
	250 CY @ $15/CY	$ 3, 750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$1, 082,800
	Total design head 341 ft. (148 psi)	
	Pump and motor 2 – 16,8500 GPM @ $335,000 2 - 10,000 GPM @ $206,400	
D.	Valves	$ 174,000
E.	Pipework	$ 237, 800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$1,722,850
K.	Engineering and Contingencies (25% of Line J)	$ 430,720
L.	Total Construction Cost (Line J + Line K)	$2,153,570

Detailed Worksheet – Sam Rayburn Alternative

Reach 3
Demand Center Lake Eastex
Water Source Sam Rayburn

M. Operation and Maintenance

a.	Labor and materials (0.5% of Line L)	$ 10,900
b.	Annual Power Cost	$ 1,421,540

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 3
Demand Center Lake Eastex
Water Source Sam Rayburn

VI. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 2 to Lake Eastex (New Summerfield)
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 118,200 feet
4. Diameter: 54 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Pipeline Head

a.	Static		
	High point elevation	-	545 msl
	Low point elevation	-	458 msl
	Static head	-	87 feet
b.	Friction head loss in pipe	-	254 feet
c.	Total pump head	-	341 feet (148 psi)

B. Pipeline Construction Cost Data

1.	Transmission Pipe	$26,240,400
a.	Concrete pressure pipe 118,200 L.F. 54" pipe @ $222/LF	
2.	Special Items	
a.	Clearing and grubbing 27 acres @ $4,300/acre	$ 116,100
b.	Bored highway crossings 72" steel pipe casing - 220 LF @ $1,000/LF	$ 220,000

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 3
Demand Center Lake Eastex
Water Source Sam Rayburn
Page 12 of 13

	c.	Highway and roadway crossings	$ 12,500
		Roadway - 10 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 7,800
		Minor crossings – 3 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 12,750
		72" steel pipe casing – 30 LF @ $425/LF	
3.	Land for right-of-way		$ 76,950
		27 acres @ $2,850/acre	
4.	Construction Cost (Items 1 – 3)		$26,686,500
5.	Engineering and Contingencies (25% Of Line 4)		$ 6,671,630
6.	Total Construction Cost (Line 4 + Line 5)		$33,358,130
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 6)	$ 166,800

Detailed CostWorksheet – Sam Rayburn Alternative

Reach 1 – 3
Demand Center Lake Eastex
Water Source Sam Rayburn

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$ 2,608,100	$ 162,589	$1,513,610	$ 1,676,199
II.	Pipeline Sam Rayburn to Pump Station No. 1	$ 63,858,320	$3,980,928	$ 319,300	$ 4,300,228
III.	Pump Station No. 2	$ 2,153,570	$ 134,254	$1,471,980	$ 1,606,234
IV.	Pipeline P.S. No. 1 to P.S. No. 2	$ 40,316,350	$2,513,322	$ 201,600	$ 2,714,922
V.	Pump Station No. 2	$ 2,153,570	$ 134,254	$1,432,440	$ 1,566,694
VI.	Pipeline to Lake Eastex Site	$ 33,358,130	$2,079,546	$ 166,800	$ 2,246,346
VII.	Total Estimated Cost	$144,448,040	$9,004,893	$5,105,730	$14,110,623

