US Army Corps of Engineers ®
Tulsa District

INVESTIGATION OF EXISTING AND POTENTIAL SOURCES OF WATER SUPPLY AND COST OF RED RIVER WATER

WICHITA RIVER BASIN REEVALUATION
RED RIVER CHLORIDE CONTROL PROJECT
2001 UPDATE

Volume I
Main Report

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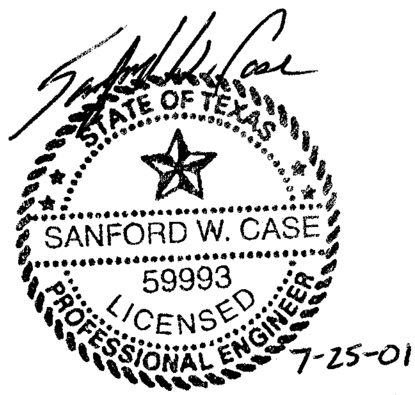
RED RIVER CHLORIDE CONTROL PROJECT

FOR THE

U.S. ARMY CORPS OF ENGINEERS, TULSA DISTRICT



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Background

Approximately 3,300 tons of chlorides (Cl) are introduced into the Red River and its tributaries daily from natural sources. The large chloride concentration along with high sulfates (SO_4) and total dissolved solid (TDS) make the water unsuitable for most municipal, industrial, and agricultural uses.

Studies began in 1957 to identify these natural sources and possible methods to reduce the chloride pollution. Ten major sources were identified in the initial studies. By 1966, chloride control plans were developed for the three identified sources in the Wichita River Basin and five of the six sources in the Upper Red River Basin. In 1976, detailed studies were completed and a formal chloride control plan was recommended in *Design Memorandum No. 25*[1]. The recommended plan involved the collection and disposal of brine prior to its reaching the Red River. Low flow dams were proposed to collect the brine. The collected brine would then be pumped to brine lakes for evaporation.

In 1980, the Corps of Engineers Tulsa District prepared a supplement to *Design Memorandum No. 25*. The purpose of the study was to further quantify benefits of the proposed project. Based on the supplemental data, construction was funded and completed for Area VIII of the project. Since the completion of this area, budgetary cutbacks and continuing questions as to the need and necessity have followed the project. At the same time, significant changes were occurring within the river basin. Tremendous population growth along with increasing water demands has occurred especially within the Dallas/Fort Worth metropolitan area. Usage of untreated Red River water has also increased in the basin.

In 1991, the Assistant Secretary of the Army (ASA) (Civil Works) requested a current economic analysis be performed to accurately reflect the current conditions within the basin and evaluate various combinations of the remaining portions. The *Limited Reevaluation Report*[2] (LRR) evaluated six possible plans for completion of the project. The LRR updated cost and damages data from the 1980 study using the same methodology. The LRR recommended the project be completed as originally proposed.

In the following years, environmental opposition to the project increased and political support for the project decreased. Strong opposition from the State of Oklahoma made construction of the proposed Area VI, XIV, and XIII facilities unlikely. Updates were again needed for both the Environmental Impact Study and economic benefits for the changed project. The *Supplemental Assessment Report*

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[1] Department of the Army, Tulsa District Corps of Engineers, *"Arkansas-Red River Basin Chloride Control, Red River Basin, Design Memorandum No. 25*", July 1976.
[2] Department of the Army, Tulsa District Corps of Engineers, "*Limited Reevaluation Report*", June 1993.

(SAR)[3] was prepared by the Tulsa District to explore the feasibility of desalination, mixing/blending, and partnership options. One recommendation of the SAR was to complete the Wichita River Basin portion of the project. A follow-up economic study[4] was also prepared by the Tulsa District to determine if there was a reasonable chance of economic justification for the Wichita River Basin portion of the project.

Based on the economic report, a formal reevaluation of the Wichita River Basin was requested by the ASA (Civil Works). The reevaluation study is to include development of the cost of using Red and Wichita River (and/or affected tributaries) water. The cost categories to be considered include:

(a) Treatment of Red/Wichita River water to acceptable water quality standards as a source of water supply.

(b) Damages to municipal and industrial users of the Red River and Wichita River.

(c) Costs of blending Red River water with existing sources of water supply for municipal and industrial use.

Costs developed in this study are to be incorporated into the economic re-evaluation of salinity control measures in the Wichita River Basin. The purpose of economic evaluation of the Wichita River portion of the Red River Chloride Control Project (RRCCP) is to measure the improvement of water quality by comparing the "without project" condition to the "with project" condition. Modifications to the Wichita River Basin features of the authorized RRCCP may then be made to meet or exceed acceptable water quality standards and to maximize National Economic Development (NED) benefits. The area of primary focus for this study is the Wichita Falls, Dallas/Fort Worth, and Sherman/Denison areas of Texas and the Shreveport/Bossier City area of Louisiana.

[3] Department of the Army, Tulsa District Corps of Engineers, *"Red River Chloride Control Project, Supplemental Assessment Report"*, February 1997.
[4] Department of the Army, Tulsa District Corps of Engineers, *"Red River Chloride Control Project, Evaluation of Wichita River Basin Completion"*, October 1987.

Review of Past Assumptions

Past economic updates of the RRCCP have used Engineering News Record (ENR) construction index values and Bureau of Reclamation index values to update the anticipated alternate source costs, transportation costs, and determine the associated damages from using Red River water. A major task of this study is to re-examine the past methodology and the major assumptions used in previous studies for their applicability to current conditions.

Since the 1950's, most major municipalities in the study area have been aggressively pursuing new and/or alternate sources of water. Many communities are no longer satisfied with poor quality, high mineral content drinking water. Environmental legislation has also required utilities to test and treat their water for numerous pollutants.

Treated Water Quality

One assumption of past studies has been to evaluate treatment of Red River water to the EPA drinking water standard limits of 500 mg/l of TDS, 250 mg/l of Cl, and 250 mg/l of SO_4. Many of the smaller communities (<50,000 population) in the Red River basin do not currently meet this limit. All groundwater within the Red River basin exceeds these limits. The State of Texas has established it's own water quality limits of 1,000 mg/l of TDS, 300 mg/l of Cl, and 300 mg/l of SO_4. Most communities in the study area do meet the State of Texas limits with their current supplies, however; many of these same communities are the ones also looking to improve their treated water quality. As such, the EPA limits remain a better indication of the acceptable and desired water quality.

Alternate Source Thresholds

Another assumption of past studies has been to evaluate Red River water against assumed threshold levels for all alternate sources available to a demand center. A review of the water quality data indicates these thresholds may have been too high for several reaches. We have averaged the TDS levels for existing sources and researched the anticipated water quality for proposed reservoirs to develop new alternate source threshold values. These thresholds are shown in Table 1. The net result is some benefits may have been understated in past studies. The adjusted Alternate Source Threshold(s) will more accurately capture benefits in the Dallas/Fort Worth and Wichita Falls areas.

Table 1 Water Quality Thresholds for Alternate Water Supply Sources		
Reach	**Old Assumed TDS Threshold mg/l**	**New Assumed TDS Threshold mg/l**
1	200	200
2-4	100	100
4T-A	200	200
5	500	500
5T-A1	400	200
5T-A2	200	200
5T-A3	200	200
6, 7	500	500
8	500	315
9-15	500	500

See Figure 1 for the general location of the Study Area, Reach Boundaries, and significant reservoirs.

<u>Wastewater Reuse</u>

Initial studies envisioned wastewater reuse as a way to supplement future water supplies. In the 30+ years of this project, only a few reuse projects have been developed. The majority of these utilize wastewater plant effluent for irrigation and/or to maintain aesthetic lake levels at golf courses. No reuse projects exist which use the water to supplement drinking water supplies. Public sentiment is still against direct reuse and may continue to be this way for many years to come. One pilot project is underway by the Tarrant Regional Water District (TRWD, formerly know as the Tarrant County Water Control and Improvement District No. 1). The TRWD discharges its treated wastewater to the Trinity River in the DFW area. The TRWD is then withdrawing water from the Trinity River near Richland Chambers Reservoir, approximately 90 miles downstream. The river water is pumped to a wetlands system, which it flows through before entering the reservoir. The attempt to permit this withdrawal is facing opposition due to the possible over-allocation of river flows within the Trinity River basin. Furthermore, Texas Senate Bill 1 requires any request for a “bed and banks” conveyance permit for the indirect reuse of wastewater must consider downstream water rights and environmental resources. Senate Bill 1 also allows the TNRCC to amend water rights permits’ to require a minimum return flow

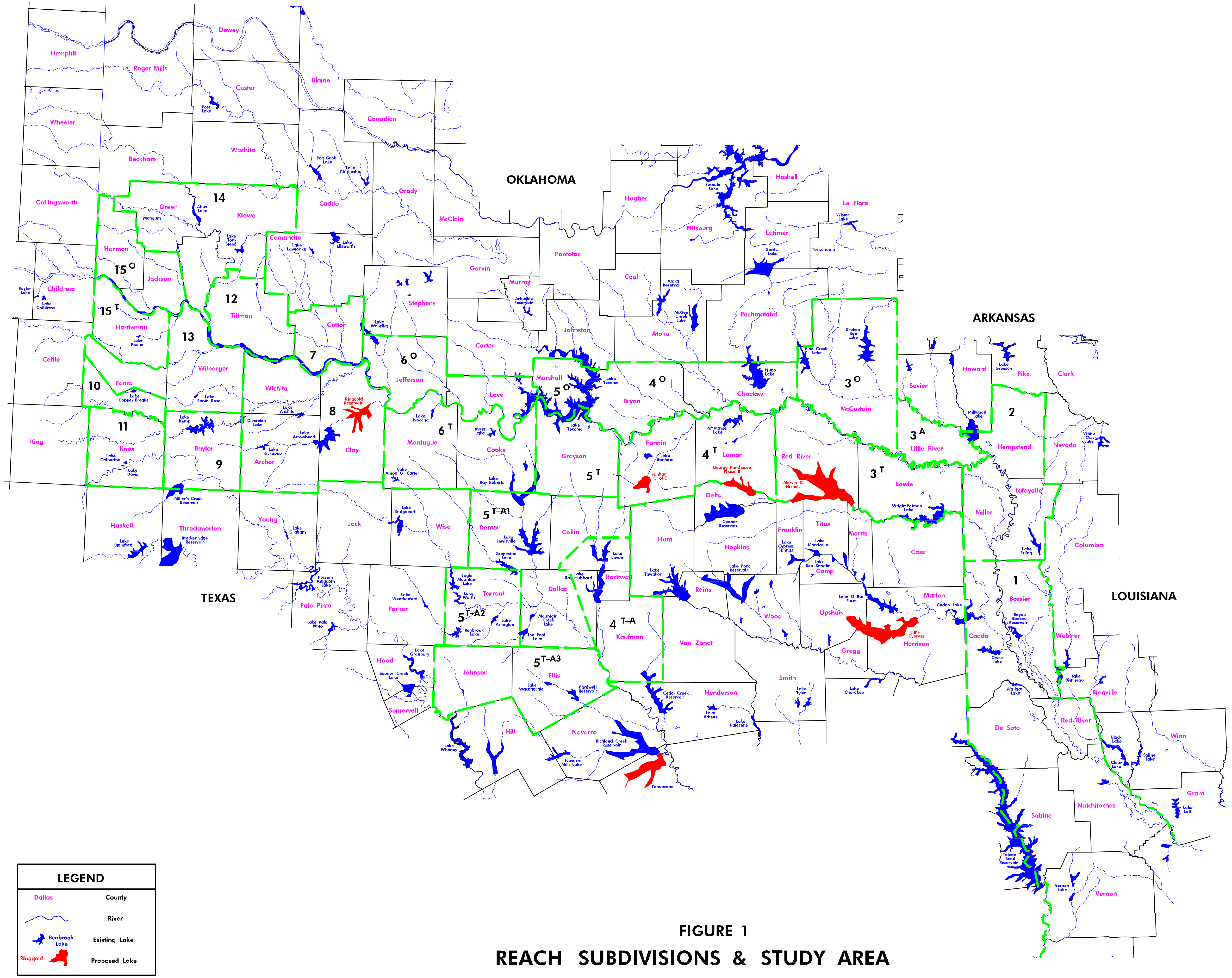

FIGURE 1

REACH SUBDIVISIONS & STUDY AREA

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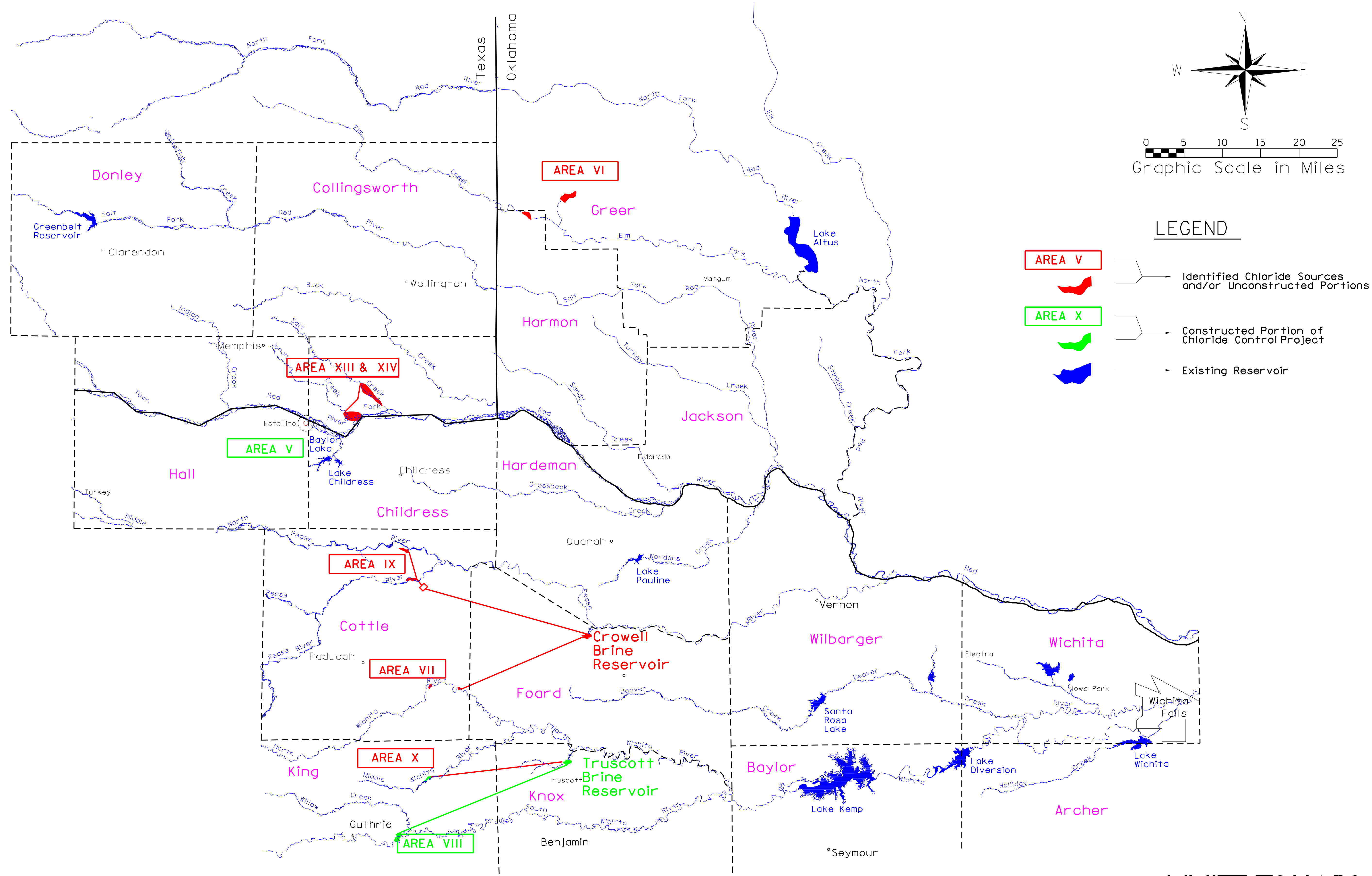

FIGURE 2

RED RIVER CHLORIDE CONTROL PROJECT FEATURES

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Huitt-Zollars, Inc./Engineering/Architecture which possibly may limit the ability to directly reuse wastewater[5]. Based on the current legislation and the downstream water users, the TRWD would most likely need to pipe its treated wastewater directly to the wetlands. This would effectively make the project cost prohibitive and unfeasible. Overall, the concept of any significant wastewater reuse is unlikely during the planning period of this study.

The Least Costly Source Will Be Added First

The basis of benefit allocation in past studies has been predicated on the premise that the least costly source will be used first. This is not necessarily the case. Three separate situations fall into this category.

?? Artificially Low Alternate Source Costs.
Many of the alternative sources identified have lower unit costs than the same quantity of Red River water. This is due to the alternate sources having very large yields. These alternate sources also have costs have capital commitments exceeding $100 million. Few cities in the study area (with the possible exception of Dallas and Fort Worth) can service the debt on this magnitude of investment making these alternate sources impractical.

?? Any Community Can Build An RO/EDR Plant:
A small 1 MGD RO or EDR plant, complete with all site peripherals and brine disposal facilities, will cost between $3 and $5 million to construct. Even for many of the smaller communities, $3 million of debt service would be difficult to support without State or Federal assistance.

?? Prior Use of Red River Water:
Past use of Red River water also effects the concept of using the least costly source. The City of Dallas used Red River water during the drought of the late 1950's. Millions of dollars of damage to water pipes, water heaters, and household fixtures was blamed on the poor quality water. Even though it has been over forty years since this occurred, the City of Dallas remains opposed to even considering Lake Texoma (Red River) as a possible future water supply source, even though it appears to be more economical than other alternative sources.

In summary, many alternatives with higher unit costs may be selected due to their reduced capital commitments or perceived impact.

[5] Texas Water Development Board, *Water For Texas*, August 1997, p.2-33.

New Reservoirs Can Be Built to Meet Demand

In the early stages of the RRCCP, new reservoirs were a viable alternative for cities to increase their water supply. Federal and State funds assisted with the building of many reservoirs in Texas in the 1960's and 70's. Since that time, stronger environmental regulations, the increased use of litigation, and stronger competition for the available funds have virtually stopped reservoir construction. The current process takes on average over thirty years to complete with relatively small reservoirs costing over $100 million dollars to build. The process includes numerous planning studies, environmental impact studies, mitigation plans, public hearings, acquisition and/or condemnation of the land, contracts for water purchases, water rights permitting, operational agreements, financing agreements, design of the reservoir, and relocation of effected structures (roads, utilities, etc.) all before construction can begin. The last reservoirs to be built in the State of Texas (Richland Chambers Reservoir, Joe Pool Lake, Cooper Reservoir) all began this process back in the late 1960's. Planning studies have been done for several potential reservoirs in the study area, however; only Ringgold Reservoir has even begun informal land acquisition. Given today's environmental constraints, construction of new reservoirs is uncertain at best.

Another drawback to new reservoirs is the high unit costs during the initial years of use. The calculated costs for reservoirs deal with utilization of the entire yield. Partial use of the yield can raise the unit costs by several orders of magnitude.

Damages

The concept of "damages" related to the use of water with high TDS, Cl, and/or SO_4 has been the subject of considerable debate throughout the life of the RRCCP. Much of the criticism of past studies has centered on the debate of the relative magnitude of the damages and thresholds below which no damages would occur. Several users of Red River water including the NTMWD have taken the position that minimal or no adverse effects[6] will occur at blended threshold levels of 200 mg/l TDS and below. Our investigation has not discovered any research to support this position. In fact, published papers[7] tend to indicate the relationship of TDS to damages is fairly linear over the TDS entire range of 0-3000 mg/l. Furthermore, the high TDS values have been shown to decrease the life expectancy of household items thus reinforcing the concept of real damages.

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[6] James M. Montgomery, Consulting Engineers, "*A Study of Water Quality Blending Lake Lavon and Red River*", December 1980, Page 5-30.

[7] Tihansky, Dennis, Damage Assessment of Household Water Quality, Journal of the Environmental Engineering Division of the American Society of Civil Engineers, Vol. 100, No. EE4, August 1974, pp 905-918

Municipal Damage Coefficient

There is a significant amount of published research related to water quality and plumbing fixtures, however, very little of the research has specifically addressed decreased life expectancy of the plumbing devices as a function of Total Dissolved Solids (TDS) or Chlorides (Cl) in the water. While some recent research has been conducted on the effects of TDS on water heaters, very little recent research has been done on other household items. Initial research into the effects of high TDS water on household components was published in a 1968 article[8]. This data served as the basis for the development of the municipal damage coefficient in a 1975 study[9] for the Corps of Engineers. The major household items factored into the coefficient were:

Water Pipes	Wastewater Pipes	Water Heaters
Faucets	Toilet Mechanisms	Garbage Grinders
Washing Equipment	Washable Fabrics	Detergent Use

Additional municipal factors related to the utility's facilities were also included in the domestic damage coefficient. They were:

Water Supply and Production Facilities
Distribution System Piping and Valves
Distribution System Storage
Utility Service Lines
Water Meters
Sewage Facilities

The initial study calculated the annual capital cost differential between the listed items at 250 mg/l and 1750 mg/l of TDS. The annual cost differential was distributed over the annual residential usage of 100,000 gallons. This value was further distributed over the difference in TDS to develop a "damage coefficient" in terms of dollars per 1,000 gallons per 100 mg/l of TDS. This methodology remains a logical approach for the calculation of the municipal damage coefficient. As such, we have revised the costs for the listed items based on 1999 costs and indexed these costs to January 2001 using the appropriate consumer price indexes. Appendix A summarizes the calculation of the household and municipal components. Table 2 combines these factors to develop a "new municipal damage coefficient" of $0.1636 per 1000 gallons per 100 mg/l of TDS. It should be noted that this new coefficient is ±64.7% of the expected value of $0.2527 based on straight indexing using the Engineering News Record (ENR) Building Cost Index (BCI) from 1967 to January 2001.