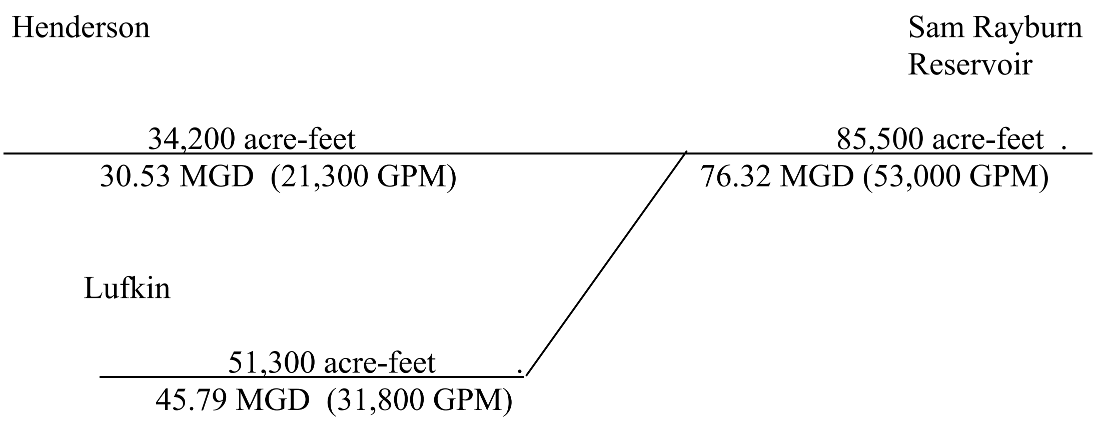
Appendix E

SAM RAYBURN SPLIT DELIVERY

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Sam Rayburn Reservoir to delivery points near Lufkin (51,300 acre-feet) and Henderson (34,200 acre-feet).

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)



Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No. 1
Water Source Sam Rayburn
Page 1 of 13

I.	Intake Structure and Pump Station		
	A	Excavation	
		8,000 CY @ $8.11/CY	$ 64,880
	B.	Concrete	
		350 CY @ $400/CY	$ 140,000
	C.	Pumps	$1,082,800
		Total design head 337 ft. (146 psi)	
		Pump and motor 2 – 16,800 GPM @ $335,000 2 – 10,000 GPM @ $206,400	
	D.	Valves	$ 174,000
	E.	Pipework	$ 237,800
	F.	Electrical Controls	$ 150,000
	G.	Pump Building	
		600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
	H.	Sluice Gates 2 Ea. @ $10,250	$ 20,500
	I.	Standby Power (Diesel Generator)	$ 32,500
	J.	Dewatering	$ 115,000
	K.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 45,000
	L.	Construction Cost (Items A-K)	$1,086,480
	M.	Engineering and Contingencies (25% of Line L)	$ 521,620

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1.
Demand Center Pump Station No. 1
Water Source Sam Rayburn.

N.	Total Construction Cost (Line L + Line M)	$ 2,608,100
O.	Operation and Maintenance	
	1. Labor and Materials (0.5% of Line Q)	$ 13,100
	2. Annual Power Cost	$ 1,478,570

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No. 1.
Water Source Sam Rayburn .

II. Pipeline

A. Pipeline Design Information

1. From Sam Rayburn to Pump Station No. 1
2. Pipeline Capacity: 66" - 76.32 MGD (53,000 GPM)
   48" – 30.53 MGD (21,200 GPM)
3. Length: 71,000 Feet OF 66" & 84,700 Feet of 48"
4. Diameter: 66-inch & 48-Inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Intake station pump head

a. Static
   High point elevation - 380 msl
   Intake water elevation - 164 msl
   Static head - 216 feet
b. Friction head loss in pipe - 121 feet
c. Total pump head - 337 feet (146 psi)

B. Pipeline Construction Cost Data – Sam Rayburn to Pump Station No. 1

1. Transmission Pipe $37,430,400

a. Concrete pressure pipe

71,000 L.F. 66" pipe @ $322/LF
84,700 L.F. 48" pipe @ $172/LF

2. Special Items

a. Clearing and grubbing $ 335,400

78 acres @ $4,300/acre

b. Bored highway crossings $ 126,500

96" steel pipe casing - 110 LF @ $1,150/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 1
Demand Center Pump Station No.1
Water Source Sam Rayburn

	c.	Bored railroad crossings	$ 248,500
		96" steel pipe casing 170 LF @ $1,250/LF 66" steel pipe casing 40 LF @ $ 900/LF	
	d.	Highway and roadway crossings	$ 15,000
		Roadway - 12 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 30,800
		Major crossings - 1 @ $25,600 Ea. Minor crossings - 2 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 18,750
		96" steel pipe casing – 30 LF @ $625/LF	
3.	Land for right-of-way 78 acres @ $2,850/acre		$ 222,300
4.	Construction Cost – (Items 1 – 3)		$38,427,650
5.	Engineering and Contingencies (25% of Line 4)		$ 9,606,920
6.	Total Construction Cost (Line 4 + Line 5)		$48,034,570
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 9)	$ 240,180