[8] Patterson, W.L., and Banker, R.F., "Effects of Highly Mineralized Water on Household Plumbing and Appliances", *Journal of the American Water Works Association*, Vol. 60, No. 9, Sept. 1968, pp 1060-1069.
[9] Black and Veatch, "*Report on Determination of Economic Values for Improved Water Quality in the Red River Basin*", prepared for the US Army Corps of Engineers, Tulsa District, 1975.

Table 2 Combined Municipal Damage Coefficient (January 2001 Basis)	
Component:	Avg. Annual Cost
Residential:	
Water Piping	$22.55
Wastewater Piping	$12.54
Water Heaters	$39.86
Faucets	$48.35
Toilet Flushing Mechanisms	$11.64
Garbage Disposals	$10.96
Washing Equipment (Dishes & Clothes)	$36.05
Cooking Utensils	$6.10
Washable Fabrics (4 people @ $800/ea.)	$27.64
Soap and Detergent Use	$18.55
Subtotal Residential Damages	$234.25
Public:	
Supply & Production Equipment	$3.49
Distribution Piping	$0.45
Storage Facilities	$0.38
Utility Service Lines	$0.28
Water Meters	$0.25
Sewage Facilities	$6.32
Subtotal Public Damages	$11.17
Total Annual Damage Cost Differential	$245.42
Damage Cost per 1,000 Gallons (With Assumed 100,000 Gallon Annual Usage)	$2.454
Damages per 1,000 Gal per 100 mg/l TDS	$0.1636

While some construction methods and materials have changed since the late 1960's, many residential construction items remain the same. The use of plastic pipe and materials is now quite common. Virtually all wastewater piping used in residential construction is now PVC thus lowering the negative effect of water quality on the wastewater piping. However, most under slab water piping remains copper and is still affected by the water quality. Decorative faucets and plumbing fixtures have also become a more significant expense in residential construction, both of which are effected by poor water quality. The damage coefficient is assumed to be a linear value across the range. While this may not be the case at very low (below 100 mg/l) and at very high (above 5,000 mg/l) values, it does adequately depict the relationship within the anticipated TDS range examined in this report.

One relevant study did evaluate the effects of water quality on water heaters. The Gas Research Institute (GRI) conducted a four-year study on the "Effect of Water Quality on Residential Water Heater Life-Cycle Efficiency"[10]. This study evaluated identical water heaters on identical plumbing systems at four geographic locations (Columbus, OH; Lisle, IL; Roswell, NM; Marshall, MN). Each test site evaluated six gas and six electric water heaters using "hard water", "softened water", and "softened water with phosphate". The water heaters were operated under similar water draw cycles at all sites. As expected, the "hard water" units developed tremendous amounts of scale which led to decreased efficiency and failure of the heating elements in the electric units and overheating (burn-through) of the metal tanks on the gas units. The "softened water" units developed less scale, but the increased Cl from softening led to increased anode consumption and quicker failure of the tanks due to corrosion. The study also documented increased steel and galvanized steel corrosion at the sites with higher chloride levels. The sites with higher sulfates produced more copper and brass corrosion.

While the GRI study did not address the specific variables of concern for the Wichita River Basin Re-Evaluation, some conclusions can be drawn. The natural conditions of the Red River water represent the "worst case" conditions from the GRI study. The water is hard (high TDS) and has the high chlorides of softened water. The expected result would be significant scaling and rapid anode consumption in the water heater at the same time. With the average life expectancy of a hot water heater at 10-15 years, increased TDS and/or Cl can shorten the water heater life expectancy to 7-10 years.

[10] S. G. Talbert, D. C. Newman, G. H. Stickford, Jr., W. N. Stiegelmeyer, and D. W. Locklin, *The Effect of Water Quality on Residential Water Heater Life-Cycle Efficiency*, (Columbus, OH: Battelle Columbus Laboratories for the Gas Research Institute, June 1983, October 1984, December 1985, May 1987).

Industrial Damage Coefficient

The industrial damage coefficient is somewhat more difficult to quantify. Poor quality water affects process water, boiler feed and cooling water operations among others. These processes typically require the addition of chemicals to control scaling, fouling, and corrosion. Industrial users must increase the quantity of chemicals needed for water pre-treatment when the raw water used is high in TDS, Cl, and/or SO_4. High-pressure boilers require a very pure water supply. Demineralization and chemical treatment are typically required. The treatment costs for demineralization of the boiler feed water also increase. One study[11] prepared for the NTMWD estimated the chemical usage for industrial users to increase by 50 to 55 percent for an increase in TDS from 110 mg/l to 255 mg/l. The increase in TDS was due to the anticipated blending of Red River water into Lake Lavon. Another indirect cost to the industrial customer is the additional water used. The additional water use is necessitated by more frequent blow-down's of cooling water systems to offset the concentrating effects of evaporation and scale formation.

A 1975 report[12] developed the original Industrial Damage Coefficient. The coefficient was a composite value of $0.014 per 1000 gallons per 100 mg/l of TDS (in 1967 dollars). The value was compiled from an average of four previous studies prepared between 1959 and 1972. These reports were summarized in a 1974 report[13] that attempted to quantify the benefits derived from reductions in TDS.

The complexity of the variables in the industrial damage coefficient makes the development of a new coefficient a difficult process. An extensive survey of industrial water users in each SIC code over a 3-5 year period would be required along with water quality monitoring. A simplified approach is to factor the original Industrial Damage Coefficient by the corresponding increase in the BCI and then reduce down by a proportion similar to the reduction calculated in the new Municipal Damage Coefficient. Therefore, the original industrial damage coefficient will be indexed and adjusted (as described below) using the ENR BCI.

As previously stated, if the municipal damage coefficient had been indexed from 1967, its value would have been $0.2527/1000 gal/100 mg/l TDS instead of the $0.1636/1000 gal/100 mg/l TDS that was calculated. The recalculated value is only ±64.7% of the indexed value. For consistency, we will use 64.7% of the indexed value for the industrial damage coefficient or $0.0489/1000 gal/100 mg/l TDS (see Table 3).

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[11] James M. Montgomery, Consulting Engineers, p. 5-32.
[12] Black & Veatch, 1975, p. D-24.
[13] Daniel, Mann, Johnson & Mendenhall/Koebig & Koebig, Inc., *"Comprehensive Water Quality Control Plan – Los Angeles River Basin"*, 1974.

Table 3 Industrial Damage Coefficient ($/1000 Gal/100 mg/l of TDS)			
Year	ENR BCI	Indexed Coefficient	Adjusted Coefficient
1967 (Avg.)	676	$0.0144	-
1980 (Jan.)	1895	$0.0404	-
1999 (Jan.)	3425	$0.0730	$0.0445
2000 (Jan.)	3503	$0.0746	$0.0448
2001 (Jan.)	3545	$0.0755	$0.0489

Past studies have calculated the estimated treatment costs for industrial users of Red River water based on a calculated average daily water use for each SIC code. The water usage data was obtained from a Department of Commerce report, *Census of Manufactures - Water Use in Manufacturing.* This report was discontinued after 1982. No similar information could be located to provide revised average industrial water use. As such, the consensus average daily water use per establishment values from the 1980 study were maintained for continuity. These are summarized in Table 4.

Table 4 Average Daily Water Use Per Industry			
SIC	**Description**	**MGD**	**TDS Threshold (mg/l)**
20	Food and Kindred Products	0.70	500
22	Textile Mill Products	1.00	200
24	Lumber and Wood Products	2.00	500
26	Paper and Allied Products	12.00	500
28	Chemicals and Allied Products	2.00	800
291	Petroleum and Coal Products	3.00	800
33	Primary Metal Industries	29.00	900
35	Machinery, except Electrical	0.50	750
371	Motor Vehicles and Equipment	1.00	750
39	Miscellaneous Manufacturing Industries	0.50	750

Anticipated Water Quality

A primary goal of this study is to evaluate the cost of alternative water supplies and the associated costs of Red River water for five possible water quality scenarios. The scenarios represent different combinations of projects in the original Red River Chloride Control Project. Figure 2 shows the significant features of the originally proposed project. The possible water quality plans evaluated are:

Natural: No portion of the RRCCP constructed (Pre-Project).
Plan "8": Only Area 8 constructed and operational (Existing Condition).
Plan "8 & 10": Area(s) 8 and 10 constructed and operational.
Plan "7 & 8": Area(s) 7 and 8 constructed and operational.
Plan "7, 8, & 10": Area(s) 7, 8, and 10 constructed and operational.

The plans to be evaluated represent different possible water quality scenarios for various configurations and alternatives for the Wichita River Basin portion of the RRCCP. The twelve alternatives being evaluated by the District's economic analysis correspond to the Water Quality plans as follows:

Plan	Plan 8	Plan 8 & 10	Plan 7 & 8	Plan 7, 8, 10
Alternative	None	12	4, 6, 8, 9, 10, 11	1, 2, 3, 5, 7

For the 2000 Update, the Tulsa District Corps of Engineers has developed new concentration/duration curves for each of these plans. This data is tabulated in Appendix B. The weighted averages of the TDS loads are summarized in Table 5. The weighted averages of the Cl loads are summarized in Table 6. The weighted averages of the SO_4 loads are summarized in Table 7. Shaded areas in the tables represent values that exceed the allowable EPA limit. Curves have also been developed for +10% and –10% loading to further define the ranges of the expected treatment costs.

Several facts are apparent from the revised concentration/duration curve data. There is minimal improvement in water quality in and downstream of Lake Texoma from any of the proposed plans. The most comprehensive plan ("Plan 7, 8, & 10") offers only a 7.7% reduction in the anticipated TDS loads at Lake Texoma. The TDS levels in Lake Texoma will exceed allowable limits 99% of the time, the chloride levels will exceed allowable limits between 50 and 80% of the time, and the sulfate levels will exceed allowable limits between 20% and 50% of the time. Demineralization treatment or significant blending with a better quality source will still be required to utilize water from Lake Texoma.

Farther upstream, the Wichita River at Wichita Falls (Reach 8) will exceed allowable TDS limits between 90 and 99% of the time. Chloride levels will be exceeded between 90 and 99% of the time and sulfate levels will be exceeded between 50 and 95% of the time. This indicates the water in the Wichita River will require demineralization at least 90% of the time under any of the proposed plan to reduce the TDS, chlorides, and sulfates to acceptable limits. The revised curves for Reach 9 (Lake Kemp/Lake Diversion) indicate reduced water quality over those expected in Reach 8. TDS, Chlorides, and Sulfates will require demineralization at least 95% of the time. The project will increase the blendable quantities of water in Lake Kemp/Lake Diversion over the current natural conditions.

Table 5
Weighted Average TDS Concentrations (mg/l)
Expected Loading

Reach	Natural	Area 8	Area 8 & 10	Area 7 & 8	Area 7, 8, & 10
1	446	441	435	424	419
5	973	944	933	909	898
8	3,789	2,829	2,449	1,669	1,288
9	3,279	2,426	2,103	1,420	1,092

EPA limit of 500 mg/l, shaded numbers exceed allowable limit.
Source: Corps of Engineers, Tulsa District

Table 6
Weighted Average Cl Concentrations (mg/l)
Expected Loading

Reach	Natural	Area 8	Area 8 & 10	Area 7 & 8	Area 7, 8, & 10
1	120	116	115	110	109
5	338	323	319	307	303
8	1,603	1,143	1,013	636	506
9	1,349	914	793	440	319

EPA limit of 250 mg/l, shaded numbers exceed allowable limit.
Source: Corps of Engineers, Tulsa District

Table 7
Weighted Average SO_4 Concentrations (mg/l)
Expected Loading

Reach	Natural	Area 8	Area 8 & 10	Area 7 & 8	Area 7, 8, & 10
1	86	85	84	83	82
5	221	218	215	213	209
8	612	512	419	344	249
9	734	640	550	481	391

EPA limit of 250 mg/l, shaded numbers exceed allowable limit.
Source: Corps of Engineers, Tulsa District

Existing & Potential Water Supply Sources

Reach 1: Shreveport/Bossier City Louisiana

Reach 1 includes the Parishes of Avoyelles, Rapides, Natchitoches, Red River, Bossier, Grant, and Caddo in Louisiana. Only the Shreveport/Bossier City (Caddo and Bossier Parishes) areas are included in this Wichita River Basin Reevaluation. These cities utilize a combination of ground and surface water for their water supplies. Figure 3 details the features of this Reach.

Existing Water Supplies:

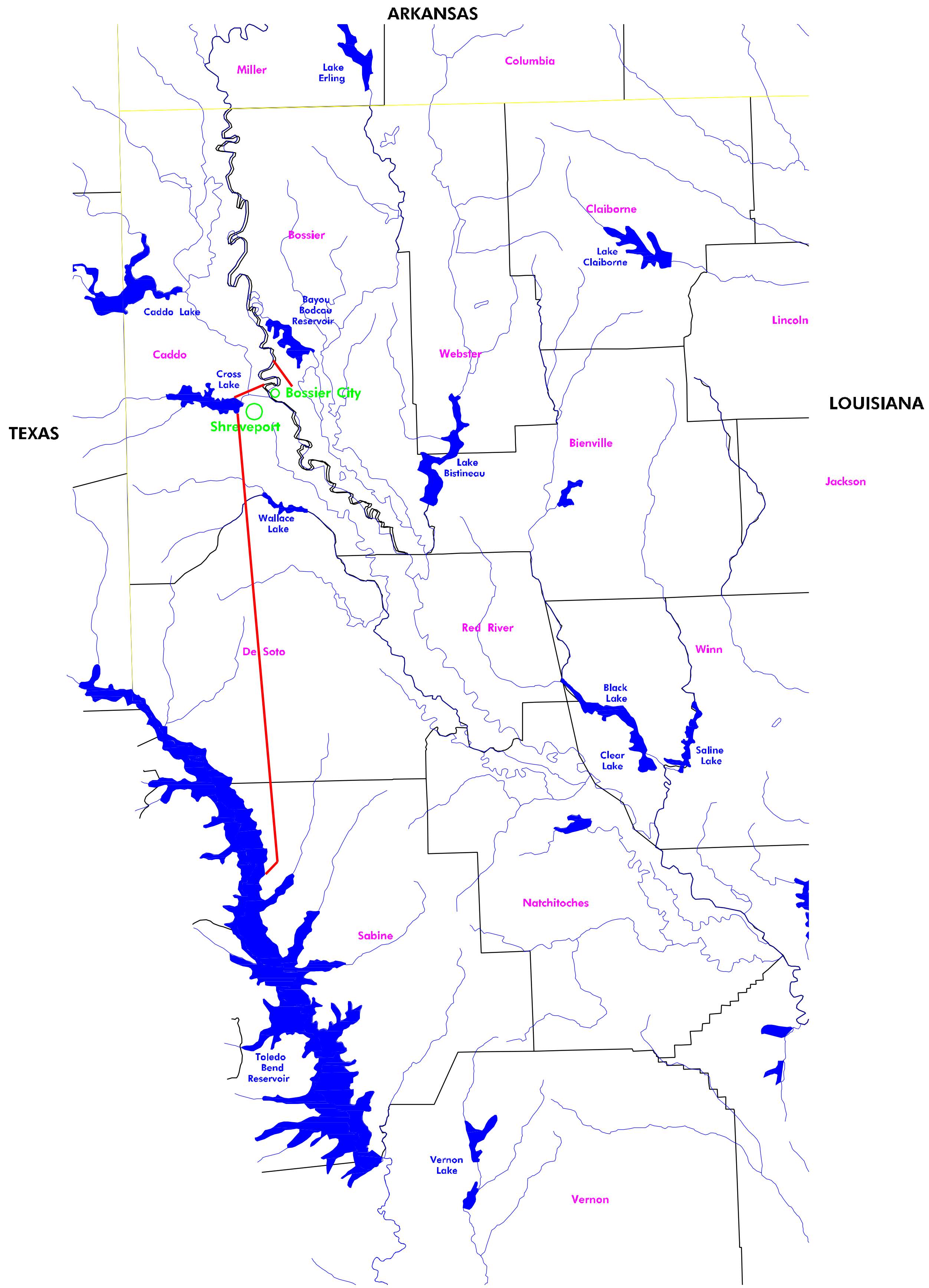
Caddo Lake straddles the State line between Texas and Louisiana in the Cypress River Basin approximately 20 miles northwest of Shreveport, Louisiana. Caddo Lake has excellent quality water with a dependable yield of 99.5 MGD, however; use of the water is regulated under the *Red River Compact*. The City of Shreveport currently uses water from Caddo Lake that overflows into Twelve-Mile Bayou. The City has pumps in place to transfer water from Caddo Lake into Twelve-Mile Bayou during low water periods, however; these pumps have never been used. Caddo Lake is located in an environmentally sensitive natural area that all but precludes it from further development as a significant water supply. Caddo Lake is the only naturally occurring lake in the State of Texas; all other lakes in the State are man-made.

Twelve-Mile Bayou is a low flow stream downstream of Caddo Lake. The reported dependable yield is 5.1 MGD. The City of Shreveport pumps ±10 MGD from the Bayou into Cross Lake. The Bayou receives natural overflow from Caddo Lake during normal periods to supplement its yield. The completion of Lock and Dam No.5 on the Red River in 1996 raised the river pool 5 feet above the low head structure on Twelve-Mile Bayou. This has led to a reported decrease in water quality in Twelve-Mile Bayou.

Cross Lake is the third major supply for the City of Shreveport. The Lake has a dependable yield of 33.0 MGD. The lake is owned by the City of Shreveport, which utilizes the entire available yield. The lake has good quality water.

Ground water sources for the Shreveport/Bossier City area are of poor quality or limited quantity and therefore are not considered adequate potential sources.

Bossier City is currently using the Red River as a water supply source. The city pumps water from the Red River into a city reservoir (approximately 100 acres) and from the reservoir to the head of the treatment works. This has allowed the city to minimize the transfer of water from the river when water quality is poor.



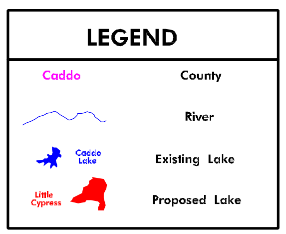


FIGURE 3

REACH 1 – SHREVEPORT /BOSSIER CITY

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Potential Water Supplies:

There are no reservoirs proposed for construction in this portion of the study area. Three existing reservoirs are potential future water supplies for the region. Cypress Black Reservoir No. 1 is an agricultural water storage reservoir operated by the Bossier Recreation and Water Conservation District. The lake has a dependable yield of 13.8 MGD, however; only 2.1 MGD is available for municipal use and 11.7 MGD is allocated to agricultural uses. Reallocation of the agricultural allotment may be possible to meet the anticipated demands of Bossier City.

Cypress Black Reservoir No. 2 is another agricultural water storage reservoir operated by the Bossier Recreation and Water Conservation District. The lake has a limited dependable yield of 4.9 MGD with 3.7 MGD allocated to agriculture and 1.2 MGD available for municipal use. The small overall yield makes this reservoir impractical as a possible water supply source.

Table 8
Existing & Potential Water Supply Sources
Reach 1

Source	User	Total or Potential Yield (MGD)	Acceptable Source Yield (MGD)	Useable Quantity (MGD)	Additional Available to Transport (MGD)
Caddo Lake	Shreveport	99.5	43.5	0.0	(a) 0.0
Cross Lake	Shreveport	33.0	33.0	33.0	0.0
Twelve Mile Bayou	Shreveport	5.1	5.1	10.0	0.0
Red River	Bossier City	860.0	430.0	9.5	0.0
Terrace (GW)	Bossier Parish	155.0	0.9	0.9	0.0
Carrizo Sand (GW)	Caddo Parish	5.1	0.0	0.0	0.0
Cypress-Black Reservoir No.1	Bossier Parish	13.8	13.8 (b)	0.0	13.8
Cypress-Black Reservoir No.2	Bossier Parish	4.9	4.9 (c)	0.0	4.9
Toledo Bend Reservoir	Desoto & Sabine Parish	1,851	1,851	925.5	81.0

(a) Environmental concern will restrict possible use.
(b) Includes agricultural allocation of 11.7 MGD.
(c) Includes agricultural allocation of 3.7 MGD.

Toledo Bend Reservoir, on the Texas/Louisiana border, is the fifth largest body of water in the United States based on surface area. The lake has a dependable yield of 1,851 MGD, which is equally shared by Texas and Louisiana.

Approximately 81 MGD of the Louisiana portion remains unallocated. The lake is owned and operated by the Sabine River Authority (SRA). The water is of fairly good quality. The lake also provides a significant amount of hydroelectric power to the region. Water is available to transport to the Shreveport/Bossier City area.

Reach 4T-A: North Texas Municipal Water District (Collin County, TX)

Reach 4T-A comprises Collin and portions of Kaufman, Rockwall, and Dallas Counties in north central Texas. The general boundary of this Reach is the area served by the North Texas Municipal Water District (NTMWD). The NTMWD provides wholesale water and wastewater service to numerous communities within its boundary. The cities of Plano, Richardson, Garland, Mesquite, and McKinney are a few of the larger municipalities receiving all or part of their service from the NTMWD. The main water treatment plant for NTMWD is located near Lake Lavon. The district receives it surface water supply from three primary sources. Figure 4 details the feature of this Reach.

Existing Water Supplies:

Lake Lavon is located on the East Fork of the Trinity River approximately one-mile northwest of Lavon, Texas. The lake was built by the COE in 1953 for flood control and water supply purposes. It has a dependable yield of 92.0 MGD. The entire yield is allocated and contracted to the NTMWD. The lake also receives up to 24.0 MGD of effluent from the Wilson Creek Wastewater Treatment Plant and is the receiving point for interbasin transfers of water from Lake Texoma and Lake Cooper. Facilities are in place to utilize the entire available yield of Lake Lavon.

Cooper Reservoir (a.k.a. Jim Chapman Lake) is a COE reservoir on the South Sulphur River completed in 1992. The reservoir has a dependable yield of ±107.1 MGD. Three entities share the allocated water rights; NTMWD - 39.5 MGD, the City of Irving - 39.5 MGD, and the Sulphur River Municipal Water District (SRMWD) - 28.1 MGD. Each entity is permitted to divert at a maximum rate of 122% of allocated yield. The SRMWD has contracted a portion of its yield to the Upper Trinity Regional Water District (UTRWD) for use in the Denton County, Texas area. NTMWD has facilities in place to transfer up to 110 MGD of water from Cooper Lake to Lake Lavon.

Lake Texoma on the Red River near Denison, Texas is the third surface water source utilized by the NTMWD. Lake Texoma water is pumped and gravity flowed to Lake Lavon and blended for subsequent use. The NTMWD has contractual rights to divert up to 75.0 MGD of water from Lake Texoma. The blending of this water will be discussed in more detail in a later section.

Ground water sources for the NTMWD area are of poor quality or limited quantity and therefore are not considered adequate potential sources.

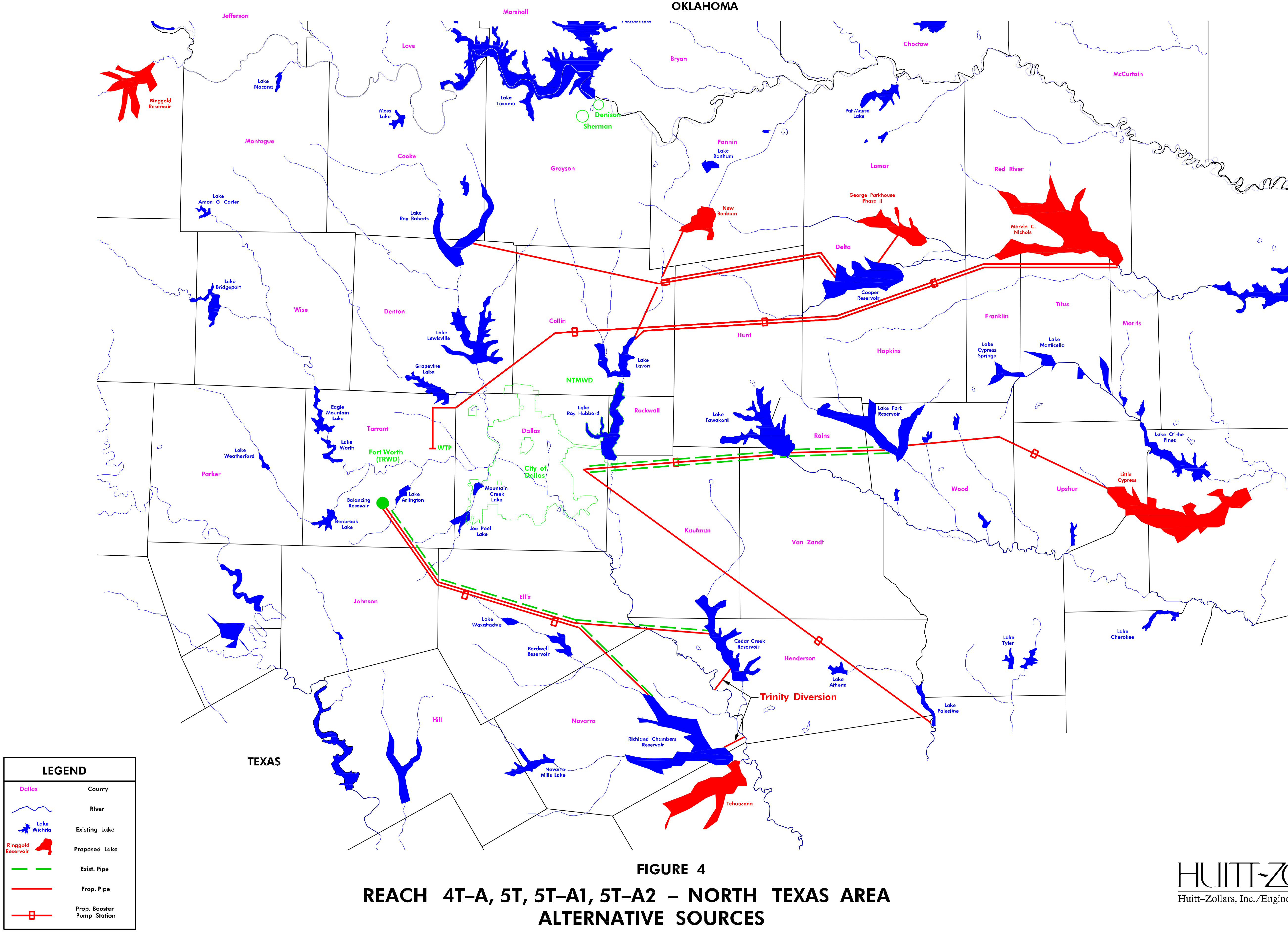

FIGURE 4

REACH 4T–A, 5T, 5T–A1, 5T–A2 – NORTH TEXAS AREA ALTERNATIVE SOURCES

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Potential Water Supplies:

There are no reservoirs proposed for construction in this Reach. New Bonham Reservoir, George Parkhouse, and Marvin C. Nichols Reservoir are under consideration as possible water supply sources outside of the Reach by NTMWD.

George Parkhouse Reservoir is a potential impoundment proposed for development on the Sulphur River, immediately downstream from Cooper Reservoir. The reservoir is suited for a two stage development with an ultimate estimated combined yield of ±227.4 MGD. Stage I would be constructed on the South Sulphur River and have a yield of ±107.4 MGD. Stage II would be constructed on the North Sulphur River and have a yield of ±120.0 MGD. Several entities including the NTMWD have examined the potential development of George Parkhouse I and II as a future source. The George Parkhouse II project was included in the 1997 State Water Plan's list of recommended projects, however; it has been omitted from the current State Water Plan[14].

New Bonham or Bois d'Arc Reservoir is proposed on Bois d'Arc Creek, a tributary of the Red River in Fannin County (Reach 4T). The estimated yield is 83.7 MGD. The reservoir is under consideration by both the NTMWD and the Red River Authority. This project is included in the *Water for Texas* list of recommended projects.

Table 9
Existing & Potential Water Supply Sources
Reach 4T-A

Source	User	Total or Potential Yield (MGD)	Acceptable Source Yield (MGD)	Useable Quantity (MGD)	Additional Available to Transport (MGD)
Lake Lavon	NTMWD	92.0	92.0	92.0	0.0
Lake Texoma (a)	NTMWD	150.0	150.0	75.0	(b) 0.0
Lake Cooper (c)	NTMWD	39.5	39.5	39.5	0.0
George Parkhouse II	Proposed	120.0	120.0	-	120.0
Marvin Nichols I	Proposed	420.0	120.0 (d)	-	120.0 (d)
New Bonham Reservoir	Proposed	89.7	89.7	-	89.7

(a) Available yield of Lake Texoma is 150.0 MGD allocated to each state (TX & OK). NTMWD has contracted for 75.0 MGD.
(b) 75 MGD is the maximum blendable quantity with existing supplies.
(c) Total yield of lake is 107.1 MGD of which 39.5 MGD is allocated to NTMWD.
(d) Proposed available yield split between Reaches.

[14] Texas Water Development Board, *Water For Texas*, Summary of Regional Water Plans, February 1, 2001, p. 8.

Marvin Nichols Reservoir is another potential two-stage impoundment on the Sulphur River and White Oak Creek in southwestern Bowie and Morris Counties. Stage I will have an estimated yield of ±420 MGD (±557 MGD if Parkhouse is not developed) and Stage II will have an estimated yield of 263.2 MGD. NTMWD, TRWD, and DWU are all evaluating the project as a potential future supply. Phase I of this project is included in the *Water for Texas – Summary of Regional Water Plans, February 2001*.

Reach 5-T: Sherman/Denison, Texas Area

Reach 5-T is made up of Grayson County, Texas. This section is bordered on the north by Lake Texoma. The cities of Sherman and Denison jointly make up the demand center for this Reach. Figure 4 also details this portion of the study area.

Existing Water Supplies:

Lake Texoma is a COE lake completed in 1944. It is the largest impoundment within the Red River Basin. The primary purpose of the reservoir is flood control and power generation. The lake currently has 150.0 MGD allocated to each state (Texas and Oklahoma) for water supply purposes. Less than 5 MGD of the available Oklahoma water rights have been allocated. Approximately half of the Texas water rights have been allocated. The water quality within Lake Texoma is high in total dissolved solids (TDS) and chlorides (Cl^-). These levels exceed EPA drinking water limits on public water supplies and thus water from the lake requires desalination treatment or blending prior to conventional water treatment for potable use.

The only reservoir other than Lake Texoma is Lake Randell, northwest of Denison, Texas. The dependable yield is 4.7 MGD. The reservoir is primarily used to regulate the diversions of water from Lake Texoma for treatment and use by the City. Due to the high TDS levels in the water, demineralization treatment is necessary.

Groundwater supplies in this Reach are high in dissolved solids and are generally unsuitable for use. Many smaller communities still must use the groundwater due to the lack of any other suitable supplies.

The City of Sherman obtains approximately 60% of its water from wells. The other 40% is from Lake Texoma and is demineralized by Electrodialysis Reversal (EDR). The City of Denison obtains approximately 0.12 MGD of its 3.5 MGD average demand from wells. Denison also has the capacity to transfer 6.0 MGD from Lake Texoma to Lake Randell.

Potential Water Supplies:

No reservoirs have been proposed, identified or investigated for this Reach.

Table 10
Existing & Potential Water Supply Sources
Reach 5T

Source	User	Total or Potential Yield (MGD)	Acceptable Source Yield (MGD)	Useable Quantity (MGD)	Additional Available to Transport (MGD)
Lake Texoma (a)	Sherman	150.0	75.0	10.0	65.0
Lake Randell	Denison	4.7	4.7	4.7	0.0
Groundwater	Sherman	(b)	0.0	0.0	0.0
Groundwater	Denison	(b)	0.0	0.0	0.0

(a) Available yield of Lake Texoma is 150.0 MGD allocated to each state. NTMWD (Reach 4T-A) has contracted for 75.0 MGD which is blended into Lake Lavon. The City of Sherman has contracted for 10.0 MGD. The Lake Texoma water used by Sherman is treated using demineralization (EDR).
(b) Groundwater yield undetermined.

Reach 5T-A1: Dallas Water Utilities (including Denton County, Texas)

Reach 5T-A1 includes most of Dallas, Denton, and portions of Rockwall and Kaufman Counties. For the purpose of this study, the City of Dallas/Dallas Water Utilities (DWU) is the major demand center and wholesale service supplier to this Reach. In actuality, several other wholesale watersuppliers exist in this Reach including the City of Denton, Upper Trinity Regional Water District (UTRWD), and the Trinity River Authority (TRA). This Reach comprises the majority of the demands found within the entire study area. The City of Dallas, Irving, Grand Prairie, Carrollton, and many others receive all or part of their water service from DWU. This Reach is supplied from six major existing reservoirs with three other existing reservoirs awaiting connection and/or completion of their transportation systems. Figure 4 details this portion of the study area.

Existing Water Supplies:

Lake Lewisville is a COE reservoir constructed in 1955 for flood control, water supply, and recreation. It is located on the Elm Fork of the Trinity River approximately six miles east of Lewisville, Texas. The total dependable yield of the reservoir is approximately 168.9 MGD (including Ray Roberts) of which 144.8 MGD is allocated to DWU and 24.1 MGD to the City of Denton. Water from Lake Lewisville and Ray Roberts is released into the Elm Fork of the Trinity River and withdrawn downstream by DWU at both the Carrollton Dam and Frasier Dam for diversion to the Elm Fork (300 MGD Capacity) and Bachman Lake (115 MGD) Water Treatment Plants (WTP).

Lake Ray Roberts is another impoundment on the Elm Fork of the Trinity River above Lake Lewisville. This COE reservoir was completed in 1987 for flood control, water supply, water quality, recreation, and fish and wildlife conservation. The yield of Ray Roberts is combined with that of Lake Lewisville for reporting purposes. As a part of the construction of Ray Roberts, the level in Lewisville was raised by seven feet and some flood control storage reallocated to Ray Roberts. Water in Ray Roberts flows by gravity to Lake Lewisville and continues on by gravity to the treatment plants. Existing facilities are in place to utilize the entire available yield from both reservoirs.

Lake Grapevine is a COE reservoir completed in 1952 for flood control, water supply, and recreation. The dam is located on Denton Creek, a tributary of the Elm Fork of the Trinity River approximately 2 miles northeast of Grapevine, Texas. The dependable yield of the reservoir is 19.3 MGD. DWU, Grapevine, and the Park Cities Municipal Utility District all hold water rights in the reservoir. The reservoir is over permitted well beyond its dependable yield. Diversions of 143.95 MGD are allocated.

Lake Ray Hubbard is owned by the City of Dallas and is located on the East Fork of the Trinity River approximately 2 miles upstream from US Highway 80. The lake is directly downstream of Lake Lavon. The dependable yield of Lake Ray Hubbard is 54.1 MGD. All water rights are owned by the City of Dallas. Water from Ray Hubbard is pumped to the Eastside Water Treatment Plant (400-MGD Capacity) for treatment. The reservoir can also be used for interim storage of water diverted from Lake Tawakoni. Facilities are in place to utilize all of the available water from this reservoir.

Lake Tawakoni is located on the Sabine River approximately 50 miles east of Dallas, Texas. The lake was constructed for water supply purposes as a joint venture between the Sabine River Authority (SRA) and the City of Dallas. Dallas has the contractual rights to 162.6 MGD (±80%) of the reservoir's total yield of 204.3 MGD. DWU has a 72" and 84" pipeline in place from Tawakoni to the Eastside Treatment plant with a combined capacity of 275.0 MGD. Water from Lake Tawakoni can be temporarily stored in Lake Ray Hubbard when the water level in Lake Ray Hubbard is below elevation 432.0.

Lake Fork is a Sabine River Authority impoundment with a dependable yield of 167.0 MGD on Lake Fork Creek approximately five miles west of Quitman, Texas. In 1981, the City of Dallas acquired the rights to utilize water previously allocated to Texas Utilities Generating Company. DWU acquired the rights to 74% of the dependable yield of Lake Fork with a 107.1 MGD diversion limitation. To date, DWU has no facilities in place to utilize its portion of the yield.

Preliminary design has been completed and right-of-way acquired for the pump station and pipeline to transport the yield to Lake Tawakoni for subsequent retransmission to the Eastside Water Treatment Plant. The contract between DWU and the SRA will require renewal in 2014. DWU anticipates this reservoir will be the next source added to their system and should be on-line by 2010.

Lake Palestine is another out of basin supply for DWU. The lake is located on the Neches River, approximately 90 miles southeast of Dallas. The lake is owned and operated by the Upper Neches Municipal Water Authority. DWU has the contractual rights to divert up to 102.0 MGD to the Trinity River Basin. The current yield of the lake is approximately 193.6 MGD. The maximum authorized diversion rate for DWU is 120.0 MGD. DWU has no facilities in place to utilize Lake Palestine at this time. Planning studies and route selection have been completed. Preliminary design and right-of-way acquisition for the pipeline is ongoing.

Joe Pool Lake on the Mountain Creek tributary of the West Fork of the Trinity River was completed in 1986. The lake has a dependable yield of 14.2 MGD and was constructed for flood control, water supply and recreational purposes. The lake was constructed by the COE with the Trinity River Authority (TRA) as the local sponsor. The water rights are contracted to the cities of Midlothian (39.2%), Duncanville (7.0%), Cedar Hill (43.2%), and Grand Prairie (10.6%). Only the city of Midlothian currently has facilities to utilize its available yield

Lake Cooper (a.k.a. Jim Chapman Lake) is discussed under Reach 4T-A.

Potential Water Supplies:

There are no proposed or potential reservoirs within the immediate Reach area. George Parkhouse II, Marvin C. Nichols I Reservoir and Little Cypress Lake are under consideration as future sources behind Lake Fork and Lake Palestine for DWU. George Parkhouse II and Marvin C. Nichols Reservoir(s) are discussed under Reach 4T-A.

Little Cypress Lake is proposed on Little Cypress Bayou approximately six miles northwest of Marshall, Texas in Harrison County. There are two different potential reservoirs proposed at this location. The first is a reservoir with an estimated yield of 115.0 MGD. Unlike all other proposed reservoirs in this study, Little Cypress Lake has been approved by the Texas Natural Resource Conservation Commission (TNRCC) and a water rights permit issued to the Little Cypress Utility District. It is anticipated that the entire permitted portion of the yield will be needed within the Cypress River basin. The second proposed reservoir at this site involves a modification of the project to increase the total yield to 232.7 MGD. The incremental 117.6 MGD and its associated cost have been studied by several entities as a potential future water supply source for Reach 5T-A1. This project is no longer included in the State Water Plan list of recommended projects.

Table 11
Existing & Potential Water Supply Sources
Reach 5T-A1

Source	User	Total or Potential Yield (MGD)	Acceptable Source Yield (MGD)	Useable Quantity (MGD)	Additional Available to Transport (MGD)
Lakes Lewisville/Ray Roberts	DWU, City of Denton	168.9	168.9	168.9	0.0
Grapevine Lake	DWU, Park Cities MUD, Grapevine	19.3	19.3	19.3	0.0
Lake Ray Hubbard	DWU	54.1	54.1	54.1	0.0
Lake Tawakoni	DWU, SRA	162.6	162.6	162.6	0.0
Lake Palestine	DWU	101.7	101.7	0.0	101.7
Lake Fork	DWU	107.0	107.0	0.0	107.0
Lake Joe Pool	DWU for others	14.2	14.2	14.2	0.0
Lake Cooper	DWU for others	107.1	67.6 (a)	67.6	67.6 (a)
George Parkhouse II	Proposed	120.0	120.0	-	120.0
Marvin C. Nichols I	Proposed	420.0	180.0 (b)	-	180.0 (b)
Little Cypress Reservoir	Proposed	233.0	117.6 (c)	-	117.6 (c)

(a) Available yield split between demand centers and/or reaches.
(b) Proposed yield split between DWU (180 MGD), NTMWD (120 MGD), and TRWD (120 MGD).
(c) Proposed yield split between DWU (117.6 MGD) and Little Cypress Utility District (115.0 MGD).

Reach 5T-A2: Tarrant Regional Water District (Tarrant County, Texas)

Reach 5T-A2 is mainly comprised of Tarrant County, Texas. The Tarrant Regional Water District (TRWD) is the predominant wholesale supplier to the City of Fort Worth, Arlington, Trinity River Authority, and many other municipalities within this Reach. This Reach has eight reservoirs in operation and planning documents on several more. Figure 4 details this portion of the study area.

Existing Water Supplies:

Lake Bridgeport is located on the West Fork of the Trinity River approximately four miles west of Bridgeport, Texas in Wise County. The reservoir was completed in 1931 and is owned by and allocated to the TCWCID No. 1. The reservoir is part of the "West Reservoir System" of the TCWCID. The dependable yield of the combined West Fork Reservoir System is 70.5 MGD. Water is released from Lake Bridgeport and flows by gravity to Eagle Mountain Lake in Northern Tarrant County.

Eagle Mountain Lake, also on the West Fork of the Trinity River, is the second of three reservoirs in the West Fork Reservoir System. Eagle Mountain Lake is located approximately 14 miles northwest of Fort Worth, Texas and was completed in 1932. The City of Fort Worth has their Eagle Mountain WTP (30-MGD capacity) at the reservoir. The remainder of the yield from Eagle Mountain Lake and Lake Bridgeport is released for gravity flow downstream to Lake Worth. The dependable yield of the entire West Fork Reservoir System is 70.5 MGD.

Lake Worth is the third member of the West Fork Reservoir System. Built in 1914 by the City of Fort Worth, the lake has minimal yield of its own. Water is delivered to the reservoir from Lake Bridgeport and Eagle Mountain Lake and in turn, delivered to the Fort Worth Holly WTP which has a capacity of 150 MGD.

Richland-Chambers Reservoir is the largest impoundment supplying Reach 5T-A2. The reservoir is located on the Richland Creek and Chambers Creek tributaries of the Trinity River southeast of Corsicana, Texas. The reservoir was completed in 1987 by the TRWD, which holds the permit to the entire dependable yield of 187.5 MGD. Current pipeline facilities are in place to transport up to 150 MGD to the Rolling Hills WTP in southeast Fort Worth. It should be noted that this relatively new pipeline failed during a period of high demand during the summer 1998 drought causing widespread water supply shortages and a total ban on outdoor water use in Tarrant County for several weeks.

Cedar Creek Reservoir is the second largest impoundment in the TCWCID system. It is located on the Cedar Creek tributary of the Trinity River approximately three miles northeast of Trinidad, Texas. Construction was completed in 1966. The lake is owned, operated by, and allocated to the TRWD. The dependable yield of the reservoir is 138.4 MGD. Water from the reservoir is pumped via a pipeline over 90 miles to the Fort Worth Rolling Hills WTP. Additional deliveries are made from the pipeline to Lake Arlington, the City of Mansfield, and the TRA. Modifications to the pump stations since the 1980 report now allow the system to utilize the entire yield.

Lake Arlington is a small impoundment on the Village Creek tributary of the West Fork of the Trinity River in western Arlington. The dependable yield of the lake is only 4.3 MGD. The lake was completed in 1957. The City of Arlington's Pierce-Burch WTP with a capacity of 136 MGD is located on the lake. As mentioned above, the lake receives diversions from the Cedar Creek and Richland-Chambers pipeline systems.

Lake Benbrook is a COE reservoir on the Clear Fork of the Trinity River approximately ten miles southwest of Fort Worth, Texas. The reservoir was constructed in 1950 for navigation purposes. The dependable yield of the navigation storage is ±6.5 MGD. To date, the yield has not been needed for navigation and is under interim contracts for use as water supply. Facilities are in place to utilize the available yield.