III. Pump Station No. 1

A	Excavation	
	250 CY @ $15/CY	$ 3, 750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$ 516,000
	Total design head 339 ft. (147 psi)	
	Pump and motor cost 2 - 12,500 GPM @ $258,000	
D.	Valves	$ 90,000
E.	Pipework	$ 30,500
F.	Electrical Controls	$ 75,000
G.	Pump Building	
	450 Sq. Ft. @ $40/Sq. Ft.	$ 18,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$ 783,750
K.	Engineering and Contingencies (25% of Line J)	$ 195,940
L.	Total Construction Cost (Line J + Line K)	$ 979,690

Detailed Cost Worksheet – Sam Rayburn Alternative

M. Operation and Maintenance

a.	Labor and Materials (0.5% of Line L)	$ 5,030
b.	Annual Power Cost	$ 595,000

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 2
Demand Center Pump Sta.No. 2
Water Source Sam Rayburn
Page 7 of 13

IV. Pipeline

A. Pipeline Design Information

1. Pipeline from Pump Station No. 1 to Pump Station No. 2
2. Pipeline Capacity: 30.53 MGD (21,200 GPM)
3. Length: 112,300 feet
4. Diameter: 42 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Booster pump station head

a.	Static		
	High point elevation	-	558 msl
	Low point elevation	-	380 msl
	Static head	-	178 feet
b.	Friction head loss in pipe	-	161 feet
c.	Total pump head	-	339 feet (147 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe — $17,855,700

   a. Concrete pressure pipe

   112,300 L.F. 42" pipe @ $159/LF

2. Special Items

   a. Clearing and grubbing — $ 120,400

   28 acres @ $4,300/acre

   b. Bored highway crossings — $ 170,000

   66" steel pipe casing - 200 LF @ $850/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

c.	Bored railroad crossings	$ 54,000
	66" steel pipe casing 60 LF @ $900/LF	
d.	Highway and roadway crossings	$ 18,550
	Highway - 3 crossings @ $1,600 Ea. Roadway - 11 crossings @ $1,250 Ea.	
e.	Stream crossings	$ 105,000
	Major crossings - 4 @ $25,600 Ea. Minor crossings – 1 @ $ 2,600 Ea.	
f.	Pipeline crossings	$ 11,100
	66" steel pipe casing – 30 LF @ $370/LF	
g.	Asphalt street removed and replaced	$ 828,630
	40,500 Sq. Yds. @ 20.46/Sq. Yd.	
3.	Land - 28 acres $ $2,850/acre	$ 79,800
4.	Construction Cost (Items 1 – 3)	$19,243,180
5.	Engineering and Contingencies (25% of Line 4)	$ 4,810,800
6.	Total Construction Cost (Line 4 + Line 5)	$24,053,980
7.	Operation and Maintenance	
a.	Labor and Materials (0.5% of Line 6)	$ 120,270

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 3
Demand Center Henderson
Water Source Sam Rayburn
Page 9 of 13

VI. Pump Station No. 2

A	Excavation	
	250 CY @ $15/CY	$ 3, 750
B.	Concrete	
	20 CY @ $400/CY	$ 8,000
C.	Pumps	$ 516,000
	Total design head 309 ft. (134 psi)	
	Pump and motor cost 2 – 12,500 GPM @ $258,000	
D.	Valves	$ 90,000
E.	Pipework	$ 30,500
F.	Electrical Controls	$ 75,000
G.	Pump Building	
	450 Sq. Ft. @ $40/Sq. Ft.	$ 18,000
H.	Standby Power (Diesel Generator)	$ 32,500
I.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 10,000
J.	Construction Cost (Items A-I)	$ 783,750
K.	Engineering and Contingencies (25% of Line J)	$ 195,940
L	Total Construction Cost (Line K + Line L)	$ 979,690