Lake Weatherford is located on the Clear Fork of the Trinity River in Parker County approximately seven miles west of the City of Weatherford, Texas. The dependable yield of this impoundment is only 1.5 MGD and is entirely permitted to the City of Weatherford. The TWDB has a proposed project to pump up to 5 MGD from Lake Benbrook to Lake Weatherford to meet future demands in the Parker County area.

Potential Water Supply Projects:

There are two potential out of basin projects proposed for supplying this Reach. Tehuacana Reservoir is proposed for development by the TRWD on the Tehuacana Creek tributary of the Trinity River. This proposed reservoir would be immediately south of Richland-Chambers Reservoir. The proposed yield is 61.0 MGD. Due to the topography of the area, water can flow by gravity from Tehuacana to Richland-Chambers and then be pumped to the Rolling Hills WTP through a new pipeline system that would parallel the existing system. Extensive lignite coal deposits in the vicinity prevented Tehuacana's construction at the same time as Richland-Chambers Reservoir. Due to the lignite deposits, Tehuacana cannot be constructed until 2035-2040 at the earliest.

The second potential water supply project for this Reach is the Trinity River Diversion. This project has been selected as the first choice of the TRWD to expand their existing supply[15]. The project is a downstream indirect wastewater reuse project. The project proposes to divert return flows from the Trinity River into Cedar Creek and Richland-Chambers Reservoirs. Estimates are for diversions of ±50.0 MGD for Richland-Chambers and ±15.6 MGD for Cedar Creek, resulting in a net gain to the TRWD system of ±65.6 MGD. The majority of the costs associated with this project involve increasing the transmission systems from each reservoir to accommodate the increased yield along with construction of the wetlands system. The Trinity River downstream of Dallas has a significant portion of its total flow comprised of treated wastewater. All wastewater plants in Dallas, Denton, Tarrant and Collin Counties discharge into the Trinity River watershed. While the total proposed diversion is less than return flows from the Fort Worth Village Creek

[15] Freese and Nichols, Inc. and Alan Plummer and Associates, Inc., *Regional Water Supply Plan, Tarrant County Water Control And Improvement District Number One*, 1990.

WWTP, the project is strongly opposed by downstream water rights holders including the City of Houston. The Trinity River Basin is over-allocated and downstream users depend on the upstream return flows to fully develop the dependable yield in their reservoirs. As discussed in the wastewater reuse section of this report, the TNRCC has taken the tentative position that a water rights holder may not reclaim treated wastewater once it has been discharged into the waters of the state. In the interim, a pilot scale program continues to evaluate potential water quality issues and any undesirable effects from the reclaimed water.

Table 12
Existing & Potential Water Supply Sources
Reach 5T-A2

Source	User	Total or Potential Yield (MGD)	Acceptable Source Yield (MGD)	Useable Quantity (MGD)	Additional Available to Transport (MGD)
West Fork System	TRWD	70.5	70.5	70.5	0.0
Richland-Chambers	TRWD	187.5	187.5	150.0	37.5
Cedar Creek	TRWD	138.4	138.4	138.4	0.0
Lake Arlington	Arlington	4.3	4.3	4.3	0.0
Lake Benbrook	TRWD	6.5	6.5	6.5	0.0
Tehuacana Reservoir	Proposed	61.0	61.0	0.0	61.0
Trinity River Diversion	Proposed	65.6	65.6	0.0	(a) 0.0
Marvin Nichols I	Proposed	420.0	120.0 (b)	0	120.0 (b)

(a) Over-allocation of the existing river yield may not allow diversion to occur.
(b) Available yield split between TRWD, DWU, and NTMWD.

Reach 8: Wichita Falls, Texas

Wichita, Archer, and Clay Counties combine to form Reach 8 of the study area. The demand center and largest city within this area is Wichita Fall, Texas. While the Red River borders this Reach to the north, this Reach and its concentration duration curves deal with the Wichita River watershed, a tributary to the Red River. Ten existing reservoirs and one potential project were evaluated in this Reach. Figure 5 details this portion of the study area.

Existing Water Supplies:

Lake Arrowhead is located approximately thirteen miles southwest of Wichita Falls on the Little Wichita River. The reservoir is a significant part of Wichita Falls water supply with a dependable yield of 37.5 MGD. The water quality is considered excellent for this Reach. All water is allocated to the City of Wichita Falls and facilities are in place to utilize the yield.

Lake Kickapoo is located upstream of Lake Arrowhead on the North Fork of the Little Wichita River, approximately ten miles northwest of Archer City, Texas. Wichita Falls owns, operates, and has the water rights permit to the reservoir. The dependable yield is 19.1 MGD. The water quality is also considered to be excellent for this region. Facilities are in place to utilize the available yield.

Lake Wichita is located on Holiday Creek on the southern edge of Wichita Falls. Municipal use of the lake was discontinued in the late 1940's when Lake Kickapoo became available. Water quality in the lake is unacceptable due to high TDS concentrations. The reported dependable yield of the reservoir is 0 MGD. The lake is an emergency supply to Wichita Falls.

Lake Kemp is the largest reservoir in the Wichita Falls area. It has a dependable yield of ±103.0 MGD and allocated diversions total 172.3 MGD. The reservoir is located on the Wichita River approximately six miles north of Seymour, Texas and is physically located inside Reach 9. The reservoir is jointly owned by the City of Wichita Falls and the Wichita County Water Improvement District No. 2. The reservoir was constructed in 1922; however, the dam was reconstructed by the COE in 1974 to provide for flood control storage in addition to the existing uses of irrigation, water supply and recreation. Lake Kemp is operated in conjunction with Lake Diversion, which is downstream on the Wichita River. The water quality in the reservoir is poor (See Reach 9 Concentration/Duration curves) and the water is used mainly for irrigation purposes. The yield and development of the Lake Kemp-Lake Diversion System is regulated under the *Red River Compact*.

Lake Diversion, approximately 20 miles downstream of Lake Kemp on the Wichita River straddles the Archer/Baylor County line. The lake has no dependable yield of its own and acts as a distribution point for water from Lake Kemp. The Lake Kemp-Lake Diversion System supplies much of the irrigation water to Wichita, Archer, and Clay Counties.

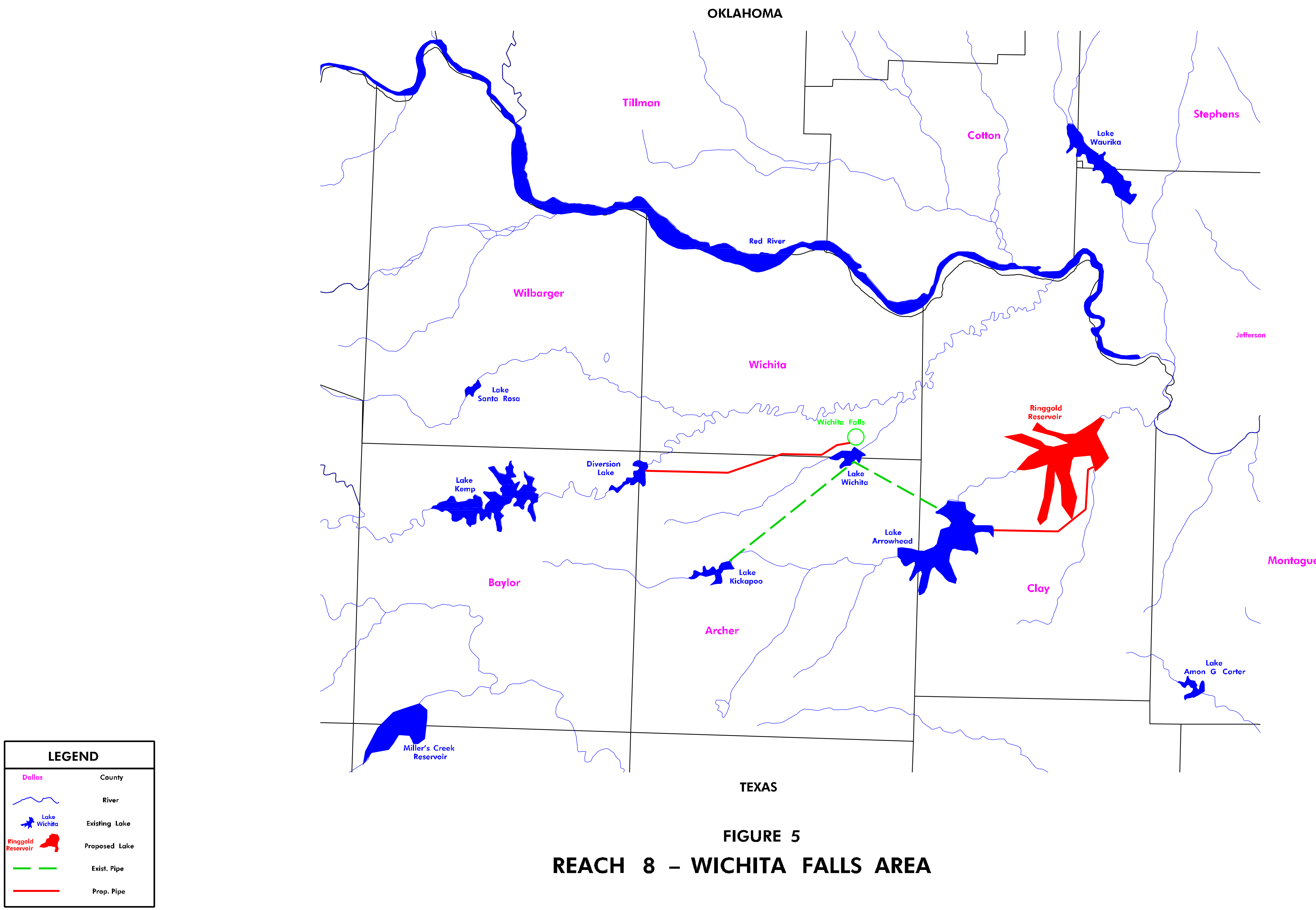

FIGURE 5

REACH 8 – WICHITA FALLS AREA

HUITT-ZOLLARS

Huitt-Zollars, Inc./Engineering /Architecture

Table 13 Existing & Potential Water Supply Sources Reach 8					
Source	User	Total or Potential Yield (MGD)	Acceptable Source Yield (MGD)	Useable Quantity (MGD)	Additional Available to Transport (MGD)
Lake Arrowhead	Wichita Falls	37.5	37.5	37.5	0.0
Lake Kickapoo	Wichita Falls	19.1	19.1	19.1	0.0
Lake Wichita	Wichita Falls	0.0	0.0	0.0	0.0
Lake Kemp – Lake Diversion	Wichita Falls & WCWID2	172.3	0.0	0.0	172.3
Lake Ringgold	Proposed	24.6	24.6	0.0	24.6

Potential Water Supplies:

One potential project exists within this Reach. Lake Ringgold is proposed on the Little Wichita River downstream of Lake Arrowhead. The estimated yield of the lake is ±24.6 MGD. The reservoir is under consideration by the City of Wichita Falls as a future supply source; however, the reservoir is not included in the *Water for Texas – Summary of Regional Water Plans, February 2001*, list of recommended projects.

Transportation Costs for Potential Water Supply Sources

For the 2001 Update, current cost indices were used to update many of the facility costs. These values are listed in Appendix C. The significant exceptions were pipeline costs and power costs. Current material cost data and installation cost data were obtained for all pipeline sizes. In all cases, the revised installed cost of the pipelines increased by more than if the values had simply been factored. Current power costs have also been incorporated to reflect actual anticipated operating conditions.

Reach 1: Shreveport/Bossier City Louisiana

Transportation costs for two potential water supply sources will be evaluated for this Reach. The potential sources are Toledo Bend Reservoir and Cypress Black Reservoir No.1.

Toledo Bend Reservoir with a dependable yield of 1,817 MGD is capable of supplying all of the anticipated future demand for the Shreveport and Bossier City areas. For this analysis, only 50 MGD will be transported to Shreveport. The required pipeline from Toledo Bend to Shreveport would be approximately 56.5 miles. Table 14 summarizes the anticipated source and transportation costs for this project.

Cypress Black Reservoir No. 1 with a dependable yield of 13.8 MGD will be transported to Bossier City, Louisiana. The reservoir is located northwest of Bossier City and will require approximately 9.9 miles of pipeline to reach the city. For this analysis, the entire 13.8 MGD will be transported. It should be noted that this use would require reallocation of existing agricultural water rights and the authorized uses for the reservoir. This project is presented as an option for a potential water supply and is not intended to imply that any reallocation has been authorized. Table 14 summarizes the anticipated source and transportation costs for this project.

Reach 4T-A: North Texas Municipal Water District (NTMWD)

Transportation costs for three potential water supply sources will be evaluated for this Reach. The potential sources are New Bonham Reservoir, George Parkhouse II, and Marvin Nichols I Reservoir.

Water from the proposed New Bonham Reservoir will require approximately 27.5 miles of pipeline to reach the headwaters of Lake Lavon. The entire yield of 89.7 MGD will be transported to Lake Lavon for use by the NTMWD. Table 14 summarizes the anticipated source and transportation costs for this project.

George Parkhouse II Reservoir is proposed on the North Sulphur River downstream of Lake Cooper. It is anticipated that the development costs for

George Parkhouse II would be shared by NTMWD and local interests. For this analysis, it is anticipated that the water from George Parkhouse II will be pumped to Lake Cooper for subsequent retransmission on to Lake Lavon (for NTMWD) or Lake Ray Roberts (for DWU). The entire yield of 120.0 MGD will be costed for both NTMWD and DWU. This project would most likely involve constructing a parallel pipeline from Lake Cooper to Lake Lavon. The 2001 *Water for Texas* Plan no longer includes this reservoir.

Marvin Nichols I Reservoir is proposed to have a dependable yield of ±420 MGD. This reservoir alone could meet most of the future water needs of North and Northeast Texas. Serious environmental issues may be raised since the project is anticipated to submerge over 36,000 acres of bottomland hardwood forest while inundating over 68,000 total acres. The cost to develop the reservoir and transportation systems will approach $1 billion dollars[16]. At this time, the project appears too large to finance even for a joint effort between the NTMWD, DWU, and TRWD. Significant State or Federal assistance would be needed to allow for construction of this project. For this analysis, 120 MGD will be transported to NTMWD, 180 MGD to DWU, and 120 MGD to TRWD.

One additional scenario has re-emerged from earlier Red River Chloride Control Project studies. Sardis Lake and Lake Hugo in Oklahoma are again being evaluated as a potential water supply sources for both NTMWD and TRWD. While once considered politically impossible, legislative inroads in Oklahoma and the need to develop additional supplies in Texas have led to further discussions on the possible inter-state transfer of water. No transportation costs have been developed for this study due to the uncertainty of the availability, however, the *2001 Water for Texas* plan does include the conveyance systems for the Oklahoma water to both NTMWD and the TRWD.

Reach 5T: Sherman/Denison, Texas

No proposed alternative water supply sources have been identified for this Reach.

Reach 5T-A1: Dallas Water Utilities (DWU) including Denton County, Texas

Five alternative water supply sources have been evaluated for the DWU system. The sources are Lake Palestine, Lake Fork, Lake Cooper, Little Cypress, George Parkhouse II Reservoir, and Marvin Nichols I Reservoir.

Lake Fork has been identified by DWU as its next water supply source to be brought on-line. The source costs for this reservoir have previously been included into the DWU water rate structure, thus no source costs are attributed in this study (i.e. The reservoir costs are incurred regardless of whether the water is ever used). The intake structure, pump station, and pipeline have been designed to transport

[16] Jack Z. Smith, "The Future of Water", *Fort Worth Star Telegram*, August 8, 1998.

the water the 21.9 miles to Lake Tawakoni for subsequent re-transmission on to the DWU Eastside Water Treatment Plant.

Lake Palestine will be the second new source brought into the DWU system. It will require approximately 81.2 miles of pipeline with one booster station to deliver the 101.7 MGD to the Southeast Water Treatment Plant. As with Lake Fork, DWU has previously included the source costs for Lake Palestine into their water rate structure since they have contracted for the water. No additional source costs will be added for this analysis.

Lake Cooper (a.k.a. Jim Chapman Lake) is another potential water source for the DWU demand center. The City of Irving and the Upper Trinity Regional Water District (UTRWD) have contracted for a combined 67.6 MGD from Lake Cooper (39.5 MGD for Irving, 28.1 MGD for UTRWD). The NTMWD currently has a pipeline from Lake Cooper to Lake Lavon with interim capacity to transport this water until George Parkhouse or Marvin Nichols is built. The most likely scenario would be to extend the existing pipeline on to Lake Ray Roberts. This would provide additional water for the UTRWD treatment plant at Lake Ray Roberts and allow Irving to gravity flow down the Trinity to either the DWU Elm Fork Treatment Plant or construct it's own treatment plant.

Little Cypress Reservoir is a potential impoundment near Marshall, Texas. A 63 mile long pipeline would be needed to transport the available 117.6 MGD of water to Lake Fork where the DWU system would then transport the water to Lake Tawakoni and eventually the Eastside Water Treatment Plant.

The George Parkhouse II Reservoir and Marvin Nichols I Reservoir projects are discussed under the Reach 4T-A analysis. Table 14 summarizes the transportation costs for the potential projects for this Reach.

<u>Reach 5T-A2: Tarrant Regional Water District (Tarrant County, Texas)</u>

Three potential projects have been evaluated for this Reach. Tehuacana Reservoir, a diversion of return flows from the Trinity River, and Marvin Nichols I Reservoir are being considered by the TRWD.

The Tehuacana project would be constructed adjacent to Richland Chambers Reservoir. Water will be able to flow via gravity into Richland Chambers Reservoir. Transportation costs will primarily involve booster station improvements. Construction of this reservoir cannot begin until after the year 2040 due to extensive deposits of lignite coal under the proposed reservoir. The LRR[17] estimated the 1992 value of the coal lignite to be in excess of $500 million dollars. This project is included in the State Water Plan's list of recommended projects, however; transportation costs for this system are summarized in Table 14.

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[17] Department of the Army, Tulsa District Corps of Engineers, "*Limited Reevaluation Report*", June 1993, p. II-142.

The second project under consideration is the Trinity River Diversion. This indirect reuse project has been discussed in several other portions of this report. The State Water Plan includes this project in the list of recommended projects, however; the plan also indicates this project may not be feasible. The third project is Marvin Nichols I Reservoir which is discussed under Reach 4T-A. Transportation costs for these projects are shown in Table 14.

Reach 8: Wichita Falls, Texas

One alternative water supply source has been examined for this Reach. Lake Ringgold is proposed for construction downstream of Lake Arrowhead on the Little Wichita River. The reservoir is expected to have excellent water quality with a dependable yield of ±24.6 MGD. The lake would require ±27 miles of pipeline to reach the mixing reservoir for the City of Wichita Falls. This project is no longer included in the State Water Plan's list of recommended projects. Transportation costs for this system are summarized in Table 14.

Table 14
Alternate Source Costs
($ per 1,000 Gallons)
(January 2001 Cost Basis)

Reach	Source	Demand Center	Qty. (MGD)	Source Cost	Trans. Costs	Total Costs
1	Toledo Bend Reservoir	Shreveport	50.0	$0.060	$1.137	$1.197
	Cypress Black Bayou No. 1	Bossier City	13.8	$0.060	$0.403	$0.463
4T-A	*New Bonham Reservoir	NTMWD	83.7	$0.289	$0.487	$0.776
	*George Parkhouse II		120.0	$0.446	$0.220	$0.666
	*Marvin Nichols Reservoir I		120.0	$0.220	$0.760	$0.980
5T-A1	Lake Fork	DWU	107.0	$0.000	$1.064	$1.064
	Lake Palestine		101.7	$0.000	$1.352	$1.352
	Cooper Reservoir		67.6	$0.063	$1.338	$1.401
	*Little Cypress Reservoir		117.6	$0.261	$1.542	$1.803
	* George Parkhouse II		100.0	$0.446	$1.413	$1.859
	*Marvin Nichols Reservoir I		180.0	$0.220	$0.907	$1.127
5T-A2	Richland Chambers Reservoir	TRWD	37.5	$0.000	$0.231	$0.231
	*Tehuacana Reservoir (Post 2035)		61.0	$0.656	$1.541	$2.197
	Trinity River Diversion		65.6	$0.083	$1.292	$1.375
	*Marvin Nichols Reservoir I		120.0	$0.220	$1.284	$1.504
8	*Ringgold Reservoir	Wichita Falls	24.6	$1.117	$0.656	$1.773

* Proposed New Impoundment

Comparison to the State Water Plan

The alternate source costs listed in the State Water Plan differ from those listed in Table 14. In most cases, the State Water Plan numbers are somewhat lower. Several factors contribute to the variances including the amortization periods, interest rates, quantities being transported, and variances in estimated pipeline lengths. Another factor is in the State Water Plan, many values represent dual pipeline systems. The State costs are based on 1999 cost data and pipeline construction costs have risen in the last few years. The methodology used in this report is somewhat more conservative on the facility costs and avoids the large contingencies used in the State Water Plan values. Regardless of which methodology proves to eventually be more accurate, since all transportation and source costs are calculated on the same basis in this report, any incremental cost savings between alternative sources would remain relatively unchanged.

Treatment Methods and Costs[18]

Desalination is a treatment process to reduce the concentration of salts and minerals in a solution. Conventional water treatment alone is not capable of removing some dissolved solids, including chlorides and sulfates, from the raw feed water. Two membrane processes are commonly used to remove or reduce these components, reverse osmosis (RO) and electrodialysis reversal (EDR). Figure 6 details these two processes.

Reverse osmosis (RO) is the most effective membrane desalination process. RO utilizes high pressures to reverse the natural osmotic process and force clean water from a source solution through a semi-permeable membrane leaving a concentrated brine solution (concentrate) on one side and clean water (permeate) on the other. Modern advances in membrane materials have allowed the membranes to become highly efficient at rejecting contaminants and more durable to high pressures, with units now capable of removing over 90% of TDS, including chlorides and sulfates, from the feed water during each pass. RO treatment is also able to remove bacteria, organics, and dissolved silica from the feed water. Health contaminants, including arsenic, asbestos, lead, mercury, and radium, can also be removed in the RO process.[19] For each pass through an RO unit, 20-30% of the total water input is wasted to the concentrated brine discharge stream. RO units are capable of demineralizing feedwater with TDS concentrations of up to 45,000 mg/l (seawater).

Electrodialysis reversal (EDR) is an electrochemical separation process which uses a direct electrical current to transfer ions through membranes from a less concentrated to a more concentrated solution. The current is reversed at set intervals (3-4 times per hour) to minimize scaling and fouling of the membranes. The stacks are comprised of thousands of alternating layers of anion and cation membranes. The membranes are resistant to pH changes and are impermeable to water under pressure. EDR is typically a low-pressure process that can recover 85-90% of the feed water. Salt removal from a given volume of water is

[18] Department of the Army, Tulsa District Corps of Engineers, "Red River Chloride Control Project – Supplemental Assessment Report", February 1997.
[19] Water Quality Research Council, *What Is...Reverse Osmosis*, Water Review Technical Brief, Volume 10, No. 3, 1995.

directly proportional to the current and inversely proportional to the flow rate through each stage.[20] EDR units' average removal of 50% of the salts in the feed water per stage, with higher purity achieved by increasing the number of EDR stages. The EDR process does not remove bacteria, organic, dissolved silica, or uncharged particles from the feed water. EDR is typically used on raw water with a TDS concentration of 2,000 mg/l or less. For each pass through an EDR unit, 10-20% of the total feed water is lost to the concentrated brine discharge stream.

Cost data for these treatment processes was analyzed in a 1992 study of U.S. desalination plants[21]. The study contains detailed cost data for 73 operating desalination plants (43 RO plants, 15 EDR plants, 7 membrane-softening plants, and 8 Seawater RO plants). Two notable findings from the study were:

1. Only 146 MGD of water is produced by desalination for potable use. This figure does not include the 72 MGD Yuma Desalting Plant operated by the Bureau of Reclamation to treat agricultural run-off.

2. The median selling price of potable water from desalination is ±$2.00/1000 gallons from plants with a capacity of 3 MGD or more.

The 1992 study indicated there were at least 169 desalination plants in operation in the U.S of which 124 utilized reverse osmosis and only 16 utilized the EDR process. The largest number of desalination plants is located in Florida, followed by the U.S. Virgin Islands, Texas, and California. Furthermore, the data indicates there are only ±32 plants (19%) of the 169 total with a capacity of 1 MGD or greater and only 10 plants (6%) with a capacity of 3 MGD or greater. (Note: The study was performed prior to the Sherman, Texas EDR Plant becoming operational.)

The cost data indicated the values used for RO and EDR costs in the SAR[22] may have been ±$0.40 per 1000 gallons too low. Another apparent trend indicates the vast majority of desalination plants currently in operation are much smaller than many of the proposed plants evaluated in previous Red River Chloride Control Project studies. The BuRec Plant in Yuma, AZ is the only operational US facility with a capacity in excess of 15 MGD. In the previous RRCCP studies, only Reach 5T was projected for facilities in the conventional 5-10 MGD range. All other reaches were evaluated with considerably larger plants. Given the magnitude of the estimated capital costs for desalination plants in the 25-75 MGD range, along with the ongoing maintenance and brine disposal costs, construction of these large plants is unlikely.

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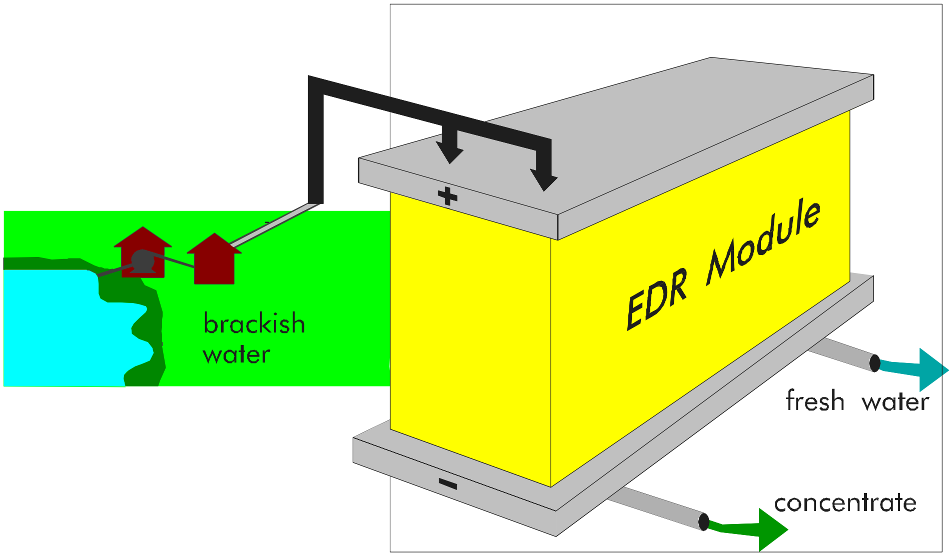
[20] Floyd H. Meller, ed., *Electrodialysis (ED) & Electrodialysis Reversal (EDR) Technology* (Watertown, MA: Ionics, Incorporated, 1984), pp. 42.

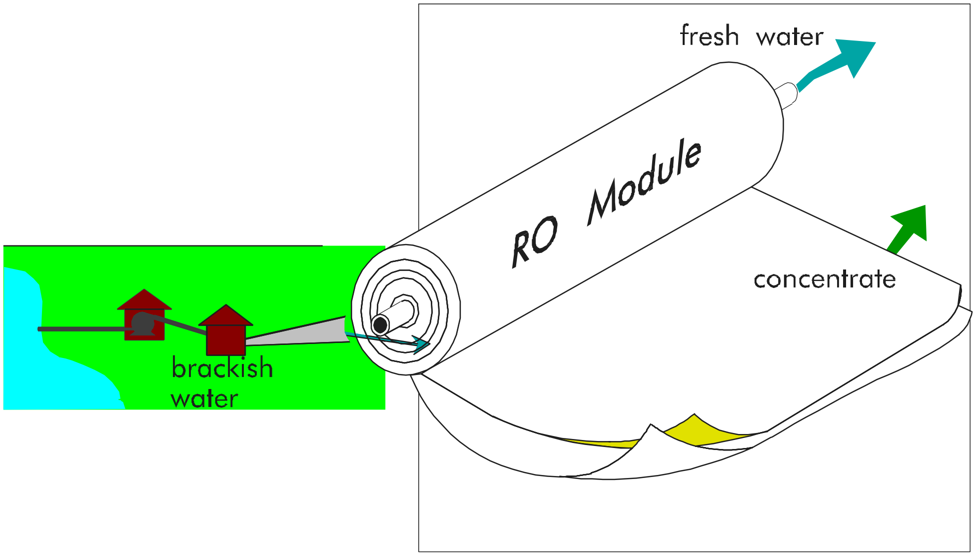
[21] Leitner, W., "*Potable Water Desalination in the U.S.: Capital Costs, Operating Costs and Water Selling Prices*," National Water Supply Improvement Association, 1992.

[22] U.S. Army Corps of Engineers, Tulsa District, *"Red River Chloride Control Project Supplemental Assessment Report*", February 1997.



ELECTRODIALYSIS REVERSAL (EDR)

In EDR, impurities are electrically removed from the water. A DC current transfers ions through the membranes, resulting in desalted fresh water and a more concentrated mineral stream. By reversing polarity two to four times per hour, the system provides constant, automatic self–cleaning that enables improved efficiency in operation and less downtime for periodic cleaning.



REVERSE OSMOSIS (RO)

In RO, the water is forced through a membrane under pressure. Purified water filters through the membrane while the impurities remain behind and are collected in a concentrated mineral stream.

FIGURE 6

Current Desalination Applications in the Red River Basin

Greater Texoma Utility Authority:

The City of Sherman, Texas operates a 10 MGD surface water treatment plant with demineralization capabilities to utilize water from Lake Texoma. Construction of the plant was financed by the Greater Texoma Utility Authority (GTUA). The plant was placed into operation in May 1993 and has received considerable publicity including a segment on the NBC Nightly News, "Fleecing of America" series on August 20, 1996, as an economical alternative to completion of the Red River Chloride Control Project.

The treatment plant receives raw water from Lake Texoma (±15 miles away) which undergoes conventional surface water treatment (coagulation, flocculation, and filtration) prior to demineralization. After filtration, a portion of the total flow (40-90%) is pumped to the EDR system for removal of dissolved solids. The plant has four EDR units manufactured by Ionics, Inc. Each unit has a capacity of 1.5 MGD (total of 6.0 MGD). Each EDR unit has two stages, with space available for the possible addition of a third stage in the future.

It should be noted that while the treated water quality for the Sherman water treatment plant meets all State of Texas criteria and standards, the treated water *does not* meet the Secondary Water Quality Limits for drinking water established by the EPA. The basis of all Red River Chloride Control studies to date has been to deliver water which would meet the EPA limits 98% of the time.

Brine from the EDR process units is diverted to a holding pond. The holding pond then discharges by gravity to the city sanitary sewer system. This results in an additional sanitary sewer flow of between 300,000 and 700,000 gallons per day. While the water plant does not incur direct costs to have the brine flow treated, the entire city must absorb the additional wastewater treatment costs and loss of capacity at the wastewater treatment plant. The City of Sherman attempted to discharge brine effluent to a local stream but withdrew its permit application due to strong opposition from downstream property owners. The current method of discharging brine from holding ponds through the city wastewater treatment facility to dilute the brine concentration avoids the necessity for Texas Natural Resource Conservation Commission (TNRCC) permitting and reduces potential impacts to the receiving stream.

The entire cost of the Sherman, Texas water treatment plant project was approximately $19.1 million. Of this, ±$14.9 million is associated with the conventional treatment plant and ±$4.2 million was for the EDR equipment and building. Addition of the fourth EDR unit cost an additional $1.0 million. The original EDR building was constructed with space for the fourth unit. The City estimated the EDR treatment costs[23] to be an additional $0.58 to $0.71 per 1,000 gallons above conventional treatment costs prior to the addition of the fourth EDR unit. Ionics, Inc., estimates the additional capital costs to add a third stage to the existing four units for improved water quality at ±$700,000.

The City of Seymour is constructing an RO plant to reduce sulfates, chlorides, nitrates, and hardness in their well water. The City evaluated the possibility of treating water from Lake Kemp but determined its cost to be approximately twice that of treating the existing well water supplies[24]. The City of Seymour estimated the cost of treating Lake Kemp water at $2.00 per 1000 gallons.

West Texas Utilities:

West Texas Utilities is another consumer of Red River water using desalinization facilities. The Oklaunion Power Plant has a contract to divert up to 20,000 acre-feet per year (17.9 MGD) of water from Lake Kemp and Lake Diversion. Of this total diversion, the plant has a 0.29 MGD reverse osmosis facility to treat boiler make-up water. The plant currently operates at an average flow of 0.08 MGD. The RO plant utilizes approximately $75,000 per year in chemicals and other consumable items. Labor, maintenance and power costs for the RO plant account for an additional $250,000 per year of expense.

The majority of the diverted water is used for make-up water in the plant's cooling towers. The current average is approximately 7 MGD. Due to the high mineral content and conductivity of the water, the facility must treat the water with flocculent, add scale inhibitors, and treat with microbial inhibitors. The plant annually spends proximately $500,000 on chemicals for these processes. The plant manager indicates that the chemical usage is significantly reduced after heavy rains when the water quality from Lake Diversion is "improved". This forms the basis for the plant managers' estimated savings[25] of $100,000 per year from improved water quality in the basin.

Estimated Treatment Costs

Past studies have used complex formulas for equipment and treatment costs which were developed in the 1960's and indexed to provide current values. Improvements in technology along with tougher environmental regulations make these old formulas unreliable. For this study, we have developed new formulas to calculate the approximate treatment costs for both RO and EDR plants. Capital equipment for the proposed plants is sized based on the 5% exceedance

[23] Information in an August 29, 1996, letter to Jim Sullivan, Tulsa District, Corps of Engineers from Jerry Chapman of the Greater Texoma Utility Authority

[24] Information in a September 14, 1998, letter to Jim Sullivan, Tulsa District Corps of Engineers from Ken Martin, P.E. with Jacobs & Martin, Inc. Consulting Engineers.

[25] Information in an October 23, 1999 letter to Jim Sullivan, Tulsa District Corps of Engineers from Mark Burton, West Texas Utilities Company, Oklaunion Power Station Plant Manager.

value from the Concentration/Duration curves. For this study, the EDR process is used to calculate the treatment costs for sources with TDS values of 2,000 mg/l or less. RO is used for TDS values over 2,000 mg/l. Appendix C details the formulas used for this analysis. Appendix D contains the calculations for the treatment costs and damages for the municipal and industrial users in the study area. Figure 7 details the treatment processes involved in both conventional and EDR treatment of surface water. The basic components included in the treatment cost for this study include:

Capital Costs:

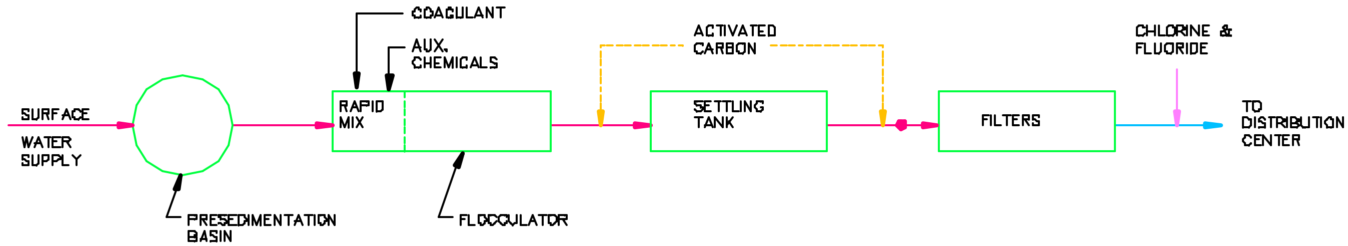
- Site Costs
- Desalination Equipment Costs
- Peripheral Facilities
- Construction Costs
- Conventional Pre and Post Treatment Facilities
- Brine Disposal Facilities

O&M Expenses

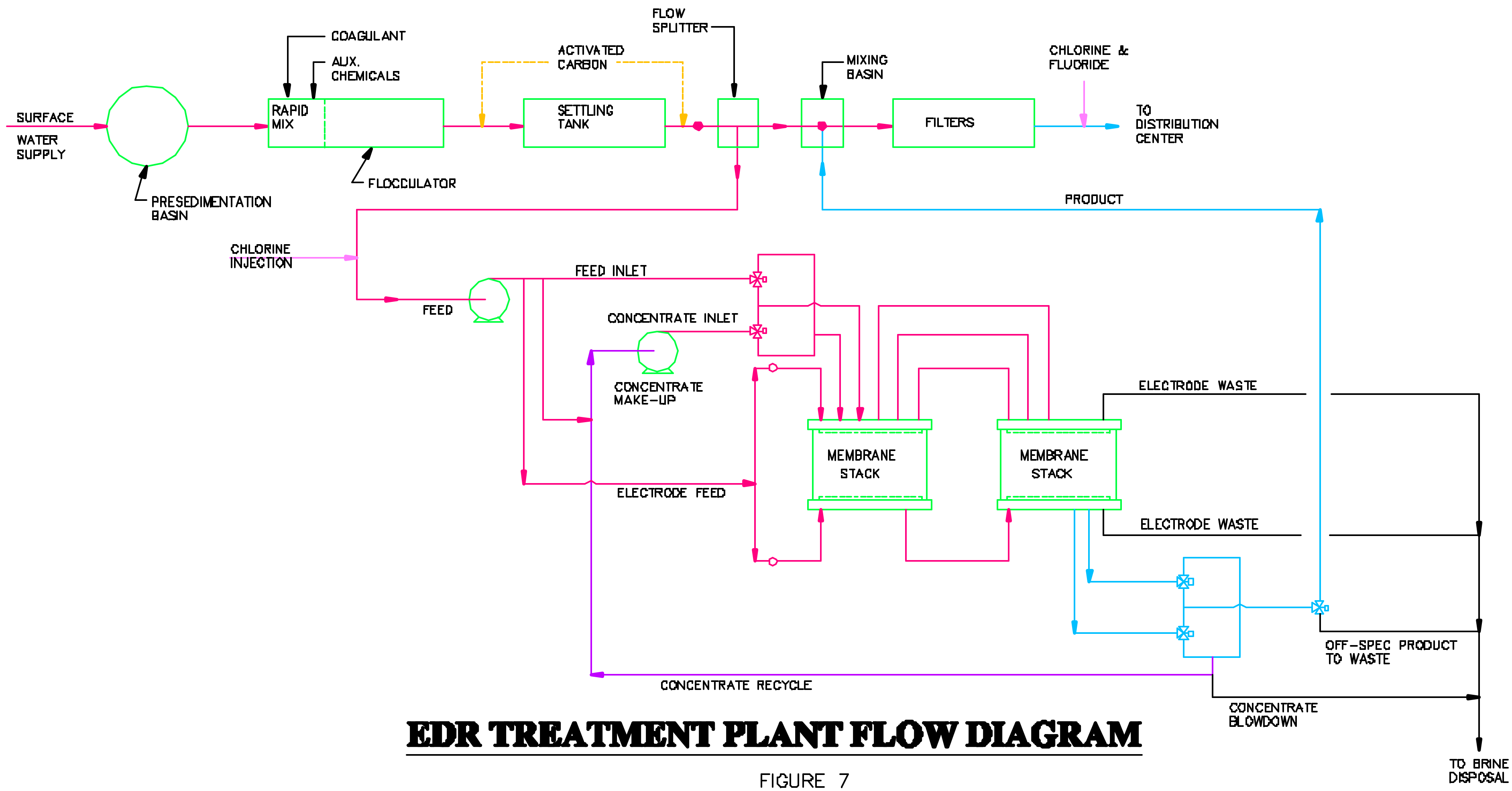
- Labor
- Chemicals
- Power
- Miscellaneous Maintenance
- Brine Disposal O&M
- Depreciation

Table(s) 15-19 summarize the estimated municipal costs for use of Red River water with and without desalination treatment. Tables 20-24 summarize the estimated industrial costs for the use of Red River water with and without desalination treatment.

Pipeline systems for Reach 1 & 8 are indicated on Figure(s) 3 and 5 respectively. Pipeline systems for transportation of Red River water to the North Central Texas area are shown on Figure 8.



CONVENTIONAL TREATMENT PLANT FLOW DIAGRAM



EDR TREATMENT PLANT FLOW DIAGRAM

FIGURE 7

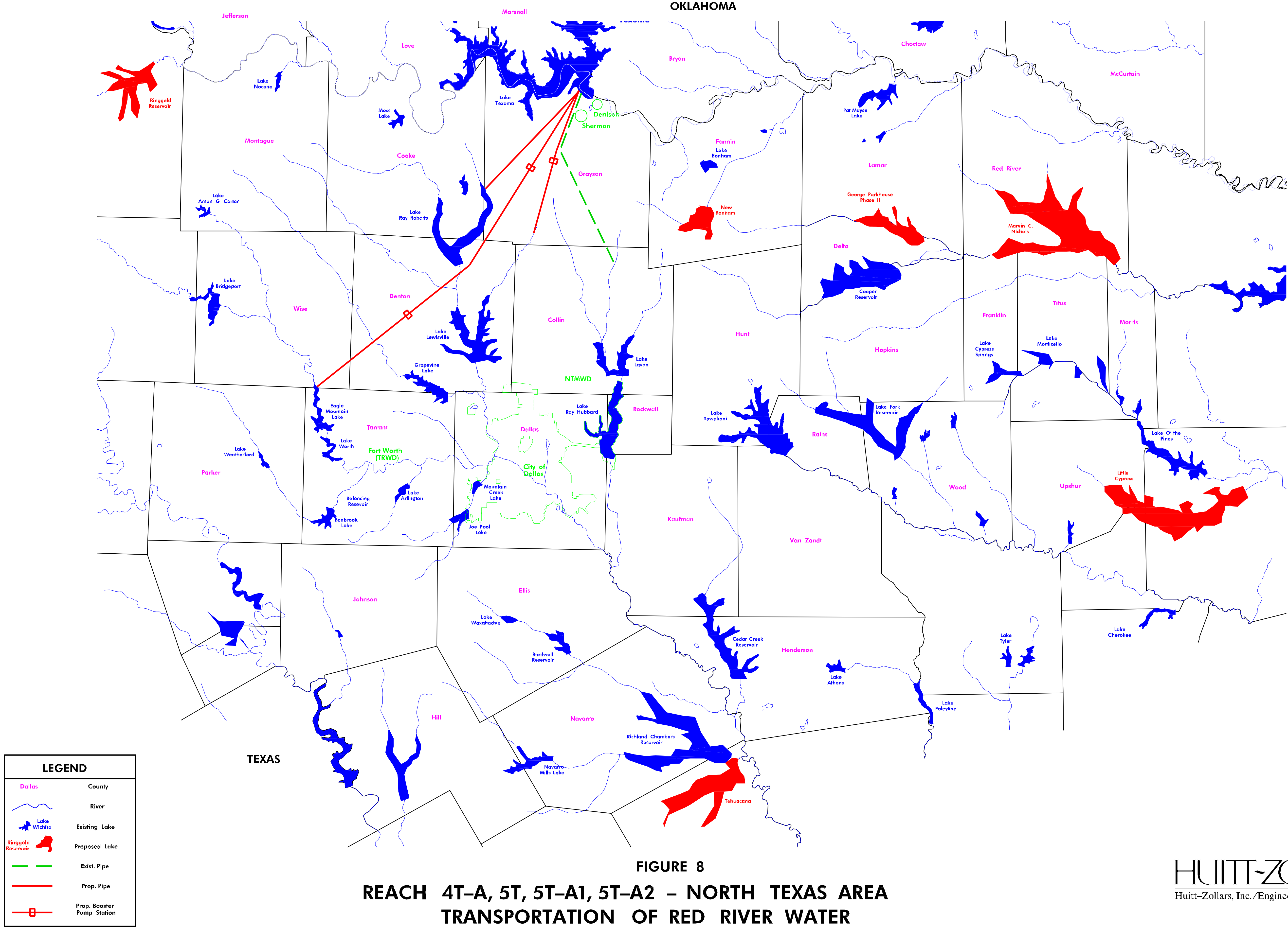


FIGURE 8

REACH 4T–A, 5T, 5T–A1, 5T–A2 – NORTH TEXAS AREA
TRANSPORTATION OF RED RIVER WATER

HUITT-ZOLLARS
Huitt–Zollars, Inc./Engineering /Architecture

Table 15
Cost of Red River Water
Natural Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.668	$ 0.417	$ 0.277	$ 0.420	$ 2.422	$ 0.897
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.601	$ 0.285	$ 0.277	$ 0.420	$ 2.223	$ 0.765
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.860	$ 0.069	$ -	$ 0.776	$ 1.989	$ 0.905
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.911	$ 0.224	$ -	$ 0.776	$ 2.195	$ 1.060
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.751	$ 0.085	$ 0.490	$ 1.265	$ 2.385	$ 1.410
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.751	$ 0.569	$ 0.490	$ 1.265	$ 2.869	$ 1.894
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.751	$ 1.292	$ 0.490	$ 1.265	$ 3.592	$ 2.617
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.799	$ 0.214	$ 0.303	$ 5.684	$ 3.376	$ 5.958
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.249	$ 0.762	$ 0.303	$ 4.849	$ 3.374	$ 5.671

All Costs in January 2001 Dollars.