Detailed Worksheet – Sam Rayburn Alternative

M. Operation and Maintenance

a. Labor and materials (0.5% of Line M) $ 5,070

b. Annual Power Cost $ 542,330

Detailed Cost Worksheet – Sam Rayburn Alternative

VI. Pipeline

A. Pipeline Design Information

1. From Pump Station No. 2 to Henderson
2. Pipeline Capacity: 30.53 MGD (21,200 GPM)
3. Length: 118,000 feet
4. Diameter: 42 inch
5. Type of pipe: Concrete pressure pipe (150 psi)
6. Pipeline Head

a. Static

High point elevation	-	552 msl
Low point elevation	-	412 msl
Static head	-	140 feet

b. Friction head loss in pipe - 169 feet

c. Total pump head - 309 feet (134 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $18,762,000

a. Concrete pressure pipe

118,000 L.F. 42" pipe @ $159/LF

2. Special Items

a. Clearing and grubbing $ 116,100

27 acres @ $4,300/acre

b. Bored highway crossings $ 187,000

66" steel pipe casing - 220 LF @ $850/LF

Detailed Cost Worksheet – Sam Rayburn Alternative

Reach 3
Demand Center Henderson
Water Source Sam Rayburn

	c.	Highway and roadway crossings	$ 12,500
		Roadway - 10 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 10,400
		Minor crossings – 4 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 11,100
		66" steel pipe casing – 30 LF @ $370/LF	
3.	Land		$ 76,950
		27 acres @ $2,850/acre	
4.	Construction Cost (Items 1 – 3)		$19,176,050
5.	Engineering and Contingencies (25% 0f Line 4)		$ 4,794,020
6.	Total Construction Cost (Line 4 + Line 5)		$23,970,070
7.	Operation and Maintenance		
	a.	Labor and Materials (0.5% of Line 6)	$ 119,850

Detailed CostWorksheet – Sam Rayburn Alternative

Reach 1 – 3
Demand Center Henderson
Water Source Sam Rayburn
Page 13 of 13

Project Summary Cost Sheet

Project Feature		Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I.	Intake Structure and Pump Station	$2,608,100	$162,589	$1,491,670	$1,654,259
II.	Pipeline Sam Rayburn to Pump Station No. 1	$48,034,570	$2,994,476	$240,180	$3,234,656
III.	Pump Station No. 1	$979,690	$61,074	$600,030	$661,104
IV.	Pipeline P.S. No. 1 to P.S. No. 2	$24,053,980	$1,499,525	$120,270	$1,619,795
V.	Pump Station No. 2	$979,690	$61,074	$547,400	$608,474
VI.	Pipeline to Henderson	$23,970,070	$1,494,294	$119,850	$1,614,144
VII.	Total	$100,626,100	$6,273,032	$3,119,400	$9,392,432

Appendix F

LAKE PALESTINE FULL AMOUNT

ESTIMATE OF COST

This estimate of cost is for pumping 85,500 acre-feet of water annually from Lake Palestine Reservoir to the proposed Eastex Reservoir site near New Summerfield, Texas.

85,500 acre-feet = 76.32 million gallons per day (MGD) = 53,000 gallons per minute (GPM)

Palestine Reservoir	Lake Eastex Reservoir New Summerfield

85,500 acre-feet .

76.32 MGD (53,000 GPM)

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex
Water Source Lake Palestine

I. Intake Structure and Pump Station

A	Excavation	
	8,000 CY @ $8.11/CY	$ 64,880
B.	Concrete	
	350 CY @ $400/CY	$ 140,000
C.	Pumps	$1,082,800
	Total design head 453 ft. (197 psi)	
	Pump and motor 2 – 16,800 GPM @ $335,000; 2 – 10,000 GPM @ $206,400	
D.	Valves	$ 174,000
E.	Pipework	$ 237,800
F.	Electrical Controls	$ 150,000
G.	Pump Building	
	600 Sq. Ft. @ $40/Sq. Ft.	$ 24,000
H.	Sluice Gates 2 Ea. @ $10,250	$ 20,500
I.	Standby Power (Diesel Generator)	$ 32,500
J.	Dewatering	$ 115,000
K.	Miscellaneous (Handrails, ladders, plumbing, etc.)	$ 45,000
L.	Construction Cost (Items A-K)	$2,086,480
M.	Engineering and Contingencies (25% of Line L)	$ 521,620

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1.
Demand Center Lake Eastex.
Water Source Lake Palestine.
Page 2 of 5.

N.	Total Construction Cost (Line L + Line M)	$ 2,608,100
O.	Operation and Maintenance	
	1. Labor and Materials (0.5% of Line O)	$ 13,100
	2. Annual Power Cost	$ 1,987,520

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex .
Water Source Lake Palestine .
Page 3 of 5 .