Table 16
Cost of Red River Water
Area 8 Only Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
Normal Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.658	$ 0.417	$ 0.274	$ 0.413	$ 2.410	$ 0.890
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.591	$ 0.285	$ 0.274	$ 0.413	$ 2.210	$ 0.758
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.842	$ 0.069	$ -	$ 0.728	$ 1.971	$ 0.857
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.893	$ 0.224	$ -	$ 0.728	$ 2.177	$ 1.012
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.733	$ 0.085	$ 0.489	$ 1.217	$ 2.367	$ 1.362
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.733	$ 0.569	$ 0.489	$ 1.217	$ 2.851	$ 1.846
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.733	$ 1.292	$ 0.489	$ 1.217	$ 3.574	$ 2.569
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.249	$ 0.214	$ 0.299	$ 4.112	$ 2.822	$ 4.386
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.192	$ 0.762	$ 0.303	$ 3.454	$ 3.317	$ 4.276
+10% Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.725	$ 0.417	$ 0.303	$ 0.481	$ 2.505	$ 0.958
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.658	$ 0.285	$ 0.303	$ 0.481	$ 2.306	$ 0.826
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.892	$ 0.069	$ -	$ 0.881	$ 2.021	$ 1.010
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.945	$ 0.224	$ -	$ 0.881	$ 2.229	$ 1.165
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.783	$ 0.085	$ 0.491	$ 1.372	$ 2.419	$ 1.517
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.783	$ 0.569	$ 0.491	$ 1.372	$ 2.903	$ 2.001
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.783	$ 1.292	$ 0.491	$ 1.372	$ 3.626	$ 2.724
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.263	$ 0.214	$ 0.301	$ 4.575	$ 2.838	$ 4.849
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.211	$ 0.762	$ 0.303	$ 3.851	$ 3.336	$ 4.673
-10% Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.575	$ 0.417	$ 0.249	$ 0.349	$ 2.301	$ 0.826
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.509	$ 0.285	$ 0.249	$ 0.349	$ 2.103	$ 0.694
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.781	$ 0.069	$ -	$ 0.576	$ 1.910	$ 0.705
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.829	$ 0.224	$ -	$ 0.576	$ 2.113	$ 0.860
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.673	$ 0.085	$ 0.486	$ 1.062	$ 2.304	$ 1.207
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.673	$ 0.569	$ 0.486	$ 1.062	$ 2.788	$ 1.691
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.673	$ 1.292	$ 0.486	$ 1.062	$ 3.511	$ 2.414
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.232	$ 0.214	$ 0.297	$ 3.650	$ 2.803	$ 3.924
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.168	$ 0.762	$ 0.303	$ 3.058	$ 3.293	$ 3.880

All Costs in January 2001 Dollars.

Table 17
Cost of Red River Water
Area 8 & 10 Only Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
Normal Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.648	$ 0.417	$ 0.271	$ 0.405	$ 2.396	$ 0.882
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.581	$ 0.285	$ 0.271	$ 0.405	$ 2.197	$ 0.750
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.835	$ 0.069	$ -	$ 0.710	$ 1.964	$ 0.839
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.885	$ 0.224	$ -	$ 0.710	$ 2.169	$ 0.994
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.726	$ 0.085	$ 0.488	$ 1.199	$ 2.360	$ 1.344
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.726	$ 0.569	$ 0.488	$ 1.199	$ 2.844	$ 1.828
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.726	$ 1.292	$ 0.488	$ 1.199	$ 3.567	$ 2.551
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.225	$ 0.214	$ 0.296	$ 3.492	$ 2.794	$ 3.766
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.159	$ 0.762	$ 0.303	$ 2.925	$ 3.284	$ 3.747
+10% Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.717	$ 0.417	$ 0.299	$ 0.471	$ 2.493	$ 0.948
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.649	$ 0.285	$ 0.299	$ 0.471	$ 2.293	$ 0.816
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.886	$ 0.069	$ -	$ 0.861	$ 2.015	$ 0.990
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.939	$ 0.224	$ -	$ 0.861	$ 2.223	$ 1.145
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.777	$ 0.085	$ 0.491	$ 1.352	$ 2.413	$ 1.497
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.777	$ 0.569	$ 0.491	$ 1.352	$ 2.897	$ 1.981
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.777	$ 1.292	$ 0.491	$ 1.352	$ 3.620	$ 2.704
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.241	$ 0.214	$ 0.298	$ 3.891	$ 2.813	$ 4.165
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.181	$ 0.762	$ 0.303	$ 3.269	$ 3.306	$ 4.091
-10% Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.565	$ 0.417	$ 0.245	$ 0.341	$ 2.287	$ 0.818
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.499	$ 0.285	$ 0.245	$ 0.341	$ 2.089	$ 0.686
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.773	$ 0.069	$ -	$ 0.560	$ 1.902	$ 0.689
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.820	$ 0.224	$ -	$ 0.560	$ 2.104	$ 0.844
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.665	$ 0.085	$ 0.486	$ 1.046	$ 2.296	$ 1.191
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.665	$ 0.569	$ 0.486	$ 1.046	$ 2.780	$ 1.675
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.665	$ 1.292	$ 0.486	$ 1.046	$ 3.503	$ 2.398
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.204	$ 0.214	$ 0.294	$ 3.091	$ 2.772	$ 3.365
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.132	$ 0.762	$ 0.303	$ 2.581	$ 3.257	$ 3.403

All Costs in January 2001 Dollars.

Table 18
Cost of Red River Water
Area 7 & 8 Only Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
Normal Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.629	$ 0.417	$ 0.265	$ 0.389	$ 2.371	$ 0.866
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.562	$ 0.285	$ 0.265	$ 0.389	$ 2.172	$ 0.734
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.821	$ 0.069	$ -	$ 0.672	$ 1.950	$ 0.801
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.870	$ 0.224	$ -	$ 0.672	$ 2.154	$ 0.956
4T-A	NRMWD	65.0	200.0	$ 0.060	$ 1.712	$ 0.085	$ 0.488	$ 1.160	$ 2.345	$ 1.305
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.712	$ 0.569	$ 0.488	$ 1.160	$ 2.829	$ 1.789
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.712	$ 1.292	$ 0.488	$ 1.160	$ 3.552	$ 2.512
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.144	$ 0.214	$ 0.294	$ 2.218	$ 2.712	$ 2.492
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.032	$ 0.762	$ 0.303	$ 1.807	$ 3.157	$ 2.629
+10% Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.699	$ 0.417	$ 0.292	$ 0.452	$ 2.468	$ 0.929
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.631	$ 0.285	$ 0.292	$ 0.452	$ 2.268	$ 0.797
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.873	$ 0.069	$ -	$ 0.819	$ 2.002	$ 0.948
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.925	$ 0.224	$ -	$ 0.819	$ 2.209	$ 1.103
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.763	$ 0.085	$ 0.490	$ 1.309	$ 2.398	$ 1.454
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.763	$ 0.569	$ 0.490	$ 1.309	$ 2.882	$ 1.938
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.763	$ 1.292	$ 0.490	$ 1.309	$ 3.605	$ 2.661
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.168	$ 0.214	$ 0.294	$ 2.490	$ 2.736	$ 2.764
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.065	$ 0.762	$ 0.303	$ 2.039	$ 3.190	$ 2.861
-10% Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.543	$ 0.417	$ 0.240	$ 0.327	$ 2.260	$ 0.804
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.478	$ 0.285	$ 0.240	$ 0.327	$ 2.063	$ 0.672
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.757	$ 0.069	$ -	$ 0.526	$ 1.886	$ 0.655
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.803	$ 0.224	$ -	$ 0.526	$ 2.087	$ 0.810
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.649	$ 0.085	$ 0.486	$ 1.011	$ 2.280	$ 1.156
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.649	$ 0.569	$ 0.486	$ 1.011	$ 2.764	$ 1.640
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.649	$ 1.292	$ 0.486	$ 1.011	$ 3.487	$ 2.363
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.115	$ 0.214	$ 0.294	$ 1.947	$ 2.683	$ 2.221
9	Wichita Falls	10.0	315.0	$ 0.060	$ 1.992	$ 0.762	$ 0.303	$ 1.575	$ 3.117	$ 2.397

All Costs in January 2001 Dollars.

Table 19
Cost of Red River Water
Area 7, 8 & 10 Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
Normal Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.620	$ 0.417	$ 0.262	$ 0.382	$ 2.360	$ 0.859
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.553	$ 0.285	$ 0.262	$ 0.382	$ 2.161	$ 0.727
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.814	$ 0.069	$ -	$ 0.655	$ 1.943	$ 0.784
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.863	$ 0.224	$ -	$ 0.655	$ 2.147	$ 0.939
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.705	$ 0.085	$ 0.488	$ 1.142	$ 2.338	$ 1.287
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.705	$ 0.569	$ 0.488	$ 1.142	$ 2.822	$ 1.771
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.705	$ 1.292	$ 0.488	$ 1.142	$ 3.545	$ 2.494
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.072	$ 0.214	$ 0.289	$ 1.597	$ 2.634	$ 1.871
9	Wichita Falls	10.0	315.0	$ 0.060	$ 1.934	$ 0.762	$ 0.303	$ 1.272	$ 3.058	$ 2.094
+10% Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.691	$ 0.417	$ 0.288	$ 0.444	$ 2.456	$ 0.921
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.623	$ 0.285	$ 0.288	$ 0.444	$ 2.256	$ 0.789
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.867	$ 0.069	$ -	$ 0.800	$ 1.996	$ 0.929
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.919	$ 0.224	$ -	$ 0.800	$ 2.203	$ 1.084
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.758	$ 0.085	$ 0.490	$ 1.289	$ 2.393	$ 1.434
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.758	$ 0.569	$ 0.490	$ 1.289	$ 2.877	$ 1.918
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.758	$ 1.292	$ 0.490	$ 1.289	$ 3.600	$ 2.641
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.102	$ 0.214	$ 0.292	$ 1.808	$ 2.668	$ 2.082
9	Wichita Falls	10.0	315.0	$ 0.060	$ 1.976	$ 0.762	$ 0.303	$ 1.451	$ 3.101	$ 2.273
-10% Curves										
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.532	$ 0.417	$ 0.238	$ 0.320	$ 2.247	$ 0.797
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.468	$ 0.285	$ 0.238	$ 0.320	$ 2.051	$ 0.665
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.749	$ 0.069	$ -	$ 0.510	$ 1.878	$ 0.639
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.795	$ 0.224	$ -	$ 0.510	$ 2.079	$ 0.794
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.641	$ 0.085	$ 0.485	$ 0.996	$ 2.271	$ 1.141
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.641	$ 0.569	$ 0.485	$ 0.996	$ 2.755	$ 1.625
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.641	$ 1.292	$ 0.485	$ 0.996	$ 3.478	$ 2.348
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.032	$ 0.214	$ 0.285	$ 1.387	$ 2.591	$ 1.661
9	Wichita Falls	10.0	315.0	$ 0.060	$ 1.882	$ 0.762	$ 0.302	$ 1.093	$ 3.006	$ 1.915

All Costs in January 2001 Dollars.

Table 20
Industrial Cost of Red River Water
Natural Conditions
($ per 1,000 Gallons)

Reach	SIC Code	SIC Threshold mg/l	Source Costs	Treatment Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	SIC 20	500.0	$ 0.060	$ 3.022	$ -	$ 0.043	$ 3.082	$ 0.103
	SIC 22	200.0	$ 0.060	$ 2.471	$ 0.083	$ 0.126	$ 2.614	$ 0.186
	SIC 24	500.0	$ 0.060	$ 1.919	$ -	$ 0.043	$ 1.979	$ 0.103
	SIC 26	500.0	$ 0.060	$ 1.650	$ -	$ 0.043	$ 1.710	$ 0.103
	SIC 28	800.0	$ 0.060	$ 1.919	$ -	$ 0.008	$ 1.979	$ 0.068
	SIC 291	800.0	$ 0.060	$ 1.739	$ -	$ 0.008	$ 1.799	$ 0.068
	SIC 33	900.0	$ 0.060	$ 1.592	$ -	$ 0.002	$ 1.652	$ 0.062
	SIC 35	750.0	$ 0.060	$ 3.705	$ -	$ 0.011	$ 3.765	$ 0.071
	SIC 371	750.0	$ 0.060	$ 2.510	$ -	$ 0.011	$ 2.570	$ 0.071
	SIC 39	750.0	$ 0.060	$ 3.705	$ -	$ 0.011	$ 3.765	$ 0.071
4T-A, 5, 5T-A1, & 5T-A2	SIC 20	500.0	$ 0.060	$ 3.190	$ -	$ 0.232	$ 3.250	$ 0.292
	SIC 22	200.0	$ 0.060	$ 2.678	$ 0.146	$ 0.378	$ 2.884	$ 0.438
	SIC 24	500.0	$ 0.060	$ 2.108	$ -	$ 0.232	$ 2.168	$ 0.292
	SIC 26	500.0	$ 0.060	$ 1.842	$ -	$ 0.232	$ 1.902	$ 0.292
	SIC 28	800.0	$ 0.060	$ 2.108	$ -	$ 0.097	$ 2.168	$ 0.157
	SIC 291	800.0	$ 0.060	$ 1.928	$ -	$ 0.097	$ 1.988	$ 0.157
	SIC 33	900.0	$ 0.060	$ 1.784	$ -	$ 0.062	$ 1.844	$ 0.122
	SIC 35	750.0	$ 0.060	$ 3.874	$ -	$ 0.117	$ 3.934	$ 0.177
	SIC 371	750.0	$ 0.060	$ 2.678	$ -	$ 0.117	$ 2.738	$ 0.177
	SIC 39	750.0	$ 0.060	$ 3.874	$ -	$ 0.117	$ 3.934	$ 0.177
8	SIC 20	500.0	$ 0.060	$ 3.986	$ -	$ 1.608	$ 4.046	$ 1.668
	SIC 22	200.0	$ 0.060	$ 3.544	$ 0.147	$ 1.755	$ 3.750	$ 1.815
	SIC 24	500.0	$ 0.060	$ 3.027	$ -	$ 1.608	$ 3.087	$ 1.668
	SIC 26	500.0	$ 0.060	$ 2.783	$ -	$ 1.608	$ 2.843	$ 1.668
	SIC 28	800.0	$ 0.060	$ 3.027	$ -	$ 1.465	$ 3.087	$ 1.525
	SIC 291	800.0	$ 0.060	$ 2.921	$ -	$ 1.465	$ 2.981	$ 1.525
	SIC 33	900.0	$ 0.060	$ 2.714	$ -	$ 1.418	$ 2.774	$ 1.478
	SIC 35	750.0	$ 0.060	$ 4.577	$ -	$ 1.489	$ 4.637	$ 1.549
	SIC 371	750.0	$ 0.060	$ 3.544	$ -	$ 1.489	$ 3.604	$ 1.549
	SIC 39	750.0	$ 0.060	$ 4.577	$ -	$ 1.489	$ 4.637	$ 1.549
9	SIC 20	500.0	$ 0.060	$ 3.514	$ -	$ 1.359	$ 3.574	$ 1.419
	SIC 22	200.0	$ 0.060	$ 3.010	$ 0.147	$ 1.506	$ 3.217	$ 1.566
	SIC 24	500.0	$ 0.060	$ 2.456	$ -	$ 1.359	$ 2.516	$ 1.419
	SIC 26	500.0	$ 0.060	$ 2.232	$ -	$ 1.359	$ 2.292	$ 1.419
	SIC 28	800.0	$ 0.060	$ 2.456	$ -	$ 1.212	$ 2.516	$ 1.272
	SIC 291	800.0	$ 0.060	$ 2.272	$ -	$ 1.212	$ 2.332	$ 1.272
	SIC 33	900.0	$ 0.060	$ 2.173	$ -	$ 1.163	$ 2.233	$ 1.223
	SIC 35	750.0	$ 0.060	$ 4.185	$ -	$ 1.237	$ 4.245	$ 1.297
	SIC 371	750.0	$ 0.060	$ 3.010	$ -	$ 1.237	$ 3.070	$ 1.297
	SIC 39	750.0	$ 0.060	$ 4.185	$ -	$ 1.237	$ 4.245	$ 1.297

All Costs in January 2001 Dollars.

Table 21
Industrial Cost of Red River Water
Area 8 Only Conditions
($ per 1,000 Gallons)

Reach	SIC Code	SIC Threshold mg/l	Source Costs	Treatment Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	SIC 20	500.0	$ 0.060	$ 3.013	$ -	$ 0.041	$ 3.073	$ 0.101
	SIC 22	200.0	$ 0.060	$ 2.463	$ 0.082	$ 0.123	$ 2.605	$ 0.183
	SIC 24	500.0	$ 0.060	$ 1.909	$ -	$ 0.041	$ 1.969	$ 0.101
	SIC 26	500.0	$ 0.060	$ 1.640	$ -	$ 0.041	$ 1.700	$ 0.101
	SIC 28	800.0	$ 0.060	$ 1.909	$ -	$ 0.007	$ 1.969	$ 0.067
	SIC 291	800.0	$ 0.060	$ 1.729	$ -	$ 0.007	$ 1.789	$ 0.067
	SIC 33	900.0	$ 0.060	$ 1.583	$ -	$ 0.002	$ 1.643	$ 0.062
	SIC 35	750.0	$ 0.060	$ 3.697	$ -	$ 0.010	$ 3.757	$ 0.070
	SIC 371	750.0	$ 0.060	$ 2.501	$ -	$ 0.010	$ 2.561	$ 0.070
	SIC 39	750.0	$ 0.060	$ 3.697	$ -	$ 0.010	$ 3.757	$ 0.070
4T-A, 5, 5T-A1, & 5T-A2	SIC 20	500.0	$ 0.060	$ 3.175	$ -	$ 0.218	$ 3.235	$ 0.278
	SIC 22	200.0	$ 0.060	$ 2.662	$ 0.146	$ 0.364	$ 2.868	$ 0.424
	SIC 24	500.0	$ 0.060	$ 2.090	$ -	$ 0.218	$ 2.150	$ 0.278
	SIC 26	500.0	$ 0.060	$ 1.824	$ -	$ 0.218	$ 1.884	$ 0.278
	SIC 28	800.0	$ 0.060	$ 2.090	$ -	$ 0.086	$ 2.150	$ 0.146
	SIC 291	800.0	$ 0.060	$ 1.910	$ -	$ 0.086	$ 1.970	$ 0.146
	SIC 33	900.0	$ 0.060	$ 1.766	$ -	$ 0.051	$ 1.826	$ 0.111
	SIC 35	750.0	$ 0.060	$ 3.858	$ -	$ 0.104	$ 3.918	$ 0.164
	SIC 371	750.0	$ 0.060	$ 2.662	$ -	$ 0.104	$ 2.722	$ 0.164
	SIC 39	750.0	$ 0.060	$ 3.858	$ -	$ 0.104	$ 3.918	$ 0.164
8	SIC 20	500.0	$ 0.060	$ 3.372	$ -	$ 1.140	$ 3.432	$ 1.200
	SIC 22	200.0	$ 0.060	$ 2.942	$ 0.145	$ 1.285	$ 3.148	$ 1.345
	SIC 24	500.0	$ 0.060	$ 2.441	$ -	$ 1.140	$ 2.501	$ 1.200
	SIC 26	500.0	$ 0.060	$ 2.232	$ -	$ 1.140	$ 2.292	$ 1.200
	SIC 28	800.0	$ 0.060	$ 2.441	$ -	$ 0.998	$ 2.501	$ 1.058
	SIC 291	800.0	$ 0.060	$ 2.327	$ -	$ 0.998	$ 2.387	$ 1.058
	SIC 33	900.0	$ 0.060	$ 2.173	$ -	$ 0.950	$ 2.233	$ 1.010
	SIC 35	750.0	$ 0.060	$ 3.945	$ -	$ 1.021	$ 4.005	$ 1.081
	SIC 371	750.0	$ 0.060	$ 2.942	$ -	$ 1.021	$ 3.002	$ 1.081
	SIC 39	750.0	$ 0.060	$ 3.945	$ -	$ 1.021	$ 4.005	$ 1.081
9	SIC 20	500.0	$ 0.060	$ 3.464	$ -	$ 0.942	$ 3.524	$ 1.002
	SIC 22	200.0	$ 0.060	$ 2.960	$ 0.147	$ 1.089	$ 3.167	$ 1.149
	SIC 24	500.0	$ 0.060	$ 2.403	$ -	$ 0.942	$ 2.463	$ 1.002
	SIC 26	500.0	$ 0.060	$ 2.176	$ -	$ 0.942	$ 2.236	$ 1.002
	SIC 28	800.0	$ 0.060	$ 2.403	$ -	$ 0.795	$ 2.463	$ 0.855
	SIC 291	800.0	$ 0.060	$ 2.219	$ -	$ 0.795	$ 2.279	$ 0.855
	SIC 33	900.0	$ 0.060	$ 2.117	$ -	$ 0.746	$ 2.177	$ 0.806
	SIC 35	750.0	$ 0.060	$ 4.136	$ -	$ 0.820	$ 4.196	$ 0.880
	SIC 371	750.0	$ 0.060	$ 2.960	$ -	$ 0.820	$ 3.020	$ 0.880
	SIC 39	750.0	$ 0.060	$ 4.136	$ -	$ 0.820	$ 4.196	$ 0.880

All Costs in January 2001 Dollars.