II. Pipeline

A. Pipeline Design Information

1. From Lake Palestine to Lake Eastex near New Summerfield
2. Pipeline Capacity: 76.32 MGD (53,000 GPM)
3. Length: 65,000 feet of 60 inch & 24,000 feet of 54 inch
4. Diameter: 60 inch and 66 inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Intake Pump Station Head:

a. Static

High point elevation	- 695 msl
Intake water elevation	- 345 msl
Static head	- 350 feet

b. Friction head loss in pipe - 103 feet

c. Total pump head - 453 feet (197 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $26,302,000

a. Concrete pressure pipe

65,000 L.F. 60" Pipe @ $278/LF
24,000 L.F. 66" pipe @ $343/LF

2. Special Items

a. Clearing and grubbing $ 107,500

25 acres @ $4,300/acre

b. Bored highway crossings $ 132,000

84" steel pipe casing – 120 LF @ $1,100/LF

c. Bored Railroad Crossings $ 120,000

84" steel pipe casing – 100 LF @ $1,200/LF

Detailed Cost Worksheet – Lake Palestine Alternative

	d.	Highway and roadway crossings	$ 11,600
		Highway - 1 crossings @ $1,600 Ea. Roadway - 8 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 5,200
		Minor crossings - 2 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 110,400
		84" steel pipe casing – 240 LF @ $460/LF	
3.	Land for right-of-way - 62 acres @ $2,850/acre		$ 176,700
4.	Construction Cost (Items 1 – 3)		$26,965,400
5.	Engineering and Contingencies (25% of Line 4)		$ 6,741,350
6.	Total Construction Cost (Line 4 + Line 5)		$33,706,750
7.	Operation and Maintenance		
	a.	Labor and Materials (.5% of Line 6)	$ 168,540

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1 – 3
Demand Center Lake Eastex
Water Source Lake Palestine
Page 5 of 5

Project Summary Cost Sheet

Project Feature	Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I. Intake Structure and Pump Station	$ 2,608,100	$ 162,589	$ 2,000,620	$2,163,209
II. Pipeline Lake Palestine to Lake Eastex Site	$33,706,750	$2,101,279	$168,540	$2,269,819
III. Total	$36,314,850	$2,263,868	$ 2,169,160	$4,433,028

Appendix G

LAKE PALESTINE REDUCED AMOUNT

ESTIMATE OF COST

This estimate of cost is for pumping 21,000 acre-feet of water annually from Lake Palestine Reservoir to the proposed Eastex Reservoir site near New Summerfield, Texas.

21,000 acre-feet = 18.75 million gallons per day (MGD) = 13,000 gallons per minute (GPM)

Palestine Reservoir	Lake Eastex Reservoir New Summerfield

21,000 acre-feet

18.75 MGD (13,000 GPM)

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex .
Water Source Lake Palestine .

I. Intake Structure and Pump Station

A. Excavation

8,000 CY @ $8.11/CY — $ 64,880

B. Concrete

350 CY @ $400/CY — $ 140,000

C. Pumps — $ 578,000

Total design head 459 ft. (199 psi)

Pump and motor 2 – 13,000 GPM @ $289,000

D. Valves — $ 90,000

E. Pipework — $ 30,500

F. Electrical Controls — $ 75,000

G. Pump Building

600 Sq. Ft. @ $40/Sq. Ft. — $ 24,000

H. Sluice Gates 2 Ea. @ $10,250 — $ 20,500

I. Standby Power (Diesel Generator) — $ 32,500

J. Dewatering — $ 115,000

K. Miscellaneous (Handrails, ladders, plumbing, etc.) — $ 45,000

L. Construction Cost (Items A-K) — $1,215,380

M. Engineering and Contingencies (25% of Line L) — $ 303,850

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1

Demand Center Lake Eastex

Water Source Lake Palestine

N.	Total Construction Cost (Line L + Line M)	$1,519,230
O.	Operation and Maintenance	
	1. Labor and Materials (0.5% of Line O)	$ 7,600
	2. Annual Power Cost	$ 494,750

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex
Water Source Lake Palestine

II. Pipeline

A. Pipeline Design Information

1. From Lake Palestine to Lake Eastex near New Summerfield
2. Pipeline Capacity: 18.75 MGD (13,000 GPM)
3. Length: 89,000
4. Diameter: 36 inch
5. Type of pipe: Concrete pressure pipe (200 psi)
6. Intake Pump Station Head:

a. Static
High point elevation - 695 msl
Intake water elevation - 345 msl
Static head - 350 feet
b. Friction head loss in pipe - 109 feet
c. Total pump head - 459 feet (199 psi)

B. Pipeline Construction Cost Data

1. Transmission Pipe $11,659,000

a. Concrete pressure pipe

89,000 L.F. 36" Pipe @ $131/LF

2. Special Items

a. Clearing and grubbing $ 107,500

25 acres @ $4,300/acre

b. Bored highway crossings $ 66,000

54" steel pipe casing – 120 LF @ $550/LF

c. Bored Railroad Crossings $ 61,000

54" steel pipe casing – 100 LF @ $610/LF

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1
Demand Center Lake Eastex .
Water Source Lake Palestine .

	d.	Highway and roadway crossings	$ 11,600
		Highway - 1 crossings @ $1,600 Ea. Roadway - 8 crossings @ $1,250 Ea.	
	e.	Stream crossings	$ 5,200
		Minor crossings - 2 @ $2,600 Ea.	
	f.	Pipeline crossings	$ 57,600
		54" steel pipe casing – 240 LF @ $240/LF	
3.	Land for right-of-way - 62 acres @ $2,850/acre		$ 176,700
4.	Construction Cost (Items 1 – 3)		$12,144,600
5.	Engineering and Contingencies (25% of Line 4)		$3,036,150
6.	Total Construction Cost (Line 4 + Line 5)		$15,180,750
7.	Operation and Maintenance		
	a.	Labor and Materials (.5% of Line 6)	$ 76,000

Detailed Cost Worksheet – Lake Palestine Alternative

Reach 1 – 3
Demand Center Lake Eastex
Water Source Lake Palestine
Page 5 of 5

Project Summary Cost Sheet

Project Feature	Construction and O&M Cost	Amortized Construction Cost	Annual O&M Cost	System Annual Cost
I. Intake Structure and Pump Station	$ 1,519,230	$ 94,709	$502,350	$ 597,059
II. Pipeline Lake Palestine to Lake Eastex Site	$15,180,750	$ 946,368	$ 76,000	$1,022,368
III. Total	$16,699,980	$1,041,077	$578,350	$1,619,427

Appendix H

ENGINEERING COST ESTIMATING METHODOLOGY

ENGINEERING COST ESTIMATING METHODOLOGY

These estimates are based on cost data furnished by material and equipment suppliers, published cost data, and construction experience. Concrete pressure pipe is used throughout. Friction head loss was developed using the parameters set out in the American Waterworks Association's *Manual of Water Supply Practices, Concrete Pressure Pipe, Second Edition* and *Cameron Hydraulic Data*. Both of these publications are widely used in the design of water systems. Static head loss is based on profiles taken from *USGS Quadrangle Maps, 7.5 Minute Series.* To achieve pipe economy, 150 psi pipe is used where practical, and 200 psi pipe is used where head loss exceeds 150 psi. Booster pump stations are placed at locations along the pipelines to keep system pressure within these constraints. Total head loss used to size pipelines and pumps is the sum of static head and friction head. Estimated annual maintenance and operating costs and power costs are included in the detailed estimates.

Highway, street, railroad, pipeline, and stream crossing locations were obtained from the quadrangle maps. Generally, the routes of the pipelines follow area highways, but in some reaches they parallel railroads, electric transmission lines, and pipelines or run across country. Most of area highways have broad rights-of-way, and the four-lane highways have wide grass medians. Where space permits, the pipelines are placed on highway rights-of-way, because very little clearing will be required, which will result in less interference with traffic. This results in purchasing less right-of-way and lower gradients where pipelines cross over hills. Steel casings are bored beneath all railroad crossings and major highway crossings. These casings are a minimum of six inches larger than the outside diameter of the pipeline. Water lines crossing beneath pipelines also are in steel pipe casings, but are open cut. Secondary highways, streets, county roads and private roads are open cut. The unit costs for these facilities include replacing the pavement surfaces in-kind.

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