Table 22
Industrial Cost of Red River Water
Area 8 & 10 Only Conditions
($ per 1,000 Gallons)

Reach	SIC Code	SIC Threshold mg/l	Source Costs	Treatment Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	SIC 20	500.0	$ 0.060	$ 3.005	$ -	$ 0.040	$ 3.065	$ 0.100
	SIC 22	200.0	$ 0.060	$ 2.454	$ 0.081	$ 0.121	$ 2.595	$ 0.181
	SIC 24	500.0	$ 0.060	$ 1.899	$ -	$ 0.040	$ 1.959	$ 0.100
	SIC 26	500.0	$ 0.060	$ 1.630	$ -	$ 0.040	$ 1.690	$ 0.100
	SIC 28	800.0	$ 0.060	$ 1.899	$ -	$ 0.006	$ 1.959	$ 0.066
	SIC 291	800.0	$ 0.060	$ 1.719	$ -	$ 0.006	$ 1.779	$ 0.066
	SIC 33	900.0	$ 0.060	$ 1.573	$ -	$ 0.002	$ 1.633	$ 0.062
	SIC 35	750.0	$ 0.060	$ 3.688	$ -	$ 0.010	$ 3.748	$ 0.070
	SIC 371	750.0	$ 0.060	$ 2.492	$ -	$ 0.010	$ 2.552	$ 0.070
	SIC 39	750.0	$ 0.060	$ 3.688	$ -	$ 0.010	$ 3.748	$ 0.070
4T-A, 5,	SIC 20	500.0	$ 0.060	$ 3.168	$ -	$ 0.212	$ 3.228	$ 0.272
5T-A1, &	SIC 22	200.0	$ 0.060	$ 2.656	$ 0.146	$ 0.358	$ 2.862	$ 0.418
5T-A2	SIC 24	500.0	$ 0.060	$ 2.084	$ -	$ 0.212	$ 2.144	$ 0.272
	SIC 26	500.0	$ 0.060	$ 1.817	$ -	$ 0.212	$ 1.877	$ 0.272
	SIC 28	800.0	$ 0.060	$ 2.084	$ -	$ 0.081	$ 2.144	$ 0.141
	SIC 291	800.0	$ 0.060	$ 1.903	$ -	$ 0.081	$ 1.963	$ 0.141
	SIC 33	900.0	$ 0.060	$ 1.759	$ -	$ 0.047	$ 1.819	$ 0.107
	SIC 35	750.0	$ 0.060	$ 3.852	$ -	$ 0.099	$ 3.912	$ 0.159
	SIC 371	750.0	$ 0.060	$ 2.656	$ -	$ 0.099	$ 2.716	$ 0.159
	SIC 39	750.0	$ 0.060	$ 3.852	$ -	$ 0.099	$ 3.912	$ 0.159
8	SIC 20	500.0	$ 0.060	$ 3.349	$ -	$ 0.955	$ 3.409	$ 1.015
	SIC 22	200.0	$ 0.060	$ 2.919	$ 0.145	$ 1.100	$ 3.123	$ 1.160
	SIC 24	500.0	$ 0.060	$ 2.417	$ -	$ 0.955	$ 2.477	$ 1.015
	SIC 26	500.0	$ 0.060	$ 2.208	$ -	$ 0.955	$ 2.268	$ 1.015
	SIC 28	800.0	$ 0.060	$ 2.417	$ -	$ 0.813	$ 2.477	$ 0.873
	SIC 291	800.0	$ 0.060	$ 2.302	$ -	$ 0.813	$ 2.362	$ 0.873
	SIC 33	900.0	$ 0.060	$ 2.149	$ -	$ 0.767	$ 2.209	$ 0.827
	SIC 35	750.0	$ 0.060	$ 3.922	$ -	$ 0.837	$ 3.982	$ 0.897
	SIC 371	750.0	$ 0.060	$ 2.919	$ -	$ 0.837	$ 2.979	$ 0.897
	SIC 39	750.0	$ 0.060	$ 3.922	$ -	$ 0.837	$ 3.982	$ 0.897
9	SIC 20	500.0	$ 0.060	$ 3.435	$ -	$ 0.784	$ 3.495	$ 0.844
	SIC 22	200.0	$ 0.060	$ 2.931	$ 0.147	$ 0.930	$ 3.138	$ 0.990
	SIC 24	500.0	$ 0.060	$ 2.372	$ -	$ 0.784	$ 2.432	$ 0.844
	SIC 26	500.0	$ 0.060	$ 2.143	$ -	$ 0.784	$ 2.203	$ 0.844
	SIC 28	800.0	$ 0.060	$ 2.372	$ -	$ 0.637	$ 2.432	$ 0.697
	SIC 291	800.0	$ 0.060	$ 2.188	$ -	$ 0.637	$ 2.248	$ 0.697
	SIC 33	900.0	$ 0.060	$ 2.085	$ -	$ 0.588	$ 2.145	$ 0.648
	SIC 35	750.0	$ 0.060	$ 4.107	$ -	$ 0.662	$ 4.167	$ 0.722
	SIC 371	750.0	$ 0.060	$ 2.931	$ -	$ 0.662	$ 2.991	$ 0.722
	SIC 39	750.0	$ 0.060	$ 4.107	$ -	$ 0.662	$ 4.167	$ 0.722

All Costs in January 2001 Dollars.

Table 23
Industrial Cost of Red River Water
Area 7 & 8 Only Conditions
($ per 1,000 Gallons)

Reach	SIC Code	SIC Threshold mg/l	Source Costs	Treatment Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	SIC 20	500.0	$ 0.060	$ 2.988	$ -	$ 0.037	$ 3.048	$ 0.097
	SIC 22	200.0	$ 0.060	$ 2.437	$ 0.079	$ 0.116	$ 2.576	$ 0.176
	SIC 24	500.0	$ 0.060	$ 1.881	$ -	$ 0.037	$ 1.941	$ 0.097
	SIC 26	500.0	$ 0.060	$ 1.611	$ -	$ 0.037	$ 1.671	$ 0.097
	SIC 28	800.0	$ 0.060	$ 1.881	$ -	$ 0.004	$ 1.941	$ 0.064
	SIC 291	800.0	$ 0.060	$ 1.701	$ -	$ 0.004	$ 1.761	$ 0.064
	SIC 33	900.0	$ 0.060	$ 1.554	$ -	$ 0.001	$ 1.614	$ 0.061
	SIC 35	750.0	$ 0.060	$ 3.671	$ -	$ 0.008	$ 3.731	$ 0.068
	SIC 371	750.0	$ 0.060	$ 2.476	$ -	$ 0.008	$ 2.536	$ 0.068
	SIC 39	750.0	$ 0.060	$ 3.671	$ -	$ 0.008	$ 3.731	$ 0.068
4T-A, 5,	SIC 20	500.0	$ 0.060	$ 3.156	$ -	$ 0.201	$ 3.216	$ 0.261
5T-A1, &	SIC 22	200.0	$ 0.060	$ 2.643	$ 0.146	$ 0.347	$ 2.849	$ 0.407
5T-A2	SIC 24	500.0	$ 0.060	$ 2.069	$ -	$ 0.201	$ 2.129	$ 0.261
	SIC 26	500.0	$ 0.060	$ 1.803	$ -	$ 0.201	$ 1.863	$ 0.261
	SIC 28	800.0	$ 0.060	$ 2.069	$ -	$ 0.072	$ 2.129	$ 0.132
	SIC 291	800.0	$ 0.060	$ 1.889	$ -	$ 0.072	$ 1.949	$ 0.132
	SIC 33	900.0	$ 0.060	$ 1.744	$ -	$ 0.038	$ 1.804	$ 0.098
	SIC 35	750.0	$ 0.060	$ 3.839	$ -	$ 0.089	$ 3.899	$ 0.149
	SIC 371	750.0	$ 0.060	$ 2.643	$ -	$ 0.089	$ 2.703	$ 0.149
	SIC 39	750.0	$ 0.060	$ 3.839	$ -	$ 0.089	$ 3.899	$ 0.149
8	SIC 20	500.0	$ 0.060	$ 3.272	$ -	$ 0.575	$ 3.332	$ 0.635
	SIC 22	200.0	$ 0.060	$ 2.842	$ 0.143	$ 0.718	$ 3.044	$ 0.778
	SIC 24	500.0	$ 0.060	$ 2.340	$ -	$ 0.575	$ 2.400	$ 0.635
	SIC 26	500.0	$ 0.060	$ 2.129	$ -	$ 0.575	$ 2.189	$ 0.635
	SIC 28	800.0	$ 0.060	$ 2.340	$ -	$ 0.437	$ 2.400	$ 0.497
	SIC 291	800.0	$ 0.060	$ 2.220	$ -	$ 0.437	$ 2.280	$ 0.497
	SIC 33	900.0	$ 0.060	$ 2.070	$ -	$ 0.396	$ 2.130	$ 0.456
	SIC 35	750.0	$ 0.060	$ 3.845	$ -	$ 0.458	$ 3.905	$ 0.518
	SIC 371	750.0	$ 0.060	$ 2.842	$ -	$ 0.458	$ 2.902	$ 0.518
	SIC 39	750.0	$ 0.060	$ 3.845	$ -	$ 0.458	$ 3.905	$ 0.518
9	SIC 20	500.0	$ 0.060	$ 3.341	$ -	$ 0.450	$ 3.401	$ 0.510
	SIC 22	200.0	$ 0.060	$ 2.828	$ 0.147	$ 0.596	$ 3.035	$ 0.656
	SIC 24	500.0	$ 0.060	$ 2.277	$ -	$ 0.450	$ 2.337	$ 0.510
	SIC 26	500.0	$ 0.060	$ 2.014	$ -	$ 0.450	$ 2.074	$ 0.510
	SIC 28	800.0	$ 0.060	$ 2.277	$ -	$ 0.300	$ 2.337	$ 0.360
	SIC 291	800.0	$ 0.060	$ 2.097	$ -	$ 0.300	$ 2.157	$ 0.360
	SIC 33	900.0	$ 0.060	$ 1.954	$ -	$ 0.248	$ 2.014	$ 0.308
	SIC 35	750.0	$ 0.060	$ 4.024	$ -	$ 0.328	$ 4.084	$ 0.388
	SIC 371	750.0	$ 0.060	$ 2.828	$ -	$ 0.328	$ 2.888	$ 0.388
	SIC 39	750.0	$ 0.060	$ 4.024	$ -	$ 0.328	$ 4.084	$ 0.388

All Costs in January 2001 Dollars.

Table 24
Industrial Cost of Red River Water
Area 7, 8, & 10 Conditions
($ per 1,000 Gallons)

Reach	SIC Code	SIC Threshold mg/l	Source Costs	Treatment Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	SIC 20	500.0	$ 0.060	$ 2.980	$ -	$ 0.036	$ 3.040	$ 0.096
	SIC 22	200.0	$ 0.060	$ 2.429	$ 0.078	$ 0.114	$ 2.568	$ 0.174
	SIC 24	500.0	$ 0.060	$ 1.872	$ -	$ 0.036	$ 1.932	$ 0.096
	SIC 26	500.0	$ 0.060	$ 1.602	$ -	$ 0.036	$ 1.662	$ 0.096
	SIC 28	800.0	$ 0.060	$ 1.872	$ -	$ 0.003	$ 1.932	$ 0.063
	SIC 291	800.0	$ 0.060	$ 1.692	$ -	$ 0.003	$ 1.752	$ 0.063
	SIC 33	900.0	$ 0.060	$ 1.545	$ -	$ 0.001	$ 1.605	$ 0.061
	SIC 35	750.0	$ 0.060	$ 3.663	$ -	$ 0.007	$ 3.723	$ 0.067
	SIC 371	750.0	$ 0.060	$ 2.468	$ -	$ 0.007	$ 2.528	$ 0.067
	SIC 39	750.0	$ 0.060	$ 3.663	$ -	$ 0.007	$ 3.723	$ 0.067
4T-A, 5, 5T-A1, & 5T-A2	SIC 20	500.0	$ 0.060	$ 3.150	$ -	$ 0.196	$ 3.210	$ 0.256
	SIC 22	200.0	$ 0.060	$ 2.637	$ 0.146	$ 0.341	$ 2.843	$ 0.401
	SIC 24	500.0	$ 0.060	$ 2.063	$ -	$ 0.196	$ 2.123	$ 0.256
	SIC 26	500.0	$ 0.060	$ 1.796	$ -	$ 0.196	$ 1.856	$ 0.256
	SIC 28	800.0	$ 0.060	$ 2.063	$ -	$ 0.068	$ 2.123	$ 0.128
	SIC 291	800.0	$ 0.060	$ 1.883	$ -	$ 0.068	$ 1.943	$ 0.128
	SIC 33	900.0	$ 0.060	$ 1.738	$ -	$ 0.034	$ 1.798	$ 0.094
	SIC 35	750.0	$ 0.060	$ 3.833	$ -	$ 0.085	$ 3.893	$ 0.145
	SIC 371	750.0	$ 0.060	$ 2.637	$ -	$ 0.085	$ 2.697	$ 0.145
	SIC 39	750.0	$ 0.060	$ 3.833	$ -	$ 0.085	$ 3.893	$ 0.145
8	SIC 20	500.0	$ 0.060	$ 3.202	$ -	$ 0.391	$ 3.262	$ 0.451
	SIC 22	200.0	$ 0.060	$ 2.772	$ 0.141	$ 0.532	$ 2.973	$ 0.592
	SIC 24	500.0	$ 0.060	$ 2.270	$ -	$ 0.391	$ 2.330	$ 0.451
	SIC 26	500.0	$ 0.060	$ 2.057	$ -	$ 0.391	$ 2.117	$ 0.451
	SIC 28	800.0	$ 0.060	$ 2.270	$ -	$ 0.252	$ 2.330	$ 0.312
	SIC 291	800.0	$ 0.060	$ 2.145	$ -	$ 0.252	$ 2.205	$ 0.312
	SIC 33	900.0	$ 0.060	$ 1.999	$ -	$ 0.218	$ 2.059	$ 0.278
	SIC 35	750.0	$ 0.060	$ 3.775	$ -	$ 0.269	$ 3.835	$ 0.329
	SIC 371	750.0	$ 0.060	$ 2.772	$ -	$ 0.269	$ 2.832	$ 0.329
	SIC 39	750.0	$ 0.060	$ 3.775	$ -	$ 0.269	$ 3.835	$ 0.329
9	SIC 20	500.0	$ 0.060	$ 3.255	$ -	$ 0.289	$ 3.315	$ 0.349
	SIC 22	200.0	$ 0.060	$ 2.742	$ 0.147	$ 0.436	$ 2.949	$ 0.496
	SIC 24	500.0	$ 0.060	$ 2.180	$ -	$ 0.289	$ 2.240	$ 0.349
	SIC 26	500.0	$ 0.060	$ 1.916	$ -	$ 0.289	$ 1.976	$ 0.349
	SIC 28	800.0	$ 0.060	$ 2.180	$ -	$ 0.140	$ 2.240	$ 0.200
	SIC 291	800.0	$ 0.060	$ 2.000	$ -	$ 0.140	$ 2.060	$ 0.200
	SIC 33	900.0	$ 0.060	$ 1.857	$ -	$ 0.106	$ 1.917	$ 0.166
	SIC 35	750.0	$ 0.060	$ 3.938	$ -	$ 0.171	$ 3.998	$ 0.231
	SIC 371	750.0	$ 0.060	$ 2.742	$ -	$ 0.171	$ 2.802	$ 0.231
	SIC 39	750.0	$ 0.060	$ 3.938	$ -	$ 0.171	$ 3.998	$ 0.231

All Costs in January 2001 Dollars.

Blending

Blending is the mixing of "good" quality water with "poorer" quality water to obtain a mixture of "acceptable" quality water. Blending is not a new concept to water treatment. It is best described as treatment through dilution. Blending of Red River water does not reduce or eliminate any of the total pounds of dissolved solids, chlorides, and sulfates introduced into a source. The apparent concentration of contaminates in the mixture is lower per gallon, however; the total gallons affected is much greater. The net effect is a lower quantity of damages is distributed to the entire water system. Since no threshold has been identified below which damages will not occur, the damages will remain constant per gallon of Red River water used.

The calculation of blendable quantities is a complex procedure involving the analysis of water chemistry, environmental impacts, and reservoir inflows. For this analysis, a simplified procedure is used to calculate a safe blendable quantity which will maintain the TDS of the mixture at or below 500 mg/l at all times. A maximum blendable quantity will also be calculated which will maintain the average annual TDS at or below 500 mg/l.

Appendix E contains a sample calculation of the safe blendable quantity and maximum drought quantity. Table(s) 30-35 summarize the costs of transporting and blending Red River water to various sources. Transportation systems are sized to carry the drought quantity of water, however; costs are based on the safe blendable quantity.

Two options are costed for Reach 4T-A in this analysis. Lake Texoma is blended with Lake Lavon (existing blending operation) and Lake Texoma is blended with Lake Lavon and Lake Cooper water in Lake Lavon (also currently possible). Three scenarios are evaluated for Reach 5T-A1. Lake Texoma is blended with Lake Ray Roberts, Lake Texoma is blended with Lake Lewisville, and Lake Texoma is blended with the combined flows of Lake Ray Roberts and Lake Lewisville in Lake Lewisville. The third scenario is the most likely condition since Lake Ray Roberts flows into Lake Lewisville. Only one blending option exists for Reach 5T-A2. Lake Texoma is blended with Eagle Mountain Lake. The long transportation distance and relatively small blendable quantity make this alternative unlikely. Two blending options are evaluated for Wichita Falls and the Reach 8 Demand Center. The first involves blending water from the Wichita River at Wichita Falls with the flow from Lake Kickapoo and Lake Arrowhead. The second option involves piping water from Lake Kemp-Lake Diversion to Wichita Falls to blend with the flow from Lake Kickapoo and Lake Arrowhead.

Table 25
Expected Safe Blendable Quantities
Normal Operating Conditions
(All Quantities in MGD)

Red River Water Blended With:		Natural	Area 8	Area 8 & 10	Area 7 & 8	Area 7, 8, & 10
Reach 4T-A						
	+10% Load		23.1	23.6	24.7	25.1
Lake Lavon	Normal Load	25.6	27.0	27.6	28.9	29.5
	-10% Load		32.3	33.2	34.8	35.6
	+10% Load		39.0	39.8	41.6	42.4
Lake Lavon & Lake Cooper	Normal Load	43.2	45.5	46.5	48.7	49.7
	-10% Load		54.5	55.9	58.7	60.0
Reach 5T-A1						
	+10% Load		25.2	25.7	26.9	27.4
Lake Ray Roberts	Normal Load	27.9	29.4	30.0	31.4	32.1
	-10% Load		35.2	36.1	37.9	38.8
	+10% Load		29.2	29.8	31.2	31.7
Lake Lewisville	Normal Load	32.3	34.0	34.8	36.5	37.2
	-10% Load		40.8	41.9	44.0	45.0
	+10% Load		54.4	55.5	58.0	59.1
Lake Lewisville & Lake Ray Roberts	Normal Load	60.2	63.4	64.9	67.9	69.3
	-10% Load		76.0	78.0	81.8	83.7
Reach 5T-A2						
	+10% Load		16.7	17.0	17.8	18.1
Eagle Mountain Lake	Normal Load	18.5	19.4	19.9	20.8	21.3
	-10% Load		23.3	23.9	25.1	25.7
Reach 8						
	+10% Load		1.5	1.8	2.7	3.6
Lake Kickapoo & Lake Arrowhead	Normal Load	1.2	1.7	2.0	3.0	4.1
(From Wichita River)	-10% Load		1.9	2.2	3.4	4.7
Reach 9						
	+10% Load		2.3	2.7	4.5	6.1
Lake Kickapoo & Lake Arrowhead	Normal Load	1.8	2.6	3.1	5.1	7.0
(From Lake Diversion)	-10% Load		2.9	3.5	5.9	8.1

Table 26
Maximum Blendable Quantities
Drought Operating Conditions
(All Quantities in MGD)

Red River Water Blended With:		Natural	Area 8	Area 8 & 10	Area 7 & 8	Area 7, 8, & 10
Reach 4T-A						
	+10% Load		52.8	54.0	56.9	58.2
Lake Lavon	Normal Load	60.1	64.0	65.7	69.5	71.4
	-10% Load		81.4	83.7	89.3	92.1
	+10% Load		79.3	81.1	85.4	87.4
Lake Lavon & Lake Cooper	Normal Load	90.2	96.2	98.7	104.3	107.2
	-10% Load		122.2	125.7	134.2	138.3
Reach 5T-A1						
	+10% Load		43.7	44.7	47.1	48.2
Lake Ray Roberts	Normal Load	49.7	53.0	54.4	57.5	59.1
	-10% Load		67.4	69.3	74.0	76.3
	+10% Load		50.7	51.9	54.6	55.9
Lake Lewisville	Normal Load	57.7	61.5	63.1	66.7	68.5
	-10% Load		78.2	80.4	85.8	88.5
	+10% Load		94.4	96.6	101.7	104.1
Lake Lewisville & Lake Ray Roberts	Normal Load	107.4	114.5	117.5	124.3	127.6
	-10% Load		145.5	149.7	159.8	164.7
Reach 5T-A2						
	+10% Load		32.9	33.6	35.4	36.2
Eagle Mountain Lake	Normal Load	37.4	39.9	40.9	43.3	44.4
	-10% Load		50.7	52.1	55.6	57.3
Reach 8						
	+10% Load		2.9	3.4	5.6	8.2
Lake Kickapoo & Lake Arrowhead	Normal Load	2.3	3.2	3.9	6.4	9.5
(From Wichita River)	-10% Load		3.7	4.4	7.5	11.4
Reach 9						
	+10% Load		3.5	4.1	7.1	0.7
Lake Kickapoo & Lake Arrowhead	Normal Load	2.7	3.9	4.7	8.2	12.7
(From Lake Diversion)	-10% Load		4.5	5.4	9.7	15.6

Table 27
Blended Cost of Red River Water
Natural Conditions
($ per 1,000 Gallons)

Reach	Red River Blended w/	Quantity (MGD)	Source Costs	Transport Costs	Untreated Damages	Untreated Cost w/ Damages
Normal Curves						
4T-A1	Lake Lavon	25.6	$ 0.060	$ 0.085	$ 1.265	$ 1.410
4T-A1	Lake Lavon & L. Cooper	43.2	$ 0.060	$ 0.085	$ 1.265	$ 1.410
5T-A1	Lake Ray Roberts	27.9	$ 0.060	$ 0.715	$ 1.265	$ 2.040
5T-A1	Lake Lewisville	32.3	$ 0.060	$ 0.640	$ 1.265	$ 1.965
5T-A1	Ray Roberts & Lewisville	60.2	$ 0.060	$ 0.594	$ 1.265	$ 1.919
5T-A2	Eagle Mountain Lake	18.5	$ 0.060	$ 2.028	$ 1.265	$ 3.353
8	Kickapoo & Arrowhead	1.2	$ 0.060	$ 0.806	$ 5.684	$ 6.550
9	Kickapoo & Arrowhead	1.8	$ 0.060	$ 2.398	$ 4.849	$ 7.307

Table 28
Blended Cost of Red River Water
Area 8 Only Conditions
($ per 1,000 Gallons)

Reach	Red River Blended w/	Quantity (MGD)	Source Costs	Transport Costs	Untreated Damages	Untreated Cost w/ Damages
Normal Curves						
4T-A1	Lake Lavon	27.0	$ 0.060	$ 0.085	$ 1.217	$ 1.362
4T-A1	Lake Lavon & L. Cooper	45.5	$ 0.060	$ 0.085	$ 1.217	$ 1.362
5T-A1	Lake Ray Roberts	29.4	$ 0.060	$ 0.691	$ 1.217	$ 1.968
5T-A1	Lake Lewisville	34.0	$ 0.060	$ 0.740	$ 1.217	$ 2.017
5T-A1	Ray Roberts & Lewisville	63.4	$ 0.060	$ 0.578	$ 1.217	$ 1.855
5T-A2	Eagle Mountain Lake	19.4	$ 0.060	$ 1.955	$ 1.217	$ 3.232
8	Kickapoo & Arrowhead	1.7	$ 0.060	$ 0.605	$ 4.112	$ 4.777
9	Kickapoo & Arrowhead	2.6	$ 0.060	$ 1.906	$ 3.454	$ 5.420
+10% Curves						
4T-A1	Lake Lavon	23.1	$ 0.060	$ 0.085	$ 1.372	$ 1.517
4T-A1	Lake Lavon & L. Cooper	39.0	$ 0.060	$ 0.085	$ 1.372	$ 1.517
5T-A1	Lake Ray Roberts	25.2	$ 0.060	$ 0.077	$ 1.372	$ 1.509
5T-A1	Lake Lewisville	29.2	$ 0.060	$ 0.678	$ 1.372	$ 2.110
5T-A1	Ray Roberts & Lewisville	54.4	$ 0.060	$ 0.631	$ 1.372	$ 2.063
5T-A2	Eagle Mountain Lake	16.7	$ 0.060	$ 2.202	$ 1.372	$ 3.634
8	Kickapoo & Arrowhead	1.5	$ 0.060	$ 0.670	$ 4.575	$ 5.305
9	Kickapoo & Arrowhead	2.3	$ 0.060	$ 2.131	$ 3.851	$ 6.042
-10% Curves						
4T-A1	Lake Lavon	32.3	$ 0.060	$ 0.085	$ 1.062	$ 1.207
4T-A1	Lake Lavon & L. Cooper	54.5	$ 0.060	$ 0.085	$ 1.062	$ 1.207
5T-A1	Lake Ray Roberts	35.2	$ 0.060	$ 0.747	$ 1.062	$ 1.869
5T-A1	Lake Lewisville	40.8	$ 0.060	$ 0.662	$ 1.062	$ 1.784
5T-A1	Ray Roberts & Lewisville	76.0	$ 0.060	$ 0.581	$ 1.062	$ 1.703
5T-A2	Eagle Mountain Lake	23.3	$ 0.060	$ 1.731	$ 1.062	$ 2.853
8	Kickapoo & Arrowhead	1.9	$ 0.060	$ 0.554	$ 3.650	$ 4.264
9	Kickapoo & Arrowhead	2.9	$ 0.060	$ 1.729	$ 3.058	$ 4.847

All Costs in January 2001 Dollars.

Table 29
Blended Cost of Red River Water
Area(s) 8 & 10 Only Conditions
($ per 1,000 Gallons)

Reach	Red River Blended w/	Quantity (MGD)	Source Costs	Transport Costs	Untreated Damages	Untreated Cost w/ Damages
Normal Curves						
4T-A1	Lake Lavon	27.6	$ 0.060	$ 0.085	$ 1.199	$ 1.344
4T-A1	Lake Lavon & L. Cooper	46.5	$ 0.060	$ 0.085	$ 1.199	$ 1.344
5T-A1	Lake Ray Roberts	30.0	$ 0.060	$ 0.683	$ 1.199	$ 1.942
5T-A1	Lake Lewisville	34.8	$ 0.060	$ 0.729	$ 1.199	$ 1.988
5T-A1	Ray Roberts & Lewisville	64.9	$ 0.060	$ 0.570	$ 1.199	$ 1.829
5T-A2	Eagle Mountain Lake	19.9	$ 0.060	$ 1.917	$ 1.199	$ 3.176
8	Kickapoo & Arrowhead	2.0	$ 0.060	$ 0.532	$ 3.492	$ 4.084
9	Kickapoo & Arrowhead	3.1	$ 0.060	$ 1.630	$ 2.925	$ 4.615
+10% Curves						
4T-A1	Lake Lavon	23.6	$ 0.060	$ 0.085	$ 1.352	$ 1.497
4T-A1	Lake Lavon & L. Cooper	39.8	$ 0.060	$ 0.085	$ 1.352	$ 1.497
5T-A1	Lake Ray Roberts	25.7	$ 0.060	$ 0.760	$ 1.352	$ 2.172
5T-A1	Lake Lewisville	29.8	$ 0.060	$ 0.670	$ 1.352	$ 2.082
5T-A1	Ray Roberts & Lewisville	55.5	$ 0.060	$ 0.623	$ 1.352	$ 2.035
5T-A2	Eagle Mountain Lake	17.0	$ 0.060	$ 2.171	$ 1.352	$ 3.583
8	Kickapoo & Arrowhead	1.8	$ 0.060	$ 0.578	$ 3.891	$ 4.529
9	Kickapoo & Arrowhead	2.7	$ 0.060	$ 1.842	$ 3.269	$ 5.171
-10% Curves						
4T-A1	Lake Lavon	33.2	$ 0.060	$ 0.085	$ 1.046	$ 1.191
4T-A1	Lake Lavon & L. Cooper	55.9	$ 0.060	$ 0.085	$ 1.046	$ 1.191
5T-A1	Lake Ray Roberts	36.1	$ 0.060	$ 0.734	$ 1.046	$ 1.840
5T-A1	Lake Lewisville	41.9	$ 0.060	$ 0.653	$ 1.046	$ 1.759
5T-A1	Ray Roberts & Lewisville	78.0	$ 0.060	$ 0.572	$ 1.046	$ 1.678
5T-A2	Eagle Mountain Lake	23.9	$ 0.060	$ 1.184	$ 1.046	$ 2.290
8	Kickapoo & Arrowhead	2.2	$ 0.060	$ 0.514	$ 3.091	$ 3.665
9	Kickapoo & Arrowhead	3.5	$ 0.060	$ 1.470	$ 2.581	$ 4.111

All Costs in January 2001 Dollars.

Table 30
Blended Cost of Red River Water
Area(s) 7 & 8 Only Conditions
($ per 1,000 Gallons)

Reach	Red River Blended w/	Quantity (MGD)	Source Costs	Transport Costs	Untreated Damages	Untreated Cost w/ Damages
Normal Curves						
4T-A1	Lake Lavon	28.9	$ 0.060	$ 0.085	$ 1.160	$ 1.305
4T-A1	Lake Lavon & L. Cooper	48.7	$ 0.060	$ 0.085	$ 1.160	$ 1.305
5T-A1	Lake Ray Roberts	31.4	$ 0.060	$ 0.665	$ 1.160	$ 1.885
5T-A1	Lake Lewisville	36.5	$ 0.060	$ 0.566	$ 1.160	$ 1.786
5T-A1	Ray Roberts & Lewisville	67.9	$ 0.060	$ 0.555	$ 1.160	$ 1.775
5T-A2	Eagle Mountain Lake	20.8	$ 0.060	$ 1.855	$ 1.160	$ 3.075
8	Kickapoo & Arrowhead	3.0	$ 0.060	$ 0.408	$ 2.218	$ 2.686
9	Kickapoo & Arrowhead	5.1	$ 0.060	$ 1.150	$ 1.807	$ 3.017
+10% Curves						
4T-A1	Lake Lavon	24.7	$ 0.060	$ 0.085	$ 1.309	$ 1.454
4T-A1	Lake Lavon & L. Cooper	41.6	$ 0.060	$ 0.085	$ 1.309	$ 1.454
5T-A1	Lake Ray Roberts	26.9	$ 0.060	$ 0.737	$ 1.309	$ 2.106
5T-A1	Lake Lewisville	31.2	$ 0.060	$ 0.653	$ 1.309	$ 2.022
5T-A1	Ray Roberts & Lewisville	58.0	$ 0.060	$ 0.607	$ 1.309	$ 1.976
5T-A2	Eagle Mountain Lake	17.8	$ 0.060	$ 2.091	$ 1.309	$ 3.460
8	Kickapoo & Arrowhead	2.7	$ 0.060	$ 0.440	$ 2.490	$ 2.990
9	Kickapoo & Arrowhead	4.5	$ 0.060	$ 1.276	$ 2.039	$ 3.375
-10% Curves						
4T-A1	Lake Lavon	34.8	$ 0.060	$ 0.085	$ 1.011	$ 1.156
4T-A1	Lake Lavon & L. Cooper	58.7	$ 0.060	$ 0.085	$ 1.011	$ 1.156
5T-A1	Lake Ray Roberts	37.9	$ 0.060	$ 0.711	$ 1.011	$ 1.782
5T-A1	Lake Lewisville	44.0	$ 0.060	$ 0.636	$ 1.011	$ 1.707
5T-A1	Ray Roberts & Lewisville	81.8	$ 0.060	$ 0.555	$ 1.011	$ 1.626
5T-A2	Eagle Mountain Lake	25.1	$ 0.060	$ 1.894	$ 1.011	$ 2.965
8	Kickapoo & Arrowhead	3.4	$ 0.060	$ 0.373	$ 1.947	$ 2.380
9	Kickapoo & Arrowhead	5.9	$ 0.060	$ 1.158	$ 1.575	$ 2.793

All Costs in January 2001 Dollars.

Table 31
Blended Cost of Red River Water
Area(s) 7, 8, & 10 Conditions
($ per 1,000 Gallons)

Reach	Red River Blended w/	Quantity (MGD)	Source Costs	Transport Costs	Untreated Damages	Untreated Cost w/ Damages
Normal Curves						
4T-A1	Lake Lavon	29.5	$ 0.060	$ 0.085	$ 1.142	$ 1.287
4T-A1	Lake Lavon & L. Cooper	49.7	$ 0.060	$ 0.085	$ 1.142	$ 1.287
5T-A1	Lake Ray Roberts	32.1	$ 0.060	$ 0.656	$ 1.142	$ 1.858
5T-A1	Lake Lewisville	37.2	$ 0.060	$ 0.699	$ 1.142	$ 1.901
5T-A1	Ray Roberts & Lewisville	69.3	$ 0.060	$ 0.549	$ 1.142	$ 1.751
5T-A2	Eagle Mountain Lake	21.3	$ 0.060	$ 1.823	$ 1.142	$ 3.025
8	Kickapoo & Arrowhead	4.1	$ 0.060	$ 0.338	$ 1.597	$ 1.995
9	Kickapoo & Arrowhead	7.0	$ 0.060	$ 1.002	$ 1.272	$ 2.334
+10% Curves						
4T-A1	Lake Lavon	25.1	$ 0.060	$ 0.085	$ 1.289	$ 1.434
4T-A1	Lake Lavon & L. Cooper	42.4	$ 0.060	$ 0.085	$ 1.289	$ 1.434
5T-A1	Lake Ray Roberts	27.4	$ 0.060	$ 0.723	$ 1.289	$ 2.072
5T-A1	Lake Lewisville	31.7	$ 0.060	$ 0.648	$ 1.289	$ 1.997
5T-A1	Ray Roberts & Lewisville	59.1	$ 0.060	$ 0.600	$ 1.289	$ 1.949
5T-A2	Eagle Mountain Lake	18.1	$ 0.060	$ 2.069	$ 1.289	$ 3.418
8	Kickapoo & Arrowhead	3.6	$ 0.060	$ 0.374	$ 1.808	$ 2.242
9	Kickapoo & Arrowhead	6.1	$ 0.060	$ 1.125	$ 1.451	$ 2.636
-10% Curves						
4T-A1	Lake Lavon	35.6	$ 0.060	$ 0.085	$ 0.996	$ 1.141
4T-A1	Lake Lavon & L. Cooper	60.0	$ 0.060	$ 0.085	$ 0.996	$ 1.141
5T-A1	Lake Ray Roberts	38.8	$ 0.060	$ 0.700	$ 0.996	$ 1.756
5T-A1	Lake Lewisville	45.0	$ 0.060	$ 0.628	$ 0.996	$ 1.684
5T-A1	Ray Roberts & Lewisville	83.7	$ 0.060	$ 0.548	$ 0.996	$ 1.604
5T-A2	Eagle Mountain Lake	25.7	$ 0.060	$ 1.859	$ 0.996	$ 2.915
8	Kickapoo & Arrowhead	4.7	$ 0.060	$ 0.310	$ 1.387	$ 1.757
9	Kickapoo & Arrowhead	8.1	$ 0.060	$ 0.891	$ 1.093	$ 2.044

All Costs in January 2001 Dollars.

Alternative Treatment Levels:

All treatment and damage evaluation up to this point has been based on the EPA drinking water standards of 500 mg/l of TDS, 250 mg/l of Cl and 250 mg/l of SO_4. The State of Texas drinking water standards allow 1,000 mg/l of TDS, 300 mg/l of Cl and 300 mg/l of SO_4. Questions have been raised about the relative magnitude of the "damages" from using Red River water when evaluated against the State standards. While the State of Texas standards do allow a 100% increase above EPA standards for TDS levels in treated drinking water, only a 20% increase in Cl and SO_4 levels are allowed. It also should be noted that the State of Louisiana has adopted the EPA standards, therefore, no reduction in treatment levels is possible for Reach 1.

In this study (and all previous studies), the damages only costs have been evaluated against the alternative source thresholds for the respective reaches (See Table 1). For users in Texas reaches with alternative source thresholds below 500 mg/l of TDS (Reach 3, 4, 4T-A, 5T-A1, 5T-A2, 5T-A3, and 8), State of Texas water quality standards will have no effect on the "damages only" cost of Red River water. The "treated damages" costs will also increase since the degree of treatment is not as great (i.e. more damages). Only the treatment costs will be lowered. Tables 32-36 depict the results of the revised calculations using the state TDS limit. It should be noted that the treatment costs were lowered by 20-25%, however; the overall treated costs with damages were only lowered by 10-15%.

Table 32
Cost of Red River Water Treated to Texas Standards
Natural Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.668	$ 0.417	$ 0.417	$ 0.420	$ 2.563	$ 0.897
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.601	$ 0.285	$ 0.417	$ 0.420	$ 2.363	$ 0.765
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.860	$ 0.069	$ 0.293	$ 0.776	$ 2.282	$ 0.905
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.911	$ 0.224	$ 0.293	$ 0.776	$ 2.489	$ 1.060
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.751	$ 0.085	$ 1.167	$ 1.265	$ 3.063	$ 1.410
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.751	$ 0.569	$ 1.167	$ 1.265	$ 3.547	$ 1.894
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.751	$ 1.292	$ 1.167	$ 1.265	$ 4.270	$ 2.617
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.799	$ 0.214	$ 1.099	$ 5.684	$ 4.172	$ 5.958
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.249	$ 0.762	$ 1.121	$ 4.849	$ 4.192	$ 5.671

Table 33
Cost of Red River Water Treated to Texas Standards
Area 8 Only Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.658	$ 0.417	$ 0.411	$ 0.413	$ 2.546	$ 0.890
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.591	$ 0.285	$ 0.411	$ 0.413	$ 2.347	$ 0.758
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.842	$ 0.069	$ 0.268	$ 0.728	$ 2.239	$ 0.857
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.893	$ 0.224	$ 0.268	$ 0.728	$ 2.445	$ 1.012
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.733	$ 0.085	$ 1.137	$ 1.217	$ 3.015	$ 1.362
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.733	$ 0.569	$ 1.137	$ 1.217	$ 3.499	$ 1.846
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.733	$ 1.292	$ 1.137	$ 1.217	$ 4.222	$ 2.569
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.249	$ 0.214	$ 1.088	$ 4.112	$ 3.611	$ 4.386
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.192	$ 0.762	$ 1.121	$ 3.454	$ 4.135	$ 4.276

Table 34
Cost of Red River Water Treated to Texas Standards
Area 8 & 10 Only Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.648	$ 0.417	$ 0.403	$ 0.405	$ 2.529	$ 0.882
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.581	$ 0.285	$ 0.403	$ 0.405	$ 2.330	$ 0.750
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 0.060	$ 0.069	$ 0.259	$ 0.710	$ 0.448	$ 0.839
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.885	$ 0.224	$ 0.259	$ 0.710	$ 2.428	$ 0.994
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.726	$ 0.085	$ 1.126	$ 1.199	$ 2.997	$ 1.344
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.726	$ 0.569	$ 1.126	$ 1.199	$ 3.481	$ 1.828
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.726	$ 1.292	$ 1.126	$ 1.199	$ 4.204	$ 2.551
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.225	$ 0.214	$ 1.076	$ 3.492	$ 3.575	$ 3.766
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.159	$ 0.762	$ 1.121	$ 2.925	$ 4.102	$ 3.747

Table 35
Cost of Red River Water Treated to Texas Standards
Area 7 & 8 Only Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.629	$ 0.417	$ 0.389	$ 0.389	$ 2.496	$ 0.866
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.562	$ 0.285	$ 0.389	$ 0.389	$ 2.296	$ 0.734
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.821	$ 0.069	$ 0.241	$ 0.672	$ 2.191	$ 0.801
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.870	$ 0.224	$ 0.241	$ 0.672	$ 2.395	$ 0.956
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.712	$ 0.085	$ 1.102	$ 1.160	$ 2.959	$ 1.305
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.712	$ 0.569	$ 1.102	$ 1.160	$ 3.443	$ 1.789
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.712	$ 1.292	$ 1.102	$ 1.160	$ 4.166	$ 2.512
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.144	$ 0.214	$ 1.034	$ 2.218	$ 3.452	$ 2.492
9	Wichita Falls	10.0	315.0	$ 0.060	$ 2.032	$ 0.762	$ 1.107	$ 1.807	$ 3.961	$ 2.629

Table 36
Cost of Red River Water Treated to Texas Standards
Area 7, 8 & 10 Conditions
($ per 1,000 Gallons)

Reach	Demand Center	Qty. (MGD)	Alt. Source Threshold mg/l	Source Costs	Treatment Costs	Transport Costs	Treated Damages	Untreated Damages	Treated Cost w/ Damages	Untreated Cost w/ Damages
1	Bossier City, LA	10.0	200.0	$ 0.060	$ 1.620	$ 0.417	$ 0.382	$ 0.382	$ 2.479	$ 0.859
1	Shreveport, LA	25.0	200.0	$ 0.060	$ 1.553	$ 0.285	$ 0.382	$ 0.382	$ 2.280	$ 0.727
5	Sherman, TX (GTUA)	10.0	500.0	$ 0.060	$ 1.814	$ 0.069	$ 0.235	$ 0.655	$ 2.178	$ 0.784
5	Denison, TX	5.0	500.0	$ 0.060	$ 1.863	$ 0.224	$ 0.235	$ 0.655	$ 2.382	$ 0.939
4T-A	NTMWD	65.0	200.0	$ 0.060	$ 1.705	$ 0.085	$ 1.091	$ 1.142	$ 2.942	$ 1.287
5T-A1	DWU	65.0	200.0	$ 0.060	$ 1.705	$ 0.569	$ 1.091	$ 1.142	$ 3.426	$ 1.771
5T-A2	TRWD	65.0	200.0	$ 0.060	$ 1.705	$ 1.292	$ 1.091	$ 1.142	$ 4.149	$ 2.494
8	Wichita Falls	10.0	315.0	$ 0.060	$ 2.072	$ 0.214	$ 0.984	$ 1.597	$ 3.330	$ 1.871
9	Wichita Falls	10.0	315.0	$ 0.060	$ 1.934	$ 0.762	$ 1.031	$ 1.272	$ 3.787	$ 2.094